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ADVANCED MANUFACTURING INDUSTRY STUDY
GROUP PAPER
"GETTING AGILE & FAST – A 2003 *OVERTURE* TO PRE-EMINENCE"

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ADVANCED MANUFACTURING

ABSTRACT: The central question addressed in this paper is the status of advanced manufacturing in

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the United States, its important role in the economy and its critical contribution to the defense industry. Simply stated, a robust advanced manufacturing sector is essential to support national defense and to provide a balanced, diversified economy.

While the observation of manufacturing operations in the United States, Sweden and Ireland were the highlight of our year, academic research, and a full curriculum of national resource policy informed our view. This mix helped us conduct an educated analysis of the manufacturing industry as a whole.

What we discovered is a highly competitive environment that favors brains over brawn. Manufacturing has become a sprint to identify customer requirements, and in turn, produce products that meet them faster than the competition. In this environment, competitive prices, precise operations, and quality products are entry criteria. What differentiates certain companies is a unique ability to create a competitive advantage in this environment—these manufacturers think and do faster—and by definition, these advantages make them *advanced.*

Manufacturing is the engine that has driven our national economy for decades, and it will continue to do so. The ability of American manufacturers to remain competitive and keep advancing in today's environment is a national imperative. While other nations are racing to overtake some of our advantages, we are in the unenviable position of running a marathon at a sprinter's pace.

U.S. manufacturers face five primary challenges:

- To create concurrency of operations;
- To find the right mix of manpower and automation;
- To create agile processes that match the changing demand of customers;
- To find economies and eliminate waste;
- To leverage knowledge.

We believe manufacturing will need the help of the U.S. Government to meet these challenges, particularly in the areas of creating a more technical workforce and developing standards that enable company-to-company collaboration, both within the U.S. and with international partners. Retaining our world leadership in manufacturing will remain a critical component of our national security and military strategies and it is prudent to study it. In addition to covering the advanced manufacturing industry in Ireland and Sweden, this paper addresses two related topics in greater detail – micro electro-mechanical systems (MEMS) and nanotechnology.

PARTICIPANTS

Seminar participants included uniformed members from all four services, Armed Forces civilians from the Department of the Navy, the Defense Contract Management Agency, National Imagery and Mapping Agency, and an international fellow from the Lithuanian Air Force.

Lt Col Mark Allen, ANG	**Lt Col Chris Chambliss, USAF**
CDR Ken Dunscomb, USN	**Mr. Tim Frank, DCMA**
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PLACES VISITED:

The advanced manufacturing seminar visited multiple locations in Virginia, Maryland, and North Carolina. The seminar traveled to Sweden and Ireland as part of the international travel program. In Sweden, we visited Stockholm and other smaller cities to the south. While visiting Ireland, we spent the majority of our time in and around the capital city of Dublin.

Domestic

Boeing	Harley Davidson
Dupont	General Dynamics, Ordnance
Northrup Grumman	Flextronics
Caterpillar	General Electric Aircraft Engines
Newport News Shipbuilding	Naval Air Depot, Cherry Point
Wilmington Machine	Tompkins Associates

Sweden

Elekta	BT Industries
Saab Training Systems	Jonkoping International Business School
Kosta-Boda Glass	ABB Robotics
Scania AB	

Ireland

US Embassy Ireland	Intel Ireland
Daon LTD	Voice Vault
IBM	Lucent Technologies

INTRODUCTION. Peter Illitch Tchaikovsky wrote his *1812 Overture* as a tribute to the Russian people's repulsion, and ultimate retreat, of Napoleon's invading army in 1812. The oft-performed but still magnificent final movement captures the heart and spirit of this tribute in four musically perfect waves. Led by a crescendoing horn section, the first wave forewarns the Russian people of Napoleon's imminent attack. Culminating decisively, the second wave features the string section in *retardando* to symbolize Napoleon's invasion and Russia's gradual halting of this invasion. In the third wave, the Russian people rejoice - symbolized by a majestic, fully orchestrated, chorus-filled piece. The final wave (also made famous by the 1970's movie *Bad News Bears*), led by cannon fire and decidedly *allegretto*, symbolizes Russia's expulsion of Napoleon's army and a return to freedom for the Russian people.

In many ways, Tchaikovsky's *1812 Overture* is a fitting metaphor for the current state and challenges facing the U.S. manufacturing industry. Like the Russian empire of the early 1800's, U.S. manufacturing is under attack. While manufacturing remains globally pre-eminent – the largest workforce, the greatest capacity, the most output. However, there are Napoleonic-like forces that threaten U.S. manufacturers' stature. These include a 1950's infrastructure; global competition in the form of cheap labor, competitors' easy access to raw materials and business-friendly governments; and a manufacturing labor force that is aging and increasingly under-skilled. How are U.S. manufacturers dealing with these challenges? Will the U.S. manufacturing industry succumb to these threats and share the world's center-stage with other rising giants like China or the European Union? Or will U.S. manufacturers, like the Russian people 191 years ago, repulse these threats through innovation, process re-engineering and increased productivity, and remain globally supreme? It is these questions and many others like them that we set out to answer within the Advanced Manufacturing Industry study.

Like Tchaikovsky's *1812 Overture,* our group paper summaries the Advanced Manufacturing industry in four waves:

- First, we outline the current conditions in manufacturing. We use metrics such as production capacity, total employment, total capital expenditures and total revenues to paint its health as decidedly mixed but improving. We also address manufacturing's productivity, labor quality and its use of Information Technology (IT) and Robotics.
- Next, we address the challenges facing Advanced Manufacturing. Specifically, we enumerate five challenges: the need to transition to concurrent manufacturing, finding the right balance between man and machine, manufacturers' transition to agile processes, manufacturers' need to promote economy and eliminate waste, and manufacturers' need to make better and more timely decisions in a global, competitive environment.
- Third, we outline what we believe to be government's goals and role vis-à-vis Manufacturing. We advocate numerous polices including: promoting true open trade, reforming the legal system, and implementing health care reform.
- Finally, we write about four areas of interest in the Advanced Manufacturing industry: the state of manufacturing in both Ireland and Sweden (countries that we visited during our international travel), and the advent of micro electro-mechanical systems (MEMS) technology, and nanotechnology.

THE INDUSTRY DEFINED. There is no consensus on the definition of "advanced manufacturing". The Bureau of Economic Analysis lists 21 categories under the heading of manufacturing ranging from motor vehicles and equipment, to leather and leather products. In addition, during the course of our studies, the seminar made numerous field trips to observe processes that were neither technologically "advanced" nor even "manufacturing" in the traditional sense. The point is not to debate the definition, but to acknowledge that the term has different interpretations.

The Industrial College of the Armed Forces defines advanced manufacturing as, "…the mechanical, physical, or chemical transformation of materials and substances into new products." Further, "advanced manufacturing" is the incorporation of "…new technology, improved processes, or management methods to improve the manufacturing process."[1] Other industry representatives that we met with proposed to define advanced manufacturing in terms of investments in research and development. This definition suggests a link between how much an industry or company invests in research and development, and its associated qualification as "advanced." In this vein, advanced manufacturing uses new approaches, techniques, or systems to create or assemble a product out of separate, constituent parts more efficiently.

Ultimately, our seminar chose to define advanced manufacturing as *the insertion of new technology, improved processes and management methods to improve the manufacturing of products.* It is differentiated from normal manufacturing by *improving how you make what you make.*

CURRENT CONDITIONS. Overall, the advanced manufacturing industry continues to recover from the economic downturn of 2000-2001, and the shock to industry following the September 11, 2001 attacks on the U.S. Generally speaking manufacturing started slow but gained momentum as the year wore on. Furthermore, manufacturers exported more product more efficiently using newer technology, with fewer people. On the down side, manufacturers produced less, reduced their capital investments, and continued to deal with an aging, relatively less skilled workforce.

All this added up to a nominal increase in 2002 manufacturing revenue--1.1% before adjusting for inflation. Manufacturing costs, particularly for health and other insurance, continued to rise throughout the year. Significantly higher energy costs further squeezed already thin margins. Domestic and foreign competition resulted in unchanged final goods prices, meaning that manufacturers had to absorb virtually all operating cost increases.

Increased Production Activity & Exports. According to the Institute for Supply Management (ISM), we have witnessed a *sustained increase* in manufacturing activity during the latter part of 2002 and early 2003. Economists attributed this increase to low inventories and a falling dollar.[2] Furthermore, production capacity *increased* by 1.4% last year when compared to 2001, another indicator of an upswing in the industry.[3] Company executives attributed this increase to increased hours worked with existing personnel and the replacement of existing equipment with technologically advanced equipment. As of Dec 2002, manufacturing companies were operating at 79.2% of this increased production capacity, *up* from 77.5% in Dec 2001, but decidedly *down* from a peak of 87.4% in May 2000.

All of this production activity should have added up to more output, but it did not. Overall, U.S. manufacturers made 1.1% *less product* in 2002 than in 2001. Output fell in the last half of 2002 following a seven month period of increased outputs culminating with a 0.3 % increase in July.[4] However, new export orders grew every month during 2002, as well as in Jan/Feb 2003, albeit at a slowing rate of growth.

The decline in output for 2002 marks the second year in a row where manufacturing output declined, but a marked improvement over 2001 which saw 4.9% less product manufactured than the year before. Before 2001, annual output increased every year since 1992.

Reduced Capital Investment. Manufacturers had capital expenditures of over $154 billion in 2002. which was a 6% reduction compared to 2001*[5]*. Worse yet, this was the first reduction in capital investment reported by manufacturers in fifteen years. Manufacturing industries experiencing the most significant reductions included computers, transportation, rubber and plastics, fabricated metals, and chemicals.[6]

More Productive, But With Fewer People. As of April 2003, manufacturers employed more than 16,500,000 workers in over 362,000 establishments with payrolls exceeding $363 billion.[7] However, manufacturing has shed 549,000 jobs in the past twelve months and 2.2 million jobs since July 2000. Furthermore, the National Association of Manufacturers (NAM) reported that there have been 33 consecutive months of job losses, including 95,000 in April 2003.[8]

On the other hand, manufacturing productivity *rose* a remarkable 4.5% in 2002. This represents a significant improvement over the small productivity increase in 2001 of 0.8%. Labor productivity, a key indicator of industry health, rose at a healthy annual rate of 3.9 % in 2002.[9] In total, productivity increased in six straight quarters following the September 11 attacks, another indicator that the U.S. manufacturing industry is recovering.

As stated earlier, U.S. manufacturers made 1.1% *less product* in 2002 than in 2001. However, they required 5.4% *fewer manhours* of labor to produce this product. Speaking at the U.S. Department of Labor and American Enterprise Institute Conference in Washington, DC, Federal Reserve Chairman Alan Greenspan identified four broad reasons why he believed there was such a strong productivity increase given a period of modest economic growth:

- Tepid demand and virtually no pricing power had driven corporate managers to cut costs in 2002. Corporate managers cut costs, reorganizing work processes to eliminate waste, and reallocated capital resources to use them more productively. The material cost borne by manufacturers *decreased* an aggregate 0.6% last year as compared to 2001. Furthermore, manufacturers *reduced* their on-hand inventories for the thirteenth consecutive *year*.
- As capital spending fell during 2001-2002, so too did the disruptions associated with implementing capital investments.
- Conversely, 2001-2002 productivity gains may have continued to result from capital investments made during the 1990's, particularly in IT.[10] In fact, so great were the contributions made by IT investments (and their associated innovations) that Mr. Greenspan viewed this as a permanent transition to a higher level of productivity and likely not yet completed.
- There were indicators that corporate managers may have employed their existing workforce more intensively.[11]

In conclusion, despite the painful loss of 2.2 million manufacturing jobs, efficiencies gained from the improved processes and capital investments over the last decade resulted in increased productivity.

Labor Quality and the Aging Workforce. The quality of the workforce (also called labor quality) continued to fall in 2002 resulting in a less skilled workforce in relative terms[12]. This continued a trend that began in the last decade that reduced labor quality's contribution to overall labor productivity from 16% to 7%.[13]

Three facts aggravated the issue of declining labor quality growth since the late 90's:

- Since 1995, there has been a significant introduction of less skilled and less educated *workers* into the workforce.
- The %age of skilled manufacturing *jobs* relative to total manufacturing jobs has risen dramatically from 40% in 1950 to 70% in 2001 and is projected to rise to 85% in 2005.[14]
- The impending baby boomer retirements will start to remove the most skilled and experienced members of the manufacturing workforce.[15]

The manufacturing workforce also continues to gray. During our industry visits, average ages ranged from the mid 40s to mid 50s. Since these industries are highly unionized, their propensity is to favor seniority. Unionized positions also tend to experience lower turnover rates due to higher wages and better benefits than non-union jobs. These facts simply exacerbate the effects of an aging workforce.[16] Furthermore, the current labor situation resists automation and any process improvements that could have a potentially detrimental effect on the size of the labor force. As a result, we have concluded that there exists a fundamental and institutional distrust of management (and vice-versa). This distrust has, in turn, blocked any reasonable attempt to improve quality and consequently increase market share.

Without the ability to compete in labor costs in the near term, and since manufacturing labor is burdened with long-term costs of pensions and health care, companies, such as auto manufacturers, have had to resort to a judicious use of common platforms, shared engines, and ingenious marketing to remain competitive. These techniques, however "lean" they may be, are only going to serve as a bridge to an eventual restructuring of the labor force.

The Use of Information Technology (IT). Continuing a trend started in the mid-90s, IT contributed to higher productivity, lower production unit costs, and ultimately, increased revenues and profits in 2002. The majority of companies that we visited leveraged IT to achieve competitive advantage by streamlining manufacturing processes and enabling communications across divisions. However, while highly desirable, IT was not linked throughout the supply chain and knowledge management systems were underdeveloped in most manufacturing companies.

The most prevalent use of IT was in the manufacturing process. Virtually every company that we visited leveraged IT to achieve ‘six sigma’ quality in isolated lean manufacturing assembly lines or manufacturing cells. Even in the more conventional assembly lines, workers were collecting process data to ensure maximum throughput, to trouble-shoot station problems, and to resolve assembly process bottlenecks. Process managers also used IT to streamline process flows, reduce cycle time, identify non-value added steps, minimize in-process inventory, and eliminate in-process waste. We also found that the rate of change of IT and the demand for an agile, multi-skilled workforce, drove training programs to increase worker cross-utilization.

The use of Enterprise Resource Planning (ERP) and Manufacturing Resource Planning (MRP) solutions, and robust supply-chain management appeared to be a work-in-progress. Many companies have begun using ERP solutions to enable communications across divisions. However, we found little evidence of a single company-wide ERP solution, and virtually no ERP connectivity with suppliers. At this point, different companies have different ways of managing their supply chains, but none holistically integrate with each other. One of the more advanced companies leveraged their ERP solution to create a Preferred Suppliers Program – a tool they used to directly communicate with their suppliers. Another company used IT to share defect data with their strategic distributors.

The Use of Robotics. The manufacturing world is changing rapidly as new high-tech innovations enable us to live and work differently. During the first half of 2000, worldwide investments in robotics grew 12% with the European Union leading the way. In 1999, the greatest demand for robots came from U.S. manufacturers, who learned what the Japanese had known for years - robots can play a significant role in improving productivity, quality, flexibility, and time-to-market. The U.S. is the world's third largest robotics user with approximately 130,000 systems. This pales in comparison to Japanese and European Union robotics integration.[17] Ironically, according to some industry analysts, less than 10% of manufacturing companies that could benefit from robots have installed them, providing a large potential market.

Plummeting robot prices and radically improved performance have spurred growth in robot investment. The price of an average robot in 1999 was one-fifth the cost of an equivalent robot in 1990. [18] Consequently, it is common today to hear of one to two year returns on investment. Meanwhile, manufacturing labor costs have risen by 30% during the same period. Furthermore, the economic life of a robot (except in car production lines) is from 12 to 16 years, significantly enhancing the competitiveness of robot users.

Other positive factors are also at work. Today, robots are more sophisticated and better performers, opening up a range of new applications. In some countries, a shortage of industrial labor is driving the investment in robotics. Current demographic trends will further aggravate this shortage, thereby stimulating additional investment in robots.

Another driving force behind robotization is the requirement for components and sub-assemblies of high and consistent quality. Only automation can achieve this degree of quality. Undoubtedly, the robotic industry has a promising future.

CHALLENGES. The forces that define the age of globalization have reshaped the manufacturing industry. The business environment has never been more competitive. Today’s best companies see the world as their market and search the world for the best solutions to their manufacturing challenges. In this market, protective niches are becoming increasingly rare and only the smartest companies survive.

There is no magic management solution for gaining strategic advantage, and in this environment, the half-life of strategic advantage is diminishing. Agility and economy defined the best companies we saw. They clearly demonstrated that brains trumps brawn every time in the global marketplace, and we were often impressed at how simple (logically arranged manufacturing processes with little or no automation) the best companies appear.

Given this environment, we concluded there are five strategic challenges manufacturers must address if they want to thrive, or even survive, in the future. First, they have to compress time by reducing the time it takes to move products from the drawing board to marketplace. Second, they need to define the right role for machines in their manufacturing process to optimize the mix of man and machine in the production of goods. Third, they need to create agile enterprises that can move to the sounds of market drums more rapidly than their competitors can. Fourth, they must apply innovative processes to eliminate waste and decrease scale. Finally, they must leverage knowledge to think and act faster than their competitors.

Concurrent Manufacturing. Based on our industry visits, we concluded that the best way to compress the time it takes to bring a product to market is to achieve concurrency in all operations. Sequential production, which described the industrial age, is outdated and inefficient. The very best companies we visited have found ways to retool their organizations so that every stakeholder participated in the design and production of new products. Their collaborative effort closed the time gap that traditionally separated the journey from blueprint to market. The term *concurrent manufacturing* describes this process; meaning that planning, development, and implementation will be done in parallel, rather than sequentially, increasing innovation, decreasing waste, reducing time-to-market and improving quality.

Balancing Manpower and Automation. We discovered companies increasing automation and companies stepping away from it. We found companies who had “been there and done that” when it came to robotics and others who were certain that it was the answer to their quality problems. In the end, each company has to determine the right mix of man and machine to optimize their production process. The most critical component of this mix is the right kind of worker. As stated previously, the aged workforce we observed in the U.S. surprised us. Replacing a workforce that is closer to a pension than a prom will not be easy. Most manufacturers complained of a dearth of skilled labor. This could prove problematic in an era where the technical complexity of most manufacturing job descriptions is increasing. Finding workers who can optimize the production process in this environment will be a major challenge for manufacturers.

Agile Manufacturing Processes. Unfortunately, optimizing a single production process is not the entire answer. A company might make the very best widget in the world at the most competitive price but if nobody wants it, the business will fail. Today’s companies have to meet fickle customer specifications. We witnessed an unambiguous trend toward demand-driven production. Clearly a far cry from Henry Ford’s adage, “You can have any color you want, as long as it’s black.” In this environment, the best manufacturers use lean manufacturing processes to postpone procurement and production until they have a specific order and then their agile processes support creation of a product answering the individual customer’s preferences. They reduce inventories of completed goods, work in progress, and raw materials.

Finding Economies and Eliminating Waste. Finally, manufacturers face the challenge of eliminating waste and decreasing scale. This requires innovation in the production process and we saw companies approach this problem in a variety of ways. Perhaps the most common approach was to simply improve quality. The most impressive companies insisted on near-perfect performance in their own outputs, and the outputs of their suppliers. Waste drives up cost in myriad ways and manufacturers are attacking it with vigor. Programs like six sigma and others improve quality awareness and standards. Other manufacturers looked to process innovation to reduce the scrap associated with bending, cutting, and forming metal and other building materials.

Leveraging Knowledge. In the end, only the smartest companies survive in this global environment. No matter how they build their strategic advantage, advanced manufacturers differentiate themselves by speed to market, flexibility, quality, and economy. These qualities all come from implementing smarter processes than their competitors. The very best companies think fast! They have processes to assess the information they gather externally and internally, and turn it into knowledge they can act on. Their ability to think faster allows them to act faster in a highly competitive environment that rewards the first to market. This will require a highly educated, thinking workforce, capable of converting information into timely decisions.

GOVERNMENT: GOALS AND ROLE. This section will examine contemporary policy issues and assess how government supports the national aim of a viable and healthy advanced manufacturing industry. The government's role in regulating the manufacturing industry has evolved. Deregulation, privatization, and faith in the magic of the market has given way to a more aggressive approach that celebrates free competition rather than free markets, and recognizes that promoting competition may force departure from the concept of *laissez-faire*.[19]

The National Association of Manufacturers (NAM) describes the three most important that require policy maker attention as: (1) unfair trade practices; (2) intense foreign and domestic competition, making it impossible to raise prices; and (3) accelerated technological change, making it increasingly difficult to achieve high productivity growth because of inadequate capital investment and workforce skill deficiencies. Enumeration of government policies that might improve the competitiveness of U.S. advanced manufacturing are outlined below:

True Open Trade. Manufacturers would like to see open trade that follows global rules. This means letting the market determine the value of the dollar, particularly in China where they suspect that the government is buying $75B - $100B of intervention to over-value the dollar.

Further Tax Reform. Manufacturing would benefit from a permanent R&D tax credit, pension reforms, and a repeal of the alternative minimum tax.

Reform of the Legal System. Frivolous lawsuits and excesses of our tort liability culture cripple manufacturing through increased health costs and higher liability insurance premiums. Estimates reflect that manufacturers spend $100B annually on legal counsel. Congress needs to reform two specific aspects of the legal system – class action lawsuits and medical malpractice. Specifically, manufacturers would like to see a limitation placed on lawyers' ability to expand the class to include *potentially* afflicted litigants in class action lawsuits. As an example NAM estimates that manufacturers have already paid out $54B in asbestos claims, yet 90% of the recipients were determined not to be sick.

Energy Legislation and Environmental Regulation. Legislation is required to provide reliable energy more affordably, including incentives for R&D investments in new technology. However, the Kyoto Protocol and quotas or caps on energy use are very harmful to the industry. Compliance with health, safety, environmental laws and associated regulations cost manufacturers $700B per year. Policymakers should only use sound science and accurate data to develop energy, safety, and environmental policies. [20]

Responsible Corporate Stewardship. Prosecution of criminal activity to restore investor confidence and closing loopholes to increase investor information is a long overdue action. From a pro-competition perspective, the real issue is to raise capital and attract investors.

Health Care Reform. Health care costs are crippling competitiveness of virtually all manufacturers. Legislation is needed to modernize and improve Medicare, give seniors better access to preventative medicine, establish new drug programs, reform medical liability, and allow patients to choose their own doctors. Reform of medical malpractice is also necessary. A recent study reported an alarming trend--health care costs rose by 21% the past two years.[21]

Government Investment in Research and Development (R&D). The government must maintain current levels of funding to promote basic R&D. Through organizations like the National Science Foundation, the government partners with industry in R&D. These partnerships are important because they promote the transition of basic research into product development. This ensures continued U.S. competitiveness in the global marketplace. The DOD uses initiatives such as the Manufacturing Technology Program to help reduce cost and schedule risk for acquisition programs by creating reliable tools and production processes for critical DOD needs where commercial markets will not invest, and by adapting commercial processes where available.

Government's Role in Establishing Standards. The National Institute of Standards and Technology (NIST) to develops and promotes measurement, standards, and technology to enhance productivity, facilitate trade, and improve the quality of life.

Intellectual Property Protection. The U.S. must apply diplomatic and economic pressure on countries that infringe on intellectual property rights. For any knowledge-based economy to function effectively, it must have intellectual property protection. Advanced manufacturers rely on strong consistent protections that permit them to recoup their investments in advanced technologies and profit from their innovations.

CONCLUSION. Advanced manufacturing is critical to the U.S. economy. Industry leaders have responded to the challenges of globalization and have begun to reposition the manufacturing industry for the increasingly competitive 21st century marketplace. In other words, the overture to manufacturing pre-eminence has begun!

Why is manufacturing critical to the U.S. economy? First, it remains one of the U.S. primary employers – 16.5 million good-paying jobs in over 362,000 establishments. Second, manufacturers continue to produce and export innovative and leading edge products. Third, even during economically slower times, manufacturing is surviving. Last year, manufacturers increased their production activity, increased their production capacity, and became decidedly more productive – all critical attributes in a global competitive marketplace. In summary, manufacturing remains an unrivaled catalyst to the U.S. economy.

More importantly, U.S. manufacturers are responding to the challenges of the 21st century global marketplace. They have begun to transition to a concurrent (vice sequential) manufacturing environment to reduce the time it takes to bring product to market. They have begun to transition towards agile and lean manufacturing processes, and demand-driven production. Manufacturers are actively rooting out waste in their manufacturing processes and focusing on delivering first-time quality throughout the manufacturing process. All of this activity requires significant re-capitalization of 50-year-old infrastructure and yesterday's business cultures. Nevertheless, U.S. manufacturers recognize the need to do so and are moving out with a sense of urgency driven by the desire for ultimate survival and growth.

Manufacturers continue to leverage automation and IT to gain competitive advantages through an integrated supply chain and knowledge management. While works-in-progress, these benefits will blossom over the next five to ten years. They require manufacturers to apply the right amounts of automation, touch labor, and IT. This too, is a work-in-progress as evidenced by last year's statistics – 4.5% more productive with 550,000 fewer workers.

In summary, like the Russian people 191 years earlier, U.S. manufacturers will also fight off today's Napoleons. In the end, U.S. manufacturers will remain globally pre-eminent in the 21st century marketplace - by being smarter, faster, and more agile than their competitors.

ESSAYS ON MAJOR ISSUES.

"Advanced Manufacturing in Ireland: The Celtic Tiger"

Without a doubt, the Republic of Ireland has had one of the most successful economies of the last decade earning the nickname "Celtic Tiger". Ireland's success has surprised many, as it was not a particularly promising country for the type of open trade, high-technology economy it has now. As one of the poorest countries in the European Union (EU) in the 1970s, Ireland's emphasis had been on a self-sustaining economy based on agriculture. Today it is a country with strong regional and international associations, a force to be reckoned with in the EU, and a leading model of what a small nation can do to survive and even prosper in the global economy. Industry accounts for 38 % of GDP, and exports are the primary engine for Ireland's robust growth.

Decisive Role of Government. The Irish government has played a significant role in promoting a strong economy. Over the past decade, the government implemented a series of national economic programs designed to curb inflation, reduce government spending, increase labor force skills, and promote foreign investment. For example, Ireland boasts a special 10 % rate of corporate taxation and grants to attract foreign investment. Ireland's educational system, one of the best in the world, receives heavy government investment. Deciding to further integrate with the European Union, Ireland joined in launching the Euro currency system in January 1999 along with ten other nations. Because Ireland spends a fraction of its GDP on defense (.7 %), it has more resources to invest in its economy. In addition, Ireland was the recipient of more U.S. foreign direct investment during the 1990s than any other country.

Challenges and the Economy. The economy felt the impact of the global economic slowdown in 2001, particularly in the high-tech export center; the growth rate was cut by nearly half. Infrastructure suffers from under-investment; in particular the road network outside of the capital in Dublin. Infrastructure in Ireland requires substantially more resources to create an environment better suited to compete in the global economy. But other features of the economy are impressive. The unemployment rate has stayed around 3.8 % (2001), despite a dramatic rise in labor force participation rate and substantial net immigration. While the unemployment statistics might paint a picture of prosperity, the numbers favor the Dublin area at the expense of rural Ireland. Labor productivity has increased, while hours worked has decreased substantially.

The Manufacturing Sector. Ireland has diversified manufacturing, with most of it developed since 1930. The transformation from a weak, heavily agricultural economy to a rapidly growing, largely manufacturing economy, has been remarkable. The growth in the manufacturing sector is the result of a more cooperative approach among the social partners – labor, management, and government – than had been achieved at any time in the past. A key development was the weakening of the trade union movement in 1980s because of devastating job losses and soaring unemployment. The government adopted a conciliatory approach and pro-business attitude with policies to match.

The rapid growth rate in manufacturing can be attributed to the huge output increases in a small number of high-tech sectors, made possible by high levels of direct investment by foreign multinationals since the late 1980s. Manufacturing occupies a central role in Ireland's economy, comprising 45 % of the economy, 80 % of exports, and 28 % of employment. Approximately 1000 foreign-owned manufacturing companies now operate in Ireland, attracted by a skilled, flexible, and a relatively inexpensive workforce, unimpeded access to the EU market, and a range of incentives. The foreign-owned manufacturing sector accounts for over half of total manufacturing output, around 45% of manufacturing employment, and over two-thirds of manufactured exports.

Problem Areas. At least two major problems cloud Ireland's economic success -- unemployment and poverty. Ireland's unemployment rate has been, and continues to be, well above the average for Europe as a whole, and it appears to have increased even more over European levels. The highest unemployment rates are found in the more rural areas, among the less educated and older sectors of the population, those least able to benefit from the newfound prosperity, and those lacking the skills and training to move into the new work culture.

The second problem is poverty. According to a government report released in the mid-1990s, conditions have improved over the late 1980s, but still leave much to accomplish. Again, the most affected are those in the rural area and the older sectors of the population.

Conclusion. The United States and Ireland enjoy long-standing political, economic, commercial relations, and a close cultural affinity. The commercial environment in Ireland is highly conducive for U.S. companies interested in trade, investment, and a myriad of joint ventures/strategic partnerships. U.S. investment has been particularly important to the growth and modernization of Irish industry over the past 25 years, providing new technology, export capabilities, and employment opportunities. The stock of U.S. investment in Ireland was valued at $33 billion in 2001. Currently, there are more than 590 U.S. subsidiaries, employing approximately 100,000 people and spanning activities from manufacturing of high-tech electronics, computer products, medical supplies, and pharmaceuticals to retailing, banking and finance, and other services.

Many U.S. businesses find Ireland an attractive location to manufacture for the EU market, since it is inside the EU customs area. Government policies are generally formulated to facilitate trade and inward direct investment. The availability of an educated, well-trained, English-speaking work force and relatively moderate wage costs have been important factors. Ireland offers good long-term growth prospects for U.S. companies under an innovative financial incentive program, including capital grants and favorable tax treatment, such as a low corporation income tax rate for manufacturing firms and certain financial services firms. **Author: Lt Col Mark Allen, ANG**

“Sweden: A Hub for Manufacturing”

Globalization has had a significant impact on the Swedish manufacturing industry. Sweden’s history, as well as her geographical location, has provided opportunities for Sweden to become one of the manufacturing hubs in the Baltic region and in the world market. Sweden has undergone a continuous evolution since the industrial revolution came to Sweden in 1850.

The international community once characterized Sweden as a social welfare state with high taxes. It has, however, become one of the top ranked countries for attracting foreign investment and private sector innovation. This high standard has been a result of Sweden’s governmental policy to lead the industrialized world in R&D investment as a %age of GDP. This investment has led to the development of a high tech and transportation infrastructure and an education system that has produced a highly motivated and educated labor market. Access to raw materials, skilled workers, and innovative talent has helped Sweden achieve a manufacturing industry that is dominating the Baltic region and is expected to expand into western and southern Europe as the EU markets broaden.[22]

The government's commitment to fiscal discipline resulted in a substantial budgetary surplus in 2001, which was cut by more than half in 2002, due to the global economic slowdown, revenue declines, and spending increases.[23] The Swedish central bank (the Riksbank) is focusing on price stability with its inflation target of 2 %%. Growth should pick up to 2.3 % in 2003, assuming a moderate global recession.

International Interest in Sweden. International investors continue to be attracted to Sweden's comparative advantages of low corporate taxes and highly educated workforce. This fact solidifies the nation's position as one of the top investment destinations in the world. Telecommunications, automotive, forestry, and service sectors are among the most crucial sectors. Foreign investment activity for 2001 produced inflows of about 14.5B Euros and outflows of 8.9B Euros that reflects a net inflow of 5.6B Euros. During the past five years the U.K., Finland, Germany, and the U.S. have been the largest investors in Sweden.[24] Overall, foreign-owned companies employed almost 20 % of the business sector workforce. American companies are Sweden's largest foreign employers.[25]

Another source of international success for the Swedish economy is the industrial culture. Sweden is home to more multinational companies, per capita, than almost any other country. Generations of free trade and dependence on exports have fostered an international perspective and business acumen. The European Commission has ranked Sweden as the most innovative EU nation. Sweden is attractive for business expansion as well as a prime market for testing and launching of new products.

Manufacturing Sector. Privately owned firms account for about 90 % of industrial output. Approximately one-fifth of the total labor force is employed in manufacturing. For example, Eskilstuna is a well-known manufacturer of high-quality steels. Furthermore, Sweden is a well-known exporter of such precision items as Volvo and Saab automobiles, SKF ball bearings, ASEA high-voltage cable and other electrical equipment, L. M. Eriksson electrical and telephone equipment, and Electrolux electrical appliances.

The manufacturing sector in Sweden, as in practically all other industrialized countries, is becoming smaller as a % of GDP.[26] While the manufacturing sector shrank from 1,100,000 jobs in 1960 to 800,000 in 2000, the number of employees in the service sector has risen from 2,000,000 to 3,100,000 over the same timeframe. Due to spin-offs of company service units into separate corporations during the past few decades, independent service companies perform many services such as marketing, development work, computer support, shipping, and cleaning. In many cases, these companies are part of large industrial groups. As a result, the overall job market directly driven by manufacturing and related services total approximately 40 % of GDP.

The engineering industry is Sweden's largest manufacturing sector and has grown faster than any other in Sweden. In fact, the international community has come to recognize Swedish engineering products as "Swedish" specialties. The engineering sector has five main sub-sectors that include, metal products, mechanical engineering, electrical engineering, and transportation equipment and instruments. Easy access to high quality iron and steel contributed greatly to the development of Swedish engineering.

Another factor was the emergence of numerous inventors who established firms based on their inventions and improvements. In recent years, Sweden has become a global innovator, ranked second in the world in patents per capita. Government policies that granted academic researchers the opportunity to commercialize their discoveries, have spurred entrepreneurial activity and helped create new companies.

The engineering industry attributes its success to continued improvement of products and production processes in order to compete in the world market. Large sums are spent on R&D and training.[27] In 2002, the engineering industry accounted for 69% of R&D costs in Sweden's manufacturing sector.

The Swedish telecommunications industry is one of the fastest growing in the world. With Ericsson Telecommunications Group as the i dominant force in Europe. The main reason for this boom is the rapid growth in the mobile cellular telephone sector. Collaboration between the government and the private sector helped generate a range of products and services that were quickly accepted by Swedish and other users. By the early 21st century, Sweden was among the world's leading IT nations in terms of per capita computers, PCs, mobile (cellular) telephones, fixed phone lines, and Internet access.

Pharmaceuticals are the second fastest growing manufacturing sector in Sweden. This surge is directly attributable to the founding of two global healthcare providers, Astra and Pharmecia, in Sweden. The competitive market environment has led to Swedish companies collaborating with the Swedish Medical Products Agency to develop a cost effective and speedy drug approval and medical procedure process.

The partnership between the government, industry, and universities has allowed Sweden to become one of the world leaders in R&D expenditures as % of GDP.[28] Last year the Organization for Economic Cooperation and Development (OECD) ranked Sweden the world's most *knowledge-based economy*. The criterion for developing the ranking includes R&D, higher education, and software expenditure as a %age of GDP. In 2001, Sweden spent approximately 6.5% of GDP on that criterion. One third of the funding for R&D is provided by the public sector while two thirds is derived from the private sector.

Conclusion. Sweden is poised to expand its current market share of the EU market. There are a number of factors vital for Swedish expansion: access to important markets, competitive costs, access to a skilled workforce, and advanced technologies. Sweden has transformed itself from an agrarian-based society to a manufacturing and knowledge-based society. The key factors that have allowed Sweden to become successful include government policies that have made the business environment friendly to foreign and domestic investment. These policies include a corporate tax that is one of the lowest in the EU. A long-term partnership with academia has resulted in innovative industries. Responsible fiscal policies have led to taming of inflation, low unemployment, and controlled government spending.

Author: Nidak Sumrean

"Micro Electro-Mechanical Systems (MEMS)"

Micro Electro-Mechanical Systems (MEMS) is an integrative manufacturing technology for miniaturizing systems, that combines multiple disciplines such as optics, mechanical engineering, electrical engineering, physics, biomedical science, and chemistry. These systems have such enormous potential that there seems to be few boundaries to their applicability. Yet, despite its far-reaching potential, moving these small, powerful devices from laboratories to commercial products creates significant near-term challenges for MEMS producers.

Background and Current Status. The acronym MEMS is used almost universally to describe an entire field of devices that are produced by micromachining – a process where parts of a silicon wafer or surface layers are selectively etched away and new structural layers are added to create tiny machines like pumps, filters, or other moving parts. This technology enables manufacturers to fabricate entire systems on a single chip and subsequently replicate the system in batches.

While commercial applications are just surfacing, MEMS have been around for several decades and are an outgrowth of the Integrated Circuit (IC) and microchip industries. Although many of the microfabrication techniques and materials used to produce MEMS have been borrowed from the IC Industry, the field of MEMS has driven the development and refinement of other microfabrication processes. The advancement of these processes combined with the use of non-traditional materials has set the stage for MEMS commercial future.

Micromachining technology is the basis for all microsystems, such as micro structures, sensors, and actuators. The miniaturization of this new generation of mainstream manufacturing technology adds considerable value because new methods of manufacture promise powerful functionality at a very low cost.

The two most common methods of MEMS manufacturing are surface micromachining and bulk micromachining. Surface micromachining is a method of producing MEMS by depositing, patterning, and etching a sequence of thin films (~1 um thick). Surface micromachining has helped to commercially produce MEMS in volumes greater than a million parts per month.[29]

MEMS devices fall into two categories--sensors and actuators. Sensors measure the environment without modifying it. Sensor categories are inertia, pressure, biological/chemical/gas, biometric, humidity, and infrared. Actuators provide or manage some type of action. Actuators categories are Lab-on-a-chip, micromotors, microphones, mirror arrays, and radio frequency MEMS. On average, sensors cost a few dollars, where actuators cost more than a thousand dollars. On a unit basis, the market for sensors is in the tens of millions and the market for actuators is in the tens of thousands.[30]

The $1.3 billion U.S. MEMS industry markets include automotive, computer, communications, consumer, industrial and medical.[31] Current applications of MEMS include micronozzles in ink-jet printers, accelerometers in airbag-deployment systems and pressure sensors in blood-pressure monitors. Compared to old accelerometers used in airbags, MEMS perform the same task at less than 10% of the cost, and are smaller, lighter, more energy-efficient and more reliable.[32]

MEMS financial investment appears to be strong. One of the most exciting trends to develop since 2001 is the increased interest from venture capitalists. Despite the venture capital (VC) crunch and recent high-tech slowdown, VCs have continued to shower MEMS start-ups with funding. VCs invested nearly $510 million in MEMS companies during the first quarter of 2001 and continues to grow. [33]

New Processes Key to MEMS Future. Some predict that the ability to merge and fabricate microelectronics and micromachines on one piece of silicon will have the same impact over the next 30 years as microelectronics have had over the last 30. While semiconductor-based manufacturing techniques excel at producing high-volume integrated circuits using standard Complimentary Metal-Oxide Semiconductor (CMOS) processing, to date, MEMS manufacturers cannot match the volume due to the complexity of systems like three-dimensional micromirrors. Optical MEMS companies have found that developing precision optical components using silicon micromachining is a slow and expensive process. For example, it is not unusual for a single MEMS prototyping run to last 12 weeks or more, and building a MEMS fabrication facility typically costs $50 million.[34]

A new approach called Electrochemical Fabrication (EFAB) creates miniature three-dimensional shapes based on 3-D computer-aided design data. EFAB is a batch process suitable for high volume production of fully functional devices in engineering materials. This new technique eliminates the need for subsequent bonding or assembly steps.

The Sandia National Laboratories have advanced MEMS design and fabrication and are developing breakthrough technology in compact weapons, nanosatellites, and optical telecommunications. Sandia has progressively overcome a number of limitations that slowed widespread use of microscopic machines and are currently operating complex MEMS for billions of revolutions. Longer lifetimes were achieved through better control of drive signals, better mechanical design practices, and improved engineering of contacting surfaces to reduce wear."[35]

MEMS Financial Future. The development of new processes is highly proprietary because of the high cost associated with making the transition from laboratory to commercial production. Investment into new processes is costly. In slow economic times, this barrier to entry is too high for companies that lack sufficient capital. Still, the U.S. market for MEMS devices is expected to grow over 20 % annually through 2006--driven by innovations that lower costs, improve performance and expand applications. [36] The best growth prospects are expected in telecommunication switches, biomedical-related products, automotive sensors and telematics, consumer electronics and military/aerospace, but experts envision applications in the agriculture, aerospace, and medical industries as well. Some analysts expect fundamental changes in device complexity and cost to help worldwide MEMS revenues to nearly quadruple by 2005. The telecommunications market is expected to account for nearly a third of total

MEMS consumption by 2005. Revenues for MEMS are forecast to grow from just under $4 billion in 2001 to more than $9 billion in 2006.[37]

Conclusion. By definition, MEMS manufacturing is *advanced*. In it lies the promise to change our future just as significantly as the integrated circuit changed our recent past. While significant investments by the U.S. government and venture capitalists have failed to move MEMS from the laboratory to low-cost production on the shop floor, it is the next-generation of MEMS integration onto a single chip that holds the greatest potential to revolutionize our lives by enhancing space exploration, aerospace safety, public health, domestic security, and military capabilities. **Author: LtCol Jay Huston, USMC**

"Nanotechnology"

Nanotechnology is an innovative capability with numerous applications. However, because of multiple difficulties, defining nanotechnology is difficult because there are several accepted definitions. Even scientists cannot agree on the definition. For our purposes, nanotechnology is science at the microscopic level and nanotechnology products are manufactured atom by atom. Because of this, they are capable of very precise production standards. For comparison, a single red blood cell is about 8 microns in diameter, which is over 80 times larger in linear dimensions than a 100-nanometer processor, which would be capable of many things, including fitting easily into the circulatory system of a medical patient for treatment.[38]

Advanced Manufacturing. Nanotechnology production requires advanced manufacturing techniques. Since each atom or molecule is important, advanced methods of production are required. By definition, nanotechnology manufacturing is advanced. A few promising applications of nanotechnology such as powders, particles, coatings and films cross boundaries into many industries. These nano-products are primarily used to strengthen materials, combat corrosion, prevent scratching and reduce reflexivity.[39] This application has proven very useful in coating the face of instruments on machinery, aircraft, spacecraft, and computers to extend the life of the instrument or monitor and protect it from damage. Nanotech coatings perform more effectively than epoxy or paints because of their durability and cost. In addition, advanced materials are possible with nano-manufacturing. Manufacturers can tailor these applications for various purposes and applications to include smart fertilizers in agriculture, stronger and stiffer materials for the aerospace industry, molecular tools including computers for precision medical applications, superior building materials for the construction of physical structures, and continued miniaturization of electronic components.

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