Developing a 21st Century Aerospace Workforce

Version 2 - White Paper

For Submission to:

Human Capital Task Force,
The U.S. Commission on the Future of the Aerospace Industry

Developed by:

Joel Cutcher-Gershenfeld, Betty Barrett, Eric Rebentisch,
Thomas Kochan and Rob Scott
(With additional contributions by: Geoff Andrew, Greg Herweg, Kevin Long,
Shannon O'Callaghan, Eric Partlan, Karl Pilon, Irwin Rodrigues, and Larry Siegel)

MIT Labor Aerospace Research Agenda and Lean Aerospace Initiative

Foreword by:

Sheila Widnall,
Former Secretary of the Air Force and MIT Institute Professor

November 2001

Table of Contents

"The right people with the right skills at the right place at the right time."

Developing a 21st Century Aerospace Workforce

Executive Summary

The future of the U.S. aerospace industry depends on how we attract, retain, and develop the skills and capabilities of the workforce. This industry has always been driven by the innovations of a handful of experts and the talents of many others. As we look forward into the 21st Century, however, the challenge is much greater. The problem is three-fold:

- **Challenges in Attracting and Retaining a 21st Century Workforce:** With the end of the cold war, the rise of global competition, maturation of many industry products, instability in funding and technology, and growth in other sectors of the economy, the U.S. aerospace industry has lost its premier status as the employer of choice for many types of professional, technical and production workers – raising deep concerns about attracting and retaining a 21st Century workforce.

- **Inadequate Infrastructure Enabling Wise Investment in Human Capital:** The U.S. aerospace industry – government and private organizations – does not have current data, future projections, or adequate institutional mechanisms when it comes to developing the specific skills and capabilities that are required for success – raising the specter of ineffective, misdirected, wasteful and missing investments in human capital.

- **Limited Mechanisms for Diffusing Best Practices Across the Aerospace Enterprise:** Innovations around the implementation of new work systems and employment arrangements for engineering and production workforces stand as "islands of success" without a clear process in place for the sort of enterprise transformation needed in U.S. aerospace industry – particularly given the new sense of urgency facing both the military and civil segments of this industry.

In response, we recommend five specific initiatives – each designed to have a transformational impact – and an overall recommendation around the importance of research and development spending as a "pull" for the next generation workforce. The specific initiatives are:

- **Public Policy Priority Protecting Investment in Intellectual Capital:** Establishing mechanisms to mitigate instability and other threats to investment in "intellectual capital," which could include developing longer-term procurement contracts, targeted attention to intellectual capital issues at key stages of the procurement process, requiring "intellectual capital impact statements" when funding is to be cut or re-directed in significant ways, and other related issues.

- **Aerospace Capability Network:** Developing a public/private partnership network organization in which all key stakeholders in the aerospace industry coordinate the establishment and dynamic evolution of a full set of relevant skill standards, future capability requirements, and relevant workforce data.

- **National Training and Development Partnership:** Establishing a multi-stakeholder, public/private partnership supporting strategic investment in skills and capabilities that are central to industry success and that would not otherwise receive adequate investment – especially involving investment in building capability across organizations along what can be termed "mission critical" value streams.

- **Regional and Local Workforce Initiatives:** Demonstration grants providing targeted support for pilot local and regional innovations that effectively attract, retain and cross-utilize the aerospace workforce, as well as “best practices” with new work systems. Additional support should also be targeted at piloting mechanisms for regional and national diffusion of successful innovations. This could include matching funds from local foundations, governments and industry – with implications for national policy where appropriate.

- **Innovation by Government as an Employer:** Establishing mechanisms to develop and diffuse innovations in strategic human resource management at government aerospace labs, depots and bases. This is particularly important in the aerospace sector where major classes of employees are hired into the private sector after a period of time building skills and capabilities in the public sector.

In addition to these specific initiatives, we urge an overall look at R & D spending – with its implications for attracting and retaining the next generation workforce. Not only have we “hollowed out” the standing armies, there is some evidence that we have also “hollowed out” our practical experience and capability when it comes to basic and applied research expanding technical frontiers. In key ways, this addresses what can be called the “demand” side of the labor market – creating a dynamic engine for attracting and retaining talented people into the U.S. aerospace enterprise.

All of the above recommendations require substantial contributions from public and private sectors – not just contributions of funds, but of leadership time and attention. In this respect, we call for a deep commitment to fundamental cultural change in this industry – valuing human capital as the key to future success.

Foreword by Sheila Widnall[1]

The Aerospace industry serves the public interest by significant contributions to four core missions:[2]

- Enabling the global movement of people and goods;
- Enabling the global acquisition and dissemination of information and data;
- Advancing national security interests; and
- Providing a source of inspiration by pushing the boundaries of exploration and innovation.

These missions will never be routine. They will always require a highly skilled and talented workforce to conceive, design, develop, build and operate the aircraft, spacecraft, infrastructure and other means needed to accomplish these goals.

In recent years, the aerospace industry has been undergoing a set of dramatic transformations that have affected every facet of our professional lives and our industrial base. These transformations include moving from a focus on aircraft that flew "higher, faster, farther" to the industry providing value to its customers through the provision of a wide variety of aerospace goods and services. It includes the change in focus of the industry and its customers from a platform-centric view—focusing on individual airframes, their development and use—to a network view, aerospace vehicles as nodes in a network of information and capability. And it includes moving from an industry with a preeminent place in the competition for societal resources—as we saw in the Apollo era—to an industry that competes with many sectors for societal resources.

These changes have given rise to a cruel dilemma. It is people's knowledge, skills and mindsets that are essential to addressing the transformation: transformations of skills and capabilities, of tools and approaches, of expectations and opportunities. At the same time, it is these same people who must deal with skill gaps, mixed messages, displacements, and various forms of instability inherent in the way the industry operates today.

The aerospace industry has long been able to count on the passion of its employees for the accomplishments of the field. However, for too long, we have counted on this passion to sustain their commitment to aerospace without taking affirmative steps to sustain and develop skills on this base. We took it for granted that there would always be a ready pool of people coming into aerospace. And it is the experience base of the people in aerospace today that will make possible the advances of the future—a resource not to be squandered.

There have been pockets of success that stand in contrast to this trend. Many aerospace facilities have found powerful ways to build new skills and understanding in order to implement lean practices and principles, for example. Here at MIT, we fundamentally transformed the curriculum and even the composition of the faculty in the Aero/Astro Department in order to address the growing importance of computer software and other changes taking place in the

[1] Dr. Sheila Widnall is Institute Professor, MIT, and served as Secretary of the Airforce from 1993 to 1997.
[2] Earll Murman, Tom Allen, Kirkor Bozdogan, Joel Cutcher-Gershenfeld, Hugh McManus, Debbie Nightingale, Eric Rebentisch, Tom Shields, Fred Stahl Myles Walton, Joyce Warmkessel, Stanley Weiss, and Sheila Widnall. Lean Enterprise Value: Insights from MIT's Lean Aerospace Initiative, New York: Palgrave/Macmillan (Forthcoming, 2002).

industry. During my tenure as Secretary of the Air Force we made a number of targeted decisions to address identified areas of skill shortages. We also sought to address underlying systems barriers. Still, when it comes to workforce development, most of the changes were, at best, what we call "islands of success." They may have been – and may still be – successful initiatives, but they have not fully transformed the industry in ways needed to address the challenges ahead.

But we must look forward not backward: we must look to the skills of the future, not the skills of the past. Recently, I challenged the AIAA to fundamentally rethink how it serves the aerospace profession. As incoming president to this association I believe nothing short of a fundamental transformation in the definition of aerospace engineering will be sufficient. My message to the rest of the industry – military and commercial – is the same. People are the key to our success, but we must be bold and systematic if we are to deliver on this promise.

Of all the issues and challenges being considered by this Presidential Commission, I believe that these human capital issues represent one of the areas where we have the greatest potential to do something that is innovative and transformational in its impact.

There are many actions we can take to ensure the needed skills for the future; many of these are discussed in the following document. For example, the possibility of investing in R & D as a "pull" for the 21st Century workforce is not a new idea, but it gets to the root cause. Is the demand really there for the kind of work and the kind of workforce we need to have? How do we look at R & D from the point of view of building future capability – investing in human capital – not just completing a given project or program? This means that the definition of R & D priorities must be made with multiple stakeholders input to anticipate future needs – taking more of a long-term, strategic approach to such investments.

Ultimately, what distinguishes aerospace from other professions is our shared passion for air and space. We are at risk of seeing that passion undercut by incomplete attention to the human side of the enterprise. I believe we owe it to ourselves and to future generations to take this challenge on and accept nothing less than industry-wide success.

Preface on LARA and LAI

The United States aerospace industry relies on people to fund, design, engineer, build, maintain, and lead the process of creating vehicles of great power and grace. The expertise and determination of this workforce has powered tremendous successes in national defense and commercial productivity. This is a point of great pride for the people who work in the U.S. aerospace industry – some of the most highly skilled and talented professionals and technicians in world. As the aerospace industry has matured and consolidated, the workforce has aged and jobs have decreased. These changes highlight the critical need to insure that the United States can maintain its position as a global leader in aerospace design, production and support.

Established in 1998, The Labor Aerospace Research Agenda (LARA) conducts research and education that is centered on this workforce. Our research is focused on the impact of instability on employment and work practices, the diffusion of new work systems, and the development of appropriate institutional infrastructure and other mechanisms for investment in intellectual capital – all in the aerospace industry. The research is conducted by an MIT-based research team, under sponsorship and advisory input of key unions in this industry -- led by the IAM. Funding is provided via the Manufacturing Technology Initiative of the U.S. Air Force.

Established in 1993, The Lean Aerospace Initiative (LAI) has grown to be a consortium of 25 private organizations, 15 government organizations, and additional representatives from labor and academe. LAI also conducts research on issues concerning people and organizations in this industry, as well as on functional processes, such as product development, manufacturing, supply chains, and overall enterprise challenges. LAI is a predecessor and, in many ways, a parent organization for LARA. LAI also receives funding from the Manufacturing Technology Initiative of the U.S. Air Force, as well as from its many member organizations.

This report was developed by faculty and research staff affiliated with LARA and LAI. The views expressed here are not necessarily the views of all member organizations of either LARA or LAI, though it does feature input from key leaders on both initiatives.

Acknowledgements

We would like to thank that many individuals and organizations who contributed their time and thoughts to the preparation of this document, including: Sherry Balster, Rosie Behel, Randy Buck, Susan Cass, Jim Conley, Mark E. Correll, Tracy Covington, Jaffray Cuyler, Carlos DaCosta, Wayne E. Flory, Mike Flynn, Lynnette Freese, Mike Gregory, Brian Heins, Gary Jackson, Charles Johnson, the Joint Training Team, Dr. Daniel Kruger, Dr. Morgan Lewis, Brad Markel, Dr. Rodney L. Mickelson, Doug Monroe, Pat Parmley, Anita Perkins, Clifford M. Purington, the Resource Room Team, Steve Sleigh, Jerry Thomas, Kevin L. Weiss.

Introduction

The aerospace industry of the 21st century bears little resemblance to the strong, dependable industry that armed the allies in World War II and then drove the growth of commercial aircraft design and the very frontiers of space exploration. It is an industry that simultaneously features increased technical capability and constrained social capability. Even as science has advanced, the dominant mindsets, organizations, and cultures of today's aerospace enterprises are not ready for the world we face.

Across the industry there are leaders at every level who are being challenged to think and act in new ways. The same is true for this commission. This can't be a "business as usual" review of the industry's status. As the first such government commission in this new century we are faced with a unique opportunity and a unique set of challenges. In this paper we provide analysis and recommendations on human capital issues that are simultaneously designed to be practical and visionary – aimed to address root causes, not symptoms. Anything less will fall short on our duty to the country.

We need to begin with a view of the industry as a whole. As Dr. Widnall observed in the forward to this paper, drawing on the book *Lean Enterprise Value,*[3] there are "human capital" challenges are woven throughout all four of the core missions or ways in which aerospace serves the public interest. These four core missions are:

- Enabling the global movement of people and goods;
- Enabling the global acquisition and dissemination of information and data;
- Advancing national security interests; and
- Providing a source of inspiration by pushing the boundaries of exploration and innovation.

In each case, the way people have been trained, organized and led is experiencing unprecedented stress and strain. We will briefly review each of these themes from the book – highlighting the human capital implications.

The first mission – the global movement of people and goods – includes the commercial aircraft sector, as well as the vast array of airlines, maintenance, airports, and other related activities. Plausibly, it even reaches to include inter-modal innovations that link travel in the air to travel by car, train, boat and other means. Even before September 11, 2001, the rise of global competition, the increased congestion in many locations, the emergence of new business models for engine maintenance, the growth of regional jets, and many other factors suggested that this was not business as usual. New clusters of skills and abilities are emerging in some locations and deteriorating in others – driven by these dramatic product market changes.

In the second mission – the global acquisition and dissemination of information and data – the combination of space-based and land-based mechanisms for the movement of information and data continues to evolve in unpredictable ways. Not only is there uncertainty about the demand and supply of the professional and technical workforce needed for various aspects of the space sector, but it is not fully clear how this workforce will be linked to land-based aspects of the telecommunications industry.

[3] Earll Murman, et. al., (forthcoming, 2002).

With respect to national security interests – the third mission – the end of the Cold War brought a shift away from the constant imperative to go higher, faster and further. The new demands to be faster, cheaper and better require a fundamental re-thinking of defense acquisition policies, product development and manufacturing processes, supply chain integration and life-cycle sustainment. The further imperative centered on the challenge of fighting global terrorism has scientists, engineers, managers, production workers, and countless others asking core questions about job security, skills and capabilities, career prospects, and other related matters.

Finally, the fourth mission – pushing the boundaries of exploration and innovation – has too often been victim to the resource constraints associated with uncertainty and decline in the first three missions. Simply put, the best and the brightest are not choosing aerospace careers in the same numbers and intensity as was the case in prior decades.

The industry has thus far survived cycles of boom and bust tied to Congressional budgets and global market trends. In a downturn, companies have focused on cost cutting but deterioration continues. The time has come to shift to a strategy centered on creating value. What will it take to create value for all the stakeholders in the aerospace industry? The answers to that question rely on the move to a more knowledge-driven work system and the creation of an effective institutional infrastructure for developing and maintaining a highly capable, motivated workforce.

Creating a knowledge driven work system is impossible without a highly capable, motivated workforce. Aerospace workers must not only develop the necessary skills, they must be convinced to exercise those skills in a responsible, resourceful way within the industry. Concurrently, industry must support the workforce by providing a measure of stability in employment, well-planned skills development, and a vision of future needs that translates into careers and professional development job paths for aerospace workers. Such strategic planning needs to be dynamic, with industry wide input and breadth of vision so that employers and workers can depend on the U.S aerospace industry to provide a high standard of living. More importantly, building such capabilities into the workforce will sustain and deepen the viability of an industry critical to the national economy and security.

Equally critical to the continued strength and capability of the aerospace industry is the development of a responsive institutional infrastructure that can guide the maintenance of aerospace competency while promoting the interests of all stakeholders. Such an infrastructure must have shared governance, stable funding mechanisms, and measurable impact. The most effective responses to difficult problems are shaped from an understanding of the current situation and an exploration of potential elements of a solution. This white paper is focused on these two goals.

1.0 Statement of the problem

The future of the U.S. aerospace industry depends on how we attract, retain, and develop the skills and capabilities of the workforce. This industry has always been driven by the innovations of a handful of experts and the talents of many others. As we look forward into the 21st Century, however, the challenge is much greater.

1.1 Attracting and retaining the future aerospace workforce

With the end of the cold war, the rise of global competition, maturation of many industry products, instability in funding and technology, and growth in other sectors of the economy, the U.S. aerospace industry has lost its premier status as the employer of choice for many types of professional, technical and production workers – raising deep concerns about attracting and retaining a 21st Century workforce. [4]

What factors make aerospace an attractive industry for the next generation work force? In terms of sheer excitement of products and challenges, it would seem that aerospace would have much in its favor. Yet, the trend is pointing in a less favorable direction. Despite the intrinsic excitement of soaring in the air and operating in outer space, many of the leading tools, technologies and products in this industry have not changed significantly for one or two decades.

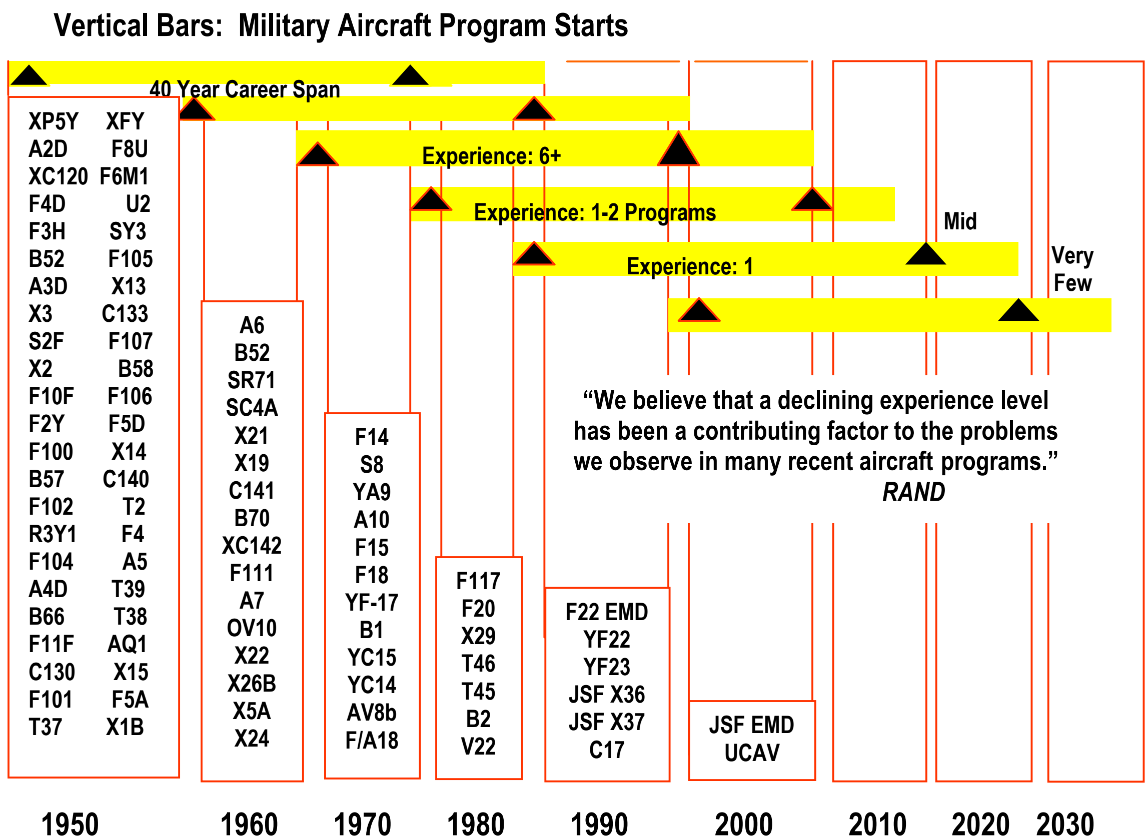
As Figure 1.1 suggests, the opportunities to participate in the breakthrough innovation opportunities associated with new programs has been declining in the defense aircraft sector. As this chart indicates, an aerospace engineer or production worker beginning a career in the 1950s entered an industry in which there were 46 new military aircraft platforms on which this person could anticipate working. In successive decades that number has shrunk to the point that someone entering the field today would find only 2 new military aircraft platforms for work in this field.

Similar declines in opportunities can be found in the commercial aircraft sector. While aspects of the space sector are newer, these same concerns may be on the horizon in this sector as well. Moreover, the cycle time to produce some of the early military jets was a year or two. For example the first operational jet fighter, Lockheed's P-80, was designed and built in six months. In contrast, today's products can have development times measured in decades. For example, an engineer could have been working on the F-22 for 20 years in advance of completion of the design and initial construction.[5]

---

[4] See, for example, Defense Science Board (November 2000); articles by William B. Scott in *Aviation Week & Space Technology* (cited earlier); and John R. Harbison, Gen. Thomas A. Moorman, Jr., Michael W. Jones, and Jikun Kim, 'US Defense Industry Under Siege — An Agenda for Change', Booz, Allen & Hamilton Viewpoint (2000).
[5] Murman, et. al., op. cit.

Figure 1.1
Declining Experience Levels -- Military Aircraft Programs



Ref: RAND Study (chart by Northrop Grumman)

Another indicator of opportunities to be part of cutting edge innovation is patents per employee. Here, aerospace ranks last among almost all high-tech industries. Again, not a draw for people seeking opportunity and challenge.

What of a more mundane draw – the promise of growth? If we look at sales per employee, an indication of productivity, aerospace also ranks last.[6]

What of an even more basic factor – compensation? Here, lifetime earnings in aerospace compare well with those for similar employees in other sectors. Aerospace technical employees are among the highest paid engineers and scientists (exceeded only slightly by electrical,

[6] Aerospace productivity has grown at a rate of 2.6 percent per year since 1979, compared with a productivity growth rate of 3.7 percent for utilities, 3.9 percent for the Fortune 500 median firms, 4.3 percent for pharmaceuticals, and 8.1 percent for computer and office equipment manufacturers (all based on Fortune 500 data). However, aerospace productivity increases do exceed those of other heavy manufacturers, notably industrial and farm equipment (2.3 percent) and autos (1.5 percent).

computer, and software engineers). The issue here is that some of these 'rocket scientists' are being drawn into other sectors of the economy at higher levels of compensation.[7]

Among the hourly workforce, organized labor plays a crucial role in the aerospace industry. In fact, aerospace is one of the most highly unionized industries in the United States. Some 40 percent of all production employees, or one-fifth of all industry employees, are represented by a union. The typical union aerospace worker earns wages 50 percent higher than does the average worker in manufacturing, and enjoys comprehensive benefits.[8] The promise of a higher standard of living may be a critical factor in once again attracting young people into the skilled trades. Dr. Morgan Lewis, who has been studying a broad range of issues associated with technical education since the early 1960s, says "I have the belief that basically the market will work. However, young people need salaries commiserate with the average college graduate to be attracted to skilled and technical work."[9]

Beyond the impact of unions on wages and other bargaining matters, labor organizations shape the work context in front-line operations and in strategic decision making.[10] Although unions and employers in this industry are joined together in a wide range of partnerships around training, new technology and new work systems, these same parties also find themselves embroiled in deep and contentious conflicts around union organizing, outsourcing, movement of work across locations, handling efficiency improvements and other matters. There is a core need to help ensure robust relationships between employers and unions so that the inevitable contentious issues can be addressed in constructive ways – without resulting in escalating and destabilizing conflict.

Perhaps most telling of all are the results from a recent survey of nearly 500 US aerospace engineers, managers, production workers, and technical specialists. Among other questions, they were asked whether they would 'highly recommend that their children work in this industry?' Only 17 percent of the engineers agreed or strongly agreed with this statement and the numbers were similar for the other groups. Overall, four out of five people in the aerospace industry would *not* recommend it to their children. In individual interviews, people said that they were very proud of this industry and their own contributions. It was the instability and related factors, they said, that led them to what is really — for them — a heart-wrenching conclusion.[11]

1.2 Defining and developing needed skills and capabilities

The U.S. aerospace industry does not have current data, future projections, or adequate institutional mechanisms when it comes to developing the specific skills and capabilities that are

---

[7] National Science Board, 'Science and Engineering Indicators — 2000' (Arlington, Va.: National Science Foundation, 2000), p. A-147.
[8] Eric Rebentisch, 'Creating Value Across the Enterprise: Pathways to a Robust and Prosperous US Aerospace Enterprise', LAI Position Paper (April 2000).
[9] Personal Communication with Dr. Morgan Lewis, Coordinator of Need Sensing and Technical Assistance, National Dissemination Center for Career and Technical Education, November 13, 2001 with Betty Barrett
[10] This three-tier framework — with relations at the workplace, in collective bargaining, and at strategic levels — derives from the analysis by Thomas Kochan, Harry Katz, and Robert McKersie, *The Transformation of American Industrial Relations* (New York: Basic Books, 1994).
[11] 'The 21st Century Aerospace Workforce', presentation to the LAI Executive Board by the MIT's Labor Aerospace Research Agenda (May 2001) and cited in Murman, et. al., op. cit.

required for success – raising the specter of ineffective, misdirected, wasteful and missing investments in human capital.

In preparing this report we found numerous gaps regarding basic questions about available data. To be sure, even defining the boundaries for the industry is a difficult task. In addition to Standard Industry Codes for aerospace (SIC 372 – Aircraft and Parts; SIC 376 – Guided Missiles, Space Vehicles, Parts) there are many second and third tier suppliers who fall into other categories. As well, there are emerging areas such as computer software systems that are increasingly central to the industry, but that again fall into other categories.

Still, we found limitations in the way that government and industry skills standards and other key workforce indicators for this industry are compiled and reported. For example, when we sought to identify the number of people in aerospace apprenticeship programs, we were told that data did exist for some specific aviation and transportation occupations, but not for many other domains of the aerospace industry. Individuals are certified by the government upon completion of approved apprenticeship programs, but the standards and information on the people in the programs is not readily available. Internal corporate systems vary considerably in terms of the amount of current data on workforce skills as well – and none of these data are available in a way that would inform policy makers or industry leaders. The National Skills Standards Board has taken on some of these issues as part of its agenda, but there is not a strong aerospace involvement in these activities – at least not an involvement that we could see.

We did attempt to assemble for this report the specific time and learning required to effectively serve in the broad range of jobs that are found in this industry. The results of this analysis, which are included in the appendix to this white paper, are highly instructive. The development time required,for example, for a skilled machinist involves a four-year apprenticeship and an additional two years of on-the-job training. As we will see in the root cause analysis section of this paper (part 3.0), there has been virtually no investment in sending new apprentices into these training programs. The result is a gap in the pipeline that will soon be evident and that will not be easy to remedy.

Note that the data in the appendix represents the available information that we were able to identify for a portion of professions relevant to this industry, which covers the following:

Aircraft and Spacecraft Design and Manufacturing Professions

- Aerospace Engineers
- Engineering Technicians
- Aircraft Assemblers
- Computer Engineers
- Drafters
- Precision assemblers
- Metalworking and Plastics-working Machine Operators
- Machinists
- Tool and Die makers
- Painters
- Welding and Soldering Technicians
- Technical Writers
- Blue Collar Supervisors
- Managers and Executives

Air Lines and Transportation Infrastructure Professions

- Air Traffic Controllers
- Aircraft Pilots
- Flight Engineers
- Aircraft Mechanics and Service Technicians

The gaps in information on some professions and even gaps and concentrations in the mix of job categories is reflective of how information is collected – not necessarily how it should be organized for future planning in the industry. This, too, is a key finding of this paper – the difficulty in even assembling this information and the gaps that we have identified are obstacles to future workforce planning in aerospace.

Of particular interest is the vital role that interpersonal skills play in the interviews held with training representatives who were involved with day-to-day training issues at the facility level. Although this is an area where more research must be done, it is clear that for many of these experts, interpersonal skills and the ability to relate to others in the workplace was critical to productivity and successful implementation of modern work organization systems. At a Boeing facility in Everett, Washington, the co-director of the QTTP program told us that in a recent employee survey aimed at identifying the training needs that employees felt were most crucial, the top 4-5 responses were 'soft skills' such as how to deal with difficult people and effective listening skills. In an industry where employment is often highly unstable, it is instructive to hear that employees requested soft skills over the more technical developmental skills they might use to improve their job security. One immediate need for these interactive skills comes from the shift to cellular manufacturing techniques that require far greater interaction between members of the workforce across many functions.

The challenge is perhaps even greater when it comes to the training and development of the scientists and engineers needed by this industry. Critically important is not just undergraduate and graduate schooling, but also sufficient breadth of experience to serve as a next generation leader. Data is not available at aggregate levels, but there is anecdotal evidence of a number of demographic gaps in the system. First, there was a substantial fall off in students entering science and engineering programs in the early and mid 1970's – with the shift in national mood away from a focus on winning the space race and toward a focus on whether to continue supporting the Viet Nam war.

More recently, there is anecdotal and systematic evidence of a growing number of new engineers and scientists turning away from aerospace in the mid to late 1990's. For example, in 1991 there were 4,072 total engineering degrees (undergraduate and graduate) awarded in aerospace and that number has shown a relatively steady decline of over 50% to 2,175 degrees in the year 2000. This contrasts, for example, with computer engineering degrees (undergraduate and graduate), which nearly doubled during the same time period from 8,259 to 15,349. Similarly, biomedical engineers increased from 1,122 in 1991 to 1,919 in the year 2000.[12] The combination of recent educational trends and past hiring clusters points to both a senior leadership gap and a new entrants gap hitting the industry at the same time.

Further complicating the picture, is the substantial portion of the workforce that is eligible for retirement in this industry. For example, the average age of production workers in the US

[12]National Science Foundation, Division of Science Resources Statistics, Science and Engineering Doctorate Awards: 2000 [Early Release Tables], Arlington, VA [October 2001].

military sector is 53 years, with more than 20 percent eligible to retire in the next five years.[13] The numbers are even higher for engineers, with one study suggesting that 33 percent of scientists and technicians are or will be eligible for retirement in the next five years.[14]

Were all of this not enough cause for concern, there is also the impact of successive waves of layoffs as a result of organizational restructuring and economic downturns. As was noted in *Aviation Week and Space Technology:*

> A management and Wall Street preoccupation with cost-cutting, accelerated by the Cold War's demise, has forced large layoffs of experienced aerospace employees. In their zeal for saving money, corporations have sacrificed some of their core capabilities--and many don't even know it. [15]

We do not have sufficient, reliable data on the skills and capabilities that have been lost through restructuring or the skills and capabilities that are about to be lost through retirements or the skills and capabilities unavailable as a result of the demographic gaps or the new skills. Nor do we have sufficiently clear information on the projected skills and capabilities that are likely to be needed in the years to come. The information that we do have, however, drives a strong sense of urgency around addressing these issues.

At its core, there are two countervailing trends. On the one hand, employers seem to be distancing themselves from investment in human capital and other commitments to the workforce. On the other hand, workforce capability is more central than ever to organizational success. This is a core tension in all sectors, but is particularly acute in aerospace.

1.3 Achieving fundamental transformation in operations

Innovations around the implementation of new work systems stand as “islands of success” without a clear process in place for the sort of enterprise transformation needed in U.S. aerospace industry – particularly given the new sense of urgency facing both the military and civil segments of this industry.

There are many notable innovations around the use of lean practices and principles, the implementation of high performance work systems, the use of Six Sigma tools and methods, and other such efforts. In *Lean Enterprise Value,* dozens of these case examples were characterized as “islands of success.” Included here were the dramatic cost savings and quality improvements achieved by the C-17, which also featured a strong labor-management partnership; the significant innovations in acquisition operations achieved by the JDAM program; and numerous other examples. In each case, however, the success has been tempered by the incomplete diffusion of these innovations to other parts of their enterprises.

While there is no existing time-series data tracking the diffusion of workplace innovations in the aerospace industry, there is some evidence to suggest that the diffusion of certain innovations in these sectors lags behind other parts of the economy. For example, a cross-sectional survey

---

[13] These numbers are based on an analysis by the strategic resources department of the International Association of Machinists and Aerospace Workers – as cited in Murman, et. al.
[14] Booz-Allen, Hamilton 1999 study cited in ‘The New Industrial Reality: Ensuring America’s Future National Security (DoD briefing, May 2002) – as cited in Murman, et. al.
[15] William Scott, June 21, 1999, see http://www.aviationweek.com/aviation/aw63-66.htm

conducted in 1999 with a sample of 198 facilities asked about the presence or absence of over a dozen common change initiatives in these facilities. The two most common responses were "employee involvement" (67%) and "Total Quality Management" (58%) – both types of initiatives that were dominant in the overall U.S. economy in the 1980s. By contrast, "lean production" initiatives were reported by 40% of the facilities, "team-based production" was reported by 30% of the facilities and various forms of "pay for performance" were reported by just 25% of the facilities.[16] In other sectors of the economy, the use of lean principles, team-based work systems, or performance based pay are more broadly diffused. It is true that some innovations, such as the use of integrated product and process design teams is quite advanced in aerospace, but even here the diffusion of such innovations is not complete.

While this challenge is not unique to aerospace, it is of particular concern in this sector. The full and effective utilization of "human capital" can only happen in work systems that are designed to value workforce knowledge. Investing in new skills and capabilities, but then managing the workforce in traditional ways, is a virtual guarantee that the investment will not be well spent. For these reasons, innovative work systems must be linked to human capital investment strategies. This includes not just lean initiatives centered on efficiency improvements, but linkages around new business models as suggested by GE's "power by the hour" service model that is replacing engine sales or early experiments with inter-modal transport utilizing regional jets, rental cars, and other forms of transport. With all of these innovations, there are direct implications for the mix of jobs in the industry and the ways in which people help to enable (or limit) the experimentation.

Underlying many of the challenges around the diffusion of innovation is a key dilemma. Organizations that invest in building new skills and sharing innovative practices always fear that they will lose the investment if employees leave the firm or that they will lose competitive advantage by sharing innovations. A key to addressing these concerns involves integrating institutions – that share the risk across many organizations and that establish norms centered on reciprocity and mutual gain. When exploring these challenges at a recent aerospace workshop, the instinctive comment of a participating union leader helped to put things in perspective:

> "The only thing worse than training employees and losing them is not training employees and keeping them!"

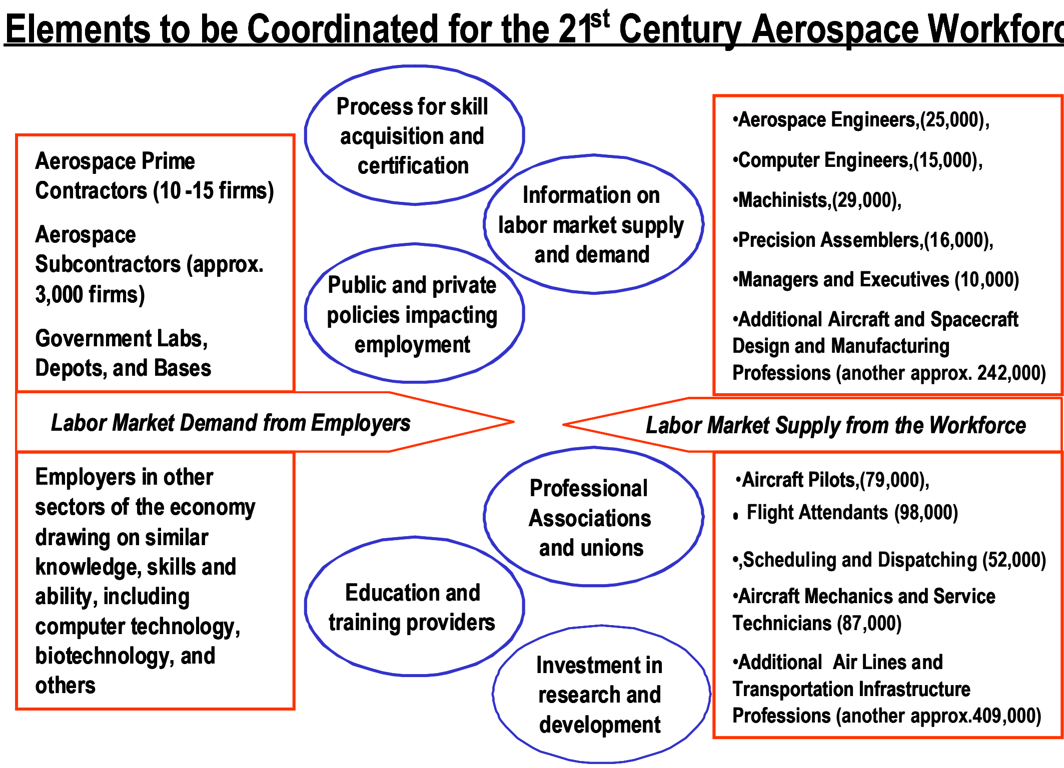
While all of these factors were significant challenges facing the industry prior to September 11th, it is now even more important. In the civil aviation sector major airlines are at risk of going out of business, while aircraft manufacturers and suppliers are braced for a long-term loss of orders. In these cases, the discussion of the employment implications of various innovations must be joined with the need for innovation around re-training and re-deploying larger numbers of employees that may never work in the aerospace industry again. In the military sector, responses to terrorist threats may involve increased government investment, but here too, the investment in responses to bio-hazards, civic preparedness, and other emerging aspects of security leaves uncertain the remaining investment available for aerospace products.

A summary of the challenge ahead is provided in Figure 1.2, which illustrates labor market demand from employers on the left side and labor market supply on the right side. Notice that demand may come from employers in aerospace or in other sectors. Also, there are both internal and external labor markets – the supply and demand can involve movement within an

[16] Labor Aerospace Research Agenda, 1999 facility survey results.

organization as well new entry into an organization. The labor supply is both in the aerospace design and manufacturing professions and in the air transport and infrastructure professions. Notice, however, that some professions such as computer engineers or machinists have skills easily transferable into other sectors. In the middle of the figure are some of the intermediate processes and institutions – which can serve as enablers or barriers. The key motivation for this white paper is that there are significant "disconnects" in every part of this illustration – all of which impair our ability to ensure the right people at the right place with right skills at the right time.

Figure 1.2



2.0 Root Causes and Research Findings

2.1 The end of the Cold War and the rise of global competition

The current capability of the aerospace industry to design and build advanced technological systems rests on a foundation laid by pioneering work begun decades ago. Much of this work was part of or depended upon the effort to prevail during the Cold War. Work on specific programs or classes of systems such as fighter aircraft created not only experience and skills in individuals, but also specialized organizations, tools, and infrastructure such as test facilities that enabled the design, development, and production of today's advanced aerospace products. Both commercial and defense aerospace enterprises benefited from these capabilities, although in recent years their technological trajectories diverged as the commercial sector was driven to address product cost-effectiveness more stringently and earlier than was the defense sector.

With the end of the Cold War, much of the logic that demanded the existence of such specialized capabilities in the defense sector has significantly changed. More importantly, the levels of funding that sustained those capabilities have declined significantly. Since the end of Cold War, Department of Defense (DoD) investment in research, development, test, and evaluation (RDT&E) declined by over 19%. DoD procurement spending declined by over 50% during the same period[17].

During this period, civil aerospace faced increasing international competition. Airbus Industries began making significant progress in aircraft orders in what was previously a U.S.-dominated industry. In 2000, for the first time ever, Airbus booked more aircraft orders than did rival Boeing. European launch provider Arianespace received a significant market advantage with the Challenger disaster in 1986 and the then-prevailing U.S. launch policy. In the years that followed, it led in its share of the global launch market. In the 1990s, former Cold War adversaries became competitors in a launch market with many capable systems vying for a few launch payloads, increasing the pressure on U.S. launch providers. Export policy turmoil in the late 1990s gave foreign satellite manufacturers a temporary advantage vis-à-vis U.S. suppliers as potential buyers were faced with the uncertainty of whether their operating strategies would be held hostage to U.S. policy and bureaucratic entanglements.

While the historical events just cited can and do affect both domestic and foreign suppliers, and are unpredictable, they signal some major trends facing the aerospace industry that have implications for the human capital base. Aerospace technology, in most cases pioneered in the U.S., has now diffused globally with many competent (and in some cases, world-class) suppliers competing for the same customers as U.S. suppliers. During the 1990s, imports of aircraft and parts rose from 8% to 18%[18]. At the same time that domestic aerospace providers were seeing reduced market share as a result of global competition, the U.S. domestic defense market shrank significantly.

For a variety of reasons, the number of employees in aerospace and directly related industries shrank by over 500,000, or almost 40% during the 1990s[19]. Several firms disappeared or were subsumed into the surviving aerospace firms. During the so-called defense "procurement holiday" in that period, many organizations within government and industry had a "hiring holiday"

---

[17] Source: Department of Defense Greenbook
[18] Source: Rob Scott, Economic Policy Institute
[19] Source: AIA

(e.g., hiring freezes or reduced rates that resulted in net attrition of the workforce) to accommodate the need to downsize organizations and cope with diminished budgets. What we see today in many aerospace organizations today is a bimodal distribution of employee tenure. There is a significant population of older, more experienced employees nearing retirement (as discussed in section 1.2), and a smaller but also significant population of younger employees that have been hired in recent years to respond to the need to staff programs and organizations. Between the two lies a smaller cohort of experienced employees that represents the bridge in knowledge between the senior and junior employees and which is the pool from which future leaders will be drawn.

2.2 Industry "maturity" with reduced opportunities for innovation

Defense aerospace has been a leader in advancing technology for several decades. This was certainly true during the dawning of the jet age and space age. To provide perspective, though, those dawning events took place decades ago. Over time, aerospace vehicle technologies have matured, with increasing emphasis being placed the cost-effectiveness of the technology rather than absolute performance[1]. Many aerospace products have become "dominant designs" where the product architecture and the relationships between major sub-elements are relatively stable[2]. Overall system performance in dominant designs increases incrementally through integration of new technology within the prevailing architecture or through advances in individual subsystem performance. For instance, many of today's aircraft, missiles, or launchers are architecturally quite similar to those of their 1st generation predecessors (e.g., the Boeing 707 aircraft, the Atlas launcher, etc.)

Once a dominant design emerges, economics play a much larger role in the frequency with which new product generations are created. For instance, mature products often have decreasing returns from investment in technology performance; each incremental advance in performance costs more than the previous[3]. This has an impact on the creation and diffusion of human capital within that sector. Additionally, in a mature stage of technology evolution the locus of "cutting edge" technology innovation often shifts from the platform level to the sub-element or subsystem level, creating new opportunities to create human capital through experience in new sectors. Innovations producing significant changes in new aircraft system performance often result from improvements in avionics, propulsion systems, or materials.

Over time, enough of these innovations at the subsystem accumulate to warrant the creation of a new generation of system, such as the F-22 fighter aircraft. This leads to longer time spans between major product generations. With fewer new designs, people also have fewer opportunities to exercise critical design, test, and production skills. They also have fewer opportunities to experience the full range of contingencies that might arise during the design and production lifecycle of a new product. This phenomenon largely explains the decline in the number of new aircraft platforms and the resulting drop in the number of programs any individual has worked on during his/her career, shown in Figure 1.1.

Mature technology arenas or industries aren't by nature necessarily un-innovative or unattractive places for creative people to seek their careers. Both the aerospace and auto industries emerged around the beginning of the 20th century, and over the last hundred years have seen dramatic improvements in technologies as well as several new product generations on which to work. Both industries are integral to the 21st century economy and its ultimate performance. They serve markets that are large enough to provide a fairly consistent demand for increased product performance or functionality. Consequently they provide jobs that are both interesting and rewarding. And this occurs in the context of two mature industries.

A mature industry does potentially face a human capital challenge when it must compete for the same human resources with a younger technology sector that offers greater long-term career growth opportunities, more opportunity for discovery or technical challenge, and possibly higher compensation. The computer and software sectors emerged in the middle of the 20th century, for instance. They are both enormous markets, still offering substantial new technological challenges to overcome, and can offer attractive compensation and quality of work life combinations. Biotechnology has emerged more recently than computing technology, and at this point may be only remotely related to aerospace technology. Consequently, aerospace does not compete directly with this new technology sector, except perhaps for people at the very beginning of their careers considering which field to enter and which arenas offer the most potential for long-term career interest and growth. Consider, for example, that the world's fastest computers have historically been tested against complex aerodynamic calculations. Recently, however, IBM announced that it will now replace aerodynamics with the sequencing of a protein as its benchmark challenge. For the very best and brightest students, there is a clear signal here.

2.3 Instability in funding, technology, and organizations

Instability has always played a role in aerospace decision making. As early as 1898, Congress approved the allocation of $50,000 to Samuel Piermont Langley to build a man-carrying aerodrome to aid in the Spanish American War.[20] When Langley's aerodrome failed to fly, nine days before the Wright brothers flight at Kitty Hawk in 1903, Congress failed to appropriate more money for Langley's experiment. Although this is, perhaps the earliest example of funding instability in aerospace, there are many more. As the industry developed, instability began to affect increasing numbers of employees. In 1943, the industry employed 1.46 million people but by 1946 when the war ended, that number had dropped to 219,000.[21] In 1971 when commercial sales and military sales dropped precipitously, the U.S. aerospace industry suffered huge human and financial losses. Whenever demand began to increase again due to sales or conflict in the world, the industry recalled thousands of workers.

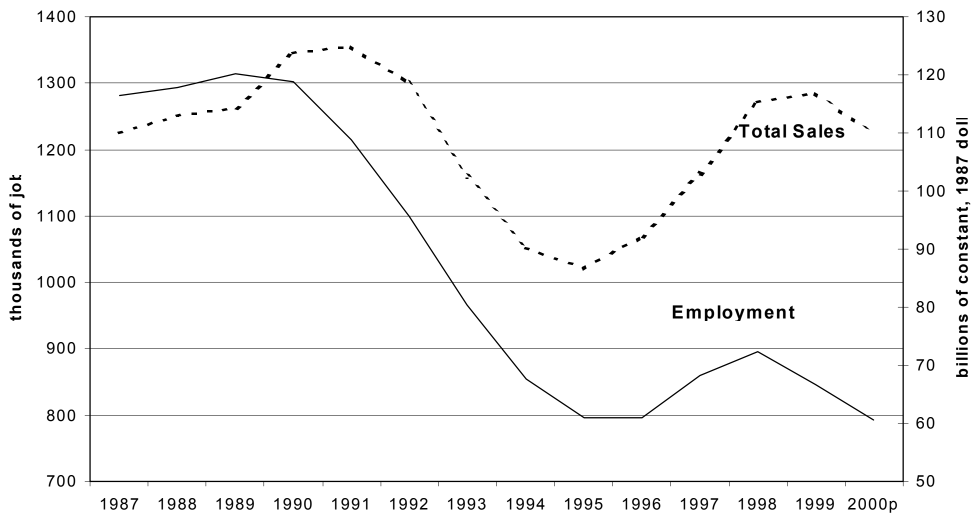
More recently, the cyclical nature of U.S. aerospace industry has continued, but not always with the same level of recall during subsequent periods of growth. Figure 2.1 illustrates the movement of total U.S. aerospace sales and total U.S. aerospace employment from 1984 to 2000. While sales dropped to a low in 1995 during that year's global economic crisis, they have in the interim returned to 1987 levels. Jobs have not followed this same pattern. Employment in the industry has fallen by roughly a third despite a slight recovery in 1998.

Additional analysis by Robert Scott at the Economic Policy Institute pointed to very different long-term scenarios for employment in aerospace. In the first and most positive scenario, U.S.

[20] Freudenthal, E. E. (1940). The Aviation Business: From Kitty Hawk to Wall Street. New York, The Vanguard Press. Freudenthal chronicles the early history of the aviation industry. She details the evolution of the business with facts and stories.
[21] Bluestone, B., P. Jordan, et al. (1981). Aircraft Industry Dynamics: An Analysis of Competition, Capital, and Labor. Boston, MA, Auburn House Publishing Company. Bluestone and colleagues use econometric measures to trace the development of the aerospace industry. They emphasize the impact of change on labor as well as the role of labor in the industry.

employment rises by 146,000 jobs based on an optimistic, early 2001 Boeing Company market share projection. Other scenarios were based on then current trends and the outlook for outsourcing of work to international suppliers. For example, imports of engines and parts for aircraft production has increased from 8% of sales in 1981 to over 18% of sales in 1999. Taking into account this trend and the growth in market shared by Airbus, the number of jobs drops radically. Moreover, these numbers do not factor in the current additional decline and instability.

Figure 2.1
U.S. Aerospace Employment and Sales 1987 - 2000



Source: Robert Scott, EPI and LARA, 2000, adapted from AIA data

Just how bad can this blight of instability be as it crosses the enterprise? One study of defense acquisition in the mid-1990s[22] found that programs, on average, experienced roughly 8 percent annual cost growth and around 24 percent schedule slip. In real terms, that means that a five-year development program would exceed its initially planned cost by some 40 percent, and take a year longer to execute. And instability's problems don't stop with immediate program performance. In the same study, defense contractors indicated that instability had caused the profitability of their programs to decline. They also indicated that the more unstable the program, the greater the proportion of suppliers of critical parts that might exit from the defense supplier base.[23]

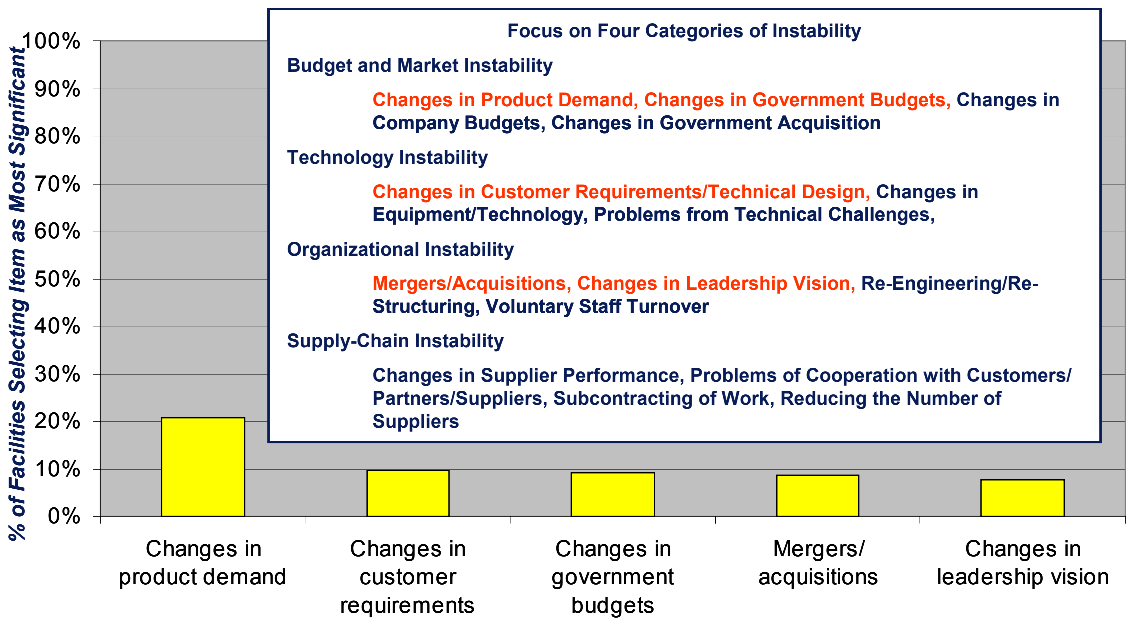
Additional, research on instability has identified four main types, which are 1) substantial shifts in market forces or program funding, 2) major organizational changes (mergers, restructuring, etc.), 3) the adaptation or introduction of technologies and 4) supply-chain instability.

---

[22] Eric Rebentisch, 'Preliminary Observations on Program Instability', Lean Aerospace Initiative White Paper #Lean 96-03 (October 1996). The study was based on more than 154 survey responses from US government program offices and more than 106 survey responses from defense contractors. The program managers identified the extent to which various factors introduced instability into their programs, and attributed cost and schedule deviations to budget changes, technology problems, requirements changes, or other sources. The programs reported that their instability came, on average, as much from changing requirements or technical problems as from budget cuts.
[23] Murman, et. al., op. cit., chapter 9.

Specifically, we define instability as “unplanned or unanticipated changes in the budget, technology, organizational structure, or the supply chain associated with a given program or facility.” Figure 2.2 based on data from the LARA facility survey (2000) indicates how aerospace facility managers responded when asked to identify the most important types of instability. The top five identified are changes in product demand, changes in customer requirements, changes in government budgets, mergers/acquisitions, and changes in leadership vision

Figure 2.2



In further analysis on these data, we compared those facilities experiencing high levels of instability in these top five categories with the rest of the facilities in the survey. Over 50% of the facilities experiencing instability reported a substantial loss of people with critical skills, while only 25% of the balance reported such loss. This suggests that instability makes it twice as likely to lose people with critical skills.

While the aggregate data point to substantial employment loss in aerospace in the coming years, the existing projections by the U. S. Department of Labor do point to a 33.4 percent increase in employment of aircraft and aircraft parts machinists by 2008. This is a projected increase of 9,240 positions in this category. It is the single largest projected change in the employment figures for machinists listed by the BLS**.** Figure 2.3 contains data on employment levels in 1998 as well as the BLS projected numbers in selected groups of aerospace occupations. The percentage of growth in each occupational group in Figure 2.3 indicates the relative number of people that need to be recruited and trained in each category by 2008. Another perspective from which to view this issue is raised by DOL projections of 40,000 job openings for aircraft mechanics, 7,000 openings for aircraft assemblers, and 13,000 job openings for aerospace engineers by the year 2008.[25] The numbers of workers needed in

---

[25] Monthly Labor Review, November 1999, pp 51-77, Table 2, projections for job openings revised in May 2000.

many of these categories takes on even greater significance when considered in the context of length of time needed to adequately prepare many occupational groups, the types of training most effective in each case, and the global industrial parameters that are shaping aerospace.

Note, however, that these projections are based on optimistic market assumptions that are no longer valid. If we follow BLS projections, we will want to invest substantial resources in workforce development. On the other hand, the analysis by Rob Scott would suggest that far more resources are needed on displaced worker programs. The instability in employment is itself a serious concern and things are further complicated given the way the instability also constrains our ability to construct useful workforce projections.

Figure 2.3

Aircraft and Spacecraft Design and Manufacturing			
	1998	Expected Growth to 2008	Expected Employment in 2008
Administrative Managers	10,000	43.00%	14300
Aerospace Engineers	25,000	11.80%	27950
Aircraft Assemblers	16,000	19.50%	19120
Aircraft Mechanics and Service Technicians	19,000	11.20%	21128
Blue Collar Supervisors	22,000	26.30%	27786
Computer Engineers	15,000	28.90%	19335
Electrical and Electronic Assemblers	11,000	23.80%	13618
Electrical and Electronic Engineers	10,000	41.70%	14170
Engineering and Science Technicians	29,000	23.40%	35786
General and Executive Managers	7,000	19.80%	8386
General Labor	10,000	20.60%	12060
Handworkers	33,000	23.60%	40788
Industrial Engineers	14,000	31.20%	18368
Inspectors and Testers	25,000	8.00%	27000
Machine Setters and Setup Operators	41,000	42.20%	58302
Machinists	29,000	32%	38280
Mechanical Engineers	15,000	27.40%	19110
Purchasing Agents	8,000	25%	10000
Systems Analysts	7,000	85.90%	13013

Airlines Transportation and Infrastructure			
	1998	Expected Growth to 2008	Expected Employment in 2008
Aircraft Mechanics and Service Technicians	87,000	14.70%	99789
Blue-collar Supervisors	28,000	23.90%	34692
Machinery Mechanics	11,000	14.10%	12551
Precision Production	9,000	12.80%	10152
Flight Attendants	98,000	30.00%	127400
Pilots	78,960	32%	104227
Flight Engineers (Second Officers)	8,000	Negative	???
Helpers, Laborers, Movers	171,000	21.90%	208449

Truckdrivers	155,000	23.80%	191890
Scheduling and Dispatching	52,000	14.70%	59644
Office Mangers and Supervisors	17,000	20.40%	20468
General and Executive Managers	10,000	20.20%	12020

According to the Bureau of Labor Statistics, "a larger proportion of workers in the aerospace industry have education beyond high school than the average for all industries."[26] Efforts to encourage or provide the higher than average levels of education needed for aerospace work are not adequate to meet the needs. Employers are increasingly becoming aware of this gap in training and education.

Excellent training facilities are available in this country to provide the specializations such as air traffic safety, aviation maintenance, or aerospace engineering and technical training. Despite the existence of an array of facilities, it is not clear if they all provide an appropriate level or range of training capability nor is it clear given current staffing projections such as projected shortages in highly trained specialties such as air traffic controllers or master machinists, whether these facilities are adequate to meet the needs.

2.4 Gaps in the training and development infrastructure

The Office of Apprenticeship Training, Employer and Labor Services (OATELS) Bureau of Apprenticeship and Training (BAT) reports that there were an estimated 279,393 apprentices registered in the U.S. at the end of FY'00.[27] There are no figures that identify how many if any of these apprentices were learning aerospace related skills and it appears that the data on apprenticeship cannot be easily validated because there is a loose consortium of states and territories that report the figures regularly. Labor and industry organizations support apprenticeship programs as reliable mechanisms for transferring knowledge across generations of the work force. In addition to the explicit knowledge learned through apprenticeship training, the process allows for a deeper understanding of the complexities of a skilled trade. Globally, apprenticeship programs are used extensively to ensure and to develop future workforce capability.

In the U.S. aerospace industry the leading labor organizations, the IAM and the UAW both support apprenticeship programs. The IAM website states:

> "The International Association of Machinists and Aerospace Workers is resolved to establish a uniform apprenticeship and training system. Training by the adoption of IAMAW apprenticeship standards is intended to protect the future of industries, the union and the apprentice and to propose a comprehensive apprenticeship system whereby future apprentices will be carefully selected and properly trained in all of the mechanical and theoretical aspects of the industry. . . .While emphasis on specific work processes may vary from local-to-local or area-to-area, the standards have been formulated so that apprenticeship activities within the jurisdictional area of this program can be carried out in an orderly and efficient manner throughout the United States and Canada."

[26] Bureau of Labor Statistics, 2001, U.S. Department of Labor Career Guide; http://stats.bls.gov/oco/cg/cgs006.htm

[27] Based on the National Apprenticeship System Programs and Apprentices Fiscal Year 2000 report and figures from the Apprenticeship Information Management System (AIMS) .

Apprenticeship programs in the U.S. have several forms; individual firms establish their own programs, firms sponsor training programs in conjunction with a community college or other institution, community coalitions or other types of consortia set up programs, unions set up programs to train members, or joint labor/management programs are established. The scope of these programs is usually quite narrow and specific, i.e. we are training aviation mechanics for the San Antonio area. Apprenticeship programs also seem to be more wide spread in Europe than in this country. Nonetheless apprenticeship programs are generally 4-5 year programs of in class work mixed with hands on training at a job site. They provide an opportunity for young workers to learn the skills of the job from older more experienced workers. Thus these young workers have access to explicit knowledge as well as the tacit knowledge of the senior worker.

While apprenticeship training is a well-established traditional form of on-the-job training, it also forms part of a contemporary skills sustainment and competency development system. Potentially innovative links are emerging. For example, one regional cluster of aerospace firms, the Connecticut Industry Cluster Program reports that although there is not "programmatic link" between the Industry Clusters Initiative and apprenticeship training, companies that are involved in one are becoming involved in the other.[28] These informal relationships may point the way to future, advantageous arrangements.

Among successful apprenticeship programs, the joint program at Rolls Royce in Indianapolis, Indiana stands out. Officials from United Auto Workers Local 933 work together with Rolls Royce management to create and sustain a vigorous training program that includes a state of the art $7 million training center. One of the key elements of this training initiative is an apprenticeship program that integrates four years of classroom and on-the-job training in fourteen skilled trades including electrician, pipe fitter, machine repair, heating and air conditioning, sheet metal, and millwrights.[29] Apprentices work with experienced journeymen within the facility, rotating through different work areas in six-month rotations. Upon completion of the training the apprentices receive certification from the Department of Labor and a journeyman's card from the UAW.

Participation levels in the program are linked to the workforce population in the facility. Apprentices are enrolled in the program to fill projected workforce vacancies caused by retirements or productivity changes. Currently there are 22 apprentices in the program although the largest single enrollment was 122 with 63 as a recent high. Jerry Thomas, Apprentice and Employee-In-Training Program Director, listed the following criteria for a successful program:

- It must be administered properly
- You must select good people
- You must have good qualified trainers
- You must have the appropriate classes.

Thomas went on to add, "The most important thing about any apprentice, however, is how well they get along with everyone in the shop. The program tries to teach people how to work together to solve a problem as quickly as possible."

[28] See the OLR research report for the Connecticut Industry Clusters Initiative by John Moran, January 2001.

[29] The four year program is 7328 hours of on-the-job training and 576 hours of classroom training required in math, science, and courses related to their trade. This works out to about 144 hours each year.

Bob Woodcock, UAW Local 933 Bargaining Chairman, explained that the apprenticeship program originated as part of the collective bargaining process. He described the roles of union and management in the training process by saying:

> "We often see training as a joint effort between the two of us but I think the union is more involved than maybe the company. We play a role and we have to be cooperative while management has to be more focused on output and work in progress. We have more people who study training and who are dedicated to it."

Training and the apprenticeship program are seen as competitive tools. Mike Gregory, the UAW Joint Training Representative, explained that training. . .

> "has become crucial in a global world. A few years ago aircraft component suppliers were limited to several major domestic suppliers, but that has changed. Today's suppliers are lean and cost conscious and could be located anyplace in the world. Training will play a bigger role to remain competitive. We're not ever going to be at a place where training is over. Advances in technology are the main reason training must continue. New processes, alternative materials, and increasingly sophisticated equipment require that skills be updated continuously. Training will only increase in the future."

At this facility training is helping to enable a future organizational vision with flexibility and problem solving at its core.

2.5 Imports, offsets, and other global dynamics

In some respects, this is a highly global industry. At the same time, the dominant mindset is often domestically focused. This is driven, in part, by the very real need by the defense sector to maintain U.S. capability and national security. In the commercial sector as well, international competitive challenges have come later than in other parts of the economy. As a result, discussions over imports, offsets and other global dynamics often represent a contested terrain. Concurrently, there are a growing array of international partnerships, joint ventures and interdependencies. Our aim in this part of the white paper is to summarize some of the data here to add a global context to the discussions.

Trade volume has grown rapidly in the U.S. aerospace industry (i.e., volume of exports and imports) over time. In the decade between 1989 and 1999, U.S. aerospace exports rose by $18 billion (in constant dollars), or 59 percent, while U.S. aerospace imports rose by $10 billion (in constant dollars), or 104 percent. The top five U.S. aerospace export markets since 1996 have included Japan, the United Kingdom, France, Germany, and Canada with Saudi Arabia (1997 and 1998) and Korea (1996) making appearances.[30] The top suppliers to the U.S. during this same period include Japan, the United Kingdom, France, Germany, and Canada. At the same time that trade values were rising, employment levels were declining. International sourcing has increased in subsectors of the industry including aircraft parts and equipment (including engines and engine parts). This reflects, as the presidential commission on international trade states, "a significant rise in international sourcing by U.S. and foreign firms. Between 1989 and 1999,

[30] U.S. Department of Commerce website, http://www.ita.doc.gov/td/aerospace/inform/Trade.htm, sources cited include Department of Commerce, Bureau of Census and ITA.

exports in this subsector rose by $6 billion (in constant dollars), or 39 percent; imports rose by $5 billion, or 80 percent."

On February 15, 2001 the Presidential commission on "offsets" in International Trade Issues issued a status report on the "extent and impact of offsets in both defense and commercial trade." The full report is due in Fall 2001 and will no doubt include recommendations that pertain to U.S. workers and their jobs. While it is clear as the report states "defense offsets supplant a significant amount of work/jobs that would go to U.S. firms if export sales occurred without offsets" and "facilitate exports," an equally critical issue from our perspective is the impact of the use of offsets on the skill and competencies of the U.S. aerospace workforce. At the heart of the offsets debate are core issues of competition and competitiveness. By offering offsets, companies make their products more competitive and increase their market share. Workers in other countries also increase their competitiveness and potential market share by learning through the technology transfers that offsets frequently represent. An important consideration not addressed here is whether the only loss in offsets is jobs or whether there is a long-term loss of skills and competencies.

The commission's status report describes 25,300 work-years or $2.3 billion in U.S. work that was supplanted over 1993-1998 by offsets with most of this "borne by suppliers to the U. S. exporters." The commission further figured that the percentage of aerospace jobs lost due to offsets amounted to "0.5 percent of total employment in the U.S. aerospace industry in 1999 and 1.2 percent of employment in the U.S. *defense* aerospace industry." This estimate of job loss only includes the loss of jobs resulting from direct offsets in defense trade, not job loss resulting from indirect offsets in defense trade or commercial offsets.

The commission report also estimated that "commercial exports among the eight firms (major defense firms surveyed) would fall by approximately $2 billion annually (translating to 22,000 work-years) if they decided unilaterally not to sign commercial offset agreements." This suggests that job losses would be greater if offsets were discontinued. Clearly more research must be done in this important area. The need for clarity is heightened by the fact that many countries have legal or regulatory policies mandating offsets on defense contracts.[31]

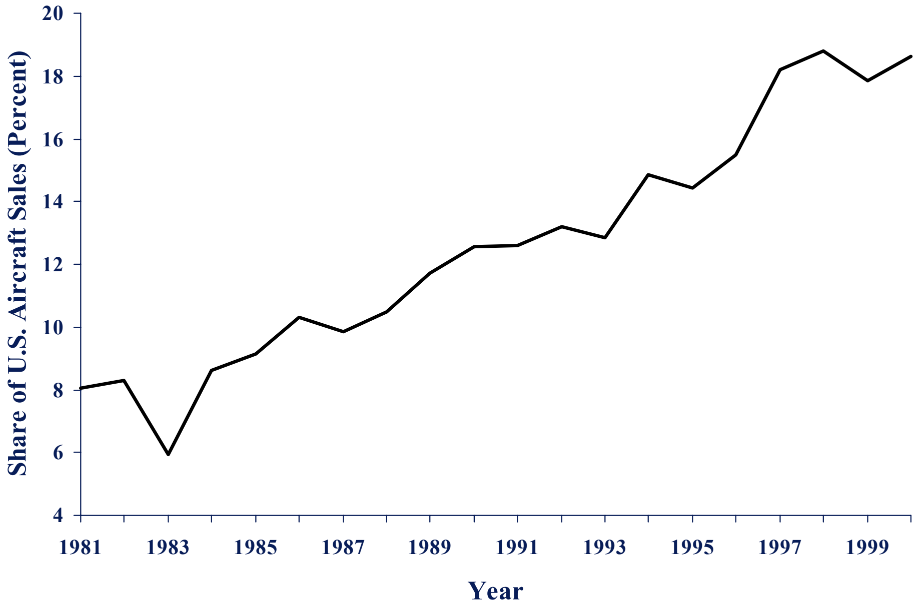
Industry observers including David Mowery from the University of California at Berkley have commented on these trends toward internationalization of the aerospace industry, noting, for example, that since the 1970s no large U.S. commercial air transport or engine has been developed without major participation by foreign firms in technology development, manufacturing, or marketing. Mowery comments that such international collaboration by U.S. firms may be essential to new aircraft and engine development, providing the firms with access to foreign technology, foreign markets, and foreign sources of capital to share in the huge costs and risks of new product development.

As an example, Boeing's success in developing the 767 and 777 commercial aircraft may be attributable, in significant part, to its success in forging risk-sharing relationships in development of the aircraft with a consortium of Japanese aerospace firms as well as with Irish, Italian, and Swedish firms. By contrast, McDonnell Douglas' failure to develop a more effective international collaboration strategy may have contributed to the firm's failure to expand its product line

[31] *Offsets in Defense Trade: Fourth Annual Report to Congress*, U.S. Department of Commerce, Bureau of Export Administration, October 1999, pp. 56-74. Countries identified in the report include Canada, Finland, Switzerland, and the United Kingdom

sufficiently to remain a viable competitor in the commercial aircraft industry.[32] It is, however, unclear what it will mean to U.S. aerospace capability or workforce competencies to foster collaborative global relationships, which could, in effect, result in outsourcing highly skilled as well as well paid jobs in the U.S. aerospace industry. Consider Figure 2.4, which tracks the importing of engine and other aircraft parts.

Figure 2.4
U.S. Engines and Parts Imports as a Share of Total Aircraft Sales, 1981-2000



2.6 Underlying assumption that responsibility lies at the level of the individual firm/facility

Underlying many of the above root cause factors is a key assumption, which is that it will be possible to attract, retain and fully engage a 21st Century aerospace workforce entirely through independent actions at the level of individual organizations and facilities. This assumption may never be explicitly stated, but it is built into actions by policy makers and leaders at all levels. In fact, this assumption is flawed in many respects. An atomistic labor market of individual employers and job seekers will contribute to stagnation and decline in the industry.

The actions required to revitalize interest and enthusiasm in aerospace will require a fundamental overhaul in the skill acquisition and certification process. It will require a substantial improvement in the quality of information on many key aspects of labor supply and demand. It will require careful attention to public and private policies the impact on employment – especially policies that drive instability. It will require a rethinking of the roles and responsibilities of professional associations and unions. It will require new appreciation and attention to the roles of research and development in shaping new frontiers for the industry. In short, it will require coordinated public and private action in a variety of ways to rebuild the type of social infrastructure needed for the 21st Century.

---

[32] "Offsets in Commercial and Military Aerospace: An Overview," David Mowery, in *Trends and Challenges in Aerospace Offsets*, op. cit., no.19, p. 85.

3.0 Selected Innovative Models and Linkages

This section of the report features case examples and other illustrations of new ways to address complex human capital challenges. These are not offered as best-practice “solutions” to be immediately replicated on a larger scale. Yet each offers a key insight in how to address some of the deep challenges facing the industry. They are offered to illustrate what is possible and how it was achieved. For example, most of the cases offered here involved the inclusion of multiple stakeholders, agreements that sustained that involvement, and non-traditional ways of interacting. Others are indicative of how to revitalize long-standing initiatives, such as apprenticeship programs. In each case, these involve individuals who are out in front exploring new frontiers and who are willing to share lessons learned.

3.1 School-to-work transition programs in selected communities

School to work programs provide important gateways for young people into work in many traditional industries. The young people can study the fundamentals needed for all jobs as well as gain real experience and insight into what the day-to-day reality of those jobs will be. The school-to-work movement is strong in the United States and there are many local programs that are helping companies to recruit new workers who understand the workplace much better. The Alamo Area Aerospace Academy is an important example of this type of program.

Alamo Area Aerospace Academy

Collaborative efforts are a possible solution to the costs of large-scale training programs. One example is the Alamo Area Aerospace Academy, which is a consortium of 8 business, 17 independent school districts, a junior college, and local governmental partners designed to meet the workforce skills and competency needs of companies in the San Antonio, Texas area.[33] This is a new initiative, opened in the fall of 2001.

The San Antonio area aerospace industry faces a problem comparable to the industry at large: “finding a sufficient flow of new high skill workers to support business expansion and replace the large flow of retirees expected from the current workforce over the next decade.”[34] The urgency about staffing shortages facilitated a cooperative effort among companies that normally compete with each other for personnel.

Lockheed Martin and Boeing are two of the biggest companies involved in the San Antonio efforts. Lockheed Martin holds a $2.6 billion contract with the Air Force to maintain, overhaul and repair jet engines and Boeing has just received a contract to overhaul the avionics of the C130 transport planes[35]. With this level of activity, the companies estimate that they “will need to fill at least 700 new maintenance positions each year to meet demand.”[36] This need for highly skilled workers dovetails with the community’s desire to maintain employment levels in

---

Collective bargaining agreement between the Boeing Company and the International Association of Machinists. Article 20.2(c), 1999.

[35] As per telephone interview with Doug Monroe, assistant to the academy’s director, Charles Johnson, on October 19, 2001.
[36] Aldridge, James, 2000, Effort under way to launch aerospace group, San Antonio Business Journal, May12, 2000.

San Antonio when the Air Force Base is privatized. The city established the Greater Kelly Development Authority that was charged with converting Kelly to a private sector operation.

One part of this effort is the Alamo Area Aerospace Academy that was established to train high school students for aerospace jobs. The high school juniors and seniors in the academy will receive traditional basic courses in English, math and history in the morning at their own high schools and then transfer to one of two technical campuses for training in airframe and power plant mechanics. Richard Butler, CEO of the Academy and economics professor at Trinity University says[37] "The academy offers a taste of higher education to high school students. We hope that some will learn about the mechanics of airplanes and want to design them. They can go on to a four-year college like Trinity and earn an engineering degree." Upon successful completion of their high school studies the students will also have earned 30 semester college credits. These credits are applied toward associate degrees and are transferable to four-year institutions such as Embry-Riddle Aeronautical University.

The first class for this new endeavor was held on August 27, 2001. The school has a capacity of 160 students with 116 enrolled the first year. Current plans are to enroll 80 students each year to replace those who graduate. Aerospace companies in the area will hire the graduates starting at $10.00 an hour with increases to $13-$15 an hour after 90 days. The academy hopes to expand its offerings to meet the needs of the employers. This means the addition of avionics and CNC training as soon as it can be arranged. The curriculum includes basic electricity, turbine engine theory, introductory courses, FAA regulatory courses as well as other topics.

Although getting a program with this many stakeholders off the ground was difficult, the initial problems with coordination among school districts, transportation and funding have been overcome. Funding for the program comes from a variety of sources such as the city of San Antonio, the state workforce commission, and grants from aviation foundations.

3.2 Lean/high performance workplace transformation initiatives in selected locations

The many lean and high performance workplace initiatives have been well documented elsewhere.[38] It is important to highlight here the many ways that such initiatives represent a fundamentally different view of human capital. There is always a tension around the degree to which people are seek as a cost of operations or as the driver creating value. As these new work systems engage people in the processes of continuous improvement, the calculus becomes more clearly one of creating value. In this regard, issues of training and development can't be separated from the work system context in which they operate.

This interconnection was highlighted in the initial problem statement and in some of the root causes discussion. The connections are also evident in many of the examples included in this section of the report. We must note, however, that many lean and other workplace change initiatives are still narrowly focused on eliminating waste. In this regard, they do not fully place value on human capital. In contrast, where the definition of lean is broader – to emphasize eliminating waste in order to create value – then the linkage is clear and strong. Indeed, lean thinking has even begin to shape approaches to classic human resource issues, such as the

[37] Quotes drawn from Trinity University Public Relations Department Tip Sheet issued by the Office of Public Relations and last updated on March 8, 2001.
[38] Murman, et. al., op. cit.

establishment of "just-in-time" training or the use of process flow analysis on training delivery and other work force systems.

The challenge of fully realizing the potential gains from such initiatives is evident, for example, at Boeing's Wichita operations. Here there is a strong HPWO (High Performance Work Organization) initiative involving a partnership agreement between Boeing and the IAM. At the same time there is a separate "lean" initiative focused on continuous improvement. As well, there is a pilot Activity Based Cost (ABC) initiative. Ideally, the union-management partnership would provide an appropriate joint governance framework for the appropriate application of lean practices and principles. Further, the ABC initiative would effectively track and value time spent in training and other developmental activities. In fact, as is documented in a recent case study,[39] the challenge of coordinating and integrating these initiatives is substantial.

Another highly instructive case involves the way lean practices and principles utilized in Textron's Wilmington, MA, manufacturing operations have come to influence supply chain management. When leaders in this organization applied these principles to their supplier relations, the quickly saw the need for long-term contracts, open sharing of information, and sharing of gains from improvement efforts. In a case study of this initiative,[40] we found that the long-term agreement represented an important form of stability for both the Textron and the supplier organizations that would not have happened in the absence of the lean improvement efforts.

From these sample cases we get a glimpse of the potential importance that initiatives such as lean, HPWO, ABC, Six Sigma, and others have for any discussion of human capital – but also the sustained effort required to realize this sort of value.

3.3 Joint training partnerships among major employers and unions

Increasingly labor organizations and enterprise management teams are finding common ground around the human capital and knowledge management issues that develop in today's industrial environments. Highly effective programs such as the Quality Through Training Program (QTTP) described below have learned to gather critical input from their customers in the workplace to shape future initiatives and curricula. The results of these collaborations include cost cutting, competitive competencies and heightened appreciation for the value of what? and gained from the ability to work effectively together.

Language first inserted in the 1989 collective bargaining agreement between the International Association of Machinists and Aerospace Workers (IAM) and the Boeing Corporation created a joint training program aimed at giving life to what was then its rather ineffective "technology" committee language in Article 20 of the collective bargaining agreement.[41] While the language in the old article called for the company and union to work together to introduce new technology and involve the workforce, in reality not much of this was being done. The joint program that evolved out of this sense of frustration illustrates the potential of this type of joint effort for bringing life long learning to hourly workers in a world of continuous technological and organizational change.

---

[39] "Three Into One," MIT Labor Aerospace Research Agenda case study by Thomas Kochan, 2001.
[40] Textron Case, MIT Labor Aerospace Research Agenda by Joel Cutcher-Gershenfeld, 2001.
[41] The following description was adapted from a case study written by Thomas Kochan for the Labor Aerospace Research Agenda Project at MIT in 2001.

The IAM/Boeing Joint Programs are financed by a fund that receives 14 cents per payroll hour for all bargaining unit employees[42]. In 1992, the company and union agreed to ensure a $14 million minimum annual budget in the event that the payroll hour formula falls below this threshold. Additional funds beyond these levels are provided to cover the costs of the employee tuition assistance plan. Funds not spent in a calendar year are carried over to the next year. In 1999, the budget for the Joint Programs was approximately $25 million. “This is a high level of funding but the importance and credibility of the training program is highlighted even more with the news that even in the current period of downturn, the company has allocated an additional $1.25 million based on the program’s proven value.” Gary Jackson, QTTP IAM Co-Director from District 751explained that each shop floor area has it’s own performance metrics that reflect the added value of the training programs. Floor managers now come and ask for help because of the levels of performance improvement in other areas.

Facilities in three states, Washington, Oregon and Kansas, currently have QTTP initiatives underway. They are governed by a board consisting of international and district level union representatives, and company line and employee and union relations executives. The company and union each appoint a co-director who oversees a full time staff. The staff is responsible for “developing, recommending and implementing training programs.”[43] They use internal and external resources for curricular development and instruction. A critical aspect of this program is its linkage to the shop floor through the input and participation of shop floor managers and hourly workers in the development and implementation of training. Training topics and needs are determined by the recommendations from the shop floor.

Among the Joint Programs’ initiatives are two of primary interest to this report;

1. <u>Layoff and Redeployment Assistance</u>. The first several years of the program were focused on providing training opportunities for laidoff Boeing employees. This reflected the most pressing issue of the early 1990s as cuts in defense spending and the effects of the 1991-92 recession reduced demand for Boeing’s military and commercial products and produced significant layoffs. Laid off employees are entitled to up to $2,500 a year educational assistance.[44] Employees eligible for government training funds under the Trade Adjustment Act (where the layoff was determined to be caused by foreign competition) must exhaust these public funds before drawing on their Boeing benefits. From time to time, the company and union have also obtained supplemental training funds from other government programs

2. <u>Career and Personal Development</u>. The Career and Personal Development services offered under the program are perhaps the most sophisticated of any such program in the country. Active employees can receive payment of the full cost of tuition and books for courses and or classes that are regionally or nationally accredited as well as up to $2,000 ($2,500 for laid off workers) tuition assistance for non-accredited courses. Allowing employees to choose what to study represented a shift from an earlier company tuition assistance program that required two levels of management to certify that a

---

[42] The original agreement provided for two separate activities, a Quality Through Training Program and a Health and Safety Institute.

[43] Language from 1999 collective bargaining agreement between the Boeing Company and the International Association of Machinists. Article 20.2(c)

[44] Current economic conditions and large numbers of laid off workers forced the reduction of this sum from $4,000 each year per worker (as per interview with Gary Jackson on October 19, 2001).

proposed course was job relevant. Under that program, payment was made only after providing evidence the course was completed successfully. Only 300 hourly employees participated in that program in the three years prior to the beginning of the current program.

From 1996 through 2000, over 23,000 individuals have participated in the educational assistance program, receiving course vouchers for approximately 35,500 courses. There was some fear (and some criticism) that allowing people to take any course of their choosing would lead many employees to use the funds to pursue personal hobbies or other courses of dubious career relevance. This has not been the experience to date. Computer classes consistently rank as the top course selection, with courses on hobbies ranking at or near the bottom of list of courses taken.

One of the most innovative career services offered by the joint program is its career advising and planning initiative. By integrating a thorough analysis of the qualifications of the jobs open to hourly workers with personal counseling aided by an simple but flexible computer-based training, certification, and application system, the program has built a state-of-the-art individual career assessment and planning tool. Program staff, many of whom are union members, conducts on-site assessments and employee interviews to identify the knowledge, skills, and abilities required to qualify for different bargaining unit jobs. This information is then translated into a list of courses or skills certifications employees must have to apply for each position. These data are then placed on the program's website. Interested employees can scan the website for these jobs and see the list of courses and/or certifications that are needed to apply for different positions. Then, employees can sit down with a job counselor and use the web based information and software to create an individual training plan that shows the requirements they have met and those courses or "challenge" exams they need to complete before being eligible to file an Employee Request for Transfer (ERT) for a given position. The system also can tell employees how many others have applied for a given position, thus allowing an assessment of one's chances of bidding successfully for the jobs available. As of November 6, 2001, guides for 832 different bargaining unit jobs have been completed (with the balance to be completed in 2002). The plan is to have all bargaining unit jobs analyzed and on line within the next year. When completed, these guides should provide an extremely useful tool for creating an individual career plan for individual employees.

The joint training programs have a number of attractive design features for promoting and extending life long learning opportunities to the hourly workforce. A steady stream of funds are provided via the hourly payroll formula and the parties have seen fit to establish a minimum budget to assure that adequate funding is available if work hours fall below a certain threshold. The program is jointly governed and staffed and thereby provides shared ownership and buy-in from management, the union, and the workforce. This helps it to avoid being held hostage to the ups and downs of normal labor relations—union elections, bargaining rounds, management and/or union leadership turnover, etc. It is flexible and can be demand driven, as illustrated by the ASL and Personal Enrichment classes. It can take on specific high priority concerns such as health and safety training, HPWO training, and if the parties choose to use it for this purpose, lean production training. It can support career development and life-long learning for both current employees and those on lay off.

Several challenges face this program despite its high level of creative and excellent programming. Its full potential will be realized only when line managers and shop stewards in different areas of Boeing's vast operations see it as a natural resource to be used to assist in whatever set of organizational and/or technological changes they anticipate or experience.

Moving to this next level of development is one of the challenges and opportunities facing this innovative union-management learning and change initiative. Despite the superb program supported by Boeing and the IAM, it can still be held hostage to industry instability cycles and the rapid advances in technology.

3.4 Industry-level forecasting and training in Canada

Including multiple stakeholders in any effort is a demanding challenge. The outcome of such efforts can have long term rewards. As the U.S. aerospace industry searches for new ways to increase its success, one model may be a broad consortium of the parties who have a stake in the health of the industry. The diversity of inputs and the early recognition of potential roadblocks are among the benefits from an industry wide national effort.

The Canadian Aviation Maintenance Council (CAMC) was established in 1991 in response to a critical shortage of skilled personnel in the aviation maintenance industry. Four primary goals were set for the Council; "defining occupational standards for the industry; establishing training programs and core curricula, recruiting new entrants to the industry; and developing ongoing mechanisms for industry-wide resource planning.[45]" CAMC is organized as a non-profit consortium led by a staff and a Board of Directors with input from the industry. The Board of Directors is comprised of an equal number of employer and employee organizations, each with one representative on the board. The member organizations are: The Air Transport Association of Canada, the Aerospace Industry Association of Canada, the Canadian Business Aircraft Association, the International Association of Machinists and Aerospace Workers, the Canadian Federation of AME Associations, the Department of National Defense/Air Command and the National Training Association.

The organization members each represent a vital group of stakeholders in the aerospace industry. Together they have created a system that works to assure an adequate supply of skilled aviation mechanics across all segments of the Canadian industry. The Canadian system includes a tracking system that allows employers to evaluate mechanics' experience levels at the time they are hired. Each mechanic has a logbook that is filled out to reflect the types of work the mechanic has done or the competencies they have acquired in their work. CAMC also has worked to create standardized base skills through curricular and licensing consistency. These regulations apply to all aviation mechanics in Canada whether they are unionized or not.

The council provides a forum for all stakeholders in the industry to meet and discuss issues of common interest. It was formed because there was no successful forum in which complex issues could be discussed. In addition as the projected staffing shortages were identified, it became clear that standards for curricula and certification would make it possible for employers to hire workers with greater certainty that they possessed needed skills. The joint operation of CAMC was successful where a unilateral attempt by Transport Canada to accomplish many of these same activities was never able to provide the same levels of service to the industry.

CAMC is currently sponsoring the third human resources study for its membership. The study (to be completed by December 2001) is focused on "forecasting human resource (HR)

---

[45] Information drawn from the Canadian Aviation Maintenance Council website at http://www.camc.ca/new/faq.html as well as through interviews with Carlos DaCosta, Board Member from the International Association of Machinists.

requirements" for aviation sectors for the next five, ten, and fifteen years. As with previous studies, this report will preview the current state of the industry, outline the specific occupational tasks and technologies reviewed, preview technology trends, review employment practices, training and skills bases, occupational demographics, recruitment, and make future recommendations. The report provides a comprehensive resource for all stakeholders. Such a knowledge resource does not appear to exist or have been undertaken on a national level in the United States.

3.5 Linking R&D funding to workforce attraction and intellectual capital development

If we examine recent government trends in R & D funding (basic and applied), it is a relatively favorable picture. Government funding for advanced technology development (what is termed 6.3 funding) has been in decline since the end of the Cold War. At the same time, however, funding for basic research (6.1 funding) and applied research (6.2 funding) has increased in the areas that are directly related to air and space technology.

On the one hand, this situation contradicts critics who claim that R & D funding is in such a state of decline that only a massive infusion of funds will solve the problem. On the other hand, however, the administration of R & D investment has largely been done in ways that are separate from any systematic attention to what might be called knowledge management or human capital investment. Stated more bluntly, it is not fully clear what skills and capabilities are being established through the R & D investments and how future R & D activity can draw on past investments.

To some extent the Defense Advanced Research Projects Agency (DARPA) does facilitate links from R & D investment in new technologies with industry applications. People involved in R & D may be brought forward to be involved in commercialization efforts, but this depends too often on individual initiative.

3.6 A Case Example of Integrated Learning and Development

A recent trip to Rockwell Collins in Cedar Rapids Iowa revealed a company finding solutions to the human capital issues facing the aerospace industry today. The presentations and discussion spanned corporate and facility-level plans to manage the strategic knowledge bases needed to ensure competitiveness. In addition to corporate campus facilities, we visited two manufacturing plants facing very different but familiar problems. The Cedar Rapids plant produces commercial parts and is facing very severe layoffs. The Coralville plant builds defense products and faces few, if any lay-offs. Together, these two facilities represent a microcosm of the entire U.S. aerospace industry. Yet in each of these distinctive situations, the facilities are grappling with human capital and learning issues. Tracking existing competencies as well as future skills needs has become critical for all job classifications - hourly and salaried - to maintain the skills base and plan for succession/continuity.

At the Corporate Level: The corporate learning and development staff in Cedar Rapids, led by Cliff Purington, described an innovative and exciting plan to increase learning and reduce costs while shifting a corporate learning culture from the classroom to the individual desktop or work station. Technology and global organizational dispersion drive training outside the classroom and require overhauling attitudes among all those involved in the process.

The corporate plan has three components:

- a computer-based training system that allows Rockwell Collins employees around the world to have 24x7 access to training and information,
- skills assessment software that allows salaried employees to track the skills within their department and the organization, diagnose their own individual training needs, and eventually allow 360 degree performance evaluations,
- a series of CD-based lessons called Quick Learns that are video segments taught by actual hourly employees of how they perform elements of their work.

Although the entire program is not yet complete, Purington reports that his department can already report major successes. Almost 90% of the training curriculum is online so that employees anywhere in the company can access it at anytime. The workforce is not dependent on travel for training and is not constrained by a static classroom training regimen, but rather they can access training materials at their own pace and as needed. To date the reported results of this new program are dramatic and encouraging, learning has continued and training costs have been reduced by 40%.

In the current downturn, the company and its employees benefit from this new system because learning can continue as employees access the system to develop new skills necessary to daily operations. The company can continue to offer training and development opportunities despite the restrictions imposed by cost reduction pressure. A skills base is being preserved despite the retirement or departure of employees.

Corporate executive succession planning is underway with a "goal to identify, assess and develop a diverse leadership talent pool."[46] The company is concerned about maintaining an adequate knowledge and expertise base among its white-collar ranks. The plan is aimed at identifying people who can fill management jobs quickly as well as nurturing employees who have the potential to fill other higher level positions during their careers. A mentoring program has been set up to help employees gain professional skills and insight.

Rod Mickelson, Director of Advanced Technology Engineering, described the recruitment and training of engineers in Cedar Rapids. He said that young engineers were attracted to the technical challenges offered by Rockwell Collins. He did admit that younger engineers were often attracted to companies located on the coasts rather than in the Midwest, but as people began to raise families they were more easily attracted to work and life in Iowa. He sees teamwork as crucial for his work in R&D and is trying to foster this among his engineers.

Efforts are also underway to support the development of "communities of practice" among engineers to allow innovation to flourish while also building a greater shared base of knowledge. This shared knowledge is vital to maintaining the level of essential competencies needed to operate in an environment where layoffs will mean the loss of skilled employees.

Plant Level Activities: At the main plant in Cedar Rapids, the Resource Room Team met with us in the training area that they have organized and staffed since 1994. Members of the workforce are encouraged to utilize the resource room to improve their computer and technical skills. Team members described how they provide essential skills training for work as well as for completion of the company's computer-based training. The resource room is located on the

---

[46] From internal company documents provided by Kevin Weiss, Director of Human Resources for Rockwell Collins, October, 2001.

upper deck overlooking the workroom floor. This team sets its goals based on meeting customer needs and expectations for the services they provide. The team also creates training materials and reference guides. The results of this training effort were especially visible when the company implemented SAP (a popular Enterprise Resource Planning software) as employees were able to respond quickly and efficiently to this new computer-based system.

Learning and development activities are underway throughout Rockwell Collins. The Joint Training Team has established a continuing education program for test technicians. Contractual language mandates that test techs must have six hours of training each year to maintain wage upgrades. The committee assesses training needs on a yearly basis and helps to find in-house or alternative training resources - including local community colleges. The training may be web-based or traditional classroom training.

In Coralville, the plant is busy shifting to a lean work environment. Whole areas of the plant are being redesigned to streamline flow, reduce cycle time, and facilitate more cellular manufacturing. Cross-functional teams of employees who are analyzing and mapping the flow of their work areas are completing much of this redesign work. As this work progresses they are reducing waste through improving process efficiency and space utilization. The results here have also been dramatic. For example, in the last five months the time required to complete one portable GPS unit has been reduced from 5.5 hours to 1.9 hours. Productivity has also more than doubled in the same time period. The workforce is very involved with the introduction of lean manufacturing and is conscious of the need to be competitive.

Leadership Concerns: Labor and management leaders at both plants have built relationships based on mutual respect, shared information, and concern for the success of the business. There is a remarkable level of shared responsibility among the union and management for the growth of the business as well as for the workforce. Moreover, it is also clear that each group has separate organizational and legal responsibilities that they exercise fully. The union clearly defined its role of representing its members and fulfilling a collective bargaining obligation while management stressed the need to run the operations.

Comments by Managers Wayne Flory (Senior Director of Manufacturing Operations in Cedar Rapids) and Mark Correll (Director of Coralville Operations) reflected how the current state of events at their respective facilities influenced their concerns about human capital and knowledge management. Flory first expressed concern for his employees and then described the frightening impact of layoffs on the skills base of the facility. He described the costs associated with the "bumping" – the process of more senior employees knocking less senior employees out of jobs as layoffs occur - as outlined in the collective bargaining agreement and its impact on productivity. Correll's concerns were focused on maintaining skills levels to keep up with changing technology and capturing critical skill sets. He expressed the belief that "you've always got to learn" and endorsed joint efforts to analyze needs and support training.

Rosie Behel, the IBEW Business Agent for Local 1362 worked hard to create support for laid-off workers. He hoped to minimize the loss of workers who did not return when economic conditions improved. After the last round of layoffs only about 30% of those laid-off returned when recalled. This is an important concern because technology advances so fast that training and learning are continual. When trained workers are lost, it may cause the company to be less competitive. He believes that it is critically important to share business information and concerns with the bargaining unit. In fact information has to flow both ways. Behel explained, "If you share the information and tell them (the Bargaining Unit) the problems, these people will go off and solve the problems."

Brian Heins, Vice President of IBEW Local 1634 in Coralville described a sense of mutual responsibility that characterizes the plant environment at this time. He described union and management leadership who realize that they have separate, important interests but who also share critical common interests in the success of the business.

3.7 Construction industry educational partnership

Industries in this country are finding an increasing number of benefits to joining forces to develop goals and strategies for future growth. A skilled work force is one of the critical needs that drives these activities. Employers benefit from a consistent skill base and a dependable level of performance while the workforce enjoys greater opportunities for employment. The customer is among the biggest beneficiaries since the final products derived from cooperative excellence are outstanding.

“The New America requires that many things be re-thought,” is how Dr. Daniel Kruger introduces the educational initiatives he is developing with the organizations representing the construction trades and contractors.[47] The United Association of Journeymen and Apprentices of the Plumbing and Pipe Fitting Industry of the United States and Canada or "UA" as it is commonly known is a multi-craft union whose members are engaged in the fabrication, installation and servicing of piping systems.[48] Founded in 1889, the United Association is one of the most respected and influential building trades unions in the U.S. and Canada today. It serves as a collective voice for workers through negotiation and collective bargaining with employing contractor groups, such as the Mechanical Contractors of America Association and National Association of Plumbers and Heating and Cooling Contractors.

Jointly these organizations have agreed through collective bargaining to fund the development of an extensive educational effort that trains apprentices and instructors for those apprentices. At this time there are five regional training centers in operation or under construction in Michigan, South Carolina, California, Mississippi, and New York. These centers are responsible for training instructors as well as giving indentured apprentices and journeypersons of the United Association of Plumbers and Pipefitters the opportunity to apply their work in a trade specialty toward an associate's degree in Construction Supervision or Industrial Training.[49] According to Dr. Kruger, the United Association spent approximately $140 million for training in 2000 and currently has 35,000 apprentices in presently in training.

Training the trainers or educating the instructors who will teach in local union training programs is just as important to the UA's training efforts as is the apprentice and journeyman training that they will do. UA instructors must be kept abreast of any technological changes, such as the newest methods and latest equipment, as well as any codes and regulations that will affect what they teach UA members in their home locals. Participants attend the program for 40 hours each year for five years, completing a total of 200 hours of instruction. Of this, 100 hours consist of

---

[47] Notes from telephone interview with Daniel Kruger on October 31, 2001 by Betty Barrett, LARA Project Research Manager.

[48] Information taken from United Association web page at http://www.ua.org/ on October 31, 2001. There are approximately 291,000 highly-skilled United Association members who belong to 418 individual local unions across North America.

[49] Additional information on courses and requirements can be found at http://www.uarts.org/ or at the Washtenaw Community College website.

professional, "how-to-teach" courses and 100 hours are applied in knowledge courses. This program dates back to 1954.[50] According to Kruger "The apprenticeship training program is a unique cooperative initiative involving the UA, the Washtenaw Community College in Ann Arbor Michigan and the School of Labor and Industrial Relations of Michigan State University."

Due to their extensive training efforts and the constant introduction of new programs the UA leads the industry in supplying a well-trained workforce for the 21st century construction industry. The training efforts involve approximately 100,000 journeymen and apprentices in over 400 local training facilities at any given time. In addition to five-year apprenticeship programs, the United Association offers continuing education opportunities that include journeyman training and certifications in fields such as valve repair, welding, backflow prevention, medical gas installation, and the safe removal of refrigerants. These programs are offered in cooperation with a select number of universities, which will grant college credit as part of the apprenticeship program. Importantly the training programs of the UA as with many other building trades groups are financed through collective bargaining rather than tax dollars.

3.8 Core challenge: Moving beyond "islands of success"

The above examples are just a sampling of initiatives and activities that illustrate new ways of approaching the human capital challenges facing the aerospace industry. None of the examples could be applied on a universal basis, but many have features that could be more broadly diffused. In depth analysis of the strengths and weaknesses of these initiatives could offer fundamental factors upon which to base future actions. It is important to distill the elements that provide roadmaps for others to follow. However, absent coordinated action, these and many other success stories are at risk of being "islands of success."

---

[50] The 47th Annual UA Instructor Training Program held August 12-18, 2000, had 1697 instructors attending 266 sections of 91 unique course subjects, a participation which represented over 264 local unions across the United States and Canada and included a record 384 individuals who were attending for the first time. This group of 1697 "instructor students" were taught by 215 instructors from the United Association, industry, government, and various institutions of higher learning, including Michigan State University, Eastern Michigan University, Washtenaw Community College. In 2000, 169 graduates completed the five-year program, making a total of 4,181 graduates in the program's history. These program graduates receive a certificate entitled "Certified Instructor of Journeymen and Apprentices of the Plumbing and Pipe Fitting Industry" and leave well-prepared to train new UA apprentices and journeyman back in their home local unions. Over 43,000 individuals have participated in this unique program during its history.

4.0 Recommendations and Conclusions

In developing recommendations, we have sought to balance the importance of getting to root causes in ways that will have a significant impact and the importance of actions that are realistic and feasible. Toward that end, we highlight five programmatic recommendations and a sixth category that deals with the overall approach to research and development. These recommendations are as follows:

- 4.1 Public Policy Priority Protecting Investment in Intellectual Capital
- 4.2 Aerospace Capability Network
- 4.3 National Training and Development Partnership
- 4.4 Regional and Local Workforce Initiatives
- 4.5 Innovation by Government as an Employer
- 4.6 R&D Investment Driving Demand for the 21st Century Workforce

In each case, we have identified key stakeholders and relevant considerations in implementing such recommendations. Ultimately, each would have to be shaped through further stakeholder dialogue and input.

4.1 Public Policy Priority Protecting Investment in Intellectual Capital

It is critical to establish mechanisms to mitigate instability and other threats to investment in "intellectual capital." For example, the funding for the F-22 has been shifted in significant ways over 70 times, with directly related delays of approximately 7-10 years and countless implications for individual careers and workforce investment. This same dynamic can be found across many military programs. Similar instability exists in the private sector due to mergers, acquisitions, corporate restructuring, market shifts and other dynamics. What is to be done?

First, support should be given to current experiments around multi-year development contracts, such as the pilot initiative involving what is termed the "small diameter bomb." This involves a fundamental shift in mindset for Congress, the military acquisition community and industry – to make commitments that will hold over years beyond a given budgetary cycle.

Second, a related and longer-term dimension of this issue involves greater consideration of life-cycle costs in the military procurement process. Among these life cycle costs are the various stages of hiring, retention and displacement of the workforce – costs that can be particularly significant when it comes to field sustainment for aerospace products.

Third, there is substantial churning of assignments on military and commercial sides, which requires constant establishment and re-establishment of critical relationships and knowledge. This churning is driven both by the desire to provide career advancement opportunities and the concern over relationships that are "too cozy." In fact, the advantages of close-long term leadership partnerships may outweigh the risks. As well, knowledge management methods can be developed to ensure a level of continuity of information even with leadership and staff turnover. This requires building into the procurement process, funding for the development of the knowledge management infrastructure needed to provide continuity – as well as the training and other social support systems to ensure a full return on the investment.

Finally, we introduce the concept of an "Intellectual Capital Impact Statement" being required to accompany major shifts in program funding. This might be analogous to the requirement for an environmental impact statement at the outset of a new initiative, though our focus here is at critical junctures where investment has been made and could be at risk. Methods can be developed to assess these risks and help ensure that they are considered in advance of shifts in funding. The same set of methods may be of use for the private sector as well.

Among the key stakeholders who would need to help shape such policy changes, would be the following:

- Congressional Representatives
- DoD Acquisition
- US Department of Labor
- Prime Contractors
- Sub-Contractors
- Union Leaders
- AIAA, AIA, and other Professional Associations
- Subject Matter Experts

This is a domain where a highly collaborative approach would be required – a trend that is increasing in the development and rule-making phases of many types of public policy changes.

4.2 Aerospace Capability Network

In contrast to some recommendations that may come before the commission involving relatively incremental changes or adjustments, this recommendation requires establishing a new kind of capability in this industry. We recommend developing a public/private partnership network organization in which all key stakeholders in the aerospace industry coordinate the establishment and dynamic evolution of a full set of relevant skill standards, future capability requirements, and relevant workforce data.

Simply put, this information is not presently available and is urgently needed for strategic planning at every level. In fact, people struggle in the absence of such information – they try to anticipate future needs and requirements, but are left doing this on a piece-meal basis. Often, instead of trying to sort these issues out, organizations will layoff one group of employees and then try to find others with new skills in the labor market. Not only does this involve substantial transaction costs – including significant human suffering, but it also fails to capture the value of the institutional knowledge that is lost. At a time when the workforce was, in effect, recycled among other aerospace companies the loss was not as severe as it is now, when much of the knowledge may be lost to the industry as a whole.

It is always hard to see the need for what does not yet exist. It is even harder to create the institutional momentum to create such an entity. Yet that is precisely what is required.

Among the key stakeholders who would need to help shape such an organization, would be the following:

- Congressional Representatives
- DoD Representatives
- US Department of Labor
- Prime Contractors
- Sub-Contractors

- Union Leaders
- AIAA, AIA, and other Professional Associations
- Subject Matter Experts

There are a variety of practical agreements that would be required, including:

- Organizational structure
- Mission statement
- Funding mechanisms
- Roles and responsibilities
- Staffing process
- Governance structure
- Data integrity and confidentiality policies
- Other aspects of a public/private initiative

4.3 National Training and Development Partnership

A similar form of institution building would be the establishment of a National Training and Development Partnership. Here the focus would be on establishing a multi-stakeholder, public/private partnership supporting strategic investment in skills and capabilities that are central to industry success and that would not otherwise receive adequate investment. Especially important would be investment in building capability across organizations along what can be termed “mission critical” value streams.

Funding for such an organization could be modeled on the Boeing/IAM agreement in which 14 cents for each hour worked enters a training fund that is then subject to joint governance. It represents a willingness by the workforce to forgo a certain amount of individual compensation and a willingness by the company to channel training investment in this way. Experience has shown that such systems (with have also been utilized in the auto industry) help to shield training dollars from cyclical cost cutting pressures. Also, the quality of the programs and the commitment to their success increases with the additional stakeholder involvement.

Expanding the concept beyond individual firms and including non-represented parts of the workforce raises some complex structural issues – though these have been effectively addressed by many community and regional labor-management committees.

4.4 Regional and Local Workforce Initiatives

Demonstration grants could play a key role in providing targeted support for pilot local and regional innovations that effectively attract, retain and cross-utilize the aerospace workforce, as well as initiatives that represent “best practices” with new work systems to be documented for broader replication. Examples of initiatives that might be of interest could include portable pension plans and health benefits, worker “loan” programs, shared training initiatives,

Support should also be targeted at piloting mechanisms for regional and national diffusion of successful innovations. This can include enabling cross-site benchmarking, establishment of a “best practices” database, and establishing “community of practice” groups among folks leading implementation efforts.

All of these activities could be supported with matching funds from local foundations, governments and industry – with implications for national policy where appropriate.

4.5 Innovation by Government as an Employer

Establishing mechanisms to develop and diffuse innovations in strategic human resource management at government aerospace labs, depots and bases. This is particularly important in the aerospace sector where major classes of employees are hired into the private sector after a period of time building skills and capabilities in the public sector.

Among the key stakeholders would be the following:

“Enterprise” and Facility Leaders Across a Range of Government Operations
Federal Personnel and Human Resources Professionals
Federal Union Representatives
Leadership in the Federal Scientists and Engineering Community

4.6 R&D Investment Driving Demand for the 21st Century Workforce

Increased investment in research and development has to be driven by a “pull” from the “war fighter” so that it is more than a “make-work” program.

R & D is a way of building a strong human capital base. This will not just happen by a simple increase in R & D spending. It requires strategic analysis and investment, which depends on strong input from key stakeholders in this process including:

- Department of Defense
    - War fighter
    - Scientist and technology community
    - Acquisition community
- Industry
    - Prime contractors
    - Sub-contractors
- Universities
- Professional associations, unions and other representative organizations

What is at stake here is a fundamental shift in how we view R & D spending. It must be simultaneously focused on immediate, practical needs and on long-term strategic areas of needed capability. It is a bridge from targeted DARPA investment into deeper building of science and engineering capability.

4.7 Implementation of Recommendations

People in the field are being forced by circumstances to step out of their traditional roles in order to tackle new challenges in new ways. For this commission there is a parallel implication. It must ensure that the handling of the work force issues doesn’t just become limited to recommendations without corresponding implementation and action.

The general implementation model urged for all of these recommendations is the model from the book, *Lean Enterprise Value*,[51] which involves a three-step process:

I. Value Identification
II. Value Proposition
III. Value Delivery

The motivation for using this model is that success for this industry will not be limited to one dimension, such as quality, cost, shareholder returns, safety, or other factors. It will require the delivery of value, which encompasses multiple dimensions – and which plays out differently across different stakeholders.

In this case, each of the proposals requires a clear articulation of the stakeholder involved and the value that this represents for them – that is step one. The second step is an interactive, negotiated process where the various understandings about value are combined into durable agreements or understandings. Finally, there is the third step, which involves delivery on the agreements and understandings – a process of implementation and continual improvement. This model is used as an illustrative framework for the two recommendations that involve establishing new organizations.

Value Creation Framework for Aerospace Capability Network and for National Aerospace Training and Development Partnership

Key Factors	I. Value Identification	II. Value Proposition	III. Value Delivery
Primary Focus	Informal dialogue and formal summit session(s) clarifying stakeholder "interests" and generating options with key stakeholders including: ▪ Congressional Representatives ▪ DoD Acquisition ▪ US Department of Labor ▪ Prime Contractors ▪ Sub-Contractors ▪ Union Leaders ▪ AIAA, AIA, and other Professional Associations ▪ Subject Matter Experts	Specific agreements regarding: ▪ Organizational structure ▪ Mission statement ▪ Funding mechanisms ▪ Roles and responsibilities ▪ Staffing process ▪ Governance structure ▪ Data integrity and confidentiality policies ▪ Other aspects of a public/private initiative	Launch of new organization and ongoing calibration around impact on relevant outcomes
Estimated Time Frame	3-6 months	6-18 months	2-3 years
Additional Comments	▪ Build on and extend existing government and private initiatives	▪ Explore web-based mechanisms to collect and aggregate data	

[51] Earll Murman, et. al., op. cit.

4.8 Conclusion:

The aerospace industry faces unique challenges in building the capability to attract, retain, and energize a 21st Century workforce. While the maturing of key product lines and other industry dynamics may be unavoidable, many other aspects of the industry's future are within our control. A key finding highlighted by this white paper centers on the significant gaps in the infrastructure associated with human capital. As a result, innovations are at risk of becoming "islands of success" and key needs are not being met or will not be met in the future.

The policy recommendations presented here are all highly actionable, but they require a willingness to work in new forms of public-private coalitions and networks. Ultimately, this is an industry in which there can and should be great passion and enthusiasm about the work we do – but it will take a deep conviction around the importance of investment in human capital. It will take a shared commitment to ensuring that we always have the right people, with the right skills, at the right place, at the right time.

Appendix

Table 1: Aircraft and Spacecraft Design and Manufacturing Professions

Table 2: Air Lines and Transportation Infrastructure Professions

Table 1: Aircraft and Spacecraft Design and Manufacturing Professions

	Educational Prerequisites	Training	Approximate Length of Preparation before Assuming Position	Curricular Requirements/Standards	Licensing or Certification
Aerospace Engineers	Entry-level: Bachelor's Degree in engineering preferred from a college accredited by the Accreditation Board for Engineering and Technology (ABET). Sometimes accepted - physical science or mathematics, or 4-year technology program. Higher-level: Graduate training enhances promotion opportunities.	Begin work under supervision of experienced engineers. May receive formal classroom or seminar training. On the job training.	Bachelor's Degree: 4-5 years	In the last 2 years of Bachelor's degree, most courses are in engineering, usually with a concentration in one branch. For example, the last 2 years of an aerospace program might include courses such as fluid mechanics, heat transfer, applied aerodynamics, analytical mechanics, flight vehicle design, trajectory dynamics, and aerospace propulsion systems. Some programs offer a general engineering curriculum; students then specialize in graduate school or on the job.	Licensure required in all 50 States and D.C. for engineers whose work may affect life, health, or property. Licensed engineers are called Professional Engineers (PE). Requirements: degree from an ABET-accredited engineering program, 4 years of relevant work experience, and successful completion of State examination. Two-stage examination: those who pass first part receive Engineers in Training (EIT) certification typically valid for 10 years. After acquiring necessary work experience, EIT's take second part of exam, Principles and Practice of Engineering Exam to become PE's.
Aircraft Assemblers (http://www.bls.gov/oco/cg/cgs006.htm)	Unskilled: A high school diploma is preferred, but not required, and some vocational training in electronics or mechanics is also favored. Production workers may enter the aerospace industry with minimal skills. Mechanical aptitude and good hand-eye coordination are usually necessary.	Unskilled production workers typically start by being shown how to perform a simple assembly task. Through experience, on-the-job instruction provided by other workers, and brief, formal training sessions, they expand their skills. Their pay increases as they advance into more highly skilled or responsible jobs. For example, machinists may take additional training to become tool programmers or tool and die or instrument makers. Inspectors are usually promoted from assembly, machine operation, and mechanical occupations.	To enter some of the more highly skilled production occupations, workers must go through a formal apprenticeship before they can become fully qualified for their positions. Machinists, sheetmetal workers, and electricians go through apprenticeships that can last up to 4 years.	Due to the increasing reliance on computers and computer-operated equipment, classes in computer skills are becoming more common. With training, production workers may be able to advance to supervisory or technician jobs. Apprenticeships usually include classroom instruction and shop training.	

Aircraft Mechanics and Service Technicians	Although a few people become mechanics through on-the-job training, most learn their job in one of about 200 trade schools certified by the FAA. About one-third of these schools award 2- and 4-year degrees in avionics, aviation technology, or aviation maintenance management.	FAA regulations require current experience to keep the A & P certificate valid. Applicants must have at least 1,000 hours work experience in the previous 24 months or take a refresher course. As new and more complex aircraft are designed, more employers are requiring mechanics to take on-going training, to update their skills. Recent technological advances in aircraft maintenance necessitate a strong background in electronics—both for acquiring and retaining jobs in this field. FAA certification standards also make ongoing training mandatory. Every 24 months, mechanics are required to take at least 16 hours of training to keep their certificate. Many mechanics take courses offered by manufacturers or employers, usually through outside contractors.		FAA standards established by law require that certificated mechanic schools offer students a minimum of 1,900 actual class hours. Courses in these trade schools normally last from 24 to 30 months and provide training with the tools and equipment used on the job. Aircraft trade schools are placing more emphasis on technologies such as turbine engines, composite materials—including graphite, fiberglass, and boron—and aviation electronics, which are increasingly being used in the construction of new aircraft. Less emphasis is being placed on old technologies, such as woodworking and welding. Additionally, employers prefer mechanics who can perform a variety of tasks. Some aircraft mechanics in the Armed Forces acquire enough general experience to satisfy the work experience requirements for the FAA certificate but will require additional study and need to pass the certifying exam.	3 major FAA certifications: "airframe mechanic," "power plant mechanic," or "avionics repair specialist." Mechanics who also have an inspector's authorization can certify work completed by other mechanics and perform required inspections. Uncertificated mechanics are supervised by those with certificates. 18 months of work experience required for an airframe, power plant, or avionics repairer's certificate. For a combined A & P certificate, at least 30 months of experience working with both engines and airframes is required. Completion of a program at an FAA certificated mechanic school can substitute for the work experience requirement. Also must pass written and oral tests and demonstrate ability to do the work authorized by the certificate. To obtain an inspector's authorization, a mechanic must have held an A & P certificate for at least 3 years. Most airlines require that mechanics have a high school diploma and an A & P certificate.
Blue Collar Supervisors	Minimum: High School Diploma Aerospace employers may require a bachelor's degree or technical school training.	Training in Human Resources, Computer Software, and Management is generally a prerequisite. Promotion from supervisor to department head or production manager typically requires a degree in business or engineering, combined with in-house training.		human resources, computer software, and management	

Computer Engineers	Computer hardware engineers need bachelor's degree in computer engineering or electrical engineering. Software engineers more likely to hold a degree in computer science or software engineering. A Ph.D., or at least a master's degree, in computer science or engineering is usually required for jobs in research laboratories or academic institutions.	Technological advances come so rapidly in the computer field that continuous study is necessary to keep skills up to date. Employers, hardware and software vendors, colleges and universities, and private training institutions offer continuing education. Additional training may come from professional development seminars offered by professional computing societies.			Technical or professional certification is a way to demonstrate a level of competency or quality in a particular field. Product vendors or software firms also offer certification and may require professionals who work with their products to be certified. Many are widely sought and considered industry standards. Voluntary certification is also available through other organizations. Professional certification may provide a job seeker a competitive advantage.
Drafters (http://www.bls.gov/oco/ocos111.htm)	Employers prefer applicants for drafting positions who have completed postsecondary school training in drafting, which is offered by technical institutes, community colleges, and some 4-year colleges and universities.	Entry level or junior drafters usually do routine work under close supervision. After gaining experience, intermediate level drafters progress to more difficult work with less supervision. They may be required to exercise more judgment and perform calculations when preparing and modifying drawings. Drafters may eventually advance to senior drafter, designer, or supervisor. Many employers pay for continuing education, and with appropriate college degrees, drafters may go on to become engineering technicians, engineers, or architects.			The American Design Drafting Association (ADDA) has established a certification program for drafters. Although drafters are not usually required to be certified by employers, certification demonstrates that nationally recognized standards have been met. Individuals who wish to become certified must pass the Drafter Certification Test, which is administered periodically at ADDA-authorized test sites. Applicants are tested on their knowledge and understanding of basic drafting concepts such as geometric construction, working drawings, and architectural terms and standards.

Precision assemblers	Most precision assemblers are promoted from the ranks of workers in lesser skilled jobs in the same establishment. The ability to do accurate work at a rapid pace is a key job requirement. A high school diploma is preferred.	Applicants need specialized training for some precision assembly jobs. For example, employers may require that applicants for electrical or electronic assembler jobs be technical school graduates or have equivalent military training. Some companies may also provide extensive on-the-job training or classroom instruction on the broad range of assembly duties that employees may be required to perform.			
Engineering Technicians	Most employers prefer to hire someone with at least a 2-year associate degree in engineering technology. Training is available at technical institutes, community colleges, extension divisions of colleges and universities, public and private vocational-technical schools, and through some technical training programs in the Armed Forces.	Engineering technicians usually begin by performing routine duties under the close supervision of an experienced technician, technologist, engineer, or scientist. As they gain experience, they are given more difficult assignments with only general supervision. Some engineering technicians eventually become supervisors. Those trained in the Armed Forces may require additional training.		Most 2-year associate degree programs accredited by the Technology Accreditation Commission of the Accreditation Board for Engineering and Technology (TAC/ABET) require that, at a minimum, college algebra, trigonometry, and one or two basic science courses be completed at the high school level. Graduates of ABET-accredited programs are usually recognized to have achieved an acceptable level of competence in the mathematics, science, and technical courses required for this occupation.	Certification generally not required, but can provide a competitive advantage. The National Institute for Certification in Engineering Technologies (NICET) has established a voluntary certification program for engineering technicians. Certification is available at various levels, each level combining a written examination in one of over 30 specialties with a certain amount of job-related experience.

Machinists	A high school or vocational school education, including courses in mathematics, blueprint reading, metalworking, and drafting, is generally a prerequisite for becoming a machinist or CNC programmer. Basic knowledge of computers and electronics is also helpful because of the increased use of computer-controlled machine tools. Experience with machine tools is extremely important. In fact, many entrants to these occupations have previously worked as machine tool operators or setters.	Machinist training varies from formal apprenticeship and postsecondary programs to informal on-the-job training. As new automation is introduced, machinists and CNC programmers normally receive additional training to update their skills. A representative of the equipment manufacturer or a local technical school usually provides this training. Some employers offer tuition reimbursement for job-related courses.		Apprentice programs consist of shop training and related classroom instruction. In shop training, apprentices learn filing, handtapping, and dowel fitting, as well as the operation of various machine tools. Classroom instruction includes math, physics, blueprint reading, mechanical drawing, and shop practices. In addition, as machine shops have increased their use of computer-controlled equipment, training in the operation and programming of CNC machine tools has become essential. Such formal apprenticeships are relatively rare, however, as a growing number of machinists and CNC programmers receive most of their formal training from community or technical colleges.	To boost the skill level of machinists and to create a more uniform standard of competency, a number of training facilities and colleges have recently begun implementing curriculums incorporating national skills standards developed by the National Institute of Metalworking Skills (NIMS). After completing such a curriculum and passing a performance requirement and written exam, a NIMS credential is granted to trainees, providing formal recognition of competency in a metalworking field. This designation can lead to advancement or confirmation of skills during a job search.
Technical Writers (http://www.bls.gov/oco/ocos089.htm)	Technical writing requires a degree in, or some knowledge about, a specialized field—engineering, business, or one of the sciences, for example. In many cases, people with good writing skills can learn specialized knowledge on the job. Some transfer from jobs as technicians, scientists, or engineers. Others begin as research assistants, or trainees in a technical information department, develop technical communication skills, and then assume writing duties.				

Welding and Soldering technicians	Training for welders can range from a few weeks of school or on-the-job training for low skilled positions to several years of combined school and on-the-job training for highly skilled jobs. Formal training is available in high schools, vocational schools, and post secondary institutions, such as vocational-technical institutes, community colleges, and private welding schools. The Armed Forces operate welding schools as well.	On-the-job training is typical, sometimes in combination with school. Training for welders can range from a few weeks of school or on-the-job training for low skilled positions to several years of combined school and on-the-job training for highly skilled jobs. In addition, welders increasingly need to be willing to receive training and perform tasks in other production jobs.	Training for welders can range from a few weeks of school or on-the-job training for low skilled positions to several years of combined school and on-the-job training for highly skilled jobs.	Some employers provide training to help welders improve their skills. Courses in blueprint reading, shop mathematics, mechanical drawing, physics, chemistry, and metallurgy are helpful. Knowledge of computers is gaining importance, especially for welding machine operators, as some welders are becoming responsible for the programming of computer-controlled welding machines, including robots.	Some welders become certified, a process whereby the employer sends a worker to an institution, such as an independent testing lab or technical school, to weld a test specimen to specific codes and standards required by the employer. The inspector will then certify the welder being tested as able to work with a particular welding procedure. Testing procedures are based on the standards and codes set by one of several industry associations with which the employer may be affiliated.
Painters (http://www.bls.gov/oco/ocos240.htm)	Completion of high school is generally not required but is advantageous. Additional instruction is offered at many community colleges and vocational or technical schools.	Some employers sponsor training. This training is available from manufacturers of chemicals, paints, or equipment or from other private sources. It may include safety and quality tips and knowledge of products, equipment, and general business practices.			Doesn't appear to be similar certification for Aircraft Painters (Voluntary certification by the National Institute for Automotive Service Excellence (ASE) is recognized as the standard of achievement for automotive painters. For certification, painters must pass a written examination and have at least 2 years of experience in the field. High school, trade or vocational school, or community or junior college training in automotive painting and refinishing may substitute for up to 1 year of experience. To retain certification, painters must retake the examination at least every 5 years.)

Managers and Executives (http://www.bls.gov/oco/ocos012.htm)	The educational background of managers and top executives varies as widely as the nature of their responsibilities. Many general managers and top executives have a bachelor's degree or higher in liberal arts or business administration. Their major often is related to the departments they direct. Graduate and professional degrees are common. Many managers in administrative, marketing, financial, and manufacturing activities have MBA's. Managers in highly technical manufacturing and research activities often have a master's degree in engineering or a doctoral degree in a scientific discipline. A law degree is mandatory for managers of legal departments; hospital administrators generally have a master's degree in health services administration or business administration.	Advancement may be accelerated by participation in company training programs that impart a broader knowledge of company policy and operations. Managers can also help their careers by becoming familiar with the latest developments in management techniques at national or local training programs sponsored by various industry and trade associations. Senior managers who often have experience in a particular field, such as accounting or engineering, also attend executive development programs to facilitate their promotion to general managers. Participation in conferences and seminars can expand knowledge of national and international issues influencing the organization and can help develop a network of useful contacts.		General managers and top executives must have highly developed personal skills. An analytical mind able to quickly assess large amounts of information and data is very important, as is the ability to consider and evaluate the interrelationships of numerous factors. General managers and top executives must also be able to communicate clearly and persuasively. Other qualities critical for managerial success include leadership, self-confidence, motivation, decisiveness, flexibility, sound business judgment, and determination.	

Metalworking and Plastics-working Machine Operators (http://www.bls.gov/oco/ocos224.htm)	Although no special education is required for most operating jobs, employers prefer to hire applicants with good basic skills. Many require employees to have a high school education and to read, write, and speak English. This is especially true for NC machine operators, who may need constant retraining as the company introduces new equipment.	Metalworking and plastics-working machine operators learn their skills on the job. Trainees begin by observing and assisting experienced workers, sometimes in formal training programs. Under supervision they may supply material, start and stop the machine, or remove finished products from the machine. They then advance to more difficult tasks such as adjusting feed speeds, changing cutting tools, or inspecting a finished product for defects. Eventually they become responsible for their own machines			
Tool and die makers (http://www.bls.gov/oco/ocos225.htm)	Tool and die makers learn their trade through 4 or 5 years of education and training in formal apprenticeships, postsecondary programs, or informal on-the-job training. A growing number of tool and die makers receive most of their formal classroom training from community and technical colleges.	Workers who become tool and die makers without completing formal apprenticeships generally acquire their skills through a combination of informal on-the-job training and classroom instruction at a vocational school or community college. They often begin as machine operators and gradually take on more difficult assignments. Many machinists become tool and die makers. In fact, tool and die makers are often considered highly specialized machinists	4-5 years		

Information in rows that are not specifically referenced within the table is taken from the *Occupational Outlook Handbook, 2000-01 Edition (Bureau of Labor Statistics, http://stats.bls.gov/oco/home.htm).*

Table 2: Air Lines and Transportation Infrastructure Professions

	Educational Prerequisites	Training	Approximate Length of Preparation before Assuming Position	Curricular Requirement s/Standards	Licensing or Certification
Air Traffic Controllers Source: National Air Traffic Controllers Association (NATCA) website page "Become an Air Traffic Controller": link, http://www.natca.org/AboutNATCA/HowToBeAnATC.htm	There are several ways to become an air traffic controller. Many are trained while in the military. After their term, the FAA can hire them. If not a part of the armed forces, civilians attend one of the 14 colleges the FAA recognizes that give degrees in aviation administration with an emphasis in air traffic control. Graduates from the acclaimed colleges, then go on to the Federal Aviation Administration Air Traffic Control Academy. Although these are the two main ways to become an air traffic controller, other avenues for employment may be opened at the discretion of the FAA.	After the FAA hires them, an intensive training process begins. Controllers may pick from two areas of traffic control: en route or terminal. Controllers begin the en route training as an air traffic assistant. This part is known as the A-Side of the process. As the assistant, training consists of two weeks of preparatory class and on-the-job-training. Controllers then begin three to six months of "seasoning," which is performing the duties they were trained for. After successful completion, controllers go to D-School. This schooling entails classroom and simulator training for eight weeks and on-the-job-training for three to nine months, followed by certification and seasoning. Once certified on the D-side controllers season for as long as a year before proceeding to R-School. Now enrolled in R-School, the controllers attend classroom and simulator training for eight weeks and then complete the on-the-job-training in nine months to a year. Terminal training begins with intensive classes teaching controllers how to separate or control traffic on three levels: clearance, ground and local traffic. Each of the three classes is followed by on-the-job-training and then seasoning. This process varies in length depending on the complexity of the facility.	En Route Training can take from 2 years to 3.75 years (approximately)		After finishing of all of the training, controllers are certified, but only for the area of specialization in the facility where they were trained.

Aircraft Pilots (http://www.bls.gov/oco/ocos107.htm)	Although some small airlines will hire high school graduates, most airlines require at least 2 years of college and prefer to hire college graduates; about 90 percent of all pilots have completed some college. In fact, most entrants to this occupation have a college degree. If the number of college-educated applicants continues to increase, employers may make a college degree an educational requirement. The Armed Forces have always been an important source of trained pilots for civilian jobs. This primarily reflects the extensive flying time military pilots receive. Persons without armed forces training also become pilots by attending flight schools. The FAA has certified about 600 civilian flying schools, including some colleges and universities that offer degree credit for pilot training. Over the projection period, Federal budget reductions are expected to reduce military pilot training. As a result, FAA certified schools will train a larger share of pilots than in the past. Prospective pilots may also learn to fly by taking lessons from individual FAA-certified flight instructors.	To qualify for licenses, applicants must be at least 18 years old and have at least 250 hours of flight experience. The time can be reduced through participation in certain flight school curricula approved by the FAA. Applicants must pass a written test that includes questions on the principles of safe flight, navigation techniques, and FAA regulations. They also must demonstrate their flying ability to FAA or designated examiners.To fly in periods of low visibility, pilots must be rated by the FAA to fly by instruments. Pilots may qualify for this rating by having 105 hours of flight experience, including 40 hours of experience in flying by instruments; they also must pass a written examination on procedures and FAA regulations covering instrument flying and demonstrate to an examiner their ability to fly by instruments. Airline pilots must fulfill additional requirements. Pilots must have an airline transport pilot's license. Applicants for this license must be at least 23 years old and have a minimum of 1,500 hours of flying experience, including night and instrument flying, and pass FAA written and flight examinations. Usually they also have one or more advanced ratings, such as multi-engine aircraft or aircraft type ratings dependent upon the requirements of their particular flying jobs. Once trained and "on the line," pilots are required to attend recurrent training and simulator checks twice a year throughout their career.	Depending on the type of aircraft, new airline pilots start as first officers or flight engineers. Initial training for airline pilots includes a week of company indoctrination, 3 to 6 weeks of ground school and simulator training, and 25 hours of initial operating experience, including a check-ride with an FAA aviation safety inspector. Organizations other than airlines usually require less flying experience. Many pilots start as flight instructors, building up their flying hours while they earn money teaching. As they become more experienced, these pilots occasionally fly charter planes or perhaps get jobs with small air transportation firms, such as air taxi companies. Some advance to business flying jobs. A small number get flight engineer jobs with the airlines.In the airlines, advancement usually depends on seniority provisions of union contracts. After 1 to 5 years, flight engineers advance according to seniority to first officer and, after 5 to 15 years, to captain. Seniority also determines which pilots get the more desirable routes. In a non-airline job, a first officer may advance to pilot and, in large companies, to chief pilot or director of aviation in charge of aircraft scheduling, maintenance, and flight procedures.		All pilots who are paid to transport passengers or cargo must have a commercial pilot's license with an instrument rating issued by the FAA. Helicopter pilots must hold a commercial pilot's certificate with a helicopter rating. (detail presented in "Training" column). They also must pass a strict physical examination and, because pilots must be able to make quick decisions and accurate judgments under pressure, many airline companies reject applicants who do not pass required psychological and aptitude tests. All licenses are valid as long as a pilot can pass the periodic physical examinations and tests of flying skills required by Federal Government and company regulations.

Flight Engineers (see aircraft pilot)		Some large aircraft have a third pilot—the flight engineer—who assists the other pilots by monitoring and operating many of the instruments and systems, making minor in-flight repairs, and watching for other aircraft. New technology can perform many flight tasks, however, and virtually all new aircraft now fly with only two pilots, who rely more heavily on computerized controls. As older, less technologically sophisticated aircraft continue to retire from airline fleets, flight engineer jobs will diminish.			

Information in rows that are not specifically referenced within the table is taken from the *Occupational Outlook Handbook, 2000-01 Edition (Bureau of Labor Statistics, http://stats.bls.gov/oco/home.htm).*

[1] LAI book reference
[2] Utterback reference
[3] Clay Christensen reference