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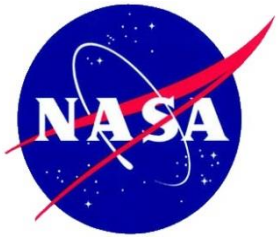
MANAGEMENT OF THE LOW-BOOM FLIGHT DEMONSTRATOR PROJECT

May 6, 2020

Report No. IG-20-015



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RESULTS IN BRIEF

Management of the Low-Boom Flight Demonstrator Project

May 6, 2020

IG-20-015 (A-17-017-01)

WHY WE PERFORMED THIS AUDIT

Within the next 20 years, the projected growth of passenger air travel worldwide will require revolutionary improvements in aircraft performance and technology to make flying more safe, efficient, scalable, and environmentally friendly. NASA's aeronautics programs are working on near-term solutions to address several of these challenges by developing innovations in commercial supersonic aircraft. Since 1973, the Federal Aviation Administration (FAA) has banned commercial aircraft from flying overland within the United States at supersonic speeds—faster than the speed of sound—due to the loud sonic boom the aircraft produces.

In March 2018, NASA contracted with the Lockheed Martin Corporation (Lockheed Martin) to develop a single experimental aircraft or X-plane known as the Low-Boom Flight Demonstrator (LBFD) that produces a quieter sonic boom while flying at supersonic speeds. The Agency is building the aircraft to develop a database of community responses to overland supersonic flights for use by the FAA and International Civil Aviation Organization (ICAO) at a planned 2025 meeting to support development of a new noise-based standard for supersonic overland flight.

In this audit, we examined whether NASA was effectively managing the LBFD Project to accomplish its technical objectives while meeting established milestones and controlling costs. Specifically, we reviewed the Project's (1) acquisition and contract management, (2) project management and risk, (3) Joint Cost and Schedule Confidence Level (JCL) estimate, (4) Earned Value Management (EVM), and (5) lessons learned from NASA and other federal agencies' acquisitions. To complete this work, we reviewed the acquisition, management, and oversight of Lockheed Martin project staff along with the effectiveness of the EVM program and implementation of JCL; analyzed LBFD-specific documentation from NASA, the LBFD Project, and Lockheed Martin; examined the LBFD contract with Lockheed Martin; and interviewed LBFD Project personnel, other NASA officials, and key staff at Lockheed Martin.

WHAT WE FOUND

LBFD is the Aeronautics Research Mission Directorate's (ARMD) first attempt at a large-scale (over $250 million) development project. We found that LBFD management instituted a sound acquisition strategy when Lockheed Martin was issued a task order under an existing contract for the preliminary design of the aircraft and was then selected as the contractor for LBFD's subsequent phases after NASA conducted a full and open competition. The LBFD Project also implemented an innovative project management structure that leveraged geographically dispersed aeronautics expertise across multiple NASA Centers rather than designating a single Center as the lead for LBFD development. In addition, the Project provided the contractor more-than-expected amounts of government furnished equipment (GFE) that saved procurement costs.

LBFD is also the first ARMD project required to develop a JCL analysis (a statistical estimating tool that produces a cost and schedule baseline to predict the probability of a project being completed at a certain cost and on a certain schedule). The Project's JCL resulted in an Agency Baseline Commitment of $583 million that included 13 months of schedule reserve and $134 million in cost reserve to build and complete low-boom acoustic validation flights by

October 2023. However, the cost and schedule baselines have been negatively impacted by a 5-week government shutdown from December 2018 to January 2019 and reassignment of a test location. Overall, the contract is estimated to cost $37 million more at completion than originally expected and Lockheed Martin is 2 months behind its planned schedule due to challenges in hiring qualified technical personnel. Thus, NASA needs to ensure contingency plans are in place to account for flight or data collection delays to guarantee delivery of the database of community responses to the ICAO in 2025.

We also found Lockheed Martin and LBFD Project managers experienced difficulties implementing EVM, a project management tool for measuring and assessing a project's performance and progress. The NASA FAR Supplement requires the contractor to use an Earned Value Management System (EVMS) and provide documentation showing compliance with EVM guidelines and also specifies that the Agency shall request the Defense Contract Management Agency (DCMA) determine the adequacy of proposed EVMS plans and system compliance. NASA used an online database rather than directly request DCMA to verify Lockheed Martin's EVMS certification. Due to clerical and database errors, NASA discovered Lockheed Martin's Palmdale, California, location did not have a DCMA-certified EVMS as believed, and as a result LBFD managers expended a substantial amount of time and effort verifying the reliability and accuracy of EVM data provided by Lockheed Martin. Consequently, the Agency will spend approximately $130,000 for DCMA to perform surveillance and certification testing at the Palmdale location.

WHAT WE RECOMMENDED

To ensure Low-Boom Flight Demonstration Mission success, increase accountability for future X-plane developments, improve EVM-related processes and reporting, and improve DCMA involvement with NASA contracts , we made the following recommendations to NASA management: (1) finalize the schedule-driven contingency plan for the community response testing and account for the personnel and costs it will require to implement; (2) perform a cost-benefit analysis of implementing internal EVM during Phase D of LBFD development; (3 and 4) document and provide both the project management approach and JCL analysis approach used by LBFD management to the NASA Chief Knowledge Officer; (5) establish a process to be used during source evaluation boards and source selections that includes direct contact with the Center EVM Working Group Representative and cognizant DCMA office to verify all contractor proposed information related to EVM; (6) establish NASA requirements for programs and projects to perform internal EVM reporting that follow the same timeline as contractor reporting; (7) evaluate whether the monetary threshold for performing internal EVM is sufficient or additional criteria would be beneficial regarding the dollar-value of tasks related to providing GFE and performing in-house development work compared to NASA personnel performing integration, review, and management functions; and (8) provide information and training on the availability, use, and responsibilities of DCMA during source evaluation boards and source selections.

We provided a draft of this report to NASA management who concurred with six of our eight recommendations and described corrective actions it will take. We consider management's comments to those recommendations responsive and therefore, the recommendations are resolved and will be closed upon completion and verification of the proposed corrective actions. Management did not concur with Recommendations 6 and 7 related to adjusting requirements and implementing additional criteria for in-house EVM reporting. These recommendations will remain unresolved pending further discussion with the Agency.

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Acronyms

ARMD	Aeronautics Research Mission Directorate
CAEP	Committee on Aviation Environmental Protection
CBAR	Contract Business Analysis Repository
CDR	Critical Design Review
DCMA	Defense Contract Management Agency
EVM	Earned Value Management
EVMS	Earned Value Management System
FAA	Federal Aviation Administration
FAR	Federal Acquisition Regulation
FY	fiscal year
GAO	Government Accountability Office
GFE	government furnished equipment
IASP	Integrated Aviation Systems Program
ICAO	International Civil Aviation Organization
JCL	Joint Cost and Schedule Confidence Level
KDP	Key Decision Point
LBFD	Low-Boom Flight Demonstrator
NPR	NASA Procedural Requirements
OCFO	Office of the Chief Financial Officer
PDR	Preliminary Design Review

INTRODUCTION

Within the next 20 years, the projected enormous growth of passenger air travel worldwide will require revolutionary improvements in aircraft performance to maintain safe, efficient, and scalable operations. According to the International Air Transport Association and others, commercial passenger trips are projected to increase from 3.3 billion in 2014 to 11 billion by 2050, requiring approximately 36,000 new airplanes.[1] The increased number of flights and aircraft are expected to triple the amount of carbon dioxide emissions over 2015 levels based on current technology, as well as increased noise pollution absent the development of new aircraft technology.

To help address these global aviation challenges, NASA's aeronautics programs conduct research on the growing demand for mobility; sustainability of the environment; and advances in information, communication, and automation technologies. With support from the aviation industry, the Agency is working on near-term solutions to some of these challenges through innovations in commercial supersonic aircraft.

Since 1973, the Federal Aviation Administration (FAA) has banned aircraft from flying within the United States at speeds faster than Mach 1, the speed of sound, outside of special use airspace such as military installations, due to the loud sonic boom the aircraft produces. To test new technologies, in March 2018 NASA contracted with the Lockheed Martin Corporation (Lockheed Martin) to develop a single experimental aircraft known as a Low-Boom Flight Demonstrator (LBFD) to validate technology that produces quieter supersonic flights.[2] The LBFD Project is the NASA Aeronautics Research Mission Directorate's (ARMD) first large-scale (over $250 million) development project.

Depiction of Low-Boom Flight Demonstrator

Source: NASA.

Our objective in this audit was to examine NASA's management of the LBFD Project and evaluate whether it was accomplishing its technical objectives while meeting established milestones and controlling costs. To meet this objective, we reviewed the Project's (1) acquisition and contract management, (2) project management and risk, (3) Joint Cost and Schedule Confidence Level (JCL),

[1] The International Air Transport Association is a trade association that represents the civilian airline industry.

[2] Use of LBFD in this report solely refers to the Low-Boom Flight *Demonstrator* Project, one of the projects that fall under the Low-Boom Flight *Demonstration* Mission.

(4) Earned Value Management (EVM), and (5) lessons learned from NASA and other federal agencies' acquisitions.[3] See Appendix A for details of the audit's scope and methodology.

Background

Aeronautics Research Mission Directorate

NASA's ARMD conducts research into and develops solutions to transform the way we fly by making aviation safer and more environmentally friendly. In fact, technology developed by NASA to improve efficiency and safety can be found in every U.S. commercial aircraft and air traffic control tower. For example, NASA research that led to the widely adopted use of upturned tips of aircraft wings, known as winglets, has saved commercial and business jet operators more than 10 billion gallons of jet fuel, resulting in a corresponding global reduction of over 105 million tons to carbon dioxide emissions since their introduction in 1992. Further, NASA's long-term aeronautics research has provided the government and private industry innovative aviation concepts that stress the use of industry-wide improvements in safety assurance, alternative fuels, and vehicle efficiency. To accomplish its goals, ARMD has identified three overarching drivers that will shape the needs of aeronautical research in the coming years and six specific strategic thrusts to address these challenges.[4]

Table 1: ARMD Strategic Thrusts

Strategic Thrust	Research Area
1	Safe, Efficient Growth in Global Operations
2	Innovation in Commercial Supersonic Aircraft
3	Ultra-Efficient Commercial Vehicles
4	Transition to Low-Carbon Propulsion
5	Real-Time System-Wide Safety Assurance
6	Assured Autonomy for Aviation Transformation

Source: NASA.

New Aviation Horizons Initiative

NASA launched its New Aviation Horizons Initiative in 2017 to address the challenge of safe, efficient, and scalable global aviation operations given the projected increase in passenger demand. Under this initiative, NASA intended to design, build, and fly a series of experimental aircraft—known as X-planes—over a period of 10 years to accelerate adoption by the aeronautics industry of advanced green aviation

[3] JCL is a statistical estimating tool that produces a cost and schedule baseline to predict the probability of a project being completed at a certain cost and on a certain schedule. EVM is a tool used to measure the actual costs of completing individual tasks compared to planned costs and schedule. JCL and EVM are further defined in the Background section of this report.

[4] These drivers include (1) global growth in demand for high-speed mobility; (2) global climate change, sustainability, and energy use; and (3) materials, manufacturing, energy, and information and communication technologies that will transform aeronautical capabilities. ARMD has formulated the six strategic thrusts to act as the link between its strategic vision and research plans, and represent ARMD's response to the drivers and constitute a vision for the future of aviation. ARMD's strategic planning addresses research needs associated with these strategic thrusts.

technologies. However, these anticipated X-planes were advanced concept configurations for potential future technology development and as of fiscal year (FY) 2020, Congress has provided NASA approximately $410 million to design, fabricate, and test only the first of these X-planes under the Low-Boom Flight Demonstration Mission.

NASA's Low-Boom Flight Demonstration Mission

The Concorde introduced commercial supersonic transportation in 1976 when it became the first airplane to fly paying passengers faster than the speed of sound.[5] The Concorde's maximum speed was more than twice the speed of sound and the aircraft could fly from London to New York in less than 3.5 hours, about half the amount of time it took typical airliners to fly the same distance. The Concorde consumed jet fuel at the rate of 1 ton per seat for a round-trip transatlantic flight that cost an average of $12,000. Given the high ticket costs, most flights flew half full. Eventually, British Airways and Air France eliminated routine flights from London and Paris to all locations except New York. Airline executives—recognizing the limits of the Concorde's future as a viable transportation vehicle—ended passenger service in May 2003.

Concorde

Source: Smithsonian National Air and Space Museum (NASM 2003-20225-8).

Supersonic air travel brought with it sonic booms—the loud, thunder-like noise heard by people on the ground when a supersonic aircraft flies overhead. Test flights in the United States and abroad predating the Concorde found sonic boom noise unacceptable to the general public. In 1973, after years of research and public debate, the FAA banned aircraft from flying overland (outside of special use airspace such as military areas) faster than Mach 1—the speed of sound—unless the aircraft was entering or leaving the United States and would not cause a sonic boom to reach the surface.[6]

NASA's Low-Boom Flight Demonstration Mission is intended to test and validate technology that reduces the loudness of sonic booms.[7] The overall goal is to develop a database of community responses to overland supersonic flights that incorporate new aircraft designs and technology. NASA plans to provide this data to the FAA and the International Civil Aviation Organization's (ICAO) Committee on Aviation Environmental Protection (CAEP) in support of their development of a new

[5] The Concorde was a joint venture between British and French aircraft manufacturers. The Soviet Union also operated a supersonic passenger airplane that flew 55 flights between 1977 and 1978. This Soviet aircraft was also used by NASA to conduct research flights in 1998 and 1999.

[6] This FAA regulation was finalized with minor changes on March 28, 1973, and is now codified at 14 CFR 91.817 and Appendix B to Part 91. Supersonic speeds, which vary based on air temperature and atmospheric conditions, are referred to by Mach numbers with any flight faster than Mach 1 deemed supersonic.

[7] NASA's Low-Boom Flight Demonstration Mission directly supports ARMD's Strategic Thrust 2—Innovation in Commercial Supersonic Aircraft.

noise-based standard for supersonic overland flight by 2025.[8] Renewed interest in civil supersonic flights represents a potentially large new market for aircraft manufacturers and airlines worldwide.[9]

Elements of NASA's supersonic technology research are organized within two of the Agency's aeronautics programs—the Advanced Air Vehicles Program and Integrated Aviation Systems Program (IASP). The LBFD tasks are managed under three separate aeronautics projects (see Figure 1) operating in parallel—LBFD Project, Flight Demonstrations and Capabilities Project, and Commercial Supersonic Technology Project. The Low-Boom Flight Demonstration Mission phases are:

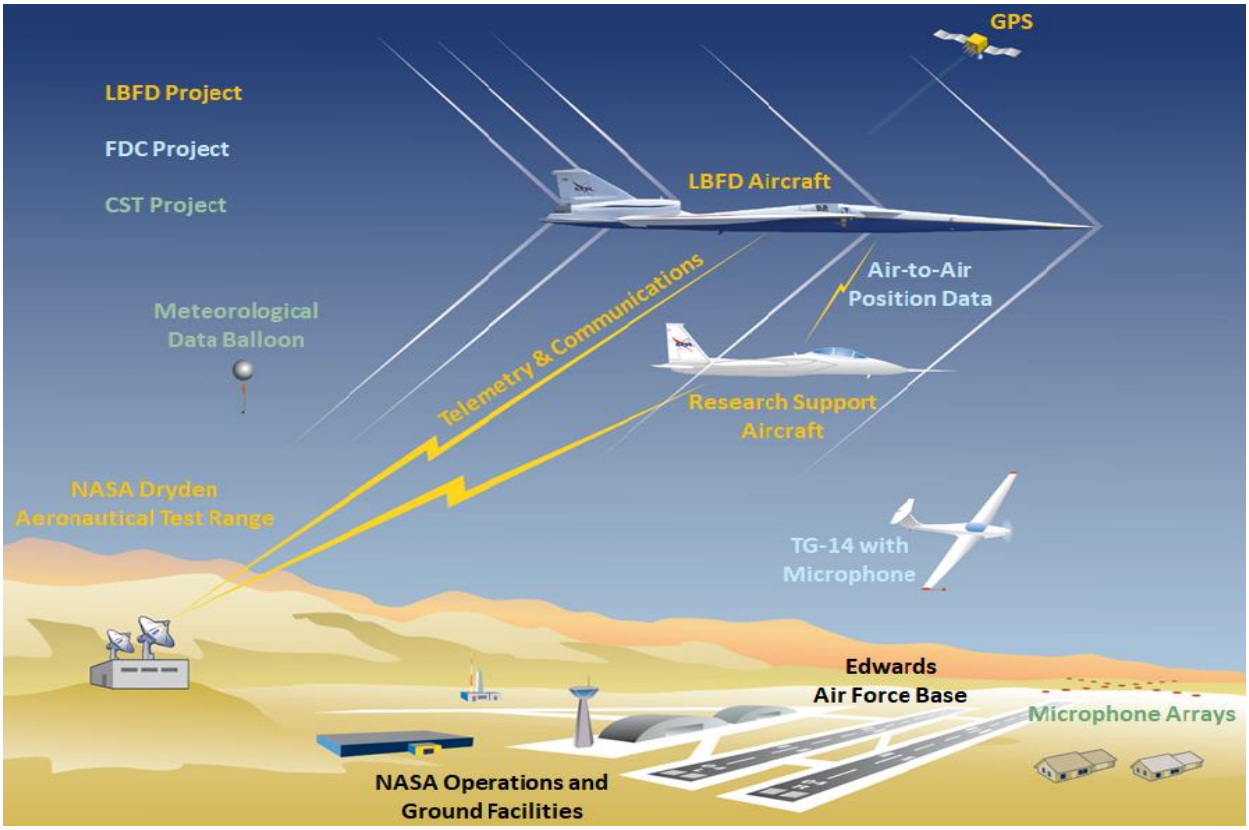
- *Aircraft Development—Phase 1* (approximately 30 to 50 flights) will cover development activities from aircraft design through fabrication concluding with functional checkouts, the initiation of test flights, and envelope expansion.[10]
- *Acoustic Validation—Phase 2* (approximately 60 flights) includes performance of low-boom acoustic validation flights of the LBFD aircraft built in Phase 1. The LBFD Project is responsible for flight operations and the Flight Demonstrations and Capabilities and Commercial Supersonic Technology Projects will gather research data for acoustic validation.
- *Community Response Testing—Phase 3* (approximately 300 flights) is the initial community response overflight study involving communities near NASA's Armstrong Flight Research Center (Armstrong) located at Edwards Air Force Base in southern California followed by multiple flights over varied locations to capture a representative spectrum of communities, geography, and meteorological conditions across the United States.

[8] The CAEP, of which the FAA is a member, is a technical committee of the ICAO Council established in 1983 that meets every 3 years. The CAEP assists the Council in formulating new policies and adopting new standards and recommended practices related to aircraft noise, emissions, and environmental impacts. NASA intends to present a database of community responses to LBFD flights at the 2025 meeting hoping that the CAEP will formally accept the Project generated data and revise its overland certification requirements to allow supersonic flights.

[9] China is working to launch supersonic passenger jets by 2035 that could potentially cut existing flight times in half.

[10] Envelope expansion is the first phase of flight testing when the aircraft is incrementally flight tested culminating in full flight envelope (speed, altitude, and maneuverability) clearance, validating the airworthiness of the aircraft.

Figure 1: Low-Boom Flight Demonstration Mission Responsibilities by Project



Source: NASA Office of Inspector General adaptation of an Agency illustration.

Note: FDC is Flight Demonstrations and Capabilities Project while CST is Commercial Supersonic Technology Project.

Acquisition History

Beginning in 2012, NASA's Commercial Supersonic Technology Project conducted a series of feasibility studies to develop an aircraft that would validate the design tools and technologies for a low sonic boom.

Following completion of these early concept studies, in February 2016 NASA partnered with Lockheed Martin under an existing basic and applied research contract for preliminary design of a single supersonic aircraft that would successfully demonstrate that low-boom technology could produce a quieter sonic boom.[11] Although NASA awarded a task order to Lockheed Martin for the aircraft's preliminary design, this approach was premised upon NASA conducting a full and open competition for subsequent detailed design and build phases.

[11] NASA issued a task order under Langley Research Center's Basic and Applied Research Technology contract for approximately $22 million.

Following the competition for the critical design, fabrication, and test phases, in which the Agency expected to receive offers from several companies, NASA awarded a cost-plus-incentive-fee contract in March 2018 to Lockheed Martin, the only bidder, valued at approximately $247 million.[12] The amount of incentive fee the contractor can earn will be based initially upon its effectiveness in meeting performance standards followed by an assessment of the contractor's actual costs compared to targeted costs. NASA anticipates evaluating incentive fee for the first time in the summer of 2020.

Low-Boom Flight Demonstrator Project

The LBFD Project is responsible for developing the aircraft and undertaking the low-boom acoustic validation flights (Phases 1 and 2 of the overall mission). Specifically, Lockheed Martin's Skunk Works facility in Palmdale, California, is designing and building a single-pilot, full-scale supersonic X-plane that will fly over select U.S. communities to gather data on human responses to the low-boom flights.[13] The plane, referred to as the Low-Boom Flight Demonstrator (or X-59 Quiet Supersonic Technology) experimental aircraft is designed with a wingspan similar to that of an F-16 aircraft, but takes advantage of a long, slender shape—twice as long as the F-16—as well as other modifications to its exterior surfaces and placement of internal structures to decrease the noise of a sonic boom.[14] NASA's objective for the aircraft is to create a sonic boom at ground level with a perceived loudness level of 75 decibels or less during supersonic cruising speed (greater than Mach 1.4)—akin to a soft clap or muted background noise.[15] In comparison, the calculated loudness level for the Concorde was a perceived decibel level of 105 at its supersonic cruising speed. Although LBFD is smaller in size than potential future supersonic passenger airliners, its shape should create a sonic boom ground signature that will be similar to that of larger aircraft using the same aircraft shape.

F-16 Aircraft

Source: NASA.

With a projected life-cycle cost of more than $580 million, this Project is the first major development acquisition for ARMD that meets a higher Agency threshold requiring increased oversight and reporting requirements.[16] Specifically, given the cost of the project, the ARMD Associate Administrator at Headquarters as opposed to a Center Director becomes the project's Decision Authority and is also

[12] A cost-plus-incentive-fee contract is a cost-reimbursement contract that provides for the initially negotiated fee to be adjusted later using a formula based on the relationship of total allowable costs to total target costs. This contract type specifies a target cost, a target fee, minimum and maximum fees, and a fee adjustment formula.

[13] Under the contract, the government receives unlimited data and retains all rights and patents developed for aircraft design elements such as shape, performance, system details, acoustic validation data, and community response data.

[14] Quiet Supersonic Technology or QueSST was the name of the LBFD aircraft in the preliminary design phase.

[15] Perceived decibel level is a rating of the noisiness of a sound calculated from acoustic measurements.

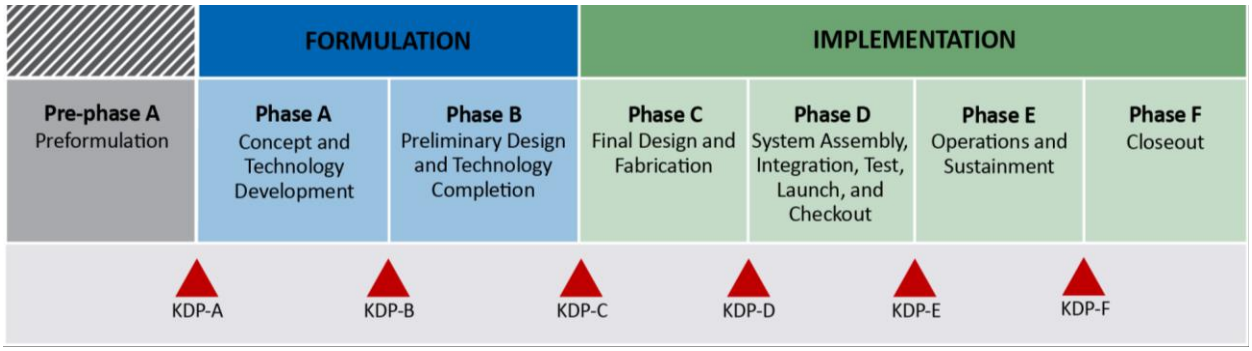
[16] As defined in NASA Procedural Requirements (NPR) 7120.5E, *NASA Space Flight Program and Project Management Requirements (Updated w/Change 18)* (August 14, 2012), projects are categorized based primarily on the life-cycle cost estimate of the effort. Projects with a life-cycle cost of over $1 billion are designated as Category 1 while those with a life-cycle cost between $250 million and $1 billion are designated as Category 2.

responsible for establishing the project's budget and overseeing performance. Additionally, given its total life-cycle cost, the Project is required under NASA Procedural Requirements to develop a Joint Cost and Schedule Confidence Level (JCL) estimate and use Earned Value Management (EVM) tools.[17]

Project Life-Cycle Cost, Schedule, and Status

NASA divides the life cycle of its flight projects into Phases A through F (see Figure 2). This structure allows managers to assess the progress of their projects at Key Decision Points (KDP) throughout the process, or points in time when the Decision Authority (approving official) makes a decision on the readiness of the project to progress to the next life-cycle phase.

Figure 2: Project Life Cycle



Source: NASA Procedural Requirements 7120.5E, *NASA Space Flight Program and Project Management Requirements (Updated w/Change 18)* (August 14, 2012).

During Phases A and B (Formulation), projects develop and define requirements, cost and schedule projections, acquisition strategy, project design, and complete development of mission-critical technology. Towards the end of Phase B, project personnel conduct a Preliminary Design Review (PDR) and present results to an independent Standing Review Board that (1) evaluates the completeness and consistency of the planning, technical, cost, and schedule baselines; (2) assesses compliance of the preliminary design with applicable requirements; and (3) determines if the project is sufficiently mature to begin Phase C (final design and fabrication).

To receive management approval to proceed to Phase C (the start of Implementation), a NASA project must pass through KDP-C, which includes a final assessment of the preliminary design and a determination that the project is sufficiently mature. As part of the KDP-C review process, cost and schedule baselines are established against which the project is measured. To establish these baselines, NASA policy requires that projects with an estimated life-cycle cost greater than $250 million develop a

[17] A JCL analysis is used to inform management of the likelihood of a project's programmatic success. The analysis is used to establish cost and schedule baselines and determine the probability that cost will be equal to or less than the targeted cost, and schedule will be equal to or less than the targeted schedule date. EVM is a tool for measuring and assessing project performance through the integration of technical scope with schedule and cost objectives during project development. EVM provides quantification of technical progress, enabling management to gain insight into project status and project completion costs and schedules.

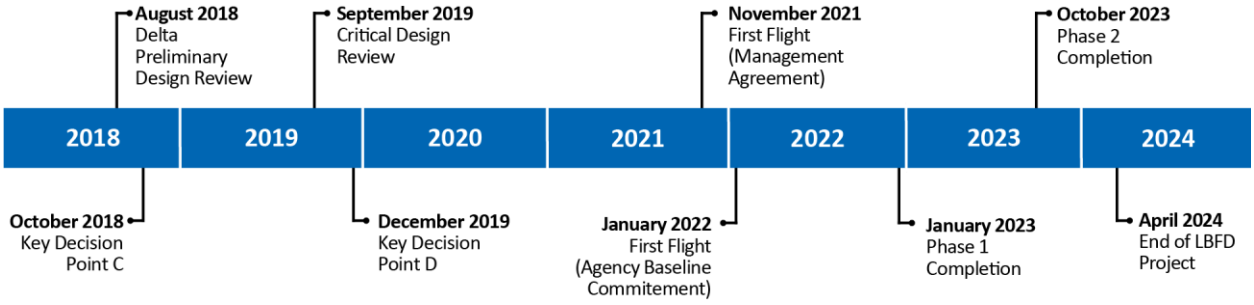
resource-loaded schedule and perform a risk-informed probabilistic analysis that produces a JCL.[18] This analysis measures the likelihood a project will complete all remaining work at or below the budgeted levels and on or before the planned completion of Phase D (all activities prior to the start of operations).

The Standing Review Board performs an independent assessment of a project's JCL analysis with the results of that review presented to the relevant Decision Authority who makes the final budget and schedule determination to establish the Management Agreement and Agency Baseline Commitment.[19] Once approval is received to move from KDP-C to the next phase, the project prepares its final design, fabricates test units that resemble the actual hardware, and tests those components during the first half of Phase C. A second design review known as the Critical Design Review (CDR) occurs later in Phase C. The purpose of the CDR is to demonstrate the design is sufficiently mature to proceed to Phase D, which entails full-scale fabrication, assembly, integration, and testing, and that the technical effort is on track to meet performance requirements within identified cost and schedule constraints. Phase E consists of operations and sustainment, while Phase F is project closeout.

The LBFD Project successfully completed KDP-C in late October 2018 and began implementation on November 9, 2018. The Project received an Agency Baseline Commitment life-cycle cost estimate of $583 million with an expected completion date of October 2023 for all planned activities through Phase 2. In December 2019, the Project completed the CDR and was recommended to proceed into Phase D. LBFD Project managers are planning the first flight of the LBFD aircraft for November 2021. The Agency Baseline Commitment for the first flight is January 2022.

Prior to transferring the aircraft from Lockheed Martin's Palmdale facility to Armstrong, NASA will hold a review to ensure all logistics are in place and ready to support operations. Also upon completion of Phase 2, the Project will hold an Aircraft Transfer Review to ensure NASA's Flight Demonstrations and Capabilities Project is ready to assume responsibility for aircraft operations. See Figure 3 for Low-Boom Flight Demonstration Mission milestones.

Figure 3: Low-Boom Flight Demonstration Mission Milestones



Source: NASA LBFD Project data.

Note: The LBFD Project completed life-cycle Phases A and B between March 2014 and October 2018. The planned November 2021 first flight date refers to the Agency's internal Management Agreement, while NASA's Agency Baseline Commitment to Congress and the Office of Management and Budget for the first flight is January 2022.

[18] A resource-loaded schedule is the process of recording resource requirements—time and cost—for a scheduled task or group of tasks.

[19] The Management Agreement is between the Agency and project manager and provides the parameters and authorities over which the project manager is accountable. The Agency Baseline Commitment contains the cost and schedule parameters NASA submits to Congress and the Office of Management and Budget.

The Project is operating as a System Project Office across multiple NASA Centers rather than designating a single Center as the lead.[20] Project members span both aeronautics programs (Advanced Air Vehicles Program and IASP) and all four of NASA's aeronautical research field Centers: Langley Research Center (Langley) in Virginia; Glenn Research Center (Glenn) in Ohio; and Ames Research Center (Ames) and Armstrong, both in California.

Earned Value Management

EVM is a project management tool for measuring and assessing a project's performance and progress. Using this tool, the value of a task is determined based on how much project personnel initially estimate the task will cost to complete, with the project then "earning" that value when it completes the task. In other words, earned value is the estimated cost of the actual work completed. EVM quantifies the project's technical progress, enabling management to gain insight into project status, completion costs, and schedules using a Cost Performance Index and Schedule Performance Index.

The Cost Performance Index is the measure of cost efficiency and compares the budgeted cost or work performed to the actual cost to perform that work. The Schedule Performance Index is the measure of schedule efficiency and compares the budgeted cost or work performed to the work scheduled. For both indexes, if the project is over budget or behind schedule the respective index would be less than one, on budget or schedule the index would be equal to one, and under budget or ahead of schedule the index would be greater than one.

NASA requires contractors to have an Earned Value Management System (EVMS) that complies with the guidelines of the Electronic Industries Alliance 748, *Earned Value Management Systems*, on cost or fixed-price incentive-fee contracts valued at $100 million or more.[21] Additionally, NASA requires the use of an EVMS on all development contracts.

[20] The System Project Office has also been referred to as a Virtual Project Office.

[21] The Electronic Industries Alliance 748, *Earned Value Management Systems*, is the standard for Department of Defense EVM programs, and was adopted in August 1998 for application to major defense acquisition programs.

EARLY MANAGEMENT DECISIONS ESTABLISHED GOOD FOUNDATION FOR LBFD PROJECT DEVELOPMENT

The Low-Boom Flight Demonstrator (LBFD) Project is ARMD's first time managing a large-scale development project—estimated to have a life-cycle cost of $583 million. We found that LBFD management has instituted a sound acquisition strategy, provided more-than-expected amounts of government furnished equipment (GFE) to save costs, implemented an innovative project management structure and approach, and appropriately conducted the JCL analysis on this first-of-its-kind ARMD project.

Acquisition Strategy

According to the Federal Acquisition Regulation (FAR), effective acquisition planning is essential for ensuring government projects are undertaken in the most effective, economical, and timely manner.[22] Agencies should perform acquisition planning as early as possible to identify project needs, develop specifications, and solicit offers to provide for full and open competition.

In March 2013 and June 2014, NASA competed and awarded task orders under existing Langley contracts to The Boeing Company and Lockheed Martin for initial concept formulation studies and to mature and refine proposed low-boom concepts.[23] These early studies demonstrated that a change to the aircraft shape could significantly reduce the sonic boom. However, according to the Contracting Officer, ARMD was limited in both budget and time in moving the project forward to provide the database of community responses to LBFD flights at the 2025 ICAO meeting. ARMD typically awards small-dollar contracts—$5 million or less—for research and study concepts advancing state-of-the-art technologies to address aeronautical challenges.

To receive the approval of senior management and the financial resources necessary to contract for the design, fabrication, and testing of an approximately $250 million experimental aircraft, ARMD allocated $63 million ($23.5 million in FY 2017 and $39.5 million in FY 2018) to obtain a preliminary design for the LBFD aircraft. In addition to this being ARMD's first large-scale major development project, LBFD Project personnel were under a tight schedule to conduct a PDR (the evaluation of the project's baselines, preliminary design, and maturity to begin Implementation) in order to ensure LBFD life-cycle milestones would be in sync with the ICAO's 2025 meeting.

[22] FAR Part 7, *Acquisition Planning* (2020).

[23] NASA initially awarded tasks under the existing Structures, Materials, Aerodynamics, Aerothermodynamics, and Acoustics Research and Technology contract, and later under the Basic and Applied Research Technology contract.

In February 2016, NASA issued a $22 million task order under an existing Langley contract to Lockheed Martin for the preliminary design of the LBFD aircraft.[24] This acquisition approach, approved by NASA Headquarters, was predicated upon the Agency conducting a full and open competition for the critical design, fabrication, and test phases.[25] Once Lockheed Martin completed its preliminary design for the LBFD aircraft, NASA conducted a full and open competition for the Project's subsequent phases. While allowed under the FAR, most projects do not typically perform a full and open competition following the selection of a contractor for the preliminary design phase. As a result of taking this approach, the LBFD Project had to take additional steps to ensure a fair and open competition. For example, to minimize the risks of releasing the preliminary data, the Project employed a unique strategy of conducting responsibility determinations on all interested offerors prior to the release of the request for proposal.[26] NASA then shared Lockheed Martin's preliminary design data with only potential qualified bidders.

Although these efforts were taken to ensure all interested bidders had a fair opportunity to compete, NASA understood that companies may not want to submit a proposal since Lockheed Martin developed the LBFD aircraft's preliminary design. To mitigate this concern, the Agency specified in the solicitation that proposers could either use the Lockheed Martin preliminary design or propose their own design to meet specified performance standards. This enabled NASA to evaluate designs from multiple companies and not just Lockheed Martin to ensure interested bidders were not excluded from competing for the larger follow-on contract.

Even with these additional procurement steps, LBFD Project personnel completed all procurement tasks in a timely manner. To its credit, ARMD selected a Project Manager who had experience both at NASA and the Department of Defense managing large-scale acquisition efforts and a Deputy Project Manager and Contracting Officer who also had experience with acquisitions over $250 million.

Government Furnished Equipment, Parts, and Systems

As a cost savings measure, NASA included GFE, parts, and various subsystems available for use by the contractor during contract performance.[27] Under the contract, NASA planned to provide the engine, ejection seat, canopy system, life support system, flight test instrumentation system, and power distribution system. The Agency also agreed to provide additional aircraft parts such as valves, actuators, and switches as GFE to reduce procurement costs and lead times. After contract award,

[24] The FAR requires agencies to award contracts through full and open competition and allows for exceptions to this requirement under certain conditions. Contracts awarded using other than full and open competition must be supported by written justification and approved by the Assistant Administrator for Procurement, Deputy Assistant Administrator for Procurement, or the Center's Deputy Director depending on the estimated value of the contract.

[25] The Agency conducts a Procurement Strategy Meeting or completes a written acquisition plan for awards of $10 million and above. During this meeting, representatives from both Headquarters and the appropriate Center program and procurement offices agree upon the final acquisition strategy.

[26] Responsibility determinations are typically performed by an agency on the successful offeror following the competition but prior to award to determine their eligibility to receive a government contract. For prospective contractors to be deemed responsible they must satisfy seven criteria, including having adequate financial resources to perform the contract, or the ability to obtain them; and the ability to comply with the required delivery or performance schedule.

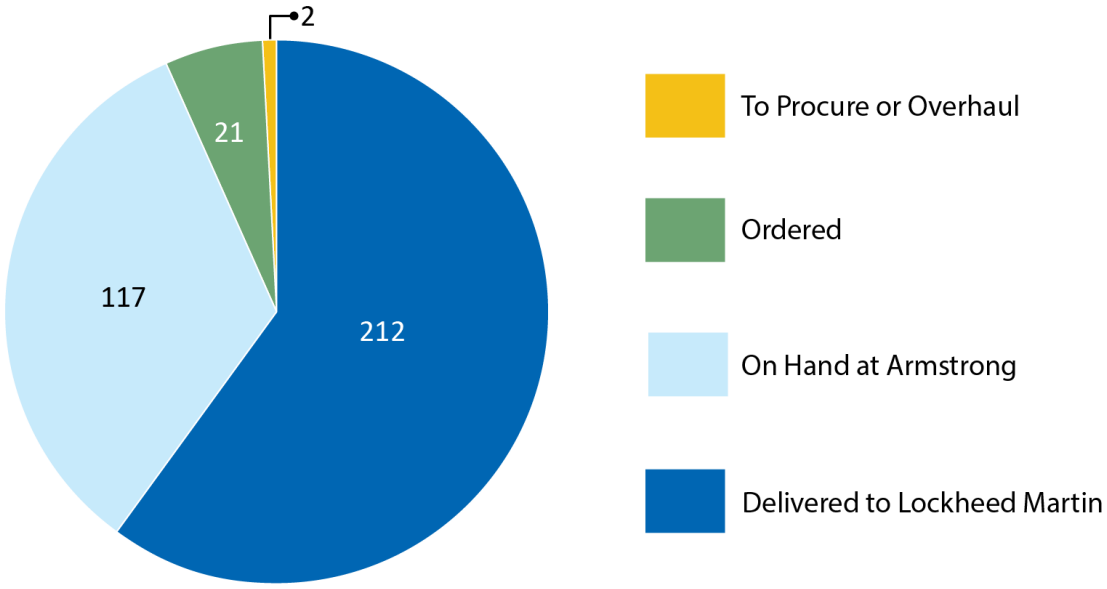
[27] GFE is a tangible item or property in the possession of, or directly acquired by, the government and subsequently furnished to the contractor for performance of a contract.

NASA and Lockheed Martin further refined the list of GFE, officially baselining the list at the delta-PDR.[28] This baseline included Lockheed Martin's requested aircraft parts, which at that time totaled 479 items including spares.

Following that review, however, the number of items NASA agreed to provide increased approximately 37 percent as Lockheed Martin experienced difficulties obtaining items they had originally planned to procure and the need for additional parts developed as the Project defined the aircraft's design in greater detail. For example, although several manufacturers and suppliers had committed to providing Lockheed Martin with parts or subsystems prior to its contract award in 2018, when Lockheed Martin pursued the procurements post-award many suppliers did not want to commit or they increased the cost of materials above what they originally agreed upon. LBFD managers explained that NASA's long-standing relationships with these manufacturers allowed the Agency to obtain the parts more easily than Lockheed Martin. As of February 2020, the number of GFE totaled 658 items, 352 of which are parts needed for the aircraft manufacture with the remainder spares.

As of February 2020, 329 (93 percent) of the required manufacture parts were on hand at Armstrong or had been delivered to Lockheed Martin, and the last of the remaining 23 items, planned to be delivered in May 2020, are not expected to impact the Project's schedule. See Figure 4 for the status of 352 items of GFE.

Figure 4: Status of Demonstrator GFE Aircraft Parts (Without Spares)



Source: NASA LBFD Project data.

The Contracting Officer is finalizing the list of GFE and developing a negotiation position to seek consideration—that is, a reduction in the total estimated cost of the contract—from Lockheed Martin for the 179 additional items that initially were not included in the baselined agreement. A modification to the contract reflecting consideration for the supplemental GFE was expected in late March 2020.

[28] A delta-PDR focuses on design updates since the PDR was conducted during the technology development phase.

Project Management Structure and Approach

System Project Office

When NASA initiates projects the responsible Mission Directorate typically assigns them to a NASA Center or selects a lead Center through a competitive process such as an Announcement of Opportunity.[29] Under such a scenario, Center Directors are responsible for all programs and projects at their Centers and must ensure they are properly planned and executed in accordance with Agency policy and Center best practices. Each Center has established processes and forums, including Center Management Councils that perform periodic reviews to assess a project's technical and programmatic progress.

Rather than designate a single Center as the lead for LBFD development, the IASP is utilizing a System Project Office approach under which LBFD's System Project Office reports directly to ARMD's IASP Director and coordinates with the Agency's four aeronautics Centers (Ames, Armstrong, Glenn, and Langley). The Associate Administrator for ARMD serves as the Decision Authority for the Project and is supported by the Directorate Program Management Council. Instead of reporting the status and progress to a Center Management Council, the Project reports its progress to an Integrated Center Management Council comprised of senior management from the four Centers. The LBFD's tailored management structure includes a Project Manager at Langley, Deputy Project Manager at Armstrong, and other personnel to include Associate Project Managers at each of the four Centers. The Associate Project Managers are responsible for ensuring that Center activities have appropriate support to meet budget and schedule commitments and for supporting implementation plans that involve their respective Centers.

During our review, we interviewed IASP and LBFD Project management and found the System Project Office approach appeared to be working well for LBFD and identified no management issues due to this unusual governance structure. Project management attributed much of their success with this approach to the quality of communication and level or expertise of personnel assigned to the Project. ARMD has developed an IASP Program Plan and X-plane Governance Charter that specify top level project schedule, resource, and change management requirements to guide development of the LBFD and subsequent large X-plane projects. IASP and LBFD Project management said this governance model leverages best practices across the Agency. For example, the Project has incorporated both Langley and Armstrong guidance related to aircraft flight hardware development and lessons learned, tailoring the process for LBFD Project-specific applications. In addition, the System Project Office has the advantage of reporting directly to the Mission Directorate for decision-making, which according to the LBFD Project team saves time and proves more efficient than reporting through a Center Director.

[29] An Announcement of Opportunity is a form of a broad Agency announcement of public or private competition. NASA solicits, accepts, and evaluates proposals submitted by all categories of proposers in response to an Announcement of Opportunity, including academia, industry, not-for-profits, government laboratories, federally funded research and development centers, NASA Centers, and the Jet Propulsion Laboratory.

Tailored Project Management Requirements to Meet LBFD Project Needs

Because there was no existing project development policy specifically designed for non-space flight projects, management tailored NASA's existing space flight project management requirements to support their needs. The Project was developed following guidance from the July 2017 Agency Program Management Council that the LBFD Project should use "...a tailored approach to NPR [NASA Procedural Requirements] 7120 project guidance to ensure applicability of appropriate programmatic rigor in consideration of the unique nature of X-plane flight demonstrator projects."

The requirements detailed in the NPR recognize that each program or project has unique aspects that must be accommodated to achieve mission success. When an alternate approach provides for better implementation, the program or project manager should tailor the requirement as noted in the Compliance Matrix.[30] Tailoring is the process used to adjust or seek relief from a prescribed requirement to meet the needs of a project. The Compliance Matrix documents the project's compliance with NPR requirements or how the program or project tailored them. Tailoring is both an expected and accepted part of establishing project requirements.

Of the 108 requirements statements listed in the Compliance Matrix, the LBFD Project tailored or found not applicable 36 (33 percent). Analysis conducted by IASP senior management concluded that 20 of the 36 requirements (56 percent) were due, all or in part, to the nature of major aeronautics development projects. For example, LBFD will not establish Human Rating Certification Packages because it is not a human space flight mission, but instead the LBFD aircraft will be certified for manned flight by following the Armstrong Airworthiness and Flight Safety Review process. As another example, the Project does not need to develop a Planetary Protection Plan or Nuclear Safety Launch Approval Plan because the LBFD aircraft will neither operate in a space environment nor is it a launch vehicle that contains nuclear materials.

During interviews, the ARMD Chief Engineer indicated that the tailoring of requirements on the LBFD Project was related to aeronautical projects in general and were not specific to LBFD. In our opinion, LBFD has established a methodology and governance model that may be useful for developing future X-planes.

Implementation of JCL

As a project with a total projected life-cycle cost of $583 million (the agreed upon Agency Baseline Commitment), the LBFD Project was required to develop a JCL at KDP-C. The development of the Project's JCL was the first time ARMD was required to conduct this type of analysis, and because cost growth data for flight demonstrator programs were not available, the Project had to rely on historical data from aircraft development projects external to NASA, specifically an Air Force Institute of

[30] The compliance matrix can be found in NPR 7120.5E, Appendix C.

Technology study.[31] In developing its JCL, the Project used a 21 percent factor to account for cost growth typically experienced on new military aircraft acquisitions. Project management stated this anchored their JCL model and accounts for universal aircraft development risks.

In addition to utilizing JCL tools and models, Project management examined and compared its approach with other large-scale Science Mission Directorate projects such as the Transiting Exoplanet Survey Satellite, Landsat 9, Lucy, Joint Polar Satellite System-2, and Restore-L and concluded that its JCL methodology was sound.[32] Cost uncertainties for NASA and Lockheed Martin were also evaluated and increases in cost estimates were made for known risk areas highlighted during the Integrated Baseline Review and other internal reviews.[33] For example, risk areas included the potential for the sonic boom level being unacceptable and that structural damage to the test equipment could occur during ground testing.

The Project's JCL analysis determined the Agency Baseline Commitment of a $583 million budget and a 5-year development schedule—containing $134 million of cost reserve (23 percent) and 13 months of schedule reserve (22 percent)—had a greater than 70 percent chance of success. In the KDP-C Decision Memorandum, the ARMD Program Management Council stated that the Project is sufficiently mature to begin Phase C, and the cost and schedule are adequate to enable mission success with acceptable risk. Overall, the Project's approach to conducting the JCL analysis appears sound and could serve as a template for future ARMD projects.

[31] Air Force Institute of Technology, *Predicting Cost Growth Using Programs Reviews and Milestones for Department of Defense Aircraft* (March 24, 2016).

[32] Launched in April 2018, the Transiting Exoplanet Survey Satellite is searching for planets outside of our solar system, including those that could support life, by surveying 200,000 of the brightest stars near the Sun for transiting exoplanets. Landsat 9 will continue the Landsat series' observation of the Earth's global land surface that shows both natural and human-induced change. NASA plans to launch the Lucy spacecraft in October 2021 as the first space mission to study Jupiter's Trojan asteroids. The Joint Polar Satellite System-2, which NASA plans to launch in 2022, is the second of the National Oceanic and Atmospheric Administration's latest generation U.S. polar-orbiting environmental satellites for which NASA serves as the program's procurement agent. Restore-L, scheduled to launch in 2023, is a robotic spacecraft equipped to service on-orbit satellites in order to extend their lifespans.

[33] An Integrated Baseline Review is a risk-based review conducted by project management to ensure a mutual understanding between the customer and supplier of the risks inherent in the supplier's Performance Measurement Baseline and that the Performance Measurement Baseline is realistic for accomplishing all of the authorized work within the authorized schedule and budget. The Performance Measurement Baseline is defined as the time-phased cost plan for accomplishing all authorized work scope in a project's life cycle, which includes both NASA internal costs and supplier costs.

CONTROLLING, REPORTING, AND MONITORING PROJECT COST AND SCHEDULE PROVES CHALLENGING

Although the LBFD Project has implemented a sound project management structure, challenges related to the 2018 to 2019 government furlough, reassignment of a test location, hiring and assigning qualified contractor technical personnel, and late delivery of parts contributed to cost growth and schedule delays. In addition, difficulties implementing earned value management (EVM) have affected both Lockheed Martin and LBFD, requiring additional time and effort to review and validate Project performance data.

Cost and Schedule Concerns

Baseline Cost and Schedule

NASA requirements state that at KDP-C the Mission Directorate establishes, via a Decision Memorandum, a baseline cost and schedule commitment for the project.[34] In October 2018, the ARMD Program Management Council evaluated the readiness of the LBFD Project to proceed to Phase C in its life cycle using a tailored approach to the requirements outlined in NPR 7120.5. Based on the Council's evaluation, ARMD granted approval for the Project to enter Phase C (the start of Implementation).

Management established and approved two JCL-based cost and schedule estimates, the Management Agreement and Agency Baseline Commitment. The Management Agreement cost and schedule estimates are viewed as a contract between the Agency and the project manager. The Agency Baseline Commitment establishes an integrated set of project requirements, cost, schedule, technical content, and an agreed-to JCL that forms the basis for NASA's cost and schedule commitment to Congress and the Office of Management and Budget. Specifically, the Management Agreement is required to have a greater than 50 percent confidence level, and the Agency Baseline Commitment is required to have a greater than 70 percent confidence level. In short, those confidence levels mean the project must have a greater than 50 percent likelihood (for the Management Agreement) and greater than 70 percent likelihood (for the Agency Baseline Commitment) that it will meet its cost estimate and planned schedule. At KDP-C, LBFD's baseline budget met the 70 percent JCL requirement for schedule and exceeded the 70 percent JCL requirement for cost.

[34] NPR 7120.5E.

Table 2: KDP-C Cost and Schedule Baseline Commitments

	Management Agreement	Agency Baseline Commitment
Project Life-Cycle Cost	$571 million	$583 million
Phase 2 Complete (Aircraft Transfer Review to Flight Demonstrations and Capabilities Project)	August 2023	October 2023
Joint Cost and Schedule Confidence Level	Greater than 50%	Greater than 70%

Source: NASA.

NASA's approved cost and schedule baselines provided the LBFD Project with a total of $134 million of cost reserve—$122 million managed at the Project-level and the remaining $12 million held in reserve by NASA Headquarters—and a total of 13 months of schedule reserve to meet the Agency's commitment to complete Phase 2, Acoustic Validation, and transfer the aircraft to the Flight Demonstrations and Capabilities Project by October 2023.

Project Review Team Believes LBFD Project May Exceed Cost and Schedule Baselines

In September 2019, less than 1 year after KDP-C, the LBFD Project conducted its Critical Design Review (CDR), which determines whether the design can proceed to full-scale fabrication, assembly, integration, and testing. The Project Review Team (Team) assessed the Project's progress in accordance with relevant CDR-related criteria.[35] In December 2019, the Team reported favorably on the Project's progress, noting that it exceeded expectations for this stage in the life cycle and that the completed analysis work was high quality and provided a sound basis for ensuring the design satisfied airworthiness and mission requirements. They also found that the technical design of the aircraft was sound and, in most cases, matured to or beyond what was expected at CDR. The Team unanimously recommended the LBFD Project be approved to continue into Phase D, noting that the maturity of the design was appropriate to support proceeding with full-scale fabrication, assembly, integration, and testing, and the technical effort was on track to complete the flight and ground system development and mission operations to meet mission performance standards. The Project formally entered Phase D in December 2019.

However, in spite of the sound project management structure in place, the Team also identified concerns that represent issues the Project should address but do not at this time present excessive risk to the Project. Specifically, the Team cited technical concerns with the Flight Test Instrumentation System, Environmental Control System, engine, and main landing gear.[36] They believed these items, along with other less technical issues identified during the review, coupled with the Project's cost and schedule performance to date, made completing the Project within current cost and schedule estimates unlikely. Further, the Team's subject matter experts assigned greater probabilities and cost and

[35] The Project Review Team is a multi-Center team of independent subject matter experts that facilitates review of Project progress through the LBFD life-cycle review process to inform the KDPs. Relevant criteria for the CDR can be found in NPR 7120.5E.

[36] The Flight Test Instrumentation System monitors and records equipment fitted to an aircraft during a flight test and is mainly used on experimental aircraft to monitor temperature of specific components and the speed of engines.

schedule impacts to multiple project-identified risks as well as incorporated seven new risks and stated, "the single most serious threat to the Project's likelihood of success is exceeding the cost and schedule constraints articulated in the Management Agreement and Agency Baseline Commitment."

In terms of cost, the Team estimated that for Phase 2 completion the Project will require the allocation of additional reserve as the Project will exceed the Management Agreement cost by $1.5 million (0.3 percent) and Agency Baseline Commitment cost by approximately $7 million (1.4 percent). As for schedule, the Team estimated the Agency Baseline Commitment for Phase 2 completion should be March 2024 (5 months later than LBFD Project's estimated date of October 2023). Although LBFD Project management did not fully agree with the Team's assessment that the Project has a significant potential of exceeding the Agency Baseline Commitment, they acknowledged that the 70 percent confidence level would now be approximately 58 percent.

As of February 2020, the Project had depleted 2 months of its 13 month schedule reserve. According to LBFD Project management, the government shutdown (late December 2018 through late January 2019) consumed 5 weeks of schedule reserve and impacted the schedule for the CDR, KDP-D, and Flight Readiness Review.[37] The associated cost impact of this delay was $5.4 million, which LBFD Project management indicated has increased the risk and eroded the Project's confidence in meeting KDP-C commitments. Further, NASA reassigned the Ground Loads Test location from Palmdale, California, to Fort Worth, Texas, to ensure proper insight and oversight, which consumed an additional 3 weeks of schedule reserve. Lastly, in March 2020 in response to the Coronavirus Disease 2019 (COVID-19) pandemic, the Agency moved to mandatory telework and restricted travel. While Lockheed Martin continues work on LBFD, NASA's oversight and inspections will be almost exclusively conducted virtually. The long-term impacts of the pandemic on the Project's cost and schedule are unknown at this time.

Lockheed Martin Underperforming

The initial total contract value to design, build, and test the LBFD aircraft was $247 million. As of February 2020, Lockheed Martin's estimate at completion was $284 million, a 15 percent cost increase that does not fully account for all potential future risks. The contractor was also approximately 2 months late when compared to its planned work schedule and continues to experience manufacturing issues such as supplier delivery delays and poor parts quality. The contractor revised its schedule estimate for first flight from April 2021 to August 2021.

Our analysis showed that contract cost increases and schedule delays have resulted primarily from Lockheed Martin's inability to accurately define and execute near-term LBFD schedule plans. Specifically, these delays have been caused by challenges with hiring qualified technical personnel—an aerospace industry-wide issue—and late delivery of parts from subcontractors. For example, the Flight Test Instrumentation System delivery and engineering drawing release schedules have fallen behind due to a shortage of needed stress analysts and difficulty getting subcontractors under contract resulting in late parts deliveries.[38] The shortage of these key engineering personnel has led to late design

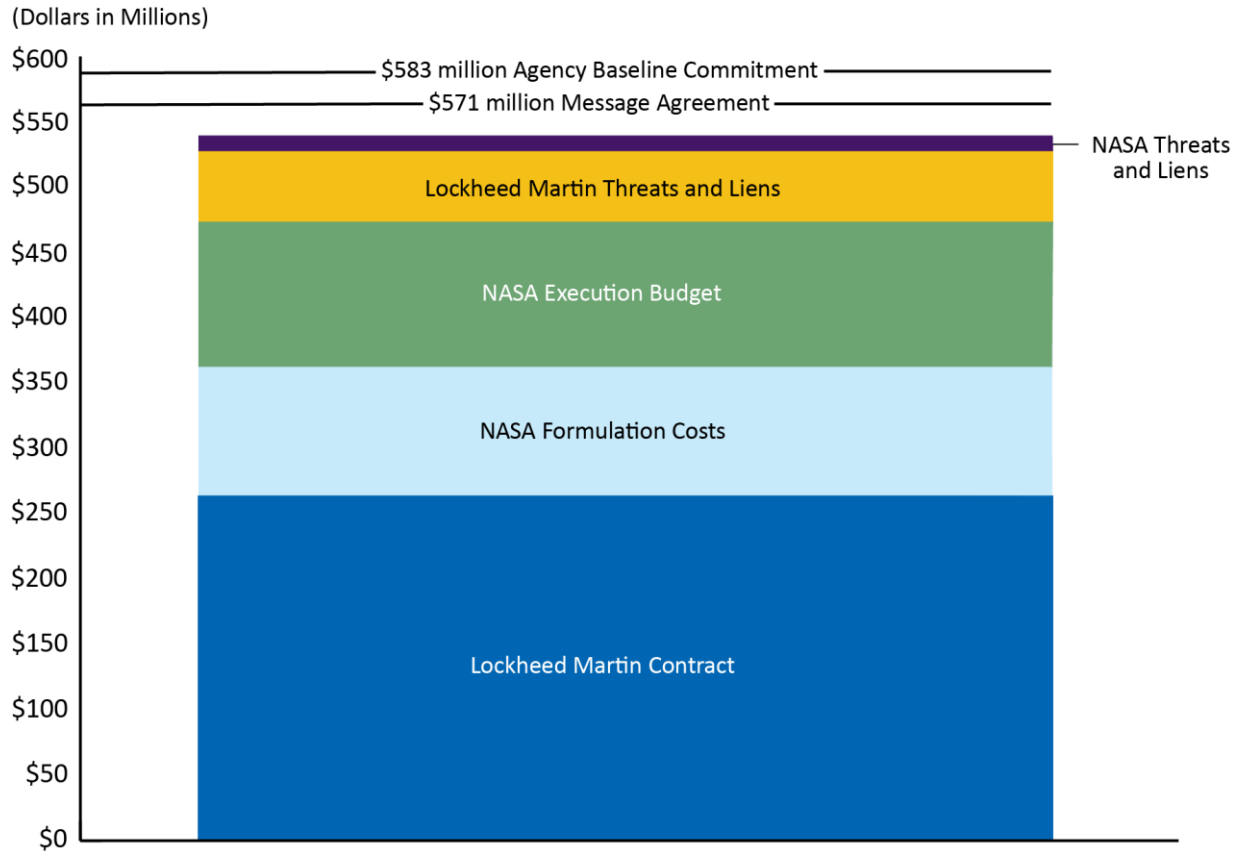
[37] The Flight Readiness Review occurs in Phase D and examines tests, demonstrations, analyses, and audits that determine the system's readiness for a safe and successful flight or launch and for subsequent flight operations. It also ensures that all flight and ground hardware, software, personnel, and procedures are operationally ready.

[38] Stress analysis is an engineering discipline that uses multiple methods to determine the stresses and strains in materials and structures subjected to forces. Engineering drawings graphically convey the information required for construction and include details such as dimensions, how a component functions, how it is to be built, the materials to be used, and the processes required to fabricate and test it.

completion and a longer procurement process. Consequently, as of February 2020 Lockheed Martin was approximately 2 months behind its planned schedule and a comprehensive estimate-at-completion analysis determined the contract would cost $284 million, about $37 million more than the initial contract value.

Although Lockheed Martin was approximately 2 months behind its planned schedule, the LBFD Project had approximately 7 months of schedule reserve between the contractor target completion date (April 2021) and Management Agreement date (November 2021) for first flight, as well as the additional 2 months of schedule reserve held by NASA (delta of Management Agreement and Agency Baseline Commitment to Congress and the Office of Management and Budget). As for cost, in January 2020 LBFD Project management assessed the likelihood of completing the Project within the established baseline budgets considering all current risks—threats and liens—and on-going performance factors.[39] According to their evaluation, the life-cycle cost would total $539 million, $32 million less than the KDP-C Management Agreement of $571 million and $44 million less than the Agency Baseline Commitment (see Figure 5).

Figure 5: Budget Comparison to Agreements



Source: NASA Office of Inspector General presentation of Agency information.

[39] Threats are all risks with an unlikely to high (5 to 75 percent) likelihood of occurring that have potential cost impacts. Liens are all risks with a very high (greater than 75 percent) likelihood that have potential cost impacts and are usually realized, at least in part. Liens are calculated and budgeted at 100 percent of the estimated cost impact.

Lockheed Martin is undertaking a "Return to Green" effort to get back on schedule that includes adding manufacturing work shifts, and company officials are optimistic the Project will recover some of the lost schedule time. However, LBFD Project management stated that while these efforts are showing some progress, the schedule recovery plan is not having the full impact expected. Consequently, LBFD management has increased its engagement with Lockheed Martin leadership to ensure that LBFD remains a high priority and to more clearly understand the root causes of development issues as well as the contractor's recovery strategies.

Further Delays Could Threaten Mission Goals

While there have been no changes to LBFD's key milestone dates that fall after the Agency Baseline Commitment first flight date of January 2022, the Project and CDR Project Review Team have documented multiple technical and schedule risks during development that threaten future cost and schedule performance and meeting the Mission timeline. The ICAO's CAEP 2025 meeting dates are fixed, and therefore so is NASA's goal to complete the collection and analysis of community response data. For the Low-Boom Flight Demonstration Mission to succeed, NASA needs to provide to CAEP in 2025 a database of community responses to supersonic overland flights. If Phase 2 completion (Aircraft Transfer Review to the Flight Demonstrations and Capabilities Project) were delayed beyond the Agency Baseline Commitment of October 2023, the Low-Boom Flight Demonstration Mission has developed a preliminary mitigation plan that includes 10 months of schedule reserve during Phase 3 to help ensure timely delivery of the database to CAEP. In October 2019, ARMD began more focused planning for the Community Response Testing effort (Phase 3) scheduled for 2024.

Earned Value Management Concerns

External Earned Value Management System Issues Cost NASA Time and Money

The LBFD Project has encountered issues with EVM since its inception. As previously noted, EVM is a project management tool for measuring and assessing a project's performance and progress where earned value is the estimated cost of the actual work completed. NASA's request for proposal included clauses from the NASA FAR Supplement requiring the use of an EVMS in performance of the contract. These clauses require the contractor to provide documentation that their proposed EVMS complies with EVM guidelines and standards or if their system does not meet the guidelines and standards, submit a comprehensive plan for government approval on how they plan to achieve compliance.[40] The NASA FAR Supplement also specifies that contracting officers shall request the assistance of the Defense Contract Management Agency (DCMA) and the applicable NASA Center EVM Focal Point in determining the adequacy of proposed EVMS plans and procedures and system compliance.[41]

[40] NASA FAR Supplement Part 1852.234-1, *Notice of Earned Value Management System* (April 2015) and Part 1852.234-2, *Earned Value Management System* (April 2015).

[41] NASA FAR Supplement Part 1834.201, *Earned Value Management System, Policy* (September 2015). NASA established the EVM Working Group, comprised of personnel known as EVM Focal Points from each Center and Mission Directorate and chaired by the NASA Chief Engineer, to ensure there is Agency-wide representation in EVM implementation. The Group helps develop an integrated, consistent approach for implementing EVM throughout NASA and serves as an open forum for Center officials to share their experiences and develop a network of support within the NASA EVM community.

Additionally, NASA has a Memorandum of Understanding with DCMA for EVMS acceptance and surveillance and EVM project surveillance. DCMA is normally delegated the responsibility for reviewing contractor EVMS plans and verifying initial compliance with NASA and Department of Defense EVMS criteria and conformity with Electronic Industries Alliance 748, *Industry Guidelines for Earned Value Management Systems*. Under the agreement, DCMA is expected to provide NASA with evidence supporting its acceptance of the contractor's EVMS. Where a contractor does not have prior government acceptance of its EVMS, DCMA will assist the NASA procuring Contracting Officer or Source Selection Board in determining the adequacy of the proposed EVMS plan. The purpose of evaluating the EVMS plan is to gain an understanding of the contractor's proposed internal EVMS and, more specifically, its intended application on a particular NASA contract.

EVMS Certification

Lockheed Martin Palmdale included an EVMS certification letter dated November 2013 in its proposal to NASA; however, Agency representatives questioned the validity of the certification since the letter specifically referenced Lockheed Martin Aeronautics in Fort Worth, Texas. NASA Source Evaluation Board representatives did not request assistance from the cognizant DCMA office to verify the certification as delineated by the NASA FAR Supplement, but queried the online Contract Business Analysis Repository (CBAR), an eTool operated by DCMA that captures contract-related information about companies. The information in CBAR indicated that Lockheed Martin Palmdale had its EVMS certification and therefore a comprehensive compliance plan was not required.

Issues surrounding EVMS surfaced again shortly after the LBFD contract was awarded to Lockheed Martin in March 2018. Lockheed Martin disclosed in May 2018 that they were transitioning to new financial software tools. The transition brought with it challenges such as a lack of in-depth knowledge with the new tools. These challenges required on-site support from the software vendor and additional staff from Lockheed Martin to correct. Other issues with the new tools included system anomalies, implementation delays, and consistency issues with Lockheed Martin's cost factors and overhead. These issues required multiple troubleshooting encounters and changes to the accounting system to reconcile differences.

The transition to new financial software along with an inability to provide the detailed reports required by the contract raised further EVMS certification questions at NASA. Meanwhile, the Agency's Contracting Officer was in communication with DCMA to coordinate support for LBFD in accordance with a Memorandum of Understanding between the two agencies. The DCMA Divisional Administrative Contracting Officer assigned to Lockheed Martin provided NASA a September 2018 status report that indicated Lockheed Martin Palmdale's EVMS was "not applicable" with a note explaining that the contractor was switching to a new reporting system and that DCMA was planning on performing a limited implementation review to verify the new tool set was working and that the data was valid, accurate, timely, and auditable.

In November 2018, DCMA approved a surveillance plan for Lockheed Martin Palmdale and conducted its first surveillance event during their visit to the facility in May 2019.[42] DCMA stated that CBAR

[42] Surveillance is a function of contract administration used to determine or assess a contractor's progress and/or compliance through data collection and analysis. At DCMA, surveillance is often a multifunctional insight effort to review and analyze contractor plans, schedules, policies, procedures, systems, processes, process outputs, and/or products to determine compliance to contractual, statutory, regulatory, or contractor requirements.

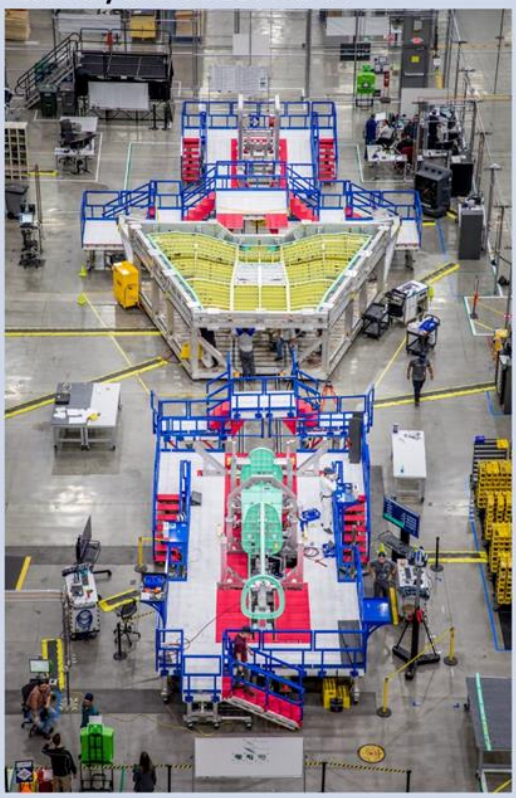
information has at times been erroneous and clarified Lockheed Martin Palmdale did not have an evaluation in CBAR and no EVMS site certification. Consequently and in accordance with contract requirements, NASA required Lockheed Martin to revise its EVM Plan to reflect implementation and current usage of their new financial software and submit a certification plan. DCMA has continued surveillance at Lockheed Martin Palmdale and performed EVM certification in March 2020, but has not yet issued the final report to NASA.[43]

Although the NASA Source Evaluation Board representatives attempted to electronically verify Lockheed Martin's EVMS certification using CBAR, the information used in their decision-making process was inaccurate. NASA representatives could have contacted the DCMA representative responsible for that particular area or contractor considering the inaccuracies of the CBAR system. We spoke with the NASA EVM Working Group Deputy Chair who stated that although the Agency has established requirements for performing such verifications in the NASA FAR Supplement, it lacks a process and adequate training on how to perform them. The Deputy Chair, who is also the Kennedy Space Center EVM Focal Point, added they recently experienced a similar issue with inaccurate CBAR information on a separate acquisition project at their Center.

Data Fidelity

During its transition to new financial software, Lockheed Martin was not able to provide all the required details in their financial reports required by the LBFD contract and therefore NASA had to waive those requirements for over a year. While Lockheed Martin did provide information and reports monthly, it was not to the level of detail or in the format required by the contract. Further, some of the reports were late while others were rejected for containing inaccurate and erroneous data. Ultimately, NASA and Lockheed Martin agreed to revise the reporting requirements and modify the contract to incorporate those revisions.

Low-Boom Flight Demonstrator Main Assembly at Lockheed Martin



Source: Lockheed Martin.

For over a year after contract inception, NASA had to review and perform testing on the data provided by Lockheed Martin to determine its accuracy and reliability. During this period, Lockheed Martin's monthly financial deliverables contained inaccuracies and errors, a trend that continued for several months even though these errors were identified and included in a corrective action plan. NASA reiterated that the flawed submissions were creating substantial financial reporting issues for the LBFD Project as well as significant rework of their internal financial reports. For example, the estimates and forecasts provided over a 3-month period in 2019 lacked the level of reliability

[43] Lockheed Martin stated that Palmdale site specific recertification was limited by the lack of appropriate, unclassified contracts for DCMA to audit.

needed for NASA to report credible financial data related to the Project. Lockheed Martin's issues with its software transition and reporting delays created several risks to the Project identified and reported by the LBFD team. Specifically, the new software maintained the official Performance Measurement Baseline and was simultaneously configured to define and execute Lockheed Martin's business processes; full financial reporting per the contract was not being provided to NASA; and errors in configuration could result in miscalculated performance measurements and other reporting challenges. The Contracting Officer said these issues would be included in Lockheed Martin's performance evaluation.

Lockheed Martin Palmdale's lack of a certified EVMS and subsequent financial software transition required NASA to spend additional money, time, and effort to resolve the issues. NASA estimates it will cost approximately $130,000 for DCMA to perform surveillance and certification testing. NASA has also expended a substantial amount of time and effort verifying the reliability and accuracy of the data provided by Lockheed Martin as well as coordinating and working through these issues with the contractor and DCMA in order to perform the certification procedures at the Palmdale location. While the Agency completed validation tests on the data and is confident the risks have been mitigated by these efforts, and DCMA did not identify any major non-compliance issues with the EVMS while performing surveillance, the possibility exists that data previously provided to NASA and used to make decisions at key milestones during the life-cycle process may have included errors.

LBFD Project Not Performing Required Internal EVM Reporting

Office of Management and Budget guidance states that in-house work must be managed with the same rigor as contractor work, with both expected to achieve cost, schedule, and performance goals to ensure the project's success.[44] The requirements for good project management, including the use of EVM in accordance with federal standards, are applicable for development efforts or multiple projects in a program.[45]

The FAR and NASA FAR Supplement discuss the requirements for EVM reporting on contracts and contractors, while NASA policy details the requirements for internal EVM reporting. In December 2017, NASA made a significant change to its requirements based on a recommendation made during the Agency's Business Services Assessment of budget management.[46] The Mission Support Council raised the EVM project threshold more than tenfold—from $20 million to a $250 million life-cycle cost for internal work. The Decision Memorandum specified that EVM is no longer required on internal work for

[44] Capital Programming Guide Version 3.0, *Supplement to Office of Management and Budget Circular A-11: Planning, Budgeting, and Acquisition of Capital Assets* (2018).

[45] National Defense Industrial Association Integrated Program Management Division, *Earned Value Management Systems EIA-748-D Intent Guide* (August 28, 2018).

[46] Business Services Steering Committee, *Mission Support Council Package: Business Services Assessment Budget Management Deep Dive Recommendations* (November 10, 2016). The Budget and Management Business Services Assessment core team presented key findings on the close integration of budget processes with project management practices. Based on these findings, the Committee collected additional information and data on related activities impacting budget processes. This resulted in identified opportunities for optimization and findings to promote excellence, effectiveness, and efficiency across the Agency in areas such as cost estimating, cost assessment (including JCL), resources management, scheduling, and EVM.

new projects with a life-cycle cost less than $250 million prior to KDP-B.[47] Despite this change, the LBFD Project still exceeded the new threshold and EVM reporting was expected to commence within 60 days following KDP-C approval but as of March 2020 has not.

Although the LBFD Project exceeds NASA's threshold for reporting internal EVM performance, the Agency has failed to fulfill its own internal EVM reporting requirements on the Project. LBFD Project managers explained it was not their intent to disregard internal EVM reporting requirements and cited several events, along with Project timing, as reasons why it was not performed. KDP-C was held on October 31, 2018, at which time the Performance Measurement Baseline was established and the LBFD team began preparations to start EVM reporting. However, on December 22, 2018, the government furlough began and lasted until January 25, 2019. These events are significant since KDP-C is when the project transitions from Formulation to Implementation. While the contractor must begin EVM reporting shortly after contract inception, NASA does not require internal EVM reporting to commence until KDP-C. After the furlough, Project managers decided that the benefit of internal EVM reporting would be significantly reduced given the time required to revise the master schedule and the Performance Measurement Baseline, while simultaneously moving forward with LBFD development. LBFD Project managers also stated that the amount of discrete work tasks remaining (e.g., providing GFE or performing in-house development work) was insignificant compared to level-of-effort tasks such as integration, oversight, and management functions, making EVM reporting not worthwhile.

ARMD's Deputy Associate Administrator for Strategy also acknowledged issues with implementing internal EVM after the government shutdown, stating that it called into question the veracity of the EVM data and required EVM performance metrics to be reset. We believe this situation potentially could have been avoided if NASA required implementation of internal EVM reporting on the same timeline it expects contractors with EVM reporting requirements to follow—90 days post award. Doing so could also provide decision makers comparative cost and schedule performance data when deciding whether to assign work in-house or to the contractor.

LBFD Project management has not implemented internal EVM reporting and waited until February 2020 to submit a waiver request through the Office of the Chief Financial Officer (OCFO), the cognizant Agency technical authority over EVM implementation.[48] The ARMD Deputy Associate Administrator for Strategy indicated the OCFO will likely not approve LBFD's waiver request because of the precedent it would set for other projects. In addition, ARMD's Deputy Associate Administrator for Programs explained the NASA EVM Working Group has been pushing the LBFD team to implement internal EVM reporting on all aspects of the Project because they want to use the Project to illustrate the usefulness of EVM. The Deputy Associate Administrator for Programs also said that although the LBFD team is being pressured to use internal EVM, he believes it would provide no value to the Project at this point.

[47] The analysis used to support the assessment reviewed the impact of raising the threshold to $100 million, with an option for raising it to $250 million. The assessment stated that raising the threshold to $100 million would exclude 57 contracts worth approximately $2.5 billion from internal EVM reporting. KPD-B occurs in Phase A and helps determine whether the proposed mission or system architecture is credible and responsive to program requirements and constraints including resources, the project is mature enough to proceed to Phase B, and the mission can likely be achieved within available resources with acceptable risk.

[48] A waiver is a documented authorization releasing a program or project from meeting a requirement. When a program or project meets the requirements for EVM application yet wants to implement a management system not fully compliant with the guidelines in EIA-748, a waiver request must be submitted to the NASA EVM Program Executive. The NASA EVM Program Executive will evaluate waiver requests and decide based on the data provided and the risk to the Agency if a waiver is granted.

Despite the dissenting opinions, in June 2019 the LBFD Project Planning and Control Lead stated they were in the process of requesting relief from reporting internal EVM data. However, by August 2019 the Project Manager had not yet submitted the waiver and said their Program Office was requesting the Independent Review Board evaluate the Project's cost and schedule control processes as part of the CDR to identify any gaps or shortcomings.[49] Based on that input, the Program Office would decide the best path forward relative to internal EVM reporting. The LBFD team believed that if the CDR found the Project to be well-managed, they could continue to forego performing internal EVM but if the review found the Project not well-managed, they would have to establish internal EVM reporting. Almost a year after internal EVM reporting was supposed to begin, IASP Program Office management was seeking to validate their decision using the CDR Project Review Team.

While reviewing LBFD's progress during the CDR, the Review Team was asked to assess how the Project was being managed internally. Although Project managers told us there was an insignificant number of discrete work tasks remaining, the Review Team concluded there was approximately $33 million worth of in-house work to be completed over the next 17 months, with a sufficient number of discrete tasks to justify the need for improved cost and schedule integration. The Team also cautioned that the current management approach (which does not include EVM reporting) increases the risk that valid, accurate, and timely performance measurement data will not be available to support informed management decisions or a forecast of cost at completion.

The NASA EVM Working Group Deputy Chair added that the ramifications of not performing internal EVM go beyond the LBFD Project. In September 2018, Agency senior leadership determined a new Agency-level Corrective Action Plan was necessary to continue driving improvements in NASA's program and project management policies.[50] The plan was necessary to address issues identified in previous Government Accountability Office (GAO) High Risk Reports, Priority Recommendations Letters, annual programmatic reviews of NASA's major projects, as well as internal analyses conducted by the Agency.[51] One of the Corrective Action Plan initiatives is to "Enhance Earned Value Management Implementation," and NASA reports its status on the initiatives outlined in the plan annually to GAO. During NASA's Corrective Action Plan assessment officials determined that the success of EVM implementation was predicated upon successful adoption and execution by all affected projects, programs, and mission directorates. The team also found it critical that NASA senior leadership emphasize the need for EVM performance data and act upon the data when anomalies are identified. Some of the impediments and challenges they identified include:

- Enforcement of current requirements and guidance is a challenge and calls for senior management emphasis and action. The OCFO owns the functional responsibility for

[49] The IASP, in cooperation with ARMD, established an Independent Review Board for oversight during the life of the LBFD Project. The Board utilized a Standing Review Board-like process and structure to perform an independent assessment of the entire scope of the LBFD Project–technical, cost, schedule, and risk. The Board is comprised of a Chair, Deputy Chair, and multi-disciplinary Project Review Team (as previously discussed in footnote 36). The Project Review Team reports to the Board Chairs so that they can provide summaries, findings, assessments, and recommendations from life-cycle reviews to inform the KDP reviews.

[50] NASA's *Corrective Action Plan: In Response to Recent Programmatic Performance and NASA's Designation on GAO's High Risk List* was published on December 14, 2018.

[51] GAO originally designated NASA's acquisition management as a "high risk" area in its inaugural High Risk List released in 1990, citing what was at the time considered a history of persistent cost growth and schedule delays in the majority of the Agency's major products. In 2007, NASA established a Corrective Action Plan consisting of five broad focus areas and seven tactical initiatives that provided an Agency-wide coordinated approach to improve NASA's program and project management activities. GAO has acknowledged that considerable progress toward strengthening and integrating NASA's acquisition management functions resulted from those efforts.

enforcement, but projects implement the EVM requirement. Currently, the EVM community is splintered because the resources are owned by projects, which have varying approaches for implementation that may not be consistent with overall Agency policies and goals.

- The perception that the cost of EVM is too high, which leads projects and programs to resist EVM and request waivers and deviations from flow-down of EVM requirements to contractors.

The NASA EVM Working Group Deputy Chair reiterated that waiving EVM requirements could also negatively impact the Agency's efforts to be removed from GAO's High Risk List.

While the LBFD Project and ARMD management might not support performing internal EVM reporting on the LBFD Project, the Review Team explained there is adequate budget, schedule, and discrete work remaining on the Project to justify the benefits of completing internal EVM reporting. The Review Team also noted that if internal EVM reporting would have been implemented earlier in the Project life cycle, it would have been useful for identification of cost and schedule performance issues during NASA development efforts.

In January 2020, the Deputy Director for IASP stated that the LBFD Project Decision Memorandum for KDP-D had not been signed and was pending the establishment of an agreement with the OCFO for tracking performance of internal work. In February 2020, the Deputy Director stated the Decision Memorandum was still pending and that a waiver package was being prepared. Later in February 2020, the OCFO confirmed that a waiver for LBFD internal EVM reporting had been received and stated that it would take several weeks to make a decision on the waiver.[52]

[52] Although the Chief Financial Officer's preliminary recommendation was to disapprove the LBFD Project management's waiver request, in consultation with senior Agency leadership in March 2020 and given the national crisis with COVID-19, the decision was made to approve the waiver request.

CONCLUSION

While the Concorde aircraft ushered in an era of supersonic commercial air travel in the 1970s, its viability as a commercial transportation system was doomed in part by the loud sonic boom it generated that restricted use of its top speed overland. NASA hopes to provide air travel regulators in the United States and Europe with data to reassess existing regulations regarding supersonic flight overland by designing the LBFD to produce a sonic boom tolerable to the general population. The Agency believes the results of its efforts could move the FAA and the ICAO's CAEP toward supporting development of a noise-based standard for supersonic flight overland. Consequently, NASA's efforts have generated renewed interest in civil supersonic aircraft and represents a potentially large new market for aircraft manufacturers and operators worldwide.

LBFD is ARMD's first attempt at a large-scale development project, and as such we found management instituted a sound acquisition strategy, provisioned additional GFE to save costs, and implemented an unorthodox project management structure and approach to leverage the geographically dispersed aeronautics expertise across the Agency. In addition, LBFD was the first ARMD project required to apply the JCL analysis. Use of the JCL resulted in an Agency Baseline Commitment that provided the Project with $134 million in cost reserve and 13 months of schedule reserve for the LBFD team to build and complete low-boom acoustic validation flights by October 2023. However, as of February 2020, the contract was estimated to cost $37 million more at completion than originally anticipated and Lockheed Martin was 2 months behind its planned schedule. These cost and schedule increases were traced to Lockheed Martin's challenges in hiring and assigning qualified technical personnel, which led to schedules falling behind, getting suppliers under contract later than anticipated, and longer procurement times prior to production of the aircraft. Also, the worldwide COVID-19 pandemic and its effect on the Project are not yet known. Thus, NASA needs to ensure contingency plans are in place to account for any flight or data collection delays to guarantee timely delivery of a database of community responses to quiet supersonic aircraft overflight to the ICAO in 2025.

We also found issues with Lockheed Martin and LBFD managements' implementation of EVM. Specifically, due to clerical and database errors, NASA discovered that Lockheed Martin Palmdale did not have a DCMA-certified EVMS. As a result, LBFD managers expended a substantial amount of time and effort verifying the reliability and accuracy of EVM data provided by Lockheed Martin, and it will cost the Agency approximately $130,000 for DCMA to perform surveillance and certification testing at the company's Palmdale location. In addition, LBFD managers are not reporting in-house EVM as required by NASA policy and waited until February 2020 to submit a waiver to bypass this requirement—more than a year after the Project was supposed to begin in-house EVM reporting.

RECOMMENDATIONS, MANAGEMENT'S RESPONSE, AND OUR EVALUATION

To help ensure Low-Boom Flight Demonstration Mission success within its established funding and schedule, we recommended NASA's Associate Administrator for ARMD require Mission management to:

1. Finalize the schedule-driven contingency plan for the community response testing and account for the resources (personnel and costs) it will require to implement.

To increase accountability and lessons learned for future X-plane developments, we recommended the Associate Administrator for ARMD require the LBFD Project Manager to:

2. Perform a cost-benefit analysis of implementing internal EVM during Phase D of LBFD development.
3. Document and provide the project management approach used by LBFD to the NASA Chief Knowledge Officer to serve as a reference for future large-scale X-plane development projects to be shared across the Agency.
4. Document and provide the JCL analysis approach used by LBFD to the NASA Chief Knowledge Officer to serve as a reference for future large-scale X-plane development projects.

In addition, we recommended NASA's Acting Chief Financial Officer:

5. Establish a process to be used during source evaluation boards and source selections that includes direct contact with the Center EVM Working Group Representative and cognizant DCMA office to verify all contractor proposed information related to EVM.
6. Establish NASA requirements for programs and projects to perform internal EVM reporting that follow the same timeline as contractor reporting—90 days after the prime contract start date—but no later than KDP-C.
7. Evaluate whether the monetary threshold for performing internal EVM is sufficient or additional criteria would be beneficial regarding the dollar-value of tasks related to providing GFE and performing in-house development work (discrete work) compared to NASA personnel performing integration, review, and management functions (level-of-effort work).

We also recommended the Assistant Administrator for Procurement:

8. Provide information and training to contracting officers and source evaluation board members on the availability, use, and responsibilities of DCMA during source evaluation boards and source selections. Specifically, the NASA FAR Supplement and NASA-DCMA Memorandum of Understanding for Earned Value Management.

We provided a draft of this report to NASA management who concurred with six of our eight recommendations. We consider management's comments to those six recommendations responsive; therefore, the recommendations are resolved and will be closed upon completion and verification of the proposed corrective actions.

Management did not concur with Recommendation 6, stating that implementing EVM prior to establishing the Agency Baseline Commitment at KDP-C is unwarranted since a project would not have a firm baseline at that point in development.

While we agree that a baseline needs to be established to implement EVM, we disagree with management's assertions that a firm baseline is (1) needed to implement in-house EVM and this only occurs at KDP-C and (2) established with the contractor from which there are no deviations. NPR 7120.5E states that a project's Formulation Agreement documents "proposed milestones for in-house work" as well as identification of acquisition risks and funding requirements for procurement activities. Furthermore, requirements that programs and projects with life-cycle costs estimated to exceed $1 billion perform a JCL analysis at KDP-B provides the information needed to implement EVM before KDP-C for larger projects.[53] Lastly, as we previously stated, contractor requirements regarding GFE continued to evolve during LBFD development necessitating changes to both in-house and contractor "baseline" work.

Management also did not concur with Recommendation 7, stating that the Mission Support Council decided to set the EVM threshold for in-house EVM work at $250 million. However, this statement is unresponsive to our recommendation to the Acting Chief Financial Officer, which was to consider whether additional criteria might be beneficial since every project is different relative to the balance of in-house development work that could benefit from EVM monitoring.

Both Recommendations 6 and 7 remain unresolved pending further discussions with Agency management.

Management's comments are reproduced in Appendix B. Technical comments provided by management and revisions to address concerns about proprietary information regarding public release of this report have also been incorporated as appropriate.

Major contributors to this audit and report include Ray Tolomeo, Science and Aeronautics Research Director; Diane Choma, Project Manager; Theresa Becker; Scott Collins; Jason Hensley; Greg Lokey; Lauren Suls; Matt Ward; and Earl Baker.

If you have questions 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.

Paul K. Martin
Inspector General

[53] NASA Interim Directive 7120.122, *Joint Cost and Schedule Confidence Level (JCL) Requirements Updates* (May 24, 2019).

APPENDIX A: SCOPE AND METHODOLOGY

We performed this audit from October 2017 through March 2020 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 audit initially began as a concerted review of the New Aviation Horizons Initiative with the survey phase conducted between October 2017 and January 2018. The audit was announced with an overall objective to review management of the New Aviation Horizons Initiative. On January 18, 2018, although the Project had not completed some major milestones, we suspended the audit having found that the Initiative was reasonably and efficiently managed to that point. The audit resumed in April 2019 with an overall objective to determine whether NASA was effectively managing the LBFD Project to accomplish its technical objectives while meeting established milestones and controlling costs. The scope of this audit was project management, specifically NASA's overall management of costs, schedule, and technical requirements. This included the review of the acquisition, management, and oversight of the LBFD contractor along with the effectiveness of the EVM program and implementation of JCL.

To answer our objective and gain an understanding of the Agency's management of the LBFD Project, we conducted numerous interviews with personnel located at NASA Headquarters, Ames, Armstrong, Glenn, Goddard Space Flight Center, Kennedy Space Center, and Langley. Personnel interviewed at NASA Headquarters included the ARMD Deputy Associate Administrator for Strategy, Deputy Associate Administrator for Programs, Deputy Director for IASP, and the Chief Engineer. At the respective Centers we interviewed various project managers, the contracting officer, the contracting officer representative, EVM specialists, and LBFD Project staff, as appropriate. We also interviewed key managers on the LBFD Project from Lockheed Martin Palmdale and toured their manufacturing facility.

In addition, we reviewed and analyzed NASA and LBFD-specific Project documentation providing us insight into the overall management, cost, schedule, performance, and contract management of the Project. Those documents included LBFD Project Management, Risk Management, Safety, Implementation, and EVM plans; the LBFD contract with Lockheed Martin; LBFD Monthly Status Reviews, Interim Reports, Quarterly Reports, and Decision Memorandums; Lockheed Martin Property Management, Performance Management, and EVM plans; and various lessons learned from the NASA Engineering Network Lessons Learned repository.

Use of Computer-Processed Data

The computer-processed data used in this audit did not materially affect the findings and therefore, we did not test the reliability and validity of the data.

Review of Internal Controls

We performed an assessment of internal controls associated with NASA's New Aviation Horizons Initiative, the Quiet Supersonic Technology Project, and the LBFD Project. We reviewed federal regulations and NASA policies and procedures to determine NASA's internal controls for ensuring effective management of Agency projects. We analyzed the execution of the policy requirements as it related to cost, schedule, performance, and contract management. The control weaknesses we identified are discussed in the body of this report, and our recommendations, if implemented, should correct the weaknesses identified. We specifically reviewed the following documentation:

- NPR 7120.5E, *NASA Space Flight Program and Project Management Requirements (Updated w/Change 18)* (August 14, 2012)
- NPR 7120.8, *NASA Research and Technology Program and Project Management Requirements (w/change 4 dated 01/04/2017)* (February 5, 2008)
- NPR 7123.1B, *NASA Systems Engineering Processes and Requirements (Updated w/Change 4)* (April 18, 2013)
- NPR 8715.3D, *NASA General Safety Program Requirements (Updated w/Change 1)* (August 1, 2017)
- NASA/SP-2011-3422 Version 1.0, *NASA Risk Management Handbook* (November 2011)
- Federal Acquisition Regulation
- NASA FAR Supplement
- NASA Procurement Information Circular 15-06, *Guidance on the Integrated Program Management Report for Earned Value Management* (April 28, 2015)
- NASA Procurement Class Deviation 15-05, *Class Deviation to NFS 1834.2, 1834.203-70, 1852.234-1 and 1852.234-2—Earned Value Management System Threshold* (November 10, 2015)

Prior Coverage

During the last 20 years, the NASA Office of Inspector General and GAO have issued 8 reports of significant relevance to the subject of this report. Unrestricted reports can be accessed at https://oig.nasa.gov/audits/auditReports.html and https://www.gao.gov/, respectively.

NASA Office of Inspector General

X-37 Technology Demonstrator Project Management (IG-01-021, March 30, 2001)

X-34 Technology Demonstrator (IG-00-029, March 30, 2000)

X-33 Cooperative Agreement (IG-99-019, March 29, 1999)

NASA X-33 Funding Issues at Marshall Space Flight Center (IG-99-001, November 3, 1998)

Government Accountability Office

NASA: Assessments of Major Projects (GAO-19-262SP, May 30, 2019)

Priority Open Recommendations: National Aeronautics and Space Administration (GAO-19-424SP, April 12, 2019)

NASA: Assessments of Major Projects (GAO-18-280SP, May 1, 2018)

NASA: Assessments of Major Projects (GAO-16-309SP, March 30, 2016)

APPENDIX B: MANAGEMENT'S COMMENTS

National Aeronautics and
Space Administration

Headquarters
Washington, DC 20546-0001

April 21, 2020

Reply to Attn of: Aeronautics Research Mission Directorate

TO: Assistant Inspector General for Audits

FROM: Associate Administrator for Aeronautics Research Mission Directorate
Acting Chief Financial Officer
Assistant Administrator for Procurement

SUBJECT: Agency Response to OIG Draft Report, "Management of the Low-Boom Flight Demonstrator Project" (A-17-017-01)

The National Aeronautics and Space Administration (NASA) appreciates the opportunity to review and comment on the Office of Inspector General (OIG) draft report entitled, "Management of the Low-Boom Flight Demonstrator Project" (A-17-017-01), dated March 31, 2020.

In the draft report, the OIG makes eight recommendations intended to help ensure Low-Boom Flight Demonstration (LBFD) Mission success within its established funding and schedule.

Specifically, the OIG recommends the following:

To help ensure Low-Boom Flight Demonstration (LBFD) Mission success within its established funding and schedule, the OIG recommends NASA's Associate Administrator for Aeronautics Research Mission Directorate (ARMD) require LBFD Mission Management to:

Recommendation 1: Finalize the schedule-driven contingency plan for the community response testing and account for the resources (personnel and costs) it will require to implement.

Management's Response: NASA concurs. The LBFD Mission Manager will lead a team to conduct an LBFD Mission risk-weighted resource assessment. The team will identify risks to successfully complete community response testing in support of the LBFD Mission and will conduct a risk-informed cost and schedule impact assessment that includes necessary resources to mitigate the identified risks. Thereafter, resources will be allocated by ARMD to enable mitigations.

Estimated Completion Date: March 31, 2021.

To increase accountability and lessons learned for future X-plane developments, the OIG recommends the Associate Administrator for ARMD require the LBFD Project Manager to:

Recommendation 2: Perform a cost-benefit analysis of implementing internal Earned Value Management (EVM) during Phase D of LBFD development.

Management's Response: NASA concurs. A cost-benefit analysis of implementing internal Earned Value Management (EVM) during Phase D of LBFD development will be performed.

Estimated Completion Date: May 31, 2020.

Recommendation 3: Document and provide the project management approach used by LBFD to the NASA Chief Knowledge Officer to serve as a reference for future large-scale X-plane development projects to be shared across the Agency.

Management's Response: NASA concurs. A narrative that describes the project management approach used by LBFD Project will be furnished to the NASA Chief Knowledge Officer.

Estimated Completion Date: June 30, 2020.

Recommendation 4: Document and provide the Joint Cost and Schedule Confidence Level (JCL) analysis approach used by LBFD to the NASA Chief Knowledge Officer to serve as a reference for future large-scale X-plane development projects.

Management's Response: NASA concurs. A narrative that describes the Joint Cost and Schedule Confidence Level (JCL) analysis approach used by the LBFD Project will be furnished to the NASA Chief Knowledge Officer.

Estimated Completion Date: September 30, 2020.

In addition, the OIG recommends NASA's Acting Chief Financial Officer:

Recommendation 5: Establish a process to be used during source evaluation boards and source selections that includes direct contact with the Center EVM Working Group Representative and cognizant Defense Contract Management Agency (DCMA) office to verify all contractor proposed information related to EVM.

Management's Response: NASA concurs. A corrective action plan will be developed, management approval will be obtained, and the process will be communicated to organizational EVM points of contact and source evaluation boards.

Estimated Completion Date: September 30, 2020.

Recommendation 6: Establish NASA requirements for programs and projects to perform internal EVM reporting that follow the same timeline as contractor reporting—

90 days after the prime contract start date—but no later than Key Decision Point (KDP)-C.

Management's Response: NASA does not concur (non-concur). For in-house EVM, the Agency Baseline Commitment (ABC) is established at KDP-C. The implementation of EVM prior to the ABC is unwarranted since the project would not have a firm baseline, which is required for EVM. The timeline for contracts to implement EVM is different because the work scope has been agreed upon and a baseline can be established.

Estimated Completion Date: N/A

Recommendation 7: Evaluate whether the monetary threshold for performing internal EVM is sufficient or additional criteria would be beneficial regarding the dollar-value of tasks related to providing Government furnished equipment (GFE) and performing in-house development work (discrete work) compared to NASA personnel performing integration, review, and management functions (level-of-effort work).

Management's Response: NASA does not concur (non-concur). The benefits of performing EVM on activities at any scale are well recognized. However, the decision to increase EVM thresholds to $250M for in-house work was codified by the Mission Support Council on December 11, 2017, in the budget Business Services Assessment Decision #6.

Estimated Completion Date: N/A

The OIG also recommends the Assistant Administrator for Procurement:

Recommendation 8: Provide information and training to contracting officers and source evaluation board members on the availability, use, and responsibilities of DCMA during source evaluation boards and source selections. Specifically, the NASA Federal Acquisition Regulation (FAR) Supplement and NASA-DCMA Memorandum of Understanding for Earned Value Management.

Management's Response: NASA concurs. The Source Selection Capability Group (SSCG) is responsible for policy guidance and training for source selection activities. The HQ Office of Procurement (OP) Pricing Leads coordinate DCMA support for the Agency. The SSCG will update the Source Selection Guide to: 1) include information regarding DCMA engagement and; 2) direct Source Evaluation Board Managers to seek input from the NASA HQ OP Pricing Leads and update their Boards on how to engage with DCMA on Earned Value Management support.

Estimated Completion Date: January 15, 2021.

We have reviewed the draft report for information that should not be publicly released. As a result of this review, we have identified information that should not be publicly released and communicated our concerns to the OIG.

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 Natasha McNeil on (202) 358-2638.

Robert A. Pearce

Melanie W. Saunders

Melanie Saunders

WILLIAM ROETS Digitally signed by WILLIAM ROETS Date: 2020.04.21 17:09:06 -04'00'

for Monica Y. Manning

APPENDIX C: REPORT DISTRIBUTION

National Aeronautics and Space Administration

Administrator
Deputy Administrator
Associate Administrator
Chief of Staff
Acting Chief Financial Officer
Associate Administrator for Aeronautics Research Mission Directorate
Assistant Administrator for Procurement

Non-NASA Organizations and Individuals

Office of Management and Budget
    Deputy Associate Director, Energy and Space Programs Division

Government Accountability Office
    Director, Contracting and National Security Acquisitions

Congressional Committees and Subcommittees, Chairman and Ranking Member

Senate Committee on Appropriations
    Subcommittee on Commerce, Justice, Science, and Related Agencies

Senate Committee on Commerce, Science, and Transportation
    Subcommittee on Aviation and Space

Senate Committee on Homeland Security and Governmental Affairs

House Committee on Appropriations
    Subcommittee on Commerce, Justice, Science, and Related Agencies

House Committee on Oversight and Reform
    Subcommittee on Government Operations

House Committee on Science, Space, and Technology
    Subcommittee on Investigations and Oversight
    Subcommittee on Space and Aeronautics

(Assignment No. A-17-017-01)