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STRATEGY FOR SPACE SCIENCE AND TECHNOLOGY

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Abstract—Historic changes have occurred in the world in the past few years. In the United States the Administration focused its agenda on improving the. economy, and emphasis has been placed on federating the development of civilian technologies to help create new products and services that will stimulate economic growth. Partnerships between Government and Industry are viewed as a catalyst for this process

Space Science faces many challenges. The most significant of these is to succeed in utilizing new technologies to achieve space science goals with smaller, shorter, and less expensive missions, while providing tangible returns to the economy. Last year the NASA Office of Space Science has developed the Integrated Technology Strategy to meet this challenge

The Strategy represents a substantial reorientation of the priorities of the Office of Space Science. Its successful implementation will result in the continued commitment– by everyone in the space science community—to develop, utilize, and transfer technologies that provide the Nation with scientific and economic returns that are globally competitive. The challenge is to continue to achieve scientific excellence in a new way: through new, advanced technology that also yields potential benefits for commercial uses. Thus, space science programs, while always designed to accomplish the objectives of the space science community, must also recognize—as a customer-the American public, who anticipates economic returns through technology transfer to the private sector.

INTRODUCTION

In April 1994 the NASA Office of Space Science (OSS), together with the Office of Advanced Concepts and Technology (OACT), issued the Integrated Technology Strategy (Huntress and Reck, 1994). It is a new component of the strategic plan for space science which is now prepared in three volumes. The Integrated Technology Strategy ("Strategy" in this paper) is followed by the Scientific Strategic Plan -- to be released in October 1994 – and by an Education Plan that will be published later in 1995.

The Strategy represents a marked departure from the past in the posture of United States space science, which has reoriented itself from a risk–averse technology user to an aggressive [ethnology' developer and co-developer -- in joint endeavors with other NASA offices, with universities and with industry.

The Strategy is both a response to dramatically changing external circumstances, as described in the following section, and an autochthonous thrust to renew the space science community by offering new perspectives and new opportunities.

CHANGING ENVIRONMENT FOR SPACE SCIENCE

The late 80's and early 90's were a period of great growth for NASA: its yearly budgets about doubled in half a dozen years and space science grew apace receiving a constant share of the total. This both required and induced the formulation of ever more ambitious and richer programs to justify and take advantage of the budgets available.

The beginning of a vicious cycle set in: the apparent exhaustion of the set of easily reachable scientific targets led to missions that were larger, more complex. of longer

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duration, and less frequent, to the point where each one might be viewed by scientists as "the opportunity of a lifetime." This was a strong incentive for further increases of the payload, of the complexity, and rarity of the project. The consequences of a mission failure were often catastrophic.

The new international climate and the reduction of emphasis on defense and national prestige in favor of economic competitiveness of the last couple of years brought two related changes: the disappearance of "double digit" growth for NASA -- perhaps the onset of declining budgets — and the requirement imposed by the new '92 Administration (Clinton and Gore, 1993) that all Federal R&D programs be evaluated according to the Administration goals of: long term economic growth, a government more productive an responsive to citizens' needs, and world leadership in science, mathematics and engineering.

The changes have been swift and required short term actions: they have been accommodated by large scale structuring - and sometimes cancellation — of many programs. These actions alone, however, would relegate space science to fewer missions yet and directed at mundane objectives.

The aggressive use of advanced technology was recognized as the potential solution that might simultaneously reduce the size and cost of space science missions and provide another, more tangible, measure of their value — in addition to the cultural and motivational ones we are familiar with.

Advanced technology — specifically: extreme miniaturization and ultimately the *spacecraft-on-a-chip* prospected by modern electronics and microfabrication — could dramatically reduce the cost of missions, increase the number that would fit in a fixed budget, while still permitting exciting scientific projects and perhaps enabling entirely new mission concepts. All the while terrestrial applications of technology advances driven by space science could result in new products for the marketplace and ultimately new jobs and economic growth. Concern of greater risk always accompanies the application of new technologies unless a pathway is carefully crafted for its controlled insertion into flight missions

Thus a strategy was needed for marshaling the technical resources of the Agency, orienting them toward revolutionary solutions for space science with a view towards terrestrial applications, while managing the risk of this approach.

STRATEGY

The strategy is articulated through the *vision* statement; the four *goals* and associated *strategic objectives*; the *policy* statement, the *implementation process*, and the *metrics*.

Development of the Strategy

The Strategy was formulated in the Summer of 1993 by a Process Action Team representing the involved offices, divisions, and centers. In the preparatory phase, the team examined the legislative framework within which OSS operates (from the National Aeronautics and Space Act of 1958 to the Directive on National Space Policy of 1989 and the 1993 report on "Technology for America's Economic Growth); reviewed studies performed by the National Research Council (NRC, 1993) and by internal NASA teams (Creedon, 1992 and Littles, 1992). The National Research Council and the internal teams found that NASA does not function as an integrated system in identifying, developing, and inserting technologies into its space programs: that better mechanisms were needed to ensure infusion of OACT developed technologies into space science missions: and that the activities associated with transferring NASA technology to its target customers are riot supported by many of the formal processes in NASA's infrastructure.

The Process Action Team – continuing the preparation — identified OSS's principal stakeholders (Figure 1) and evaluated the relationship with them by analyzing: how the stakeholder influences OSS: what OSS needs from the stakeholder; and the criteria the stakeholder uses to judge OSS's performance.

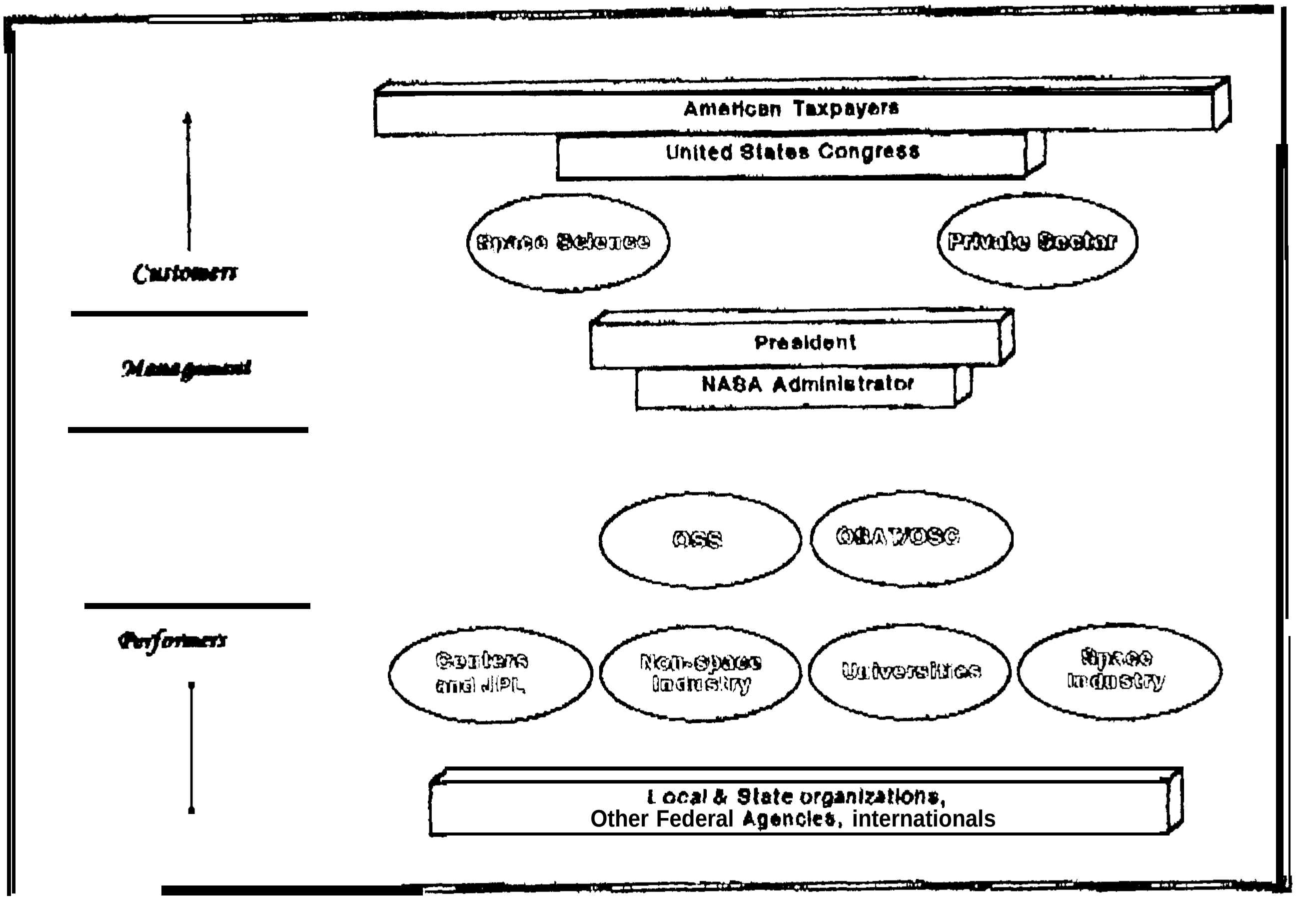

Figure 1. Stakeholders

After formulating the strategic technology *vision* and *goals, the Process* Action Team analyzed the strengths, weaknesses, opportunities, and challenges of OSS's Position in fulfilling them and, from this analysis, derived a set of strategic objectives for each goal. Throughout the task of crafting the strategy periodic briefings were held with representative audiences of key communities to communicate developments and receive recommendations.

Vision

This is a summary of the OSS "vision of success" for its Integrated Technology Strategy:

"The Office of Space Science embodies, at all levels and across all disciplines, a continued commitment to develop, utilize and transfer technologies that provide scientific and globally competitive economic returns to the nation.

"OSS technology policy and guidelines have been clearly communicated to its principal stakeholders and are accepted by them. The responsibilities and processes to identify, develop, infuse and transfer technologies are recogni zeal, supported, and routinely implemented within OSS projects.

"OSS can point to any of its missions and readily identify the many benefits realized as a result of successful advanced technology utilization. Because early attention is paid to technology development and validation, the risk of utilizing new technologies in space science missions is maintained within acceptable limits.

"The science community is profiting from NASA's technology successes. New technologies have enabled bolder scientific investigations and have significantly enhanced the data return from all OSS missions. Scientific breakthroughs are being achieved as a direct result of the OSS's successful commitment to foster new technologies. These technologies have reduced mission costs, making more research opportunities available to the space science community.

Early and continued OSS support for the development and transfer of commercially relevant space technologies to the private sector have resulted in frequent public recognition of NASA's technology transfer successes. As a result, the non-space industry routinely seeks and engages in productive, synergistic enterprises with NASA and its university and space industry partners.

The Agency has reaped the benefits of OSS's successes. Public, administration and congressional support is strong. NASA has become a widely recognized leader in fueling the technological engine that is vital to the nation's economy.

Goals and Strategic Objectives

The four goals of the Integrated Technology Strategy and their associated strategic objectives are:

1 OSS will identify and support the development of promising new technologies which will enable or enhance space science objectives and reduce mission life-cycle costs.

In summary, the associated strategic objectives are to: implement life-cycle cost analysis and — through it -- to determine early in the mission design process, the benefits associated with advanced technologies: establish a process for identifying, prioritizing and communicating technology requirements to technology providers; and to establish and maintain a viable OSS advanced technology development program.

2 OSS will infuse these technologies into space science programs in a manner that is cost effective with acceptable risk.

Project managers and technology providers must agree, at the earliest phase of each study, on the technologies and process for incorporating them into the project. The process must be incorporated into the project development plan so as to control costs and risks of technology infusion,

In summary, the associated strategic objectives are to: contribute to the advancement of technologies for spacecraft, science instruments or ground systems and incorporate them into space science missions: to facilitate and reward successful infusion of technology into OSS projects: to establish mechanisms to retire risk early.

3 OSS will establish technology transfer as an inherent element of the space science project life cycle.

In summary, the associated strategic objectives are to: implement modifications in the language of all OSS solicitations, grants, and contracts: reinforce awareness of technology transfer responsibilities through training, performance evaluation and award structure: utilize routinely NASA's technology transfer infrastructure; and explore the feasibility and potential benefits of issuing separate solicitations for participation in science missions strictly for the purpose of transferring technology to the private sector,

4 OSS will develop strong and lasting implementing partnerships among industry, academia and government to assure the nation reaps maximum scientific and economic benefit from its Space Science Program,

The principal associated strategic objective is to establish a space science partnership initiative which will synergistically address OSS and private sector technology needs and contribute to the achievement of the national goal for DoE, NASA, and DoD of devoting at least 10-20% of the budget to R&D partnerships with industry, Partnership arrangements with the private sector will be encouraged in R&D grants and will be required in selected award fee contracts.

Policy

The commitment of the Office of Space Science to: advancing technology, seeking aggressively new techniques and new approaches for its missions, and achieving the four goals and their associated strategic objectives is expressed in the central policy statement established by the Integrated Technology Strategy.

Policy: "Each OSS mission will contribute to the advancement of space flight technologies, science instrument technologies or ground systems technologies to ensure that new technologies continue to become available for use on future missions".

Implementation Process

The Strategy defines in detail the steps for its execution, Key elements of the implementation process — in addition to the responsibilities of the various organizations — arc: the approach to risk reduction, the new function of Project 'f'ethnologist, and the Technology Advisory Panel.

Risk reduction

There is a common view that advanced technology implies greater risk: wc believe that this view is incorrect and that risk, and the costs associated with it. can be controlled through extensive testing during the development of the technology. To accomplish this a pathway must be charted from the research bench to the flight application. The Office of Space Science — in collaboration with the Office of Advanced Concepts and Technology (now Office of Space Access and Technology} – has identified three steps: redirecting the applied research phase, establishing flight system testbeds, and creating opportunities for flight demonstrations:

Redirecting the applied research phase

Annually OSS will update and prioritize the technology requirements for the near- and far- term elements of its mission set. Through strategic alliances with technology providers, applied research plans will be defined that will balance the need for stable research programs and the requirements of a mission set that changes according to scientific findings and budget appropriations. An essential element of the plans is the "infusion" path: the definition of the. steps, performance levels, and respective responsibilities — of technology provider and flight project user — that will lead a given technology from the bench to the flight system, if the development is technically successful.

Testbeds

Flight testbeds are been established at the Flight Centers. In these facilities breadboards and brassboards developed in the applied research phase can be thoroughly -- and inexpensively --- tested. modified, and upgraded in environment that faithfully simulates the actual operation during a flight mission. Successful performance in the flight testbeds is a key step in the technology "infusion" process: it verifies performance parameters of the new technology in a rigorous environment — engineered to flight standards and designed to build user confidence.

Flight opportunities

Flight experiments are the final step in the pathway toward risk reduction. These are opportunity to validate the technology in flight, but in non-critical situations, so that a failure of the technology will not result in a failure of the mission. Several types of such opportunities are pursued currently:

First, new spacecraft or instrument technology experiments are flown as payloads of opportunity on science missions where mass, power and other cm–hoard resources cart be spared without significant effect on science and at reasonable cost. A cw-rent example is the flight of new gyroscope systems as technology experiments on NAsA's X-ray Timing Explorer (XTE) mission, scheduled for launch in 1995.

Second. engineering flights of new spacecraft can be considered where several such spacecraft will be flown later in science missions. An example in the planetary program is the Mars Pathfinder mission to be launched in 1996. It is developing a very low-cost transportation system to the surface of Mars: a prototype of a system to be used again in the future — directly or through modifications — to place small science payloads on the surface of Mars.

A variant of this approach is to launch technology-driven, as opposed to science-driven, spacecraft expressly to test new technologies. These "space-test spacecraft" are built with a philosophy where higher risk and relatively short mission design life are tolerated. Two examples are presently underway in the just initiated NASA "SmallSat" program: microsatellites be launched on Pegasus-class vehicles that will test innovative spacecraft technology, while yielding new imaging spectrometry of the Earth surface.

Useful science is expected from all of these space tests even though the primary objective is technological.

Project technologist

In recognition of the pivotal role of the technology infusion phase in bringing applied research to flight use, the Strategy introduces the new function of Project Technologist - a requirement of all projects, pre-projects, and mission studies. The principal responsibility of this function is the preparation, in collaboration with the technology provider, of a technology development plan for the mission. In particular, the plan must describe the technology infusion and technology transfer processes.

A significant innovation is the assignment to the Project Technologist of the management of selected technology tasks that are sponsored by both the technology provider and the project. This approach whereby the technology provider delegates to the project certain development tasks is intended to insure a direct part and responsibility for the technology infusion process.

Technology Advisory Panel

The Strategy emphasizes the value of peer review and establishes an external review body with multidiscipline representation from a broad cross-section of communities: scientific research, space systems and related technologies, systems and operations analysis, economics/policy expertise, university and federal laboratories, and private industry.

The function of the Technology Advisory Panel is to consult with and advise NASA with respect to strategies, plans, and progress for development and infusion of new technologies into OSS programs and missions, and for maximizing the subsequent transfer of technologies developed under NASA auspices to the private sector for broader commercial application.

The Panel reports to the Advisory Committees of the Office of Space Science and of the Office of Space Access and Technology – both standing committees of the NASA Advisory Council.

Metrics

The strategy recommends quantitative and qualitative measures of accomplishment: the former to provide objectivity, the latter to insure that mere numerical accomplishments may distract from the spirit and intent of the strategy. It also recognizes that some of the goals can only be achieved in the long term and therefore it is important to measure progress in the short term. Table I indicates the principal measures identified.

PROGRESS

The OSS Integrated Technology was approved in the Fall 1993 and formally released on April 1994. A measure of the commitment of OSS is the creation — in the Spring of 1995 — of a new senior management position: Assistant Associate Administrator for Technology, now held by the second author.

During the last year significant progress has been achieved in the implementation of the Strategy:

Goal 1. A new NASA Management Instruction requires life-cycle cost analysis in project reviews: this approach favors the proper evaluation of the worth of technologies which in the past have dismissed on the basis of the development cost, Technology requirement documents have been prepared for all the space science divisions and for key projects and the space science program recommended for future years devotes about

8-1 0% to technology . In August 1 994 OSS has formally announced that the proposal evaluation criteria for its newest science program "DISCOVERY" will include consideration of t echnol ogy infusion and transfer, in addition to scientific value. Shortly after the announcement OSS in collaboration with OSAT held a Technology Fair and offered opportunities to potential bidders to become acquainted with the latest technology development in various areas, including spacecraft subsystems, instruments. and ground systems. In the Summer of 1994 NASA also announced two technology driven missions for Earth orbit (part of the SmallSat program mentioned above): "Lewis and Clark."

MEASURES	Progress towards goal	Achievement of goal
Quantitative	• T .evel of leveraging of 0SS funds • Number of new missions concepts inspired by technology advances • N umber and mo netary val uc of 101 nt technology efforts • Number of new flight-vali dated technologies available • Number of partnerships with non-space indus try	• New technolog y in spare science nlissions • N umber of awards to implementers of technology infusion • Royalties received
Qualitative	• Positive reviews by advisory commi - tees • Consistency and stability of requirements and requirements definition process • Interactions between OSS senior management and non-space firms	• OSS technology requirements addressed by technology providers • Quality of partnerships with non-space industries

Table 1. Metrics

Goal 2. All project and studies have filled the Project Technologists function and Flight System Testbeds have been established am-l are currently used for new mission under study (eg.: Rosetta, Pluto Fast Flyby, SOFIA, SIRTF). Flight opportunities for technology experiments are under study (in addition to the on- gōing experimental rover for the 1996 launc of Mars Pathfinder): X-ray Tinting Explorer, Gravity Probe B, and Small Explorers, and an electric propulsion experiment to be performed jointly with the Department of Defense.

Goal 3. Several key steps were taken. The Strategy was widely distributed to the stakeholders communities and all solicitations now contain a requirement to address technology transfer (e.g.: Mars Surveyor, Discovery, Solar Terrestrial Probes, and the Planetary Instrumentation Development Program New Research Announcement).

From a management view point. the performance plans of 0SS I Headquarters staff now include responsibility es for the impl ementation of the strategy. The Technolgy Fair for Discovery. mentioned earlier, devoted a special session to a description the infrastructure and aids available for transferring technology and to accounts of successful transfers,

Goal 4. The Parall el Application Tech - nology Program was establi shed in January 1994 as a partnership involving the Cray Research Corporation and the Jet Propulsion Laboratory. It promotes advances in supercomputing, specifically in massive parallel processing, Its first application will be three-dimensioned animation for planetary exploration and visualization. OSS anticiptes that several partnerships will be uncertaken under one of the recent solicitations mentioned above.

CONCLUSIONS

The OSS Integrated Technology Strategy -- after a brief early uncertainty, due to its newness -- has found rapid and widespread acceptance among all the stakeholder communities and technology considerations are already stimulating and strengthening new concepts for future missions.

Progress in its application has been generally steady: with excellent results in some areas (management approache s and structure), slower in others (establishment of space science partnerships,). and uneven in certain sectors such as the establishment of development programs joint ly with technology providers.

There, is recognition that the Strategy is a paradigm of a very rapid evolution in space science — some call it a revolution, The change is engendering some trepi dation and there arc uncertainties as to how it will succeed, but the release of innovative energy and creative skills we are all witnessing is a wonderful and awe–inspiring event, As the Associate Administrator for Space Science has recently stated: this "revolution must happen, or we won't."

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