

National Security Space Program Management

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The National Security Space (NSS) enterprise is a construct composed of systems planned and fielded by Department of Defense and civil and intelligence elements of the U.S. government to meet national security objectives. APL has long supported NSS sponsors' needs for advanced technical solutions. Strong, flexible space program management plays a pivotal role in achieving NSS technical excellence by building and guiding programs to produce critical contributions for NSS sponsors.

INTRODUCTION

APL's academic roots and its perspective as a not-for-profit problem solver create an atmosphere of innovative technical excellence and collegial teamwork. The Laboratory's not-for-profit University Affiliated Research Center (UARC) charter and special sole-source contracting provisions foster lasting relationships of trust with sponsors who recognize APL as a government-chartered center of technical and scientific expertise.

Since its early days experimenting with V-2 rockets immediately after the Second World War, the Laboratory has applied a space program management approach that leverages APL's outstanding cultural attributes: an environment that encourages innovation; an ingrained systems approach to problem definition and solution; delegated accountability for results, coupled with a spirit

of collaboration; a close working relationship between quality assurance and engineering; and, finally, staff excellence and resilience. These attributes are ingredients that contribute to the success of the Laboratory's approach to space programs with compressed development schedules. Each warrants consideration of how it fits into the recipe.

INNOVATION

In an environment of intense, shorter-term, mission-centric development opportunities, APL must keep its technical tools sharp and its academic and industrial reputation strong as it seeks new challenges. Fast-paced and dynamic, National Security Space (NSS) programs

present a challenge that speaks to one of APL's special attributes: the creative energy of its technical staff. The incentives of professional reward and the opportunity to make critical contributions combine to create a fertile environment for energetic creativity.

Independent research and development (IR&D) candidates compete for internal Laboratory funding to advance key NSS technologies. These IR&D initiatives give the developmental engineer or scientist an opportunity to be an NSS entrepreneur. The Laboratory hones its technology edge by keeping the creative talents of the staff in touch with sponsor needs and mission priorities.

Engineers and scientists are encouraged to take on challenges that push technical and scientific limits while also offering reasonable opportunity for success. The Laboratory has historically encouraged the staff member to "give yourself a chance to be lucky," which was a favorite saying of the Space Department's founding leader, Dr. R. B. Kershner. The department similarly challenges individuals to do things more systematically and at lower cost, with the discipline to first define a problem and then determine an appropriate solution.

APL technologies first developed for civil programs that have translated into NSS applications include independent tactical tasking, neural network anomaly detection capabilities, lightweight optics, onboard software autonomy, and long-term operational capabilities. NSS applications with civil benefit include satellite navigation, ionospheric space weather sensors, miniature synthetic aperture radars, combination navigation/communication capabilities, satellite bus standardization, lightweight optics, and antenna technologies.

Recognizing the Space Department's record of managing outstanding critical contributions, NSS sponsors often let the Space Department manage programs the way it sees fit. Decision-making is characteristically done in small groups; the department is very good at putting the right people on decision-making teams in a culture that values professional excellence and encourages creative, sound decisions.

SYSTEMS APPROACH

APL's legacy of success with complex systems in diverse mission areas has produced a systems-oriented perspective throughout the Space Department. Program teams investigate NSS mission challenges in terms of system needs. Once they devise a system plan, resources are applied to develop balanced solutions in the context of interaction among system components—the whole as distinct from the parts. Technical issues are considered in terms of root causes and mission requirements, not in terms of preidentified solutions or favored technologies.

In the past, the Space Department kept its systems engineers sharp in their chosen field by returning them

to their functional groups after they stepped into the system role on a given project. This practice avoided the appearance of systems engineering isolation at a time when it was viewed as special duty versus an engineering discipline. Over time, responding to increases in system complexity, systems engineering did evolve to become a distinct and specialized discipline. As the Space Department's early organization gave way to a functionally based organization, a Space Systems Engineering Section was formed as part of the Integration and Testing Group, and later an independent System Engineering Analysis Group was established. One intention was to create a home for recent college graduates attracted to systems engineering as a career discipline. The overall effect was to create a center of knowledge, expertise, continuity, and mentoring for advancing system-level approaches within the Space Department. Initially focused on payload systems, Space Department systems engineering evolved to include the expanded roles of the spacecraft systems engineer and the mission systems engineer, providing end-to-end space solutions. In response to the complexities of NSS system architectures, Space Department systems engineering further expanded its approach to encompass "systems of systems."

NSS program managers typically identify a lead systems engineer to guide the program's technical solutions and orchestrate technical contingencies to meet the range of program and mission needs. Except on very small projects, the program manager and the technical systems lead are two different people. They work together to frame a "full mission viewpoint" as the central theme of the team's approach to solving the sponsor's critical challenges. Both must possess keen awareness of the sponsor's operations flow and mission perspective. Working together closely, they guide program progress, streamline requirements and concepts, organize the program's systems approach, and staff the program team accordingly.

The Laboratory's emphasis on clear requirements and open-minded conceptual thinking motivates teams to ask tough questions to identify elemental system requirements of both function and performance. The answers to these questions point to the root issues behind challenging problems and clear the path for innovative, optimal system solutions. This approach to problem definition at APL allowed the historic demonstration of successful space-based intercept capability early in the U.S. missile defense program despite broad industry consensus that it couldn't be done within the government's cost and schedule. The same approach was used in 2009 by an APL NSS team to define elements of the Air Force's Integrated Space Situation Awareness (ISSA). This trait of the APL Space Department is evident in both NSS and Civilian Space programs; discipline and a strong focus on requirements helped APL propose an innovative Solar Probe design solution for NASA that

is allowing the mission to proceed after a hiatus of more than 30 years since it was first formulated by the science community.

In addition to yielding clearer program focus at APL, up-front requirements clarification promotes early technical insight for government sponsors. Such early familiarity with key issues helps sponsors achieve more informed and effective program oversight, especially in the early and mid-term stages. Potential technical risks of a program can thus be mitigated up front, when the cost and schedule impacts are less severe. The benefits continue throughout a program's execution stage, when a well laid foundation of sponsor insight can enable more stable program advocacy within the government, and therefore more reliable funding for program implementation.

Software's role in space programs warrants special mention because it has so influenced the evolution of the Space Department's systems-oriented culture. The increasing importance of software has been a catalyst for the department's reorganization into functional groups. Software's complexity has highlighted the need for a more systematic development approach. Space Department programs typically use an incremental development model for space system software; such a model mitigates risk in performance and schedule and accommodates evolving software requirements as a project moves forward. Software has influenced advancements in the use of space program metrics and has historically served as a *de facto* proving ground for evolving work measurement techniques (e.g., identifying trends versus merely observing linear events). Much of the process rigor and systematic discipline the Space Department employs is traceable to software as a factor of complexity in space system development. NSS program management is thus influenced by software engineering's innately disciplined approach.

Sound risk management is essential to managing complex space systems and programs. NSS program managers adhere to the Space Department's rigorous process for identifying and actively managing program risks before the start of a program and throughout the life of the task. Risk-reduction efforts achieve the greatest return during the earliest program stages. Early-program risk-reduction efforts, especially during concept exploration and advanced development, are the most effective in reducing total program cost and schedule uncertainties. Once engineering design work commences, the most valuable opportunities for efficient risk reduction have passed.

Schedule risks carry special significance because they are often leading indicators of risks in other areas, such as staffing, funding, external interfaces, and technical maturity. Schedule impacts are often the first sign of an underlying problem. Thus, schedule changes must be assessed as potential harbingers of issues in other areas of a program.

Parts procurements with long lead times can pose particular risk to space hardware-fabrication schedules. NSS programs at APL benefit from the Space Department's well developed capability to identify, procure, screen, and qualify long-lead-time parts at the earliest stages of design. The department implements the concept of parts pools and, with sponsor concurrence, transfers parts between programs. The flexibility provided by these transfers reduces schedule risk typically associated with long-lead parts procurement.

The Space Department's tendency toward short time frames (historically targeted by APL not to exceed 36 months from preliminary design review to launch) sets a rhythm for programs within the Space Department and reinforces discipline in identifying requirements. Programs start and end with discreet completion points that motivate teams, in contrast to unending efforts that inspire no special investment by team members to complete. The value and feasibility of setting this pace of tasks with shorter time frames was articulated in a government-sponsored APL study in which the department advised the National Reconnaissance Office how to create a similar climate for major NSS acquisitions.¹ The study advocates a three-stage "Ready-Set-Go" approach to program execution. The "Ready" phase consists of defining user needs, identifying candidate technologies, and provision of necessary funding. The "Set" phase completes preparatory initiatives and prepares for execution. The "Go" phase is the period between critical design review and system operation. The duration of the Go phase can be shortened, depending on the success of the two preparatory phases. The Space Department takes the challenge of a short program timeline to heart on the principle that if one can keep a schedule short, one can ultimately contain development costs.

ACCOUNTABILITY

A program's biggest challenge is sometimes managerial rather than technical. Recognizing this, the Space Department promotes a strong climate of time-responsive accountability, by delegation of authority to the lowest management level and streamlined decision-making. NSS program planning occurs with top-down and bottom-up estimations and extensive space program experience upon which to draw. For large programs, a work breakdown structure (WBS) is created to define the activities for achieving program requirements contained in the contract Statement of Work. Unless sponsor requirements indicate otherwise, the Space Department favors a standardized product- and function-based WBS to compare cost and schedule among missions. This can be used for future estimation exercises and to collect lessons learned from past programs.

Through all program phases, NSS program teams are constituted using a matrix approach across the APL functional groups to organize program teams for accountability and collaboration. WBS elements are allocated within the department to establish clear cost and schedule accountability. An individual staff member's name is identified for each detailed element of the WBS; these elements become control accounts, and the individuals assigned become control account managers (CAMs). CAMs are identified through a selection process coordinated between the group supervisor and the program manager. Figure 1 illustrates this model.

Free and open communication between program managers and group supervisors ensures that the team staffing matrix is complete; it is the single most valuable management communication link for ensuring a program's technical success. Group supervisors and program managers oversee the performance of the CAMs in accomplishing their program tasks; however, they approach their oversight task with different objectives. The group supervisor bears responsibility for the technical output of his or her functional group and seeks to cultivate and sustain strong technical capabilities within the group. The program manager seeks to successfully accomplish program objectives within cost and schedule limits.

Close attention to schedule by NSS program teams manifests in a sense of pride in timely work. The CAM concept of cost and schedule delegation creates a tangible stakeholder mentality among team members. Accountability for program success is shared, as is recognition for program success. Concern for a program's schedule and cost is matched by a persistent focus on collaborative technical success that promotes efficient program action without cutting corners. This culture of cooperation extends without bias to external partners. For instance, when APL chaired the Integrated Systems Engineering Team (ISET) effort to develop bus standards for Operationally Responsive Space (ORS) vehicles (Fig. 2), the effort was judged by its government sponsor as a "badgeless" success. NSS teams view projects as opportunities to push new boundaries of technical strength to meet a sponsor's needs, with success reflected by the degree to which customer expectations are exceeded.

APL experience has shown that the way to keep a program schedule short is to start with a short schedule. A short time frame from preliminary design review to launch, on the order of 36 months, focuses the project team on a close objective and defines the project's time boundaries. It is best for teams to approach milestones in the near term rather than in the long term. Adequate, stable, and responsive funding profiles; streamlined contracting; and careful coordination of multiple user needs are easier to achieve when using a shorter timeline.

NSS program teams are kept as small as possible. NSS program managers foster a climate of direct communications within program teams to identify and assess

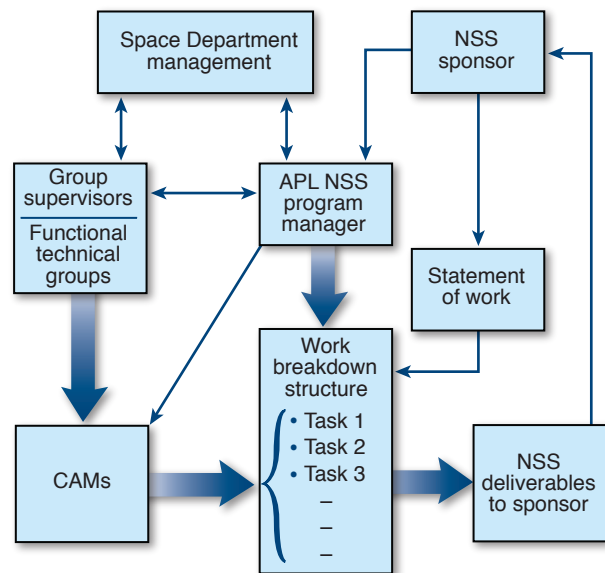


Figure 1. NSS task oversight.

emerging issues before they become critical. Small team size, delegation of technical tasks, and clear accountability produce teams with shared identity, common vision, and strong commitment.

Once planning and initial organization are complete, the primary role of the program manager is to provide continuous leadership throughout all phases of program development. This ensures that necessary attributes remain in place for rapid and successful program delivery. NSS program managers have ultimate accountability both to the sponsor and to Space Department management. Department reviews are periodic, with periodicity based on program priority and needs. Some programs receive quarterly reviews, others monthly, and still others weekly, depending on their urgency, maturity, and other factors.

NSS program managers maintain straightforward accountability to the sponsor through streamlined contracting agreements designed to reduce cost accounting, tasking, and staff continuity problems. Simple, direct interfaces increase program transparency, improve sponsor awareness and involvement, and enhance APL responsiveness.

Program accountability requires careful management when program scope increases. For instance, APL's engineering role in the Mini-RF Instrument Program (Fig. 3) escalated over 6 months from providing technical and programmatic assistance to include hosting system integration and testing, leading RF systems engineering, software development, and even some design and fabrication of hardware. Program sponsorship was transferred between two government agencies and switched contracts in between two instrument delivery milestones.

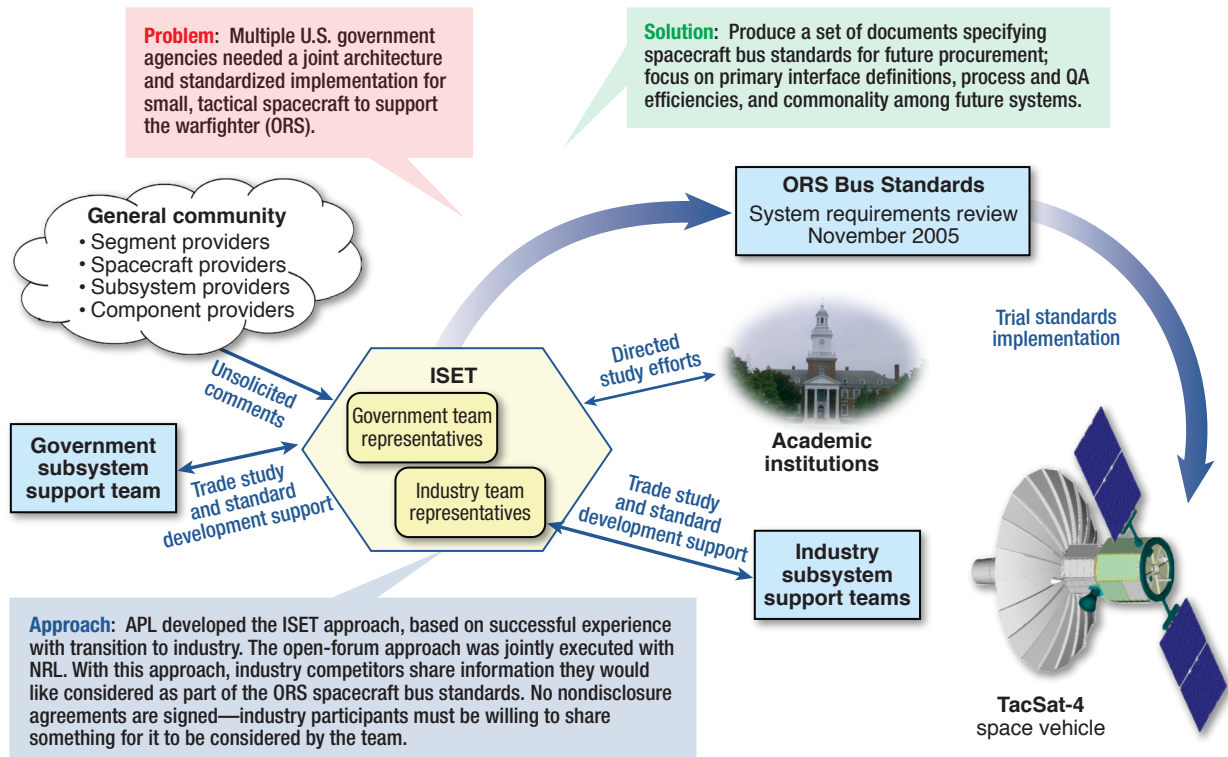


Figure 2. Air Force Research Laboratory is developing TacSat-4, one in a series of small spacecraft intended to demonstrate capabilities needed to rapidly produce small, tactical spacecraft. APL teamed with the Naval Research Laboratory (NRL) to develop the TacSat-4 satellite bus relying on spacecraft bus standards developed by an APL-led industry team.

The challenge to maintaining effective accountability and teamwork within the program made clear communication and continuity of vision critically important. Resourcefulness made possible with CAMs, coordinated action by small teams within the larger program, and an empowered program management cadre supported by Space Department and Laboratory senior management made the APL program team cohesive, resilient, flexible, and unerringly focused during a year of immense pressures and change.

QUALITY

The proper balance between engineering and quality-assurance (QA) priorities in program management can be elusive, which creates an ever-present risk of obstructing true mission assurance whenever engineering and QA become adversarial

- SAR payload on India’s Chandrayaan-1 lunar science mission
- Operated in S-band SAR
- Launched October 2008
- 2-year primary mission
- APL conducted payload operations and provided Western Hemispheric mission ground station for Chandrayaan-1

- SAR payload on NASA’s LRO
- Dual S- and X-band operating modes
- 1-year primary mission with 1-year option
- Launched June 2009
- APL currently conducts payload operations

Figure 3. Details of the Mini-RF Instrument Program, sponsored by NASA in collaboration with DoD. APL-led systems engineering, integration, and testing was credited by NASA with making the Mini-RF synthetic aperture radar (SAR) instruments a success. Systems on board the Chandrayaan-1 and Lunar Reconnaissance Orbiter (LRO) spacecraft have both yielded remarkable radar images of the lunar surface. The Chandrayaan-1 mission terminated in 2009; LRO has continued its mission into 2010. Both radars have functioned fully during their respective mission durations.

or even too closely allied. In one of its most significant accomplishments benefiting program management, the Space Department has made a thoughtful and effective balance between engineering and QA. This relationship reduces the temptation to overdocument or oversell quality-management policies. The department's commitment to disciplined quality is explicitly marked by its AS9100 certification. From a program manager perspective, the challenge of implementing QA rigor while keeping bureaucratic burden in check is met through the growth of strong mission-assurance awareness among staff members.

QA plays an integral role in APL's NSS programs. Each NSS program developing hardware or software for a sponsor is assigned a system assurance manager (SAM) from the Space Department's Safety and Quality Assurance Group. SAMs work jointly with project engineering staff to develop program solutions. SAMs (not systems engineers) manage system configuration control. All QA disciplines are brought together in the Safety and Quality Assurance Group for the project SAM to draw on for function-specific expertise in safety, configuration management, electrostatic discharge, contamination control, inspection, internal audits and standards compliance, and supplier quality management. SAMs thus manage program mission assurance with constant reach-back access to functional quality experts.

Engineers and SAMs work side by side. The engineering staff understands that the quality-assurance staff does not impose technical quality requirements for the projects; rather it ensures that programs meet standards set by their contracts. As SAMs and engineers cooperate on a program's technical solutions, the SAMs approach their task with an overriding accountability to department leadership for protecting the department's standards and best practices.

Active participation in mission assurance extends to the top of the department. The executive-level Space Department Quality Council meets biweekly to review QA issues regarding both policy issues and ongoing activities. When program managers report to senior management, their program's SAM presents an independent assessment of program mission-assurance status, issues, and risks. Ideally, the program manager and SAM present aligned but mildly dissimilar reports, thereby providing a balanced view to the department from two informed, responsible parties independently reporting the degree to which the program is on track to succeed. Wide variances between the reports signal the presence of issues requiring department management attention.

The Space Department's careful balance between engineering and quality assurance has paid off. A 2008 NASA Contract Assurance Services audit stated that the APL Space Department "is a model for organizations required to redefine and transform their safety, quality, and mission assurance systems . . . more positive obser-

vations were cited during this APL audit than during any supplier audit in recent memory." The report noted "the positive attitude and management commitment to quality and continual improvement at APL."² The engineering groups work as closely with the QA group as they work with each other. Their partnership improves the mission-assurance climate throughout the department and enables the QA staff to contribute as full NSS program teammates.

EXCELLENCE

Space Department staff members are typically excited about the programs to which they contribute. The work is often what they dreamed of while in school—applying science and technology to critical mission challenges in space. This richness of opportunity makes it possible for the Space Department to attract and retain highly accomplished and talented personnel. It is said that one Space Department staff member's annual performance review contained simply the following handwritten words from his supervisor: "best in the world" in his specialty. The inherent quality of the technical staff's abilities gives program managers high confidence that their teams can and will follow through with outstanding results.

The Space Department's collegial, solutions-oriented environment encourages staff to find their best niche in program efforts. No penalties are assessed if a line manager voluntarily steps out of a position of organizational responsibility to pursue a mission challenge. Notably excellent Space Department branch and group supervisors have relinquished line management duties to become space program managers or technical leads. This fluidity within the organization in pursuit of professional challenges matches staff talents with the sponsor needs, giving the staff greater opportunity for job satisfaction.

The Space Department serves as an end-to-end space system development and operations house. Engineers and scientists work together so each is afforded greater understanding of the other's challenges. APL engineers gain useful insight into the distillation of the scientific queries driving mission need, and scientists appreciate the engineering aspects of system development. This synergy fosters optimum working relationships, enabling APL to perform at its highest level of effectiveness to develop mission systems.

NSS missions encompass multiple technical disciplines, including some in which other APL departments retain primary expertise. NSS program managers are encouraged and empowered to reach outside the Space Department to draw on these talents as needed. For example, APL's independent assessment of Global Positioning System ground architecture alternatives for the Air Force Space and Missile Systems Center drew skilled team members from the Space, Global Engagement, Air

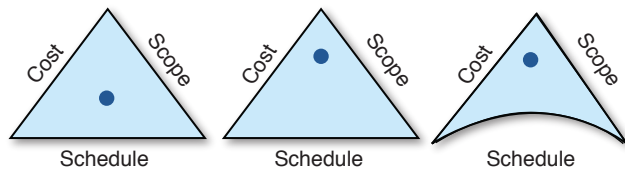


Figure 4. Flexing the cost–schedule–scope triangle. Triangle 1, Program in equilibrium among cost, schedule, and scope. Triangle 2, External influences emphasize scope and cost. In the classic situation, schedule objectives are sacrificed. Triangle 3, APL’s technical and scientific capability and strength creates elasticity—the triangle can flex. Schedule objectives are covered through contributions by talented, collaborative staff.

and Missile Defense, and Applied Information Science Departments, as well as from APL’s Milton Eisenhower Research Center. Program managers’ ability to access technical capabilities wherever they reside in the Laboratory enables NSS teams to best address sponsor needs rapidly and efficiently.

Staff excellence pays off in a way that distinctively marks APL’s ability to execute sponsored programs by bending the commonly recognized rigid triangle of program cost, schedule, and scope constraints (Fig. 4). Conventionally, an improvement in two areas is possible only at the expense of the other. However, superior staff talent, properly engaged, constitutes a game changer. The resilience and capability of APL staff provides NSS program managers an ace-in-the-hole resource to deal with program challenges. In essence, the walls of the cost–schedule–scope triangle become elastic. Staff experience and talent boosts a program team’s resilience to accommodate trade space impacts and enables APL’s demonstrated schedule adherence, cost management, and technical excellence. The sum of the staff mem-

bers’ individual expert abilities constitutes a reservoir of capacity that is a time-tested Laboratory resource; it is a resource that NSS program managers know they can count on to counteract program challenges when they push the program to cost and schedule limits.

MOVING FORWARD

APL’s NSS program management delivers a proven and reliable capability to systematically define and creatively solve sponsor’s critical challenges. The methodology involved combines technical and programmatic knowledge, successful experience, and the best attributes of APL’s creative culture of achievement. The specifics of that chemistry are unique, as they often are in singular organizations, yet still provide a valuable real-world example of what can happen when organizational characteristics and professional talents are combined in the right measure. Small, focused technical teams, accountability of CAMs and program managers, systematic engineering discipline, a proactive QA approach, experience, lessons learned, and technical ingenuity are key attributes. APL’s program management contributions to NSS challenges will continue to embody the efficiency, effectiveness, resourcefulness, and innovation their sponsors have come to depend on to accomplish many of the nation’s outstanding space system achievements.

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