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Report to the Ranking Member, Subcommittee on National Security, Homeland Defense and Foreign Operations, Committee on Oversight and Government Reform, House of Representatives

June 2011

SPACE AND MISSILE DEFENSE ACQUISITIONS

Periodic Assessment Needed to Correct Parts Quality Problems in Major Programs

GAO-11-404

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Highlights

Highlights of GAO-11-404, a report to the Ranking Member, Subcommittee on National Security, Homeland Defense and Foreign Operations, Committee on Oversight and Government Reform, House of Representatives

Why GAO Did This Study

Quality is key to success in U.S. space and missile defense programs, but quality problems exist that have endangered entire missions along with less-visible problems leading to unnecessary repair, scrap, rework, and stoppage; long delays; and millions in cost growth. For space and missile defense acquisitions, GAO was asked to examine quality problems related to parts and manufacturing processes and materials across DOD and NASA. GAO assessed (1) the extent to which parts quality problems affect those agencies' space and missile defense programs; (2) causes of any problems; and (3) initiatives to prevent, detect, and mitigate parts quality problems. To accomplish this, GAO reviewed all 21 systems with mature designs and projected high costs: 5 DOD satellite systems, 4 DOD missile defense systems, and 12 NASA systems. GAO reviewed existing and planned efforts for preventing, detecting, and mitigating parts quality problems. Further, GAO reviewed regulations, directives, instructions, policies, and several studies, and interviewed senior headquarters and contractor officials.

What GAO Recommends

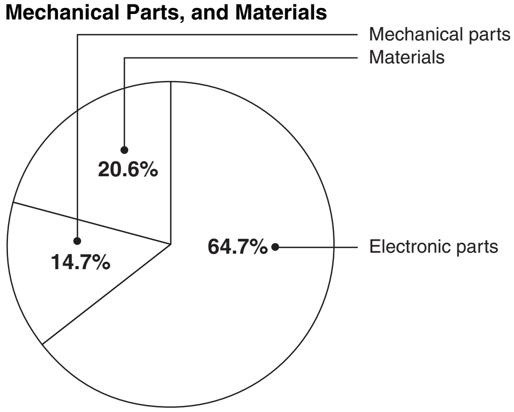
DOD and NASA should implement a mechanism for periodic assessment of the condition of parts quality problems in major space and missile defense programs with periodic reporting to Congress. DOD partially agreed with the recommendation and NASA agreed. DOD agreed to annually address all quality issues, to include parts quality.

View GAO-11-404 or key components. For more information, contact Cristina Chaplain at (202) 512-4841 or chaplainc@gao.gov.

What GAO Found

Parts quality problems affected all 21 programs GAO reviewed at the Department of Defense (DOD) and National Aeronautics and Space Administration (NASA). In some cases they contributed to significant cost overruns and schedule delays. In most cases, problems were associated with electronic versus mechanical parts or materials (see figure). In several cases, parts problems discovered late in the development cycle had more significant cost and schedule consequences. For example, one problem cost a program at least $250 million and about a 2-year launch delay.

Distribution of Quality Problems Found in Programs Reviewed Grouped by Electronic Parts, Mechanical Parts, and Materials



Source: GAO analysis of DOD and NASA data.

The causes of parts quality problems GAO identified were poor workmanship, undocumented and untested manufacturing processes, poor control of those processes and materials and failure to prevent contamination, poor part design, design complexity, and an inattention to manufacturing risks. Ineffective supplier management also resulted in concerns about whether subcontractors and contractors met program requirements.

Most programs GAO reviewed began before the agencies adopted new policies related to parts quality problems, and newer post-policy programs were not mature enough for parts problems to be apparent. Agencies and industry are now collecting and sharing information about potential problems, and developing guidance and criteria for testing parts, managing subcontractors, and mitigating problems, but it is too early to determine how much such collaborations have reduced parts quality problems since such data have not been historically collected. New efforts are collecting data on anomalies, but no mechanism exists to use those data to assess improvements. Significant barriers hinder efforts to address parts quality problems, such as broader acquisition management problems, workforce gaps, diffuse leadership in the national security space community, the government's decreasing influence on the electronic parts market, and an increase in counterfeiting of electronic parts. Given this, success will likely be limited without continued assessments of what works well and must be done.

Contents

Figures

Abbreviations

BMDS	Ballistic Missile Defense System
CDR	Critical Design Review
DOD	Department of Defense
GPS	Global Positioning System
LSI	Lead System Integrator
MAP	Mission Assurance Provisions
MDA	Missile Defense Agency
MOU	Memorandum of Understanding
NASA	National Aeronautics and Space Administration
SIBC	Space Industrial Base Council
TSPR	Total System Performance Responsibility

G A O
Accountability * Integrity * Reliability

United States Government Accountability Office
Washington, DC 20548

June 24, 2011

The Honorable John F. Tierney
Ranking Member
Subcommittee on National Security, Homeland Defense
and Foreign Operations
Committee on Oversight and Government Reform
House of Representatives

Dear Mr. Tierney:

The Department of Defense (DOD) space and missile defense systems play a vital role in protecting national and homeland security, the National Aeronautics and Space Administration's (NASA) space systems provide global weather forecasting and all government space organizations facilitate important scientific research.[1] Because of these systems' complexity, the environments they operate in, and the high degree of accuracy and precision needed for their operation, quality is paramount to their success. Yet in recent years, many space and missile defense programs, which rely on many of the same contractors, have struggled with quality problems. For example, the Air Force's Advanced Extremely High Frequency communications satellite was launched on August 14, 2010, but has yet to reach its intended orbit because of a blockage in a propellant line that was most likely caused by a small piece of cloth inadvertently left in the line during the manufacturing process. In 2009, a major test for the Missile Defense Agency's (MDA) Terminal High Altitude Area Defense missile system was not completed because of a design and quality problem affecting the target. While these two cases were widely reported by the media, other space and missile defense programs have struggled with less-visible quality problems that have resulted in unnecessary repair, scrap, and rework, and in some cases, a complete halt in large-scale programs, months of delay, and millions of dollars in cost growth. Often, such problems have arisen at the tail end of problematic, long-term development efforts, creating a great deal of frustration for program and government officials. Moreover, while attention has increased in recent years on problems related to counterfeit parts, we have

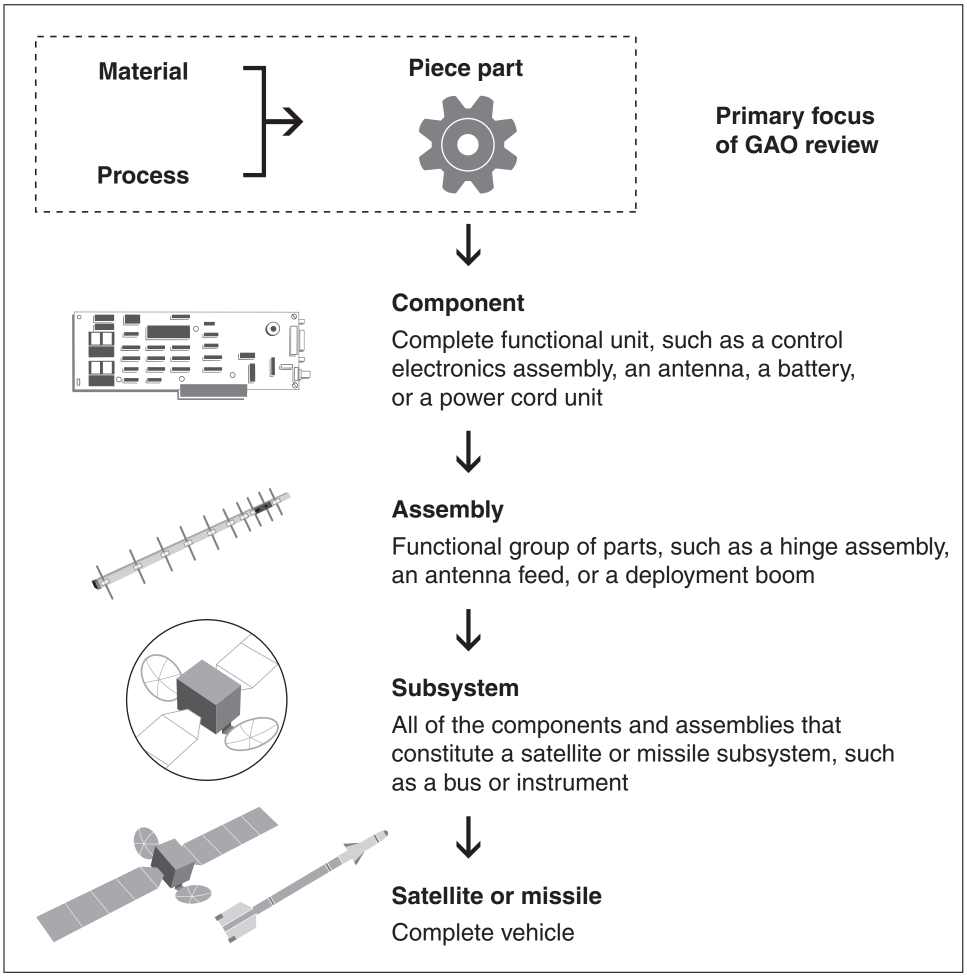
[1] Within DOD, the Air Force is the Executive Agent for Space and through its Space and Missile Systems Center is responsible for acquiring most of DOD's space systems, while the Missile Defense Agency is responsible for acquiring ballistic missile defense systems, and some associated space systems.

reported that problems affecting major missile defense and space programs have generally been the result of other issues, such as design instability and technology maturity.[2]

In view of the cost and importance of space and missile defense acquisitions, you asked that we examine parts quality problems affecting satellites and missile defense systems across DOD and NASA. Our review of parts quality problems includes problems with the materials and processes used in manufacturing. Parts are the basic elements of a system; their manufacturing must be dependable if a system's hardware is to be reliable. Moreover, given the span of agencies and systems we were examining, our focus on parts enabled consistent analysis of problems, causal factors, and improvement efforts. At the same time, however, our scope excluded quality problems that arose during assembly and integration of larger subsystems, assemblies, and components, unless such problems were tied to a specific part. Figure 1 depicts the focus of our review and figure 2 defines materials, process, and parts.

[2] GAO, *Defense Acquisitions: Assessments of Selected Weapon Programs*, GAO-10-388SP (Washington, D.C.: Mar. 30, 2010); *Space Acquisitions: DOD Poised to Enhance Space Capabilities, but Persistent Challenges Remain in Developing Space Systems*, GAO-10-447T (Washington, D.C.: Mar. 10, 2010); and, *Missile Defense: Actions Needed to Improve Transparency and Accountability*, GAO-11-372 (Washington, D.C.: Mar. 24, 2011).

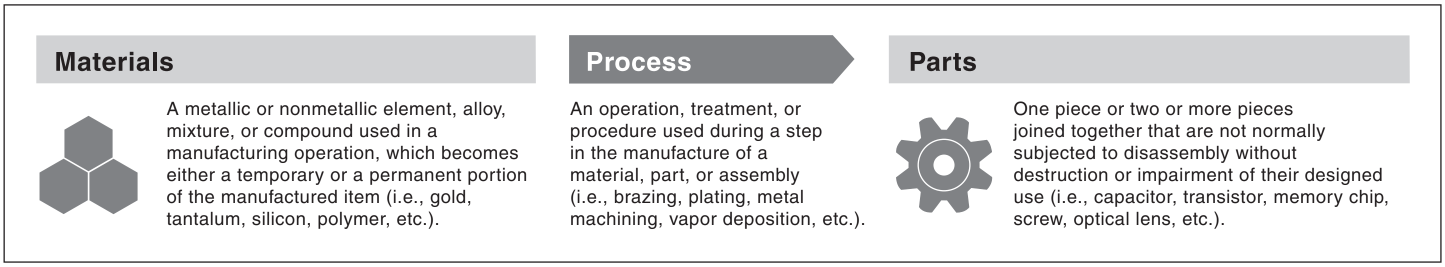
Figure 1: Description of Hardware Levels That Result in a Finished Satellite or Missile System[3]



Sources: GAO analysis of satellite development literature (data); ArtExplosion (images).

[3] James R. Wertz and Wiley J. Larson, *Space Mission Analysis and Design*, El Segundo, Calif.: Microcosm Press, 2003.

Figure 2: Definitions of Materials, Process, and Parts Used in Satellite and Missile Manufacturing



Source: GAO analysis of DOD and NASA documents.

Our specific objectives were to assess (1) the extent to which parts quality problems are affecting DOD and NASA space and missile defense programs; (2) the causes behind these problems; and (3) initiatives to prevent, detect, and mitigate parts quality problems.

To determine the extent to which parts quality problems affected a program's cost, schedule and performance, we identified 21 DOD and NASA major acquisitions[4] that had completed their critical design reviews (CDR) as of October 2009.[5] This universe of 21 programs includes 9 DOD systems (4 Air Force, 1 Navy,[6] and 4 MDA) and 12 NASA systems. We asked officials from all 21 programs to identify the most significant parts

[4] DOD defines major defense acquisition programs as those requiring an eventual total expenditure for research, development, test, and evaluation of more than $365 million or for procurement of more than $2.190 billion in fiscal year 2000 constant dollars. DOD Instruction 5000.02 (Dec. 2, 2008). The NASA projects selected were those with a life cycle cost exceeding $250 million.

[5] DOD defines CDR as a multi-disciplined technical review to ensure that a system can proceed into fabrication, demonstration, and test and can meet stated performance requirements within cost, schedule, risk, and other system constraints. Generally this review assesses the system final design as captured in product specifications for each configuration item in the system's product baseline, and ensures that each configuration item in the product baseline has been captured in the detailed design documentation. CDR is normally conducted during the Engineering and Manufacturing Development phase and is intended to assess whether the maturity of the design is appropriate to support proceeding with full-scale fabrication, assembly, integration, and test. NASA's definition is similar to DOD's, and CDR typically occurs during NASA's implementation phase. See the *Defense Acquisition Guidebook* and DOD Instruction 5000.02 (Dec. 2, 2008). NASA's definition is similar to DOD's, and CDR typically occurs during NASA's implementation phase. See NASA Interim Directive NM 7120-81 (2009).

[6] Although the Air Force is responsible for acquiring most of DOD's space systems, the Navy is acquiring a replacement to its Ultra High Frequency Follow-On satellite system called Mobile User Objective System.

quality problems that had affected their programs, as well as the associated cost and schedule impacts, causes, and contributing factors. A quality problem is the degree to which the product attributes, such as capability, performance, or reliability, did not meet the needs of the customer or mission, as specified through the requirements definition and allocation process.

From the 21 systems examined, we selected 2 from DOD (1 Air Force and 1 MDA program) and 1 from NASA with known quality problems, as identified in previous GAO reports,[7] for further review to gain greater insight into the root causes of the parts quality problems. We are unable to make generalizable or projectable statements about parts quality problems related to space and missile programs beyond this stated scope. We reviewed regulations, directives, instructions, and policies to determine how DOD, the Air Force, MDA, and NASA define and address parts quality. We interviewed senior DOD, MDA, and NASA headquarters officials, as well as system program and contractor officials from the Air Force, MDA, and NASA, about their knowledge of parts problems on their programs. We also reviewed several studies on parts quality from the Aerospace Corporation[8] and met with officials to discuss their findings. To identify the extent to which parts problems are common across DOD, MDA, and NASA, we collected and reviewed failure review board reports, advisory notices, and cost and schedule analysis reports on parts problems affecting the 21 identified systems and interviewed program officials. To identify initiatives planned and practices used by DOD, MDA, and NASA to prevent and detect parts quality problems, we interviewed program officials at DOD, the Air Force, MDA, and NASA responsible for systems engineering and quality and obtained, reviewed, and discussed their parts quality policies and factors contributing to parts problems. For more on our scope and methodology, see appendix I.

We conducted this performance audit from October 2009 to May 2011 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and

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[7] See GAO-10-388SP. Also, see GAO, *NASA: Assessments of Selected Large-Scale Projects*, GAO-10-227SP (Washington, D.C.: Feb. 1, 2010).

[8] The Aerospace Corporation is a federally funded research and development center that provides systems engineering and technical services to national security and civil space programs.

conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Background

DOD and NASA build costly, complex systems that serve a variety of national security and science, technology, and space exploration missions. Within DOD, the Air Force's Space and Missile Systems Center is responsible for acquiring most of DOD's space systems; however, the Navy is also acquiring a replacement satellite communication system. MDA, also within DOD, is responsible for developing, testing, and fielding an integrated, layered ballistic missile defense system (BMDS) to defend against all ranges of enemy ballistic missiles in all phases of flight.[9] The major projects that NASA undertakes range from highly complex and sophisticated space transportation vehicles, to robotic probes, to satellites equipped with advanced sensors to study the Earth. Requirements for government space systems can be more demanding than those of the commercial satellite and consumer electronics industry. For instance, DOD typically has more demanding standards for radiation-hardened parts, such as microelectronics, which are designed and fabricated with the specific goal of enduring the harshest space radiation environments, including nuclear events. Companies typically need to create separate production lines and in some cases special facilities. In the overall electronics market, military and NASA business is considered a niche market.

Moreover, over time, government space and missile systems have increased in complexity, partly as a result of advances in commercially driven electronics technology and subsequent obsolescence of mature high-reliability parts. Systems are using more and increasingly complex parts, requiring more stringent design verification and qualification practices. In addition, acquiring qualified parts from a limited supplier base has become more difficult as suppliers focus on commercial markets at the expense of the government space market—which requires stricter controls and proven reliability.

Further, because DOD and NASA's space systems cannot usually be repaired once they are deployed, an exacting attention to parts quality is

[9] The National Reconnaissance Office develops and operates overhead reconnaissance satellite systems and conducts intelligence-related activities for U.S. national security. The National Reconnaissance Office was excluded from our review because of the sensitive nature of its work.

required to ensure that they can operate continuously and reliably for years at a time through the harsh environmental conditions of space. Similarly, ballistic missiles that travel through space after their boost phase to reach their intended targets are important for national security and also require reliable and dependable parts. These requirements drive designs that depend on reliable parts, materials and processes that have passed CDRs, been fully tested, and demonstrated long life and tolerance to the harsh environmental conditions of space.

Shifts in Government Oversight and Management of Parts

There have been dramatic shifts in how parts for space and missile defense systems have been acquired and overseen. For about three decades, until the 1990s, government space and missile development based its quality requirements on a military standard known as MIL-Q-9858A. This standard required contractors to establish a quality program with documented procedures and processes that are subject to approval by government representatives throughout all areas of contract performance. Quality is theoretically ensured by requiring both the contractor and the government to monitor and inspect products. MIL-Q-9858A and other standards—collectively known as military specifications—were used by DOD and NASA to specify the manufacturing processes, materials, and testing needed to ensure that parts would meet quality and reliability standards needed to perform in and through space.[10] In the 1990s, concerns about cost and the need to introduce more innovation brought about acquisition reform efforts that loosened a complex and often rigid acquisition process and shifted key decision-making responsibility—including management and oversight for parts, materials, and processes—to contractors. This period, however, was marked by continued problematic acquisitions that ultimately resulted in sharp increases in cost, schedule, and quality problems.

For DOD, acquisition reform for space systems was referred to as Total System Performance Responsibility (TSPR). Under TSPR, program managers' oversight was reduced and key decision-making responsibilities

[10] Specifications and standards evolved from the need to ensure proper performance and maintainability of military equipment. The proliferation of specifications and standards, numbered in the thousands, was believed to impose unnecessary restrictions, increase cost to contractors and hence the government, and impede the incorporation of the latest technology. Secretary of Defense William Perry issued a memorandum in 1994 that prohibited the use of most defense standards without a waiver, and many defense standards were canceled.

were shifted onto the contractor. In May 2003, a report of the Defense Science Board/Air Force Scientific Advisory Board Joint Task Force stated that the TSPR policy marginalized the government program management role and replaced traditional government "oversight" with "insight." In 2006, a retired senior official responsible for testing in DOD stated that "TSPR relieved development contractors of many reporting requirements, including cost and technical progress, and built a firewall around the contractor, preventing government sponsors from properly overseeing expenditure of taxpayer dollars."[11] We found that TSPR reduced government oversight and led to major reductions in various government capabilities, including cost-estimating and systems-engineering staff.[12] MDA chose to pursue the Lead Systems Integrator (LSI) approach as part of its acquisition reform effort. The LSI approach used a single contractor responsible for developing and integrating a system of systems within a given budget and schedule. We found in 2007 that a proposal to use an LSI approach on any new program should be seen as a risk at the outset, not because it is conceptually flawed, but because it indicates that the government may be pursuing a solution that it does not have the capacity to manage.[13]

Within NASA, a similar approach called "faster, better, cheaper" was intended to help reduce mission costs, improve efficiency, and increase scientific results by conducting more and smaller missions in less time.[14] The approach was intended to stimulate innovative development and application of technology, streamline policies and practices, and energize and challenge a workforce to successfully undertake new missions in an era of diminishing resources. We found that while NASA had many

[11] Thomas Christie, "What Has 35 Years of Acquisition Reform Accomplished?" *United States Naval Institute Proceedings*, vol. 132, no. 2 (2006).

[12] GAO, *Space Acquisitions: Actions Needed to Expand and Sustain Use of Best Practices*, GAO-07-730T (Washington, D.C.: Apr. 19, 2007).

[13] GAO, *Defense Acquisitions: Role of Lead Systems Integrator on Future Combat Systems Program Poses Oversight Challenges*, GAO-07-380 (Washington, D.C.: June 6, 2007).

[14] In 1992, the NASA Administrator initiated the "faster, better, cheaper" philosophy as a way of managing programs and projects. The goal was to shorten program development times, reduce cost, and increase scientific return by flying more and smaller missions in less time. To do this, the NASA Administrator challenged agency personnel to do projects faster, better, and cheaper by streamlining practices and becoming more efficient.

successes, failures of two Mars probes revealed limits to this approach, particularly in terms of NASA's ability to learn from past mistakes.[15]

As DOD and NASA moved from military specifications and standards, so did suppliers. According to an Aerospace Corporation study, both prime contractors and the government space market lost insight and traceability into parts as suppliers moved from having to meet military specifications and standards to an environment where the prime contractor would ensure that the process used by the supplier would yield a quality part. During this time, downsizing and tight budgets also eroded core skills, giving the government less insight, with fewer people to track problems and less oversight into manufacturing details.[16]

As DOD and NASA experienced considerable cost, schedule, and performance problems with major systems in the late 1990s and early 2000s, independent government-sponsored reviews concluded that the government ceded too much control to contractors during acquisition reform. As a result, in the mid-to late 2000s, DOD and NASA reached broad consensus that the government needed to return to a lifecycle mission assurance approach aimed at ensuring mission success.[17] For example, MDA issued its *Mission Assurance Provisions* (MAP) for acquisition of mission and safety critical hardware and software in October 2006. The MAP is to assist in improving MDA's acquisition activities through the effective application of critical best practices for quality safety and mission assurance. In December 2008, DOD updated its acquisition process which includes government involvement in the full range of requirements, design, manufacture, test, operations, and readiness reviews.

[15] GAO, *NASA Management Challenges: Human Capital and Other Critical Areas Need to be Addressed*, GAO-02-945T (Washington, D.C.: July 18, 2002).

[16] B. Tosney and S. Pavlica, *A Successful Strategy for Development and Testing* (El Segundo, Calif.: Aerospace Corporation, 2003).

[17] The *Aerospace Corporation Mission Assurance Guide* defines mission assurance as the disciplined application of general systems engineering, quality, and management principles toward the goal of achieving mission success. Mission assurance uses independent technical assessments as a cornerstone throughout the acquisition and operations lifecycle. Mission success is defined as the achievement of not only specified performance requirements but also the expectations of the users and operators in terms of safety, operability, suitability, and supportability. In contrast, acquisition success can be defined in terms of performance, cost, and schedule.

Also in the last decade, DOD and NASA have developed policies and procedures aimed at preventing parts quality problems.[18] For example, policies at each agency set standards to require the contractor to establish control plans related to parts, materials, and processes. Policies at the Air Force, MDA, and the NASA component we reviewed also establish minimum quality and reliability requirements for electronic parts—such as capacitors, resistors, connectors, fuses, and filters—and set standards to require the contractor to select materials and processes to ensure that the parts will perform as intended in the environment where they will function, considering the effects of, for example, static electricity, extreme temperature fluctuations, solar radiation, and corrosion. In addition, DOD and NASA have developed plans and policies related to counterfeit parts control that set standards to require contractors to take certain steps to prevent and detect counterfeit parts and materials.[19] Table 1 identifies the major policies related to parts quality at DOD and NASA.

Table 1: Policies to Prevent and Detect Parts Quality Problems at DOD and NASA

Agency	Policy	Issue date
DOD—Air Force Space and Missile Systems Center	DOD Instruction 63-106, *Specifications and Standards Instruction*	October 2009
	DOD Standard SMC-S-009, *Parts, Materials and Processes Control Program for Space and Launch Vehicles Standard*[a]	January 2009
DOD—Missile Defense Agency	Assurance Provisions	October 2006
	Parts, Materials, and Processes Mission Assurance Plan	March 2008
NASA	NASA Policy Directive 8790.2C, NASA Parts Policy	November 2008
	Goddard Space Flight Center, EEE-INST-002, *Instructions for Electrical, Electronic and Electromechanical Parts Selection, Screening, Qualification and Derating*[b]	May 2003

Source: GAO analysis of DOD and NASA data.

[a]The Navy's Mobile User Objective System is supported by this standard.

[b]Although this policy is a NASA/Goddard-specific policy, all of the NASA systems we reviewed followed this policy.

Government policies generally require various activities related to the selection and testing of parts, materials, and processes. It is the prime contractor's responsibility to determine how the requirements will be

[18] These policies alone do not bind the contractors—the contracts themselves must link or incorporate these policies.

[19] GAO, *Defense Supplier Base: DOD Should Leverage Ongoing Initiatives in Developing Its Program to Mitigate Risk of Counterfeit Parts*, GAO-10-389 (Washington, D.C.: Mar. 29, 2010).

managed and implemented, including the selection and management of subcontractors and suppliers. In addition, it is the government's responsibility to provide sufficient oversight to ensure that parts quality controls and procedures are in place and rigorously followed. Finally, DOD and NASA have quality and mission assurance personnel staff on their programs to conduct on-site audits at contractor facilities. Table 2 illustrates the typical roles of the government and the prime contractor in ensuring parts quality.

Table 2: Typical Roles of Government and Prime Contractors in Ensuring Parts Quality

<table>
<tr><th>Government</th><th>Prime contractor</th></tr>
<tr><td>Defines requirements for parts, materials, and processes and may require the prime contractor to conduct various activities related to the following:
• Selection of parts, materials, and processes
• Selection of suppliers
• Testing (screening, qualification, and inspection)</td><td rowspan="3">Defines and documents how parts, materials, and process activities will be managed and implemented
• Ensures that requirements are met through thorough, complete, and traceable documentation and verification
• Ensures that all discrepancies/nonconformances are reported and resolutions are customer approved
• Establishes and/or follows a parts, materials, and processes control board that includes subcontractors to coordinate the program's parts, materials, and process controls program
• Is responsible for flow-down and implementation of requirements to all subcontractors, sub-tiers, and suppliers</td></tr>
<tr><td>Ensure that parts, materials, and process controls and procedures are in place and rigorously followed</td></tr>
<tr><td>Conduct quality assurance audit functions and supplier surveillance</td></tr>
</table>

Source: GAO analysis of the Aerospace Corporation's *Mission Assurance Guidebook.*

DOD and NASA also have their own oversight activities that contribute to system quality. DOD has on-site quality specialists within the Defense Contract Management Agency and the military services, MDA has its Mission Assurance program, and NASA has its Quality Assurance program. Each activity aims to identify quality problems and ensure the on-time, on-cost delivery of quality products to the government through oversight of manufacturing and through supplier management activities, selected manufacturing activities, and final product inspections prior to acceptance. Likewise, prime contractors employ quality assurance specialists and engineers to assess the quality and reliability of both the parts they receive from suppliers and the overall weapon system. In addition, DOD and NASA have access to one or more of the following databases used to report deficient parts: the Product Data Reporting and Evaluation Program (PDREP), the Joint Deficiency Reporting System (JDRS), and the Government Industry Data Exchange Program (GIDEP). Through these systems, the government and industry participants share information on deficient parts.[20]

Parts Quality Problems Are Widespread and in Some Cases Have Had a Significant Effect on Cost, Schedule, and Performance

Parts quality problems reported by each program affected all 21 programs we reviewed at DOD and NASA and in some cases contributed to significant cost overruns, schedule delays, and reduced system reliability and availability. In most cases, problems were associated with electronics parts, versus mechanical parts or materials. Moreover, in several cases, parts problems were discovered late in the development cycle and, as such, tended to have more significant cost and schedule consequences.

Table 3 identifies the cost and schedule effects of parts quality problems for the 21 programs we reviewed. The costs in this table are the cumulative costs of all the parts quality problems that the programs identified as most significant as of August 2010 and do not necessarily reflect cost increases to the program's total costs. In some cases, program officials told us that they do not track the cost effects of parts quality problems or that it was too early to determine the effect. The schedule effect is the cumulative total of months it took to resolve a problem. Unless the problems affected a schedule milestone such as launch date, the total number of months may reflect problems that were concurrent and may not necessarily reflect delays to the program's schedule.

[20] PDREP is an automated information system managed by the Navy to track quality, including part deficiencies. JDRS is an automated information system that the Naval Air Systems Command developed for reporting of part deficiencies for aeronautics. GIDEP is a Web-based database that allows government and industry participants to share information on deficient parts, including counterfeits. We did not use these systems in our review because of the delay associated with obtaining current information. We previously reported that a DOD military standard required the use of GIDEP, but that the standard was canceled during acquisition reform in 1996. We also cited concerns related to delayed reporting and liability issues. See GAO-10-389.

Table 3: Cost and Schedule Effect of Parts Quality Problems at DOD and NASA

Agency/system[a]	Cost (dollars in millions)	Schedule
DOD—Air Force		
Advanced Extremely High Frequency Satellites	$250[b]	24 month launch delay[c]
Global Positioning System Block IIF	$0.2	Not reported
Space-Based Infrared System	Not reported	Not reported
Space-Based Space Surveillance	$3.3	1 month
DOD—Navy		
Mobile User Objective System	Not reported	18 months
DOD—Missile Defense Agency		
Aegis Ballistic Missile Defense	$1.9	No impact
Ground-Based Midcourse Defense	$19	25 months
Space Tracking and Surveillance System	$7.8	5 months[d]
Targets and Countermeasures	$0.9	1-2 weeks impact or no impact
NASA		
Aquarius	$0.1	1 month
Global Precipitation Measurement Mission	$0.3	16 months
Glory	$72.2	20-month launch delay
Gravity Recovery and Interior Laboratory	$0.4	1 month
James Webb Space Telescope	$5	6 months
Juno	$4.5	13 months
Landsat Data Continuity Mission	$5	25 months
Magnetospheric Multiscale	Not reported	Not reported
Mars Science Laboratory	$10.5	26 months
National Polar-orbiting Operational Environmental Satellite System Preparatory Project	$105.2	27-month launch delay
Radiation Belt Storm Probes	Not reported	Not reported
Tracking and Data Relay Satellite System	Not reported	3 months

Source: GAO analysis of DOD and NASA data.

Note: "Not reported" can mean that there was no effect or that the effect was unknown. The cost and schedule effects do not necessarily reflect increases to the program's total cost or schedule.

[a]See app. II for a description of the systems.

[b]Program officials identified eight parts quality problems that they considered to be the most significant; however, they initially reported that the costs associated with the problems were "unknown." Officials later stated that one of the eight problems reported added an additional cost of at least $250 million.

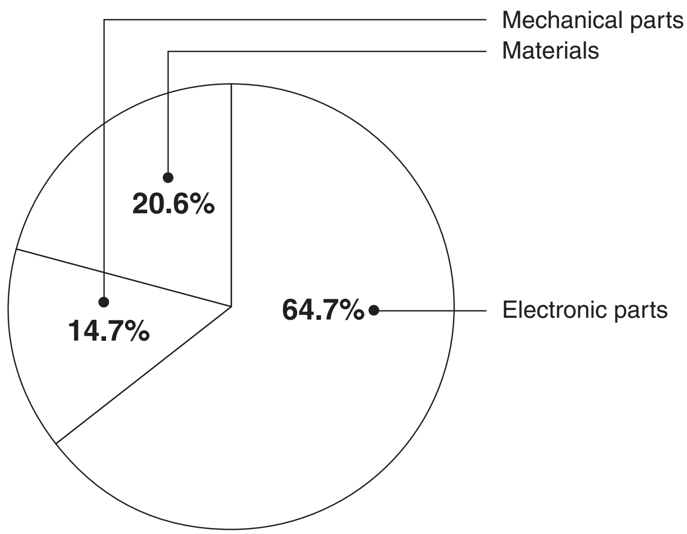
[c]Program officials did not identify any schedule effects with the eight parts quality problems they reported. However, based on prior GAO work, we determined that parts quality problems contributed to a 2-year launch delay.

[d] According to program officials, parts quality problems contributed to but were not the main cause of a 2-year launch delay as described in GAO-09-326SP and GAO-06-391.

Programs Are Primarily Experiencing Quality Problems with Electronic Parts

The programs we reviewed are primarily experiencing quality problems with electronic parts that are associated with electronic assemblies, such as computers, communication systems, and guidance systems, critical to the system operations. Based on our review of 21 programs, 64.7 percent of the parts quality problems were associated with electronic parts, 14.7 percent with mechanical parts, and 20.6 percent with materials used in manufacturing. In many cases, programs experienced problems with the same parts and materials. Figure 3 identifies the distribution of quality problems across electronic parts, mechanical parts, and materials.

Figure 3: Distribution of Quality Problems Found in Programs Reviewed and Grouped by Electronic Parts, Mechanical Parts, and Materials

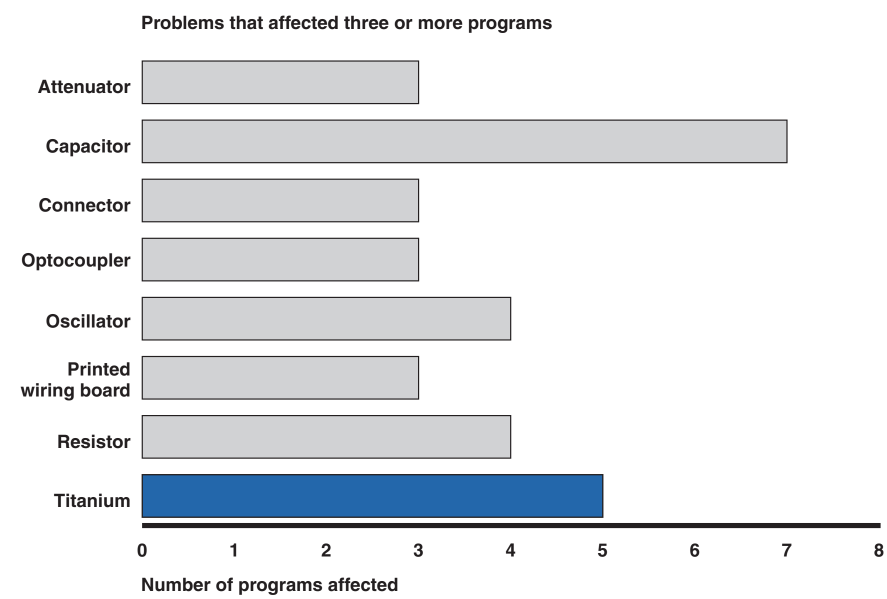


Source: GAO analysis of DOD and NASA data.

In many cases, programs experienced problems with the same parts and materials. For electronic parts, seven programs reported problems with capacitors, a part that is widely used in electronic circuits. Multiple programs also reported problems with printed circuit boards, which are used to support and connect electronic components. While printed circuit boards range in complexity and capability, they are used in virtually all but the simplest electronic devices. As with problems with electronic parts, multiple programs also experienced problems with the same materials.

For example, five programs reported problems with titanium that did not meet requirements. In addition, two programs reported problems with four different parts manufactured with pure tin, a material that is prohibited in space because it poses a reliability risk to electronics.[21] Figure 4 identifies examples of quality problems with parts and materials that affected three or more programs.

Figure 4: Examples of Quality Problems with Electronic Parts and Manufacturing Materials That Affected Three or More Programs



Electronic parts

Attenuator is a part that reduces the strength of an alternating signal.

Capacitor is a part that, among other things, stores energy.

Connector is a part that connects two or more types of wiring items.

Optocoupler is a part that transfers electrical signals using light waves.

Oscillator is a part that provides timing signals in digitial and analog circuits.

Printed circuit board is a part used to support and provide connection of an electronic circuit.

Resistor is a part that opposes the flow of current in an electrical circuit.

Manufacturing materials

Titanium is a strong, corrosion-resistant material frequently used in jet engines, missiles, and spacecraft.

Electronic parts
Manufacturing materials

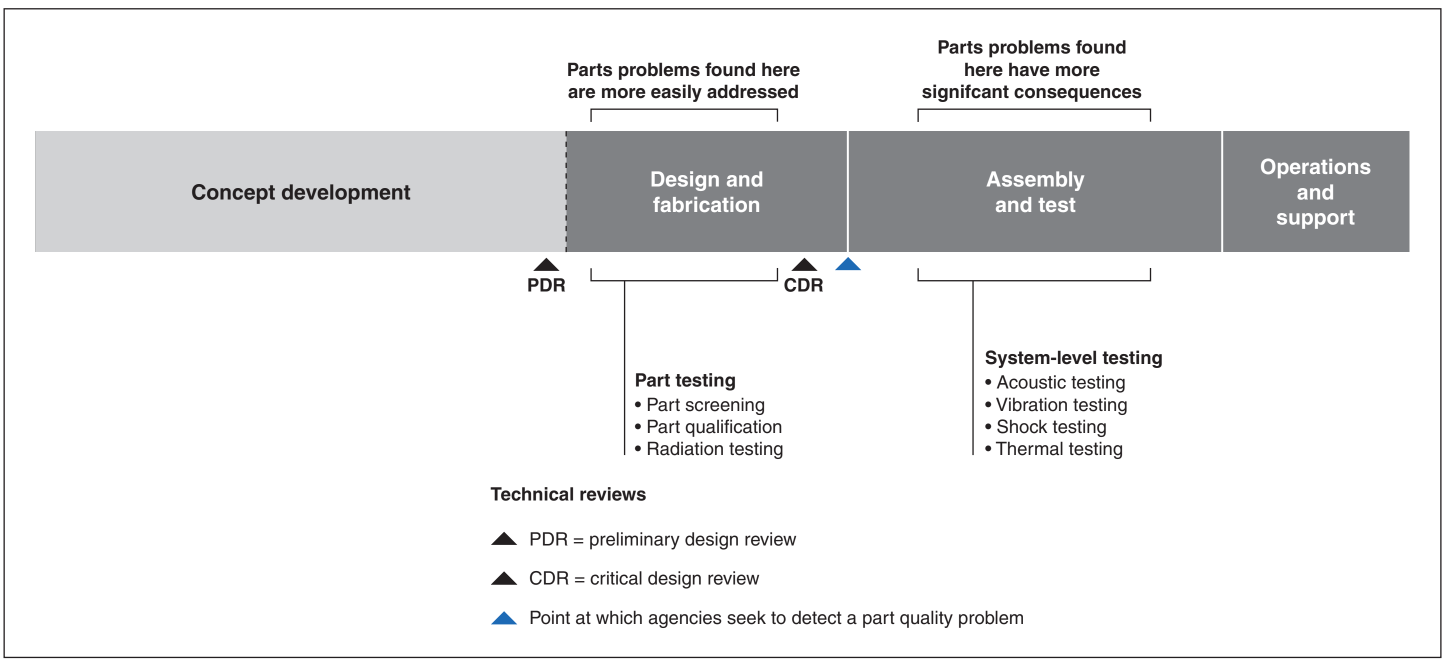
Source: GAO analysis of DOD and NASA data.

[21] Electrically conductive crystalline structures of tin, or “tin whiskers,” can grow from surfaces where pure tin is used, potentially causing short circuits and posing a serious reliability risk to electronic assemblies. According to NASA’s Electronic Parts and Packaging Program, tin whisker-induced short circuits have resulted in on-orbit failure of commercial satellites and have caused failures of medical devices and consumer products. Alloys of tin and lead reduce the propensity for whisker growth; however, the electronics industry is largely moving away from the use of potentially hazardous materials, such as lead.

Parts Problems Discovered Late in Development Cycle Had More Significant Consequences

While parts quality problems affected all of the programs we reviewed, problems found late in development—during final integration and testing at the instrument and system level—had the most significant effect on program cost and schedule. As shown in figure 5, part screening, qualification, and testing typically occur during the final design phase of spacecraft development. When parts problems are discovered during this phase, they are sometimes more easily addressed without major consequences to a development effort since fabrication of the spacecraft has not yet begun or is just in the initial phases. In several of the cases we reviewed, however, parts problems were discovered during instrument and system-level testing, that is, after assembly or integration of the instrument or spacecraft. As such, they had more significant consequences as they required lengthy failure analysis, disassembly, rework, and reassembly, sometimes resulting in a launch delay.

Figure 5: Summary of Typical Key Testing Practices to Identify Parts Quality Problems



Source: GAO analysis of DOD and NASA data.

Our work identified a number of cases in which parts problems identified late in development caused significant cost and schedule issues.

- Parts quality problems found during system-level testing of the Air Force's Advanced Extremely High Frequency satellite program contributed to a launch delay of almost 2 years and cost the program at least $250 million. A power-regulating unit failed during system-level thermal vacuum testing because of defective electronic parts that had to be removed and replaced. This and other problems resulted in extensive rework and required the satellite to undergo another round of thermal vacuum testing. According to the program office, the additional thermal vacuum testing alone cost about $250 million.
- At MDA, the Space Tracking and Surveillance System program discovered problems with defective electronic parts in the Space-Ground Link Subsystem during system-level testing and integration of the satellite. By the time the problem was discovered, the manufacturer no longer produced the part and an alternate contractor had to be found to manufacture and test replacement parts. According to officials, the problem cost about $7 million and was one of the factors that contributed to a 17-month launch delay of two demonstration satellites and delayed participation in the BMDS testing we reported on in March 2009.[22]
- At NASA, parts quality problems found late in development resulted in a 20-month launch delay for the Glory program and cost $71.1 million. In August 2008, Glory's spacecraft computer failed to power up during system-level testing. After a 6-month failure analysis, the problem was attributed to a crack in the computer's printed circuit board, an electronic part in the computer used to connect electronic components. Because the printed circuit board could not be manufactured reliably, the program had to procure and test an alternate computer. The program minimized the long lead times expected with the alternate computer by obtaining one that had already been procured by NASA. However, according to contractor officials, design changes were also required to accommodate the alternate computer. In June 2010, after the computer problem had been resolved, the Glory program also discovered problems with parts for the solar array drive assembly that rendered one of the arrays unacceptable for flight and resulted in an additional 3-month launch delay.[23]
- Also at NASA, the National Polar-orbiting Operational Environmental Satellite System Preparatory Project experienced $105 million in cost

[22] GAO, *Defense Acquisitions: Assessments of Selected Weapon Programs*, GAO-09-326SP (Washington, D.C.: Mar. 30, 2009).

[23] The Glory satellite launched on March 4, 2011, and failed to reach orbit because of a problem with the satellite launch vehicle.

increases and 27 months of delay because of parts quality problems.[24] In one case, a key instrument developed by a NASA partner failed during instrument-level testing because the instrument frame fractured at several locations. According to the failure review board, stresses exceeded the material capabilities of several brazed joints—a method of joining metal parts together. According to officials, the instrument's frame had to be reinforced, which delayed instrument delivery and ultimately delayed the satellite's launch date. In addition, officials stated that they lack confidence in how the partner-provided satellite instruments will function on orbit because of the systemic mission assurance and systems engineering issues that contributed to the parts quality problems.

For some of the programs we reviewed, the costs associated with parts quality problems were minimized because the problems were found early and were resolved within the existing margins built into the program schedule. For example, the Air Force's Global Positioning System (GPS) program discovered problems with electronic parts during part-level testing and inspection. An investigation into the problem cost about $50,000, but did not result in delivery delays. An independent review team ultimately concluded that the parts could be used without a performance or mission impact. At NASA, the Juno program discovered during part-level qualification testing that an electronic part did not meet performance requirements. The program obtained a suitable replacement from another manufacturer; it cost the program $10,000 to resolve the issue with no impact on program schedule.

In other cases, the costs of parts quality problems were amplified because they were a leading cause of a schedule delay to a major milestone, such as launch readiness. For example, of the $60.9 million cost associated with problems with the Glory spacecraft computer found during system-level testing, $11.6 million was spent to resolve the issue, including personnel costs for troubleshooting, testing, and oversight as well as design, fabrication, and testing of the new computer. The majority of the cost—$49.3 million—was associated with maintaining the contractor during the

[24] The National Polar-orbiting Operational Environmental Satellite System Preparatory Project (NPP) is a joint mission with the National Oceanic and Atmospheric Administration and the Air Force. Three of the five NPP contracts for instruments were issued by the Air Force's Space and Missile Systems Center and managed jointly by the National Polar-orbiting Environmental Satellite System Integrated Program Office. According to NASA NPP program officials, management of those contracts is being transferred to NASA's Goddard Space Flight Center.

15-month launch delay. Similarly, problems with parts for Glory's solar array assembly cost about $10.1 million, $2.7 million to resolve the problem and $7.4 million resulting from the additional 3-month schedule delay. Similarly, program officials for NASA's National Polar-orbiting Environmental Satellite System Preparatory Project attributed the $105 million cost of its parts quality problems to the costs associated with launch and schedule delays, an estimated $5 million a month.

In several cases, the programs were encountering other challenges that obscured the problems caused by poor quality parts. For example, the Air Force's Space-Based Infrared System High program reported that a part with pure tin in the satellite telemetry unit was discovered after the satellite was integrated. After an 11-month failure review board, the defective part was replaced. The program did not quantify the cost and schedule effect of the problem because the program was encountering software development issues that were already resulting in schedule delays. Similarly, NASA's Mars Science Laboratory program experienced a failure associated with joints in the rover propulsion system. According to officials, the welding process led to joint embrittlement and the possibility of early failure. The project had to test a new process, rebuild, and test the system, which cost about $4 million and resulted in a 1-year delay in completion. However, the program's launch date had already been delayed 25 months because of design issues with the rover actuator motors and avionics package—in effect, buying time to resolve the problem with the propulsion system.

In Some Cases, Parts Quality Problems Affected System Reliability and Availability

In addition to the launch delays discussed above, parts quality problems also resulted in reduced system reliability and availability for several other programs we reviewed. For example, the Air Force's GPS program found that an electronic part lacked qualification data to prove the part's quality and reliability. As a result, the overall reliability prediction for the space vehicle was decreased. At MDA, the Ground-Based Midcourse Defense program discovered problems with an electronic part in the telemetry unit needed to transmit flight test data. The problem was found during final assembly and test operations of the Exoatmospheric Kill Vehicle resulting in the cancellation of a major flight test. This increased risk to the program and the overall BMDS capability, since the lack of adequate intercept data reduced confidence that the system could perform as intended in a real-world situation. Also, MDA's Aegis Ballistic Missile Defense program recalled 16 missiles from the warfighter, including 7 from a foreign partner, after the prime contractor discovered that the brackets used to accommodate communications and power cabling were improperly adhered to the Standard Missile 3 rocket motor. If not corrected, the problem could have resulted in catastrophic mission failure.

The Costs of Parts Quality Problems Are Primarily Borne by the Government

Regardless of the cause of the parts quality problem, the government typically bears the costs associated with resolving the issues and associated schedule impact. In part, this is due to the use of cost-reimbursement contracts. Because space and missile defense acquisitions are complex and technically challenging, DOD and NASA typically use cost-reimbursement contracts, whereby the government pays the prime contractor's allowable costs to the extent prescribed in the contract for the contractor's best efforts. Under cost-reimbursement contracts, the government generally assumes the financial risks associated with development, which may include the costs associated with parts quality problems. Of the 21 programs we reviewed, 20 use cost-reimbursement contracts. In addition, 17 programs use award and incentive fees to reduce the government's risk and provide an incentive for excellence in such areas as quality, timeliness, technical ingenuity, and cost-effective management. Award and incentive fees enable the reduction of fee in the event that the contractor's performance does not meet or exceed the requirements of the contract.[25] Aside from the use of award fees, senior quality and acquisition oversight officials told us that incentives for prime contractors to ensure quality are limited.

Parts Quality Problems Were Caused by Poor Manufacturing Controls, Design, and Supplier Management

The parts quality problems we identified were directly attributed to poor control of manufacturing processes and materials, poor design, and lack of effective supplier management. Generally, prime contractor activities to capture manufacturing knowledge should include identifying critical characteristics of the product's design and then the critical manufacturing processes and materials to achieve these characteristics. Manufacturing processes and materials should be documented, tested, and controlled prior to production. This includes establishing criteria for workmanship, making work instructions available, and preventing and removing foreign object debris in the production process.

[25] We have reported on agencies' use of cost-plus-award-fee contracts, finding in some cases that award fees had been paid to contractors regardless of acquisition outcomes. GAO, *Federal Contracting: Guidance on Award Fees Has Led to Better Practices but Is Not Consistently Applied*, GAO-09-630 (Washington, D.C. May 29, 2009).

Poor workmanship was one of the causes of problems with electronic parts.[26] At DOD, poor workmanship during hand-soldering operations caused a capacitor to fail during testing on the Navy's Mobile User Objective System program. Poor soldering workmanship also caused a power distribution unit to experience problems during vehicle-level testing on MDA's Targets and Countermeasures program. According to MDA officials, all units of the same design by the same manufacturer had to be X-ray inspected and reworked, involving extensive hardware disassembly. As a corrective action, soldering technicians were provided with training to improve their soldering operations and ability to perform better visual inspections after soldering. Soldering workmanship problems also contributed to a capacitor failure on NASA's Glory program. Analysis determined that the manufacturer's soldering guidelines were not followed.

Programs also reported quality problems because of the use of undocumented and untested manufacturing processes. For example, MDA's Aegis Ballistic Missile Defense program reported that the brackets used to accommodate communications and power cabling were improperly bonded to Standard Missile 3 rocket motors, potentially leading to mission failure. A failure review board determined that the subcontractor had changed the bonding process to reduce high scrap rates and that the new process was not tested and verified before it was implemented. Similarly, NASA's Landsat Data Continuity Mission program experienced problems with the spacecraft solar array because of an undocumented manufacturing process. According to program officials, the subcontractor did not have a documented process to control the amount of adhesive used in manufacturing, and as a result, too much adhesive was applied. If not corrected, the problem could have resulted in solar array failure on orbit.

Poor control of manufacturing materials and the failure to prevent contamination also caused quality problems. At MDA, the Ground-Based Midcourse Defense program reported a problem with defective titanium tubing. The defective tubing was rejected in 2004 and was to be returned to the supplier; however, because of poor control of manufacturing materials, a portion of the material was not returned and was inadvertently

[26] Workmanship is defined as the control of design features, materials, and assembly processes to achieve the desired reliability for subassembly interconnections, such as those for printed wiring assemblies, and the use of inspection techniques and criteria to ensure quality, according to NASA's Workmanship Standards Program.

used to fabricate manifolds for two complete Ground-Based Interceptor Exoatmospheric Kill Vehicles. The vehicles had already been processed and delivered to the prime contractor for integration when the problem was discovered. Lack of adherence to manufacturing controls to prevent contamination and foreign object debris also caused parts quality problems. For example, at NASA, a titanium propulsion tank for the Tracking Data and Relay Satellite program failed acceptance testing because a steel chip was inadvertently welded onto the tank. Following a 3-month investigation into the root cause, the tank was scrapped and a replacement tank was built.

Design Flaws Also Resulted in Parts Quality Problems

In addition to problems stemming from poor control of manufacturing processes and materials, many problems resulted from poor part design, design complexity, and inattention to manufacturing risks. For example, attenuators for the Navy's Mobile User Objective System exhibited inconsistent performance because of their sensitivity to temperature changes. Officials attributed the problem to poor design, and the attenuators were subsequently redesigned. At NASA, design problems also affected parts for the Mars Science Laboratory program. According to program officials, several resistors failed after assembly into printed circuit boards. A failure review board determined that the tight design limits contributed to the problem. Consequently, the parts had to be redesigned and replaced.

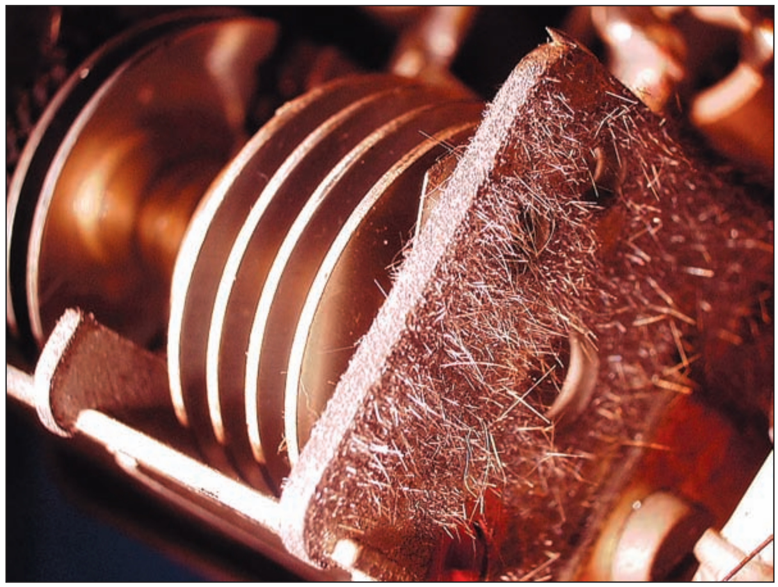
Programs also underestimated the complexity of parts design, which created risks of latent design and workmanship defects. For example, NASA's Glory project experienced problems with the state-of-the-art printed circuit board for the spacecraft computer. According to project officials, the board design was almost impossible to manufacture with over 100 serial steps involved in the manufacturing process. Furthermore, failure analysis found that the 27,000 connection points in the printed circuit board were vulnerable to thermal stresses over time leading to intermittent failures. However, the quality of those interconnections was difficult to detect through standard testing protocols. This is inconsistent with commercial best practices, which focus on simplified design characteristics as well as use of mature and validated technology and manufacturing processes.

Supplier Management Contributed to Quality Problems

Program officials at each agency also attributed parts quality problems to the prime contractor's failure to ensure that its subcontractors and suppliers met program requirements. According to officials, in several cases, prime contractors were responsible for flowing down all applicable program requirements to their subcontractors and suppliers. Requirements flow-down from the prime contractor to subcontractors and suppliers is particularly important and challenging given the structure of the space and defense industries, wherein prime contractors are subcontracting more work to subcontractors.[27] At MDA, the Ground-Based Midcourse Defense program experienced a failure with an electronics part purchased from an unauthorized supplier. According to program officials, the prime contractor flowed down the requirement that parts only be purchased from authorized suppliers; however, the subcontractor failed to execute the requirement and the prime contractor did not verify compliance. Program officials for NASA's Juno program attributed problems with a capacitor to the supplier's failure to review the specification prohibiting the use of pure tin. DOD's Space-Based Infrared System High program reported problems with three different parts containing pure tin and attributed the problems to poor requirements flow-down and poor supplier management. Figure 6 shows an example of tin whiskers on a capacitor, which can cause catastrophic problems to space systems.

[27] According to some DOD and industry experts, prime contractors are subcontracting more work on the production of weapons systems and concentrating instead on systems integration. Based on some estimates, 60 to 70 percent of work on defense contracts is now done by subcontractors. See GAO, *Defense Acquisitions: Additional Guidance Needed to Improve Visibility into the Structure and Management of Major Weapon System Subcontracts*, GAO-11-61R (Washington, D.C.: Oct. 28, 2010).

Figure 6: Example of a Capacitor with Tin Whiskers



Source: NASA Electronic Parts and Packaging Program.

Agency and Industry Efforts to Address Parts Quality Problems Face Significant Challenges

DOD and NASA have instituted new policies to prevent and detect parts quality problems, but most of the programs we reviewed were initiated before these policies took effect. Moreover, newer programs that do come under the policies have not reached the phases of development where parts problems are typically discovered. In addition, agencies and industry have been collaborating to share information about potential problems, collecting data, and developing guidance and criteria for activities such as testing parts, managing subcontractors, and mitigating specific types of problems. We could not determine the extent to which collaborative actions have resulted in reduced instances of parts quality problems or ensured that they are caught earlier in the development cycle. This is primarily because data on the condition of parts quality in the space and missile community governmentwide historically have not been collected. And while there are new efforts to collect data on anomalies, there is no mechanism to use these data to help assess the effectiveness of improvement actions. Lastly, there are significant potential barriers to success of efforts to address parts quality problems. They include broader acquisition management problems, workforce gaps, diffuse leadership in the national security space community, the government's decreasing influence on the overall electronic parts market, and an increase in counterfeiting of electronic parts. In the face of such challenges, it is likely that ongoing improvements will have limited success without continued assessments to determine what is working well and what more needs to be done.

Agencies Are Undertaking Efforts to Strengthen Parts Quality Management

As noted earlier in this report, the Air Force, MDA, and NASA have all recently instituted or updated existing policies to prevent and detect parts quality problems. At the Air Force and MDA, all of the programs we reviewed were initiated before these recent policies aimed at preventing and detecting parts quality problems took full effect. In addition, it is too early to tell whether newer programs—such as a new Air Force GPS development effort and the MDA's Precision Tracking Space System—are benefiting from the newer policies because these programs have not reached the design and fabrication phases where parts problems are typically discovered. However, we have reported that the Air Force is taking measures to prevent the problems experienced on the GPS IIF program from recurring on the new GPS III program. The Air Force has increased government oversight of its GPS III development and Air Force officials are spending more time at the contractor's site to ensure quality.[28] The Air Force is also following military standards for satellite quality for GPS III development. At the time of our review, the program had not reported a significant parts quality problem. Table 4 highlights the major differences in the framework between the GPS IIF and GPS III programs.

[28] GAO, *Global Positioning System: Significant Challenges in Sustaining and Upgrading Widely Used Capabilities*, GAO-09-325 (Washington, D.C.: Apr. 30, 2009).

Table 4: Key Differences in Program Framework between GPS IIF and GPS III

	GPS IIF	GPS III
Requirements	Addition of requirements after contract award.	Not allowing an adjustment to the program to meet increased or accelerated requirements.
Development	Immature technologies.	Incremental development, while ensuring technologies are mature.
Oversight	Limited oversight of contractor, relaxed specifications and inspections, and limited design reviews.	More contractor oversight with government presence at contractor facility; use of military standards; and multiple levels of preliminary design reviews, with the contractor being held to military standards and deliverables during each review.

Source: GAO analysis based on discussions with the GPS program office officials and review of program documentation.

In addition to new policies focused on quality, agencies are also becoming more focused on industrial base issues and supply chain risks. For example, MDA has developed the supplier road map database in an effort to gain greater visibility into the supply chain in order to more effectively manage supply chain risks. In addition, according to MDA officials, MDA has recently been auditing parts distributors in order to rank them for risk in terms of counterfeit parts. NASA has begun to assess industrial base risks and challenges during acquisition strategy meetings and has established an agency Supply Chain Management Team to focus attention on supply chain management issues and to coordinate with other government agencies.

Agencies and industry also participate in a variety of collaborative initiatives to address quality, in particular, parts quality. These range from informal groups focused on identifying and sharing news about emerging problems as quickly as possible, to partnerships that conduct supplier assessments, to formal groups focused on identifying ways industry and the government can work together to prevent and mitigate problems. As shown in table 5, these groups have worked to establish guidance, criteria, and standards that focus on parts quality issues, and they have enhanced existing data collection tools and created new databases focused on assessing anomalies.

Table 5: Examples of Organizations and Their Collaborative Efforts and Outcomes for Addressing Parts Quality

Organizations	Examples of collaborative efforts	Examples of outcomes
Government • Air Force Space and Missile Systems Center • Defense Contract Management Agency • International agencies • Missile Defense Agency • National Aeronautics and Space Administration • National Reconnaissance Office • Space and Naval Warfare Systems Command **Industry** • Prime contractors • Subcontractors **Other** • Aerospace Corporation	**Councils and senior leader forums** • Joint Mission Assurance Council • Mission Assurance Summit • Space Industrial Base Council • Space Quality Improvement Council • Space Supplier Council **Government/industry technical committees** • Government-Industry Fastener Working Group (GIFWG) • NASA EEE Parts Assurance Group (NEPAG) • Pb-free Electronics Risk Management (PERM) Consortium • SAE G-19 Technical Committee, Counterfeit Parts Avoidance • TechAmerica G-11 and G-12, Component Parts **Working groups** • Mission Assurance Improvement Workshop • National Security Space Advisory Forum • Space Industrial Base Working Groups • Space Parts Working Group **Other activities** • Joint supplier audits and assessments • Meetings between agencies to share parts issues and assist in building quality assurance programs	**Communication among agencies, industry, and their leadership** • Venues for senior agency leadership to discuss quality issues and lessons learned • Venues to discuss specific areas of interest and concerns, for example, problems with electronic parts and risk mitigation strategies • New memorandum of understanding to increase interagency cooperation **Tools/actions** • Guidelines for flight unit qualification • Mitigation plan for problems affecting batteries, solar cells and arrays, and traveling wave tube amplifiers • Subcontractor management standards • Supplier assessments jointly conducted by Defense Contract Management Agency, other agencies, and industry **Data collection/sharing enhancements** • Aerospace Corporation database of orbit and preflight anomalies • National Security Space Advisory Forum—Web-based alert system for space system anomaly data and problem alerts; this supplements current GIDEP reporting system

Source: GAO analysis of DOD, NASA and space industry efforts.

One example of the collaborative efforts is the Space Industrial Base Council (SIBC)—a government-led initiative—which brings together officials from agencies involved in space and missile defense to focus on a range of issues affecting the space industrial base and has sparked numerous working groups focused specifically on parts quality and critical suppliers. These groups in turn have worked to develop information-sharing mechanisms, share lessons learned and conduct supplier assessments, soliciting industry's input as appropriate. For instance, the SIBC established a critical technology working group to explore supply chains and examine critical technologies to put in place a process for strategic management of critical space systems' technologies and capabilities under the Secretary of the Air Force and the Director of the National Reconnaissance Office. The working group has developed and initiated a mitigation plan for batteries, solar cells and arrays, and traveling wave tube amplifiers.[29] In addition, the Space Supplier Council was established under the SIBC to focus on the concerns of second-tier and lower-tier suppliers, which typically have to go through the prime contractors, and to promote more dialogue between DOD, MDA, NASA, other space entities, and these suppliers. Another council initiative was the creation of the National Security Space Advisory Forum, a Web-based alert system developed for sharing critical space system anomaly data and problem alerts, which became operational in 2005.

Agency officials also cited other informal channels used to share information regarding parts issues. For example, NASA officials stated that after verifying a parts issue, they will share their internal advisory notice with any other government space program that could potentially be affected by the issue. According to several government and contractor officials, the main reasons for delays in information sharing were either the time it took to confirm a problem or concerns with proprietary and liability issues. NASA officials stated that they received advisories from MDA and had an informal network with MDA and the Army Space and Missile Defense Command to share information about parts problems. Officials at the Space and Missile Systems Center also mentioned that they have informal channels for sharing part issues. For example, an official in the systems engineering division at the Space and Missile Systems Center stated that he has weekly meetings with a NASA official to discuss parts issues.

In addition to the formal and informal collaborative efforts, the Air Force's Space and Missile Systems Center, MDA, NASA, and the National Reconnaissance Office signed a memorandum of understanding (MOU) in February 2011 to encourage additional interagency cooperation in order to strengthen mission assurance practices. The MOU calls on the agencies to develop and share lessons learned and best practices to ensure mission success through a framework of collaborative mission assurance. Broad objectives of the framework are to develop core mission assurance practices and tools; to foster a mission assurance culture and world-class

[29] Batteries identified were lithium-ion. A traveling wave tube amplifier is employed as a microwave power amplifier and can have application in both receiver and transmitter systems.

workforce; to develop clear and executable mission assurance plans; to manage effective program execution; and to ensure program health through independent, objective assessments. Specific objectives include developing a robust mission assurance infrastructure and guidelines for tailoring specifications and standards for parts, materials, and processes and establishing standard contractual language to ensure consistent specification of core standards and deliverables.

In addition, each agency is asked to consider the health of the industrial base in space systems acquisitions and participate in mission assurance activities, such as the Space Supplier Council and mission assurance summits. In signing the MOU, DOD, MDA, NASA, and the National Reconnaissance Office acknowledged the complexity of such an undertaking as it typically takes years to deliver a capability and involves hundreds of industry partners building, integrating, and testing hundreds of thousands of parts, all which have to work the first time on orbit—a single mishap, undetected, can and has had catastrophic results.

Although collaborative efforts are under way, we could not determine the extent to which collaborative actions have resulted in reduced instances of parts quality problems to date or ensured that they are caught earlier in the development cycle. This is primarily because data on the condition of parts quality in the space and missile community governmentwide historically have not been collected. The Aerospace Corporation has begun to collect data on on-orbit and preflight anomalies in addition to the Web alert system established by the Space Quality Improvement Council. In addition, there is no mechanism in place to assess the progress of improvement actions using these data or to track the condition of parts quality problems across the space and missile defense sector to determine if improvements are working or what additional actions need to be taken. Such a mechanism is needed given the varied challenges facing improvement efforts.

Improvement Efforts Face Potential Barriers to Success

There are significant potential barriers to the success of improvement efforts, including broader acquisition management problems, diffuse leadership in the national security space community, workforce gaps, the government's decreasing influence on the overall electronic parts market, and an increase in counterfeiting of electronic parts. Actions are being taken to address some of these barriers, such as acquisition management and diffuse leadership, but others reflect trends affecting the aerospace industry that are unlikely to change in the near future and may limit the extent to which parts problems can be prevented.

- **Broader acquisition management problems:** Both space and missile defense programs have experienced acquisition problems—well beyond parts quality management difficulties—during the past two decades that have driven up costs by billions of dollars, stretched schedules by years, and increased technical risks. These problems have resulted in potential capability gaps in areas such as missile warning, military communications, and weather monitoring, and have required all the agencies in our review to cancel or pare back major programs. Our reports have generally found that these problems include starting efforts before requirements and technologies have been fully understood and moving them forward into more complex phases of development without sufficient knowledge about technology, design, and other issues. Reduced oversight resulting from earlier acquisition reform efforts and funding instability have also contributed to cost growth and schedule delays. Agencies are attempting to address these broader challenges as they are concurrently addressing parts quality problems. For space in particular, DOD is working to ensure that critical technologies are matured before large-scale acquisition programs begin, requirements are defined early in the process and are stable throughout, and system designs remain stable. In response to our designation of NASA acquisition management as a high-risk area,[30] NASA developed a corrective action plan to improve the effectiveness of its program/project management, and it is in the process of implementing earned value management within certain programs to help projects monitor the scheduled work done by NASA contractors and employees.[31] These and other actions have the potential to strengthen the foundation for program and quality management but they are relatively new and implementation is uneven among the agencies involved with space and missile defense. For instance, we have found that both NASA and MDA lack adequate visibility into costs of programs. Our reports also continue to find that cost and schedule estimates across all three agencies tend to be optimistic.
- **Diffuse leadership within the national security space community:** We have previously testified and reported that diffuse leadership within the national security space community has a direct impact on the space acquisition process, primarily because it makes it difficult to hold any one person or organization accountable for

[30] GAO, *High-Risk Series: An Update*, GAO-07-310 (Washington, D.C.: Jan. 31, 2007).

[31] GAO, *Additional Cost Transparency and Design Criteria Needed for National Aeronautics and Space Administration (NASA) Projects*, GAO-11-364R (Washington, D.C.: Mar. 3, 2011).

balancing needs against wants, for resolving conflicts among the many organizations involved with space, and for ensuring that resources are dedicated where they need to be dedicated.[32] In 2008, a congressionally chartered commission (known as the Allard Commission) reported that responsibilities for military space and intelligence programs were scattered across the staffs of DOD organizations and the intelligence community and that it appeared that "no one is in charge" of national security space.[33] The same year, the House Permanent Select Committee on Intelligence reported similar concerns, focusing specifically on difficulties in bringing together decisions that would involve both the Director of National Intelligence and the Secretary of Defense.[34] Prior studies, including those conducted by the Defense Science Board and the Commission to Assess United States National Security Space Management and Organization (Space Commission),[35] have identified similar problems, both for space as a whole and for specific programs. Changes have been made this past year to national space policies as well as organizational and reporting structures within the Office of the Secretary of Defense and the Air Force to address these concerns and clarify responsibilities, but it remains to be seen whether these changes will resolve problems associated with diffuse leadership.

- **Workforce gaps:** Another potential barrier to success is a decline in the number of quality assurance officials, which officials we spoke with pointed to as a significant detriment. A senior quality official at MDA stated that the quality assurance workforce was significantly reduced as a result of acquisition reform. A senior DOD official responsible for space acquisition oversight agreed, adding that the government does not have the in-house knowledge or resources to adequately conduct many quality control and quality assurance tasks. NASA officials also noted the loss of parts specialists who provide technical expertise to

[32] GAO, *Space Acquisition: DOD Poised to Enhance Space Capabilities, but Persistent Challenges Remain in Developing Space Systems*, GAO-10-447T (Washington, D.C.: Mar. 10, 2010).

[33] Institute for Defense Analyses, *Leadership, Management, and Organization for National Security Space: Report to Congress of the Independent Assessment Panel on the Organization and Management of National Security Space* (Alexandria, Va.: July 2008).

[34] House Permanent Select Committee on Intelligence, *Report on Challenges and Recommendations for United States Overhead Architecture* (Washington, D.C.: October 2008).

[35] Department of Defense, *Report of the Commission to Assess United States National Security Space Management and Organization* (Washington, D.C.: Jan. 11, 2001).

improve specifications and review change requests. According to NASA officials, there is now a shortage of qualified personnel with the requisite cross-disciplinary knowledge to assess parts quality and reliability. Our prior work has also shown that DOD's Defense Contract Management Agency (DCMA), which provides quality assurance oversight for many space acquisitions, was downsized considerably during the 1990s.[36] While capacity shortfalls still exist, DCMA has implemented a strategic plan to address workforce issues and improve quality assurance oversight. The shortage in the government quality assurance workforce reflects a broader decline in the numbers of scientists and engineers in the space sector. The 2008 House Permanent Select Committee on Intelligence report mentioned above found that the space workforce is facing a significant loss of talent and expertise because of pending retirements, which is causing problems in smoothly transitioning to a new space workforce. Similarly, in 2010 we reported that 30 percent of the civilian manufacturing workforce was eligible for retirement, and approximately 26 percent will become eligible for retirement over the next 4 years.[37] Similar findings were reported by the DOD Cost Analysis Improvement Group in 2009.[38]

- **Industrial base consolidation:** A series of mergers and consolidations that took place primarily in the 1990s added risks to parts quality—first, by shrinking the pool of suppliers available to produce specialty parts; second, by reducing specialized expertise within prime contractors; and third, by introducing cost-cutting measures that de-emphasize quality assurance. We reported in 2007 that the GPS IIF program, the Space-Based Infrared High Satellite System, and the Wideband Global SATCOM system all encountered quality problems that could be partially attributed to industry consolidations.[39] Specialized parts for the Wideband Global SATCOM system, for example, became difficult to obtain after smaller contractors that made these parts started to consolidate. For GPS, consolidations led to a series of moves in facilities that resulted in a

[36] GAO, *DOD Personnel: DOD Actions Needed to Strengthen Civilian Human Capital Strategic Planning and Integration with Military Personnel and Sourcing Decisions*, GAO-03-475 (Washington, D.C.: Mar. 28, 2003).

[37] GAO, *Best Practices: DOD Can Achieve Better Outcomes by Standardizing the Way Manufacturing Risks Are Managed*, GAO-10-439 (Washington, D.C.: Apr. 22, 2010).

[38] Office of the Secretary of Defense, Cost Analysis Improvement Group, *National Security Space Industrial Base Study 2008 Update* (Washington, D.C.: January 2009).

[39] GAO, *Space Acquisitions*: *DOD Needs to Take More Action to Address Unrealistic Initial Cost Estimates of Space Systems*, GAO-07-96 (Washington, D.C.: Nov. 17, 2006).

loss of GPS technical expertise. In addition, during this period, the contractor took additional cost-cutting measures that reduced quality. Senior officials responsible for DOD space acquisition oversight with whom we spoke with for this review stated that prime space contractors have divested their traditional lines of expertise in favor of acting in a broader "system integrator" role. Meanwhile, smaller suppliers that attempted to fill gaps in expertise and products created by consolidations have not had the experience and knowledge needed to produce to the standards needed for government space systems. For instance, officials from one program told us that their suppliers were often unaware that their parts would be used in space applications and did not understand or follow certain requirements. Officials also mentioned that smaller suppliers attempting to enter the government space market do not have access to testing and other facilities needed to help build quality into their parts. We recently reported that small businesses typically do not own the appropriate testing facilities, such as thermal vacuum chambers, that are used for testing spacecraft or parts under a simulated space environment and instead must rely on government, university, or large contractor testing facilities, which can be costly.[40]

- **Government's declining share of the overall electronic parts market:** DOD and NASA officials also stated that the government's declining share of the overall electronic parts market has made it more difficult to acquire qualified electronic parts. According to officials, the government used to be the primary consumer of microelectronics, but it now constitutes only a small percentage of the market. As such, the government cannot easily demand unique exceptions to commercial standards. An example of an exception is DOD's standards for radiation-hardened parts, such as microelectronics, which are designed and fabricated with the specific goal of enduring the harshest space radiation environments, including nuclear events. We reported in 2010 that to produce such parts, companies would typically need to create separate production lines and in some cases special facilities.[41] Another example is that government space programs often demand the use of a tin alloy (tin mixed with lead) for parts rather than pure tin because of the risk for growth of tin whiskers. According to officials, as a result of

[40] GAO, *Space Acquisitions: Challenges in Commercializing Technologies Developed under the Small Business Innovation Research Program*, GAO-11-21 (Washington, D.C.: Nov. 10, 2010).

[41] GAO, *Briefing on Commercial and Department of Defense Space System Requirements and Acquisition Practices*, GAO-10-315R (Washington, D.C.: Jan. 14, 2010).

European environmental regulations, commercial manufacturers have largely moved away from the use of lead making it more difficult and costly to procure tin alloy parts, and increasing the risk of parts being made with pure tin. Similarly, officials noted concerns with the increased use of lead-free solders used in electronic parts. Moreover, officials told us that when programs do rely on commercial parts, there tends to be a higher risk of lot-to-lot variation, obsolescence, and a lack of part traceability.

- **An increase in counterfeit electronic parts:** Officials we spoke with agreed that an increase in counterfeit electronics parts has made efforts to address parts quality more difficult. "Counterfeit" generally refers to instances in which the identity or pedigree of a product is knowingly misrepresented by individuals or companies. A 2010 Department of Commerce study identified a growth in incidents of counterfeit parts across the electronics industry from about 3,300 in 2005 to over 8,000 incidents in 2008.[42] We reported in 2010 that DOD is limited in its ability to determine the extent to which counterfeit parts exist in its supply chain because it does not have a departmentwide definition of "counterfeit" and a consistent means to identify instances of suspected counterfeit parts.[43] Moreover, DOD relies on existing procurement and quality control practices to ensure the quality of the parts in its supply chain. However, these practices are not designed to specifically address counterfeit parts. Limitations in the areas of obtaining supplier visibility, investigating part deficiencies, and reporting and disposal may reduce DOD's ability to mitigate risks posed by counterfeit parts. At the time of our review, DOD was only in the early stages of addressing counterfeiting. We recommended and DOD concurred that DOD leverage existing initiatives to establish anticounterfeiting guidance and disseminate this guidance to all DOD components and defense contractors.

Conclusions

Space and missile systems must meet high standards for quality. The 2003 Defense Science Board put it best by noting that the "primary reason is that the space environment is unforgiving. Thousands of good engineering decisions can be undone by a single engineering flaw or workmanship error, resulting in the catastrophe of major mission failure. Options for

[42] Department of Commerce, *Defense Industrial Base Assessment: Counterfeit Electronics* (Washington, D.C., January 2010).

[43] GAO, *Defense Supplier Base: DOD Should Leverage Ongoing Initiatives in Developing Its Program to Mitigate Risk of Counterfeit Parts*, GAO-10-389 (Washington, D.C.: Mar. 29, 2010).

correction are scant."[44] The number of parts problems identified in our review is relatively small when compared to the overall number of parts used. But these problems have been shown to have wide-ranging and significant consequences. Moreover, while the government's reliance on space and missile systems has increased dramatically, attention and oversight of parts quality declined because of a variety of factors, including the implementation of TSPR and similar policies, workforce gaps, and industry consolidations. This condition has been recognized and numerous efforts have been undertaken to strengthen the government's ability to detect and prevent parts problems. But there is no mechanism in place to periodically assess the condition of parts quality problems in major space and missile defense programs and the impact and effectiveness of corrective measures. Such a mechanism could help ensure that attention and resources are focused in the right places and provide assurance that progress is being made.

Recommendations for Executive Action

We are making two recommendations to the Secretary of Defense and the NASA Administrator. We recommend that the Secretary of Defense and the Administrator of NASA direct appropriate agency executives to include in efforts to implement the new MOU for increased mission assurance a mechanism for a periodic, governmentwide assessment and reporting of the condition of parts quality problems in major space and missile defense programs. This should include the frequency such problems are appearing in major programs, changes in frequency from previous years, and the effectiveness of corrective measures. We further recommend that reports of the periodic assessments be made available to Congress.

Agency Comments and Our Evaluation

We provided draft copies of this report to DOD and NASA for review and comment. DOD and NASA provided written comments on a draft of this report. These comments are reprinted in appendixes III and IV, respectively. DOD and NASA also provided technical comments, which were incorporated as appropriate.

[44] Office of the Under Secretary of Defense for Acquisition, Technology and Logistics, *Report of the Defense Science Board/Air Force Scientific Advisory Board Joint Task Force on Acquisition of National Security Space Programs*, (Washington, D.C.: May 2003).

DOD partially concurred with our recommendation to include in its efforts to implement the new MOU for increased mission assurance a mechanism for a periodic, governmentwide assessment and reporting of the condition of parts quality problems in major space and missile defense programs, to include the frequency problems are appearing, changes in frequency from previous years, and the effectiveness of corrective measures. DOD responded that it would work with NASA to determine the optimal governmentwide assessment and reporting implementation to include all quality issues, of which parts, materials, and processes would be one of the major focus areas. In addition, DOD proposed an annual reporting period to ensure planned, deliberate, and consistent assessments. We support DOD's willingness to address all quality issues and to include parts, materials, and processes as an important focus area in an annual report. Recent cases of higher-level quality problems that did not fall within the scope of our review include MDA's Terminal High Altitude Area Defense missile system and the Air Force's Advanced Extremely High Frequency communications satellite, which were mentioned earlier in our report. It is our opinion that these cases occurred for reasons similar to those we identified for parts, materials, and processes. We recognize that quality issues can include a vast and complex universe of problems. Therefore, the scope of our review and focus of our recommendation was on parts, materials, and processes to enable consistent reporting and analysis and to help direct corrective actions. Should a broader quality focus be pursued, as DOD indicated, it is important that DOD identify ways in which this consistency can be facilitated among the agencies. In response to our second recommendation, DOD stated that it had no objection to providing a report to Congress, if Congress desired one. We believe that DOD should proactively provide its proposed annual reports to Congress on a routine basis, rather than waiting for any requests from Congress, which could be inconsistent from year to year.

NASA also concurred with our recommendations. NASA stated that enhanced cross-agency communication, coordination, and sharing of parts quality information will help mitigate threats poses by defective and nonconforming parts. Furthermore, NASA plans to engage other U.S. space agencies to further develop and integrate agency mechanisms for reporting, assessing, tracking, and trending common parts quality problems, including validation of effective cross-agency solutions.

As agreed with your office, unless you publicly announce the contents of this report earlier, we plan no further distribution until 30 days from the report date. At that time, we will send copies to the appropriate congressional committees, the Secretary of Defense, the Administrator of the National Aeronautics and Space Administration, and other interested parties. The report also will be available at no charge on the GAO Web site at http://www.gao.gov.

If you or your staff have any questions about this report, please contact me at (202) 512-4841 or chaplainc@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. Key contributors to this report are provided in appendix V.

Sincerely yours,

Cristina T. Chaplain
Director
Acquisition and Sourcing Management

Appendix I: Scope and Methodology

Our specific objectives were to assess (1) the extent to which parts quality problems are affecting Department of Defense (DOD) and National Aeronautics and Space Administration (NASA) space and missile defense programs; (2) the causes of these problems; and (3) initiatives to prevent, detect, and mitigate parts quality problems.

To examine the extent to which parts quality problems are affecting DOD (the Air Force, the Navy, and the Missile Defense Agency (MDA)) and NASA cost, schedule, and performance of space and missile defense programs, we reviewed all 21 space and missile programs—9 at DOD, including 4 Air Force, 1 Navy, and 4 MDA systems, and 12 at NASA—that were, as of October 2009, in development and projected to be high cost, and had demonstrated through a critical design review (CDR)[1] that the maturity of the design was appropriate to support proceeding with full-scale fabrication, assembly, integration, and test.[2]

DOD space systems selected were major defense acquisition programs—defined as those requiring an eventual total expenditure for research, development, test, and evaluation of more than $365 million or for procurement of more than $2.190 billion in fiscal year 2000 constant dollars. All four MDA systems met these same dollar thresholds. NASA programs selected had a life cycle cost exceeding $250 million. We chose these programs based on their cost, stage in the acquisition process—in development and post- CDR—and congressional interest. A quality problem was defined to be the degree to which the product attributes, such as capability, performance, or reliability, did not meet the needs of the customer or mission, as specified through the requirements definition and allocation process.

[1] DOD and MDA define CDR as a multidisciplined technical review to ensure that a system can proceed into fabrication, demonstration, and test and can meet stated performance requirements within cost, schedule, risk, and other system constraints. Generally, this review assesses the system's final design as captured in product specifications for each configuration item in the system's product baseline, and ensures that each configuration item in the product baseline has been captured in the detailed design documentation. CDR is normally conducted during the engineering and manufacturing development phase. See the *Defense Acquisition Guidebook* and DOD Instruction 5000.02 (Dec. 2, 2008). NASA's definition is similar to DOD's, and CDR typically occurs during NASA's implementation phase. See NASA Interim Directive NM 7120-81 (2009).

[2] Since we started this review, two DOD space satellites and one NASA satellite have been completed and launched. The Space Based Surveillance System satellite launched on September 25, 2010; the Advanced Extremely High Frequency satellite launched on August 14, 2010; and the Glory satellite launched on March 4, 2011. The Glory satellite failed to reach orbit because of a problem with the satellite launch vehicle.

For each of the 21 systems we examined program documentation, such as parts quality briefings, failure review board reports, advisory notices, and cost and schedule analysis reports and held discussions with quality officials from the program offices, including contractor officials and Defense Contract Management Agency officials, where appropriate. We specifically asked each program, at the time we initiated our review, to provide us with the most recent list of the top 5 to 10 parts, material or processes problems, as defined by that program, affecting its program's cost, schedule, or performance. Based on additional information gathered through documentation provided by the programs and discussions with program officials, we reviewed each part problem reported by each program to determine if there was a part problem, rather than a material, process, component, or assembly level problem. In addition, when possible we identified the impact that a part, material, or process quality problem might have had on system cost, schedule, and performance. We selected one system with known quality problems, as previously reported in GAO reports, within the Air Force (Space-Based Space Surveillance System), MDA (Ground-Based Midcourse Defense), and NASA (Glory) for further review to gain greater insight into the reporting and root causes of the parts quality problems. Our findings are limited by the approach and data collected. Therefore, we were unable to make generalizable or projectable statements about space and missile programs beyond our scope. We also have ongoing work through our annual DOD assessments of selected weapon programs and NASA assessments of selected larger-scale projects for many of these programs, which allowed us to build upon our prior work efforts and existing DOD and NASA contacts. Programs selected are described in appendix II and are listed below.

DOD—Air Force

- Advanced Extremely High Frequency Satellites
- Global Positioning System Block IIF
- Space-Based Infrared System High Program
- Space-Based Space Surveillance Block 10

DOD—Navy

- Mobile User Objective System

DOD—MDA

- Aegis Ballistic Missile Defense
- Ground-Based Midcourse Defense
- Space Tracking and Surveillance System

- Targets and Countermeasures

NASA

- Aquarius
- Global Precipitation Measurement Mission
- Glory
- Gravity Recovery and Interior Laboratory
- James Webb Space Telescope
- Juno
- Landsat Data Continuity Mission
- Magnetospheric Multiscale
- Mars Science Laboratory
- National Polar-orbiting Operational Environmental Satellite System Preparatory Project
- Radiation Belt Storm Probes
- Tracking and Data Relay Satellite Replenishment

DOD and NASA have access to one or more of the following databases used to report deficient parts: the Product Data Reporting and Evaluation Program, the Joint Deficiency Reporting System, and the Government Industry Data Exchange Program. We did not use these systems in our review because of the delay associated with obtaining current information and because it was beyond the scope of the review to assess the utility or effectiveness of these systems.

To determine the causes behind the parts quality problems, we asked each program to provide an explanation of the root causes and contributing factors that may have led to each part problem reported. Based on the information we gathered, we grouped the root causes and contributing factors for each part problem. We reviewed program documentation, regulations, directives, instructions, and policies to determine how the Air Force, MDA, and NASA define and address parts quality. We interviewed senior DOD, MDA, and NASA headquarters officials, as well as system program and contractor officials from the Air Force, MDA, and NASA, about their knowledge of parts problems on their programs. We reviewed several studies on quality and causes from the Subcommittee on Technical and Tactical Intelligence, House Permanent Select Committee on Intelligence; the Department of Commerce; and the Aerospace Corporation to gain a better understanding of quality and challenges facing the development, acquisition, and execution of space systems. We met with Aerospace Corporation officials to discuss some of their reports and findings and the status of their ongoing efforts to address parts quality. We relied on previous GAO reports for the implementation status of planned program management improvements.

To identify initiatives to prevent, detect, and mitigate parts quality problems, we asked each program what actions were being taken to remedy the parts problems. Through these discussions and others held with agency officials, we were able to obtain information on working groups. We reviewed relevant materials provided to us by officials from DOD, the Air Force, MDA, NASA, and the Aerospace Corporation. We interviewed program officials at the Air Force, MDA, NASA, and the Aerospace Corporation responsible for quality initiatives to discuss those initiatives that would pertain to parts quality and discuss the implementation status of any efforts.

We conducted this performance audit from October 2009 to May 2011 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Appendix II: Description of DOD Satellite Systems, MDA Systems, and NASA Systems[1]

DOD Satellite Systems

Advanced Extremely High Frequency (AEHF) Satellites

The Air Force's AEHF satellite system will replenish the existing Milstar system with higher-capacity, survivable, jam-resistant, worldwide, secure communication capabilities for strategic and tactical warfighters. The program includes satellites and a mission control segment. Terminals used to transmit and receive communications are acquired separately by each service. AEHF is an international program that includes Canada, the United Kingdom, and the Netherlands.

- Program start: April 1999
- Development start: September 2001
- Design review: April 2003
- First launch: August 2010
- Total program cost: $12,919.6 in millions

Global Positioning System (GPS) Block IIF

The Air Force's GPS includes satellites, a ground control system, and user equipment. It conveys positioning, navigation, and timing information to users worldwide. In 2000, Congress began funding the modernization of Block IIR and Block IIF satellites. GPS IIF is a new generation of GPS satellites that is intended to deliver all legacy signals plus new capabilities, such as a new civil signal and better accuracy.

- Program start: January 1999
- Development start: February 2000
- Production decision: July 2002
- First satellite launch: May 2010
- Total program cost as of March 2010: $7,282.1 in millions in fiscal year 2010 dollars

[1] Descriptions of DOD and NASA systems are based on the following GAO reports: GAO, *Defense Acquisitions: Assessments of Selected Weapon Programs*, GAO-11-233SP (Washington, D.C.: Mar. 29, 2011); *Defense Acquisitions: Assessments of Selected Weapon Programs*, GAO-10-388SP (Washington, D.C.: Mar. 30, 2010); *NASA: Assessments of Selected Larger-Scale Projects*, GAO-11-239SP (Washington, D.C: Mar. 3, 2011); and *Missile Defense: Actions Needed to Improve Transparency and Accountability*, GAO-11-372 (Washington, D.C.: Mar. 24, 2011). All program costs are expressed in fiscal year 2011 dollars in millions and are current as of March 2011 unless otherwise noted.

Mobile User Objective System (MUOS)

The Navy's MUOS, a satellite communication system, is expected to provide a worldwide, multiservice population of mobile and fixed-site terminal users with an increase in narrowband communications capacity and improve availability for small terminals. MUOS will replace the Ultra High Frequency Follow-On satellite system currently in operation and provide interoperability with legacy terminals. MUOS consists of a network of satellites and an integrated ground network.

- Program start: September 2002
- Development start: September 2004
- Design review: March 2007
- On-orbit capability: March 2012
- Total program cost: $6,830.2 in millions

Space-Based Infrared System (SBIRS) High Program

The Air Force's SBIRS High satellite system is being developed to replace the Defense Support Program and perform a range of missile warning, missile defense, technical intelligence, and battlespace awareness missions. SBIRS High consists of four satellites in geosynchronous earth orbit plus two replenishment satellites, two sensors on host satellites in highly elliptical orbit plus two replenishment sensors, and fixed and mobile ground stations.

- Program start: February 1995
- Development start: October 1996
- Design review: August 2001
- Satellite launch: May 2011
- Total program cost: $15,938.5 in millions

Space-Based Space Surveillance (SBSS) Block 10

The Air Force's SBSS Block 10 satellite is intended to provide a follow-on capability to the Midcourse Space Experiment / Space Based Visible sensor satellite, which ended its mission in July 2008. SBSS will consist of a single satellite and associated command, control, communications, and ground processing equipment. The SBSS satellite is expected to operate 24 hours a day, 7 days a week, to collect positional and characterization data on earth-orbiting objects of potential interest to national security.

- Program start: February 2002
- Development start: September 2003
- Design review: November 2006
- Satellite launch: September 2010
- Total program cost as of March 2010: $873.2 in millions in fiscal year 2010 dollars

MDA Systems

Aegis Ballistic Missile Defense (BMD)

MDA's Aegis BMD is a sea-based missile defense system being developed in incremental, capability-based blocks to defend against ballistic missiles of all ranges. Key components include the shipboard SPY-1 radar, Standard Missile 3 (SM-3) missiles, and command and control systems. It will also be used as a forward-deployed sensor for surveillance and tracking of ballistic missiles. The SM-3 missile has multiple versions in development or production: Blocks IA, IB, and IIA.

- Program start: October 1995
- Transition to MDA: January 2002
- Design review: May 2009
- Total program cost as of March 2010: $9,232.5 in millions in fiscal year 2010 dollars

Ground-Based Midcourse Defense (GMD)

MDA's GMD is being fielded to defend against limited long-range ballistic missile attacks during their midcourse phase. GMD consists of an interceptor with a three-stage booster and exoatmospheric kill vehicle, and a fire control system that formulates battle plans and directs components integrated with Ballistic Missile Defense System (BDMS) radars. We assessed the maturity of all GMD critical technologies, as well as the design of the Capability Enhanced II (CE-II) configuration of the Exoatmospheric Kill Vehicle (EKV), which began emplacements in fiscal year 2009.

- Program start: February 1996
- Design review: May 2006
- Total program cost as of March 2010: $33,129.7 in millions in fiscal year 2010 dollars

Space Tracking and Surveillance System (STSS)

MDA's STSS is designed to acquire and track threat ballistic missiles in all stages of flight. The agency obtained the two demonstrator satellites in 2002 from the Air Force SBIRS Low program that halted in 1999. MDA refurbished and launched the two STSS demonstrations satellites on September 25, 2009. Over the next 2 years, the two satellites will take part in a series of tests to demonstrate their functionality and interoperability with the BMDS.

- Program start: 2002
- Demonstration satellite launches: September 2009

- Total program cost: Not available

Targets and Countermeasures

The Targets and Countermeasures program provides ballistic missiles to serve as targets in the MDA flight test program. The targets program involves multiple acquisitions—including a variety of existing and new missiles and countermeasures.

- Program start: Multiple
- Design review: Not applicable
- Total program cost: Not applicable

NASA Systems

Aquarius

Aquarius is a satellite mission developed by NASA and the Space Agency of Argentina (Comisión Nacional de Actividades Espaciales) to investigate the links between the global water cycle, ocean circulation, and the climate. It will measure global sea surface salinity. The Aquarius science goals are to observe and model the processes that relate salinity variations to climatic changes in the global cycling of water and to understand how these variations influence the general ocean circulation. By measuring salinity globally for 3 years, Aquarius will provide a new view of the ocean's role in climate.

- Formulation start: December 2003
- Design review: September 2006
- Satellite launch: June 2011
- Total project cost: $279.0 in millions

Global Precipitation Measurement (GPM) Mission

The GPM mission, a joint NASA and Japan Aerospace Exploration Agency project, seeks to improve the scientific understanding of the global water cycle and the accuracy of precipitation forecasts. GPM is composed of a core spacecraft carrying two main instruments: a dual-frequency precipitation radar and a GPM microwave imager. GPM builds on the work of the Tropical Rainfall Measuring Mission and will provide an opportunity to calibrate measurements of global precipitation.

- Formulation start: July 2002
- Design review: December 2009
- Launch core spacecraft: July 2013
- Total project cost: $928.9 in millions

Glory

The Glory project is a low-Earth orbit satellite that will contribute to the U.S. Climate Change Science Program. The satellite has two principal science objectives: (1) collect data on the properties of aerosols and black carbon in the Earth's atmosphere and climate systems and (2) collect data on solar irradiance. The satellite has two main instruments —the Aerosol Polarimetry Sensor (APS) and the Total Irradiance Monitor (TIM)—as well as two cloud cameras. The TIM will allow NASA to have uninterrupted solar irradiance data by bridging the gap between NASA's Solar Radiation and Climate Experiment and the National Polar-orbiting Operational Environmental Satellite System. The Glory satellite failed to reach orbit when it was launched on March 4, 2011.

- Formulation Start: September 2005
- Design review: July 2006
- Launch readiness date: February 2011
- Total project cost: $424.1 in millions

Gravity Recovery and Interior Laboratory (GRAIL)

The GRAIL mission will seek to determine the structure of the lunar interior from crust to core, advance our understanding of the thermal evolution of the moon, and extend our knowledge gained from the moon to other terrestrial-type planets. GRAIL will achieve its science objectives by placing twin spacecraft in a low altitude and nearly circular polar orbit. The two spacecraft will perform high- precision measurements between them. Analysis of changes in the spacecraft-to-spacecraft data caused by gravitational differences will provide direct and precise measurements of lunar gravity. GRAIL will ultimately provide a global, high-accuracy, high-resolution gravity map of the moon.

- Formulation start: December 2007
- Design review: November 2009
- Launch readiness date: September 2011
- Total project cost: $496.2 in millions

James Webb Space Telescope (JWST)

The JWST is a large, infrared-optimized space telescope that is designed to find the first galaxies that formed in the early universe. Its focus will include searching for first light, assembly of galaxies, origins of stars and planetary systems, and origins of the elements necessary for life. JWST's instruments will be designed to work primarily in the infrared range of the electromagnetic spectrum, with some capability in the visible range. JWST will have a large mirror, 6.5 meters (21.3 feet) in diameter and a sunshield the size of a tennis court. Both the mirror and sunshade will not fit onto the rocket fully open, so both will fold up and open once JWST is in outer space. JWST will reside in an orbit about 1.5 million kilometers (1 million miles) from the Earth.

- Formulation start: March 1999
- Design review: March 2010
- Launch readiness date: June 2014
- Total project cost: $5,095.4 in millions

Juno

The Juno mission seeks to improve our understanding of the origin and evolution of Jupiter. Juno plans to achieve its scientific objectives by using a simple, solar-powered spacecraft to make global maps of the gravity, magnetic fields, and atmospheric conditions of Jupiter from a unique elliptical orbit. The spacecraft carries precise, highly sensitive radiometers, magnetometers, and gravity science systems. Juno is slated to make 32 orbits to sample Jupiter's full range of latitudes and longitudes. From its polar perspective, Juno is designed to combine local and remote sensing observations to explore the polar magnetosphere and determine what drives Jupiter's auroras.

- Formulation start: July 2005
- Design review: April 2009
- Launch readiness date: August 2011
- Total project cost: $1,107.0 in millions

Landsat Data Continuity Mission (LDCM)

The LDCM, a partnership between NASA and the U.S. Geological Survey, seeks to extend the ability to detect and quantitatively characterize changes on the global land surface at a scale where natural and man-made causes of change can be detected and differentiated. It is the successor mission to Landsat 7. The Landsat data series, begun in 1972, is the longest continuous record of changes in the Earth's surface as seen from space. Landsat data are a resource for people who work in agriculture, geology, forestry, regional planning, education, mapping, and global change research.

- Formulation start: October 2003
- Design review: May 2010
- Launch readiness date: June 2013
- Total project cost: $941.6 in millions

Magnetospheric Multiscale (MMS)

The MMS is made up of four identically instrumented spacecraft. The mission will use the Earth's magnetosphere as a laboratory to study the microphysics of magnetic reconnection, energetic particle acceleration, and turbulence. Magnetic reconnection is the primary process by which energy is transferred from solar wind to Earth's magnetosphere and is the physical process determining the size of a space weather storm. The spacecrafts will fly in a pyramid formation, adjustable over a range of 10 to 400 kilometers, enabling them to capture the three-dimensional structure of the reconnection sites they encounter. The data from MMS will be used as a basis for predictive models of space weather in support of exploration.

- Formulation start: May 2002
- Design review: August 2010
- Launch readiness date: March 2015
- Total project cost: $1,082.7 in millions

Mars Science Laboratory (MSL)

The MSL is part of the Mars Exploration Program (MEP). The MEP seeks to understand whether Mars was, is, or can be a habitable world. To answer this question, the MSL project will investigate how geologic, climatic, and other processes have worked to shape Mars and its environment over time, as well as how they interact today. The MSL will continue this systematic exploration by placing a mobile science laboratory on the Mars surface to assess a local site as a potential habitat for life, past or present. The MSL is considered one of NASA's flagship projects and will be the most advanced rover yet sent to explore the surface of Mars.

- Formulation start: November 2003
- Design review: June 2007
- Launch readiness date: November 2011
- Total project cost: $2,476.3 in millions

NPOESS Preparatory Project (NPP)

The National Polar-orbiting Operational Environmental Satellite System NPP is a joint mission with the National Oceanic and Atmospheric Administration and the U.S. Air Force. The satellite will measure ozone, atmospheric and sea surface temperatures, land and ocean biological productivity, Earth radiation, and cloud and aerosol properties. The NPP mission has two objectives. First, NPP will provide a continuation of global weather observations following the Earth Observing System missions Terra and Aqua. Second, NPP will function as an operational satellite and will provide data until the first NPOESS satellite launches.

- Formulation start: November 1998
- Design review: August 2003

- Launch readiness date: October 2011
- Total project cost: $864.3 in millions

Radiation Belt Storm Probes (RBSP)

The RBSP mission will explore the sun's influence on the Earth and near-Earth space by studying the planet's radiation belts at various scales of space and time. This insight into the physical dynamics of the Earth's radiation belts will provide scientists data with which to predict changes in this little understood region of space. Understanding the radiation belt environment has practical applications in the areas of spacecraft system design, mission planning, spacecraft operations, and astronaut safety. The two spacecrafts will measure the particles, magnetic and electric fields, and waves that fill geospace and provide new knowledge on the dynamics and extremes of the radiation belts.

- Formulation start: September 2006
- Design review: December 2009
- Launch readiness date: May 2012
- Total project cost: $685.9 in millions

Tracking and Data Relay Satellite (TDRS) Replenishment

The TDRS replenishment system consists of in-orbit communication satellites stationed at geosynchronous altitude coupled with two ground stations located in New Mexico and Guam. The satellite network and ground stations provide mission services for near-Earth user satellites and orbiting vehicles. TDRS K and L are the 11th and 12th satellites, respectively, to be built for the TDRS replenishment system and will contribute to the existing network by providing high bandwidth digital voice, video, and mission payload data, as well as health and safety data relay services to Earth-orbiting spacecraft, such as the International Space Station.

- Formulation start: January 2007
- Design review: February 2010
- Launch readiness date for TDRS K: December 2012
- Launch readiness date for TDRS L: December 2013
- Total project cost: $434.1 in millions

Appendix III: Comments from the Department of Defense

OFFICE OF THE UNDER SECRETARY OF DEFENSE
3000 DEFENSE PENTAGON
WASHINGTON, DC 20301-3000

ACQUISITION, TECHNOLOGY AND LOGISTICS

JUN 13 2011

Ms. Cristina Chaplain
Director, Acquisition and Sourcing Management
U. S. Government Accountability Office
441 G Street, NW
Washington, DC 20548

Dear Ms. Chaplain:

This is the Department of Defense (DoD) response to the GAO Draft Report, GAO-11-404, "SPACE AND MISSILE DEFENSE ACQUISITIONS: Periodic Assessment Needed to Correct Parts Quality Problems in Major Programs," dated May 6, 2011 (GAO Code 120864).

The DoD partially concurs with the draft report's recommendation. The rationale for our position is included in the enclosure. I submitted separately a list of technical and factual errors for your consideration.

We appreciate the opportunity to comment on the draft report. My point of contact for this effort is Mr. David Crim, David.Crim@osd.mil, 703-697-5385.

Sincerely,

David G. Ahern
Deputy Assistant Secretary of Defense
Portfolio Systems Acquisition

Enclosure:
As stated

GAO Draft Report Dated May 6, 2011
GAO-11-404 (GAO CODE 120864)

"SPACE AND MISSILE DEFENSE ACQUISITIONS: PERIODIC ASSESSMENT NEEDED TO CORRECT PARTS QUALITY PROBLEMS IN MAJOR PROGRAMS"

DEPARTMENT OF DEFENSE COMMENTS TO THE RECOMMENDATIONS

RECOMMENDATION: The GAO recommends that the Secretary of Defense and the Administrator of NASA direct appropriate agency executives to include in efforts to implement the new memorandum of understanding for increased mission assurance a mechanism for a periodic, government-wide assessment and reporting of the condition of parts quality problems in major space and missile defense programs, including the frequency such problems are appearing in major programs, change in frequency from previous years, and the effectiveness of corrective measures. The GAO further recommends that reports of the periodic assessments be made available to the Congress. (See pages 40 through 41/GAO Draft Report.)

DOD RESPONSE: **Partially Concur**. DoD will work with NASA to determine the optimal government-wide assessment and reporting implementation to include all quality issues, of which Parts, Materials and Processes would be one of the major focus areas. The DoD will propose the period of reporting be annual to ensure planned, deliberate, and consistent assessments. Subject to the approval of our partner in the memorandum of understanding, the DoD has no objections to providing the report to Congress, should Congress desire. The DoD will continue to work with NASA and other US government space community stakeholders through the Space Industrial Base Council's working groups to address concerns about parts quality.

Enclosure 1

Appendix IV: Comments from the National Aeronautics and Space Administration

National Aeronautics and Space Administration
Headquarters
Washington, DC 20546-0001

June 03, 2011

Reply to Attn of: Office of Safety and Mission Assurance

Ms. Cristina Chaplain
Director
Acquisition and Sourcing Management
United States Government Accountability Office
Washington, DC 20548

Dear Ms. Chaplain:

The National Aeronautics and Space Administration (NASA) appreciates the opportunity to review and comment on the Government Accountability Office (GAO) draft report entitled, "Space and Missile Defense Acquisitions: Periodic Assessment Needed to Correct Parts Quality Problems in Major Programs." NASA considers parts quality to be a vital component of mission success and greatly values the constructive information and insights shared by GAO during the course of this effort. We further appreciate the extreme professionalism demonstrated by your review team and the continued open communications maintained between GAO and NASA.

In the draft report, GAO provides one recommendation to the NASA Administrator (see below). In addition to directly responding to the GAO recommendation, our office provided clarification on key points and corrections of errors in fact at the exit conference on May 18, 2011. NASA's response to this recommendation immediately follows.

Recommendation: The Secretary of Defense and the Administrator of NASA direct appropriate agency executives to include in efforts to implement the new memorandum of understanding for increased mission assurance a mechanism for a periodic, government-wide assessment and reporting of the condition of parts quality problems in major space and missile defense programs, including the frequency such problems are appearing in major programs, changes in frequency from previous years, and the effectiveness of corrective measures. We further recommend that reports of the periodic assessment be made available to the Congress.

Management's Response: NASA concurs with GAO's recommendation. We fully agree that enhanced cross-agency communication, coordination, and sharing of parts quality information will help mitigate threats posed by defective and nonconforming parts. To this end, NASA will engage other U.S. space agencies (Missile Defense Agency, National Reconnaissance Office, and Air Force Space Command) to further develop and integrate agency mechanisms for reporting, assessing, tracking, and trending common parts quality problems, including the institution and validation of effective cross-agency solutions. NASA currently enjoys a positive collaborative relationship with these agencies through a variety of ongoing venues such as the

2

Joint Mission Assurance Council, Space Quality Improvement Council, and Mission Assurance Summits and will employ these venues for regular open discussions concerning parts quality. These forums will be directly supported by me, NASA's Chief Engineer, and our executive staff in order to provide the strongest advocacy for aggressive, timely, and effective resolution of parts quality problems of mutual interest to United States space programs.

NASA looks forward to continued work with the GAO in order to measure and improve our performance related to the procurement, installation, and deployment of quality parts.

Thank you for the opportunity to comment on this draft report. If you have any questions or require additional information, please contact Kelly Kabiri at (202) 358-0590.

Sincerely,

FOR Bryan O'Connor
Chief, Safety and Mission Assurance

Appendix V: GAO Contact and Staff Acknowledgments

GAO Contact

Cristina T. Chaplain, (202) 512-4841 or chaplainc@gao.gov

Staff Acknowledgments

In addition to the contact named above, David B. Best, Assistant Director; Maricela Cherveny; Heather L. Jensen; Angie Nichols-Friedman; William K. Roberts; Roxanna T. Sun; Robert S. Swierczek; and Alyssa B. Weir made key contributions to this report.

Related GAO Products

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