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National Aeronautics and Space Administration

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NASA's Research Efforts and Management of Unmanned Aircraft Systems

September 18, 2017

Report No. IG-17-025

Office of Inspector General

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Results in Brief

NASA's Research Efforts and Management of Unmanned Aircraft Systems

September 18, 2017 IG-17-025 (A-16-018-00)

Why We Performed This Audit

Hobbyists, scientists, the military, other government agencies, and commercial enterprises are rapidly expanding their use of remotely piloted, unmanned aircraft systems (UAS or drone aircraft). The Federal Aviation Administration (FAA) forecasts that the UAS hobbyist fleet will more than triple in size over the next 5 years from 1.1 million units in 2016 to more than 3.5 million by 2021. Even more dramatically, the commercial drone aircraft fleet is expected to increase 10-fold during the same period – from 42,000 to 420,000 units. These drones range from micro vehicles used by hobbyists measuring inches in size and ounces in weight to large aircraft weighing more than 30,000 pounds used for scientific research or warfare. In addition, public, private, and government organizations are exploring UAS for package delivery, agricultural monitoring, border surveillance, crime scene investigations, search and rescue missions, and disaster response. However, the rising number of aerial drones presents a significant challenge to the safety of passenger and military aircraft in the National Airspace System (NAS), other UAS, and people, livestock, and structures on the ground.

While the FAA plays the central role in regulating UAS activities, NASA conducts research and develops technologies to meet the rapidly changing needs of a domestic aviation sector that must find ways to safely accommodate an increasing number of aerial drones. Currently, the Agency is working with the FAA on two research efforts: (1) the UAS in the NAS (UAS-NAS) Project, which is developing operational performance standards, and (2) the UAS Traffic Management (UTM) Project, which is developing a traffic management system for aerial drones operating in the Nation's airspace. In addition to these research efforts, NASA maintains a fleet of more than 400 UAS – ranging in size, complexity, and technical capability – to conduct aeronautic and science missions as well as physical security and maintenance inspections.

In this audit, we assessed NASA's research efforts to help safely integrate UAS into the national airspace as well as the Agency's use of its own drone resources. To complete this work, we interviewed NASA, FAA, and other relevant officials; inspected UAS inventory at NASA Centers; and reviewed relevant purchase records and transfer documentation.

What We Found

To date, NASA's primary aerial drone-related research efforts – the UAS-NAS and UTM Projects – have made significant contributions toward the development of performance standards and a prototype system to enable UAS operations in the national airspace. Specifically, NASA has performed research related to data exchange and information architecture, sense and avoidance of manned and unmanned vehicles, and communication and navigation. These research efforts have been managed in compliance with NASA research and technology development policy and have achieved all planned schedule and technical milestones within allocated time and budgets. NASA's research should positively affect the FAA's efforts to integrate aerial drones into the national airspace. Ultimately, private industry will be required to adopt technologies to meet the FAA's yet-to-be-defined performance and safety standards – standards that are being developed and informed by NASA's research.

Although effectively supporting the FAA's efforts to introduce aerial drones into the national airspace, the Agency's oversight of its own UAS assets needs improvement. Agency policy written in 2009 and updated in 2015 details procedures for procuring UAS and tracking their use in NASA's property system, including the need for prior approval before purchasing and the use of tracking barcodes on all UAS. However, ineffective Center implementation of these policies has led to poor inventory control and unauthorized acquisition of UAS. For example, we found that 231 of the 410 (56 percent) UAS acquired since 2009 were obtained without the required prior approvals. In addition, inaccurate and incomplete information about UAS in NASA's property system hinders the Agency's ability to effectively share unmanned aircraft assets between Centers. Center officials are also not routinely excessing unneeded assets in a timely manner and therefore the assets are not available to other potential UAS users either within NASA or outside the Agency.

Without proper prior approvals and accurate inventory, NASA officials cannot ensure that UAS meet required safety standards, increasing NASA's risk posture if an unauthorized UAS causes damage to facilities or personal injury. Furthermore, failure to include all UAS in the Agency's property system renders them invisible and unavailable for use by other projects or Centers, possibly leading potential users to acquire new UAS rather than utilizing existing assets, thus wasting NASA resources.

What We Recommended

To increase transparency, accountability, and oversight of NASA's UAS inventory, we recommended the Assistant Administrator for Strategic Infrastructure direct the Aircraft Management and Logistics Management Division Directors to (1) ensure that Center Directors have developed an effective process to routinely inform all potential NASA end users of procedures and logistics requirements required to obtain UAS; (2) create or incorporate into existing policy criteria for defining and distinguishing UAS and determining the number of UAS spare parts to maintain; (3) create a checklist for Center personnel to ensure proper acquisition procedures are followed for a UAS transfer, purchase, or in-house build; (4) reinforce barcode requirements to track all UAS; (5) require Centers to identify and dispose of unneeded UAS or aerial drones, or identify a reason they should be maintained; and (6) work with Center aviation management offices to implement records management procedures to ensure that once approval has been received to obtain a UAS, all supporting documentation is filed together or cross-referenced for ease of identification.

In response to a draft of this report, NASA management concurred or partially concurred with our recommendations and described its planned actions. We consider management's comments responsive; therefore, the recommendations are resolved and will be closed upon completion of the proposed actions and verification of corrective action plans.

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Acronyms

COA	Certificate of Waiver or Authorization
FAA	Federal Aviation Administration
NAS	National Airspace System
NextGen	Next Generation Air Transportation System
NPR	NASA Procedural Requirements
OIG	Office of Inspector General
TCL	Technology Capability Level
UAS	Unmanned Aircraft System
UTM	Unmanned Aircraft System Traffic Management

INTRODUCTION

Hobbyists, scientists, the military, other government agencies, and commercial enterprises are expanding their use of remotely piloted, unmanned aircraft systems (UAS or drone aircraft) with usage poised to explode over the coming years.[1] The Federal Aviation Administration (FAA) forecasts that the UAS hobbyist fleet will more than likely triple in size over the next 5 years, increasing from 1.1 million units in 2016 to more than 3.5 million units by 2021. Even more dramatically, the commercial UAS fleet is expected to increase 10-fold by 2021 compared to 2016 – from 42,000 to 420,000 units.[2]

These drones range from micro vehicles used by hobbyists measuring inches in size and ounces in weight to large aircraft weighing more than 30,000 pounds that are used for scientific research or warfare. In 2013, the expanding UAS market was predicted to generate more than $82 billion in economic activity between 2015 and 2025 and account for more than 103,000 new jobs.[3] Public, private, and government organizations are exploring using UAS for package delivery, agricultural monitoring, border surveillance, crime scene investigations, search and rescue missions, disaster response, and military operations. However, alongside these benefits come significant challenges, such as ensuring that the increasing number of drones in the national airspace do not present a danger to passenger and military aircraft; other drone aircraft; and people, livestock, and structures on the ground.

While the FAA plays the central role in regulating UAS activities, NASA – through its Aeronautics Research Mission Directorate – conducts research and develops technologies to meet the rapidly changing needs of a domestic aviation sector that must find ways to safely accommodate an increasing number of drones.

In its own work, NASA has been flying remotely piloted aerial vehicles for more than 40 years. As early as the 1970s, NASA began using UAS to test spin recovery techniques for out-of-control U.S. Air Force fighter jets, eliminating the risk to a pilot.[4] Today, NASA maintains a fleet of more than 400 UAS ranging in size, complexity, and technical capability. The Agency uses these aerial drones to support the FAA's research goals as well as to conduct research for aeronautic and science missions and non-research applications such as physical security and maintenance inspections.

In this audit, we assessed NASA's research efforts to help safely integrate UAS into the national airspace as well as NASA's use of its own drone resources. See Appendix A for details on the audit's scope and methodology.

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1 The term "drone," while commonly used to refer to UAS, can also refer to unmanned cars and boats. However, for ease of reference in this report, we use the term in the colloquial sense to mean a powered or unpowered aerial vehicle, aerial drone, or unmanned aircraft that does not carry a human operator.

2 FAA, "FAA Aerospace Forecast Fiscal Years 2017-2037," available at https://www.faa.gov/data_research/aviation/aerospace_forecasts/media/FY2017-37_FAA_Aerospace_Forecast.pdf (last accessed September 7, 2017).

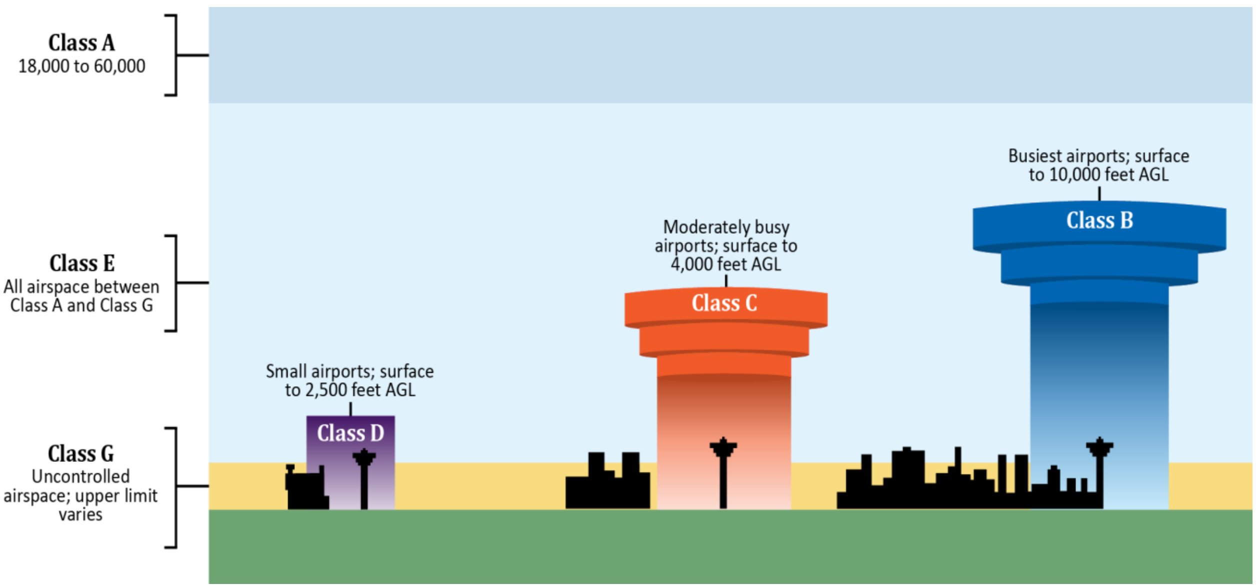
3 Association for Unmanned Vehicle Systems International, "The Economic Impact of Unmanned Aircraft Systems Integration in the United States," March 2013, available at http://www.auvsi.org/auvsiresources/economicreport (last accessed September 7, 2017). The Association is a nonprofit organization that seeks to advance unmanned systems and robotics.

4 These remotely piloted research vehicles were 3/8-scale, unpowered F-15 aircraft launched from a B-52.

Background

Beginning with the air traffic control system's first flagmen in the late 1920s at an airfield in St. Louis, Missouri, the past 100 years have seen rapid advances in aviation technology that have transformed the Nation's skies. Fixed-wing and rotary aircraft of various sizes, weights, and speeds operate across the country from populated metropolitan areas and remote airfields supporting small communities. All aircraft, including UAS, operate in what is known as the National Airspace System (NAS). As shown in Figure 1, the NAS ranges from essentially ground-level to about 11 miles above ground, and is classified as either controlled or uncontrolled airspace. Controlled airspace is a generic term that covers five different gradations where FAA traffic control is provided. For example, Class A (18,000 to 60,000 feet) includes the airspace where most passenger aircraft fly, while Class D (up to 2,500 feet above ground level) generally includes the airspace around small airports. Class G – all other airspace not otherwise designated and loosely defined as from the ground surface to a variable upper limit – is deemed uncontrolled airspace and the only airspace within which the FAA allows aerial drones to operate without special permission.

Figure 1: National Airspace System



Source: NASA Office of Inspector General (OIG) depiction of FAA information.

Note: Above ground level (AGL).

For more than 25 years, NASA has conducted air traffic management research in partnership with the FAA, providing a variety of computer-based tools that help improve flight efficiency, reduce delays, and reduce fuel use and emissions in increasingly crowded skies. With the advent of drone aircraft, NASA is working with the FAA to develop an air traffic management system to help ensure these newest entrants into the airspace do not collide with buildings, larger aircraft, or one another.

The widespread use of small UAS – typically defined as weighing less than 55 pounds – in low-altitude uncontrolled airspace by hobbyists and private sector businesses such as Google and Amazon has necessitated the development of infrastructure to safely manage their operations. Among the many commercial uses for UAS, currently, precision agriculture and public safety are two of the most promising, estimated to comprise approximately 90 percent of the known potential UAS market.[5]

In 2012, Congress directed the FAA, in coordination with NASA, to introduce civil UAS into the national airspace and continue research to develop a UAS traffic management system.[6] However, Congress did not specifically direct NASA to conduct drone-related research independent of that requested by the FAA.

The FAA defines a UAS, regardless of size, as an aircraft and as such requires all UAS adhere to applicable aircraft requirements. Drone aircraft operate under a Certificate of Waiver or Authorization (COA) issued by the FAA to a public operator (government or university) for a specific unmanned aircraft activity. COAs may impose constraints on when a drone can be flown (e.g., daylight only), the weather conditions under which a drone can be flown (e.g., visual meteorological conditions only), or where a drone can be flown (e.g., unpopulated areas only). NASA has obtained COAs when using its drone aircraft for aeronautic, meteorological, and environmental research flights. However, as the number of potential uses for UAS rapidly expands to include, among others, aerial photography, surveying land and crops, communications, monitoring forest fires, and protecting critical infrastructure, the FAA process of reviewing individual COA applications and granting approvals on a case-by-case basis has become cumbersome. Consequently, the FAA provides a blanket COA for civil and commercial unmanned aircraft operators who qualify under Section 333 of the FAA Modernization and Reform Act of 2012.[7]

NASA Research Efforts and Management of Unmanned Aircraft Systems

In June 2014, the Department of Transportation Office of Inspector General issued an audit report critical of the FAA's progress in implementing the congressional mandate to introduce UAS into the national airspace.[8] Also in 2014, the National Research Council's Committee on Autonomy Research for Civil Aviation, Aeronautics and Space Engineering Board expressed concerns about the technological readiness of the national airspace for safe integration of unmanned aircraft.[9]

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[5] Association for Unmanned Vehicle Systems International, "The Economic Impact of Unmanned Aircraft Systems Integration in the United States" (March 2013). Precision agriculture encompasses two segments of the farm market: remote sensing and precision application. Remote sensors are used to scan plants for health problems, while precision application is a practice whereby farmers utilize efficient spraying techniques to more selectively cover crops, thereby reducing the amount of spray used and, in turn, their costs and harmful environmental impacts.

[6] Pub. L. No. 112-95, "FAA Modernization and Reform Act of 2012," February 14, 2012.

[7] The Secretary of Transportation has the authority to grant case-by-case authorizations for certain unmanned aircraft to perform commercial operations prior to the finalization of the Small UAS Rule that will be the primary method for authorizing small UAS operations.

[8] Department of Transportation Office of Inspector General, "FAA Faces Significant Barriers to Safely Integrate Unmanned Aircraft Systems into the National Airspace System" (AV-2014-061, June 26, 2014). The Department of Transportation Office of Inspector General found that the FAA was significantly behind schedule in meeting tasks outlined in the FAA Modernization and Reform Act of 2012. Specifically, the FAA had completed only 9 of the Act's 17 UAS-related directives, was behind schedule in implementing the remaining 8, and had missed the statutory deadlines for most of the provisions.

[9] National Research Council, "Autonomy Research for Civil Aviation: Toward a New Era of Flight," 2014.

To address these and other concerns, in March 2012 the FAA created the Unmanned Aircraft Systems Integration Office. NASA currently works with this office on two research efforts aimed at developing operational performance standards and a traffic management system for UAS operating in the Nation's airspace: the UAS in the NAS (UAS-NAS) Project and the UAS Traffic Management (UTM) Project.

UAS in the NAS Project

The FAA Modernization and Reform Act of 2012 promoted the civilian use of UAS and directed the FAA, in coordination with other Federal agencies, to accelerate integration of aerial drones into the national airspace. The Act also sought to improve aviation capacity and safety, provide a framework for safely integrating new UAS technologies into the national airspace, and accelerate implementation of the FAA's Next Generation Air Transportation System (NextGen).[10] The Act directs the FAA to "consult with" NASA; the Department of Defense; RTCA, Inc.; and other stakeholders when developing industry standards for integrating UAS in the national airspace.[11]

Follow-on legislation known as the FAA Extension, Safety, and Security Act of 2016 mandated development of a framework to reduce cybersecurity risks to the national airspace and a pilot project to detect and mitigate unauthorized operation of unmanned aircraft near airports and other critical infrastructure.[12] Neither the 2012 Act nor 2016 Act contain direct tasking to NASA regarding the Agency's research on UAS issues.

Even without a specific mandate from Congress, NASA allocated $208.9 million to the UAS-NAS Project for fiscal years 2011 through 2017 to fund aeronautics research efforts in support of the FAA.[13] For fiscal years 2018 to 2020, the Project is budgeted to receive an additional $101.5 million to continue these efforts. Managed by the Armstrong Flight Research Center (Armstrong), NASA's research focuses on overcoming safety-related and technical barriers to safely integrate UAS into the national airspace. Among other issues, NASA's research helps inform the FAA's development of performance standards known as Minimum Operating Performance Standards for aerial drone operations in the national airspace.

UAS Traffic Management Project

The UTM Project, managed at Ames Research Center (Ames), is working with the FAA on research that will further the goal of developing a prototype traffic management system for safely operating small aerial drones (55 pounds or less) in low-altitude FAA-uncontrolled airspace.[14] The Project received a

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[10] NextGen is the FAA's multibillion-dollar transportation infrastructure project intended to modernize the Nation's aging air traffic system through satellite navigation and advanced digital communications. The FAA began developing NextGen in 2007 and anticipates implementation by 2025.

[11] RTCA, Inc., founded in 1935 as the Radio Technical Commission for Aeronautics, is a private, not-for-profit association that facilitates public-private collaboration on air transportation safety and efficiency issues. RTCA acts as a Federal Advisory Committee in its work with the FAA on aviation-related issues.

[12] Pub. L. No. 114-190, "FAA Extension, Safety, and Security Act of 2016," July 15, 2016.

[13] The UAS-NAS Project is organized under the Aeronautics Research Mission Directorate's Integrated Aviation System's Program, which conducts flight-oriented, system-level research and technology development in an effort to mature advanced aeronautic technologies into future air vehicles and operational systems.

[14] The UTM Project is a sub-project under the Safe Autonomous Systems Operations Project through fiscal year 2017. In fiscal year 2018, it will be its own project organized under the Aeronautics Research Mission Directorate's Airspace Operations and Safety Program, which works with the FAA, industry, and academic partners to develop air transportation system technologies to improve the safety of current and future aircraft.

total of $47.6 million for fiscal years 2015 through 2017 and is slated to receive another $40 million for fiscal years 2018 to 2020.

NASA's UTM research efforts are directed toward developing a research platform that would facilitate combining test and services data from UAS flight operations with research software in order to analyze traffic management concepts, technologies, and procedures. NASA and the FAA plan to apply the experiences gained from using the UTM research platform in future tests involving increasingly complex UAS operations to gain further insights into what will be required to develop a UTM system. Furthermore, NASA will transfer these capabilities and technologies to the FAA while collaborating with the agency in a pilot program to develop a working traffic management system for aerial drones in the national airspace.

The 2016 FAA Extension Act directs the FAA Administrator to coordinate with the NASA Administrator to develop a traffic management pilot program for aerial drones prior to deploying a UTM system that can operate alongside the FAA's existing and future air traffic management systems.[15] The FAA is required to update Congress on the status of the pilot program in January 2018, with NASA expected to transfer its research results to the FAA the following year for further testing.

NASA-FAA Collaboration

The FAA is collaborating with a variety of stakeholders, including drone manufacturers, industry trade associations, technical standards organizations, academic institutions, and NASA and other Government agencies to improve data exchange and sharing of information about communication and navigation-related issues for manned and unmanned vehicles. As part of this collaboration, the FAA established two organizations to facilitate the transfer of drone-related NASA research.

To address issues related to UAS in the national airspace, the FAA's Unmanned Aircraft Systems Integration Office is working with RTCA, which formed an advisory committee and a number of special committees to develop performance standards the FAA can use to certify the safety and efficiency of new UAS equipment and technologies. This includes safely integrating numerous different types of aerial drones into airspace occupied by manned and other unmanned aircraft. For its part, NASA is a key member of the RTCA special committee that contributed to the FAA's development of standards for civil UAS to operate in Class A airspace (18,000 to 60,000 feet) and continues to work on developing standards for commercial drone activity for the other airspace classes.

With respect to traffic management, NASA and the FAA established Research Transition Teams to ensure that the research and development needed for NextGen implementation is conducted and effectively transferred to the FAA. The Research Transition Teams are expected to (1) provide a structured forum for researchers and implementers to work together on a continuing basis; (2) ensure that planned research results will be fully utilized and sufficient to enable implementation of NextGen air navigation concepts; and (3) provide a forum for NASA and FAA stakeholders involved in planning, conducting, and utilizing research conducted by the Research Transition Teams.

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[15] Pub. L. No. 114-190.

NASA's Management of its UAS Fleet

NASA Centers maintain a wide variety of UAS ranging in size, complexity, and technical capabilities to support the Agency's aeronautics and science research goals and day-to-day operations.[16] For example, the Hexacopter shown in Figure 2 is located at Johnson Space Center (Johnson) and is used for aerial photography and building inspections. The handmade Prandtl-M shown in Figure 2 is located at Armstrong, has a wingspan of 3 feet, and is designed for possible use on Mars to collect high-resolution topographic images to help identify potential future landing sites.

Figure 2: Examples of NASA Aerial Drones

Hexacopter

Prandtl-M

Source: NASA.

Armstrong also maintains several of NASA's largest UAS – the Global Hawks and the Ikhana (see Figure 3).[17] The sophisticated Global Hawk, with a wingspan of more than 116 feet, is capable of high-altitude, long-duration Earth science missions to monitor remote Earth locations not practical with piloted aircraft. The Ikhana, with a wingspan of 66 feet, supports Earth science missions and advanced aeronautical technology development. Additionally, NASA uses the Ikhana as a test bed for developing capabilities and technologies to improve the utility of UAS.

[16] NASA has unmanned aircraft systems at Ames, Armstrong, Glenn Research Center, Goddard Space Flight Center at the Wallops Flight Facility, Jet Propulsion Laboratory, Johnson Space Center, Kennedy Space Center, Langley Research Center, and Marshall Space Flight Center.

[17] NASA obtained its five Global Hawks from the U.S. Air Force, and the vehicles have an 8,500-nautical-mile range and can remain airborne for up to 24 hours. NASA purchased the Ikhana in 2006 from the manufacturer, General Atomics Aeronautical Systems, Inc. The vehicle can fly above 40,000 feet on flights lasting more than 20 hours.

Figure 3: Global Hawk and Ikhana

Source: NASA.

As programs explore more cost effective and efficient means to conduct research, the use of UAS technology is proliferating within NASA. For example, Ames recently sent eight aerial drones to Hawaii to measure volcanic plume activity; Kennedy Space Center (Kennedy) uses unmanned aircraft for facility surveillance, operational photography, security operations, and pre- and post-rocket launch operations; and several Centers utilize UAS in support of UAS-NAS and UTM testing. NASA's use of UAS is expected to increase in future years as scientists identify new applications and science missions that lend themselves to this technology.

Aviation Asset Management

The Logistics Management Division of the Office of Strategic Infrastructure at NASA Headquarters is responsible for developing policy and procedures for the acquisition, management, identification, and use of NASA-owned equipment and property, including aerial drones.[18] Keeping accurate information on the Agency's aerial drones is important to maintaining financial accountability and reusability of the assets. To track equipment and help ensure accountability, Agency policy requires use of the NASA Integrated Asset Management Property, Plant, and Equipment System. In April 2015, the Logistics Management Division designated all Agency unmanned aircraft – regardless of size, flight range, or acquisition cost – as "sensitive equipment" that require enhanced control and accountability.

The Office of Strategic Infrastructure's Aircraft Management Division manages NASA's aviation resources, including UAS. The Division is responsible for ensuring safety standards are met; aircraft resources are available; and the Agency's policies for acquisition, use, and disposal of aircraft meet Federal and NASA regulations. This includes reporting to the General Services Administration the acquisition of all aircraft that exceed the Agency's asset capitalization threshold of $500,000.[19]

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[18] NASA Procedural Requirements (NPR) 4200.1H, "NASA Equipment Management Procedural Requirements," March 8, 2017.

[19] NPR 9250.1C, "Property, Plant, and Equipment and Operating Materials and Supplies," October 29, 2015, prescribes the policy for reporting property, plant, and equipment. NASA's capitalization threshold increased from $100,000 to $500,000 in November 2015.

Aviation assets are considered Agency-wide resources available to support all NASA programs and missions. Where practical, NASA seeks to use aircraft, including UAS, that can support multiple mission requirements; therefore, NASA policy promotes cross-Center utilization of aviation assets.[20] Before purchasing UAS and other aircraft assets, Centers are required to evaluate existing equipment and consider leasing, borrowing, or using contractor-owned equipment.

NASA's Aircraft Operations Management Manual outlines the requirements, responsibilities, and procedures for managing the Agency's aircraft resources and flight operations.[21] Under this policy, each Center operating manned aircraft or UAS is required to maintain an independent Flight Operations Office to direct the operations, maintenance, and safety of all Center-assigned or contracted air assets.

In November 2009, the Manual was updated to include requirements for managing UAS. At that time, Agency officials were required to submit an acquisition request to the Office of Strategic Infrastructure for approval prior to acquiring an aerial drone. In March 2015, the Office delegated acquisition approval to Center Directors for UAS below the $500,000 asset threshold.[22]

Aircraft management officials measure the adequacy of controls over aircraft through biennial reviews conducted by the Inter-Center Aircraft Operations Panel.[23] As the use of UAS across the Agency has increased over the last few years, these reviews now include NASA's management of UAS.

NASA's UAS Inventory

As of June 2017, we identified 460 UAS at 9 NASA Centers worth a total of at least $141.5 million. While 98 percent of the Agency's UAS fall below the $500,000 capital asset threshold, 7 aerial drones – 6 at Armstrong and 1 at Ames – are valued above $500,000.[24] The UAS over the half-million dollar threshold are subject to more stringent controls applicable to capitalized assets, including separate identification, funding, and tracking in NASA's accounting system. Management of the remaining 453 UAS is delegated to the Centers.

NASA acquired its UAS fleet through a combination of (1) excess property transfers from other Federal agencies, (2) commercial purchases, and (3) in-house builds. Although the acquisition value of NASA's UAS assets totals more than $141.5 million, NASA obtained $125 million of the assets from other agencies at no cost. In addition, NASA spent approximately $16.7 million on commercial UAS purchases and $226,180 on in-house builds. Figure 4 shows the location and acquisition method of NASA's UAS assets.

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[20] NASA Policy Directive 7900.4D, "NASA Aircraft Operations Management," July 7, 2014.

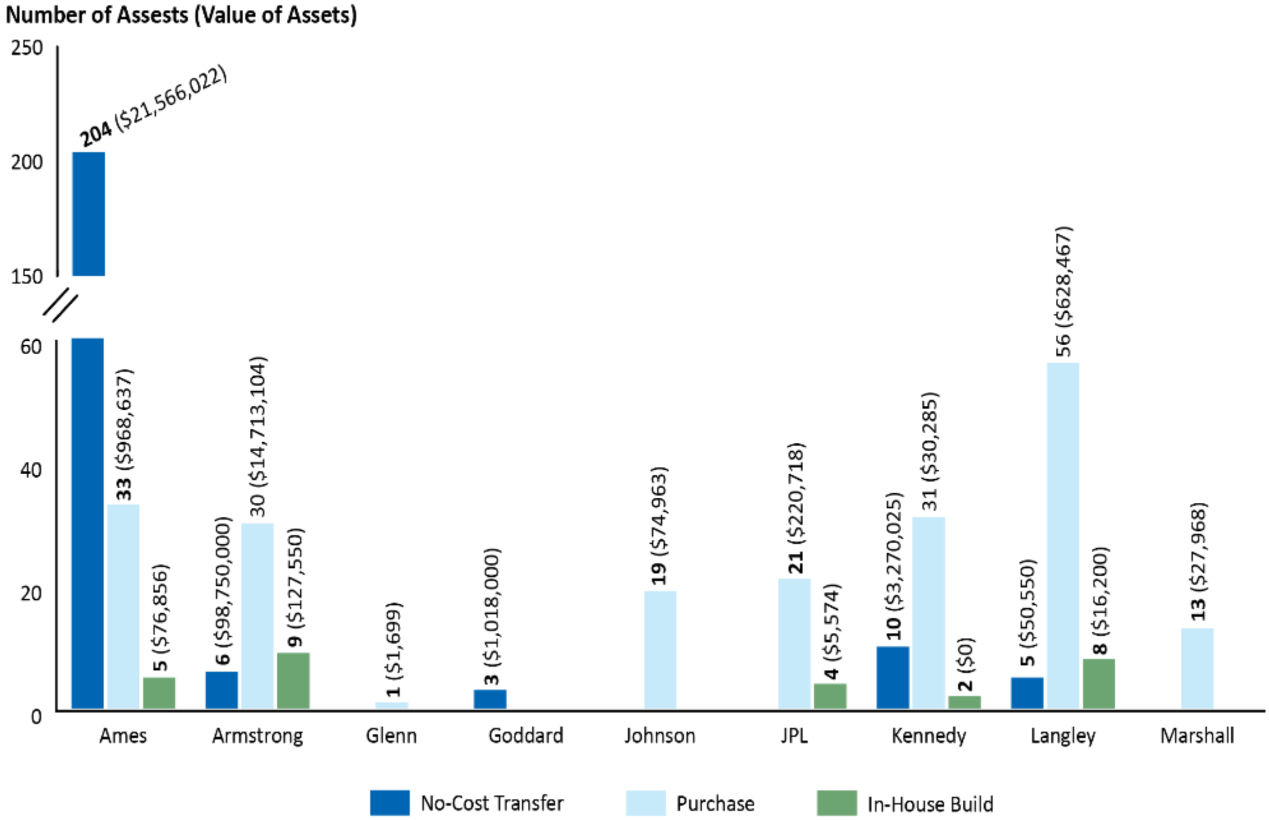
[21] NPR 7900.3D, "Aircraft Operations Management Manual," May 1, 2017. Prior to the popularity of UAS, the manual was written specifically for manned aircraft. Chapter 5, "Unmanned Aircraft Systems Operations," was later added to address the increasing use of UAS.

[22] NASA's Office of Strategic Infrastructure maintains the acquisition approval authority for UAS over the capitalization threshold.

[23] The Inter-Center Aircraft Operations Panel advises the Assistant Administrator for the Office of Strategic Infrastructure regarding operational, management, and safety policies for NASA aircraft. Each Panel is chaired by a Center Chief of Flight Operations and includes personnel from NASA Centers tasked with reviewing Center aircraft operations, airfield facilities and services, and aircraft management processes.

[24] Asset values could not be accurately determined for every UAS we reviewed. For example, NASA had 78 UAS with a combined value of at least $2.1 million that were being excessed. In addition, the value of at least 16 other aerial drones could not be determined.

Figure 4: NASA's UAS Inventory in Number of Assets and Value



Source: NASA OIG.

Note: Headquarters did not report and the NASA OIG did not identify any UAS inventory at the Stennis Space Center. Glenn Research Center (Glenn), Goddard Space Flight Center (Goddard), Jet Propulsion Laboratory (JPL), Langley Research Center (Langley), and Marshall Space Flight Center (Marshall).

NASA RESEARCH CONTRIBUTING TO FAA DEVELOPMENT OF STANDARDS AND AN AIR TRAFFIC MANAGEMENT SYSTEM FOR AERIAL DRONES

To date, NASA's primary aerial drone-related research efforts – the UAS-NAS and UTM Projects – have contributed research into key elements required for developing performance standards and a prototype system to enable UAS operations in the national airspace: data exchange and information architecture, sense and avoidance of manned and unmanned vehicles, and communication and navigation. Further, these research Projects have been managed in compliance with NASA research and technology development policy and have achieved all planned schedule and technical milestones within allocated time and budgets.[25] NASA's success with these research Projects should positively affect the FAA's efforts to integrate aerial drones into the national airspace. Ultimately, private industry will be required to adopt technologies to meet the FAA's yet-to-be-defined performance and safety standards that are being developed and informed by NASA's research.

NASA Technical Objectives for UAS-NAS and UTM Projects Support FAA Requirements

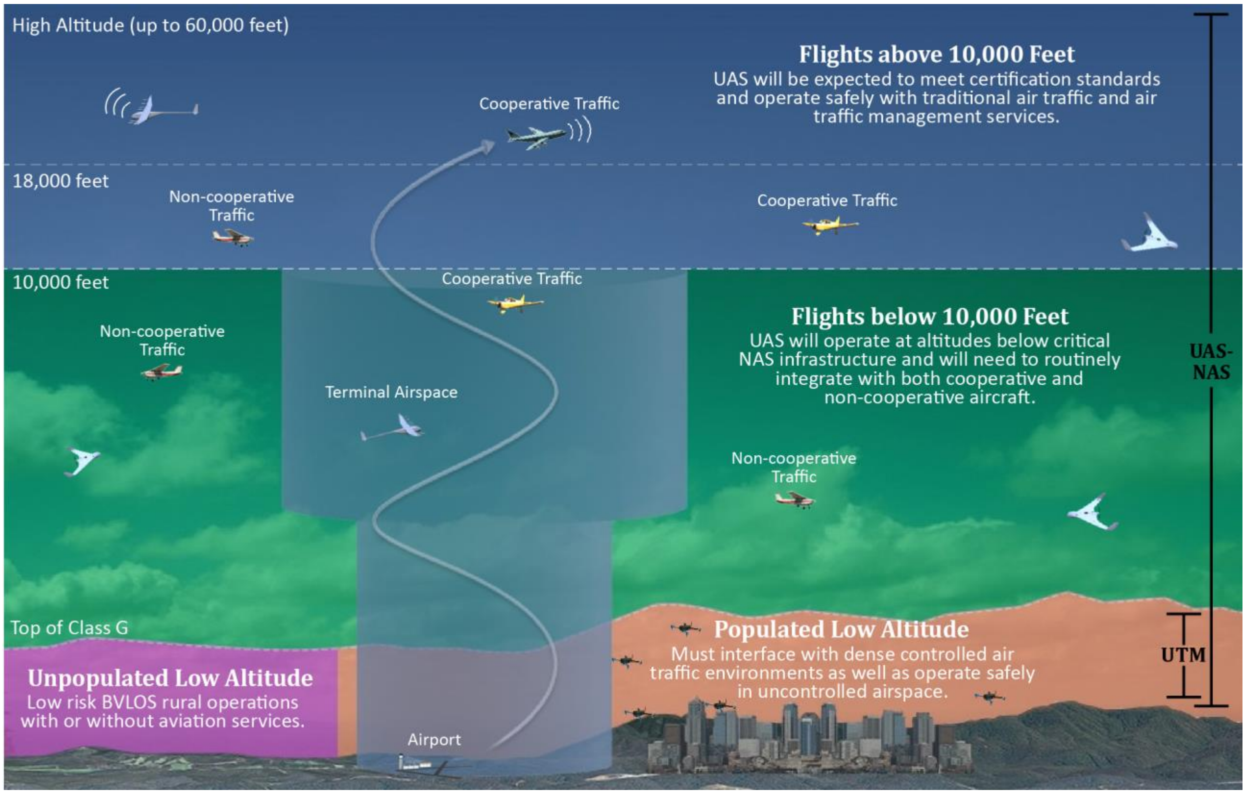
Through an interagency agreement with the FAA, NASA is performing a variety of research to support the FAA's goal of safe, routine UAS flight operations in the national airspace. FAA officials confirmed that NASA's research was useful, relevant, and timely. Through interviews with FAA and NASA officials and review of project documentation, we determined NASA's ongoing research on UAS advanced the FAA's goal of developing standards to ensure the safety and efficiency of UAS operations.

UAS-NAS Project

The UAS-NAS Project is providing critical research to the FAA and RTCA to improve the safety and operation of aerial drones in the national airspace (see Figure 5). Specifically, the Project is testing UAS capabilities to help the FAA develop a set of minimum performance standards – airworthiness, structural design, system reliability, avionics, and maneuverability – needed to enable safe integration of aerial drones into the national airspace. To support these research efforts, the Project is providing the infrastructure for a testing environment that simulates skies filled with air traffic. The test environment is comprised of air traffic control workstations, constructive and virtual aircraft simulators, UAS ground control stations, and manned and unmanned aircraft operating together to provide researchers with a relevant airspace environment to test UAS operations.

[25] NPR 7120.8, "NASA's Research and Technology Program and Project Management Requirements," February 5, 2008.

Figure 5: UAS in the National Airspace System



Source: NASA as modified by the NASA OIG.

Note: Beyond visual line of sight (BVLOS).

The goal of the UAS-NAS Project research is to demonstrate solutions to a series of technical challenges faced by aerial drones critical to their operating safely in the national airspace. These challenges are listed in the Project Plan as Detect and Avoid and Command and Control. We describe each challenge below.

Detect and Avoid

Detect and Avoid technologies enable UAS to maintain communication, navigation, and surveillance capabilities required to detect and avoid other manned and unmanned air traffic.[26] The UAS-NAS Project intends to recommend minimum detect and avoid performance standards for all aerial drones and test these standards by assessing UAS performance during a variety of aircraft encounter scenarios.

Command and Control

The Command and Control challenge entails developing commercially viable satellite and terrestrial technologies to maintain communication and control of aerial drones. The system is needed to ensure UAS have adequate communication, navigation, and surveillance capabilities. The UAS-NAS Project is developing a communication system prototype that will use a dedicated frequency of the radio spectrum to maintain communication with aerial drones and meet proposed international and national standards.

[26] Instrument flight rule operations are rules and regulations developed by the FAA that govern flight under conditions in which relying on visual reference is unsafe; therefore, such flights depend on navigation using electronic signals.

As the UAS-NAS Project works to develop effective Detect and Avoid and Command and Control technologies, it is also focusing on system integration and operationalization of these technologies. Specifically, the Project is developing ground station displays, controls, and procedures for UAS operations in the national airspace. Test flights of aerial drones help inform development of FAA policy to regulate UAS communication, navigation, and surveillance capabilities consistent with existing standards for manned aircraft. The goal is to obtain FAA's approval to demonstrate these integrated technologies on an unmanned aircraft in a realistic air traffic control environment.

UTM Project

NASA and the FAA are collaborating on research with the goal of enabling small UAS to operate in FAA-uncontrolled, low-altitude airspace. As private industry develops additional drone capabilities, these civilian UAS will need to ensure they can fly without a "hands-on" operator by using maps or GPS for navigation and sensors to avoid air- or land-based obstacles. Although most current UAS do not have radar-based detect and avoid technology, future aerial drones will likely use onboard systems to maneuver around manned and unmanned traffic, hazardous weather, terrain, and man-made and natural obstacles. For example, deliveries from Amazon and other commercial UAS operators will need to operate safely in close proximity to buildings, telephone wires, and other ground-based structures in low-altitude airspace and manned aircraft while operating in FAA-controlled, higher-altitude airspace (see Figure 6).

Figure 6: Unmanned Air Traffic Management (Theoretical)

Source: NASA.

The FAA's current Concept of Operations seeks to enable various types of aerial drones over time to operate in the national airspace in incremental steps as the responsibilities of the key players – UAS operators, data providers (terrain, weather, surveillance, and performance information), the UAS service supplier network (the conduit that connects national airspace systems and provides directives and operational constraints to UAS operators), and the FAA – continue to evolve. Furthermore, the Concept of Operations does not require a human operator to continuously monitor every aerial drone, but instead will allow human operators to use data to make decisions about initiating, continuing, and terminating UAS flights.

The UTM system envisions shared responsibility between the FAA, UAS operators, and UAS service suppliers:

- The *FAA* would be responsible for providing direction for collision-avoidance in the national airspace above uncontrolled airspace. Specifically, the FAA's National Airspace Air Traffic System would maintain operational authority for airspace and traffic operations above uncontrolled airspace involving manned and unmanned aircraft with the authority to terminate UAS flights for safety-related reasons.
- *UAS operators* would share responsibility for assuring the registration, communication, navigation, and surveillance of each vehicle; the training and qualification of UAS operators; and avoidance of other aircraft and ground-based obstacles.
- *UAS service suppliers* would support safe airspace operations by providing real-time data on airspace operations (e.g., operational constraints, modifications, notifications, and other relevant information) through the service supplier network to individual drone operators for route planning and de-confliction within the airspace.

The Concept of Operations has two over-arching philosophies. The first, "flexibility where possible, structure when necessary," gives UAS operators the flexibility to operate as necessary where there is no demand or capacity imbalance. Conversely, when demand exceeds capacity – that is, when multiple aerial drones are operating in the same airspace at the same time – more structure such as corridors, altitude direction, and crossing restrictions will be employed. The Concept's second philosophy, "risk-based airspace requirements," means risks on the ground or in the airspace will determine airspace structure and control. Therefore, risk-based airspace requirements may be different for urban airspace with multiple UAS operators and obstacles compared to rural areas with fewer operators or obstacles.

These two philosophies underlie five operating principles needed to safely enable small UAS to operate in low-altitude airspace:

1. All UAS, operators, and communications are authenticated before use of the airspace.
2. UAS will avoid each other and other objects.
3. UAS will stay separated from manned aviation.
4. All of the constraints, including temporary constraints imposed for public safety operations, are available to all stakeholders for common situational awareness.
5. Access will be fair and efficient.

NASA's UAS Research Projects are Progressing as Designed

NASA's research activities related to both the UAS-NAS and UTM Projects are progressing as planned within allocated cost and schedule resources. As a result of UAS flight tests in realistic operating environments, NASA researchers have made progress in addressing specific technology challenges for each operational environment.

UAS-NAS Project

NASA researchers are providing critical data to stakeholders, primarily the FAA and RTCA, by conducting flight tests of aerial drones in both real and simulated airspace environments that incorporate actual and virtual aircraft to enable the safe, concurrent operation of manned and unmanned aircraft in the national airspace. As of June 2017, the UAS-NAS Project was addressing its technical challenges on schedule and within budget.

Because NASA's research activities contribute to specifying the yet-to-be-defined performance standards for future UAS integration in the national airspace, the UAS-NAS Project does not have quantifiable performance goals as normally required by NASA policy for research and technology development efforts.[27] Rather, the Project manages its performance by addressing the technical challenges and measures its success using individualized progress indicators. These indicators track all major Project activities, including activity start and end dates, technology transfer, status and health, and maturity of the data and information required to overcome each challenge. For example, the progress indicator for the Command and Control technical challenge shows that the Project's delivery of research findings in July 2016 met RTCA's requirements. We reviewed the progress indicators for each technical challenge and found that the UAS-NAS Project had completed or was on track to complete on schedule the technical transfer of research data to RTCA.

In June 2016, NASA researchers conducted the fourth in a series of flight tests at Armstrong consisting of 19 flights over a 9-week period involving more than 260 scripted encounters between the Ikhana and manned "intruder" aircraft. The flights tested Detect and Avoid algorithms developed by NASA and industry partners that, for the first time, could successfully generate alerts necessary for the pilot controlling the Ikhana drone from the ground to avoid collisions. Since testing included the flight of unmanned aircraft that cannot presently fly in the national airspace without restrictions and waivers from the FAA, the UAS-NAS Project developed a simulation and flight test environment that combines live, virtual, and constructive (or background) air traffic scenarios (see Figure 7). This environment allows Project researchers to incorporate real and simulated manned and unmanned aircraft in a virtual airspace to test concepts, technologies, and procedures intended to facilitate safely flying both manned and unmanned aircraft concurrently in the same airspace.

[27] NPR 7120.8.

Figure 7: UAS-NAS Project Simulation Testing

Source: NASA.

In January 2017, the UAS-NAS Project provided research findings on Detect and Avoid and Command and Control technologies to the FAA and RTCA. The research focused on terrestrial communications (UAS-to-ground). One aspect of these research efforts was a series of simulations and integrated flight tests using Ikhana equipped with radar, Automatic Dependent Surveillance-Broadcast, and the Traffic Alert and Collision Avoidance System to detect and resolve conflicts with nearby air traffic.[28]

UTM Project

NASA's UTM Project seeks to develop an air traffic control system to enable small UAS access to low-altitude airspace in a safe and efficient manner. NASA's efforts are being managed in four stages called Technology Capability Levels (TCL), each of which builds upon proven capabilities from the preceding stages.

- *TCL 1* involved field-testing rural UAS operations for agriculture, firefighting, and infrastructure monitoring.
- *TCL 2* demonstrated applications that operate beyond visual line of sight of the operator in sparsely populated areas. The system will provide flight procedures and traffic rules for longer-range applications.

[28] The Automatic Dependent Surveillance-Broadcast uses GPS technology to share precise aircraft location information. The Traffic and Collision Avoidance System – internationally known as the Airborne Collision Avoidance System – is a federally mandated device that functions independently of the ground-based Air Traffic Control System to provide collision avoidance protection for aircraft by providing collision threat alerts and traffic display.

- *TCL 3* will include capabilities for tracking cooperative and uncooperative (unauthenticated or uncontrolled) UAS to ensure safety of manned and unmanned operations over moderately populated areas.
- *TCL 4* will involve higher-density urban areas for aerial drones used for news gathering and package delivery.

TCL 1 concluded in April 2016 and focused on visual-line-of-sight operations in rural locations where the interaction with other unmanned aircraft, manned aircraft, structures, and people is low. During the 3-hour testing window, more than 100 NASA and commercial UAS conducted continuous flight testing and completed 67 simulated operations.[29] Based on the results of the TCL 1 testing, researchers met the planned goals and personnel from the six FAA-selected national test sites gained practical experience with the UTM concept.[30]

NASA began TCL 2 testing at the Reno-Stead Airport in Nevada in October 2016 using 11 aerial drones, which the audit team observed.[31] The flight test scenarios included simultaneous operation of multiple UAS at varying altitudes, introduction of an intruder aircraft, a simulated critical emergency (earthquake scenario) that included public safety and security operations, re-routing of a flight while the aircraft was aloft, and secondary conflicts resulting from contingency actions taken in response to emergency scenarios. For example, TCL 2 capabilities were tested when an unplanned intruder fixed-wing aircraft entered the test airspace. All of the aerial drones aloft during the test reacted as planned and immediately descended to ground level.

Simultaneous beyond-visual-line-of-sight and visual-line-of-sight operations increase operational complexity and risk by creating potential airborne hazards. NASA researchers are working to overcome the technological challenges inherent with multiple aerial drones flying simultaneously beyond line of sight of operators. These challenges include the inability to assure safe separation from other aircraft; management of communications, surveillance, and navigation links; and contingency management in atypical conditions (e.g., lost communication link). For example, based on the UTM Project's research findings, multiple-altitude, high-density UAS operations conducted in close proximity to other aircraft are not recommended until both on-board collision avoidance technology capabilities and improved weather information are available.

Based on the Reno tests, researchers and flight crews identified several issues expected to impact future research and industry standards. For example, it will be necessary for manned and unmanned aircraft to employ either the same or comparable altitude measurement reference (e.g., barometric altimeter setting or flight-above-ground-level measurement) to ensure safe vertical separation of intersecting

29 UTM research requires multiple live tests as well as computer simulated test flights. While the live tests demonstrate certain functionalities and approaches to meeting test requirements, the tests are costly and raise safety issues. Consequently, the research platform allows data from simulated flights to be combined with live flight data. This type of testing environment enables researchers to evaluate system capabilities that would not be practical to test in a live setting, such as high-density operations with vehicles in close proximity to each other.

30 In December 2013, the FAA selected the University of Alaska, the State of Nevada, New York's Griffiss International Airport, North Dakota Department of Commerce, Texas A&M University – Corpus Christi, and Virginia Polytechnic Institute and State University from 25 submissions for UAS test site operators who will assist with research and operational experiences to help ensure the safe integration of UAS into the national airspace.

31 The UTM Project continued TCL 2 testing through June 2017.

flight paths. However, the overall conclusion from the Reno flight tests confirmed that a traffic management system could manage TCL 2-level aerial drone operations if the following changes were implemented:

- Each UAS operator would display their respective airspace information to the UTM system via their UAS or ground control station connection, thereby providing all drone operators access to information from other nearby aircraft.
- Altitude reporting for each UAS would be consistent and comparable, and weather information should be augmented with reports from individual UAS and ground stations and shared with all UAS operators in the airspace.
- Initially, routine beyond-visual–line-of-sight and vertical-simultaneous UAS operations are not recommended in close proximity to other aircraft without a common altitude reference measurement and until weather information is improved and on-board collision avoidance technology becomes available.
- Planned UAS flight trajectories should be contained within a defined airspace and programmed into the UTM system to obtain pre-flight authorization to conduct the flight. Future UAS operators may be required to file flight plans with the UTM system and stay within specified geographical boundaries. Therefore, UTM system data needs to be consistent with the ground stations and UAS to enforce the boundaries.

UTM Project officials said technical risks, rather than cost or schedule, are the most significant risks to NASA's efforts of developing a prototype UTM system. Specifically, the technical risks include UAS-to-UAS and UAS-to-ground communication systems and UAS navigation systems reliability and redundancy, on-board UAS detection and avoidance capability to include corresponding collision avoidance rules, data exchange and information systems architecture and design, and overall technology-based risk that corresponds to the need to miniaturize UAS technology due to payload weight constraints. As of June 2017, the Project had adequate funding to undertake the planned research efforts and approximately 1 year of schedule flexibility.

TCL 3 is planned for January 2018, and NASA anticipates TCL 4 – NASA's final research engagement under the UTM Project – to take place in October 2019.

Future Research Goals and Challenges for UAS-NAS and UTM Projects

Through at least 2020, NASA will continue to conduct testing and provide research to demonstrate the capabilities needed to help the FAA define minimum operational performance standards for UAS integration into controlled and uncontrolled airspaces.

UAS-NAS Project

For fiscal years 2017 to 2020, the UAS-NAS Project is budgeted to receive a total $132.4 million, or about $33 million per year. As the Project enters Phase 2, NASA will conduct additional testing to help the FAA develop Detect and Avoid and Command and Control performance standards. The goal of NASA's research is to help the FAA develop performance standards for a broader range of civilian UAS, specifically those using communications capable of safely operating in Class D, E, and G airspace.

Similar to Phase 1, the research will involve Ikhana flight tests that evaluate key algorithms and include two "intruder" aircraft to test collision avoidance capabilities of aerial drones. Additionally, the flights will include more complex flight patterns that test the aircraft's Traffic Alert, Detect and Avoid, Command and Control, and Collision Avoidance System interoperability.

Detect and Avoid

The UAS-NAS Project's approach for meeting the Detect and Avoid technical challenge involves modeling and simulation, validation of technologies to set performance standard requirements, and modification of national and international standards for safe operation of UAS. NASA researchers on the Project intend to assist the FAA and RTCA in developing these performance standards.

Command and Control

In coordination with the FAA and RTCA, the UAS-NAS Project intends to develop a "white paper" concept for the FAA to use when defining initial Command and Control requirements. In addition, the Project plans to solicit help from private industry to develop radio communication technologies and perform an assessment of satellite-based communications. Lastly, NASA researchers intend to address system integration and operationalization by leveraging Phase 1 developments for Detect and Avoid and Command and Control technologies. Ultimately the goal is to obtain approval from the FAA to permit aerial drones equipped with the Detect and Avoid system in the national airspace with as few restrictions as possible.

UTM Project

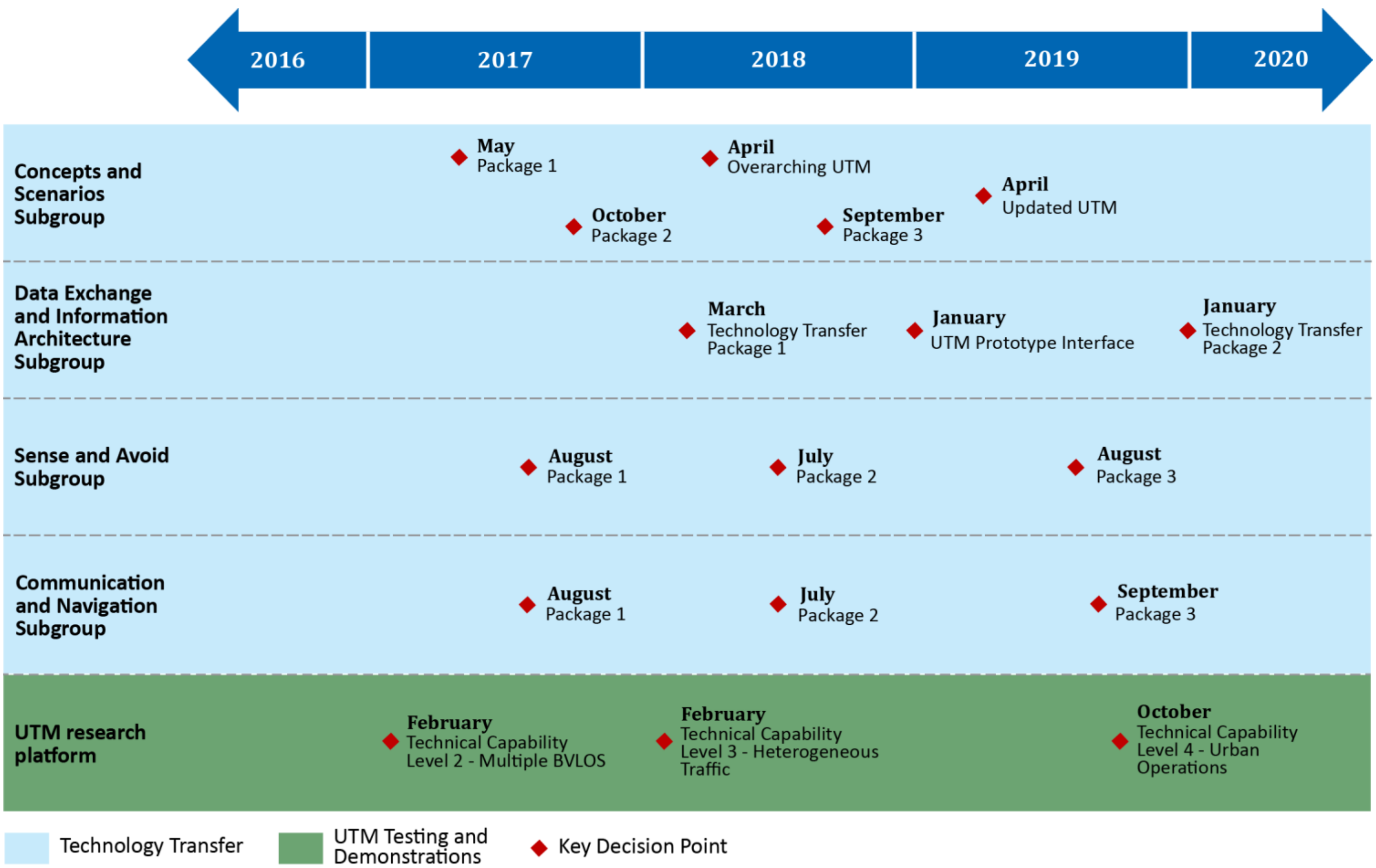
NASA began UTM flight validation testing in August 2015, and as of May 2017, researchers have completed one level of testing and intend to complete the remaining three by the end of 2019. NASA, in collaboration with the FAA, has divided the planned UTM research into four subgroups – Concepts and Scenarios, Data Exchange and Information Architecture, Sense and Avoid, and Communications and Navigation.

- The *Concepts and Scenarios* subgroup is tasked with ensuring consistent messaging of a coordinated FAA and NASA view of UTM, guiding the efforts of the other UTM research transition team working groups, and supporting the development of the UTM pilot program. The subgroup expects to focus on scenarios to test capabilities – called use cases – such as one developed for TCL 2 flight validation involving a lost hiker that UAS operators had to locate. In addition, they will develop a plan to allocate resources for different aspects of UTM operations including the roles and responsibilities of the FAA, UAS operators, and manned aircraft operators.
- The *Data Exchange and Information Architecture* subgroup is tasked with researching and developing technical capabilities for the data exchange needed to support UAS operations in the national airspace. Specifically, the subgroup is expected to identify gaps in proposed data exchange associated with the UTM concept needed to support safe UAS operations. Any information gaps identified would be analyzed to help develop architecture requirements, recommended updates to data standards, and technical documentation to support technology transfer to stakeholders.

- The *Sense and Avoid* subgroup plans to explore operator solutions to ensure that UAS do not collide with other manned or unmanned aircraft. In collaboration with the Communications and Navigation subgroup, they expect to analyze the effectiveness of sharing established flight route information with active avoidance capabilities. The subgroup also intends to explore the balance between an aerial drone's sensing and detecting capability and its maneuverability to avoid collisions.
- The *Communications and Navigation* subgroup will explore solutions to ensure that UAS are under a pilot's operational control – to the extent required by the test scenario – and remain in the defined area of operation.

As shown in Figure 8, each research subgroup has deadlines to produce a "package" of research data. For example, in August 2019 the Sense and Avoid subgroup is expected to present its findings to the other Research Transition Teams subgroups for possible use in their respective research areas.

Figure 8: UTM Research Timeline



Source: NASA as modified by the NASA OIG.

Note: Beyond visual line of sight (BVLOS).

Outlook on NASA's Research Efforts

Historically, NASA's collaboration with the FAA has been focused on solving knowledge gaps to improve national airspace operations through basic or exploratory research that enables the FAA to implement solutions to specific problems. After receiving NASA's input, FAA researchers conduct applied and operational research to develop operational systems. This approach is consistent with current NextGen research collaboration conducted by NASA and the FAA to modernize the piloted air traffic control system.

Our review found that NASA successfully conducted flight validation testing and initiated a pilot program to produce an operationalized UTM system for FAA implementation. Further, NASA has collaborated effectively with the FAA in a process that will transfer research on technological issues necessary to improve future UAS operations. We believe NASA's research efforts should have an overall positive effect on the FAA's efforts to meet its congressional mandates and implement a safe and workable system of UAS operations.

NASA's future work will include exploratory research into noise reduction involving aerial drones. Research related to human noise intolerance focuses on the characteristics of noise (e.g., pitch, frequency, and proximity) that can irritate or harm individuals. NASA's research is designed to mitigate these noise-related issues, an important challenge to successful UTM implementation that will likely become unavoidable as more powerful aerial drones with larger payloads take to the skies.

Lastly, UAS technology-based capabilities claimed by commercial operators have not been verified by NASA research. Agency researchers expect that the technology required to meet the FAA-developed performance standards needed to integrate UAS into the national airspace will require private industry involvement.

Lack of Adequate Controls Over NASA's Aerial Drones Increases Risk and Reduces Resource Sharing

Poor attention to acquisition policies and lack of proper inventory control over NASA's unmanned aircraft has unnecessarily increased the risks associated with the Agency's rapidly increasing use of UAS. Agency policy written in 2009 and updated in 2015 details procedures for procuring and inventory tracking of UAS. However, ineffective implementation of these policies has led to poor inventory control and unauthorized acquisition of UAS. In addition, inaccurate and incomplete information about UAS in NASA's property system hinders the Agency's ability to effectively share unmanned aircraft assets between Centers.

Failure to Obtain Required Approvals Increases Risk Posture

Center officials are responsible for safe operation of all aircraft – including UAS – assigned to or operating from their Centers. UAS acquisition procedures implemented in November 2009 added controls to require submission of an acquisition request to the Headquarters Aircraft Management Division prior to acquiring any unmanned aircraft. These procedures were updated in March 2015 to increase controls over the approval of UAS below the Agency's capital asset threshold of $500,000 while delegating this responsibility to Center Directors. However, our review of acquisition documentation found that 231 of the 410 (56 percent) UAS acquired since 2009 were obtained without the required prior approvals.

We found the Center Directors did not take effective steps to ensure required approvals were obtained before acquisition of UAS. Specifically, following issuance of the March 2015 policy, Center Directors did not establish an effective process or mechanism to inform end users of the revised requirements for UAS acquisitions. As a result, many aerial drone users were not aware that acquisition of unmanned aircraft required advance approval.

Aircraft Management Division personnel told us they held a web information session, established web information pages, and collaborated informally with Center Flight Operations Chiefs to publicize the policy. Despite this, technical officials at multiple Centers told us they were unaware of the policy or they did not realize the policy applied to them, particularly officials who built vehicles in-house or acquired vehicles for non-research purposes such as wind tunnel testing. For example, several Ames personnel said they did not think pre-authorization was required for UAS acquired specifically for use indoors or in a laboratory. In another case, NASA Office of Inspector General staff had UAS assets transferred from Marshall Space Flight Center (Marshall) to Johnson in order to test possible operational use without knowledge of approval and operational use requirements.

In several instances, we questioned expenditures associated with acquiring UAS assets without prior approval. For example, both Glenn Research Center (Glenn) and Marshall personnel purchased UAS assets – one costing $1,699 and two others at a total cost of $2,377 – in June and August 2015 without required Center Director approvals and as of June 2017 had never flown the vehicles due to the Center's inability to meet Agency unmanned vehicle flight requirements. In total, we identified more than $17,000 spent on UAS that should not have been acquired. (See further discussion and complete listing in Appendix B.)

Headquarters Aircraft Management officials confirmed that the approval requirement applies to any method in which UAS are acquired, including transfers from other agencies, commercial purchases, and in-house builds. Further, according to these officials, the policy does not distinguish between UAS designated as lab-only or outdoor flight assets, and as such, all UAS acquired after November 2009 require prior approval.

The importance of establishing controls over its UAS inventory was also raised during the most recent Inter-Center Aircraft Operations Panel conducted at Langley Research Center (Langley) in June 2016. The Panel emphasized that managing the control and proliferation of UAS at NASA requires adherence to the pre-approval process. Specifically, the Panel stressed the importance of Center management's role in ensuring compliance with Federal policies by only acquiring UAS to meet mission requirements and not exceeding the number of assets needed for proposed missions.

Confusion over the applicability of Agency policy coupled with the fact that Centers acquired more than 50 percent of their UAS without prior approval illustrates that the requirement has not been well communicated or implemented effectively. We spoke with Center aviation officials who noted there may be additional UAS assets used by organizations at their Centers of which they have no knowledge. For example, while the Johnson Aircraft Operations Division manages the UAS fleet at Johnson and nearby Ellington Field, Division personnel were unaware that the Center's Engineering Directorate acquired two aerial drones for robotics development research.

Failure to obtain required approvals can result in the unauthorized use of unmanned aircraft for NASA programs and research. In addition, without an accurate inventory of these vehicles, aviation officials and Center Directors cannot ensure that required safety standards are met for their operation, increasing NASA's risk if an unauthorized UAS causes damage to facilities or personal injury.

NASA's Ability to Share UAS Resources Hindered by Incomplete and Unreliable Inventory

Centers do not record and properly track all UAS in NASA's property control system. Both aviation and logistics officials told us they are not confident that a complete listing of the Agency's fleet of UAS are included in the property system as required. As a result, potential users may meet mission requirements by acquiring new UAS rather than utilizing existing assets, wasting NASA resources. Additionally, improper tracking of UAS increases the risk of loss or theft.

Equipment Control Numbers Not Obtained

NASA's property regulations identify UAS as a sensitive asset requiring "exceptional physical security, protection, control, and accountability due to sensitive but unclassified and privacy protection, national security and export control regulations. These items can be pilferable or potentially dangerous to the public."[32] NASA requires controlled assets like UAS be marked with an Equipment Control Number barcode and entered into the NASA property system within 3 days of receipt. However, we found almost 50 of 460 UAS did not have the required barcode and over 130 additional aircraft had requests pending for barcodes (requested after announcement of our audit) despite being in NASA's inventory for years.

Some of the missing barcodes were found on unmanned aerial vehicle manuals, cases, notebooks, or Center inventory records. In other cases, we were told physical barcodes were not used because the Centers are moving toward virtual tagging.[33] However, Logistics Management Officials at Headquarters indicated UAS do not meet the requirements for virtual tagging, and therefore, unless the size of the UAS prohibits affixing a barcode, all UAS should contain a barcode. Flying vehicles without identifiable barcodes compounds inventory tracking issues and can increase liability if the asset causes damage or personal injury.

Center Officials Not Excessing Unused UAS in a Timely Manner

Based on information obtained during our Center visits, we determined NASA had a total of 460 UAS, including unused assets either intended for future use, deemed not flyable because they were broken or obsolete, or for which they had no future use. In addition, several Centers – including Ames, Glenn, Johnson, Kennedy, and Marshall – had usable assets they were expecting to excess as well as new unused assets potentially usable by other Centers or projects. Finally, several Centers maintained inactive assets that under Agency and Government rules should be excessed.[34]

In addition, several Centers had more UAS than they currently needed. For example, just prior to our January 2017 site visit to Ames, officials excessed 62 Dragon Eye UAS.[35] Ames officials were also planning to excess approximately 100 Raven UAS after receiving an interagency transfer from the Department of the Interior that included 27 unmanned systems and 35 cases of spare parts, equating to approximately 120 Ravens even though only 20 were expected (Figure 9).[36] Given what we found during our site visits, Center officials are not routinely excessing unneeded assets in a timely manner and therefore the assets are not available to other potential UAS users either within NASA or outside the Agency through the General Services Administration's excess property system known as GSAXcess.[37] Moreover, NASA has no easy way for its Aircraft Management Division to alert Center officials of available assets before they are entered into GSAXcess.

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[32] NPR 4200.1H.

[33] NPR 4200.1H states that virtual tagging is done by exception and only on equipment items that cannot be physically tagged due to form, fit, or function.

[34] NPR 7900.3D states that owners shall disposition inactive aircraft within 5 years to reduce the Agency's infrastructure footprint and associated logistics support burden.

[35] A Dragon Eye is a 5-pound, modular UAS used primarily for local remote sensing.

[36] A Raven is a hand-launched, 4-pound UAS originally designed for surveillance and reconnaissance.

[37] GSAXcess is web-based site for Federal agencies to report excess property for transfer by the General Service Administration to other Federal and state agencies.

Figure 9: Display Model Dragon Eye and Raven UAS Fuselages at Ames

Source: NASA OIG.

Policy on Spare Parts Has Not Been Developed

During our review, we found several Centers maintained a large amount of spare parts for aerial drones – in some cases, enough to build multiple additional UAS vehicles. NASA has not developed a consistent policy for distinguishing what constitutes a UAS or how to account for spare parts that could potentially be used to construct a UAS. Additionally, we found little consistency among Centers as to the number of UAS spare parts kept on hand. For example, an official at Kennedy indicated the Center has an unwritten understanding that if an end user can take a frame and add a motor, propellers, and any other needed parts to make it flyable in a day they should consider that a UAS. If it took longer than a day to fabricate, it was considered parts. Without a clearly communicated NASA policy, the potential exists for additional UAS to be built using spare parts yet remain unaccounted for in the Agency's property system.

UAS Cost Information Unreliable

We found that the value of UAS assets was not accurately accounted for in NASA's property system, Aircraft Management Division's records, or Center records. For example, we were unable to obtain adequate, or in some cases any valuation support for UAS at six Centers. In other cases, values for some aerial drones in the NASA property system did not match values on letters of transfer or purchase documents we reviewed. For example, Kennedy took possession of 10 UAS from the Department of Defense, but documentation only supported transfer of 5 assets, each valued at $437,670. Rather than assigning the other 5 the same value, the total was divided among the 10 assets and each was valued at $216,335, effectively undervaluing the assets and creating inaccurate records. In another example, acquisition values were not properly captured in Langley's property system with UAS values both over- and understated. For one Langley asset, the Aircraft Management Division's records showed the acquisition value as $3,350 while the documentation supported $2,753. For another asset, the Division's records captured the asset value at $17,045 while the documentation supported $19,421.

We also found end users were unclear as to which costs, such as controllers and batteries, should be included when valuing a UAS asset's cost. Finally, in most cases we were unable to identify any values for assets built in-house even though these UAS met NASA's criteria for controlled equipment.

Improved Records Management Needed

We found that Centers did not have strong procedures for identifying which UAS vehicles were authorized under which approval letter. In some cases, the Center Director approved future purchases up to a certain number of UAS; however, we were unable to trace which assets were purchased under those authorizations. For example, although Kennedy has an internal checklist to ensure proper procedures are followed and approvals obtained before acquisition of aerial drones, the Center does not associate specific assets against specific approvals. In one instance, the Kennedy Center Director signed a blanket approval for purchase of up to 10 UAS. At the time of our review, we were told the Center had purchased six assets under this approval – although some were purchased prior to receiving the signed approval – but it was unclear which six UAS were purchased against the approval. Therefore, it is possible that additional assets above the 10 authorized may be purchased under the authorization.

CONCLUSION

NASA is effectively supporting the FAA's efforts to introduce civil aerial drones into the national airspace. With a forthcoming explosion in the use of aerial drones by hobbyists, private companies, the government, and military, NASA is working with the FAA to develop an air traffic management system to ensure these newest entrants in the airspace do not collide with buildings, larger aircraft, or one another. Our review shows that NASA is contributing to the research and development of UAS-NAS performance standards and a UTM system prototype. Moreover, we found that NASA's research efforts should have an overall positive effect on the FAA's efforts to meet its congressional mandates and to implement an operationalized UAS system.

However, NASA's oversight of its own UAS assets needs improvement. Many aerial drone users are unaware of Agency policy requiring prior approval when acquiring UAS, which increases the Agency's risk and at times has resulted in unnecessary expenditure of funds. In addition, information on UAS assets is not being entered in NASA's property system – including acquisition costs – and therefore is not tracked as inventory. Furthermore, failure to include all aerial drones in the Agency's property system renders them invisible and unavailable for use by other projects or Centers. Consequently, policy and procedural improvements are needed to control and mitigate associated safety and inventory control risks.

Recommendations, Management's Response, and Our Evaluation

To increase transparency, accountability, and oversight of NASA's UAS inventory, we recommended the Assistant Administrator for Strategic Infrastructure direct the Aircraft Management and Logistics Management Division Directors to do the following:

1. Ensure that Center Directors have developed an effective process to routinely inform all potential NASA end users of the acquisition and approval procedures and logistics requirements required before obtaining UAS.
2. Create or incorporate into existing policy criteria for defining the UAS subject to acquisition and tracking requirements, distinguishing an aerial drone from a collection of spare parts, and the criteria Centers should use for determining the number of UAS spare parts to maintain.
3. Create a checklist for Center personnel covering all acquisition and approval processes, logistics requirements, and cost accounting data to ensure proper acquisition procedures are followed regarding the transfer, purchase, or in-house build of UAS below the capitalization asset threshold.
4. Reinforce the requirement that Centers obtain Equipment Control Numbers for all UAS assets regardless of use, size, or cost; properly affix the Equipment Control Numbers to the asset; and maintain the assets in secure locations.
5. Require Centers to identify unneeded UAS or aerial drones unused for more than 5 years and dispose of them properly or identify a reason they should be maintained.
6. Work with Center aviation management offices to implement records management procedures to ensure that once approval has been received to obtain a UAS – either through transfer, purchase, or in-house build – all supporting documentation is filed together or cross-referenced for ease of identification and references the granted approval document.

We provided a draft of this report to NASA management, who concurred or partially concurred with each of the recommendations and described actions the Agency plans to take to address them. We consider management's comments responsive; therefore, the recommendations are resolved and will be closed upon completion of the proposed actions and verification of corrective action plans.

Management's comments are reproduced in Appendix C. Technical comments provided by management have also been incorporated, as appropriate.

Major contributors to this report include Ray Tolomeo, Science and Aeronautics Research Director; Diane Choma, Project Manager; Theresa Becker; Scott Collins; Greg Lokey; and Sarah McGrath.

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

Paul K. Martin
Inspector General

APPENDIX A: SCOPE AND METHODOLOGY

We performed this audit from September 2016 through August 2017 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

To conduct the audit, we held a series of interviews with representatives from the FAA and the Government Accountability Office concerning their completed, ongoing, and future work related to UAS and NASA's role in their development. We also spoke with staff from the FAA's Center of Excellence to determine research status on collision testing. We held discussions with Headquarters, Center, and project management representatives for UAS-NAS, UTM, and the Safe Efficient Crew Autonomy Teaming Project to determine project goals and objectives, milestones, and budgets, and reviewed key NASA and FAA project management and performance standards documents.[38] We attended the October 2016 TCL 2 Flight Validation test in Reno, Nevada, and the 2nd Annual UTM Convention in Syracuse, New York. We interviewed NASA members on key research teams and reviewed flight validation test results.

To conduct inventory reviews at the Centers, we utilized resident NASA Office of Inspector General staff at each Center who verified UAS inventory records as provided by the Aircraft Management Division and identified any other assets not on the inventory list. We obtained purchase records and transfer documentation to confirm values, Headquarters or Center Director approvals, and with the end users physically inspected the assets.

Use of Computer-Processed Data

We used computer-processed data to complete our audit, as provided by NASA's Aeronautics Research Mission Directorate, Aircraft Management Division, Logistics Management Division, and the Centers. Specifically, we obtained data related to the budgets for the UAS-NAS Project for fiscal years 2011 through 2017 and for the UTM Project for fiscal years 2015 through 2020. Additionally, we used computer-processed data as provided by the Headquarters Aircraft Management Division to identify a preliminary universe and value of UAS across the Agency. The universe data obtained from the Agency was incomplete and specifically did not include any assets at Jet Propulsion Laboratory. We attempted to verify and update this information during our site visits to conduct UAS inventory at the various Centers. We also obtained inventory records from some Centers that identified assets they were managing. However, we are still uncertain that all assets were identified considering local aircraft operations offices also were not aware of all UAS at their respective Centers. As for the dollar value of the assets, documentation was not available for all UAS in our sample, and we had to ultimately utilize either the estimate suggested by the Center or the value originally provided by Headquarters.

[38] Audit work related to the Safe Efficient Crew Autonomy Teaming project was curtailed due to a restructuring of the Airspace Operations and Safety Program.

Review of Internal Controls

We performed an assessment of internal controls associated with NASA's research, operation, approval, and accounting of UAS. Throughout the audit, we reviewed controls associated with the audit objectives and determined that NASA's internal controls need improvement in the area of UAS inventory management. The control weaknesses we identified are discussed in the report. Our recommendations, if implemented, should correct the identified control weaknesses. We specifically reviewed the following documentation:

- NASA Policy Directive 7900.4D, "NASA Aircraft Operations Management," July 7, 2014
- NASA Procedural Requirements (NPR) 4200.1G, "NASA Equipment Management Procedural Requirements," March 30, 2010
- NPR 4200.1H, "NASA Equipment Management Procedural Requirements," March 8, 2017
- NPR 7120.8, "NASA Research and Technology Program and Project Management Requirements," February 5, 2008
- NPR 7900.3C, "Aircraft Operations Management Manual," July 15, 2011
- NPR 7900.3D, "Aircraft Operations Management Manual," May 1, 2017
- NPR 9250.1C, "Property, Plant, and Equipment and Operating Materials and Supplies," October 29, 2015
- Ames, APD-7910.1, "Flight Operations," July 18, 2016
- Ames, Code JO-3 Flight Operations, "Flight Operations Manual at Moffett Federal Airfield," April 1, 2014
- Armstrong, DPR-7900.3-001, "Unmanned Aerial System (UAS) Development/Acquisition," October 12, 2016
- Armstrong, DCP-O-030, "Aircraft Documentation," January 15, 2016
- Armstrong, DCP-F-605, "Asset Management (Personal, Real and Industrial Property)," July 25, 2016
- Armstrong, DOP-O-028, "Model Laboratory," May 6, 2016
- Armstrong, DCP-O-025, "Aircraft Flight Operations Manual," May 17, 2016
- Armstrong, DPL-1000.0-002, "Governance and Strategic Management Interim," May 11, 2016
- Armstrong, DCP-X-008, "Tech Brief and Mini Tech Brief," March 4, 2016
- Glenn, Policy Letter, "Accountability of Unmanned Aircraft Systems (UAS)," April 28, 2015
- Goddard, 830-FOM-0001, "Goddard Space Flight Center Flight Operations Manual," July 26, 2013

- Goddard and Wallops Flight Facility, 830-FOM-0002B, "UAS Flight Operations Manual," March 31, 2016
- Johnson, Policy Letter, "Johnson Space Center UAS Center Policy," June 4, 2014
- Kennedy, KTI-7900, "Kennedy Space Center Unmanned Aircraft Systems Operations Manual," April 13, 2016
- Marshall, Policy Letter, "Policy Amplification for MSFC Unmanned Aircraft Systems," August 24, 2015

Prior Coverage

During the last 5 years, the Government Accountability Office, Department of Justice Office of Inspector General, Department of Transportation Office of Inspector General, and the United States Postal Service Office of Inspector General issued 11 reports and provided 7 testimonies of significant relevance to the subject of this report. Unrestricted reports can be accessed at http://www.gao.gov, https://oig.justice.gov/reports/all.htm, https://www.oig.dot.gov/audits?field_type_tid=3, and https://www.uspsoig.gov/audit, respectively.

The GAO also issued a podcast that is relevant to this report, which can be accessed at http://www.gao.gov/multimedia/podcasts/671766.

Government Accountability Office

Aviation Research and Development: FAA Could Improve How It Develops Its Portfolio and Reports Its Activities (GAO-17-372, April 24, 2017)

Unmanned Aerial Systems: Air Force and Army Should Improve Strategic Human Capital Planning for Pilot Workforces (GAO-17-53, January 31, 2017)

Border Security: DHS Surveillance Technology, Unmanned Aerial Systems and Other Assets (GAO-16-671T, May 24, 2016)

Unmanned Aerial Systems: Further Actions Needed to Fully Address Air Force and Army Pilot Workforce Challenges (GAO-16-527T, March 16, 2016)

Unmanned Aerial Systems: FAA Continues Progress toward Integration into the National Airspace (GAO-15-610, July 16, 2015)

Unmanned Aerial Systems: Actions Needed to Improve DOD Pilot Training (GAO-15-461, May 14, 2015)

Unmanned Aerial Systems: Status of Test Sites and International Developments (GAO-15-486T, March 24, 2015)

Unmanned Aerial Systems: Efforts Made toward Integration into the National Airspace Continue, but Many Actions Still Required (GAO-15-254T, December 10, 2014)

FAA Reauthorization Act: Progress and Challenges Implementing Various Provisions of the 2012 Act (GAO-14-285T, February 5, 2014)

Unmanned Aircraft Systems: Continued Coordination, Operational Data, and Performance Standards Needed to Guide Research and Development (GAO-13-346T, February 15, 2013)

Unmanned Aircraft Systems: Measuring Progress and Addressing Potential Privacy Concerns Would Facilitate Integration into the National Airspace System (GAO-12-981, September 14, 2012)

Unmanned Aircraft Systems: Use in the National Airspace System and the Role of the Department of Homeland Security (GAO-12-889T, July 19, 2012)

Department of Justice Office of Inspector General

Department of Justice's Use and Support of Unmanned Aircraft Systems (Audit Division 15-11, March 2015)

Interim Report on the Department of Justice's Use and Support of Unmanned Aircraft Systems (Report 13-37, September 2013)

Department of Transportation Office of Inspector General

FAA Lacks a Risk-Based Oversight Process for Civil Unmanned Aircraft Systems (AV-2017-018, December 1, 2016)

FAA's Progress and Challenges in Integrating Unmanned Aircraft Systems into the National Airspace System (CC-2015-002, December 10, 2014)

FAA Faces Significant Barriers to Safely Integrate Unmanned Aircraft Systems into the National Airspace System (AV-2014-061, June 26, 2014)

United States Postal Service Office of Inspector General

Public Perception of Drone Delivery in the United States (RARC-WP-17-001, October 11, 2016)

APPENDIX B: QUESTIONED COSTS

Table 1 summarizes the questioned costs identified during our audit and discussed in this report. These funds are a result of obtaining UAS assets without regard to flight requirements, without the required acquisition approvals and training prior to receipt, and therefore the UAS have been unused since receipt.

Table 1: Summary of Questioned Costs

Center	Number of Assets	Amount Questioned[a]
Ames	0	$0
Armstrong	1	$200
Glenn	1	$1,699
Goddard	0	$0
Jet Propulsion Laboratory	0	$0
Johnson	1	$3,000
Kennedy	0	$0
Langley	2	$5,201
Marshall	2	$7,208
Total Questioned Costs	**7**	**$17,308**

Source: NASA OIG analysis.

[a] Questioned costs are expenditures that are questioned by the Office of Inspector General because of an alleged violation of legal, regulatory, or contractual requirements, are not supported by adequate documentation at the time of audit, or are unallowable, unnecessary, or unreasonable.

Appendix C: Management's Comments

National Aeronautics and Space Administration
Headquarters
Washington, DC 20546-001

September 13, 2017

Reply to Attn of: Office of Strategic Infrastructure

TO: Assistant Inspector General for Audits

FROM: Assistant Administrator for Strategic Infrastructure

SUBJECT: Agency Response to OIG Draft Report, "NASA's Research Efforts and Management of Unmanned Aircraft Systems" (A-16-018-00)

NASA appreciates the opportunity to review and comment on the Office of Inspector General (OIG) draft report entitled, "NASA's Research Efforts and Management of Unmanned Aircraft Systems" (A-16-018-00), dated August 16, 2017.

In the draft report, the OIG makes six recommendations addressed to the Assistant Administrator for Strategic Infrastructure (AA/OSI) intended to increase transparency, accountability, and oversight of NASA's unmanned aircraft systems (UAS) inventory.

Specifically, in order to increase transparency, accountability, and oversight of NASA's UAS inventory, the AA/OSI should direct the Aircraft Management and Logistics Management Division (AMD and LMD) Directors to:

Recommendation 1: Ensure that Center Directors have developed an effective process to routinely inform all potential NASA end users of the acquisition and approval procedures and logistics requirements required before obtaining UAS.

Management's Response: Concur. OSI will direct Centers to develop a corrective action plan to routinely inform end users of existing and new policies governing approval, acquisition and logistical requirements that must occur prior to and after acquiring UASs. The Center plans will require AMD and LMD approval prior to Center implementation. Additionally, NASA Purchase Card Procedures and Instruction have been updated effective May 30, 2017, to require specific approval authority from the Center Flight Operations Representative for UAS procurements that cost up to $2,500. For UAS that are below the Agency Capital asset threshold (currently $500,000), Center Directors must approve the acquisition. Additionally, Center Directors shall ensure training is provided to all Purchase Card holders and acquisition professionals regarding UAS acquisitions. The Center's updated policy will be periodically reviewed during the Inter-Center Aircraft Operations Panel Review (IAOP) and LMD Compensating Controls Review (CCR) to ensure proper implementation and oversight.

Estimated Completion Date: December 31, 2018.

Recommendation 2: Create or incorporate into existing policy criteria for defining the UAS subject to acquisition and tracking requirements, distinguishing an aerial drone from a collection of spare parts, and the criteria Centers should use for determining the number of UAS spare parts to maintain.

Management's Response: Concur. OSI will develop policy criteria for Centers to:

1. Distinguish between a collection of parts and a small UAS that would be subject to acquisition and tracking requirements and ensure Centers disseminate the updated policies.

2. Determine the appropriate amount of UAS spare parts and update the applicable policy documents to reflect the new processes and procedures.

The Center's updated policy will be periodically reviewed during the Inter-Center Aircraft Operations Panel Review (IAOP) and LMD Compensating Controls Review (CCR) to ensure proper implementation and oversight.

Estimated Completion Date: December 31, 2018.

Recommendation 3: Create a checklist for Center personnel covering all acquisition and approval processes, logistics requirements, and cost accounting data to ensure proper acquisition procedures are followed regarding the transfer, purchase, or in-house build of UAS below the capitalization asset threshold.

Management's Response: Partially Concur. For UAS below the capitalization asset threshold, there are no aircraft cost accounting and reporting requirements internal or external to the Agency. However, AMD/LMD will assist in the development of a checklist that identifies approvals for acquisitions, logistics accountability, and cost accounting requirements, after which they will engage with Procurement Policy Office to develop and implement a checklist on NASA Form 1707, *Special Approvals and Affirmations of Requisitions*, to ensure proper acquisition procedures are followed for UAS below the capitalization asset threshold.

Estimated Completion Date: December 31, 2018.

Recommendation 4: Reinforce the requirement that Centers obtain Equipment Control Numbers for all UAS assets regardless of use, size, or cost; properly affix the Equipment Control Numbers to the asset; and maintain the assets in secure locations.

Management's Response: Concur. LMD will direct Centers to develop and implement a plan to reinforce the policy requirement to tag all UASs with an Equipment Control Number (ECN) and identify and place an ECN tag on untagged UASs. An LMD UAS Tiger Team will visit NASA Centers to evaluate systemic process and procedure gaps related to inventory management of UASs and make appropriate policy changes to remedy any policy gaps.

Estimated Completion Date: December 31, 2018.

Recommendation 5: Require Centers to identify unneeded UAS or aerial drones unused for more than 5 years and dispose of them properly or identify a reason they should be maintained.

Management's Response: Partially concur. NPR 7900.3D, Aircraft Operations Management, Chapter 8 addresses aircraft acquisitions and dispositions. Paragraph 8.1.1 states "This chapter establishes policy for acquisition and disposition of all NASA aircraft, including UAS." Paragraph 8.5.1.1 states "Unless extended or waived by AMD, all Inactive Aircraft shall be dispositioned within 5 years of inactive status in coordination with Center Logistics." Hence, AMD believes the requirements are addressed; however, AMD will direct Centers to develop a corrective action plan to ensure adherence to the existing policy.

Estimated Completion Date: December 31, 2018.

Recommendation 6: Work with Center aviation management offices to implement records management procedures to ensure that once approval has been received to obtain a UAS – either through transfer, purchase, or in-house build – all supporting documentation is filed together or cross-referenced for ease of identification and references the granted approval document.

Management's Response: Partially concur. NASA believes this recommendation is better directed to the Center procurement offices rather than OSI. NPR 7900.3D, Section P.4 includes NPR 1441.1E, NASA Records Management Program Requirements, as applicable. The acquisition and procurement process captures the required documentation for all information addressed in this recommendation. This documentation is required to be retained in accordance with Records Management Program Requirements. However, OSI will direct Centers to develop a corrective action plan to ensure adherence to these requirements.

Estimated Completion Date: December 31, 2018.

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

Once again, thank you for the opportunity to review and comment on the subject draft report. If you have any questions or require additional information regarding this response, please contact Fatima Johnson on (202) 358-1631.

RL Moore for C.F.W.
Calvin F. Williams

cc:
Associate Administrator for Aeronautics Research Mission Directorate/Dr. Shin

APPENDIX D: REPORT DISTRIBUTION

National Aeronautics and Space Administration

Acting Administrator
Acting Deputy Administrator
Associate Administrator for Aeronautics Research
Associate Administrator for Mission Support
Assistant Administrator for Strategic Infrastructure
Center Director, Ames Research Center
Center Director, Armstrong Flight Research Center
Center Director, Glenn Research Center
Center Director, Goddard Space Flight Center
Center Director, Jet Propulsion Laboratory
Center Director, Johnson Space Center
Center Director, Kennedy Space Center
Center Director, Langley Research Center
Center Director, Marshall Space Flight Center
Center Director, Stennis Space Center

Non-NASA Organizations and Individuals

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

Government Accountability Office
    Director, Office of Acquisition and Sourcing Management

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 Space, Science, and Competitiveness
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 Government Reform
    Subcommittee on Government Operations

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

(Assignment No. A-16-018-00)