MACHINE VISION MARKETS

2008 Results and Forecasts to 2013

AUTOMATED IMAGING ASSOCIATION

Market Intelligence for Sales Maximization

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The AIA Market Study: Market Intelligence for Sales Maximization

Machine Vision Markets

2008 Results and Forecasts to 2013

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Chapter 1:
Executive Summary

1.0 What's New in this Chapter?
This chapter is entirely new with the exception of section 1.2.

1.1 Introduction
Until recently, many believed that growth in machine vision (MV) sales would continue unabated with little variation year-to-year. Since then of course, that belief has succumbed to the hard realities of recession. However, in its place, the opposite belief has emerged. Despite the MV industry's highly successful, 26-year history, some now extrapolate its current weakness into the future and question its staying power.

A longer-term view of our industry's sales performance, however, shows that it is normal for both the peaks and troughs of the business cycle to reflect themselves in MV sales volumes over time, and that, most importantly, the trend line that underlies MV sales volumes is linear and positive. This means that sales will be weak in some years, strong in others, while always fluctuating around an underlying trend line. Or to put it differently, MV sales over time show atypical strength and weakness in response to the business cycle but always return to their trend line.

The latest evidence of this is the impact of the prior recession, which ended in 2001. Historical sales data for MV companies in North America show clearly that the 2001 US recession hit MV sales hard; some MV product markets took several years to recover. But recover, they did. Tapping into pent-up demand, those markets experienced a sharp upturn, and then moderated, displaying growth through 2006.

We have every reason to believe that future MV sales will repeat this cycle. They will experience a period of weakness, followed by a recovery, and then show moderate, steady growth, indicating their return to the trend line.

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In keeping with this longer-term view, and the economic forecasts and analysis upon which it is based, our fundamental conclusion in this study is therefore that machine vision sales have experienced, and will continue to reflect, weakness as a consequence of the business cycle, at least through the first half of 2010. A recovery will then begin in the latter half of 2010. It will be driven by pent-up demand and will be characterized by atypically strong rates of growth. In the years that follow, MV sales growth rates will moderate but stay positive.

Accounting for the long-term trend in MV sales is the basic value proposition of machine vision technology, which is cost containment, productivity and quality control. Because these values are important needs of manufacturers that machine vision satisfies, machine vision is indispensable and has become increasingly important in an ever-competitive, global economy. Machine vision will also find growing acceptance beyond the factory in new, high-tech industries. Because of its increasing penetration of an expanding number of economic sectors, machine vision is, and will remain, a major automation technology in developed countries.

Increasingly, machine vision will, moreover, take root in countries with modernizing economies, such as China and India, where it will serve as an enabling force of industrialization. Demand for MV products will therefore grow in these countries as well, contributing to a bright future for machine vision.

In this study, we present a comprehensive, in-depth view of machine vision markets. While we believe the future of machine vision to be bright, we recognize that success is far from automatic. Sales growth is difficult to achieve and highly resource-intensive. Resources, however, are very finite. That is why AIA supports the efficient utilization of sales resources through market intelligence. To machine vision companies, and their successful use of market intelligence, we dedicate this study.

1.2 Study Overview

This 2009 study is based on 2008 actual results but also contains historical sales data to show buying trends and makes sales forecasts based on historical and economic data. The study is organized primarily around the major machine vision (MV) product markets in North America and the world: optics, lighting, cameras, imaging boards, smart cameras and application-specific machine vision (ASMV) systems. The study begins with an overview of the report (Chapter 2) and ends with a set of major conclusions (Chapter 21). An appendix provides a glossary of key words.

Major MV Product Categories

	Chapter
Optics	10
Lighting	9
Cameras	7
Imaging boards	8
Software	13
Smart cameras	12
Application-specific MV (ASMV) systems	11

Theme of this Year's Study

This 2009 study also focuses on new market opportunities in three major Latin American countries, Argentina, Brazil and Mexico, and in two new industries, MEMS (Micro Mechanical Electrical Systems) and solar panels and cells.

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Purpose

The purpose of this market study is to help MV companies maximize sales with actionable market intelligence. To succeed in the marketplace, MV companies need carefully formulated market plans. AIA wishes to encourage MV companies to thoroughly utilize the data and analysis of this study as major inputs into their market plans. Important information that AIA has included in this study for this purpose are enumerated below.

Recommended Market Plan Inputs
■ Estimation of actual and forecast MV product market size ■ Estimation of actual and forecast MV market growth ■ Analysis of changes in MV growth patterns ■ Determination of MV market trends and major characteristics ■ Analysis of MV sales by product feature ■ Identification of new MV market opportunities

Type of Machine Vision Study

The AIA study is a true "market" study - in contrast to an "industry" study, an altogether different type of study of machine vision sales activity. As a market study, this AIA study focuses on sales that occur within geographic markets. As such, it cannot be compared to industry studies, such as those prepared by JIIA and EMVA, which analyze the worldwide sales of the Japanese and European MV industries. Both types of studies represent equally valid but completely dissimilar (and thus incomparable) perspectives. The following table shows the difference between market and industry sales and why the different types of studies cannot be compared.

	Companies	Sales
Market	All the companies that sell into the same geographic market	■ Total Market Sales = In-region sales + Imports ■ Total Market Sales = Domestic Sales + Imports
Industry	All the companies with HQs located in the same geographic area	■ Total Industry Sales = Total global sales of companies with in-region HQs ■ Total Industry Sales = In-region sales + Out-of-region sales of companies with in-region HQs ■ Total Industry Sales = Domestic sales + Out-of-region sales where "domestic" refers to the same geographic area

Scope of this Study

The boundaries of this study have been set as follows:

- Geography: The study focuses primarily on North America. In Chapter 3, however, we present regional and worldwide estimates of product market sizes, as previously noted. In Chapters 17, 18 and 19, we also examine the Argentine, Brazilian and Mexican MV markets to estimate their respective opportunities.

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- Time Period: The major focus is 2008, with historical data included, where possible, for the 2001 to 2007 period. The forecast period of the study is 2009 through 2013.

- Definition of Machine Vision: By "machine vision" we mean all industrial and non-industrial applications where a combination of hardware and software provide operational guidance to devices in the execution of their functions based on the capture and processing of images. Typically, this involves *lighting* to render visible the object to be imaged; *optics* to focus the image of the object; a *camera* to "see" the image; an *imaging board* to capture the image from the camera and convert it into data; and lastly, *software* that is used to manipulate the digitized image to optimize operational decision-making. It is important to note that, according to our definition, machine vision is not limited to the factory floor but instead extends to new, innovative applications, which broadens the scope of what has been traditionally referred to as machine vision. Despite this, it must nevertheless be noted that most data collected for the study still represent a traditional, factory-oriented definition. It is expected that - as the machine vision industry increasingly broadens the scope of its activities - the operational definition of machine vision will correspondingly evolve with members of AIA and the MV industry at large arriving at a consensus.

Machine Vision Definition
By "machine vision" we mean all industrial and non-industrial applications where a combination of hardware and software provide operational guidance to devices in the execution of their functions based on the capture and processing of images.

- Level of Analysis: This study focuses on MV sales activity on the component and system level. Sub-component sales are thus beyond the scope of this study.

- Market Players: The scope of this study can be further defined in terms of the type of market players from which data are collected, as shown below.

Types of Market Players Included:	**Types of Market Players Excluded:**
■ Component Suppliers ■ Smart Camera Suppliers ■ ASMV System Suppliers	■ Subcomponent Suppliers ■ OEMs ■ Integrators ■ Distributors/Resellers/VARs

Eventually, we would like to broaden the scope of this study to include system integrators. (Thus far, the number of system integrators willing to participate in data collection has not made this possible.)

- Product Markets and Types of Units Sold: This study examines product markets in terms of their corresponding types of units sold.

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Product Markets	Type of Units Sold
Components	
■ Optics……………………………….>	■ Lenses (multi-element optical devices)
■ Lighting (or Illumination)…………..>	■ Single lighting configurations
■ Cameras…………………………….>	■ Cameras including board-level cameras
■ Imaging Boards……………………..>	■ Frame grabbers and vision processors
■ Software…………………………….>	■ Software packages
Integrated MV Equipment	
■ Smart Cameras……………………...>	■ Smart cameras, embedded vision processors and vision sensors
■ Application-Specific MV Systems…>	■ Individual ASMV systems

It should be noted that there is not a single machine vision market but rather multiple markets that correspond to major product categories, each of which represents a major machine vision function or an integration of multiple functions.

<u>Major Changes from the Previous Study</u>

Consisting of 21 different chapters to address a wide range of topics important to machine vision companies, this study is the result of a year-long undertaking to update and expand the prior study. Major changes from the previous study include:

- Latest, actual sales data and analysis for 2008
- New sales forecasts for 2009 - 2013
- Four-year area charts in Chapters 7 through 13 to detect trends on the product feature level
- New estimates of regional and world MV product markets (Chapter 3)
- 11 all-new chapters:
  - **Executive Summary** (Chapter 1)
  - **Worldwide Machine Vision Markets** (Chapter 3): This chapter was rewritten to address the loss of sales in the global and regional MV markets that result from the recession.
  - **North American Economies** (Chapter 4): This chapter was rewritten in response to the global recession. It contains forecasts and discusses the causes of the recession.
  - **North American Machine Vision Markets** (Chapter 6): A new summary of annual growth and market size of North American product markets is accompanied by a discussion of total MV financial transactions.
  - **Machine Vision in MEMS Production - New Market Opportunity Assessment** (Chapter 15)
  - **Machine Vision in Solar Cell Production - New Market Opportunity Assessment** (Chapter 16)
  - **The Argentine Machine Vision Market - New Market Opportunity Assessment** (Chapter 17)
  - **The Brazilian Machine Vision Market - New Market Opportunity Assessment** (Chapter 18)

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- **The Mexican Machine Vision Market - New Market Opportunity Assessment** (Chapter 19)
- **The Future of the Machine Vision Industry** (Chapter 20)
- **Conclusions** (Chapter 21)

1.3 Economic Overview

The current, global economic crisis began in the United States, where a subprime mortgage crisis led to a liquidity (a.k.a. credit) crisis. Facing insolvency, some major institutions - long pillars of the financial sector - collapsed, while others were kept afloat only by virtue of massive government bailouts. Despite bailouts, the Federal Reserve's lowering of interest rates, and other monetary actions, US banks have generally refrained from lending money to consumers and businesses, thus spreading the financial contagion to the rest of the US economy. With decreased consumer confidence and demand for products, domestic industrial production, as well as demand for imported goods, has greatly decreased. In response, the US government has attempted to jump start the economy with stimulus packages and large budgetary expenditures. (The efficacy of these measures remains to be seen.)

As the US's largest trading partner, Canada has followed the US into recession. With the worldwide reduction in commodity prices (most notably oil), Canada was no longer able to offset weakness in the manufacturing sector with strength in commodities. However, unlike the US, the financial sector in Canada has remained relatively healthy with Canadian banks, for the most part, having avoided the questionable lending practices of their American counterparts.

In Europe, however, the financial sector was not so prudent. Not only due to their exposure to the US subprime crisis but also to their risky lending practices, many European banks found themselves greatly over-leveraged and facing insolvency because of it. Massive bailouts and stimulus packages have become the order of the day, as a number of European countries (including the United Kingdom) have fallen into recession.

In Asia, the recession has also made itself felt. Japan, the world's second largest economy, has gone into recession, and even China, which once feared an over-heating of its economy, is now experiencing a slowdown. This has resulted from a sizeable reduction in exports, upon which both the Japanese and Chinese economies are heavily dependent. As other countries affected by the global recession, Japan and China have instituted a number of fiscal and monetary measures to boost their economies. Fortunately, unlike the US and Europe, Japan and China are sitting atop large reserves of foreign currency, which they can use to stimulate economic activity.

We believe that most of the world will remain mired in recession throughout 2009 and part of 2010. According to the forecasts of the International Monetary Fund (January 2009 Outlook) and the Organization for Economic Cooperation and Development (November 2008 view), a recovery will begin in the latter half of 2010. Forecasts for selected, major countries taken from the IMF and OECD views are shown in Exhibit 1.1. GDP (Gross Domestic Product) figures highlighted in yellow indicate recession; figures

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shown in the blue cells indicate recovery. As these figures show, North America, Europe and Japan are largely in recession in 2008 and 2009 but are expected to experience a mild recovery in 2010. China, by contrast, is not expected to enter into recession but instead undergo a slowdown. The IMF expects the world economy as a whole in 2009 to approach a virtual standstill. Importantly, we expect the recovery in MV sales to lag the economic recovery.

Exhibit 1.1: Annual Percent Change in Real GDP: 2007 - 2010

	2007 Actual	2008 IMF	2008 OECD	2009 IMF	2009 OECD	2010 IMF	2010 OECD
China	13.0	9.0	-	6.7	-	8.0	-
India	9.3	7.3	-	5.1	-	6.5	-
Japan	2.4	-0.3	0.5	-2.6	-0.1	0.6	0.6
Korea	5.0	4.1	4.2	3.5	2.7	-	4.4
UK	3.0	0.7	0.8	-2.8	-1.1	0.2	0.9
Germany	2.5	1.3	1.4	-2.5	-0.8	0.1	1.2
France	2.2	0.8	0.9	-1.9	-0.4	0.7	1.5
Italy	1.5	-0.6	-0.4	-2.1	-1.0	-0.1	0.8
Spain	3.7	1.2	1.3	-1.7	-0.9	-0.1	0.8
Euro Area	2.6	1.0	1.0	-2.0	-0.6	0.2	1.2
Canada	2.7	0.6	0.5	-1.2	-0.5	1.6	2.1
USA	2.0	1.1	1.4	-1.6	-0.9	1.6	1.6
Brazil	5.7	5.8	-	1.8	-	3.5	-
Mexico	3.2	1.8	1.9	-0.3	0.4	2.1	1.8
World	5.2	3.4	-	0.5	-	3.0	-

1.4 Worldwide and Regional MV Sales

In addition to North American sales, we also estimated 2008 - 2013 worldwide and regional MV sales in terms of total MV financial transactions, reflecting the effects of the global recession. (Note: Total MV financial transactions are the sum of total MV component sales, smart camera sales and ASMV system sales.) In doing so, we prepared three recessionary forecasts: best case, worse case, mid-range, and a base case forecast (a trend line forecast without recessionary impacts). Our mid-range forecast is shown in Exhibit 1.2.

Exhibit 1.2: Mid-Range Recessionary Forecast ($ Billions)

	North America	Europe & Israel	Asia Pacific	Rest of World	Total World
2008	$1.586	$1.881	$2.006	$0.275	$5.749
2009	$1.509	$1.902	$2.068	$0.288	$5.767
2010	$1.485	$2.070	$2.383	$0.315	$6.253
2011	$1.735	$2.216	$2.723	$0.341	$7.015
2012	$1.796	$2.301	$2.965	$0.361	$7.423
2013	$1.857	$2.373	$3.061	$0.372	$7.664

Reflected in this forecast are the estimated recessionary impacts shown in Exhibit 1.3. For the total world, we estimated that $297 million in sales, or 5.2 percent of total sales, was lost due to the recession in 2008. For 2009, we forecast losses at $616 million, or 10.7 percent of total sales, and for 2010 losses are expected to decline to $482 million, or 7.7 percent of total sales. No losses are predicted for 2011 through 2013 in keeping with the economic forecasts we used.

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Exhibit 1.3: Mid-Range Estimates of Recessionary Impacts ($ Billions)

	North America	Europe & Israel	Asia Pacific	Rest of World	Total World	Percent of World Sales Lost
2008	-$0.079	-$0.093	-$0.110	-$0.015	-$0.297	-5.2%
2009	-$0.209	-$0.156	-$0.233	-$0.018	-$0.616	-10.7%
2010	-$0.290	-$0.065	-$0.120	-$0.008	-$0.482	-7.7%
2011	$0.000	$0.000	$0.000	$0.000	$0.000	0.0%
2012	$0.000	$0.000	$0.000	$0.000	$0.000	0.0%
2013	$0.000	$0.000	$0.000	$0.000	$0.000	0.0%

Our forecasts of total MV financial transactions were based on forecasts of MV sales by individual product market by region that were prepared, employing a top-down estimation technique. For 2008, we sized the total world machine vision components market at $721.4 million, the worldwide smart camera market at $458.6 million and the worldwide ASMV systems market at $4,568.9 million. By 2013, we expect these worldwide markets to grow as follows: total components at $1,158.9 million, smart cameras at $668.8 million and ASMV systems at $5,835.8 million.

Our regional forecasts indicate that the Asian-Pacific market is largest at 34.9 percent of world markets in 2008. By comparison, the North American and European markets represent 27.6 and 32.7 percent. Because Asia-Pacific is expected to grow faster than Europe and North America, we forecast Asia-Pacific at 40.0 percent of world markets by 2013.

1.5 North American MV Product Markets

To determine MV market performance in North America, we were able to employ a bottom-up approach that relied upon survey-based data collection. This enabled us to determine MV sales results by individual machine vision product market in terms of units sold, sales revenue, their associated rates of growth and annual average unit prices. Exhibit 1.4 provides an overview of these results.

Based on our survey results, we assessed growth patterns for the various product markets and their typical rates of growth, as well as their underlying trend lines. These findings, which are summarized in Exhibit 1.4, show that machine vision product markets have been cyclical with noticeable peaks and declines, despite underlying linear growth. Generally speaking, 2002 and 2003 were not very good years for machine vision sales in North America, as indicated by negative rates of growth. This negative growth is largely attributable to the lagging effects of the 2001 recession in the US. By contrast, a different pattern has been evident since 2004, with machine vision sales generally exhibiting high rates of growth across product markets until 2007, when weaker growth re-emerged. Clearly, 2004 was a very strong recovery year for MV companies. In keeping with forecasts for the economy previously cited, 2011 should also be a good year.

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Exhibit 1.4: North American Machine Vision Product Markets - Actual and Forecast Sales Revenue ($ Millions), Units Sold and Average Unit Price

	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	
Optics	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**CAGR**
Revenue ($M)	$29.1	$26.1	$26.0	$28.7	$30.9	$31.6	$31.9	$32.1	-
%	-	-10.4%	-0.3%	10.4%	7.7%	2.1%	0.9%	0.7%	1.3%
Units				64,824	76,724	77,331	81,978	82,446.	-
%	-	-	-	-	18.4%	5.2%[e]	6.0%	0.6%	2.4%
Average Price	-	-	-	$443	$403	$408	$389	$389	-
Lighting	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**CAGR**
Revenue ($M)	$42.0	$36.5	$35.7	$34.1	$31.5	$29.3	$29.5	$31.2	-
%	-	-13.0%	-2.2%	-4.5%	-7.5%	-7.0%	0.7%	4.2%[e]	-2.2%
Units	44,800	50,250	52,100	66,621	72,333	81,594	80,570	82,860	-
%	-	12.2%	3.7%	27.9%	8.6%	12.8%	-1.3%	2.8%[e]	5.6%
Average Price	$936	$726	$685	$512	$436	$359	$366	$376	-
Camera	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**CAGR**
Revenue ($M)	$70.7[c]	$49.9	$53.4	$68.6	$75.6	$92.4	$93.2	$92.0	-
%	-	-29.4%	6.9%	28.5%	10.3%	16.8%[e]	0.9%	-1.3%	6.7%
Units	111,70	63,000	48,736	62,724	69,726	85,535	84,937	78,522	-
%	-	-43.6%	-22.6%	28.7%	11.2%	13.9%[e]	-0.7%	-7.6%	4.05
Average Price	$633	$792	$1,095	$1,093	$1,084	$1,081	$1,097	$1,171	-
Imaging Boards[a]	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**CAGR**
Revenue ($M)	$47.3[c]	$21.4	$26.5	$35.4	$28.6	$30.4	$30.5	$23.4	-
%	-	-54.8%	23.8%	33.6%	-19.2%	-10.8%[e]	0.3%	-23.3%	-9.9%
Units	30,365	17,117	15,133	22,012	27,538	35,153	38,783	28,991	-
%	-	-43.6%	-11.6%	45.5%	25.1%	7.8%[e]	10.3%	-25.2%	1.7%[e]
Average Price	$1,558	$1,250	$1,751	$1,608	$1,039	$852	$786	$806	-
Software	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**CAGR**
Revenue ($M)	$17.5	$16.3	$13.3	$18.3	$20.4	$21.0	$20.7	$20.3	-
%	-	-6.9%	-18.4%	37.6%	11.6%	2.8%	-1.4%	-1.9%	2.5%
Smart Cameras[b]	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**CAGR**
Revenue ($M)	$32.5	$40.9	$58.6	$86.7	$99.2	$114.2	$116.6	$126.5	-
%	-	25.8%	43.3%	48.0%	14.4%	15.2%	2.1%	8.5%	9.9%
Units	8,935	14,306	18,296	19,695	23,448	27,091	28,750	30,863	-
%	-	60.1%	27.9%	7.6%	19.1%	15.5%	6.1%	7.3%	11.9%
Average Price	-	$2,859	$3,203	$4,402	$4,231	$4,217	$4,055	$4,097	-
ASMV	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**CAGR**
Revenue ($M)	$1,203.9[c]	$1,038.1	$1,012.8	$1,108.6	$1,180.0	$1,215.3	$1,244.2[f]	$1,260.4	-
%	-	-13.8%	-2.4%	9.5%	6.4%	3.0%	2.4%[f]	1.3%	3.3%
Units	12,708[c]	5,752	6,566	7,667	8,710	9,319	9,683	9,806	-
%	-	-54.7%	14.2%	16.8%	13.6%	7.0%	3.9%	1.3%	6.3%
Average Price	-	$180,476	$154,249	$144,594	$135,475	$130,415	$127,347	$128,531	-

Note: Historical Period CAGRs are for 2003 to 2008

[a] Includes vision processor boards.
[b] Includes vision sensors and embedded vision processors.
[c] Outliers. Data points are atypical compared to historical time series.
[d] Excludes outlier in 2001.
[e] Growth rate adjusted for change in company mix.

Exhibit 1.4: North American Machine Vision Product Markets – Actual and Forecast Sales Revenue ($ Millions), Units Sold and Average Unit Price (Continued)

	Actual	Forecast	Forecast	Forecast	Forecast	Forecast	
Optics	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**CAGR**
Revenue ($M)	$32.1	$31.0	$30.4	$33.3	$33.7	$34.1	-
%	0.7%	-3.5%	-2.0%	9.7%	1.2%	1.2%	2.4%
Units	82,447	79,442	79,070	88,470	90,489	92,509	-
%	0.6%	-3.6%	-0.5%	11.9%	2.3%	2.2%	3.9%
Average Price	$389	$390	$384	$377	$373	$369	-
Lighting	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**CAGR**
Revenue ($M)	$31.2	$29.8	$30.0	$31.7	$33.4	$34.7	
%	5.7%	-4.4%	0.8%	5.6%	5.3%	4.0%	3.9%
Units	82,860	81,011	82,631	87,589	91,968	96,107	-
%	2.8%	-2.2%	2.0%	6.0%	5.0%	4.5%	4.4%
Average Price	$376	$368	$363	$362	$363	$361	-
Camera	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**CAGR**
Revenue ($M)	$92.0	$87.5	$85.7	$111.4	$126.1	$141.1	-
%	-1.3%	-4.8%	-2.1%	30.0%	13.1%	11.9%	12.7%
Units	78,522	72,295	68,513	88,222	100,216	112,629	-
%	-7.6%	-7.9%	-5.2%	28.8%	13.6%	12.4%	11.7%
Average Price	$1,171	$1,211	$1,251	$1,263	$1,258	$1,253	-
Imaging Boards[a]	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**CAGR**
Revenue ($M)	$23.4	$18.4	$17.5	$17.0	$16.8	$16.6	-
%	-23.3%	-21.1%	-5.1%	-2.8%	-1.3%	-1.0%	-2.6%
Units	28,991	24,378	24,770	26,109	27,894	29,321	-
%	-25.2%	-15.9%	1.6%	5.4%	6.8%	5.1%	4.7%
Average Price	$806	$756	$706	$651	$601	$566	-
Software	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**CAGR**
Revenue ($M)	$20.3	$19.7	$20.8	$21.9	$22.4	$22.9	-
%	-1.9%	-2.6%	5.4%	5.1%	2.4%	2.4%	3.8%
Smart Cameras[b]	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**CAGR**
Revenue ($M)	$126.5	$121.4	$129.4	$170.6	$182.6	$199.8	-
%	8.5%	-4.0%	6.6%	31.8%	7.0%	9.4%	13.3%
Units	30,863	29,379	31,790	41,110	46,290	53,196	-
%	7.3%	-4.8%	8.2%	29.3%	12.6%	14.9%	16.0%
Average Price	$4,097	$4,131	$4,070	$4,150	$3,945	$3,756	-
ASMV	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**CAGR**
Revenue ($M)	$1,260.4	$1,201.1	$1,171.1	$1,348.8	$1,381.3	$1,407.3	-
%	1.3%	-4.7%	-2.5%	15.2%	2.4%	1.9%	4.0%
Units	9,806	9,344	9,177	10,680	11,074	11,446	-
%	1.3%	-4.7%	-1.8%	16.4%	3.7%	3.4%	5.2%
Average Price	$128,531	$128,546	$127,605	$126,289	$124,735	$122,950	-

Note: CAGRs are for 2008 to 2012

[a] Includes vision processor boards. [b] Includes vision sensors and embedded vision processors.

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1.6 Conclusions

Based on our analysis of the economy, the survey results collected for this study and other supplementary information, we derived the following conclusions for the various product, geographic and industrial markets covered in this study.

1.6.1. Product Markets

Cameras

In last year's market study, we concluded that "(t)he typical portrait of an MV camera sold in North America today is that of a digital, area scan, monochrome camera with an IEEE-1394 interface and resolution higher than one megapixel." As shown in this year's study, that is still largely true for 2008 sales, except for a noticeable increase in analog cameras.

The effects of the recession are clearly evident in the data for 2008. Importantly, not only has the recession decreased total camera sales; it has also affected the mix of cameras sold. In hindsight, this is of course expected, since in a recession less funds are available for purchases and buyers must "trade down" (much like consumers) to stay within their means. Accordingly, cameras purchased in 2008 have been on average less advanced in technology and correspondingly of lower capability. This has meant at least a temporary interruption in some key trends. In previous studies, we found that MV cameras sold in North America were becoming increasingly digital and higher in resolution, more frequently used a Camera Link interface than previously and were more apt to use color instead of monochrome light than in prior years. But 2008 for the most part did not show a continuation of these trends. (Most revealing was the fact that for the first time in a long time analog sales exceeded digital sales.)

Since economic conditions are expected to worsen in most of 2009, a further departure from these trends is likely. Once economic conditions improve, however, sales data should show a return to these trends as well as healthier sales volumes.

With the recovery, camera sales will improve gradually in response to pent up demand, and the utilization of more advanced applications will once again drive demand for more sophisticated cameras that offer more advanced technological capabilities.

An important key to success is for MV camera suppliers to adjust their sales tactics to current economic realities but at the same time prepare to ramp up production of more sophisticated products, once the recovery is felt.

Imaging Boards

With the announced development of GigE Vision cameras, dire predictions about the fate of MV imaging boards were widely announced. According to these predictions, their demise was just a matter of time. To be sure, revenue from imaging board sales has markedly declined over time and is expected to decrease still further. However, only a portion of this downward trend can be ascribed to the introduction of GigE Vision cameras. For one thing, GigE Vision cameras have not yet achieved sufficient penetration to account for the large decline in imaging board revenue. For another thing, many imagining board manufacturers reacted peremptorily to the introduction of GigE

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Vision cameras by slashing their prices. Today, the average price of a GigE Vision camera and NIC is significantly higher than the average price of an analog camera with an included imaging board. Still, going forward, GigE Vision camera sales will increase, as will also IEEE-1394 camera sales and the sales of smart cameras, all of which do not use an imaging board. At the same time, some offset to the resultant loss in imaging boards will occur as a consequence of growing Camera Link sales. These cameras use relatively expensive imaging boards, but their sale will produce revenue that is insufficient to neutralize the imaging board revenue loss resulting from the sale of “frame-grabberless” cameras.

Against this backdrop, the economy is also taking its toll on imaging board sales. The effects of the North American recession are expected to extend from 2008 to 2010. Not until 2011 are sales expected to reflect the economic recovery forecast to begin in late 2010.

In response to the anticipated decline in imaging board sales, imaging board manufacturers might consider a three-prong strategy: continue to address the low-end of the market with analog boards, address the high-end with Camera Link boards and focus on creating higher-end USB, NICs and IEEE-1394 boards that have greater capabilities to support more demanding applications. If, in fact, the differences between these types of boards and imaging boards are eroding, why should not imaging board manufacturers take advantage of it? This is of course a question of fundamental strategy; or more specifically, a question of how the business is defined. Will imaging board manufacturers stay as such, or will they redefine themselves more broadly as board manufacturers?

Lighting

In last year’s study, we concluded that “(t)he MV lighting market will continue to experience significant change for a number of years to come.” That conclusion is even more valid today based on our findings for 2008. Long a contracting market, the MV lighting market appears to have found some new strength in 2008 - despite the recession which began in December of 2007 in the United States. That is truly remarkable and should be taken as a source of pride by lighting suppliers, should it turn out to be more than a “blip” in the data.

Responsible for the revenue growth in 2008 was not just an increase in units sold but also an increase in certain types of non-LED lighting. Accordingly, while we expect the share of LED sales to continue to grow, we also believe that other types of lighting will continue to serve important niches and therefore contribute to revenue growth and the general viability of the MV lighting market. Of course, only time will tell whether this is an accurate prediction.

Optics

The current recession also adversely affected MV optics sales in 2008, which are expected to remain weak in 2009 and 2010. 2011 is the first year in which optics sales are expected to reflect the recovery.

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Apart from economic impacts, no discontinuities or radical changes in the MV optics market are foreseen. The dynamics of the MV optics market will continue to be driven by the MV camera and lighting markets.

Because of the importance of optics to MV systems, and since camera and lighting developments drive changes in the development of optics products, cooperation and communication between lens makers, sensor manufacturers and lighting suppliers is essential to the viability of the machine vision industry. This communication and cooperation is particularly necessary in the area of standards and product development.

ASMV Systems

The ASMV systems market is very diverse, with applications varying greatly from industry to industry. Because the needs of users in different industries are highly dissimilar, the ASMV system builders that serve them tend to perceive little commonality and in many cases identify with the industry served and not with a greater ASMV system market. Not surprisingly then, demand for ASMV systems varies greatly across industries in accordance with their different dynamics. The performance of the printing industry, for example, has little direct relationship to the dynamics of the pharmaceutical industry.

Reflecting this fragmentation of end-user needs, perceptions and industry dynamics, ASMV systems manufacturers are forced to specialize in a limited number of applications that are in turn found in a limited number of industries. As a consequence, they tend to view themselves as participants in specific end-user industries, who incidentally use machine vision (along with other technologies), rather than as participants in a greater machine vision market.

As a consequence of this fragmentation, component suppliers, distributors and integrators who sell to ASMV system suppliers must understand the special needs of specific end-user industries - what ASMV systems suppliers must do to address these needs and not just the capabilities of their machine vision products.

Smart Cameras

The big surprise about smart cameras in 2008 was their rate of growth in total sales. In 2007, the rate of growth was anemic. Based on the repeated, downward revisions of economic forecasts for 2008, there was every reason to believe that smart camera sales in that year would be even weaker than in 2007. But that is not what happened; the 2008 rate of growth was stronger than forecast. As a consequence of this, we have revised upward our longer-term sales forecast for this study. To be sure, we still expect a lower rate of growth in 2009 than in 2008, but according to our forecast that growth rate should nevertheless be relatively healthy, in comparison to rates of growth of other MV product markets.

Of course, many unforeseen events could occur between now and the end of 2009 that would depress demand for smart camera products below our expectations. But if any MV product market is to do relatively well in 2009, it is smart cameras.

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Software
Beyond its functional role as an essential component of any MV system, third-party MV software also plays an important marketing role for a MV system provider. It represents an important means of adding value to, and differentiating an MV system from, other MV systems. An MV software package that has a wide array of image processing and analysis capabilities, while providing a choice between a graphical interface for user-friendliness and code-based programming for versatility, is particularly valuable and can be targeted to multiple market segments. If users can purchase the package on a module-by-module basis to save money, it is additionally valuable.

Going forward, third-party MV software will continue its important functional and marketing roles. At the same time, it will evolve in response to the needs of MV system builders and to the evolution of operating systems and computer hardware. The developmental direction of processors will be of particular importance in this regard.

3D Machine Vision
The future of 3D machine vision is bright. 3D MV systems have demonstrated their capabilities and serve a number of important applications. The performance of 3D MV systems has moreover improved; however, additional progress is needed in reducing costs and increasing user friendliness. As this progress is made, the value proposition of 3D machine vision will increase and with it the extent of market penetration. When this occurs, 3D MV products will no longer be niche offerings but instead very much “main stream” in the overall ASMV market.

1.6.2 Geographic Markets
In addition to focusing on worldwide, regional and North American product markets, this study focused on important country-specific MV markets in Latin America in search of new market opportunities.

The Argentine Machine Vision Market
Market opportunities await MV companies in Argentina, but they are largely long-term, and MV companies should proceed cautiously in realizing them. This would involve considerable due diligence, including analysis of specific industry sectors and geographic locations, evaluation of distributor candidates, and the development of an extensive web of business relationships. The quickest and least risky way to enter the market is to work through domestically-based, knowledgeable distributors who have been properly vetted.

Given the importance of meat packaging and the food and beverage industry in general, MV companies offering systems that inspect meat and other types of food, packaging and bottling are the first, logical candidates for a successful market entry.

Their success is more likely today, given the increased stability of the economic environment and robust economic growth that is projected to continue. While the economy in aggregate - and industrial production more specifically - paint a favorable picture currently, it is important, however, not to lose sight of the possibility of a

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recurrence of economic instability and obstacles (such as corruption), which necessitate a measure of caution.

The Brazilian Machine Vision Market

Brazil is a large and modernizing nation that seeks to become a manufacturing powerhouse on the world stage. Much progress has been made in this regard as the consequence of substantial Foreign Direct Investment (FDI) and the presence of large manufacturers in country.

Likely candidates for adoption of machine vision are the largest companies serving those industries for which MV applications have been developed; in particular, automotive, the food and beverage, pharmaceutical and metal and electronics industries.

MV companies are already targeting businesses operating in these and other sectors. For the most part, the MV products being sold into the Brazilian market are not Brazilian but rather foreign in origin. Indigenous MV manufacturers are largely non-existent.
All in all, the market opportunities for foreign suppliers of MV products appear limited. Direct exporting is very difficult due to the challenges of complying with a complicated import regime. That necessitates the use of domestic distributors, who - as the gatekeepers to the Brazilian market - must add sales fees to the already steep import taxes imposed on MV products. This results in high prices for MV products, which of course cut into margins and limit customer demand. Both factors thus constrict market opportunity.

The way around this problem for foreign MV manufacturers might be to set up production facilities in country, but - as previously mentioned - this is an expensive strategy that requires deep pockets. Finding a Brazilian partner with sufficient capital might be the solution, however. Brazilian MV distributors might also elect this approach, raising capital to set up production facilities; that is, vertically integrating in order to replace expensive foreign MV products with lower cost, domestically produced MV products.

However the obstacles to greater adoption of MV technology are surmounted, one thing is clear. If Brazil is to become a world class exporter of manufactured goods, it will have to achieve cost efficiencies, productivity and quality control in manufacturing, which will bode well for machine vision. The greater question is how will that demand be met and what strategy will enable which MV companies to realize the greatest market opportunity.

The Mexican Machine Vision Market

The Mexican government has pursued a trade-friendly policy, making it easier to do business in Mexico. Highly protectionist trade barriers are generally not in evidence and in this fundamental respect, Mexico is much different than Brazil. Market opportunities for machine vision companies exist in Mexico. However, they are long-term in nature and should mature, as Mexican companies increasingly embrace a new “culture of quality”. MV companies should therefore expect to spend considerable time building production capabilities or distributor networks in place of instant, “slam dunk” sales. A

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valuable sales approach might be to focus on small, entry projects that can be used to build knowledge about, and confidence in, machine vision as an enabler of efficiency, productivity and quality in manufacturing operations.

1.6.3 New Industrial Markets

Since new market opportunities are related to not only geographic but also industrial markets, this study has also examined two promising industrial markets, MEMS and solar cell/panel production.

Machine Vision in MEMS Production

The market opportunity for MV companies that serve the MEMS industry is potentially large by virtue of the market growth that the MEMS industry is expected to enjoy. This growth will be driven by the increasing emergence and market acceptance of indispensable "smart" products that utilize embedded MEMS devices. There appears, however, to be a "Catch 22". For MV companies to grow MEMS related sales, they must know what kind of MEMS fabrication processes to support, since the MEMS industry is highly diverse in terms of production techniques, materials and applications. This means that MEMS companies must first make strategic choices and invest accordingly on a large scale. It specifically requires the selection of fabrication techniques, materials and the establishment of standards to reduce market ambiguity. However, the efficacy of the selected production processes will also largely depend upon the capability to assure product quality through fast, efficient and accurate inspection, since without that capability, MEMS production costs, production cycles and time to market would unavoidably suffer. In short, to achieve the production efficiencies needed for mass market product introductions, machine vision must first be incorporated in MEMS production. So what will come first? A wider deployment of machine vision in MEMS production, or the strategic investments of MEMS manufacturers? Or perhaps a different scenario will occur, such as a series of reciprocating, reinforcing steps, with leading players in the MV and MEMS industries gradually ramping up their strategic commitments to cooperate.

Regardless of which scenario plays out, it would appear that the interdependence of MEMS manufacturers and MV companies needs a wider perception, followed by dialog to better identify opportunities for cooperation. With the establishment of working relationships across industries, synergies could well emerge that are mutually beneficial, resulting in sizeable market opportunities for both industries. If MEMS is the wave of the future, then the chances are that MV companies will be riding it.

Machine Vision in Solar Cell Production

The demand for alternative energy will continue to drive solar cell and panel sales at impressive double-digit rates. This is very good news for the machine vision industry, particularly since current levels of solar cell and panel production lag demand, and machine vision offers a much needed productivity boost. As we have seen, several MV companies are positioning themselves to ride the wave of the solar cell industry. With further tweaking of MV applications used in the semiconductor industry, a still greater

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market opportunity might emerge for a larger cross-section of the machine vision industry.

1.7 The Future of Machine Vision

The MV industry is poised for a bright future. While the effects of the business cycle are ever present, resulting in short-term fluctuations in demand, no less than four growth paths will propel MV sales upwards in the long-term. These growth paths are the increasing value of MV products; the role machine vision will play in the "factory of the future"; the penetration of MV technology into non-traditional, non-industrial sectors of the economy and increased reliance on MV technology as an enabler of economic modernization in developing countries. The deployment of MV technology will thus expand geographically to developing countries, and within developed countries its acceptance will increase in economic sectors currently served by it, while spreading to additional, non-traditional sectors. As a consequence of this four-front expansion, the MV industry as a whole will achieve impressive growth.

The evolution of the factory will affect machine vision in a number of ways, as outlined in the following predictions:

- *Prediction 1*: MV companies will play an increasingly important role in supporting the automated production processes of the factory of the future (particularly in the case of vision-guided robotics).
- *Prediction 2*: MV companies will increasingly have to position/market their products in support of factory-of-the-future work flows and production processes.
- *Prediction 3:* MV companies will increasingly rely on factory-of-the-future principles for the manufacture of their own products.
- *Prediction 4:* MV companies will increasingly utilize mass customization to address a wide array of applications in support of individual customer needs.
- *Prediction 5*: MV companies will be able to utilize mass customization only after component interoperability is achieved through standardization. Standardization is essential!!! MV industry must achieve the degree of interoperability achieved by the PC industry.
- *Prediction 6:* Customer ordering of MV systems will be Internet-driven but carefully structured given the complexity of MV systems.
- *Prediction 7:* System integration will be performed almost exclusively by larger system builders once interoperability is achieved. Small system integrators will decrease in numbers.
- *Prediction 8:* Consortiums of MV component suppliers will emerge and will be strategically linked and dedicated to large MV system builders. (This is the concept of "business ecology" or "business eco-system", an example of which would be Microsoft and its partners.)

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While the factory will continue into the future as an important focal point for the MV industry, it will not be the only source of market opportunity. MV technology will increasingly expand beyond the factory to other, non-manufacturing sectors of the economy with a wide array of new applications.

The future of the MV industry will also be affected by the dispersion of MV technology in developing countries, where it will serve as an enabler of economic modernization. Initially, these countries will enjoy a lower cost advantage in the global economy based on inexpensive labor. However, it will be increasingly hard to sustain that competitive advantage, as consumers in the global economy demand not just low commodity prices but also high product quality. To achieve both objectives, developing nations will have to automate production, and as part of this overall modernization, deploy machine vision as a critical means of establishing quality control.

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Chapter 2: Report Overview

2.0 What's New in this Chapter?

- 2.1 Introduction
- 2.2 The Theme of this Year's Study
- 2.4 How to Get More Value Out of this Study
- 2.8 Major Differences from the Previous AIA Market Study

2.1 Introduction

We provide in this chapter an overview of the study in terms of its general organization, purpose, scope, methodology and major changes from the 2008 study. To facilitate the understanding and interpretation of study results, we also explain key concepts.

This 2009 study is based on 2008 actual results. As in previous AIA market studies, it is organized primarily around the major machine vision (MV) product markets: optics, lighting, cameras, imaging boards, smart cameras and application-specific machine vision (ASMV) systems. A separate chapter is dedicated to each product market, comprising Chapters 7 through 13. Each of these chapters consists of four parts: an introduction, survey results, a summary of major findings and conclusions.

We have expanded this study to provide readers with additional value; the study consists of 21 chapters, beginning with an Executive Summary (Chapter 1) and ending with a summary of major findings and a set of major conclusions (Chapter 21). An appendix provides supplemental information, including a glossary of key words.

2.2 The Theme of this Year's Study

The theme of this year's study is new market opportunities in Latin America and in emergent, high-tech industries. We analyze these market opportunities and current MV product markets in the context of an increasingly challenging economy. No less than five "new market opportunity assessment" chapters are contained in this study. We hope that MV companies will be able to exploit these market opportunities and in so doing blunt the impacts of the current recession.

2.3 Purpose and Scope

The primary purpose of this market study is sales maximization through market

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intelligence, or simply said, to help machine vision companies sell their products. In support of this purpose, this study is intended as a valuable input into the sales tactics and strategies of machine vision companies. Therefore, it is designed not just as a barometer of market conditions for the MV industry in North America and the world, but also as a compendium of well-organized and clearly analyzed, actionable market intelligence that - once included in a *market plan* - will drive successful sales decisions. Of course, actionability presupposes specificity, and specificity in turn requires depth and breadth. That accounts for the wide-ranging focus of this study and its data-richness. In place of this sales-centric approach, the collection of industry statistics would have been far easier and less resource-intensive, but it would offer little guidance in sales-related decision-making.

2.4. How to Get More Value Out of this Study

As pointed out in our article appearing on Machine Vision Online, "How to Use Market Intelligence in Sales Decisions", there are at least six generic ways in which companies can use market intelligence to boost their sales efforts:

1. **Validation of Market Assumptions:** Best-of-breed companies don't simply make assumptions about the market; they test them with market data. Over the course of time, it is easy for an institutional, self-reinforcing mindset to develop that is based on conjecture, outdated findings about the market and/or a limited, unrepresentative set of customer interactions. Consulting fresh market intelligence allows companies to avoid this pitfall.

2. **Product Development:** Companies with successful products are not inward-directed but instead outward-focused. Specifically, they look to market intelligence to learn about customer needs and use that as the basis for product development. In this way, they are able to avoid a "field of dreams" approach ("If we build it, they will come") where product development is based mainly on internal engineering capabilities.

3. **Market Direction/Trend Analysis:** Failure to consider the direction in which the market is evolving can result in the obsolescence of a company's products. To avoid being left by the wayside, companies therefore use market intelligence to learn the market's direction. Specifically, they use market intelligence to understand major trends and align their actions accordingly.

4. **Sales Strategies and Tactics:** In best-of-breed companies, market intelligence is a major input to the sales strategies and tactics of the market plan. Market intelligence plays an important role in defining market targets and setting parameters for pricing, packaging and promoting products. It can therefore help answer important questions such as, "What market should we be in?" "What segment should we target?" "How should/can we differentiate our products?" and "How should we position them in the marketplace?"

5. **Performance Benchmarking:** Well-run companies also want to know how their sales performance (in terms of volumes and growth) compares to the market as a whole. They use market intelligence to form benchmarks, against which they can determine whether they are leading the market or falling behind. (Comparative growth rates and company market share are two commonly used metrics.)

6. **Market Opportunities:** Because the best-run companies are by definition strongly growth-oriented, they are always on the lookout for new market opportunities. Market intelligence can uncover these opportunities by identifying under-served areas in the current market, new markets for existing products and new products that can open up new markets. These new opportunities

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can involve product extensions, repackaging and/or repositioning of current products, new geographic markets and altogether new products.

As these applications illustrate, market intelligence boosts sales success by minimizing market uncertainty.

In a separate article appearing in "Kellett's Corner", we also explained the specific ways in which machine vision companies can use this market study to increase sales. These ways relate to market players, market size, market growth, market direction, market opportunities, product features and economic environments. We believe a quick review of these specific uses will help the reader to get the most out of this study.

1. Market Players

This AIA market study identifies the major companies vying for sales in specific product markets. By definition, these are the competitors that your company must face when selling your products. Their products are the competitive substitutes that a potential customer will compare to your products. Knowing their identities gives you a better idea of what you're up against when you attempt to influence the purchase decision of potential customers. Additionally, knowing the number and relative size of other market players provides insights into the degree of market rivalry and the degree of resources that must be expended to achieve sales success in that market. This information thus can serve as a starting point for the competitive analysis conducted by a company. (Note: AIA itself does not perform competitive analysis, since the AIA Non-Disclosure Agreement bars the release of company-specific information.)

The ***uses*** for this specific information are therefore:

- Identification of competitors as a starting point for competitive analysis
- Determining the extent of market rivalry
- Assessing the extent of resources needed for gaining/retaining customers
- Assessing the costs/risks of market entry in markets where your company is not yet a participant
- Assessing the cost avoidance of market exit, where your company is a participant

The ***questions*** this information can help answer are:

- Who are my competitors in this market?
- Is there significant competition in this market?
- Will I require a lot of resources to achieve sales in this market?
- Is it worth entering or staying in this market?

The ***decisions*** this information will influence are:

- Amount of sales resources worth expending in the market
- Market entry or exit

2. Market Size

The AIA market study also sizes individual product markets. This involves quantifying the aggregate sales in the market during a specific time period, an important market descriptor. With this information, you can assess the overall sales opportunity represented by the market. You can also compare market size over time to assess relative market health. Additionally, the size of different product markets can be compared to determine the relative sales opportunity associated with different product categories. A comparison of total market size to your company sales (where the latter is the numerator and the former the denominator in a ratio calculation) will tell you your company's market share (assuming the same point in time and the same types of products). This can tell you whether you're a market leader or follower and thus whether you

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have market power to dictate prices for the market. By looking at market share over time, you can also judge the effectiveness of your sales campaigns over time. Should you find that your company has lost share, then you'll know to take corrective action before your share further erodes. (As this illustrates, data on market size by itself does not provide specific, tactical guidance on how to sell products, but combined with other types of market information, it provides an overall understanding of the market, which supports a successful sales plan.)

The ***uses*** for this specific information are therefore:

- Determining overall sales opportunity
- Comparing the sales opportunities associated with different product categories
- Assessing relative market health, when comparisons are made over time
- Assessing your company's relative market power based on market share
- Judging the effectiveness of sales efforts over time and whether changes are needed

The ***questions*** this information can help answer are:

- How large is the overall sales opportunity of the market?
- How does the sales opportunity of the market compare with that of other markets?
- How healthy is the market?
- How much market power does our company have?
- Have your sales efforts been successful or should they be changed?

The ***decisions*** this information will influence are:

- Adequacy of the sales opportunity in the market
- Whether to enter, exit or stay in the market
- Acting as the price leader or setting company prices based on other companies' prices
- Changing or keeping current sales strategies and tactics

3. Market Growth

In the AIA market study, market growth is calculated by comparing market size at two points in time. (Market size for one year is simply divided by market size for the preceding year and expressed as a percentage. This is done for both units sold and revenue.) You can use market growth data as a means of assessing the health of the market as well as an additional benchmark for assessing your company's performance.

The ***uses*** for this specific information are therefore:

- Assessing market health and performance
- Comparing overall market growth to a company's growth to determine whether the company has over or under-performed the market

The ***questions*** this information can help answer are:

- Is the market growing, contracting or staying flat? (Is the market healthy or weak?)
- Is this a good market to be in (in terms of expected sales volumes) going forward?

The ***decisions*** this information will influence are:

- Entering, exiting or staying in the market
- Changing or maintaining sales strategies and tactics

4. Market Direction

"Market direction" refers to the direction in which the market is evolving. It is determined by trend analysis; that is, an ascertainment of dominant marketing or technological trends that are shaping the market. These trends can pertain to a wide range of developments, such as pricing trends, the emergence of new products, technologies and applications, growing demand for products with certain features, changing customer preferences, etc. Companies monitor market direction to keep pace with the market and prevent product obsolescence.

The ***uses*** for this specific information are therefore:

- Avoiding product obsolescence
- Inferring/predicting changing customer preferences
- Aligning the company with changes in market direction

The ***questions*** this information can help answer are:

- Are our products becoming obsolete?
- Is our product development, and are our sales strategies and tactics, aligned to the direction of the market?

The ***decisions*** this information will influence are:

- Product development decisions
- Revising or maintaining current sales strategies and tactics

5. Market Opportunities
The AIA market study focuses on market opportunities primarily in terms of extending MV technology to new industries and targeting new geographic markets with current types of MV products.

The ***uses*** for this specific information are therefore:

- Understanding the potential for new sales
- Assessing the obstacles to, and the costs of, realizing the market opportunity
- Comparing different approaches to market entry, where the opportunity can be realized

The ***questions*** this information can help answer are:

- Is the potential market worth targeting?
- Are the obstacles too large to justify market entry?
- What are the success drivers? What must we do to achieve the market opportunity?
- What’s the best way to enter the geographic or industry-defined market in order to maximize market opportunity?

The ***decisions*** this information will influence are:

- “Go/no go” decision re: market entry
- Means of market entry (assuming a “go” decision)

6. Product Features
The AIA market study breaks down product sales by product type and within product type by product feature. From this, you can infer current and past customer preferences for specific product features. (This approach is far more economical than querying thousands of potential customers.) Where product trends are revealed at the feature level, you can also predict the direction of change in customer preferences by means of simple extrapolation. This information can represent an important input into product development decisions.

The ***uses*** for this specific information are therefore:

- Assessing relative customer demand for alternative product features
- Assessing trends in product features

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- Predicting future demand for specific product features

The ***questions*** this information can help answer are:

- What product features are the best sellers?
- What product features are growing in popularity among customers?
- What features should our new products have?

The ***decisions*** this information will influence are:

- Product development

6. Economic Environments
As we all know, the selling process occurs in an economic context – not in a vacuum. In good economic times, customers have a greater ability to purchase MV products. In bad economic times, they conversely cut back on their capital expenditures in order to maintain sufficient liquidity. For that reason, the AIA market study carefully examines the economic context, taking it into consideration when predicting future product sales, market size and market growth.

The ***uses*** for this specific information are therefore:

- Understanding the probable impacts of the economy on sales

The ***questions*** this information can help answer are:

- Will the economy significantly affect sales volumes? If so, how?

The ***decisions*** this information will influence are:

- Should we budget more or less sales expense?
- Should we manufacture more or less products?

Importantly, MV companies should have a well thought out market plan (including sales strategies and tactics) and use the market intelligence of the study as a major input to the plan. Of course, no one piece of market intelligence should drive sales decisions; instead, MV companies should base decisions on a wide range of information extracted from both the study and other sources. The fundamental marketing objective of all MV companies should be to have an accurate, coherent view of the market and, based on that, a solid plan of attack for maximizing sales.

2.5 The Intended Audience for this Study

In accordance with the purpose of this study, the primary audience of this study is MV sales and marketing personnel (both machine vision subject matter experts and industry members seeking knowledge outside their particular product market). A secondary audience is comprised of all interested parties outside the industry, such as the investment community, who seek an overall knowledge of the performance of the machine vision industry in North America.

2.6 The Scope of this Study

The scope of this study can be delineated several ways.

- Geography: The study focuses primarily on North America. In Chapter 3, however, we present some regional and worldwide estimates of product market sizes. In Chapters 17, 18 and 19 we also examine the Argentine, Brazilian and Mexican MV markets.

- Time Period: The major focus is 2008 with historical data included where possible for the 2004 to 2007 period. The forecast period of the study is 2009 through 2013.
- Definition of Machine Vision: Since the scope of this study is also largely a function of what the term "machine vision" encompasses, it is essential to define this key term. **By "machine vision" we mean all industrial and non-industrial applications where a combination of hardware and software provide operational guidance to devices in the execution of their functions based on the capture and processing of images.** Typically, this involves *lighting* to render visible the object to be imaged; *optics* to focus the image of the object; a *camera* to "see" the image; an imaging board to capture the image from the camera and convert it into data; and lastly *software* that is used to manipulate the digitized image to optimize operational decision-making. It is important to note that according to our definition machine vision is not limited to the factory floor but instead extends to new, innovative applications, which broadens the scope of what has been traditionally referred to as machine vision. Despite this, it must nevertheless be noted that most data collected for the study still represent a traditional, factory-oriented definition. It is expected that - as the machine vision industry increasingly broadens the scope of its activities - the operational definition of machine vision will correspondingly evolve with members of AIA and the MV industry at large arriving at a consensus.
- Market Players: The scope of this study can be further defined in terms of the type of market players from which data are collected.

Types of Market Players Included:	**Types of Market Players Excluded:**
■ Component Suppliers ■ Smart Camera Suppliers ■ ASMV System Suppliers	■ Subcomponent Suppliers ■ OEMs ■ Integrators ■ Distributors/ Resellers/VARs

Eventually, we would like to broaden the scope of this study to include integrators. (Thus far, the number of system integrators willing to participate in data collection has not made this possible.)

- Product Markets and Types of Units Sold: The scope of this study is also demarcated in terms of specific product markets, which are as follows:

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Product Markets	Type of Units Sold
Components	
■ Optics……………………………….>	■ Lenses (multi-element optical devices)
■ Lighting (or Illumination)………….>	■ Single lighting configurations
■ Cameras…………………………….>	■ Cameras including board-level cameras
■ Imaging Boards……………………..>	■ Frame grabbers and vision processors
■ Software…………………………….>	■ Software packages
Integrated MV Equipment	
■ Smart Cameras……………………...>	■ Smart cameras, embedded vision processors and vision sensors
■ Application-Specific MV Systems…>	■ Individual ASMV systems

As shown above, there is not a single North America machine vision market but rather multiple markets that correspond to major product categories, each of which represents a major machine vision function - as previously described - or an integration of multiple functions.

It should be noted that there are two major types of product markets: *components* and *integrated MV equipment*. The latter type of market is distinguished from the former by the fact it is comprised of MV equipment sales that in every case consist of more than one type of component or the functions performed by components.

A few additional, definitional notes are in order regarding the major product categories:

1) *Vision processor boards* are included with *frame grabbers* in the definition of the imaging board market, since they are in effect high-end frame grabbers characterized by their ability to perform two or more complex functions. (Lower-end MV frame grabbers perform less than two complex functions.) Both are considered “imaging boards”.
2) *Vision sensors* are included with *smart cameras*, because - based on the use of this term in the industry - they are either low-end smart cameras or simply another term for smart camera. Also included with smart cameras are *embedded vision processors*, because they have the same functionality as smart cameras and differ only in terms of their form factor. (Instead of consisting of a single, self-contained unit, they involve a camera tethered to a box in which the computational power resides.) For more definitions used in this study, please refer to the glossary of key machine vision terms found in the appendix.
3) The size of product categories is measured in terms of the number of units sold and the associated sales revenue.
4) The machine vision markets of North America that correspond to the major product categories we have identified are also operationally defined in terms of the companies that sell the units and generate the corresponding revenue that are used to measure

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market size. In almost every case, these companies are those major market participants identified in previous AIA market studies.

5) The size of a single, all encompassing machine vision market cannot be derived by adding up sales revenue or units for all of the major product categories. This would result in double-counting component sales, since by definition integrated MV equipment contains two or more components. Thus, we avoid referring to a single machine vision market except in the geographic sense, when we distinguish between different world regions. At the same time, it is perfectly acceptable to add the sales of all major product categories to measure the total MV-related economic activity within a geographic market; however, this falls outside the purpose and scope of a market study.

6) As in past studies, we distinguish between the terms "*market*" and "*industry*" where the former denotes all the sales occurring in a specified geographic area regardless of the origin of the companies recording the sales, and where the latter includes the total worldwide sales of the companies resident within the geographic area (that is, the in-region and out-of-region sales of companies based within the region).

Market Perspective

Sales Included: All in-region sales regardless of the national origin of companies making the sales.

Example (Sales in $M)

Company	NA	Europe	Asia	Other	Total
"A*"	10	5	3	2	20
"B*"	7	15	4	1	27
"C"	5	6	7	8	26
	22	26	14	11	73

NA _market_ equals $22 million

*Companies headquartered in N.A.

Industry Perspective

Sales Included: All worldwide sales of companies with headquarters located in the same region.

. **Example (Sales in $M)**

Company	NA	Europe	Asia	Other	Total
"A*"	10	5	3	2	20
"B*"	7	15	4	1	27
"C"	5	6	7	8	26
	22	26	14	11	73

NA _industry_ equals $47 million

*Companies headquartered in N.A.

In this study, we focus primarily on the market, since our charge is to complete a market study. However, in Chapter 5 we estimate the North American industry in order to form a basis for eventual comparison with industry-oriented studies such as the study prepared by the European Machine Vision Association (EMVA).

2.7 Methodological Overview

The methodology employed in this study is essentially identical to that of the 2008 study and therefore reflects the following parameters:

- Data Sources: Study data is obtained primarily from our market surveys. Where we could not directly obtain data on specific machine vision companies because of their refusal to participate, we utilized company profiles from the Dun & Bradstreet database. In the case of larger, publicly traded companies that did not

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participate in data collection, we extracted data from their financial reports and used estimation techniques to fill in gaps in the available data.

- Data Collection Tools: We designed and updated market surveys for three specific purposes: to render them more user-friendly, more secure and to capture more product detail designated as essential by subject matter experts. Based on Microsoft Excel, the market surveys reflect the input and advice of subject matter experts in all major product categories. In early November we distributed the surveys to company contacts in machine vision companies. Upon receiving completed surveys, we safeguarded all company-specific data pursuant to the stringent provisions of our AIA Non-Disclosure agreement (NDA).
- Treatment of Excluded Sales Categories: Where a company derived part of its machine vision revenue by acting as a distributor, reseller, original equipment manufacturer (OEM) or system integrator, we asked that company to identify that portion, which was excluded from data collection.
- Treatment of Cases Where Companies are Active in More than One Product Market: In our surveys, we asked companies to report revenue for all product markets in which they were active even though the survey submitted to the company pertained to one single product market. This allowed us to capture all product market revenue instead of allowing it to "fall between the cracks". For example, our practice is to send an optics market survey to companies that are primarily involved in the manufacture and sale of MV optics products. However, some of these companies might also manufacture a limited selection of lighting products. To avoid losing track of that lighting revenue, we ask those optics companies to also identify that revenue on the optics survey. That data is then included in the calculation of total sales for lighting.
- Forecasting: We based our forecasts on our professional judgment reflecting primarily the underlying trend line of a historical time series modified by economic assumptions, recent rates of growth and growth estimates of companies submitting data. In ascertaining a trend line we take into consideration "outliers", data points lying well outside the fitted line that best minimizes variance. Our trend extrapolation technique involves the calculation of composite annual growth rates (CAGR) where CAGR equals ((End Value/Start Value)^(1/(Periods - 1)) -1 . However, we cannot simply assume that each annual sales volume for the forecast period will grow at the historical CAGR, since that mathematically by definition would assume an exponential trend line, and there is no evidence that MV revenue and units sold have grown exponentially or will do so suddenly going forward. A more linear-shaped curve must therefore be imposed on the forecast trend line to avoid over-stating forecast amounts. In doing so, revenue and units sold must be forecast together in order to avoid a distortion of their relationship, which we ascertain based on historical data. Once we determine the basic forecast trend line, we must then impose economic assumptions upon the trend line for those years where the business cycle is expected to reflect an economic slowdown or recession. (To not do so would be to again risk a gross over-statement of sales results.) To increase the accuracy of this procedure, we use a consensual economic forecast as shown in Chapter 4. We perform this imposition of economic assumptions primarily qualitatively in the absence of a sufficient

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data sample size required to perform statistical forecasts, such as those based on a structural equation model where revenue or units sold comprise the dependent variable and economic variables the independent variables (or "regressors" in the case of regression). Unfortunately, our data goes back only to 2001, which means that we have only a sample size of seven. With such a small sample size it is not possible to satisfy the assumptions upon which statistical forecasting techniques are based. Consequently, problems such as "restricted range" problems and the inability to achieve statistical significance (where each regressor exhausts a degree of freedom) become unavoidable. The solution to these problems would be to have quarterly data collections (which would increase the number of data points going forward by a factor of four) but it is questionable as to whether MV companies would be willing to assume such a burden. In all likelihood, quarterly data collection would entail a pronounced deterioration in the participation rate of companies in data collection. Accordingly, we are forced to operate within the constraints of the data.

Finally, it should also be noted that we based our forecast of imaging boards on our camera forecast.

- Data Verification: We compared company-specific data for 2008 to corresponding data for earlier years. Where these company-specific comparisons turned up possible anomalies, the companies were contacted to obtain an explanation and adjustments were made as appropriate.
- Key Methodological Challenges in Preparing this Study Involved the Following: We faced a number of severe methodological challenges in preparing this study:
  - Considerable data constraints limiting our analytical and forecasting techniques as previously noted
  - Obtaining the participation of key companies in data collection
  - Data gaps managed through data estimation techniques where necessary
  - Verifying data as pure machine vision as opposed to data containing sales for non-machine vision use. This challenge derived from the fact that various types of components, such as cameras, lighting and optics, have multiple applications, only one of which is machine vision. In many cases, participating companies do not have perfect knowledge of the end-users of their products and thus the uses to which their products are applied. The distribution channels for their products can be varied and complex with multiple layers of intermediaries (distributors, resellers, OEMs and system integrators) that obscure the identities of end-users. Consequently, participating companies must use their best judgment in estimating the percent of their sales used in machine vision. In some cases, this estimation is not problematic, because products are positioned and/or labeled as machine vision products. However, these cases tend to be the exception and not the rule.
- Comparison of Studies: It should be noted that not all market study results are comparable. In addition to different definitions, categories, data collection

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procedures and assumptions, machine vision studies can fundamentally differ in terms of study type. For example, MV studies prepared by the European Machine Vision Association (EMVA) and the Japanese Industrial Imaging Association (JIIA) are *industry* studies and as such cannot be directly compared to the *market* study of AIA, as that would involve a comparison of apples to oranges. Going forward, AIA hopes to bridge this gap by preparing some industry data within the body of its market study. AIA believes that methodological harmonization aiming at the comparability of data across regions is an important objective and welcomes the cooperation of other MV trade associations in this regard.

2.8. Major Differences from the Previous AIA Market Study

The 2009 study contains a number of significant changes from the 2008 study. These changes were made to stay current with market developments and to continuously improve the depth and breadth of our market intelligence in response to the needs of AIA members and the MV industry as a whole. These changes are:

- Up-to-date findings and conclusions based on the latest actual data for 2008
- New estimates of regional and world MV product markets (Chapter 3) based on an enhanced estimation technique
- An all-new chapter on North American economies (Chapter 4) addressing the causes and impacts of the economic recession
- An updated chapter summarizing annual growth and market size for North American product markets (Chapter 6)
- Four-year area charts in Chapters 7 through 13 that better enable us to detect possible trends on the product feature level
- A separate chapter dedicated to 3D machine vision (Chapter 14)
- An all-new chapter on machine vision in MEMS production, a new market opportunity assessment (Chapter 15)
- An all-new chapter on machine vision in solar cell production, a new market opportunity assessment (Chapter 16)
- An all-new chapter on the Argentine MV market (Chapter 17), a new market opportunity assessment
- An all-new chapter on the Brazilian MV market, a new market opportunity assessment (Chapter 18)
- An all-new chapter on the Mexican MV market, a new market opportunity assessment (Chapter 19)
- An all-new Executive Summary (Chapter 1)

Having explained the general organization, purpose, scope, methodology and major changes of this study, we next turn to an overview of worldwide machine vision markets.

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Chapter 3: Worldwide Machine Vision Markets

3.0 What's New in this Chapter?

- New estimates of regional and world MV product markets based on an improved estimation technique
- Cross-regional economic forecasts
- Estimates of the global recession's impact on worldwide machine vision sales

3.1 Introduction

In this chapter we present "top-down" (non-survey-based) estimates of regional MV product markets for Europe, Asia-Pacific and the Rest of the World (RoW) in terms of revenue for years 2008 through 2013. We compare these estimates to our "bottom-up" North American findings in order to ascertain the relative size of regional product markets and derive estimates for worldwide product markets. To better explain these forecasts, we present cross-regional economic forecasts and estimates of the impact of the global recession on worldwide MV sales.

3.2 Cross-Regional Comparative Machine Vision Sales

We developed estimates of regional MV product markets by first determining the relative size of the industrialized portion of regional economies and then applying these relationships to the bottom-up estimates for North America in 2008 by individual product market. For this purpose we used the latest available GDP estimates for individual countries, which were aggregated regionally and weighted by the corresponding regional rates of industrialization. Regional rates for industrialization were developed by taking the complement of the percent agriculture of total GDP for the respective regions. For years 2009 through 2013, we next grew 2008 estimates by average, regional rates of industrial production based on data obtained from the latest CIA World Fact Book.

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Based on these sources, we used an annual growth rate of 3.2 percent for Europe, 8.2 percent for Asia-Pacific and 5.0 percent for the Rest of the World. Lastly, we factored in the anticipated impacts of the global recession using a ratio technique that compared average regional rates of real GDP for 2008 with the same for 2009 and 2010. (No recessionary impacts were assumed for years 2011, 2012 and 2013.) These ratios were applied to the cyclical component of regional sales to avoid overstating recessionary impacts, which would otherwise occur, if recessionary impacts were applied to the trend components as well.

Our top-down estimation procedure can thus be summarized as follows:

North American Sales Volumes
X Relative Regional Sizing Ratios based on GDP (purchasing power parity)
X Regional Percent of the non-agricultural sector to total GDP
X Regional growth rates (average percent industrial production)
X Recessionary adjustments for 2009 through 2011 (applied to cyclical component)
= Estimated regional sales volumes

This top down approach thus takes into consideration the relative size of regional economies, variation in the extent of industrialization, differences in the average rate of regional growth in industrial production and differences in the extent of recessionary impacts.

While representing a more refined approach than that of previous studies, the resultant estimates of regional sales remain very approximate at best. More precise estimates require a bottom-up approach using surveys for major countries in all regions. (Such an approach remains far beyond our resources, thus necessitating a top-down approach based on available cross-sectional data.) It should also be noted that in all likelihood our approach over-estimates sales for the residual region, "Rest of the World", since it mainly sizes regional MV sales volumes on the relative size of regional economies, thus not taking into consideration cultural, trade and legal barriers to sales activity. (In the future, we will attempt to address these additional variables.)

3.3 Cross-Regional Economic Forecasts

Exhibit 3.1: Annual Percent Change in Real GDP: 2007 - 2010

	2007 Actual	2008 IMF	2008 OECD	2009 IMF	2009 OECD	2010 IMF	2010 OECD
China	13.0	9.0	-	6.7	-	8.0	-
India	9.3	7.3	-	5.1	-	6.5	-
Japan	2.4	-0.3	0.5	-2.6	-0.1	0.6	0.6
Korea	5.0	4.1	4.2	3.5	2.7	-	4.4
UK	3.0	0.7	0.8	-2.8	-1.1	0.2	0.9
Germany	2.5	1.3	1.4	-2.5	-0.8	0.1	1.2
France	2.2	0.8	0.9	-1.9	-0.4	0.7	1.5
Italy	1.5	-0.6	-0.4	-2.1	-1.0	-0.1	0.8
Spain	3.7	1.2	1.3	-1.7	-0.9	-0.1	0.8
Euro Area	2.6	1.0	1.0	-2.0	-0.6	0.2	1.2
Canada	2.7	0.6	0.5	-1.2	-0.5	1.6	2.1
USA	2.0	1.1	1.4	-1.6	-0.9	1.6	1.6
Brazil	5.7	5.8	-	1.8	-	3.5	-
Mexico	3.2	1.8	1.9	-0.3	0.4	2.1	1.8
World	5.2	3.4	-	0.5	-	3.0	-

Economic assumptions that were used to forecast worldwide MV sales were based on the International Monetary Fund (IMF)'s January 2009 Outlook and the Organization for Economic Cooperation and Development (OECD)'s

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November 2008 view. Forecasts for selected, major countries taken from the IMF and OECD views are shown in Exhibit 3.1. Figures highlighted in yellow indicate recession; figures shown in the blue cells indicate recovery. As these figures show, North America, Europe and Japan are largely in recession in 2008 and 2009 but are expected to experience a mild recovery in 2010. China, by contrast, is not expected to enter into recession but instead undergo a slowdown. The IMF expects the world economy as a whole in 2009 to approach a virtual standstill.

3.4. Recessionary Impacts on Worldwide MV Sales

It is possible to estimate worldwide MV sales loss due to the global recession by subtracting a forecast of worldwide MV sales reflecting recessionary economic assumptions from a business as usual forecast (or "*base case*") forecast that by definition excludes recessionary impacts. In other words:

Estimated Recessionary Impacts = Base Case Forecast Less Recessionary Forecast

The base case forecast was constructed by determining the underlying trend line in historical MV sales data and then extrapolating it out into time. This was accomplished by means of statistical regression. To create a *mid-range* recessionary forecast, regional growth factors were estimated based on economic forecasts and then applied to the base case forecast for years 2009 through 2010. For 2008, it was assumed that actual sales results already reflected recessionary impacts, since the US recession officially began December 2007. Thus, 2008 recessionary impacts were calculated by taking the difference between trend line values for 2008 and actual 2008 sales results. Finally, a prediction interval was placed around the recessionary forecast to construct "*best case*" and "*worst case*" recessionary forecasts. Best case and worse case estimates of MV sales lost due to the recession are summarized in Exhibit 3.2 for total MV financial transactions.

Exhibit 3.2: Estimated Recessionary Impacts (Lost MV Sales) in $ Billions

Region	2008	2009	2009	2010	2010
		Best Case	Worst Case	Best Case	Worst Case
North America	-$0.079	-$0.178	-$0.241	-$0.246	-$0.333
Europe & Israel	-$0.093	-$0.133	-$0.179	-$0.055	-$0.074
Asia Pacific	-$0.110	-$0.198	-$0.268	-$0.102	-$0.138
Rest of World	-$0.015	-$0.016	-$0.021	-$0.007	-$0.009
Total World	**-$0.297**	**-$0.524**	**-$0.709**	**-$0.410**	**-$0.554**
% Lost Sales	**4.9%**	**8.2%**	**11.1%**	**6.1%**	**8.2%**

As Exhibit 3.2 shows, an estimated $297 million in sales was lost in 2008 or 4.9 percent of total sales. For 2009, the estimated sales loss ranges from $524 million to $709 million or from approximately 8 to 11 percent of total sales. For 2010 (where a lagged effect is assumed) the estimated loss varies from $410 million to $554 million or from approximately 6 to 8 percent of total sales. Of course, if current governmental efforts to stem the tide of recession fail, MV sale losses will probably be worse.

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3.5 Global MV Sales Forecasts

The results of the forecasting approach previously described are summarized in Exhibits 3.3 and 3.4. Exhibit 3.3 shows total MV financial transactions; that is, the sum of total MV component sales plus smart camera sales and ASMV system sales. Exhibit 3.4 breaks these results down further into sales by individual product market in $ billions.

Exhibit 3.3: Mid-Range, Worse and Best Case Recessionary Forecasts (Total MV Financial Transactions)

Mid-Range Recessionary Forecast

	North America	Europe & Israel	Asia Pacific	Rest of World	Total World
2008	$1.586	$1.881	$2.006	$0.275	$5.749
2009	$1.509	$1.902	$2.068	$0.288	$5.767
2010	$1.485	$2.070	$2.383	$0.315	$6.253
2011	$1.735	$2.216	$2.723	$0.341	$7.015
2012	$1.796	$2.301	$2.965	$0.361	$7.423
2013	$1.857	$2.373	$3.061	$0.372	$7.664

Worse Case Recessionary Forecast

	North America	Europe & Israel	Asia Pacific	Rest of World	Total World
2008	$1.586	$1.881	$2.006	$0.275	$5.749
2009	$1.477	$1.879	$2.033	$0.285	$5.675
2010	$1.441	$2.061	$2.365	$0.314	$6.181
2011	$1.735	$2.216	$2.723	$0.341	$7.015
2012	$1.796	$2.301	$2.965	$0.361	$7.423
2013	$1.857	$2.373	$3.061	$0.372	$7.664

Best Case Recessionary Forecast

	North America	Europe & Israel	Asia Pacific	Rest of World	Total World
2008	$1.586	$1.881	$2.006	$0.275	$5.749
2009	$1.540	$1.925	$2.103	$0.291	$5.860
2010	$1.528	$2.080	$2.401	$0.316	$6.326
2011	$1.735	$2.216	$2.723	$0.341	$7.015
2012	$1.796	$2.301	$2.965	$0.361	$7.423
2013	$1.857	$2.373	$3.061	$0.372	$7.664

It should be noted that 2008 figures are the same in every case, since 2008 is not a forecast year. Only figures for years 2009 and 2010 vary, since no recessionary impacts are assumed for years 2011 through 2013 based on the scenarios foreseen by the IMF and OECD. What is not shown in Exhibit 3.3 is the base case forecast, which is used in determining estimated recessionary sales losses, as previously mentioned.

Finally, it should be noted that the next exhibit, Exhibit 3.4, provides a break down only of the mid-range forecast into forecast sales by individual product market.

As Exhibit 3.4 shows, the mid-range forecast sizes the total world machine vision components market in 2008 at $721.4 million (USD), the smart camera market at $458.6

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million and the worldwide ASMV systems market at $4,568.9 million. By 2013, we expect these worldwide markets to grow as follows: total components at $1,184.9 million, smart cameras at $669.1 million and ASMV systems at $5,918.4 million.

Exhibit 3.4 also reveals that Asian Pacific markets are largest at 34.9 percent of world markets in 2008. By comparison, the North American and European markets represent 27.6 and 32.7 percent respectively. Because the Asia-Pacific market is expected to grow faster than European and North American markets, we forecast Asia-Pacific's share of world markets to reach 42.8 percent of world markets by 2013.

Exhibit 3.4: Estimated 2008 – 2013 MV Sales by Region by Product Category Based on Relative Size of Economies and Rates of Economic Growth

Product Market 2008	North America	Europe & Israel	Asia Pacific	Rest of World	Total World
Optics	$32.1	$38.1	$40.6	$5.6	$116.4
Lighting	$31.2	$37.0	$39.5	$5.4	$113.1
Cameras	$92.0	$109.1	$116.4	$16.0	$333.5
Imaging Boards	$23.4	$27.8	$29.6	$4.1	$84.8
3rd Party Software	$20.3	$24.1	$25.7	$3.5	$73.6
Total Components	$199.0	$236.1	$251.7	$34.5	$721.4
Smart Cameras	$126.5	$150.1	$160.0	$22.0	$458.6
ASMV Systems	$1,260.4	$1,495.3	$1,594.5	$218.7	$4,568.9
% of World	27.6%	32.7%	34.9%	4.8%	100.0%

Product Market 2009	North America	Europe & Israel	Asia Pacific	Rest of World	Total World
Optics	$31.0	$39.6	$43.0	$6.0	$119.6
Lighting	$29.8	$32.5	$35.2	$4.9	$102.4
Cameras	$87.5	$130.3	$142.0	$19.7	$379.5
Imaging Boards	$18.4	$32.3	$35.3	$4.9	$90.9
3rd Party Software	$19.7	$24.6	$26.7	$3.7	$74.7
Total Components	$186.4	$259.2	$282.3	$39.2	$767.1
Smart Cameras	$121.4	$153.9	$167.4	$23.3	$465.9
ASMV Systems	$1,201.1	$1,489.0	$1,618.5	$225.5	$4,534.2
% of World	25.9%	33.1%	36.0%	5.0%	100.0%

Product Market 2010	North America	Europe & Israel	Asia Pacific	Rest of World	Total World
Optics	$30.4	$44.2	$50.9	$6.7	$132.2
Lighting	$30.0	$30.6	$35.1	$4.7	$100.5
Cameras	$85.7	$161.9	$186.6	$24.6	$458.9
Imaging Boards	$17.5	$37.6	$43.4	$5.7	$104.2
3rd Party Software	$20.8	$26.8	$30.9	$4.1	$82.6
Total Components	$184.4	$301.2	$347.0	$45.8	$878.4
Smart Cameras	$129.4	$168.8	$194.3	$25.7	$518.1
ASMV Systems	$1,171.1	$1,600.4	$1,841.5	$243.6	$4,856.6
% of World	23.0%	33.4%	38.5%	5.1%	100.0%

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Exhibit 3.4: Estimated 2008 – 2013 MV Sales by Region by Product Category Based on Relative Size of Economies and Rates of Economic Growth (Continued)

Product Market 2011	North America	Europe & Israel	Asia Pacific	Rest of World	Total World
Optics	$33.3	$48.3	$59.4	$7.4	$148.5
Lighting	$31.7	$30.5	$37.4	$4.7	$104.3
Cameras	$111.4	$188.5	$231.6	$29.0	$560.5
Imaging Boards	$17.0	$39.4	$48.4	$6.1	$110.9
3rd Party Software	$21.9	$28.6	$35.2	$4.4	$90.1
Total Components	$215.3	$335.3	$412.0	$51.7	$1,014.3
Smart Cameras	$170.6	$180.1	$221.3	$27.7	$599.8
ASMV Systems	$1,348.8	$1,700.5	$2,089.8	$262.0	$5,401.1
% of World	22.4%	32.6%	40.0%	5.0%	100.0%
Product Market 2012	**North America**	**Europe & Israel**	**Asia Pacific**	**Rest of World**	**Total World**
Optics	$33.7	$51.2	$66.0	$8.0	$159.0
Lighting	$33.4	$30.3	$39.0	$4.7	$107.5
Cameras	$126.1	$210.0	$270.6	$32.9	$639.7
Imaging Boards	$16.8	$39.2	$50.5	$6.1	$112.6
3rd Party Software	$22.4	$29.5	$38.0	$4.6	$94.6
Total Components	$232.4	$360.3	$464.2	$56.5	$1,113.4
Smart Cameras	$182.6	$185.8	$239.5	$29.1	$637.0
ASMV Systems	$1,381.3	$1,754.9	$2,261.2	$275.1	$5,672.5
% of World	21.2%	32.2%	41.5%	5.1%	100.0%
Product Market 2013	**North America**	**Europe & Israel**	**Asia Pacific**	**Rest of World**	**Total World**
Optics	$34.1	$52.9	$71.4	$8.4	$166.9
Lighting	$34.7	$31.3	$40.3	$4.9	$111.2
Cameras	$141.1	$216.8	$279.3	$34.0	$671.2
Imaging Boards	$16.6	$39.2	$50.5	$6.1	$112.4
3rd Party Software	$22.9	$30.5	$39.3	$4.8	$97.4
Total Components	$249.4	$370.6	$480.8	$58.2	$1,158.9
Smart Cameras	$199.8	$191.8	$247.1	$30.1	$668.8
ASMV Systems	$1,407.3	$1,811.0	$2,333.5	$283.9	$5,835.8
% of World	20.4%	31.7%	42.8%	5.1%	100.0%

3.6 Other Machine Vision Studies

Several machine vision studies are currently available for different regions and countries. Caution is in order when attempting to compare their results, as differences in study scopes, major questions addressed, product categories included, methodologies, definitions and assumptions can yield vastly different and largely incomparable results. In the absence of a consensus across studies regarding these basic parameters, it would be incorrect to assume that differences in study results are due merely to error. Some study results differ simply because they reflect different perspectives. A case in point is the difference between this latest study by the AIA and the study from the European Machine Vision Association (EMVA). This latter study provides excellent and highly detailed information on the European machine vision *industry* by focusing on sales won by

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European MV companies within and outside of Europe. By contrast, the AIA study focuses on the North American *market*, that is, all MV sales occurring in North America regardless of the origin of the companies. This difference between *industry* and *market* (which is explained in Chapter 2) is so fundamental that the results of both studies are not comparable. To allow direct, cross-regional comparisons of study results in the future, AIA and EMVA continue to explore the possibility of adopting supplemental approaches.

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Chapter 4:
North American Economies

4.0 What's New in this Chapter?
All sections have been updated.

4.1 Introduction
During this period of global recession, it is necessary more than ever to consider the role of the economy as a determinant of the demand for machine vision products. In this chapter, we first consider the role of the economy in general terms. We then provide broad overviews of US and Canadian economies, and then narrow our focus by examining outlooks for the manufacturing sectors. We next narrow our focus still further by turning to an examination of specific industries. Finally, we consider the stock market with emphasis on the performance of machine vision companies and then offer a brief summary of the chapter with conclusions.

4.2 The Role of the Economy
Why consider the economies of North America in a machine vision market study? The answer is clear. Capital spending drives demand for machine vision (MV) products. The higher the capital spending, the more money is spent on machine vision products (all things being equal). At the same time, capital spending (a.k.a. capital expenditures, CAPEX, or business fixed investment) is an important (although small) component of real GDP (inflation-adjusted gross domestic product), which is the single most important measure of an economy. (The percent change in real GDP is correspondingly the most important measure of overall economic growth for a country.) The link between CAPEX and MV sales volumes is perhaps best understood by sales people, who know that, when businesses experience or foresee weak earnings growth, they cut back on outlays - including hiring and capital expenditures - to maintain solvency. Indeed, the fiduciary responsibility of CFOs requires them to manage CAPEX very carefully. As a consequence, recessions and slowdowns - and the periods preceding them - make it more likely that little or no growth in MV sales volumes will occur. But this is not to suggest

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that the relationship between the economy and MV sales volumes is simple. To the contrary, it is quite complex. For example, changes in MV sales volumes can lag the economy or lead it, as businesses react to fears of earning declines in advance of their occurrence or wait until production ramps up to threshold levels where sufficient internal capital is generated for discretionary CAPEX. Delays inherent in the order cycle can also mean "lagged" economic impacts on machine vision sales. Finally, different MV product markets can be affected differently by different sectors of the economy, which tend to exhibit different rates of growth. (For example, MV companies selling to the automobile industry might be impacted well before those MV companies selling to pharmaceutical companies.)

While the relationship between real GDP and MV sales volumes (units sold) is complex, it is interesting to note that MV growth rates are nevertheless quite strong when the percent change in real GDP is around or above 3%. Exhibit 4.1 juxtaposes the percent annual change in real GDP in the US and Canada with the percent annual growth in total machine vision financial transactions, an overall measure of machine vision growth (which is based on the sales volumes of total MV components combined with MV smart camera sales and the sales of ASMV systems).

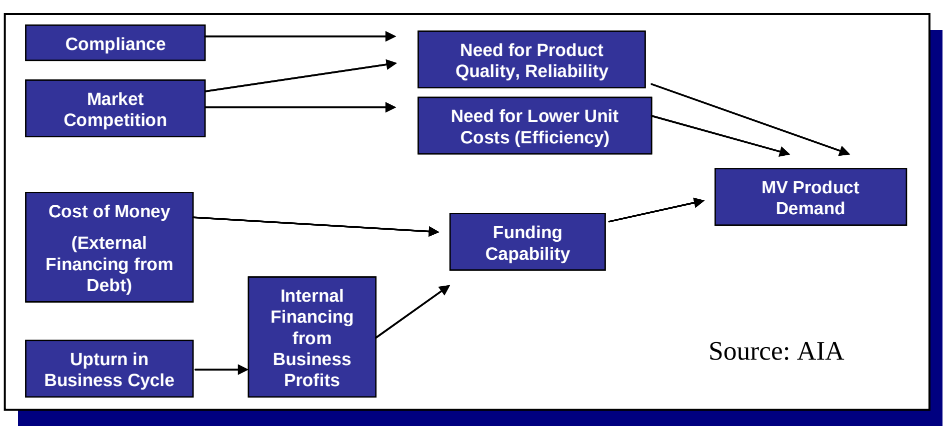
Exhibit 4.1: A Comparison of Growth Rates for Total MV Financial Transactions Annual Change in Real GDP

	Recession in US							
	2001	2002	2003	2004	2005	2006	2007	2008
Total MV Financial Transactions	NA	-14.8%	-0.2%	12.6%	6.2%	4.6%	2.1%	1.1%
Real GDP - US	0.8%	1.6%	2.5%	3.6%	3.1%	2.9%	2.0%	1.1%
Real GDP - Canada	1.8%	2.9%	1.9%	3.1%	3.1%	2.8%	2.5%	0.6%

Source: AIA and OECD

It is particularly interesting to note that, following the recession in 2001 in the US, the percent change in annual total MV financial transactions went negative in 2002 and 2003, suggesting a lagged impact on MV sales. Based on this empirical evidence, it is possible that MV sales growth could again lag the economic recovery (expected to begin in late 2009). Finally, it must be emphasized that - while the economy is an important determinant of

Exhibit 4.2: A Conceptual Model of MV Product Demand



Source: AIA

MV demand - MV demand is not exclusively driven by macro-economic factors but also by a host of micro-economic factors, as shown by Exhibit 4.2.

4.3 Broad Overview of North American Economies

All indications are that the economy of the US is in recession. The economic outlook is not as dire for Canada but the latest forecast also expects it to fall into recession or at best narrowly miss it.

4.3.1 The US Economy

For six years, the US economy enjoyed a boom but now is in the painful grips of recession. Not mincing words, the International Monetary Fund said in its October 2008 World Outlook that the US and world face “the most dangerous financial shock in mature financial markets since the 1930s”. Other organizations and economists have voiced similar concerns. Most are hopeful that a complete financial meltdown will be averted but not a recession, which is expected to be both deep and of longer duration than the last US recession in late 2001.

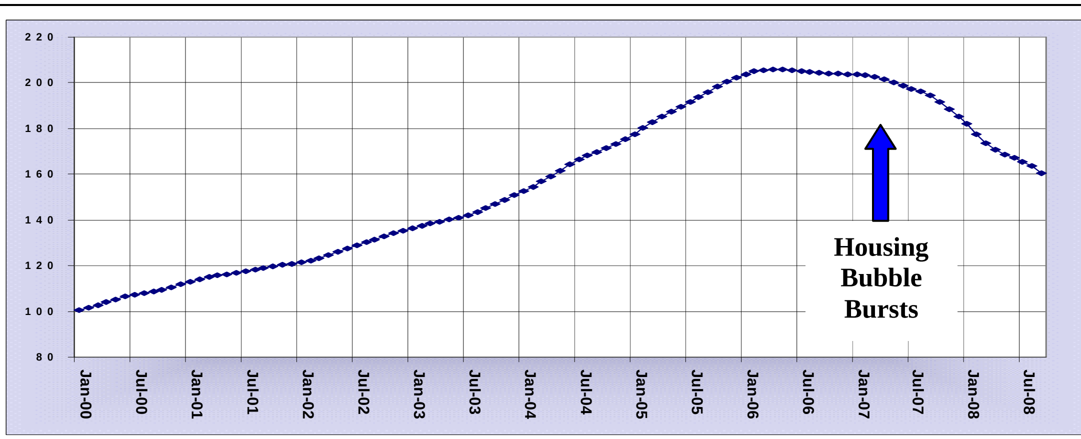
According to the National Bureau of Economic Research, the current recession in the US officially began in December of 2007. The consensus forecast among economists as of this writing assumes a recession continuing through 2009 and part of 2010, with a slow recovery beginning in the latter part of 2010. Not until 2011, at the earliest, will the US economy have righted itself according to most economists.

Responsible for the current crisis is the subprime mortgage crisis, which began with the sharp reduction in housing prices and has led to a general liquidity crisis. The sharp rise in commodity prices also helped to push the economy over the brink into recession.

<u>The Subprime Mortgage Crisis</u>

The subprime mortgage crisis made itself felt in 2007 and 2008 with the bursting of the housing bubble and a dramatic increase in the default rate on subprime rate mortgages (ARMs) in the United States. Lax lending standards allowed to flourish by weak regulation, easy initial borrowing terms and rising housing prices encouraged borrowers to assume that they would be able to refinance risky mortgages. Instead, what happened

Exhibit 4.3: Sharp Decline in US Housing Prices – House Price Index



Source: Standard & Poors Composite 20 Housing Index (SPCS20R-SA) Jan. 2000 to Sept. 2008 was a rise in interest rates and a drop in housing prices that made refinancing very difficult. As the easy, initial terms of mortgages expired, homeowners found themselves exposed, with the result that defaults and foreclosure activity increased markedly.

The Liquidity Crisis

The crisis in the US housing sector soon spread to the financial sector. The inability of homeowners to make their mortgage payments jeopardized the viability of banks with heavy concentrations of mortgage assets on their books. Indy Mac Bank, the largest mortgage lender in the US, was first to succumb to the crisis and was subsequently seized by federal regulators. Fannie Mae and Freddie Mac were soon thereafter placed into conservatorship.

Many mortgage assets were "securitized"; that is, turned into very complicated, financial instruments, lacking transparency, as they traded hands through multiple transactions. A large portion of these securities were held by US investment banks, which - when faced with the crisis - either went bankrupt like Lehman Brothers or were acquired at bargain basement prices like Merrill Lynch by Bank of America. The biggest bank failure in the US occurred when Washington Mutual collapsed and was purchased by JP Morgan Chase. All in all, some 28 US banks failed in 2008. Additionally, large insurance companies were also affected like AIG, which obtained a rescue loan from the Federal Reserve. In response, the Treasury Department made a number of major bailouts. As a consequence of these developments, the landscape of the US financial sector was radically changed, as summarized by Exhibit 4.4.

Exhibit 4.4: The Changing Landscape of the US Financial Sector

Banks and S&Ls	Securities Firms	Insurance Companies
• **23 banks failed in 2008** • **Indy Mac** failed (seized by government) • **Freddie Mac** & **Fannie May** (bailed out) • **Washington Mutual** collapsed (acquired by JP Morgan Chase) • **CITI Bank** (bailed out) • **Bank of America** (bailed out) • **Wells Fargo** (bailed out) • **JP Morgan Chase** (bailed out) • **State Street** (bailed out) • **Bank of NY Mellon:** (bailed out)	• **Lehman Bros** failed • **Wachovia** acquired by Wells Fargo • **Morgan Stanley** (Mitsubishi 20% stake) • **Merrill Lynch** (acquired by Bank of America)	• **AIG** bailed out 3 times

The liquidity crisis had the effect of spreading the contagion to the broader economy. As major financial institutions crashed, confidence in the economy evaporated. Shell shocked and fearing insolvency, banks - even those not holding subprime mortgages - became afraid to lend money to other banks and to business customers. Credit, the "oil" upon which the economy runs, consequently became very tight. The effects on the broader economy, which heretofore had been relatively healthy, were both immediate and drastic. Without credit, businesses had to sharply curtail their activities and lay off large portions of their workforce. Unemployment unavoidably rose.

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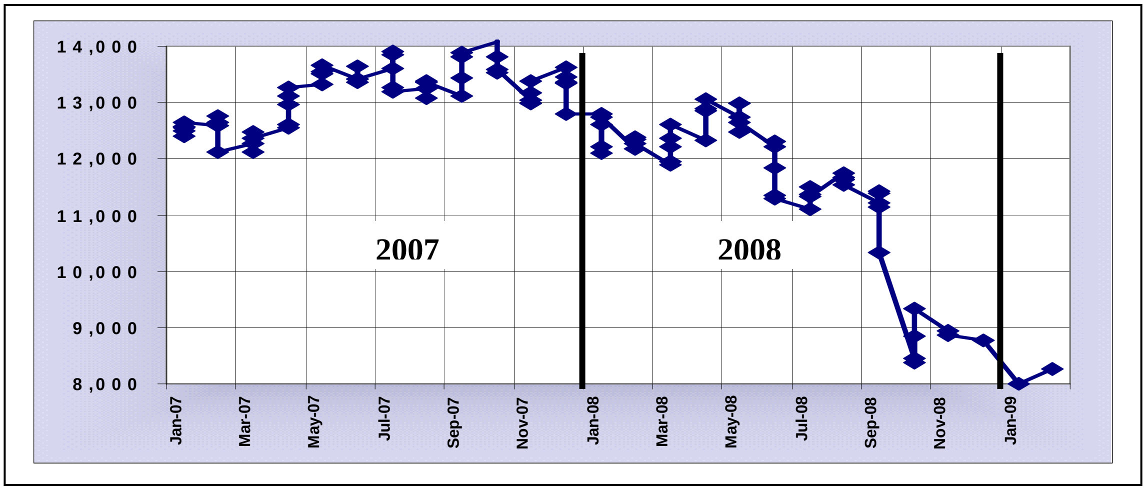
The Stock Market

The effects were of course immediately felt in the stock market, as investors were shocked by the collapse of major financial institutions. Losing confidence in the market, they pulled out in fits of panic, sending the Dow reeling. Subsequently, negative earnings reports of financial and non-financial businesses alike sent the market down even further. As of January 2009, the market lost approximately 40 percent of its value (compared to October 2007), placing in jeopardy retirement funds, 401Ks and other widely held types of holdings.

Exhibit 4.5: Dow Jones Industrial Average



The Steep Rise in Commodity Prices

A steep rise in commodity prices, particularly oil, dealt an additional shock to much of the US economy, creating a near perfect storm. As Exhibit 4.6 shows, the price of West Texas inter-mediate crude oil rose from an average of \$35 per barrel in 1st quarter 2004 to

Exhibit 4.6: West Texas Intermediate Crude Oil Prices

Short-Term Energy Outlook, November 2008

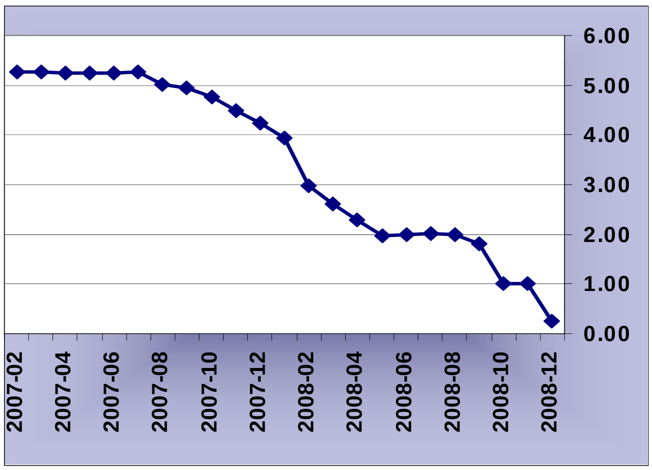
Source: Energy Information Administration (EIA), US Energy Department

$124 USD in 2nd quarter 2008, before decreasing somewhat because of falling demand in the second half of 2008. (As of this writing, the spot price of crude is hovering around $40 USD.)

Responses of the US Federal Reserve, Congress and Treasury Department

Facing the most serious financial crisis since the Great Depression, the "Fed", Congress and the Treasury Department, abandoned their long-held "hands off" approach to the economy and embraced a number of interventionist measures involving both fiscal and monetary policy. The Fed has repeatedly cut interest rates to ease borrowing costs. As Exhibit 4.7 shows, the Federal Funds Effective Rate was cut to only 0.25 (virtually zero) percent in December of 2008.

Exhibit 4.7: US Federal Funds Effective Rate



Source: US Federal Reserve

The US Congress and administration also passed a $150 billion economic stimulus package in February of 2008, which appears to have temporarily helped boost real GDP in the second quarter of 2008.

Following a series of ad hoc market interventions to bail out firms, the Federal Reserve (the "Fed"), Treasury and US Congress patched together a $700 billion bail out program (Emergency Economic Stabilization Act of 2008) to inject liquidity into the financial sector (under the Troubled Assets Relief Program or "TARP") and boost confidence in the economy. Subsequently, Treasury changed the orientation of the program from buying up "toxic" assets to buying equity stakes in nine, large banks, using $250 billion. With great reluctance, the Treasury Department under Secretary Hank Paulson also agreed to loan the automobile companies $17.4 billion out of the TARP fund. Altogether, the Bush administration spent roughly half or $350 billion of the TARP fund, reserving the remainder to the Obama administration.

In February of 2009, the new Treasury Secretary of the Obama administration, Tim Geithner, announced a multi-pronged program to spend the remaining $350 billion TARP dollars. The program consisted of a public-private partnership that would finance the purchase of "troubled" or "toxic" assets from banks' balance sheets. The program also provided for direct capital injections into banks, a vast lending program aimed at financing consumer loans and a separate initiative enabling mortgage holders facing imminent foreclosure to renegotiate their mortgage terms. Underlying the announced plan was also a "stress test", to which banks would be subjected to see whether they

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could withstand a tough economic environment before further remedial action was taken by the government. Unclear as of this writing is how bad assets would be valuated and whether the government could be forced to seize temporary control of the banks.

Other actions aimed at the US financial sector included the Federal Reserve buying up to $600 billion in mortgage-backed assets, consisting of $100 billion in direct obligations from Fannie Mae, Freddie Mac and the Federal Home Loan Banks and $500 billion in mortgage-backed securities. The Fed also announced that it would lend up to $200 billion to the holders of securities backed by various types of consumer loans such as credit cards, auto loans and student loans.

Despite all these actions, it is expected that liquidity will be restored only gradually, as financial institutions "deleverage"; that is, shed debt. Correspondingly, the Fed expects banks to lend more funds to businesses and thus jump-start the stalled economy. Only time will tell if these measures are effective in ending the credit crunch.

To address weakness in the broader economy (the non-financial sector in which products are manufactured and services delivered), the Obama administration crafted a second stimulus package in February 2009 (which at the time of this writing has not yet been enacted into law). It is expected that this stimulus package will dwarf the February 2008 stimulus package in size, totaling in excess of $800 billion, and will consist of a mixture of tax cuts, incentives and infrastructure investments aimed at job creation.

Exhibit 4.8: A Comparison of Forecasts of Annual Percent Change in Real GDP - US

	2008	2009	2010
Global Insight	1.5%	0.2%	-
The Economist	1.8%	0.5%	-
Morgan Stanley	1.0%	0.2%	-
Merrill Lynch	NA	-0.5%	-
OECD	1.4%	-0.9%	1.6%
IMF	1.1%	-1.6%	1.6%
Blue Chip Survey	-	-1.9%	-
Average GDP Forecast	**1.4%**	**-0.6%**	**1.6%**

As previously mentioned, the US economy officially went into recession in December of 2007. For 2008, a sampling of forecasts for real GDP is shown in Exhibit 4.8. Based on these numbers, the consensus forecast for 2008 was 1.4% and -0.6% in 2009. Underlying most of these forecasts is the expectation that the recession will be more severe than the 2001 recession, lasting at least through out the first half of 2009, followed by very a slow, gradual recovery beginning in the latter part of 2009. Growth in 2009 as a whole, however, will be negative at -0.6%, as previously mentioned. 2010 is expected to be the first full year of recovery, but according to both the IMF and OECD, real GDP in the US will reach only 1.6%.

The historical and predicted changes in annual real GDP for the US are displayed by Exhibit 4.9. As shown, a modest recovery is forecast for 2010.

The recession officially began in the US in December of 2007 and will probably extend to the latter part of 2009. The recovery is expected to be both very gradual and weak, beginning in the latter part of 2009. 2010 will be the first full year of recovery, but real GDP in that year will probably reach only 1.6%.

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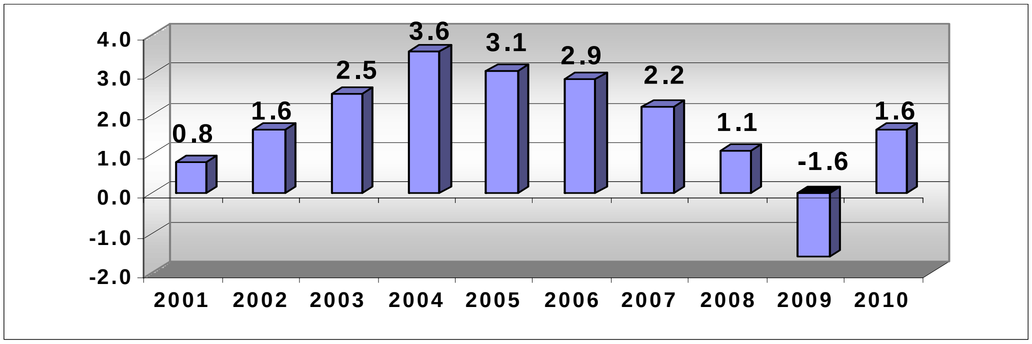
Exhibit 4.9: Historical and Predicted Changes in Real GDP – US (In Percent)



Source: IMF January Outlook

4.3.2 The Canadian Economy

Forecasts of real GDP for 2008 suggest that Canada has lagged the US somewhat in terms of economic growth, despite the benefits of increased commodity prices (primarily oil and metals) for much of the year. Reflecting higher commodity prices, the “loonie”, the Canadian dollar, has been relatively strong, which has spurred retail shopping, including cross-border shopping in the US, where consumer prices have been generally lower and not burdened by the “GST”, a goods and services value-added tax. A strong loonie, however, has placed downward pressure on the export of manufactured goods, making them less competitive.

In October of 2008, however, the strong increase in commodity prices came to an abrupt end, as prospects of a global recession loomed large. This dramatically lowered the value of the loonie, which - as of this writing - has fallen from its peak of $1.10 USD to approximately $0.80 USD. It remains to be seen how much this precipitous drop will stimulate exports to the US and other countries.

Exhibit 4.10: Comparison of Forecasts of Annual % Change in Real GDP - Canada

	2008	2009	2010
Bank of Canada	NA	0.6%	-
OECD	0.5%	-0.5%	2.1%
UBS	NA	0.4%	-
IMF	1.1%	-1.6%	1.6%
RBC	0.9%	NA	-
Scotia Bank	0.7%	1.4%	-
The Economist	NA	0.9%	-
Average GDP Forecast	**0.8%**	**0.2%**	**1.9%**

While there was initially some disagreement among economists about whether Canada would follow the US into recession, the most recent forecasts of the OECD and IMF predict a recession in Canada in 2009.

Presently, the consensus forecast for 2008 is 0.8%. Less economic growth is predicted for 2009, as shown by Exhibit 4.10. It should be noted however the consensus forecast includes some older predictions that were made during more favorable times and thus should be discounted somewhat. The forecast of the IMF is the most recent and is depicted in Exhibit 4.11 along with historical, actual data. As shown, a modest recovery is expected for 2010.

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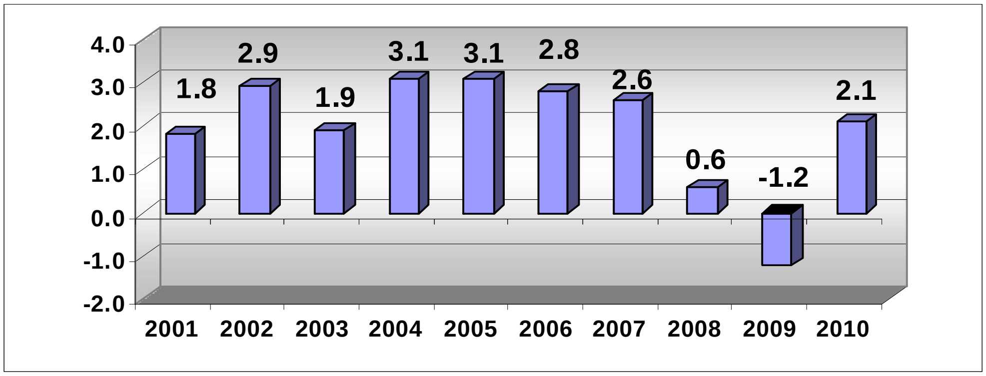
Exhibit 4.11: Historical and Predicted Changes in Real GDP – Canada (In Percent)



Source: IMF January 2009 Outlook

Regarding the recovery of the Canadian economy, Bank of Canada Governor Mark Carney told the House of Commons Finance Committee in February of 2009 that the decisions by the US and other countries to eliminate bad bank assets were also key to Canada's recovery. If these decisions were incorrect and/or untimely, Canada's economic recovery would be both "attenuated and delayed". At the same time, he noted a quicker recovery would be possible by dint of Canada's hefty interest rate cuts, a well-functioning banking system, a depreciated loonie, fiscal stimulus and relatively limited business and consumer debt.

Responses of the Bank of Canada and the Federal Government

In response to the recession, the Bank of Canada cut the official bank rate to 1.5 percent and took over $25 billion (CAD) of bank mortgages. The Federal Government's actions involved a $4 billion (CAD) bailout of the automobile companies and a stimulus package worth $30 billion (CAD) over two years. (The opposition parties had said they would topple the minority government of Stephen Harper, if no stimulus package were offered.)

4.4 Outlook for the US and Canadian Manufacturing Sectors

In our overview of the US and Canadian economies, we now narrow our focus by examining the manufacturing sectors of these economies.

4.4.1 The US Manufacturing Sector

In 2007, the US manufacturing sector continued to expand according to the US Federal Reserve. Exhibit 4.12 displays the annual output of the manufacturing sector by year, indexed to 2002.

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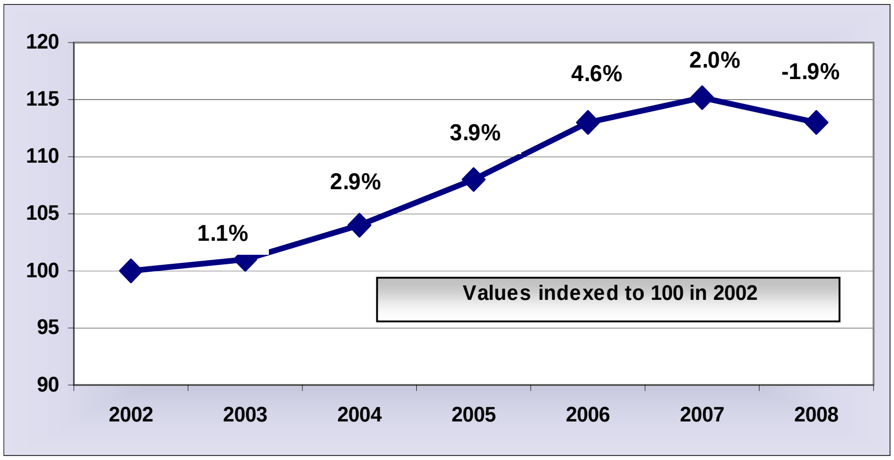
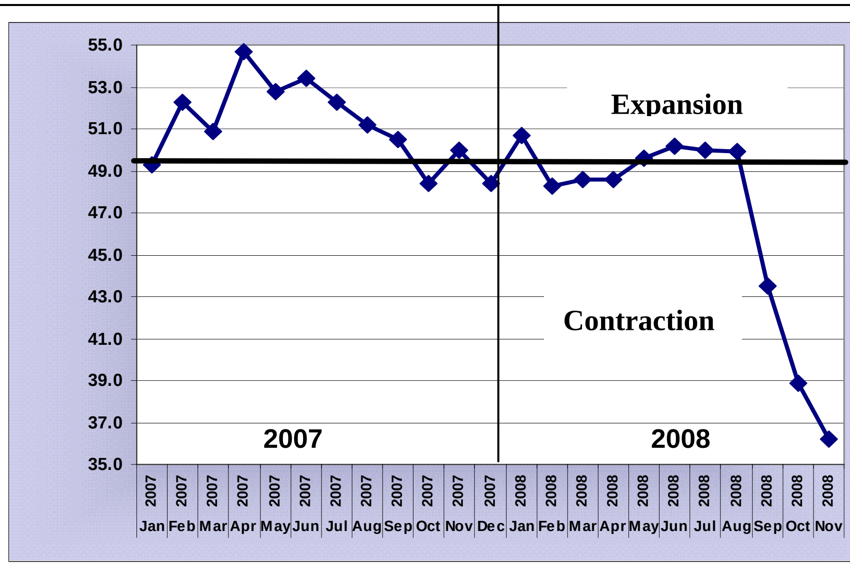
Exhibit 4.12: US Industrial Production – Manufacturing (Indexed to 2002 Level)



Source: US Federal Reserve

However, the rate of change in industrial manufacturing decreased markedly for most of 2008. This reflects the fact that manufacturing activity in the US declined in the last quarter of 2007, as revealed by the Institute of Supply Management's (ISM) purchasing managers index (PMI), which is plotted for 2007 and 2008 in Exhibit 4.13.

Exhibit 4.13: Monthly Plot of the ISM's Purchasing Managers Index 2008



Source: Data obtained from Institute of Supply Management

This plot leaves little doubt that the manufacturing sector in the US went through a period of sustained contraction in 2008.

4.4.2 The Canadian Manufacturing Sector

The picture has been different in Canada with respect to the manufacturing sector. While contraction occurred for most of 2008 in the US, manufacturing sales actually grew in Canada during much of that time. March and August 2008 were the only exceptions based on available data as of this writing, but at least some observers believed that

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August would represent the beginning of a downward decline. At the same time, this downward trend was mitigated somewhat by the falling loonie, making Canadian products more price competitive. In the words of Toronto-Dominion Bank economist Millan Mulraine, "Looking ahead, with the US economy (the key destination for Canadian manufacturing products) continuing to weaken, and the slump in commodity prices continuing unabated, we expect to see further weakness in Canadian manufacturing activity, though the weaker Canadian dollar will provide some important offset to these headwinds."

Exhibit 4.14: 2007 Manufacturing Sales in Canada

	$ Millions	% Change
August 2007	50,054	-2.0
September 2007	49,743	-0.6
October 2007	49,795	+0.1
November 2007	50,569	+1.6
December 2007	48,535	-4.0
January 2008	48,999	+1.0
February 2008	50,211	+2.5
March 2008	49,326	-1.8
April 2008	50,102	+1.6
May 2008	51,509	+2.8
June 2008	52,588	+2.1
July 2008	54,000	+2.7
August 2008	52,088	-3.5
September 2008	52,163	+0.1
October 2008	51,707	-0.9
November 2008	48,414	-6.4

Source: Statistics Canada

4.5 Specific Industry Outlooks

We next narrow our focus still further by examining outlooks for specific industries. We first list the various forecasts of the Manufacturers Alliance and then zero in on two industries of special interest to machine vision companies - the semiconductor and automobile industries.

4.5.1 Economic Forecasts by Industry

Every quarter the Manufacturers Alliance/MAPI provides a detailed look at the health of the manufacturing sector by reviewing and forecasting the performance of its most important subsectors or industries. The latest look (October 2008) is summarized in Exhibit 4.14, which shows forecasted growth rates by industry for 2008 and 2009.

Exhibit 4.15: Economic Forecasts by Industry – US

Industry	2008	2009
Housing	**-30%**	**5%**
Motor Vehicle & Parts Production	**-13%**	**1%**
Household Appliance Production	**-10%**	**-8%**
Pharmaceuticals and Medicine	**2%**	**3%**
Iron & Steel Production	**2%**	**-1%**
Alumina & Aluminum Production	**6%**	**0%**
Fabricated Metal Product Production	**-1%**	**-3%**
Computers	**2%**	**1%**
Communications Equipment Production	**17%**	**9%**
Navigational, measuring, Electromedical & Control Instruments Production	**5%**	**4%**
Electric Lighting Equipment Production	**-10%**	**-9%**
Electric Equipment Production	**7%**	**-4%**
Medical Equipment & Supplies Production	**2%**	**3%**
Aerospace Product & Parts Production	**4%**	**10%**
Basic Chemicals Production	**-1%**	**0%**
Paper Production	**-2%**	**0%**

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Exhibit 4.15: Economic Forecasts by Industry – US (Continued)

Construction Machinery Production	**-9%**	**-8%**
Mining, Oil & Gas Machinery Production	**13%**	**6%**
Industrial Machinery Production	**-8%**	**-2%**
Ventilation & HVAC Production	**-7%**	**2%**
Metalworking Machinery Production	**-2%**	**-2%**
Source: Manufacturers Alliance/MAPI		

It is interesting to note that the Manufacturers Alliance believes that eleven of the industries examined were in recession in 2008 (those with negative growth) and eight will be in recession in 2009. For the most part, these hard-hit industries are the capital equipment industries, of which most are served by machine vision companies.

It should be noted that there are other industries of great importance to the machine vision industry that are not included in Exhibit 4.15, such as the flat panel display (FPD) industry. However, it should be remembered that only those industries based in North America are relevant to this study, given this study's *market* perspective.

The Business Survey Committee of the Institute for Supply Management (ISM) has also prepared projections for the US economy in 2009. Based on the views of purchasing and supply management executives, the projections reveal that economic growth will vary by industry sector but by and large the adverse conditions experienced in the second half of 2008 are expected to continue in manufacturing in 2009. Revenue in 2009 is expected to decline in 12 of 18 industries for an overall decrease of -1.1 percent, an improvement over the -2.2 percent decrease reported for 2008. Capital spending in both the manufacturing and non-manufacturing sectors is expected to decline a combined -7.6 percent.

According to the Business Survey Committee's survey, "manufacturing industries expecting improvement over 2008 - listed in order - are: Petroleum & Coal Products; Electrical Equipment, Appliances & Components; Printing & Related Support Activities; Miscellaneous Manufacturing; Food, Beverage & Tobacco Products; Apparel, Leather & Allied Products; and Chemical Products. Industries expecting a decline over 2008 - listed in order - are: Primary Metals; Nonmetallic Mineral Products; Fabricated Metal Products; Textile Mills; Computer & Electronic Products; Machinery; Paper Products; Furniture & Related Products; Transportation Equipment; and Plastic & Rubber Products."

The Business Survey Committee concludes that all in all, "manufacturing purchasing and supply executives lack their usual optimism about their organizations' prospects as they consider the first half of 2009; however, they are somewhat more positive about the second half."

We next consider two industry segments of particular importance to machine vision companies, semiconductors and automobiles.

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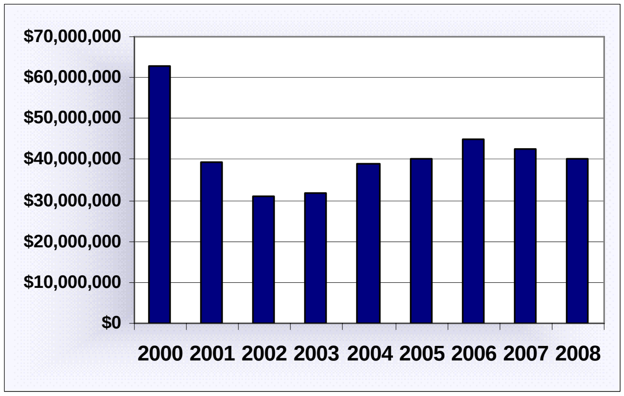
Exhibit 4.16: Semiconductor Shipments – Americas



Source: Semiconductor Industry Association (SIA) and World Semiconductor Trade Statistics

4.5.2 Semiconductor Industry

Past AIA market studies have left little doubt of the importance of the semiconductor industry to machine vision companies. This reflects the fact that, while many production facilities have moved to Asia, the semiconductor industry still has an important presence in North America. We thus make specific reference to this industry in this chapter.

One important indication of the health of the semiconductor industry is its volume of shipments.

Shipments in the Americas are displayed in Exhibit 4.16. Importantly, as shown by this exhibit, shipments in this region declined in 2007 and 2008. All things being equal, this suggests a reduced ability to fund capital spending.

Of course, focusing directly on capital spending by semiconductor companies has greater relevance to our study's purpose. However, available data on capital spending is worldwide only.

Such data - obtained from Gartner Dataquest as of December 2008 and recorded in Exhibit 4.17 - shows capital spending in 2008 down by -27.3 percent. Importantly, growth rates in all areas of semiconductor capital and equipment spending were down. The prospects for 2009 are even worse at -34.1 percent. Not until 2010 does semiconductor capital spending improve.

Exhibit 4.17: Percent Change in Annual Spending – Semiconductors

	2007	2008	2009	2010	2011	2012
Semiconductor Capital Spending	5.4	-27.3	-34.1	13.9	26.4	18.5
Capital Equipment	6.4	-30.6	-31.7	17.7	25.7	16.3
Wafer Fab Equipment	10.6	-30.6	-33.1	16.3	29.2	18.9
Packaging and Assembly Equipment	-3.7	-28.6	-30.7	26.0	14.2	6.6
Automated Test Equipment	-13.7	-30.0	-19.8	18.9	12.3	5.9
Other Spending	3.1	-19.2	-39.0	5.0	27.5	23.4

Source: Gartner Dataquest

IC Insights made a similar prediction for capital spending plans in 2008. In July of 2008, it placed the change in capital expenditures at -15 percent. These are clearly sobering numbers; to the extent that these forecasts are representative of capital spending within

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the North American semiconductor industry, they clearly do not bode well for machine vision sales growth in North America in 2008.

4.5.3 Automobile Industry

The automobile industry is another industry worthy of our specific attention. It is also an industry that exhibited a decline in sales growth in 2008. As shown by Exhibit 4.18, vehicle production through August of 2008 was down by -16.4 percent in the US and down by -16.2% percent in Canada. In the US, car and light truck sales fell -18 percent to 13.2 million vehicles for the year as a whole.

Exhibit 4.18: North American Vehicles Production

US	2007	2008	%Change
Car	2,668,483	2,604,941	-2.4
Light Truck	4,487,246	3,384,926	-24.6
Medium/Heavy Truck	201,117	162,906	-19.0
Total Vehicles	7,356,846	6,152,773	**-16.4**
Canada	**2007**	**2008**	**%Change**
Car	907,876	793,147	-12.6
Light Truck	793,004	631,412	-20.4
Medium/Heavy Truck	26,055	22,123	-15.1
Total Vehicles	1,726,935	1,446,682	**-16.2**

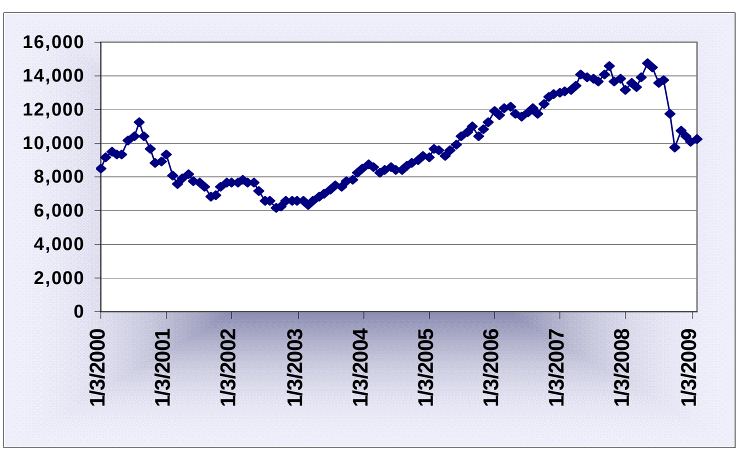
Source: WARD's North American Vehicle Production Summary

For 2009, the Manufacturers Alliance forecasts an improvement of 1 percent. This is more optimistic than the forecasts made by Ford Motor Co. and General Motors in January of 2008. Ford expects industry-wide US auto sales to reach somewhere between 12 and 12.5 million, a decline of 700,000 to approximately 1.1 million vehicles. GM expects an even greater decline with vehicle production totaling only 10.5 million industry-wide. It is believed that both Ford and GM will have to further shrink their operations to break even at these sales volumes.

4.6 Stock Market Performance

Stock market performance gives us additional insights into the economy as well as the performance of machine vision companies in the marketplace. Many economists consider the stock market to be a leading indicator of economic activity, as well as a predictor of recession. We have already noted the 40 percent loss in

Exhibit 4.19: Stock Market Performance in Canada (TSX Composite)



Source: Yahoo Financials

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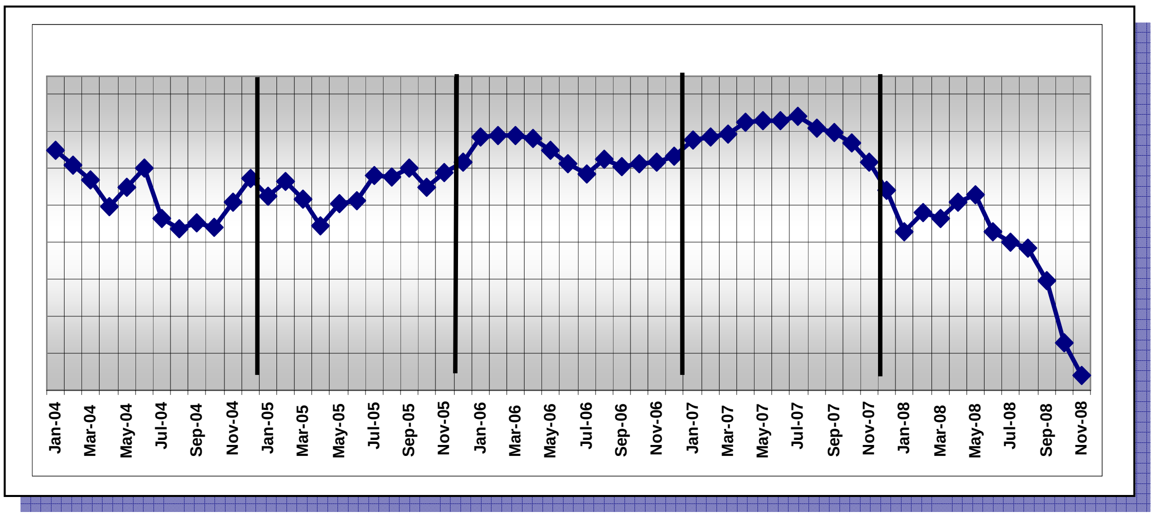
the Dow Jones as of January 2009 in the case of the US. See Exhibit 4.5.

When we compare the high point of the 2000 – 2008 period with the latest available data point, February 2009, we find a 30 percent decline for the Toronto exchange (not quite as bad as the Dow Jones), which is shown by Exhibit 4.19.

How did machine vision companies fare in the stock market by comparison? It is interesting to note that machine vision companies followed a similar pattern. As Exhibit 4.20 shows, the stocks of machine vision companies lost considerable value in 2008.

Exhibit 4.20: Composite Weekly MV Stock Prices Weighted by Market Capitalization: 2004 - 2008



In fact, when the composite price of MV stocks is compared at the beginning of 2008 with the beginning of November 2008, a 36 percent reduction in the value of MV stocks is revealed, a more severe loss than experienced by the Dow Jones and TSX. Like stocks in general, MV stocks clearly took a real beating in 2008.

4.7 Conclusion

We began this chapter by noting the important but also complex relationship of the economy to MV sales performance. We then described the major problems that confronted the US and Canadian economies in 2008 and will continue to plague them in 2009. The US has faced a "perfect storm" of a burst housing bubble, a credit crunch and an oil shock. In both the US and Canada, real GDP decreased in 2008 and in all likelihood will remain weak in 2009. Recession has clearly seized the US economy with Canada not far behind.

Concerning the manufacturing sector, the outlook has been encouraging neither for the US nor for Canada. All indications are of contraction.

In terms of individual sectors, the performance of the economy has varied. Capital equipment industries in the US have been hit hard in 2008 and will no doubt suffer in 2009 and part of 2010. In the individual sectors represented by the semiconductor and

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automobile industries, 2008 sales have been weak. As a consequence, these industries have curtailed capital spending, which we would expect to have a negative impact on MV product sales.

For the economies of the US and Canada, the bottom line is therefore unfavorable conditions for growth in MV product sales in both 2008, 2009 and part of 2010. The MV industry may not start to see relief until the end of 2010. Not until 2011 will the economies of North America return to normal.

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Chapter 5:
The North American Machine Vision Industry

5.0 What's New in this Chapter?

- 5.1.2 North American Industry Sales

5.1 Introduction

In this chapter we determine the size and growth of the North American MV industry by product market. It should be noted that this is the only chapter of this study in which we show *industry* data. Importantly, industry data cannot be compared to *market* data, which appear in all other chapters of this study.

Because the difference between *industry* and *market* data is important, we provide here a more extensive explanation than appears in Chapter 2.

<u>Industry vs. Market</u>

In AIA market studies, we have consistently distinguished between the concepts of *market* and *industry*. Both concepts take into consideration geography and product markets but in fundamentally different ways. In a nutshell, the difference boils down to this: "*Market*" refers to all the sales that occur within a geographic market; thus, the "North American market" includes all the sales that occur within the geographic boundaries of North America regardless of the origin of the products sold or the origin of the company selling the products. "*Industry*" refers to the global sales of companies that are headquartered within the same geographic territory. Thus, the North American *industry* encompasses the worldwide sales of companies with headquarters in North America.

The difference between *industry* and *market* can also be defined in terms of *exports, imports* and *domestic* sales. *Industry* sales include both the *exports* (out of region) and

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domestic (in-region) sales of all MV companies headquartered within the same geographic area. *Market* sales include *domestic* sales plus *imports* within the same geographic area. These differences are summarized in Exhibit 5.1.

Exhibit 5.1: Comparisons of Definitions: "Market" versus "Industry"

	Companies	Sales
Market	All the companies that sell into the same geographic market	■ Total Market Sales = In-region Sales + Imports ■ Total Market Sales = Domestic Sales + Imports
Industry	All the companies with HQs located in the same geographic area	■ Total Industry Sales = Total global sales of companies with in-region HQs ■ Total Industry Sales = In-region sales + Out-of-region sales of companies with in-region HQs ■ Total Industry Sales = Domestic sales + Out-of-region sales where "domestic" refers to the same geographic area

The main purpose of this chapter is to size the North American MV industry by individual product markets. To do this, we first identify the MV companies with headquarters in North America. We then aggregate their worldwide sales for the respective product markets. By ascertaining North American industry sales, we enable a comparison with industry sales in other regions, as determined by other MV trade associations. Thus, our ultimate objective in this chapter is to enable cross-regional comparisons of MV data.

5.1.1 North American MV Companies

Exhibit 5.2 identifies the leading North American MV companies by product market.

Exhibit 5.2: North American MV Companies by Product Market

Optics	Edmund Optics, Light Works, Melles Griot, Navitar, Qioptiq
Lighting	Advanced illumination, Dolan-Jenner, Fiberoptics Technology, Illumination Technologies, Metaphase Technologies, Spectrum Illumination, StockerYale
Cameras	Cohu, DALSA, Fairchild Imaging, FLIR, Illunis, Imperx, IQinVision, LMI Technologies, Lumenera, PixeLink, Point Grey Research, Prosilica, QImaging, Redlake

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Exhibit 5.2: North American MV Companies by Product Market (Continued)

Imaging Boards	Alacron, BitFlow, CyberOptics, DALSA Coreco, EPIX, Foresight Imaging, Imperx, Matrox, National Instruments, Pleora Technologies
Software	AccuSoft, Braintech, FSI Automation, Mnemonics, NorPix, Precise Automation, Radix Controls, SHAFI, Soft Automation, Way-2-C
Smart Cameras	Cognex, Banner Engineering, FastVision, Matrox, National Instruments, Pixel Velocity, PPT Vision, Southern Vision Systems, Wintriss
ASMV Systems	AccuSentry, American SensoRx, Applied Vision, Automated Vision, Automated Visual Inspection Systems, Avalon Vision Solutions, Averna, AVT, Cognex, Coherix, Comact, Dunkley, ESI, Image Labs, Inovec, Inspection Systems, Interactive Design, Inx-Systems, Key Technologies, Laser-View Technologies, Lixi, Lucidyne Technologies, Machine Vision Products, Micro-Metric, Papertech, Perceptics (Northrup Grumman), Perceptron, Pressco Technology, Retina Systems, Robot & Vision Manufacturing, Ross Inspection, Rudolph Technologies, Softac, STI, Teradyne, TruColor Vision Systems, USNR, Webview, Xiris

5.1.2 North American Industry Sales

Exhibit 5.3 indicates the size of the MV product markets for the North American MV industry in terms of sales. Sales results were mixed for 2008; while smart cameras were up over 2007, total component sales were flat compared to the previous year. This stems primarily from weakness in imaging board sales, as indicated by the corresponding negative rate of annual change. ASMV system sales were also down in 2008.

Exhibit 5.3: Total North American Industry Sales by Product Market by Year

	2005	2006		2007		2008	
	$Mil	$Mil	%	$Mil	%	$Mil	%
Optics	$42.2	$42.0	-0.5%	$39.3	-6.4%	$40.4	2.8%
Lighting	$17.2	$18.6	8.5%	$19.9	6.6%	$20.9	5.2%
Imaging Boards	$65.4	$67.5	3.2%	$58.1	-14.0%	$49.8	-14.2%
Cameras	$66.7	$81.6	22.4%	$80.7	-1.1%	$87.6	8.5%
Total Components	$191.5	$209.8	9.6%	$198.0	-5.6%	$198.7	0.4%
Smart Cameras	$115.3	$132.2	14.6%	$140.6	6.3%	$159.1	13.2%
ASMV Systems	$571.7	$626.8	9.7%	$646.8	3.2%	$625.3	-3.3%

5.2 Conclusions

Calculating North American industry sales data, as we have in this chapter, enables harmonization of study methodologies, thus permitting cross-regional comparisons.

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Chapter 6: North American Machine Vision Markets

6.0 What's New in this Chapter?

Sales results for 2008 and forecast results for 2009 through 2013 are all-new. Additionally, we focus briefly on total financial transactions involving machine vision sales in North America.

6.1 Introduction

In this chapter we provide an updated, multi-year overview of sales results in North America by individual machine vision product market in terms of units sold, sales revenue, their associated rates of growth and annual average unit prices.

Exhibit 6.1 summarizes these historical results for the 2001-2008 timeframe. We extracted results for 2001 through 2007 from earlier AIA studies, having previously restated some annual results to insure comparability over time. This comparability is necessary to more accurately assess growth patterns for the various product markets, their typical rates of growth and their underlying trend lines. It is our hope that - once historical data are collected for additional years – statistical, analytical and forecasting techniques, which require larger sample sizes, will become eventually possible.

6.2 Findings

The historical data of Exhibit 6.1 suggest that machine vision product markets have been somewhat cyclical with noticeable peaks and declines, despite underlying linear growth.

Generally speaking, 2002 and 2003 were not very good years for machine vision sales in North America, as indicated by negative rates of growth. This negative growth is largely attributable to the lagging effects of the 2001 recession in the US (See Chapter 4.) By contrast, a different pattern has been evident since 2004 (a strong recovery year) with machine vision sales generally exhibiting high rates of growth across product markets until 2007, when weaker growth re-emerges.

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Exhibit 6.1: Summary of Historical MV Product Market Sales Results: 2001 – 2008

	Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual	
Optics	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**CAGR**
Revenue ($M)	$29.1	$26.1	$26.0	$28.7	$30.9	$31.6	$31.9	$32.1	-
%	-	-10.4%	-0.3%	10.4%	7.7%	2.1%	0.9%	0.7%	1.3%
Units				64,824	76,724	77,331	81,978	82,446.	-
%	-	-	-	-	18.4%	5.2%[e]	6.0%	0.6%	2.4%
Average Price	-	-	-	$443	$403	$408	$389	$389	-
Lighting	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**CAGR**
Revenue ($M)	$42.0	$36.5	$35.7	$34.1	$31.5	$29.3	$29.5	$31.2	-
%	-	-13.0%	-2.2%	-4.5%	-7.5%	-7.0%	0.7%	4.2% [e]	-2.2%
Units	44,800	50,250	52,100	66,621	72,333	81,594	80,570	82,860	-
%	-	12.2%	3.7%	27.9%	8.6%	12.8%	-1.3%	2.8% [e]	5.6%
Average Price	$936	$726	$685	$512	$436	$359	$366	$376	-
Camera	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**CAGR**
Revenue ($M)	$70.7 [c]	$49.9	$53.4	$68.6	$75.6	$92.4	$93.2	$92.0	-
%	-	-29.4%	6.9%	28.5%	10.3%	16.8%[e]	0.9%	-1.3%	6.7%
Units	111,70	63,000	48,736	62,724	69,726	85,535	84,937	78,522	-
%	-	-43.6%	-22.6%	28.7%	11.2%	13.9%[e]	-0.7%	-7.6%	4.05
Average Price	$633	$792	$1,095	$1,093	$1,084	$1,081	$1,097	$1,171	-
Imaging Boards[a]	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**CAGR**
Revenue ($M)	$47.3 [c]	$21.4	$26.5	$35.4	$28.6	$30.4	$30.5	$23.4	-
%	-	-54.8%	23.8%	33.6%	-19.2%	-10.8%[e]	0.3%	-23.3%	-9.9%
Units	30,365	17,117	15,133	22,012	27,538	35,153	38,783	28,991	-
%	-	-43.6%	-11.6%	45.5%	25.1%	7.8%[e]	10.3%	-25.2%	1.7% [e]
Average Price	$1,558	$1,250	$1,751	$1,608	$1,039	$852	$786	$806	-
Software	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**CAGR**
Revenue ($M)	$17.5	$16.3	$13.3	$18.3	$20.4	$21.0	$20.7	$20.3	-
%	-	-6.9%	-18.4%	37.6%	11.6%	2.8%	-1.4%	-1.9%	2.5%
Smart Cameras[b]	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**CAGR**
Revenue ($M)	$32.5	$40.9	$58.6	$86.7	$99.2	$114.2	$116.6	$126.5	-
%	-	25.8%	43.3%	48.0%	14.4%	15.2%	2.1%	8.5%	9.9%
Units	8,935	14,306	18,296	19,695	23,448	27,091	28,750	30,863	-
%	-	60.1%	27.9%	7.6%	19.1%	15.5%	6.1%	7.3%	11.9%
Average Price	-	$2,859	$3,203	$4,402	$4,231	$4,217	$4,055	$4,097	-
ASMV	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**CAGR**
Revenue ($M)	$1,203.9 [c]	$1,038.1	$1,012.8	$1,108.6	$1,180.0	$1,215.3	$1,244.2 [f]	$1,260.4	-
%	-	-13.8%	-2.4%	9.5%	6.4%	3.0%	2.4% [f]	1.3%	3.3%
Units	12,708 [c]	5,752	6,566	7,667	8,710	9,319	9,683	9,806	-
%	-	-54.7%	14.2%	16.8%	13.6%	7.0%	3.9%	1.3%	6.3%
Average Price	-	$180,476	$154,249	$144,594	$135,475	$130,415	$127,347	$128,531	-

Note: Historical Period CAGRs are for 2003 to 2008

[a] Includes vision processor boards
[b] Includes vision sensors and embedded vision processors
[c] Outliers. Data points are atypical compared to historical time series.
[d] Excludes outlier in 2001
[e] Growth rate adjusted for change in company mix

Exhibit 6.2: Summary of Forecast MV Product Market Sales Results: 2008 – 2013

	Actual	Forecast	Forecast	Forecast	Forecast	Forecast	
Optics	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**CAGR**
Revenue ($M)	$32.1	$31.0	$30.4	$33.3	$33.7	$34.1	-
%	0.7%	-3.5%	-2.0%	9.7%	1.2%	1.2%	2.4%
Units	82,447	79,442	79,070	88,470	90,489	92,509	-
%	0.6%	-3.6%	-0.5%	11.9%	2.3%	2.2%	3.9%
Average Price	$389	$390	$384	$377	$373	$369	-
Lighting	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**CAGR**
Revenue ($M)	$31.2	$29.8	$30.0	$31.7	$33.4	$34.7	
%	5.7%	-4.4%	0.8%	5.6%	5.3%	4.0%	3.9%
Units	82,860	81,011	82,631	87,589	91,968	96,107	-
%	2.8%	-2.2%	2.0%	6.0%	5.0%	4.5%	4.4%
Average Price	$376	$368	$363	$362	$363	$361	-
Camera	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**CAGR**
Revenue ($M)	$92.0	$87.5	$85.7	$111.4	$126.1	$141.1	-
%	-1.3%	-4.8%	-2.1%	30.0%	13.1%	11.9%	12.7%
Units	78,522	72,295	68,513	88,222	100,216	112,629	-
%	-7.6%	-7.9%	-5.2%	28.8%	13.6%	12.4%	11.7%
Average Price	$1,171	$1,211	$1,251	$1,263	$1,258	$1,253	-
Imaging Boards[a]	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**CAGR**
Revenue ($M)	$23.4	$18.4	$17.5	$17.0	$16.8	$16.6	-
%	-23.3%	-21.1%	-5.1%	-2.8%	-1.3%	-1.0%	-2.6%
Units	28,991	24,378	24,770	26,109	27,894	29,321	-
%	-25.2%	-15.9%	1.6%	5.4%	6.8%	5.1%	4.7%
Average Price	$806	$756	$706	$651	$601	$566	-
Software	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**CAGR**
Revenue ($M)	$20.3	$19.7	$20.8	$21.9	$22.4	$22.9	-
%	-1.9%	-2.6%	5.4%	5.1%	2.4%	2.4%	3.8%
Smart Cameras[b]	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**CAGR**
Revenue ($M)	$126.5	$121.4	$129.4	$170.6	$182.6	$199.8	-
%	8.5%	-4.0%	6.6%	31.8%	7.0%	9.4%	13.3%
Units	30,863	29,379	31,790	41,110	46,290	53,196	-
%	7.3%	-4.8%	8.2%	29.3%	12.6%	14.9%	16.0%
Average Price	$4,097	$4,131	$4,070	$4,150	$3,945	$3,756	-
ASMV	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**CAGR**
Revenue ($M)	$1,260.4	$1,201.1	$1,171.1	$1,348.8	$1,381.3	$1,407.3	-
%	1.3%	-4.7%	-2.5%	15.2%	2.4%	1.9%	4.0%
Units	9,806	9,344	9,177	10,680	11,074	11,446	-
%	1.3%	-4.7%	-1.8%	16.4%	3.7%	3.4%	5.2%
Average Price	$128,531	$128,546	$127,605	$126,289	$124,735	$122,950	-

Note: CAGRs are for 2008 to 2012

[a] Includes vision processor boards
[b] Includes vision sensors and embedded vision processors

For 2008 product market sales, we find a few surprises. Revenue from smart cameras and lighting sales are up over 2007. For smart cameras this is not surprising, representing - as it does - a return to the trend line. But in the case of lighting, the increase is very much out of line with trend and therefore totally unexpected. Lighting revenue has declined for a number of years with the exception of 2007, when it rose slightly. Another important change in 2008 is the marked decrease in imaging board revenue.

In keeping with forecasts for the economy cited in Chapter 4, 2009 product market sales will be a still weaker than in 2008. In 2010, a weak recovery in the economy should improve machine vision sales, but not until 2011 is a return to the underlying, upward sales trend expected across most MV product markets.

To get a handle on machine vision sales as a whole in North America, it is helpful to examine total MV financial transactions over time. These amounts are calculated by simply adding total ASMV system sales and smart camera sales to total MV component sales, where the latter is comprised of optics, lighting, imaging board, camera and software sales. As Exhibits 6.3 and Exhibit 6.4 show, total 2008 and 2009 MV financial transactions indicate weak growth.

Exhibit 6.3: Plot of Total MV Financial Transactions in North America by Actual and Forecast Year ($ Millions)

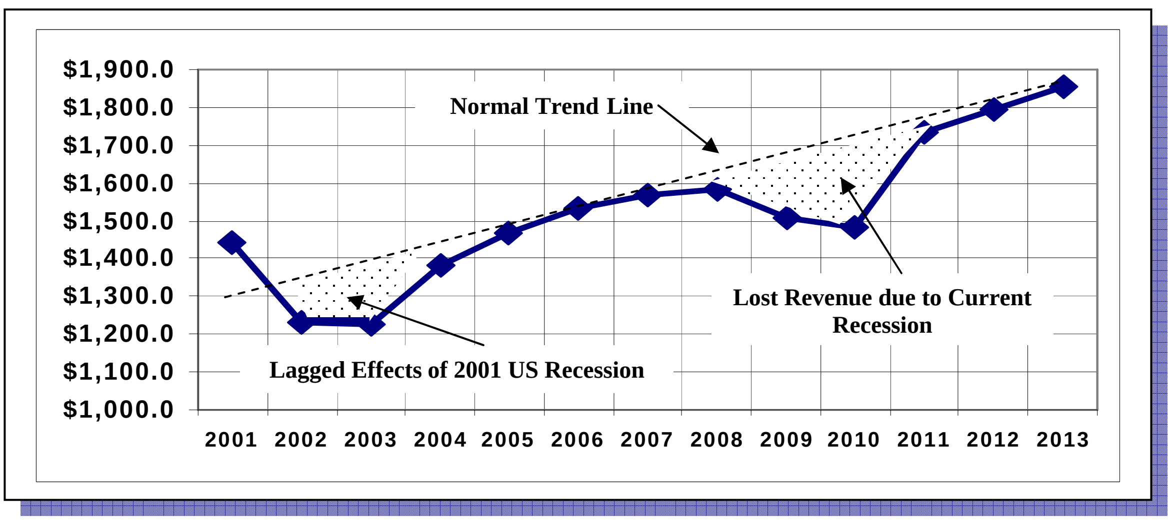

Exhibit 6.4: Table of Total MV Financial Transactions in North America by Actual and Forecast Year ($ Millions)

Actual	Actual	Actual	Actual	Actual	Actual	Actual	Actual
2001	2002	2003	2004	2005	2006	2007	2008
$1,443.0	$1,229.2	$1,226.3	$1,380.4	$1,466.2	$1,534.2	$1,566.6	$1,584.5
	-14.8%	-0.2%	12.6%	6.2%	4.6%	2.1%	1.1%
Forecast	**Forecast**	**Forecast**	**Forecast**	**Forecast**			
2009	2010	2011	2012	2013			
$1,508.9	$1,484.9	$1,734.7	$1,796.3	$1,856.5			
-4.8%	-1.6%	16.8%	3.6%	3.4%			

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In the following chapters, we explain the results for 2008 and provide additional insights along with findings relating to product features.

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Chapter 7: MV Camera Market

Quick Navigation Buttons:

7.1 Introduction | 7.2 Survey Results | 7.4 Summary of Major Findings | 7.5 Conclusions

7.0 What's New in this Chapter?

- 7.1.6 New Camera Standards: 10 GigE Vision, USB 3.0 and PoCL-Lite
- 7.1.9 New Product Introductions
- 7.2 Survey Results
- 7.3 Total Sales Revenue and Units by Major Product Feature
- 7.4 Summary of Major Findings
- 7.5 Conclusions

7.1 Introduction

The importance of the role played by cameras in an MV system is perhaps the most obvious of all machine vision (MV) components; cameras are nothing less than the "eyes" of an MV system or the "vision" in machine vision.

In this chapter we analyze the important MV camera market in great detail, including for the first time in this study new product introductions. (See section 7.1.7.) We begin with a broad perspective to size the market and to determine its growth. We then break down sales from the standpoint of major product features that correspond to the leading technologies that have shaped the market landscape. In doing so, we also ascertain major trends and developments to make sense of the direction in which this market is headed. Finally, we summarize all major findings and derive conclusions about this market.

7.1.1 Overview of Machine Vision Camera Market

We define the MV camera market in terms of the product sales of MV camera suppliers operating at the front end of the MV supply chain in accordance with the overall methodological approach of this study and past AIA MV market studies, as outlined in

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Chapter 2. Distributors and other market intermediaries are thus not included in this "front-end component" market. Moreover, to avoid double-counting, all camera sub-components, such as sensor chips, are excluded from the scope of this study.

The North American MV camera market is substantial in size as measured in terms of both sales volumes and the number of market participants. Expressed in revenue, sales volumes for camera equipment have varied from $68.6 million (USD) in 2004 to $92.0 million in 2008, reflecting a composite annual growth rate of 7.6%. (See Exhibit 7.9 for more details.) Within this market, there are also many participants, 41 in number, which together offer a wide variety of camera products. In the next sections we examine both products and participants of the MV camera market.

7.1.2 Major Product Types and Features

All product types examined in this chapter are MV cameras. We define MV *camera* as an imaging device utilized in an MV system that contains an *imaging sensor chip* and various electronic-based functionalities that together convert a visual image of an object into electronic impulses. It is important to note that vision sensors, smart sensors and smart cameras are not identified as MV cameras for purposes of this study. Also, imaging sensor chips by themselves are regarded as sub-components and thus do not constitute MV cameras.

In the MV camera market, cameras are classified mainly by sensor, sensor size, scan and interface technologies, thus revealing the importance of technology as a determinant of the market landscape. (It is also customary to identify cameras by the portion of the spectrum that is utilized, as in the case of x-ray cameras and infrared cameras, and to distinguish between cameras intended for color versus white light.) Product features that are examined include resolution, color versus monochrome and single versus multi-tap outputs in the case of line scan cameras.

7.1.3 Machine Vision Cameras

As determined by their underlying technology, the major categories of MV cameras are:

- *CCD* versus *CMOS* cameras (Categories based on *sensor* technology)
- *Area scan* versus *line scan* (Categories based on *scanning* technology)
- *Analog* versus a slew of *digital* interfaces (Categories based on *interface* technologies)

7.1.4 Major Suppliers

At present we find 41 MV camera suppliers in the North American market, suggesting a robust, highly competitive market. The identities of these suppliers are showed in Exhibit 7.1.

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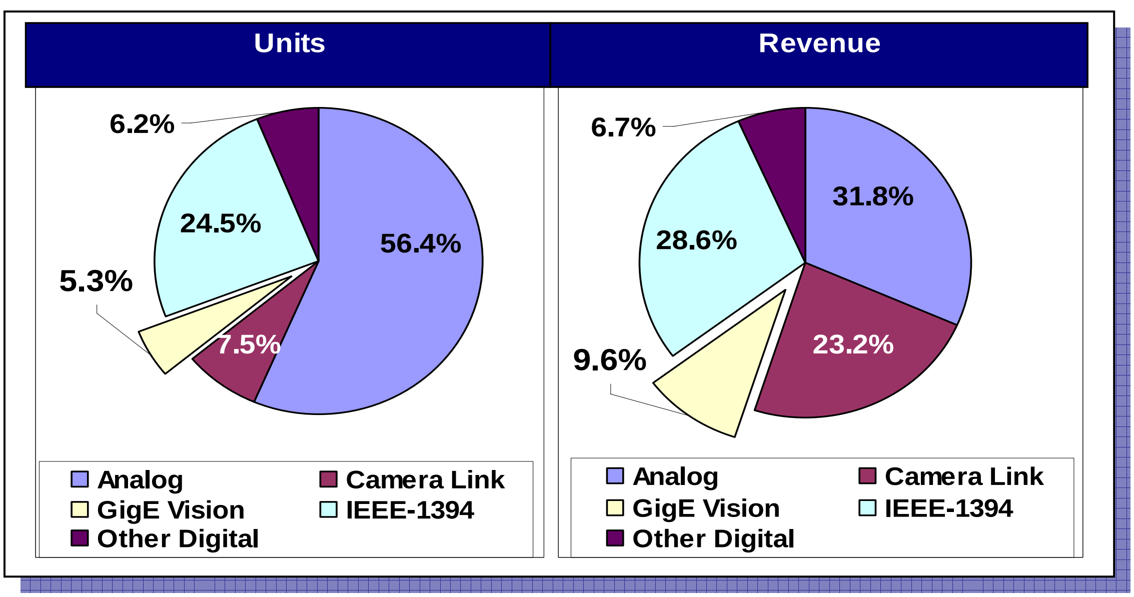
Exhibit 7.1: Major MV Camera Suppliers

Adimec	Imaging Solutions Group	Prosilica Inc. (now AVT)
Allied Vision Technologies	IMI Technology	QImaging Corporation
Artray Co.	Imperx	Redlake
e2v	Integrated Design Tools	Sensor Technologies America (Sentech)
Basler Vision Technologies	JAI	SICK IVP
Baumer	Leutron Vision	SONY
Cohu	Lumenera Corporation	SVS-Vistek Cameras Inc.
DALSA Corporation	Mikrotron GmbH	Tattile S.R.L.
Electrim Corp.	NET USA	Thermo Electron CIDTEC
Fairchild Imaging	Panasonic	Toshiba
FLIR Systems	Photonfocus AG	Toshiba Teli Corporation
Hamamatsu Corporation	PixeLINK	TVI Vision
Hitachi Denshi America	Point Grey Research	Video Scope International (VSI)
illunis LLC	Princeton Instruments	

7.1.5 Emergence of GigE Vision and its Impact on the MV Camera Market

The adoption of the GigE Vision standard in May of 2007 represents a major market development; however, its effects have not yet been fully felt. In 2006, only 0.8% of total MV camera units sold, corresponding to 1.8% of total sales revenue, were from pre-standard "GigE" camera sales. By 2008, GigE Vision sales grew to 5.3% of units and 9.6% of revenue, as shown by Exhibit 7.2. Importantly**, revenue from GigE Vision sales almost doubled in one year (the period between 2007 and 2008).**

Exhibit 7.2: Percent of GigE Vision Cameras of Total MV Camera Sales in 2008



Going forward there is every reason to believe that GigE Vision camera sales will continue to increase, affecting demand for other types of digital cameras. Based on Exhibit 7.3, which compares cameras of different digital interfaces on price and bandwidth, we would expect GigE Vision cameras to compete primarily with IEEE-1394

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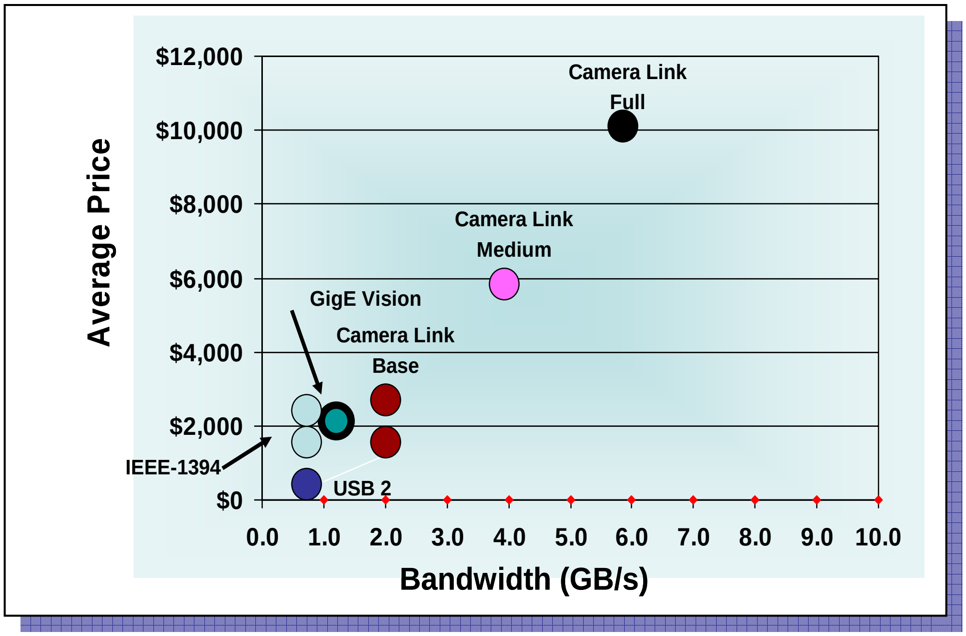
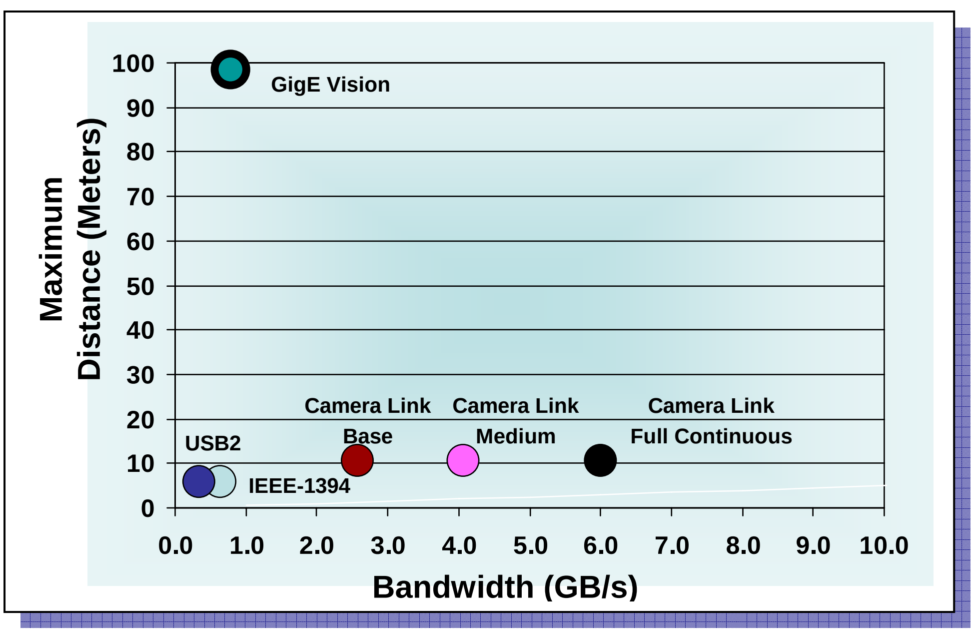
cameras and Camera Link base cameras (that is, to the extent that price and bandwidth constitute purchase decision criteria).

Exhibit 7.3: Market Map of Digital Camera Interfaces: Bandwidth and Price



However, when it comes to transport distance, GigE Vision is clearly in a class by itself, as shown by Exhibit 7.4.

Exhibit 7.4: Market Map of Digital Camera Interfaces: Bandwidth and Maximum Distance



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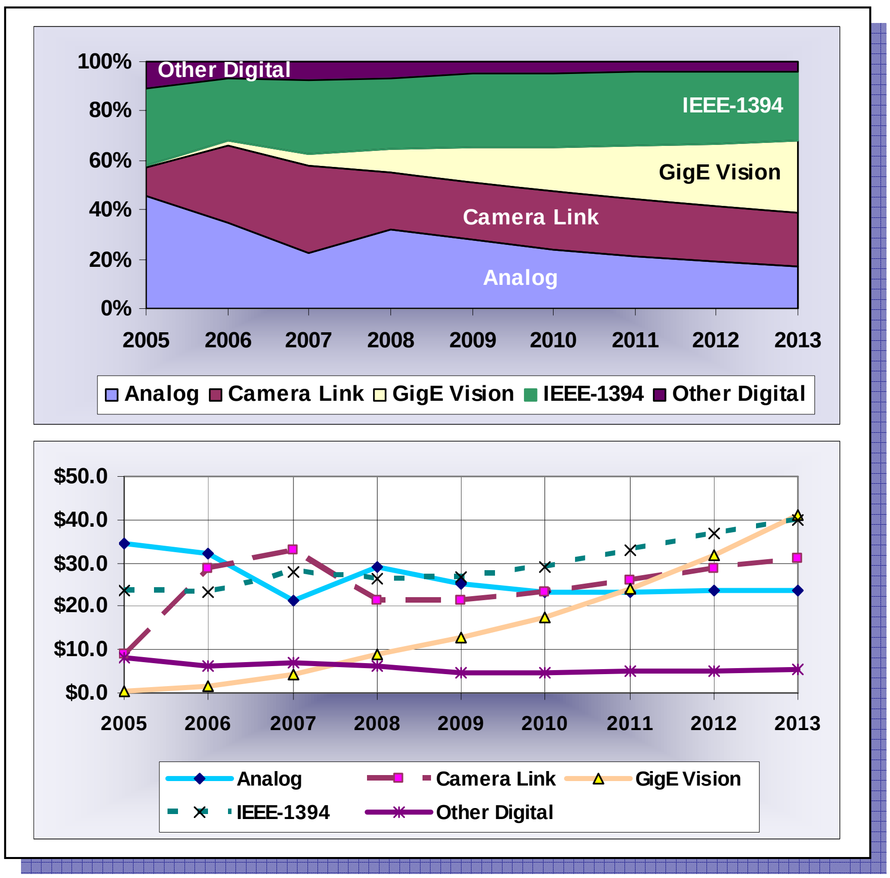
All things being equal, we would expect the greater distance of GigE Vision to constitute a competitive advantage in video surveillance and in those situations where cost savings and environmental safeguards justify an arrangement consisting of centrally located computers that serve multiple cameras such as in large, modern factories. Here, the value proposition offered by GigE Vision would clearly be a gigabit of bandwidth at a competitive price with Ethernet-based connectivity over a much greater distance. Based on the comparison of digital interfaces that we have presented, we would expect GigE Vision cameras to gain an increasing share of total MV camera sales over time but not to supplant all other types of cameras. Exhibit 7.5 portrays a possible scenario.

Exhibit 7.5: The Future of GigE Vision Camera Sales



7.1.6 New Camera Standards: 10 GigE Vision, USB 3.0 and Other Standards-Related Developments

The cross-elastic impacts between camera interfaces are certain to become even more complex, as new interfaces are introduced to the marketplace as illustrated by Exhibit 7.6. The following is a brief overview of standards-related activities and the future direction that camera interfaces might take.

<u>USB</u>

At the lower end of the bandwidth continuum, USB has become faster with the introduction of the USB 3.0 protocol in November of 2008. USB 3.0, which was

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championed by HP, Intel, Microsoft, NEC, NXP and Texas Instruments; offers 4.8 Gpbs and is ten times faster than USB 2.0. In the future, it is likely that USB cameras used for machine vision will be built according to the specifications of USB 3.0. Wireless USB, a short range, higher bandwidth wireless protocol, has not found acceptance in machine vision as of yet. It provides 480 Mbps at three meters and 110 Mbps at ten meters and should be viewed as competitive alternatives to Bluetooth and WiFi.

Camera Link

In the future, Camera Link might also offer more bandwidth. The AIA Camera Link Committee has formed a subcommittee to explore “Camera Link 2”, which is aimed at greater bandwidth and longer cable distances. Other work by the greater committee involves revising the specification for the current cable.

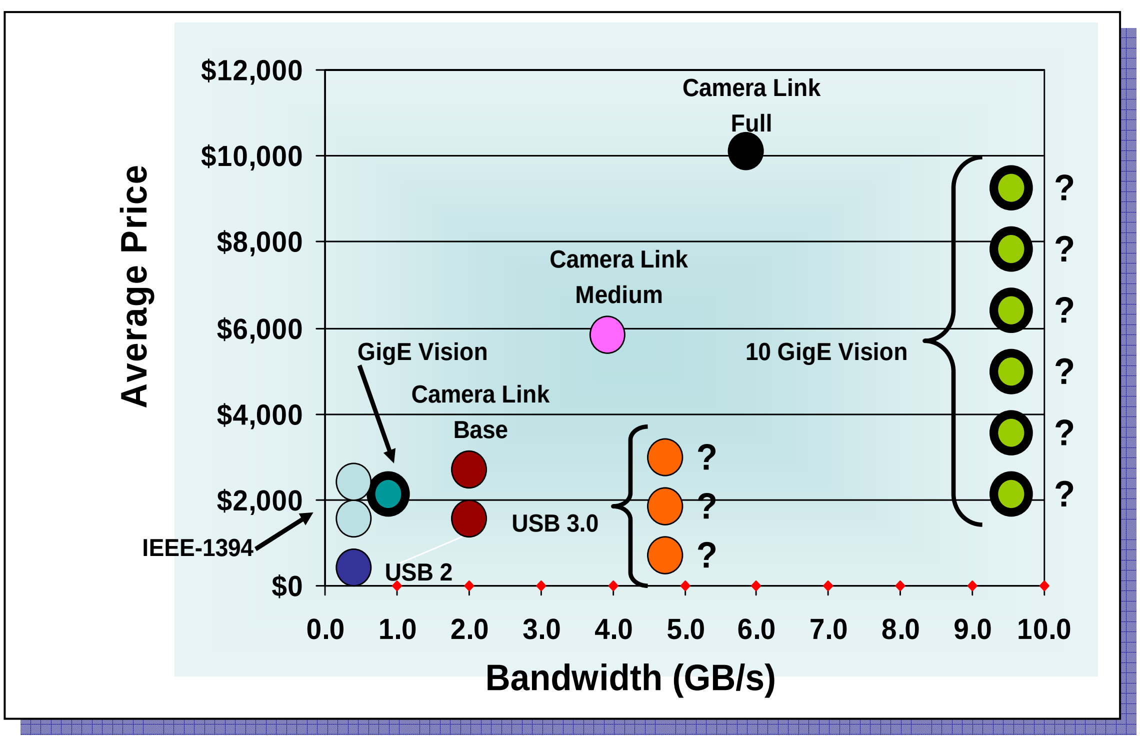
10 GigE Vision

The AIA GigE Vision Committee has formed a subcommittee to explore a “higher speed transmission using GigE Vision protocol”, which is envisioned to be on the order of 10 Gigabit. It is possible that the evolution to 10 GigE Vision can occur within the framework of the current GigE Vision standard.

PoCL Lite

The Japanese Industrial Imaging Association (JIIA) is pursuing development of a PoCL-Lite (power over Camera Link lite) standard that would have lower cost and the smallest size digital I/F. As such, it is intended to provide the “best solution” for the analog 12P to digital upgrade.

Exhibit 7.6: Market Map of Digital Camera Interfaces: Bandwidth and Price with USB 3.0 and 10 GigE Vision Included



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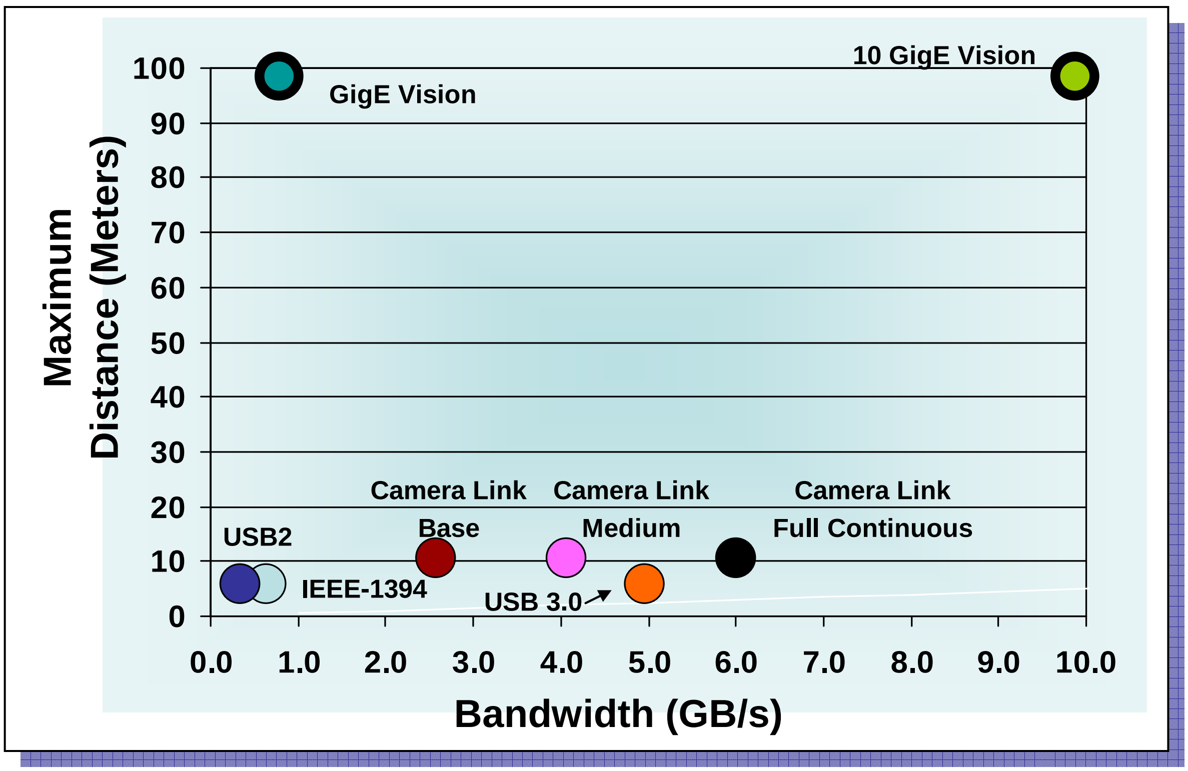
The introduction of new camera interfaces will alter the market map for digital interfaces, creating new cross-competitive relationships. Until the prices of 10 GigE Vision and USB 3.0 MV cameras are known, however, it will be difficult to pinpoint areas of competition.

It is possible, though, to compare the relationships between bandwidth and distance, assuming that 10 GigE Vision would have the same maximum distance as GigE Vision. As Exhibit 7.7 shows, 10 GigE Vision would represent a very attractive alternative to Camera Link, if Camera Link does not offer increased bandwidth in the future.

Exhibit 7.7: Market Map of Digital Camera Interfaces:
Bandwidth and Maximum Distance Including USB 3.0 and 10 GigE Vision



7.1.7 Market Trends and Developments

Based on the previous discussion in this chapter, we identify the following market trends and developments in the North American MV camera market as follows:

- Growing use of digital CCD cameras over analog CCD cameras (although 2008 represents a minor, temporary departure from this trend due to depressed economic conditions, as will be seen later in this chapter).
- Increasing market penetration by CMOS cameras with cross-elastic demand impacts for CCD cameras as the consequence of CMOS cameras' higher resolution and lower cost. Initially, this has been evident at the lower-end of the market but could gradually extend to more demanding applications as the consequence of evolving technologies.

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- A gradual convergence of capabilities and benefits occurring to some extent between CMOS and CCD sensors, entailing a technological coexistence between CMOS and CCD cameras within the overall MV camera market. (Currently, these technologies address different market segments for the most part, as previously noted.)
- Overall improvements in camera capabilities reflecting increasing compute power, improved read-out speed, higher resolution and additional, embedded functionality (such as pre-processing and I/O handling in the case of frame grabber-free solutions).
- Increased prominence of cameras with digital interfaces with a concomitant reduction in demand for cameras with analog interfaces (although 2008 represents a minor, temporary departure from this trend due to depressed economic conditions, as will be seen later in this chapter).
- A growing need for bandwidth resulting from the trend towards higher resolution and speed.
- A growing reliance on FPGAs within digital cameras to perform image pre-processing tasks, thus possibly eroding somewhat the distinction between a camera and smart camera.
- A technological coexistence between various digital interfaces, with different interfaces addressing different niche applications, but at the same time with migration between interfaces, as users move up the “bandwidth ladder”.

We also offer some predictions based on the observations and insights of industry experts. These are:

- Continued migration from analog to lower bandwidth digital (USB2) and to IEEE-1394 (but with some temporary delay due to economic conditions).
- Migration from lower bandwidth digital (USB2) to IEEE-1394.
- Migration from IEEE-1394 to GigE Vision and to Camera Link.
- Continued refinement in the Camera Link standard, entailing increasing demand for cameras with this interface.
- Increasing demand for GigE Vision cameras driven by the need for remote controllability over longer distances and high bandwidth.
- Growing cross-elastic demand between Camera Link and GigE Vision cameras, as demand for GigE Vision cameras ramps up during the early adoption stage of the product-life cycle.
- Continuation of changes in the MV camera market strongly reverberating through the MV imaging board market. Continued use of USB2 and IEEE-1394 cameras will dampen demand for lower-end boards, while the growing acceptance of Camera Link will stimulate demand for higher-end boards. At the same time, the increasing acceptance of GigE Vision cameras could well lessen demand for some imaging boards, while creating demand for GigE boards that relieve the host processor of some of its image loading and memory transfer tasks.

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7.1.8 Major Characteristics of the MV Camera Market

The MV camera market in North America is a robust, highly competitive, technology-driven market with numerous suppliers and products vying for sales. Major characteristics of this market are as follows:

- A market size of $92.0 million (USD) currently.
- Strong growth for most years but little growth at present because of economic conditions. Between 2006 and 2008 sales revenue has been essentially flat and has fallen off somewhat in 2008.
- High degree of product diversity driven largely by differences in sensor and scanning technologies, the portions of the spectrum addressed and interface technologies.
- Strong dependence on technological development.
- Migration between analog and digital and between different digital interfaces as users move up the "bandwidth ladder". (However, there is evidence that this upward migration has been delayed by bad economic conditions with customers more willing to stick with less expensive analog cameras than in previous years.)
- A high degree of product innovation.

7.1.9 New Product Introductions

In this section we provide a list of the many new MV cameras introduced in 2008. (Note: While we intend this list to be all-inclusive, it is possible that we have inadvertently omitted some models. Should this be the case, we offer our humble apologies.) As Exhibit 7.8 shows, the number of new product offerings is impressive, evidencing a high degree of research and development in the MV camera market. What is striking is that most of the new cameras were Gig E and Camera Link; this suggests that going forward the portion of camera sales that are Gig E and Camera Link will continue to increase. We also see that in terms of sensor technology, CCD predominated. Area scan was also far more common than line scan. Beyond these observations, generalizations about product features are not possible. These new cameras offer a wide range of speeds and resolutions to address the needs of many different applications.

Exhibit 7.8: New Product Introductions in 2008

Company	Product Name	Interface	Sensor	Speed	Resolution
Adimec	OPAL-1000	Camera Link	CCD	120 fps	1024x1024, 5.5um square pixels
Adimec	OPAL-1600/2000	Camera Link	CCD	68 fps	1600 x 1200 and 5.5um square pixels
Adimec	ONYX-1000	Gig E	CCD	60 fps	1024x1024, 5.5um square pixels
Adimec	ONYX-1600/2000	Gig E	CCD	34 fps	1600 x 1200 and 5.5um square pixels

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Exhibit 7.8: New Product Introductions in 2008 (Continued)

Company	Product Name	Interface	Sensor	Speed	Resolution
AVT/Prosilica	Pike F-505		CCD	15 fps	High 5MP
AVT/Prosilica	Stingray	1394b	NA	NA	NA
AVT/Prosilica	GE1050/GE1050C	Gig E	CCD	60 fps	1024 x 1024
AVT/Prosilica	GE1660	Gig E	CCD	34 fps	2 MP
AVT/Prosilica	GB Series Single Board	Gig E	CCD	15, 30, 90, 120 fps	659x493, 1360x1024, 2448x2050
AVT/Prosilica	GS Series Periscope-type	NA	CCD	NA	NA
Basler	Pilot piA2400-17	Gig E	CCD	17 fps	2448 x 2050, 5 MP
Basler	Sprint Line Scan	Camera Link	CMOS	70, 39 or 140 kHz	2k, 4k and 8k
Basler	Scout scA1300-32	Gig E, 1394a	CCD	32 fps	1280 x960, 1.2MP
Basler	Runner Line Scan Camera	GigE and GenICam	CCD	NA	NA
Basler	Scout Light Series	1394b	CCD and CMOS	17 fps, 30 fps, 60 fps	782 x 480, 1034 x 779, 1392 x 1040
CIS Americas	VCC-F60FV19GE	Gig E	CCD		5 MP
CIS Americas	G60FV11GE	Gig E	CCD	15 fps	5 MP
DALSA	FA-20-01 M1H	Camera Link	CMOS	100 fps	1400 x 1024, 1.4 MP
DALSA	Spyder3 (line scan)	Gig E, Camera Link	NA	NA	1024 x2 to 4096 x 2
DALSA	Genie C1410 & Genie M1410	Gig E	CCD	22 fps	NA
DALSA	Genie C1600 & M1600	Gig E	CCD	15 fps	2 MP
EPIX	SILICON VIDEO 9C10	Ethernet	CMOS	7.2 fps to 93.5 fps	9 MP, 3488 x 2616, 1280 x 1024, 640 x 480
FLIR	ThermoVision A320G	Gig E and GeniCam	NA	NA	NA
Imaging Solutions Group	LightWise	1394b	CMOS	12 fps	5 MP, 2592 x 1944
IMI Technology	Amazon Series	Gig E	CCD	200 fps	VGA to 16 MP
IMI Technology	Pearl	1394b	CCD, CMOS		VGA to 3 MP
Imperx	BOBCAT	Camera Link	CCD	15 , 16 , 25 , 110 , 210 fps	640x480, 1392x1040, 1628x1236, 2456x2058
Imperx	LYNX IPX-16M3-G, LYNX IPX-16M3-GC	Gig E	NA	3fps	4872x3248
JAI	BM-500GE (monochrome), BB-500CL (color)	Gig E, Camera Link	CCD	15 fps	2448 x 2050,5 MP
JAI	AG-7000 ICCD	Analog	CCD	NA	NA
JAI	CM-040GE, CB-040GE	Gig E	CCD	30 fps	XGA, 1032 x 778
JAI	CM-080GE,CB-080GE	Gig E	CCD	60 fps	776 x 582
JAI	AD-80CL	NA	2CCD	NA	1024 x 768

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Exhibit 7.8: New Product Introductions in 2008 (Continued)

Leutron Vision	PicSight-GigE-Smart501	GigE	CCD, CMOS	NA	NA
Leutron Vision	PicSight-USB2	USB2	CCD, CMOS	NA	VGA to 5MP
Lumenera	Lm085	USB	CMOS	60 fps	752 x 480
Matrix Vision	mvBlueCOUGAR-P	Gig E and GenICam	CCD, CMOS	16 fps to 100 fps	640 x 480 to 1280 x 1024
Mikron Infrared (LumaSense Technologies)	M7816DV (thermal imaging)	USB	NA	NA	160 x 120
Mikron Infrared (LumaSense Technologies)	MCL320MF (thermal imaging)	RS 232, Ethernet	NA	NA	320x240
NET USA	RB600	SDI, USB 2.0	NA	NA	758 x492
NET USA	GimaGO	Gig E	CCD	16 fps to 86 fps	VGA to UXGA
Photonfocus	MV-D1024E-3D01	Camera Link	CMOS	150 fps	1024 x 1024
PixeLink	PL-B761 and PL-B762	IEEE 1394, Gig E, USB 2.0	CMOS	60 fps	752 x 480
Point Grey Research	Chameleon	USB 2.0	CCD	18 fps	1.3 MP
Point Grey Research	Ladybug3		CCD		12 MP, 1600x1200
Point Grey Research	Grasshopper	1394b	CCD	200 fps	640 x 480
Point Grey Research	Flea2	1394b	CCD	30 fps	1.3 & 5 MP
Princeton Instruments	MegaPlus	Gig E, 1394a, Camera Link	NA	4.5 fps to 30 fps	1.6 to 16 MP
SONY	XCD Series	IEEE 1394b	CCD	15, 30, 90 fps	VGA (640x480), SXGA (1280x960), UXGA (1600x1200)
Tattile	Nuova TAG 3	Gig E	NA	NA	NA
Toshiba	Toshiba IK-52V and IK-53V	NA	CCD	NA	659 x 494
Toshiba Teli	CLS800CL Line Scan	Camera Link	CCD	NA	NA
XenICs Nv	Cheetah	NA	NA	NA	640 x 512@ 1,730 Hz

7.2 Survey Results

Expanding upon the information of the previous sections, we next examine the market in terms of sales volumes expressed in revenue and units. Our focus is the historical period of 2004 through 2008 and the forecast period of 2009 through 2013.

7.2.1 Historical Growth Patterns

As shown by Exhibit 7.9, revenue has grown from $68.6 million (USD) in 2004 to $92.0 million in 2008. During this period, units increased from 62,724 in 2004 to 78,522 in

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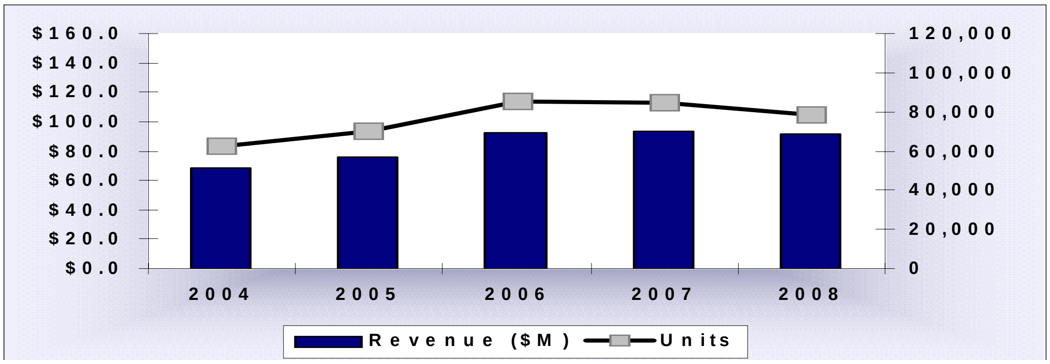
2008. Composite growth rates for the 2004 to 2008 period are 7.6 percent for revenue and 4.0 percent units sold. It should be noted that revenue has been essentially flat for the last three years (2006 - 2008).

Exhibit 7.9: Camera Sales in Revenue ($ Millions) and Units: 2004 to 2008

	2004	2005	2006	2007	2008	CAGR*
Revenue ($M)	$68.6	$75.6	$92.4	$93.2	$92.0	-
%	28.5%	10.3%	22.2%	0.8%	-1.3%	7.6%
Units	62,724	69,726	85,535	84,937	78,522	-
%	28.7%	11.2%	22.7%	-0.7%	-7.6%	4.0%
Average Price	$1,093	$1,084	$1,081	$1,097	$1,171	-



Rates of sales growth in 2008 were down considerably from prior levels. Sales revenue in 2008 decreased -1.3 percent from 2007; units sold were down -7.6 percent. This decline coincides with a slowdown in the US manufacturing sector.

7.2.2 Forecasts

For the forecast period, Exhibit 7.10 shows both revenue and units increasing gradually over time after a further decline in 2009. Revenue first decreases from $92.0 million in 2008 to $87.5 million in 2009, a decline of -4.8 percent, and then gradually increases to $141.1 million by 2013. This reflects a CAGR (compound annual growth rate) of 12.7 percent for the entire forecast period. (However, it must be noted that the forecasts for 2009 and 2010 carry significant downside risk; that is to say, rates of growth for those years could prove significantly weaker, if the economy does not rebound as expected.) Between 2008 and 2009, units are expected to decrease from 78,522 to 72,295, reflecting a growth rate of -7.9 percent. However, after the anticipated recessionary impacts play out, units are expected to increase to 112,629 by 2013, reflecting a CAGR of 11.7 percent for the entire forecast period. (Again, we must emphasize that actual growth in 2009 and 2010 could be significantly weaker than forecast, if the anticipated economic improvement does not materialize.)

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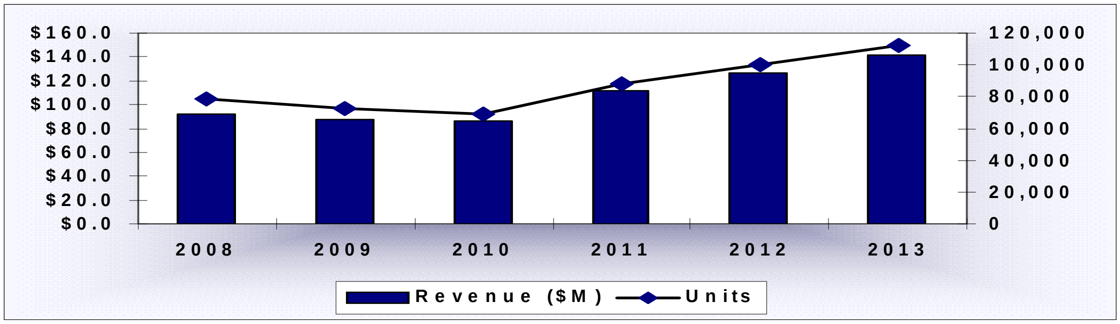
Exhibit 7.10: Forecast Camera Sales in Revenue ($ Millions) and Units: 2008 - 2012

	2008	2009	2010	2011	2012	2013	CAGR
Revenue ($M)	$92.0	$87.5	$85.7	$111.4	$126.1	$141.1	-
%	-1.3%	-4.8%	-2.1%	30.0%	13.1%	11.9%	12.7%
Units	78,522	72,295	68,513	88,222	100,216	112,629	-
%	-7.6%	-7.9%	-5.2%	28.8%	13.6%	12.4%	11.7%
Average Price	$1,171	$1,211	$1,251	$1,263	$1,258	$1,253	-

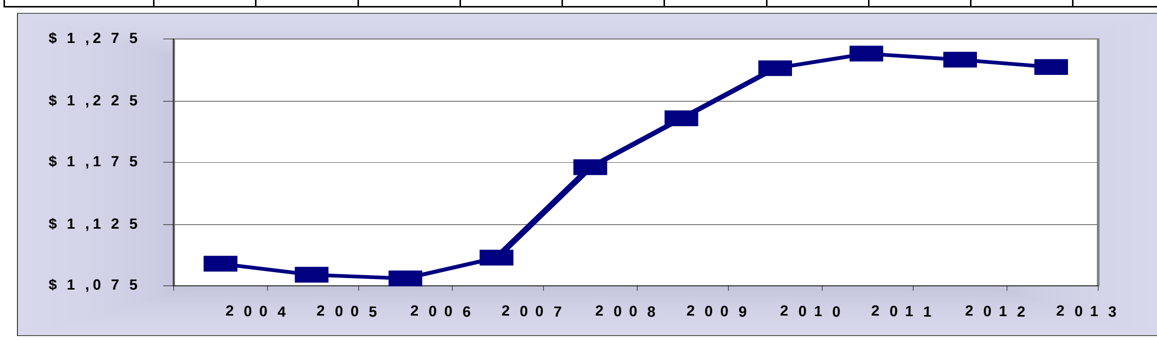


7.2.3 Price Analysis

We also find an interesting pattern in the average price. As Exhibit 7.11 shows, the average price of an MV camera has held more or less steady. Currently, the average price of an MV camera is approximately $1,171. Going forward, the average price should increase over time, as users upgrade their cameras. In part, this will reflect increasing migration from lower-priced monochrome, analog cameras with lower resolutions and shutter speeds. However, there is some evidence that this trend in part could be temporarily interrupted in the short-term by the economy, as customers shy away from the purchase of more expensive cameras.

Exhibit 7.11: Average Camera Price: 2003 - 2012

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Average Price	$1,093	$1,084	$1,081	$1,097	$1,171	$1,211	$1,251	$1,263	$1,258	$1,253



In purchasing cameras, buyers must also consider the cost of imaging boards for the various types of cameras. With this in mind, some manufacturers of imaging boards

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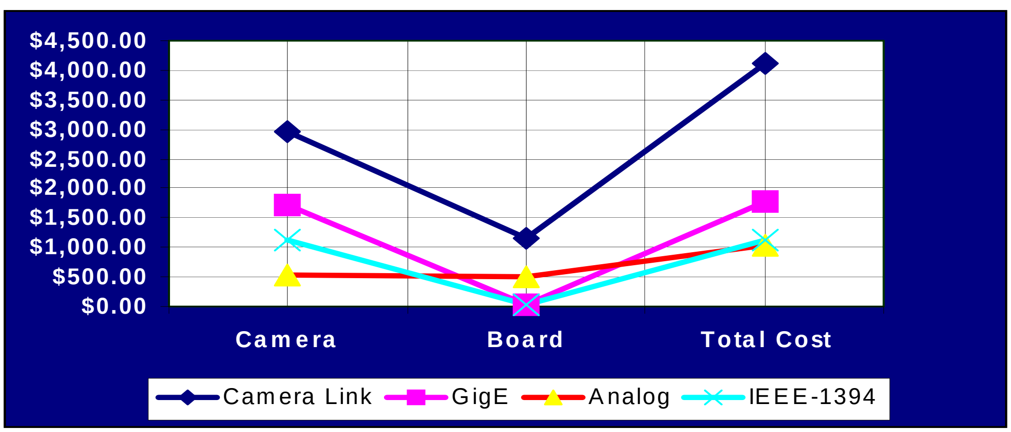
sharply discounted their prices in 2005 as a competitive response to the impending market introduction of GigE and GigE Vision cameras, which do not require imaging boards. This was intended to preemptively "lock-in" imaging board sales and thus limit inroads caused by the sale of GigE Vision cameras. This response occurred against a backdrop of much speculation in the MV industry concerning the demise of the frame grabber.

Our survey data show that the discounting of imaging boards has in fact largely succeeded in removing the cost advantage that GigE Vision cameras might otherwise possess. Exhibit 7.12 shows that - based on the 2008 data collected for this study - GigE Vision cameras have even become more expensive on average than analog and IEEE - 1394. Camera Link is the most expensive, but of course offers far greater bandwidth for data throughput.

Interestingly, the market response of imaging board suppliers to the introduction of GigE and GigE Vision cameras did not involve only deep price discounts. Some imaging board suppliers also introduced new products that enable cameras of different interfaces to work over GigE connections by either changing out the back-end interface electronics with a compact board that is mounted within the camera or by means of a stand-alone box (external to the camera) that captures images from a multitude of cameras and transfers them over GigE links.

Exhibit 7.12: Average Price Comparisons of Different Camera-Card Combinations



	Average Camera Price	Average Board Price	Total Price
Camera Link®	$2,962	$1,156	$4,118
GigE Vision™	$1,729	$40	$1,769
Analog	$538	$498	$1,036
IEEE-1394	$1,116	$20	$1,136

7.3 Total Sales Revenue and Units by Major Product Feature

To increase our understanding of the MV camera market, we next examine sales results in terms of product features. These features include the camera sensor type, sensor resolution, area scan versus line scan, camera interface, monochrome versus color and single-tap versus multi-tap line.

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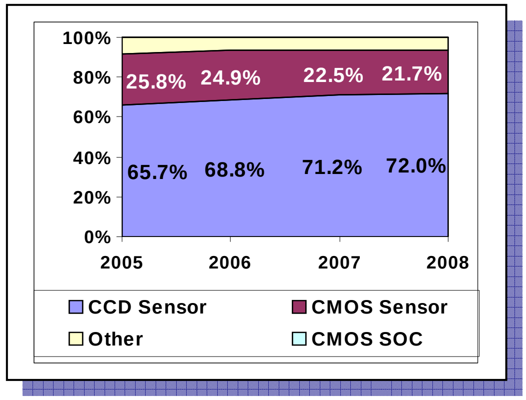
Camera Sales by Sensor Type

As noted in section 7.1, two major sensor types are CCD and CMOS. Of the two sensor technologies, CCD sensors have been used in machine vision for a longer time and are thus more established. This is reflected in Exhibit 7.13, which indicates that 72.0 percent of all cameras sold in 2008 were based on CCD sensor technology. By contrast, 21.7 percent utilized CMOS sensors with the remainder representing "other" technologies. Interestingly, the percentage of CMOS cameras sold has decreased between 2005 and 2008.

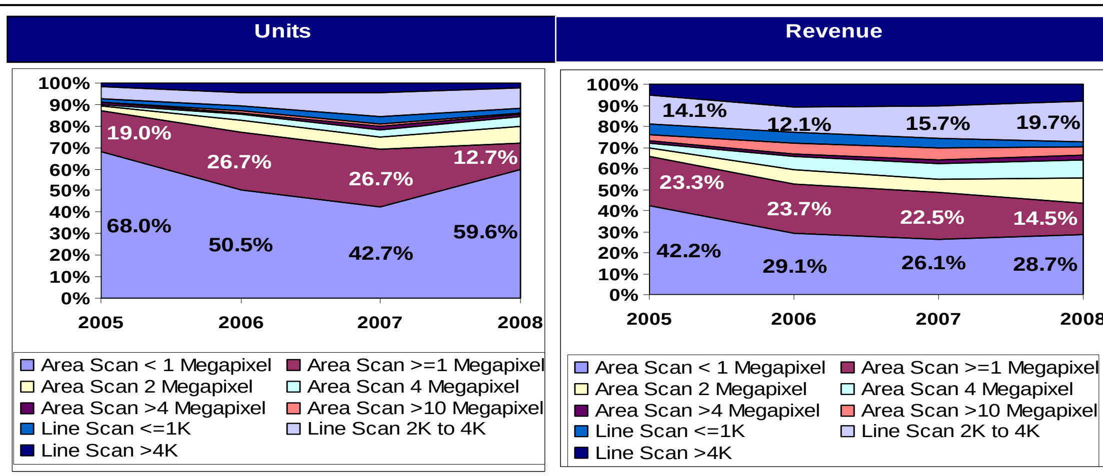
Exhibit 7.13: Camera Sales by Sensor Type - Percent of Total Sales



Camera Sales by Sensor Resolution

Exhibit 7.14 provides a detailed breakdown of MV camera sales by camera type and resolution for 2005 through 2008. In terms of both units and revenue, it is clear that the most common category of camera is the area scan camera with resolution of less than one megapixel. In 2008, 59.6 percent of all units sold and 28.7 percent of total sales revenue has a resolution of less than one megapixel. The remainder of 2008 unit sales (40.4 percent) had a resolution higher than one megapixel. This suggests that the trend toward higher resolutions evidenced in earlier years has been at least temporarily disrupted.

Exhibit 7.14 Total Camera Sales by Sensor Resolution - Percent of Total Sales



	2005 Units	2006 Units	2007 Units	2008 Units	2005 Rev	2006 Rev	2007 Rev	2008 Rev
Area Scan < 1 MP	68.0%	50.5%	42.7%	59.6%	42.2%	29.1%	26.1%	28.7%
Area Scan >=1 MPI	19.0%	26.7%	26.7%	12.7%	23.3%	23.7%	22.5%	14.5%
Area Scan 2 MP	2.3%	5.5%	5.3%	7.8%	4.2%	6.8%	6.2%	12.1%
Area Scan 4 MP	0.6%	2.7%	3.2%	4.4%	2.3%	6.3%	7.3%	8.7%
Area Scan >4 MP	1.0%	0.8%	1.9%	1.2%	1.1%	0.9%	1.9%	2.1%
Area Scan >10 MP	0.3%	1.1%	1.2%	0.7%	2.8%	5.0%	5.5%	4.3%
Line Scan <=1K	1.7%	2.3%	3.3%	1.8%	5.0%	5.4%	4.7%	1.9%
Line Scan 2K to 4K	5.6%	6.1%	11.3%	9.7%	14.1%	12.1%	15.7%	19.7%
Line Scan >4K	1.6%	4.2%	4.3%	2.2%	5.1%	10.7%	10.1%	8.0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

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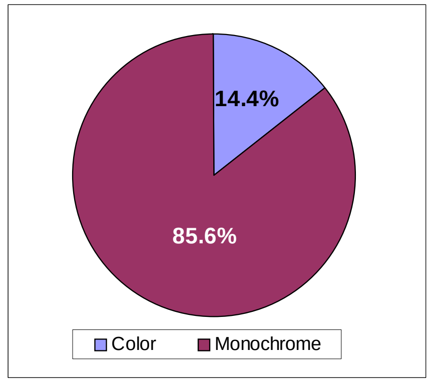
Camera Sales by Color versus Monochrome
How important is color in overall camera sales? In 2008, 14.4 percent of all camera sales were color, accounting for 19.5 percent of total sales revenue, as shown by Exhibit 7.15. Importantly, this is down from 2007 when nearly a third of all camera sales were color.

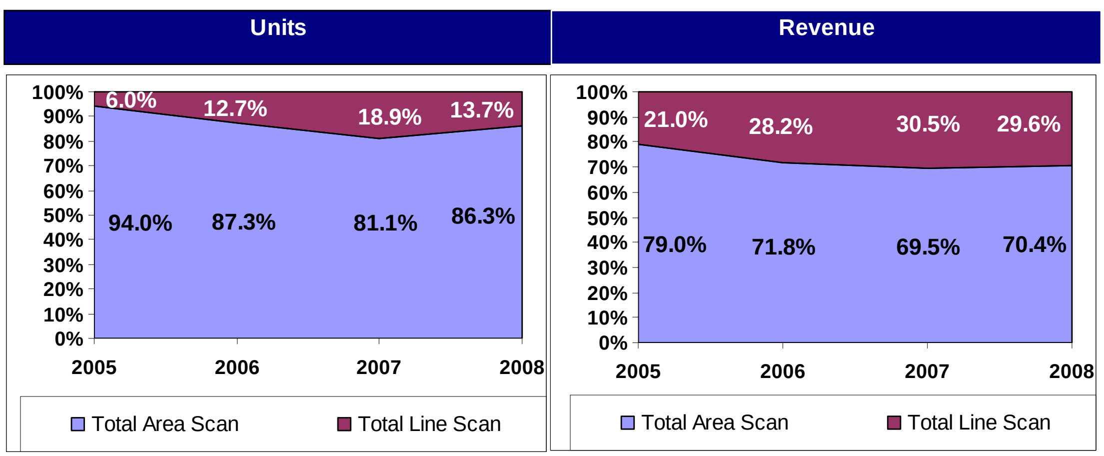
Exhibit 7.15: Camera Sales by Color versus Monochrome



	2008 Units	2008 Revenue
Color	14.4%	19.5%
Monochrome	85.6%	80.5%
Total	100.0%	100.0%

Area Scan versus Line Scan Camera Sales
Our findings also allow us to identify the portion of camera sales that are area scan versus line scan. As dramatically shown by Exhibit 7.16, the overwhelming portion of MV cameras sold was area scan, at 86.3 percent of all cameras in 2008, accounting for 70.4 percent of total revenue in 2008. It is important to note that the percentage of line scan camera sales has decreased, suggesting at least a temporary departure from the trend towards greater use of line scan cameras.

Exhibit 7.16: Area Scan vs. Line Scan Camera Sales – Percent of Total Sales



	2005 Units	2006 Units	2007 Units	2008 Units	2005 Rev	2006 Rev	2007 Rev	2008 Rev
Area Scan	91.1%	87.3%	81.1%	86.3%	75.9%	71.8%	69.5%	70.4%
Line Scan	8.9%	12.7%	18.9%	13.7%	24.1%	28.2%	30.5%	29.6%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Exhibit 7.17 breaks down these figures even further by looking at sales in terms of both area scan versus line scan and color versus monochrome. Clearly, monochrome area scan camera sales in 2008 constituted a commanding portion of total sales at 66.6% of units sold and 52.8% of total sales revenue.

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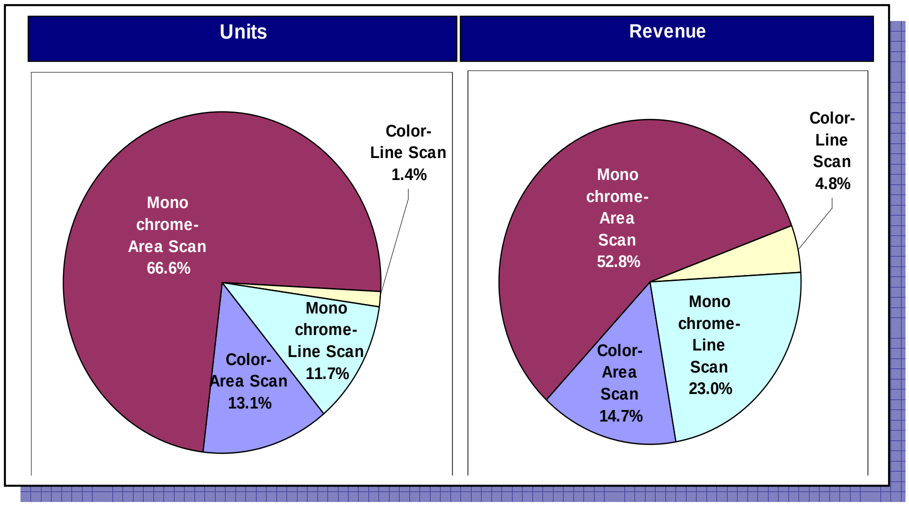
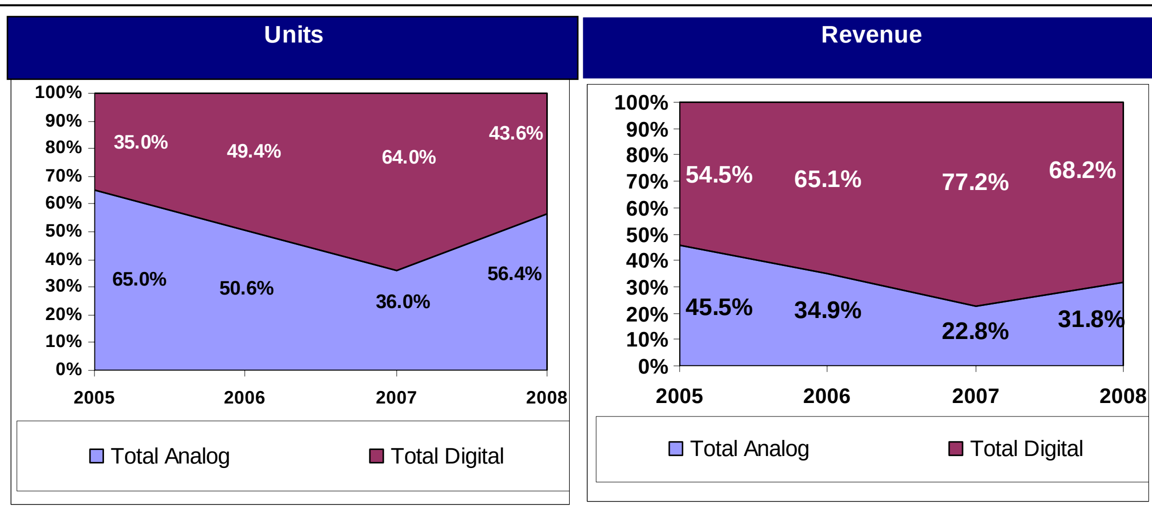
Exhibit 7.17: Area Scan vs. Line Scan by Color vs. Monochrome



<u>Area Scan Camera Sales by Analog versus Digital</u>

Looking closer at area scan camera sales, we next determine the extent to which digital technology has made inroads into the market. As Exhibit 7.18 shows, digital cameras have (at least temporarily) stopped growing as a percentage of total sales. As of 2008, digital sales represented 43.6 percent of all units sold, accounting for 68.2 percent of sales revenue. As the economy improves, we could well see a return to the trend towards greater digital camera sales.

Exhibit 7.18: 2008 Sales of Digital and Analog Area Scan Cameras - Percent of Total Sales



	2005 Units	2006 Units	2007 Units	2008 Units	2005 Rev	2006 Rev	2007 Rev	2008 Rev
Analog	65.0%	50.6%	36.0%	56.4%	45.5%	34.9%	22.8%	31.8%
Digital	35.0%	49.4%	64.0%	43.6%	54.5%	65.1%	77.2%	68.2%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

We can shed additional light on these results by breaking them down even further by interface. As shown by Exhibit 7.19, IEEE-1394 is the most widely used digital interface, accounting for 24.5 percent of total camera sales, which equates to 28.6 percent of total revenue in 2008. Camera Link follows in second place in terms of units sold at 7.5 percent of units in 2008, accounting for 23.2 percent of sales revenue. Importantly, while

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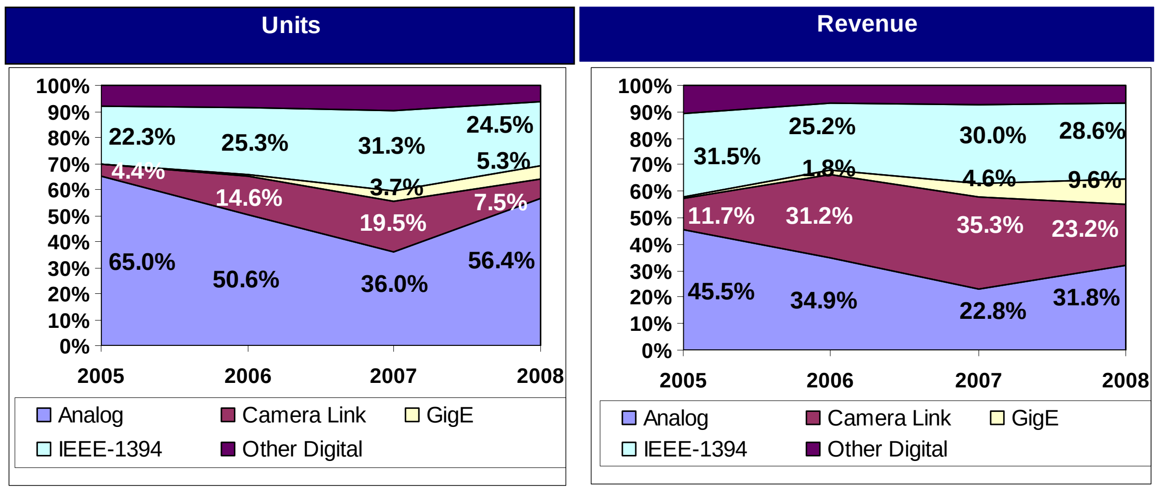
GigE Vision sales have increased, Camera Link and IEEE-1394 sales have decreased in 2008.

Exhibit 7.19: Total Area Scan Camera Sales by Interface - Percent of Total Sales



	2005 Units	2006 Units	2007 Units	2008 Units	2005 Rev	2006 Rev	2007 Rev	2008 Rev
Analog	65.0%	50.6%	36.0%	56.4%	45.5%	34.9%	22.8%	31.8%
Camera Link	4.4%	14.6%	19.5%	7.5%	11.7%	31.2%	35.3%	23.2%
GigE & GigE Vision	0.3%	0.8%	3.7%	5.3%	0.7%	1.8%	4.6%	9.6%
IEEE-1394	22.3%	25.3%	31.3%	24.5%	31.5%	25.2%	30.0%	28.6%
Other Digital	8.0%	8.7%	9.5%	6.2%	10.7%	6.9%	7.3%	6.7%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

We also break down area scan sales by interface, color versus monochrome and resolution. Exhibit 7.20 focuses on area scan monochrome cameras only that have a resolution of less than one megapixel. These cameras are overwhelmingly analog at 76.7 percent of units and 65.9 percent of revenue for this camera category.

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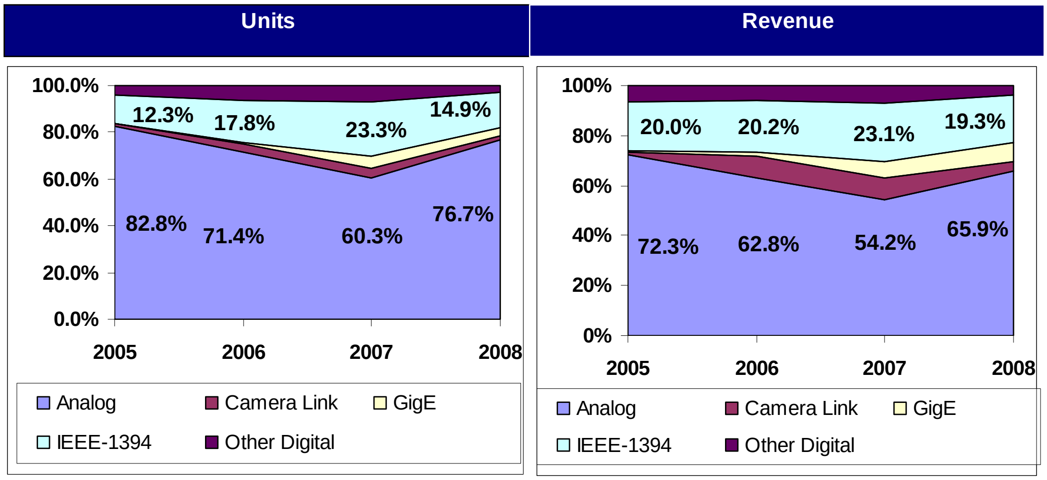
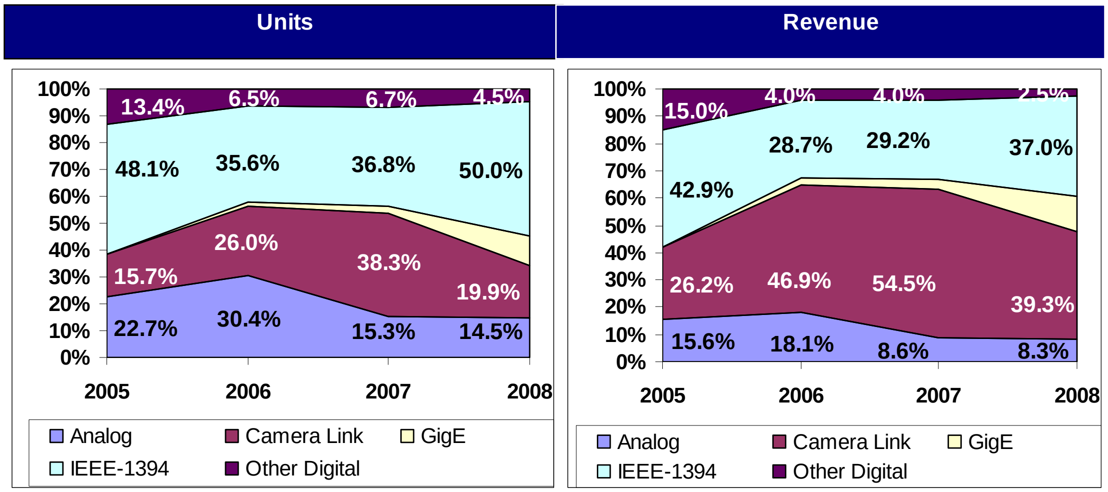
Exhibit 7.20: Camera Sales by Interface- Percent of Total Area Scan Monochrome Cameras - Less Than 1 Megapixel Only



	2005 Units	2006 Units	2007 Units	2008 Units	2005 Rev	2006 Rev	2007 Rev	2008 Rev
Analog	82.8%	71.4%	60.3%	76.7%	72.3%	62.8%	54.2%	65.9%
Camera Link	0.7%	3.8%	4.5%	1.7%	1.3%	9.2%	8.8%	3.5%
GigE & GigE Vision	0.0%	0.5%	4.8%	3.7%	0.0%	1.6%	6.6%	7.6%
IEEE-1394	12.3%	17.8%	23.3%	14.9%	20.0%	20.2%	23.1%	19.3%
Other Digital	4.2%	6.5%	7.2%	3.0%	6.4%	6.2%	7.3%	3.7%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

We see a markedly different pattern when we focus on higher resolution cameras. As shown by Exhibit 7.21, the percent of area scan monochrome cameras that are analog drops to 14.5 percent of units and 8.3 percent of revenue in 2008. Thus, these higher resolution cameras are predominantly digital. In terms of units sold, the largest category of high resolution monochrome cameras is IEEE-1394 at 50.0 percent of units. In terms of revenue, IEEE-1394 comprised 37.0 percent of sales in 2008. However, contributing the largest share of sales revenue is Camera Link at 39.3 percent.

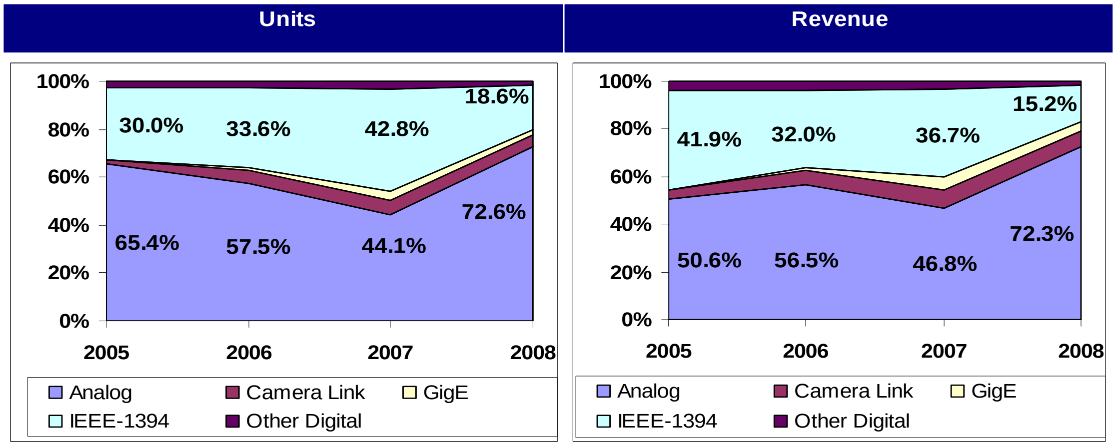
Exhibit 7.21: Camera Sales by Interface- Percent of Total Area Scan Monochrome Cameras *More* Than 1 Megapixel Only



	2005	2006	2007	2008	2005	2006	2007	2008
	Units	Units	Units	Units	Rev	Rev	Rev	Rev
Analog	22.7%	30.4%	15.3%	14.5%	15.6%	18.1%	8.6%	8.3%
Camera Link	15.7%	26.0%	38.3%	19.9%	26.2%	46.9%	54.5%	39.3%
GigE & GigE Vision	0.2%	1.5%	2.9%	11.1%	0.2%	2.4%	3.7%	12.9%
IEEE-1394	48.1%	35.6%	36.8%	50.0%	42.9%	28.7%	29.2%	37.0%
Other Digital	13.4%	6.5%	6.7%	4.5%	15.0%	4.0%	4.0%	2.5%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

What about color area scan cameras? If we shift our focus from monochrome to color area cameras, we learn that in the case of low resolution cameras, the interface is predominantly analog. In fact, 72.6 percent of all low resolution, color area scan cameras sold in 2008 were analog or 72.3 percent of total revenue for this camera category.

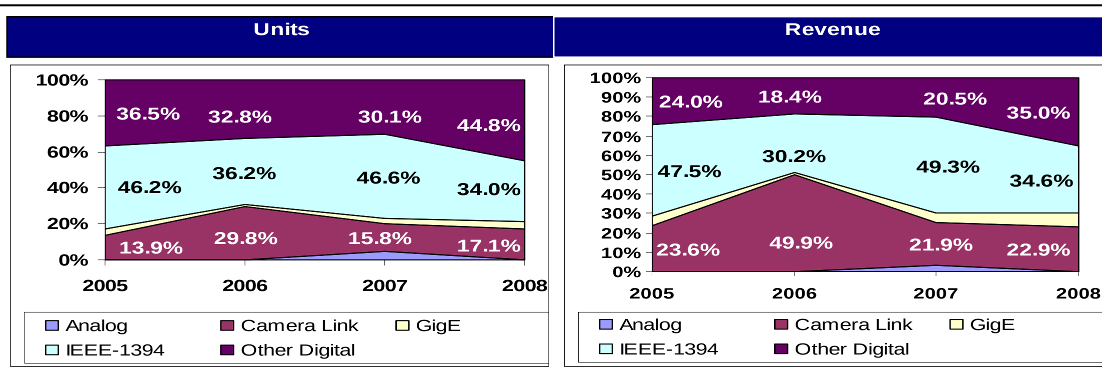
Exhibit 7.22: Camera Sales by Interface - Percent of Total Color Area Scan Cameras - *Less* Than 1 Megapixel Only



	2005 Units	2006 Units	2007 Units	2008 Units	2005 Rev	2006 Rev	2007 Rev	2008 Rev
Analog	65.4%	57.5%	44.1%	72.6%	50.6%	56.5%	46.8%	72.3%
Camera Link	1.9%	5.3%	5.9%	4.7%	3.6%	6.4%	7.3%	6.8%
GigE & GigE Vision	0.1%	0.9%	4.1%	2.4%	0.1%	1.1%	5.6%	3.8%
IEEE-1394	30.0%	33.6%	42.8%	18.6%	41.9%	32.0%	36.7%	15.2%
Other Digital	2.5%	2.7%	3.1%	1.6%	3.8%	4.0%	3.5%	1.9%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

We found almost the exact opposite results when we looked at high resolution, color area scan cameras. As shown by Exhibit 7.23, 0.0 percent of cameras sold were analog. 44.8 percent of these cameras sold in 2008 were Other Digital, comprising 35.0 percent of the total revenue for this camera category. IEEE 1394 comprised 34.0 percent of units sold and 34.6 percent of total revenue.

Exhibit 7.23: Camera Sales by Interface – Percent of Total Color Area Scan Cameras - *More* Than 1 Megapixel Only



	2005 Units	2006 Units	2007 Units	2008 Units	2005 Rev	2006 Rev	2007 Rev	2008 Rev
Analog	0.0%	0.0%	4.6%	0.0%	0.0%	0.0%	3.5%	0.0%
Camera Link	13.9%	29.8%	15.8%	17.1%	23.6%	49.9%	21.9%	22.9%
GigE & GigE Vision	3.5%	1.2%	3.0%	4.1%	4.9%	1.5%	4.8%	7.4%
IEEE-1394	46.2%	36.2%	46.6%	34.0%	47.5%	30.2%	49.3%	34.6%
Other Digital	36.5%	32.8%	30.1%	44.8%	24.0%	18.4%	20.5%	35.0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

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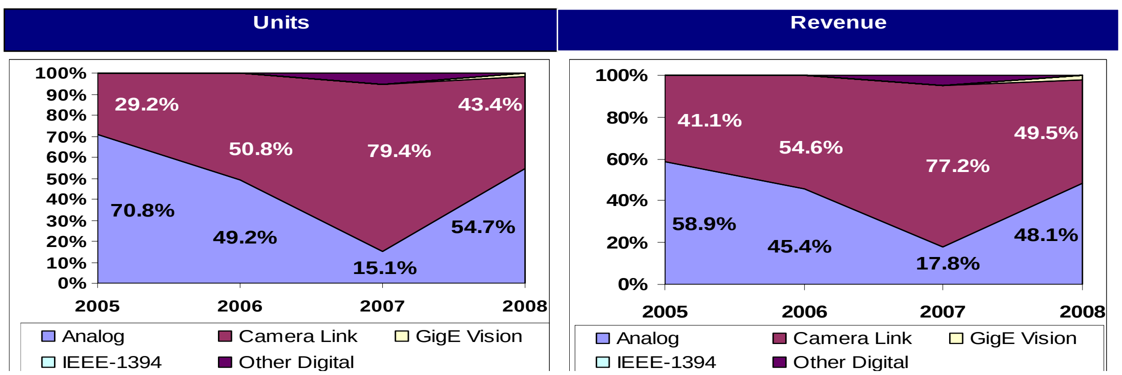
In the case of 3 CCD area scan cameras, we found that most units sold in 2008 were analog at 54.7 percent of units sold and 48.1 percent of total revenue for this category, as revealed by Exhibit 7.24. This represents a departure from the trend witnessed during the previous three years when Camera Link expanded its share of sales.

Exhibit 7.24: Camera Sales by Interface - 3 CCD Area Scan Cameras

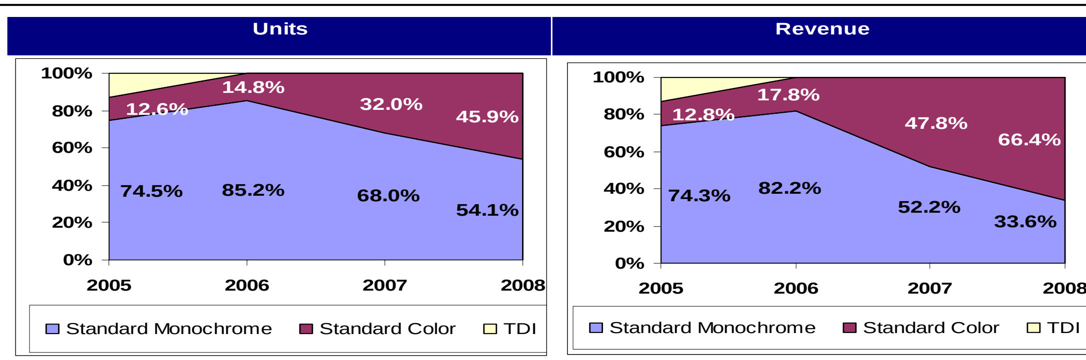


	2005	2006	2007	2008	2005	2006	2007	2008
	Units	Units	Units	Units	Rev	Rev	Rev	Rev
Analog	70.8%	49.2%	15.1%	54.7%	58.9%	45.4%	17.8%	48.1%
Camera Link	29.2%	50.8%	79.4%	43.4%	41.1%	54.6%	77.2%	49.5%
GigE & GigE Vision	0.0%	0.0%	0.0%	1.9%	0.0%	0.0%	0.0%	2.4%
IEEE-1394	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Other Digital	0.0%	0.0%	5.5%	0.0%	0.0%	0.0%	5.0%	0.0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Line Scan Camera Sales by Major Type

Thus far, we have focused on area scan cameras. We turn now to an examination of results for line scan cameras, beginning with Exhibit 7.25.

Exhibit 7.25: Single Tap Line Scan Camera Sales by Type



	2005	2006	2007	2008	2005	2006	2007	2008
	Units	Units	Units	Units	Rev	Rev	Rev	Rev
Standard Monochrome	74.5%	85.2%	68.0%	54.1%	74.3%	82.2%	52.2%	33.6%
Standard Color	12.6%	14.8%	32.0%	45.9%	12.8%	17.8%	47.8%	66.4%
TDI	13.0%	0.0%	0.0%	0.0%	12.9%	0.0%	0.0%	0.0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

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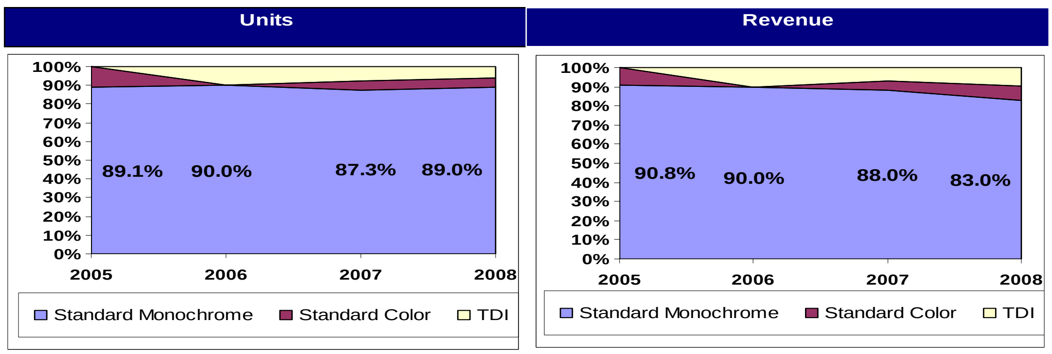
As Exhibit 7.25 reveals, most single-tap line scan cameras sold in 2008 (54.1 percent) were standard monochrome with corresponding sales revenue of 33.6 percent. (Standard color, however, accounted for most of the revenue.) No TDI camera sales were recorded for 2008.

We find a similar breakdown in the case of multi-tap line scan cameras. As Exhibit 7.26 shows, the overwhelming majority of multi-tap line scan cameras sold in 2008 was standard monochrome cameras at 89.0 percent of units and 83.0 percent of revenue.

Exhibit 7.26: Multi-Tap Line Scan Camera Sales by Type

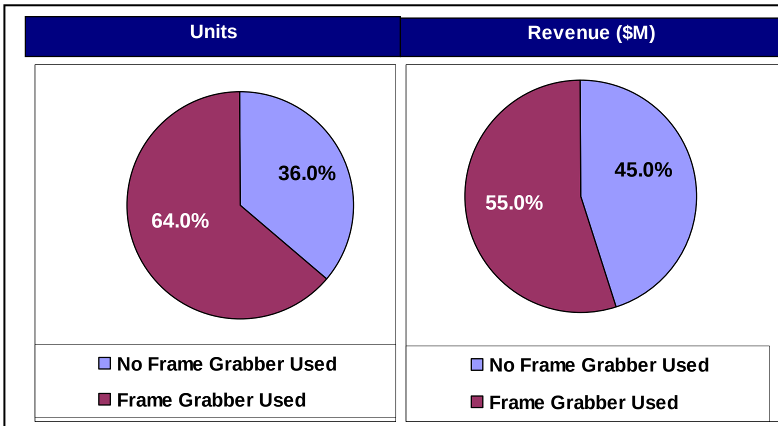


	2005 Units	2006 Units	2007 Units	2008 Units	2005 Rev	2006 Rev	2007 Rev	2008 Rev
Standard Monochrome	89.1%	90.0%	87.3%	89.0%	90.8%	90.0%	88.0%	83.0%
Standard Color	10.9%	0.0%	4.7%	5.2%	9.2%	0.0%	5.0%	7.5%
TDI	0.0%	10.0%	7.9%	5.8%	0.0%	10.0%	7.0%	9.5%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Area Scan Sales: Frame Grabber Vs. No Frame Grabber

Has the MV industry in North America reached the point where most cameras are used without frame grabbers?

Exhibit 7.27: Percent of Area Scan Cameras Sold that Do Not Use a Frame Grabber



According to Exhibit 7.27, this point has not yet been reached. In 2008, 36.0 percent of area scan cameras sold did not require use of a frame grabber; in other words, the majority (64.0 percent of area scan cameras) sold in 2008 did use frame grabbers. This largely reflects the resurgence of analog cameras.

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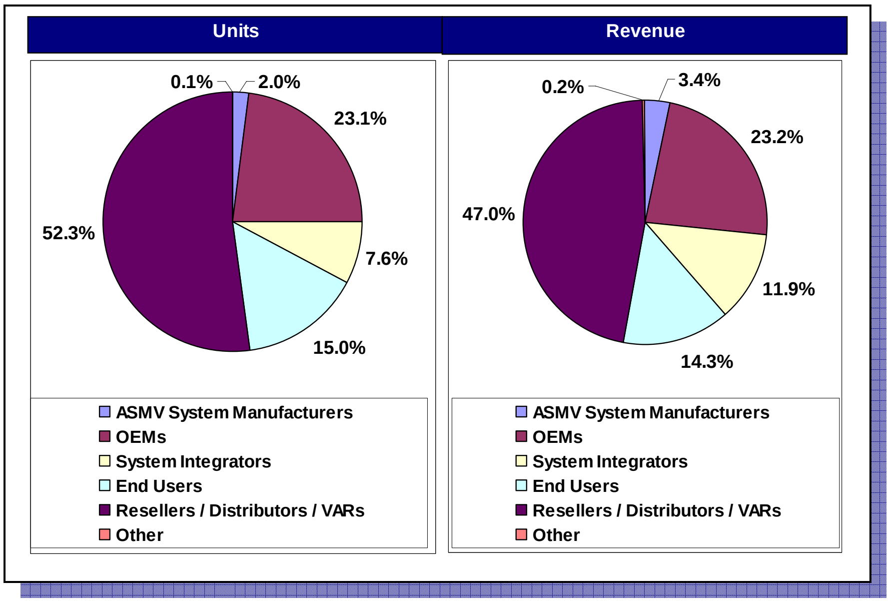
Sales by Type of Customer
Finally, we examine 2008 MV camera sales by type of customer.

Exhibit 7.28: Total Sales by Type of Customer



As Exhibit 7.28 indicates, the overwhelming portion of camera sales made by suppliers in 2008 was to resellers, distributors or value-added resellers (VARs). Over 52.3 percent of units were sold to that group, which accounted for 47.0 percent of the total sales revenue earned by suppliers.

7.4 Summary of Major Findings

The major findings of this chapter are as follows:

- **Market Characteristics:** The MV camera market is characterized by a great diversity of suppliers and products with product development reflecting a strong technological focus.
- **Major Trends and Developments:** Important long-term trends and developments include increasing demand for digital interfaces, the concomitant decline in analog cameras, growing demand for cameras involving greater bandwidth entailing migration from cameras with lower-end interfaces to ones with higher-end interfaces, increasing reliance on FPGAs to perform image preprocessing tasks within cameras, and, in general, continuous enhancements in camera capabilities. In the short-term, however, we have seen a departure from these long-term trends as a consequence of the economy. Older technology, such as that represented by analog cameras, is less expensive than newer technology. Similarly, cameras with less advanced features do not cost as much as cameras with greater capabilities such as faster shutter speed, higher resolution and higher bandwidth interfaces. It is perhaps not surprising that in a recession, demand for less expensive cameras has increased. Once the economy recovers, however, we would expect a return to the long-term trends reflected in the historical data.
- **Historical Sales**: Revenue has grown from $68.6 million (USD) in 2004 to $92.0 million in 2008. During this period, units increased from 62,724 in 2004 to 78,522 in 2008. Composite growth rates for the 2004 to 2008 period are 7.6 percent for

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revenue and 4.0 percent units sold. It should be noted that revenue has been essentially flat for the last three years (2006 - 2008). Rates of sales growth in 2008 were down considerably from prior levels. Sales revenue in 2008 decreased -1.3 percent from 2007; units sold were down at -7.6 percent. This decline coincides with a slowdown in the US manufacturing sector.

- **Forecast Sales:** For the forecast period, both revenue and units are expected to increase gradually over time after a further decline in 2009. Revenue will initially decrease from $92.0 million in 2008 to $87.5 million in 2009, a decline of -4.8 percent, and then gradually increase to $141.1 million by 2013. This reflects a CAGR (compound annual growth rate) of 12.7 percent for the entire forecast period. (However, it must be noted that the forecasts for 2009 and 2010 carry significant downside risk; that is to say, rates of growth for those years could prove significantly weaker, if the economy does not rebound as expected.) Between 2008 and 2009, units are expected to decrease from 78,522 to 72,295, reflecting a growth rate of -7.9 percent. However, after the anticipated recessionary impacts play out, units are expected to increase to 112,629 by 2013, reflecting a CAGR of 11.7 percent for the entire forecast period. (Again, we must emphasize that actual growth in 2009 and 2010 could be significantly weaker than forecast, if the anticipated economic improvement does not materialize.)
- **Average Price**: The average price of an MV camera has held more or less steady. Currently, the average price of an MV camera is approximately $1,171. Going forward, the average price should increase over time, as users upgrade their cameras. In part, this will reflect increasing migration from lower-priced monochrome, analog cameras with lower resolutions and shutter speeds. However, evidence suggests that the economy could temporarily interrupt this trend in the short-term, if customers continue to shy away from the purchase of more expensive cameras.
- **More on Price**: In purchasing cameras, buyers also consider the cost of imaging boards. Mindful of this, some imaging board manufacturers sharply discounted their prices in 2005 as a competitive response to the impending market introduction of GigE and GigE Vision cameras (which do not require imaging boards). This occurred against a backdrop of much speculation in the MV industry concerning the demise of the frame grabber and was intended to preemptively "lock-in" imaging board sales and thus limit inroads caused by the sale of GigE Vision cameras. Our 2008 survey data show that the discounting of imaging boards has in fact largely succeeded in removing the cost advantage that GigE Vision cameras might otherwise possess. GigE cameras have even become more expensive on average than analog and IEEE - 1394. Camera Link is the most expensive, but of course offers far greater bandwidth for data throughput.
- **Sales by Sensor Technology:** 72.0 percent of all cameras sold in 2008 were based on CCD sensor technology. By contrast, 21.7 percent utilized CMOS sensors with the remainder representing "other" technologies. Interestingly, the percentage of CMOS cameras sold has decreased between 2005 and 2008.
- **Sales by Color versus Monochrome:** In 2008, 14.4 percent of all camera sales were color, accounting for 19.5 percent of total sales revenue.
- **Sales by Scanning Technology:** The overwhelming portion of MV cameras sold was area scan at 86.3 percent of all cameras in 2008, accounting for 70.4 percent of total

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revenue in 2008. The percentage of line scan camera sales has decreased, suggesting at least a temporary departure from the trend towards greater use of line scan cameras.

- **Sales by Scanning Technology and Monochrome versus Color**: When sales are broken down in terms of both area scan versus line scan and color versus monochrome, it is evident that monochrome area scan camera sales in 2008 were dominant at 66.6 percent of total units sold and 52.8 percent of total sales revenue.
- **Area Scan Sales by Analog versus Digital:** Digital cameras have (at least temporarily) stopped growing as a percentage of total sales. As of 2008, digital sales represented 43.6 percent of all units sold, accounting for 68.2 percent of sales revenue. As the economy improves, we could well see a return to the trend towards greater digital camera sales.
- **Area Scan Sales by Interface**: IEEE-1394 is the most widely used digital interface, accounting for 24.5 percent of total camera sales, which equates to 28.6 percent of total revenue in 2008. Camera Link follows in second place in terms of units sold at 7.5 percent of units in 2008, accounting for 23.2 percent of sales revenue. Importantly, while GigE Vision sales have increased, Camera Link and IEEE-1394 sales have decreased in 2008.
- **GigE Vision Sales**: GigE Vision cameras continue to increase their share of camera sales, despite the fact that digital cameras lost share to analog cameras in 2008. In 2008, GigE Vision sales accounted for 5.3 percent of units and 9.6 percent of revenue.
- **Monochrome Area Scan Sales by Interface with Lower Resolution (Less than One Megapixel):** Area scan monochrome cameras with a resolution of less than one megapixel continue to be overwhelmingly analog at 76.7 percent of units and 65.9 percent of revenue in 2008.
- **Monochrome Area Scan Sales with Higher Resolution:** Higher resolution, monochrome, area scan cameras continue to be predominantly digital. In terms of units sold, the largest category of these cameras is IEEE-1394 at 50.0 percent of units in 2008. In terms of revenue, Camera Link had the largest share, comprising 39.3 percent) of sales in 2008.
- **Color Area Scan Cameras by Interface with Lower Resolution:** 72.6 percent of all low resolution, color area scan cameras sold in 2008 was analog or 72.3 percent of total revenue for this camera category.
- **Color Area Scan Cameras by Interface with Higher Resolution:** No color, area scan cameras sold were analog. 44.8 percent of these cameras sold in 2008 were Other Digital or about 35.0 percent of the total revenue for this camera category. IEEE-1394 comprised 34.0 percent of units sold and 34.6 percent of total revenue.
- **3 CCD Area Scan Cameras by Interface:** Most 3 CCD area scan cameras sold in 2008 were analog at 54.7 percent of units sold and 48.1 percent of total revenue. This represents a departure from the trend witnessed during the previous three years when Camera Link expanded its share of sales.
- **Single Tap Line Scan Camera Sales:** Most single-tap line scan cameras sold in 2008 (54.1 percent) were standard monochrome with corresponding sales revenue of 33.6 percent. (Standard color, however, accounted for most of the revenue.) No TDI camera sales were recorded for 2008.

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- **Multi-Tap Line Scan Cameras:** The overwhelming majority of multi-tap line scan cameras sold in 2008 was standard monochrome cameras at 89.0 percent of units and 83.0 percent of revenue.
- **Use of Frame Grabbers:** The majority (64.0 percent) of area scan cameras sold in 2008 used frame grabbers. This is up over 2007, reflecting the increase in analog camera sales.
- **Camera Sales by Type of Customer:** The overwhelming portion of camera sales made by suppliers in 2008 was to resellers, distributors or value-added resellers (VARs). Over 52.3 percent of units were sold to that group, which accounted for 47.0 percent of the total sales revenue earned by suppliers.

These findings are in part summarized by Exhibits 7.29 and 7.30.

Exhibit 7.29: Selected 2008 Camera Sales Data at a Glance (Units)

Sales by Sensor Technology:	72.0% CCD	21.7% CMOS
Sales by Sensor Resolution:	59.6% <1MP	40.4% >1MP
Sales by Color vs. Monochrome:	14.4% Color	85.6% Monochrome
Sales by Scanning Technology:	86.3% Area Scan	13.7% Line Scan
Area Scan Sales:		
	15.0% Color	85.0% Monochrome
	56.4% Analog	43.6% Digital
Line Scan Sales:		
	11.6% Single Tap	88.4% Multi Tap
	14.4% Color	85.6% Monochrome

Exhibit 7.30: Major Camera Sales Characteristics by Category at a Glance (Based on Units)

Category	Dominant Characteristic in 2008
Sensor Technology	CCD
Color vs. Monochrome	Monochrome
Scanning Technology	Area Scan
Digital Vs. Analog Interface	Analog
Type of Digital Interface	IEEE-1394
Frame Grabber Used Vs. No Frame Grabber Used	Frame Grabber Used
Type of Customer	Reseller/ Distributor/ VAR

7.5 Conclusions

The effects of the recession are clearly evident in the data for 2008. Importantly, not only has the recession decreased total sales; it has also affected the mix of products sold. In hindsight, this is of course expected, since in a recession less funds are available for purchases and buyers must “trade down” (much like consumers) to stay within their means. Accordingly, cameras purchased in 2008 have been on average less advanced in

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technology and correspondingly of lower capability. This has meant at least a temporary interruption in some key trends. In previous studies, we found that MV cameras sold in North America were becoming increasingly digital and higher in resolution, more frequently used a Camera Link interface than in previous years and were more apt to use color instead of monochrome light than previously. But 2008 for the most part did not show a continuation of these trends. (Most revealing was the fact that for the first time in a long time analog sales exceeded digital sales.)

Since economic conditions are expected to worsen in 2009, a further departure from these trends is likely. Once economic conditions improve, however, sales data should show a return to these trends as well as healthier sales volumes.

With the recovery, camera sales will improve gradually in response to pent up demand and the utilization of more advanced applications will once again drive demand for more sophisticated cameras that offer more advanced technological capabilities.

An important key to success is for MV camera suppliers to adjust their sales tactics to current economic realities but at the same time prepare to ramp up production of more sophisticated products, once the recovery is felt.

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Chapter 8: MV Imaging Board Market

Quick Navigation Buttons:

8.1 Introduction | 8.2 Survey Results | 8.3 Summary of Major Findings | 8.4 Conclusions

8.0 What's New in this Chapter?

- 8.1.6 New Product Introductions in 2008
- 8.2 Survey Results
- 8.3 Summary of Major Findings
- 8.4 Conclusions

8.1 Introduction

Imaging boards perform the central role of linking the camera to the computer by "grabbing" an image, processing it and transmitting it to the host computer. Although simple in concept, the essential role of an imaging board can be difficult to execute. For one thing, the imaging board must fit the camera. It must have the proper interface, camera controls (trigger, strobe and synchronization) and sufficient I/O (input/output capacity). It must also have the proper computer bus interface and software to support image processing functions. With the myriad of imaging boards available in the market and the exacting requirements of a range of different cameras, integrating an imaging board with a camera and host computer can be very challenging.

8.1.1 Overview of the MV Imaging Board Market

We define the imaging board market in terms of the product sales of MV imaging board suppliers operating at the front end of the MV supply chain in accordance with the overall methodological approach of this study and past AIA MV market studies, as

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outlined in Chapter 2. Distributors and other market intermediaries are thus not included in this “front-end component” market. Moreover, to avoid double-counting, all imaging board sub-components are excluded from the scope of this study.

Despite its contraction, the North American MV imaging board market remains important in size as measured in terms of both sales volumes and the number of market participants. Expressed in revenue, sales volumes for imaging boards have varied from $35.4 million (USD) in 2004 to $23.4 million in 2008, reflecting a composite annual growth rate of -9.9 percent. (See Exhibit 8.5 for more details.) Within this market, there are also many participants, over 30 in number, which together offer a wide variety of imaging board products. (See Exhibit 8.1.) In the next sections, we examine both products and participants of the MV imaging board market.

8.1.2 Major Product Types and Features

All product types examined in this chapter are MV imaging boards. We define an MV imaging board as an imaging device utilized in an MV system that consists of a camera interface (the front end of the board), a host computer interface (back end of the board) and connection in between, which enables the exchange of data between the camera and host computer. Additionally, MV imaging boards typically perform video synchronization and controls, including camera trigger inputs, strobe outputs and exposure control.

MV imaging boards include frame grabbers, vision processor boards, embedded vision processor boards (not to be confused with embedded vision processors addressed in the chapter on smart cameras) and image processor boards that are used in machine vision. The difference between MV frame grabbers and vision processor boards, embedded vision processor boards and image processor boards that are used in machine vision pertains to the number of complex image processing capabilities involved. In essence, vision processor boards, embedded vision processor boards and image processor boards are high-end MV frame grabbers. For purposes of this study, they typically can perform more than two complex image processing functions (such as blob analysis or pattern recognition), while MV frame grabbers have two or less functions.

It is important to note that not all frame grabbers are MV frame grabbers. Some frame grabbers, which are intended for the consumer market, are nothing more than video cards used in PCs. Still, other frame grabbers are low-end FIFO (first in, first out) cards used for low-end microscopy and security applications. Importantly, both video cards and low-end FIFO cards are excluded from our definition of MV imaging boards. Included in our definition of MV imaging board are higher-end FIFO cards, frame grabbers with on-board memory and frame grabbers with on-board processors that are intended for use in machine vision.

It should be noted that within the MV industry there is some disagreement about whether an MV frame grabber should have on-board memory. Some frame grabber suppliers argue that in the case of PCI (Peripheral Component Interconnect) frame grabbers, the PCI bus feeds data directly into the host computer’s memory without loss, and therefore,

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in contrast to older ISA (Industry Standard Architecture) frame grabbers; large memory buffers are not needed. FIFOs, which serve as “way stations” for holding data while the frame grabber gets permission to send it to the host computer’s CPU, suffice in place of on-board RAM.

Other frame grabber suppliers argue that on-board memory is needed as a security measure against losing data when the PCI bus gets congested and to accelerate image processing functions that would over-tax the capabilities of the host computer’s CPU. (Our decision to include higher-end FIFO cards in our definition of MV imaging boards indicates neither acceptance nor rejection of these positions.)

Additionally, we note that not all camera interface boards are considered MV imaging boards for purposes of this study. Some cameras do not use frame grabbers. USB cameras utilize either USB (universal serial bus) cards or USB functionality embedded in the host computer’s motherboard. IEEE-1394 (FireWire) cameras use IEEE-1394 cards, and GigE Vision cameras utilize a NIC (network interface card).

The following graphic sums up our definition of ‘MV imaging board’ by listing inclusions and exclusions:

Definition of MV Imaging Board

Included	Excluded
▪ Vision Processor Boards ▪ Embedded Vision Processor Boards ▪ Image Processor Boards ▪ Higher-end FIFO Frame Grabbers ▪ Frame Grabbers with On-board Memory ▪ Frame Grabbers with On-board Processing	▪ Video Cards ▪ Lower-end FIFO Security and Microscopy Frame Grabbers ▪ USB Cards ▪ Simple IEEE-1394 Cards ▪ Simple NICs (Network Interface Cards)

It should be noted that the line is blurring between those cards included in our definition and those that are excluded. Higher-end IEEE-1394 cards and sophisticated GigE NICs are emerging that contain processing cores that can provide acceleration or offloading of image processing functions, thus freeing up the host processor to some extent. Should these cards become commonplace, it will become necessary to revisit our definition of ‘imaging board’, or at least to separately track sales of these cards.

In the market, there is a wide variety of MV imaging boards, which are typically segmented based on product features relating to types of camera interfaces, computer busses and the amount of on-board processing.

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8.1.3 Major Suppliers

At present, we find 33 MV imaging board suppliers in the North American market, suggesting a robust, highly competitive market. The identities of these suppliers are shown in Exhibit 8.1.

Exhibit 8.1: Major MV Imaging Board Suppliers

Active Silicon	EPIX	MATRIX VISION
Adept Electronic Solutions	ESI	Matrox Imaging
Alacron	Euresys	Moritex USA
American ELTEC	FEITH Sensor to Image	MuTech Corp.
ARVOO Imaging Producs	Foresight Imaging	National Instruments
BitFlow	IDS Imaging Development Systems	Pleora Technologies
Cognex Corporation	Image Labs International	Point Grey Research
DALSA Corporation	Imperx	PixelSmart
CyberOptics/ Imagenation	Integral Technologies	RVSI Acuity CiMatrix
Data Translation	IO Industries	SELDES S.A.
EDT	Leutron Vision	Silicon Software

8.1.4 Market Trends and Developments

An examination of the North American MV imaging board market reveals a number of distinct trends and developments:

- Market Size: As of 2008, the North American MV imaging market has declined in terms of both units sold and sales revenue. In previous years, only sales revenue declined. (See Exhibit 8.5.) Recessionary impacts are evident.
- Average Unit Price: The decline in overall sales revenue has reflected a drop in the average unit price over previous years, as is later shown in section 8.2. Reasons for the decline in the average unit price appear to be at least two-fold:
  - Declining Sub-component Costs: The cost of sub-components used in the production of imaging boards has steadily declined over time.
  - Market Response to GigE Vision Camera Introduction: Some manufacturers of imaging boards sharply discounted their prices in 2005 as a competitive response to the market introduction of GigE Vision cameras. This was intended to preemptively "lock-in" imaging board sales and thus limit inroads caused by the sale of GigE Vision cameras. This response occurred against a backdrop of much speculation in the MV industry concerning the demise of the frame grabber.

  In 2008, however, we see a modest deviation in the trend with the average price rising slightly. This reflects an average increase in the price of a frame grabber of $39 ($550 versus $511), which given the greater preponderance of frame grabber sales compared to vision processor board sales, has more than off-set a steep decline in the average price of vision processor boards ($1,630 versus $2,666). This is of course somewhat counter-intuitive, since we would expect - all things being equal - prices to fall in a weak economy. It remains to be seen whether in fact 2008 represents a true deviation from the trend or just a "blip" in the data.
- Greater Price Competitiveness: The discounting of imaging boards that we have seen in previous years has significantly diminished the cost advantage that GigE Vision

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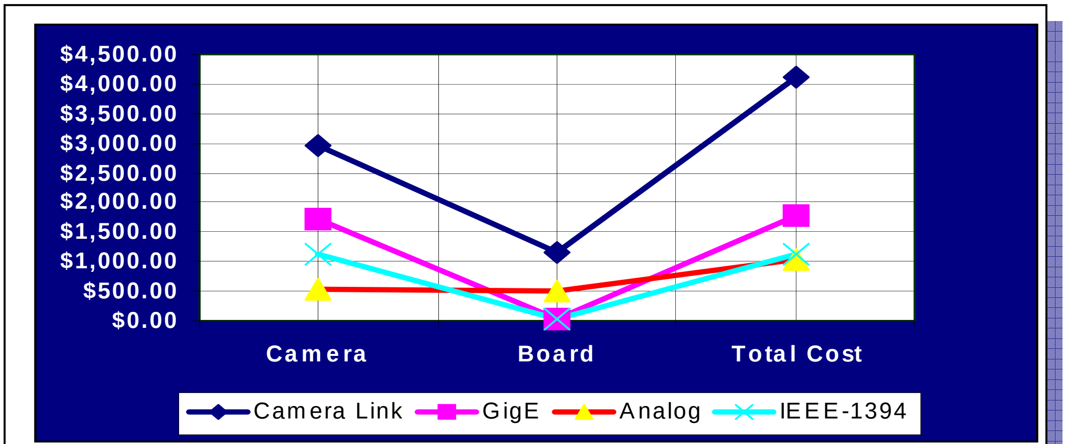
cameras might otherwise possess (even with the rise in the average price of a frame grabber in 2008). Exhibit 8.2 shows that based on the 2008 data collected for this study, GigE Vision cameras with NICs are more expensive on average than analog and IEEE-1394 cameras with their corresponding cards. Because of their far greater bandwidth for data throughput, Camera Link cameras with their corresponding boards included are not surprisingly far more expensive than analog, GigE Vision and IEEE-1394 camera-board combinations.

Exhibit 8.2: Average Price Comparisons of Different Camera-Board Combinations



	Average Camera Price	Average Board Price	Total Price
Camera Link	$2,962	$1,156	$4,118
GigE Vision	$1,729	$40	$1,769
Analog	$538	$498	$1,036
IEEE-1394	$1,116	$20	$1,136

- Overall Market Response to the Introduction of GigE Vision Cameras: The market response of imaging board suppliers to the introduction of GigE Vision cameras did not involve only deep price discounts. Some imaging board suppliers also introduced new products that enabled cameras of different interfaces to work over GigE connections by either changing out the back-end interface electronics with a compact board that is mounted within the camera or by means of a stand-alone box (external to the camera) that captures images from a multitude of cameras and transfers them over GigE links. Both products are intended to preserve the investment in non-GigE Vision cameras, while affording the benefits of GigE connectivity. (Suppliers that have taken this approach include Pleora Technologies and DALSA.)

  Products have also been introduced that add a processing core to GigE NICs and IEEE-1394 cards, in effect creating GigE based and IEEE-1394-based imaging boards. (Companies taking this approach include Matrox and National Instruments.) These products are targeted to higher-end applications.

  Still other imaging board suppliers chose to not respond at all to GigE Vision cameras, refusing to view it as a competitive threat.

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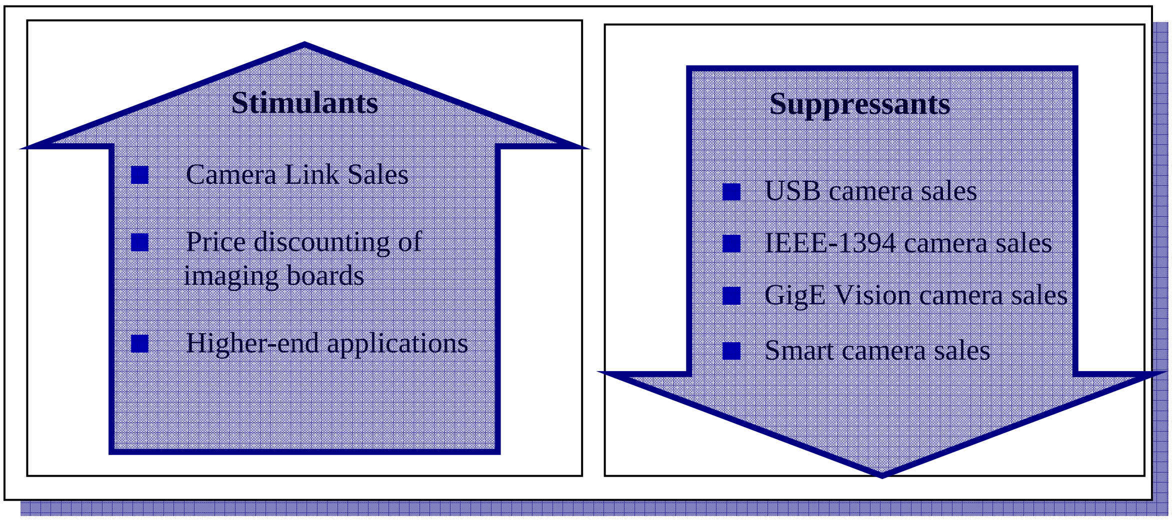
- Within the imaging board market are found various stimulants (drivers) and suppressants of demand.
  - All things being equal, demand for USB, IEEE-1394 and GigE Vision cameras has depressed demand for imaging boards, where these cameras are used for lower-end applications.
  - Demand for smart cameras has also tended to be cross-elastic with demand for imaging cards, since smart cameras contain internal image processing functionality in place of a separate imaging board.
  - Demand stimulants include Camera Link camera sales, price discounting of imaging boards and the need for image preprocessing associated with higher-end applications.

These demand stimulants and suppressants are summarized in Exhibit 8.3.

Exhibit 8.3: Micro-Economic Demand Stimulants and Suppressants for Imaging Boards



It should be noted that, thus far, demand stimulants have more than offset suppressants, as indicated by the annual unit growth rates. Also, the fact that units sold are increasing annually indicates that demand suppressants are not chiefly responsible for sales revenue contraction in this market. (If demand suppressants were taking a serious toll on this market, units sold would not be increasing.) As previously mentioned, it is price discounting that accounts for the decline in total sales revenue.

- To keep pace with demand for faster speeds in image processing, slower busses have given way to faster ones, as evidenced by the general replacement of ISA/ EISA with PCI. The growing acceptance of PCI EXPRESS is the latest manifestation of this longer-term trend.
- The demand for higher bandwidth driven by faster camera frame rates and higher resolution has also entailed greater reliance on on-board processing. To accelerate image processing functions beyond the capabilities of the host computer's CPU,

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imaging board suppliers have increasingly added DSPs, FPGAs and CPUs along with additional memory.

- Other technology trends affecting the imaging board market include:
  - Growing demand for NIR cameras as night and impaired visibility applications for automobiles and package inspection applications are increasingly deployed
  - Increasing use of multi-spectral imaging
  - Evolving camera standards
  - Evolving sensor technology

These trends and developments suggest that the fate of the MV imaging board market is largely influenced by trends in the camera market as well as the broader issue of whether compute power for imaging processing functions should reside in the camera, the host computer or in the imaging board.

8.1.5 Major Characteristics of the MV Imaging Board Market

The MV imaging board market in North America is a robust, highly competitive, technology-driven market with numerous suppliers and products vying for sales. Major characteristics of this market are as follows:

- A market size of $23.4 million (USD) in 2008.
- The year-over-year revenue growth rate was -23.3 percent in 2008, revealing a sharp decline from 2007 levels. The compound average growth rate for the 2004 - 2008 timeframe was -9.9 percent. (The market contracted by almost 10 percent.) Units sold, contracted by -25.2 percent in 2008 but grew 1.7 percent on average for the historical period. The upshot: The decline in MV imaging board revenue, while reflecting largely the dynamics of the camera market, has been worsened by the recession in North America.
- A high degree of supplier diversity indicative of market rivalry.
- A high degree of product diversity reflecting different technological approaches with respect to PC busses, camera interfaces and the location of compute power for image processing functions.
- Competitive pressure from product substitutes, such as IEEE-1392 cards, GigE NICs and USB cards (without processing cores), and alternative approaches such as smart cameras with built-in image processing functionality and host processing.
- Product development that is closely tied to the camera market and changes in PC technology as relates in particular to developments in bus and processor technologies.

8.1.6 New Product Introductions in 2008

In this section we provide a list of the new MV imaging boards introduced in 2008. (Note: While we intend this list to be all-inclusive, it is possible that we have inadvertently omitted some models, in which case we offer sincere apologies.) As Exhibit 8.4 shows, a number of new imaging boards were introduced to the market. Most were PCI or PCI Express, as expected. Camera Link was the most common, single interface. It is interesting to note that some GigE "imaging boards" were introduced.

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Exhibit 8.4: New MV Imaging Board Products in 2008

Company	Product Name	Interface	Buss Type
Active Silicon	Phoenix HD-SI	HD-SDI	PCI Express
Alacron	Fast-X	GigE and Camera Link	PCI
	Fast-Xe	GigE and Camera Link	PCI Express
Data Translation	DT9812-10V-OEM	USB	NA
EPIX	PIXCI ECB1	Base Camera Link	*Express*Card
Euresys	PICOLO Alert Compact	PAL/NTSC	PCI
	PICOLO Alert Compact PCIe	PAL/NTSC	PCIe
Imperx	FrameLink Express	Camera Link	PCMCIA
MATRIX VISION	mvBlueLYNX-M7	Gig E , USB 2.0	miniPCI Tpe III
	mvHYPERION-CLF	Camera Link	PCI Express
Matrox Imaging	Morphis Evo	NTSC, PAL, RS-170, CCIR	PCIe short card
	Concord	1394, Gig E	PCI, PCI Express
Pleora Technologies	iPORT Nyx-Mini	Gig E	NA
Point Grey Research	Firepro	1394b	PCI Express

We next turn to an examination of survey results in the remainder of this chapter.

8.2. Survey Results

Expanding upon the information of the previous sections, we next examine the market in terms of sales volumes expressed in revenue and units. Our focus is the historical period of 2003 through 2007 and the forecast period of 2008 through 2012.

8.2.1 Historical Growth Patterns

As shown by Exhibit 8.5, the MV imaging board market has decreased over time from $35.4 million in 2004 to $23.4 million in 2008. During this same period, units sold increased from 22,012 to 28,991. The compound annual growth rates (CAGRs) for this period was -9.9 percent for revenue and 1.7 percent for units sold.

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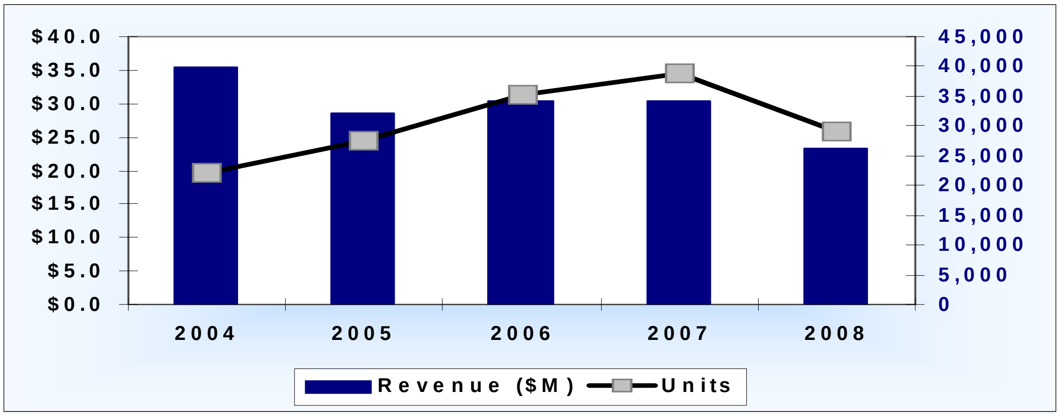
Exhibit 8.5: Imaging Board Sales Revenue ($ Millions) and Units: 2004 - 2008

	Actual 2004	Actual 2005	Actual 2006	Actual 2007	Actual 2008	*CAGR
Revenue ($M)	$35.4	$28.6	$30.4	$30.5	$23.4	-
%	33.6%	-19.2%	-10.8%	0.3%	-23.3%	-9.9%
Units	22,012	27,538	35,148	38,783	28,991	-
%	45.5%	25.1%	7.8%	10.3%	-25.2%	1.7%
Average Price	$1,608	$1,038	$866	$786	$806	-

* Growth rates adjusted for change in company mix between 2005 and 2006



8.2.2 Forecasts

For the forecast period, further contraction is expected. As indicated by Exhibit 8.6, revenue is expected to decline from $23.4 million (USD) in 2008 to $16.6 million in 2013. It should be noted that years 2009 and 2010 reflect the anticipated impacts of the recession. 2011 is the first year in which the forecast recovery is expected, but, even in that year and beyond, the market dynamics of the camera market are expected to result in a further decrease in sales revenue. Units sold, however, do exhibit modest positive growth for the forecast period, growing from 28,991 in 2008 to 29,321 in 2013. In terms of compound annual growth, the revenue forecast represents a -2.6 percent CAGR, while the unit forecast reflects a 4.7 percent CAGR.

Finally, it should be noted that this forecast of imaging board units and revenue is driven by our camera market forecast, which shows a sizeable increase in GigE Vision and IEEE-1394 cameras (both of which do not utilize imaging boards). An increase in Camera Link cameras is also forecast, but this increase is far surpassed by the anticipated increase in GigE Vision and IEEE-1394 cameras.

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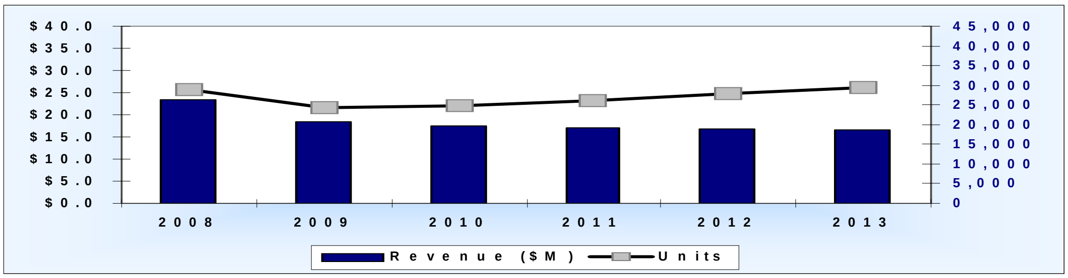
Exhibit 8.6: Forecast Imaging Board Sales Revenue ($ Millions) and Units: 2008 – 2012

	Actual 2008	Forecast 2009	Forecast 2010	Forecast 2011	Forecast 2012	Forecast 2013	CAGR
Revenue ($M)	$23.4	$18.4	$17.5	$17.0	$16.8	$16.6	-
%	-23.3%	-21.1%	-5.1%	-2.8%	-1.3%	-1.0%	-2.6%
Units	28,991	24,378	24,770	26,109	27,894	29,321	-
%	-25.2%	-15.9%	1.6%	5.4%	6.8%	5.1%	4.7%
Average Price	$806	$756	$706	$651	$601	$566	-

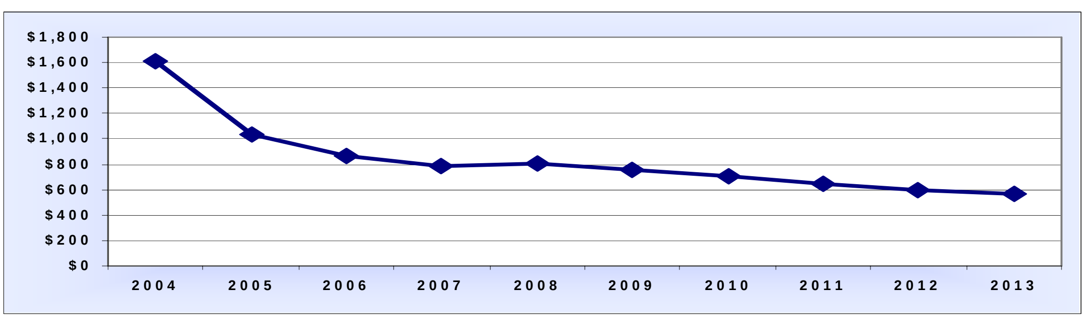


8.2.3 Price Analysis

With revenue declining faster than units sold over most of the historical period, and units sold growing faster than revenue during the forecast period, price erosion has occurred and is expected to continue. As shown by Exhibit 8.7, the average price of an imaging board (frame grabbers + vision processor boards) has dropped from $1,608 in 2004 to $806 in 2008 and is projected to decrease still further to $566 by 2013. As noted earlier, 2008 is a slight exception to this trend with the average price increasing by $20 over 2007. This reflects an average increase in the price of a frame grabber of $39 ($550 versus $511), which given the greater preponderance of frame grabber sales compared to vision processor board sales, has more than off-set a steep decline in the average price of vision processor boards ($1,630 versus $2,666).

Exhibit 8.7: Average Price of an Imaging Board: 2004 - 2013

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Average Price	$1,608	$1,038	$866	$786	$806	$756	$706	$651	$601	$566



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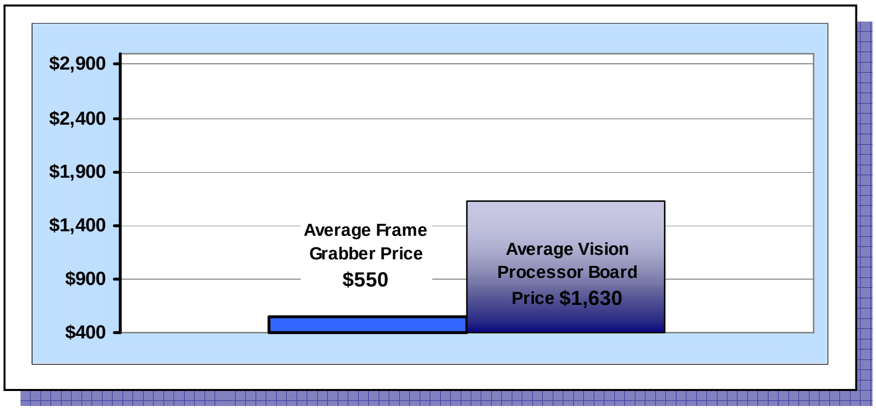
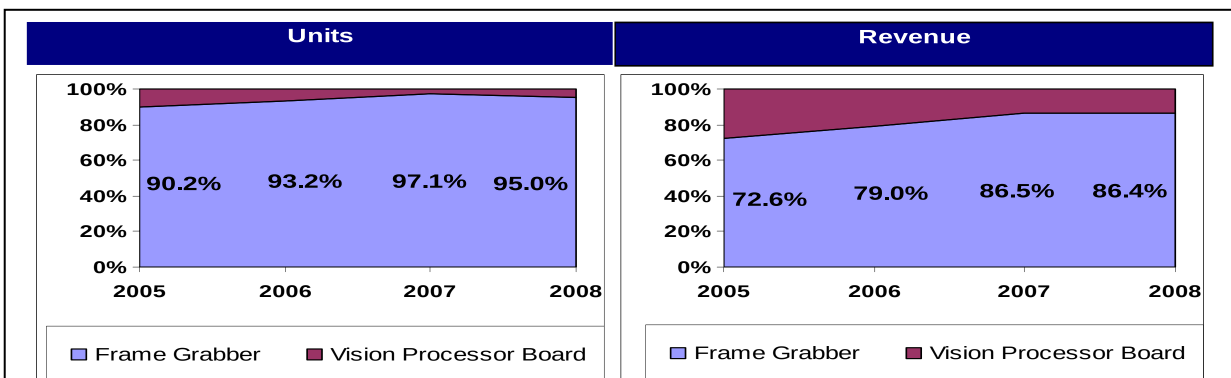
We again note that the data shown in Exhibits 8.7 reflect frame grabbers and vision processor boards combined. When vision processor boards are broken out, it is clear that they are on average far more expensive than frame grabbers. While the average price of a frame grabber in 2008 was $550, the average price of a vision processor board was $1,630, as shown by Exhibit 8.8. This higher price of course reflects the greater functionality of a vision processor board.

Exhibit 8.8: Average Price of a Frame Grabber vs. Vision Processor Board



It should be noted that the average price of an imaging board is closer to that of a frame grabber by virtue of the fact that far more frame grabbers were sold in 2008. As shown by Exhibit 8.9, 95.0 percent of the units sold in 2008 were frame grabbers, which accounted for 86.4 percent of the total revenue from the sale of imaging boards. In comparison, 5.0 percent of the units sold that year were vision processor boards, which yielded 13.6 percent of the total revenue from imaging board sales. In previous years, the percentage of imaging boards comprised by frame grabbers has steadily risen, but in 2008 this percentage declined slightly, reflecting perhaps demand stimulation due to a sizeable decrease in the average price of a vision processor board.

Exhibit 8.9: Percent Frame Grabber and Vision Processor Board Sales of Total Imaging Boards Sold



	2005	2006	2007	2008	2005	2006	2007	2008
	Units	Units	Units	Units	Rev	Rev	Rev	Rev
Frame Grabber	90.2 %	93.2 %	97.1 %	95.0%	72.6 %	79.0 %	86.5 %	86.4%
Vision Processor Board	9.8 %	6.8 %	2.9 %	5.0%	27.4 %	21.0 %	13.5 %	13.6%
Total	100.0 %	100.0 %	100.0 %	100.0%	100.0 %	100.0 %	100.0 %	100.0%

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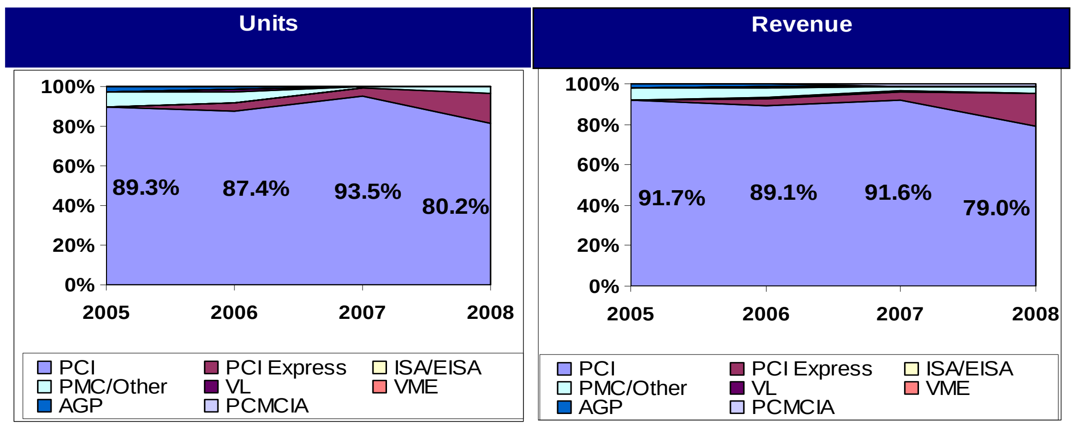
8.2.4 Total Sales Revenue and Units by Major Product Feature

To gain additional insights into the imaging board market, we next examine 2008 sales results by product feature, beginning with bus interface.

Bus Interface

As shown by Exhibit 8.10, PCI is by far the most common bus interface. Approximately 80.2 percent of units sold accounting for 79.0 percent of the revenue in 2008 were PCI. These percentages are expectedly down from 2007 levels due to greater acceptance of PCI Express in 2008.

Exhibit 8.10: Imaging Board Sales by Bus Interface in Percent



	2005 Units	2006 Units	2007 Units	2008 Units	2005 Rev	2006 Rev	2007 Rev	2008 Rev
PCI	89.3 %	87.4 %	93.5 %	80.2%	91.7 %	89.1 %	91.6 %	79.0%
PCI Express	0.1 %	4.1 %	3.7 %	14.4%	0.1 %	3.7 %	4.6 %	16.1%
ISA/EISA	0.1 %	0.0 %	0.4 %	0.0%	0.3 %	0.3 %	0.2 %	0.3%
PMC/Other	7.7 %	5.7 %	0.8 %	3.7%	5.7 %	5.0 %	2.2 %	3.3%
VL	0.0 %	1.3 %	0.0 %	0.0%	0.0 %	0.9 %	0.0 %	0.0%
VME	0.0 %	0.0 %	0.0 %	0.0%	0.0 %	0.0 %	0.0 %	0.0%
AGP	2.7 %	1.5 %	0.0 %	0.0%	2.0 %	1.1 %	0.0 %	0.0%
PCMCIA	0.1 %	0.0 %	1.6 %	1.8%	0.1 %	0.1 %	1.4 %	1.4%
Total	100.0 %	100.0 %	100.0 %	100.0%	100.0 %	100.0 %	100.0 %	100.0%

Camera Interface

Analog camera interfaces are also fairly typical for imaging boards sold in 2008 but less so than in 2007. As shown by Exhibit 8.11, 65.2 percent of all imaging boards sold were analog, which accounted for 52.2 percent of the total revenue from imaging board sales. 34.8 percent of all boards sold were intended for use with a digital camera, representing 47.8 percent of total revenue.

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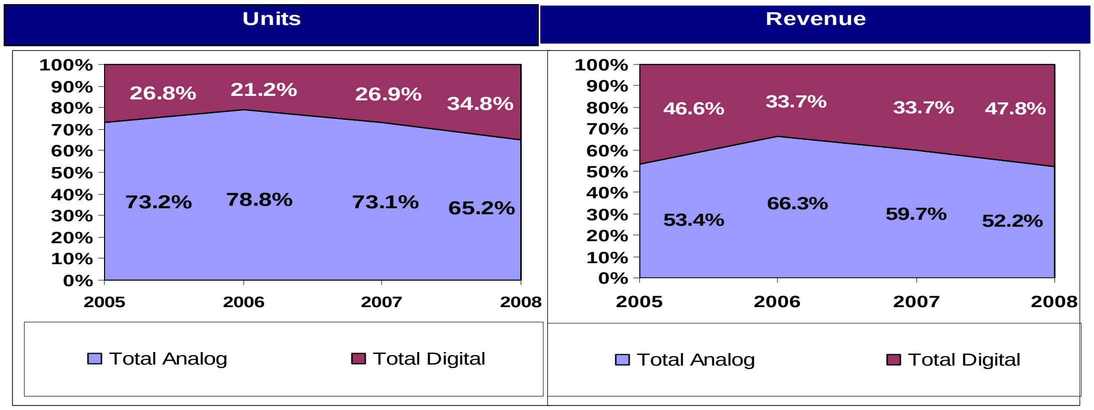
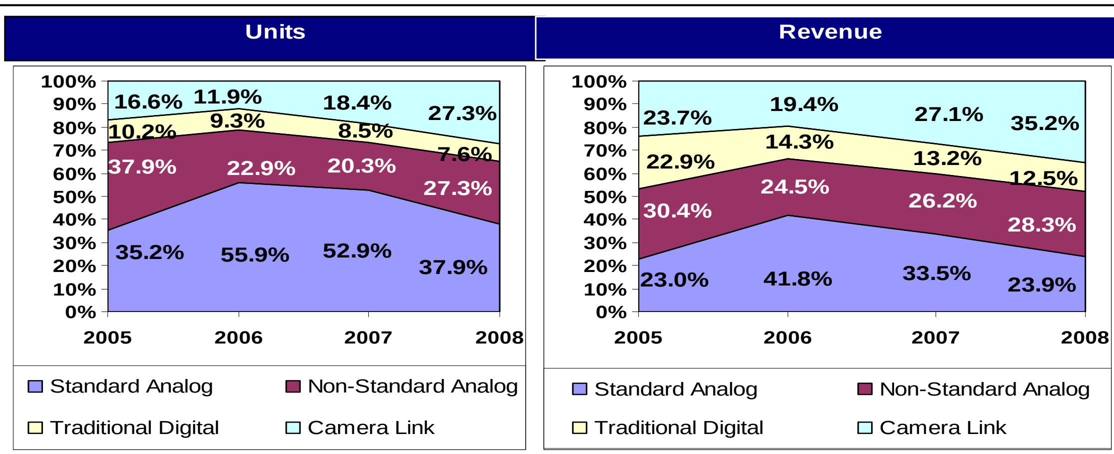
Exhibit 8.11: Analog and Digital Imaging Board Sales in Percent



	2005 Units	2006 Units	2007 Units	2008 Units	2005 Rev	2006 Rev	2007 Rev	2008 Rev
Total Analog	73.2 %	78.8 %	73.1 %	65.2%	53.4 %	66.3 %	59.7 %	52.2%
Total Digital	26.8 %	21.2 %	26.9 %	34.8%	46.6 %	33.7 %	40.3 %	47.8%
Total	100.0 %	100.0 %	100.0 %	100.0%	100.0 %	100.0 %	100.0 %	100.0%

Exhibit 8.12 provides a finer breakdown of sales by interface. Analog is split between standard and non-standard analog, while digital is broken down by traditional digital and Camera Link. What this exhibit shows is that standard analog is still the most common camera interface (at 37.9 percent of units, which accounts for 23.9 percent of revenue) but less so than in 2007. Camera Link is the most popular digital camera interface (in the case of cameras that use imaging boards) at 27.3 percent of total units sold and 35.2 percent of total revenue from imaging board sales. It should be noted that Camera Link's share of units sold and revenue in 2008 was up over 2007 and that Camera Link contributed the greatest share of revenue in 2008.

Exhibit 8.12: Imaging Board Sales by Camera Interface



	2005 Units	2006 Units	2007 Units	2008 Units	2005 Rev	2006 Rev	2007 Rev	2008 Rev
Standard Analog	35.2 %	55.9 %	52.9 %	37.9%	23.0 %	41.8 %	33.5 %	23.9%
Non-Standard Analog	37.9 %	22.9 %	20.3 %	27.3%	30.4 %	24.5 %	26.2 %	28.3%
Traditional Digital	10.2 %	9.3 %	8.5 %	7.6%	22.9 %	14.3 %	13.2 %	12.5%
Camera Link	16.6 %	11.9 %	18.4 %	27.3%	23.7 %	19.4 %	27.1 %	35.2%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0 %	100.0 %	100.0%

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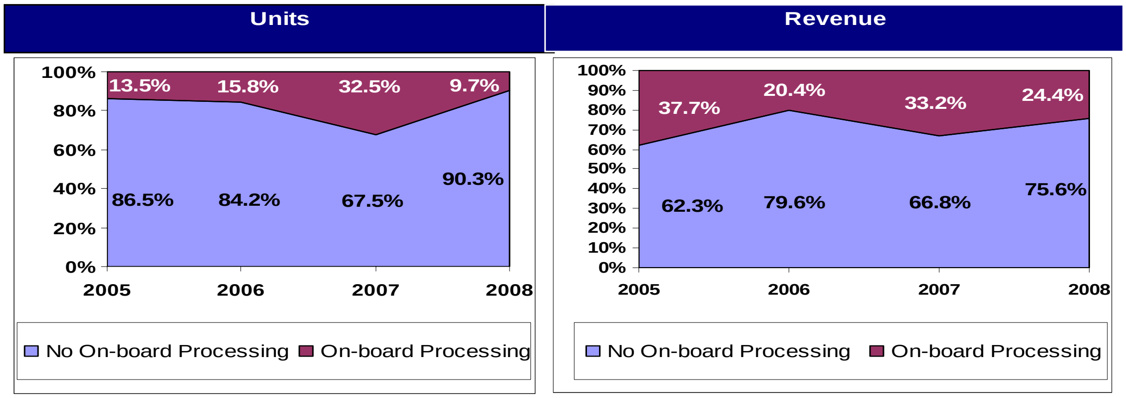
On-Board Processing

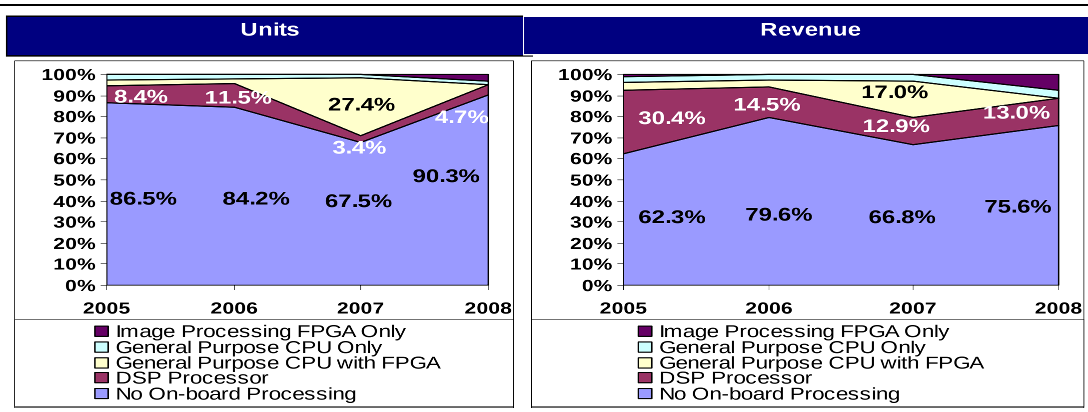
According to Exhibit 8.13, on-board processing grew in acceptance in the previous three years but not in 2008. In fact, the share of units sold that had on-board processing dropped dramatically in 2008 from 2007 (9.7 percent in 2008 versus 32.5 percent in 2007).

Exhibit 8.13: Imaging Board Sales with On-board Image Processing in Percent



	2005 Units	2006 Units	2007 Units	2008 Units	2005 Rev	2006 Rev	2007 Rev	2008 Rev
No On-board Processing	86.5%	84.2%	67.5%	90.3%	62.3%	79.6%	66.8%	75.6%
On-board Processing	13.5%	15.8%	32.5%	9.7%	37.7%	20.4%	33.2%	24.4%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Exhibit 8.14: Imaging Board Sales by Type of On-board Image Processing Capability



	2005 Units	2006 Units	2007 Units	2008 Units	2005 Rev	2006 Rev	2007 Rev	2008 Rev
No On-board Processing	86.5 %	84.2 %	67.5 %	90.3%	62.3 %	79.6 %	66.8 %	75.6%
DSP Processor	8.4 %	11.5 %	3.4 %	4.7%	30.4 %	14.5 %	12.9 %	13.0%
General Purpose CPU with FPGA	2.5 %	2.1 %	27.4 %	0.0%	3.3 %	3.0 %	17.0 %	0.0%
General Purpose CPU Only	2.6 %	2.2 %	1.6 %	2.0%	3.0 %	2.8 %	3.3 %	3.6%
Image Processing FPGA Only	0.1 %	0.0 %	0.0 %	3.0%	1.0 %	0.0 %	0.0 %	7.8%
Total	100.0 %	100.0 %	100.0 %	100.0%	100.0 %	100.0 %	100.0 %	100.0%

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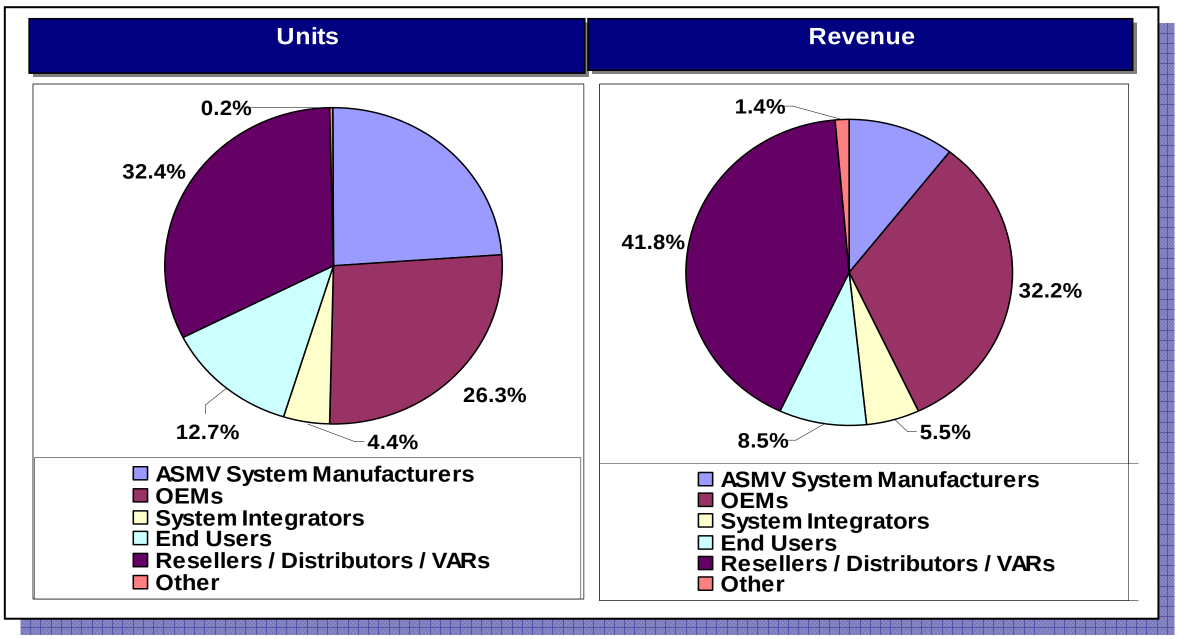
If we disaggregate the results in Exhibit 8.13, we find that most boards with on-board processing use a DSP processor. As Exhibit 8.14 shows, 4.7 percent of the units sold in 2008 had a DSP processor. What is most noticeable, however, is the sharp decline in the share of boards that use a general purpose CPU with FPGA. The overwhelming share of boards sold had no on-board processing capability.

Sales by Type of Customer

Finally, we analyze sales by type of customer. As Exhibit 8.15 shows, most imaging boards sold in 2008 were sold to resellers, distributors or VARs. In fact, 32.4 percent of the total units sold by suppliers were to this class of customer, which accounts for 41.8 percent of total sales. OEMs are the next most important class of customers with 26.3 percent of units sold, which accounts for 32.2 percent of sales revenue.

Exhibit 8.15: 2008 Imaging Board Sales by Type of Customer



8.3 Summary of Major Findings

The major findings of this chapter are as follows:

- **Market Dynamics:** The dynamics of the MV imaging board market have been driven not surprisingly by developments in the camera market, the evolution of the components and peripherals of the personal computer and the economy.

  Because of the growing adoption of cameras that do not utilize imaging boards, and price declines in imaging boards made in response to this development, the MV imaging board market has contracted over time, despite the increase in units sold in past years. Added to this has been the impact of the recession, which slowed revenue growth to almost zero in 2007 and decreased it in 2008. In 2009 and 2010, we expect

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recessionary impacts to continue, although to a lesser extent in 2010. Not until 2011 do we expect the impact of the recession to subside.

Going forward, we thus expect the contraction of the MV imaging board market to continue. We also predict the continued fall in the average unit price, despite the slight bump upward that occurred in 2008.

The dominant characteristics of MV imaging boards will also continue to evolve, as buss types become faster and interfaces become increasingly digital. The importance of on-board processing, however, remains to be seen. It is also very much a matter of conjecture whether the differences between NICs and frame grabbers will erode over time.

As previously mentioned, a major dynamic of the MV imaging board market has been, and will continue to be, the steady decline in average unit price of an imaging board. This has not only reflected decreasing sub-component costs but also market responses to developments in the camera market, most notably the introduction of GigE Vision cameras.

- In response to the market introduction of GigE Vision cameras, manufacturers of imaging boards have sharply discounted their prices, altering the cost calculus involved with the purchase of GigE Vision cameras in relation to cameras using frame grabbers. This was intended to “lock-in” sales preemptively against inroads caused by the sale of GigE Vision cameras and must also be viewed as a general response to predictions heralding the demise of the MV frame grabber industry.
- The market response of imaging board suppliers to the introduction of GigE Vision cameras also entailed the production of new products.

The dynamics of the MV imaging board also involve stimulants (drivers) and suppressants of demand.

- Demand for USB, IEEE-1394 and GigE Vision cameras depress demand for imaging boards, since they obviate the need for imaging boards.
- Demand for smart cameras is also cross-elastic with demand for imaging boards, since smart cameras contain image processing functionality and do not utilize an imaging board.
- Demand stimulants included Camera Link camera sales, price discounting of imaging boards and the need for image preprocessing associated with higher-end applications.

- **Historical Sales:** The MV imaging board market has decreased over time from $35.4 million in 2004 to $23.4 million in 2008. However, during this same period, units sold increased from 22,012 to 28.991. The compound annual growth rates (CAGRs) for this period was -9.9 percent for revenue and 1.7 percent for units sold.

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- **Forecast Sales:** For the forecast period, further contraction is expected. As indicated by Exhibit 8.6, revenue is expected to decline from $23.4 million (USD) in 2008 to $16.6 million in 2013. It should be noted that years 2009 and 2010 reflect the anticipated impacts of the recession. 2011 is the first year in which the recovery is expected, but - even in that year and beyond - the market dynamics of the camera market are expected to result in a further decrease in sales revenue. Units sold, however, do exhibit modest positive growth for the forecast period, growing from 28,991 in 2008 to 29,321 in 2013. In terms of compound annual growth, the revenue forecast represents a -2.6 percent CAGR, while the unit forecast reflects a 4.7 percent CAGR.
- **Average Price:** The average price of an imaging board (frame grabbers + vision processor boards) has dropped from $1,608 in 2004 to $806 in 2008 and is projected to decrease still further to $478 by 2013. However, 2008 was a slight exception to this trend with the average price increasing by $20 over 2007. This reflected an average increase in the price of a frame grabber of $39 ($550 versus $511), which given the greater preponderance of frame grabber sales compared to vision processor board sales, more than off-set a steep decline in the average price of vision processor boards ($1,630 versus $2,666).
- **New Product Introductions:** In 2008, a number of new imaging boards were introduced to the market. Most were PCI or PCI Express, as expected. Camera Link as the most common, single interface. Some Gig E “imaging boards” were also introduced.
- **Sales by Frame Grabber vs. Vision Processor Board:** 95.0 percent of the units sold in 2008 were frame grabbers, which accounted for 86.4 percent of the total revenue from the sale of imaging boards. In comparison, 5.0 percent of the units sold that year were vision processor boards, which yielded 13.6 percent of the total revenue from imaging board sales.
- **Sales by Bus Type:** PCI is by far the most common bus interface. Approximately 80.2 percent of units sold accounting for 79.0 percent of the revenue in 2008 were PCI. These percentages are expectedly down from 2007 levels due to greater acceptance of PCI Express in 2008.
- **Sales by Analog vs. Digital Interface:** Analog camera interfaces were fairly typical for imaging boards sold in 2008 but less so than in 2007. 65.2 percent of all imaging boards sold were analog, which accounted for 52.2 percent of the total revenue from imaging board sales. 34.8 percent of all boards sold were intended for use with a digital camera, representing 47.8 percent of total revenue
- **Sales by Type of Interface:** Standard analog is still the most common camera interface (at 37.9 percent of units, which accounts for 23.9 percent of revenue) but less so than in 2007. Camera Link was the most popular digital camera interface (in the case of cameras that use imaging boards) at 27.3 percent of total units sold and 35.2 percent of total revenue from imaging board sales. Camera Link’s share of units sold and revenue in 2008 was up over 2007; it contributed the greatest share of revenue in 2008.
- **Sales by On-Board Processing:** On-board processing grew in acceptance in the previous three years but not in 2008. In fact, the share of units sold that had on-board

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processing dropped dramatically in 2008 from 2007 (9.7 percent in 2008 versus 32.5 percent in 2008).

- **Sales by Processor Type:** Most boards with on-board processing use a DSP processor. 4.7 percent of the units sold in 2008 had a DSP processor. The share of boards that use a general purpose CPU with FPGA dropped very sharply in 2008. The overwhelming share of boards sold had no on-board processing capability.
- **Sales by Type of Customer:** Most imaging boards sold in 2008 were sold to resellers, distributors or VARs. 32.4 percent of the total units sold by suppliers were to this class of customer, which accounts for 41.8 percent of total sales. OEMs were the next most important class of customers with 26.3 percent of units sold, which accounted for 32.2 percent of sales revenue.

8.4 Conclusions

With the announced development of GigE Vision cameras, dire predictions about the fate of the MV imaging market were widely announced. According to these predictions, the demise of imaging boards was just a matter of time. To be sure, revenue from imaging board sales has markedly declined over time and is expected to decrease still further. However, only a portion of this downward trend can be ascribed to the introduction of GigE Vision cameras. For one thing, GigE Vision cameras have not yet achieved sufficient penetration to account for the large decline in revenue. (See camera chapter.) For another thing, many imagining board manufacturers reacted peremptorily to the introduction of GigE Vision cameras by slashing their prices. Today, the average price of a GigE Vision camera and NIC is significantly higher than the average price of an analog camera with an included imaging board. Still, going forward, GigE Vision camera sales will increase, as will also IEEE-1394 camera sales and the sales of smart cameras, all of which do not use an imaging board. At the same time, some offset to the resultant loss in imaging boards will occur as a consequence of growing Camera Link sales. These cameras use relatively expensive imaging boards, but their sale will produce revenue that is insufficient to neutralize the imaging board revenue loss resulting from the sale of "frame-grabberless" cameras.

Against this backdrop, the economy is also taking its toll. The effects of the North American recession are expected to extend from 2008 to 2010. Not until 2011 are sales expected to reflect the economic recovery forecast to begin in late 2010.

In response to the anticipated decline in imaging board sales, imaging board manufacturers might consider a three-prong strategy: Continue to address the low-end of the market with analog boards, address the high-end with Camera Link boards and focus on creating higher-end USB, NICs and IEEE-1394 boards that have greater capabilities to support more demanding applications. If, in fact, the differences between these different types of boards and imaging boards are eroding, why should not imaging board manufacturers take advantage of it? This is of course a question of fundamental strategy; or more specifically, a question of how the business is defined. Will imaging board manufacturers stay as such, or will they redefine themselves more broadly as board manufacturers?

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Chapter 9: MV Lighting Market

Quick Navigation Buttons:

9.1 Introduction | 9.2 Survey Results | 9.3 Summary of Major Findings | 9.4 Conclusions

9.0 What's New in this Chapter?

- 9.1.7 New Product Introductions
- 9.2 Survey Results
- 9.2.3 Pricing Analysis
- 9.3 Summary of Major Findings
- 9.4 Conclusions

9. 1 Introduction

Lighting is critically important in machine vision. Without it, machine vision (MV) systems simply cannot run the applications for which they were designed. In this chapter we therefore focus on the important MV lighting market, identifying key market participants and the wide variety of product types. We also examine major market trends and historical and future demand for illumination products expressed in terms of sales revenue and units sold.

The importance of lighting can be readily appreciated by thinking of the interdependent components of a machine vision system as the links of a chain. If one link is weak, the strength of the whole chain is diminished. Similarly, if lighting is not closely matched to the optics and sensors of an MV system, the system falters.

However, proper lighting is not easily achieved, as a number of challenges typically exist. These include a lack of physical interface standards between light heads and cameras, as

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well as matching the amount and type of illumination with the aperture of a lens and a camera's sensitivity and speed.

Importantly, where the correct lighting solution is not selected, serious imaging problems can result. These problems include blooming, hot spots and shadowing, which can hide important image information. Additionally, non-uniform lighting can entail a low signal-to-noise ratio. Finally, failure to choose the proper lighting can increase the burden of software development, as complex, sophisticated image processing algorithms are required to mitigate imaging problems that otherwise could have been eliminated by proper lighting. For that reason, and to insure a proper installation envelope, lighting vendors emphasize the need to select the proper lighting at the front end of the system design process.

Selecting the proper illumination, unfortunately, is not easy, requiring what some regard as a mixture of science and art. To achieve the proper lighting, there are many variables to manage. These include key characteristics of the object to be imaged, most notably surface geometry and specularity. The geometry of an object's surface can vary from planar (such as flat paper) to faceted (e.g. wrinkled paper). Surface specularity can vary from diffuse (such as in the case of copy paper) to a highly reflective, mirror-like surface (as in the case of a semiconductor wafer die).

Other challenges include selecting the correct amount of light intensity (as measured in footcandles or Lux), the optimal color or wavelength (white, red, green, ultraviolet, infrared, etc.), the right angle of incidence, the number of light sources, the placement of the illumination device (i.e. behind or in front of the object), the frequency of the light beam (strobe versus continuous) and the shape of the illumination device (ring, spot, line, etc.). As this illustrates, selecting the optimal lighting solution necessitates consideration of numerous variables that must be matched up with surface characteristics of the object to be imaged along with the requirements of the optics and sensor deployed, as previously noted. Clearly, finding the right mix of lighting variables to fit a specific application is demanding. At the same time, lighting vendors do have a number of technologies and techniques at their disposal to address these challenges, as will be noted shortly.

In addition to finding the right mix of lighting variables, there are a number of customer-related challenges with which lighting vendors are faced. Because one lighting solution does not fit all applications, the lighting vendor must understand the specific needs of the customer and provide the solution within the time constraints imposed by the customer (oftentimes in just one to two weeks). Where a custom solution is required and the cycle time for readying the product is short, the challenge can be formidable. Other customer-related challenges in the lighting market are meeting the downward pressure on price where the customer expects more for less, and the high degree of customization driven by the wide variation between the many, highly dissimilar machine vision applications that exist in various industry sectors.

With this information in mind, we turn now to a more detailed examination of the MV lighting market in North America.

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9.1.1 Overview of Machine Vision Lighting Market

In accordance with the overall methodological approach of this study and past AIA MV market studies as outlined in Chapter 2, we define the MV lighting market in terms of the product sales of MV lighting suppliers operating at the front end of the MV supply chain. Distributors and other intermediaries are thus not included in this “front-end component” market. Moreover, to avoid double-counting, sub-component sales (e.g. lighting power supplies) are also not included.

Reflecting the importance of lighting in the machine vision industry, the North American MV lighting market is substantial in size as measured in terms of both sales volumes and the number of market participants. Expressed in revenue, sales volumes for lighting equipment have varied from $35.7 million (USD) in 2003 to $29.5 million in 2007, reflecting a composite annual growth rate (CAGR) of -4.7 percent. (See Exhibit 9.2 for more details.) At the same time, units sold have exhibited a CAGR of 11.5 percent.

Within this market, there are also many major participants, 20 in number, which together offer a wide variety of lighting products. In the next sections, we examine both products and participants of the MV lighting market.

9.1.2 Major Product Types and Features

An examination of the North American MV lighting market reveals a wide range of products much too numerous to list individually here. This great diversity derives largely from the many technical and technology-related approaches that exist for insuring proper lighting. These approaches, which have resulted in distinct product types, include:

- *Lighting Configuration*: ring versus line versus spot
- *Lighting Techniques:* brightfield/backlight, darkfield, point versus diffuse; coaxial lighting; light tents; polarization and collimation
- *Lighting Sources/Technologies*: incandescent, LED, fluorescent, xenon, quartz halogen, HID, laser (structured) and fiber optic
- *Color and Wavelength*: visible wavelengths, ultraviolet (UV) and Infrared (IR)
- *Electric Sources:* continuous versus pulsed (strobe)
- *Special Product Features:* feedback loop for output stability

In the remainder of this section, we briefly explain these approaches representing major product types, noting where possible their commonly perceived advantages and disadvantages, which can affect their relative demand in the marketplace. More fundamentally, our brief focus on lighting technologies in this chapter derives from the fact that the MV lighting market is largely technology-driven with major product categories defined by technology. Accordingly, a basic understanding of product categories necessitates a rudimentary understanding of the major lighting technologies.

9.1.3 Major Suppliers

Given the great variety of MV illumination products, it is not surprising to learn that the North American MV lighting market is well covered by vendors. In fact, there are

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approximately 22 companies offering illumination products in this market, as shown by Exhibit 9.1.

Exhibit 9.1: Overview of Major Machine Vision Lighting Companies

Advanced illumination	Lumitex	SCHOTT
CCS America	MERCRON	Smart Vision Lights
Cohu Electronics	Metaphase Technologies	Spectrum Illumination
Dolan-Jenner	Moritex USA	StockerYale
Fiberoptic Systems	Navitar	Volpi USA
Fiberoptics Technology	Nebula	Vision & Control
Hamamatsu Corporation	Phoenix Imaging	
Illumination Technologies	Microscan (Siemens – Nerlite)	

Some of these vendors offer a wide lighting product portfolio; others specialize in offering products targeted to niche applications.

The large numbers of lighting vendors and the different product mixes they offer is indicative of a highly vibrant, dynamic and competitive market that is largely technology driven.

9.1.4 Market Trends and Developments

A number of trends involving lighting are discernible, when one examines the machine vision market since its inception over twenty-five years or so. One clear trend is the increase in the number of lighting technologies and products based on them. In the early days of the North American machine vision market, lighting products were limited in type and tended to represent canned solutions borrowed from other industries and thus intended for different applications. Over the course of time, as the machine vision market expanded, the need for greater specialization in terms of a larger selection of machine vision products arose. New technologies were utilized to provide this expanded lighting library. Incandescent and fluorescent lighting were joined by halogen, HID and Xenon. The use of fiber optics to transport light, the utilization of lasers for scanning and to provide structured lighting for 3D applications came more recently (although the earliest patents were issued in the 1960’s), as did LEDs. Additionally, lighting products became increasingly available in different shapes, sizes, wavelengths and techniques.

This expanded lighting library enabled greater customization. Instead of providing one-size-fits-all solutions, lighting vendors became increasingly capable of offering customization based on specialization in response to the unique needs of customers and their specific machine vision applications.

Major trends in the North American lighting market have thus greater product variety based on an increasing number of available lighting technologies, and correspondingly, a greater ability to offer customized lighting solutions for specific custom needs and machine vision applications.

Within this overall trend, a number of developments are also evident.

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- Average Price: The average price of a lighting unit has been decreasing over time and we anticipate that it will continue to decline. (See section 9.2.3.) Customers are expecting more for less, which has exerted downward pressure on prices, thus decreasing the aggregate sales revenue of lighting vendors. Prices are also falling as a consequence of the market entry of smaller LED suppliers with lower overhead costs to recover; these suppliers (several of which remain unidentified) offer LEDs at lower prices, thus driving down overall market prices, as more established lighting suppliers must lower their prices to respond to the competition.
- Market Size: As measured in revenue, the overall size of the MV lighting market has declined over time. (However, 2007 does represent a small exception.) The growth in units sold has generally not offset the revenue impact of declining prices.
- The Rise of the LED: LEDs have become increasingly important in the MV lighting market and today are the most important lighting technology in terms of percent of total sales. (See Exhibit 9.8) What was once dismissed as a stereo indicator light, the LED appears in some cases to have displaced fluorescent and halogen lights. However, it is clear from Exhibit 9.9 that no single type of lighting is optimal for all applications and thus, despite the rise of the LED, other types of lighting will co-exist for some time.
- Increasing LED Output: LEDs are becoming increasingly brighter. High-output LED light engines first appeared on the scene about five years ago.
- More LED Wavelengths: LEDs have been increasingly available in a wider assortment of wavelengths including IR and UV.
- Improvements in Fiber Optics Lighting: Fiber optic lighting solutions are increasingly digitally linked, smart and niche focused. Additionally, fiber optic lighting designers are increasingly combining different lighting sources, such as UV, IR, HID and LED, with fiber optic assemblies to shed light upon surfaces that were previously inaccessible.
- Demand for Fiber Optic Lighting: The overall use of fiber optics, however, has lessened over time.

Other developments involve feedback control, camera-related trends and trends involving optics.

- Feedback Control: Feedback control has emerged as a feature of some lighting products to allow for the calibration of light properties (most notably intensity and temperature) in order to maintain stability. While most types of lights degrade over time and thus require adjustments to insure a repeatable light source, not all applications require stable light. Should those that do grow in relative importance, we would expect increased emphasis on feedback control as an essential product feature.
- The Impact of Camera-Related Developments: To some extent, camera-related developments, such as the rise of CMOS cameras, appear to be spilling over into the lighting domain. Because CMOS sensors do not generally have the same light sensitivity as CCD cameras, different considerations for specifying lighting arrangements are emerging. (See Chapter 7.) Also, the increased use of color cameras is necessitating lighting with the best possible color rendition.

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- The Impact of Optics-Related Developments: Given the importance of optics to lighting, we would similarly expect developments in optics to affect lighting. Should, for example, a trend toward the use of increased magnification arise, we would anticipate the utilization of more intense light sources.

9.1.5 The Emergence of New Lighting Technologies

The rise of the LED and its revolutionary impact on the MV lighting industry leaves little doubt that this market is to a great extent technology-driven. Are there any other technologies that could similarly entail disruptive effects? There are several technologies that warrant monitoring:

- OLED (Organic Light Emitting Diode): First developed by Dr. Ching W. Tang of Eastman Kodak Company, OLEDs are LEDs whose electroluminescent layer consists of organic compounds. A polymer substance is used that allows the organic compounds to be "printed" in rows and columns on a flat carrier, forming a matrix of pixels. This matrix can emit different wavelengths.
- While OLEDs can be used for large area lighting, they are currently attracting the most interest as an alternative to LCDs (liquid crystal displays) in flat panel displays and televisions. Unlike LCDs, OLEDs do not require a backlight and thus consume less power. On the other hand, OLEDs are prone to degradation, thus making stability problematic. Most importantly, OLEDs emit far less light than LEDs; therefore, OLEDs are not yet suitable as point-light sources. Further advances in this technology, however, could eliminate these drawbacks.
- PLED (Polymer Light Emitting Diodes): PLEDs utilize an electroluminescent conductive polymer in place of organic materials to emit light. Their advantages include a wide spectrum, low power consumption, flexibility and low cost. Light output, however, is low, making PLEDs thus far unsuitable for point-lighting.
- POLED (Patternable Organic Light Emitting Device): POLEDs use a light or heat activated electroactive layer containing a material called PEDOT-TMA.

9.1.6 Major Characteristics of the MV Lighting Market

Before turning to an examination of the historical and forecast demand for MV lighting products, it is useful to briefly summarize the major characteristics of the MV lighting market, which are as follows:

- A market size of $31.2 million (USD) currently.
- A positive rate of annual growth in 2008, preceded by almost no growth in 2007 and a market contraction from 2001 to 2006. In terms of revenue, the year-over-year growth rate was 5.7 percent in 2008, while averaging -2.2 percent in the 2004 - 2008 historical time frame. Units sold display grew 2.8 percent in 2008 and had a CAGR of 5.6 percent for the historical time frame. (See Exhibit 9.3.) Thus, for most of the historical period units grew faster than revenue.
- Increasing product diversity driven by technology and differences in technical approaches to optimal lighting solutions.
- The importance of technology as a driver of product diversity.
- Sensitivity to trends in optics and cameras.

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- Growing importance of LEDs in the overall market product mix.
- Increasing customization driven by growing specialization in MV applications.
- Multiple challenges to customer satisfaction including short cycle times and increasing value expectations.
- Intense downward pressure on price from competition (especially from imports from the Pacific Rim countries) and customer expectations.
- High competition as evidenced by a plethora of products and participants including a number of new, smaller LED suppliers.

9.1.7 New Production Introductions in 2008

A number of new MV products were introduced in 2008, as shown by Exhibit 9.2. (Note: While we intend this list to be all-inclusive, it is possible that we have inadvertently omitted some models. Should this be the case, we offer our sincere apologies.)

Exhibit 9.2: New MV Lighting Products Introduced in 2008

Company	Product Name	Lighting Technology	Spot	Ring	Back Lighting	Dome	Line	Strobe	Diffuse Axial
CCS (America)	HPR - 250 BL, HPR 400 RD	LED		X					
Dolan-Jenner	Fiber-Lite DC950H (fiber Optic)	Halogen							
Fiberoptics Technology	RGB LED Light Engine	LED							
Metaphase Technologies	RoboLight	LED							
Microscan (Siemens Nerlite)	LT430	LED			X				
Moritex USA	MG Wave	LED	X	X	X	X			
Smart Vision Lights	OverDrive	LED						X	
Vision & Control	Vicolux LA7/LA14, LDI7/ LD14	LED					X		
Vision & Control	HPD - 250 BL, HPF - 400 RD	LED				X			
Vision & Control	MetaLight Diffused Axial Light DAL601	LED							X
Vision & Control	MetaTight LED Lighting	LED	X						
Vision & Control	MetaWhite ISO-14-W-24	LED							
Vision & Control	MetaBright (for fiber optic coupling)	LED							
Vision & Control	High Power Line Light 5" MB-LL20-X	LED					X		
Vision & Control	Long Range Strobe Light MB-LRS-605	LED						X	
Vision & Control	Adjustable Focus miniature spot light	LED	X						

It should be noted that, overwhelmingly, these products were based on LED technology. This suggests that going forward LEDs will represent an even greater portion of total MV lighting sales. It is also interesting to note that LED lighting nowadays is used for a wide range of lighting configurations, testimony to the growing versatility of LED lighting.

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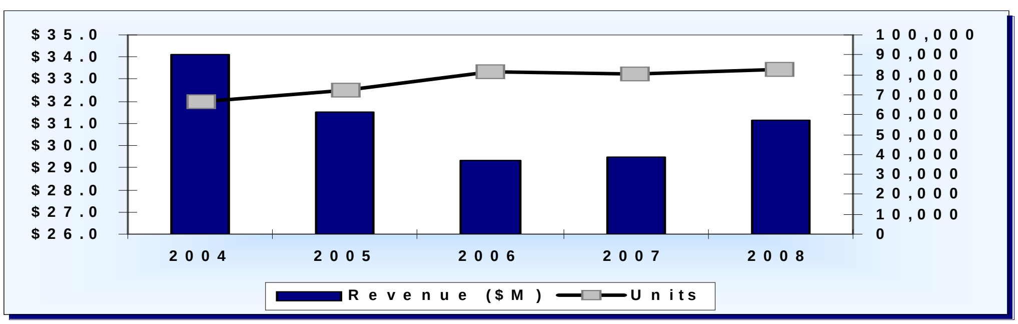
9.2 Survey Results
In this section of the chapter we examine survey results for the MV lighting market.

Expanding upon the information of the first section, we examine the market in terms of sales volumes expressed in revenue and units. Our focus is the historical period of 2004 through 2008 and the forecast period of 2009 through 2013.

9.2.1 Historical Growth Patterns
As shown by Exhibit 9.3, the MV lighting market has stabilized and even grew in 2008, a sharp contrast to the contraction of previous years and most surprising in view of the impacts of the economy on other MV product markets. For the historical period as a whole, revenue declined from $34.1 million in 2004 to $31.2 million in 2008. 2007 was essentially flat compared to 2006, and 2008 was up over 2007, as previously noted. During the historical period, units sold increased from 66,621 in 2004 to 82,860 in 2008. The corresponding compound annual growth rates (CAGRs) for the historical period were -2.2 percent for revenue and 5.6 percent for units sold.

Exhibit 9.3: Lighting Sales Revenue ($ Millions) and Units: 2004 to 2008

	Actual 2004	Actual 2005	Actual 2006	Actual 2007	Actual 2008	CAGR
Revenue ($M)	$34.1	$31.5	$29.3	$29.5	$31.2	-
%	-4.5%	-7.5%	-7.0%	0.5%	5.7%	-2.2%
Units	66,621	72,333	81,594	80,570	82,860	-
%	27.9%	8.6%	12.8%	-1.3%	2.8%	5.6%
Average Price	$512	$436	$359	$366	$376	-



9.2.2 Forecasts
Exhibit 9.4 shows revenue and units sold for the forecast period. As shown by this table, we expect revenue and units sold to increase during this period with the exception of 2009, when the recession is expected to depress sales. For 2010, we also expect weak sales due to the lingering effects of the recession. Not until 2011 do we expect the economic recovery to reflect itself in MV lighting sales.

For the forecast period as a whole, we expect compound average growth of 3.9 percent for revenue and 4.4 percent for units sold.

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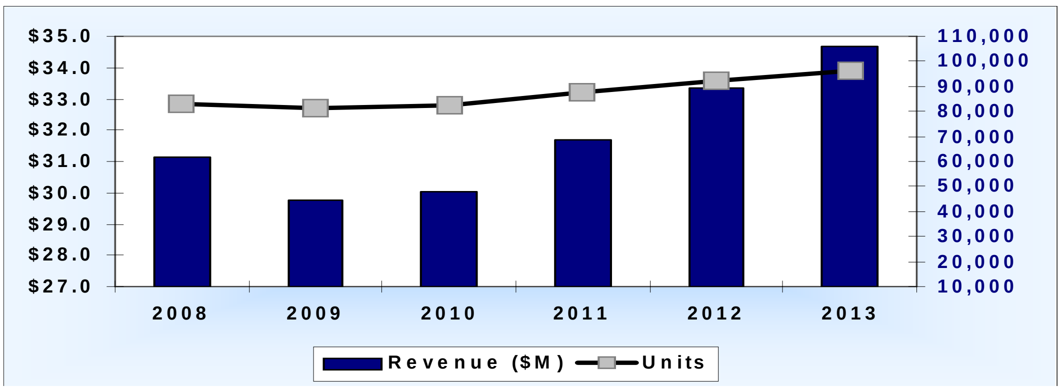
Exhibit 9.4: Forecast Lighting Sales Revenue ($ Millions) and Units: 2008 to 2013

	Actual 2008	Forecast 2009	Forecast 2010	Forecast 2011	Forecast 2012	Forecast 2013	CAGR
Revenue ($M)	$31.2	$29.8	$30.0	$31.7	$33.4	$34.7	-
%	5.7%	-4.4%	0.8%	5.6%	5.3%	4.0%	3.9%
Units	82,860	81,011	82,631	87,589	91,968	96,107	-
%	2.8%	-2.2%	2.0%	6.0%	5.0%	4.5%	4.4%
Average Price	$376	$368	$363	$362	$363	$361	-



9.2.3 Price Analysis

In previous AIA MV market studies we noted a steady decline in the average unit price of MV lighting and ascribed it mainly to the growing share of LED lighting and their declining average price. We also noted that price erosion could not go on forever and that a point would be reached where the average unit price would stabilize. In support of this predicted price equilibrium, we cited several possible factors:

- Increasingly demanding applications will require sophisticated lighting solutions such as high-end light engines with Ethernet-based controllability. Low-end lighting units that have flooded the market will lack the reliability, durability and thermal manageability to address the requirements of emerging applications. As a consequence, market competition will shift from price to functionality with the latter factor becoming the main differentiator of a company's products.
- New generation LEDs with greater light intensity will require added thermal manageability, the costs of which must be recovered through pricing.
- Stability in the cost of lighting sub-components, such as housings, base plates and electronics, will contribute to the existence of a price floor, beyond which prices cannot sink without erasing the margins upon which economic survival depends.
- Market consolidation through merger and acquisition could lead to the emergence of larger suppliers that wield greater pricing power and thus are able to effectively end price erosion to protect margins.

Subsequently, we found evidence that the equilibrium point might have in fact been reached in 2007, with a discovery of a slight increase in average unit, as shown in Exhibit

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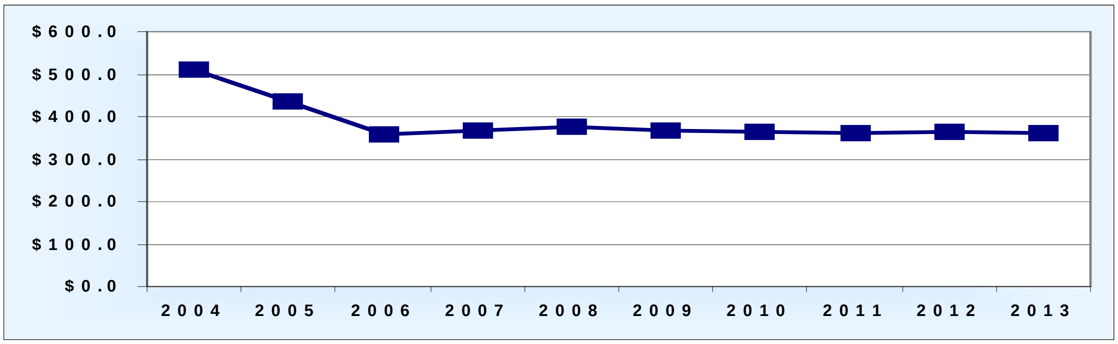
9.5. In this study, we also found a further price increase for 2008, indicating a possible reversal of the previous, multi-year price decline. Of course, two years do not make a trend, and thus it is very difficult to predict future average unit pricing. The forecast contained in Exhibit 9.5 assumes a return to the long-term trend of price decline, but it must be viewed as subject to change.

Exhibit 9.5: Average Price of Lighting: 2004 - 2013

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Average Price	$511.7	$435.9	$359.5	$366.0	$376.1	$367.5	$363.2	$361.8	$362.7	$361.0



To understand what has happened to the average unit price for MV lighting, we must understand the price decline of previous years and the subsequent price increase.

What occurred between 2001 and 2006 that accounted for the price decline of that five-year period? Our data indicates that much of this decline reflects the growing popularity of LEDs, which have become increasingly less expensive because of competition and greater production efficiencies. Importantly, the increasing number of lighting units sold has not fully offset the revenue impact of price erosion, thus resulting in revenue contraction for this market during years 2001 to 2006. Anecdotal evidence suggests that the integration of "home grown" lighting units into smart cameras might have further contributed to reduced total market sales revenue during this period.

For the 2007-08 period, we analyzed the average unit price increase by breaking down the total average unit price by technology, geometry and mode of power control in Exhibit 9.6. In terms of the technology mix, we learned that LEDs do not account for the price increase, since they continued to decline in average price during this latter period. We found that what in fact changed was the pricing of non-LED lighting. Specifically, fluorescent, halogen and laser lighting all became more expensive on average.

What we also learned from the data of Exhibit 9.6 was that in terms of geometry, dome and line configurations became more expensive during the 2007-08 period and that in terms of power control, 24 volt non-adjustable continuous and continuous, advanced features (computer control, multiple set points, etc.) also had higher prices during those years.

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The increase in average unit pricing, which (all-things-being-equal) we would have not predicted for a recessionary period, is thus ascribable to price increases in fluorescent, halogen or laser lighting with dome or line configurations and advanced power control features.

Exhibit 9.6: Average Lighting Unit Price by Technology, Geometry and Power Control

	2005	2006	2007	2008	2007-08 Direction Over 2005-06
Total	**$435.9**	**$359.5**	**$366.0**	**$376.1**	**Increase**
By Technology					
LED	$553.9	$413.5	$397.0	$383.5	**Decrease**
Non-LED	$305.9	$293.1	$323.9	$362.7	**Increase**
Fluorescent	$326.7	$299.2	$315.8	$360.9	**Increase**
Halogen	$408.1	$418.8	$619.9	$637.4	**Increase**
Laser	$286.8	$268.5	$310.0	$354.0	**Increase**
Other	$671.4	$598.9	$733.8	$403.9	**Mixed**
By Geometry					
Spot	$425.9	$305.5	$261.9	$347.3	**Mixed**
Ring	$525.4	$354.7	$290.8	$426.7	**Mixed**
Area	$464.4	$387.7	$374.3	$420.4	**Mixed**
Line	$353.9	$277.5	$323.2	$423.1	**Increase**
Backlight	$592.1	$479.4	$471.6	$485.0	**Mixed**
Beamsplitter	$619.3	$554.9	$349.7	$487.4	**Mixed**
Dome	$582.4	$411.2	$542.3	$714.9	**Increase**
Other	$419.9	$463.4	$587.2	$226.0	**Mixed**
By Power Control					
12V Non Adj Con	$439.5	$430.8	$322.4	$417.7	**Mixed**
24V Non Adj Con	$464.7	$401.7	$407.4	$447.7	**Increase**
Con Adj Intensity	$403.3	$351.3	$333.1	$292.5	**Mixed**
Con Advanced	$454.8	$287.4	$346.5	$373.7	**Increase**
Strobe	$404.4	$406.7	$494.2	$468.3	**Mixed**

9.2.4 Total Sales Revenue and Units Sold by Major Product Feature

To increase our understanding of the MV lighting market, we next examine 2008 sales results by major product feature. Our analysis in this study is aided for the very first time by use of three-year area charts, which can uncover important trends at the product feature level.

<u>Source</u>

As suggested by the previous sections of this chapter, a major attribute of MV illumination products is the technology utilized to produce light, i.e. the lighting source. According to the data of this study, the single most important lighting source is represented by LEDs. Over half (64.2 percent) of all units sold in 2008 were LEDs, which account for 65.4 percent of total sales revenue. Next in importance is laser

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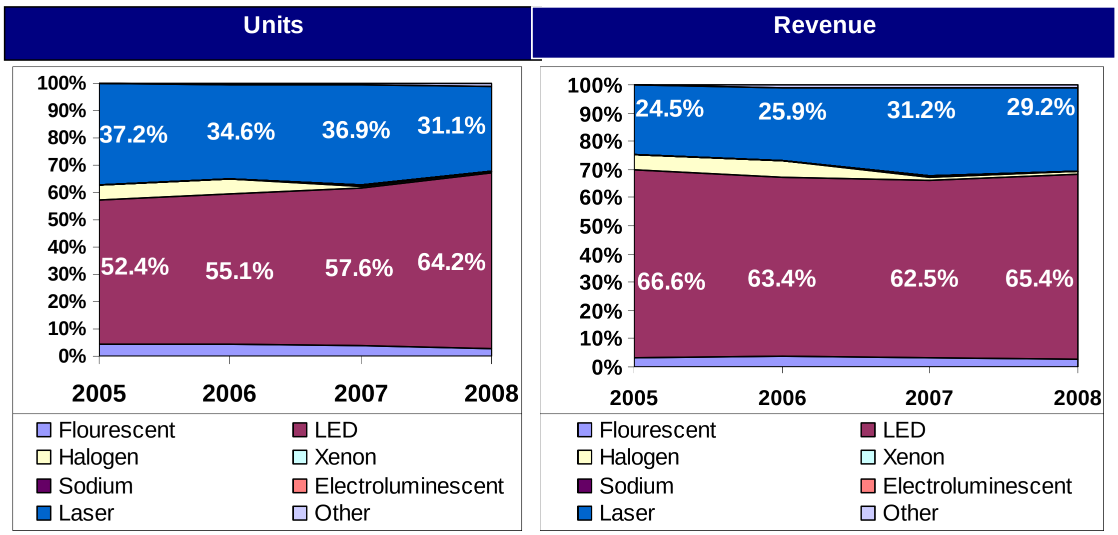
lighting at 31.1 percent of units sold, which produce 29.2 percent of the total sales revenue. Fluorescent follows in a distant third place. Halogen decreased in 2007 from 2006 levels and is essentially unchanged in 2008 from 2007.

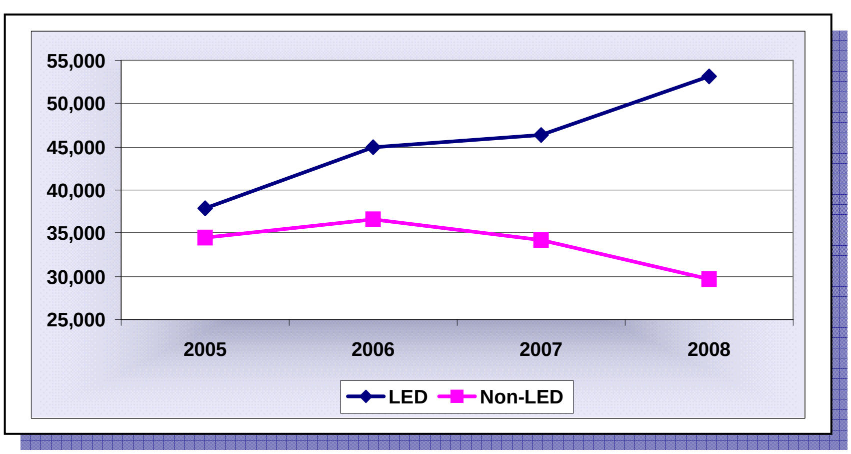
Exhibit 9.7: Lighting Sales – Percent Distribution by Lighting Source



	2005 Units	2006 Units	2007 Units	2008 Units	2005 Rev	2006 Rev	2007 Rev	2008 Units
Fluorescent	4.6%	4.4%	4.0%	2.9%	3.5%	3.7%	3.4%	2.8%
LED	52.4%	55.1%	57.6%	64.2%	66.6%	63.4%	62.5%	65.4%
Halogen	5.7%	5.4%	0.9%	0.8%	5.3%	6.2%	1.5%	1.3%
Xenon	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%
Sodium	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Electroluminescent	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Laser	37.2%	34.6%	36.9%	31.1%	24.5%	25.9%	31.2%	29.2%
Other	0.1%	0.5%	0.6%	1.1%	0.1%	0.8%	1.3%	1.2%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

The growing importance of LEDs is also revealed by Exhibit 9.8.

Exhibit 9.8: LED versus Non-LED Lighting Units Sold



<u>Geometry</u>

We next broke down sales in terms of geometry. What we learned from the data is that line configurations continued to be the most common. As revealed by Exhibit 9.9, this particular geometry accounted for 35.3 percent of the

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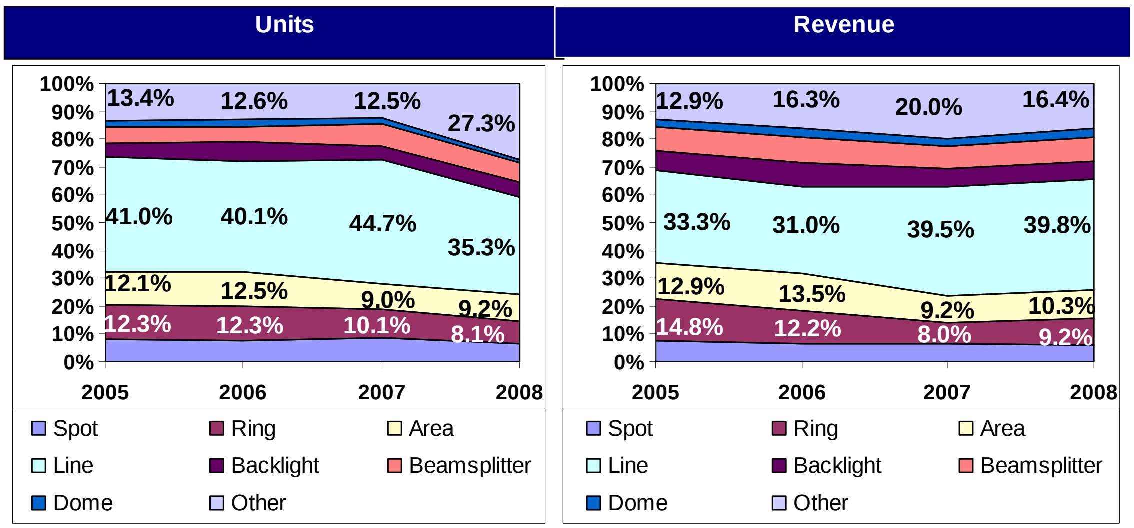
units sold and 39.8 percent of the total sales revenue. In comparison, area lighting represented 9.2 percent of the units sold and 10.3 percent of the revenue. Next in importance were ring configurations, which comprised 8.1 percent of units sold and 9.2 percent of the total revenue. Ring and area lighting remained close in terms of the percentage of total sales they represented. Beamsplitter, spot and backlighting continued to be near equally popular with sales around 5 to 7 percent of total units sold.

Exhibit 9.9: Lighting Sales – Percent Distribution by Geometry



	2005 Units	2006 Units	2007 Units	2008 Units	2005 Rev	2006 Rev	2007 Rev	2008 Rev
Spot	8.0%	7.3%	8.7%	6.7%	7.8%	6.2%	6.2%	6.2%
Ring	12.3%	12.3%	10.1%	8.1%	14.8%	12.2%	8.0%	9.2%
Area	12.1%	12.5%	9.0%	9.2%	12.9%	13.5%	9.2%	10.3%
Line	41.0%	40.1%	44.7%	35.3%	33.3%	31.0%	39.5%	39.8%
Backlight	5.2%	6.5%	5.1%	5.2%	7.1%	8.7%	6.6%	6.7%
Beamsplitter	5.8%	5.9%	8.1%	6.7%	8.3%	9.1%	7.7%	8.7%
Dome	2.2%	2.7%	1.8%	1.5%	2.9%	3.1%	2.7%	2.8%
Other	13.4%	12.6%	12.5%	27.3%	12.9%	16.3%	20.0%	16.4%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Power Source

A wide variety of power sources are used for MV lighting. Most common in 2008 were strobe power supplies. As shown by Exhibit 9.10, they accounted for 31.2 percent of all power sources used, which equated to 36.7 percent of total sales revenue. Next in importance were continuous, advanced power supplies at 30.8 percent of units and 28.9 percent of revenue, followed by continuous adjustable power supplies at 20.9 percent of units and 15.4 percent of revenue. No trends are evident for years 2005 through 2008.

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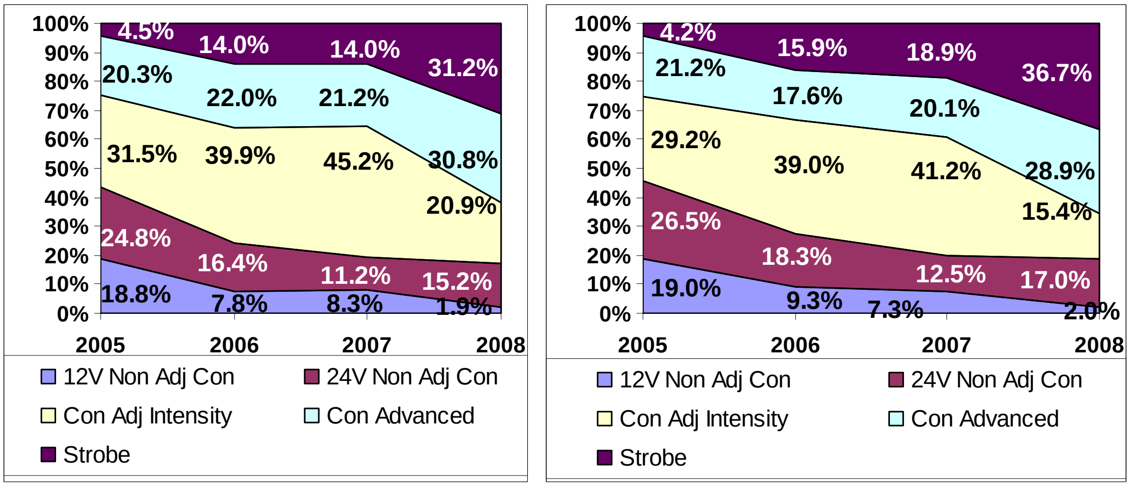
Exhibit 9.10: Lighting Sales - Percent Distribution by Power Source

Units | Revenue



	2005 Units	2006 Units	2007 Units	2008 Units	2005 Rev	2006 Rev	2007 Rev	2008 Rev
12V Non Adj Con	18.8%	7.8%	8.3%	1.9%	19.0%	9.3%	7.3%	2.0%
24V Non Adj Con	24.8%	16.4%	11.2%	15.2%	26.5%	18.3%	12.5%	17.0%
Con Adj Intensity	31.5%	39.9%	45.2%	20.9%	29.2%	39.0%	41.2%	15.4%
Con Advanced	20.3%	22.0%	21.2%	30.8%	21.2%	17.6%	20.1%	28.9%
Strobe	4.5%	14.0%	14.0%	31.2%	4.2%	15.9%	18.9%	36.7%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

<u>Control Interface to Vision System</u>

Another major product feature investigated in this study is the control interface to the vision system. What we learned from the data is that most lighting units still do not have a control interface. As shown by Exhibit 9.11, 62.8 percent of the units sold and 62.2 percent of the revenue earned did not involve control interfaces. Where control interfaces were used, “other”, undisclosed types of interfaces were still the most common. Interestingly, Ethernet-based control interfaces barely appeared on our radar screen. In 2008, they represented only 0.4 percent of units sold and 0.6 percent of sales revenue.

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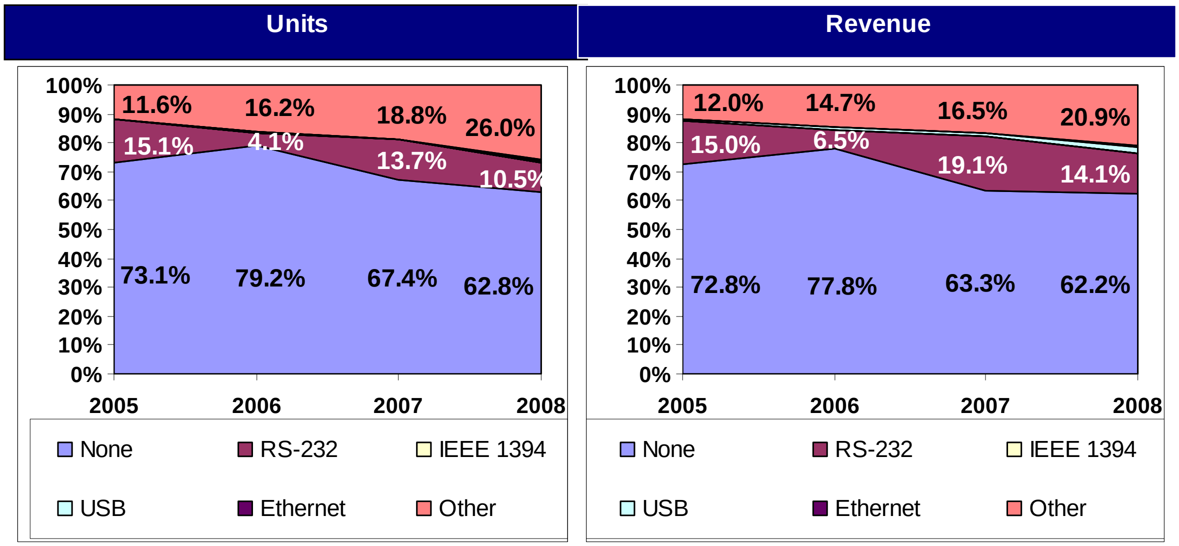
Exhibit 9.11: Lighting Sales - Percent Distribution by Control Interface

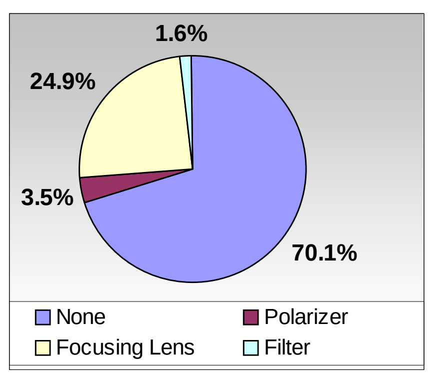


	2005 Units	2006 Units	2007 Units	2008 Units	2005 Rev	2006 Rev	2007 Rev	2008 Rev
None	73.1%	79.2%	67.4%	62.8%	72.8%	77.8%	63.3%	62.2%
RS-232	15.1%	4.1%	13.7%	10.5%	15.0%	6.5%	19.1%	14.1%
IEEE 1394	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
USB	0.2%	0.6%	0.1%	0.2%	0.2%	0.9%	1.1%	2.1%
Ethernet	0.0%	0.0%	0.0%	0.4%	0.0%	0.0%	0.1%	0.6%
Other	11.6%	16.2%	18.8%	26.0%	12.0%	14.7%	16.5%	20.9%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Accessories Sold with Lighting Systems

Although not a product feature per se, accessory sales can constitute an important revenue supplement in some cases. However, as shown by Exhibit 9.12, the overwhelming majority of sales (70.1 percent) did not entail the sale of accessories. Still, where accessories were sold, they were most likely to be focusing lenses, which corresponded to 24.9 percent of total sales. By contrast, only 1.6 percent of all sales of lighting units involved the sale of filters and only 3.5 percent of sales involved polarizers.

Exhibit 9.12: 2008 Lighting Sales - Percent Distribution by Type of Accessory



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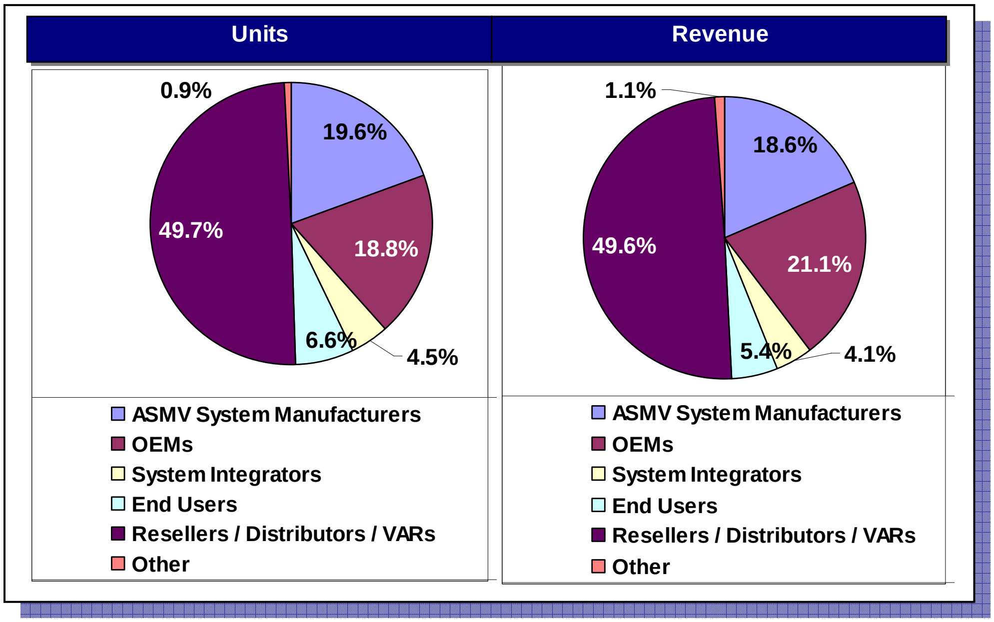
Lighting Sales by Type of Customer

Finally, we also broke down sales by type of customer. As Exhibit 9.13 shows, approximately half (49.7 percent) of all units sold were sold to resellers, distributors or VARs, which accounted for 49.6 percent of total sales revenue. Next in importance were ASMV system manufacturers at 19.6 percent of units sold and 18.6 percent of total sales revenue.

Exhibit 9.13: Lighting Sales by Type of Customer



9.3 Summary of Major Findings

The major findings of this chapter are as follows:

- **Market Characteristics**: The MV lighting market is characterized by declining revenue, an increasing number of units sold, decreasing average prices, product diversity reflecting a variety of technological options, sensitivity to trends in the MV optics and camera markets, an evolving technology mix in which LEDs have grown in importance, increasing customization, growing competition and the existence of multiple challenges to satisfying customer satisfaction.
- **Major Trends and Developments**: Important trends and developments in the MV lighting market include an increasing number of technology options and a resultant ability to offer greater customization, greater product variety, declining unit prices and the rise of the LED to a position of prominence within an evolving technology mix.
- **New Trends Detected at the Product Feature Level**:
  - We have found unmistakable evidence that LEDs continue to increase as a percent of total lighting sales.
  - Sales of lighting units with Ethernet-based control interfaces do not yet evidence a trend; in 2008 they represented only the smallest of blips on our radar screen. Our expectation is that over time, demand for these new interfaces will increase.

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- **New Product Introductions:** Most new lighting products introduced in 2008 were LED units.
- **Historical Sales:** The MV lighting market has stabilized and even grew in 2008, a sharp contrast to the contraction of previous years and most surprising in view of the impacts of the economy on other MV product markets. For the historical period as a whole, revenue declined from $34.1 million in 2004 to $31.4 million in 2008. 2007 was essentially flat compared to 2006, and 2008 was up over 2007, as previously noted. During the historical period, units sold increased from 66,621 in 2004 to 82,860 in 2008. The corresponding compound annual growth rates (CAGRs) for the historical period was -2.2 percent for revenue and 5.6 percent for units sold.
- **Forecast Sales**: Revenue and units sold will increase during the forecast period period with the exception of 2009, when the recession is expected to depress sales. For 2010, we also expect weak sales due to the lingering effects of the recession. Not until 2011 do we expect the economic recovery to reflect itself in MV lighting sales. For the forecast period as a whole, revenue will increase from $31.2 million in 2008 to $34.7 million by 2013. Units will grow from 82,860 in 2008 to 96,107 by 2013. Correspondingly, we expect compound average growth of 3.9 percent for revenue and 4.4 percent for units sold for the forecast period of 2008-13. .
- **Average Unit Price:** We found in earlier market studies an unmistakable downward trend in the average unit price of MV lighting products with this price dropping from $936 in 2001 to $359.5 in 2006. However, for 2007, we saw the beginnings of a possible reversal of that trend or at the very least a price stabilization with the average unit price at $366.0. For 2008, we then saw an increase to $376.1. Beyond 2009, it is most difficult to forecast the average unit price, since a new trend cannot be ascertained from only two year's data. Accordingly, we are predicting that the average unit price will hover around the $360 mark for the forecast period. Finally, we found that accounting for the reversal in trend in 2007 and 2008 were price increases in fluorescent, halogen or laser lighting as well as in MV lighting products with dome or line configurations and advanced power control features.
- **Sales by Lighting Technology:** The most widely used lighting technology was LEDs (64.2 percent of units and 65.4 percent of total revenue), followed by lasers (31.1 percent of units sold and 29.2 percent of revenue). Percentagewise, fluorescent follows in a distant third place, while halogen sharply declined in 2007 but eroded no further in 2008.
- **Sales by Configuration:** Line configurations represent the most popular lighting geometry (35.3 percent of the units sold and 39.8 percent of the total sales revenue), followed by area lighting (9.2 percent of the units sold and 10.3 percent of the revenue) and ring configurations (8.1 percent of units sold and 9.2 percent of total revenue).
- **Sales by Power Supply:** The most popular type of power supplies is strobe (31.2 percent of units sold and 36.7 percent of revenue), followed by continuous, advanced power supplies (30.8 percent of units and 28.9 percent of revenue) and continuous adjustable power supplies (20.9 percent of units and 15.4 percent of revenue).

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- **Sales by Control Interface:** Most lighting units still do not have a control interface. 62.8 percent of the units sold and 62.2 percent of the revenue earned did not involve control interfaces. Where control interfaces were used, "other", undisclosed types of interfaces were still the most common. Interestingly, Ethernet-based control interfaces barely appeared on our radar screen. In 2008, they represented only 0.4 percent of units sold and 0.6 percent of sales revenue.
- **Sales by Accessory:** The overwhelming majority of sales (70.1 percent) did not entail the sale of accessories. Still, where accessories were sold, they were most likely to be focusing lenses, which corresponded to 24.9 percent of total sales. By contrast, only 1.6 percent of all sales of lighting units involved the sale of filters and only 3.5 percent of sales involved polarizers.
- **Sales by Customer Type:** Approximately half (49.7 percent) of all units sold were sold to resellers, distributors or VARs, which accounted for 49.6 percent of total sales revenue. Next in importance were ASMV system manufacturers at 19.6 percent of units sold and 18.6 percent of total sales revenue.

9.4 Conclusions

In last year's study, we concluded that "The MV lighting market will continue to experience significant change for a number of years to come." That conclusion is even more valid today based on our findings for 2008. Long a contracting market, the MV lighting market appears to have found some new strength in 2008 - despite the recession which began in December of 2007 in the United States. That is truly remarkable and should be taken as a source of pride by lighting suppliers, should it turn out to be more than a "blip" in the data.

As we have seen, responsible for the revenue growth in 2008 was not just an increase in units sold but also an increase in certain types of non-LED lighting. Accordingly, while we expect the share of LED sales to continue to grow, we also believe that other types of lighting will continue to serve important niches and therefore contribute to revenue growth and the general viability of the MV lighting market. Of course, only time will tell whether this is an accurate prediction. 2009 data will be critical in this regard. Stay tuned.

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Chapter 10: MV Optics Market

Quick Navigation Buttons:

10.1 Introduction | 10.2 Survey Results | 10.3 Summary of Major Findings | 10.4 Conclusions

10.0 What's New in this Chapter?

- 10.1.6 New Product Introductions
- 10.2 Survey Results
- 10.3 Summary of Major Findings
- 10.4 Conclusions

10.1 Introduction

Optics is an essential part of every machine vision system. Much like a vision impaired individual who lacks the proper prescription glasses, cameras cannot "see" without the correct optics. Cameras require optics to, firstly, place an object's image area (a.k.a. *Field of View* or *FOV*) in focus upon their sensors and, secondly, to modify light in order to remove unwanted information (a form of image processing typically involving filters).

To perform these critical functions, optics must be matched to the camera, and this is by no means an automatic or easy process. If the proper optical equipment is not selected, aberrations can be introduced, undermining the faithful reproduction of an object's projected image. Given the possible pitfalls confronting MV optics suppliers and integrators, and their need to avoid these problems, the proper optical specifications must be determined in the process of system design. Specifically, optics suppliers and integrators must understand the specific MV application in terms of the illumination that

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will be used, the specifications of the camera, the object size and geometry, and physical constraints affecting *working distance* and available space. Stated more precisely, optical suppliers and integrators must know minimally the *Field of View, Working Distance, Depth of Field, Camera Sensor Size, Camera Pixel Size* and *Resolution* or *Modulation Transfer Function (MTF)*. Obtaining this information from customers, however, can be most challenging. Typically, customers are not optical engineers who can accurately identify the optical specifications of their particular application. This forces the optical supplier and/or integrator to thoroughly understand the application as well as the selected lighting and camera equipment. This challenge is compounded by the fact that lighting and sensor technologies are constantly evolving, thus presenting a moving target. Additionally, even where the optical specifications of an application are readily known, a custom solution might be required, the costs and lead times of which might make it economically feasible only for large scale production. Alternatively, the optical supplier/integrator could select modular lenses with flexible features (such as adjustable irises and zoom capabilities), but increased flexibility can reduce resolution and throughput. As this illustrates, a number of trade-offs arise between optical parameters and between cost and performance as well, thus entailing formidable challenges.

Another formidable challenge is presented by the limited communication between camera manufacturers and lens companies. This has resulted in a paucity of standards for the optical interface of cameras beyond such common standards as C-mount and F-mount.

This limited communication has also entailed a lack of coordination in product development cycles between sensor manufacturers and lens makers. For the most part, sensors are being developed without specific reference to the capabilities of lens makers, which results in mismatching that in turn can lead to mediocre system performance. This problem is currently illustrated by the trend toward smaller sensor pixel sizes. While sensor pixel size is trending downward, most lenses on the market have been incapable of matching them. As a consequence, problems with contrast, resolution, image plane energy-uniformity, light throughput and non-uniform focus have arisen. In addition, resources are wasted where an expensive camera is used with an ill-suited lens. To be sure, avoiding the mismatching stemming from smaller pixel sizes for sensors is possible but requires more sensitive designs consisting of more optical elements, which means more complexity and higher prices.

Optics companies endeavor to keep up with sensor developments but considerable time lags can exist given the differences in development cycles for sensors and lenses.
In the case of sensors, product development might require several years for a new technology or far less if an existing platform is used, but even with an existing technology many months might be required for working out the specification, designing, processing, testing, characterizing and qualifying of a new sensor. In the case of optics, the time required for development of a new lens similarly depends on whether lenses are simply recycled from other industries or must be developed entirely anew. Recycled

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lenses can take less than six months to repackage, while new lens designs can take from 9 to 24 months to develop and bring to market. What all this means is that cameras can come on the market with sensors for which no suitable lenses exist for a substantial period, during which lens makers must make a mad rush to catch-up. For this reason, some optics companies advocate a coordination of development cycles for sensors, cameras and optics.

Having briefly outlined the important functions performed by optics and the challenges faced in the design process, we turn now to an overview of the North American MV optics market.

10.1.1 Overview of the Machine Vision Optics Market

In accordance with the overall methodological approach of this study and past AIA MV market studies as outlined in Chapter 2, we define the MV optics market in terms of the product sales of MV optics suppliers operating at the front-end of the MV supply chain. Distributors and other intermediaries are thus not included in this "front-end component" market. Moreover, to avoid double-counting, sub-component sales (e.g. sales of optical glass, beam-splitters, polarizers, diffusers, extension tubes, etc.) are also not included as distinct, stand alone products.

Based on the aforementioned definition, we find that the North American MV optics market is of substantial size as measured in terms of sales volumes. Expressed in revenue, sales volumes for optical equipment have varied from $28.7 million (USD) in 2004 to $32.1 million in 2008, reflecting a composite annual growth rate (CAGR) of 1.3 percent. (See Exhibit 10.4 for more details.)

These sales volumes are generated by approximately 22 market participants, which offer a wide assortment of optical products. In the next sections of this chapter, we examine both the products and participants of the North American MV optics market.

10.1.2 Major Product Types and Features

Major categories of MV optical products in this study are comprised exclusively of lenses as defined in this section. A "lens" is often defined as a single piece of optical glass that serves to collect and focus rays of light to form a sharp image (a.k.a. "element"). For purposes of this study, however, we use the term "lens" to exclusively denote the multi-element optical devices that can contain mountings, filters, beam-splitting prisms or other optical sub-components in addition to optical glass.

MV lenses used are of several major types. One basic way to distinguish between these types is the nature of the light that passes through the lens. Some lenses are designed for *visible light*, while others handle *non-visible* ultraviolet (UV) or near-infrared (near-IR) light. Among lenses intended for visible light, a further distinction can be made between lenses that have a *fixed focal length* and those with a *zoom* capability. Still another basic distinction that is commonly found in the marketplace is between *macro* and *large* format.

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It is also common to identify lenses in terms of their special capabilities, such as *telecentric*, *microscopic objectives*, *board level* (micro video), *ultra-fast* (low light) and *lenses for 3-chip, beam-splitting prisms*.

Although optics suppliers do not always agree on the best way to classify lenses, it is possible to take the most common categories of lenses and derive an underlying classificatory scheme for describing the market, which for purposes of this study is as follows:

Major Categories of MV Lenses
Visible Lenses
Fixed Focal Length
Macro Non-telecentric/Non-board level
Macro Telecentric
Microscopic Objectives
Board Level (Micro Video)
Ultra Fast (Low-Light)
Lenses for 3-Chip, Beam Splitting Prisms
Zoom
General Zoom
Macro Zoom
Non-visible Lenses
Ultraviolet
Near Infrared
Line Scan

Within this classificatory scheme, "macro" refers to the ability to focus sharply at close distances. "Telecentric" lenses correct for perspective errors and maintain constant magnification despite varying distances. "Microscopic objectives" are lenses for viewing minute detail. "Board Level" refers to lenses used on cameras with board-mounted sensors for micro-level video. "Ultra Fast" lenses are designed for low light conditions. "Lenses for 3-Chip, Beam Splitting Prisms" are used with color CMOS and CCD cameras that utilize three chips. "Zoom" lenses allow changes in magnification while maintaining f-stop and focus. "Non-visible lenses" are intended for use with either ultraviolet or near-infrared light. Finally, "line scan" lenses permit a wide angle of viewing to conform to the dimensions of sensors used in line scan cameras.

<u>Definitions</u>

Based on the provided descriptions, we define for purposes of data collection and analysis the various classes of lenses as follows:

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Definitions of Major Classes of Lenses

- **Visible Lenses:** Lenses that use visible light.
- **Non-Visible Lenses:** Lenses that use ultraviolet (UV) or near infrared (N-IR) light.
- **Fixed Focal Length Lenses:** Non-zoomed lenses where the distance between the sensor and center of the lens is fixed.
- **Zoom Lenses:** Lenses with variable focal lengths that have the ability to shift magnification smoothly and continuously while maintaining focus and f-stop.
- **Telecentric Lenses:** Parallax corrective lenses maintaining, within a certain range of working distances, a constant viewing angle at any point across the clear aperture of the objective lens, thus allowing the machine vision system to generate dimensionally accurate images for measurement.
- **Macro Lenses:** Lenses that can focus sharply very close to an object to capture minute surface detail.
- **Macro Non-telecentric/Non-board Level Lenses:** Fixed focal length lenses that can focus very close to an object to capture surface detail but cannot correct for perspective errors (parallax) and are not used for board level cameras.
- **Microscopic Objectives:** Fixed focal length lenses used for capturing extremely small detail (regardless of their other possible characteristics).
- **Board Level Lenses:** Fixed focal length lenses used on cameras with board-mounted sensors (regardless of their other possible characteristics).
- **Ultra Fast Lenses:** Fixed focal length lenses used with cameras with high frame rate cameras for low light applications (regardless of their other possible characteristics).
- **Lenses for 3-Chip, Beam-splitting Prisms:** All fixed focal length lenses used with 3-chip CCD or CMOS color cameras (regardless of their other possible characteristics).
- **General Zooms:** Zoomed lenses without a macro capability (See "Zoom Lenses").
- **Macro Zoom:** Zoomed lenses with a macro capability.
- **Line Scan Lenses:** All lenses used with Line Scan cameras (regardless of their other possible characteristics).

Major Product Features

It should be noted that lenses can be further distinguished in terms of their product features. Two important features of lenses in this study are *lens control* (where the focus and iris can be either manual, motorized or auto) and *ruggedization* (where lenses may or may not be ruggedized to handle harsh environmental conditions such as heat and vibration).

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10.1.3 Major Suppliers

No less than 23 suppliers actively compete in the North American MV optics market. Many of these suppliers are headquartered in the US and Canada, but many are also European and Japanese, with and without direct sales channels physically located in North America. An overview of major MV optical suppliers in North America is provided by Exhibit 10.1.

Exhibit 10.1: Major MV Optical Component Suppliers

CBC (America)	Light Works	Nikon
Canon	Qioptiq LINOS	Schneider Optics
Coastal Optical Systems (Jenoptik)	CVI Melles Griot	Sunex
Edmund Optics	Moritex (Schott)	Tamron USA
Fujinon	Navitar	Thales Optem
Goyo Optical	NET USA	Universe Kogaku America
Kowa Optimed	PENTAX	Vision & Control
Kyocera Optec	Nebula	

As identified on their websites, suppliers' product lines indicate a wide diversity, suggesting both a large measure of differentiation as well as dissimilar approaches to categorizing MV optical products in the market. Additionally, Exhibit 10.2 reveals that few suppliers of MV optical components in North America offer a complete selection of optical systems, specializing instead in different areas of the MV optics market.

Exhibit 10.2: Description of MV Optical Product Lines by Selected Major Supplier

Supplier	Description
CBC (America)	Mega-pixel, telecentric, macro, zoom and IR lenses
Edmund Optics	Telecentric, zoom, variable magnification, fixed magnification, micro video, high-power, medium-power and low-power MV lenses
Fujinon	Fixed focal high resolution, c-mount lenses
Goyo Optical	Manual, high resolution, 1 inch, F0.95, manual vari-focal zoom, manual zoom and motorized zoom lenses
Kowa Optimed	Fixed focal manual iris, fixed focal manual iris megapixel/telecentric and zoom manual iris lenses
Kyocera Optec	CCD, scanner, fixed focus, telecentric and line sensor lenses
Light Works	Telecentric lenses
Qioptiq LINOS	Singlets, achromats, NIR doublets and various optical components; scan lenses; lenses for laser optics; zoom and UV reflecting and macro lenses
CVI Melles Griot	Singlets, multi-element, cylindrical, achromatic, aspheric and meniscus lenses
Moritex (Schott)	Low magnification macro, macro zoom, macro for line CCDs, non-telecentric macro and fixed and zoom micro lenses
Navitar	High magnification zoom, fixed, large format, low magnification video, telecentric, fluorescence imaging/microscopy, auto focus zoom and motorized lenses
Nebula	2/3" and ½" c-mount lenses and telecentric lenses
Nikon	Not listed
PENTAX	Zoom, standard, telephoto, macro, wide angle and special purpose lenses

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Exhibit 10.2: Description of MV Optical Product Lines by Selected Major Supplier (Continued)

Supplier	Description
Schneider Optics	C-mount standard, macro, compact, unifoc, telecentric, linescan and hi-res scan lenses
Sunex	Miniature CCD/CMOS lenses, zoom, macro and other lenses; IR and optical-low pass filters and custom optics
Tamron USA	High resolution and super high resolution mono-focal and other lenses
Thales Optem	Fixed-magnification, retro zoom, zoom, NIR zoom, telecentric zoom, macro video zoom
Universe Kogaku America	High resolution, CCD, Pinhole CCD, diode laser lens assemblies, microscope objectives
Source: supplier websites	

10.1.4 Market Trends and Developments

A major event in the MV optics market has been the rise of the telecentric lens. In contrast to a standard lens, a telecentric lens holds magnification constant despite changes in focus and reduces distortion resulting from parallax. This has been of great benefit to metrology applications. (It is important to note that different types of telecentric lenses exist, depending on whether telecentricity exists on the object side, the image side or both sides of the lens.) An object-sided telecentric lens can be modified on the image side for different focal lengths on the object plane to increase or decrease the magnification of the lens. This is known as a “zoom telecentric” lens. Unlike object-sided telecentric lenses, image-sided telecentric lenses are not as often used in machine vision. (Examples of this type of lens in machine vision are lenses truly designed to go through 3CCD prism focal plane arrays and “micro lenslets” contained in sensors.)

An emergent trend is the increased use of *magnetic based technology* for the grinding and polishing of glass elements to produce more accurate optical surfaces, greater repeatability from lens to lens, complex surface shapes and reduced cycle times in production.

Other possible trends are the broader use of diffractive or hybrid refractive/diffractive lenses and wire grid polarizers.

Clearly, some trends in the optics market will be driven by changes in the camera market. For example, camera manufacturers now provide 22-mm megapixel arrays in cameras with a one-inch format, necessitating larger lenses. Because few lenses currently are available for this size sensor, one would expect optical suppliers to increase production of these lenses in response to demand.

10.1.5 Major Characteristics of the MV Optics Market

As we have seen, the MV optics market in North America is characterized by the following:

- Market size of $32.1 Million (USD) in 2008.

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- Revenue growth of 0.7 percent in 2008 (over 2007); CAGR for 2004 to 2008 is 1.3 percent.
- Unit growth of 0.6 percent in 2008 (over 2007).
- Sensitivity to the MV camera market in terms of demand levels and technology (e.g. the impact of smaller sensor pixel size on lens development).
- Formidable challenges to suppliers and/or integrators in end-user customer sales as a consequence of a myriad of trade-offs between optical parameters and cost/performance considerations.
- A high degree of product diversity in the market as a function of different combinations of lens types, mountings and accessories that are available.
- No commonly accepted classification of MV optical products exists; suppliers conceptually approach the MV product market with somewhat dissimilar definitions.
- Specialization: In targeting the market, suppliers tend to specialize, offering product lines that are often differentiated in their composition.
- Complete product lines offered by few suppliers.
- Product development sizes are six months for repackaging in the case of lenses recycled from other industries and 9 to 24 months in the case of all-new designs.

10.1.6 New Product Introductions

In this section we provide a list of the new MV optics products introduced in 2008. (Note: While we intend this list to be all-inclusive, it is possible that we have inadvertently omitted some models. Should this be the case, we offer our humble apologies.)

Exhibit 10.3: New MV Optics Products in 2008

Company	Product Name	Lens Type	Focal Length	Magnifi-cation	Mount Type	Zoom Range	Motorized
Kyocera	Lens for Line Sensor 55mm F2.6	Line Sensor	55mm	0.067 x to 0.35 x	F	NA	NA
Kyocera	Lens for Line Sensor 108mm F3.6	Line Sensor	108mm	0.7 x	M72 P0.75	NA	NA
Kyocera	High Res Lens	Fixed Focus Telecentric	130mm	NA	C	NA	NA
Qioptiq LINOS	mag.x	UV reflecting	NA	NA	RMS	NA	NA
Qioptiq LINOS	inspec.x	UV macro	50mm	NA	NA	NA	NA
Qioptiq LINOS	Fetura Advanced Zoom	Zoom	NA	NA	C	12.5.1	X
Moritex	SOD-10X	Telecentric	55mm	x10	C	NA	NA
Moritex	MML-HR Series	Hi res	NA	NA	NA	NA	NA
Net USA	VS-MC Series	Macro	4,6,5,10,25,35,5 0,75mm	Various	C, M15.5, P-0.5, M10.5, P-0.5	NA	NA
Schneider Optics	Macro-Varon 4.5/85mm	Hi res line scan	85mm	0.5 x to 2.0 x	V	NA	NA

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Exhibit 10.3: New MV Optics Products in 2008 (Continued)

Company	Product Name	Lens Type	Focal Length	Magnifi-cation	Mount Type	Zoom Range	Motorized
Tamron USA	M118FM08	Hi Res, Fixed Focal	8mm	NA	C	NA	NA
Tamron USA	M118FM016	Hi Res, Fixed Focal	16mm	NA	C	NA	NA
Tamron USA	M118FM25	Hi Res, Fixed Focal	25mm	NA	C	NA	NA
Tamron USA	M118FM50	Hi Res, Fixed Focal	50mm	NA	C	NA	NA
Vision & Control	Vicotar T24 Series	Telecentric	30 to 38.4mm	NA	NA	-3:1, -2.5:1, -2:1, -1.5:1	NA
Vision & Control	T42/1.4	Telecentric	102mm	NA	NA	-1.4:1	NA
Vision & Control	T43/1.4	Telecentric	102mm	NA	NA	-1.4:1	NA
Vision & Control	T51/1.7	Telecentric	49m	NA	NA	1.73:1	NA

What is particularly striking is the wide variety of new products offered. Very little overlap is evident, suggesting that each company is expanding its product mix in different directions. This emphasizes the tremendous diversity of products in the MV optics market.

10.2 Survey Results

We next examine the market in terms of sales volumes expressed in revenue and units. Our focus is the historical period of 2004 through 2008 and the forecast period of 2009 through 2013.

10.2.1 Historical Growth Patterns

Historical data on optics sales revenue and units has only been available in more recent AIA market studies. These studies, however, have provided data on optics sales revenue on an estimated basis for prior years. As shown by Exhibit 10.4, annual revenue growth has varied widely from 10.4 percent in 2004 to 0.7 percent in 2008. While annual year-over-year growth was relatively weak at 0.7 percent in 2008, growth for the 2004 - 2008 period as a whole has been somewhat stronger at a CAGR of 1.3 percent.

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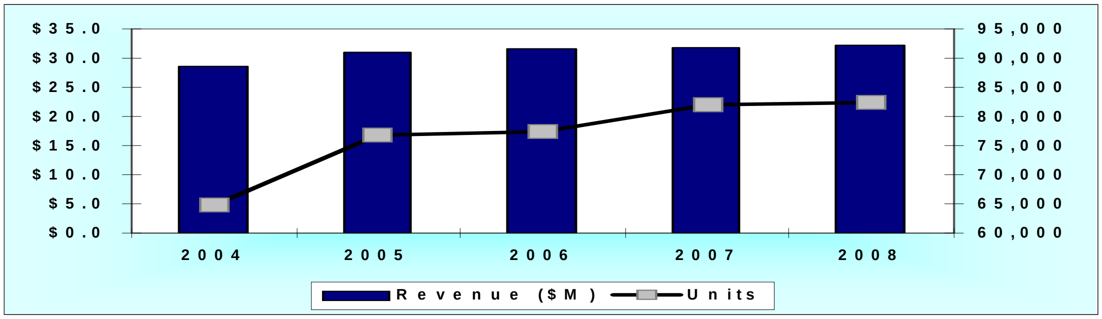
Exhibit 10.4: Optics Sales Revenue ($ Millions) and Units: 2004 to 2008

	2004	2005	2006	2007	2008	CAGR
Revenue ($M)	$28.7	$30.9	$31.6	$31.9	$32.1	-
%	10.4%	7.7%	2.1%	1.0%	0.7%	1.3%
Units	64,824	76,724	77,331	81,978	82,447	-
%	-	18.4%	0.8%	6.0%	0.6%	2.4%
Average Price	$443	$403	$408	$389	$389	-



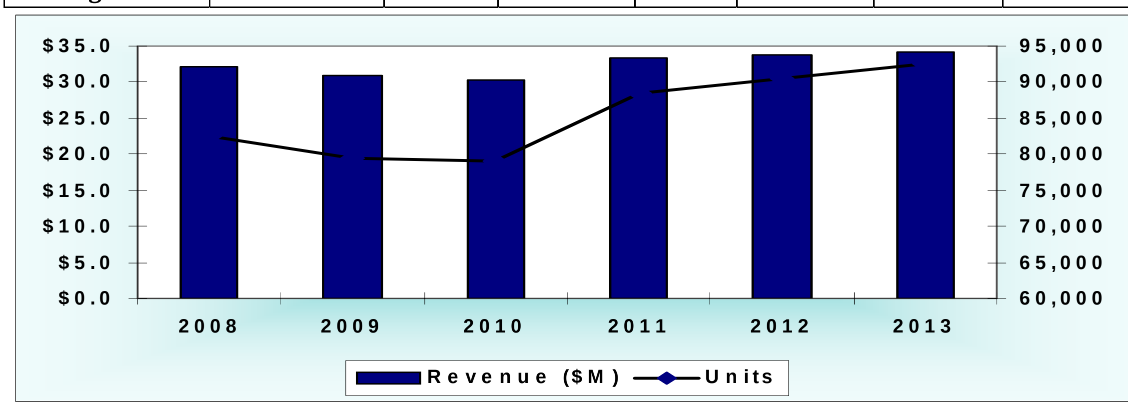
*Growth rate adjusted for change in company mix between 2005 and 2006

10.2.2 Forecasts

For the forecast period, we expect weak growth in 2009 and 2010, reflecting the recession. Optics sales revenue is forecast to increase from $32.1 million in 2008 to $34.1 million in 2013, reflecting a CAGR of 2.4 percent. For the same time frame, we anticipate even greater growth for units sold. We expect units to grow from 82,447 in 2008 to 92,509 in 2013, reflecting a CAGR of 3.9 percent.

Exhibit 10.5: Forecast Optics Sales Revenue ($ Millions) and Units: 2008 to 2013

	2008	2009	2010	2011	2012	2013	CAGR
Revenue ($M)	$32.1	$31.0	$30.4	$33.3	$33.7	$34.1	-
%	0.7%	-3.5%	-2.0%	9.7%	1.2%	1.2%	2.4%
Units	82,447	79,442	79,070	88,470	90,489	92,509	-
%	0.6%	-3.6%	-0.5%	11.9%	2.3%	2.2%	3.9%
Average Price	$389	$390	$384	$377	$373	$369	-



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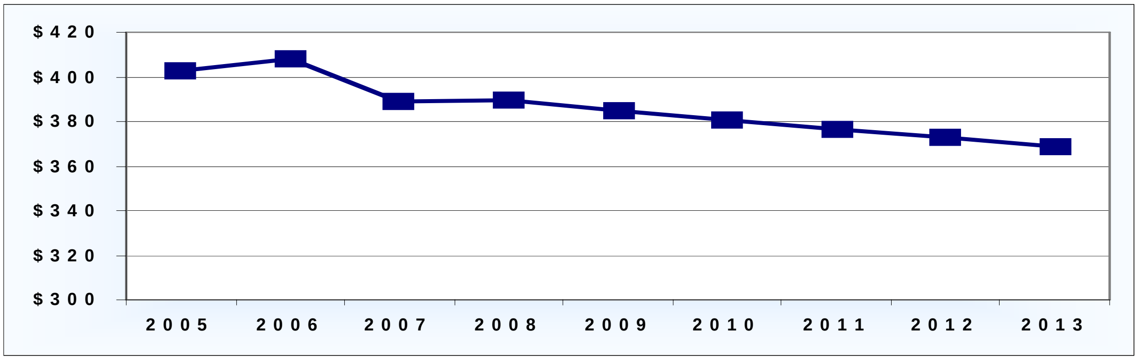
10.2.3 Price Analysis

With units sold growing faster than sales revenue, it is evident that the average price for an MV optical system has declined and will continue to decrease over time. This steady erosion in price is evident in Exhibit 10.6. This decline is very much in line with the price patterns of other types of MV components.

Exhibit 10.6: Average Price of Optics: 2004 - 2013

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Average Price	$443	$403	$408	$389	$389	$385	$381	$377	$373	$369



10.2.4 Total Sales Revenue and Units by Major Product Feature

To increase our understanding of the MV optics market, we next examine 2008 sales results by major product feature. It should be noted that this is the first year the AIA MV market study has had four comparable years of sales data by product feature, which help us to detect trends on the product feature level.

<u>Total Lens Sold by Type</u>

In examining product features, a logical point of departure is the type of lens sold in accordance with the classificatory scheme outlined in section 10.1.2. As revealed by Exhibit 10.7, a wide diversity of MV lenses was sold between 2005 and 2008.

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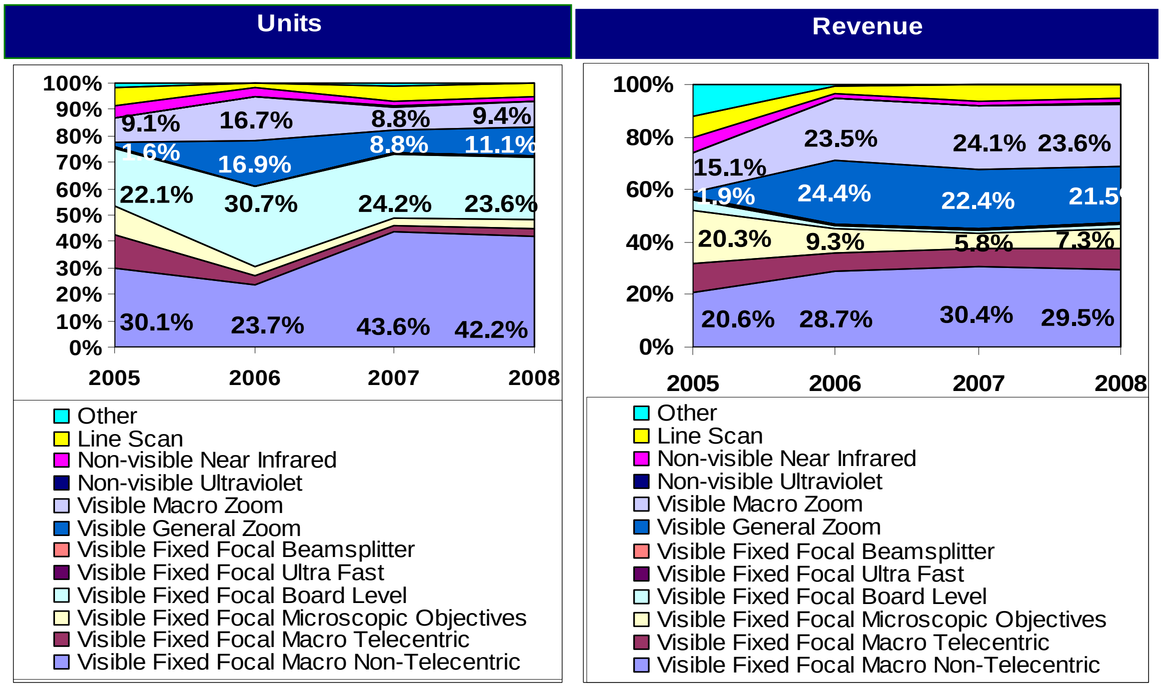
Exhibit 10.7: Optics Sales – Percent Distribution by Type of Lens Sold



	2005 Units	2006 Units	2007 Units	2008 Units	2005 Rev	2006 Rev	2007 Rev	2008 Rev
Visible Fixed Focal Macro Non-Telecentric	30.1%	23.7%	43.6%	42.2%	20.6%	28.7%	30.4%	29.5%
Visible Fixed Focal Macro Telecentric	12.7%	3.3%	2.3%	2.9%	11.2%	7.1%	7.3%	8.0%
Visible Fixed Focal Microscopic Objectives	10.5%	3.3%	3.1%	3.3%	20.3%	9.3%	5.8%	7.3%
Visible Fixed Focal Board Level	22.1%	30.7%	24.2%	23.6%	3.9%	1.4%	1.3%	1.7%
Visible Fixed Focal Ultra Fast	0.7%	0.0%	0.2%	0.3%	0.8%	0.3%	0.4%	0.9%
Visible Fixed Focal Beamsplitter	0.1%	0.1%	0.1%	0.0%	0.1%	0.0%	0.2%	0.2%
Visible General Zoom	1.6%	16.9%	8.8%	11.1%	1.9%	24.4%	22.4%	21.5%
Visible Macro Zoom	9.1%	16.7%	8.8%	9.4%	15.1%	23.5%	24.1%	23.6%
Non-visible Ultraviolet	0.0%	0.0%	0.1%	0.1%	0.0%	0.0%	0.2%	0.2%
Non-visible Near Infrared	4.6%	3.6%	1.8%	1.7%	5.5%	1.9%	1.8%	1.8%
Line Scan	7.0%	1.6%	5.9%	5.4%	8.3%	2.9%	6.0%	5.2%
Other	1.5%	0.0%	1.2%	0.0%	12.2%	0.4%	0.2%	0.2%
	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

The most common lens sold was the visible fixed focal non-telecentric lens. In 2008, this type of lens accounted for 42.2 percent of the total units sold and 29.5 percent of the total sales revenue. Next in importance were visible fixed focal board level lenses at 23.6 percent of total units sold but only 1.7 percent of total sales revenue. Visible general zoom and visible macro zoom lenses were also important. No clear trends here are evident.

As one would expect, the overwhelming majority of lenses sold are designed for visible light. Of the total MV optics sales in 2008, only 1.8 percent of the units sold and 2.0 percent of the revenue were for use with non-visible (ultraviolet and near infrared) lighting, as shown by Exhibit 10.8. This exhibit also shows that only 5.4 percent of the units sold were intended for use with line scan cameras, which accounted for 5.2 percent

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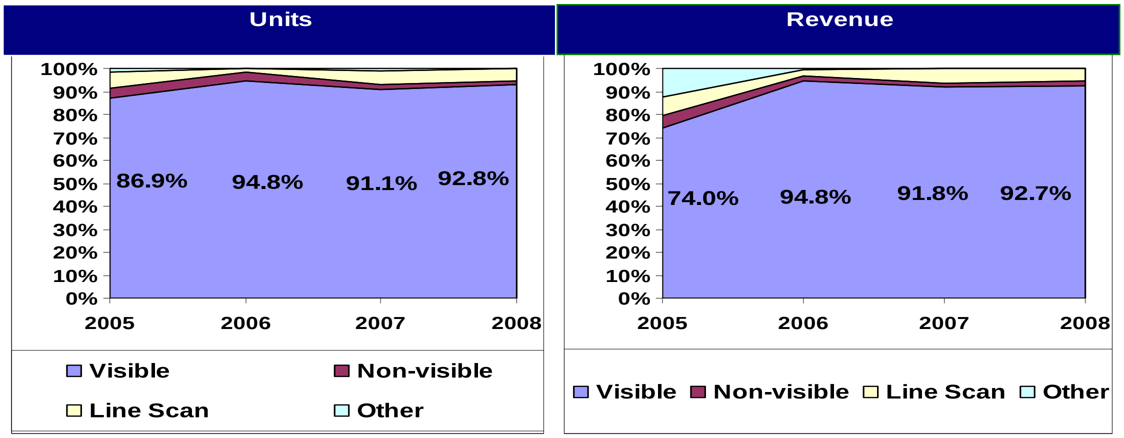
of the total sales revenue.

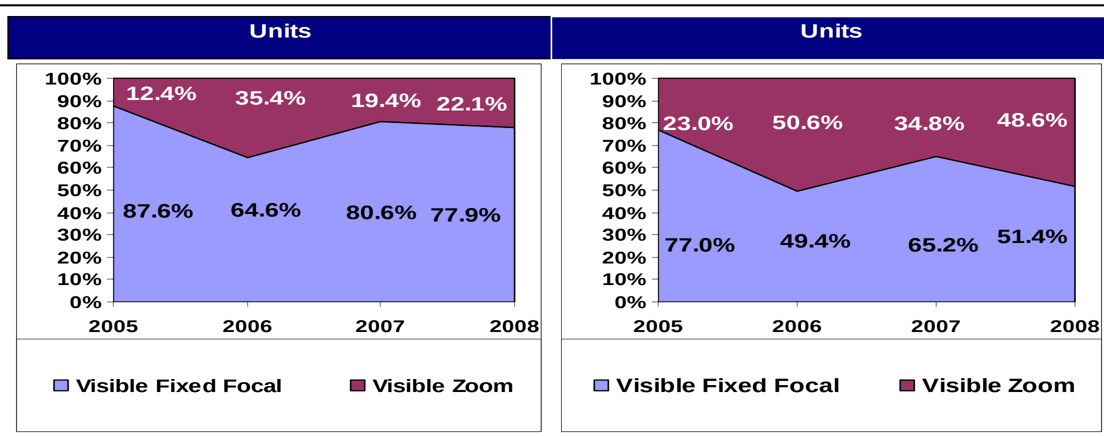
Exhibit 10.8: Optics Sales by Major Lens Category (in Percent)



	2005 Units	2006 Units	2007 Units	2008 Units	2005 Rev	2006 Rev	2007 Rev	2008 Rev
Visible	86.9%	94.8%	91.1%	92.8%	74.0%	94.8%	91.8%	92.7%
Non-visible	4.6%	3.6%	1.8%	1.7%	5.5%	1.9%	2.0%	2.0%
Line Scan	7.0%	1.6%	5.9%	5.4%	8.3%	2.9%	6.0%	5.2%
Other	1.5%	0.0%	1.2%	0.0%	12.2%	0.4%	0.2%	0.2%
Total	86.9%	94.8%	91.1%	100.0%	100.0%	100.0%	100.0%	100.0%

As suggested by the results we have thus far seen, most lenses used in machine vision are of the fixed focal variety as opposed to zoom lenses. In fact, our market survey data indicate that approximately one-fifth (22.1 percent) of all lenses sold in 2008 were zoom lenses, which accounted for 48.6 percent of the total sales revenue, as shown in Exhibit 10.9. This difference in the percentages for units and revenue suggests that zoom lenses on average are considerably more expensive than fixed lenses.

Exhibit 10.9: Optics Sales by Fixed Focal Vs. Zoom (Visible)



	2005 Units	2006 Units	2007 Units	2008 Units	2005 Rev	2006 Rev	2007 Rev	2008 Rev
Visible Fixed Focal	87.6%	64.6%	80.6%	77.9%	77.0%	49.4%	65.2%	51.4%
Visible Zoom	12.4%	35.4%	19.4%	22.1%	23.0%	50.6%	34.8%	48.6%
Total Visible	100.0%	100.0%	100.0%	100.0	100.0%	100.0%	100.0%	100.0%

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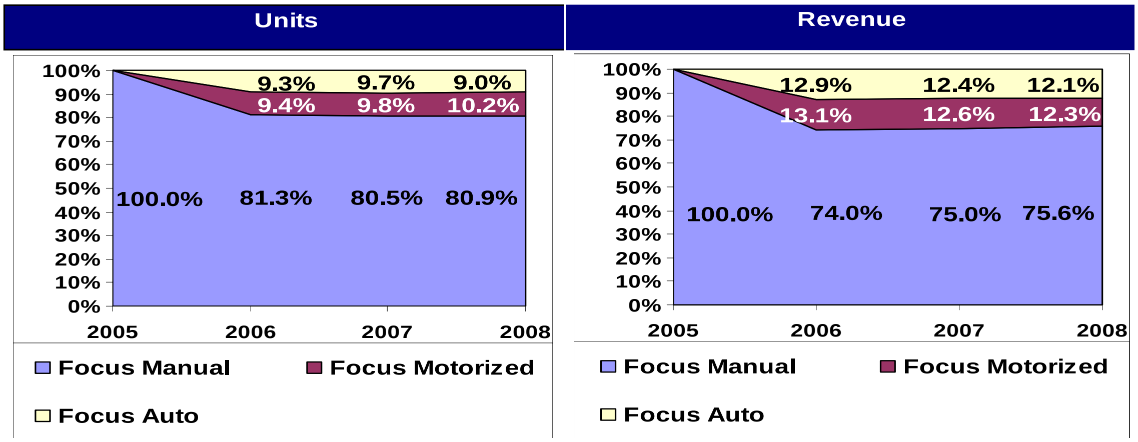
Optics Sales by Lens Control

We next break down sales by lens control. As Exhibit 10.10 clearly shows, sales in 2008 involved predominantly manual lens controls.

Exhibit 10.10: Optics Sales by Lens Control

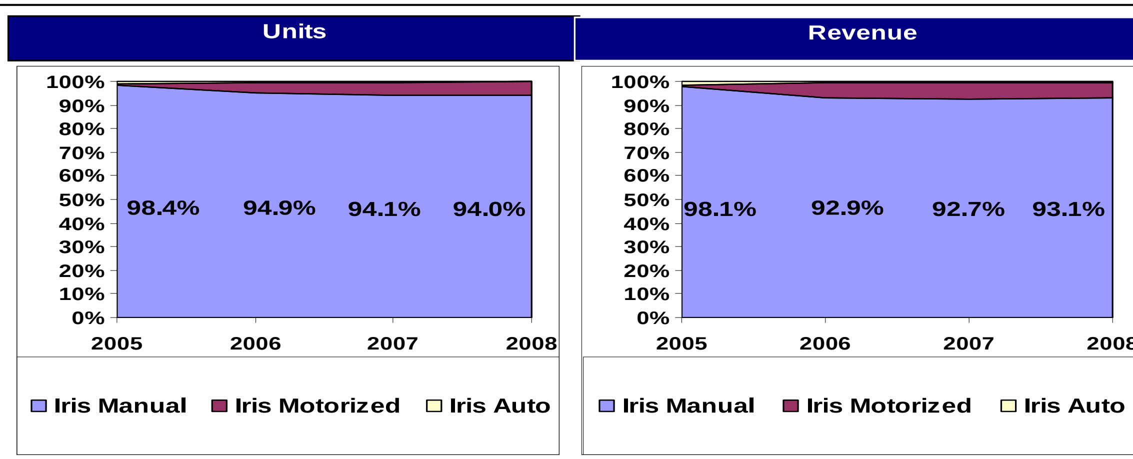


	2005 Units	2006 Units	2007 Units	2008 Units	2005 Revenue	2006 Revenue	2007 Revenue	2008 Revenue
Focus Manual	100.0%	81.3%	80.5%	80.9%	100.0%	74.0%	75.0%	75.6%
Focus Motorized	0.0%	9.4%	9.8%	10.2%	0.0%	13.1%	12.6%	12.3%
Focus Auto	0.0%	9.3%	9.7%	9.0%	0.0%	12.9%	12.4%	12.1%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Optics Sales by Iris Control

Most optics sales also have manual iris controls as shown by Exhibit 10.11.

Exhibit 10.11 Optics Sales by Iris Control



	2005 Units	2006 Units	2007 Units	2008 Units	2005 Revenue	2006 Revenue	2007 Revenue	2008 Revenue
Iris Manual	98.4%	94.9%	94.1%	94.0%	98.1%	92.9%	92.7%	93.1%
Iris Motorized	0.5%	4.8%	5.6%	5.7%	0.6%	6.6%	6.6%	6.3%
Iris Auto	1.2%	0.3%	0.3%	0.2%	1.4%	0.5%	0.7%	0.5%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

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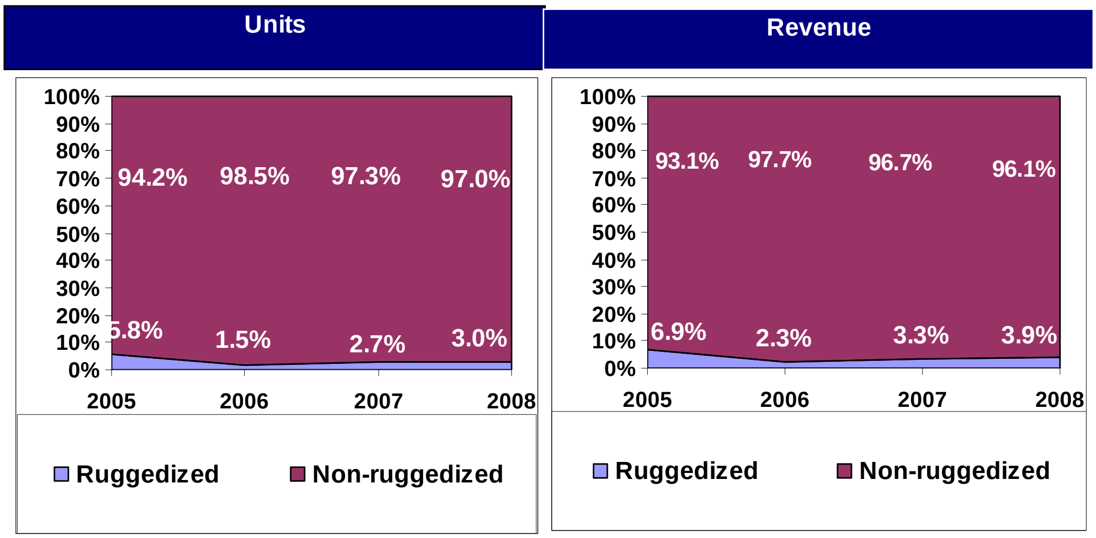
Optics Sales - Ruggedization

Another important product feature is ruggedization. Here we are interested in determining the extent to which units sold in 2008 were intended for use under harsh environmental conditions. What we find is, as shown by Exhibit 10.12, that 3.0 percent of all lenses sold in 2008 were ruggedized, which accounts for 3.9 percent of the total sales revenue from machine vision lenses.

Exhibit 10.12: Optics Sales – Ruggedized vs. Non-ruggedized Sales



	2005 Units	2006 Units	2007 Units	2008 Units	2005 Rev	2006 Rev	2007 Rev	2008 Rev
Ruggedized	5.8%	1.5%	2.7%	3.0%	6.9%	2.3%	3.3%	3.9%
Non-ruggedized	94.2%	98.5%	97.3%	97.0%	93.1%	97.7%	96.7%	96.1%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Total Lenses Sold by Type of Customer

Finally, we also examine sales in terms of the type of customer purchasing optics. Interestingly, we found that approximately half (51.9 percent) of all units sold in 2008 were sold to OEMs, which accounted for 44.7 percent of total revenue. Sales to end users followed at 25.5 percent of units and 8.7 percent of revenue. ASMV system manufacturers followed next in size at 10.4 percent of units and 21.4 percent of revenue. Surprisingly, resellers accounted for only a small portion of total sales (5.7 percent of units and 9.8 percent of revenue).

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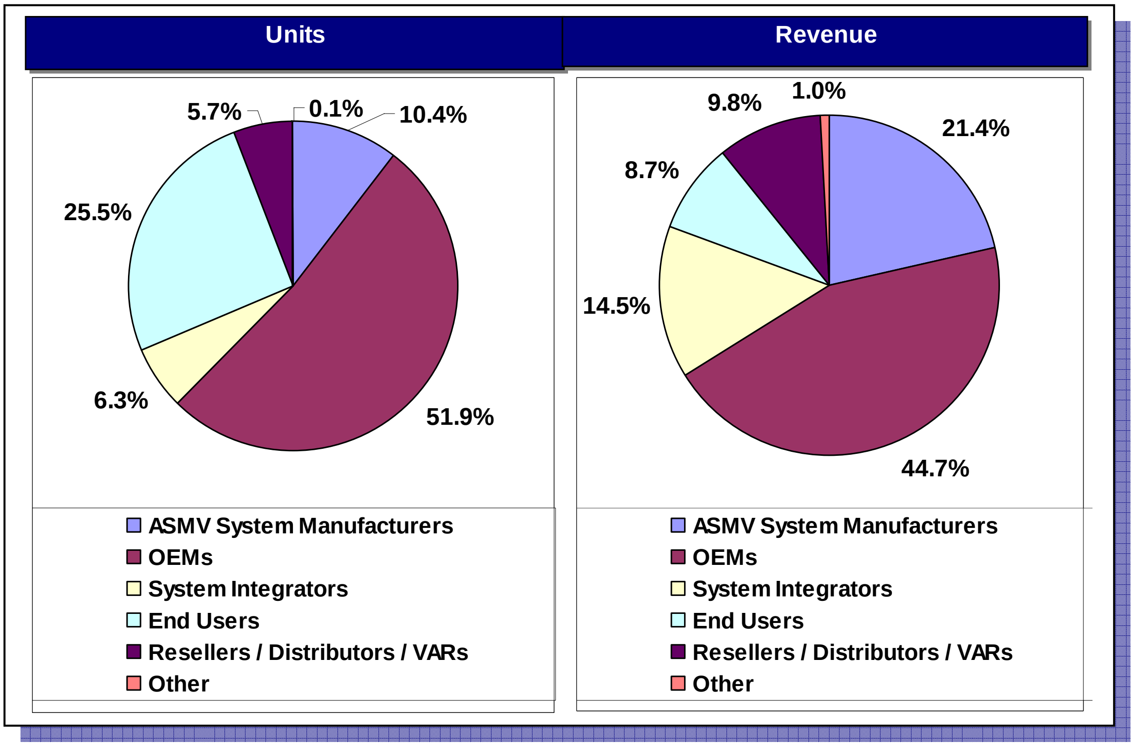
Exhibit 10.13: Optics Sales – By Type of Customer



10.3 Summary of Major Findings

The major findings of this chapter are as follows:

- **Major Market Characteristics:** The MV optics market in North America is characterized by a high degree of dependence on the direction and performance of the MV camera market, formidable challenges in meeting customer needs, a high degree of product diversity and specialization, as well as a lack of uniformity in the way leading suppliers segment the market in terms of major product categories.
- **Historical Sales:** The MV optics market in North America has performed unevenly over time. Revenue growth for 2004 and 2005 was robust, but for preceding years it was negative, and in 2007 and 2008 it was only 1.0 and 0.7 percent, respectively. As a consequence of this uneven pattern, overall revenue growth for the historical period of this study (2004 through 2008) was 1.3 percent.
- **Forecast Sales:** Going forward**,** a continuation of single digit growth is foreseen. A CAGR of 2.4 percent for MV optics revenue and a CAGR of 3.9 percent for units sold are predicted for the forecast period.
- **Average Price:** Reflecting the differential rates of annual growth for revenue and units sold, the average price of an MV optical system has been declining. Currently, the average price is around $389. By 2013 it is forecast to decrease to $369.
- **New Product Introductions:** 2008 saw a wide variety of new products. Very little overlap was evident between them, suggesting that each company with new offerings

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is expanding its product mix in different directions. This of course adds to the tremendous diversity of products in the MV optics market.

- **Fixed Focal Non-Telecentric Lens Sales:** The largest single category of MV lenses sold in 2008 was fixed focal non-telecentric lenses. In 2008, this type of lens accounted for 42.2 percent of the total units sold and 29.5 percent of the total sales revenue.
- **Fixed Focal Board Level Lens Sales:** Next in number of sales were fixed focal macro board level lenses at 23.6 percent of total units sold but only 1.7 percent of total sales revenue.
- **Macro Telecentric Lens Sales:** Only about 2.9 percent of all MV lenses sold in 2008 were macro-telecentric lenses.
- **Zoom Lens Sales:** Zoom lenses accounted for 17.6 percent of all MV lenses sold in 2008.
- **Line Scan Lens Sales:** Only about 5.4 percent of all MV lenses sold in 2008 were intended for use with line scan cameras.
- **UV and IR Lens Sales:** Only about 1.8 percent of all units sold in 2008 were designed for use with ultraviolet or near infrared light.
- **Sales by Focus Type:** About 10.2 percent of 2008 sales had motorized focus and 9.7 percent had auto focus features.
- **Sales by Iris Control:** Only 5.7 percent of optics sales in 2008 involved motorized irises.
- **Sales by Ruggedness vs. Non-Ruggedness:** About 3.0 percent of all MV lenses sold in 2008 were intended for use in harsh environmental conditions.
- **Sales by Type of Customer:** Approximately half (51.9 percent) of all units sold in 2008 were sold to OEMs, which accounted for 44.7 percent of total revenue. Sales to end users followed at 25.5 percent of units and 8.7 percent of revenue. ASMV system manufacturers followed next in size at 10.4 percent of units and 21.4 percent of revenue. Surprisingly, resellers accounted for only a small portion of total sales (5.7 percent of units and 9.8 percent of revenue).

10.4 Conclusions

Because of the current recession, sales growth in 2008 was weak and is expected to remain weak in 2009 and 2010. 2011 is the first year in which optics sales are expected to reflect the recovery.

Apart from economic impacts, no discontinuities or radical changes in the MV optics market are foreseen. The dynamics of the MV optics market will continue to be driven by the MV camera and lighting markets.

Because of the importance of optics to MV systems, and since camera and lighting developments drive changes in the development of optics products, cooperation and communication between lens makers, sensor manufacturers and lighting suppliers is essential to the viability of the machine vision industry. This communication and cooperation is particularly necessary in the area of standards and product development.

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Chapter 11: Application-Specific Machine Vision Systems Market

Quick Navigation Buttons:

11.1 Introduction | 11.2 Survey Results | 11.3 Summary of Major Findings | 11.4 Conclusions

11.0 What's New in this Chapter?

- 11.2 Survey Results
- 11.3 Summary of Major Findings

11.1 Introduction

In this chapter, we focus on application-specific machine vision (ASMV) systems, turnkey machine vision (MV) systems that address specific applications. These MV systems combine the functionality of optics, lighting, cameras, imaging boards and software in standalone, integrated devices, which are used in a wide range of industries to perform a number of generic functions, including 2D and 3D metrology, surface flaw/cosmetic analysis, mechanical/electronic assembly verification, visual servoing (3D and 2D), robot guidance, location analysis, character recognition, part recognition, 2D symbol reading and other applications.

Our purpose in this chapter is to quantify historical and projected demand for ASMV systems in terms of units sold and sales revenue. We also disaggregate that demand by generic application and industry and examine average pricing for the historical and forecast periods.

To clarify our findings, we first revisit descriptions of how ASMV systems are deployed in selected, major industry sectors.

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11.1.1 Overview of ASMV Systems in Selected Major Industries

ASMV systems are as diverse as the industries they serve. In this section, we briefly examine selected end-user industries and how machine vision systems are used to perform specific applications within them. We begin with traditional, manufacturing industries and then shift our focus to newer industries that represent emerging opportunities for machine vision companies.

11.1.1.1 Manufacturing

The manufacturing industries in which machine vision is widely deployed include the automotive, container, electronics, fastener, food and beverage, wood products, pharmaceutical, printing and semiconductor industries.

11.1.1.1.1 The Automotive Industry

The automobile manufacturing industry is one of the largest industries within the US, representing over 5 percent of GDP. According to the most recent economic census available for the US (2002), total shipments in automobile manufacturing in 2002 were worth $85.9 billion. Although the US remains the world's largest producer and consumer of motor vehicles with production reaching 12.2 million units in 2002, the US automobile industry has been highly cyclical and competitive and is undergoing profound structural change. The industry does not depend significantly on foreign exports (unlike the Japanese and European automotive markets), relying mostly on its own domestic market and the Canadian market (which are highly integrated).

The automobile industry consists of all companies that manufacture or assemble automobiles as well as their suppliers. In North America, the largest domestic manufacturers of automobiles are Daimler/Chrysler (headquartered in Germany), Ford and General Motors. A number of other automakers have assembly operations in North America (including Toyota, Honda, BMW and the Mercedes division of Daimler/Chrysler). Additionally, there are numerous suppliers comprising a $200 billion industry in North America (according to the Chicago Fed).

Because the North American auto market is highly competitive, automobile manufacturers and suppliers can ill afford production errors. To achieve the quality that customers demand, they are increasingly relying on machine vision.

In the automotive industry, machine vision (MV) is used in a range of applications involving primarily *inspection* and *robotic guidance*. Using embedded vision sensors to find objects in 2 or 3-dimensional space and adjusting paths for the positions of the objects, robots utilize machine vision for far greater accuracy in critical activities, including auto racking (picking parts out of racks), bin picking and the positioning of parts (such as doors and panels) for assembly.

MV systems also efficiently perform various types of inspections, determining essentially whether the sundry items comprising an automobile pass muster and rejecting those that do not. This includes *surface inspection* for cosmetic flaws (such as dings, dents and wrinkles in body panels) as well as detection of functional flaws (such as irregularities on

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the bearing surfaces of automotive rocker arms or the correct spacing and size of mounting holes on disk brake pads). Machine vision systems also *verify the presence* (or absence) *of parts* and the correctness of their shapes (such as in the case of gears, which can have missing or malformed teeth). Finally, machine vision inspections for *assembly verification* insure error-free assembly (such as with closure panels that include doors, hoods, lift gates and tail gates).

MV systems also perform *parts recognition.* For example, they can read treads of different makes and types of tires and direct their correct routing by conveyor belt to designated vehicles. MV systems can also perform parts recognition via OCR functions where printed labels have been attached to parts.

Machine vision moreover enables *dimensional gauging* of precision machined components (such as fasteners, transmissions and other sub-assemblies). In so doing, MV systems insure that only parts falling within the correct tolerances find their way into vehicles departing the assembly line.

Finally, machine vision can also be used for *2D data matrix reading*. An example of this application is the reading of codes that are laser-etched in a camshaft bar stock to provide precise instructions for grinding the camshaft, insuring a correct fit between cam and engine block.

The major machine vision applications used by the three largest, domestic manufacturers are as follows:

Exhibit 11.1: Major MV Applications by Domestic Manufacturer

Manufacturers	Major MV Applications
Daimler/Chrysler	■ Vision-guided robotic material handling ■ Inspection of adhesive materials ■ Dimensional validation ■ Process control ■ 3D inspections
Ford	■ Traceability ■ Error-proofing ■ In-station process control ■ Robotic guidance ■ Dimensional control
General Motors	■ Inspection/error proofing ■ Part ID/tracking ■ Gauging ■ Robotic guidance

In the automobile industry, ASMV system sales in 2008 were $95.2 million (USD), as indicated by Exhibit 11.24 in section 11.2.

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11.1.1.1.2 The Container Industry

The container industry is comprised of sub-sections of the glass and glass product manufacturing, fabricated metal product manufacturing and plastics and rubber products manufacturing industries. Of these industry sub-sections, plastic bottle manufacturing has the largest number of establishments and paid employees in the US, but metal can manufacturing has the greatest value of shipments.

Exhibit 11.2: Profile of the US Container Industry

	Establishments	Value of Shipments	Paid Employees
Glass Containers	66	$4.4B	16,102
Metal Cans	209	$11.5B	20,329
Plastic Bottles	404	$8.0B	34,138

Source: US Census

<u>Glass Containers</u>

In the production process, materials move through three parts of the factory: the *batch house* (which contains raw materials), the *hot end* (where the furnaces and forming machines are located) and the *cold end* (where containers are labeled and packaged for shipment). In the forming process two main methods are deployed: the *blow and blow* method and the *press and blow* method, both of which manipulate a *gob* of molten glass by means of molds. With the first of these methods, the glass is blown twice into different molds. With the second method, a plunger is used to push the glass into the first mold and is then blown into a second mold.

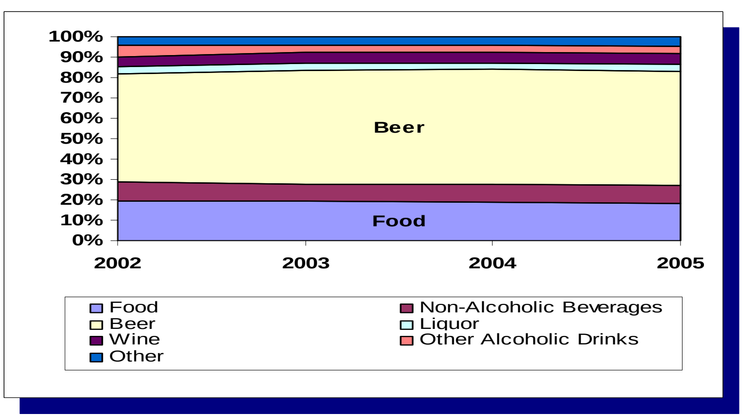
Total gross shipments of glass containers in the US have hovered around 240 million annually.

Exhibit 11.3: Annual Gross Shipments of Glass Containers in the US (Millions)

2002	2003	2004	2005	2006 (est)	2007 (est)	2008 (est)
245.3	238.4	239.7	244.9	248.1	251.4	254.6

The largest use of glass containers in the US is to hold beer, as shown by Exhibit 11.4.

Exhibit 11.4: Glass Containers in the US in Percent of End Use



Source: US Census

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Approximately 95 percent of all glass containers are used for food and beverages. The glass manufacturing industry utilizes machine vision in both hot and cold-end operations (depending on whether the MV system is designed for the hot or cold-end). Hot-end MV applications include:

- Mold identification based on a code located on either the heel or bottom of the bottle.
- Detection of "freaks" (misshapen bottles that do not conform to height, diameter and lean parameters).
- Detection of defects (such as overpressed finish, press up flange, birdswing, checks and slit finish, choked necks, chipped sealing surface, slug necks, contamination, unfilled finish, unfilled sharp handle, stuck glass, etc.).

These applications lower production costs by removing imperfect containers at the hot-end and affording timely corrective actions. MV systems designed to operate at the cold-end perform the same functions.

Reliance on machine vision does not stop with the production of glass containers, as it is also used in bottling operations where glass containers are filled with their contents. These applications include the following:

- Inspection of bottles in crates to sort out dissimilar bottles.
- Identification of improperly positioned bottles (which could otherwise interrupt production).
- Inspection of the crate itself (for correct appearance, handle, etc.).
- Verification of fill levels.
- Closure inspection (verification of proper sealing for elimination of missing caps, misapplied caps, foreign caps, broken or missing tamper bands).
- Detection of foreign substances.
- Inspection of crate for fullness.

A number of MV companies offer systems for glassware manufacturing and filling, as shown by Exhibit 11.5.

Exhibit 11.5: Machine Vision Companies Serving Glass Container Production and Filling by Operation

Supplier	Glassware Hot-end	Glassware Cold-end	Filler Pre-Fill	Filler Post-Fill
AGR International	X	X		X
Emhart Glass		X	X	X
Industrial Dynamics			X	X
Inex Vision Systems	X	X	X	X
Insight Control Systems		X		
Heuft			X	X
Krones			X	X
Photon Dynamics			X	
Pressco Technology		X	X	

Source: AIA article by N. Zuech

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<u>Metal Cans</u>
Traditionally, the metal can industry was divided along the lines of the raw material used in production: steel and aluminum. Over the course of time, aluminum cans largely displaced steel cans for beverages. However, later were themselves faced with stiff competition from *polyethylene terephthalate* (*PET*) plastic bottles in the beverage market. Today, many soft drinks are contained in plastic bottles, while beer continues to be supplied primarily in thin aluminum cans.

Another important industry trend has been the move toward thinner can walls and lids. The lid has been the most costly part of the can. By making it and the walls of the can thinner, manufacturers have cut their production costs, but in doing so have experienced some process issues, which has lead to greater reliance on machine vision.

Steel cans are typically made of three pieces: top, bottom and body. The body of the can is rolled and then bonded at the seam with solder, welding or cement. The top and bottom are then affixed. Food, juices, spices and non-food items (such as paints and glues) are typically contained in 3-piece steel cans. Some 2-piece steel cans are manufactured with the draw and iron process and are used for food and various non-food items. Whether 3-piece or 2-piece, steel cans are made from flat sheets cut from coils of tin-plated or tin-free steel.

Aluminum cans are either 1 or 2-piece and are produced via the *draw and iron* method. This involves feeding a metal coil into a cupper which stamps out metal cups which in turn are placed on a cylinder and forced through a series of rings to further draw out the walls of the can.

In the production of metal cans, machine vision is utilized to inspect can ends, can interiors and exteriors. Specific MV applications include:

- Inspection of can dimensions: height, flange width, flange angle, seam width and height, bead height, etc.
- Inspection of can end ("consumer end" and other end)
- Inspection of can outer surface for dents, holes, scratches, wrinkles, etc.
- Inspection of can labeling
- Inspection of can interior

Machine vision is also utilized in the filling of cans.

MV companies serving the metal container manufacturing and filling industries are listed in Exhibit 11.6.

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Exhibit 11.6: Machine Vision Companies Serving Metal Container Production and Filling by Operation

Supplier	Can End Product	Can End Consumer	Can Dimensions	Inside Can/ Manufacturer	Outside Can	Inside Can/Filler
Ibea	X	X	X	X		X
Emhart Glass	X	X		X		
Industrial Dynamics	X	X	X	X	X	
Insight Control Systems	X					
Krones						X
Pressco Technology	X	X	X	X	X	X

Source: AIA article by N. Zuech

Plastic Bottles

Plastic bottles are manufactured by *blow molding* of which there are four major types:

1. Extrusion blow molding
2. Injection blow molding
3. Stretch blow molding and
4. Reheat and blow molding

Extrusion blow molding is a method wherein a hot tub of plastic is extruded, placed into a water-cooled mold and filled with air blown through the neck or top of the container until it stops expanding at the walls of the mold and assumes a rigid shape.

Injection blow molding involves injecting hot plastic material into a cavity where it surrounds a blow stem, which creates the neck. The material then is subjected to extrusion blow molding at the next station in the production process.

Stretch blow molding makes use of a *preform*, which is first created through injection molding and then blown into a rigid form and ejected.

Reheat and blow molding is identical to stretch blow molding except the preform is purchased from another vendor. Use of stock preforms allows manufacturers to save on equipment costs by utilizing simpler machinery that is used for heating and blowing only.

In the manufacture of plastic containers, machine vision has multiple applications:

- Inspection for container integrity
- Thickness measurements
- Cosmetic inspection
- Label inspection
- Lot tracking
- Dimensional inspections to track wear and tear on molds
- Inspection of preforms for geometric properties and conditions such as short shots, nicked or oval finishes, length, diameter, gate length and straightness
- Closure inspection

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Inspection can be performed at multiple points in the production process; on preforms and on bottles inside the blow molder or on an external conveyer. (By detecting and discarding defective preforms, blow molder efficiency can be improved.) Inspection can also be performed on multiple areas of the bottle; the base, the neck, the seal and label.

Many of the MV companies offering inspection systems for glass containers do so for plastic containers as well. These companies are listed in Exhibit 11.7.

Exhibit 11.7: Machine Vision Companies Serving Plastic Container Production by Operation

Supplier	Preform	Blow Molded Container	In-Mold Labeling
AGR International	X	X	X
Ibea	X		
Industrial Dynamics	X	X	X
Insight Control Systems		X	X
Pressco Technology	X	X	X

Source: AIA article by N. Zuech

In the container industry, sales of MV systems in 2008 amounted to $46.2 million (USD) as indicated by Exhibit 11.24 in section 11.2.

11.1.1.1.3 The Electronics Industry

For purposes of this study the electronic industry consists primarily (but not exclusively) of *printed circuit board* (*PCB*) manufacturing and assembly. According to the US Census Bureau, this industry consists of 1,818 establishments with shipments worth $29.8B as follows:

Industry Sector	No. of Establishments	Value of Shipments
Bare PCB manufacturing	944	$ 6.4 B
PCB Assembly	874	$23.4 B
Total	1,818	$29.8 B

Despite the smaller number of establishments involved with it, PCB assembly represents the lion's share of industry shipments.

It should be noted that the US industry has substantially contracted over the last five years, as Asian countries (most notably Japan and China) have garnered an increasing share of global PCB sales. According to Dr. Hayao Nakahara, seven US PCB manufacturers were found among the top 20 PCB manufacturers in the world in 2000; by 2005, however, that number had dwindled down to only three. At the same time, US companies have closed an increasing number of their US facilities in order to move off-shore to lower cost areas as well as to size production to demand. All things being equal, these trends suggest reduced demand for *Automatic Optical Inspection* (*AOI*) machines, the major devices employing machine vision technology in PCB assembly. However,

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these effects are at least partially offset by the trend towards component and lead miniaturization (which makes visual inspection increasingly inadequate) and the response to *RoHS (Restriction of Hazardous Substances)* international standards (which - in requiring the elimination of lead from solder - has made the placement of solder on boards more problematic and thus in greater need of precise verification).

The assembly of PCBs today makes use of *surface-mount technology* (SMT), which has replaced the older *through-hole* technique. As the former term suggests, the current approach to constructing electronic circuit boards involves attaching components (known as *surface-mount devices* or *SMDs*) to boards.

In the assembly of PCBs, the first step is the application of *solder paste* to *solder pads*m which are found on the surface of the bare boards. (The solder pads are small, metallic pads to which components are attached by means of solder paste, which consists of flux and solder particles.) In the second step, *pick-and-place machines* take small SMDs and place them on the boards at the proper locations. The second-side components are placed first and attached to the boards by means of adhesive dots that are cured quickly with low heat or UV radiation. The boards are then flipped over and the first-side components are attached. In the third step, the boards are conveyed into a *reflow soldering oven*, entering first in a pre-heat zone where temperatures are raised slowly and then into a zone where the temperature is capable of melting the solder, thus bonding the SMDs to the boards. After reflow soldering, heat-sensitive components may be attached by hand or by means of *focused infrared beam (FIB)* equipment. This then is followed by a washing of the boards to remove flux residue and bits of solder, which otherwise could short out leads.

During these production steps, machine vision is utilized mainly for solder paste inspection, inspection of SMD placement and post-reflow inspection. Prior to these steps, machine vision is utilized by the bare-board manufacturer to inspect “artwork”, inner/outer layer circuit patterns, drill-hole patterns and solder mask and coatings. Specific MV applications for bare-board manufacturing and PCB assembly include the following:

<u>PCB Assembly</u>

- Inspection of solder paste and epoxy for presence and volume
- Verification of co-planarity of component leads
- Post-solder verification of presence and position of components
- Post-solder verification of solder presence and inspection of properties
- Alignment of boards to assure position of patterns, epoxy, component placement and board pattern position

<u>Bare Board Manufacturing</u>

- Inspection of artwork
- Inspection of inner/outer layer circuit patterns
- Inspection of drill-hole patterns
- Inspection of solder mask and coatings

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It should be noted that both 2D and 3D machine vision applications are utilized in the electronics industry. 3D applications include:

- Solder paste inspections
- Inspections for preloaded board warpage and
- Inspections of wire bonds.

Given the importance of machine vision to the electronics industry, it is not surprising to find a number of companies serving this industry, as listed in Exhibit 11.8.

Exhibit 11.8: Machine Vision Companies Serving the Electronics Industry

Aceris 3D Inspection	Excellon Automation	Qualectron
Agilent Technologies	GSI Lumonics	Radiant Imaging
AOI Industries	Landrex Technologies	Saki (Seika)
BeamWorks	Lloyd Doyle	ScanCad
Camtek	LPKF	Surpass Technologies
Ceco Industries	Machine Vision Products	Testronics
CyberOptics Semiconductor	Mania Technologie AG	Unichem Industries
Diagnosys Systems	Midas Vision Systems	Vectron
DisplayCheck	Omron Electronics	Vi Technology
Douthitt	Orbotech	Viscom
Ekra America	Photon Dynamics	YesTech

In the electronics industry, sales of MV systems in 2008 amounted to $123.4 million as indicated by Exhibit 11.24 in section 11.2.

11.1.1.1.4 The Fastener Industry

The fastener industry consists of companies that produce or distribute screws, bolts, nuts, rivets, washers, clamps and the like. In North America, fastener production is strongly tied to the manufacture of automobiles, aircraft, appliances, agricultural machinery and equipment and the construction of commercial buildings and infrastructure.

In 2005, the fastener industry in the US operated about 350 manufacturing facilities with 40,000 employees, according to the Industrial Fasteners Institute. Annually, more than 200 billion fasteners are consumed in the US worth $9.9 billion. US production of fasteners in 2004 was $8.5 billion, of which $1.7 billion was exported. In that same year, imports to the US totaled $3.1 billion (mainly from Taiwan, Japan and China).

During the last forty years, the fastener industry in North America experienced dramatic change, involving considerable market consolidation as characterized by a sharp decline in the number of companies and concomitant emergence of larger companies involved with the production of fasteners. Increasingly, fastener companies have focused more on global markets as well as the production of highly engineered, technologically advanced fasteners and fastening systems.

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The fastener industry has utilized one form or another of machine vision for quite some time. For the most part, vision-based sorting systems are used to insure the integrity of fasteners. Systems verify minimum conditions for a host of key properties, identify anomalies, and exclude them from the batch. Bulk sorters typically use a vibratory bowl feeder to singulate and feed individual fasteners past vision sensors at rates up to 500 to 1200 per minute. However, some systems operate as laboratory instruments to sample-check a batch such as vision-based optical coordinate measuring machines to spot check critical diameters. Typically, inspection and sorting does not occur in production facilities but at points of distribution to perform a final sort before shipment to customers. Companies offering vision-based sorting systems for fasteners are listed in Exhibit 11.9.

Exhibit 11.9: Companies Offering Vision-Based Sorting Systems for Fasteners

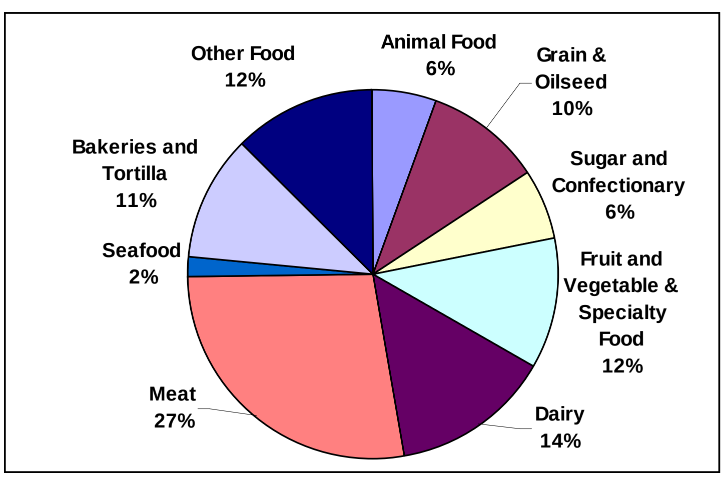
Dunkley International	Mectron Engineering	SIDAC Automated Systems
Jerhen Industries	Retina Systems, Inc.	SWD, Inc. Fastener Sorting Corp.

In the fastener industry, sales of MV systems in 2008 amounted to $0.4 million (USD) as indicated by Exhibit 11.24 in section 11.2.

11.1.1.1.5 The Food & Beverage Industry

In the words of the US Department of Agriculture's Economic Research Bureau, "(the food and beverage industry)… transforms raw agricultural materials into intermediate foodstuffs or edible products through the application of labor, machinery, energy and scientific knowledge." It is a highly diverse industry, comprised of a wide range of segments: meats, seafood, grains, sugars, dairy, fruits and vegetables, bakery, animal food, other and beverages. Of these segments, meats (livestock and poultry slaughter, processing and rendering) account for the largest share of shipments, as shown by Exhibit 11.10:

Exhibit 11.10: Food and Beverage Segments in Percent of Total Shipments



Source: US Department of Agriculture, Economic Research Service

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Taken together, manufacturing plants in these segments accounted for 13 percent of the value of shipments from all US manufacturing plants in 2001. According to the Census of Manufacturers, there are 29,000 food processing plants in the US, which are owned by about 22,000 companies. Approximately 1.7 million, or slightly more than one percent of the US workforce, is employed in these plants. Although the number of plants is high, their average size is small with the largest 20 food manufacturing firms accounting for 35 percent of shipments. In beverage manufacturing, market concentration is even higher with the largest 20 firms accounting for 66 percent of total shipments. For the food and beverage industry as a whole, the top 50 firms account for 51 percent of food shipments and 74 percent of beverage shipments.

In food processing, machine vision is used in a variety of applications including fruit and vegetable sorting and grading, automatic portioning, inspection for foreign objects and general package-line applications.

High-capacity, vision-based sorters have been around since the 1980's. Examples of sorting applications include detection and elimination of nightshade (a poisonous weed) in green peas, insects in blueberries and rot on the skins of potatoes. As these examples illustrate, vision-based sorters play a necessary role in insuring food quality by separating wanted commodities from waste, including off-color, rotted or diseased produce and foreign matter such as stems, leaves, soil, insects and stones.

In automatic sorting equipment for fruits and vegetables, color image analysis is widely used. It is also used for quality assurance in the case of other food items such as the color determination of beer and sugar and the analysis of the color attributes of white shrimp. In some cases, color inspection is used to detect bacterial contamination. In food packaging, one finds a number of machine vision applications, including:

- Inspection of label quality (to determine correct positioning of labels, tears or product spills)
- Cap and fill level inspection (to prevent leaks and under-filled bottles)
- Package contents verification (to insure the correct number of items in each carton such as chocolates in boxes)
- Date/lot code inspection (to make sure codes are readable)
- Verification of vacuum seals on jars and bottles (to insure product integrity)
- Detection of faulty carton seals (to detect unglued and imperfect seams on wrap-around carton seals)
- Inspection of cap closures (to check integrity of sealing liners)
- Identification of bag seal jams (to detect improper seals caused by product jams)

In the beverage industry, quality inspection of containers, fill level inspection and closure inspection are among the leading applications.

ASMV system suppliers targeting the food and beverage industry in North America are listed in Exhibit 11.11.

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Exhibit 11.11: Companies Offering ASMV Systems in the Food & Beverage Industry

Autoline/Aweata	Durand Wayland	Key Technology
Baader Food Processing Machinery	Electronic Sorting Systems	Odenberg Engineering
BBC Technologies	eMerge Interactive	Satake
Best USA	Exeter Engineering	Sortex
Color Vision Systems	FMC FoodTech	Woodside Electronics
Delta Technology Corp.	Focused Technologies	
Dipix	Greefa	

In the food and beverage industry, sales of MV systems in 2008 amounted to $98.4 million (USD) as indicated by Exhibit 11.24 in section 11.2.

11.1.1.1.6 The Wood Products Industry

Companies in the North American wood products industry manufacture products such as lumber, plywood, veneers, wood containers, wood flooring, wood trusses, manufactured homes and prefabricated wood buildings. Production processes in this industry include sawing, planning and shaping of logs, as well as laminating and assembly of wood products.

In the US, shipments of wood products, produced by some 37,471 manufacturing facilities, are valued at $262.3 billion (USD), contributing 1.2 percent of total GDP. With a timberland base of about 490 million acres, close to 19 billion cubic feet of softwood and hardwood are harvested by forestry product companies annually, of which almost half is used for construction and building materials. (By comparison, European demand for wood products is tied to furniture, since - unlike in North America - homes are not constructed primarily out of wood.) Because demand for wood products in the US is closely tied to the housing market, it is highly cyclical. In the early 1990s, the industry was hit hard by the recession, as a consequence of which significant downsizing and restructuring occurred.

In Canada, wood product shipments total $19.6 billion (CD) annually, accounting for 4.6 percent of Canadian manufacturing shipments. A large portion (64 to 77 percent) of Canadian wood products is exported. Of these exports, over 70 percent goes to the US.

The transformation of logs into lumber involves a number of mill processes depending on the specific wood products to be manufactured. Typical mill operations for softwood involve debarking (removal of bark), bucking (cross-cutting of a felled tree into specific log lengths), primary and secondary breakdown (live and cant cutting of saw logs into lengths), edging, trimming, planing, sorting of green lumber and drying. (Operations for hardwood used in the production of veneers involve a different set of processes.)

To operate profitably, mills must utilize logs to their maximum potential. Given the competitive nature of the wood products industry and the high cost of logs (which

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accounts for almost 80 percent of the cost of lumber), wood product companies have increasingly embraced machine vision to maximize processing efficiency and value recovery. Machine vision's key role in process optimization derives from its capability to accurately determine at production speeds log geometry, as well as external and internal features considered as defects.

The importance of machine vision in wood products industry is further indicated by its many generic applications. These include:

- Scanning for size verification (lumber size control)
- Scanning/control in bucking operations
- Scanning/control in primary and secondary breakdown
- Edging optimization
- Planer optimization based on knot/defect and profile/wane scans
- Scanning for secondary breakdown
- Grading and grade optimization
    - Scanning for knots and defects
    - Scanning for color
    - Scanning for roughness
    - Scanning for automatic patching of defects using cutting dies

The number of MV companies serving the wood products industry is also indicative of the industry wide importance of machine vision. These companies are shown in Exhibit 11.12.

Exhibit 11.12: Companies Supplying ASMV Systems for the Wood Products Industry

Argos Controls	Gemofor (Optifor)	Sicam Systems
Autolog Sawmill Automation	Inx-Systems	Softac Systems
Barr-Mullin	Lucidyne Technologies	Timber Machines Technologies
Canadian Mill Equipment	Michael Weinig	Ultimizers
Coe Newnes McGehee	Nelson Brothers Engineering	USNR/Perceptron
Comact	Optimil Machinery	Ventek
Corley Manufacturing	Porter Engineering	Woodeye
Esterer WD	Raute Wood	

Regarding the technology utilized by MV companies, we must note a high degree of sophistication. Mill operations do not merely rely on 2D MV systems. Today, 3D scanning of wood is also fairly established in the industry, especially in primary breakdown, curve sawing, cant and edger operations. Because 3D scanners can better handle "out of round" (oblong) logs, they can optimize value by getting the best recovery in terms of straightness, reduced wane (missing wood) and visual defects (knots, slits,

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etc.) This increase in recovery can cost-justify the higher cost of 3D scanners over 2D scanners in most operations, with the possible exceptions of bucking and pre-sorting. Technologically, MV systems also differ in terms of whether they are camera - or laser - based. Functionally, MV systems also differ in terms of the specific operations they support, further suggesting a wide range of MV products designed for this industry.

In the wood products industry, sales of MV systems in 2008 amounted to $164.3 million (USD) as indicated by Exhibit 11.24 in section 11.2.

11.1.1.1.7 The Pharmaceutical Industry

The pharmaceutical and medicine manufacturing industry consists primarily of establishments manufacturing "pharmaceutical products intended for internal and external consumption in such forms as ampoules, capsules, vials, ointments, powders, solutions and suspensions." In the United States, approximately 2,798 such establishments exist, with product shipments worth $140.6 billion according to the latest US economic census (reflecting 2002 data). In Canada, pharmaceutical sales totaled almost $6 billion (USD) in 1994, approximately 2 percent of the world pharmaceutical market. The pharmaceutical industry in Canada consists of 111 establishments (based on 1995 data) according to Statistics Canada, and is dominated by large, foreign-owned nationals.

Quality is important for most products; in packaging of pharmaceuticals, however, it is absolutely critical. Medicines that are mislabeled, inadequately protected against tampering, or containing impurities can have disastrous consequences. Even the inadvertent exclusion of a single hyphen on a label can entail a dangerous outcome, where directions on a bottle, for example, indicate a dosage of "1 2" instead of "1-2" pills. Recognizing the critical nature of correct medical labeling and packaging, the US Federal Drug Administration (FDA) issued federal regulation CFR211, which requires 100 percent inspection and tracking of products destined for use inside the human body. As a means of insuring compliance with this requirement, machine vision has played an important role, particularly given the frailties of human inspections.

Major needs addressed by machine vision in the industry are package integrity, product traceability (the ability to trace an individual container of medicine throughout the supply chain) and label accuracy. Correspondingly, major generic MV applications in the pharmaceutical industry include:

- Inspection of filled and unfilled vials and ampoules
    - Verification of fill level
- Packing of solid dosages
    - Blister pack inspection to detect foreign, broken or contaminated packs
    - Presence/absence detection and placement/ positioning at various production stations
- Proofreading of labels and inserts/outserts
    - Label inspection (presence/absence and position)
    - Print quality inspection

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  - Consistency with code ID on label
- Data and code verification
  - OCR/OCV (data correctness)
  - 2D Bar code print identification on labels
  - Verify correct and readable ID code on container
- Miscellaneous ("Other") applications
  - Slat counter verification (verification of tablet counts per bottle)
  - Empty container or vial/ampoule inspection
  - Robot guidance for palletizer

Reliance on machine vision in the packaging of medicines is not limited. It plays a critical roll at every production station on the pharmaceutical line, as illustrated by Exhibit 11.13, in the case of tablets contained in bottles.

Exhibit 11.13: MV Application by Production Station

Production Station	MV Application
Unscrambler	Verification of correct positioning of bottles
Bottle Marking Station	Inspection of printed code
Slat Counter	Counting of tablets entering bottles
Cottoner	Inspection of presence/absence/placement and positioning
Capper	Inspection of presence/absence/placement and positioning
Safety Sealer	Inspection of presence/absence/placement and positioning
Surge Table	Inspection of presence/absence/placement and positioning
Labeler	Inspection for data correctness, consistency with code on label, label presence/absence and position
Bottle Reading Station	Verification of correct and readable ID code on bottle
Cartoner	Inspect for presence of insert/ insure barcode correctness on insert and carton
Palletizer	Guide robot performing palletization

Source: Based on diagram from Cognex

MV companies serving the pharmaceutical industry are listed in Exhibit 11.14 by generic application.

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Exhibit 11.14: MV Companies Serving the Pharmaceutical Industry by Generic Application

Company	OCR/ OCV	2D BC	Label Ins.	Print Quality Inspection	X-ray	Solid Dosage	Blister	Vial/ Ampoule	Proof Reading	Other
AC Compacting	x	x	x			x	x			x
Accu-Sort	x	x	x							
AGR International	x	x	x							x
American SensoRx	x	x	x			x	x			x
Automated Visual Inspection Systems, Inc	x		x	x			x			
Brevetti								x		
Cognex	x	x	x	x			x			x
Complete Inspection Systems	x	x	x	x					x	x
Maschinpex/ Driam						x				
Eisai						x		x	x	
Global Vision Inc	x	x		x					x	x
Industrial Dynamics							x			x
Key Technology						x	x			
M.W. Technologies						x				
Micron Automation							x			x
Optel Vision	x	x	x							
Rotoflex				x						
RVSI/Acuity	x	x	x							
Safeline					x					
Seidenader/SV Research	x	x	x			x	x			
SYSTECH	x	x	x	x			x			x
Thermo Electron					x					
Xyntek	x	x	x	x			x		x	

Source: Based on table from AIA article authored by N. Zuech.

In the pharmaceutical industry, sales of MV systems in 2008 amounted to $49.6 million (USD) as indicated by Exhibit 11.24 in section 11.2.

11.1.1.1.8 The Printing Industry

Establishments in this industry engage in printing on apparel, textile products, paper, metal, glass, plastics and other materials. They make use of a host of different processes including lithography, gravure, screen, flexography, digital printing and letterpress. According to the US Census Bureau, there are approximately 34,146 printing establishments in the US with annual shipments worth $90.4 billion. According to the Printing Industry of America, printing is the biggest business in the US with nearly one million employees. In Canada, printing is the fourth largest manufacturing employer with more than 84,000 employees working in 5,834 establishments.

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Although large in comparison to other industries, the printing industry is comprised mainly of small, independent firms. According to the US EPA Printing Industry Cluster Profile, nearly 80 percent of all printing firms have fewer than 20 people. This, of course, has important implications for MV companies serving the printing industry. Smaller firms might lack the financial wherewithal to afford all but the least expensive MV systems, which range from $5.5K to over $300K in price. The companies that use machine vision are, for the most part, *converters*, companies that add value to paper.

The major rationale for deploying MV systems in the printing industry is the opportunity to reduce print waste by 20 to 40 percent. These savings are achieved by means of the following, major MV applications:

- Monitoring and controlling *registration*, the placement of print with regards to the edges of paper
- Detection and prevention of print defects (such as *halo, plate squeeze, fill-in or spread, striation, roller marks, beading, ragged edges, chalking, pinholes and fisheyes*)
- Color control
    - Color to color registration
    - Monitor and control line and screen color consistency
- Monitor and control *traps* (where one ink or coating is printed over ink)
- Bar code inspection
- Monitor perforation and die-cut quality
- Reading and verifying information on print-mail inserts, verifying key information on invoices and reading serial numbers on lottery tickets

Of these applications, registration control is the most widespread in the industry.

MV systems performing these functions are of two types: *passive* and *active*. *Passive* systems automate either the entire process or specific elements of it and thus eliminate or limit the role of a human operator. *Active* systems, on the other hand, involve the intervention of an operator. Also, not all systems inspect 100 percent of the web; some perform inspection of only an area, inspecting that area for the entirety of the web or a sampling of it.

MV companies serving the print industry are listed in Exhibit 11.15.

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Exhibit 11.15: MV Companies Serving the North American Printing Industry

Advanced Vision Technology	Giesecke & Devrient	Quality Engineering Associates
Bobst	ImageXpert	Symbology
BST Pro Mark	ISRA VISION	Tekmatex
CC1	Label Vision Systems	Videk
Double E Company	Lake Image Systems	Vigitek
Doyle Systems	Nireco America	VRP Web Technology
Eltromat	PC Industries	Web Printing Controls
Fife Corp.	QuadTech	Webscan

In the printing industry, sales of MV systems in 2008 amounted to $20.3 million (USD) as indicated by Exhibit 11.24 in section 11.2.

11.1.1.1.9 The Semiconductor Industry

Establishments in this industry engage in the manufacture of semiconductors and related components for electronic applications. According to the US Census Bureau, 5,450 establishments in the US had 437,906 paid employees and annual shipments of approximately $110.5 billion. According to the Semiconductor Industry Association (SIA), 73 percent of the US industry's revenue is earned outside the US; however, over three-fourths of US-owned wafer capacity is located within the US, thus indicating a significant volume of exports. Semiconductor production capacity in the US has declined in comparison to worldwide capacity from 36 percent in 1999 to approximately 20 percent in 2004, indicating primarily a marked increase in production capacity in Asian countries such as Taiwan, Korea, Singapore and China. Thus, the US semiconductor industry has faced (and continues to face) stiff competition from abroad.

The same downward trend is found in equipment purchases of semiconductor manufacturing equipment. US semiconductor firms still account for the largest percentage of purchases in the world, but that lead has dropped rapidly. In 2001, the purchases of US firms totaled over 43 percent. By 2004, the US portion of worldwide semiconductor equipment purchases decreased to roughly 25 percent. Today, two-thirds of the world's new 300mm fabrication plants ("fabs") are being built in Asia, and these plants will turn out the most powerful and advanced ICs.

The semiconductor industry in Canada is comprised of 235 establishments employing 20,494 individuals and accounting for 1.2 percent of GDP.

The manufacture of semiconductors involves two fundamental tasks:

1. The production of semiconductor wafers and

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2. The "packaging" of the wafer, (i.e. the enclosure of the chip in a protective casing with outer electrical connections). Packing can be broadly divided into two categories: single-chip packing (SCM) and multi-chip packaging (MCM).

Machine vision has played a major role with respect to both fundamental tasks, enabling automation of manufacturing and the inspection of materials and components. The resultant increase in efficiency has entailed significantly increased yields.

The key role of machine vision in each step in the IC fabrication process can be best appreciated with a cursory examination of major MV applications in the semiconductor industry. For the production and packaging of wafers, these applications include the following:

Wafer Production

- Inspection of bare, photoresist-coated and pre-patterned wafers
- Inspection of photomasks and reticles for defects
- Inspection of film thickness
- Inspection of overlay registration
- Inspection/verification of critical dimensions
- Recognition of wafer alignment patterns
- Inspection of pattern registration
- Detection of patterned wafer defects
- Detection of faulty marked dies
- Detection of die damage
- Detection of saw damage

Wafer Packaging

- Detection of cosmetic concerns on the package
- OCV
- Print quality inspection of markings
- Verification of lead straightness
- Verification of lead co-planarity

It is important to note that MV applications in the semiconductor industry are not limited to 2D. A host of 3D MV applications are also found in this industry:

- Measuring the height of each and every solder bump across an entire *flip chip wafer* (a wafer mounted without wire bonds)
- Verifying coplanarity of leads of semiconductors
- 3D metrology and defect detection to verify the dimensional and cosmetic integrity of wafers
- Inspection of fully assembled packages and sockets. 3D-based MV techniques can be used for *BGA* (*ball grind array)* inspection (*BGA* is a type of memory chip package

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that is directly mounted to the module by solder balls found on the underside of the chip) and *CSP (chip scale packaging)* inspection (*CSP* is a style of integrated circuit package that has no pins or wires but uses contact pads).

- Inspection of the height, shape and existence of *solder paste balls* (the splatter resulting from *beading*)

Of these 3D applications, the most widely used is *co-planarity measurements on leaded IC packages*.

Going forward, machine vision will play a still greater role. The reason for this is the movement of semiconductor manufacturers to 300mm wafers, 0.13 micro gates and new high density packaging standards in order to achieve faster switching speeds, miniaturization and lower power consumption. As the result of this trend, the investment represented by each chip becomes so great that each wafer will require inspection rather than just batches. Accordingly, we expect strong growth in long-term demand for MV systems.

Stronger demand for MV systems will expectantly affect all types of MV systems utilized in the semiconductor industry, of which there are three:

- Wafer inspection systems (for the location, counting and characterization of particles, contamination and other wafer defects)
- Metrology systems (for measurement of circuit line widths and misregistration of patterns from layer to layer)
- Package inspection systems (to detect cosmetic concerns on the package, OCV, print quality inspections on the markings, verification of lead straightness, lead co-planarity and solder bump problems)

Reflecting the importance of machine vision in the semiconductor industry, the number and relative size of MV companies serving this industry is noteworthy. A list of these companies is provided in Exhibit 11.16.

Exhibit 11.16: MV Companies Serving the Semiconductor Industry

Accent Optical Technologies	Hologenix	Orbotech
Accretech/TSK America	ICOS Vision Systems	Raytex Corp.
ADE Optical Systems	Nanometrics	Rudolph Technologies
Applied Materials	Negevtech	Ultratech
Camtek	Nikon	Viscom
Carl Zeiss	Nline Systems	Vistec
Daitron	Nova Measuring Instruments	

In the semiconductor industry, sales of MV systems in 2008 amounted to $492.0 million (USD) as indicated by Exhibit 11.24 in section 11.2.

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11.1.1.2 Non-manufacturing Industries

Machine vision companies are increasingly addressing market opportunities outside of manufacturing. While the factory floor remains the focal point of the industry, some companies no longer view themselves as exclusively wed to manufacturing. For that reason, we include brief descriptions of non-manufacturing industries in which opportunities for MV companies appear to be emerging.

11.1.1.2.1 Lab Automation/ Drug Discovery

Providers of laboratory automation ("lab automation") systems for use in drug discovery comprise this industry. Lab automation involves the application of automation and robotics for processes used in scientific laboratories and is typically used throughout the pre-clinical drug discovery process; that is, before drugs are tested on subjects. The key role of lab automation in drug discovery is to enable *high throughput screening* (HTS), which involves the rapid screening of large numbers of compounds as potential drug candidates for activity against a specific disease.

11.1.1.2.2 Medical Imaging

Medical imaging companies provide equipment that enables physicians to examine and evaluate an internal part of the human body for either diagnostic or research-related reasons. Such equipment is based on a range of different technologies or "modalities", including *radiology* (*x-ray imaging), computed tomography* (*CT*), *ultrasound*, *magnetic resonance imaging* (*MRI*) and *nuclear imaging*. Of these modalities, radiology is the most established and widely utilized technology, and has the greatest relevance to machine vision, since other modalities are not based on photonic electromagnetic radiation.

11.1.1.2.3 Nanotechnology

Nanotechnology is a very broad, umbrella term for a range of technologies involving the creation and use of materials, devices and systems through the manipulation of matter at scales of one to five-hundred nanometers or (according to those more stringent) at under 100 nanometers. Nanotechnology is not an industry in itself, but rather a part of other industries including medicine, chemistry, energy and consumer goods. The use of nanotechnology in machine vision has not yet been defined.

11.1.1.2.4 High-End Security

The high-end security industry, as it is defined in this study, consists of companies that provide either video surveillance systems or biometric systems to secure locations where individuals congregate or critical infrastructure exists (such as airports, ports, oil refineries, bridges, government institutions, private businesses, etc.). Some systems involve conventional arrangements of surveillance cameras and peripheral equipment (optics and possibly lighting). Other systems are much "higher-tech" in nature and are referred to as "high-end surveillance systems". Importantly, these latter systems utilize machine vision; the former systems do not.

The central defining difference between conventional and higher-end video surveillance systems lies in the way video signals are processed. In the case of conventional systems,

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humans process the signals with their eyes and brains and then determine appropriate responses. By contrast, Intelligent Video Surveillance (IVS) utilizes sophisticated software to process video signals for decision making. IVS is thus largely an automated, software-driven approach to surveillance.

Biometric systems provide access control for security based on scanning of measurable, biological characteristics of an individual. Biological characteristics typically involve fingerprints, voice patterns, retinal and iris scans, facial scans and dermis patterns. Once biological characteristics are read by a biometric device, they are compared in real-time with computerized records. Where a match is made authenticating an individual's identity, the individual is granted access.

11.1.1.2.5 Transportation

The transportation industry is highly diverse. Within it, machine vision is used in three areas: Intelligent Traffic Systems (ITS), License Plate Recognition (LPR) and Smart Car/ Telematics.

- Suppliers of Intelligent Traffic Systems (a.k.a "Intelligent Transportation Systems") provide a range of traffic management and surveillance tools, the major purposes of which have been to insure efficient and safe use of roadways through video-based traffic management and the collection of tolls.
- Suppliers of License Plate Recognition (a.k.a. "License Plate Identification" or "Automatic License Plate Recognition") systems offer the capability to distinguish individual vehicles that are either moving or stationary by recognizing and recording the alphanumerics of their license plates.
- Smart car system suppliers have designed a wide array of capabilities that are either available today to automobile manufacturers and drivers or will be in the near-term. These capabilities include Rear-Vision Monitoring, Blind Spot Detection/Monitoring Systems, Lane Change and Departure Warning Systems, Interior Passenger Detection and Position, Adaptive Cruise Control (ACC), Pedestrian Protection and Night Vision.

11.1.2 Major MV Applications by End User Industry

To summarize this section, we list major machine vision applications by industry.

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Exhibit 11.17: Major MV Applications by End-user Industry

Industry	Applications
Automotive	<u>Inspection</u> ■ Surface inspection for cosmetic flaws (error proofing) ■ Surface inspection for functional flaws (error proofing) ■ Verification of presence/absence of parts ■ Assembly verification ■ Parts recognition & tracking (traceability) ■ Dimensional gauging/control <u>Robotic Guidance</u> ■ Robotic guidance for material handling o Auto racking o Bin picking o Positioning of parts for assembly
Container	<u>Glass Container Manufacture</u> ■ Mold identification based on a code located on either the heel or bottom of the bottle ■ Detection of “freaks” (misshapen bottles) ■ Detection of defects <u>Glass Container Filling</u> ■ Inspection of bottles in crates to sort out dissimilar bottles ■ Identification of improperly positioned bottles ■ Inspection of the crate itself ■ Verification of fill levels ■ Closure inspection ■ Detection of foreign substances ■ Inspection of crate for fullness <u>Metal Can Manufacture</u> ■ Inspection of can dimensions ■ Inspection of can end (“consumer end” and other end) ■ Inspection of can outer surface for dents, holes, scratches, wrinkles, etc. ■ Inspection of can labeling ■ Inspection of can interior <u>Metal Can Filling</u> ■ Verification of fill levels <u>Plastic Bottle Manufacture</u> ■ Inspection for container integrity ■ Thickness measurements ■ Cosmetic inspection ■ Label inspection ■ Lot tracking ■ Dimensional inspections to track wear and tear on molds ■ Inspection of preforms for geometric properties and conditions

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Exhibit 11.17: Major MV Applications by End-user Industry (Continued)

Industry	Applications
Container (Continued)	Plastic Bottle Filling ■ Closure inspection ■ Fill level verification
Electronics	PCB Assembly ■ Inspection of solder paste and epoxy for presence and volume ■ Verification of co-planarity of component leads ■ Post-solder verification of presence and position of components ■ Post-solder verification of solder presence and inspection of properties ■ Alignment of boards to assure position of patterns, epoxy, component placement and board pattern position Bare Board Manufacturing ■ Inspection of "artwork" ■ Inspection of inner/outer layer circuit patterns ■ Inspection of drill-hole patterns ■ Inspection of solder mask and coatings Other Electronics ■ LCD panel inspection
Fastener	■ Inspection/sorting of fasteners at distribution point
Food & Beverage	Food Processing ■ Fruit and vegetable sorting and grading ■ Automatic portioning ■ Inspection for foreign objects Food Packaging ■ Inspection of label quality (to determine correct positioning of labels, tears or product spills) ■ Cap and fill level inspection (to prevent leaks and under-filled bottles) ■ Package contents verification (to insure the correct number of items in each carton, such as chocolates in boxes) ■ Date/lot code inspection (to make sure codes are readable) ■ Verification of vacuum seals on jars and bottles (to insure product integrity) ■ Detection of faulty carton seals (to detect unglued and imperfect seams on wrap-around carton seals) ■ Inspection of cap closures (to check integrity of sealing liners) ■ Identification of bag seal jams (to detect improper seals caused by product jams) Beverage Packaging ■ Quality inspection of containers ■ Fill level inspection ■ Closure inspection
Wood Products	■ Scanning for size verification (lumber size control) ■ Scanning/control in bucking operations ■ Scanning/control in primary and secondary breakdown ■ Edging optimization ■ Planer optimization based on knot/defect and profile/wane scans ■ Scanning for secondary breakdown ■ Grading and grade optimization

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Exhibit 11.17: Major MV Applications by End-user Industry (Continued)

Industry	Applications
Pharmaceutical	Inspection of filled and unfilled vials and ampoules ■ Verification of fill level Packing of solid dosages ■ Blister pack inspection to detect foreign, broken or contaminated packs ■ Presence/absence detection and placement/positioning at various production stations Proofreading of labels and inserts/outserts ■ Label inspection (presence/absence and position) ■ Print quality inspection ■ Consistency with code ID on label Data and code verification ■ OCR/OCV (data correctness) ■ 2D bar code print identification on labels ■ Verify correct and readable ID code on container Miscellaneous ("Other") applications ■ Slat counter verification (verification of tablet counts per bottle) ■ Empty container or vial/ampoule inspection ■ Robot guidance for palletizer
Printing	■ Monitoring and controlling *registration*, the placement of print with regards to the edges of paper ■ Detection and prevention of print defects (such as *halo, plate squeeze, fill-in or spread, striation, roller marks, beading, ragged edges, chalking, pinholes and fisheyes*) ■ Color control ■ Color to color registration ■ Monitor and control line and screen color consistency ■ Monitor and control *traps* (where one ink or coating is printed over ink) ■ Bar code inspection ■ Monitor perforation and die-cut quality ■ Reading and verifying information on print-mail inserts, verifying key information on invoices and reading serial numbers on lottery tickets
Semiconductor	Wafer Production ■ Inspection of bare, photoresist-coated and pre-patterned wafers ■ Inspection of photomasks and reticles for defects ■ Inspection of film thickness ■ Inspection of overlay registration ■ Inspection/verification of critical dimensions ■ Recognition of wafer alignment patterns ■ Inspection of pattern registration ■ Detection of patterned wafer defects ■ Detection of faulty marked dies ■ Detection of die damage ■ Detection of saw damage Wafer Packaging ■ Detection of cosmetic concerns on the package ■ OCV ■ Print quality inspection of markings ■ Verification of lead straightness ■ Verification of lead co-planarity

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Exhibit 11.17: Major MV Applications by End-user Industry (Continued)

Industry	Applications
Lab Automation/ Drug Discovery	■ Vision-guided laboratory robotics in HTS
Medical Imaging	■ Digital image acquisition & processing in radiology
Nanotechnology	■ None as of yet
Security	■ Higher-end video surveillance ■ Biometric inspection/ recognition for access control
Transportation	■ License plate recognition ■ Vision-based smart car capabilities ■ Toll inspection/ collection ■ Some forms of video-based traffic management (e.g. camera-based intersection control)

11.2 Survey Results

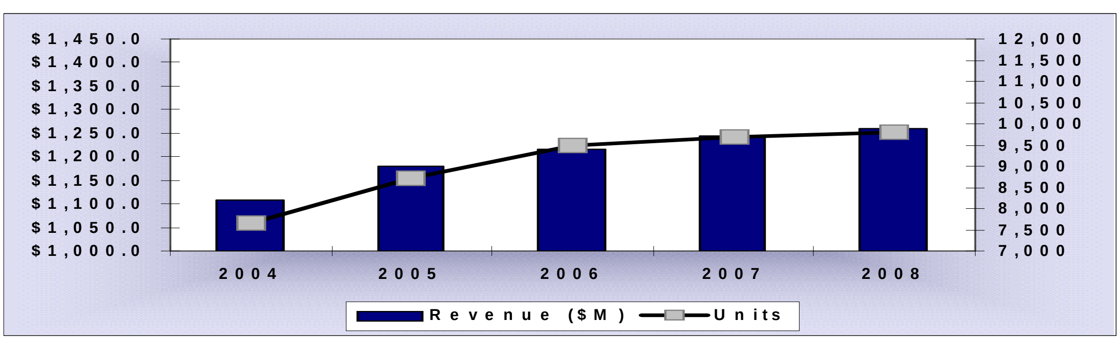
We next examine the market in terms of sales volumes expressed in revenue and units. Our focus is the historical period of 2004 through 2008 and the forecast period of 2009 through 2013.

11.2.1 Historical Growth Patterns

As shown by Exhibit 11.18, revenue has grown from $1,108.6 million (USD) in 2004 to $1,260.4 million in 2008. During this period, units increased from 7,667 to 9,806. Composite growth rates (CAGRs) for the 2004 to 2008 period are 3.3 percent and 6.3 percent for revenue and units sold, respectively.

Exhibit 11.18: ASMV Sales Revenue ($ Millions) and Units: 2004 to 2008

	Actual 2004	Actual 2005	Actual 2006	Actual 2007	Actual 2008	CAGR*
Revenue ($M)	$1,108.6	$1,180.0	$1,215.3	$1,244.2	$1,260.4	-
%	9.5%	6.4%	3.0%	2.4%	1.3%	3.3%
Units	7,667	8,710	9,475	9,683	9,806	-
%	16.8%	13.6%	7.0%	2.2%	1.3%	6.3%
Average Price	$144,594	$135,468	$130,415	$127,349	$128,531	-



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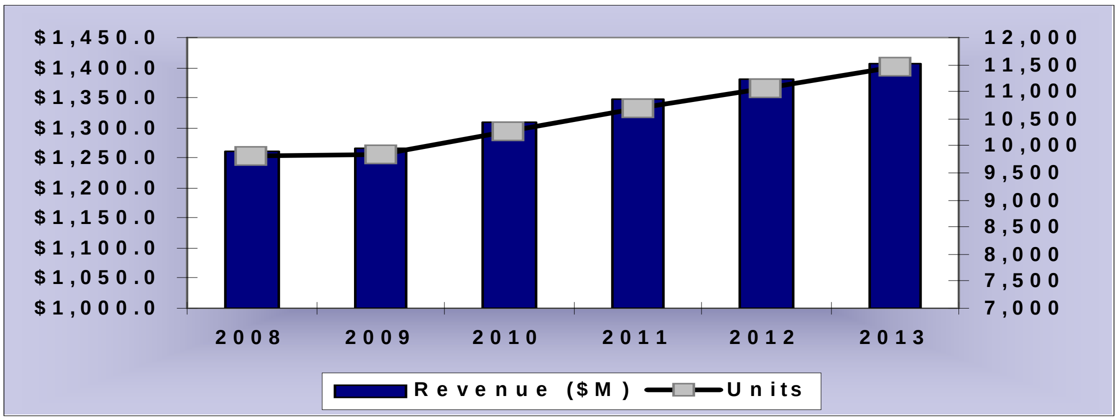
11.2.2 Forecasts

ASMV system sales revenue is forecast to increase from $1,260.4 million in 2008 to $1,407.3 million in 2013, reflecting a CAGR of 4.0 percent. For the same time frame, we anticipate even greater growth for units sold. We expect unit sales to grow from 9,806 in 2008 to 11,446 in 2013, reflecting a CAGR of 3.8 percent.

Exhibit 11.19: Forecast ASMV Sales Revenue ($ Millions) and Units: 2008 - 2013

	Actual 2008	Forecast 2009	Forecast 2010	Forecast 2011	Forecast 2012	Forecast 2013	CAGR
Revenue ($M)	$1,260.4	$1,201.1	$1,171.1	$1,348.8	$1,381.3	$1,407.3	-
%	1.3%	-4.7%	-2.5%	15.2%	2.4%	1.9%	4.0%
Units	9,806	9,344	9,177	10,680	11,074	11,446	-
%	1.3%	-4.7%	-1.8%	16.4%	3.7%	3.4%	5.2%
Average Price	$128,531	$128,546	$127,605	$126,289	$124,735	$122,950	-



11.2.3 Price Analysis

With units sold growing faster than sales revenue, it is evident that the average price for an ASMV system has declined and will continue to decrease over time. This steady erosion in price is evident in Exhibit 11.20. The average unit price for an ASMV system has dropped from $144,594 in 2004 to $128,531 in 2008 and is forecast to decline even further to $122,950 by 2013.

It should be noted that the average unit price for an ASMV system spans a wide variety of systems in a number of different industries. In some industries, the average price of an ASMV system is much lower than in others and is closer to $50K per system. In other industries, the average unit price is much higher. Adding to the diversity is also the different composition of ASMV systems. Some systems are unequivocally MV systems, consisting of imaging components and peripheral components that have no standalone functionality but instead are appendages of the system's MV core. With other systems, however, it is not always so clear whether all their components are classifiable as machine vision and thus whether 100 percent of the cost can be attributed to machine vision. Of course, to the extent that non-MV component costs are included in the price,

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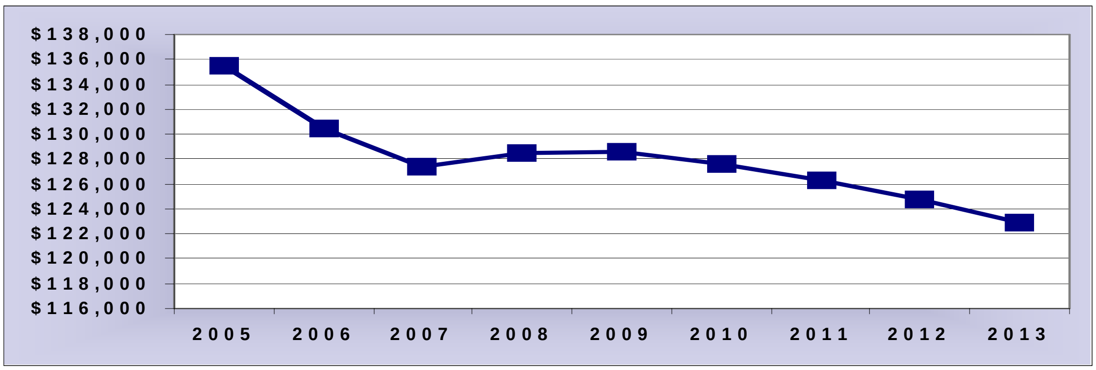
the average MV unit cost is inflated. We believe there is a strong possibility that the average unit cost is in fact inflated. However, in the absence of a system by system analysis of components and cost for a very large number of systems, it is not possible to make this determination let alone correct it, if it is ascertained.

Exhibit 11.20: Average ASMV System Price: 2004 - 2013

	2004	2005	2006	2007	2008
Average Price	$144,594	$135,468	$130,415	$127,349	$128,531
	2009	**2010**	**2011**	**2012**	**2013**
Average Price	$128,546	$127,605	$126,289	$124,735	$122,950



11.2.4 Total Sales Revenue by Major Product Feature

Sales by Application

We next examine ASMV system market performance more closely by disaggregating sales results by major, generic application. The results of this activity are summarized in Exhibit 11.21. As revealed by the area charts of this exhibit, the most common application by far (for which ASMV systems were sold in 2008) is surface flaw/cosmetic analysis, which accounts for 35.0 percent of all units sold and 39.4 percent of total revenue. Next in importance is 2D, 3D metrology at 28.5 percent of units and 39.1 percent of revenue.

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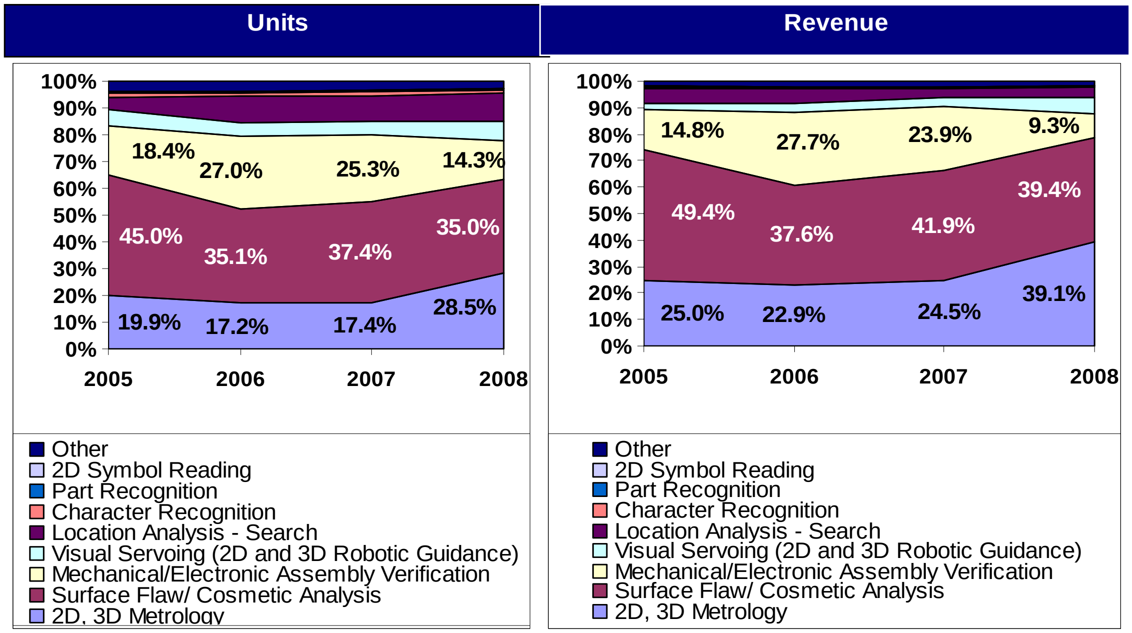
Exhibit 11.21: ASMV Sales by Application



	2005 Units	2006 Units	2007 Units	2008 Units	2005 Rev	2006 Rev	2007 Rev	2008 Rev
2D, 3D Metrology	19.9%	17.2%	17.4%	28.5%	25.0%	22.9%	24.5%	39.1%
Surface Flaw/ Cosmetic Analysis	45.0%	35.1%	37.4%	35.0%	49.4%	37.6%	41.9%	39.4%
Mechanical/Electronic Assembly Verification	18.4%	27.0%	25.3%	14.3%	14.8%	27.7%	23.9%	9.3%
Visual Servoing	6.1%	5.2%	5.0%	7.4%	2.4%	3.5%	3.5%	5.7%
Location Analysis - Search	4.4%	9.9%	9.6%	10.2%	5.4%	5.6%	3.4%	4.1%
Character Recognition	1.8%	1.1%	1.3%	1.2%	0.8%	0.2%	0.3%	0.2%
Part Recognition	0.7%	0.5%	0.5%	0.4%	0.3%	0.3%	0.3%	0.2%
2D Symbol Reading	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
Other	3.8%	3.8%	3.4%	2.8%	1.8%	2.2%	2.1%	1.7%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Sales by Industry

We also disaggregate ASMV system sales by industry. Exhibits 11.22 and 11.23 record the results of our analysis. Both exhibits show that the semiconductor industry remains the most important in terms of MV sales. The rank ordering of industries in terms of revenue is semiconductor, wood, electronics/electrical, food and automotive. In terms of units sold, the rank order is semiconductor, automotive, electronics/electrical, and food.

For 2008, sales by industry for units sold and revenue are shown by Exhibit 11.24.

Finally, Exhibit 11.25 reveals that MV sales still overwhelmingly involve sales to manufacturing industries. Only 3.8 percent of total units sold and 1.6 percent of sales revenue came from non-manufacturing industries.

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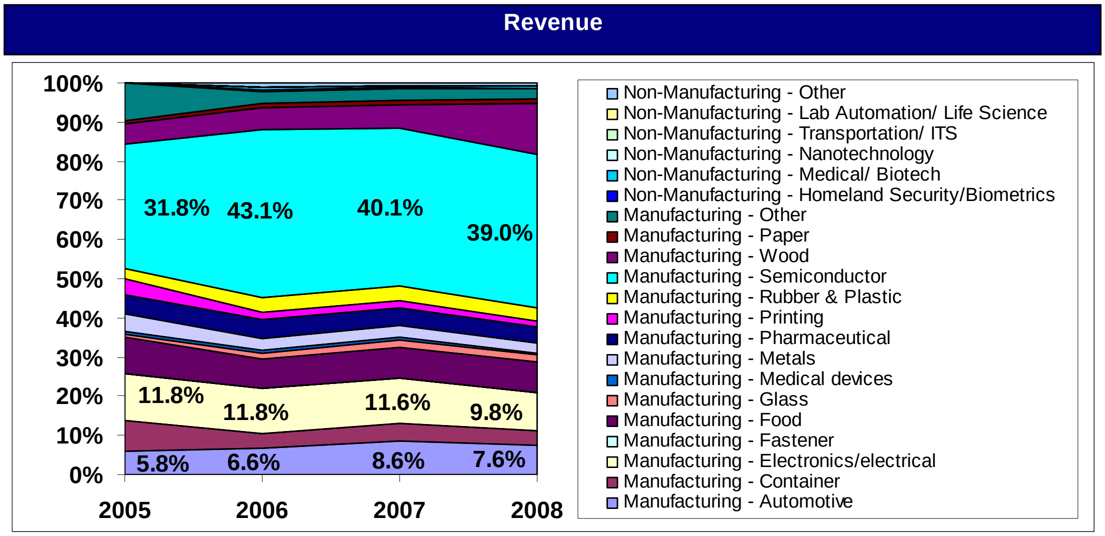
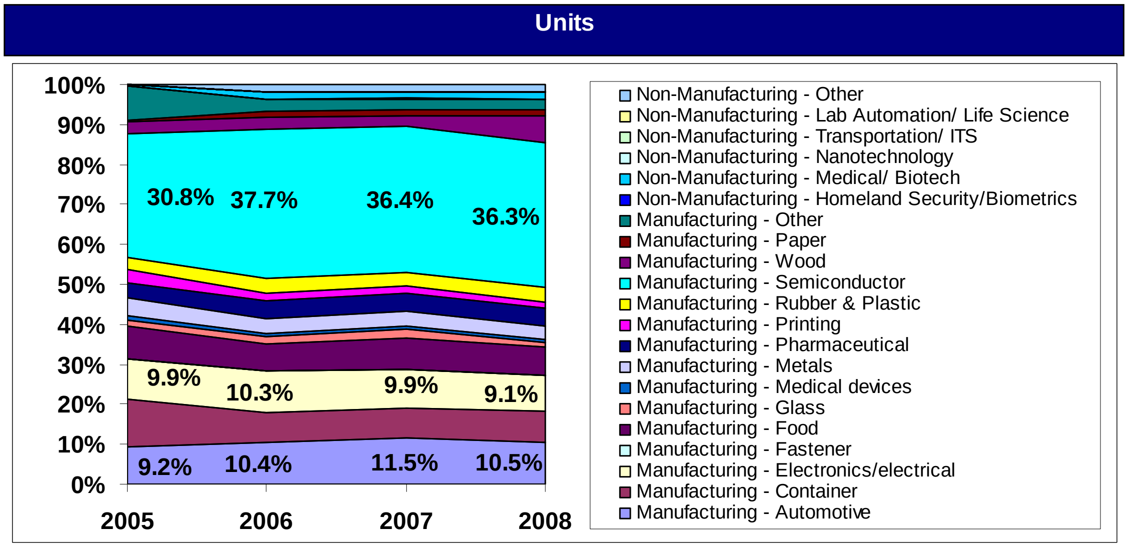
Exhibit 11.22: ASMV System Sales by Industry in Revenue (by Percent of Total)



	2005	2006	2007	2008
	Percent	Percent	Percent	Percent
Manufacturing - Automotive	5.8%	6.6%	8.6%	7.6%
Manufacturing - Container	8.0%	3.8%	4.3%	3.7%
Manufacturing - Electronics/Electrical	11.8%	11.8%	11.6%	9.8%
Manufacturing - Fastener	0.2%	0.0%	0.0%	0.0%
Manufacturing - Food	9.1%	7.3%	8.0%	7.8%
Manufacturing - Glass	1.0%	1.5%	1.6%	1.7%
Manufacturing - Medical devices	0.7%	0.6%	0.7%	0.5%
Manufacturing - Metals	4.4%	3.2%	3.3%	2.7%
Manufacturing - Pharmaceutical	4.7%	4.7%	4.4%	3.9%
Manufacturing - Printing	4.2%	1.9%	2.0%	1.6%
Manufacturing - Rubber & Plastic	2.7%	3.7%	3.6%	3.2%
Manufacturing - Semiconductor	31.8%	43.1%	40.1%	39.0%
Manufacturing - Wood	5.0%	5.5%	6.3%	13.0%
Manufacturing - Paper	0.7%	1.2%	1.1%	1.3%
Manufacturing - Other	9.7%	3.1%	3.0%	2.5%
Non-Manufacturing - Homeland Security/Biometrics	0.1%	0.1%	0.1%	0.1%
Non-Manufacturing - Medical/Biotech	0.0%	1.0%	0.6%	0.7%
Non-Manufacturing - Nanotechnology	0.0%	0.0%	0.0%	0.0%
Non-Manufacturing - Transportation/ ITS	0.0%	0.0%	0.0%	0.0%
Non-Manufacturing - Lab Automation/Life Science	0.0%	0.0%	0.0%	0.0%
Non-Manufacturing - Other	0.1%	1.0%	0.6%	0.8%
Total	100.0%	100.0%	100.0%	100.0%

Exhibit 11.23: ASMV System Sales by Industry in Units (by Percent of Total)



	2005	2006	2007	2008
	Percent	Percent	Percent	Percent
Manufacturing - Automotive	9.2%	10.4%	11.5%	10.5%
Manufacturing - Container	12.1%	7.7%	7.4%	7.7%
Manufacturing - Electronics/electrical	9.9%	10.3%	9.9%	9.1%
Manufacturing - Fastener	0.2%	0.0%	0.0%	0.0%
Manufacturing - Food	8.1%	6.7%	7.5%	7.1%
Manufacturing - Glass	1.6%	1.7%	2.4%	1.2%
Manufacturing - Medical devices	0.9%	0.8%	0.7%	0.6%
Manufacturing - Metals	4.4%	3.7%	3.9%	3.5%
Manufacturing - Pharmaceutical	3.9%	4.7%	4.5%	4.3%
Manufacturing - Printing	3.5%	1.6%	1.7%	1.3%
Manufacturing - Rubber & Plastic	2.9%	3.6%	3.4%	3.7%
Manufacturing - Semiconductor	30.8%	37.7%	36.4%	36.3%
Manufacturing - Wood	3.1%	2.9%	2.8%	6.7%
Manufacturing - Paper	0.6%	1.4%	1.4%	1.5%
Manufacturing - Other	8.5%	3.0%	2.9%	2.6%
Non-Manufacturing - Homeland Security/Biometrics	0.1%	0.1%	0.1%	0.1%
Non-Manufacturing - Medical/Biotech	0.1%	1.8%	1.8%	1.9%
Non-Manufacturing - Nanotechnology	0.0%	0.0%	0.0%	0.0%
Non-Manufacturing - Transportation/ ITS	0.0%	0.0%	0.0%	0.0%
Non-Manufacturing - Lab Automation/Life Science	0.0%	0.0%	0.0%	0.0%
Non-Manufacturing - Other	0.0%	1.8%	1.7%	1.8%
Total	100.0%	100.0%	100.0%	100.0%

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Exhibit 11.24: 2008 ASMV System Sales by Industry in Revenue ($ Millions) and Units

	2008	2008
	Revenue ($ Mil)	Units
Manufacturing - Automotive	$95.2	1,026
Manufacturing - Container	$46.2	760
Manufacturing - Electronics/electrical	$123.4	888
Manufacturing - Fastener	$0.4	3
Manufacturing - Food	$98.4	697
Manufacturing - Glass	$21.1	119
Manufacturing - Medical devices	$6.7	62
Manufacturing - Metals	$34.1	340
Manufacturing - Pharmaceutical	$49.6	426
Manufacturing - Printing	$20.3	132
Manufacturing - Rubber & Plastic	$40.9	365
Manufacturing - Semiconductor	$492.0	3,559
Manufacturing - Wood	$164.3	658
Manufacturing - Paper	$16.0	147
Manufacturing - Other	$32.0	260
Non-Manufacturing - Homeland Security/Biometrics	$0.8	5
Non-Manufacturing - Medical/Biotech	$9.1	183
Non-Manufacturing - Nanotechnology	$0.0	0
Non-Manufacturing - Transportation/ ITS	$0.0	1
Non-Manufacturing - Lab Automation/Life Science	$0.0	0
Non-Manufacturing - Other	$9.6	177
Total	$1,260.4	9,806

Exhibit 11.25: 2008 ASMV System Sales: Manufacturing vs. Non-Manufacturing by Percent of Total Units Sold and Sales Revenue

	2008	2008
	Units	Revenue
Manufacturing	96.2%	98.4%
Non-Manufacturing	3.8%	1.6%
Total	100.0%	100.0%

11.3 Summary of Major Findings

The major findings of this chapter are as follows:

- **Historical Sales:** Revenue has grown from $1,108.6 million (USD) in 2004 to $1,260.4 million in 2008. During this period, units increased from 7,667 to 9,806. Composite growth rates (CAGRs) for the 2004 to 2008 period are 3.3 percent and 6.3 percent for revenue and units sold, respectively.
- **Projected Sales:** ASMV system sales revenue is forecast to increase from $1,260.4 million in 2008 to $1,407.3 million in 2013, reflecting a CAGR of 4.0 percent. For the same time frame, we anticipate even greater growth for units sold. We expect unit sales to grow from 9,806 in 2008 to 11,446 in 2013, reflecting a CAGR of 3.8 percent.
- **Average ASMV Price:** The average unit price for an ASMV system has dropped from $144,594 in 2004 to $129,531 in 2008 and is forecast to decline even further to $122,950 by 2013. It should be noted that the average unit price for an ASMV system spans a wide variety of systems in a number of different industries. In some

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industries, the average price of an ASMV system is much lower than in others and is closer to $50K per system. In other industries, the average unit price is much higher. Adding to the diversity is also the different composition of ASMV systems. In short, the average unit price for the ASMV system market is less meaningful than for other MV product markets.

- **Sales by Application:** The most common application by far (for which ASMV systems were sold in 2008) is surface flaw/cosmetic analysis, which accounts for 35.0 percent of all units sold and 39.4 percent of total revenue. Next in importance is 2D, 3D metrology at 28.5 percent of units and 39.1 percent of revenue.
- **Sales by Industry:** The semiconductor industry remains the most important in terms of MV sales. The rank ordering of industries in terms of revenue is semiconductor, wood, electronics/electrical, food and automotive. In terms of units sold, the rank order is semiconductor, automotive, electronics/electrical, and food.
- **Sales in Manufacturing vs. Non-Manufacturing:** MV sales still overwhelmingly involve sales to manufacturing industries. Only 3.8 percent of total units sold and 1.6 percent of sales revenue came from non-manufacturing industries.

11.4 Conclusions

As we have seen, the ASMV systems market is very diverse, with applications varying greatly from industry to industry. Because the needs of users in different industries are highly dissimilar, the ASMV system builders that serve them tend to perceive little commonality and in many cases identify with the industry served and not with a greater ASMV system market. Not surprisingly then, demand for ASMV systems varies greatly across industries in accordance with their different dynamics. The performance of the printing industry, for example, has little direct relationship to the dynamics of the pharmaceutical industry.

Reflecting this fragmentation of end-user needs, perceptions and industry dynamics, ASMV systems manufacturers are forced to specialize in a limited number of applications that are in turn found in a limited number of industries. As a consequence, they tend to view themselves as participants in specific end-user industries, who incidentally use machine vision (along with other technologies), rather than as participants in a greater machine vision market.

As a consequence of this fragmentation, component suppliers, distributors and integrators who sell to ASMV system suppliers must understand the special needs of specific end-user industries, ASMV systems suppliers must address these needs and not just the capabilities of their machine vision products.

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Chapter 12:
MV Smart Camera Market

Quick Navigation Buttons:

12.1 Introduction | 12.2 Survey Results | 12.3 Summary of Major Findings | 12.4 Conclusions

12.0 What's New in this Chapter?

- 12.1.10 New Product Introductions
- 12.2 Survey Results
- 12.3 Summary of Major Findings
- 12.4 Conclusions

12.1 Introduction

Combining the functionality of complete MV systems with lower prices, smart cameras (and their functional equivalents) have extended the reach of applied MV technology by increasing the number of tasks that can be cost effectively addressed with MV-based applications. As a consequence, the smart camera market has experienced explosive growth, but - as will be seen in this chapter - even dynamic markets, such as this, are subject to the vagaries of the economy and may temporarily diverge from their strongly positive sales trends.

12.1.1 Overview of Smart Camera Market

The North American MV smart camera market is substantial in size as measured in terms of both sales volumes and the number of market participants. Expressed in revenue, sales volumes for smart camera have varied from $86.7 million (USD) in 2004 to $126.5 million in 2008, reflecting a composite annual growth rate of 9.9 percent. (See Exhibit 12.14 for more details.) This market consists of three types of products: smart cameras, vision sensors and embedded vision processors/computers, offered by approximately 32

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suppliers within three major segments. The smart camera market is relatively new, finding itself in the early stages of the product life cycle, which is characterized by high growth and intense competition between a myriad of suppliers. Finally, it should be noted that smart cameras and their functional equivalents are viewed as competitive substitutes for PC-based MV systems.

Definition of Smart Camera Market

We define the smart camera market in terms of three types of products:

- Smart cameras (a.k.a. “intelligent cameras”)
- Vision sensors
- Embedded vision processors (a.k.a. embedded vision computers and compact vision systems)

These three types of products are included in our definition because of their sharing of the following features:

- Integration: At least some key functions of an MV system are integrated instead of being performed by modular components (as in the case of PC-based MV systems)
- Computational intelligence based on a processor running software
- Capability to perform multiple functions (not just detection of presence/absence as in the case of a simple sensor)

Excluded from our definition of the smart camera market are:

- Bar code readers/scanners (because of their lack of computational intelligence)
- PC-based MV systems, including ASMV systems (because of their lack of integration)
- Simple sensors (because of their lack of computational intelligence)

Since we define the smart camera market in terms of three types of products, it is necessary to define them. The definitions used in this study are as follows:

- *Smart Camera*: A complete or nearly complete vision system contained in the camera body itself. Lighting and optics may or may not be integrated. At a minimum, a smart camera combines a camera with image processing and MV-related programs within the same housing. Sometimes smart cameras are called “intelligent cameras" and "vision sensors".
- *Vision Sensor*: In some cases vision sensors are lower-end smart cameras. In other cases they have the same functionality and flexibility as smart cameras and thus are merely another term for smart camera.
- *Embedded Vision Processor*: A configuration of machine vision equipment where a camera is tethered to a specialized, mini-computer (not a PC). Unlike the smart camera and vision sensor, the computational power for processing images is external to the camera's housing. Also known as a “compact vision system” and an “embedded vision computer”.

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12.1.2 Major Product Features

We can further define smart cameras and their functional equivalents by examining the major features of these product types. These major product features include the type of imager, processor type, lighting type and configuration, programming and operator interfaces, internal operating system and software.

In the case of imagers, the basic choice is between a *CCD* (charge-coupled-device) and *CMOS* (complementary metal oxide semiconductor) imager. Regardless of the type of imager used, smart cameras can differ in terms of how the imager is configured; it might be embedded on or housed with the processor, or it might be separate from the processor. Imagers also differ in terms of their resolution and whether they are line scan or not. Resolution can exist at less than 640x480; can be standard (approximately 640x480) and high (approximately 1K horizontally). In the case of processors, smart cameras can use *RISCs* (reduced instruction set computers), *DSPs* (digital signal processors) and *CPUs* (mainly Intel Pentium-class or Motorola PowerPC processors). Smart cameras can also vary in terms of how they use lighting. Lighting can be attached to or integrated in the smart camera. Lighting, for example, can be an array of LEDs built into the camera bodies around the lens mount, which are fired by the camera at the moment of inspection. Smart camera interfaces are of two major types: interfaces for programming and for operator interfaces. Programming interfaces (a.k.a. application programming interfaces or APIs) can be native to the smart camera's processor or provided from an external PC. Operator interfaces can be provided (a) solely by the smart camera; (b) either by the smart camera or external PC; or (c) by the external PC exclusively. Different smart cameras can run on different operating systems such as Windows, LINUX/UNIX or a proprietary operating system. It is also possible to differentiate smart cameras in terms of the software they use. Typically, software packages are manufacturer-specific and can vary widely in terms of their functions. Some smart camera manufacturers provide very flexible, PC-like, menu-driven, machine vision software, while others offer more rudimentary software that provides less flexibility. The software used by the smart camera might be supplied by the original manufacturer of the unit or might be added by a system integrator to create smart cameras targeted for special applications.

12.1.3 Smart Cameras Compared to Other Types of Integrated MV Systems

Smart cameras are often contrasted with *PC-based machine vision (MV) systems*, which are based on a different physical configuration and which often compete with each other in the marketplace, as noted in section 12.1.8.

There are two types of PC-based MV systems: off-the-shelf turn-key systems, or what we call "application-specification MV (ASMV) systems", and customized systems. As shown by Exhibit 12.1, they have different target markets and are produced by different types of manufacturers. ASMV systems are targeted to customers with similar needs within an industry, while customized systems are intended for customers with unique needs. Accordingly, ASMV systems are manufactured by turnkey system builders, whereas customized systems are built by system integrators.

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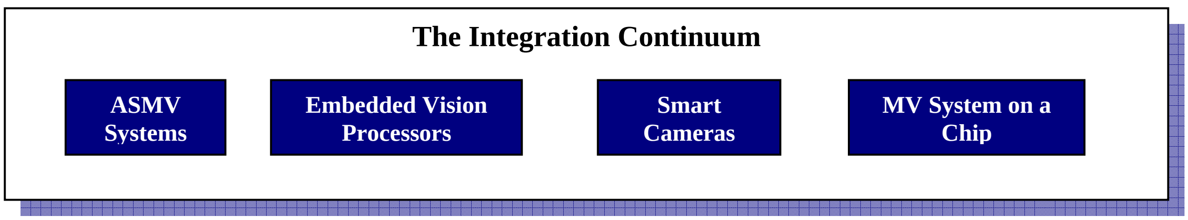
Exhibit 12.1: Types of PC-based MV Systems

	PC-based MV Systems	
	ASMV Systems	Customized Systems
Target Market	Customers with Similar Needs	Customers with Unique Needs
Manufacturers	Turnkey System Builders	System Integrators

Based on a modular, (i.e. non-integrated) configuration, a PC-based MV system consists of a PC, camera, software, frame grabber, optics and lighting that are separable and distinct components. Accordingly, PC-based MV systems and smart cameras represent nearly opposite ends of an integration continuum. In fact, among types of MV systems, only an *MV system on a chip*, as proposed by NASA, would be more integrated than smart cameras, as shown by Exhibit 12.2. Exhibit 12.2 also shows that embedded vision processors are less integrated than smart cameras because of their different form factor, which involves a camera that is tethered to a unit containing the computational intelligence of the system.

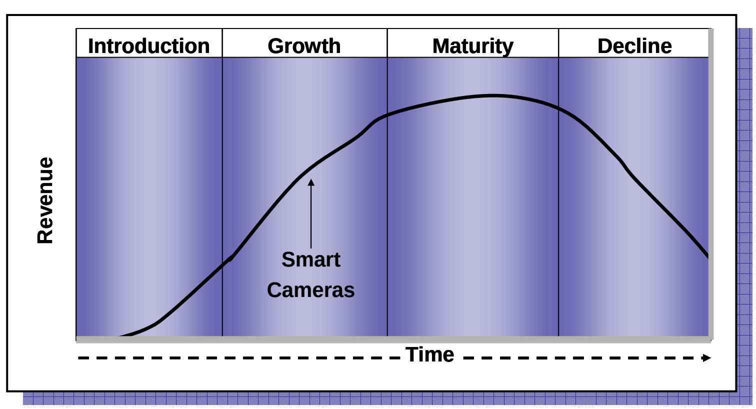
Exhibit 12.2: Smart Cameras in the System Integration Continuum



In addition to physical configuration, PC-based MV systems differ from smart cameras in other respects. In comparison to smart cameras, PC-based MV systems are generally more expensive, more flexible in terms of the applications they can serve, and correspondingly harder to program given their broader range of applications. PC-based MV systems can also generally handle multiple camera inputs in contrast to smart cameras, which are single socket units. (However, as noted later, some embedded vision processors, which are smart camera functional equivalents, can handle multiple cameras.)

PC-based MV systems and smart cameras are examined further in section 12.1.8.

Exhibit 12.3: Product Life Cycle of Smart Cameras



12.1.4 The Growth of the Smart Camera Market

A salient characteristic of the smart camera is its impressive sales growth, as previously noted, and as shown by the growth rates of Exhibit 12.3. This growth and the relative newness of this type of product

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indicate that smart cameras find themselves in the so-called "growth stage" of their product life cycle, as illustrated by Exhibit 12.3. In large part, this growth has been fueled by the ability of smart cameras - more than any other type of MV product - to ride the wave of multiple technological innovations, which together have made possible unique capabilities in support of a wide range of applications. These technological innovations, as shown by Exhibit 12.4, are miniaturization, the integration of components and sub-components, increasing processor speed, expanding memory and the decline in electronic component and sub-component costs. Examples of applications that are supported by smart cameras are shown in Exhibit 12.5.

Exhibit 12.4: Technological Innovations Utilized by Smart Cameras

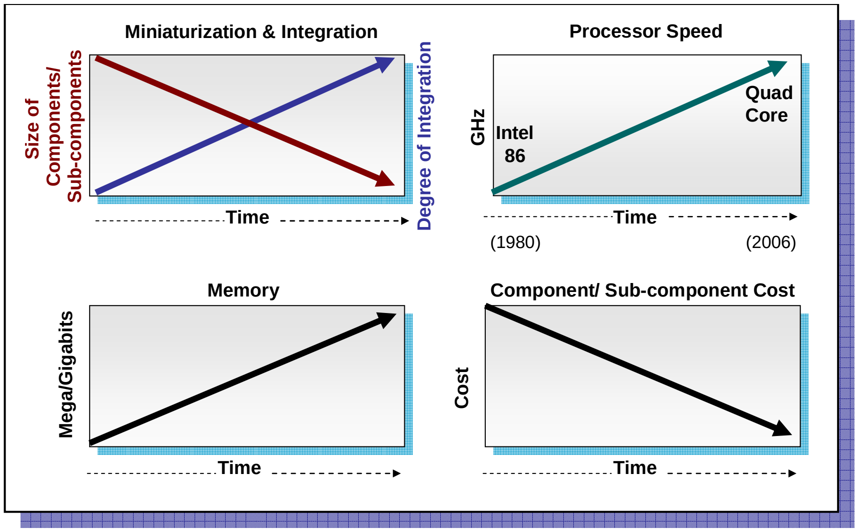

Exhibit 12.5: Examples of Smart Camera Applications by End-User Industry

Automotive	Electronics	Medical/Pharmaceutical	Metal Fabrication	Packaging	Plastic
Aluminum wheel inspection	Chip capacitor inspection	Dialysis filter inspection	Fastener inspection	Can contents verification	Web inspection
Assembly adhesive inspection	Connector assembly inspection	High precision needle inspection		Digital wheel print quality inspection	Extrusion inspection
Color fuse inspection	Image stitching application	Needle inspection with image stitching		Fiber marker tip orientation application	
Console faceplate inspection	Multi-snap, universal pin/contact inspection	Snap ring inspection		Label stack verification	
Registration marking identification application	Pin tips and solder tails inspection	Glass vial inspection		Mold cavity OCR	
	Electrical terminal strips inspection	Caulk container inspection			
		Part placement verification			

Source: PPT VISION website

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12.1.5 Major Suppliers Comprising the Smart Camera Market

We can also define the smart camera market in terms of the suppliers of smart cameras, vision sensors and embedded vision processors. As explained in Chapter 2, this list of suppliers excludes distributors and other market intermediaries in the food chain. Shown in Exhibit 12.6, this list (which has continued to grow over time) now identifies no less than 32 smart camera suppliers and their product brands or product family names.

Exhibit 12.6: Smart Camera Product Brands/ Product Family Names by Company (As of December 2008)

Company	Product Brand/ Product Family Name
Basler Vision Technologies	Excite
American Eltec	HiPerCam
Banner Engineering	PresencePLUSPro, PresencePLUS P4 Sensors
Cedes Corp. of America	ESPROS/QA-100
Cognex/DVT	In-Sight, DVT 515 through 554
Eutecus/Analogic	Bi-i
FastVision	FastCamera13, FastCamera40
Imaging Solutions Group	LightWise
Jadak Technologies	EVS-204
Keyence	CV-2600, 2100, 701, 501, 301, 110
Leutron Vision	LVmPC
Matrix Vision	MvCAM, mvBlueLYNX
Matrox	Iris P-Series
National Instruments	CVS-1455 Compact Vision System and NI 1700 series*
Omron	F-Series Vision Sensors
Photon Focus*	SM2-D1024-80
Pixel Velocity	Intelligent Cameras
PPT VISION	Impact
Quest Innovations*	Condor and Raptor
Sharp*	IV-S series
SICK IVP	IVC 2D
Siemens	SIMATIC
Sightech	Eyebot
SONY	XCI series
Southern Vision Systems	SpecterView
Tattile	TAG, RIGEL
Tichawa	IC 640/IC1280/ IC 128
Vision & Control	VICOSYS, PICTOR
Vision Components	VC44xx, VC40xx, VC4002L
Visual Inspection Systems	C6, Mxx, SBC50, VCxx
Webview	Sentinel, Web-I, WEBVIEW
Wintriss Engineering	Web Ranger, OPSIS

***New Entries**

The existence of this number of suppliers suggests a competitive, vibrant market in which sundry products compete with each other in addition to vying with PC-based MV systems.

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12.1.6 Segmentation of the Smart Camera Market

Corresponding to the three types of products comprising the smart camera market are the following market segments:

- Segment 1: Lower-end vision sensors
- Segment 2: Smart cameras, intelligent cameras and higher-end vision sensors
- Segment 3: Embedded vision processors, embedded vision computers and compact vision systems

Identification of these segments is based on the seven segmentation criteria shown in Exhibit 12.7. It should be noted that no two segments have the same rankings for all indicated segmentation criteria. For example, while segments "2" and "3" are ranked the same in terms of price, flexibility/programmability, I/O, processing power and resolution, they are different in terms of memory configuration and form factor.

Not surprisingly, different suppliers compete in different segments. As Exhibit 12.8 shows, a supplier can compete across different segments, but no two segments have the same supplier mix.

Exhibit 12.7: Smart Camera Market Segments

	Segment "1"	Segment "2"	Segment "3"
Form Factor	Integrated	Integrated	Less Integrated
Price	Lower-End of Market $3K	Higher-End of Market $6K	Higher-End of Market $6K
Flexibility/ Programmability	Lower	Higher	Higher
I/O	Simple	More Complex	More Complex
Processing Power	Less	More	More
Memory Configuration	Low	Medium	Highest
Resolution	Lower	Higher	Higher

Smart camera segments also differ in terms of their strategic trade-offs; that is, their mix of competitive advantages and disadvantages, as shown by Exhibit 12.9.

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Exhibit 12.8: Smart Camera Supplier Mix by Segment (as of December 2008)

Segment "1"	Segment "2"	Segment "3"
Banner Engineering Cognex/DVT Imaging Solutions Group Jadak Technologies PPT Vision Siemens (formerly Acuity CiMatrix) Tattile Vision & Control	Banner Engineering Basler Cognex/DVT Eutecus/Analogic Fast Vision Imaging Solutions Group (ISG) Matrix Vision Matrox National Instruments* Photon Focus* Pixel Velocity PPT Vision Quest Innovations* Sharp* SICK/IVP Sony Southern Vision Systems (SVSi) Tattile Tichawa Vision Components Vision & Control Webview Wintriss Engineering *New Entries	American Eltec Banner Engineering Imaging Solutions Group Keyence Matrox National Instruments Omron PPT Vision Sightech Tattile

Exhibit 12.9: Strategic Trade-offs in Smart Camera Market Segments

Competitive Advantages

Segment "1"	Segment "2"	Segment "3"
Lower Cost Ease of use Integrated Lighting Smaller form factor than "3"	Less maintenance than "3" Direct access of processor to sensor unlike "3" More flexibility & programmability than "1" Can handle more advanced applications than "1"	Can use more than one camera Camera flexibility in some cases (can use different cameras) Improved processor performance Can handle more advanced applications than "1"

Competitive Disadvantages

Segment "1"	Segment "2"	Segment "3"
Less programmability (can only handle a limited number of simpler functions) Less configurability	Harder to use than "1" More expensive than "1"	Harder to use than "1" and "2" More expensive than "1"

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12.1.7 Market Trends and Developments

Smart cameras have undergone major changes in the marketplace in terms of processing power, flexibility and consequently the range of serviceable applications. When smart cameras were first invented, their capabilities were quite limited. Their lack of tools and processing power meant that they were generally suitable only for a narrow range of the simplest of applications. Typically, these early smart cameras were used for detecting the presence or absence of items and thus were not particularly "smart" by today's definition. For example, they could determine whether a box contained an item or was empty. Higher-order applications were left exclusively to PC-based MV systems by dint of their greater processing power and programming flexibility.

Over time smart cameras grew dramatically in capability and sophistication. Because of this and their generally lower cost compared to PC-based MV systems, they have also grown in popularity and have been used for a wider range of applications.

Because of this, some have argued that differences in capability between smart cameras and PC-based MV systems have nearly vanished and that smart cameras will soon supplant PC-based MV systems. Others have argued that the gap is still substantial, since PC-based MV systems have benefited from the very same technological trends that have enabled the advance of smart cameras. In other words, while smart cameras have improved in terms of their capabilities, PC-based MV systems have not stood still. In particular, both have benefited from faster processors.

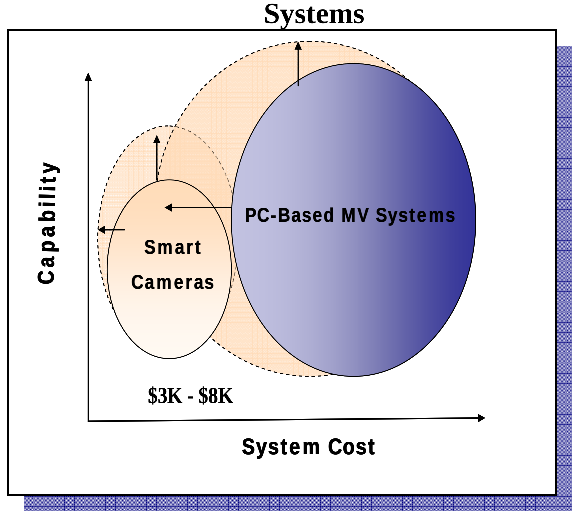
Is lower cost a discernible trend? As section 12.2 explains, the pricing data of this study does show that smart cameras are becoming somewhat less expensive but not anywhere to the extent exhibited by other, more mature MV products.

Other trends affecting smart cameras are the reduction in component size, the use of smaller storage devices, increasing imager resolution and growing reliance on CMOS technology. All of this will also contribute to the improved performance of smart cameras.

12.1.8 Smart Cameras vs. PC-based Systems

In a more immediate sense, demand for smart cameras is also a function of their increasing capabilities, as suggested by the previous sections. As the consequence of faster processors, improved storage and more versatile software, smart cameras have become increasingly attractive. Their relative cost, typically ranging from $2K to $8K, has also made them attractive for various applications. However, lower-cost and more capable PC-based MV systems have also been introduced to the market, as a reflection of the overall trend

Exhibit 12.10: Cost and Capability Trends: Smart Cameras Versus PC-Based MV Systems



Based on diagram from Applied Vision

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toward lower prices. This is illustrated by Exhibit 12.10.

Some have argued that smart cameras and PC-based MV systems are not direct competitive substitutes but rather complementary products that are aimed at different customer segments. With their greater ease of use, smart cameras - according to this view - are targeted more to end users, while PC-based systems, with their greater capability and complexity, are intended primarily for OEMs. Similarly, some view smart cameras and PC-based MV systems as dependent on the specific needs of the customer, such that it could make better sense to use smart cameras in some instances but PC-based MV systems in others. Major differences between PC-based MV systems and smart cameras are summarized in Exhibit 12.11.

Exhibit 12.11: Major Differences between PC-Based MV Systems and Smart Cameras

	Smart Cameras	PC-Based MV Systems
Type of Applications	Less Demanding	More complex
Number of Applications	Less	More
Processing Power	Less	More
Cost	Lower	Higher
Architecture	Integrated	Modular
User Friendliness	Easier	More Difficult
Form Factor	Smaller/Compact	Larger

12.1.9 Major Market Characteristics

Based on our examination thus far, the picture of the smart camera market that emerges is that of a relatively young, high-growth market consisting of three main segments in which a number of suppliers offer a wide range of products that compete with each other and PC-based MV systems. Major characteristics are summarized by Exhibit 12.12.

Exhibit 12.12: Major Characteristics of the Smart Camera Market (Updated)

- **Market Size**:
  - 2008 *sales revenue:* $126.5 Million USD
  - 2008 *units sold*: 30,863
- **Market Performance:**
  - Average historical revenue growth rate for 2004– 2008: 9.9% (CAGR)
  - Average historical unit growth rate for 2004-2008: 7.3% (CAGR)
  - 2008 revenue growth rate: 8.5%
  - 2008 unit growth rate: 7.3%
- **Market Segments:**
  - Segment 1: Lower-end vision sensors
  - Segment 2: Smart cameras, intelligent cameras, higher-end vision sensors
  - Segment 3: Embedded vision processors/computers, compact vision systems
- **Market Players and Products**
  - Approximately 32 suppliers
  - Wide range of available products
- **Major Market Trends:**
  - Increasing capabilities (expanding range of applications)
  - Increasing processing power
  - Increasing sophistication and flexibility of software
  - Decreasing component size, enabling smaller form factors
  - Relatively modest price declines

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12.1.10 New Product Introductions

A number of new MV products were introduced in 2008, as shown by Exhibit 12.13. (Note: While we intend this list to be all-inclusive, it is possible that we have inadvertently omitted some models. Should this be the case, we offer our sincere apologies.) From the wide variety of new products offered, it is evident that most new smart cameras were CCD and monochrome but were available in a wide range of resolutions, speeds and interfaces. Vision Components, SONY and Quest Innovations had the greatest number of new product introductions.

Exhibit 12.13: New Smart Camera Products in 2008

Company	Product Name	Imager	Interface	Resolution	Color	Mono-chrome	Processor	Speed
Fast Vision	FastCamera40	CMOS	USB 2.0, Camera Link	4.0 MP, 2352x1728	X		NA	200 fps
Fast Vision	FastCamera13	CMOS	Camera Link	1.3 MP, 12820X1024	X		NA	500 fps
Matrox	Iris GT	CCD	Ethernet	640 x 480 1280 x 960		X	1.6 GHz Intel	100 fps 22.5 fps
Photon Focus	SM2-D1024-80	CMOS	GigE	1024 x 1024		X	TMS 320	75 fps
PPT Vision	IMPACT T3X	CCD	Ethernet, serial	640 x 480, 1024 x 768, 1600 x 1200		X	NA	12 fps to 60 fps
PPT Vision	IMPACT A20	CMOS	Ethernet, serial	752 x 480		X	NA	60 fps
Quest Innovations	Condor-1000 MS-5	5 CCD sensors	Fiber, Camera Link, GigE	1280 x 1024	Multi-spectral		5 x 32-Bit 5 x Multi-Pixel	150 fps
Quest Innovations	Raptor - 1000	CMOS	GigE	1280 x 1024	X	X	NA	27 fps
Quest Innovations	Raptor - 2000	CMOS IBIS 5	GigE		X	X	QUADCore IP & 32 Bit	27 fps
Sharp	IV-S210X	CCD	Camera Link	512 x 480, 1600 x 1200		X	NA	NA
Sharp	IV-S51M	CCD	Ethernet	800 x 600 x 24		X	NA	NA
SONY	XCI-SX100/XP SXGA B/W	CCD	GigE, USB 2.0	1280 x 960		X	x86 CPU	30 fps
SONY	XCI-V100/XP VGA B/W	CCD	USB 2.0	640 x 480		X	x86 CPU	90 fps
SONY	XCI-SX100C/XP SXGA	CCD	USB 2.0	1280 x 960	X		x86 CPU	30 fps
SONY	XCI-V100C/XP VGA Color	CCD	USB 2.0	640 x 480	X		x86 CPU	90 fps
Vision Components	VCSBC4012	CMOS	Ethernet	5 MP		X	TI 400 MHz	11,6 fps
Vision Components	VC4438	CCD	Serial, Ethernet	640 x 480		X	TI 1 GHz	63 fps
Vision Components	VC4067	CCD	Serial, Ethernet	1280 x 1024		X	TI 400 MHz	14 fps
Vision Components	VC4465/C	CCD	Serial, Ethernet	768 x 582	X		TI	55 fps
Vision Components	VC4002L (Line Scan)	CMOS	Serial, Ethernet	2048 x 1		X	TI 400 MHz	max11kHz

12.2 Survey Results

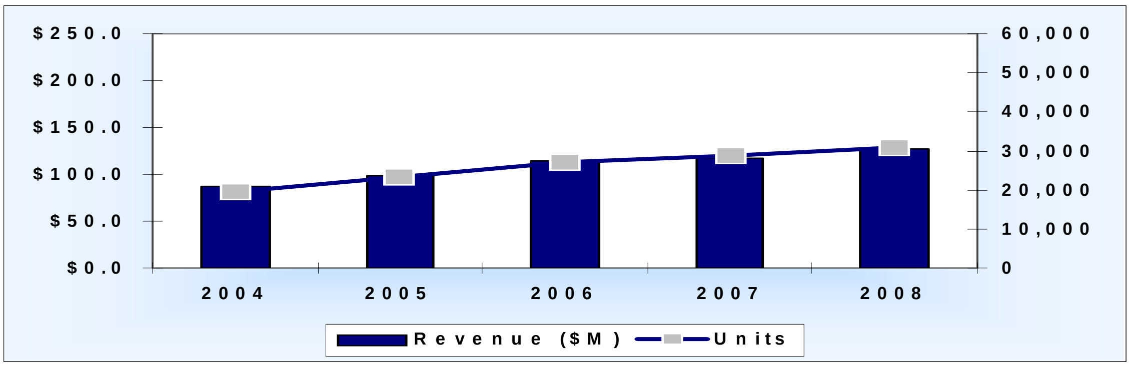
We now examine the market in terms of sales volumes expressed in revenue and units, based on the results of submitted market surveys. Our focus is the historical period of 2004 through 2008 and the forecast period of 2009 through 2013.

12.2.1 Historical Growth Patterns

As shown by Exhibit 12.14, the MV smart camera market (including functional equivalents) has grown from $86.7 million (USD) in 2004 to $126.5 million in 2008. During this period, units sold increased from 19,695 to 30,863. The compound annual growth rates (CAGRs) for this period were 9.9 percent for revenue and 11.9 percent for units sold. The growth rates for 2008 were 8.5 percent for revenue and 7.3 percent for units sold. In view of the recession, these 2008 results were surprisingly strong.

Exhibit 12.14: Smart Camera Sales Revenue ($ Millions) and Units: 2004 to 2008

	Actual 2004	Actual 2005	Actual 2006	Actual 2007	Actual 2008	CAGR
Revenue ($M)	$86.7	$99.2	$114.2	$116.6	$126.5	-
%	48.0%	14.4%	15.2%	2.1%	8.5%	9.9%
Units	19,695	23,448	27,091	28,750	30,863	-
%	7.60%	19.1%	15.5%	6.1%	7.3%	11.9%
Average Price	$4,402	$4,230	$4,217	$4,055	$4,097	-



12.2.2 Forecasts

For 2009, we expect a somewhat weaker rate of growth due to the recession, which is explained in Chapter 4. Specifically, as shown by Exhibit 12.15, we expect smart camera sales revenue to decrease in 2009 to $121.4 million, a -4.0 percent rate of annual change. We forecast units for 2009 at 29,379, a -4.8 percent decrease from 2008.

For the forecast period as a whole, our prediction is that revenue in 2009 will grow to $199.8 million by 2013, reflecting a CAGR of 13.3 percent. For the same time frame, we anticipate even greater growth for units sold; that is, an increase to 53,196 in 2013, reflecting a CAGR of 16.0 percent.

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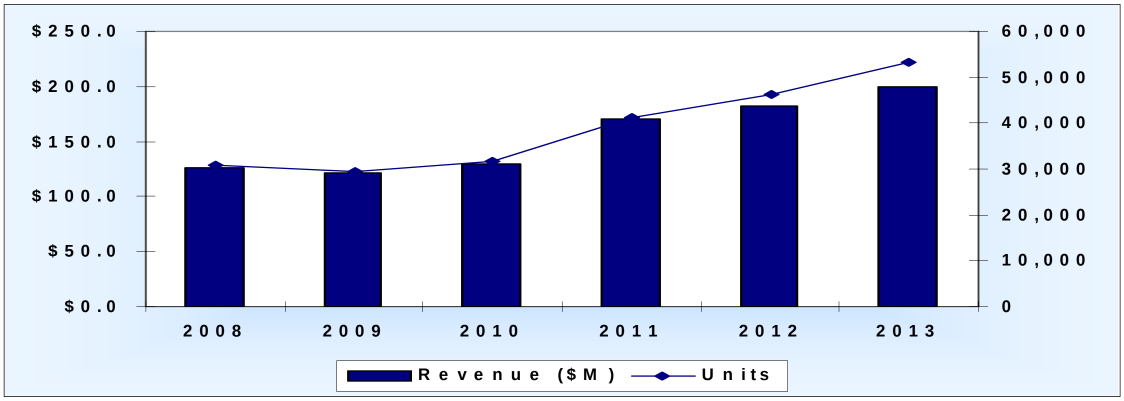
Exhibit 12.15: Forecast Smart Camera Sales Revenue ($ Millions) and Units: 2008 to 2013

	Actual 2008	Forecast 2009	Forecast 2010	Forecast 2011	Forecast 2012	Forecast 2013	CAGR
Revenue ($M)	$126.5	$121.4	$129.4	$170.6	$182.6	$199.8	-
%	8.5%	-4.0%	6.6%	31.8%	7.0%	9.4%	13.3%
Units	30,863	29,379	31,790	41,110	46,290	53,196	-
%	7.3%	-4.8%	8.2%	29.3%	12.6%	14.9%	16.0%
Average Price	$4,097	$4,131	$4,070	$4,150	$3,945	$3,756	-

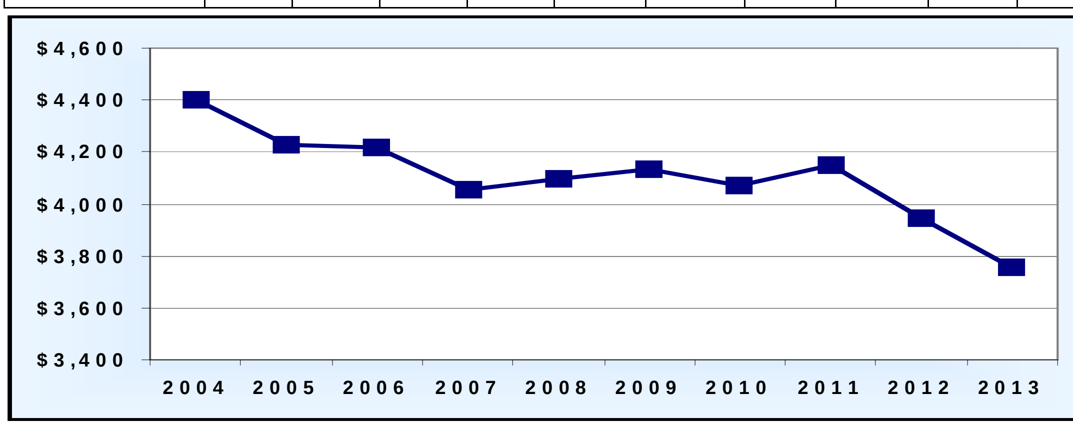


12.2.3 Price Analysis

Reflecting the growth patterns in revenue and units sold, average smart camera prices decreased from $4,402 in 2004 to $4,097 in 2008 and are expected to decline to $3,756 by 2013, as shown in Exhibit 12.16.

Exhibit 12.16: Average Price of a Smart Camera: 2004 - 2013

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Average Price	$4,402	$4,230	$4,217	$4,055	$4,097	$4,131	$4,070	$4,150	$3,945	$3,756



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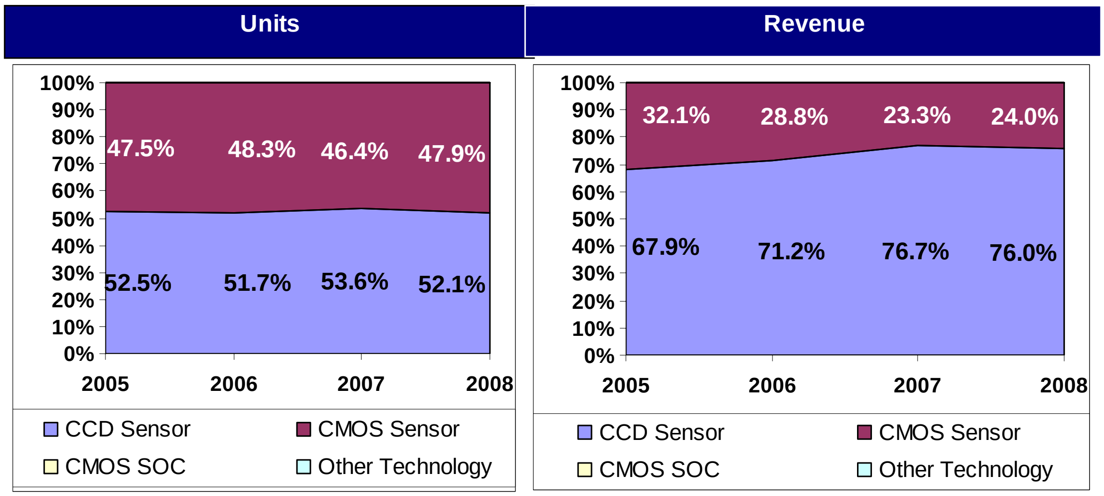
12.2.4 Total Sales Revenue and Units by Major Product Feature

To increase our understanding of the smart camera market, we now examine 2008 sales results by product feature, beginning with the type of sensor used. As previously discussed, the two main *types of sensors* used in smart cameras are CCD and CMOS.

Exhibit 12.17: Smart Camera Sales by Sensor Type



	2005	2006	2007	2008	2005	2006	2007	2008
	Units	Units	Units	Units	Rev	Rev	Rev	Rev
CCD Sensor	52.5%	51.7%	53.6%	52.1%	67.9%	71.2%	76.7%	76.0%
CMOS Sensor	47.5%	48.3%	46.4%	47.9%	32.1%	28.8%	23.3%	24.0%
CMOS SOC	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Other Technology	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

As shown by Exhibit 12.17, both types of sensors were used almost equally in smart cameras. 47.9 percent of the units sold in 2008 used CMOS sensors; 52.1 percent used CCD sensors. However, these proportions were different for revenue. Smart cameras with CMOS sensors, which were less expensive on average, accounted for 24.0 percent of the total revenue, while smart cameras with CCD sensors comprised 76.0 percent of the total revenue.

What frame rates do smart cameras typically have? As Exhibit 12.18 shows, 60.2 percent of the smart cameras sold in 2008 had a *sensor frame rate* of 60 fps (frames per second), which accounted for 72.3 percent of total revenue. 37.8 percent of the units sold had a rate of 30 fps, which corresponded to 25.6 percent of total revenue. In addition, the data suggest some important trends. The portion of sales involving 60 fps has increased over time; correspondingly, portions of sales of slower than 60 fps (30 fps) and faster than 60 fps have steadily declined. 60 fps appears to be the sweet spot.

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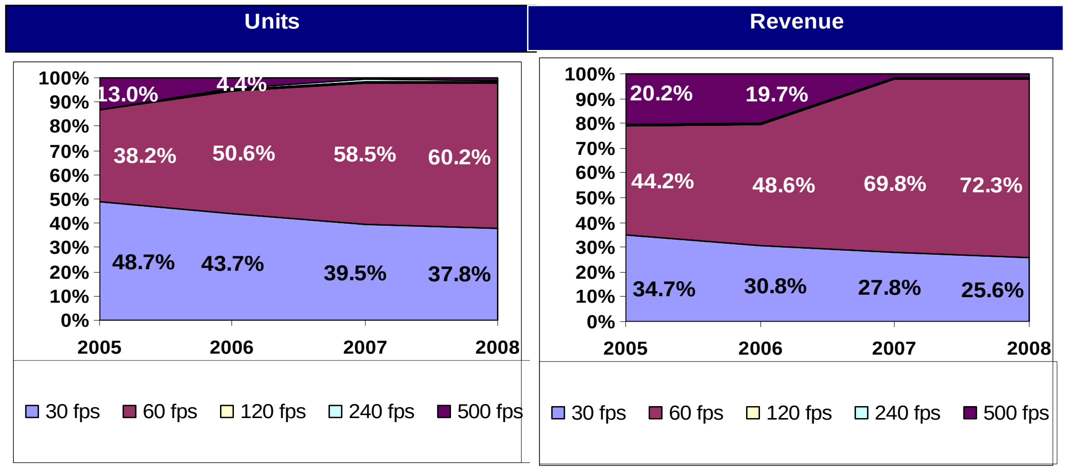
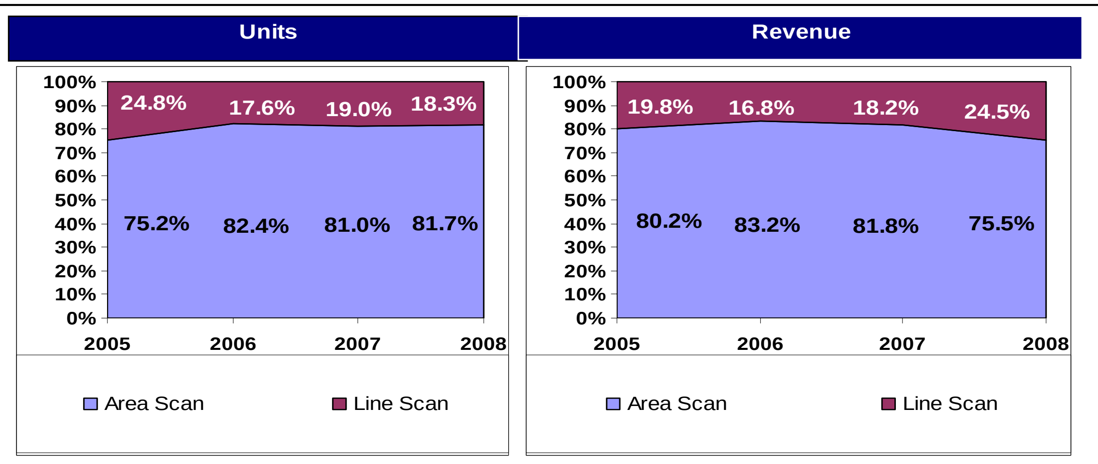
Exhibit 12.18: Smart Camera Sales by Sensor Frame Rate



	2005 Units	2006 Units	2007 Units	2008 Units	2005 Rev	2006 Rev	2007 Rev	2008 Rev
30 fps	48.7%	43.7%	39.5%	37.8%	34.7%	30.8%	27.8%	25.6%
60 fps	38.2%	50.6%	58.5%	60.2%	44.2%	48.6%	69.8%	72.3%
120 fps	0.0%	0.6%	0.5%	0.5%	0.0%	0.2%	0.2%	0.2%
240 fps	0.2%	0.7%	0.6%	0.6%	0.9%	0.7%	0.6%	0.2%
500 fps	13.0%	4.4%	0.8%	0.9%	20.2%	19.7%	1.5%	1.8%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

We next analyzed sales in terms of area scan versus line scan. As one would expect, the overwhelming majority of smart cameras sold were area scan cameras. As Exhibit 12.19 shows, 81.7 percent of all smart cameras sold in 2008 were identified as area scan, as opposed to 18.3 percent identified as line scan cameras. In terms of total revenue, area scan cameras accounted for 75.5 percent of the sales, while line scan cameras represented 24.5 percent of the sales.

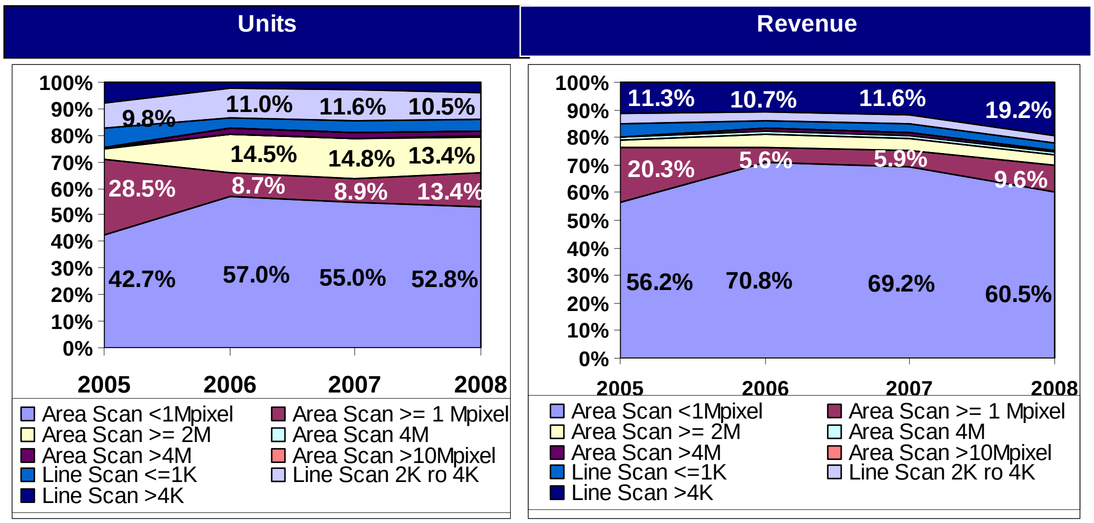
Exhibit 12.19: Smart Camera Sales – Area Scan vs. Line Scan



	2005 Units	2006 Units	2007 Units	2008 Units	2005 Rev	2006 Rev	2007 Rev	2008 Rev
Area Scan	75.2%	82.4%	81.0%	81.7%	80.2%	83.2%	81.8%	75.5%
Line Scan	24.8%	17.6%	19.0%	18.3%	19.8%	16.8%	18.2%	24.5%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Exhibit 12.19 identifies sales by type of camera and resolution.

Exhibit 12.20: Smart Camera Sales by Type of Camera and Resolution



	2005	2006	2007	2008	2005	2006	2007	2008
	Units	Units	Units	Units	Rev	Rev	Rev	Rev
Area Scan <1Mpixel	42.7%	57.0%	55.0%	52.8%	56.2%	70.8%	69.2%	60.5%
Area Scan >= 1 Mpixel	28.5%	8.7%	8.9%	13.4%	20.3%	5.6%	5.9%	9.6%
Area Scan >= 2M	3.6%	14.5%	14.8%	13.4%	2.5%	5.0%	4.4%	3.6%
Area Scan 4M	0.4%	0.3%	0.2%	0.2%	1.2%	0.7%	1.1%	0.9%
Area Scan >4M	0.0%	2.0%	2.1%	1.9%	0.0%	1.1%	1.2%	1.0%
Area Scan >10Mpixel	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Line Scan <=1K	7.2%	4.3%	4.6%	4.1%	4.5%	2.7%	3.0%	2.4%
Line Scan 2K to 4K	9.8%	11.0%	11.6%	10.5%	4.0%	3.4%	3.5%	2.9%
Line Scan >4K	7.7%	2.2%	2.9%	3.7%	11.3%	10.7%	11.6%	19.2%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

The most common type of smart camera sold in 2008 was a low resolution (less than one mega pixel) area scan camera, which accounted for 52.8 percent of all units sold and 60.5 percent of total revenue. The next most common camera was a higher resolution (more than two mega pixel) area scan camera. 13.4 percent of all units sold fell into this category and accounted for 3.6 percent of total revenue. Line scan cameras between 2K and 4K accounted for 10.5 percent of units and 2.9 percent of revenue in 2008.

Next we sought to determine how common smart cameras with integrated lighting were versus smart cameras sold with separate (non-integrated) lighting or no lighting. What we found was that lighting is still typically provided on a non-integrated basis, but the extent of lighting integration has generally increased over the four-year period of 2005 through 2008. 35.0 percent of the units sold had integrated lighting, which yielded 24.1 percent of total revenue, as illustrated by Exhibit 12.21. By comparison, 42.7 percent had separate lighting, which corresponded to 38.0 percent of total revenue. Exhibit 12.21 also shows that smart camera sales not including lighting were far less typical, occurring in 22.3 percent of the cases, which represented 37.9 percent of total revenue.

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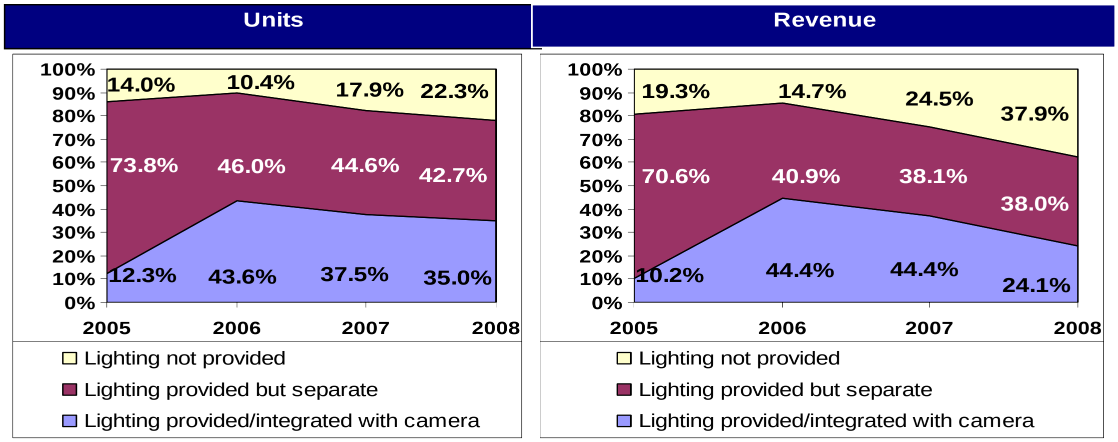
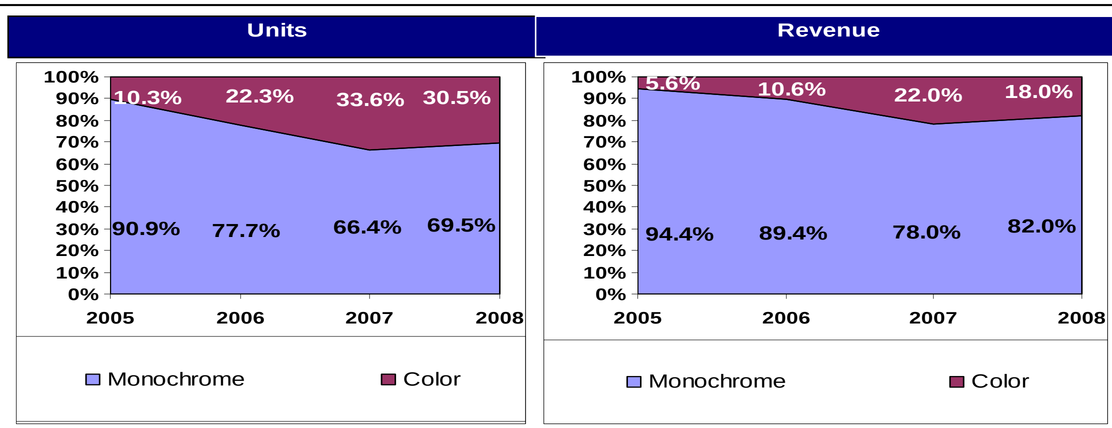
Exhibit 12.21: Smart Camera Sales by Lighting Configuration



	2005	2006	2007	2008	2005	2006	2007	2008
	Units	Units	Units	Units	Rev	Rev	Rev	Rev
Lighting provided/integrated with camera	12.3%	43.6%	37.5%	35.0%	10.2%	44.4%	37.4%	24.1%
Lighting provided but separate	73.8%	46.0%	44.6%	42.7%	70.6%	40.9%	38.1%	38.0%
Lighting not provided	14.0%	10.4%	17.9%	22.3%	19.3%	14.7%	24.5%	37.9%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Exhibit 12.22: Smart Camera Sales - Color vs. Monochrome



	2005	2006	2007	2008	2005	2006	2007	2008
	Units	Units	Units	Units	Rev	Rev	Rev	Rev
Monochrome	90.9%	77.7%	66.4%	69.5%	94.4%	89.4%	78.0%	82.0%
Color	10.3%	22.3%	33.6%	30.5%	5.6%	10.6%	22.0%	18.0%
Total	101.2%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

To what extent do smart cameras utilize color imaging? According to Exhibit 12.22, 69.5 percent of all smart cameras sold in 2008 were monochrome; approximately one-third (30.5 percent) were color. In terms of revenue, monochrome smart cameras were 82.0 percent of sales; 18.0 percent were color. Importantly, we find another important trend: the percent of color smart cameras has tended to rise over the four-year period, nearly tripling from 10.3 percent of units in 2005 to 30.5 percent in 2008.

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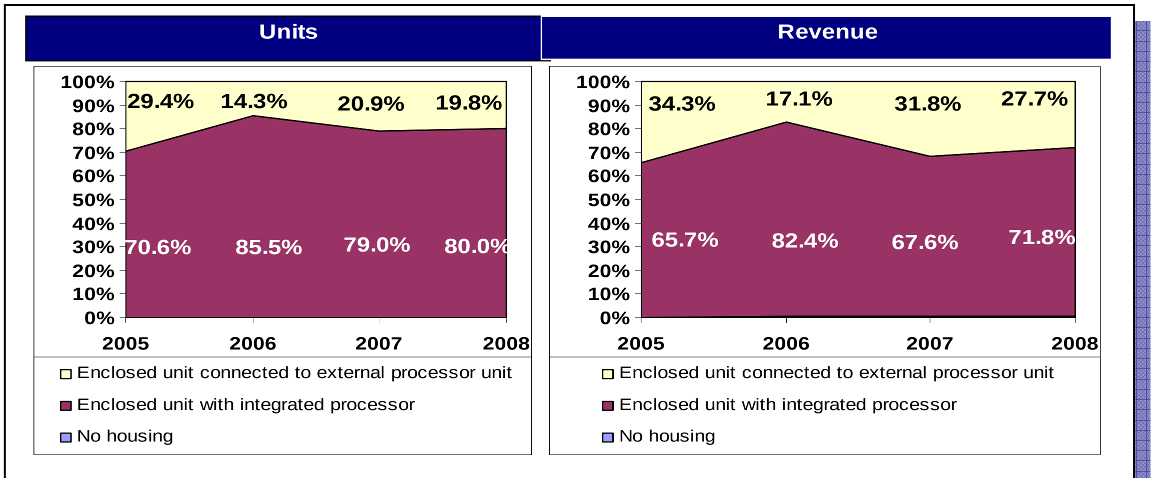
Most smart cameras sold in 2008 also were enclosed units with an integrated processor. This is shown clearly by Exhibit 12.23, which places the percent of sales of smart cameras with this form factor at 80.0 percent in terms of units and 71.8 percent in terms of revenue. Only 19.8 percent of units sold, equating to 27.7 percent of total revenue, involved an external processor. (Note: In this study, we have referred to this latter form factor as an embedded vision processor or embedded vision computer.)

Exhibit 12.23: Smart Camera Sales by Housing



	2005 Units	2006 Units	2007 Units	2008 Units	2005 Rev	2006 Rev	2007 Rev	2008 Rev
No housing	0.0%	0.1%	0.1%	0.1%	0.0%	0.5%	0.6%	0.5%
Enclosed unit with integrated processor	70.6%	85.5%	79.0%	80.0%	65.7%	82.4%	67.6%	71.8%
Enclosed unit connected to external processor unit	29.4%	14.3%	20.9%	19.8%	34.3%	17.1%	31.8%	27.7%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	0.5%

We also broke down smart camera sales by application to see how end-user customers deploy smart cameras. In particular, we wanted to see if smart cameras are used for a narrow or broad set of generic applications.

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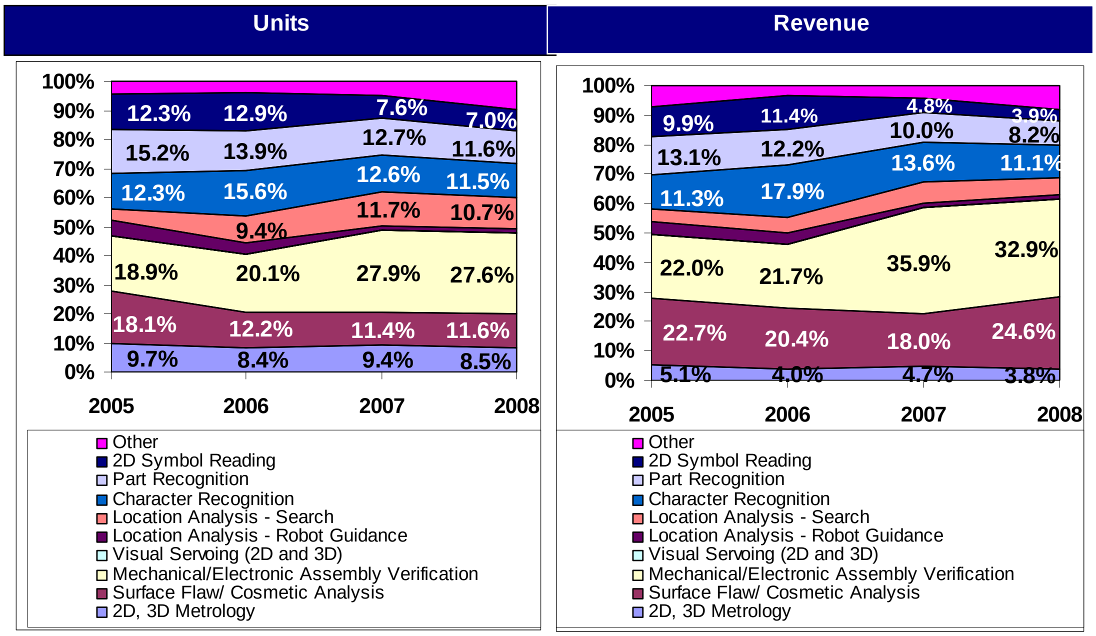
Exhibit 12.24: Smart Camera Sales - Percent Distribution by Application



	2005 Units	2006 Units	2007 Units	2008 Units	2005 Rev	2006 Rev	2007 Rev	2008 Rev
2D, 3D Metrology	9.7%	8.4%	9.4%	8.5%	5.1%	4.0%	4.7%	3.8%
Surface Flaw/Cosmetic Analysis	18.1%	12.2%	11.4%	11.6%	22.7%	20.4%	18.0%	24.6%
Mechanical/Electronic Assembly Verification	18.9%	20.1%	27.9%	27.6%	22.0%	21.7%	35.9%	32.9%
Visual Servoing (2D and 3D)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Location Analysis - Robot Guidance	5.6%	3.6%	1.8%	1.7%	4.0%	3.9%	1.7%	1.5%
Location Analysis - Search	3.6%	9.4%	11.7%	10.7%	4.5%	5.2%	7.0%	5.8%
Character Recognition	12.3%	15.6%	12.6%	11.5%	11.3%	17.9%	13.6%	11.1%
Part Recognition	15.2%	13.9%	12.7%	11.6%	13.1%	12.2%	10.0%	8.2%
2D Symbol Reading	12.3%	12.9%	7.6%	7.0%	9.9%	11.4%	4.8%	3.9%
Other	4.3%	4.0%	4.9%	9.9%	7.4%	3.3%	4.3%	8.2%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

As Exhibit 12.24 shows, smart cameras were used for a wide variety of applications, attesting to their great versatility in machine vision. The most common application was mechanical and electronic assembly verification at 27.6 percent of units sold and 32.9 percent of total revenue. Both part recognition and surface flaw/cosmetic analysis followed at 11.6 percent of units sold with 8.2 and 24.6 percent of total revenue, respectively. As a portion of the total units sold, character recognition, part recognition, 2D symbol reading and surface flaw/cosmetic analysis have tended downward during the four-year period of 2005 through 2008. Conversely, mechanical/electronic assembly verification has grown as a percentage of total units sold.

The versatility of smart cameras is further revealed by identifying the industries in which they are used. As Exhibit 12.25 illustrates, smart cameras sold were intended for use in a wide range of manufacturing and non-manufacturing industries. The five most important end-user industries in order of the number of units sold were electronics/electrical, semiconductor, food, pharmaceutical and automotive.

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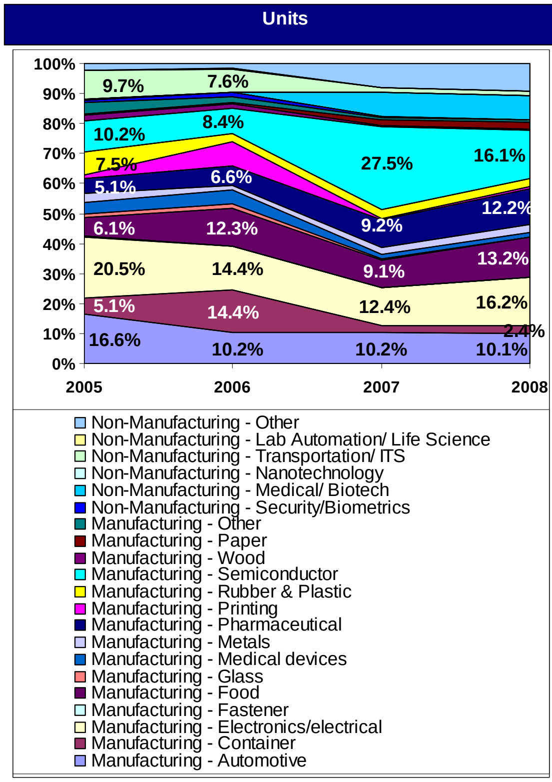
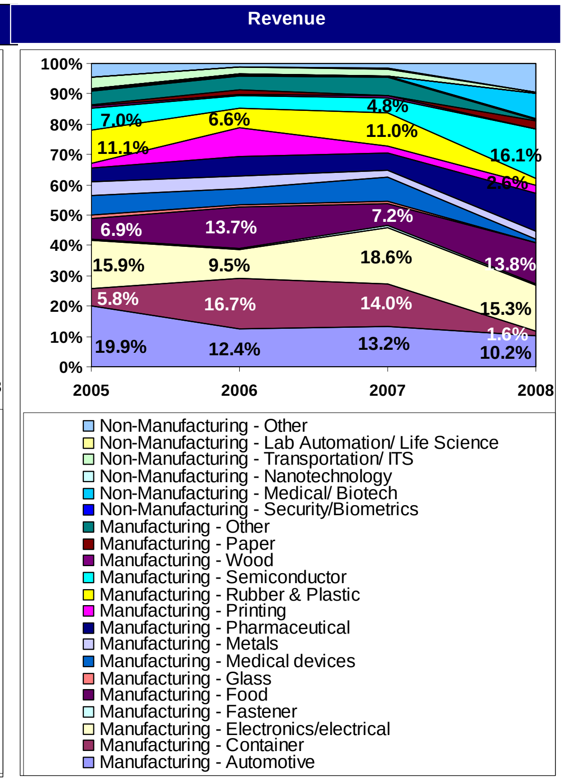
Exhibit 12.25: Smart Camera Sales by Industry





	2005	2006	2007	2008	2005	2006	2007	2008
	Units	Units	Units	Units	Rev	Rev	Rev	Rev
Manufacturing - Automotive	16.6%	10.2%	10.2%	10.1%	19.9%	12.4%	13.2%	10.2%
Manufacturing - Container	5.1%	14.4%	2.6%	2.4%	5.8%	16.7%	14.0%	1.6%
Manufacturing - Electronics/Electrical	20.5%	14.4%	12.4%	16.2%	15.9%	9.5%	18.6%	15.3%
Manufacturing - Fastener	0.3%	0.2%	0.1%	0.1%	0.5%	0.4%	0.9%	0.1%
Manufacturing - Food	6.1%	12.3%	9.1%	13.2%	6.9%	13.7%	7.2%	13.8%
Manufacturing - Glass	1.3%	1.6%	0.4%	0.3%	0.9%	0.8%	0.7%	0.1%
Manufacturing - Medical devices	3.9%	4.6%	1.5%	1.5%	6.4%	5.3%	7.8%	0.9%
Manufacturing - Metals	2.8%	1.7%	2.3%	2.4%	4.7%	4.0%	2.4%	2.7%
Manufacturing - Pharmaceutical	5.1%	6.6%	9.2%	12.2%	4.5%	6.5%	5.5%	12.7%
Manufacturing - Printing	1.3%	8.1%	0.5%	0.4%	1.6%	9.4%	2.6%	2.3%
Manufacturing - Rubber & Plastic	7.5%	2.7%	2.9%	3.0%	11.1%	6.6%	11.0%	2.6%
Manufacturing - Semiconductor	10.2%	8.4%	27.5%	16.1%	7.0%	3.9%	4.8%	16.1%
Manufacturing - Wood	1.9%	1.4%	0.3%	0.3%	0.7%	0.4%	0.6%	0.1%
Manufacturing - Paper	0.4%	0.3%	2.1%	2.1%	0.6%	1.6%	0.0%	2.5%
Manufacturing - Other	3.9%	1.9%	0.7%	0.7%	4.4%	4.5%	6.0%	0.7%
Non-Manufacturing - Security/Biometrics	1.0%	1.5%	0.3%	0.3%	0.5%	0.6%	0.5%	0.1%
Non-Manufacturing - Medical/Biotech	0.3%	0.2%	8.0%	7.9%	0.4%	0.2%	0.1%	8.6%
Non-Manufacturing - Nanotechnology	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Non-Manufacturing - Transportation/ ITS	9.7%	7.6%	1.7%	1.5%	3.7%	2.2%	2.5%	0.3%
Non-Manufacturing - Lab Automation/Life Science	0.0%	0.2%	0.0%	0.1%	0.1%	0.2%	0.1%	0.0%
Non-Manufacturing - Other	2.2%	1.6%	8.0%	9.0%	4.4%	1.1%	1.7%	9.4%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

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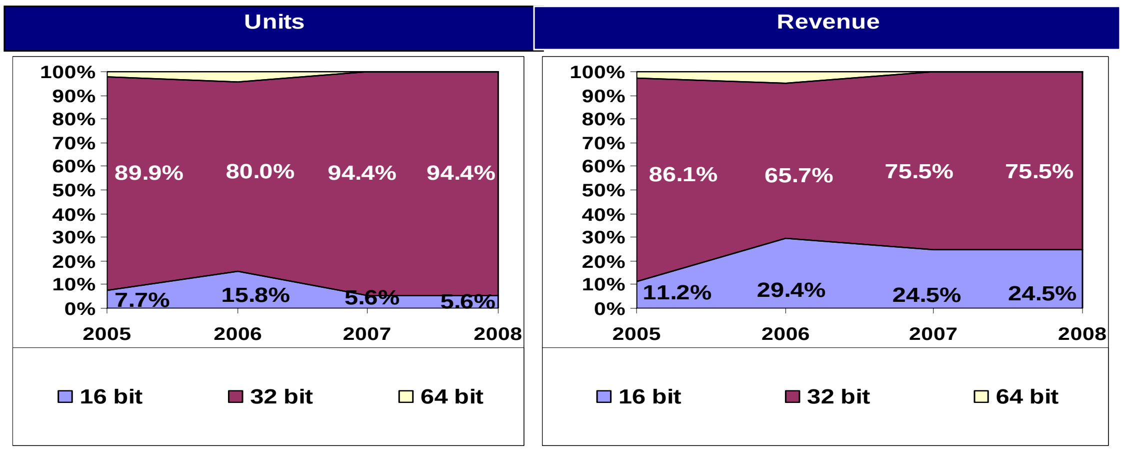
The last product features we use to break down sales are bit processor rate and processor type. According to Exhibit 12.26, smart cameras sold most frequently use 32 bit processors.

Exhibit 12.26: Smart Camera Sales by Bit Processor Rate



	2005 Units	2006 Units	2007 Units	2008 Units	2005 Rev	2006 Rev	2007 Rev	2008 Rev
16 bit	7.7%	15.8%	5.6%	5.6%	11.2%	29.4%	24.5%	24.5%
32 bit	89.9%	80.0%	94.4%	94.4%	86.1%	65.7%	75.5%	75.5%
64 bit	2.4%	4.2%	0.0%	0.0%	2.7%	4.9%	0.0%	0.0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

According to Exhibit 12.27**,** more than half of the smart cameras sold in 2008 employed something other than a Pentium, PowerPC or DSP; the "other" category accounted for 52.2 percent of total units sold or 37.8 percent of total revenue. By contrast, Pentium processors were hardly used. Importantly, DSP-based smart cameras constituted 22.0 percent of units sold and 17.9 percent of sales revenue in 2008. By contrast, PowerPC comprised 20.9 percent of units sold and 33.6 percent of sales revenue in 2008.

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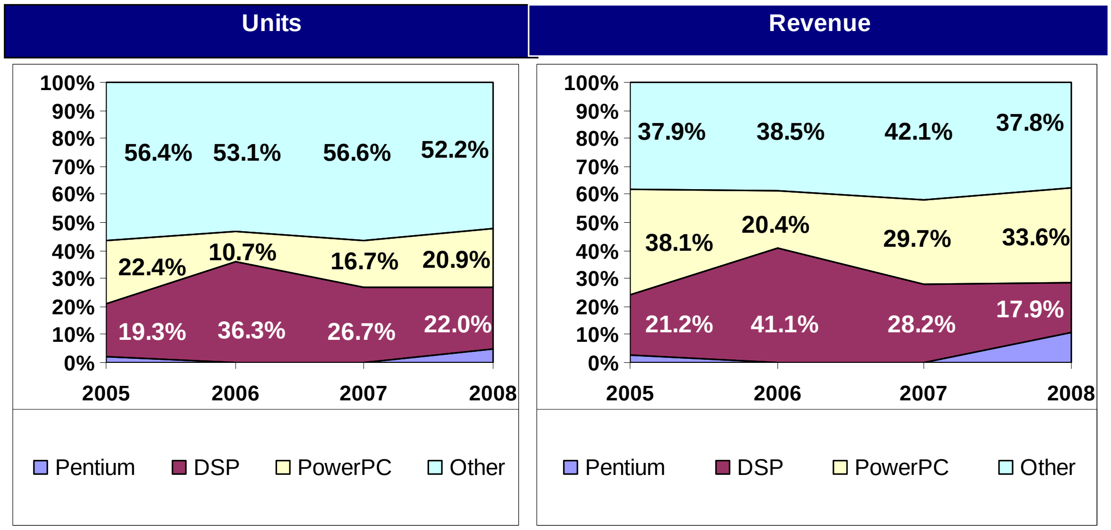
Exhibit 12.27: Smart Camera Sales by Processor Type



	2005 Units	2006 Units	2007 Units	2008 Units	2005 Rev	2006 Rev	2007 Rev	2008 Rev
Pentium	1.9%	0.0%	0.0%	4.9%	2.8%	0.0%	0.0%	10.8%
DSP	19.3%	36.3%	26.7%	22.0%	21.2%	41.1%	28.2%	17.9%
PowerPC	22.4%	10.7%	16.7%	20.9%	38.1%	20.4%	29.7%	33.6%
Other	56.4%	53.1%	56.6%	52.2%	37.9%	38.5%	42.1%	37.8%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

If we piece together the findings of this section, we gain a clear picture of the typical features of a smart camera sold in 2007, which is presented in Exhibit 12.28.

Exhibit 12.28: Typical Features of a Smart Camera Sold in 2008

Sensor type…………………………CCD
Sensor Frame Rate…………………60 fps
Scanning technology………………Area scan
Resolution and Scanning…………..Area scan <1 Mpixel
Lighting Configuration…………….Separate lighting
Color or Monochrome……………..Monochrome
Housing (Architecture)…………….Enclosed with internal processor
Application ……………………… Multiple applications
Bit processor rate………………… 32 bit
Processor type…………………… Other than Pentium, DSP or PowerPC

The typical smart camera sold in 2008 was a monochrome, area scan unit with a frame rate of 60 fps that was housed in a single enclosure and used a CCD sensor, non-integrated lighting and an internal processor other than Pentium, DSP or PowerPC.

<u>Smart Camera Sales by Type of Customer</u>

Finally, we analyze 2008 sales results in terms of customer classification. As revealed by Exhibit 12.29, smart camera suppliers typically sell their products to intermediaries in the distribution channel; i.e. resellers, distributors or value-added resellers (VARs). Of the total units sold in 2008, 64.1 percent went to these intermediaries, which accounted for

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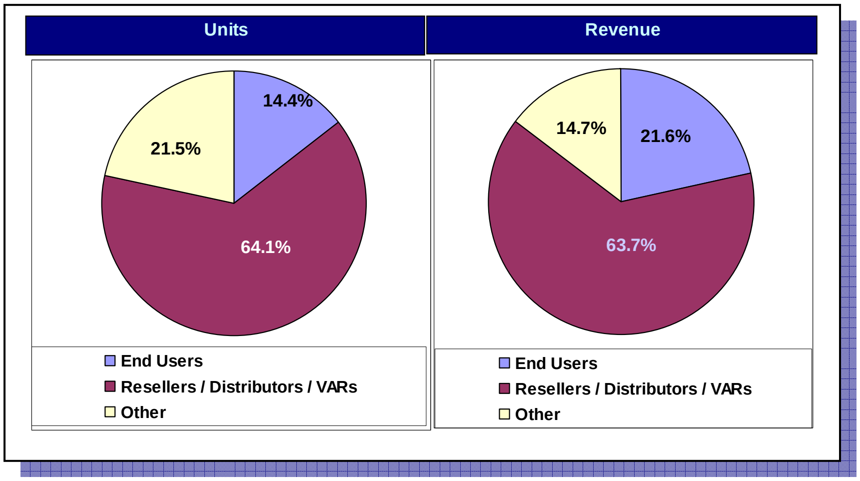
Exhibit 12.29: Smart Camera Sales by Type of Customer



63.7 percent of total sales revenue earned by suppliers. Direct sales to end users accounted for 14.4 percent of units sold corresponding to 21.6 percent of total sales revenues, an increase over 2007. These results leave little doubt that most smart camera sales reach end users indirectly through distribution channels.

12.3 Summary of Major Findings

The major findings of this chapter are as follows:

- **Market Characteristics:** The smart camera market in North America is a relatively young, high-growth market consisting of three main segments in which a number of suppliers offer a wide range of products that compete with each other and PC-based MV systems.
- **Market Competitiveness:** In just one year's time, the total number of smart camera suppliers (now standing at 32) rose by 3, evidencing greater market competitiveness. This is very much in keeping with the view that high growth markets (such as the smart camera market) attract new market entrants.
- **Historical Sales:** The MV smart camera market (including functional equivalents) has grown from $86.7 million (USD) in 2004 to $126.5 million in 2008. During this period, units sold increased from 19,695 to 30,863. The compound annual growth rates (CAGRs) for this period were 9.9 percent for revenue and 11.9 percent for units sold. The growth rates for 2008 were 8.5 percent for revenue and 7.3 percent for units sold. In view of the recession, these 2008 results show surprising growth for smart cameras.
- **Forecast Sales:** For 2009, we expect a weaker rate of growth due to the recession. Specifically, we expect smart camera sales revenue to decrease in 2009 to $121.4 million, a -4.0 percent rate of annual change. We forecast units for 2009 at 29,379, a -4.8 percent decline from 2008.

  For the forecast period as a whole, our prediction is that revenue in 2009 will grow to $199.8 million by 2013, reflecting a CAGR of 13.3 percent. For the same time frame, we anticipate even greater growth for units sold; that is, an increase to 53,196 in 2013, reflecting a CAGR of 16.0 percent.

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- **Average Unit Pricing:** Reflecting the growth patterns in revenue and units sold, average smart camera prices decreased from $4,402 in 2004 to $4,097 in 2008 and are expected to decline to $3,756 by 2013.
- **New Product Introductions:** Most new smart cameras introduced to the market were CCD and monochrome but were available in a wide range of resolutions, speeds and interfaces. Vision Components, SONY and Quest Innovations had the greatest number of new product introductions.
- **Sales by Sensor Type:** CMOS and CCD sensors were used almost equally in smart cameras in 2008. 47.9 percent of the units sold in 2008 used CMOS sensors; 52.1 percent used CCD sensors. However, these proportions were different for revenue. Smart cameras with CMOS sensors, which were less expensive on average, accounted for 24.0 percent of the total revenue, while smart cameras with CCD sensors comprised 76.0 percent of the total revenue.
- **Sales by Frame Rate:** 60.2 percent of the smart cameras sold in 2008 had a *sensor frame rate* of 60 fps (frames per second), which accounted for 72.3 percent of total revenue. 37.8 percent of the units sold had a rate of 30 fps, which corresponded to 25.6 percent of total revenue. In addition, the data suggest some important trends. The portion of sales involving 60 fps has increased over time; correspondingly, portions of sales of slower than 60 fps (30 fps) and faster than 60 fps have steadily declined. 60 fps appears to be the sweet spot.
- **Sales by Scanning Technology:** The overwhelming majority of smart cameras sold were area scan cameras. 81.7 percent of all smart cameras sold in 2008 were identified as area scan, as opposed to 18.3 percent identified as line scan cameras. In terms of total revenue, area scan cameras accounted for 75.5 percent of the sales, while line scan cameras represented 24.5 percent of the sales.
- **Sales by Scanning Technology and Resolution:** The most common type of smart camera sold in 2008 was a low resolution (less than one mega pixel) area scan camera, which accounted for 52.8 percent of all units sold and 60.5 percent of total revenue. The next most common camera was a higher resolution (more than two mega pixel) area scan camera. 13.4 percent of all units sold fell into this category and accounted for 3.6 percent of total revenue. Line scan cameras between 2K and 4K accounted for 10.5 percent of units and 2.9 percent of revenue in 2008.
- **Sales by Lighting Integration:** In 2008, lighting was still typically provided on a non-integrated basis, but the extent of lighting integration generally increased over the four-year period of 2005 through 2008. 35.0 percent of the units sold had integrated lighting, which yielded 24.1 percent of total revenue. By comparison, 42.7 percent had separate lighting, which corresponded to 38.0 percent of total revenue. Smart camera sales not including lighting were far less typical, occurring in 22.3 percent of the cases, which represented 37.9 percent of total revenue.
- **Sales by Color vs. Monochrome:** 69.5 percent of all smart cameras sold in 2008 were monochrome; approximately one-third (30.5 percent) were color. In terms of revenue, monochrome smart cameras were 82.0 percent of sales; 18.0 percent were color. Importantly, the percent of color smart cameras has generally risen over the four-year period, nearly tripling from 10.3 percent of units in 2005 to 30.5 percent in 2008.

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The Typical Smart Camera Sold in 2008

The typical smart camera sold in 2008 was a monochrome, area scan unit with a frame rate of 60 fps that was housed in a single enclosure and used a CCD sensor, non-integrated lighting and an internal processor other than Pentium, DSP or PowerPC**.**

- **Sales by Processor Integration:** Most smart cameras sold in 2008 were enclosed units with an integrated processor. The percent of sales of smart cameras with this form factor was 80.0 percent in terms of units and 71.8 percent in terms of revenue. Only 19.8 percent of units sold, equating to 27.7 percent of total revenue, involved an external processor and therefore would be classified as an embedded vision processor or embedded vision computer.
- **Sales by Processor Type:** More than half of the smart cameras sold in 2008 employed something other than a Pentium, PowerPC or DSP; the “other” category accounted for 52.2 percent of total units sold or 37.8 percent of total revenue. By contrast, Pentium processors were hardly used. Importantly, DSP-based smart cameras constituted 22.0 percent of units sold and 17.9 percent of sales revenue in 2008. By contrast, PowerPC comprised 20.9 percent of units sold and 33.6 percent of sales revenue in 2008.
- **Sales by Processor Speed:** Smart cameras sold most frequently in 2008 had 32 bit processors.
- **Sales by Application:** Smart cameras continue to be used for a wide variety of applications, attesting to their great versatility in machine vision. Based on data collected for 2008, the most common application was mechanical and electronic assembly verification at 27.6 percent of units sold and 32.9 percent of total revenue. Both part recognition and surface flaw/cosmetic analysis followed at 11.6 percent of units sold with 8.2 and 24.6 percent of total revenue, respectively. As a portion of the total units sold, character recognition, part recognition, 2D symbol reading and surface flaw/cosmetic analysis have tended downward during the four-year period of 2005 through 2008. Conversely, mechanical/electronic assembly verification has grown as a percentage of total units sold.
- **Sales by Industry:** Smart cameras sold in 2008 were intended for use in a wide range of manufacturing and non-manufacturing industries. The five most important end-user industries in order of the number of units sold were electronics/electrical, semiconductor, food, pharmaceutical and automotive.
- **Sales by Type of Customer:** Smart camera suppliers typically sell their products to intermediaries in the distribution channel; i.e. resellers, distributors or value-added resellers (VARs). Of the total units sold in 2008, 64.1 percent went to these intermediaries, which accounted for 63.7 percent of total sales revenue earned by suppliers. Direct sales to end users accounted for 14.4 percent of units sold corresponding to 21.6 percent of total sales revenues, an increase over 2007. These results leave little doubt that most smart camera sales reach end users indirectly through distribution channels.

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12.4 Conclusions

The big surprise about smart cameras in 2008 was their rate of growth in total sales. In 2007, the rate of growth had been anemic. Based on the repeated, downward revisions of economic forecasts for 2008, there was every reason to believe that smart camera sales in that year would be even weaker than in 2007. But that is not what happened; the 2008 rate of growth was stronger than forecast. As a consequence of this, we have revised upward our longer-term sales forecast for this study. To be sure, we still expect a lower rate of growth in 2009 than in 2008, but according to our forecast, that growth rate should nevertheless be relatively healthy, in comparison to rates of growth of other MV product markets.

Of course, many unforeseen events could occur between now and the end of 2009 that would depress demand for smart camera products below our expectations. But if any MV product market is to do relatively well in 2009, it is smart cameras.

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Chapter 13: Third Party Machine Vision Software Market

13.0 What's New in this Chapter?

- 13.1 Introduction
- 13.1.3 Major Suppliers
- 13.2 Survey Results
- 13.3 Summary of Major Findings

13.1 Introduction

Software is a vital component of any machine vision (MV) system. Without software, hardware cannot be controlled to drive the image acquisition, processing and analysis functions of an MV system. MV software tools that process images make decision making easier by reducing or eliminating noise, enhancing recognition of significant features of an object and controlling unhelpful background information. Image processing techniques can involve pixel counting, thresholding, segmentation (including blob discovery and manipulation, recognition by components and pattern recognition), barcode reading, optical character recognition, gauging, edge detection and template matching.

MV software tools that perform image analysis make decisions for determining the location of objects, the identity of objects, robotic guidance, sorting, counting and accepting or rejecting the objects based on predetermined criteria.

Given the interdependence of hardware and software in an MV system, it is not surprising that software is frequently designed as a set of tools or routines for a specific manufacturer's hardware and offered on a bundled basis. However, in some cases the hardware supplier does not offer its own software. In these cases, software developed by a third party is used. In still other cases, the software provider might have originally developed software exclusively for its company's hardware and then subsequently decided to sell it separately on an unbundled, i.e. hardware-independent basis. (This is also considered third party software.)

13.1.1 Overview of the Third Party MV Software Market

As suggested by the previous section, third party software is non-bundled, "open system", hardware-independent software that is intended for use with equipment manufactured by multiple hardware suppliers. By contrast, all other MV software is designed to work primarily with the hardware of a single manufacturer of frame grabbers, general and application-specific MV systems or smart cameras, vision sensors or embedded vision processors.

We define the third party MV software market in terms of the product sales of third party MV software suppliers operating at the front end of the MV supply chain in accordance with the overall methodological approach of this study and past AIA MV market studies, as outlined in Chapter 2. Distributors and other market intermediaries are thus not included in this "front-end component" market.

The North American third party MV software market is relatively small in size as measured in terms of both sales volumes and the number of market participants. Expressed in revenue, sales volumes for third party MV software have varied from $18.3 million (USD) in 2004 to $20.3 million in 2008, reflecting a composite annual growth rate of 2.5 percent (see Exhibit 13.3 for more details). Within this market, suppliers are approximately twenty in number. In the following sections, we examine both products and participants of the third party MV software market.

13.1.2 Major Product Types and Features

Third party MV software packages are typically general purpose but vary in terms of programming language, operating system, development environment and the libraries they contain.

<u>Programming Language</u>

Different software packages utilize, or can accommodate, different programming languages. This is an important consideration for programmers, who typically prefer to work in the languages with which they are most familiar. Programming languages utilized by MV software packages include C, C++, Pascal and Visual Basic. Active X, Delphi, JavaScript, Microsoft's .Net command structure and other languages are also utilized.

<u>Operating System</u>

The MV software utilized must fit the operation system (OS) of the MV system. Major OSs available are 32-bit Windows, 32-bit Linux, 64-bit Windows, 64-bit Linux and Windows Server 64. 32-bit Windows suffers from a 1 gigabyte (GB) limitation on a single block of memory. This limitation can be surmounted with frame grabbers with large buffers but only up to 4 GB. However, 4 GB might not always suffice for demanding applications such as web inspection. While 64-bit OSs do not suffer from this limitation, many MV software packages have been written for the 32-bit environment. (Note: Changing to 64-bit would necessitate complete re-writes of software packages.)

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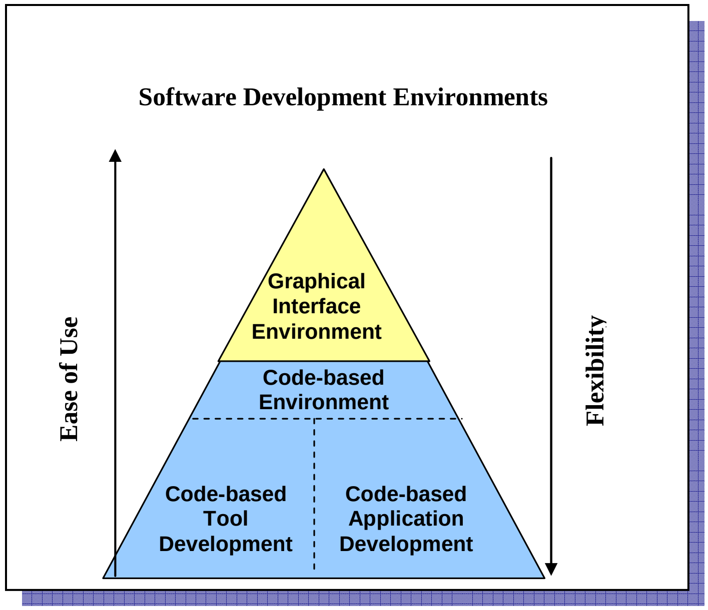
Development Environment



Some third party MV software packages provide a graphical user interface (GUI) to simplify programming. Other software packages are designed for the code-based environment where tools and application programming interfaces (APIs) are created using programming language. Still other packages accommodate both development environments. The obvious advantage of software designed for the graphical interface environment is ease of use and no requirement for programming expertise. By contrast, code-based software packages are harder to use but far more flexible, offering the opportunity to tailor specific routines to individual applications. Which type of software is used will depend on the expertise of the programmer and demands of the application.

Libraries

Third party software packages can also differ greatly in terms of their libraries of tools. Examples of typical libraries include color calibration and transformation; blob analysis; standard pattern matching and geometric pattern matching; edge detection; measurement and dimension control; and optical character inspection and verification.

13.1.3 Major Suppliers

Twenty suppliers of third party MV software (not including freeware providers) are shown in Exhibit 13.1.

Exhibit 13.1: Third Party MV Software Suppliers (Updated)

Amerinex Applied Imaging	Neurocheck
Adaptive Vision	MVTec
Amerinex Applied Imaging	Norpix
Braintech (Shafi)	RoboRealm
Cognex	STEMMER IMAGING Group
Data Translation	Tordivel
Euresys	VisionShape
Matrox	VisioMint
Mnemonics	VISIONx
National Instruments	Western Vision Software

Exhibit 13.2 identifies these suppliers in terms of their product brand name and product characteristics.

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Exhibit 13.2: Third Party MV Software Suppliers by Product Name and Product Characteristic (Updated)

Supplier	Product Brand Name	Robotic Guidance	General Purpose	GUI Enivron-ment	Code Environ-ment	Program-ming Language	Oper-ating System
Adaptive Vision	Adaptive Vision Studio and Adaptive Vision Express		■	■	■	C++	NA
Amerinex Applied Imaging	Aphelion		■	■	■	ActiveX	Windows, Linux
Braintech (Shafi)	eVisionFactory	■		■			NA
Cognex	VisionPro		■	■	■	Visual Basic, C#, managed C++	Windows
Data Translation	DT Vision Foundry		■	■	■	Microsoft Visual C++	Windows
Euresys	Open eVision, Open eVision Studio		■	■	■	C+++, . NET, ActiveX	Windows
Matrox	Matrox Imaging Library		■	■	■	Classic C/C++ , ActiveX	Windows
Mnemonics	ALIGN, BLOB, OCR		■	■		-	DOS, Windows
National Instruments	Vision Development Module, NI Vision Builder		■	■	■	NI LabView, NI LabWindow s,CVI, C/C++, Visual Basic	
NeuroCheck	NeuroCheck		■	■		-	Windows
MvTec	Halcon and ActiVTools		■	■	■	ActiveX, C and C++	Windows, Linux, UNIX
Norpix	StreamPix, Visilog 6		■	■		-	Windows
RoboRealm		■					Windoes
STEMMER IMAGING	Common Vision Blox		■		■	VB, Visual C++, Delphi	Windows
Tordivel	Scorpion		■	■		-	Windows
VisionShape	VisionX		■		■	VB 6.0, VB.Net, C#.Net, C++, JavaScript	NA
VisioMint	ViioMint		■	■	■	C++,Visual Basic, C#,Delphi	
VISIONx	VisionGauge		■	■			Windows
Western Vision Software	HLImage++		■	■	■	Visual C++	Windows

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It is interesting to note that most software products shown in Exhibit 13.2 are general purpose, and most contain a graphical user interface. The versatility and ease of use of many of these packages facilitate differentiation from closed system software packages.

13.1.4 Market Trends and Developments

Trends in the third party MV software market are largely driven by trends in MV equipment and computer hardware, including changes in operating systems and CPUs. For example, as cameras become higher-speed with faster shutter rates, larger files are generated, requiring higher bandwidth, greater memory and faster processing. Operating systems and CPUs must change to accommodate these needs, and with these changes, software products must also keep pace in order to continue to match the hardware for which they are designed. As previously mentioned, MV software will probably evolve from 32-bit to 64-bit not only to surmount memory limitations in Windows but also to work with the newer 64-bit operating systems. Independent of the needs of MV integrators and end users, CPUs continue to increase in speed with the end result that software must also evolve to reap the benefits of faster processing.

One processor-related trend we are beginning to see is software that takes advance of the parallel processing afforded by multi-core processors. Importantly, a two-core processor brings twice the processing capability and a four-core processor provides approximately 3.5 times the ability to process algorithms. But to realize this greater capability, software must be designed to divide tasks into sections that an individual core can process. Both National Instruments and MVTec say they are designing their software to do this.

Another trend is the transformation of “closed system” software into “open system” third party software. (For example, Cognex announced in 2008 that it would offer hardware-independent software.) In deciding to design and offer software as a truly open package (i.e. not only unbundled but also usable with the equipment of different hardware manufacturers), MV software companies must weigh the advantage of incremental revenues from software sales against the benefit of enhancing differentiation of the equipment and thus increasing revenue from equipment sales. This boils down to a strategic decision about the financial role of software as either an enhancer of equipment sales, or as a separate revenue stream, or both. (Where both roles are envisaged, the software is not bundled with the hardware and thus is sold separately but is designed only for one company’s hardware. This allows the supplier to target customers that desire a supplier’s hardware but not their software.) Still another possibility in the case of closed system software is to bundle it with equipment and not charge for it in order to stimulate equipment sales.

As suggested, an important and evident trend is the enhancement of software packages to support newer types of hardware. An example of this is the addition of supports for DirectShow 8.0 compatible FireWire and USB cameras. As new MV hardware options emerge, new tools must be added to software packages.

13.1.5 Major Characteristics of the Third Party MV Software Market

The third party MV software market in North America is a relatively small market with approximately twenty suppliers. Major characteristics of this market are as follows:

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- A market size of $20.3 million in 2008.
- A market growth rate of -1.9 percent in 2008 and an overall growth rate for the historical period of 2.5 percent.
- Hardware technology driven: Changes in the technology of MV and computer equipment (CPUs) are largely drive changes in MV software.

13.2 Survey Results

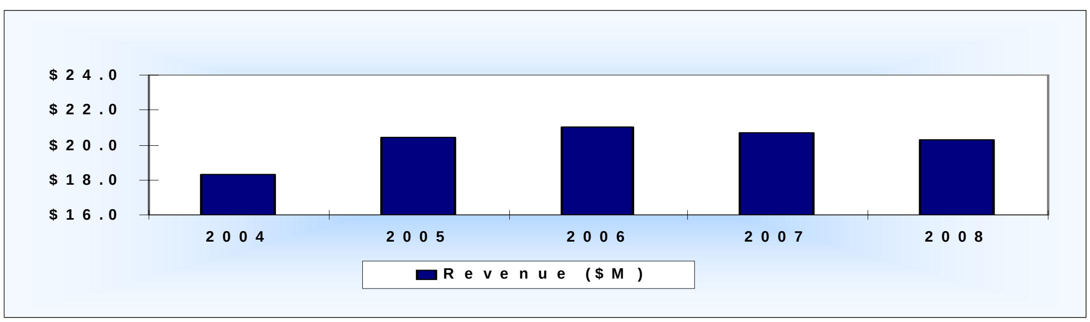
Expanding upon the information of the previous sections, we next examine the market in terms of sales volumes expressed in revenue. (We do not examine units sold due to their dissimilarity arising from the modular nature of many software packages. This precludes an examination of unit prices and pricing trends.) Our focus is the historical period of 2004 through 2008 and the forecast period of 2009 through 2013.

13.2.1 Historical Growth Patterns

As shown by Exhibit 13.3, the third party MV software market has increased in size from $18.3 million (USD) in 2004 to $20.3 million in 2008. The compound annual growth rate (CAGR) for this period was 2.5 percent. For 2008 only, revenue declined at a rate of -1.9 percent. (Revenue was essentially flat with little change between 2007 and 2008.)

Exhibit 13.3: Third Party MV Software Sales Revenue ($ Millions): 2004 - 2008

	Actual	Actual	Actual	Actual	Actual	
	2004	**2005**	**2006**	**2007**	**2008**	**CAGR**
Revenue ($M)	$18.3	$20.4	$21.0	$20.7	$20.3	-
%	37.6%	11.6%	2.8%	-1.6%	-1.9%	2.5%



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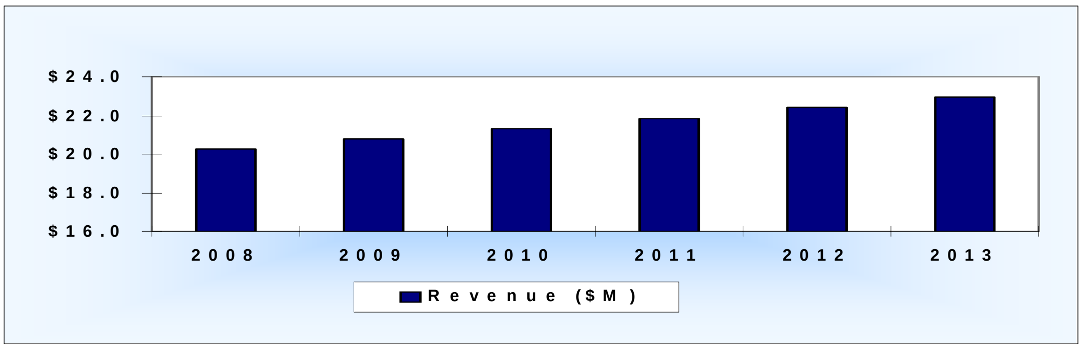
13.2.2 Forecasts

For the forecast period, we expect third party MV software sales revenue to increase from $20.3 million in 2008 to $22.9 million in 2013, reflecting a CAGR of 3.8 percent.

Exhibit 13.4: Forecast Third Party MV Software Sales Revenue ($ Millions)

	Actual 2008	Forecast 2009	Forecast 2010	Forecast 2011	Forecast 2012	Forecast 2013	CAGR
Revenue ($M)	$20.3	$19.7	$20.8	$21.9	$22.4	$22.9	-
%	-1.9%	-2.6%	5.4%	5.1%	2.4%	2.4%	3.8%



13.2.3 Total Sales Revenue by Major Product Feature

To increase our understanding of the third party MV software market, we next examine 2008 sales results by major product feature.

We first consider the type of hardware supported by third party MV software. As shown by Exhibit 13.5, the most widely supported type of hardware is the frame grabber. 76.0 percent of all hardware sales involved frame grabber support, followed by 14.6 percent for embedded vision processors, 4.5 percent for smart cameras and smart sensors and 4.9 percent for vision processor boards.

Overwhelmingly, third party MV software is also generalist in nature instead of application-specific. We see this clearly in Exhibit 13.6 where 75.0 percent of all sales involved general purpose software. Only 25.0 percent of total sales were application-specific.

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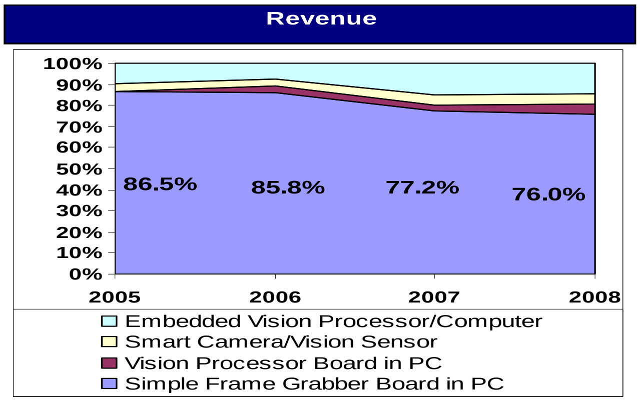
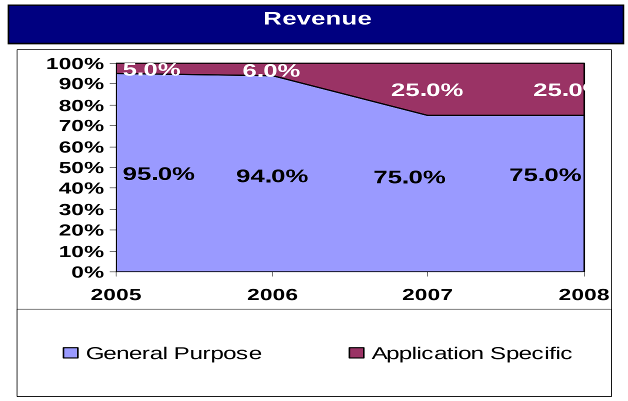
Exhibit 13.5: Percent Distribution of Third Party Software Sales by Type of MV Hardware Supported



	2005	2006	2007	2008
	Rev	Rev	Rev	Rev
Simple Frame Grabber Board	86.5%	85.8%	77.2%	76.0%
Vision Processor Board	0.0%	3.3%	3.1%	4.9%
Smart Camera/Vision Sens.	3.7%	3.3%	4.5%	4.5%
Embedded Vision Processor	9.8%	7.5%	15.2%	14.6%
Total	100%	100%	100%	100%

Exhibit 13.6: Percent Distribution of Third Party MV Software Sales by Type



	2005	2006	2007	2008
	Rev	Rev	Rev	Rev
General Purpose	95.0%	94.0%	75.0%	75.0%
Application Specific	5.0%	6.0%	25.0%	25.0%
Total	100.0%	100.0%	100.0%	100.0%

13.3 Summary of Major Findings

The major findings of this chapter are as follows:

- **Market Characteristics:** The third party MV software market in North America is relatively small in comparison to other MV markets in this region. Approximately twenty suppliers have competed in this market, which has been driven largely by changes in MV and computer hardware technology as well as the development of operating systems.
- **Historical Sales:** The third party MV software market increased in size from $18.3 million (USD) in 2004 to $20.3 million in 2008. The compound annual growth rate (CAGR) for this period was 2.5 percent. For 2008 only, revenue decreased at a rate of -1.9 percent. (Essentially, revenue was flat between 2007 and 2008.)
- **Forecast Sales:** Third party MV software sales revenues are expected to increase from $20.3 million in 2008 to $22.9 million in 2013, reflecting a CAGR of 3.8 percent.

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- **Sales by Type of Hardware Supported:** The most common type of hardware supported by software in 2008 was the frame grabber. 76 percent of all hardware sales involved frame grabber support, followed by 14.6 percent for embedded vision processors, and 4.9 percent for vision processor boards and 4.5 percent for smart cameras and vision sensors.
- **Sales by Generalist vs. Application-Specific:** Third party MV software sales were generalist in nature instead of application-specific. 75 percent of all sales in 2007 involved general purpose software. Only 25 percent of total sales were application-specific.

13.4 Conclusions

Beyond its functional role as an essential component of any MV system, third party MV software also plays an important marketing role for a MV system provider. It represents an important means of adding value to, and differentiating an MV system from, other MV systems. An MV software package that has a wide array of image processing and analysis capabilities, while providing a choice between a graphical interface for user-friendliness and code-based programming for versatility, is particularly valuable and can be targeted to multiple market segments. If users can purchase the package on a module-by-module basis to save money, it is additionally valuable.

Going forward, third party MV software will continue its important functional and marketing roles. At the same time, it will evolve in response to the needs of MV system builders and to the evolution of operating systems and computer hardware. The developmental direction of processors will be of particular importance in this regard.

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Chapter 14: 3D Machine Vision

14.0 What's New in this Chapter?
This is a new chapter consisting in part of the following entirely new sections:

- 14.2 The 3D Value Proposition
- 14.2.5 Performance Criteria
- 14.2.7 Drivers of Market Adoption
- 14.2.8 3D MV Trends
- 14.2.9 Challenges to Market Adoption
- 14.3 The Future of 3D Machine Vision

14.1 Introduction
In this chapter we consider the important role played by 3D MV systems. We begin by considering the 3D MV value proposition and the differences between 3D and 2D MV systems. We then outline the various technologies that enable 3D imaging and list the many important applications supported by 3D MV systems. We next identify performance criteria and the individual suppliers of 3D systems. As a backdrop to our 3D MV system sales forecast, we next discuss the drivers of market adoption, 3D MV trends and challenges to market adoption. We then examine 3D smart cameras and close the chapter with some forward looking comments about the future of 3D machine vision.

14.2 The 3D MV Value Proposition
Why 3D instead of 2D machine vision? This is the essential issue that suppliers of 3D MV systems must address in selling their products. By definition, 3D MV promises greater accuracy in image acquisition, since - in contrast to 2D machine vision - 3D MV systems acquire images not just along the X and Y axis…. but also based on the Z axis (height). As Genex Technologies points out, "Traditional 2D inspection systems can provide excellent edge and point-to-point measurements but lack the ability to accurately characterize a product's full dimensions and shape. 3D systems…can measure volume,

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surface area and 3D deformations (and in so doing can) … help solve complex quality control problems and enable a more robust and accurate inspection process." 3D systems also enable contrast-independent inspection.

Image acquisition that includes a third axis enables a long list of applications that cannot be performed as well or at all by 2D machine vision. As will be seen, 3D MV systems can improve the precision of inspections and thus the quality of products by measuring height, where it is a dimension critical to the performance or reliability of a manufactured item. 3D MV systems are also indispensable where a robotic operation must be guided through three dimensional space. 3D MV systems also enable high-speed, accurate metrology and support reverse engineering.

To make the case for 3D MV systems, it is necessary to show that the benefits afforded by 3D MV systems outweigh the cost differential between 2D and 3D. 3D MV systems are typically more expensive than 2D MV systems. While the cost of 3D MV systems is declining and the performance of these systems is increasing, 2D MV systems are also benefiting from the same underlying trends. This suggests that 3D MV systems will probably never completely supplant 2D MV systems, but only time will tell.

It should be noted that 3D MV systems do not just compete with 2D MV systems but also with techniques that do not utilize machine vision at all. In metrology, for example, CMMs (coordinate measuring machines) use probes that physically contact the object to be measured for purposes of recording discrete points along its surface that are fed into a computer CAD program. 3D MV systems are faster and more accurate; their value proposition thus includes speed and accuracy.

In specific terms, the value proposition of individual 3D MV products will be largely a function of meeting essential performance criteria. (See section 14.2.5.)

14.2.1 3D Machine Vision Systems

Typically used today in low or no contrast applications and where height and thickness must be determined, non-contact 3D systems were originally assembled by a group of University of Michigan researchers. Since then, they have assumed an important role in machine vision, enabled largely by faster processor speeds, improved sensor technology and lower component costs; and driven in demand primarily by the need for faster speed than possible with contact measurements and for more accurate inspections.

14.2.2 Overview of 3D Vision Systems

3D vision systems can be defined in terms of their basic difference from 2D systems. In addition to the "X" and "Y" dimensions of 2D systems, 3D systems measure height (the Z-axis). 3D devices used in machine vision include 3D smart cameras, 3D sensors and 3D scanners. Importantly, all of these devices are non-contact and optical in nature in contrast to contact 3D devices such as CMMs used in metrology.

3D devices are used to create a *point cloud* of geometric samples on the surface of an object. At each point, the scanner collects information on the distance to the surface of

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the object. Typically, multiple scans are taken from different directions and then aligned and merged to create a complete data model of the object.

There are two types of non-contact 3D scanners: *active* and *passive*. Active scanners, which are used in machine vision, emit some form of radiation and detect the reflection of that radiation to measure height. Active scanners are, in turn, of two types: *time-of-flight* and *triangulation*. Both types of active scanners typically use laser light but in different ways. A time-of-flight 3D laser scanner determines distances to the object's surface by timing the round-trip of a light pulse. By contrast, a 3D triangulation laser scanner uses the location of a laser dot upon an object's surface that is imaged by a camera to measure distance. (See next section.)

14.2.3 Approaches to 3D Imaging

As suggested, there are different approaches to 3D imaging, including laser radar, triangulation, structured light, interferometry and photogrammetry.

<u>Laser Radar</u>

Laser radar (a.k.a. laser imaging detection and ranging, "LIDAR") is an approach based on time-of-flight, wherein laser light is used in place of RF radiation. This approach is deployed primarily by the military and scientists in various fields, but can also be used to image large objects in industry.

<u>Laser Triangulation</u>

Laser triangulation is an approach wherein a low power laser mounted on an x-y translation table fires a laser beam in a series of pulses to cover an object with a blanket of laser dots. For each dot, the system calculates an x,y,z coordinate in 3D space using known information about the triangles formed by the laser light emitter, camera and the various laser dots.

<u>Structured Light</u>

Structured light is a technique that projects a light pattern (such as a sheet of light) at a known angle onto an object. This projection produces a bright line of light on the surface of the object, which - when viewed from an angle - can be translated into height variations. Some systems project a grating pattern onto an object and extract x,y,z coordinates from the resultant, deformed grating pattern. Both laser light and white light can be used in this approach.

<u>Interferometry</u>

This approach involves splitting a beam of light into two, with one beam going to the object being imaged and the other beam directed to an internal reference surface. The two beams are then recombined, undergoing constructive and destructive interference and producing a pattern of bright and dark lines. A camera then generates a 3D *interogram* of the object, which is transformed into a quantitative 3D image. Several different types of interferometry are used in machine vision, including *moiré interferometry, phase shift interferometry* and *accordion fringe interferometry*.

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Photogrammetry

In this approach, cameras produce an image of an object from which measurements are taken. *Stereo photogrammetry* uses two cameras for each region of interest (ROI) of an object where each camera is positioned differently.

14.2.4 Major 3D Applications

3D systems have four generic machine vision applications:

- Inspection
- Robotic guidance
- Metrology
- Reverse engineering (The disassembly of products to learn their design dimensions and principles.)

3D systems used for *inspection* of objects can detect surface characteristics of low contrast objects as well as the height and thickness of objects, which can be critical in sorting and screening for quality control, as well as operational control in general. In the case of *robotic guidance*, 3D systems allow robots to find objects in 3D space and to adjust their paths accordingly.

The most widely used generic application, however, is *metrology*. 3D systems are much faster than contact approaches such as CMM, which generate measurement data very slowly and require extensive operator training for both set up and operation.

In the case of *reverse engineering*, 3D data from an imaged object is used to create a CAD (computer assisted design) model of the object, which in turn is utilized in the digital design process or utilized directly for creating CNC (computer numerically controlled) tool paths.

A wide range of more specific 3D applications are found in major industries. An overview of some better known applications follows.

Electronics

In the electronics industry, 3D applications include *solder paste inspections, inspections for preloaded board warpage* and *inspections of wire bonds*.

Solder paste inspection is the biggest 3D application in electronics. These inspections measure the volume, height, coverage and position of the solder paste before component placement. As interconnect densities increase and surface mount components decrease in size, solder paste inspections have grown in importance.

3D inspections are also performed to detect *preloaded board warpage*; that is, inspection of PCBs (printed circuit boards) to verify flatness before *SMDs* (surface mounted devices) are placed on the boards.

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Wire bond inspection is also necessary to insure the absence of substrate, package and assembly warpage, semiconductor chip-carrier flatness and *coplanarity* (no bent legs or pins, which result in open circuits).

<u>Semiconductor</u>
3D applications in the semiconductor industry include:

- Measuring the height of each and every solder bump across an entire *flip chip wafer* (a wafer mounted without wire bonds).
- Verifying coplanarity of leads of semiconductors.
- 3D metrology and defect detection to verify the dimensional and cosmetic integrity of wafers.
- Inspection of fully assembled packages and sockets. 3D based MV techniques can be used for *BGA*[1] (*ball grid array)* inspection and *CSP*[2] *(chip scale packaging)* inspection.
- Inspection of the height, shape and existence of *solder paste balls* (the splatter resulting from *beading).*

Of these applications, the most widely used is *co-planarity measurements on leaded IC packages*.

<u>Wood</u>
3D scanning of wood is fairly established today especially in primary breakdown, curve sawing, cant and edger operations. Because 3D scanners can better handle “out of round” (oblong) logs, they can optimize value by getting the best recovery in terms of straightness, reduced wane (missing wood) and visual defects (knots, slits, etc.) This increase in recovery can cost-justify the higher cost of 3D scanners over 2D scanners in most operations, with the possible exceptions of bucking and pre-sorting.

<u>Automotive</u>
3D scanners are utilized for a number of applications in the automotive industry including:

- Inspection of stamped sheet metal (3D inspection is especially important in curvature areas of stamped sheet metal where small surface defects can seriously damage the quality of the overall surface).
- Inspection of castings, plastics, foam and glass
- Inspection of body assembly
- Large body welding inspection
- Prototyping (information gained from 3D scanning can be used to create CAD models from finished parts or models for prototyping)
- Robotic guidance

[1] *BGA* is a type of memory chip package that is directly mounted to the module by solder balls found on the underside of the chip.
[2] *CSP* is a style of integrated circuit package that has no pins or wires but uses contact pads.

- Control/monitoring of foundry operations such as the pouring of molten metal

Food
In the food industry, 3D scanners are utilized to optimize food production processes including:

- Backing and cooking inspection for quality assurance (misshapen food products are identified and rejected)
- Protein portioning (insuring proper portions of food products)

It should be noted that the thickness of food items, such as cookies, are essential to proper packaging, while in the case of other food items, such as meat, 3D inspection of thickness can insure proper proportioning.

Transportation
In the transportation industry, 3D MV systems have been employed in the high-speed monitoring of highway surface conditions.

Glass
3D applications include:

- Glass thickness measurement
- Cosmetic inspection

Container
In the container industry, 3D applications include:

- Inspection of labels on round bottles.

Pharmaceutical
3D applications in this industry include:

- Inspection of blister and fill levels

Packaging
In the packaging industry, 3D inspection technology is used for:

- Confirmation of the integrity of boxes

Other Industries

- Inspection of turbine blades

The many applications served by 3D MV technology clearly illustrate the growing importance of 3D MV systems.

14.2.5 Performance Criteria
The performance criteria of 3D MV systems vary somewhat by application. However, typical performance criteria include accuracy, repeatability (consistency), speed (throughput), ease of use, robustness, ease of integration in in-line systems and cost.

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14.2.6 3D MV System Suppliers

Approximately 54 companies are suppliers of 3D MV systems in North America, as shown by Exhibit 14.1. This large number of suppliers is indicative of the important role played by 3D MV technologies in the market today.

Exhibit 14.1: 3D MV System Suppliers

3D Digital	Faro	Optimet
3DM Devices	Genex Technologies	Opton
4D Technology	Geodetic Services	Perceptron
Aceris 3D Technology	ICOS Vision Systems	Point Grey Research
ASC International	INO	QMC
August Technology	Inspeck	RVSI
Automated Precision	Konica Minolta	Scanner Technology
Basis Software	Kreon	ServoRobot
Capture 3D/GOM	Laser Design	ShapeGrabber
Cognitens	LMI Technologies	SICK | IVP
Coherix	Marel	Solarius Development
Corning/Tropel	Meta Vision Systems	Solvision
Cyber Technologies	Metris	Steinbichler
Cyberware	Metron Systems	Tamar Technology
Datapixel	Metronor	Taylor Hobson
Dimensional Photonics	Neptec Design	Veeco
Direct Optical Research	Nextec	VX Technologies
Eyetronics	Nvision	Zygo

14.2.7 Drivers of Market Adoption

What accounts for the increasing sales of 3D MV systems? Demand for 3D MV systems is being driven by several factors. First, the basic demand drivers for machine vision as a whole must be mentioned. These are:

- The need for increased product quality: Marketplace competition is necessitating increases in product quality and reliability, which require precise inspection of manufactured goods and other goods (such as agricultural produce).
- The need for cost efficiency in production and processing of goods: Machine vision enables high-speed inspection that is not only more accurate but also less expensive than manual inspection and sorting.

Second, the deployment of robots that use vision guidance to perform a growing number of increasingly difficult tasks. (This is also driven by marketplace competition.)

Third and lastly, as a further manifestation of marketplace competition, competitors are analyzing and learning from each others' products by means of reverse engineering that is enabled by 3D machine vision.

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However, none of this is to suggest that the increased market penetration of 3D MV systems is automatic or pre-ordained; although favored by various trends, increased penetration requires success in overcoming various challenges that present themselves in the sales process. In the two sections that follow, we first list the trends that boost 3D MV system sales and then the challenges that, if not met, can depress sales.

14.2.8 3D MV Trends

A number of technological and market-related trends are key to understanding the growing acceptance of 3-D machine vision.

Technological Trends

3D MV systems are benefiting from the very same technological trends that are increasing the value of machine vision as a whole. These include faster processors, faster computer busses, digital cameras with higher resolution and frames per second (speed) and greater memory storage. At the same time, sub-components are becoming more powerful, they are also becoming less expensive, resulting in more performance per dollar.

Market Trends

The growing need to assure greater product quality and reliability by not just inspecting a small sample of manufactured or processed products in a batch or lot, but instead a large sample of all products that requires an automated inspection process with a high throughput. Especially, in the case of products where safety (as in MEMS manufacturing for air bags) or an unexceptional flawless performance is required (such as in electronics and semiconductors), the mode of inspection must not only be capable of great precision but also speed. (Accuracy and speed cannot be trade-offs.) It is for this reason that 3D MV-based metrology will eventually supplant CMMs.

A growing reliance on high-speed parts handling in the automotive, electronics and other industries is also a trend of note.

14.2.9 Challenges to Market Adoption

The increased adoption of 3D machine vision is, however, not automatic. It is the sum total of many sales victories in the marketplace, where 3D MV companies convince customers of the value proposition of their products. Three very important purchase decision criteria that 3D MV companies must successfully address are:

- Ease of use (3D MV systems are not always user friendly.)
- Cost (3D MV systems tend to be more expensive than other alternatives.)
- Performance (discussed in section 14.2.5)

14.2.10 3D System Forecasts

Given the importance of 3D systems, we would expect an upward trajectory in sales volumes. That is exactly what we find, as shown by Exhibit 14.2.

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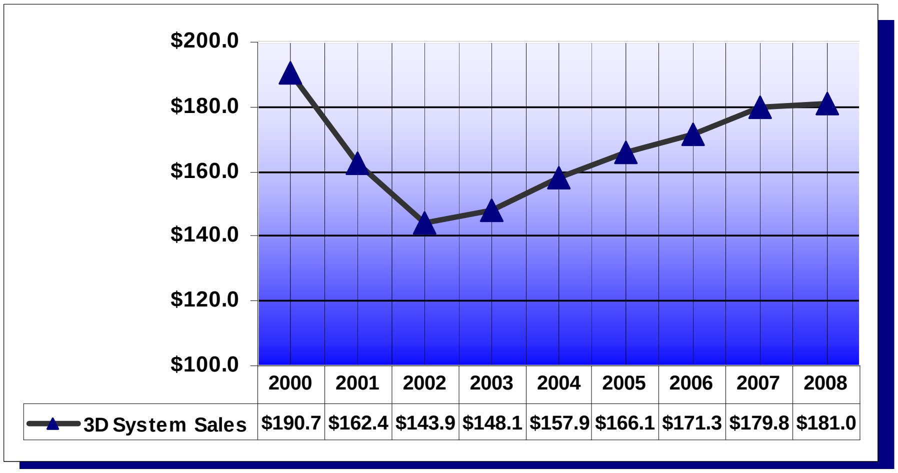
Exhibit 14.2: Estimated 3D MV System Sales ($ Millions)



Based on our data, approximately 13 to 15 percent of total ASMV system sales have been 3D. The remainder is 2D sales. Going forward, we would expect 3D sales to remain relatively healthy, since 3D systems perform unique applications that 2D systems cannot equally support.

14.2.11 3D Smart Cameras

ASMV systems are not the only type of machine vision system that utilizes 3D imaging. Smart cameras also offer this capability. In April of 2005, SICK|IVP announced the introduction of what it called "the world's first 3D smart camera", the IVC-3D. This product integrates laser optics into the unit's housing in order to provide "a stable and uniform geometry between the illumination and the camera". It operates by projecting a line of laser light upon an object, the reflection of which is evaluated using triangulation. A 3D image is created by combining up to "5,000 profile sections per second". According to the company, the IVC-3D can be used in the food and packaging industry, industrial production, robot and handling systems and in other areas. It has been reported that the IVC-3D costs approximately $14,000 USD in single quantities.

14.3 The Future of 3D Machine Vision

The future of 3D machine vision is bright. 3D MV systems have demonstrated their capabilities and serve a number of important applications. The performance of 3D MV systems has moreover improved; however, additional progress is needed in reducing costs and increasing user friendliness. As this progress is made, the value proposition of 3D machine vision will increase and with it the extent of market penetration. When this occurs, 3D MV products will no longer be niche offerings but instead very much "main stream" in the overall ASMV market.

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Chapter 15:
Machine Vision in MEMS Production –

New Market Opportunity Assessment

15.0 What's New in this Chapter?
This is an all-new chapter.

15.1 Introduction
MEMS (Micro Electro Mechanical Systems) represent an exciting, new technological development that combines microelectronics with tiny mechanical devices such as sensors, valves, mirrors, gears and actuators embedded in semiconductor chips. Not merely a futuristic vision but already a fact, MEMS are being used in various industries ranging from automobiles to medical devices. They are found today in widely used devices such as computer hard drives, inkjet printers, airbags and pacemakers. Over time, MEMS promises to revolutionize nearly every product category by bringing together silicon-based microelectronics with micromachining technology, making products "smart". This greater intelligence stems from the enhanced perception and control capabilities of microsensors and microactuators, which in turn are enabling a new generation of product designs and applications.

Not surprisingly, the MEMS market is growing by leaps and bounds. For both revenue and units, most market researchers forecast double-digit growth. At the same time, however, some uncertainty surrounds this market, which could constrain the degree of growth. For one thing, there is no single fabrication process or limited range of materials used in production. Rather, MEMS make use of multiple technologies and materials, which limits the efficiencies otherwise obtainable in production. MEMS fabrication processes are also in need of reliable, efficient inspection capabilities. That, as we shall see, is where machine vision comes into the picture. However, to realize this important

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market opportunity, machine vision must overcome a number of challenges and the MEMS industry itself must evolve in its strategic focus.

In this chapter, we assess the overall market opportunity for machine vision in the MEMS industry. To do so, we begin by further defining MEMS, examining the development of MEMS, where they are used, how they work and how they are made. We also consider the MEMS market and the future of MEMS. Within this context, we then focus on the role of machine vision and the corresponding market opportunity.

15.1.1 Definition

Sometimes referred to as Microsystems (abbreviated MST), MEMS (micro-electromechanical systems) is a micro fabrication technology that combines computers with tiny mechanical devices such as sensors, valves, gears, mirrors, and actuators embedded in semiconductor chips. (Optical sensors, such as multipixel CCD or CMOS camera chips, are usually omitted.) In terms of functions, MEMS devices typically perform sensing, processing and/or actuating functions. They process information, decide on a course of action and initiate some action to control the surrounding environment. This in turn not only enhances product affordability but also functionality and performance. Importantly, MEMS are expected to enable the development of "smart" products, particularly within the automobile, scientific, consumer goods, defense and medical industries.

15.1.2 Origin of MEMS

The commercial development of MEMs has thus far followed four stages. The *first* stage started in the late 1970s and early 1980s with bulk-etched silicon structures and back-etched membranes, which were used to make pressure sensors.

The *second* stage occurred in the 1990s and centered around the emergence of PCs and information technology. During this time, video projection based on electrostatically actuated tilting micromirror arrays and the thermally operated inkjet print head were introduced to the market.

The *third* stage began with the large scale deployment of fiber optic cable by telecommunications companies at the turn of the millennium. MEMS were used for all-optical switches and related devices, which are still in the developmental stage.

With the continuing evolution of MEMS, a *fourth* stage is expected. Applications that might emerge in this stage include biological and neural probes, lab-on-a-chip biochemical and drug development systems, microscale drug-delivery systems, static and moving devices for radio frequency passive components and silicon-based audio.

However, for MEMS to realize its true potential, increased efficiencies in production must be realized, in support of which machine vision promises to play a major role.

15.1.3 MEMS Applications

A number of MEMS applications (some of which have already been mentioned) are already touching many lives. PC hard drive read-write heads, for example, are based on

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MEMS technology. Inkjet print heads also utilize MEMS devices. In our cars, air bags utilize MEMS-based accelerometers to protect lives in the event of an accident. Other common MEMS applications include disposable blood pressure sensing, automotive ECU pressure sensing and bathroom scales' strain gauge. Applications that are not as common but might greatly increase in demand are miniature robots, microengines, locks, inertial sensors, microtransmissions, micromirrors, micro actuators, optical scanners, fluid pumps, transducers, and chemical, pressure and flow sensors.

As this suggests, MEMS applications are used in a number of industries, most notably, personal computers and the automotive sector. In the personal computer industry, inkjet print heads contribute greatly to overall MEMS revenue, with five companies in the top 10: HP, Canon, Lexmark, Seiko and STMicroelectronics (a major foundry partner to HP). In terms of overall MEMS revenue, the automotive sector is next in importance, with Bosch leading the pack. Other industries using MEMS include telecommunications (fiber optic switches) and defense (weapons guidance).

Importantly, the list of MEMS applications is expanding. In part, this stems from the use of MEMS in the miniaturization and integration of conventional devices. These new devices can sense, control, and activate mechanical processes on the micro scale, and function individually or in arrays to generate effects on the macro scale.

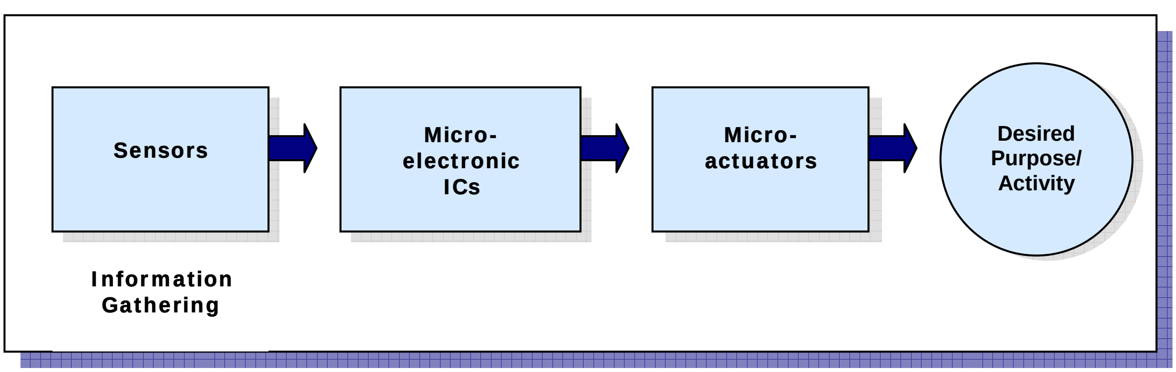
New applications that are expected to enter the market include silicon microphones, energy harvesting systems, auto focus, micro zoom and micro motors.

15.1.4 How Do MEMS Work?

MEMS provide the "eyes" and "arms" of micro-systems, enabling them to sense and control the environment. Sensors embedded in MEMS devices gather information from the environment with mechanical, thermal, biological, chemical, optical, and magnetic measurements. The micro-electronic ICs then process the sensory information, directing the actuators to respond by moving, positioning, regulating, pumping, and filtering in order to control the environment for some desired outcome or purpose.

The three essential functions of a MEMS device are depicted by Exhibit 15.1.

Exhibit 15.1: The Functional Operation of MEMS Devices



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15.1.5 Fabrication Technologies and Processes

IC (integrated circuit) fabrication technology is the primary enabling technology for MEMS development, where a silicon substrate is used. Accordingly, MEMS fabrication technology must be seen largely as an outgrowth of IC fabrication technology.

Also known as “micro-fabrication”, IC fabrication involves a series of steps (depending upon the type of IC’s manufactured). These steps are:

- Doping (application of trace amounts of other chemicals to change the conducive properties of silicon)
- Lithography (application, hardening and removal of a photo-resist upon the surface of a silicon wafer to define a pattern)
- Etching (selectively removing unwanted material from the surface of the wafer)
- Dicing (creating IC chips from a wafer)
- Packaging (encapsulation of individual IC chips)

However, not all MEMS devices utilize a silicon substrate, particularly in the biological and medical areas, where glass and plastics are often preferred. In these cases, the manufacturing processes depart from traditional electronics manufacturing.

Where the substrate does consist of silicon, several fabrication technologies (or techniques) are used to manufacture MEMS devices, an overview of which is provided by Exhibit 15.2.

Exhibit 15.2: An Overview of MEMS Fabrication Technologies

Fabrication Technology	Description
Surface micromachining	An additive technique, involving the building of the MEMS device on top of the supportive substrate.
Bulk micromachining	A subtractive technique which converts the substrate into the mechanical parts of the MEMS device. An extension of IC technology for the fabrication of 3D structures.
Deep reactive ion etching (DRIE)	A technique where chemically active ions are accelerated along electric field lines to meet a substrate perpendicular to its surface.
Substrate bonding	The binding together of silicon, glass, metal and polymeric substrates through a variety of processes including fusion, anodic, eutectic and adhesive bonding.
Plastic molding with PDMS	A process where PDMS (Polydimethylsiloxane), a transparent elastomer, is poured over a mold, polymerized, and then removed by peeling it off of the mold substrate.
Micromolding	A process similar to traditional injection molding that allows manufacturers to produce tiny parts.

Of these fabrication technologies, surface micromachining and bulk micromachining are the most widely used.

- *Surface Micromachining* involves building the device on top the surface of the supporting substrate where an anchor and sacrificial layer are first added to the substrate. A structural layer is then added, and the sacrificial layer is etched away, leaving behind the mechanical portion of the MEMS device.

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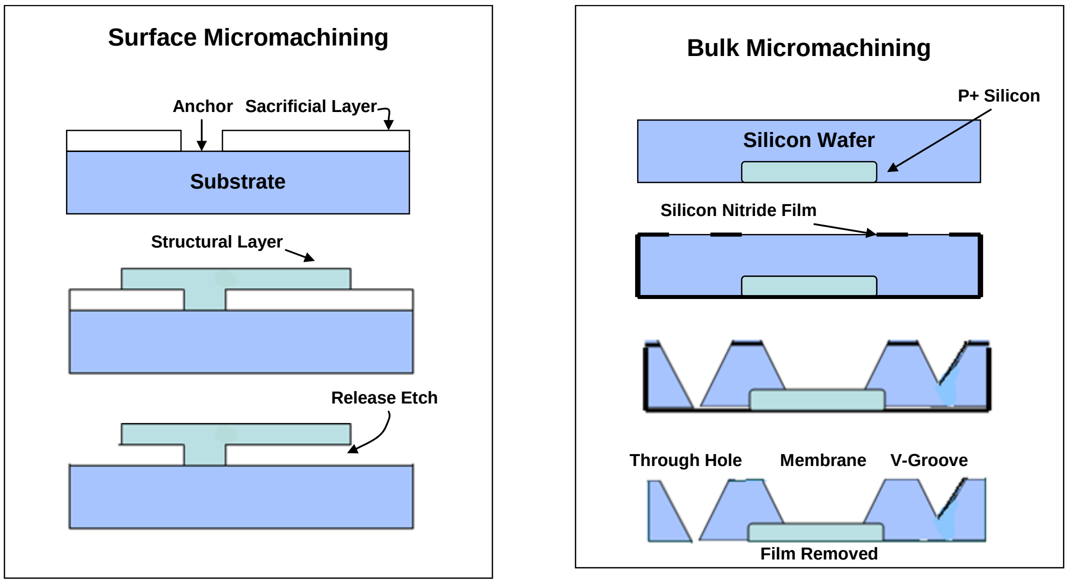
- *Bulk micromachining* is a process that etches micromechanical devices from the Si substrate in conjunction with etch masks and etch stops. As such, it is an extension of IC technology for the fabrication of 3D structures.

Both technologies are depicted in Exhibit 15.3.

Exhibit 15.3: Surface Micromachining and Bulk Micromachining



Based on diagram of Jack W, Judy, "Biomedical Applications of MEMS"

15.1.6 The Future of MEMS

If current market ambiguities are resolved, there is every reason to expect a bright future for MEMs. In fact, MEMs could well transform everyday life (to an extent similar to the personal computer), as manufacturers increasingly embed MEMS devices in larger, non-MEMS products. This trend, if manifested, would mean the emergence of new, indispensible "smart" products for home and work. Should that happen, the future of MEMS devices would be very bright indeed.

However, this future is far from assured. Presupposing it is market clarity, of which precious little presently exists. Ambiguity in the MEMS market derives from the fact that winners and losers in the market await selection; hundreds of MEMS ideas on scores of process technologies and packaging solutions are vying for market acceptance; relatively few of which have been selected. Surface micromachining and bulk micromachining might be the two most common fabrication technologies, but they are not the only ones, as we have noted. Moreover, a lack of standardization in MEMS fabrication adds to market ambiguity. Finally, the MEMS industry is highly diffuse and fragmented in its focus, by virtue of the fact that it is spread over many, diverse industries and involves sundry applications.

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All this raises issues about where and in what to invest. This is important, because each of the basic fabrication technologies mentioned employs a different set of capital and intellectual resources, which force serious strategic trade-offs in decision-making. MEMS manufacturing firms must in effect bet their futures when deciding in which technologies to invest.

It is also not yet clear from where the major breakthroughs will come. While most industry observers see a favorable future for MEMS-based products, some think the most successful applications will come from agile and innovative start-ups, while others argue that only the largest companies have deep enough pockets to ambitiously pursue the development of new MEMS applications. Who is right?

Some industry observers are also predicting that advancements in MEMS will come from a number of different countries. The United States will continue to play an important role, as will Europe. Taiwan and China may also repeat in MEMS the success that they have achieved in the world of microelectronics manufacturing. Which countries and regions will win this competition?

In discussing the future of MEMS, we must also consider the relationship of MEMS to NEMS (Nano-Electro-Mechanical-Systems), a technology similar to MEMS but operating on the nano instead of the micrometer scale. Some industry observers believe that, assuming higher levels of electronic-mechanical integration, MEMS will eventually shrink in scale, approaching the nano level, and thus giving rise to a MEMS - NEMS convergence. It is of course not clear at which point this will happen, but - if it does happen - it probably is many years into the future.

All of this of course assumes a high level of precision in production and an effective inspection capability to insure it. Accordingly, the future of MEMS will depend heavily on the ability of machine vision to assure quality in the manufacture of MEMS devices. At the same time, the market opportunity of MV companies will in turn depend upon the willingness of MEMS manufacturers to deploy machine vision.

15.2 The MEMS Market

To complete our discussion of the future of MEMS, it is helpful to examine the forecasts of leading market research firms that are tracking the MEMS market. These firms include In-Stat MDR, Venture Development, BCC Research and Yole Développement. To gain a clearer picture of the MEMS market in terms of units sold and the associated revenue, we have prepared a composite forecast that utilizes the forecasts of these research firms. According to the composite forecast (as plotted in Exhibit 15.4), units sold are expected to rise from 0.6 billion (600 million) in 2002 to 15 billion in 2013. During that same period, revenue from sales is forecast to grow from $3 billion to $15 billion. In terms of market growth, the forecast compound average growth rate (CAGR) is 25.7% for units and 15.8% for revenue. (Note: The revenue CAGR is lower than the unit CAGR due to an anticipated decrease in unit prices.)

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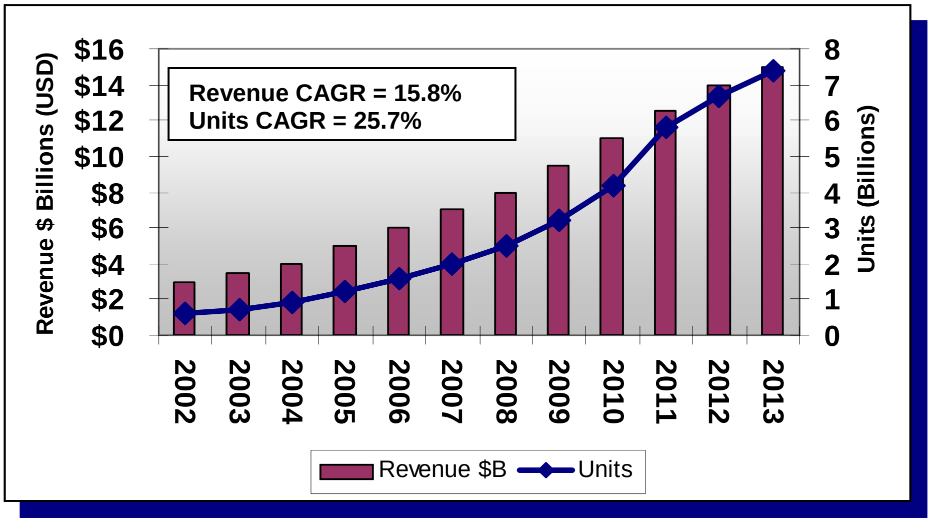
Exhibit 15.4: Estimated Global MEMS Device Sales (Revenue and Units)



It is also helpful to examine growth projections by major field of application, of which there are seven: automotive, aeronautics, consumer, defense, industrial, medical and life science, and telecom. According to Yole Développement, automotive applications will see modest growth rates of 3.5% over 2007-2012. On the other hand, medical and life science, consumer and (wireless) telecommunications will contribute to growth of the MEMS market after 2010, with growth rates of 18%, 11% and 40%, respectively. In 2012, consumer applications, including inkjet heads, inertial MEMS, micro displays and emerging MEMS devices such as energy harvesting systems, auto focus, micro zoom, and micro motors, will be more than 40% of the total market in value. "One interesting fact is that a strong growth [21%] for defense is also happening due to the use of high-value inertial MEMS for munitions guidance for instance."

15.2.1 MEMS Companies

The MEMS market can also be examined in terms of companies that produce and sell MEMS devices. Many of the largest of these companies are big chip manufacturers. Their interest in MEMS is making an increased margin on older process technologies and wafer fabs that have been fully amortized by years of manufacture. For these companies, the trailing edge of microelectronics is the leading edge of silicon MEMS manufacture. The top 30 MEMS companies are listed in Exhibit 15.5.

Exhibit 15.5: Top 30 MEMS Companies

Analog Devices	Freescale Semiconductor	Omron
Avago Technologies	GE Sensing	Panasonic
Boehringer Ingelheim Microparts	Hewlett Packard	Robert Bosch
Canon	Honeywell	Seiko Epson
Colibrys	Infineon Technologies	Silicon Sensing Systems
Continental Automotive	Knowles Electronics	Stmicroelectronics
Delphi	Lexmark	Systron Donner
Denso	Measurement Specialists Inc.	Texas Instruments
Flir Systems	Murata	ULIS
Formfactor	Olivetti-Jet	VTI Technologies

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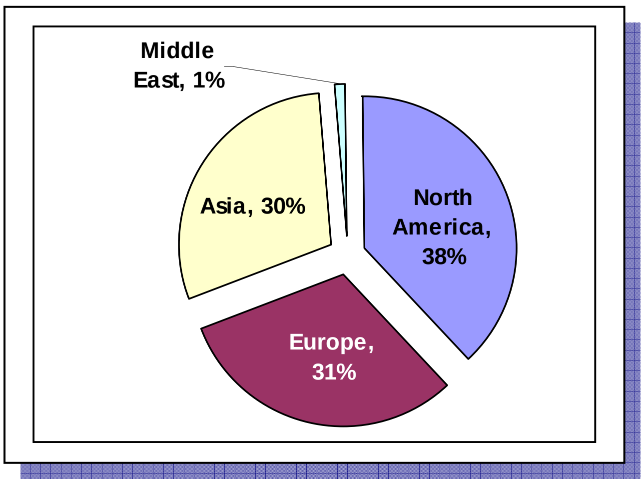
Also important are the MEMS foundries, the 10 largest of which are shown in Exhibit 15.6. Most of these foundries are found in North America, Europe and Asia, as shown by Exhibit 15.7.

Exhibit 15.6: Largest 10 MEMS Foundries

APM	Micralyne
Colibrys	Silex
DALSA Semiconductor	TMT
IMT	Tronic's
Memscap	X-Fab

Source: www.wtc-consult.de

Exhibit 15.7: Geographic Breakdown of MEMS Fabs



Source: Yole Développement

15.3 Machine Vision in MEMS Production

As previously mentioned, we believe that a strong uptake in MEMS devices presupposes efficient quality inspection, which requires the deployment of machine vision systems in MEMS production. The reason for this is simple. Only machine vision offers the capability to efficiently inspect MEMS devices at various points in the production process, particularly at the preproduction stage or front end of production, where early detection of failed devices can prevent unnecessary costs and increases in production cycles and time to market.

15.3.1 Machine Vision Challenges

To realize the capabilities of machine vision however, a number of challenges - not prevalent in the semiconductor and other industries - must be met. These challenges include:

- The need to test MEMS devices under dynamic conditions to see whether their parts are able to withstand real world impacts.
- The expense involved in testing all devices - instead of on a sampling basis - where the type of MEMS devices tested perform critical functions such as in the case of air bags.
- Diversity of devices: Each type of MEMS device has its own pecularities and structures. Machine vision cannot therefore take a "one-size-fits-all" approach.

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- The requirement that MV inspection systems focus at different levels, since each MEMS device typically has different thicknesses.
- The difficulty of achieving fast inspection speeds, given the complexity of MEMS devices.
- The absence of a standard method for inspecting MEMS devices and a lack of common quality standards.

15.3.2 Machine Vision Applications

Despite the challenges facing machine vision in MEMS production, a number of different MV applications have been established and are available for deployment today. These applications are:

- Mapping thickness of micromechanical features
- Assessing multiple bonding techniques
- Vision guidance for pick and placement of components
- Inspection of electrical pads for probe-mark damage or contamination, edges for dicing damage and cracks, the periphery for glue or glass-frit residue, glass medium for bubbles and interface between layers for void free bonding

15.3.3 Machine Vision Companies Involved with MEMS

Several machine vision companies are currently serving the MEMS industry, as shown by Exhibit 15.8. Their individual products and approaches to MEMS inspection differ widely and are listed in Exhibit 15.9.

Exhibit 15.8: Machine Vision Companies Assisting MEMS Production

Automation Engineering	ICOS Vision Systems (Now KLA-Tencor)	Veeco Instruments
Camtek	Nano-Or Technologies	Virginia Technologies
Electroglas	NanoVia	ZET Systems Oy

Exhibit 15.9: Products and Approaches of MV Companies Serving the MEMS Industry

Company	Name or/and Description of Product or Approach
Automation Engineering	AEi developed a MEMS solution based on its PMAT Platform and FlexAuto software enabling users to configure the machine to use different MV analysis tools to accurately pick and place components during alignment and attach operations. The system also dynamically integrates adhesive bond and solder attachment modes for the specific recipe of sub-components under assembly.
Camtek	Falcon 600 automated inspection system
Electroglas	QuickSilver inspection system uses a DALSA 8-tap TDI linear CCD sensor connected to multiple image processors through optical fiber to expedite the transfer of data from linear array into image processors and an ‘‘ultra-high capacity buffer’‘ to hold the high resolution images.
ICOS Vision Systems (Now KLA-Tencor)	WI-2300 Wafer Inspector performs 100% automated optical inspection and metrology of microelectronic devices on a variety of wafer substrates. This inspection system combines surface inspection and 2D Bump inspection.
Nano-Or Technologies	Nano-OR-3-Dscope2000 utilizes proprietary optics with a white-light microscope to create a vibration-insensitive interferometric map of a 3-D surface of a MEMS wafer.

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Exhibit 15.9: Products and Approaches of MV Companies Serving the MEMS Industry (Continued)

Company	Name or/and Description of Product or Approach
NanoVia	The company's interferometric system uses a Nomarski incident-light interference contrast prism, a Pulnix (JAI) camera and Matrox Meteor-II frame grabber with Delta Tau multiaxis PMAC motion control platform. Structured white light is obtained from a Schott lamp.
Veeco Instruments	Wyko DMEMS NT1100 is a table-top profiler with a dynamic MEMS measurement option, which generates animations of MEMS devices in motion. Dektak 8 is an advanced stylus profiler system delivers high repeatability, low-force sensor technology and advanced 3D data analysis for surface characterization of MEMS and thin & thick films. Wyko DMEMS NT3300 is a non-contact dynamic MEMS model of the NT3300 that delivers automated 3D measurement and analysis of micro-devices in motion.
Virginia Technologies	OMMS-1, an optical micrometer to measure MEMS device thickness, uses a PC, a PCI-1408 image acquisition board, a ValueMotion PC-Step04CX plug-in board and National Instruments' LabVIEW.
ZET Systems Oy	The company's inspection system checks for visual defects and performs measurement, using a self-developed software package and LED-illumination.

15.3.4 The Market Opportunity for Machine Vision Companies

We have made the point in this chapter that the market opportunity for MV companies that serve the MEMS industry is potentially large. It is potentially large by virtue of the market growth that the MEMS industry is expected to enjoy as the consequence of the increasing emergence and market acceptance of indispensible "smart" products that utilize embedded MEMS devices. There appears, however, to be a "Catch 22". For MV companies to grow MEMS related sales, they must know what kind of MEMS fabrication processes to support, since the MEMS industry is highly diverse in terms of production techniques, materials and applications. This means that MEMS companies must first make strategic choices and invest accordingly on a large scale. It specifically requires the selection of fabrication techniques, materials and the establishment of standards to reduce market ambiguity. However, the efficacy of the selected production processes will also largely depend up the capability to assure product quality through fast, efficient and accurate inspection, since without that capability, MEMS production costs, production cycles and time to market would unavoidably suffer. In short, to achieve the production efficiencies needed for mass market product introductions, machine vision must first be incorporated in MEMS production. So what will come first? A wider deployment of machine vision in MEMS production, or the strategic investments of MEMS manufacturers? Or perhaps a different scenario will occur such as a series of reciprocating, reinforcing steps, with leading players in the MV and MEMS industries gradually ramping up their strategic commitments to cooperate.

Regardless of which scenario plays out, it would appear that the interdependence of MEMS manufacturers and MV companies needs a wider perception, followed by dialog to better identify opportunities for cooperation. With the establishment of working relationships across industries, synergies could well emerge that are mutually beneficial,

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resulting in sizeable market opportunities for both industries. If MEMS is the wave of future, chances are MV companies will be riding it.

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Chapter 16: Machine Vision in Solar Cell Production –

New Market Opportunity Assessment

16.0 What's New in this Chapter?
This is an all-new chapter.

16.1 Introduction
Escalating global population, greater personal use of high energy consuming appliances and rapid industrialization in the world have created a huge disparity in the demand and supply of energy, causing prices to skyrocket. As sources of fossil fuel become more scarce and harder to extract, the need for alternate energy grows. Enter solar power.

Solar power is a relatively new technology that uses solar cells and sunlight to generate solar power. While still relatively expensive - even in areas with abundant sunlight -, the costs of solar electricity generation have been coming down. The chief reason for this decline in the decrease in the production costs of solar cells, as a consequence of which the price per watt of a solar module has decreased at a steady 6% a year for the last 25 years. According to Q-Cells AG and REC Group, two solar cell manufacturers, solar cell system costs will decline 40 percent from 2006 to 2010. With these reductions, many regions of the world will reach "grid parity", the point at which solar system costs are equal to those of the electric grid. When this happens, adoption of solar power is expected to skyrocket.

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To understand the market opportunity represented by the solar cell market, we examine the market and the role machine vision can and already is playing in it.

16.2 The Solar Cell Market

As the solar cell market consists of the sale of solar cells (and panels), it is necessary to describe a solar cell and explain its history, development, various types and associated costs. We also size the market, estimate its growth, identify leading manufacturers and outline production processes.

Some Definitions

A solar cell (a.k.a. photovoltaic cell) is a device that converts light directly into electricity based on the photoelectric effect. Typically, PV cells consist of silicon, which - when bombarded by photons (light) - causes positive and negative charge carriers to be emitted, thereby producing direct current (DC). A solar panel (sometimes called a “solar module” or “solar array”) is a structure consisting of multiple solar cells that are often protected with a sheet of glass. PV solar panels consist of several connected 0.6 Volt DC PV cells, which are made out of a semiconducting material sandwiched between two metallic electrodes.

The individual cells are connected either in series or parallel to create the desired voltage and amperage. (The type of connection does not of course affect the power output, which is measured in watts, since volts multiplied by amps equals watts.) As a general rule of thumb, the average power output of a solar array is 20 percent the peak power output.

All solar cells operate as quantum energy conversion devices and are subject to the so-called “thermodynamic efficient limit”. One way of increasing efficiency has been to find better materials. Another means has been to increase light intensity using concentrating optics (concentrating photovoltaics).

Two types of solar systems can be distinguished: grid-connected and stand-alone. In the case of grid-connected systems, the power is fed into the electrical grid using inverters, which among other things, convert DC into AC. In the case of stand-alone systems, power that is not immediately used is stored in batteries.

History

The term “photovoltaic” comes from the Greek word phos (meaning light) and the Italian physicist Volta (after whom “volts” are also named). Photovoltaic cells have actually been around since 1883, when Charles Fritts first invented them some 44 years after A.E. Becquerel discovered the photovoltaic effect. However, these initial cells, made of selenium coated with a thin layer of gold, were only one percent efficient and had no practical application. It wasn’t until 1946 that the modern solar cell was developed and patented by Russell Ohl. Eight years later in 1954, Bell Labs achieved another major milestone, when, experimenting with semiconductors, it developed the first PV cells consisting of silicon doped with certain impurities. The efficiency rate achieved by these cells was six percent. In the 1970s, GaAS heterostructure solar cells boosted efficiency even further, but not until the development of the metal organic chemical vapor

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deposition (MOCVD or OMCVD) production process in the 1980s did the production of these more efficient PV cells become practical. Additional, subsequent advances resulted in still greater efficiencies in the rate of conversion of light into electricity.

Types of Solar Cells

There are at least five major types of PV cells based on technology and materials:

Crystalline Silicon
- Monocrystalline (c-Si)
- Polycrystalline (c- Si)

Thin-Film
- Amorphous (a-Si)
- Cadmium telluride (CdTe)
- Copper indium (gallium) diselenide (CIS or CIGS).

PV cells based on crystalline silicon make up 93 percent of the market; newer thin-film cells comprise 7 percent. *Monocrystalline* PV cells are first generation crystalline cells; they are 12 to 16 percent efficient, the most expensive to produce, but also the most widely used in the market. *Polycrystalline* solar cells are second generation solar cells, which have medium production costs and medium levels of efficiency (11 to 13%). Thin-film cells are less expensive to produce than crystalline silicon but are also less efficient. *Amorphous silicon* cells, for example, are (8 to10 percent) efficient.

Regardless of their type, individual PV cells are typically connected and sandwiched between two layers of protective glass to form *solar panel*s (a.k.a. *solar modules* or *solar arrays*). These solar panels may or may not be used with concentrating optics to increase light intensity and therefore power output, and they may or may not be *on-grid* (connected to the electricity grid) or *off-grid* (stand-alone). Off-grid solar systems employ batteries to store power, while on-grid systems feed power to the grid using inverters (which perform a number of functions including the conversion of DC into AC).

Solar System Costs

A common method used to express economic costs of solar systems (that is the cost of electricity generated by a solar system) is to calculate a price per delivered kilowatt-hour (kWh). As of 2006, system efficiencies range between 5 percent and 19 percent. The economic costs range from 60 cents (US) per kWh in central Europe to 30 cents (US) per kWh in regions of high solar irradiation, such as the US Southwest. Over time, these costs have been decreasing at a steady 6 percent a year.

The costs to manufacture a solar system have also continued to decrease. As mentioned earlier, Q-Cells AG and REC Group expect a reduction in PV System costs by 40 percent from 2006 to 2010. With these reductions, many regions of the world will eventually reach “grid parity”, the point at which PV costs are equal to those of the electric grid.

16.2.1 Market Size and Growth

According to available market research, the solar cell market is currently around $13 billion and is expected to exceed $30 billion by 2012. Implicit in this growth projection is a compound annual growth rate (CAGR) of 29.3 percent, as shown by Exhibit 16.1:

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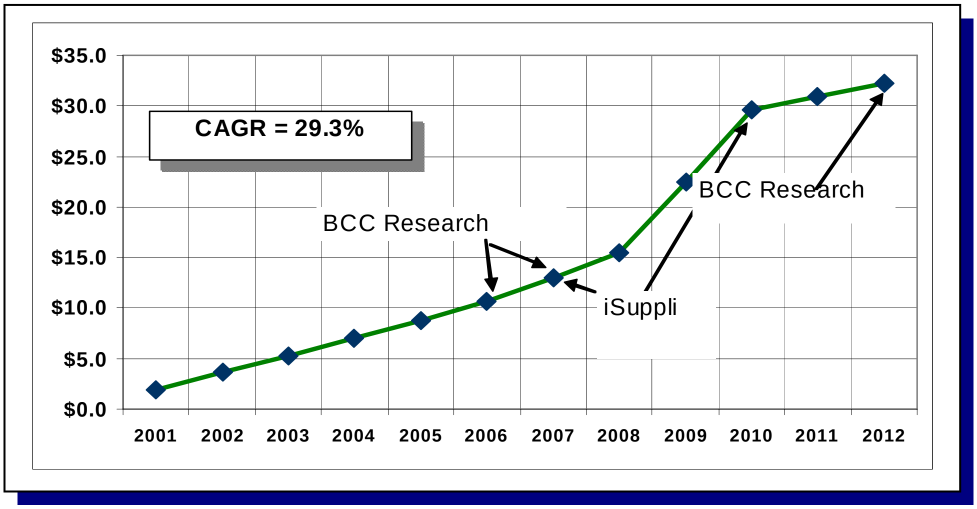
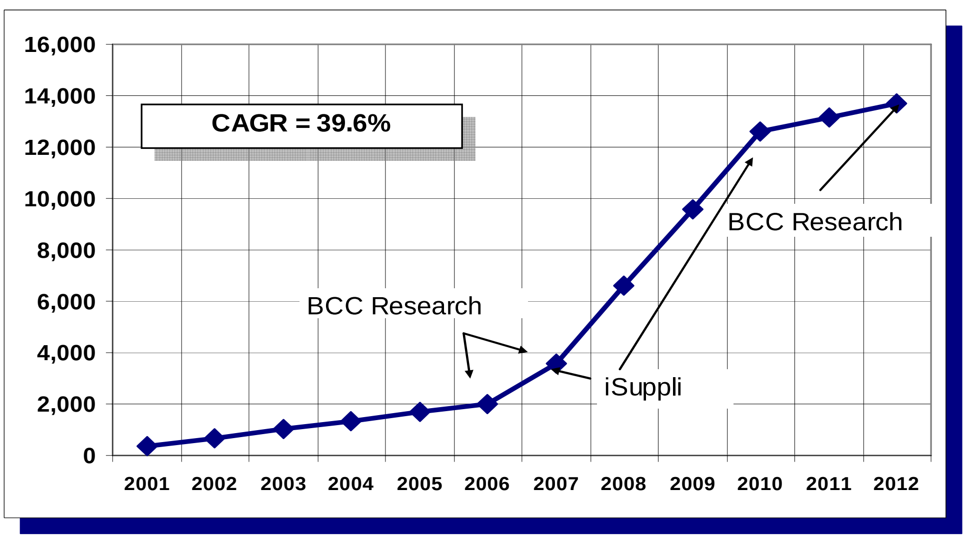
Exhibit 16.1: PV Cell Sales - Estimated Growth Curve - $ Billion USD



A different approach is to focus on the total megawatts of electricity generated by the installed base of solar systems over time, which represents cumulative (as opposed to annual) sales of solar systems. Importantly, this perspective also reveals very strong, double-digit growth. As shown by Exhibit 16.2, the CAGR is 39.6 percent.

Exhibit 16.2: PV Cell Sales - Estimated Growth Curve - Megawatts



16.2.2 Solar Cell Manufacturers

In 2001, the top five solar cell producers were Sharp, BP Solar, Kyocera, Siemens Solar and AstroPower. Today, the top producers in the world are Q-Cell, Sharp, Solar World, BP Solar, Kyocera.

Q-cell AG is focused on the development, manufacture and marketing of powerful solar cells made of monocrystalline and multicrystalline silicon. The company also wants to expand into thin-film technologies in its subsidiary companies.

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Sharp produces mono-multicrystalline and amorphous silicon solar cells. BP Solar manufactures polycrystalline and monocrystalline solar cells as well as amorphous silicon thin-film modules.

SolarWorld acquired Shell Solar, which made mono and multicrystalline silicon as well as thin-film CIS solar systems. Until 2006, Shell Solar was involved in the production of silicon solar modules, the most widely applied technology, but decided to move straight into next generation thin-film technologies. Solar World operates production facilities in Germany, Sweden and the US. In California, the largest production site in the US for solar modules and in Oregon, the largest production site in the US for solar wafers and cells are being created. In Freiberg in Saxony, the group operates one of the world's most advanced integrated solar production facilities. Among the current most important sales markets are Germany, the US and in the rest of Europe especially Spain. Sales offices in Germany, Spain, California, South Africa and Singapore service the international solar markets. In addition to on-grid solar power products, the group increasingly distributes rural solar power solutions internationally.

BP Solar has cell manufacturing facilities in Australia, India, Spain and the US but the main facilities are in the US and Germany. Sharp and Kyocera have major manufacturing facilities in Japan.

Kyocera produces off-grid systems for private homes using multicrystalline-silicon and amorphous silicon.

Exhibit 16.3: Solar Cell Manufacturers by Country

Company	Country	Cell Technology
Photovoltech NV SA	Belgium	Multicrystalline Silicon
Heliodinamica	Brazil	Crystalline Silicon
Canrom Photovoltaics	Canada	Monocrystalline Silicon
ICP Solar Technologies Inc	Canada	Amorphous Silicon Thin Film
Viva Solar Inc	Canada	Monocrystalline Silicon
Boading Yingli	China	Crystalline Silicon
EOPLLY New Energy Technology	China	Crystalline Silicon
Huamei PV Company	China	Monocrystalline Silicon
JingAo Solar Co. ltd.	China	Crystalline Silicon
Kaifeng Solar Cell Factory	China	Monocrystalline Silicon
Ningbo Solar Energy Power Co	China	Monocrystalline Silicon
Polar Photovoltaics	China	Amorphous Silicon Thin Film
Shenzhen Topray Solar Co Ltd	China	Amorphous Silicon Thin Film
Sungen (HK) Limited	China	Amorphous Silicon Thin Film
Tianjin Jinneng Solar Cell Co.,Ltd	China	Amorphous Silicon Thin Film, Mono, Multi-Crystalline
Zhejiang Sunflower Light Energy Science & Technology Co.,Ltd	China	Monocrystalline Silicon
Solarfun Power	China	Crystalline Silicon
Suntech Power Co., Ltd	China	Monocrystalline And Multicrystalline Silicon
Yunnan Semiconductor	China	Monocrystalline Silicon
Solar Cells (formerly Koncar Solar Cells)	Croatia	Amorphous Silicon Thin Film
Solartec s.r.o.	Czech Republic	Monocrystalline Silicon
Free Energy Europe	France	Amorphous Silicon Thin Film

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Exhibit 16.3: Solar Cell Manufacturers by Country (Continued)

Company	Country	Cell Technology
Photowatt International SA	France	Multicrystalline Silicon
Solems SA	France	Amorphous Silicon Thin Film
Ersol	Germany	Monocrystalline Silicon
Q-Cells AG	Germany	Multicrystalline Silicon
Schott Solar	Germany	Monocrystalline Silicon, Multi-Crystalline And Amorphous Silicon Thin Film
SolarWorld AG	Germany	Crystalline Silicon
Sunways AG	Germany	Multicrystalline Silicon
Würth Solar	Germany	Copper Indium Diselenide Thin Film
Heliodomi S.A.	Greece	Amorphous Silicon Thin Film
West Bengal Electronics Industry Development Corporation Limited (Webel SL Solar)	India	Monocrystalline Silicon
Bharat Electronics Limited	India	Multicrystalline Silicon
Bharat heavy Electricals	India	Multicrystalline Silicon And Crystalline Silicon
Central Electronics Limited	India	Monocrystalline Silicon
Maharishi solar Technology Pvt. Ltd	India	Monocrystalline Silicon
TATA/BP Solar (JV between BP Solar/TATA)	India	Monocrystalline Silicon
Usha India Ltd	India	Crystalline Silicon
Moser Baer Photovoltaic	India	Crystalline Silicon
Pentafour Solec Technology Limited (licensee of Solec International)	India	Monocrystalline Silicon
Udhaya Semiconductors Ltd	India	Crystalline Silicon
Solmecs (Israel) Ltd	Israel	Monocrystalline Silicon
EniTecnologie	Italy	Moncrystalline And Multicrystalline Silicon
Helios Technology srl	Italy	Monocrystalline Silicon
Canon Inc E business Division	Japan	Amorphous Silicon Thin Film
Fuji Electric Co Ltd	Japan	Amorphous Silicon
Kaneka Corporation	Japan	Amorphous Silicon Thin Film
Kyocera	Japan	Monocrystalline Silicon
Matsushita Battery Industrial Company (MBI)	Japan	Crystalline Silicon, Cadium Telluride Thin Film
Matsushita Seiko Co Ltd	Japan	Monocrystalline Silicon
Mitsubishi Electric Corporation	Japan	Multicrystalline Silicon
Sharp Corporation (Photovoltaics Division)	Japan	Monocrystalline And Multicrystalline Silicon
Sanyo Electric Co Ltd	Japan	Amorphous Silicon/ Monocrystalline Silicon Hybrid
Mitsubishi Heavy Industries (Power Systems Division)	Japan	Amorphous Silicon Thin Film
Photon Semiconductor & Energy Co., Ltd.	Korea	Crystalline Silicon
Solar Wind Ltd	Russia	Crystalline Silicon
Al-Afandi Solar Wafers and Cells Factory	Saudi Arabia	Multicrystalline Silicon
Isofoton Sa	Spain	Monocrystalline Silicon
Solar Wind Europe S.L.	Spain	Monocrystalline Silicon
Solterra Fotovoltaico SA	Switzerland	Monocrystalline Silicon
VHF-Technologies SA	Switzerland	Amorphous Silicon Thin Film On Plastic Substrate
Big Sun Energy Technology	Taiwan	Crystalline Silicon
E-Ton Solar Technology	Taiwan	Moncrystalline And Multicrystalline Silicon
Gintech Energy	Taiwan	Crystalline Silicon
Motech Industries Inc	Taiwan	Multicrystalline Silicon

Exhibit 16.3: Solar Cell Manufacturers by Country (Continued)

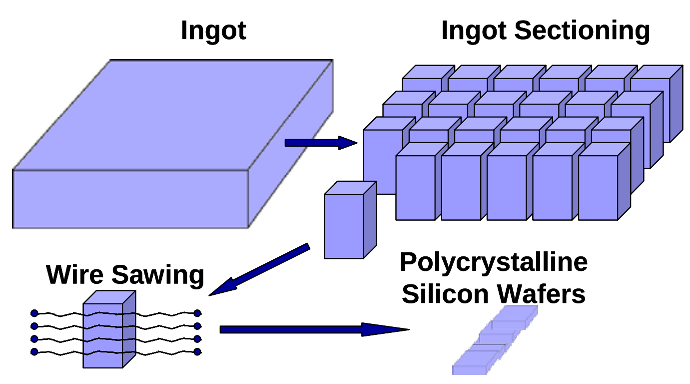
Company	Country	Cell Technology
Neo Solar Power Corp.	Taiwan	Crystalline Silicon
Sinonar Corporation	Taiwan	Amorphous Silicon Thin Film
Solartech Energy Corp.	Taiwan	Monocrystalline And Multicrystalline Silicon
Bangkok Solar co.	Thailand	Amorphous Silicon Thin Film
Kvazar JSC	Ukraine	Moncrystalline And Multicrystalline Silicon
Microsol International	United Arab Emirates	Monocrystalline Silicon
BP Solar	USA	Moncrystalline And Multicrystalline Silicon
Energy Conversion Devices (ECD Ovonics)	USA	Amorphous Silicon Thin Film
Energy Photovoltaics Inc (EPV)	USA	Amorphous Silicon And Copper Indium Diselenide Thin Film
Evergreen Solar Inc	USA	String Ribbon Crystalline Silicon
First Solar LLC	USA	Cadium Telluride
GE Energy (Solar Division)	USA	Monocrystalline Silicon
Iowa Thin Film Technologies	USA	Amorphous Silicon Thin Film On Plastic Substrate
Solar Power Industries	USA	Multicrystalline Silicon
Solec International Inc (part of Sanyo)	USA	Monocrystalline Silicon
SunPower Corporation	USA	Monocrystalline Silicon
TerraSolar Inc	USA	Amorphous Silicon Thin Film
United Solar Ovonic	USA	Amorphous Silicon Thin Film

Source: www.solarbuzz.com

16.3 Solar Cell Production

How PV cells and panels are produced is of special importance to machine vision companies, since their applications must support these manufacturing processes. The specific production techniques employed depends on the type of solar cell produced. Poly-crystalline silicon wafers, for example, are made by sectioning silicon ingots and wire-sawing the sections into very thin slices or wafers. Doping then creates the photoactive p/n junction. Using silicon nitride, anti-reflection coatings are next applied. The wafer then receives a full area metal contact that is fastened to the back surface of the wafer. On the front side, a metal contact is applied by screen printing a grid-like pattern with a metallic paste that is fired in a furnace.

Exhibit 16.4: Production of Polycrystalline Silicon Wafers



Based on slide from Evergreen Solar

16.4 Machine Vision in the Solar Cell Market

Because solar cells are semiconductor devices, they share many of the same processing and manufacturing techniques as other semiconductor devices. Machine vision (MV) companies are of course no strangers to the semiconductor industry, and so inspection tasks in the manufacture of solar cells and panels are a natural fit for many MV companies. Not surprisingly then, a number of MV companies are targeting the solar cell industry, including (in alphabetical order) Adept Technology, Automation Engineering Inc., Basler AG, ISRA VISION, ICOS Vision Systems (acquired by KLA Tencor), Tordivel, Vitronic and others.

In the production of solar cells, machine vision plays a critical role. Since raw silicon has become more expensive and in shorter supply, silicon ingot sections are being sliced increasingly thin. This makes the wafers harder to separate and handle without introducing defects, and defects of course do occur. Enter machine vision. MV-based inspection systems sort out chipping, microcracks, incorrect thicknesses, warpage, saw grooves, finger prints and impurities in the wafers. This is more challenging than semiconductor inspection, because, at least in the case of poly-crystalline silicon, every wafer has a different crystalline structure, which requires vision systems to discriminate between ordinary crystal boundaries and defects as well as use a wider field of view. Higher resolution cameras are therefore needed.

Machine vision systems are also used to inspect solar panels. The many, specific applications machine vision offers illustrates the important role played by it in the solar cell industry.

Exhibit 16.4: Specific MV Applications in the Solar Cell Industry

Inspection
- Coatings, cracks, printing and edges of wafers
- Defects, edges and format of cover glass
- Soldering and spacing of cells in finished modules (panels)

Measurement
- Curved glass and mirrors
- Wafer measurements

Sorting
- Wafers, wafer blocks and ingots

Control of Location
- Recognize position and orientation of PV cells for robotic handling
- Alignment recognition of soldering lugs for robotic handling

Examples of MV products performing these applications include the following:

Company	Product or Solution Name(s)
Adept Technology	Adept Solaris^{tm}
AEI	(No specific branding for solar cell market)
Basler AG	Basler Cell Inspection System
ISRA VISION	VIVA (Versatile Intelligence for Vision Automation)
KLA-Tencor (ICOS Vision Systems)	Inspector, Print Inspector, Cell Classifier
Tordivel	Sawmarks measurement System, 3D Wafer Block Measurement System, Scorpion 3D Scanner
Vitronic	VINSPEC^{solar} wafer, color, front, rear and classifier

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For a more complete list of companies involved with solar cell and panel inspection, please visit the ENF website, www.enf.cn.

16.5 Summary and Conclusion

Based on the information presented, we conclude that the demand for alternative energy will continue to drive solar cell and panel sales at impressive double-digit rates. This is very good news for the machine vision industry, particularly since current levels of solar cell and panel production lag demand, and machine vision offers a much needed productivity boost. As we have seen, several MV companies are positioning themselves to ride the wave of the solar cell industry. With further tweaking of MV applications used in the semiconductor industry, a still greater market opportunity might emerge for a larger cross-section of the machine vision industry.

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Chapter 17: The Argentine Machine Vision Market –

New Market Opportunity Assessment

17.0 What's New in this Chapter?
This is an all-new chapter.

17.1 Introduction
Argentina is the second largest country in South America with a geographic area covering 1.1 million square miles (2.8 million square kilometers) or approximately the Eastern half of the US. The country's roughly half trillion dollar economy has undergone some dramatic developments, including a meltdown, an unprecedented loan default and four straight years of recession followed by five consecutive years of impressive growth. Currently, the economy is robust.

Meat packing and food processing in general have been important sectors of the economy and appears to offer market opportunities for machine vision. Despite few trade barriers, the export of machine vision products to Argentina, and reliance on machine vision as a production technology, appear to be minimal. In general, the fledging machine vision industry in this country has made only minor inroads.

17.2 The Argentine Economy
Argentina has a $523.7 billion economy, the nineteenth largest in the world in terms of purchasing power parity.

Tracking Argentina's economic growth has not been not for the faint hearted. Over the last seventeen years, the country's economic performance has displayed the dramatic ups

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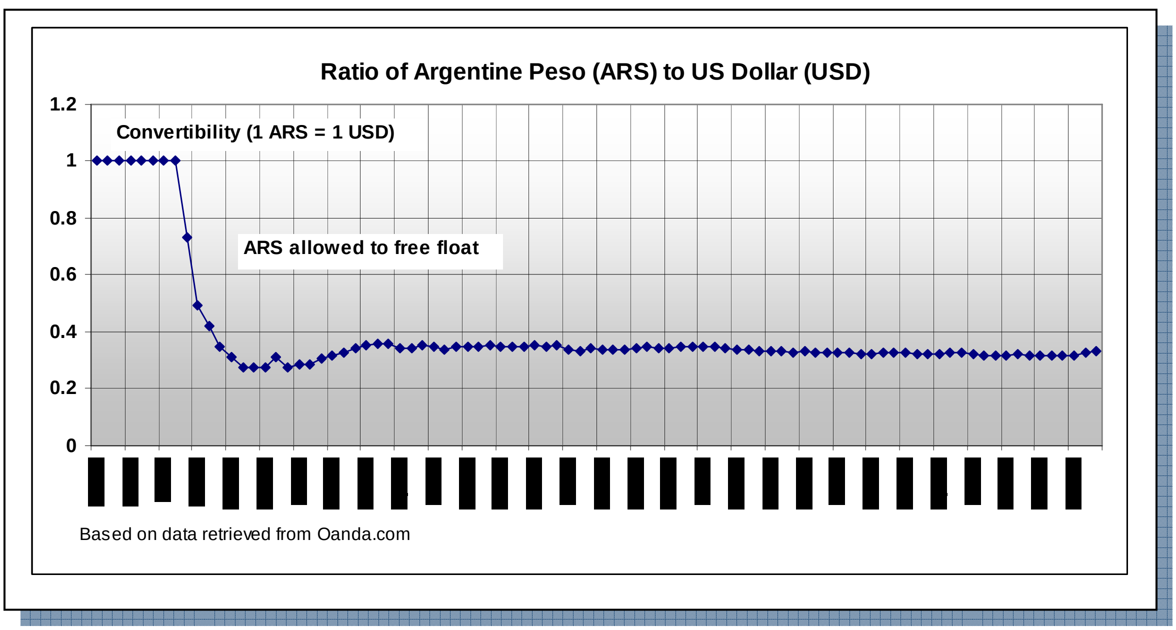
and downs of a rollercoaster. Raising headlines in the world press, an economic meltdown occurred in 2001, followed by several years of spectacular growth, which the country is still experiencing.

To understand what happened, we must look back to 1991, when the government of Argentina established “convertibility” by pegging the Argentine peso (ARS) to the US dollar (USD) at a one-to-one exchange rate. The goal of convertibility was to break the back of Argentina’s pernicious hyperinflation, which it succeeded in doing. Along with far-reaching economic reforms, including dismantling of protectionist trade barriers and privatization, convertibility also stimulated large in-flows of direct foreign investment (FDI). Over time, however, poor governance and a lack of fiscal discipline undermined Argentina’s export competitiveness. To finance the resultant, chronic deficits in the current account of the balance of payments, the government of Argentina (GOA) utilized massive borrowing, which left the country highly vulnerable to the “contagion effect” of the Asian financial crisis of 1998. This precipitated a massive outflow of capital that contributed to a 4-year recession, which culminated in the financial meltdown of 2001.

In response to the crisis, the GOA ended convertibility and defaulted on its $82 billion debt, the largest such default in world history. The ARS also lost substantial value, as shown by the dramatic tailspin (and subsequent leveling off) in the ratio of the Argentine peso to the US dollar, as depicted by Exhibit 17.1.

Exhibit 17.1: The Sharp Decline in Argentina’s Currency



At the time, many economic analysts predicted the world would severely punish Argentina for its massive default, preventing an economic recovery. But that is not what happened. In fact, the ARS stabilized and the economy surged. Due to growing demand stimulated by the government’s new fiscal, monetary and income distribution policies, real GDP (gross domestic product) took off with 9.0 percent annual growth for five

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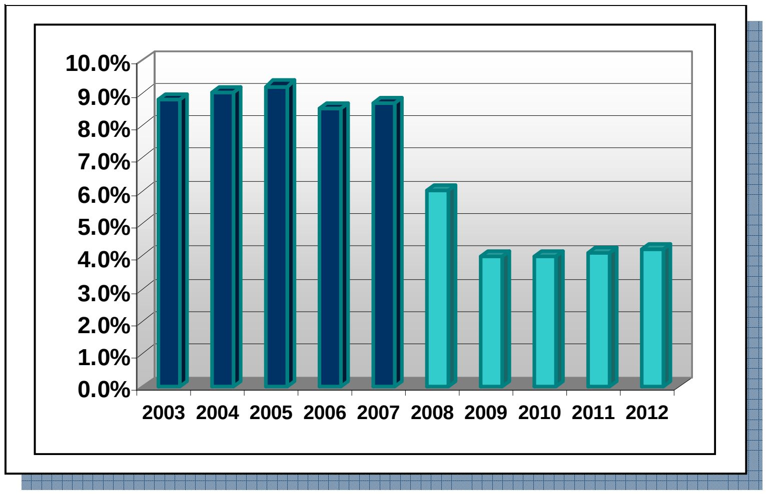
consecutive years from 2003 to 2007. (See section 17.2.1.2.) Direct foreign investment, however, has not recovered, with many investors still smarting from Argentina's massive default and consequently reluctant to risk additional losses. Against this backdrop, we examine the major characteristics of the Argentine economy.

Exhibit 17.2: Real GDP – Argentina



Source: Economist Intelligence Unit

17.2.1 Major Characteristics

In characterizing Argentina's economy, we consider size, rate of growth, structure and trade.

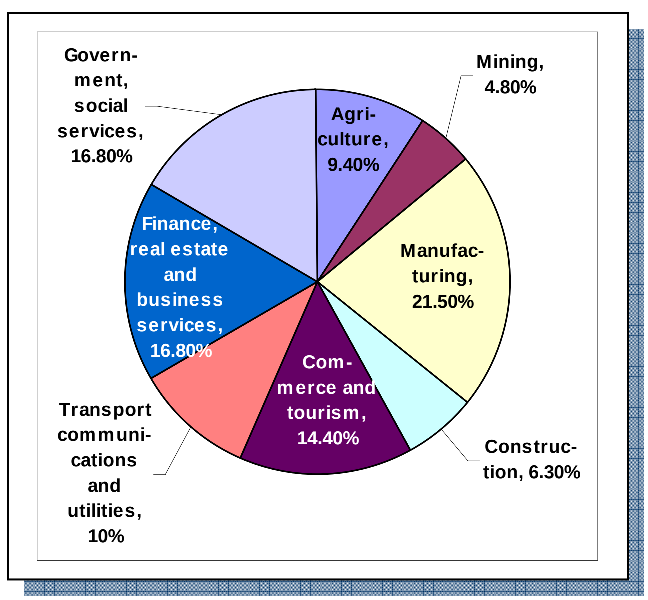
17.2.1.1 Size of the Economy

The Argentine economy is the nineteenth largest in the world in terms of purchasing power parity at $523.7 billion (USD) for 2007. On a per capital basis, Argentina ranks 57th in the world at $13,207 annually.

17.2.1.2 Economic Growth

Because of a boost in domestic demand stimulated by the government's fiscal, monetary and income distribution policies, Argentina's real GDP growth surged in 2003, reaching an impressive 8.8 percent, a strong contrast to the -10.9 percent drop experienced in 2002! In 2004 and 2005, real GDP growth continued to increase, hitting 9.0 and 9.2 percent. 2006 and 2007 were also good years, with real GDP registering 8.5 and 8.7 percent. Going forward, the Economist Intelligence Unit predicts 6.0 percent growth for 2008 and 4.0 percent growth for subsequent years, as shown by Exhibit 17.2.

Exhibit 17.3: Relative Size of Major Industries Measured in GDP



Source: Economist Intelligence Unit

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17.2.1.3 Economic Structure

By economic structure, we mean the relative size of individual segments of the economy in terms of total GDP. As shown by Exhibit 17.3, manufacturing is the largest segment, accounting for approximately one-fifth (21.5 percent) of total GDP. Government/social services and finance/real estate/business services follow at 16.80 percent each. It is somewhat surprising that agriculture contributes only 9.4 percent, since Argentina is frequently characterized as a largely agricultural country. Exhibit 17.3 leaves little doubt that this characterization is no longer accurate, except perhaps in the case of exported products.

17.2.1.4 Exports and Imports

In 2007, Argentina exported products worth an estimated $55.9 billion, while importing goods totaling $44.8 billion for a trade surplus of $11.1 billion. A break down of Argentina's trade is provided by Exhibit 17.4.

Exhibit 17.4: Foreign Trade Profile as of 2007

Major Exports		Major Imports	
	Percent of Total		Percent of Total
Processed agricultural products	34.4	Intermediate goods	47.0
Manufactured products	31.1	Capital goods	32.8
Primary products	22.3	Consumer goods	13.6
Fuels and Energy	12.2	Fuels	6.6

Source: Economist Intelligence Unit

The country's main export partners are Brazil (15.8 percent), the US (11.4 percent), Chile (11.percent) and China (7.9 percent). Its main import partners are Brazil (35.9 percent), the US (14.1 percent), China (7.8 percent) and Germany (4.5 percent).

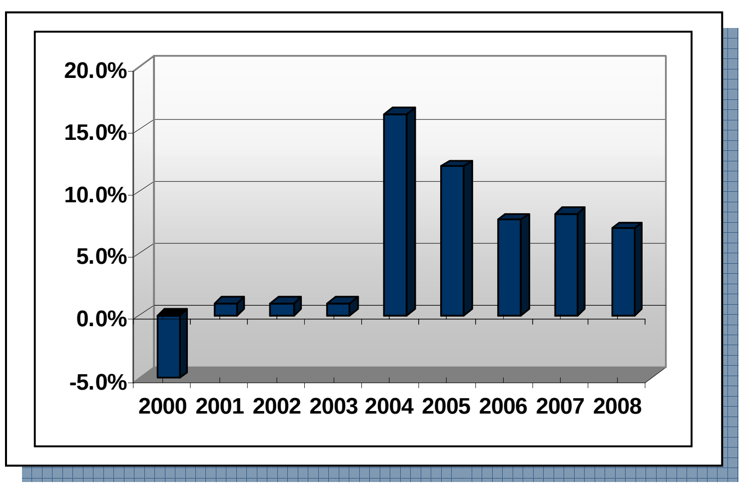
17.2.1.5 Manufacturing in Argentina

In this section we examine how fast industrial production has grown in Argentina, the location of industry in the country and the relative importance of the various manufacturing sectors.

<u>Industrial Growth</u>

Industrial production growth rates were rather weak between 2000 and 2003, reflecting the economic crisis mentioned earlier. That changed abruptly in 2004 when a rate of 16.2 percent was achieved. More recently, industrial production in Argentina grew at rates between 7 and 8 percent, as shown by Exhibit 17.5.

Exhibit 17.5: Industrial Production Growth Rates - Argentina



Source: CIA World Factbook

Geographic Concentrations of Industry

Cordoba is Argentina's major industrial center. Metalworking, particularly for motor vehicle production, is located here. Other principal industrial enterprises are heavily concentrated in and around Buenos Aires. The major industries in this area are food processing, motor vehicles, consumer durables, textiles, chemicals, printing, metallurgy and steel. The following exhibit summarizes these and other geographic concentrations of industry.

Exhibit 17.6: Geographic Concentrations of Industry in Argentina

Region	Industries
Cordoba	Metalworking
Buenos Aires	Food processing, motor vehicles, consumer durables, textiles, chemicals, printing, metallurgy and steel
Rosario	Steel, oil refining, tractor, meat-packing, chemical and tanning
Santa Fe	Zinc and copper smelting, flour milling, dairy
San Miguel de Tucuman	Sugar refining
Mendoza and Neuquen	Wine, fruit processing
Chaco	Cotton and wood
Snata Cruz, Salta, Tierra del Fuego, Chubut, Bahia Blanca	Oil refining

Source: Encyclopedia of Nations

Manufacturing Sectors

Food processing is the major manufacturing sector in Argentina. This includes primarily meatpacking and flour milling; however beef production has been of special importance.

Historically, the growth of beef production in Argentina has given rise to a host of associated industries, including those producing tinned beef, meat extracts, tallow, hides, and leather. However, the emphasis on beef production specifically, and on food processing generally, is changing. For a number of years the country has been following a trend of breaking away from dependence on food processing and consumer goods and placing greater emphasis on heavy industry. As a consequence, motor vehicles, textiles, chemicals, petrochemicals and steel have grown in importance.

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Characteristics of the Argentine Economy

- 19th largest economy in the world $523.7 billion (purchasing power parity)
- Long-term volatility (a 4-year recession followed by a financial meltdown, currency devaluation, massive loan default and then robust economic growth)
- Relatively strong economic growth from 2003 to the present with weaker –but still healthier- growth forecast for 2008 through 2012
- Manufacturing sector is largest at 21.5% of total GDP, despite the importance of agriculture (9.4% of GDP)
- Processed agricultural products are the largest exports (34.4%), followed by manufactured products (31.1%).
- Positive balance of trade (Exports: $55.9 billion, Imports: $44.8 billion, Net: $11.1 billion surplus)
- Industrial growth: weak before 2004; strong after 2004
- Major manufacturing sector is food processing

17.3 The Commercial Environment of Argentina

We next examine the commercial environment of Argentina to understand the challenges of doing business in Argentina. In this regard we consider business norms, the reality of corruption, the regulatory environment, taxation, market entry strategies, customs regulations applying to exports and foreign direct investment.

17.3.1 Business Norms

Argentina is very much a country with a relationship-driven culture. In business, this means that networks and networking are crucial to success. This is a carry-over from daily life in which Argentines maintain a web of personal relationships where friends and family call upon each other for reciprocal favors and assistance. Accordingly, they like to do business with people they know and prefer face-to-face meetings instead of phone calls and emails.

<u>Business Customs</u>

Argentine business customs are generally formal; business dress, appearance, and general demeanor are more conservative. Courtesy is very important, and efforts to rush a business deal are ill-advised. To establish trust, it is important to begin encounters by discussing family members or sports and social activities. Shaking hands with everyone in the room upon arriving and leaving is expected, and among Argentines, it is customary for men to kiss even women they meet for the first time on the right cheek, however, non-Argentines should shake hands with Argentine women, until a friendly relationship has been established.

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Prior to meetings, contacts and introductions are important and more effective than a direct "cold call" approach. Promptness is expected at business meetings, even though Argentine counterparts might be late. (This is most likely to occur, if the Argentine counterparts are higher in rank.) Business cards are usually exchanged at the beginning of the meeting.

Where possible, it is advisable to meet with business heads, who - since Argentine businesses are very hierarchical - tend to make all major decisions.

Corruption

Corruption is a fact of business life in Argentina. According to the World Bank and IFC Enterprise Survey 2006, 19 percent of companies reported that they had to pay bribes to government officials to "get things done". These under-the-table payments amounted to 0.8 percent of the sales of a typical firm and occurred in interactions with tax inspectors and bureaucrats when bidding on public tenders and when applying for licenses and permits. In the same report, 60 percent of the companies identified corruption as a major constraint on doing business in Argentina.

Regulatory Environment

Complicated and time-consuming regulations pose an obstacle for doing business in Argentina. According to the World Bank and IFC Enterprise Survey 2006, business heads spent more than 14 percent of their time on compliance with government regulations. To a large extent, this reflects a high degree of regulatory uncertainty, stemming from a lack of predictability and consistency in government officials' interpretation of regulations.

Because of regulatory uncertainty, which provides fertile ground for corruption, important business activities, such as starting a business, dealing with licenses and paying taxes, are more cumbersome in Argentina than in Latin America as a whole.

17.3.2 Business Taxation in Argentina

Taxes are assessed on consumption, imports and exports, assets, financial transactions and property and payroll. Foreign and Argentine companies face the same tax liabilities. At the national level, there are three major taxes: an income tax, export taxes, a financial transaction tax and a value added tax (VAT).

Income Taxes

All firms (foreign-based and domestic) are required to pay an income tax based on one percent of the value of their assets used in production. This applies even if the firm is not profitable. However, if the firm can show that it did not turn a profit, it can receive a reimbursement in five years. Corporate income tax is levied at 35 percent on income stemming from worldwide operations.

Export Taxes

Export taxes are tariffs ranging from 5 to 45 percent.

Financial Transaction Taxes

Established in April of 2001 as an emergency fiscal measure, a financial transaction tax was set at 0.6 percent for all financial transactions involving checking account payments

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(withdrawals) within the national banking system. Deposits are also taxed but at a somewhat lower rate of 0.4 percent.

The VAT

The VAT is a consumption tax that varies by commodity. For interest and commissions on debt, food items, newspapers and magazines and some capital goods, the VAT is 10.5 percent. For utilities, the VAT is 27 percent. Exporters are supposed to receive VAT rebates, but often wait long periods of time for reimbursement checks.

In addition to national taxes, businesses must also pay provincial sales taxes, including municipal supply taxes.

17.3.3 Market Entry

Companies typically market their products and services through an Argentine agent/representative or distributor. Customs regulations do not pose a barrier to market entry, as in the case of Brazil.

Customs in Argentina

There is a zero percent import duty on a broad range of new capital goods produced in MERCOSUR countries (Argentina, Brazil, Paraguay, Uruguay). Starting in 2003 and renewed in 2006, a zero percent import duty was also applied to goods from non-MERCOSUR countries. In addition, Argentina set up Free Trade Zones (FTZs) in 1994, with one FTZ in each of the country's 24 provinces.

While Argentine customs typically charge no duties, they do, however, enforce a number of regulations, including the following according to the US Commercial Service:

- "The Argentine government requires certificates of origin on a broad range of imports generally covering but not limited to consumer goods, textiles, apparel and footwear, printing machines, and machine tools.
- Commercial invoices must be presented in Spanish (one original and three copies), with the caption "Original Invoice."
- The bill of lading should be issued (at minimum) in one negotiable copy.
- Packing lists are necessary for customs clearance in Argentina and must describe the contents of each package. A packing list is not necessary for goods imported in bulk, such as such as coal, petroleum, sand, etc., or for articles identical in kind, characteristics, composition, weight, etc."

17.3.4 Foreign Direct Investment (FDI) in Argentina

Foreign companies can invest in Argentina without registration or government approval and are treated in the same manner as Argentine investors. They can enter the Argentine market through merger, acquisition, company start-ups or joint venture. The only restriction applies to the foreign ownership of "cultural goods", which does not apply to manufacturing.

Since 2000, Brazil has become an important investor in Argentine assets. Spanish companies have also entered the market aggressively. But in total, FDI in Argentina has been one of the lowest in Latin America. This is of course not at all surprising in view of the country's massive loan default in 2001.

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Argentina's Commercial Environment at a Glance

- Business is strongly relationship-driven
- Corruption is a serious challenge to business
- Regulatory constrains are relatively high
- Taxation: businesses must deal with income taxes, export taxes, financial transaction taxes and a value added tax at the national level; provincial sales taxes also apply
- Import duties are zero; various customs regulations do apply, however, to imported products
- Foreign investment is largely unconstrained (but nevertheless relatively depressed because of Argentina's massive loan default in 2001)

17.4 Machine Vision in Argentina

Machine vision is still in a nascent stage of development in Argentina. For the most part, the largest MV companies in the world do not have a direct, "feet-on-the-ground" presence in Argentina. Their closest offices are located in Brazil, from which the Argentine market can be targeted. At the same time, QuimiNet.com does list some companies that include vision systems ("sistemas de vision") in their product portfolio. They are listed below as MV companies, although sale of MV systems appears to be more of a sideline in most cases.

Exhibit 17.7: Argentine Companies Selling MV Systems

Name of Company	Region	Number of Employees	Volume of Business
Aumeco	Buenos Aires	Between 1 to 10	Between $1M to $5M USD
Ingeneria & Packaging	Buenos Aires	Between 1 to 10	Between $1K to $10K USD
Cientist	Buenos Aires	Between 1 to 10	Between $1K to $10K USD
Quara Argentina Sociedad Anonima	Buenos Aires	Between 1 to 10	Between $1K to $10K USD
Coester Automacion	Buenos Aires	Between 1 to 10	Between $1K to $10K USD
Murten, S.R.L. (Cognex Distributor)	Buenos Aires	?	?
TRACNOVA S.A. Medicion, Automatizacion y Control Industrial (National Instruments distributor)	LaPlata	?	?
Laseroptics SA Lavalle (Melles Griot distributor)	Buenos Aires	?	?

Source: www.quiminet.com and MV company websites

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MV companies with applications designed to inspect meat would appear to be particularly well positioned to target the Argentine market, given the importance of meat packing and processing in this country. In addition, there are other important industry sectors in Argentina that invite the close examination of MV companies as potential market opportunities including miscellaneous fabricated products, fabricated plastic and rubber, printing, beverages, paper and paper products, food processing and biotechnology and drugs. A logical starting point would be to target the largest Argentine manufacturing firms, located in industry sectors for which MV applications are well established. They are listed in Exhibit 17.8 by industry sector.

Exhibit. 17.8: MV Market Targets: Publicly Traded Argentine Manufacturing Companies

Name of Company	Industry Sector
Aluar Aluminio Argentino S.A.I.C(Parent)	Misc. Fabricated Products
Angel Estrada y Compania S.A.	Printing & Publishing
Bodegas Esmeralda SA	Beverages (Alcoholic)
Compania Industrial Cervecera S.A.	Beverages (Alcoholic)
Compania Internacional de Bebidas y Alim	Beverages (Non-Alcoholic)
Ediar SA Editora Com Ind y Fin	Printing & Publishing
Goffre, Carbone y Cia S.A.C.I.	Auto & Truck Parts
Grafex S.A.	Paper & Paper Products
Laboratorio Chile S.A. (ADR)	Biotechnology & Drugs
Ledesma S.A.A.I.	Food Processing
Massuh S.A.	Paper & Paper Products
Molinos Juan Semino S.A	Food Processing
Molinos Rio de la Plata	Food Processing

Source: Credit Risk Monitor

17.5 Conclusions

Market opportunities await MV companies in Argentina, but they are largely long-term, and machine vision companies should proceed cautiously in realizing them. This would involve considerable due diligence, including analysis of specific industry sectors and geographic locations, evaluation of distributor candidates, and the development of an extensive web of business relationships. The quickest and least risky way to enter the market is to work through domestically-based, knowledgeable distributors who have been properly vetted.

Given the importance of meat packaging and the food and beverage industry in general, MV companies offering systems that inspect meat and other types of food, packaging and bottling are the first, logical candidates for a successful market entry.

Their success is more likely today, given the increased stability of the economic environment and robust economic growth that is projected to continue. While the economy in aggregate - and industrial production more specifically - paint a favorable

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picture currently, it is important, however, to not lose sight of the possibility of a recurrence of economic instability and obstacles (such as corruption), which necessitate a measure of caution.

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Chapter 18: The Brazilian Machine Vision Market –

New Market Opportunity Assessment

18.0 What's New in this Chapter?
This is an all-new chapter.

18.1 Introduction
Brazil is a large and modernizing nation. It is the world's fifth most populous country and has the largest market in Latin America. Within the world, it has the eighth largest economy, which is currently growing around four to five percent, annually. Do these characteristics bode well for machine vision in Brazil? In this chapter we assess the market opportunity for machine vision in Brazil. We base our assessment on an examination of the Brazilian economy, commercial environment and the current state of affairs of machine vision in Brazil.

18.2 The Brazilian Economy
Brazil has a free market economy oriented heavily to exports. From within, it has enjoyed abundant natural resources including petroleum and from without, it has benefited from considerable foreign investment, as encouraged by the Government of Brazil (GOB). Brazil has used this investment to grow and modernize its manufacturing sector.

Today, the industrial sector represents approximately 25 percent of GDP and is a major producer of automobiles, steel, cement and consumer appliances such as televisions and refrigerators. Despite this impressive output, however, Brazil must still be regarded as a developing country with GDP per capita at $9,531 in 2007. Economic activity is still

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very concentrated geographically with most manufacturing located in the Southeast and South, and with wealth distributed narrowly in the populus.

18.2.1 Major Characteristics

To identify the major characteristics of the Brazilian economy, we examine economic size, growth, structure, export/import patterns, the fifty largest companies in Brazil and the manufacturing sector.

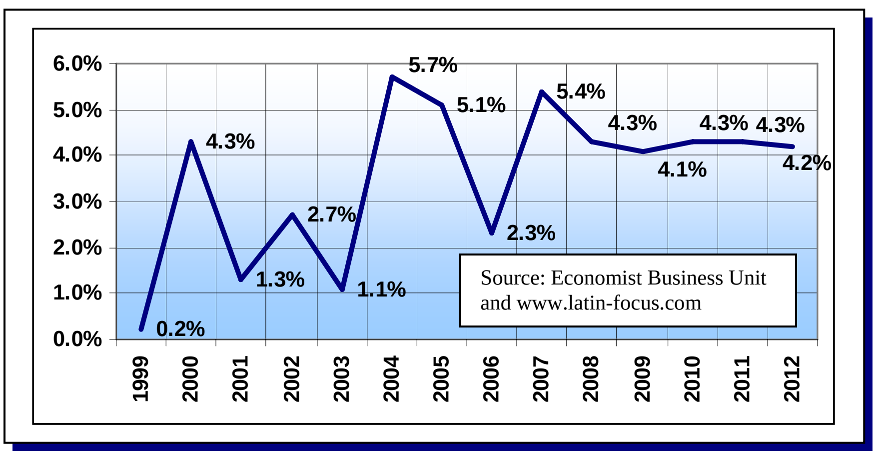
18.2.1.1 Size of the Economy

Brazil has a $1.804 trillion (USD) economy (based on 2007 GDP), making it the eighth largest economy in the world. On a per capital basis, this equates to $9,531 (USD), which is considerably lower than most Western economies.

18.2.1.2 Economic Growth

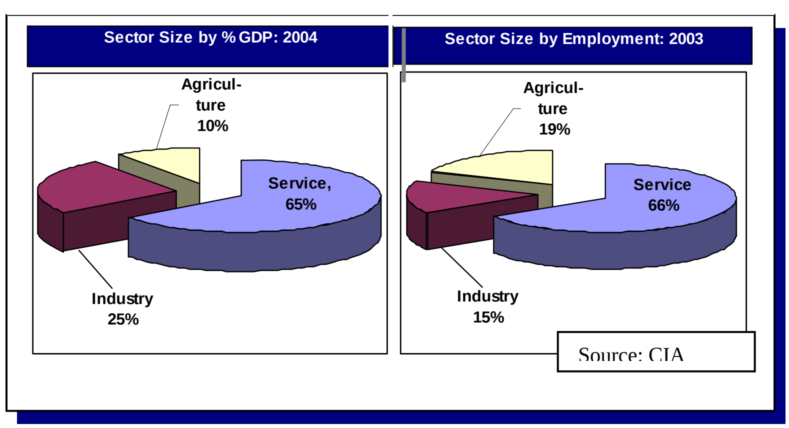
According to the Manufacturers Alliance/MAPI's "Latin America Outlook" report, "Brazil's growth has been fueled by improved credit conditions, rising internal demand and strong export activity that remains resilient in the face of continued currency appreciation."

Exhibit 18.1: Real GDP Growth in Brazil



As shown by Exhibit 18.1, Brazil's economy grew at a rate of 5.4 percent in 2007, an impressive rate of growth compared to other nations and higher than in its earlier years. Going forward, the Economist Intelligence Unit of the "The Economist" magazine expects healthy growth around 4.2 percent on average through 2012. However, more recent GDP figures are showing that Brazil is not immune to the global recession. For that reason, we expect the Economist Intelligence Unit to eventual revise their forecast downward.

Exhibit 18.2: Economic Sector Size - Brazil



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18.2.1.3 Structure of the Economy

Whether measured in terms of GDP or employment, the service sector is by far the largest sector of the Brazilian economy. By contrast, 15 percent of workers are employed in the industrial (manufacturing) sector, which accounts for 25 percent of total GDP.

18.2.1.4 Exports and Imports

Brazil is a major exporter of transport equipment and parts and metallurgical products and is an importer of machinery and electrical products, chemical products, oil and derivatives and transport equipment and parts. The country's largest trade partners are the United States, China and Argentina, as shown by Exhibit 18.3.

Exhibit 18.3: Exports and Imports in Brazil

Major Exports 2007	% of Total	Major Imports 2007	% of Total
Transport Equipment & Parts	12.5	Machinery & Electrical Equip.	26.1
Metallurgical Products	11.6	Chemical Products	15.4
Soybeans, Meals & Oils	8.2	Oil & Derivatives	16.6
Chemical Products	1.9	Transport Equipment & Parts	12.0
Leading Markets 2007	**% of Total**	**Leading Suppliers**	**% of Total**
United States	15.8	United States	15.7
Argentina	9.0	China	10.5
China	6.7	Argentina	8.6
Germany	4.5	Netherlands	0.9

Source: The Economist

18.2.1.5 Brazilian Businesses

Identifying the largest companies in Brazil provides additional insights into the nature of the Brazilian economy and reveals potential customer targets for MV companies addressing the Brazilian market. According to Exame, a Brazilian business magazine, the 50 largest companies in Brazil in order of sales (USD) for 2003 are shown in Exhibit 18.4.

Exhibit 18.4: 50 largest Companies in Brazil Ranked by Sales ($ Millions USD)

	Company	City/State	Industry Sector	$ Millions	Country
1	**Petrobras**	Rio de Janeiro, RJ	Petroleum and Energy	38,441	Brazil
2	**BR Distribuidora**	Rio de Janeiro, RJ	Wholesale (fuel)	10,567	Brazil
3	**Telemar**	Rio de Janeiro, RJ	Telecommunications	6,311	Brazil
4	**Telefonica**	São Paulo, SP	Telecommunications	5,699	Spain
5	**Ambev**	São Paulo, SP	Beer and drinks	5,344	Brazil
6	**Ipiranga**	Rio de Janeiro, RJ	Wholesale (Fuel)	5,060	Brazil
7	**Volkswagen**	São Bernardo, SP	Automobiles	4,791	Germany
8	**Shell**	Rio de Janeiro, RJ	Wholesale (Fuel)	4,382	UK/Holland
9	**General Motors**	São Caetano, SP	Automobiles	4,131	USA
10	**Brasil Telecom**	Brasilia, DF	Telecommunications	3,913	Brazil
11	**Bunge Food**	Gaspar, SC	Food and Drink	3,866	Argentina
12	**Pão de Açucar**	São Paulo, SP	Retailer	3,858	Brazil
13	**Vale do Rio Doce**	Rio de Janeiro, RJ	Mining	3,628	Brazil
14	**Carrefour**	São Paulo, SP	Retailer	3,628	France

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Exhibit 18.4: 50 largest Companies in Brazil Ranked by Sales ($ Millions USD) (Continued)

	Company	City/State	Industry Sector	$ Millions	Country
15	**Brasken**	Camacari, BA	Petrochemical	3,345	Brazil
16	**Esso**	Rio de Janeiro, RJ	Wholesale (Fuel)	3,192	USA
17	**Texaco**	Rio de Janeiro, RJ	Wholesale (Fuel)	3,175	USA
18	**Embratel**	Rio de Janeiro, RJ	Telecommunication	3,167	Mexico
19	**Cargill**	São Paulo, SP	Food and Drink	3,163	USA
20	**Eletropaulo**	São Paulo, SP	Utilities (Electricity)	3,056	Brazil
21	**Nestle**	São Paulo, SP	Food and Drink	2,916	Switzerland
22	**FIAT**	Betim, MG	Automobiles	2,813	Italy
23	**CEMIG**	Belo Horizonte	Utilities (Electricity)	2,649	Brazil
24	**C.S.N.**	Rio de Janeiro, RJ	Iron and Steel	2,573	Brazil
25	**VARIG**	Porto Alegre, RS	Transportation (air carrier)	2,375	Brazil
26	**Unilever**	São Paulo, SP	Pharmacy and Hygiene	2,319	UK/Holland
27	**Souza Cruz**	Rio de Janeiro, RJ	Tobacco	2,284	UK
28	**Embraer**	São José Campos, SP	Airplanes	2,243	Brazil
29	**Gerdau**	Porto Alegre, RS	Iron and Steel	2,206	Brazil
30	**Usiminas**	Belo Horizonte, MG	Iron and Steel	2,200	Brazil/Japan
31	**Itaipu**	Brasilia, DF	Utilities (Electricity)	2,184	Brazil/Par
32	**REFAP**	Canoas, RS	Petrochemical	2,131	Brazil
33	**Casas Bahia**	São Caetano do Sul, SP	Retailer	2,112	Brazil
34	**AGIP**	São Paulo, SP	Utilities	2,108	Italy
35	**Correios**	Brasília, DF	Postal Service	2,074	Brazil
36	**Daimler**	São Bernardo, SP	Automobiles	2,022	Germany
37	**Sadia**	Concórdia, SC	Food	1,966	Brazil
38	**Light**	Rio de Janeiro, RJ	Utilities (Electricity)	1,891	France
39	**Copesul**	Triunfo, RS	Petrochemical	1,891	Brazil
40	**Ford**	São Bernardo, SP	Automobiles	1,890	USA
41	**Vivo**	São Paulo, SP	Telecommunications	1,870	Port/Spain
42	**Furnas**	Rio de Janeiro, RJ	Utilities (Electricity)	1,757	Brazil
43	**Bunge Fertilizers**	São Paulo, SP	Fertilizers	1,725	Bermuda
44	**CPFL**	Campinas, SP	Utilities (Electricity)	1,576	Brazil
45	**Cosipa**	São Paulo, SP	Iron and Steel	1,573	Brazil
46	**Nokia**	Manaus, AM	Electronics	1,550	Finland
47	**Sabesp**	São Paulo, SP	Utilities (Water & Sewage)	1,515	Brazil
48	**Perdigão**	São Paulo, SP	Food	1,483	Brazil
49	**Basf**	São Bernardo, SP	Chemicals	1,461	Germany
50	**Copersucar**	São Paulo, SP	Wholesale (sugar & alcohol)	1,448	Brazil

As shown by this list, the largest companies in Brazil are largely engaged in petroleum, telecommunications and automobiles. It should be noted that a number of the listed companies (highlighted in blue) serve the food and beverage, automobile, pharmaceutical, metal and electronics sectors, which are industries typically served by machine vision.

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Accordingly, these companies would appear to be logical targets for non-domestic MV companies seeking to export their products to Brazil.

18.2.1.6 Manufacturing in Brazil
The key to Brazil's economic development has been its manufacturing sector, which, fostered by the Brazilian government's ambitious industrialization policy, experienced rapid growth in the late 1950s and 1970s. The objective of this policy, the replacement of imported goods with domestic products, has been largely successful. Today, the manufacturing sector represents 25 percent of GDP and is growing at a rate of 4.3 percent.

Brazil's manufacturing sector is also highly diversified. In terms of employment, the leading industries are food and metal processing, automobiles, chemicals and textiles. In terms of sales, the largest industries in rank order are chemicals, foodstuffs, metals, vehicles and engineering. Importantly, Brazil is the first country to convince ten car companies to set up assemblies on its soil.

Industry is highly concentrated geographically, with forty percent found in the state of Sao Paulo. The metropolitan areas with the most industry are Sao Paulo, Rio de Janeiro, Campinas, Porto Alegre, and Belo Horizonte.

Characteristics of the Brazilian Economy

- **Size of economy: 8th largest in world at $1.804 trillion (USD)**
- **Rate of overall economic growth: 5.4% in 2007; 4.2% on average for 2008 - 2012**
- **Size of manufacturing (industrial) sector: 25% of total GDP**
- **Rate of growth of manufacturing sector: 4.3%**
- **Major exports: transport equipment & parts and metallurgical products**
- **Major imports: machinery and electrical equipment, chemical products, oil and derivatives**
- **Petroleum, telecommunications and automobiles provided by largest companies**
- **High geographic concentration of industry in the Southeast and South**

18.3 The Commercial Environment of Brazil
The commercial environment of Brazil refers to the difficulty/ease of doing business in country from the standpoint of basic business activities, practices and norms and the obstacles surrounding market entry, export and foreign direct investment.

18.3.1 Basic Business Activities in Brazil
The World Bank's Doing Business Team has published measures indicating the difficulty/ease of doing business in Brazil compared to Latin America as a whole and to OECD (Organization for Economic Cooperation and Development) countries. (Note: Brazil does not belong to the OECD.) The picture that emerges from these statistics is of

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a country in which it is relatively difficult to start a business, obtain necessary licenses and employ workers. Protecting investors, paying taxes and enforcing contracts in Brazil, on the other hand, is comparable to conditions in the region and OECD countries. Credit can be easily obtained but expensive. Trading across boundaries is not significantly different for Brazilian companies than for businesses in other Latin American countries, but more difficult than faced by firms in OECD countries.

Exhibit 18.5: Difficulty/Ease of Basic Business Activities in Brazil

Business Activity	Compared to Region	Compared to OECD Countries
Starting a Business	More difficult	Much more difficult
Dealing with Licenses	Much longer	Much longer
Employing Workers	Much more difficult	Much more difficult
Getting Credit	Similar	Similar
Protecting Investors	Similar	Similar
Paying Taxes	Tax on profit similar	Tax on profit similar
Trading Across Boarders	Similar cost to import	Higher cost to import
Enforcing contracts	Lower costs	Similar Costs

Source: World Bank

According to the Economist, modest improvements in Brazil's business environment have occurred in terms of macroeconomic stability and domestic financing conditions. However, at the same time, the tax system remains complex and burdensome.

18.3.2 Business Practices and Norms

In its publication, "Exporting to Brazil", Brazil's Ministry of External Relations cites various business and cultural norms for doing business in Brazil. For the most part, business practices are not unlike those elsewhere in the Western world or suggested by common sense. Meetings are arranged in advance and begin punctually with formal attire. Negotiations are held in a "pleasant, relaxed atmosphere" without the expectation of achieving a prompt decision. Where sale quantities are "small" or "medium", commercial contracts are <u>not</u> typical. However, price, payment terms and the quantities offered must not be changed, once agreed upon. In the case of "large" quantities, a contract must be offered in both languages.

18.3.3 Market Entry

Non-Brazilian companies seeking to enter the Brazilian market with their products must carefully consider the major options for market entry:

- Direct export: the exporter negotiates directly with the importer.
- Selling through a Trading Company (Trading Companies are by law stock companies, which typically focus only on large orders.)
- Selling through a Commercial Company (Commercial Companies are smaller companies, including limited liability companies, that handle smaller orders.)
- Enlisting the services of a Sales Representative (Sales representatives do not typically manage an import operation and are paid on a commission basis.)
- Sales Office (Exporters set up a branch office in country, which for legal purposes is regarded as a Brazilian Commercial Company.)

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Each option has its advantages and disadvantages. Direct export is the most difficult option because of Brazil's import regime (addressed in the next section); conversely, setting up a sales office is the least onerous (although other obstacles exist with this latter option, as previously mentioned in section 18.3.1).

Other options involve establishing a domestic presence by partnering with a domestic company, acquiring a domestic company or building in-country production facilities. Partnering with, or acquiring, a Brazilian company can provide established access to purchasing, sales and marketing, engineering and system integration facilities and thus enable the non-Brazilian company to leverage existing relationships. Typically, Brazilian manufacturers will not purchase MV equipment from companies without a well-established, local, technical support team.

Still another approach would be the "build" option, building a significant local capacity from scratch. However, the lead times and cost requirements could easily prove prohibitive.

All-things-being-equal, the least risky approach for a non-domestic MV company is to sell through an intermediary; that is, a reseller or distributor. However, that approach is also not without significant costs, as explained in the next section.

18.3.4 Exporting to Brazil

While business practices are comparatively encumbered within Brazil, non-Brazilian companies seeking to address Brazilian markets through export face even greater obstacles. Simply said, exporting to Brazil is very difficult and expensive. Brazil requires all importers to register with a complex documentation and taxation system, which further requires extensive licensure. Procedures are laid out in the publication, "How to Export to Brazil", authored by Brazil's Ministry of External Relations. The end result of these procedures is that the importer must pay taxes and duties on the goods to be imported, which can add another 100% to the price of the goods (for example: 60% Import Tax + 18% ICMS + customs administrative charges). (See "Import Taxes".)

Governmental Agencies: The import/export process is heavily controlled by the Government of Brazil (GOB). Specifically, the Secretary of Foreign Trade (SECEX), the Secretary of Federal Revenue (SRF) and the Brazilian Central Bank (BCB) are responsible for licensing, customs clearance and exchange monitoring. The Foreign Trade System - SISCOMEX (Sistema integrado de Comercio Exterior) is used for processing import documents. Brazilian importers must register with SRF to use SISCOMEX and with the Importers and Exporters Registry Office of SECEX.

Licensing: Import licensing is either automatic or non-automatic, but in either case must be executed through SISCOMEX. Goods subject to non-automatic licensing must have import approval prior to shipping.

Classification of Goods: Classification of goods is based on the Mercosur Common Nomenclature (NCM), which in turn is based on the Harmonized System. Care must be

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taken to use the proper classification, or fines will be levied on the importer equal to at least one percent of the value of the imported goods. (The costs of miscalculation can add significantly to the price of the goods.)

Import Taxes: Rates correspond to the NCM as recorded in Mercosur's Common External Tariff - TEC. Additional taxes that are imposed are the Tax on Industrialized Products (IPI) and the Tax on the Circulation of Goods and Services (ICMS). (The GOB views these taxes as a "leveling of conditions" instead of tariff protectionism.) Also, air shipments are subject to a flat 60% duty and a tax on the FOB value of the shipped goods. Ocean freight is subject to a 25% Merchant Marine Renewal (MMR) Tax. There is also a 1% Brokerage Fee, a 1% Warehouse Tax and a $50 (USD) Port Tax. Clearly, the sum total of taxes that are imposed on imported goods can make them prohibitively expensive.

Customs Clearance: The process of clearing customs begins when the imported goods arrive in Brazil. The importer prepares an Import Declaration (DI) and registers it with the payment of an Important Tax, Excise Tax and SISCOMEX user fees. After some checks by a customs official, the SRF releases an Import Warrant (CI) in the SISCOMEX to confirm customs clearance. SISCOMEX then determines the method of customs clearance: "green", "yellow", "red" or "gray". Additional inspection is required, if green is not selected. Also, the importer must present to the Federal Revenue Office, an Import Declaration and proof or waiver of the ICMS. For goods falling under the gray option, a Declaration of Customs Value (DVA) must be made. Once customs is clear, goods can be delivered.

Brazil's Commercial Environment at a Glance

- **The commercial environment in Brazil favors companies with domestic sales offices as opposed to foreign companies exporting to the Brazilian market.**
- **Exporting to Brazil is very difficult and expensive; The Government of Brazil seeks to discourage foreign companies from competing with Brazilian companies.**
- **Investing in Brazil is relatively easy; The Government of Brazil encourages FDI.**
- **Setting up and managing a business in Brazil tends to be more difficult than in other Latin American countries and in OECD countries.**

18.3.5 Foreign Direct Investment in Brazil

In stark contrast to its import regime, Brazil's foreign investment rules are quite liberal. This is by design; the GOB views Brazil's economy as developing and therefore wishes to encourage investment, while discouraging external competition with its companies. As a result, foreign direct investment (FDI) in Brazil has been substantial. In 2007 alone, FDI reached $18.782 billion (USD). Over time, FDI has been a key enabler of industrialization of Brazil.

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18.4 Machine Vision in Brazil

Machine vision has made inroads in Brazil but still finds itself in a nascent stage of development. Brazilian MV companies are few in number and act primarily as distributors for non-Brazilian MV companies. A number of the largest MV companies in the world have maintained a presence in the Brazilian market through their Brazilian distributors.

18.4.1 MV Companies Selling into the Brazilian Market

MV companies selling into the Brazilian market include domestic MV companies and foreign (non-Brazilian) MV companies.

18.4.1.1 Domestic Companies

There are approximately six Brazilian MV companies, but - as previously mentioned - they are engaged in distribution and integration - not the manufacture of MV components and ASMV (off-the-shelf, turnkey MV) systems.

Brazilian machine vision companies include Attiva, InviSys, MAR Industries, Omni International, Pollux and Ponfac.

- Attiva (Altec Vision Company) is an authorized distributor for JAI, DALSA, PixeLink, Imperx, Euresys, Epix, Fujinon, Navitar, Tamron, Advanced Illumination and Matrix Vision. The company is focused on Medical Area, Industrial Inspection, Scientific and Educational Applications, Quality Control, Monitoring, OEM, and System Integrators, Research and Development. It has research laboratories in both Brazil and in the United States.

- InviSys is a distributor and integrator. In addition to distributing products for Matrox, the company also develops and integrates systems with equipment from Cognex, Prosilica, Basler and Edmund Optics. It sells its products into multiple industries: agriculture, food and beverage, pharmaceuticals, metal, printing, ceramic tiles, wood products and the electrical/electronics industry.

- Omni International is a distributor for Cognex in Brazil (along with Pollux and InviSys).

- MAR Industries is an authorized distributor for Adept Technology, a provider of vision-guided robotics and a systems integrator. The company also utilizes Siemens hardware and software.

- Pollux is a distributor for Cognex, Eureys and Avalon. Founded in 1996, Pollux is the largest MV company in Brazil with 80 direct employees, over 500 systems for more than 250 customers and facilities in São Paulo, Joinville, Campinas and Porto Alegre. Pollux focuses on the pharmaceutical, health care, automotive, food and beverage and electronics industries.

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- Ponfac is a software manufacturer and system integrator that was founded in 1997. The company utilizes its own software and hardware from Euresys, Siemens and AVT.

18.4.1.2 Foreign Companies

Non-Brazilan MV companies whose products are sold in the Brazilian market include Advanced Illumination, Adept Technology, Avalon, Basler, Cognex, DALSA, Edmund Optics, Euresys, Epix, Fujinon, Imperx, JAI, Matrix Vision, Matrox, Navitar, PixeLink. Prosilica (acquired by AVT) and Tamron. Presently, very few North American, European and Japanese companies have significantly penetrated the Brazilian market due to language barriers, the geographic size of the country and the size of key markets. Evidence suggests that these companies view Brazil as other Latin American countries and therefore fail to realize the distinct differences and challenges of language and culture. This perception - along with the other market entry obstacles previously mentioned - contributes to the decision to regard Brazil as a non-strategic market objective.

18.5 Market Opportunity in Brazil

The information we have presented strongly suggests an important role for machine vision in Brazil. Brazil is a large and modernizing nation that seeks to become a manufacturing power house on the world stage. Much progress has been made in this regard as the consequence of substantial FDI and the presence of large manufacturers in country.

As mentioned previously, likely candidates for adoption of machine vision are the largest companies serving those industries for which MV applications have been developed; in particular, automotive, the food and beverage, pharmaceutical, metal and electronics industries.

MV companies are already targeting businesses operating in these and other sectors. For the most part, the MV products being sold into the Brazilian market are not Brazilian but rather foreign in origin. Indigenous MV manufacturers are largely non-existent.
All in all, the market opportunities for foreign suppliers of MV products appear limited. Direct exporting is very difficult due to the challenges of complying with a complicated import regime. That necessitates the use of domestic distributors, who - as the gatekeepers to the Brazilian market - must add sales fees to the already steep import taxes imposed on MV products. This results in high prices for MV products, which of course cut into margins and limit customer demand. Both factors thus constrict market opportunity.

The way around this problem for foreign MV manufacturers might be to set up production facilities in country, but - as previously mentioned - this is an expensive strategy that requires deep pockets. Finding a Brazilian partner with sufficient capital might be the solution, however. Brazilian MV distributors might also elect this approach, raising capital to set up production facilities; that is, vertically integrating in order to

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replace expensive foreign MV products with lower cost, domestically produced MV products.

However the obstacles to greater adoption of MV technology are surmounted, one thing is clear. If Brazil is to become a world class exporter of manufactured goods, it will have to achieve cost efficiencies, productivity and quality control in manufacturing, which will bode well for machine vision. The greater question is how will that demand be met and what strategy will enable what MV companies to realize the greatest market opportunity.

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Chapter 19: The Mexican Machine Vision Market –

New Market Opportunity Assessment

19.0 What's New in this Chapter?
This is an all-new chapter.

19.1 Introduction
Mexico is a large country with a geographic area roughly three times the size of Texas and a population of 104 million. Its free market economy is comparatively large at $872.6 billion nominally. Taking into account relative purchasing power (purchasing power parity or "PPP" for short), the economy is over one trillion dollars at $1.353 trillion (USD), making it the thirteenth largest in the world. The country's free market economy is heavily oriented toward foreign trade and participates in no less than 12 foreign trade agreements including NAFTA, which has helped Mexico to expand its manufacturing base significantly. An important aspect of Mexico's economy is its in-bond processing or "Maquiladora" sector, consisting of factories which take in imported raw materials and intermediate goods and produce finished goods for export.

Machine vision is in a nascent stage of development in Mexico. Its adoption is somewhat constrained by the abundance of inexpensive labor. Productivity is relatively low in Mexico and thus could benefit greatly from automation technologies such as machine vision.

19.2 The Mexican Economy
Mexico's $1.353 trillion (USD), free market economy is the thirteenth largest in the world in terms of purchase power parity (as of 2007). In nominal terms, gross domestic product (GDP) grew to $872.6 billion in 2007, representing just under one-third (28.5%) of the total GDP in Latin America. This economy, which is closely integrated with the

US economy because of NAFTA, grows at rates that are strongly influenced by the business cycle in the US. Real GDP (percent annual change) was 2.9% in 2007, down from 4.8% in 2006. In 2008, real GDP is expected to slow down to approximately 2.1%.

On a per capital basis, GDP in Mexico is $8,219 (USD) nominal or $12,382 in terms of purchasing parity power, the highest per capita income in Latin America but about one-fourth of that in the US. According to the Organization for Economic Cooperation and Development (OECD), "Growth in GDP per capita has been barely sufficient to prevent the large gap vis-à-vis the wealthier countries from widening further. The low level of labor productivity is the main source of the income gap."

In terms of GDP, Mexico's economy is weighted heavily toward the service section at 69.4 percent of total GDP. Manufacturing ("industry") accounts for not quite one-third at 26.7% and the remainder (3.9%) is contributed by agriculture.

In terms of trade, Mexico is the world's fifteenth largest merchandise exporter and twelfth largest merchandise importer.

19.2.1 Major Characteristics

To identify the major characteristics of the Mexican economy, we examine economic size, growth, structure, export/import patterns and companies in Mexico and the manufacturing sector.

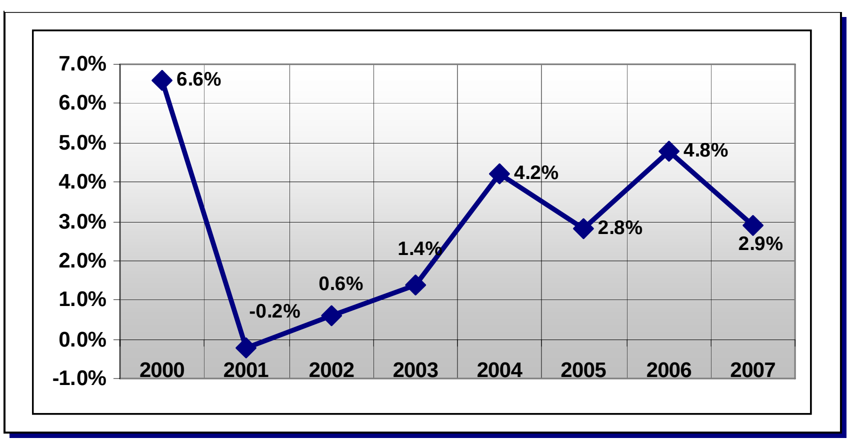
19.2.1.1 Size of the Economy

As previously mentioned, Mexico has a $1.353 billion (USD) economy (based on purchasing power parity), making it the thirteenth largest economy in the world. On a per capital basis, this equates to $12,382 (USD), which is considerably lower than most Western economies.

19.2.1.2 Economic Growth

Mexico's rate of economic growth has varied considerably over time. Real GDP growth (expressed in terms of percent annual change) was 2.9% in 2007, down from 4.8% in 2006. GDP is expected to slow down in 2008 to approximately 2.1%. Real GDP has varied greatly over time in terms of rate of growth, as shown by Exhibit 19.1. According to the OECD's economic outlook No. 82, "GDP growth is expected to accelerate in the course of 2008 and reach 4 1/4 per cent in 2009. The approval of the fiscal

Exhibit 19.1: Real GDP Growth in Mexico



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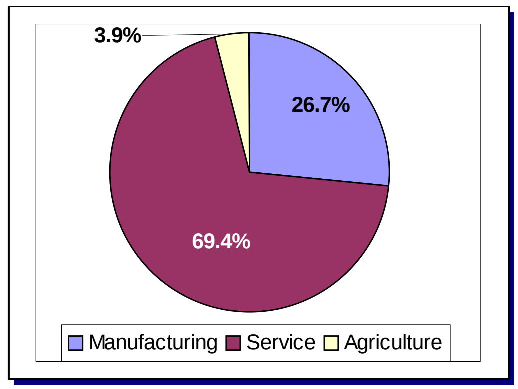
reform should boost business confidence, underpinning stronger (domestic and foreign) investment." The Economist Intelligence Unit is less sanguine. "With the US recession in the first half of 2008 under our central forecast, we expect GDP growth in Mexico to slow to 2.1% in 2008, before recovering gradually to 2.5% in 2009." (We find this less optimistic forecast more credible, given its recentness.)

19.2.1.3 Structure of the Economy

Mexico has a pronounced service sector, which contributes nearly 70 percent (69.4 percent) of total GDP. The manufacturing sector, on the other hand, produces just under one-third (26.7%) with agriculture accounting for the remainder (3.9 percent), as shown by Exhibit 19.2.

Exhibit 19.2: Structure of Mexico's Economy



Source: Economist Intelligence Unit

19.2.1.4 Exports and Imports

Exports of goods (free on board) and services have ranged from 30.0 to 31.9 percent of total GDP between 2000 and 2006. In 2006, exports amounted to $250.0 billion. For the same period, imports (free on board) have varied between 31.5 and 33.2 percent of total GDP. In 2006, imports totaled $256.1 billion.

Manufactured goods account for 81.1% of total exports. Maquiladoras, factories which take in imported raw materials and produce goods for export, are also very important, accounting for 44.7% of exports and 34.2% of imports. Their important role is addressed in section 19.2.1.6.

Exhibit 19.3: Exports and Imports in Mexico

Principal Exports 2006	$ USD Bil	Principal Imports 2006	$ USD Bil
Manufactured Goods	202.7	Intermediate Goods	188.6
Maquiladora	111.8*	Maquiladora	87.5*
Oil	39.0	Capital Goods	30.5
Agricultural Goods	7.0	Consumer Goods	37.0
Minerals	1.3		
Total	250.0	Total	256.1

*Included in manufactured goods

Source: Economist Intelligence Unit

According to the Economist Intelligence Unit's outlook for 2008-09, "The trade deficit will widen further in 2008-09, despite historically high oil prices, as a contraction in US import volumes hits export earnings." (Also see section 19.3.4.)

The Mexican economy is strongly focused on exporting with no less than 12 free trade agreements (including NAFTA) with over 40 countries. In fact, no less than 90% of

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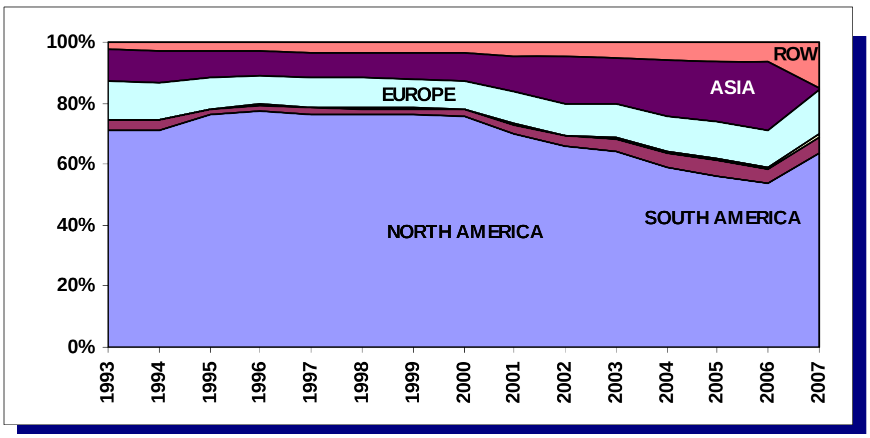
Mexico's trade is covered by free trade agreements. In Latin America, Mexico is clearly the largest exporter with a volume of sales that is roughly the equivalent of the exports of Brazil, Argentina, Venezuela, Uruguay and Paraguay combined.

On the import side of trade, slightly over half (53%) of Mexico's imports come from North America. In earlier years, North America accounted for approximately 70% of imports, but this percentage has declined, as shown by Exhibit 19.4.

Exhibit 19.4: National Origin of Mexican Imports over Time



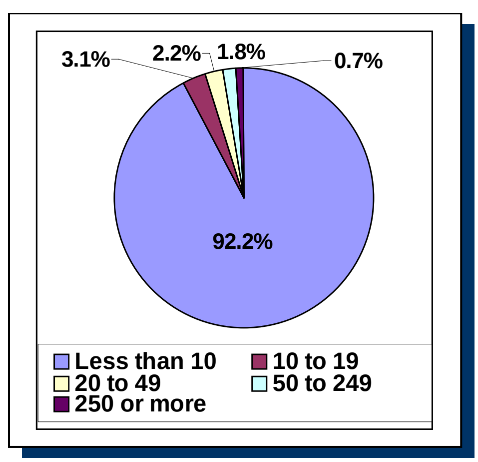
Source: Mexico Ministry of Economy, Under-ministry of International Trade Negotiations

The large volume of trade with North America results largely from the high degree of integration with the US and Canada stemming from NAFTA; close to 90% of Mexico's exports go to the US and Canada.

NAFTA

In terms of the volume of trade affected, the North American Trade Agreement (NAFTA) is the most important free trade agreement by far entered into by Mexico. Under NAFTA, all tariffs on goods exchanged between Mexico, the US and Canada were eliminated. It is important to note that NAFTA did not initiate the Maquiladora program, which was in place long before the adoption of NAFTA. Prior to NAFTA, the US allowed maquiladora manufactured goods to be imported into the US with the tariff rate only being applied to the value of non-US raw materials used to produce the goods. However, under NAFTA, the US increased tariff rates on all Maquiladora manufactured goods not covered by NAFTA. (This prevents third world countries from using maquiladoras as a back door to circumvent US customs.)

Exhibit 19.5: Percent of SMEs by Size in Terms of Number of Employees



Source: OECD

19.2.1.5 Mexican Businesses

Thirteen million business operations are located in Mexico according to the last (1998) Economic Census. Of these, 361,579 (11.5%) were manufacturers.

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Excluding large, publicly-traded companies, most (92.2 percent) small and medium enterprises (SMEs) have less than 10 employees according to the OECD.

19.2.1.6 Manufacturing in Mexico

The Mexican manufacturing sector represents a significant opportunity for companies who manufacture industrial components and equipment, as well as products used to support and maintain manufacturing operations. In 2006, manufacturing and mining accounted for 19.6% (about one-fifth) of total GDP, while industry as a whole accounted for 26.7% of total GDP. For the same year, manufacturing accounted for over half (56.0%) of all exports from Mexico.

Industrial Growth

Industry as a whole has grown modestly as of late, 3.6% in 2006 and an estimated 1.2% in 2007.

Geographic Concentrations of Industry

Principal industrial centers of Mexico include the Mexico City metro area, Monterrey and Guadalajara. The Maquiladoras are located primarily along the US border.

Manufacturing Sectors

The largest manufacturing sectors are food-related, metal products, machinery, transportation and chemicals. The relative size of the manufacturing sectors is as follows:

- Food processing, beverages, tobacco 26%
- Metal products, machinery, transportation 24%
- Textiles, clothing, footware 9%
- Chemicals 18%
- Petrochemicals 2%
- Non-metallic minerals 7%
- Basic metals 6%
- Paper, printing, publishing 5%
- Wood products 3%

Within the metal products, machinery and transportation sectors; automotive manufacture continues to be very important in Mexico. In 2001, Mexico became the ninth largest producer of automotive vehicles in the world, manufacturing 1.92 million units. In 2007, output rose to 2.1 million. (Note: Other sources show Mexico as the 11th largest producer and 10th largest exporter of autos.)

Maquiladoras

An important aspect of manufacturing in Mexico, and of the entire Mexican economy, is the important role of the maquiladoras, Mexican factories which take in imported raw materials and produce goods for export. Maquiladoras account for 31% of exports and 25.5% of imports and are largely responsible for a high degree of integration between the US and Mexican economies.

The Mexican government encouraged the establishment of maquiladora plants in border areas, beginning in 1965, to take advantage of a US customs regulation that limited the duty on imported goods assembled abroad from US components to the value added in the

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manufacturing process. Most maquiladora plants were established in or near the 12 main cities along Mexico's northern border. Electronics plants tend to be concentrated in Tijuana, while textile production is found mainly in Puebla and Guadalajara. Auto production is more dispersed, located in Puebla, Toluca, Hermosillo and Guadalajara. Most maquiladora plants are foreign-owned and situated in Mexico to take advantage of low labor costs and proximity to the US border. In addition to automobiles and related products, maquiladora plants produce goods such as electronics, clothing and furniture.

Customs treatment: All raw materials, parts and machinery are imported into Mexico on a temporary basis duty free for up to 18 months. For machinery, this can be renewed indefinitely but for raw materials and parts no such renewal is possible. If a company wishes to import a NAFTA good into the country permanently, it can avoid a duty but must pay a 10% VAT.

Maquiladoras are less important today as the consequence of globalization, which has favored lower-cost offshore assembly elsewhere. Some 529 maquiladoras have shut down since 2000, but over 3,000 remain.

Characteristics of the Mexican Economy

- **Size of economy: 13th largest in world at $1.353 trillion (USD) in Purchasing Power Parity**
- **Rate of overall economic growth: 2.9% in 2007**
- **Size of manufacturing (industrial) sector: 26.7% of total GDP**
- **Rate of growth of manufacturing (industrial) sector: 1.2% (estimate)**
- **Major exports: manufactured goods (mainly processed food products, beverages and tobacco; metal products; machinery and transportation)**
- **Major imports: intermediate goods (goods that have not yet reached their final stage of production such as parts for assembly)**

19.3 The Commercial Environment of Mexico

The commercial environment of Mexico refers to the difficulty/ease of doing business in country from the standpoint of basic business activities, practices and norms and the obstacles surrounding market entry, export and foreign direct investment.

19.3.1 Business Practices and Norms

<u>Business Customs</u>

Business in Mexico is all about relationships and people, but it should be noted that business and social customs governing relationships between people vary widely in Mexico. The Northern region has assimilated many habits and customs of the US. The Central region, on the other hand, is more provincial; business moves slower than in the North. By contrast, the South is the most underdeveloped area and therefore the most

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provincial. An example of a business norm that can differ regionally is the length of the workday. At the same time, there are some customs that are ubiquitous; they include:

- The importance of business meals and participation in social activities.
- Patience as a key to doing business in Mexico; meetings are often longer with much small talk before getting to the business at hand.
- "Yes" in Mexican social etiquette: "Yes"does not always mean "yes". (Mexicans are often too polite to say "no" when they're thinking "no".)
- Avoidance of aggressive negotiating.

19.3.2 Taxation on Business in Mexico

In Mexico, companies paying taxes must deal with the "Hacienda", the national tax authority, which plays the largest role in taxation, since most taxes are federal. There are three primary taxes at the federal level: the I.S.R. (levied on salary), IMPAC (levied on assets) and I.V.A., a 15% VAT. At the state level, the only tax is the I.S.N., which is levied on payroll with rates that vary by state.

19.3.3 Market Entry

Non-Mexican companies seeking to enter the Mexican market face two fundamental options: establishing an in-country manufacturing capability or selling through a distributor.

<u>Establishing A Manufacturing Capability</u>

There are different, generic approaches to establishing a manufacturing capability in Mexico (each which its own mix of challenges and benefits):

- Subcontracting (typically for smaller operations)
- Joint venture with indigenous party (to take advantage of partner's knowledge of the local market)
- Wholly-owned subsidiary (can be more costly, riskier and complex)
- Manufacturing shelter (A value-added outsourcing arrangement whereby manufacturers send raw materials and supervisory personnel to train and manage workers, while the shelter company performs the tasks and functions that are not core to manufacturing such as HR, plant management, procurement, logistics, etc.) The shelter company thus limits the risks to the manufacturer, allowing the manufacturer to leverage its core competencies.

<u>Selling through Mexican Distributors</u>

A number of different approaches to selling exports to Mexico exist.

- Selling direct to the end-user
- Selling through US based distributors active in Mexico
- Selling through a Mexican manufacturer
- Selling through wholesalers
- Selling through distributors/retailers
- Selling through agents

Evaluating these options requires careful analysis to avoid failure as well as an understanding customs regulations and procedures. Regardless of which option is

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selected, domestic distributors can provide invaluable knowledge and selling skills, such as language ability and knowledge of local business customs, customs regulations and tax rules. Not all distributors, however, are sufficiently prepared to sell MV products. In fact, many distributors are small and inexperienced and therefore must be carefully cultivated and trained, as they build their customer base. In the area of machine vision, large distributors with established customer bases are the exception and not the rule in Mexico. As this suggests, developing distribution channels in Mexico is apt to be a long-term undertaking.

Customs in Mexico
Under the general control of the Federal Mexican Government in the Ministry of Commerce and Industrial Development, "Aduana" (Customs) enforces very strict laws regarding proper submission and preparation of Customs documentation. According to these laws, export and import can be either temporary or permanent, but in every case require an application called the "*pedimento*". Additionally, a license might also be required for importing/exporting. Other requirements are as follows:

- Packages must be labeled in Spanish.
- Classification: Items must be identified according to their *Harmonized System* (HS) code number.
- Companies exporting to Mexico, as well as importers, must be registered with the Federal Taxation authority of Mexico, the "*Hacienda*".
- An *import permit* may be necessary along with an import duty.
- The use of *customs brokers*, which are registered with the customs authority. (Typically, the Mexican importer hires the *customs broker*.)

Import duties, if they are imposed, range from zero to 35%, with the trade-weighted average tariff of 2.9%. There is also a *15% VAT* except for the border region, where it is 10%. The duty is determined by applying the applicable tariff to the *CIF* (cost of the product + insurance + freight) value of the product. There is also a *customs processing fee* of $8/10^{th}$ of 1% of the assessed CIF value.

US companies exporting to Mexico can call the US NAFTA help desk to see if their products are covered by NAFTA. Under NAFTA, an imported product must have a *Certificate of Origin.* A *Certificate of Quality* might also be required.

19.3.4 Foreign Direct Investment in Mexico

Mexican FDI law identifies 704 activities, 606 of which are open for 100% FDI stakes. However, as reported by the OECD, there are still industries in Mexico where significant restrictions on foreign direct investment exist. Needless to say, much "on-the-ground" research is needed before making a sizeable investment.

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Mexico's Commercial Environment at a Glance

- **Wide geographic variation exists in business practices and cultural norms.**
- **Establishing an in-country manufacturing capability is a long-term, resource intensive activity.**
- **Where an in-country manufacturing capability proves too challenging, establishing distributor relationships is key but also requires a long-term commitment.**
- **Three taxes are imposed on businesses at the national level; one at the state level.**
- **Most imports are covered by trade agreements (such as NAFTA), which limit import duties. Imports thus do not face stiff hurdles.**
- **Import duties can range from 0% to 35%.**
- **A 15% VAT also applies except in border regions, where it is 10%.**

19.4 Machine Vision in Mexico

Machine vision is in a nascent stage of development in Mexico. As previously mentioned, many companies have set up production facilities as maquiladoras in Mexico to take advantage of lower labor costs. Typically, where cost containment strategies are based primarily on the abundance of inexpensive labor, acceptance of automation technologies is more limited than otherwise. At the same time, where quality control is crucial, companies that utilize machine vision in their country and also have production facilities in Mexico are logical customer targets for MV companies. There is some evidence that a new culture of quality is emerging in Mexico, which MV companies might be able to leverage with increasing success.

Machine Vision Companies

There are a number of companies selling MV equipment and software in the Mexican market, some of which are based in Mexico. These include the companies listed below.

Exhibit 19.6: Companies Selling Machine Vision Products in Mexico

MV Company	Type of Company	Place of Origin
Afa	Distributor	Mexico
Apiliatec	Distributor	Mexico
Aumeco	Authorized Distributor	Argentina
Avalon	Manufacturer	USA
Cognex	Supplier	USA
Fabrica Inteligente	Engineering Services	Mexico
Flexivel	Distributor	Mexico
Grupo Empac	Distributor	Mexico
Icesa Modicon	Distributor	Mexico

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Exhibit 19.6: Companies Selling Machine Vision Products in Mexico (Continued)

MV Company	Type of Company	Place of Origin
Icesa Modicon	Distributor	Mexico
Icraa Ing. Control Robotica y Automatizacion Avanzada	Integrator/Distributor	Mexico
Infaimon Mexico	Distributor	Mexico
Insol (Infinite Solutions) s.c.	Manufacturer	Mexico
ISEL	Distributor	Mexico
Latintec	Distributor	Mexico
Lider Control	Engineering Services	Mexico
Marllam de Matamoros	Distributor	USA
Movitren	Distributor	Mexico
National Instruments	Manufacturer	USA
Nexon Mexico	Distributor	Mexico
Pack & Process	Distributor	Mexico
Pollux	Cognex distributor	Mexico
Prefixa	The Imaging Source distributor	Mexico
Pyramid Technologies	Manufacturer	USA
Thermo Fisher Scientific	Manufacturer	USA
Vision Trade International	Authorized Distributor	Mexico

Source: QuimiNet.com and the web

19.5 Conclusion

The Mexican government has pursued a trade-friendly policy, making it easier to do business in Mexico. Highly protectionist trade barriers are generally not in evidence and in this fundamental respect, Mexico is much different than Brazil. Market opportunities for machine vision companies exist in Mexico. However, they are long-term in nature and should mature, as Mexican companies increasingly embrace a new “culture of quality”. MV companies should therefore expect to spend considerable time building production capabilities or distributor networks in place of instant, “slam dunk” sales. A valuable sales approach might be to focus on small, entry projects that can be used to build knowledge about, and confidence in, machine vision as an enabler of efficiency, productivity and quality in manufacturing operations.

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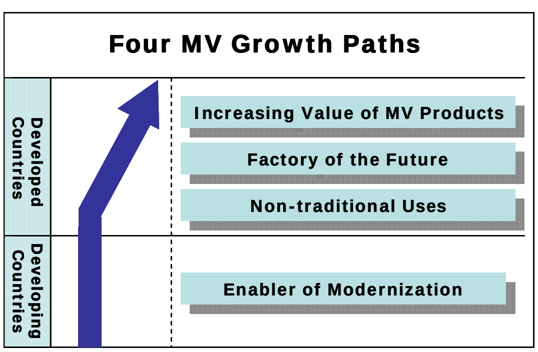
Chapter 20: The Future of the Machine Vision Industry

20.0 What's New in this Chapter?
This is an all-new chapter except section 20.4.

20.1 Introduction
The MV industry is poised for a bright future. While the effects of the business cycle are ever present, resulting in short-term fluctuations in demand, no less than four growth paths will propel MV sales upwards in the long-term. These growth paths are the increasing value of MV products, the role machine vision will play in the "factory of the future", the penetration of MV technology into non-traditional, non-industrial sectors of the economy and increased reliance on MV technology as an enabler of economic modernization in developing countries. The deployment of MV technology will thus expand geographically to developing countries, and within developed countries its acceptance will increase in economic sectors currently served by it, while spreading to additional, non-traditional sectors. As a consequence of this four-front expansion, the MV industry as a whole will achieve impressive growth.



In this chapter, we explain these four growth paths, beginning with the increasing value of MV products.

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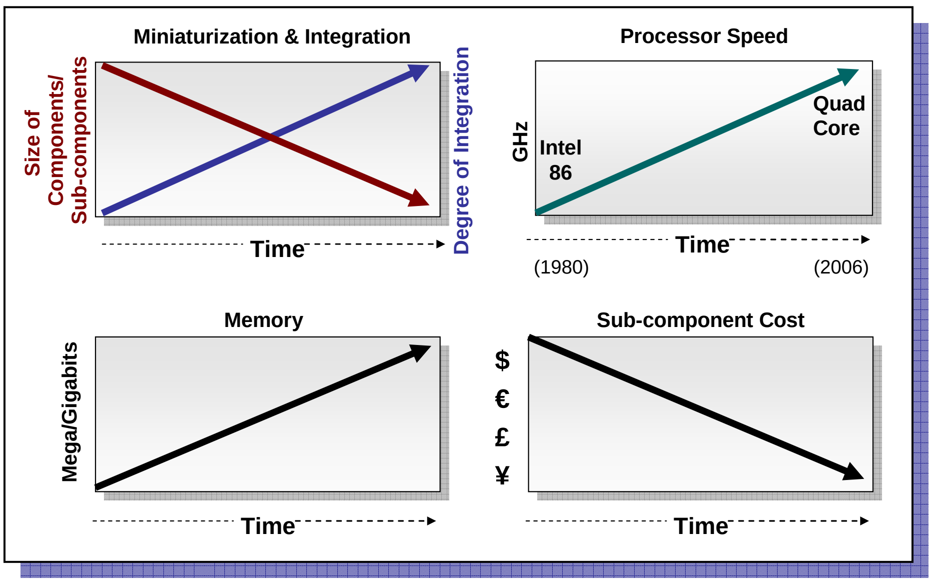
20.2 The Increasing Value of MV Products

An examination of the evolution of MV products shows a steady strengthening of the basic MV value proposition: greater productivity and higher quality at a lower cost. Simply said, MV products have generally afforded increasing value over time by enabling greater productivity and higher product quality at decreasing prices. This increasing value has, in turn, stimulated greater sales volumes, which over the longer-term has boosted, and will continue to improve, the fortunes of the MV industry.

This pattern of increasing value derives from key technological trends and decreases in the average prices of MV products. Key technological trends are increasing core capabilities and the decline in the average costs of sub-components.

Exhibit 20.1: Key Technological Trends



<u>Increasing Capabilities</u>

The capabilities of machine vision products have steadily improved over time. As explained in previous AIA market studies, computer-related, camera-related and connection-related developments outside of the machine vision industry have spilled over into the machine vision industry, greatly benefiting it.

Computer-related developments that have boosted MV capability include faster processors and bus speeds. Everyone is familiar with the steady improvement in PC CPUs, such as the evolution of Intel processors from the 286 family to the dual processors available today that permit parallel processing. In addition, different types of processors and related devices have emerged, including RISCs (reduced instruction set computers), DSPs (digital signal processors) and FGPAs (field-programmable gate arrays). Computer busses have also evolved to support faster data transfer rates. In contrast to the ISA bus, which permitted a transfer rate of only 16 MB/s, PCI Express allows 2,500 MB/s, a bus transfer rate that is 156 times faster!

Camera-related developments have also exerted a major influence on the core capabilities of MV products. In particular, these include a trend toward increasing resolutions and the introduction of faster sensor frame rates. Today, MV cameras available for sale cannot only produce images with resolutions up to 10 mega pixels but also much faster images, which accommodate rapid inspection processes.

Finally, connection-related developments have involved the introduction of interfaces able to support the transport of much larger amounts of bandwidth. Increasingly, slower interfaces (such as basic analog) are giving way to faster, digital interfaces (such as Camera Link and GigE Vision). These faster interfaces are necessary to handle the higher bandwidth signals generated by faster sensor frame rates and greater resolution.

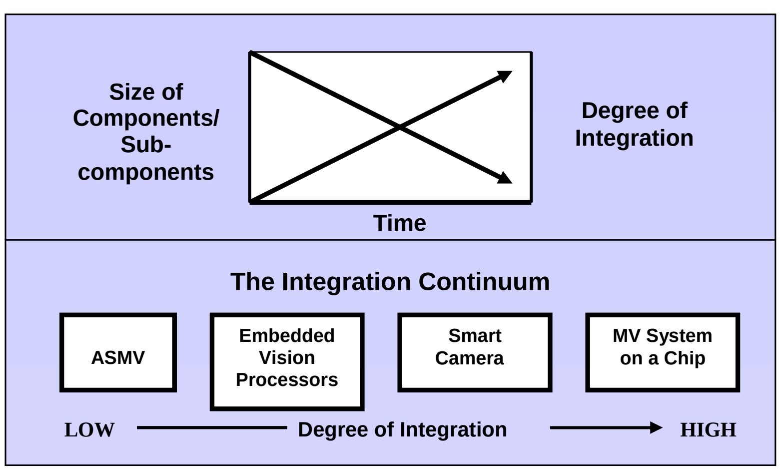
Exhibit 20.2: Expanding Core Capabilities of MV Systems

Capability Drivers	Maximum Available Then	Maximum Available Now
1. Computer-Related		
- Faster Processors	286X	Quad Core
- Faster Bus Speeds	ISA	PCI Express
2. Camera-Related		
- Higher Resolutions	1,000 Pixels	10 Mega pixels
- Sensor Frame Rate	30/s	500/s
3. Connection-Related		
- Interfaces	Basic Analog	Camera Link (Full Continuous Mode)

Declining Sub-component Costs

Another salient, fundamental trend has been the gradual decline in average unit price per capacity of sub-components used in MV and other electronic products. In the case of hard drives, for example, there has been a 90 percent increase per year in the amount of storage for the same amount of money over the last 15 years. Also illustrative of this trend is the dramatic drop in computer memory prices. In 1964, 2K of Univac memory cost $102,529. By 1979, 12K of CMOS-based memory cost $7,000. In 1988, 8 MBs of DRAM memory could be purchased for an average price of $880. In 2003, a much larger amount of memory, 512 MBs, cost only $79. Today, 2,048 MBs of DDR2 memory costs only $30! This increase in capacity per price is of course as predicted by Moore's law.

Exhibit 20.3: **Trend Three: Miniaturization and Integration**



Miniaturization and Integration

While MV products are generally becoming more capable and less expensive, they are also,

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in some cases, becoming more integrated and are assuming smaller form factors. The best known example of this is the smart camera, which integrates the functions of a complete MV system in a single physical unit. In terms of integration, a smart camera is nearly the polar opposite of a PC-based MV system, which utilizes modular components. Only an MV system on a chip, as NASA has proposed, is more integrated and smaller.

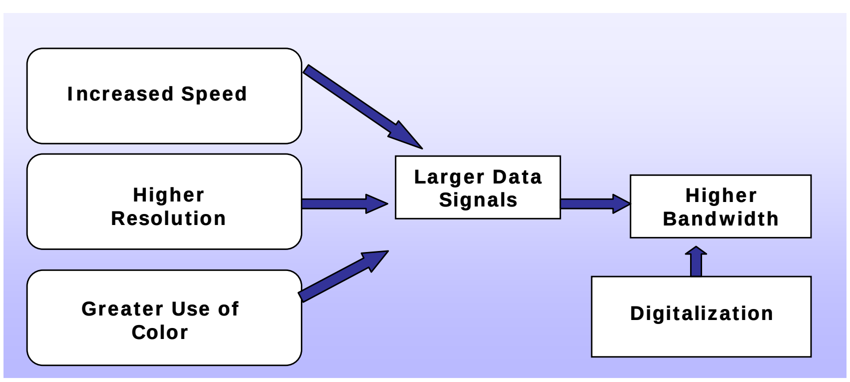
As the example of the smart camera illustrates, miniaturization and integration have gone hand in hand. The miniaturization of sub-components has enabled their integration in small form factors.

As shown by Exhibit 20.3, different types of MV systems represent differing degrees of integration and thus can be conceived of as forming a continuum. As previously mentioned, PC-based MV systems reflect a modular configuration and thus represent the least degree of miniaturization and integration. In comparison, embedded vision processors are far more integrated but not as integrated as smart cameras, since embedded vision processors do not integrate the camera with the processor unit, as is the case with smart cameras. (The embedded vision processor's camera is instead tethered to the processor unit.) Representing the ultimate in miniaturization and integration, low-powered MV systems on a chip might one day become commonplace.

MV Product Trends

Based on the technological trends just outlined and changes in dominant MV product features over time, it is possible to discern some major product trends and their inter-relationships. As shown in Exhibit 20.4, these trends are increased speed, higher resolution and greater use of color, all of which will generate larger data signals that must be processed and transported. This, in turn, will require greater bandwidth, as will also the clear trend towards digitalization.

Exhibit 20.4: Major Product Trends



Other MV product trends include greater performance, lower cost, miniaturization and greater functional integration in some cases and modularization on a smaller scale in others. (See section 20.3.6. for a discussion regarding the customization of MV products.)

If we extrapolate these product trends, and no disruptive technological events intervene, we can probably get an accurate glimpse of the MV products of the future. Performing this exercise, we would expect future MV products to have the following dominant characteristics:

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- Greater speed
- More power
- Digital
- Decreased size
- Greater integration
- Higher resolution
- Wider spectrum
- Cost effectiveness

20.3 The Factory of the Future

The emergence of the factory of the future will also bode well for the MV industry. As factories change in structure and operation, automation will play an increasingly important role. To take advantage of that development, MV companies will adjust their sales and product strategies to stay attuned to the needs of manufacturers, and so the MV industry will likewise evolve.

A brief examination of history leaves little doubt that manufacturing, and the factory itself, have changed, and continue to change, over time. In fact, factories, as we know them today, began with the industrial revolution, when a new source of power, steam, made mass production possible; that is, the standardized, cost efficient production of a large number of commodities. Prior to the advent of the factory, the craftsman era prevailed. This involved the time and cost intensive production of a small number of high quality products performed by relatively small groups of highly skilled men in small workshops.

20.3.1 Traditional Factories

The form of manufacturing brought forth by the industrial revolution completely swept aside the craftsman workshop as the dominant mode of manufacturing. With new sources of power (electrical in place of steam) and the introduction of the conveyor belt, the evolution of the factory progressed to the point where we are familiar with it today.

Since the factory of the future is typically defined in contrast to the traditional factory, it is helpful to list the defining characteristics of the traditional factory. First of all, the traditional factory is designed for mass production instead of piece work, which allowed the realization of economies of scale. (Costs could be spread over a high volume of units, resulting in low unit costs, which in turn made products highly affordable.) But the price that had to be paid for this efficiency was high. All commodities produced were identical, or in the words of Henry Ford, “People can have the model T in any color - so long as it’s black.” It also meant that workers performed largely repetitious, limited roles, such as turning the same, single screw on the same product. Of course, no special training was needed for such limited roles, and workers were consequently considered expendable.

To achieve cost efficiencies, factories also had to operate at high capacity and were structured for linear work flows where commodities being produced would pass through different work stations until completed. Similar equipment was located at the same work station, and large inventories of raw materials, work-in-progress and finished goods were

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maintained as a hedge against uncertainty in supplier delivery and quality, production rates and quality; and customer demand.

20.3.2 Lean Manufacturing

A key concept of the factory of the future is lean manufacturing. Derived from the Toyota production system, lean manufacturing is an operational strategy that aims at achieving the shortest possible cycle time by eliminating waste; that is, all non-value added activities. Implicit in this approach is an ongoing, systematic analysis of work processes to identify waste in order to drive continuous improvement. This of course represents a major, strategic commitment of the organization, but the benefits are impressive: lower costs, higher product quality and shorter production cycle times, all of which are intended to promise greater customer satisfaction. Additional benefits include half the required manufacturing space, half the human effort, half the investment in tools and half the engineering hours.

Key characteristics of lean manufacturing that differ from traditional manufacturing include:

- Single-piece production
- Just-in-time materials and pull scheduling in place of traditional inventories
- Short production cycle times
- Quick changeovers in place of lengthy retooling
- Continuous flow work cells
- Collocated machines, equipment, tools and people
- Multi-skilled employees

20.3.3 The Central Role of Information Technology

The factory of the future also makes use of information technology (IT) to a much greater extent than heretofore. In fact, it is built around IT; hence the term, “digital factory” or “smart factory”.

Within the digital factory, IT links hardware and software islands as well as the factory to customers, suppliers and other factories via the Internet. In this digital arrangement, IT is integrated with production equipment. Performance data are remotely collected across factories at different locations and monitored for benchmarking, production optimization and quality control. As part of the equipment mix, MV equipment is also networked and remotely monitored.

Importantly, IT not only enables monitoring and analysis of performance but also customer-driven production processes. In the digital factory, the customer occupies the

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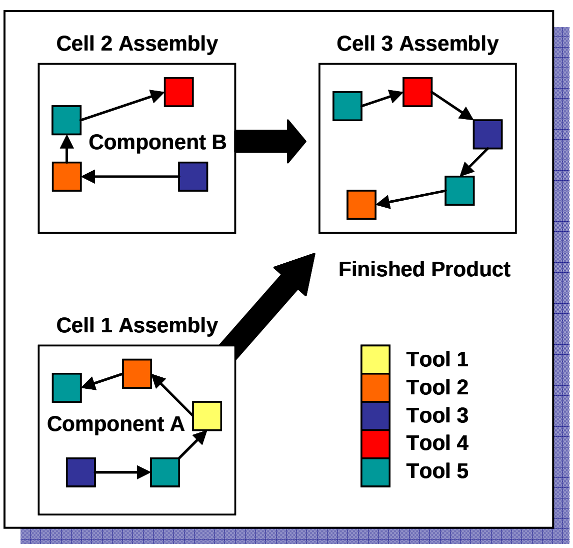
front-end of the production process. By means of the Internet, the customer communicates his/her product preference, generating an order, which flows from work cell to cell, driving all necessary, internal plant processes along the way; and finally culminates in order fulfillment.

20.3.4 Cellular Manufacturing

As previously mentioned, work flows in the factory of the future are not linear (as in the case of the traditional factory) but instead are organized in cells. As a special grouping of machines, people and materials to manufacture products or product components, each cell is responsible for its own internal control of quality, scheduling, order and record keeping. Coordination between the cells occurs via a system called "kanban", a signal that an item is needed by one cell from another. In Japanese factories, the kanban has been a card, but in a fully IT-centric factory, the signal would expectedly be electronic. Whether paper-based or electronic, the kanban serves to tie together the various cells for inventory purposes. As a form of just-in-time materials management, parts travel between cells in small batches when actually needed based on customer demand. An example of a cellular manufacturing layout is depicted by Exhibit 20.5.

Exhibit 20.5: Example of a Cellular Manufacturing Layout



Here we see three cells, each with a different configuration of tools (where some tools might be equiped with machine vision). In cell 1, component "A" is produced and in cell 2 component "B". Both components are utilized in Cell 3 to create the finished product in accordance with the customer's order.

Where different cells produce different components, cellular manufacturing enables product modularity.

20.3.5 Product Modularity

Product modularity is an approach to product architecture where components are combined in the manufacture of products. Modular products are thus the opposite of integrated products where different functionalities cannot be broken down into separately identifiable parts with clearly defined boundaries. Examples of modular and integrated product architectures in machine vision are PC-based MV systems and smart cameras, where the latter has more or less integrated functionality and the former consists of distinct components, each of which can be removed and replaced.

It should be noted that both product architectures have their respective benefits. Integration of functions can enable smaller form factors, while modularity supports greater product variety. (However, there is an exception to this generalization: If modularity is taken down to the sub-component level, and the sub-components are

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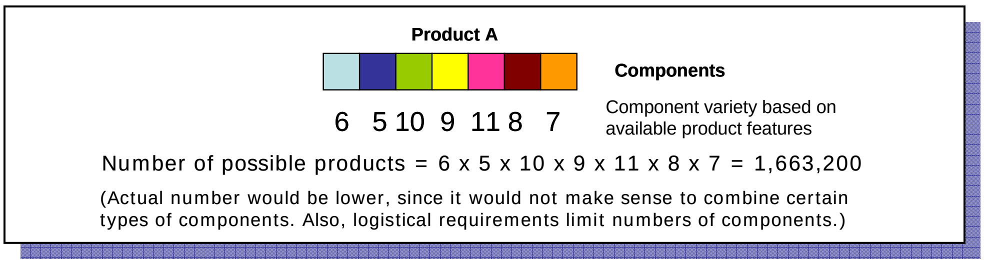
physically small, the benefits of product variety and a smaller form factor could co-exist, allowing the best of both worlds.)

The greater product variety inherent in a modular approach is depicted by Exhibit 20.6.

Exhibit 20.6: Product Variety in the Modular Approach



If a product, for example, consists of seven components and each component has multiple different types that can be selected, then the number of possible products that can be manufactured is theoretically limited only by the number of different possible component combinations. In actuality, however, some constraints on product variety would exist, as indicated in Exhibit 20.6.
It should be noted that the biggest constraint on product variety is component interoperability, or simply said, a great number of possible products can only be generated, where a lot of different components are capable of working together. This assumes a high degree of standardization, which is found only in mature industries. In the PC industry, for example, interoperability problems abounded during the early years, requiring considerable effort to get the various components of a personal computer to work together. Today, things are much different; various components such as processors, motherboards, hard drives, etc. can be more easily combined to create a PC, although of course certain constraints still apply. (For example, different types of motherboards require different types of processors, memory and hard drives.)

Why is product variety an important objective of the factory of the future? The answer is simply that the greater the variety of products that can be produced, the better the manufacturer can respond to the specific needs of the customer. Said differently, product variety enables mass customization, another key characteristic of the factory of the future.

20.3.6 Mass Customization

Mass customization is the "mass production of goods with differing individual specifications through the use of components that may be assembled in a number of different configurations." As its name implies, mass customization is a manufacturing approach that aims to combine customization, first afforded by the craftsman approach, with the cost efficiencies of mass production. By means of customization, companies hope to produce specialized or custom products at the speed, volume, cost and quality of standard products.

Mass customization is the point at which the dominant characteristics of the factory of the future come together: lean and cellular manufacturing, strong reliance on IT and product variety through modular product design. Here's how mass customization works in a

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nutshell: Based on a list of available product features corresponding to components, the customer selects a product via the company's Internet website. (An example of this would be a customer placing an online order with Dell for a new laptop computer that consists of his/her selection of the type of LCD display, hard drive, processor, type and amount of memory, operating system, loaded software, etc.) By placing the order, the customer generates a work order that initiates various work activities in the factory that are handled by various work cells in accordance with the principles of lean manufacturing and just-in-time materials management. As it speedily progresses through the work process, the work order is electronically monitored and tracked until the finished product is ready for shipping directly to the customer. In the end, the customer receives a product that has been tailored to his/her specific needs, produced in a minimum amount of time (since production cycles are short) and for this reason with a minimum amount of cost (which allows the company to charge a lower price). The end result is maximum satisfaction for the customer (since the customer gets the exact product he/she needs, gets it quickly and pays a lower price.) The company, in turn, is benefited by customer loyalty, revenue stability and increased sales through the positive image it achieves in the marketplace. In short, mass customization represents a "win-win" outcome for the customer and the company.

20.3.7 The Factory of the Future - Summary

As we have presented the concept here, the factory of the future represents the next stage in the evolution of the factory. The starting point was the workshop where craftsmen slowly and inefficiently manufactured high quality goods. This arrangement eventually gave way to the traditional factory at the time of the industrial revolution, which became increasingly more efficient with electrical power, better production equipment and linear work flows based on the use of conveyor belts with strategically placed work stations. The next logical stage is the factory of the future, manifestations of which we are starting to see with the growing reliance on IT in the factory, the re-arrangement of work based on cells, the implementation of lean manufacturing principles and the use of online product selection and ordering combined with mass customization.

These defining features of the factory of the future can be further clarified by comparing them to the dominant characteristics of the traditional factory, as summarized by Exhibit 20.7.

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Exhibit 20.7: A Comparison between the Factory of the Future and Traditional Manufacturing

Characteristic	Traditional Factory	Factory of the Future
Materials Handling	*Push* System: Keeping up with preset inventory levels or due dates for customer orders rather than customer demand	*Pull* System: Parts are not delivered to machines until they are needed based on actual demand
Work Flows	Linear (Assembly lines)	Within and between work cells
Equipment Layout	Similar equipment located in same area	Different equipment needed to manufacture part or product from start to finish located in same cell
Labor	Lower, single-skilled	Multi-skilled
Role of IT	Minimal	Central to all processes
Operational Costs	Higher	Lower
Product Variety	Lower ("one size fits all")	Higher (customized products tailored to the individual)
Production Cycles	Longer	Shorter
Customer Response Times	Longer	Shorter
Marketing	Mass market	Individual customers
Extent of Automation	Lower	Higher

20.3.7.1 How Will the Evolution to the Factory of the Future Affect the MV Industry?

We have explained the concept of the factory of the future but not the role of machine vision within it. Given the indispensable role that machine vision plays as an automation technology in the assurance of product quality and production efficiency, we make the following predictions:

- *Prediction 1*: MV companies will play an increasingly important role in supporting the automated production processes of the factory of the future (particularly in the case of vision-guided robotics).

- *Prediction 2*: MV companies will increasingly have to position/market their products in support of factory-of-the-future work flows and production processes.

- *Prediction 3:* MV companies will increasingly rely on factory-of-the-future principles for the manufacture of their own products.

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- *Prediction 4:* MV companies will increasingly utilize mass customization to address a wide array of applications in support of individual customer needs.

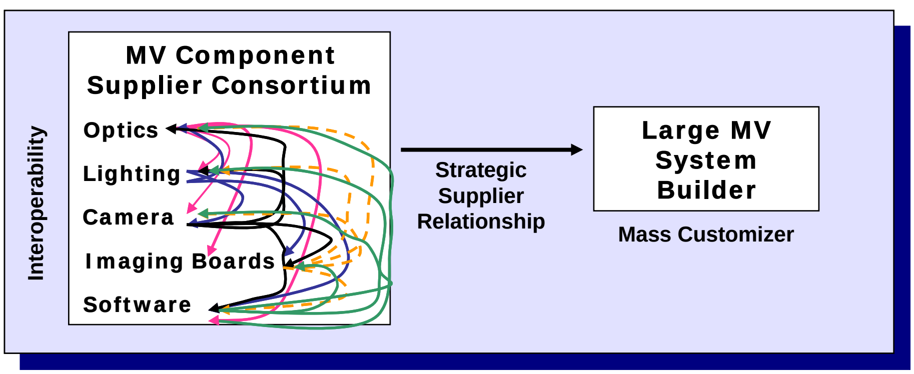
- *Prediction 5*: MV companies will be able to utilize mass customization only after component interoperability is achieved through standardization. Standardization is essential!!! MV industry must achieve the degree of interoperability achieved by the PC industry.

- *Prediction 6:* Customer ordering of MV systems will be Internet-driven but carefully structured given the complexity of MV systems. MV systems are more complex than laptop PCs!

- *Prediction 7:* System integration will be performed almost exclusively by larger system builders once interoperability is achieved. Small system integrators will decrease in numbers.

- *Prediction 8:* Consortiums of MV component suppliers will emerge and will be strategically linked and dedicated to large MV system builders. (This is the concept of "business ecology" or "business eco-system", an example of which would be Microsoft and its partners.)

Exhibit 20.8: MV Company Consortiums of the Future



As these predictions suggest, successful MV companies will evolve with the factory. The future of the MV industry will be greatly affected by the factory of the future.

20.4 Machine Vision Beyond the Factory

While the factory will continue into the future as an important focal point for the MV industry, it will not be the only source of market opportunity. As outlined in previous AIA market studies, MV technology will increasingly expand beyond the factory to other, non-manufacturing sectors of the economy with a wide array of new applications. Based on some preliminary estimations, these non-traditional applications could well prove highly lucrative to MV companies. A brief summary of these market opportunities is provided by Exhibit 20.9.

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Exhibit 20.9: Market Opportunities beyond the Factory Floor

Market	Areas of Market Opportunity for Machine Vision Companies	10% Market Penetration (USD)
High-End Security	Facial recognition, fingerprint recognition, iris recognition, retina scanning, hand geometry and high-end video surveillance	$760 million
Medical Imaging	Digital X-ray imaging (replacement of X-ray film by X-ray cameras Miniaturized, diagnostic imaging devices (e.g. "PillCam™")	$686.4 million
Lab Automation/Drug Discovery	Array vision for liquid handling Protein crystal classication Microwell inspection Barcode and 2-D barcode reading for dispensing	$290.0 million
Advanced Transportation Systems	Traffic Signal Control Electronic Toll Collection (ETC) License Plate Recognition (LPR) Rear-Vision Monitoring Blind Spot Detection & Lane Change and Departure Warning Interior Passenger Detection and Position Pedestrian Protection Night Vision	$14.2 million
Recyling	Equipment sales of recycling equipment	$315.0 million

20.5 The Geographic Expansion of Machine Vision

The future of the MV industry will also be affected by the dispersion of MV technology in developing countries, where it will serve as an enabler of economic modernization. Initially, these countries will enjoy a lower cost advantage in the global economy based on inexpensive labor. However, it will be increasingly hard to sustain that competitive advantage, as consumers in the global economy demand not just low commodity prices but also high product quality. To achieve both objectives, developing nations will have to automate production, and as part of this overall modernization, deploy machine vision as a critical means of establishing quality control.

We are beginning to see this trend in China, where the government is fostering economic modernization and businesses are becoming increasingly receptive to machine vision technology. This is not yet the case in India, where an abundance of low cost labor continues to represent an obstacle to the adoption of machine vision. (For information on

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MV market opportunities in China and India, the reader is referred to AIA's 2008 MV Market Study.) In Mexico, there are growing signs that product quality is increasingly outweighing the advantages of inexpensive labor. In Brazil, a growing emphasis on product quality and the deployment of machine vision for this purpose is already in evidence. In Argentina, on the other hand, machine vision has not yet found the same degree of acceptance as in Brazil.

In these and other developing countries, the push to modernize economically will increasingly mean additional market opportunities for the MV industry.

20.6 What Should MV Companies Do to Prepare for the Future?
As markets and technologies evolve, companies must also change to stay in the game. Here is what companies should specifically do to remain viable in the marketplace:

- Formulate and implement a strategic plan (Short-term tactics are not sufficient for long-term survival!)
- Consider expanding strategic alliances into company consortiums linked to large system builders.
- Position your company for the factory of the future, if you're targeting the industrial sector.
- Consider utilizing factory-of-the-future principles for your company's own internal production.
- Consider product modularization on the component and also possibly sub-component level.
- Support aggressive standardization efforts to foster interoperability across component categories.
- Construct a sales plan as a key part of the strategic plan.
- Utilize market intelligence as a major input into the sales plan.

20.7 Conclusion
Change is unavoidable. The MV industry will evolve in response to fundamental improvements in production processes in both developed and developing countries. It will also change, as it increasingly enables non-traditional applications in non-manufacturing sectors of the economy.

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Chapter 21: Conclusions

21.0 What's New in this Chapter?

This is an all-new chapter.

21.1 General Study Conclusions

Hard to believe, as it is now, it was not uncommon several years ago to dismiss the business cycle as largely irrelevant to machine vision sales growth. "Nothing really changes year to year in the machine vision market," was a frequent refrain stated with near fervent certitude. Since then, the harsh realities of the current recession have of course shattered that myth.

Now we are in danger of committing the opposite error; namely, extrapolating our industry's current weakness well into the future. A longer-term view of our industry's sales performance shows that both the peaks and troughs of the business cycle reflect themselves in MV sales volumes over time, and that, most importantly, the trend line that underlies MV sales volumes is linear and positive. This means that sales will be weak in some years, strong in others, while always fluctuating around an underlying trend line. Or to put it differently, MV sales over time show atypical strength and weakness in response to the business cycle but always return to their trend line.

The latest evidence of this is the impact of the prior recession, which ended in 2001. Historical sales data for MV companies in North America show clearly that the 2001 US recession hit MV sales hard; some MV product markets took several years before their rates of growth turned positive. But turn positive, they did. Tapping into pent-up demand, those markets experienced a sharp recovery, which continued more or less through 2006.

We have every reason to believe that MV sales will repeat this cycle. They will experience a period of weakness followed by a recovery and then show moderate, steady growth, indicating their return to the trend line.

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In keeping with this view, and the analysis upon which it is based, our fundamental conclusions in this study are therefore:

- Machine vision sales in North America have and will continue to experience weakness as a consequence of the business cycle, at least through the first half of 2010. A recovery will expectedly begin in the latter half of 2010. It will be driven by pent-up demand and will be characterized by atypically strong rates of growth. In the years that follow, MV sales growth rates will moderate but stay positive.

- The basic value proposition of machine vision technology (cost containment, productivity and quality control) accounts for the long-term trend in MV sales. Machine vision is indispensable, because it satisfies important needs of manufacturers in an ever-competitive global economy.

- For this reason, machine vision is and will remain a major automation technology in developed countries. In countries with modernizing economies, such as China and India, machine vision will, moreover, increasingly serve as an enabling force of industrialization. Demand for MV products will accordingly grow in these countries as well.

- The future of machine vision remains bright.

The more detailed conclusions of this study now follow.

21.2 Specific Conclusions

In addition to general conclusions, this study includes a number of specific conclusions about the US and Canadian economies, MV product markets, geographic MV markets, new industrial markets and the future of machine vision.

21.2.1 North American Economies

For six years, the US economy enjoyed a boom but now is in the painful grips of recession, which officially began in December of 2007. The consensus forecast among economists as of this writing assumes a recession, extending through much of 2009, with a slow recovery beginning in the latter part of 2010. Not until 2011 will the US economy have righted itself according to most economists.

Responsible for the current crisis is the subprime mortgage crisis, which began with the sharp reduction in housing prices and has led to a general liquidity crisis. The sharp rise in commodity prices also helped to push the economy over the brink into recession.

Despite weakness in its manufacturing sector, the Canadian economy was able to benefit from high commodity prices in 2008 and thus temporarily stave off recession. With the fall of commodity prices, however, Canada followed the US into recession and, despite the greater health of its financial sector, might not fully recover until the US pulls out of recession.

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The governments and central banks have attempted to revive their economies with a number of monetary and fiscal actions. However, as of this writing, these actions have not yet born fruit.

For the economies of the US and Canada, the bottom line is therefore unfavorable conditions for growth in MV product sales in 2009 and part of 2010. The MV industry may not start to see relief until the end of 2010. Not until 2011 do we expect the MV product markets of North America to return to normal.

21.2.2 Machine Vision Product Markets

The major conclusions of this study's chapters that focus on MV product markets are as follows.

Cameras

In last year's market study, we concluded that "(t)he typical portrait of an MV camera sold in North America today is that of a digital, area scan, monochrome camera with an IEEE-1394 interface and resolution higher than one megapixel." As shown in this year's study, that is still largely true for 2008 sales, except for a noticeable increase in analog cameras.

The effects of the recession are clearly evident in the data for 2008. Importantly, not only has the recession decreased total camera sales; it has also affected the mix of cameras sold. In hindsight, this is of course expected, since, in a recession, less funds are available for purchases and buyers must "trade down" (much like consumers) to stay within their means. Accordingly, cameras purchased in 2008 have been on average less advanced in technology and correspondingly of lower capability. This has meant at least a temporary interruption in some key trends. In previous studies, we found that MV cameras sold in North America were becoming increasingly digital and higher in resolution, more frequently used a Camera Link interface than previously and were more apt to use color instead of monochrome light than in prior years. But 2008 for the most part did not show a continuation of these trends. (Most revealing was the fact that for the first time in a long time analog sales exceeded digital sales.)

Since economic conditions are expected to worsen in most of 2009, a further departure from these trends is likely. Once economic conditions improve, however, sales data should show a return to these trends as well as healthier sales volumes.

With the recovery, camera sales will improve gradually in response to pent up demand and the utilization of more advanced applications will once again drive demand for more sophisticated cameras that offer more advanced technological capabilities.

An important key to success is for MV camera suppliers to adjust their sales tactics to current economic realities but at the same time prepare to ramp up production of more sophisticated products, once the recovery is felt.

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Imaging Boards

With the announced development of GigE Vision cameras, dire predictions about the fate of MV imaging boards were widely announced. According to these predictions, their demise was just a matter of time. To be sure, revenue from imaging board sales has markedly declined over time and is expected to decrease still further. However, only a portion of this downward trend can be ascribed to the introduction of GigE Vision cameras. For one thing, GigE Vision cameras have not yet achieved sufficient penetration to account for the large decline in revenue. For another thing, many imaging board manufacturers reacted peremptorily to the introduction of GigE Vision cameras by slashing their prices. Today, the average price of a GigE Vision camera and NIC is significantly higher than the average price of an analog camera with an included imaging board. Still, going forward, GigE Vision camera sales will increase, as will also IEEE-1394 camera sales and the sales of smart cameras, all of which do not use an imaging board. At the same time, some offset to the resultant loss in imaging boards will occur as a consequence of growing Camera Link sales. These cameras use relatively expensive imaging boards, but their sale will produce revenue that is insufficient to neutralize the imaging board revenue loss resulting from the sale of "frame-grabberless" cameras.

Against this backdrop, the economy is also taking its toll on imaging board sales. The effects of the North American recession are expected to extend from 2008 to 2010. Not until 2011 are sales expected to reflect the economic recovery forecast to begin in late 2010.

In response to the anticipated decline in imaging board sales, imaging board manufacturers might consider a three-prong strategy: Continue to address the low-end of the market with analog boards, address the high-end with Camera Link boards and focus on creating higher-end USB, NICs and IEEE-1394 boards that have greater capabilities to support more demanding applications. If, in fact, the differences between these types of boards and imaging boards are eroding, why should not imaging board manufacturers take advantage of it? This is of course a question of fundamental strategy; or more specifically, a question of how the business is defined. Will imaging board manufacturers stay as such, or will they redefine themselves more broadly as board manufacturers?

Lighting

In last year's study, we concluded that "(t)he MV lighting market will continue to experience significant change for a number of years to come." That conclusion is even more valid today based on our findings for 2008. Long a contracting market, the MV lighting market appears to have found some new strength in 2008 - despite the recession which began in December of 2007 in the United States. That is truly remarkable and should be taken as a source of pride by lighting suppliers, should it turn out to be more than a "blip" in the data.

Responsible for the revenue growth in 2008 was not just an increase in units sold but also an increase in certain types of non-LED lighting. Accordingly, while we expect the share of LED sales to continue to grow, we also believe that other types of lighting will

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continue to serve important niches and therefore contribute to revenue growth and the general viability of the MV lighting market. Of course, only time will tell whether this is an accurate prediction.

Optics

The current recession also adversely affected MV optics sales in 2008, which are expected to remain weak in 2009 and 2010. 2011 is the first year in which optics sales are expected to reflect the recovery.

Apart from economic impacts, no discontinuities or radical changes in the MV optics market are foreseen. The dynamics of the MV optics market will continue to be driven by the MV camera and lighting markets.

Because of the importance of optics to MV systems, and since camera and lighting developments drive changes in the development of optics products, cooperation and communication between lens makers, sensor manufacturers and lighting suppliers is essential to the viability of the machine vision industry. This communication and cooperation is particularly necessary in the area of standards and product development.

ASMV Systems

The ASMV systems market is very diverse, with applications varying greatly from industry to industry. Because the needs of users in different industries are highly dissimilar, the ASMV system builders that serve them tend to perceive little commonality and in many cases identify with the industry served and not with a greater ASMV system market. Not surprisingly then, demand for ASMV systems varies greatly across industries in accordance with their different dynamics. The performance of the printing industry, for example, has little direct relationship to the dynamics of the pharmaceutical industry.

Reflecting this fragmentation of end-user needs, perceptions and industry dynamics, ASMV systems manufacturers are forced to specialize in a limited number of applications that are in turn found in a limited number of industries. As a consequence, they tend to view themselves as participants in specific end-user industries, who incidentally use machine vision (along with other technologies), rather than as participants in a greater machine vision market.

As a consequence of this fragmentation, component suppliers, distributors and integrators who sell to ASMV system suppliers must understand the special needs of specific end-user industries - what ASMV systems suppliers must do to address these needs and not just the capabilities of their machine vision products.

Smart Cameras

The big surprise about smart cameras in 2008 was their rate of growth in total sales. In 2007, the rate of growth was anemic. Based on the repeated, downward revisions of economic forecasts for 2008, there was every reason to believe that smart camera sales in that year would be even weaker than in 2007. But that is not what happened; the 2008

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rate of growth was stronger than forecast. As a consequence of this, we have revised upward our longer-term sales forecast for this study. To be sure, we still expect a lower rate of growth in 2009 than in 2008, but according to our forecast that growth rate should nevertheless be relatively healthy, in comparison to rates of growth of other MV product markets.

Of course, many unforeseen events could occur between now and the end of 2009 that would depress demand for smart camera products below our expectations. But if any MV product market is to do relatively well in 2009, it is smart cameras.

Software

Beyond its functional role as an essential component of any MV system, third-party MV software also plays an important marketing role for a MV system provider. It represents an important means of adding value to, and differentiating an MV system from, other MV systems. An MV software package that has a wide array of image processing and analysis capabilities, while providing a choice between a graphical interface for user-friendliness and code-based programming for versatility, is particularly valuable and can be targeted to multiple market segments. If users can purchase the package on a module-by-module basis to save money, it is additionally valuable.

Going forward, third-party MV software will continue its important functional and marketing roles. At the same time, it will evolve in response to the needs of MV system builders and to the evolution of operating systems and computer hardware. The developmental direction of processors will be of particular importance in this regard.

3D Machine Vision

The future of 3D machine vision is bright. 3D MV systems have demonstrated their capabilities and serve a number of important applications. The performance of 3D MV systems has moreover improved; however, additional progress is needed in reducing costs and increasing user friendliness. As this progress is made, the value proposition of 3D machine vision will increase and with it the extent of market penetration. When this occurs, 3D MV products will no longer be niche offerings but instead very much “main stream” in the overall ASMV market.

21.2.3 Geographic MV Markets

This section summarizes conclusions regarding the geographic MV markets examined in this study. It also summarizes our estimates of the impacts of the global recession on these markets.

Worldwide and Regional MV Markets

The estimated size of the total world MV components market in 2008 is $721.4 million (USD), the smart camera market is $458.6 million and the worldwide ASMV systems market is $4,568.9 million. By 2013, we expect these worldwide markets to grow as follows: total components at $1,184.9 million, smart cameras at $669.1 million and ASMV systems at $5,918.4 million.

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Asian-Pacific markets are largest at 34.9 percent of world markets in 2008. By comparison, the North American and European markets represent 27.6 and 32.7 percent respectively. Because the Asia-Pacific market is expected to grow faster than European and North American markets, we forecast Asia-Pacific's share of world markets to reach 42.8 percent of world markets by 2013.

Our estimates of worldwide MV markets in 2008 reflect recessionary impacts as do our forecasts for 2009 through 2010. Consistent with the economic forecasts cited in this study, we assume no recessionary impacts for years 2011 through 2013.

Worldwide Recessionary Impacts

In forecasting worldwide MV sales, we prepared best, worse and mid-range forecasts. Best case and worse case estimates of MV sales lost due to the recession are as follows.

Estimated Recessionary Impacts (Lost MV Sales) in $ Billions

Region	2008	2009 Best Case	2009 Worst Case	2010 Best Case	2010 Worst Case
North America	-$0.079	-$0.178	-$0.241	-$0.246	-$0.333
Europe & Israel	-$0.093	-$0.133	-$0.179	-$0.055	-$0.074
Asia Pacific	-$0.110	-$0.198	-$0.268	-$0.102	-$0.138
Rest of World	-$0.015	-$0.016	-$0.021	-$0.007	-$0.009
Total World	**-$0.297**	**-$0.524**	**-$0.709**	**-$0.410**	**-$0.554**
% Lost Sales	**4.9%**	**8.2%**	**11.1%**	**6.1%**	**8.2%**

As this summary shows, an estimated $297 million in sales was lost in 2008 or 4.9 percent of total sales. For 2009, the estimated sales loss ranges from $524 million to $709 million or from approximately 8 to 11 percent of total sales. For 2010 (where a lagged effect is assumed), the estimated loss varies from $410 million to $554 million or from approximately 6 to 8 percent of total sales. Of course, if current governmental efforts to stem the tide of recession fail, MV sale losses will probably be worse.

The Argentine Machine Vision Market

Market opportunities await MV companies in Argentina, but they are largely long-term, and MV companies should proceed cautiously in realizing them. This would involve considerable due diligence, including analysis of specific industry sectors and geographic locations, evaluation of distributor candidates, and the development of an extensive web of business relationships. The quickest and least risky way to enter the market is to work through domestically-based, knowledgeable distributors who have been properly vetted.

Given the importance of meat packaging and the food and beverage industry in general, MV companies offering systems that inspect meat and other types of food, packaging and bottling are the first, logical candidates for a successful market entry.

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Their success is more likely today, given the increased stability of the economic environment and robust economic growth that is projected to continue. While the economy in aggregate - and industrial production more specifically - paint a favorable picture currently, it is important, however, to not lose sight of the possibility of a recurrence of economic instability and obstacles (such as corruption), which necessitate a measure of caution.

The Brazilian Machine Vision Market
Brazil is a large and modernizing nation that seeks to become a manufacturing powerhouse on the world stage. Much progress has been made in this regard as the consequence of substantial FDI and the presence of large manufacturers in country.

Likely candidates for adoption of machine vision are the largest companies serving those industries for which MV applications have been developed; in particular, automotive, the food and beverage, pharmaceutical and metal and electronics industries.

MV companies are already targeting businesses operating in these and other sectors. For the most part, the MV products being sold into the Brazilian market are not Brazilian but rather foreign in origin. Indigenous MV manufacturers are largely non-existent.
All in all, the market opportunities for foreign suppliers of MV products appear limited. Direct exporting is very difficult due to the challenges of complying with a complicated import regime. That necessitates the use of domestic distributors, who - as the gatekeepers to the Brazilian market - must add sales fees to the already steep import taxes imposed on MV products. This results in high prices for MV products, which of course cut into margins and limit customer demand. Both factors thus constrict market opportunity.

The way around this problem for foreign MV manufacturers might be to set up production facilities in country, but - as previously mentioned - this is an expensive strategy that requires deep pockets. Finding a Brazilian partner with sufficient capital might be the solution, however. Brazilian MV distributors might also elect this approach, raising capital to set up production facilities; that is, vertically integrating in order to replace expensive foreign MV products with lower cost, domestically produced MV products.

However the obstacles to greater adoption of MV technology are surmounted, one thing is clear. If Brazil is to become a world class exporter of manufactured goods, it will have to achieve cost efficiencies, productivity and quality control in manufacturing, which will bode well for machine vision. The greater question is how will that demand be met and what strategy will enable what MV companies to realize the greatest market opportunity.

The Mexican Machine Vision Market
The Mexican government has pursued a trade-friendly policy, making it easier to do business in Mexico. Highly protectionist trade barriers are generally not in evidence and in this fundamental respect, Mexico is much different than Brazil. Market opportunities for machine vision companies exist in Mexico. However, they are long-term in nature

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and should mature, as Mexican companies increasingly embrace a new “culture of quality”. MV companies should therefore expect to spend considerable time building production capabilities or distributor networks in place of instant, “slam dunk” sales. A valuable sales approach might be to focus on small, entry projects that can be used to build knowledge about, and confidence in, machine vision as an enabler of efficiency, productivity and quality in manufacturing operations.

21.2.4 New Industrial Markets

Since new market opportunities are related to not only geographic but also industrial markets, this study has also examined two promising industrial markets, MEMS and solar cell/panel production.

Machine Vision in MEMS Production

The market opportunity for MV companies that serve the MEMS industry is potentially large by virtue of the market growth that the MEMS industry is expected to enjoy. This growth will be driven by the increasing emergence and market acceptance of indispensible “smart” products that utilize embedded MEMS devices. There appears, however, to be a “Catch 22”. For MV companies to grow MEMS related sales, they must know what kind of MEMS fabrication processes to support, since the MEMS industry is highly diverse in terms of production techniques, materials and applications. This means that MEMS companies must first make strategic choices and invest accordingly on a large scale. It specifically requires the selection of fabrication techniques, materials and the establishment of standards to reduce market ambiguity. However, the efficacy of the selected production processes will also largely depend up the capability to assure product quality through fast, efficient and accurate inspection, since without that capability, MEMS production costs, production cycles and time to market would unavoidably suffer. In short, to achieve the production efficiencies needed for mass market product introductions, machine vision must first be incorporated in MEMS production. So what will come first? A wider deployment of machine vision in MEMS production, or the strategic investments of MEMS manufacturers? Or perhaps a different scenario will occur such as a series of reciprocating, reinforcing steps, with leading players in the MV and MEMS industries gradually ramping up their strategic commitments to cooperate.

Regardless of which scenario plays out, it would appear that the interdependence of MEMS manufacturers and MV companies needs a wider perception, followed by dialog to better identify opportunities for cooperation. With the establishment of working relationships across industries, synergies could well emerge that are mutually beneficial, resulting in sizeable market opportunities for both industries. If MEMS is the wave of future, chances are MV companies will be riding it.

Machine Vision in Solar Cell Production

The demand for alternative energy will continue to drive solar cell and panel sales at impressive double-digit rates. This is very good news for the machine vision industry, particularly since current levels of solar cell and panel production lag demand, and machine vision offers a much needed productivity boost. As we have seen, several MV companies are positioning themselves to ride the wave of the solar cell industry. With

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further tweaking of MV applications used in the semiconductor industry, a still greater market opportunity might emerge for a larger cross-section of the machine vision industry.

21.2.5 The Future of Machine Vision

The MV industry is poised for a bright future. While the effects of the business cycle are ever present, resulting in short-term fluctuations in demand, no less than four growth paths will propel MV sales upwards in the long-term. These growth paths are the increasing value of MV products, the role machine vision will play in the "factory of the future", the penetration of MV technology into non-traditional, non-industrial sectors of the economy and increased reliance on MV technology as an enabler of economic modernization in developing countries. The deployment of MV technology will thus expand geographically to developing countries, and within developed countries its acceptance will increase in economic sectors currently served by it, while spreading to additional, non-traditional sectors. As a consequence of this four-front expansion, the MV industry as a whole will achieve impressive growth.

The evolution of the factory will affect machine vision in a number of ways, as outlined in the following predictions:

- *Prediction 1*: MV companies will play an increasingly important role in supporting the automated production processes of the factory of the future (particularly in the case of vision-guided robotics).

- *Prediction 2*: MV companies will increasingly have to position/market their products in support of factory-of-the-future work flows and production processes.

- *Prediction 3:* MV companies will increasingly rely on factory-of-the-future principles for the manufacture of their own products.

- *Prediction 4:* MV companies will increasingly utilize mass customization to address a wide array of applications in support of individual customer needs.

- *Prediction 5*: MV companies will be able to utilize mass customization only after component interoperability is achieved through standardization. Standardization is essential!!! MV industry must achieve the degree of interoperability achieved by the PC industry.

- *Prediction 6:* Customer ordering of MV systems will be Internet-driven but carefully structured given the complexity of MV systems.

- *Prediction 7:* System integration will be performed almost exclusively by larger system builders once interoperability is achieved. Small system integrators will decrease in numbers.

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- *Prediction 8:* Consortiums of MV component suppliers will emerge and will be strategically linked and dedicated to large MV system builders. (This is the concept of "business ecology" or "business eco-system", an example of which would be Microsoft and its partners.)

While the factory will continue into the future as an important focal point for the MV industry, it will not be the only source of market opportunity. MV technology will increasingly expand beyond the factory to other, non-manufacturing sectors of the economy with a wide array of new applications.

The future of the MV industry will also be affected by the dispersion of MV technology in developing countries, where it will serve as an enabler of economic modernization. Initially, these countries will enjoy a lower cost advantage in the global economy based on inexpensive labor. However, it will be increasingly hard to sustain that competitive advantage, as consumers in the global economy demand not just low commodity prices but also high product quality. To achieve both objectives, developing nations will have to automate production, and as part of this overall modernization, deploy machine vision as a critical means of establishing quality control.

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Appendix

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Glossary of Machine Vision Terms Used in This Study

3rd Party Machine Vision Software	Machine Vision software that is not bundled with hardware but instead is sold as a separate product
AGP	Accelerated Graphics Port (AGP) is an interface specification that enables 3D graphics to display quickly on ordinary personal computers.
Analog	A type of signal in an electronic circuit that takes on a continuous range of values. The opposite of digital.
ASMV	Application Specific Machine Vision System: a turnkey machine vision system that addresses a specific application found throughout one or more industries
Area Lighting	Lighting used for the illumination of an area
Area Camera	All cameras covering an area at once rather than a single line at a time. Area Cameras are of two types: interlaced and progressive scan.
Backlighting	Placement of a light source behind an object so that a silhouette of that object is formed. It is used where outline information of the object and its features are important rather than surface features.
Bayer Conversion	Conversion of Bayer color (obtained from a Bayer matrix or color filter array) into RGB color
Beamsplitter used with Diffuse Lighting Source	A prismatic structure which directs a diffuse light source coaxial with the optical axis of the application. A 50/50 beamsplitter creates two beams.
Board Level Cameras	CCD cameras that are not yet housed or connected to particular terminations. These devices are completely functioning units.
Board Level Lenses	Fixed focal length lenses used on cameras with board-mounted sensors (regardless of their other possible characteristics)
Camera	Imaging devices; devices that acquire images.
Camera Link®	Camera Link® is a robust communications link using a dedicated cable connection and a standardized communications protocol.
CCD	Charge-Coupled Device: a light-sensitive chip or image sensor used in scanners and digital cameras that converts light into proportional (analog) electrical current.
CMOS	Complementary Metal Oxide Semiconductor: a new type of sensor used in scanners and digital cameras that is based upon a semiconductor process designed for digital electronics instead of analog electronics as in the CCD.

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Collimation	Involves the use of a collimating lens to yield parallel flux lines for a light source
Component Supplier	A manufacturer of machine vision (MV) optics, lighting, cameras (excluding smart cameras/smart sensors) or third party MV software. Distributors and OEMs are not considered component suppliers.
Darkfield Illumination	An illumination technique where the angle of incidence of the light relative to the surface of the object is less than 90 degrees (directly on top). As the degree of the angle decreases, less light reflects off the object's surface, thus darkening the field.
Diffuse Illumination	Lighting that is uniform, soft, relatively non-directional and lacking in concentration. The opposite of point illumination.
Digital	A method of storing, processing and transmitting information through the use of distinct electronic or optical pulses that represent the binary digits 0 and 1. The opposite of analog.
Distributor	A supplier of machine vision products manufactured by others
Dome Lighting	A spherical light source that provides even diffuse illumination
DSP	Digital Signal Processor: a specialized digital microprocessor used to efficiently and rapidly perform calculations on digitized signals that were originally analog in form
Embedded Vision Computer	Another name for Embedded Vision Processor
Embedded Vision Processor	A configuration of machine vision equipment where a camera is tethered to a specialized, mini-computer (not a PC). Unlike the Smart Camera, the computer power for processing images is external to the camera's housing.
FFC	Flat Field Correction: a CCD imager is composed of a two dimensional array of light sensitive detectors or pixels. The CCD array is mechanically quite stable with the pixels retaining a rigidly fixed geometric relationship. Each pixel within the array, however, has its own unique light sensitivity characteristics. As these characteristics affect camera performance, they must be removed through calibration. The process by which a CCD camera is calibrated is known as "Flat Fielding" or "Shading Correction".
Fixed Focal Length Lens	Non-zoomed lenses where the distance between the sensor and center of the lens is fixed
FPGA	Field Programmable Gate Array: a specially made digital semiconductor. With an FPGA, a design engineer is able to program electrical connections on site for a specific application.

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Frame Grabber	A device that interfaces with a camera and, on command, samples the video, converts the sample to a digital value (if the framegrabber is analog instead of digital) and stores that in a computer's memory. In contrast to Vision Processor boards, which have complex image processing capabilities (usually more than two functions), Frame grabbers have simple image processing capabilities (usually two or less functions).
General Purpose CPU	An off-the-shelf central processing unit developed for personal computers but also deployable in other devices requiring compute power. Example: Intel Pentium processor.
General Zoom Lens	Zoomed lenses without a macro capability (See "Zoom Lenses".)
GigE Vision™	"GigE " is an Ethernet protocol involving transmission rates of 1 Gbps (gigabits per second). GigE Vision™ is a new AIA standard that allows cameras to take advantage of GigE transmission rates.
Halogen Lighting	A type of incandescent lamp containing a small amount of halogen
HID	High-intensity discharge lamps
IEEE-1394	A high-speed data protocol involving an external bus capable of throughput up to 512 Mbps and control of up to 63 devices. Also know as "FireWire".
ILUT	Input Look Up Tables (a.k.a. format RAM): used for image data manipulation, ILUTs convert digitized image data in real-time and are often used to invert, threshold, or perform grayscale translations on the image.
Imaging Sensor Chip	A sub-component in a camera that converts light reflected off an image into electrical pulses for capture and manipulation
Imaging Board	See "Frame Grabber" and" Image Processor Board"
Image Processor Board	For purposes of the MV market study, an Image Processor Board is the same as a Vision Processor Board and Embedded Vision Processor Board. Unlike Frame grabbers, these boards are characterized by complex image processing capabilities; that is, they typically have more than 2 image processing functions. Also see "Frame grabber".
Integrated Machine Vision Product Supplier	A builder of standalone (turnkey) or near standalone machine vision systems intended for sale to groups of customers. Included are producers of smart cameras/smart sensors, embedded vision processors/computers and ASMV systems. Excluded are systems created by System Integrators.
ISA/EISA	Industry Standard Architecture: a 16-bit PC bus. The original PC bus architecture. Extended ISA is a bus architecture that extended the 16-bit ISA bus to 32 bits.
LED	Light Emitting Diode: a special type of semiconductor diode that emits incoherent narrow-spectrum light

Lens	A multi-element optical system (for purposes of the MV market study, single element lenses are not considered lenses but rather sub-components.)
Lenses for 3-Chip, Beamsplitting Prisms	All fixed focal length lenses used with 3-chip CCD or CMOS color cameras (regardless of their other possible characteristics)
Lighting	Products used to illuminate objects to be acquired and processed. Radiation produced by these products is either visible, (400 to 700nm) or invisible, of which there are two major types: ultraviolet (below 400nm) and infrared (above 700nm).
Line Lighting	Lighting configured as a line, providing narrow, intense illumination
Line Scan Camera	Cameras that use sensors that consist of a single row of photodectors. Also called a linear array camera.
LVDS	Low Voltage Differential Signaling: a type of camera interface based on the RS-644 standard, which replaced RS-422
Macro Lenses	Lenses that can focus sharply very close to an object to capture minute surface detail
Macro Non-telecentric/Non-board Level Lenses	Fixed focal length lenses that can focus very close to an object to capture surface detail but cannot correct for perspective errors (parallax) and are not used for board level cameras.
Macro Zoom Lenses	Zoomed lenses with a macro capability
Microscopic Objectives	Fixed focal length lenses used for capturing extremely small detail (regardless of their other possible characteristics)
Non-Visible	Refers to infrared (IR) and ultraviolet (UV)
OEM	Original Equipment Manufacturer: a company that offers a product that uses machine vision as a value additive feature rather than as an essential component of the product. Vision is treated as a value adder and thus does not represent the central functionality of the product.
On Board Processing	Refers to the presence of compute power for image processing on an image processing board
Optics	Lenses and adjunct equipment such as irises, filters, mountings and mechanization
PCI	Peripheral Component Interconnect: a personal computer local bus designed by Intel, which runs at 33 MHz and supports Plug and Play.
PCI Express	An emerging (2004/2005) standard for high-speed graphics, likely to result in a 20% boost over 2003-era AGP 8x performance

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PCMCIA	Personal Computer Memory Card International Association: a standard for a credit card-size memory or input/output device that fits into a notebook, laptop or personal computer
PMC	PCI Mezzanine Card: a daughtercard form factor implementation of the PCI bus specification
Polarization	A process whereby light waves are restricted in the direction of their vibration
Processor Bit Rate	The rate at which data is processed by a CPU
Ring Lighting	Lighting with a ring configuration
Ruggedized Lens	Lens capable of surviving extreme environmental conditions
Sensor Frame Rate	Frame rate, sample rate, capture rate and image (or camera) speed are interchangeable terms. Measured in frames per second, the imager's speed is one of the most important considerations in motion capture analysis. The frame rate is determined after considering the speed of the event, the size of the area under study, the number of images needed to obtain all the event's essential information, and the frame rates that are available from the motion analyzer being used. For example, at 1,000 fps, a picture is taken once every millisecond.
Smart Camera	A complete or near complete vision system contained in the camera body itself. Lighting and optics may or may not be included. At a minimum a Smart Camera combines a camera with image processing and MV related programs within the same housing. A smart camera is functionally equivalent to an Embedded Vision Processor. Sometimes smart cameras are called "intelligent cameras" and "Vision Sensors". The term "Vision Sensor" tends to apply to a lower-end Smart Camera.
Smart Sensor	A photo sensor with minimal vision algorithms
Specularity	The amount of reflectivity of an object's surface
Spot Lighting	High intensity illumination directed to a specific spot
Surface Geometry	The angularity of an object's surface, ranging from flat to very faceted
System Integrator	A machine vision (MV) company that integrates components primarily manufactured by others to create an MV system for the specific needs of an individual customer. Work is performed by integrators on a project-by-project basis instead of creating products for groups of customers.
Telecentric Lenses	Parallax corrective lenses maintaining within a certain range of working distance a constant viewing angle at any point across the clear aperture of the objective lens, thus allowing the machine vision system to generate dimensionally accurate images for measurement

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Ultra Fast Lenses	Fixed focal length lenses used with high frame rate cameras for low light applications (regardless of their other possible characteristics)
USB	Universal Serial Bus, an external bus standard that supports data transfer rates of 12 Mbps
Vision Processor Board	A device similar to a Frame grabber that fits into a bay of a PC and contains complex image processing capabilities (usually more than two functions) and can include analysis (like blob analysis or pattern recognition). See "Frame grabber").
Vision Sensor	A lower-end smart camera. A smart camera with less flexibility and programmability that is usually intended for less demanding applications.
Visible Lenses	Lenses that use visible light
VL	VESA Local-Bus: a local bus architecture
VME	Versa Module Eurocard bus: a 32-bit bus defined by the IEEE standard 1014-1987.
Xenon Lighting	A type of HID lighting principally characterized by the use of ionized Xenon gas
Zoom Lenses	Lenses with variable focal lengths that have the ability to shift magnification smoothly and continuously while maintaining focus and f-stop

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