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# SPACE: A CRITICAL ISSUES WORKSHOP
# REFLECTIONS ON THE PAST AND CONCERNS FOR THE FUTURE

September 12, 1962, was a warm, humid day in Houston. In spite of the temperature and only the hint of a breeze, there was a large crowd seated in Rice University's football stadium waiting to hear John F. Kennedy, then in the second year of his presidency, talk about outer space issues. His speech turned out to be a memorable one. In May 1961, a few months after his inauguration, he told a special joint session of Congress about his dramatic and ambitious goal of sending an American safely to the Moon before the end of the decade. His announcement was made nine months before an American had even orbited the Earth. John Glenn and *Friendship 7*'s three-orbit flight, after a number of delays, took place in February 1962. Kennedy clearly recognized the significance of his announcement and declared his decision in 1961 to "shift our efforts in space from low to high gear as among the most important decisions that will be made during my incumbency in the office of the Presidency."

Kennedy's speech took place in the city that was the new home of the National Aeronautics and Space Administration's (NASA) Manned Spacecraft Center. The president emphasized the importance of going to the Moon, and his words would be long remembered, not only by those sitting in the heat of that September day but also by a whole nation. "We choose to go to the Moon in this decade and do the other things, not because they are easy, but because they are hard, because that goal will serve to organize and measure the best of our energies and skills, because that challenge is one that we are willing to accept, one we are unwilling to postpone, and one which we intend to win, and the others, too."

That was 40 years ago. This year not only marks that anniversary but also the 30th anniversary of man's last voyage beyond Earth orbit. Much has transpired in those 30 years. The United States continued to make advances in space and in technology after the Apollo program came to an end with the splashdown of the command module in the Pacific on December 19, 1972. But with all these advancements, none have had the significance of the landing on the Moon. The challenge of going to the Moon served to provide excitement for a whole generation of young Americans, inspiring them to pursue careers in science and engineering and to dream of becoming astronauts. The investments made in research within the nation's universities and the technology derived from Apollo provided the foundation for many U.S. technological achievements over these past 40 years. Apollo became a veritable incubator—for new ideas, new skills, and new knowledge. We have literally seen the fulfillment of the prophecy the young president made that day in Rice Stadium: "The growth of our science and education will be enriched by new knowledge of our universe and environment, by new techniques of learning and mapping and observation, by new tools and computers for industry, medicine, the home, as well as the school. Technical institutions…will reap the harvest of these gains."

The intervening years since Apollo have brought dramatic changes to the aerospace industry that took America to the Moon. Having contributed significantly to U.S. technical advancements, the industry has changed significantly since the 1950s and 1960s. In those days, a significant number of companies competed fiercely for the design, development, and production of space systems and components. In the years since, companies such as Grumman, McDonnell Douglas, North American Aviation (later Rockwell), and General Dynamics have disappeared or have merged with other companies. Responding to economic forces and the end of the Cold War, the aerospace industry has consolidated, reducing the number of major system contractors to only two, three, or at best, four. Faced with major international competition, the end of the Cold War, and declining research and development budgets, the health of the industry is a major concern. Responding to this concern, Congress in 2001 created the Commission on the Future of the United States Aerospace Industry, charged with reviewing the state of the industry and recommending requisite action to reestablish world leadership in this critical industry. The commission's report is due in November 2002.

The critical element of the Apollo program and all subsequent technical achievements is the human element, the one element that will continue to be the most important factor in assuring this nation's global technological leadership. The availability of a well-educated and well-trained human resource is dependent on this country's educational system, and the state of our educational system is a cause for serious concern. Analysis by the National Science Foundation shows that university enrollment in engineering and science has been going down throughout the '80s and '90s and the proportion of men is continuing to decrease. Ethnic minorities, who traditionally have not chosen technical careers, are becoming the majority demographic groups in a number of regions throughout the United States. Clearly, improving the education of all members of the younger generation and encouraging young people to study mathematics, science, and engineering are imperative for the nation's future well-being.

The last 30 years have also seen great changes in how the United States implements its space programs. The International Space Station program, for example, is being managed by the United States, but with major contributions from a partnership made up of the European Space Agency, Canada, Japan, Russia, Brazil, and Italy. Representatives of the two major Cold War adversaries, the United States and Russia, now make up the crew of the International Space Station, working together with control centers in Moscow and Houston as one team. The American aerospace industry has also formed very effective partnerships internationally—Lockheed Martin with Khrunichev in Russia for a successful launch vehicle program and Boeing with Energia in Russia with the innovative and successful Sea Launch program. Boeing's 777 aircraft program, with major components made throughout the world, is a model for international cooperation. Major enterprises have clearly benefited from international partnerships with shared costs, contributions, and profits.

It was against this background that the Baker Institute held a workshop on May 6 and 7, 2002, to consider these various issues as well as their implications for the nation's economy. The state of the aerospace industry, the crisis with regards to education in science and engineering, international cooperation, and their implications on the economy were discussed by three groups of panelists during this May workshop.

The moderators for the workshop were Dr. Eugene Levy, provost of Rice University, and Dr. Neal Lane, senior fellow at the Baker Institute, University Professor at Rice University, and former presidential science advisor. Participants included industry executives Michael I. Mott, vice president and general manager of Human Space Flight and Exploration for the Boeing Company, and Al Smith, executive vice president of Lockheed Martin Space Systems Company. Former industry leaders who played key roles in Apollo and the space shuttle program and in the Russian human space flight program and robotic missions were also participants. They included George Jeffs, corporate vice president and president of the Aerospace and Energy Divisions for Rockwell International, and Dr. Roald Sagdeev, former director of the Space Research Institute of the Soviet Union. Astronauts who played key roles in past and present space flight activities were also panelists. These included John W. Young, veteran of six space flight missions (including two to the Moon and commander of the first shuttle mission); William Shepherd, commander of the first International Space Station crew; James Adamson, a veteran of two space flights and former group vice president and general manager of Lockheed Martin Engineering and Sciences; Dr. George Nelson, veteran astronaut and director of the Science, Mathematics, and Technology Education Program at Western Washington University; General Jean-Loup Chrétien, veteran French astronaut (his flights included two flights with Russia and a space shuttle mission); General Joseph Engle, veteran astronaut and key member of the Russian and United States Space Flight Advisory group; and Dr. James Newman, a U.S. astronaut just completing his fourth flight, a successful servicing mission of the Hubble Space Telescope.

Other panelists included noted educators from a number of universities: Dr. James J. Papike, Regents Professor in the Department of Earth and Planetary Sciences and director of the Institute of Meteorites at the University of New Mexico; Dr. Elaine Seymour, director of ethnography and evaluation research for the Bureau of Sociological Research at the University of Colorado; Dr. Leon T. Silver, W.M. Keck Foundation Professor for Resource Geology at the California Institute of Technology; Dr. Richard Tapia, professor of computational and applied mathematics and associate director of graduate studies at Rice University; Dr. Karl Doetsch, president of the International Space University; Dr. John Logsdon, director of the Space Policy Institute at George Washington University; and Dr. Douglas Duncan of the Department of Astronomy and Astrophysics and assistant director of humanities, arts, and sciences at the Graham School of the University of Chicago. Dr. Ray Marshall, former U.S. secretary of labor and professor emeritus of the Lyndon B. Johnson School of Public Affairs at the University of Texas at Austin, also served as one of the distinguished panelists.

The results of the workshop, which appear to be consonant with advice coming to policy makers from other quarters as well, have been summarized by Dr. Robert Oliver of Rice University's Space Institute as a part of this report.

The present state of the aerospace industry was the subject of considerable discussion at the workshop. The importance to the country of maintaining the vitality of the industry cannot be overemphasized. The government needs to assess consolidation in light of maintaining this vitality as well as examining U.S. educational systems and universities because of the critical role they play in maintaining this vitality. The relationship and effect of the industry on the country's economy was reviewed historically as well from today's and tomorrow's perspectives. The industry and the economy go hand and hand, and the future of each is dependent on the other. The importance of international cooperation, as well as international competition, must be recognized and balanced as industry and the nation look to the future. Maintaining our international partnerships and alliances affects the vitality of the industry, the U.S. economy, and U.S. national security. The nation has benefited from the vision and investments made after World War II and during the Cold War. The world has and will change. It will again require vision and enlightened leadership if the nation is to be successful in maintaining its role as a world leader.

The Congress, as was previously mentioned, has established a commission to review the state of the U.S. aerospace industry and will recommend the actions that should be taken to ensure continued U.S. world leadership. The commission's report will be published in November of this year. Its interim reports and the workshop's conclusions seem to be in agreement.

The commission's interim report recommends that immediate steps be taken to address issues vital to the health of the industry. It recognized that today's challenging business environment has jeopardized the nation's ability to sustain critical design and manufacturing capabilities and expertise. In the area of space infrastructure, the report states that the government needs to prioritize its requirements and seek new ways to manage them. It found that federal aerospace spending is spread across multiple government agency budgets with oversight by numerous congressional committees. This has led to a situation where none of the various government groups has an integrated view of the state of the nation's aerospace industry and its related activities, and there is a lack of White House involvement to provide such a perspective. The commission also feels that the aerospace sector is the victim of an educational system that needs to be dramatically improved, especially in the science, math, and engineering disciplines.

The present situation does not bode well for America. Today, the nation is fighting a war against terrorists. The success of this war depends on our international partnerships and alliances. At the same time, the United States is faced with a troubled economy. Once before when the nation was faced with similar and perhaps even greater problems, a challenge was made, a challenge to the nation: land a man on the Moon by decade's end. The nation benefited from that challenge and its successful fulfillment many times over during this past 40 years. The present problem is daunting: it is both a national one and international one. History could well provide a solution.

## The State of Space

The modern world has many roots, but one of the most important goes back to 1776 when a Scottish scholar named Adam Smith published a book called *The Wealth of Nations* and thus signaled the arrival of modern capitalism. From its very beginning, the capitalist system has assumed an intricate and indissoluble web of material connections binding together the peoples of the Earth. As we enter the 21st century, that lesson is becoming easier and easier to grasp. Scarcely a day goes by without some pointed reminder that the entire globe is becoming rapidly interconnected in ways and degrees that would have seemed unthinkable even a mere 15 years ago. Even as the world is more tightly bound together, the pressing necessities that lead outward from the Earth into space are becoming more acute. Need for economic expansion, new technology, and new frontiers of adventure and imagination all point into space. The economic stakes are important, indeed crucial, to the prosperity, and maybe the survival, of humanity. And the need for joint efforts to secure these stakes is critical.

However, it must be acknowledged that, as in all human activities, patterns of participation are complicated and strikingly varied. The exploration of space is still an area very much dominated by countries of the "First World." Indeed, within this group one country, the United States, has an overwhelmingly dominant presence at the moment. By at least some ways of estimation, American activities account for some 70 percent of all space exploration and operations.[1] Even within the group of countries that support space activity, motivations and goals vary sharply. As the American experience clearly demonstrates, companies, interest groups, and individuals within a given country can be sharply divided by different needs, aspirations, and outlooks.

This pattern becomes even more complicated as the rapidly changing status of Earth's population, demographics, economy, and politics are taken into account. Population increases, although falling in terms of growth rates, nevertheless promise great strains on the planet's resources, especially in countries that can least afford such strains. In many nations, perhaps particularly America, demographic trends herald major shifts in population makeup in the midterm, thus promising changes in the political terrain. Finally, the rapid rise of new economic players, particularly the People's Republic of China, will greatly affect patterns of wealth and poverty. Indeed, the entry of China also heralds a shift in the pattern of space activity, as the Chinese are dedicated to entering the "space race" with major manned missions in the near future. All of these factors argue that the time to seriously consider matters of mutual need, profit, and long-term relationships is at hand.

Nevertheless, despite this manifest and ever-increasing diversity, the world aerospace sector in general, and the space subsector in particular, must still be viewed in the context of American dominance. This leadership position of the United States in the post–World War II world has sprung historically from many factors. However, without a doubt, one of the most crucial roots of American leader-

[1] Karl Doetsch, President, International Space University. 7 May 2002.

ship over the last half of the 20th century and into the first part of the 21st has been American technological superiority. This factor is absolutely central to American economic, political, military, and diplomatic power. In the present world, technological leadership is more crucial than ever for the United States as it strives to maintain and exercise its position of leadership for the good both of its own citizens and its allies.

The aerospace sector has played an enormous role in the development and maintenance of America's technological edge. Developments in aerospace science and engineering have been absolutely central in American military strength, national prestige, economic growth, diplomatic influence, and political stability. It is, in fact, not an exaggeration to state that the aerospace sector provided the key area of struggle between the United States and the Soviet Union through the height of the Cold War. It was a Soviet challenge in the area of aerospace that led, in large part, to the massive restructuring of American industry and academics that characterized the 1950s and 1960s. It was in the arena of aerospace, that is of ballistic missiles and nuclear bomb technology, where much of the Cold War arms race played out. It was in the area of outer space in particular where the two Cold War combatants staged their most spectacular displays of technological prowess and national pride. Many of the political developments of the 1980s and early 1990s—the end of the Cold War, the collapse of Soviet Communism in Europe, and the fall of the Soviet Union itself—came about in large part due to the immense financial and technical strain of a large-scale aerospace arms race.

Therefore, our discussions of the current state of space science and space activities must play out on two levels. First, aerospace science, technology, and economics are absolutely crucial for the world economy and the world systems of scientific exploration and collective security. On the other hand, one must recognize that the activities of the United States in the aerospace venue provide the core of energy, resources, and leadership upon which the greater world aerospace effort relies. Moreover, aerospace activities are not isolated from their environment. When examining these issues, it is important to emphasize crosscutting issues that connect aerospace endeavors to the more general spheres of business, government, military affairs, and scientific enterprise.

The main issues facing space exploration, colonization, and science are:

- General imperatives for space exploration, especially pressing economic needs;
- Obstacles to investment in space, including a political environment of decreased funding and sharply increased competition among interest groups, along with organizational problems stemming from low prioritizing of space activities by some national governments and self-defeating organizational practices in private industry;
- The importance of space for security and cooperation in terms of economics, military affairs, and civil security;
- A crisis of human capital arising from a declining interest in science and engineering, demographic shifts of the population that have been poorly handled, and some dysfunctional aspects of science teaching traditions; and
- The loss of historical memory in large organizations, combined with a failure to involve appropriate actors in matters of planning, policy, and design.

## I. General and Economic and Political Imperatives

### A. The Pressing Economic Need for Space Exploration

The intense economic challenges that are even now facing the world constitute a slow simmering (and in some areas a boiling) crisis, and many factors will get worse in the easily foreseeable future. Already the world supports some six billion people, projected to grow to eight billion by the middle of this century. Of those six billion only 2.5 billion, or approximately 42 percent, are gainfully employed.[2]

Considering that most of the gain in population over the next 50 years will be in the poorest coun-

[2] Ibid.

tries, this ratio will tend to grow steadily worse. In addition, there is even now an acute shortage of shelter, food, water, energy, health resources, and educational opportunities in much of the world. These shortages will also grow increasingly dire as population mounts.

Space activities have great promise to help alleviate these problems. While it is true that no single solution offers a magic answer to the world's demographic dilemma, space is an area that is greatly underdeveloped and where one can reasonably expect large multipliers for wise investment. For instance, space activities now employ about 400,000 people worldwide, a tiny sector compared to agriculture (1.1 billion), services (0.8 billion), and industry (0.5 billion).[3] Considering such possibly profitable activities as space manufacturing, space tourism, and space-based information systems, space represents an area of economic activity nowhere close to saturation in terms of employment. It is a rare example of an economic sector where investment could quite possibly lead to reliable large-scale expansion of available jobs for some time to come.

Similarly, space activities account for $1 in every $330 of the world economy.[4] Once again, given the arguable potential of many profit-generating activities in space, the room for expansion of the space sector in terms of productivity and revenue generation is vast.

Many of the predictions concerning profit-generating activity in space can be bolstered by impressive historical precedent. Space is already the site of a satellite-based telecommunications industry worth $28.9 billion per year. Indeed, even given the current low level of general spending on space, space activities have spurred the development of an infrastructure worth some $53.6 billion.[5] Although it is true that the highly profitable business of satellite-based telecommunications has probably reached market saturation for the moment, rapid advances in satellite technology promise new uses and opportunities in the near future.

## B. Space Exploration and the American Economy

In addition to the pressing international economic issues that drive toward an expansion of space activity, particular features of the United States domestic economy point in that direction as well. The economy of the United States during the post–World War II era has been one of the wonders of modern history. From 1945 forward, and particularly following the close of the Korean War in 1953, the American economy has expanded to a phenomenal extent. This expansion has many roots. The pressing need for goods and services in war-shattered European and Asian countries fueled much of the early growth, as did the Servicemen's Readjustment Act of 1944, popularly known as the GI Bill. The latter, passed almost as an afterthought, made funds available to veterans for educational purposes and turned out to be one of the most successful pieces of legislation in American history. Powered by a flood of GI students, as well as increased government spending on research as the Cold War progressed (and especially in the wake of Sputnik), American universities blossomed, becoming the leaders of the world in terms of research and graduate education.

Following a brief period of stagnation in the wake of the Arab oil crisis and the Vietnam debacle, the United States economy entered into another period of spectacular growth. Over the last 20 years, however, this growth has largely been powered not by large-scale demand, but by increases in productivity.[6] This productivity is largely an outgrowth of technological progress, in its turn a product of the expanded research and development environment of the last half-century.

The importance of strong, stable research and development activity in the American economy is hard to overstate. The specific historical circumstances that led to the immediate post–World War II economic boom were extremely idiosyncratic and unlikely ever to be repeated. As the economies of Asia develop, particularly those of China and India, their large populations and vast potential for internal development will almost certainly lead them, especially China, past the United States in terms of gross domestic product (GDP) in the foreseeable future. The only source of superiority cur-

[3] Ibid.

[4] Ibid.

[5] Ibid.

[6] Ray Marshall, Former United States Secretary of Labor, Professor Emeritus, Lyndon B. Johnson School of Public Affairs, University of Texas at Austin. 7 May 2002.

rently available to the United States in terms of the world economy is a technological edge that is being challenged by Europe and Japan and will soon be challenged by China as well. Without the research and development necessary to maintain that edge, the United States's position as the world's leading power will be in grave jeopardy.

Research is important for reasons much more profound than the creation of particular products or even specific classes of technology. Any intense research effort will result in habits of thinking, behaving, and organizing work. These patterns, identified by former U.S. secretary of labor Ray Marshall as "ideas, skills, and knowledge,"[7] may be applied to endeavors far removed from their original frameworks. For instance, the ideas, skills, and knowledge that entered the culture and economy of the United States during the computer revolution have been successfully transferred to rapid advances in communications, transportation, organizational theory, military applications, virtual reality technology, mathematical modeling, data analysis, and too many other areas to list. Any research and development activity, but particularly those on the cutting edge, involves returns to human capital far in excess of returns to physical capital.[8] Unfortunately, this fact is widely unappreciated. The economic multipliers gained from ideas, skills, and knowledge—while intuitively and almost undoubtedly vast—are very difficult to measure compared to multipliers gained from the mundane and specific applications of particular products and technologies. This largely explains the sad, but well-documented tendency of government and corporations to undervalue research and development activity and make it the frequent target of budget cuts, often with the excuse that the economic benefit or profitability of such work is difficult to establish.

### C. Organizational Problems within the Aerospace Industry

Undoubtedly, one of the aspects of the modern aerospace enterprise that catches the eye on even a casual survey is the large-scale change in organizational structure, particularly in the private industry area, that has occurred in the recent past. However, this change, striking as it is, must be understood in the context of the overall history of the American aerospace enterprise. The aerospace enterprise, as it is usually understood, is less than one hundred years old, having begun with the famous Kitty Hawk flight of Orville and Wilbur Wright on December 17, 1903.[9] During its growth and development, it has undergone many changes and even radical shifts. Therefore, whatever the short- and long-term effects of the current events, one must keep in mind that the aerospace enterprise and particularly the private industry of aerospace, like any intellectual or economic area, cannot be expected to be immune from change, even drastic change.

During the early stages of the aerospace enterprise, that is to say the early part of the 20th century, the development of aerospace technology in America was tied intimately to the military, which utilized an "arsenal" system. Under this regime, the government in the form of the military appropriations, research, and engineering systems assumed majority leadership for both technological development and operations. Although restrictive, this system clearly assigned risks and benefits, both of which were owned by the government.[10] However, with the coming of the Cold War, a major shift occurred from an arsenal to a contractor system. Under this new organizational paradigm, the contractors, that is to say private industry, assumed much of the financial and technical risk.[11] In fairness, private industry also achieved new opportunity for the generation of profit. Also, much of the research that fueled technological innovation in this period came from academic laboratories. Under new systems of research funding, systems that had first been proposed by Vannevar Bush in his famous monograph *Science, The Endless Frontier*, funding for university-based research activities in

7 Ibid.

8 Ibid.

9 As a matter of historical interpretation, one could of course make arguments for much earlier development of the aerospace industry. Balloons, for instance, played a role in artillery spotting and triangulation during the American Civil War. Nevertheless, in that most of the modern aerospace industry relies upon technology that grows out of heavier-than-air flight, the 1903 date is immanently defensible.

10 Michael I. Mott, Vice President and General Manager of Human Space Flight and Exploration, Boeing Company. 6 May 2002.

11 Ibid.

both science and engineering mushroomed.[12] In the wake of the Sputnik crisis of 1957, this trend accelerated dramatically, fueling a radical shift in academic culture and organization.

However, this organizational model sprang from the needs of the Cold War. It is therefore not particularly surprising that the end of intense American–Soviet rivalry also undermined the consensus for such a state of industrial affairs. Two trends have dominated the private aerospace industry in the past decade. The first is major consolidation. Under the Clinton administration, the Department of Defense, then led by former congressman Les Aspin, initiated a policy of encouraging large-scale mergers in the American aerospace corporate sector. This was greatly aided by an economic climate that had already set in motion a rising tide of consolidation in many areas, perhaps most notably the commercial air-travel industry. The simplification, in terms of players, in the American aerospace industry has been "draconic."[13] From an arena marked by several key contenders, the industry has, in terms of major systems and vehicle developers, been reduced to a few major companies dominated by two members, Boeing Company and Lockheed Martin Company.

This consolidation was undertaken in an attempt to improve management efficiency and streamline systems of communication, planning, and procurement. In some sense, this has happened, with a marked decrease in the overall "lumpiness" of the industry.[14] In terms of contracting, the American aerospace industry is now characterized by dramatically fewer "primes" and "subs."[15] However, the effect of this on profitability, particularly in terms of some sectors such as airframe manufacture, has not been favorable. Indeed, in terms of airframes, the main result seems to have been a spur to European industry to effect its own consolidation. The result, Airbus, has proven to be a formidable competitor and is making large-scale inroads in the airframe market.

The consolidation has had other negative impacts. By creating two very large corporations, it has nurtured new management challenges even while alleviating some of the old ones. Although dealing with numerous separate corporations does indeed complicate management strategy, projection of management intentions through the various levels and divisions of a large company is by no means easy or assured.[16] Often the result is the de facto growth of "phantom corporations" within the existing entities. That is to say that the difficulty of communications and control leads to the evolution of localized command structures with their own seniorities and hierarchies. These structures often have priorities, traditions, and concerns that are different from those of the company as a whole. Indeed, it is not uncommon for localized "phantom corporations" to work at cross-purposes to the wishes of formal management. Although phantoms may be a useful short-term adaptation to realities of production pressure and difficult communications, the long-term challenges this poses to management are extreme.

Perhaps more importantly from the view of the health of the entire American aerospace enterprise, the consolidation of the private aerospace industry has generally reduced the base of support for certain key activities, especially outer-space initiatives. The Apollo program, for instance, involved, at some level, approximately 420,000 people.[17] More important than the absolute numbers, however, was the fact that these people were distributed among many different industries, companies, and geographic areas. Thus these 420,000 produced a "multiplier" of support by involving important bulk segments of the economy and body politic in the space effort. In the context of two larger "super-companies" and a reduced number of subcontractors, such multipliers are much harder to attain. This occurs precisely at a time when increasing diversity of the population and proliferating political and economic challenges make the garnering of such

[12] Vannevar Bush, *Science, the Endless Frontier. A Report to the President by Vannevar Bush, Director of the Office of Scientific research and Development. July 1945.* (Washington, D.C.: Office of Scientific Research and Development, 1945).

[13] Eugene H. Levy, Provost, Rice University. 6 May 2002.

[14] George Jeffs, Corporate Vice President and President, Aerospace and Energy Divisions, Rockwell International (Retired). 6 May 2002.

[15] Ibid.

[16] Ibid.

[17] Ibid.

bulk segment support absolutely crucial for any large space initiative.

Finally, the large-scale consolidation has had the inevitable result of reducing competition. Although this might create, in the short term, a more comfortable atmosphere for corporate management in the aerospace sector, in the long run the decline of competition in a capitalist system of political economy leads unavoidably to stagnation. Given the fact that, as detailed below, reductions in real government funding make concerns about marketing and cost crucial to the modern American aerospace industry, any move toward stagnation bodes ill for the health of the industry over the mid and long term.

The second major trend to affect the American aerospace industry in the recent past is the shifting pattern of government priorities. With the end of the Cold War and the decline of a sense of external threat, support for many aerospace activities, most notably the manned space program, has declined relative to pressing concerns in other areas. Over the last few years, support for research and development in aerospace for military applications has declined 45 percent in real terms, while the research and development funds allotted to the National Aeronautics and Space Administration (NASA) have declined by 18 percent in real dollars.[18] With this decline has come an emphasis on stringent justification of expenditures and a demand for tangible benefits from a given project. Government has entered into an era of passing functions to industry while making stern cost-saving demands that mean most increases in efficiency are passed directly back to the funding agency. Although there is some hope that the aftereffects of the September 11 events may lead to rethinking of these policies in the long term, it is much too early to make any predictions.[19]

The private aerospace industry has increased the problems inherent in these policies through its own organizational decisions. In keeping with modern management practices that emphasize the organization of all functions into defined profit centers, both Boeing and Lockheed Martin have segregated their space activities and engineering research and development into corporate units separate from more immediately profitable undertakings such as airframe manufacture and satellite systems operation. This creates an environment for space activity and research and development undertakings in which these functions face very thin financial margins and are tied strongly to patterns of governmental expenditure that have not been steady or dependable in the recent past. In fact, the specific procurements for space activities have fallen rather steadily as a portion of general government research and development expenditures. To make matters worse, these divisions generally face a high debt load.

In conclusion, the trends in industry organization over the last few years have not been favorable for the aerospace enterprise, particularly space initiatives. The industry consolidation into a few companies with two major players has brought some measure of efficiency in management and procurement practices at the high cost of decreased competition and decreased ability to generate a support base for new activity in space science and engineering. Downward trends in government funding, aggravated by the management and organizational practices of the companies themselves, have tended to place space activities and engineering research and development in a severely unfavorable financial position. These factors must be addressed before any kind of new space initiatives dependent on private industry—which any new space initiatives would inevitably be—can hope to thrive.

### D. Politics, Policy, and Competition

The termination of the National Space Council is a troubling development. The council, chaired by the vice president, provided the American space enterprise with a high profile locus in the heart of executive decision-making. Although it is true that the council did not reverse the problematic trends in both government and industry that have led to severe pressures on the space enterprise, the absence of such an institutionalized place in the highest levels of government planning cannot be a helpful situation. Its dissolution, part of a series of

18 Michael I. Mott. 6 May, 2002.
19 Ibid.

steps to downsize the White House support system, was perhaps a very good example of economizing interfering with good functioning.[20] Although its functions still exist in the Office of Science and Technology Policy (OSTP), it is doubtful that this office, facing its own downsizing problems, can give space initiatives the attention they deserve and require.

In this climate of troubling loss of profile for space activities, there is also renewed pressure for privatization of many space operations. Unfortunately, in this area, basic economic structures pose very large problems. Private industry is understandably quite skeptical about possibilities for profit in many space operations at this time. The industry is in fact squeezed by foreign competition in areas already privatized, particularly missile launch. Due to many factors, most especially high American labor costs, Boeing and Lockheed Martin find themselves increasingly unable to compete internationally with the European Space Agency (ESA) or Russian launch vehicles. With the development of Chinese capabilities, the future looks as if it will include more such competition, not less.

The American space enterprise now must deal with a set of problems coming from the particular political and economic framework within which it must operate. Although there is increasing recognition of the value of space-based activity in economic, military, and security terms, much of the public and the government remains ill informed in these areas. Downgrading of space activity in the government hierarchy, especially the dissolution of the National Space Council in 1993, has weakened the prestige of space activity and the ability of leaders in this area to access the highest areas of government. Finally, movement towards privatization raises many questions, particularly in a context of stiff international competition in which American products and services already find themselves at a disadvantage.

### E. Obstacles to Increased Investment

Unfortunately, expanded investment in space activities faces some tough organizational barriers. The American bureaucracy is not well adapted to the kinds of issues presented by space exploration. A unique example is the fact that Neil Armstrong, Mike Collins, and Buzz Aldrin had to pass through immigration as part of their return from the Moon.[21] More prosaically, the issue of technology transfer looms large. In an environment where privatization of space activity has achieved the level of a mantra, systems for transferring key technology from government to private hands are extremely underdeveloped.[22] Also underdeveloped is a governmental understanding of the needs of private industry, particularly the problems associated with generating acceptable profits from space activity.

Another problem exists in the area of global technology sharing. In order to build successful space industries and profitable space activities, it is necessary to build an international network of players. Only when that network is in place will a functional system of resource providers and market distributors appear. However, American export regulations are intimately tied to issues other than those of business and economics. Particularly, ideology, cultural shibboleths, and frank nationalism often interfere with rational export policies. The recent move of export control oversight from the Department of Commerce to the Department of State underscores this tendency.[23]

A factor that stymies efforts to overcome these difficulties is the lack of practical political savvy one finds evident in many discussions about space policy. Missing from many discussions are realistic appraisals of the fact that both export controls and funding decisions arise from a political environment that is subject to many conflicting forces. Any attempt to correct policy requires the willingness to delve into the often-confusing realm of day-to-day politics. For instance, as important as symbolic organizational moves—such as reestablishment of the National Space Council—may be in the long run, they cannot produce actual results unless they are energized by constant political action.

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[20] Neal Lane, University Professor, Rice University. 6 May 2002.

[21] John Logsdon, Director, Space Policy Institute, George Washington University. 7 May 2002.

[22] Ibid.

[23] Ibid.

## II. Security and Cooperation

The general importance of space-based activity to national security in both military and economic terms has been extensively noted by the Rumsfeld Commission and others.[24] Especially in the area of communications and navigation, space-based systems have become absolutely integral to daily operations. The extent of this dependence was illustrated in the recent past when a satellite malfunction left many pagers nonfunctional and thousands of users without the communications ability on which they had come to depend for business and personal activity. In the area of navigation, military targeting has become intimately tied to global positioning system (GPS) technology, while the same technology is now used routinely for most maritime navigation. Finally, the use of satellites for imaging and data-gathering activities has become a standard and necessary part of the daily work conducted by military and civilian intelligence agencies.

In the area of long-term scientific capital, space-based systems provide crucial data-gathering abilities. Such areas as meteorology, oceanography, and environmental science benefit immensely from this data, along with the more intuitively obvious fields of space physics, astronomy, and planetary science. The engineering prowess developed in space initiatives is employed in a variety of activities across the economy. The space enterprise is a research and development engine that benefits sectors far removed from initial contact with outer space exploration.[25]

Yet the activity of the government in nurturing and encouraging space initiatives has been limited in the last decade. Much activity has focused in two areas, the International Space Station (ISS) and military/national defense issues. Both of these are promising developments. The ISS marks a symbolic beginning to possibly fruitful and peaceful exploration of space. The security discussions, particularly involving concepts related to missile defense technology, are a sign that policy leaders recognize the dependence of the United States on space (indeed one of the main points of the high profile Rumsfeld Commission report) and the fact that space-based assets are extraordinarily vulnerable and difficult to defend. There is also increasing awareness of the vulnerability of the terrestrial biosphere to damage from asteroid and cometary collision and the need to develop technologies for warning and defense against such possible civilization-ending events.[26]

Many current groups in Washington, D.C., are advocating an investment heavily weighted toward military applications, particularly the development of a missile-defense system. However one stands on that particular issue, it is beyond doubt that the United States has crucial security concerns with regard to space technology and the control of space itself. Indeed, space is already heavily "militarized," if not yet "weaponized."[27] The United States military relies on space-based systems for communication, positioning, weather tracking, and navigation. To make things worse, the specific physical assets involved with these functions (mainly satellites) are highly vulnerable to attack.[28]

However, although it would be naive and probably counterproductive to insist that military and national security concerns should not have an important place in space planning, there are many other possible forms of space investment. First of all, there are the familiar research and exploration activities undertaken by NASA, the ESA, and the Russian Space Agency. These are very important in terms of gaining basic knowledge about both space and Earth. They also embody the element of adventure and national pride that has been so important historically in space science and will undoubtedly continue to be crucial in the future.

In addition to these activities, there is an important form of space activity commonly called "civil security."[29] This involves monitoring of environmental factors, gathering agricultural information, support of earth science and oceanography, and investigation of treaty compliance. These kinds of

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24 Report of the U.S. Commission to Assess National Security Space Management and Organization, 2001.

25 Al Smith. 6 May 2002.

26 John W. Young, NASA astronaut. 6 May 2002.

27 John Logsdon, 7 May 2002.

28 Ibid.

29 Ibid.

functions have important economic benefits. In the United States, they are embodied in the National Oceanic and Atmospheric Administration (NOAA), which is much less visible than NASA but might have an important role in expanding space activities in this direction. A key advantage of civil security activity is that whereas America's international partners are extremely nervous about participating in military activities in space, they might well be quite enthusiastic about civil security programs.

As the demands on the resources of the United States show no sign of decreasing appreciably in the near future, it is becoming patently obvious that new space initiatives must come in the form of international cooperative ventures. This is not a new role for the space program. NASA has always had a role as an instrument of international politics and foreign policy as well as in scientific research and space operations.[30] Indeed, the space program was one of the first and most successful attempts at American–Soviet cooperation during the Cold War era. The decision to cooperate with the Soviets was a basic policy stance that placed NASA at the forefront of Cold War international relations.[31] The Apollo-Soyuz mission opened a crack in the icy wall between nations, heralding the possibility of a relationship between Russia and the United States based on mutual effort and understanding rather than confrontation.

However, international cooperation is a dream that often vanishes with morning. The various organizations involved, including NASA, the ESA, the Russian Space Agency, and the Japanese and Chinese space endeavors, have their own goals and needs. Often these goals arise as much from national pride and cultural motivations as from rational economic policy or a desire for cooperation. A particular problem comes from the possible military applications of the United States's space effort. This tends to produce a nervous reaction among Chinese government circles and is not met favorably in Russia or Europe. Civil security measures, as we have seen, may be a much more promising area to investigate.[32]

Undoubtedly, the most important international relationship to date has been between Americans and Russians, and this has proved a testing field in which many problems of international relations become clear. Even such seemingly basic issues as translation of technical vocabulary can become extremely problematic. Witness the Russian interpreter who translated "hydraulic ram" as "water goat" in an early meeting concerning Apollo-Soyuz.[33] Other cultural issues are more intractable. For instance, styles of organization and management vary widely between nations. Whereas Americans tend toward official organizations with fluid personnel, Russians prefer stable structures based largely on personal relationships.[34] While American projects rely on official records and formal techniques, Russian management employs a folklore system in which wisdom is passed, or not, through managerial generations.[35] Given such different modes of approaching a task, the field is rife for misunderstanding, delay, and inefficiency.

Nevertheless, the importance of the Russian–American working relationship forged by NASA and its Soviet counterparts remains one of the least understood and appreciated aspects of the United States's space endeavors. Through Apollo-Soyuz and other programs, up to and including the International Space Station, NASA trained a cadre of engineers and managers who could effectively work with their Russian partners on tasks that were delicate, complex, and often touching on deep issues of security for both nations. This stands as an irrefutable example that such cooperation is possible. The importance of this cooperation to Russia was emphasized by none other than Russian president Vladimir Putin when, in a 2001 speech at Rice University, he remarked that both Russia and the Johnson Space Center (JSC) have a "joint holiday," April 13, the anniversary of Yuri Gagarin's flight. President Putin went on to express the hope that "our joint work in space exploration which is quickly gathering momentum" could provide an exam-

[30] James Newman, former astronaut. 7 May 2002.

[31] Joseph H. Engle, former astronaut. 7 May 2002.

[32] John Logsdon, 7 May 2002.

[33] Joseph H. Engle, 7 May 2002.

[34] Jean-Loup Chrétien, former NASA astronaut and Soviet cosmonaut, 7 May 2002, and James Newman, 7 May 2002.

[35] Ibid.

ple and model for future joint activities between America and Russia.[36]

However, perhaps the greatest challenge to international cooperation is found in certain characteristics of American culture. Americans tend to think of themselves, and their country, as quite straightforward and easily understandable. They are thus baffled when citizens of other countries find American attitudes and behaviors contradictory, confusing, and even infuriating. As a culture we have grown used to the protean nature of our social and cultural relations. We think little of widely differing styles of interaction in different domains. To many other people, however, this multitude of faces is disturbing and somewhat frightening.[37] Perhaps most importantly, as America has turned inward in the past years, the faces that are most readily welcomed by citizens of other nations have not been evident. As Jean-Loup Chrétien has observed, the face of the great American has not been seen in far too long.[38]

## III. The Human Factor

### A. The Educational Crisis

From 1980 to 2000, the overall labor force grew by 35 percent and the prime age workforce (ages 25–54) grew by a remarkable 54 percent; college educated workers more than doubled and increased as a fraction of the labor force from 22 percent of the total to over 30 percent.

The inevitable future sees the United States facing a human capital crisis, a crisis at the heart of its productivity engine—the source of the all-important ideas, skills, and knowledge. The American economy faces a slowdown in the total growth of the workforce and a more pronounced slowing of the growth in the educated workforce.[39]

In the next 20 years, there will be virtually no growth in the prime age workforce at all; the number of native-born white prime age workers will fall by 10 percent; growth in the prime age workforce will come almost exclusively from older workers and people of color.

The educational level of the workforce will improve far less. In the next 20 years, college graduates might rise from 30 percent to 35 percent as a strata of the workforce.

This is in part a result of the well-known demographic shift toward an older population. It is also, however, due to the failure of the American educational system to provide appropriate education to large segments of the community, namely minority groups. As the proportion of these groups in terms of the total population, particularly the proportion of the Hispanic community, becomes inevitably larger, this failure endangers the entire economic system.[40]

To make matters worse, the United States faces a growing disparity in wealth and income between the upper and lower levels of society. This disparity erodes social well-being and unity and makes the foundations of the entire political and economic system less stable. As the value of education as a determinant of social and economic position grows, the effects of inadequate educational systems will also grow. This is such a profound problem that it is within reason to appropriate medical terminology and label it a pathology of the body politic.[41]

The exploration of space and the expansion of space-based activities once again offer partial answers to these dilemmas. The type of intense research and development activities required by space exploration provides the kind of environment in which ideas, skills, and knowledge can flower. Given the huge returns to human capital and the potential economic multipliers, as well as the undeveloped nature of space as an economic sector, this seems a logical, indeed a necessary, form of investment for American government, academic institutions, and private corporations. Indeed, corporations in particular are in danger of losing the constant reinforcement of human capital needed to compete in an increasingly crowded global market.

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36 Vladimir Putin, President of the Russian Federation. 14 November 2001.

37 Ibid.

38 Ibid.

39 Ray Marshall. 7 May 2002.

40 Ibid.

41 Ibid.

**Figure 1**
**Resident Population of the United States in 1980 by Years of Age and Nativity**

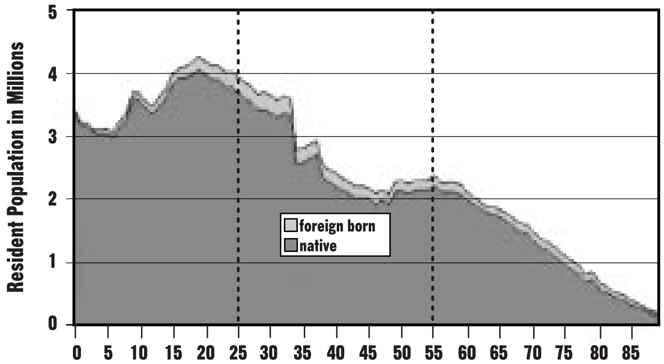


**Figure 2**
**Resident Population of the United States in 2000 by Years of Age and Nativity**

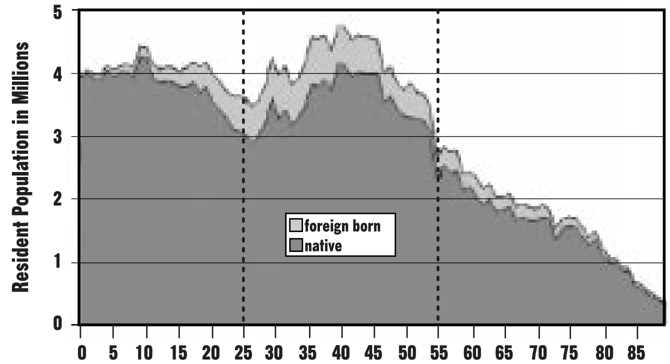


**Table 1**
**Characteristics of the Labor Force Aged 24 and Over and Components of Change 1980, 2000, 2020**

| | Labor Force in 1980 | Growth 1980–2000 | Labor Force in 2000 | Growth 2000–2020 | Labor Force in 2020 |
|---|---|---|---|---|---|
| **Age** | | | | | |
| 25–34 | 65.0 | 35.1 | 100.1 | 3.1 | 103.1 |
| 55–64 | 11.8 | 2.2 | 14.0 | 12.5 | 26.5 |
| 65– | 3.0 | 1.4 | 4.4 | 4.0 | 8.4 |
| ***Total*** | ***79.8*** | ***38.7*** | ***118.5*** | ***19.4*** | ***137.9*** |
| **Race/Ethnicity/Nativity** | | | | | |
| White Non-Hispanic – Native | 63.0 | 21.5 | 84.5 | 2.6 | 87.1 |
| Black Non-Hispanic – Native | 7.6 | 4.6 | 12.2 | 2.8 | 15.0 |
| Hispanic – Native | 2.5 | 2.3 | 4.5 | 6.8 | 11.6 |
| Other Non-Hispanic – Native | 0.8 | 1.0 | 1.8 | 1.2 | 3.0 |
| Hispanic – Foreign-Born | 1.8 | 4.5 | 6.3 | 2.8 | 9.1 |
| Non-Hispanic – Foreign-Born | 4.1 | 4.8 | 8.9 | 3.3 | 12.2 |
| ***Total*** | ***79.8*** | ***38.7*** | ***118.5*** | ***19.4*** | ***137.9*** |
| **Summary** | | | | | |
| White workers 25–54 | 50.8 | 19.3 | 70.1 | -7.7 | 62.4 |
| White workers 55 & Over | 12.2 | 2.2 | 14.4 | 10.3 | 24.7 |
| Workers of Color 25–54 | 9.4 | 7.3 | 16.7 | 7.7 | 24.4 |
| Workers of Color 55 & Over | 1.6 | 0.5 | 2.1 | 3.0 | 5.1 |
| Foreign-Born Workers | 5.9 | 9.4 | 15.3 | 6.0 | 21.3 |
| ***Total*** | ***79.8*** | ***38.7*** | ***118.5*** | ***19.4*** | ***137.9*** |

However, the development of human capital brings important issues. Like any capital development, human resources require long-range, scientific planning.[42] Although it is true that labor markets are incredibly sensitive to localized and short-term influences, and thus notoriously difficult to predict, it is also true that certain basic principles of planning hold true with labor development. Particularly, human capital must be used appropriately if it is to continue to develop. To put it in more personal terms, it does no good to educate a person if jobs that make appropriate use of that education are not available. Unless steps are taken to increase demand as well as supply, the United States will face an Indian or Bangladeshi scenario where there is a large unemployed sector of well-trained people.[43] Indeed, the United States is already in the opening stages of that scenario, as less than half the Ph.D.'s produced in many fields are even now unable to secure appropriate employment.

The current state of science and engineering education in America has been the subject of multiple laments, reports, and press opportunities. The rhetoric surrounding the situation has grown thick with technical and academic jargon, while the policies involved with science and engineering education have provided lightning rods for all kinds of "special interest" politics and wrangling over ideology. It is a field that most people on the street little understand. If they do, they are weary of hearing about it. Yet it is the issue on which the entire edifice of space exploration must eventually stand or collapse.

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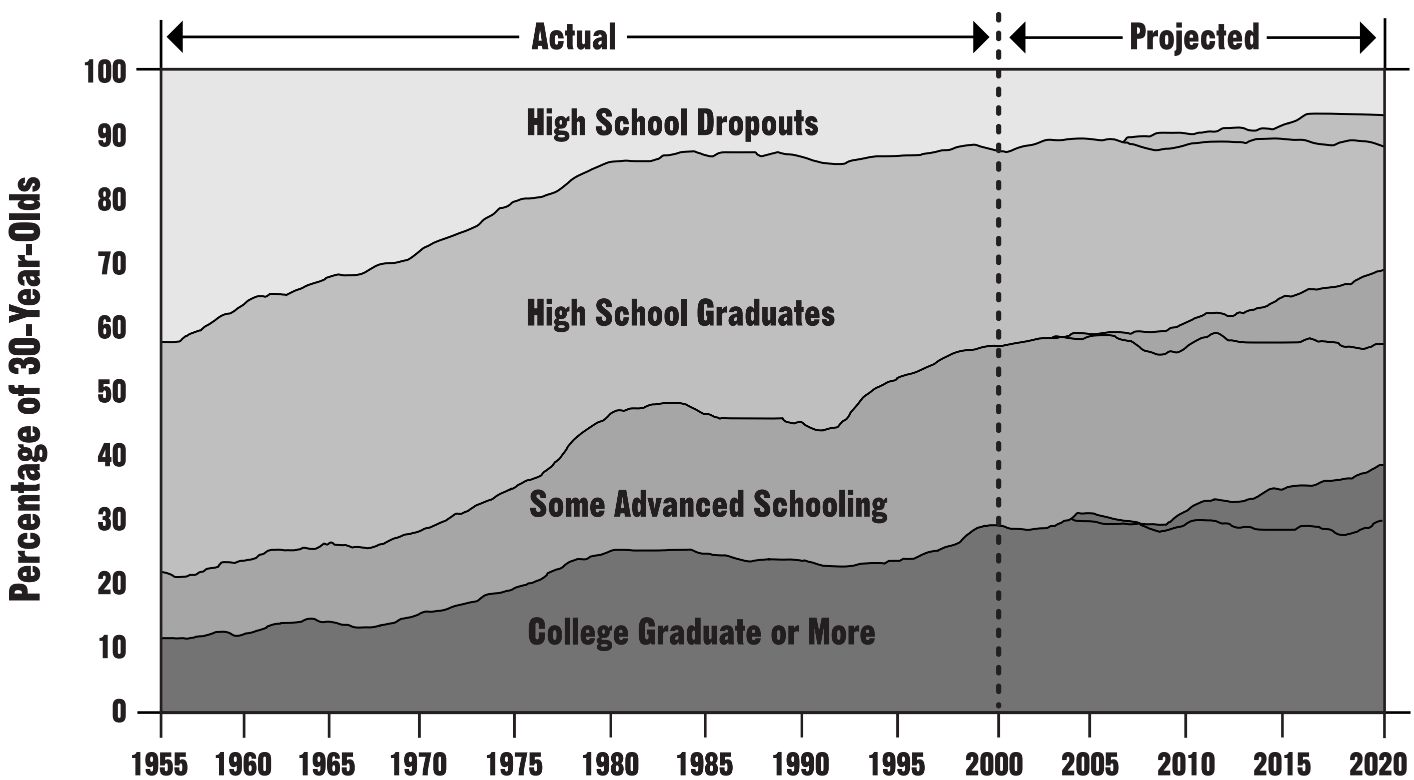
[42] Ibid.
[43] Ibid.

## Table 2
### Educational Characteristics of the Labor Force Aged 25 and Over 1980, 2000, 2020

### High Growth in Education Assumption

| | Labor Force in 1980 | Growth 1980–2000 | Labor Force in 2000 | Growth 2000–2020 | Labor Force in 2020 |
|---|---|---|---|---|---|
| **Education** | | | | | |
| Less than High School | 17.3 | -5.3 | 12.0 | -1.1 | 10.9 |
| High School Only | 31.5 | 6.3 | 37.8 | 1.5 | 39.3 |
| Some Schooling Beyond High School | 13.8 | 19.1 | 32.9 | 6.2 | 39.1 |
| College Degree or More | 17.3 | 18.5 | 35.8 | 12.8 | 48.6 |
| ***Total*** | ***79.8*** | ***38.7*** | ***118.5*** | ***19.4*** | ***137.9*** |
| *% with College Degree* | *25.6%* | | *30.2%* | | *35.2%* |

## Figure 3
### Percentage Distribution of Education Among 30-Year-Olds by Year



All surveys of current trends reveal a declining relative interest in science and engineering among American students. This is sadly significant in a world where secular trends seem to be indicating the continuing need and importance of these skills for the future.

In part, this has been masked by a contemporary glut of well-educated people on the job market—a phenomenon arising from the epidemic of corporate restructuring that began in the mid-1980s, as well as by record or near-record production in some graduate programs. The trend also has been concealed by a ready availability of talent from outside the United States—particularly from Asia. However, no glut lasts forever. The job market circumstances that have produced the current "buyer's market" will shift with the inevitable realignment of forces that always comes in a system of free competition. In addition, as Asian economies develop, the supply of young scientists and engineers from countries such as China and India will sharply decline. All of this points to a potential squeeze on American science, government, and industry—a squeeze that may well manifest sooner than many would imagine. Many American companies who assume that the current patterns of labor availability will be permanent, and who thus have failed to develop any kind of long-term human capital development policies, are likely to find themselves in dire straits as the supply of talented and educated labor, now taken for granted, dwindles.

In a society growing increasingly more complicated, the failure to attract more women and minorities into science and engineering is intensely important. This failure comes from many factors. First, many minority students do not have the type of familial support for pursuit of science and engineering education—or any kind of education—that many Caucasians can take for granted. Such students also must compete in an environment informed by and structured around systems of standardized testing that are of limited predictive ability. Although it is true that a certain threshold phenomenon does occur—that is that below roughly 1000 the SATs are a good measure of performance, whereas above that number they are not—the current social and educational practice of stressing every difference in standardized test scores as significant operates to the detriment of many minorities. As Richard Tapia has observed, "we value what we measure because we cannot measure what we value."[44]

To make matters worse, science and mathematics are considered extremely difficult by most students and parents—an attitude encouraged by certain historical developments in the sciences themselves, which have come to value their reputation for rigor and to enforce that reputation with ritualistic exercises such as the culling of the freshmen. It can be shown, for instance, that science departments "wash out" an equal proportion of prospective freshmen majors (about one third) at all institutions on all levels. Thus Ivy League schools discourage many potential science majors that other colleges might be ecstatic to have.[45] This overall attitude makes it difficult to engage in long-term discussions of the science and engineering workforce, as the academic system in some ways works deliberately against expansion.

Science classrooms may also be a difficult milieu for women, whose entry into the workforce since the 1950s has stimulated a very large percentage of American economic growth. Science education is very much based on the idea of the ordeal. That is, a new student is placed in a difficult situation (for instance, an introductory chemistry class) with little guidance or support. If he or she performs adequately, the reward is entry into a kind of guild system where support and personal camaraderie are available. Although males tend to work well in such environments—and even find them stimulating—women very often become baffled, confused, and frustrated by what they see as irrational refusal to grant the help and support they need in the early stages of their education.[46]

### B. The Loss of History

Research and development is, inherently, a diffi-

44 Richard Tapia, Professor of Computational and Applied Mathematics, Rice University. 6 May 2002.

45 Elaine Seymour, Director of Ethnography and Evaluation Research for the Bureau of Sociological Research at the University of Colorado. 6 May 2002.

46 Ibid.

cult activity to manage. Its very nature means that R&D is an open-ended activity with difficult-to-predict outcomes and inherently unstable schedules and timelines. This is perhaps particularly true with regard to the kind of high-technology research and development involved in the American aerospace enterprise in general and space initiatives in particular. The goals are complex, the work is difficult, and the people involved are extremely bright and energetic (and thus neither predictable nor always easy to guide).[47]

In addition to this normal level of difficulty in management of engineering research and development, however, modern trends in project organization have raised particular long-term problems. The "classic" form of project organization in the aerospace sector involved a point locus for most engineering functions known, at least colloquially, as "central engineering."[48] This centralized locus contained divisions and offices associated with the various aerospace engineering tasks, thus a "wing office," a "propulsion office," and so forth. The engineers associated semipermanently with these offices would work on multiple projects, having responsibility for a particular engineering function. In other words, the "wing office" would work on the wings for all ongoing development projects, while the "propulsion office" worked on all engines and the "electronics office" on all cockpits.

This kind of organization, while relatively clear and in some ways intuitive, could pose horrific difficulties for a project manager. Attempting to shepherd through a particular launch vehicle or airframe, the manager had to work with multiple offices in central engineering, each with its own lore, procedures, and traditions, each with a certain jealously guarded territory. In the late '70s and early '80s, there was a large move away from such organization, led in part by the project-oriented practices adopted with regard to the space shuttle.[49] The result, in some areas, was the creation of integrated product teams (IPTs). An IPT, or other project-oriented team, consisted of a body of persons dedicated to a particular project and working exclusively on that project. In theory, the IPT approach would allow for greater coordination, control, and flexibility and thus increase efficiency. "Central engineering" was vastly downscaled and relegated to the role of providing advisory expertise on particular well-defined issues.

Although this approach did indeed improve coordination on particular projects, over the mid and long term it has proved to engender many complications. In particular, with the loss of an active, involved central engineering, the historical knowledge base of corporations has been greatly diminished. Project teams are ephemeral bodies, arising and dispersing with particular projects. The experience gained in solving a given set of problems is no longer resident in a permanent office. Instead it exists only with individuals, who often are not available or cognizant when similar problems arise with other projects. Thus, industry spends a large amount of time and money "re-inventing the wheel" as project teams grapple with difficulties that were, unbeknownst to the individuals involved, already addressed in another project. The remaining central engineering advisory offices might, in theory, provide such historical knowledge. However, memory adheres primarily in the context of active involvement and responsibility. As modern engineering advisory offices have little active involvement and no real responsibility, such knowledge does not automatically collect. Also, corporations, unlike many government and military units, have no historical offices or archival professionals dedicated to the preservation and analysis of such knowledge, nor do modern academic institutions support historians devoted to such studies. As a result, the waste of resources is considerable.[50]

This loss of historical memory is part of a general degenerative phenomenon quite apparent in many areas of American industry. Whether one is talking about aerospace or retail or energy, fluidity of structure and rapid turnover of personnel have come to dominate the private sector. Entire companies restructure themselves regularly, and specific projects rise and depart in a kind of perpetual motion. Without reliable application of the histori-

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47 George Jeffs, 6 May 2002.
48 Ibid.
49 Ibid.
50 Ibid.

an's craft, without a memory, companies constantly find themselves entangled in a quagmire of issues not foreseen because not remembered. George Santayana said that those who do not remember the past are condemned to repeat it. This is not only illogical; it is also spectacularly unprofitable.

### C. Astronauts and Operators to the Fore

Any new space initiatives will be, by their very nature, large-scale engineering undertakings. In order to succeed, it will be necessary to keep engineering in the forefront of planning, manufacture, and operations.[51] Whereas once one could rely on the structures of central engineering to provide the necessary historical memory, accountability, visibility, and prestige, in an age of project teams the creation of these properties is increasingly problematic.

However, engineers are not the only crucial actors that need to be included in the forefront of space activities. Without doubt, the heart and spirit of the American space enterprise rests in the manned spaceflight program. The actual space exploration professionals—the astronauts and operations teams—also have unique responsibilities, accountabilities, and talents that must be recognized and institutionalized. In particular, the inclusion of astronauts and operators on teams of scientists, engineers, and planners involved in charting the course of space missions is a key component of a successful space initiative.[52]

The integration of astronauts and operators into planning, research, and development activities poses many challenges. In the financially strapped atmosphere of the modern aerospace enterprise, there are many pressures to eliminate human participation at as many points in a given process as possible. It is a truism of management that the most expensive part of any activity is people, and it is not surprising that in a plethora of areas ranging from technological design to contingency modeling to mission planning there is great temptation to eliminate or at least greatly de-emphasize costly human-in-the-loop testing. However, given that space is a unique environment in which particular humans will have to make decisions in response to factors rarely or never encountered, such pruning on the initial stages of any initiative poses grave dangers for both crew safety and mission success.

These problems multiply given that any new space initiative, particularly one that involves extended human habitation in a space environment, will mean that many activities now located on the surface will have to be conducted in situ. Therefore, there will have to be a significant development of manufacture-in-place, assemble-in-place, and repair-in-place technologies. Management procedures for these activities must be devised, which raises important questions as to which interests will be represented. It is important that both engineering and astronautics be kept in the forefront if there is to be success in these areas.

In addressing these problems, many economic realities will have to be taken into account. Given the general dearth of funds and the undeniable truth that the use of humans is very expensive, it is likely that any future space initiative will have to feature very careful planning with regard to human involvement. That is, humans must be used for those activities that require humans. Tasks that can be relegated safely and efficiently to robots, automated equipment, and unmanned launch vehicles should be so relegated.[53] It is also the case that the expense of human involvement leads naturally toward a vision of small, tightly integrated teams as opposed to large operations involving large staffs.[54] However, this approach, while conserving resources and providing flexibility and integration, risks the same problems with historical data and accountability that plague project teams.

In conclusion, many activities in the aerospace enterprise require that particular human talents and practices, particularly those of the engineer and astronaut, be kept at the fore. However, the tight funding environment exerts tremendous pressures to minimize costly human involvement in many areas. In addition, the move away from large centralized organizations toward tightly focused integrated teams, while having many advantages for

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51 Ibid.
52 William Shepherd, former astronaut. 6 May 2002.
53 Ibid.
54 Ibid.

project management, ultimately undermines the historical memory and accountability on which the health of any ongoing initiative depends.

## IV. The Long Road to the Future

Future activity aimed at a revitalization of the space program in America and the world must focus on the areas outlined above. Specifically:

- Advocates of space activity must become more comfortable with the daily practice of modern politics, including the need to explain their proposals to ever more diverse audiences.
- The organization of space activity in both the government and private sector must be rethought and rationalized with regard to efficiency at achieving long-term sustainable goals.
- The crisis of human capital must be headed off before it becomes a catastrophe, while space science and industry must take steps to appeal to an ever-widening and more diverse constituency.
- Any future space activity will be, in the nature of things, more likely to show international cooperation. We must think about the ramifications of this and examine many of our policies (e.g., export control laws) in this light.
- Memory, in the form of history, must be preserved, treasured, and learned from in a variety of environments.

First of all, the space program is poorly understood by political and economic leaders and the general public. Indeed, much of the interest among the general population in space is largely colored by science-fiction images such as those from *Star Trek*. Although the positive effects of science fiction in engendering interest in space and science must never be underestimated, it is true that this medium—designed after all to entertain and not to educate—does not convey the best information concerning space and space activities to the public. Science fiction paints space as an arena for adventure, excitement, and wonder, which is an admirable function. However, neither science fiction nor the popular science press adequately expresses the importance of space in terms of national security, commerce, science, and engineering.[55]

The task before advocates of space activity is enormous. We must plunge into the daily grind of politics with much more sophistication and understanding than we have in the past. We must be prepared to argue our case in a reasoned, respectful way against widely varying individuals and groups who honestly do not understand how investment in space is going to help the country or the world. A new emphasis is required of public speaking and writing for a variety of audiences. Advocates of space must rethink priorities in order to bring the skills of the journalist, the historian, and the media developer into clearer perspective, and advocates must learn to respect these skills in addition to those of the engineer, the physicist, and the planetologist.

The immense crisis in the nation's educational system must be addressed. A curious aspect of this crisis is the refusal to apply well-studied and scientifically proved models of education.[56] Engineers who would not even dream of approaching a critical technical problem without knowing the latest research seem to regard matters of human capital development as mysterious and unmanageable. There must be a new push for educational funding linked with strong demands that education be conducted in a scientific and well-researched manner. This must all be done with sensitivity for the growing diversity in the classroom. Such institutions as the University of Texas at El Paso are offering new insights into ways of improving education in a multicultural environment.

Both government and business must rethink their current practices with regard to space, space science, and space operations. Government must not only regularize funding, it must also reorient the priority it gives to space-related matters in its all-important organizational structure. Business must

[55] Al Smith, Executive Vice President, Lockheed Martin Space Systems Company. 6 May 2002.

[56] Ray Marshall and Elaine Seymour, 6 May 2002.

abandon many practices that might bring short-term profits and ease of control, but which undermine long-term goods. For instance, the practice of treating research and development as a profit center to be isolated from other company activities must be abandoned.

Finally, a new respect for history and memory must become the hallmark of space advocacy and activity. Without such an understanding of the past, any activity will have a tendency to behave in predictable, self-defeating, and ultimately futile ways. Only by understanding what has come before can the future be crafted. Only by knowing yesterday's mistakes can we build tomorrow's triumphs. Only by standing on the solid bedrock of the past can we launch into the vast reaches of the future.

*Dr. Robert Oliver, formerly of Rice University and now with the Air Force Research Laboratory, was the lead writer of this report. He was aided by the additional work of Dr. Paul Jeffries, formerly of Rice University, and Dr. Carolyn Sumners, adjunct professor at Rice University and director of the Houston Museum of Natural Science.*

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