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Emerging Aerospace Technologies

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SUMMARY

The Federal Government has a long history of promoting the advancement of technology to strengthen our economy and national defense. An example success story is NASA, which was formed in 1958 to establish and maintain United States space technology leadership. This leadership has resulted in technological benefits to many fields and the establishment of new commercial industries, such as satellite communications.

Currently, NASA's leading-edge technology development at Ames Research Center includes the Tilt Rotor XV-15, which provides the versatility of a helicopter with the speed of a turboprop aircraft; the Numerical Aerodynamic Simulator, which is pushing the state of the art in advanced computational mathematics and computer simulation; and the Advanced Automation and Robotics programs, which will improve all areas of space development as well as life on Earth.

One way private industry is involved in maintaining technology leadership is through NASA's Commercial Use of Space Program, which provides for synergistic relationships among government, industry, and academia. President Reagan's mandate of a civil space station by 1992 frames much of NASA's future goals and provides new areas of opportunity for both scientific and commercial endeavors. NASA's multi-faceted programs ensure both domestic space technology leadership and a resulting better life on Earth.

INTRODUCTION

The Federal Government has a long and successful history of technology venturing[1] to expand and strengthen the national economy and defense. Publicly funded programs were established to support development of energy, transportation, health care, and communications systems. This partnership of government and industry contributed significantly to the quality of life we enjoy today.

NASA was formed in 1958 with the goal of establishing and maintaining United States space technology leadership. The pursuit of this leadership role spawns innumerable technological spinoffs, spanning a broad range of public needs and conveniences. NASA transfers technology to the fields of medicine, public safety, transportation, industrial processes, and many others.

The best known commercial industry initiated as a result of NASA technology is satellite communications. Two decades ago, NASA pioneered the technology that enabled operation of satellites in geostationary orbit, thereby building the foundation for the space communication network that followed. Satellite communications now capture two-thirds of all long-distance communications, and represent 10% of the total communications market, with an estimated value of 3 billion dollars a year.

The satellite communication industry represents just one application of the many technologies that NASA currently researches. More information on the benefits to the public resulting from NASA-developed technology can be found in the annual publication, Spinoff.[2]

Here, we review three leading-edge technologies or technology areas under development at the Ames Research Center with potential future commercial application. These include the Tilt Rotor XV-15, the Numerical Aerodynamic Simulator, and the Advanced Automation and Robotics programs. Thereafter, we describe NASA's efforts leading to the Commercial Use of Space and the Space Station Programs.

TILT ROTOR XV-15

One of the new aircraft system concepts demonstrated by Ames, and the basis of the military's JVX Program, is the Tilt Rotor XV-15, shown in figure 1. The Tilt Rotor takes off and lands like a conventional helicopter. However, it flies horizontally like a turboprop aircraft at twice the speed of a conventional helicopter. Other advantages include reduced operating costs, lower fuel consumption, longer range, and lower vibration levels.

Potential civil sector markets are expected to develop after the initial federal investment. Ultimately, this technology could open up new areas of the wilderness to transportation. For example, it could be useful in servicing remote areas in Alaska, where runway access is difficult and snowplowing a runway is prohibitively expensive. It also would increase flight safety, replacing conventional aircraft now landing on dry creek beds or meadows.

The Tilt Rotor concept also would be useful for short-distance business travel. The Federal Aviation Administration projects that by 1990, 23 air carrier airports will be experiencing severe congestion. By the year 2000, that number is expected to double to 46, and severe congestion is forecasted for another 45 commuter, reliever, and general aviation airports.[3] With its ability to take off and land like a helicopter and fly horizontally with turboprop speed, the Tilt Rotor will cut the time now spent for short- to medium-range business travel and relieve some of the stress on the nation's air transportation system.

NUMERICAL AERODYNAMIC SIMULATION (NAS)

The numerical aerodynamic simulation system (NAS), one of NASA's major aeronautics new starts in the last few years, is designed to support leading-edge research in aerodynamics and other branches of computational physics. The program objectives are to provide a national computational capability that can be used by NASA, DOD, industry, academia, and other government agencies to ensure continuing leadership in computational aerodynamics and related disciplines. A secondary objective is to act as a pathfinder in supercomputer system technology. That is, advances in computer system hardware and software technology resulting from the NAS effort will be incorporated in other supercomputer systems at universities, in industry, and at other government laboratories. For example, the NAS system will be the first totally unix-based supercomputer system in the country. From the work station to the high-speed processors (supercomputers), the user will see a common interface. The obvious advantage is that a user learns only one set of protocols to operate throughout the entire system.

The initial operating configuration is scheduled for late 1986. The extended operating configuration, shown in figure 2, includes satellite and landline communication for efficient remote access, and is scheduled for 1988.

The initial high-speed processor will be the Cray II computer, expected to be delivered to Ames in September 1985. The Cray II is substantially more powerful than existing supercomputers and will have 100 times more core storage than the Cray X-MP currently operating at NASA Ames. With 256 million words of core storage and four processors, the Cray II system will open up new frontiers in computational aerodynamics and other computationally based sciences.

The introduction of high-speed computers substantially enhanced the aircraft design process in the last decade. There are a number of factors contributing to this remarkable progress. One motivating factor is the increasing cost of wind tunnel testing for the development of today's complex aircraft systems. Figure 3 shows the wind tunnel test hours required to develop various aircraft and the year they were developed. For example, the Wright flier required 50 hours of test time in the simple wind tunnel developed by the Wright brothers around the turn of the century. Today, 50,000 hours of wind tunnel test time, costing several hundred million dollars, were required for the development of the Space Shuttle Orbiter.

On the other hand, the cost of performing a given computation decreased rapidly over the last few decades due to improvements in computational systems and advances in computational mathematics techniques. In the last 15 years, the cost of performing a given calculation decreased by a factor of about 100 due solely to the introduction of new computer systems.[4] This is illustrated in figure 3. Furthermore, during the same time period, the cost of performing a given calculation decreased by another factor of 100 due to advances in computational mathematics. Hence, the cost of performing a given computation decreased by a combined factor of about 10,000 in that 15-year period. To put this into perspective, consider as a sample problem computing the viscous flow past an airfoil. Today, this computation takes a few minutes on a modern supercomputer and costs about $100. Twenty-five years ago this same computation would have cost between $100 million and $1 billion and would have required 30 years of total computing time to complete. Having submitted the computation for processing 25 years ago, one would still have to wait 5 years to obtain the result!

Cost savings in the design process were realized in a number of development projects. For example, Grumman's Gulfstream III aircraft was developed at an estimated savings of $4 million relative to the Gulfstream II.[5] The Gulfstream II required 2,000 wind tunnel test hours and 26 wind tunnel models to finalize the aerodynamic shape. By using advanced computational methods, Grumman reduced wind tunnel test hours for the Gulfstream III to 300 and the number of wind tunnel models to two.

The potential savings from reduced operational costs are even more impressive. Through the use of computational aerodynamics, the Airbus A-310 design is 20% more fuel-efficient than the A-300.[6] If one projects the savings to the customers of Airbus for a fleet of 400 aircraft, each with a 15-year life span and estimated fuel costs of $1.30/gal, the potential savings is on the order of $10 billion. Clearly, the leverage benefits for advanced methodology applied in the design process are significant.

The challenge for the future is to continue to improve the accuracy of computational aerodynamics simulations. Figure 4 shows schematically the combination of both geometrical representation and physical phenomena, such as the treatment of turbulence.

These advances will continue to reduce the uncertainty in the modeling process and alleviate the need for expensive wind-tunnel and flight test-hours. The continuation of this revolution depends directly on continued advances in computer power and computational mathematics.

Advances from the NAS system are likely to benefit a number of other computationally based disciplines, including electronic circuit design, weather and climate modeling, chemistry, astrophysics, human factors, and others. There will be a number of commercial opportunities in the hardware and software required for advanced large-scale computation, as well as in the development of techniques and applications software to solve problems in these discipline areas.

AUTOMATION AND ROBOTICS

Ames Research Center is a focal point for advanced automation and robotics technology research, and is another area from which we expect to reap tremendous benefits. The Center's interests range from Space Station applications to aeronautics, and from the operation of robots on the Space Station to the pilot "expert system" in the cockpit.

Congress sees the Space Station as an opportunity to develop technology which can serve as a foundation for building future industries in this country. A report to the House Appropriations Committee recommended that 10% of the Space Station budget be invested in automation and robotics technology.[7] If this recommendation is followed, close to one billion dollars could be invested in this new technology area.

In addition, NASA intends to leverage its investment by cooperating with the DOD, academia, and industry. As a broad-based research program, NASA will draw from industry, universities, and advanced technology companies, including those in the Silicon Valley area, near NASA Ames. The goal is to create a technology-wake which will stimulate increased commercial participation.

NASA established objectives to provide direction to the program, starting from near-term anticipated capabilities, such as the use of a single arm remote manipulator for module replacement on spacecraft. Figure 5 shows some of the more complicated ventures which will follow. Eventually, robots will be able to locate a spacecraft, dock with it, and perform the diagnostic tests and servicing required.

There are a number of potential commercial applications for intelligent robots. In manufacturing, these include welding, machining, painting, molding, assembling, and inspecting. In light industry, potential commercial applications include repair, packing and loading, and handling of hazardous materials. There are also potential applications in health care. Specifically, significant advances in providing care for the elderly and the disabled can be anticipated.

COMMERCIAL USE OF SPACE

The commercial use of space is yet another new high-technology venture for NASA. On July 4, 1982, President Reagan said, "the United States Government will provide a climate conducive to expanded private sector investment and involvement in civil space activities."[8] Congress followed the President's initiative by amending the National Aeronautics and Space Act, directing NASA "...to seek and encourage to the maximum extent possible, the fullest commercial use of space."[9]

Gravity is an inescapable quality of life on Earth and affects nearly every known physical and biological process. In space, however, the gravity-induced effects of buoyancy, convection, sedimentation, and hydrostatic pressure are absent, and the fundamental behaviors of the processes are changed. As a result, materials can be manufactured in space that cannot be produced in the 1-G environment. Materials of higher purity and in greater quantities also can be produced.

Already many extremely promising ventures are under way. For example, McDonnell Douglas and Johnson & Johnson have teamed in the Electrophoresis in Space Program to develop new and improved life-saving drugs. Electrophoresis is a process that separates materials electrically. In the absence of gravity, McDonnell Douglas proved that 700 times more material can be processed at four times the purity level of comparable Earth-based separation techniques. Following full-sized processing unit testing, and pending Federal Drug Administration approval, new space-based pharmaceuticals should be available in 1988. Drugs that provide improved cancer treatments and a possible cure for diabetes are identified as likely candidates.

Other companies are quickly following suit. Among them are John Deere, the agricultural manufacturing firm, and 3M, the giant material and chemicals firm.

Both have agreements with NASA to fly experiments on the Shuttle aimed at developing new materials in space or improving Earth-based manufacturing techniques from what can be learned in space.

The Center for Space Policy's revised estimate projects annual revenues of as much as 51 billion dollars from space products and services by the year 2000.

Activities	Cost, billions of $	
	Low scenario	High scenario
Communications	8.8	15.3
MPS	2.6	17.9
Remote-sensing	.5	2.5
On-orbit services	.6	2.8
Space transportation	.2	2.4
Ground-based services	4.1	10.4
Total revenue	16.8	51.3

NASA expects to contribute to the development of this market by forging partnerships with industry at the leading edge of technology. In order to facilitate private sector investment and involvement in the commercial use of space, NASA has developed three basic levels of working relationships: Joint Endeavor Agreements (JEA), Technical Exchange Agreements (TEA), and the Industrial Guest Investigator (IGI) Agreements. These agreements provide the flexibility necessary to meet a wide range of needs, from large organizations with strong research departments to small entrepreneurial firms that seek to develop a specific product for the market. They also provide for incremental increases in understanding and commitment by the parties involved. The government does not fund work done by the firm in any of the three agreements, but rather each party funds its own activities separately.

The goal of a JEA is to encourage early space ventures and demonstrate the use of space technology to meet marketing needs. A JEA is a legal agreement between equal participants whereby a business and NASA share common program objectives, program responsibilities, and financial risk. It is not a procurement action; no funds are exchanged between NASA and the industrial partner.

A private participant selects an experiment, technology demonstration, or both, for a joint endeavor that complies with program objectives. The private participant then conducts the necessary ground investigation and develops flight hardware at company expense. As an incentive for this investment, NASA agrees to provide free Shuttle flights for projects that meet certain basic criteria, such as technical merit, innovation, and acceptable business arrangements.

Allowing the participant to retain certain exclusive rights in inventions, patents, and proprietary information resulting from its activities under the JEA to protect its investment in the subsequent marketing of products developed from the experimental results is a further incentive. However, NASA receives sufficient data to evaluate the significance of the results, and requires that any promising technologies be applied commercially on a timely basis.

NASA developed the TEA for companies that were interested in applying microgravity or other technology, but were not ready to commit to a specific spaceflight experiment or venture. Under a TEA, NASA and a company agree to exchange technical information and cooperate in the conduct and analysis of ground-based research programs. A TEA allows a firm to become familiar with space technology and its applicability to the company product line at minimal expense. The company agrees to fund its own participation and obtains direct access to NASA facilities and research. NASA benefits by gaining the support and expertise of the private company's industrial research capability.

In an IGI agreement, a company arranges for one of its scientists to collaborate (at company expense) with a NASA-sponsored principal investigator on a spaceflight experiment after determining that NASA and the company share sufficient mutual scientific interest. Once the parties agree to the contribution to be made to the objectives of the experiment, the IGI becomes a member of the investigation team, thus adding industrial expertise and insight to the experiment.

Currently NASA has JEAs, TEAs and IGIs with several firms interested in the commercial use of space. A few of these agreements are listed in figure 6. The government does not fund any of the work done by the firm, but rather each party funds its own activity separately.

Significant opportunities exist for commercial space endeavors to benefit the nation. Commercialization offers the potential for new industries, new jobs, lower product costs, and an improved balance of trade. In addition, technological advances from the commercial use of space could help conquer diseases, produce faster and smarter computers, develop lighter and stronger metals, increase communications and information availability, and enhance our understanding of our environment and its resources.

The entrance of free enterprise into space is simply a continuation of our national tradition, for private initiative has been the foundation of our nation's development and progress from the beginning. This innovation clearly continues. Like the pioneers and settlers before them, we will soon see entrepreneurs following our astronauts into the newly accessible realm of space.

SPACE STATION

A major segment of the future United States civil space program will be structured around the Space Station. The President supports the Space Station program very strongly. In his January 1984 State of the Union Address, he said:

> We can follow our dreams to distant stars, living and working in space for peaceful, economic, and scientific gain. Tonight I am directing NASA to develop a permanently manned space station and to do it within a decade. The space station will permit quantum leaps in our research in science, communications, and in metals and life-saving medicines which can be manufactured only in space.[10]

The Space Station will serve as an orbiting laboratory, and assembly and service center, as well as a manufacturing site and observation platform. As a result, broad new areas of opportunity will be opened for both scientific and commercial endeavors. Its contribution to mankind's knowledge and well-being will range from new methods of producing rare substances to a vastly increased understanding of the origins of the universe. In addition, the Space Station will provide the foundation for free world leadership in space for the 1900s and beyond.

The Space Station is the next logical step in the methodical and orderly progress of the United States Space Program. By pursuing the development of the Space Station now, the United States is assured a position of strength in the international competition for the commercial, technological, and scientific gains that space brings.

CONCLUSION

The Federal Government has a long history of technology venturing. For the last 26 years, NASA has been at the leading-edge of federally sponsored efforts in the areas of aeronautics and space technology. As a result, the United States is established as the world leader in aerospace technology.

The Ames Research Center is continuing the tradition of technology venturing in the areas of aeronautics and space technology with such programs as the Tilt Rotor XV-15, the Numerical Aerodynamic Simulator, and Advanced Automation and Robotics. In addition, our support for the NASA efforts in the Commercial Use of Space and the Space Station Programs show enormous potential for stimulating new technology venturing opportunities.

NOTES

[1]The term "technology venturing" embraces the concept of combining public and private sector initiatives in a variety of collaborative approaches to transfer and commercialize United States technology. This paper was first presented at a conference entitled, "Technology Venturing: Making and Securing the Future," Pepperdine University, Malibu, California, May 19-21, 1985.

[2]For additional information write to: Director, Technology Utilization, Office of Commercial Programs, Washington, DC 20546 (202)453-8722.

[3]27th Annual Air Traffic Control Assn. Fall Conference Proceedings (Arlington, VA: Air Traffic Control Assn.), 1985, p. 88.

[4]Future Computer Requirements for Computational Aerodynamics (Moffett Field, CA: NASA Conference Proceedings), October 4-6, 1977, p.4.

[5]Computational Fluid Dynamics in Aerospace Design (Tullahoma, TN: University of Tennessee Space Institute Workshop), June 4-6, 1985, p.4.0.

[6]Interpolated from performance figures in Aircraft Forecast: Military and Civil (Ridgefield, CT: Forecast Associates), 1985.

[7]Public Law 98-371 of the 98th Congress, dated July 18, 1984, National Aeronautics and Space Administration Research and Development, 98 Stat. 1227, Research and Program Management Report.

[8]White House Fact Sheet, National Space Policy, July 4, 1982.

[9]Fiscal Year 1985 Amendment to the 1958 NASA Space Act as agreed by the House and Senate.

[10]President Reagan's State of the Union Address, delivered January 25, 1984.

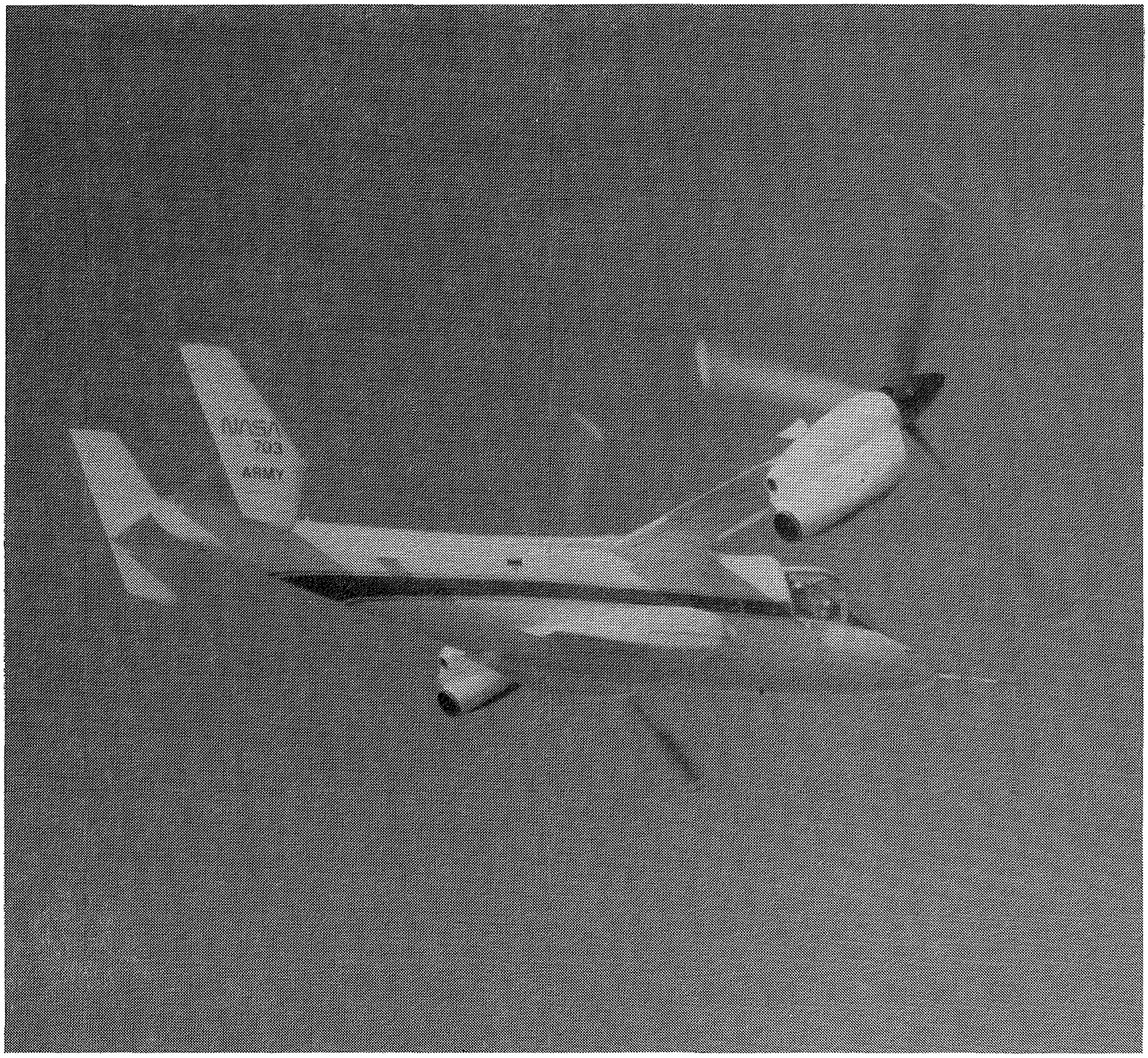

Figure 1.- Tilt-Rotor (XV-15) in transition from vertical takeoff to horizontal flight.

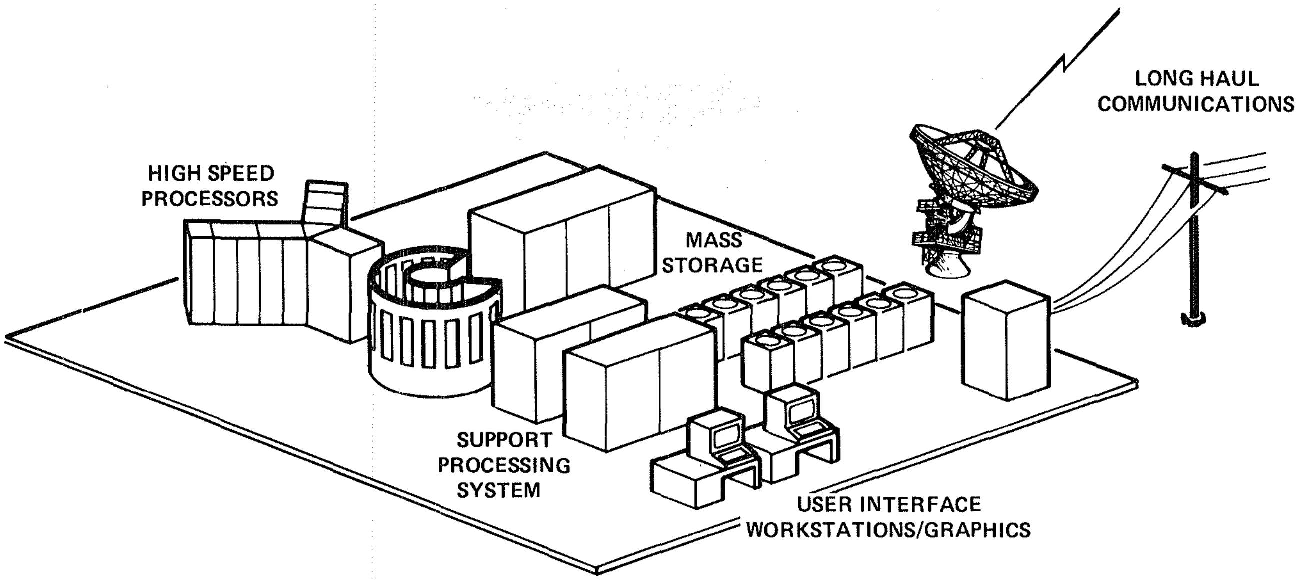

Figure 2.- Numerical aerodynamic simulation processing system network.

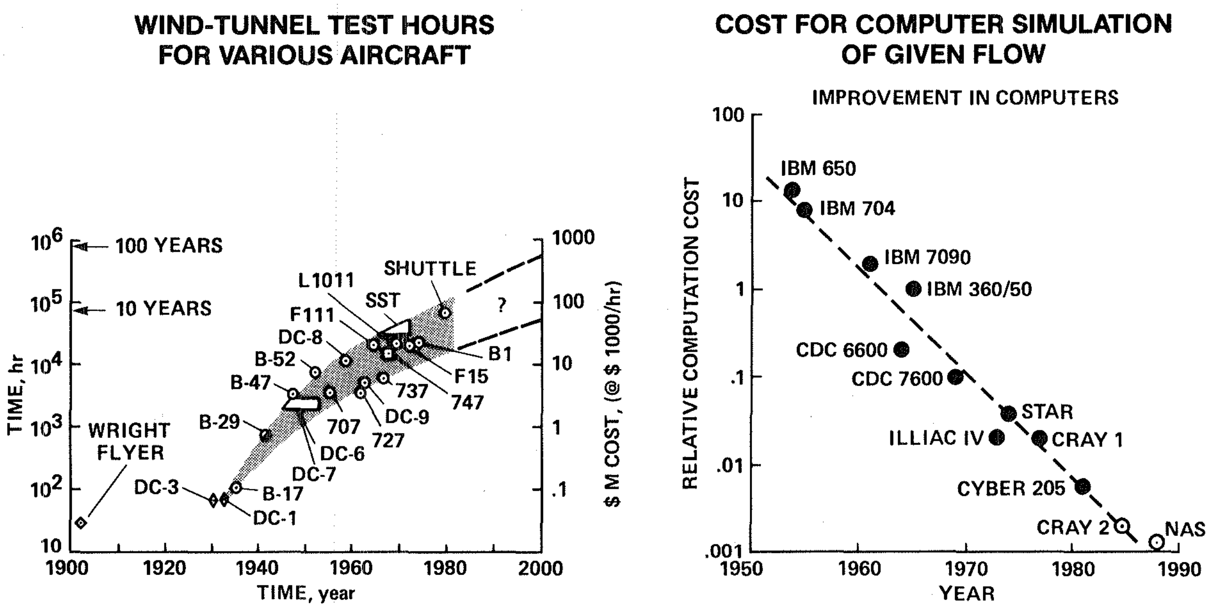

Figure 3.- Trends for wind-tunnel usage and cost of computer simulation.

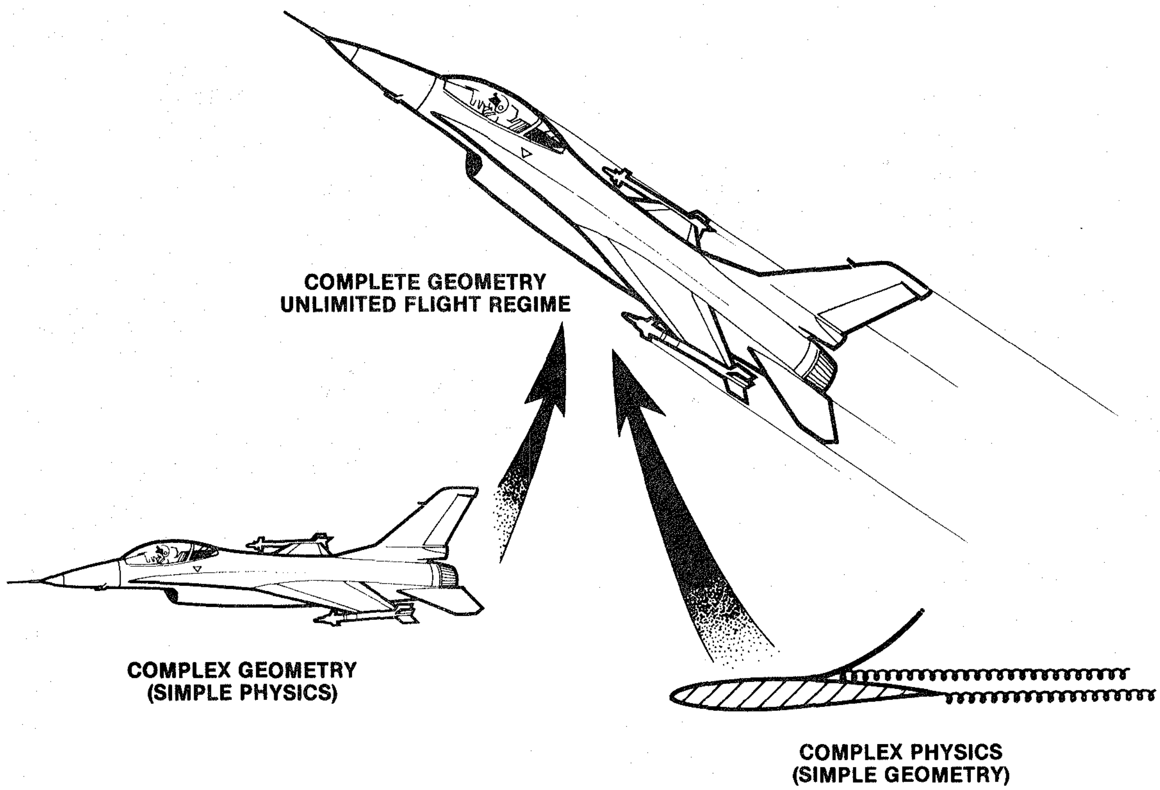

Figure 4.- Future requirement (combine complex physics with complex geometries).

TARGET CAPABILITIES

1987 – ONE-ARM REMOTE MANIPULATOR FOR SIMPLE MODULE REPLACEMENT

1989 – TWO-ARM TELEOPERATOR FOR MORE COMPLEX MODULE REPLACEMENT USING SIMPLE SUPERVISORY CONTROL COMMANDS

1991 – MODULE CHANGEOUT VIA AUTONOMOUS LOW LEVEL PLAN GENERATION AND SUPERVISED EXECUTION; ENHANCED DEXTERITY, SENSING, INTELLIGENCE

1996 – TELEROBOT FOR ST-TYPE SERVICING WITH HIGH LEVEL PLAN GENERATION AND AUTOMATED ERROR RECOVERY

2000 – COOPERATING TELEROBOTS FOR REPAIR BASED ON AUTONOMOUS PLAN GENERATION

Figure 5.- Telerobotics program.

COMPANY	VENTURE
MDAC	ELECTROPHORESIS OPERATIONS IN SPACE
MICROGRAVITY RESEARCH ASSOCIATES	MPS EXPERIMENTS
3M (2 YEAR)	RESEARCH IN ORGANIC AND POLYMER CHEMISTRY
MARTIN MARIETTA CORP.	RESEARCH-EVALUATION OF FLUID DYNAMICS DATA AT ZERO-G
ORBITAL SCIENCES CORP.	TOS UPPER STAGE
FAIRCHILD	DEVELOPMENT OF FREE-FLYING PLATFORM
SPACECO LTD	INSTRUMENTATION FOR MEASUREMENT OF PAYLOAD ENVIRONMENT
TRANSPACE CARRIERS	COMMERCIALIZATION OF DELTA ELV

Figure 6.- Signed agreements.

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