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Office of Inspector General

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NASA'S PARTS QUALITY CONTROL PROCESS

March 29, 2017

Report No. IG-17-016





Office of Inspector General

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RESULTS IN BRIEF

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WHY WE PERFORMED THIS AUDIT

To achieve its mission of advancing science, technology, aeronautics, and space exploration, NASA builds and operates launch vehicles, propulsion systems, robots, satellites, telescopes, and other complex science instruments. Generally, these devices operate in space where temperature and radiation are significantly harsher than on Earth and malfunctions cannot be easily repaired. Accordingly, the parts the Agency uses to build these instruments and hardware have high performance and quality requirements, and procuring such parts is essential to NASA's mission success.

Although mission failures are relatively infrequent, in the past 10 years NASA has incurred financial losses of approximately \$1.3 billion when parts that did not meet performance expectations or quality standards caused missions and instruments to fail. In addition to the financial impact, these failures deprived NASA and other users of valuable scientific data. In the face of pressure to take advantage of state-of-the-art technology, faster delivery, and lower costs, NASA's move toward acquiring more commercially produced "off-the-shelf" products could introduce increased risks and additional unknowns into the Agency's parts quality control processes.

In this audit, we evaluated the Agency's parts and supplier quality control processes, parts and supplier data collection and sharing practices, and processes for overseeing contractor quality management systems. We spoke with relevant Agency, Government, and industry officials; evaluated policies and procedures; interviewed personnel from several major projects; and obtained relevant documentation.

WHAT WE FOUND

Although NASA has a number of initiatives in place to help ensure the selection of quality parts from reliable suppliers, Centers generally manage their parts quality and supplier assessment data unilaterally rather than collaborating through a comprehensive, integrated, Agency-wide parts and supplier information system. Specifically, the Agency does not maintain a centralized parts quality history database or facilitate the integration of individual Center systems, track all relevant supplier performance history, or enforce requirements that Centers participate in Agency parts quality management systems. Without these control mechanisms, it is more difficult for NASA to mitigate the risk of nonconforming parts entering its project hardware supply chain. As NASA continues to rely more on commercial parts rather than parts that are custom built or built to military specifications, it is even more important that comprehensive control mechanisms are in place. Moreover, the lack of a coordinated approach may lead to higher costs and schedule delays if faulty parts are acquired and additional testing, qualification, and procurement of replacement parts becomes necessary.

In addition, NASA policy requires project managers to consider risk factors when preparing Program/Project Quality Assurance Surveillance Plans for critical and complex acquisitions. These plans document contractor operations that need Government oversight and the activities, metrics, control mechanisms, and organizations that will conduct quality assurance functions for the project. We found the Agency's current policy does not provide sufficient surveillance and audit planning guidance for project personnel to analyze and select contractor surveillance activities commensurate with the level of risk of nonconforming parts being incorporated into a product. The plans we reviewed incorporated and applied risk assessments inconsistently, and resource allocations for the associated projects may not have been commensurate with the projects' risk acceptance goals for parts quality. Inefficient surveillance activities could overburden resources or increase the risk of integrating a part of inappropriate quality into a project.

WHAT WE RECOMMENDED

To increase transparency, accountability, and oversight of NASA's parts quality management processes, we made eight recommendations to the Chief of Safety and Mission Assurance, including that he expand current NASA data sharing to integrate supplier databases with parts databases, evaluate current parts and supplier database system architectures to determine the cost and benefits of establishing an Agency-wide database system, investigate causes of gaps in reporting and formulate remedial actions to ensure compliance with reporting requirements, and review a sample of Program/Project Quality Assurance Surveillance Plans to identify deficiencies and best practices.

In response to a draft of this report, NASA management concurred with and described actions it plans to address our recommendations. We consider management's comments responsive and will close the recommendations upon completion and verification of the actions.

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Acronyms

DOD	Department of Defense
EEE	Electrical, Electronic, and Electromechanical
EPARTS	Electronic Parts Applications Reporting and Tracking System
GAO	Government Accountability Office
GIDEP	Government-Industry Data Exchange Program
GMIP	Government Mandatory Inspection Point
JPL	Jet Propulsion Laboratory
MIL-SPEC	Military Specification
NEPAG	NASA Electronic Parts Assurance Group
NEPP	NASA Electronic Parts and Packaging
NPD	NASA Policy Directive
NPR	NASA Procedural Requirements
OSMA	Office of Safety and Mission Assurance
PQASP	Program/Project Quality Assurance Surveillance Plan
S&MA	Safety and Mission Assurance
SAS	Supplier Assessment System
SLS	Space Launch System

INTRODUCTION

To achieve its mission of advancing science, technology, aeronautics, and space exploration, NASA builds and operates launch vehicles, propulsion systems, robots, satellites, telescopes, and other complex science instruments. Generally, these devices operate in space where temperature and radiation are significantly harsher than on Earth and malfunctions cannot be easily repaired. Accordingly, the parts the Agency uses to build these instruments and hardware have high performance and quality requirements, and procuring such parts is essential to NASA's mission success.

Although mission failures are relatively infrequent, in the past 10 years NASA has incurred financial losses of approximately \$1.3 billion when parts that did not meet performance or quality standards caused missions and instruments to fail. In addition to the financial impact, these failures deprived NASA and other users of valuable scientific data. In the face of pressure to take advantage of state-of-the-art technology, faster delivery, and lower costs, NASA's move toward acquiring more commercially produced "off-the-shelf" products could introduce increased risks and additional unknowns into the Agency's parts quality control processes.

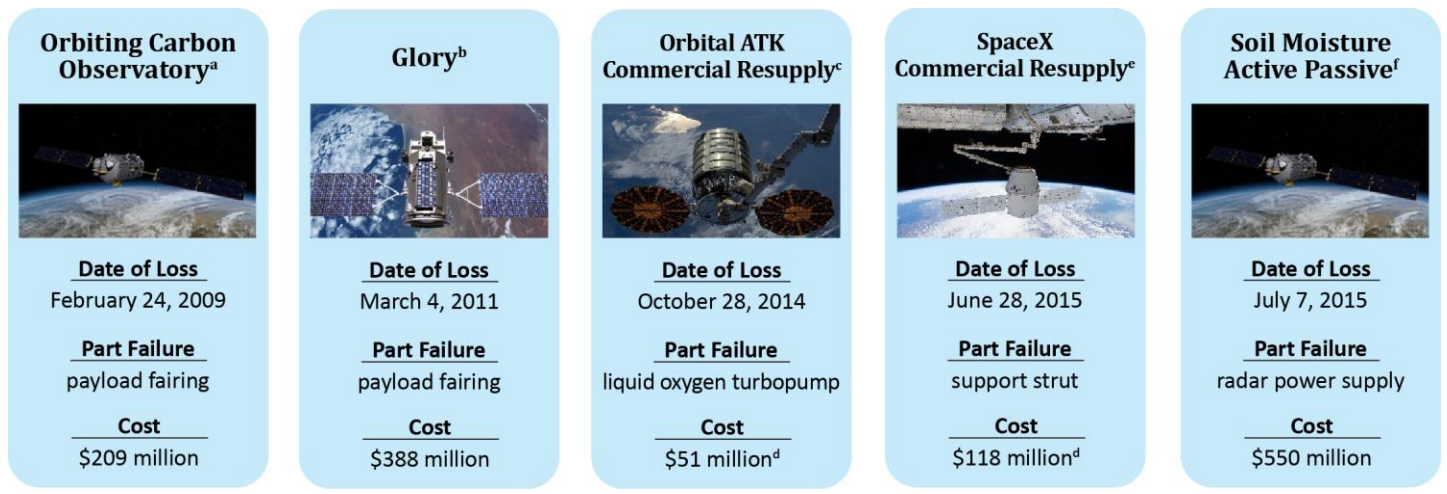
In this audit, we assessed NASA's parts quality management process. Specifically, we evaluated the Agency's parts and supplier quality control processes, parts and supplier data collection and sharing practices, and processes for overseeing contractor quality management systems. See Appendix A for details on the audit's scope and methodology.

Background

Parts are the building blocks of NASA projects, and the Agency routinely develops and procures hundreds of thousands of mechanical and electrical parts to support its diverse mission portfolio. Mechanical parts include fasteners, bearings, studs, pins, rings, shims, piping components, springs, brackets, clamps, and spacers. Electrical, electronic, and electromechanical (EEE) parts include capacitors, fuses, inductors, microcircuits, resistors, semiconductors, and thermistors. Various parts are built into assemblies that are combined to develop the components, subsystems, and instruments the Agency relies on to carry out its missions.

Deficiencies in the quality of parts may affect a project's cost and schedule performance, compromise safety, or jeopardize mission objectives. For example, since 2009 NASA has suffered four mission failures and one mission with reduced capability as a result of engineering flaws, workmanship issues, and problem parts (see Figure 1).

Figure 1: Recent Mission Losses Involving Parts Failures



Source: NASA Office of Inspector General evaluation of reported mishaps.

- ^a Mission was to provide space-based observations of atmospheric carbon dioxide.
- ^b Mission was to collect data on human-caused aerosols in Earth's atmosphere.
- ^c Lost about 5,000 pounds of supplies, science experiments, crew provisions, spare parts, and experiment hardware.
- ^d Only includes cost of cargo and excludes NASA's launch vehicle costs.
- ^e Lost more than 5,300 pounds of hardware, including an International Docking Adapter, crew supplies, and critical materials to support research investigations.
- ^f Mission has reduced capability to provide measurements of Earth's soil moisture and the freeze/thaw state.

As the Defense Science Board noted, “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 correction are scant.”¹ In short, when operating in the unforgiving environment of space, tolerance for a part’s failure or error is low. For example, it took only one flawed part to doom a 2015 resupply mission to the International Space Station by Space Exploration Technologies Corporation (SpaceX). According to SpaceX’s mishap investigation, although certified to handle 10,000 pounds of force, a commonly used strut rod end supporting the rocket’s helium system failed at 2,000 pounds of force, causing the rocket to explode and destroy more than 5,300 pounds of NASA supplies, equipment, and materials – including one of two International Docking Adapters – that would have supported more than 35 science and research investigations on the International Space Station and future flights of commercial crew vehicles under development.²

¹ 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,” May 2003.

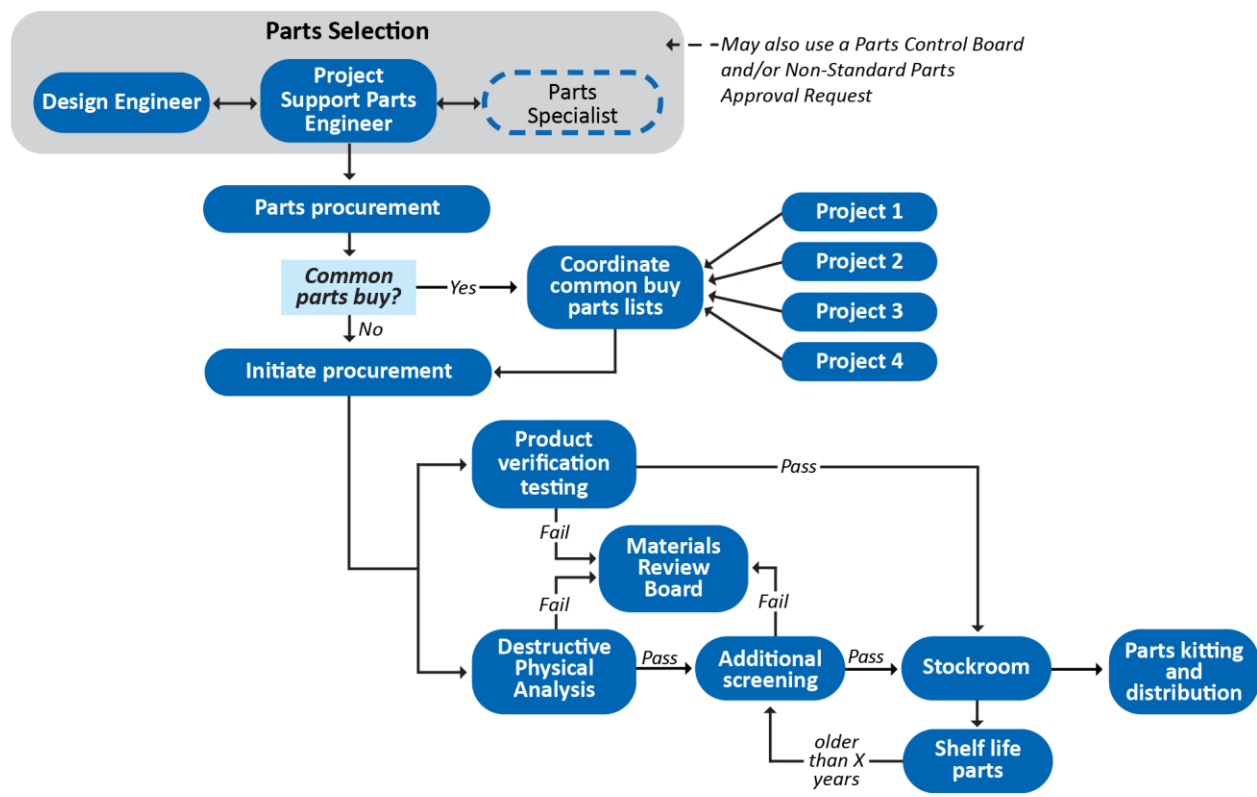
² The International Docking Adapter will allow commercial crew vehicles under development by SpaceX and The Boeing Company the ability to dock with the International Space Station.

Parts Management Process

Generally, after mission requirements are defined, engineers design system configurations and select parts to meet those requirements. Designers then complete configuration drawings and identify the parts that will meet form, fit, and function requirements. Quality and parts engineers may assist designers in determining the level of testing required either before shipping or after receipt of purchased parts.

Based on the design configurations, procurement personnel identify qualified suppliers for the required parts and begin the acquisition process. After delivery, a part will usually undergo visual inspection, physical measurements, nondestructive evaluation, a predefined testing process, or a combination of these analyses. After a thorough review of the test results, parts that meet specification requirements will then be sent to the project for fabrication, integration, or assembly. Additional testing will be done through the integration process with higher-level assemblies. For a lower tier subcontractor, the integrated hardware is usually tested to specifications and delivered to the next level subcontractor. The process repeats until final assembly into flight systems. Any anomalies identified during the testing process should be included in the respective Center’s problem reporting system and reviewed by the project’s Materials Review Board for resolution.³ Figure 2 provides a graphical representation of the overall parts management process.

Figure 2: Typical Parts Management Process



Source: NASA.

³ A Materials Review Board is a group of Government and contractor representatives that review contractor reports of an article or material that does not conform to applicable drawings, specifications, or other requirements.

Parts Quality Specifications

Depending on the hardware design requirements, parts may be build-to-specification, build to predefined military specification (MIL-SPEC), or commercial grade. As the name suggests, build-to-specification parts are built to a specified design drawing or performance requirement. NASA has procured build-to-specification parts for such projects as the high-gain antennas for Dawn, Global Precipitation Measurement, and Mars Reconnaissance Orbiter missions and the load test equipment in support of the Orion Multi-Purpose Crew Vehicle Program (Orion).⁴ Build-to-specification parts are generally more expensive than other types of parts because they are customized to specified form, fit, or function and not routinely available as part of a manufacturer's production line.

MIL-SPEC parts are rated based on the supplier's capability, the consistency of its manufacturing processes and materials, and its compliance with highly defined testing standards developed and controlled by the Department of Defense (DOD). The manufacturer has to prove that the processes and materials used will result in the production of parts that can withstand rigorous environmental stresses and are electrically stable with long-term use. The manufacturer can make changes to its processes, materials, and methods only after performing additional qualification testing and submitting the results to DOD.

Commercial parts are items customarily used by the general public or by nongovernmental entities for nongovernmental purposes and available on the open market. The manufacturers of commercial parts design them for commercial applications and establish and control the specifications for the parts' performance, configuration, and reliability (including design, materials, processes, and testing) without regard to specific end-user requirements. As such, the Government may have limited insight into how these parts are designed and does not control changes a manufacturer may make to a part's design or manufacturing process. Generally, information about commercial-grade parts is limited to published material and any other information the manufacturer is willing to release.⁵

NASA is operating in a market that increasingly uses commercial rather than MIL-SPEC parts. This shift was made to take advantage of state-of-the-art technology, faster delivery, and lower costs. For example, although DOD was the prime supporter for the MIL-SPEC standards, in 1994 the Secretary of Defense determined that DOD "must increase access to commercial state-of-the-art technology and must facilitate the adoption by its suppliers of business processes characteristic of world class suppliers" and that the use of military specifications and standards was no longer mandatory.⁶ As a result, the resources used to maintain MIL-SPEC parts, such as audits and surveillance, have been reduced. Although some suppliers claim they continue to produce MIL-SPEC parts, there is less upfront quality assurance of these parts since process audits and qualification testing may not be conducted as required

⁴ NASA launched Dawn in September 2007 to explore Vesta and Ceres in the asteroid belt. The Global Precipitation Measurement core satellite was launched in February 2014 to advance scientific understanding of Earth's water and energy cycle. The Mars Reconnaissance Orbiter entered orbit around Mars in March 2006 and as of February 2017 continues to survey the planet to investigate the history of water on Mars using detailed photography. NASA is building the Orion spacecraft to enable human exploration beyond low Earth orbit, with a planned first crewed flight in the early 2020s.

⁵ There may be additional data available for particular types of commercial parts such as automotive. For these "commercial plus" parts, users may have access to test data that can help them establish performance assumptions like random failure rate. However, as with other types of commercial parts manufacturers remain free to unilaterally change their design, configuration, material, and process to meet marketplace demand. NASA parts managers have begun to consider the feasibility of using automotive grade parts for Agency missions.

⁶ Secretary of Defense Memorandum, "Specifications & Standards - A New Way of Doing Business," June 29, 1994.

to meet MIL-SPEC standards. NASA experts maintain that despite these challenges, the MIL-SPEC system is still of great value to NASA and continues to be an excellent source of electronic parts for space applications.

Although commercial parts typically cost less to purchase than built-to-specification or MIL-SPEC parts, other costs could be associated with their use. Specifically, in addition to paying for a part, NASA or its contractors may incur additional costs associated with “upgrading” the item – that is, post-procurement processes intended to determine a part’s reliability. Efforts to “upgrade” a commercial part can include electrical verification measurements, environmental stress screening, sample-based qualification testing, destructive physical analysis, or radiation hardness testing. For example, upgrading an integrated circuit supplied by a commercial supplier may involve subjecting the device to burn-in and electrical testing over extended temperatures.⁷ According to an internal NASA study, upgrading costs for commercial-grade EEE parts can be up to 5.9 times more expensive than buying a part that is made and engineered for NASA missions with specific assurance requirements.⁸ Because a commercial-grade part may behave differently when operating outside of its manufacturing parameters for such factors as temperature, function, and radiation, NASA may also incur costs associated with troubleshooting and resolving any unexpected behavior.

Parts Quality Management

All NASA Centers have teams of quality assurance personnel tasked with ensuring the procurement, testing, and integration of quality parts on Agency flight hardware. Over the years, Centers that perform significant flight hardware development work have created systems to manage and meet the parts needs of Agency projects and programs. For example, at Goddard Space Flight Center (Goddard), project personnel upload lists of the EEE parts they use into the EEE Parts Database to assist engineers in record-keeping, data management, and decision making with respect to project parts design and selection. In addition, the Center’s Parts Analysis Lab Database captures information related to the screening and analysis of project parts submitted for testing. Similarly, the Jet Propulsion Laboratory (JPL) maintains a Parts Acquisition and Review System with data on parts from design to “kitting” and relies on its Quality Assurance Reporting System to provide mechanisms for initiating, managing, and searching for inspection reports and related discrepancy items.⁹

NASA’s Office of Safety and Mission Assurance (OSMA) at Headquarters is responsible for overseeing the implementation of the Agency’s quality assurance policies and procedures, including conducting audits of Center quality assurance processes every 3–4 years. OSMA provides several management tools to collect, analyze, and report on product quality and supplier performance information:

- The NASA Electronic Parts and Packaging (NEPP) Program provides Agency-wide guidance and infrastructure for assurance of EEE parts for use in space. The NEPP website provides access to a broad range of publications and tools associated with parts and packaging. In addition, NEPP maintains a NASA Parts Selection List that provides designers with a list of EEE parts recommended for NASA flight projects based on evaluations, risk assessments, and quality

⁷ A burn-in test is performed to stress microcircuits at or above their maximum operating time and temperature conditions for the purpose of screening or eliminating marginally performing devices.

⁸ NASA, “Cost Impacts of Upgrading Electronic Parts for Use in NASA Spaceflight Systems,” 2003. Available at <http://www.astred.net/docs/eee/Cost-Impacts-of-Upgrading-Electronic-Parts.pdf> (last accessed February 21, 2017).

⁹ Kitting is the gathering of components and parts needed for the manufacture of a particular assembly in which individual parts are gathered together as a “kit” and issued to the project.

levels. Parts included on the Selection List are capable of meeting a wide range of application needs, have established procurement specifications, and have been assessed for quality, reliability, and risk. Projects are encouraged to use parts from the Selection List because the available manufacturer has been reviewed by NASA or audited by another Government agency and has successfully completed part qualification to determine the reliability characteristics of a part over a standard environment or application range. The Parts Selection List is available to all NASA entities and DOD organizations.

- The Agency established the NASA Electronic Parts Assurance Group (NEPAG), a subset of NEPP, to capture corporate knowledge related to EEE parts assurance and protect against loss of knowledge as a result of retirements or other types of attrition. NEPAG is a cooperative group that provides knowledge, tools, and information to aid EEE parts engineers and specialists in making parts selection decisions for flight project hardware. NEPAG conducts weekly telephone conferences with all Centers, other Government agencies (e.g., Defense Logistics Agency and National Reconnaissance Office), and industry to share information and resources.
- NASA developed the Supplier Assessment System (SAS) to provide a consolidated and comprehensive online repository of audits related to supplier quality data, performance indicators, metrics, and assessment tools. NASA policy requires Centers to perform audits, surveys, and inspections to assess a supplier's performance, and to report the results of these activities to other NASA Centers by way of SAS.¹⁰ These audits assist the Agency in verifying supplier quality systems and processes and identifying risks of noncompliance with industry quality assurance system standards or contractual requirements. Audits can be performed for an entire quality management system, selected processes, or a production line. The frequency of these audits is based on the supplier's quality history but at a minimum are required to be performed at least once every 3 years.¹¹
- OSMA also sponsors a Joint Audit Planning Committee, which coordinates the planning, scheduling, monitoring, and managing of supplier audit activity. This joint Government-industry forum involves NASA, other Government agencies, and industry members that share supplier quality audit data, best practices, and lessons learned. A formal memorandum of understanding among member organizations also requires that quality data resulting from audits be shared among members by way of SAS.¹²
- The Government-Industry Data Exchange Program (GIDEP) serves as an information-sharing program for research, development, testing, and acquisition of new goods and services among Government and industry participants. The Program seeks to improve the reliability and maintainability of systems and components by avoiding the use of known problem or discontinued parts and materials. GIDEP provides a centralized database for failure mode, failure rate, and test information on parts, components, and materials. In order to fully participate and engage with the parts community, NASA policy requires OSMA exchange significant problem and nonconforming item data with GIDEP and ensure procurements of

¹⁰ NASA Policy Directive (NPD) 8730.2C, "NASA Parts Policy (Revalidated 12/6/13)," November 3, 2008.

¹¹ NASA Procedural Requirements (NPR) 8735.2B, "Management of Government Quality Assurance Functions for NASA Contracts," August 12, 2013.

¹² The Joint Audit Planning Committee Memorandum of Understanding requires member organizations to submit audit reports to the Committee Audit Coordinator and SAS Coordinator within 15 calendar days of completing an audit.

safety-critical items are screened for any GIDEP notice.¹³ Headquarters and Center GIDEP officials and NASA Advisory Coordinators assist in documenting and exchanging significant problem and nonconforming item data with GIDEP and among NASA Centers. If GIDEP information is specific to the Agency, a NASA Advisory is issued to the affected Centers. For example, in April and May 2015 NASA issued a NASA Advisory and GIDEP alert, respectively, to inform the user community of a manufacturer that may have altered mechanical properties test results and reported those results in material certifications, which was discovered as the result of an investigation by the NASA Office of Inspector General and Defense Criminal Investigative Service.

In addition, in 2011 the Office of the Chief Engineer sponsored the development of an Electronic Parts Applications Reporting and Tracking System (EPARTS) to provide a common NASA EEE parts library and streamline the EEE parts management process at the Agency and Center level. The System consists of four main modules – (1) parts management, (2) obsolescence, (3) parts search, and (4) mission assurance – and supports designers in parts selection, tracks and reports parts acquisitions, and leverages data across projects and Centers.

Parts Quality Assurance

NASA policy provides for managing the selection, acquisition, testing, and storage of mechanical and EEE parts to control the risk of nonconforming parts being integrated into flight systems.¹⁴ The Agency's ability to mitigate this risk is dependent upon its quality assurance controls, which vary depending on the type of procurement and who is developing and assembling the hardware.

NASA has direct control over parts quality assurance controls when development work is performed at its Centers. For example, Goddard largely developed the Magnetospheric Multiscale spacecraft in-house, and quality assurance controls, including supplier selection, destructive physical analysis, and integration testing, were performed by NASA project personnel.¹⁵ However, most of the Agency's major projects are not developed in-house. Rather they are developed by contractors – for example, the Orion by Lockheed Martin Corporation – or are otherwise commercial in nature, such as Orbital ATK cargo missions to the International Space Station. For such projects, the contractors are responsible for quality assurance controls with NASA limited to conducting surveillance – for instance, witnessing processes, inspections, and tests – and other types of processes to help ensure contractors' controls are functioning properly. Center and project safety and mission assurance (S&MA) personnel conduct surveillance and provide independent opinions to project management regarding parts quality assurance compliance and information for risk management decisions. The results of their surveillance activities inform final acceptance decisions throughout the project's development phase and can impact cost, schedule, and science objectives.

In critical and complex acquisitions, S&MA personnel use a Program/Project Quality Assurance Surveillance Plan (PQASP) to identify, in a single unified document, all contractor work operations

¹³ NPR 8735.1C, "Procedures for Exchanging Parts, Materials, Software, and Safety Problem Data Utilizing the Government-Industry Data Exchange Program (GIDEP) and NASA Advisories," February 13, 2013.

¹⁴ NPD 8730.2C.

¹⁵ In March 2015, NASA launched the Magnetospheric Multiscale mission, consisting of four satellites orbiting Earth, to investigate how the Sun's and Earth's magnetic fields connect and disconnect, which can affect modern technological systems such as telecommunications networks, global positioning system navigation, and electrical power grids.

requiring Government surveillance and the specific methods by which that surveillance will be provided.¹⁶ The PQASP is prepared with the statement of work and periodically adjusted as the program progresses and risks change as part of the Continuous Risk Management process.¹⁷ NASA surveillance of the contractor's controls is planned and conducted on the basis of risk to achieve confidence levels commensurate with the acceptable level of part failure risk.¹⁸ Early in a project's life cycle, engineers begin to make decisions based on the criticality, or acceptable confidence level risk of part failure. The PQASP captures the assessment of risk and guides surveillance activities to help projects reach desired confidence levels.

The Agency has categorized surveillance activities broadly into "insight" (e.g., activities that include document and record reviews and quality record reviews) and "oversight" (e.g., activities that include in-process inspection, testing, or auditing at contractor facilities) of contractors' quality assurance controls.¹⁹ Project personnel typically use a combination of insight and oversight activities to ensure conformance to the contract's quality requirements. For example, NASA's Space Launch System (SLS) defines insight as continuous assessment and oversight as a discreet approval with the Project's quality assurance practices combining both insight and oversight activities.²⁰

One of NASA's key parts-related approval activities is the Government Mandatory Inspection Point (GMIP), when Agency personnel perform mandated product assurance actions (e.g., product examination, process witnessing, and record review) at, or prior to, a specific point in the product's life cycle. NASA policy requires projects assign a GMIP to every product, process, and performance attribute where noncompliance can reasonably be expected to result in loss of life "in order to assure conformance to hardware characteristics, manufacturing process requirements, operating conditions, and functional performance criteria."²¹ The policy also allows for GMIP exemptions "based on documented risk analysis." Specifically, if the process is repetitive and the contractor control risk is assessed and verified as low then statistical GMIP samples can be applied. Similarly, if a documented risk analysis indicates acceptably low probability of noncompliance then no GMIP is required. If the consequences of nonconformance are not life threatening but pose a threat of serious personal injury; loss of a Class A, B, or C payload; loss of Category 1 or 2 mission; or loss of a mission resource valued at greater than \$2 million projects are required to assign GMIPs on a discretionary risk-informed basis.²² The policy provides risk factors, examples of information sources, and quality assurance functions to consider when analyzing, designing, and assigning GMIPs.

¹⁶ NPR 8735.2B Chapter 2 defines critical acquisition items as products or services whose failure poses a credible risk of loss of human life; serious personal injury; loss of a Class A, B, or C payload (see NPR 8705.4, "Risk Classification for NASA Payloads," June 14, 2004); loss of Category 1 or 2 mission (see NPR 7120.5, "NASA Space Flight Program and Project Management Requirements w/Changes 1-15," August 14, 2012); or loss of a mission resource valued at greater than \$2 million. Complex acquisition items are hardware products with quality characteristics not wholly visible in the end item and for which conformance can only be established progressively through precise measurements, tests, and controls. Chapter 3 identifies the PQASP requirements for preparation and content.

¹⁷ NPR 8000.4A, "Agency Risk Management Procedural Requirements (Revalidated 1/29/14)," December 16, 2008. Continuous Risk Management is NASA's term to manage risk and is a repetitive loop of five steps: identify, analyze, plan, track, and control. The process should be documented and communicated. As S&MA personnel perform activities, the assessed level of risk may need to be updated and alternatives selected.

¹⁸ NPR 8735.2B. See also, NPD 8730.5, "NASA Quality Assurance Program Policy," October 27, 2005.

¹⁹ NPR 8735.2B.

²⁰ SLS is NASA's heavy lift rocket under development to take Orion beyond low Earth orbit. The first launch of the combined SLS/Orion system is planned for September 2018.

²¹ NPR 8735.2B.

²² NASA defines payload classes in NPR 8705.4 and NPR 7120.5E.

IMPROVED SHARING OF PARTS AND SUPPLIER QUALITY INFORMATION NEEDED TO REDUCE RISK OF ACQUIRING NONCONFORMING PARTS

Although NASA has a number of initiatives in place to help ensure the selection of quality parts from reliable suppliers, we found Centers generally manage their parts and supplier data unilaterally rather than collaborating through a comprehensive, integrated, Agency-wide parts and supplier information system. Specifically, the Agency does not maintain a centralized parts history database or provide for the integration of individual Center systems, track all relevant supplier performance history, or enforce requirements that Centers participate in Agency parts management systems. Without these control mechanisms, it is more difficult for NASA to mitigate the risk of nonconforming parts entering its project hardware supply chain. As NASA continues to rely more heavily on commercial-grade parts, it is even more important that comprehensive control mechanisms are in place. Moreover, the lack of an integrated approach may lead to higher costs and schedule delays if faulty parts are acquired and additional testing, qualification, and procurement of replacement parts becomes necessary.

Cohesive Information Structure Would Make Agency Quality Assurance Management Tools More Robust

Although NASA personnel are sharing some parts and supplier knowledge by word-of-mouth and through Agency-wide working groups, much of the Agency's parts knowledge resides in Center-specific databases. Specifically, five Centers operate their own parts and supplier information databases and the Agency does not consolidate or integrate data relating to past experiences, problem reporting, or supplier performance issues across all Centers. Gathering information from both in-house and contractor-built projects and making that data available Agency-wide would help NASA parts engineers, quality assurance staff, and procurement personnel mitigate the risk of utilizing nonconforming parts from unreliable sources; avoid costly duplication of efforts related to part selection, purchase, and testing; and offer the ability to trend and analyze parts quality assurance experiences across Agency missions.

We contacted industry and other Government officials to gain a better understanding of their parts and supplier quality data systems.

- Ball Aerospace, a contractor who performed \$175 million of work for NASA in 2015, supports its quality assurance process with a database that allows users to track parts quality issues from initial receipt to final assembly and feeds into the company's supplier report card system. Database content is available to every employee across the organization.
- Lockheed Martin, a contractor who performed more than \$1 billion in work for NASA in 2015, employs a variety of tools to manage the selection of parts. These tools are integrated so users can efficiently access and analyze a large volume of data.

- The Department of the Navy employs a central database to report, collect, retrieve, and analyze supplier performance. Specifically, the Product Data Reporting and Evaluation Program collects parts and associated supplier information from the Department of the Navy as well as the U.S. Marine Corps, U.S. Army, Defense Logistics Agency, and other DOD commands. The Reporting and Evaluation Program includes a number of reporting capability tools, such as product quality deficiency reports, supplier audit program results, supply discrepancy reports, material inspection reports, and corrective action requests. In fiscal year 2015, the armed services users processed and closed approximately 23,557 product quality deficiency reports and provided material inspection reports for nearly \$2.7 billion worth of goods received from suppliers.

These entities incorporate features that provide the user with a comprehensive tool to extract, review, and analyze supplier performance information associated with a specific part – features that do not exist in a single, comprehensive NASA system.

Parts Quality Experience Data is Decentralized

In contrast to the Navy and corporate entities we spoke with, NASA lacks a centralized Agency-wide database to record parts quality experience information, including test and inspection reports, review board assessments, and successful applications. Project managers typically conduct parts design, selection, and testing activities independently, with information sharing achieved largely through engineering-level meetings and minimal integration of data from Center-specific systems and contractor-owned databases for specific projects. Although NEPP website tools and NEPAG discussions leverage Agency technical expertise and knowledge across the parts quality assurance community, there is little certainty that all parts and project specific issues will be examined or that the information will be recorded in a central, searchable database. Moreover, information captured in Center databases is often only accessible to that Center's personnel.²³

Parts quality assurance requires knowledge related to the manufacturer of the product, the manufacturer's process, and the failure modes of the part. Parts engineers therefore cannot simply rely on selecting a part from an approved list. Rather, the historical information gathered from qualification tests, inspection reports, and successful applications are valuable to understanding the risks associated with a particular part. For example, despite a history of problems with a supplier, Goddard purchased a hybrid microcircuit for a project for which there were no replacement parts available. In order to mitigate the risks involved, the project arranged for additional tests and inspections prior to shipment. These processes, including rejections and reworks, increased the part's reliability. Were the data gathered from the tests shared in an Agency-wide database, it could provide other projects with valuable information to assess risks and inform parts selection. Because the particular supplier had not been audited in some time, the data could also fill the knowledge gap about the supplier's capabilities and performance between periodic assessments.

Similarly, during testing and qualification of a printed circuit board to determine long-term reliability for a Goddard project, a specially designed EEE part failed during its destructive physical analysis. After discovering the issue, the project updated the part's requirements and authorized another supplier to provide the part and run parallel testing as a backup. While the project avoided major delays with the second parallel acquisition, project personnel told us the additional testing cost about \$14,000. Parts

²³ Access to other systems can be granted upon request, but even then unique data fields and reporting may be difficult to understand and interpret for users unfamiliar with those systems.

engineers we spoke with acknowledged that a database with information provided by all Centers could have made researching the issues easier and reduced the time invested in testing and identifying appropriate specifications for the part.

Access to a part's testing history and product data remains a significant benefit of using MIL-SPEC parts. However, as NASA gradually shifts towards purchasing more commercial-grade parts the Agency has less access to such information about the parts it is using. One NASA official we spoke with expressed concern about the potential for "nasty surprises" as the Agency selects more commercial-grade parts.

Risk mitigating procedures can be costly and may require a large sample size to improve the confidence level that a part will function as intended. For the benefit of future acquisitions of similar parts, the more knowledge a project can gather regarding the failure modes of a desired part, the more prepared and efficient a project will be in allocating resources. A senior failure analyst at NASA noted that failure rates are particularly useful when estimating reliability but that suppliers may have no interest in providing the detailed data required to help make failure rate assessments. Historical information provided by projects in a comprehensive database regarding parts use, testing, and lessons learned can address this knowledge gap and assist parts engineers and projects with purchasing versions of a part with established reliability. As the NEPP Program expressed in 2013, the more understanding parts engineers have about a part's failure modes and causes, the higher the confidence level a project can achieve to ensure the part will perform without a problem under specific environments over the lifetime of a mission.

Supplier Assessment System Does Not Capture Supplier Performance History

Controlling parts quality also involves the selection and management of qualified suppliers. Accordingly, OSMA implemented SAS in 2001 to provide a consolidated, online repository of supplier quality data, performance indicators, metrics, and assessment tools to give participants a complete picture of strengths and concerns within the supplier base and eliminate redundancies among Centers in tracking supplier performance. SAS stores records of audits that assess the supplier's overall quality management system or a specific process and facility, as well as obtains supplier rating data from the Department of the Navy and Defense Contract Management Agency on a routine basis. However, in contrast to industry and Government processes, SAS does not capture or integrate performance information related to a vendor's supplied parts, such as timeliness of delivery and occurrences of nonconforming parts – information that would provide more insight on the reliability of suppliers and assist users in making informed decisions when selecting suppliers.

Moreover, while reports stored in SAS reflect audits performed by NASA Centers, the Joint Audit Planning Committee, and NEPAG, those audits typically occur in 3- or 4-year cycles. Consequently, users could be selecting and acquiring parts based on incomplete or outdated information. In our opinion, a more dynamic environment for collecting and integrating data would broaden the knowledge base for parts acquisition decisions, which could help project managers reduce costs and the amount of retesting and inspection of parts, increase efficiencies related to the procurement of parts that were previously examined or tested, and promote the use of industry best practices for parts assurance.

Greater Center Participation Needed to Improve the Effectiveness of NASA’s Parts and Supplier Databases

NASA recognizes its parts quality assurance community may not be well integrated or using its resources as effectively as possible. For example, in late 2015 the Office of the Chief Engineer recommended to the Agency Program Management Council a consolidation of EEE parts expertise throughout the Agency. The effort considered streamlining Center capabilities and standardizing parts management tools, including the EPARTS database. Moreover, NASA policy encourages sharing knowledge and best practices “to continuously improve the performance of NASA in implementing its mission.”²⁴ Nevertheless, Centers do not consistently provide pertinent supplier audit information for inclusion in SAS or fully participate in EPARTS. Rather, quality assurance personnel are relying on local databases and routine meetings or teleconferences to exchange parts or supplier experiences. NASA’s Safety Culture Handbook describes a learning culture as one where employees collect, assess, and share information in an atmosphere of open communication, mutual trust, and shared values and lessons, with the objective of creating a safe and healthful workplace.²⁵ In our judgment, applying the same principles to parts and supplier information databases through greater Center participation would improve the Agency’s parts quality assurance process by ensuring the collection of comprehensive historical data essential for informed analyses and decision making.

Declining Trend of Supplier Assessment System Use

As noted previously, reporting audits in SAS assists the Agency in verifying supplier quality systems and processes and identifying risks of noncompliance. We reviewed the supplier audit reports posted to SAS from 2001 to 2016 and found that only JPL and Johnson Space Center (Johnson) routinely contributed to the database. Moreover, we noted a significant decline in audit reports being uploaded to SAS over this same time period (see Table 1).²⁶

²⁴ NPD 7120.6, “Knowledge Policy on Programs and Projects,” November 26, 2013.

²⁵ NASA Technical Handbook 8709.24, “NASA Safety Culture Handbook,” November 23, 2015.

²⁶ Several NASA officials suggested the decline may be due to the Space Shuttle Program ending in 2011.

Table 1: Supplier Assessment Audits Listed in SAS, 2001 through 2016

Audit Provided By	Year Audits Completed																
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	Total
Other Government Agencies							5	11	45	50	41	58	9	32	30	26	307
Joint Audit Planning Committee							9	7	5	6	1	3	4	5	7	3	50
NASA																	
Ames Research Center							1						1	1			3
Armstrong Flight Research Center									1								1
Goddard Space Flight Center	2	7	51	34	18			2	3	6	4	2					129
Jet Propulsion Laboratory	1	58	39	88	110	86	96	52	48	70	50	29	24	34	33	40	858
Kennedy Space Center			2		1	15	16	21	11	10	5						81
Johnson Space Center		40	35	53	166	128	113	105	109	89	13	6	3	2	3	1	866
Marshall Space Flight Center		30	26	35	48	33	29	40	7	5							253
Headquarters						1		1	3								5
NASA Subtotal	3	135	153	210	343	263	255	221	182	180	72	37	28	37	36	41	2,196
Total	3	135	153	210	343	263	269	239	232	236	114	98	41	74	73	70	2,553

Source: NASA Office of Inspector General evaluation of SAS.

Note: As of December 2016, Glenn Research Center, Langley Research Center, and Stennis Space Center were not identified as responsible Centers for any audit reports contributed to SAS.

Although Agency policy requires Centers to forward supplier audit and parts inspection results to SAS administrators, we found that Centers do not consistently follow this policy. For example, we examined SAS for known supplier audits conducted by the Marshall Space Flight Center between October 2014 and June 2016 and found no corresponding reports in the system. In addition, we were unable to locate several reports for audits conducted by Johnson in 2013 and 2014. Agency officials conceded that not all relevant information is posted in SAS. System administrators said they are currently conducting training and outreach sessions and intend to request Centers provide audit notification letters to ensure timely forwarding of audit results. Notwithstanding these efforts, we found OSMA does not actively enforce its policy requirements to receive and post audit and assessment results in SAS, believing their role is to provide the tool rather than police its usage.

In addition, some Center S&MA officials were not fully knowledgeable about the breadth of their reporting responsibilities. Despite making the effort to check SAS for prior audits, some officials cited a lack of time or other justification for not including information in the System, while others were unaware of SAS's existence. Some expressed a concern that SAS may allow suppliers to view competitors' proprietary information, which may also explain the decline in participation. In response to this concern, Goddard designed an information system with a supplier insight and quality management application that operates within Goddard's information technology firewall to provide the desired confidentiality protections to suppliers.

We are concerned about the inconsistency and wide variation in Center contributions to SAS, as well as the Center's lack of knowledge and adherence to Agency policy requirements. In our judgment, this is not consistent with policy and undermines the System's usefulness as a quality management tool. Beyond potential safety implications, the need for cost savings in a tight budget environment demands a more collaborative approach to selecting the appropriate supplier and SAS is a key part of meeting this challenge.

Electronic Parts Applications Reporting and Tracking System Use is Voluntary

NASA does not have a policy requiring Centers to use EPARTS and not all Centers participate. As of September 2016, only six Centers were using EPARTS, and nearly half of the data was contributed by JPL.²⁷ Although EPARTS administrators acknowledged that end user acceptance and participation is instrumental in improving the sharing of parts experience information across the Agency, Centers with more established parts data systems appear reluctant to migrate their data into EPARTS because of the time and personnel resources required for the effort and concerns about losing control of the information. Moreover, Agency personnel told us some projects and contractors are reluctant to share data in the System because they consider part design, selection, and testing as proprietary information. However, according to an EPARTS official, each Center has the ability to limit user access to data by designating their parts list as proprietary and defining what data is accessible to others.²⁸

Government-Industry Data Exchange Program Reporting Has Declined

Participation by Centers in posting Agency action notices and alerts in GIDEP has declined over the years. While there are consistent practices implemented by Center quality assurance personnel for reviewing and dispositioning GIDEP notices, as well as NASA Advisories, a GIDEP official expressed concern regarding the lack of reporting participation, noting that if the database is not receiving the reports that it should, users may no longer have sufficient, relevant, and complete knowledge to select and acquire parts and components. A decline in GIDEP participation denies NASA and the purchasing community the benefits of a large information base to make informed decisions. Failure to share problem and nonconforming item data may result in missed opportunities for collaboration, a lack of timely recognition of critical part issues, and unanticipated repair and replacement costs. Indeed, NASA attributed more than \$55 million in preventing unplanned expenditures between fiscal years 2010 and 2015 to the use of GIDEP information.²⁹

²⁷ The six Centers were Ames Research Center, Glenn Research Center, JPL, Kennedy Space Center, Langley Research Center, and Marshall Space Flight Center.

²⁸ Given the timing of our audit fieldwork, we were unable to verify this ability.

²⁹ NASA users reported a wide range of cost avoidance attributable to GIDEP alerts, including (1) replaced and prevented removal/rework of questionable parts on flight boards that could have cost about \$25,000; (2) prevented suspect parts from reaching assembly level that would have cost about \$100,000 in rework; (3) adjusted design when a part was identified as not fully functional in the required application avoiding about \$230,000 in expenses; (4) affected multiple projects that attributed more than \$520,000 in procurement cost impact; and (5) prevented the use of questionable parts on a \$50 million satellite that could have caused instrument and eventual mission failure.

Given the Office of Inspector General's first-hand experience of submitting the GIDEP notification that a manufacturer may have altered test results, we believe the practice both necessary and essential to informing the user community of an existing parts issue. However, some Agency and prime contractor officials expressed reluctance to issue GIDEP alerts for nonconforming parts based on concerns over legal repercussions or about damaging business relationships, especially when the supplier is the only available source for the part. Similarly, many project managers and prime contractors prefer to delegate their reporting responsibility to the supplier or manufacturer because they believe the supplier has a more in-depth understanding of its parts and can demonstrate goodwill by sharing them within the system. While this self-reporting approach may be preferable to the Agency, we found no evidence of a process or policy in place for projects to confirm supplier postings.

PROJECT QUALITY ASSURANCE SURVEILLANCE PLANS NEED IMPROVEMENT TO ENSURE EFFICIENT USE OF RESOURCES

NASA policy requires project managers or their designated S&MA personnel to consider risk factors when preparing a Program/Project Quality Assurance Surveillance Plan (PQASP) for critical and complex acquisitions. They are required to document contractor operations that need Government oversight, as well as the activities, metrics, control mechanisms, and organizations that will conduct quality assurance functions for the project.³⁰ However, we found the policy does not provide sufficient surveillance and audit planning guidance for project personnel to analyze and select contractor surveillance activities commensurate with the level of risk of nonconforming parts being incorporated into a product. Consequently, the PQASPs we reviewed incorporated and applied risk assessments inconsistently and S&MA resource allocations for those projects may not have been commensurate with risk acceptance goals for parts quality. Inefficient surveillance activities could overburden resources or increase the risk of integrating a part of inappropriate quality into a project.

Project Quality Assurance Surveillance Plans Do Not Properly Assess or Quantify Risk

NASA policy requires projects evaluate part and process criticality and consider and document the risk of not detecting a contractor nonconformance when developing the PQASP. The nature, timing, and extent of surveillance activities will increase or decrease based on the level of risk the project has accepted for the contractor meeting quality requirements. To select the appropriate surveillance activity given limited resources and level of criticality, the project analyzes the strengths of the contractor's controls and how likely the part or process will not conform.

Our analysis of PQASPs for seven Human Exploration and Operations Mission Directorate projects found that managers did not – despite general alignment to the Agency's policy – consistently consider and document applicable risk elements when identifying surveillance activities.³¹ While some projects excelled at evaluating and documenting risks and assigning commensurate surveillance activities, other projects were unable to substantiate PQASP decisions.

³⁰ NPR 8735.2B, Chapter 3, "Program/Project Quality Assurance Surveillance Plan (PQASP)." While a PQASP is supposed to be a single unified document, it may cite to reference procedures and plans for the performance of specific surveillance actions (e.g., inspections and tests).

³¹ We requested PQASPs and related documentation from the following programs and projects: (1) Commercial Resupply Services, (2) Launch Services Program's Jason-3 launch vehicle, (3) Orion, (4) SLS Boosters, (5) SLS Engines, (6) SLS Stages, and (7) SLS Spacecraft/Payload Integration and Evolution. The Commercial Resupply Services Program did not prepare a PQASP for the launch vehicles and instead stated they obtained assurance from related programs such as Commercial Crew, Launch Services Program, and U.S. Air Force in what managers coined "Shared Assurance Meetings." This practice appears to be inconsistent with policy requirements to document the risk strategy within a PQASP.

Inconsistent Evaluation of Risk and Correlation to Mitigating Activities

We analyzed project PQASPs, NASA policy, and contractor and industry practices and identified three common, interrelated parts surveillance risk elements that were either not fully considered or not consistently considered by project personnel:

- Contractor parts quality management process controls.
- Risk of parts nonconformance.
- Correlation of contractor controls and nonconformance risk to surveillance activities.

The PQASPs that identified, assessed, and documented these risks showed correlating support for selection of surveillance activities commensurate with an acceptable level of risk. Table 2 summarizes our analysis of project PQASPs relative to the identified three risk elements.

Table 2: Summary of Parts Surveillance Risk Elements in PQASP

Project	Contractor Process Controls	Parts Nonconformance	Correlation to Surveillance Activities
Commercial Resupply Services	No	No	No
Launch Services Program's Jason-3	Partial	Yes	Yes
Orion	Yes	Yes	Partial
SLS Boosters	Partial	Yes	Yes
SLS Engines	Partial	Yes	Yes
SLS Stages	Partial	Partial	No
SLS Spacecraft/Payload Integration and Evolution	Partial	Partial	No

Source: NASA Office of Inspector General analysis of Program and Project documentation.

Note: Yes – evidence risk quantification undertaken and documented. Partial – evidence the risk element was incorporated into PQASP but evaluation may not have been performed or documentation was incomplete.

We believe project S&MA personnel must assess and quantify all three risk elements to achieve an acceptable risk posture and develop an appropriate surveillance plan. For example, given an equally acceptable risk of nonconformance for two complex parts, a part built or purchased by a supplier with strong quality assurance controls may require less disruptive surveillance activities than the same part from a newer contractor with less proven process controls. This would also be true if supplier quality assurance controls were similar but the risk of part nonconformance were different. As surveillance activities are performed, project S&MA personnel reevaluate their assessments as part of the project's Continuous Risk Management process and may adjust surveillance activities as needed.

We discuss each individual part risk element and its relationship with risk mitigating activities in the following sections. We also identify needed improvements.

Assessment of Contractors' Parts Quality Management Processes Controls

NASA policy lists several surveillance and audit activities that help assess contractors' parts quality management controls, including contractor document review, quality system evaluation, nonconformance procedures, and performance metrics. During parts quality surveillance planning, the collective results of these activities are to be documented, updated, and used to assess a contractor's ability to implement effective management process controls. These results should also provide the basis for determining the magnitude of NASA's surveillance activity requirements. Weak contractor controls may require more robust surveillance and audit activities. For example, if a contractor has a history of accepting substandard parts from its suppliers, a project may need to increase surveillance activities.

Most of the PQASPs we reviewed included requirements for supplier audits and AS9100 certifications; however, it was unclear how this or additional information was used to assess and determine decisions about surveillance activity.³² Although AS9100 certification may show that a contractor's propensity towards overall quality management is high, thus reducing the need for Agency parts quality surveillance, the certification may not alleviate the need to assess specific contractor controls for parts quality.³³ For example, the SLS Spacecraft/Payload Integration and Evolution Project's PQASP stated the Project would use a risk-based process to identify surveillance activities and included a list of contractor processes to evaluate. However, the Project ultimately elected not to use a documented risk-based process and relied on U.S. Air Force inspections for its contractor surveillance based on an assessment of lower project criticality. Without a documented risk-based assessment to support its decision, the Project may have accepted more or less risk than intended.

Conversely, we found several projects documented and calculated the strength of a contractor's quality management controls. For example, the Orion Program PQASP considered the strength of a contractor's quality management controls predicated primarily on Defense Contract Management Agency supplier assessments. In doing so, S&MA personnel assessed contractor quality management abilities exceeding the evaluation requirements of a contractor's AS9100 Quality System and tailored their quality assurance risk assessment to better understand how much they could rely on the contractor's controls. This assessment was composed of many parts including evaluating system processes at contractor facilities, summarizing quality management process controls, and comparing them against AS9100 specific standards. In our judgment, this well documented assessment reduced the chance of measuring contractor quality process controls too high or too low and enabled risk-based informed decisions to select more effective part surveillance activities.

Assessment of Parts Nonconformance Risks

NASA policy also requires analysis of multiple factors (e.g., product and process maturity, complexity, and past performance) to ascertain the likelihood a contractor can conform to parts and process requirements. The assessment of nonconformance risk provides another consideration for determining the magnitude of NASA's surveillance activity requirements. For example, a simple part that is frequently used may require only a statistical sample review of material testing data to ensure it

³² SAE International, Aerospace Standard (AS) 9100 "Quality Management Systems – Requirements for Aviation, Space and Defense Organizations" is a set of standards that establishes a single quality management system for use within the aerospace industry. Standards include management communication, resource management, customer relations, project planning and design, purchasing, measurement and analysis, and continuous improvement documents.

³³ Examples include assessments of controls for assembly, counterfeit material mitigation, wiring functions, calibration, nondestructive testing, operational tests, soldering, packaging, and shipping processes.

conforms to specifications. Conversely, a highly complex, custom built part that requires specialized knowledge may require a project team to increase surveillance activities to give the same level of assurance.

We found almost all projects initially included instructions to consider some risk factors associated with parts nonconformance risk in their PQASPs. However, only the SLS Booster and SLS Engines PQASPs further developed their practices to enumerate nonconformance risks and document how they arrived at that calculation. For example, the SLS Booster PQASP first considered seven factors related to nonconformance risk and criticality. In some cases, those factors indicated high enough risk to require an additional risk assessment be performed. Similarly, managers for SLS Engines considered and documented nonconformance risk in sections they called “risk of process” and “risk of inspection” as narratives before ranking them high, medium, or low. While not specifically identified as nonconformance risks, many of these descriptions addressed nonconformance risk concerns. These assessments scored (quantified) the likelihood and consequence of each risk. In contrast, the SLS Stages Project also had similar nonconformance risk instructions but elected not to perform an assessment, thereby foregoing risk-informed decision making to corroborate surveillance activities with acceptable risk.

Correlation of Contractor Parts Quality Management Controls and Nonconformance Risks to Quality Assurance Surveillance Activities

NASA policy requires PQASPs identify quality assurance resources – personnel, funding, and materials – that support each project’s quality assurance surveillance and audit efforts.³⁴ However, the policy was not consistently applied to correlate part and process related risks with application of surveillance resources by ensuring they are commensurate with the accepted level of risk. Projects with best practices in developing these elements were able to demonstrate S&MA resources allocated to audit and surveillance activities based on the results of their assessments of control and nonconformance risks given an assessed level of criticality.³⁵

As previously discussed, the SLS Booster and SLS Engines Projects documented and quantified a range of relevant parts and process risks in their PQASPs and then identified the surveillance activities that would give them sufficient assurance that contractor quality controls were functioning as intended. More importantly, the PQASPs showed how that calculation impacted the selection of surveillance activities, as higher risk scores required more intensive surveillance activities. In turn, the Projects used these results to influence the schedules for S&MA staff. As the Projects progressed, this continuous risk reassessment provided management flexibility to identify alternative surveillance activities consistent with any risk level changes. For example, the SLS Engines Project identified several tests early in its quality assurance process that could likely identify potential nonconformance. As a result, another normally required test observation was eliminated. The contractor would still perform these quality checks without stopping for Government inspections, thus minimizing their process disruptions and allowing the SLS Engine Project’s quality assurance staff to perform other assessments, such as documentation reviews, at a later time for that particular quality checkpoint.

³⁴ NPR 8735.2B.

³⁵ The Government Accountability Office (GAO) provides guidance that states, in part, planning needs to consider the scope of work; an appropriate number of specialists, reviewers, and other resources to perform the audit; changing the methodology to obtain sufficient evidence; and determine the amount and type of evidence needed given audit risk and significance. See GAO, “Government Auditing Standards: 2011 Revision” (GAO-12-331G, December 2011).

Conversely, we also found incongruent correlation of risk assessments to surveillance activities in some PQASPs. For example, the Orion Program and SLS Stages Project indicated they were using a “Risk Based Surveillance Strategy” or similar methodology. However, citing that the risk-based evaluation process was too onerous, the Orion Program and SLS Stages Project elected to implement mostly mandatory inspections that are resource and schedule intensive, potentially eliminating a range of less disruptive surveillance activities that could provide equivalent quality assurance with fewer resources at lower costs and less disruption to work progress.

Selecting the appropriate level of surveillance activities is critical to mitigate the risk of nonconforming parts entering the system as early as possible in the most efficient manner. In our judgment, giving additional PQASP guidance specific to the identified risk element may give project S&MA teams more confidence in performing risk-based assessments. Moreover, by linking quality assurance and nonconformance risks to resources, NASA can more efficiently apply S&MA detection resources to decrease the risk of nonconforming parts. The Agency is also in a better position to identify points at which additional resources will not yield a significant return on investment. Balancing the risk and resources relationship enables managers to select the most efficient surveillance activities matching the project’s risk tolerance level.

CONCLUSION

As NASA continues to pursue cost, schedule, and performance efficiencies when building flight hardware, it becomes essential to achieve a more cooperative and integrated approach to parts quality assurance through active participation across all Centers. With more consistent participation by parts engineers, specialists, and quality assurance personnel in populating SAS and EPARTS, programs and projects could have better information to make important part and supplier selections. A comprehensive and integrated system may help identify issues earlier in the parts quality management process and avoid costly mistakes during assembly and throughout mission life. By supporting a more integrated, Agency-wide system for parts problem history and supplier information, OSMA and the Office of the Chief Engineer can provide a “one-stop shop” for NASA parts engineers and quality assurance personnel. In our judgment, the Agency-wide systems currently in place – SAS and EPARTS – provide suitable platforms for enhancement to integrate part and supplier performance history across all Centers.

With increasingly more contractor driven projects, the clarity of, and adherence to, NASA policy and procedures regarding development of PQASPs must continue to improve to reduce the risk of parts nonconformance while applying an appropriate amount of resources through documented quantification of risk. A policy with a clear framework to quantify and document the risk of part failure, together with improved execution of policy requirements by Center S&MA and program/project personnel, would result in more effective planning and execution of activities that match the risk allowance.

RECOMMENDATIONS, MANAGEMENT'S RESPONSE, AND OUR EVALUATION

To increase transparency, accountability, and oversight of NASA's parts quality management processes, we recommended the Chief of Safety and Mission Assurance collaborate with Center, program, and project stakeholders to:

1. Expand current NASA data sharing structure to integrate supplier databases with parts databases.
2. Investigate causes of gaps in SAS reporting and formulate remedial actions to ensure compliance with SAS reporting requirements.
3. Identify supplier performance information of common interest and modify SAS data structure to accommodate such information.
4. Collaborate with Office of the Chief Engineer to identify parts history information of common interest and modify EPARTS data structure to accommodate that information and to link to supplier information databases.
5. Examine the feasibility of further expanding NASA's parts and supplier data collection efforts to include contractor maintained data regarding parts and suppliers utilized in NASA contracts.
6. Evaluate current parts and supplier database system architectures to determine the cost and benefits of establishing an Agency-wide database system as opposed to maintaining current decentralized database systems.
7. Incorporate a feedback process to improve the Agency's tracking and recording of contractors' and suppliers' submissions of GIDEP alerts and Agency action notices.
8. Review a representative sample of PQASPs to identify deficiencies and best practices and revise policy as needed to include quantification and documentation of nonconformance and control risks for ensuring surveillance activities and resources are commensurate with part criticality and overall accepted project risk.

We provided a draft of this report to NASA management who concurred with and described planned actions to address our recommendations. We consider the proposed actions responsive to our recommendations and will close the recommendations upon completion and verification of the actions.

Management also noted that the Agency identified "[c]ausal factors" other than faulty parts for the mishaps discussed in the report and that "implementation of the recommendations would not necessarily have prevented the . . . mishaps from occurring." We do not disagree with these statements and note that the report focuses on improving NASA's polices for mitigating the risks of incorporating nonconforming parts into critical hardware rather than the particular circumstances of or the root causes associated with any particular mishap.

Management's full response to our report is reproduced in Appendix B. Their technical comments have been incorporated, as appropriate.

Major contributors to this report include, Raymond Tolomeo, Science and Aeronautics Research Directorate Director; Stephen Siu, Project Manager; Cyrus Geranmayeh; and John Schultz.

If you have questions about this report or wish to comment on the quality or usefulness of this report, contact Laurence Hawkins, Audit Operations and Quality Assurance Director, at 202-358-1543 or laurence.b.hawkins@nasa.gov.

A handwritten signature in black ink, appearing to read 'PKMJA'.

Paul K. Martin
Inspector General

APPENDIX A: SCOPE AND METHODOLOGY

We performed this audit from January 2016 through February 2017 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.

This review assessed NASA's management of its parts quality processes in order to mitigate the risks of nonconforming parts being integrated into critical hardware. We did not review the particular circumstances nor root causes that resulted in NASA's mission losses cited in Figure 1. Specifically, we evaluated (1) NASA's parts and supplier quality management control process, (2) NASA's parts and supplier data collection and sharing practices, and (3) NASA's process of overseeing contractor quality management systems. We reviewed NASA's part quality management processes at NASA Headquarters, Goddard Space Flight Center, Jet Propulsion Laboratory, Kennedy Space Center, Johnson Space Center, and Marshall Space Flight Center.

To accomplish this review, we spoke with quality assurance managers and staff from the five Centers to gain understanding of their processes and controls. Staff interviews included both civil servants and contractors' part designers, parts engineers, receiving and inspection personnel, project hardware integration teams, supplier auditors, and GIDEP administrators. We also interviewed relevant NASA officials including NASA EEE experts and personnel from OSMA, Office of the Chief Engineer, and the NASA Safety Center regarding the Agency's EPARTS, GIDEP, NEPP, and SAS, and NASA Quality System audits process. Additionally, we interviewed Government representatives managing the GIDEP and Department of the Navy's systems. We also interviewed two industry part management teams to understand their companies' parts and supplier data management systems.

To better understand how NASA has employed PQASP policies and procedures within the context of parts quality management we selected several major projects across different NASA Centers. We obtained PQASP related documentation, performed an analysis, and discussed the results with project and S&MA management. We compared the selected project documentation to the approximately 30 requirements listed in NASA Procedural Requirements (NPR) 8735.2B Chapter 3 to see if there were any major omissions or patterns. We broadly checked to see if the specific requirements were considered, as opposed to testing to ensure the activities were actually performed. We also compared the PQASPs to each other.

We obtained and examined internal and external applicable documents related to part quality management as well as NASA policy. The documents we examined included the following:

- NPR 7120.5E, "NASA Space Flight Program and Project Management w/ Changes 1-15," August 14, 2012
- NPR 8000.4A, "Agency Risk Management Procedural Requirements (Revalidated 1/29/14)," December 16, 2008
- NPR 8705.4, "Risk Classification for NASA Payloads (Updated w/ change 3)," June 14, 2004

- NPR 8705.6C, “Safety and Mission Assurance (SMA) Audits, Reviews, and Assessments,” January 9, 2017
- NASA Policy Directive 8730.2C, “NASA Parts Policy (Revalidated 12/6/13),” November 3, 2008
- NPR 8735.1C, “Procedures for Exchanging Parts, Materials, Software, and Safety Problem Data Utilizing the Government-Industry Data Exchange Program (GIDEP) and NASA Advisories,” February 13, 2013
- NPR 8735.2B, “Management of Government Quality Assurance Functions for NASA Contracts,” August 12, 2013

Use of Computer-Processed Data

We used limited computer-processed data to perform this audit. Specifically, GIDEP and SAS access data provided by the respective system’s managers. Generally, we concluded the data was valid and reliable for the purposes of the review.

Review of Internal Controls

We reviewed and evaluated internal controls related to NASA’s part quality management processes. Although we consider those internal controls to be adequate, there is room for improvement as documented in the report.

Prior Coverage

During the last 5 years, the NASA Office of Inspector General and the GAO have issued seven reports of significant relevance to the subject of this report. Unrestricted reports can be accessed at <http://oig.nasa.gov/audits/reports/FY17> and <http://www.gao.gov>, respectively.

NASA Office of Inspector General

NASA’s Commercial Crew Program: Update on Development and Certification Efforts (IG-16-028, September 1, 2016)

NASA’s Response to SpaceX’s June 2015 Launch Failure: Impacts on Commercial Resupply of the International Space Station (IG-16-025, June 28, 2016)

NASA’s Response to Orbital’s October 2014 Launch Failure: Impacts on Commercial Resupply of the International Space Station (IG-15-023, September 17, 2015)

Commercial Cargo: NASA’s Management of Commercial Orbital Transportation Services and ISS Commercial Resupply Contracts (IG-13-016, June 13, 2013)

NASA’s Challenges to Meeting Cost, Schedule, and Performance Goals (IG-12-021, September 27, 2012)

Government Accountability Office

Space and Missile Defense Acquisitions: Periodic Assessment Needed to Correct Parts Quality Problems in Major Programs (GAO-11-404, June 24, 2011)

Counterfeit Parts: DOD Needs to Improve Reporting and Oversight to Reduce Supply Chain Risk (GAO-16-236, February 16, 2016)

APPENDIX B: MANAGEMENT'S COMMENTS

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



March 27, 2017

Reply to Attn of: Office of Safety and Mission Assurance

TO: Assistant Inspector General for Audits
FROM: Chief, Safety and Mission Assurance
SUBJECT: Agency Response to OIG Draft Report, "NASA's Parts Quality Control Processes" (A-16-005-00)

NASA appreciates the opportunity to review and comment on the Office of Inspector General (OIG) draft report entitled "NASA's Parts Quality Control Processes" (A-16-005-00), dated February 23, 2017.

The Office of Safety and Mission Assurance (OSMA) agrees with the importance of ensuring technically conforming and reliable parts. OSMA further agrees that the recommendations provided in the report, upon analysis and appropriate implementation, may enhance efforts to ensure installation of conforming and reliable parts. OSMA notes, however, that implementation of the recommendations would not necessarily have prevented the cited mishaps from occurring. Causal factors for these mishaps have been identified and are being implemented independent of the recommendations.

In the draft report, the OIG makes eight recommendations addressed to the Chief, Safety and Mission Assurance, in collaboration with Center, program, and project stakeholders, intended to increase transparency, accountability, and oversight of NASA's parts quality management processes.

Specifically, the OIG recommends the following:

Recommendation 1: Expand current NASA data sharing structure to integrate supplier databases with parts databases.

Management's Response: Concur. The Chief, Safety and Mission Assurance will collaborate with the Office of the Chief Engineer (OCE) and Center, program, and project stakeholders to assess the feasibility and benefits of integrating supplier quality and parts databases currently maintained by OSMA, OCE, and NASA programs/Centers.

Estimated Completion Date: December 31, 2017.

Recommendation 2: Investigate causes of gaps in Supplier Assessment System (SAS) reporting and formulate remedial actions to ensure compliance with SAS reporting requirements.

Management's Response: Concur. The Chief, Safety and Mission Assurance will request NASA Centers to internally assess adherence to SAS reporting requirements and report results to OSMA, including planned remedial actions. OSMA will ensure Center implementation of effective corrective actions during the conduct of NASA Safety Center Quality audits.

Estimated Completion Date: December 31, 2017 (Center internal assessments).

Recommendation 3: Identify supplier performance information of common interest and modify SAS data structure to accommodate such information.

Management's Response: Concur. The Chief, Safety and Mission Assurance will convene a NASA Quality Assurance Working Group gathering for the purpose of identifying supplier performance information of common interest. The SAS data structure will be modified to accommodate new information.

Estimated Completion Date: December 31, 2017.

Recommendation 4: Collaborate with Office of the Chief Engineer to identify parts history information of common interest and modify Electronic Parts Applications Reporting and Tracking System (EPARTS) data structure to accommodate that information and to link to supplier information databases.

Management's Response: Concur. The Chief, Safety and Mission Assurance, in collaboration with the OCE, will evaluate the benefits and feasibility of potential modifications of EPARTS to accommodate parts history information and links to supplier databases.

Estimated Completion Date: December 31, 2017.

Recommendation 5: Examine the feasibility of further expanding NASA's parts and supplier data collection efforts to include contractor maintained data regarding parts and suppliers utilized in NASA contracts.

Management's Response: Concur. The Chief, Safety and Mission Assurance, will query NASA prime contractors concerning their interest in submitting parts quality data for the inclusion in NASA's SAS database and sharing of the data among all participating organizations. For contractors that provide positive replies, OSMA will assess the feasibility and costs for modifying the SAS data structure to accommodate this new information.

Estimated Completion Date: December 31, 2017.

Recommendation 6: Evaluate current parts and supplier database system architectures to determine the cost and benefits of establishing an Agency-wide database system as opposed to maintaining current decentralized database systems.

Management's Response: Concur. The Chief, Safety and Mission Assurance, in collaboration with the OCIO, Centers, and Program Offices, will evaluate the benefits and costs for establishing an Agency-wide system architecture that can accommodate cross-Agency quality parts data.

Estimated Completion Date: December 31, 2017.

Recommendation 7: Incorporate a feedback process to improve the Agency's tracking and recording of contractors' and suppliers' submissions of Government-Industry Data Exchange Program (GIDEP) alerts and Agency action notices.

Management's Response: Concur. The Chief, Safety and Mission Assurance will collaborate with Centers and Program Offices to identify and evaluate potential improvements to the Agency's tracking and recording of contractors' and suppliers' submissions of GIDEP alerts and Agency action notices.

Estimated Completion Date: September 30, 2017.

Recommendation 8: Review a representative sample of Program/Project Quality Assurance Surveillance Plans (PQASPs) to identify deficiencies and best practices and revise policy as needed to include quantification and documentation of nonconformance and control risks for ensuring surveillance activities and resources are commensurate with part criticality and overall accepted project risk.

Management's Response: Concur. The Chief, Safety and Mission Assurance will request NASA Centers to internally assess adherence to PQASP requirements and report results to OSMA, including planned remedial actions. Upon receipt and evaluation of Center replies, OSMA will review a representative sample of PQASPs to identify deficiencies and best practices and will convene a QAWG meeting in order to collaboratively evaluate the need to enhance PQASP policy.

Estimated Completion Date: December 31, 2017.

Other Matters

The Human Exploration and Operations Mission Directorate (HEOMD) does not agree that the four launch vehicle mission failure examples used in Figure 1 of the draft report are good examples of failures caused by a “parts quality” problem. Characterizing these failures as simple parts quality problems is an oversimplification of those mission failure causes. For the OCO and Glory mission failures, there were four separate mishap boards (two per each mission, with one board led by the contractor and one led by NASA), none of which were able to find the definitive technical reason for why the payload fairing failed to separate from the launch vehicle for either of those missions. It was only after two years of additional investigation led by the Launch Services Program using Kennedy Space Center laboratory testing, numerous visits to the launch vehicle contractor and its suppliers, and performing detailed frangible joint separation tests within chambers at Lawrence Livermore Labs, that the combination of factors that led to the two mission failures were discovered. As for the Antares 130 launch failure, the Orbital mishap report identified several factors that led to the AJ-26 engine explosion and for the SpaceX Falcon 9 version 1.1 launch failure; the issue that led to the launch failure wasn’t poor parts quality, but improper use of the parts. While the recommendations made by the report for improving NASA’s part quality processes are in the direction of “goodness,” none of the recommendations would have prevented the failure examples used in Figure 1.

The Goddard Space Flight Center (GSFC) agrees with the HEOMD assessment above and extends the concern to the reference to the SMAP radar payload failure and, further, would like to point out that the bulk of the report centers around Electrical, Electronic, and Electromechanical (EEE) parts, but only the SMAP failure involves an EEE part out of all of the examples. This failure is not related to parts quality but to a design issue that stressed a circuit, followed up by a radiation hit to an already-stressed radiation-hardened, military-specification, Level 1 part. The part performed as it was intended. Ultimately, GSFC objects to this report because: (1) the content of the report does not address the failures presented as a driver for the report; (2) the implication that there are broad problems in parts quality is not substantiated; and (3) the recommendations, while sounding good and benign, drive up cost and risk, and they would not have prevented or mitigated any of the failures that were used to justify this report. While we agree there would be much value in increased investment in general quality and in EEE parts efforts, the real shortfalls are not addressed in this report, and it is not apparent that the recommendations in this report address the most critical areas.

The Science Mission Directorate concurs with the aforementioned assessments from HEOMD and GSFC of the OCO, Glory, and SMAP mission failures as well as on the use of EEE parts.

We have reviewed the draft report for information that should not be publicly released. As a result of this review, we have not identified any information that should not be publicly released.

Once again, thank you for the opportunity to review and comment on the subject draft report. If you have any questions or require additional information regarding this response, please contact Kelly Kabiri on (202) 358-0590.


Terrence W. Wilcutt

cc:
Office of the Chief Engineer/Mr. Roe

APPENDIX C: REPORT DISTRIBUTION

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