United States Government Accountability Office

GAO

Report to Congressional Requesters

May 2008

UNMANNED AIRCRAFT SYSTEMS

Federal Actions Needed to Ensure Safety and Expand Their Potential Uses within the National Airspace System

GAO

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GAO-08-511

Highlights

Highlights of GAO-08-511, a report to congressional requesters

Why GAO Did This Study

Government and private-sector interest is growing in unmanned aircraft systems (UAS) for use in a variety of missions such as U.S. border protection, hurricane research, law enforcement, and real estate photography. However, UASs can fly only after the Federal Aviation Administration (FAA) conducts a case-by-case safety analysis. GAO's research questions included (1) What are the current and potential uses and benefits of UASs? (2) What challenges exist in operating UASs safely and routinely in the national airspace system? and (3) What is the federal government's response to these challenges? To address these questions, GAO reviewed the literature, interviewed agency officials and aviation stakeholders, and surveyed 23 UAS experts.

What GAO Recommends

GAO suggests that Congress create an overarching body within FAA to coordinate UAS development and integration efforts. To realize public benefits from UASs as soon as possible, GAO recommends that FAA issue its program plan and analyze the data it has collected, and that the Department of Homeland Security (DHS) assess the security implications of routine UAS access to the airspace. Relevant agencies reviewed a draft of this report. The Department of Transportation agreed to consider its relevant recommendations. DHS agreed with its relevant recommendation.

To view the full product, including the scope and methodology, click on GAO-08-511. For more information, contact Gerald L. Dillingham, (202) 512-2834 dillinghamg@gao.gov.

May 2008

UNMANNED AIRCRAFT SYSTEMS

Federal Actions Needed to Ensure Safety and Expand Their Potential Uses within the National Airspace System

What GAO Found

UASs are currently being used by federal agencies for border security, science research, and other purposes. Local governments see potential uses in law enforcement or firefighting and the private sector sees potential uses, such as real estate photography. An industry survey states that UAS production could increase in the future to meet such government and private-sector uses. Experts predict that UASs could perform some manned aircraft missions with less noise and fewer emissions.

UASs pose technological, regulatory, workload, and coordination challenges that affect their ability to operate safely and routinely in the national airspace system. UASs cannot meet aviation safety requirements, such as seeing and avoiding other aircraft. UASs lack security protection—a potential challenge if UASs proliferate as expected after obtaining routine airspace access. The lack of FAA regulations for UASs limits their operation to case-by-case approvals by FAA. Anticipated increases in requests to operate UASs could pose a workload challenge for FAA. Coordinating multiple efforts to address these challenges is yet another challenge.

FAA and the Department of Defense (DOD) are addressing technological challenges. DHS has not addressed the national security implications of routine UAS access to the airspace. FAA estimates that completing UAS safety regulations will take 10 or more years, but has not yet issued its program plan to communicate the steps and time frames required for providing routine UAS access. FAA is working to allow small UASs to have airspace access and has designated specific airspace for UAS testing. It plans to use data from this testing and from DOD to develop regulations, but has not yet analyzed data that it has already collected. To address its workload challenge, FAA is using more automation. Aviation stakeholders and experts suggested that an overarching entity could help coordinate and expedite federal, academic, and private-sector efforts. In 2003, Congress created a similar entity in FAA to coordinate planning for the next generation air transportation system among multiple federal agencies and the private sector.

Predator B UASs Used for Border Security

Source: DHS.

Contents

Abbreviations

CBP	Customs and Border Protection
COA	Certificate of Waiver or Authorization
DHS	Department of Homeland Security
DOD	Department of Defense
DOT	Department of Transportation
EUROCAE	European Organization for Civil Aviation Equipment
EUROCONTROL	European Organization for the Safety of Air Navigation
FAA	Federal Aviation Administration
ICAO	International Civil Aviation Organization
JPDO	Joint Planning and Development Office
NASA	National Aeronautics and Space Administration
NextGen	next generation air transportation system
NOAA	National Oceanographic and Atmospheric Administration
RTCA	Radio Technical Commission for Aeronautics
TSA	Transportation Security Administration
UAPO	Unmanned Aircraft Program Office
UAS	unmanned aircraft system
TCAS	Traffic Alert and Collision and Avoidance System

GAO
Accountability * Integrity * Reliability

United States Government Accountability Office
Washington, DC 20548

May 15, 2008

The Honorable John Mica
Ranking Republican Member
Committee on Transportation and Infrastructure
House of Representatives

The Honorable Jerry F. Costello
Chairman
Subcommittee on Aviation
Committee on Transportation and Infrastructure
House of Representatives

Government and private-sector interest in unmanned aircraft systems (UAS) is growing, due in large part to the U.S. military's expanded development and use of these systems in Iraq and Afghanistan. The absence of a pilot on board the aircraft allows unmanned aircraft to perform a variety of missions not generally considered favorable for manned aircraft. Some unmanned aircraft can remain aloft for 30 hours or more, because there is no need for them to land to change pilots. Unmanned aircraft can also perform dangerous missions without risking loss of life.

The federal government has used UASs for a number of years for various purposes, such as collecting scientific data, assisting with border security, and gathering weather data from inside hurricanes. Federal agencies are planning to increase their use of UASs and state and local governments envision using UASs to aid in law enforcement or firefighting. Potential commercial uses are also possible, for example, in real estate photography or pipeline inspection. The Federal Aviation Administration (FAA) is responsible for ensuring that UASs operate safely in the national airspace system and is working to develop a regulatory framework to address the unique characteristics of UASs. For example, current regulations do not indicate how, in the absence of an on-board pilot, UASs should detect, sense, and avoid other aircraft to avoid collisions. FAA's long-range goal is to permit, to the greatest extent possible, routine government and commercial UAS operations in the national airspace system while ensuring safety. Presently, because of safety concerns, FAA authorizes civil government and military UAS operations in the national airspace system on a limited basis after conducting a case-by-case safety review. Regulations do not currently permit commercial UAS operations.

You asked us to assess efforts to safely integrate UASs into the national airspace system and the potential impact of those UASs after such integration occurs. To meet this objective, we developed the following research questions: (1) What are the current and potential uses and benefits of UASs? (2) What challenges exist in operating UASs safely and routinely in the national airspace system? (3) What is the federal government's response to these challenges? and (4) Assuming that UASs have routine access to the national airspace system, how might they impact the system and the environment?

To address these questions, we reviewed the literature, FAA and Department of Defense (DOD) documents, and aviation trade association reports. We also interviewed officials from DOD, the Department of Homeland Security (DHS), and the National Aeronautics and Space Administration (NASA) about their operations and plans to operate UASs in the national airspace system. We interviewed officials in associations that represent UAS manufacturers and users of the national airspace system. To determine the expected growth of UASs, we obtained industry forecasts. Additionally, we administered a Web-based survey to 23 UAS experts, selected with the assistance of the National Academies, to obtain their opinions of the steps that FAA could take to accelerate UAS integration in the national airspace system and the impact that UASs might have on the system and the environment after integration occurs.[1] We conducted this performance audit from October 2006 to May 2008, 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. (See app. I for additional information on our scope and methods.)

Results in Brief

Federal agencies such as DHS, the Department of Commerce, and NASA use UASs in many areas, such as border security, weather research, and forest fire monitoring. These agencies have plans to expand their UAS use in domestic airspace, and local governments and commercial entities also

[1] At our request, the National Academies provided names of 26 experts in aviation regulations and safety, UAS technology, next generation air transportation system planning, airport operations, human factors, and international issues. Three experts did not respond to the survey.

have interest in using UASs. Many factors support the potential for expanded use of UASs. For example, the nation's industrial base has expanded to support military operations and the number of trained UAS operators is increasing as personnel return from overseas duty. Moreover, some of the technology used in military UAS operations could be applied to civil uses. DHS is expanding its use of UASs for border security and NASA is likely to continue using UASs to gather scientific data. Additionally, local law enforcement and firefighting agencies have expressed interest in using UASs to assist at crime scenes and wildfire locations, and commercial users envision using UASs for tasks such as photographing real estate or inspecting pipelines. According to an industry forecast, the market for government and commercial-use UASs could grow in the future. The forecast also indicates that the United States could account for 73 percent of the world's research and development investment for UAS technology over the coming decade. According to a UAS study and experts we surveyed, UAS development could lead to technological advances that could benefit all national airspace users. For example, some experts we surveyed noted that improved collision avoidance technologies developed for UASs could lead to reduced aircraft separation requirements, which could increase airspace capacity. Additionally, UASs could produce environmental benefits if they assume some missions currently performed by manned aircraft by using quieter engines that produce fewer emissions, according to experts we surveyed.

Routine UAS access to the national airspace system poses technological, regulatory, workload, and coordination challenges. A key technological challenge is providing the capability for UASs to meet the safety requirements of the national airspace system. For example, a person operating an aircraft must maintain vigilance so as to see and avoid other aircraft. However, because UASs have no person on board the aircraft, on-board equipment, radar, or direct human observation must substitute for this capability. No technology has been identified as a suitable substitute for a person on board the aircraft in seeing and avoiding other aircraft. Additionally, UASs' communications and control links are vulnerable to unintentional or intentional radio interference that can lead to loss of control of an aircraft and an accident,[2] and in the future, ground control stations—the UAS equivalent to a manned aircraft cockpit—may need physical security protection to guard against hostile takeover. Although DOD has achieved operational successes

[2] Although DOD often uses the term "mishap" to refer to UAS accidents, we use accidents throughout this report.

with its use of UASs in Iraq and Afghanistan, accidents of varying degrees of severity have resulted from UAS reliability problems and human factors issues, i.e., equipment designs that did not fully account for human abilities, characteristics, and limitations. Our analysis of 4½ years of DOD's data indicates that UAS component failures caused about 65 percent of the accidents and human factors issues—a common challenge in new technology—caused about 17 percent of the accidents. Because a regulatory framework to ensure UAS safety does not exist, UASs have had only limited access to the national airspace, which, in turn, has created additional challenges. For example, UAS developers have faced a lack of airspace for testing and evaluating their products, and data on UAS operations in the national airspace, which could aid in developing regulations, is scarce. In the coming years, FAA could face a workload challenge in responding to increasing requests from federal agencies to operate UASs in the national airspace system. However, FAA's future workload is uncertain because there is no accurate inventory of federally-owned and –leased UASs. GSA has responsibility for maintaining the inventory of federally-owned and –leased aircraft, but its regulations have not been updated to require federal agencies to report UASs. Coordinating the efforts of federal agencies with those of academic institutions that have UAS expertise, and with the private sector, which has a stake in UASs obtaining routine airspace access, serves as another challenge.

Addressing the challenges of allowing routine UAS access to the national airspace system involves the efforts of several federal agencies and could require a decade or more of additional work. FAA is addressing technological challenges by sponsoring research on topics such as detect, sense, and avoid, and taking steps to obtain dedicated radio frequency spectrum for UAS operations, which could address UAS communications and control vulnerabilities. DOD is addressing UAS reliability challenges by urging manufacturers to use redundant, fail safe designs, and has made some progress in addressing human factors challenges by standardizing some UAS ground control stations. Additionally, a federal advisory body is developing technical standards for UASs. However, DHS's Transportation Security Administration (TSA) has not yet examined the security implications of routine UAS operations in the national airspace. Fully addressing regulatory challenges to allowing all UASs to have routine access to the national airspace system may not occur until 2020, after the aforementioned advisory body completes its technical standards work and FAA incorporates those standards in its regulations. In the interim, FAA has created an Unmanned Aircraft Program Office to coordinate efforts to develop standards and regulations. FAA is also developing a UAS program plan that would inform the aviation community of the steps and time frames required for providing routine UAS access. Although the plan was being developed in December 2006, it had not been approved for issuance as of March 2008. Additionally FAA is developing regulatory procedures to allow small UAS operations in the national airspace under low-risk conditions. FAA has established a 12,000 square mile UAS test center to provide airspace for testing and evaluating UASs and to provide data for use in developing regulations. FAA expects to obtain additional data from increased coordination with DOD. However, FAA has not yet analyzed the limited data that it has already accumulated on recent UAS operations in the national airspace system, citing resource constraints. To address expected workload increases, FAA is introducing more automation into its work processes and has granted DOD authority to operate small UASs, weighing 20 pounds or less, over its installations without receiving prior FAA approval. Additionally, GSA is updating its regulations to require federal agencies to report their owned and leased UASs, which could help FAA plan for its future workload. Given the variety of federal entities involved with UAS issues, as well as the stake that the private sector has in routine UAS operations in the national airspace system, experts and stakeholders suggested that an overarching entity be established to coordinate and expedite these efforts. Congress used a similar approach in 2003 when it passed legislation to create the Joint Planning and Development Office (JPDO), within FAA, to coordinate planning for the next generation air transportation system among multiple federal agencies and the private sector.

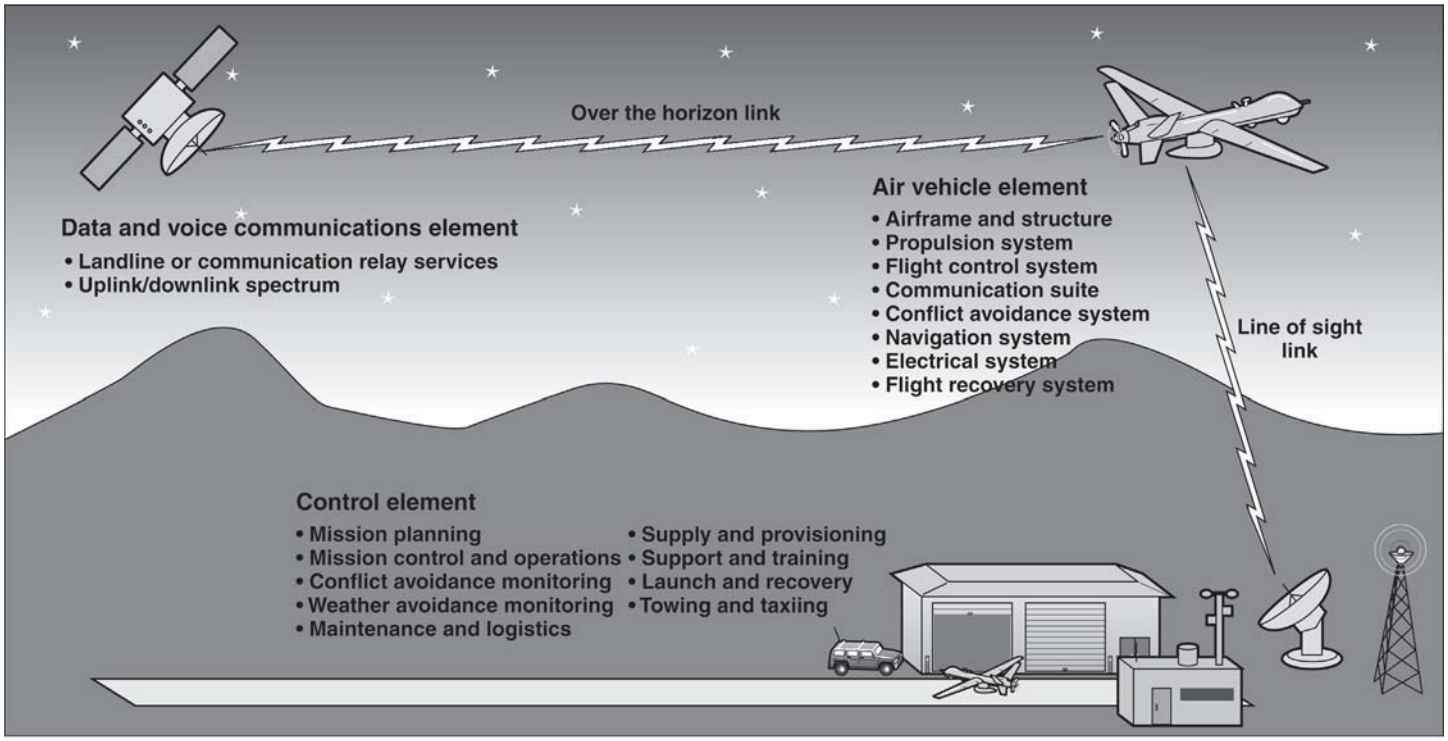
Because data on UAS operations in the national airspace system are scarce and routine operations are many years away, the impact of routine access on the system and the environment remains generally speculative. The impact will depend on a number of factors that, today, are unpredictable due to a lack of data. For example, one study notes that, while more needs to be known about the needs and capabilities of future UASs, their operations could have a disruptive impact on aviation by introducing more complexity. A federal advisory body has reported that UASs will create unique challenges because, in comparison to manned aircraft, UAS missions often involve hovering or circling in one location and UASs' speed, maneuverability, and climb rates, may differ from manned aircraft. These differences could affect air traffic flow, air traffic controller workload, and departure and arrival procedures. Many of the experts we surveyed predicted that UASs would add to the number of aircraft and therefore affect airspace and airport capacity and add to the workload of air traffic control in the same manner as additional manned aircraft. However, our experts also noted that, if UASs assume some missions currently performed by manned aircraft, and perform them with smaller and quieter engines, UASs could benefit the environment.

We suggest that Congress consider creating an overarching body within FAA, as it did when it established JPDO, to coordinate the diverse efforts of federal agencies, academia, and the private sector in meeting the safety challenges of allowing routine UAS access to the national airspace system. We also recommend that FAA issue its UAS program plan, analyze the UAS operations data that it has collected, and establish a process to analyze DOD's data on UAS research, development, and operations. In addition, we recommend that DHS examine and fully address the security implications of routine civil UAS access in the national airspace system. We provided a draft of this report to the Department of Transportation (DOT), DHS, DOD, GSA, NASA, and the Department of Commerce. DOT agreed to consider the relevant recommendations and DHS agreed with our recommendation to it. GSA commented that it will continue its efforts to ensure that FAA has accurate information on the number of federally-owned and –leased UASs. DOT commented that the report would benefit from additional information on the impact of UASs on airports. We revised the report to include DOT's concern that the impact of UASs on safety and capacity at airports requires further study. DOT, DOD, and DHS provided technical comments, which we incorporated as appropriate. NASA and the Department of Commerce had no comments.

Background

FAA defines an unmanned aircraft as one that is operated without the possibility of direct human intervention from within or on the aircraft. In the past, these aircraft were sometimes called "unmanned aerial vehicles," "remotely piloted vehicles," or "unmanned aircraft." FAA and the international community have adopted the term "unmanned aircraft system" to designate them as aircraft and to recognize that a UAS includes not only the airframe, but also the associated elements—the control station and communications links—as shown in figure 1.

Figure 1: Conceptual Unmanned Aircraft System



Sources: GAO and NASA.

The capabilities of UASs differ from manned aircraft in several ways. A UAS can operate for far longer periods than an onboard pilot could safely operate an aircraft. Future scenarios envision UASs remaining aloft for weeks or even months using fuel cell technology or airborne refueling operations. UASs may fly at slower speeds than most manned aircraft; some operate at low altitude (between buildings) while others fly well above piloted aircraft altitudes. Some UASs can fly autonomously based on pre-programmed data or flight paths, while others fly based on commands from pilot-operated ground stations. UASs also vary widely in size, shape, and capabilities. Some UASs, such as the Global Hawk, have a wingspan as large as that of a Boeing 737. Others, because they do not need the power or physical size to carry a pilot, can be small and light enough to be launched by hand, as is the case for the SkySeer UAS shown in figure 2.

Figure 2: Examples of UASs

Aerosonde®[a]

Weight: 33.5 pounds
Launch mechanism: catapult or from roof of fast moving ground vehicle
Wingspan: 9.5 feet
Maximum speed: 60 knots
Maximum altitude: 15,000 feet
Mission duration: up to 30 hours
Current application: civil and military

SkySeer

Weight: 4 pounds
Launch mechanism: hand launch
Maximum speed: 24 knots
Maximum altitude: 11,000 feet
Mission duration: 50 minutes
Current application: civil

Predator B[b]

Weight: 10,000 pounds
Launch mechanism: runway
Wingspan: 66 feet
Maximum speed: over 220 knots
Maximum altitude: 50,000 feet
Mission duration: 30 hours
Current application: civil and military

ScanEagle™

Weight: 38 pounds
Launch mechanism: catapult
Wingspan: 10.2 feet
Maximum speed: 70 knots
Maximum altitude: 16,400 feet
Mission duration: 20 hours
Current application: civil and military

RQ-4A[c]

Weight: 26,750 pounds
Launch mechanism: runway
Wingspan: 116 feet
Maximum speed: 350 knots
Maximum altitude: 65,000 feet
Mission duration: 32 hours
Current application: civil and military

Fire Scout

Weight: 3,150 pounds
Launch mechanism: vertical
Wingspan: 27.5 feet (rotor diameter)
Maximum speed: 125 knots
Maximum altitude: 20,000 feet
Mission duration: up to 8 hours
Current application: military

Sources: AAI Corporation, U.S. Navy, U.S. Air Force, and Octatron Inc.

[a]Aerosonde® is a registered trademark of Aerosonde Pty Ltd.

[b]The civil version of the Predator B is shown. The military version of the Predator B is known as the Reaper (MQ-9).

[c]Model shown is RQ-4A. The Air Force has begun procuring model 4B for which some characteristics differ. Model 4B's weight is 32,250 pounds; wingspan is 131 feet; maximum speed is 340 knots; maximum altitude is 60,000 feet; and mission duration is 28 hours.

DOD has pioneered UAS applications for wartime use and, in 2007, was the major user of UASs, primarily for ongoing conflicts in Iraq and Afghanistan. While many of DOD's UAS operations currently take place outside the United States, DOD needs access to the national airspace system for UASs to, among other things, transit from their home bases for training in restricted military airspace or for transit to overseas deployment locations.[3] DOD officials stated that the need for military UAS access to the national airspace system is under review, and also noted that increased access would also allow their UASs to be more easily used to aid in fighting wildfires.

Several federal agencies have roles related to UASs. FAA is responsible for ensuring UASs are safely integrated into the national airspace system's air traffic control procedures, airport operations, and infrastructure, and with existing commercial, military, and general aviation users of the system. When UASs operate in that system, they must meet the safety requirements of the U.S. Code of Federal Regulations, Title 14, parts 61 and 91.[4] FAA approves, on a case-by-case basis, applications from government agencies and private-sector entities for authority to operate UASs in the national airspace system. Federal, state, and local government agencies must apply for Certificates of Waiver or Authorization (COA), while private-sector entities must apply for special airworthiness certificates. In either case, FAA examines the facts and circumstances of proposed UAS operations to ensure that the prospective operator has acceptably mitigated safety risks. Special airworthiness certificates are the only means through which private-sector entities can operate UASs in the national airspace system. Because special airworthiness certificates do not allow commercial operations, there is currently no means for authorizing commercial UAS operations.

NASA has conducted UAS research in the past. NASA led the 9-year Environmental Research Aircraft and Sensor Technology Program that focused on UAS technology for high altitude, long-endurance aircraft engines, sensors, and integrated vehicles. NASA also played a key role in a partnership with other federal agencies and industry called "Access-5."

[3]DOD has more than 5,000 UASs, ranging in size from the Raven, a hand-launched UAS, to large UASs such as the Global Hawk and Predator. Most of DOD's UASs are currently deployed overseas.

[4]Part 61 addresses certification requirements for pilots, flight instructors, and ground instructors. Part 91 addresses general operating and flight rules.

Access-5 incorporated the efforts of the UAV National Industry Team, known as UNITE, formed by six private-sector aerospace firms, as well as FAA, DOD, and other industry participants. The Access-5 partnership sought to achieve routine operations for high-level, long-endurance UASs in the national airspace system. NASA contributed about 75 percent of the funding for this effort and the partnership had laid out plans through 2010. Although the partnership ended in fiscal year 2006 when NASA cancelled its funding, the project claimed a number of accomplishments, including creating productive and cohesive working relationships among key stakeholders and recommendations to advance the introduction of UASs into the national airspace system.

Other agencies and organizations have roles or interests relating to UASs. For example, DHS's TSA has authority to regulate security of all transportation modes, including non-military UASs, to ensure that appropriate security safeguards are in place. GSA has the responsibility for maintaining an inventory of all federally-owned or -leased aircraft, as reported by federal agencies. Additionally, a number of associations, representing private-sector aviation industries, such as airframe and components manufacturers, and users of the national airspace system, have interest in UASs progressing toward routine access to the system. We refer to officials of these associations as stakeholders in this report.

Federal Agencies Have Used UASs in Many Ways and Expanded Government and Commercial Use Is Possible in the Future

Several federal agencies are using UASs of varying sizes for missions ranging from forest fire monitoring to border security. These agencies are interested in expanded use of UASs and state and local governments would also like to begin using UASs for law enforcement or firefighting. UASs also could eventually have commercial applications.

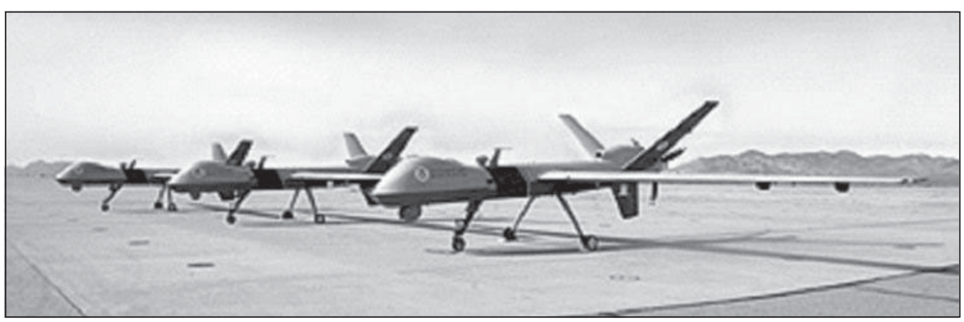
Federal Agencies Are Benefiting from Using UASs

Federal agencies use UASs for many purposes. NASA, for example, uses UASs as platforms for gathering scientific research data and has partnered with other government agencies to demonstrate and use UASs' unique capabilities. At its Wallops Island, Virginia, Flight Facility, NASA operates a small fleet of Aerosonde® UASs on a lease-to-fly basis for researchers. NASA also operates a modified Predator B UAS from its Dryden Flight

Research Center, in California, and used it to aid firefighting efforts in southern California in 2007. During 2005, the Department of Commerce's National Oceanographic and Atmospheric Administration (NOAA) partnered with NASA and industry to use a UAS to fill data gaps in several areas, including climate research, weather and water resources forecasting, ecosystem monitoring and management, and coastal mapping. During 2007, NOAA partnered with NASA to use an Aerosonde® UAS to gather data from Hurricane Noel and reported receiving valuable low-altitude data that could aid future weather forecasts and potentially reduce property damage and save lives.

Several other federal agencies have benefited from using UASs. DHS's Customs and Border Protection (CBP) uses Predator B UASs to help conduct surveillance along portions of the U.S. border with Mexico. (See fig. 3.) CBP credits its UAS operations as helping its agents make over 4,000 arrests and seize nearly 20,000 pounds of illegal drugs between September 2005 and March 2008. In the aftermath of Hurricane Katrina, UASs searched for survivors in an otherwise inaccessible area of Mississippi. Additionally, in 2004, the U.S. Geological Survey and the U.S. Forest Service used a UAS to study renewed volcanic activity at Mount St. Helens, Washington. The UAS proved useful in this study because it could operate above the extreme heat and toxic gases and solids emitted by the volcano.

Figure 3: CBP's Predator B UAS Inventory as of December 2007



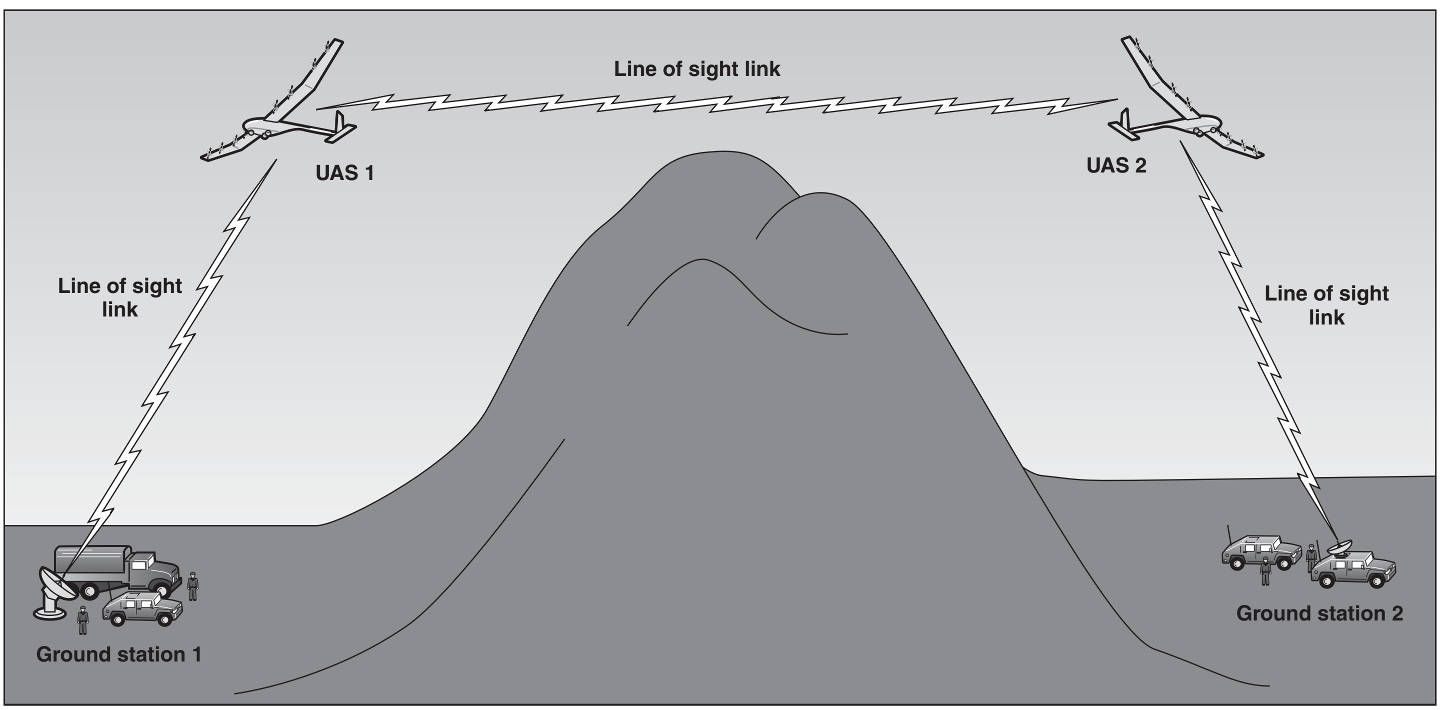
Source: DHS.

Interest Exists in Expanding UAS Operations to Obtain More Benefits

Recent events have contributed to increasing interest in expanding UAS operations. The nation's industrial base has expanded to support current overseas conflicts. Moreover, personnel returning from duty in war theaters provide a growing number of trained UAS operators. Advances in computer technology, software development, light weight materials, global navigation, advanced data links, sophisticated sensors, and component miniaturization also contribute to the heightened interest in using UASs in civilian roles.

In addition, the military's use of UASs has raised the visibility of the possible benefits of using UASs in non-military applications. For example, the military recently demonstrated how operators can use UASs as communications platforms to bridge rugged terrain as shown in figure 4. Disaster recovery officials could use UASs in a similar manner to help establish and maintain communications when the infrastructure is disabled or overloaded. The latter was an issue in the hours immediately following the terrorist attacks of September 11, 2001.

Figure 4: UASs Used as Communications Relays

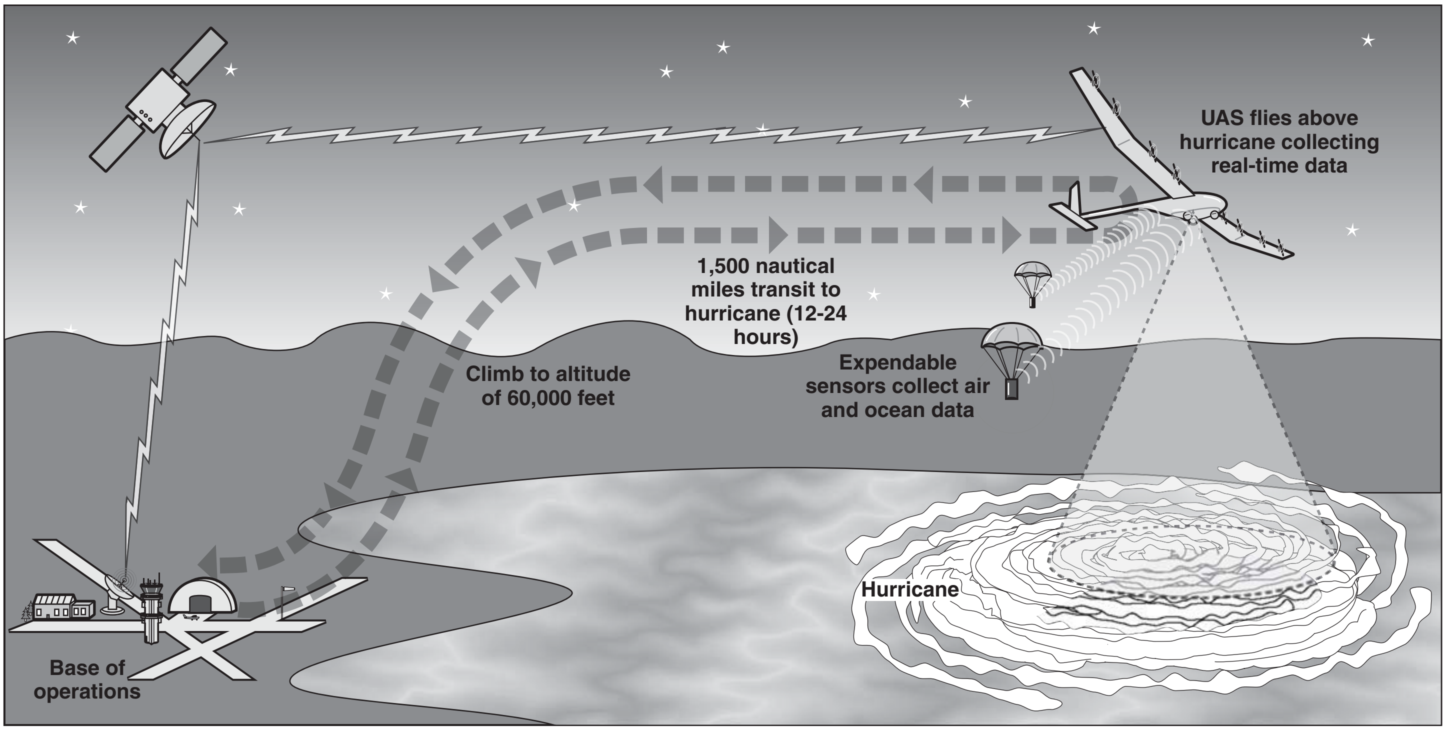


Sources: GAO and DOD.

An industry forecast anticipates that federal agencies will continue to be the main users of large UASs for much of the coming decade. CBP is expanding its fleet of Predator B UASs. The agency received its fourth aircraft in February 2008 and expects to acquire two more during fiscal year 2008. CBP also plans to expand its UAS operations along the southern U.S. border, and in the spring of 2008, begin operations along the northern U.S. border, and then eventually expand operations to the Great Lakes and Caribbean. CBP's Air and Marine Operations Center in Riverside, California, will eventually control most of the agency's UASs via satellite link. DHS's Coast Guard is evaluating various UAS designs for future use in maritime border protection, law and treaty enforcement, and search and rescue.

Expanded UAS use for scientific applications is also possible. According to NOAA, UASs have the potential to continue to fill critical observation gaps in climate change research, weather and water resources forecasting, ecosystem monitoring and management, and coastal mapping. NOAA also anticipates further use of UASs for hurricane observation. Figure 5 illustrates how a high-altitude UAS might obtain hurricane data. The National Academies recently recommended that NASA should increasingly factor UAS technology into the nation's strategic plan for Earth science. In 2007, NASA acquired two Global Hawk UASs from the Air Force for potential use in long endurance missions monitoring polar ice melt or for gathering data on hurricane development 2,500 miles off the U.S. Atlantic coast.

Figure 5: Illustration of UAS Use for Hurricane Data Collection



Sources: GAO and AeroVironment.

State and local agencies and commercial users envision using smaller UAS models. To facilitate more rapid resolution of emergency situations, an official with the International Association of Chiefs of Police envisions police and firefighting units having small, hand-deployed UASs available to assist at crime scenes and wildfire locations. According to FAA, as of January 2008, about a dozen law enforcement agencies had contacted the agency to discuss potential use of UASs. An industry forecast of UAS growth from 2008 to 2017 predicts that interest among local law enforcement agencies in operating UASs could increase late in the forecast period.[5]

In the private sector, some entrepreneurs have become interested in obtaining authorization to use small UASs to provide real estate photography services. Small UASs could also help companies survey

[5]Teal Group Corporation, *World Unmanned Aerial Vehicle Systems* (Fairfax, Va: 2008).

pipeline or transportation infrastructure. However, an industry forecast noted that, for commercial applications, manned aircraft continue to be less costly than UASs. Consequently, demand for commercial applications will be limited in the near term. While the forecast indicates that civil and commercial UAS markets will eventually emerge, the forecast notes that, for the next several years, a more likely scenario would be for a UAS leasing industry to emerge to serve the needs of businesses that do not want to invest in UAS ownership.

UASs also could provide benefits to manned aviation. Efforts to move toward routine access for UASs could produce technological improvements in areas such as materials, fuel cells, antennae, and laser communications, which could also benefit manned aviation, according to one study of UAS impact.[6] Some experts we surveyed had similar observations, noting that advancements in see and avoid technology could lead to reduced aircraft separation requirements and, in turn, to increased airspace capacity. Five experts indicated that technological improvements could benefit the airspace, and four indicated that such improvements could benefit airports.[7] Additionally, five experts predicted that UASs could provide a variety of benefits by assuming some of the missions currently performed by manned aircraft or surface vehicles. These experts predicted that UASs might perform these missions in less congested airspace or with engines that burn less fuel or produce less air pollution.

Some experts view the routine use of UASs in the national airspace system as a revolutionary change in aviation. According to one study, the state of UASs today resembles the early days of manned aviation where innovation and entrepreneurial spirit spawned a new market and permanently changed the transportation landscape. The UAS industry is poised to meet the potential demand for UASs. A 2004 study, prepared for JPDO, reported that 49 UAS manufacturers operated in the United States.[8] According to a 2007 industry estimate, UAS development and components manufacturing

[6]Matthew T. DeGarmo, *Issues Concerning Integration of Unmanned Aerial Vehicles in Civil Airspace* (McLean, Va: The MITRE Corporation, Center for Advanced Aviation System Development, November 2004).

[7]Three of these experts indicated that technology improvements could be applied to both airspace and airports.

[8]In 2003, Congress created the Joint Planning and Development Office to plan for and coordinate, with federal and nonfederal stakeholders, a transformation from the current air traffic control system to the next generation air transportation system by 2025.

involved over 400 companies in the United States.[9] An industry forecast for UASs indicates that, over the coming decade, the United States will account for 73 percent of the world's research and development investment for UAS technology.[10] The aforementioned 2004 JPDO report notes that the emergence of a civil UAS industry could provide a number of economic, social, and national security benefits, such as extending U.S. aerospace leadership in the global UAS market; sustaining, and perhaps increasing, employment in the U.S. aerospace industry; contributing to expanding the U.S. economy by increasing domestic productivity and aerospace exports; and creating the potential for a UAS civil reserve fleet for use in major national and international emergencies.[11]

Routine Access to the National Airspace System Poses Technological, Regulatory, Workload, and Coordination Challenges

Routine UAS access to the national airspace system poses a variety of technological, regulatory, workload, and coordination challenges. Technological challenges include developing a capability for UASs to detect, sense, and avoid other aircraft; addressing communications and physical security vulnerabilities; improving UAS reliability; and improving human factors considerations in UAS design. A lack of regulations for UASs limits their operations and leads to a lack of airspace for UAS testing and evaluation and a lack of data that would aid in setting standards. Increased workload would stem from FAA's expectation of increased demand for UAS operations in the national airspace system without a regulatory framework in place. In addition, coordination of efforts is lacking among diverse federal agencies as well as academia and the private sector in moving UASs toward meeting the safety requirements of the national airspace system.

[9]Testimony of Steven M. Silwa, Chief Executive Officer and President of Insitu Inc., before the House Subcommittee on Aviation, Committee on Transportation and Infrastructure (Mar. 22, 2007).

[10]Teal Group Corporation, 2008.

[11]Unmanned Aerial Vehicle National Task Force, *The Impact of Unmanned Aerial Vehicles on the Next Generation Air Transportation System: Preliminary Assessment* (Oct. 22, 2004).

Several Technological Issues Must Be Addressed before UASs Can Routinely Access the National Airspace System

FAA requires UASs to meet the national airspace system's safety requirements before they routinely access the system. However, UASs do not currently have the capability to detect, sense, and avoid other aircraft and airborne objects in a manner similar to manned aircraft. UASs also have communications and physical security vulnerabilities. Moreover, some UASs have demonstrated reliability problems and lack human-machine interface considerations in their design.

UASs Cannot Detect, Sense, and Avoid Other Aircraft in a Manner Similar to Manned Aircraft

Although research, development, and testing of sense and avoid technologies has been ongoing for several years, no suitable technology has been identified that would provide UASs with the capability to meet the detect, sense, and avoid requirements of the national airspace system. These requirements call for a person operating an aircraft to maintain vigilance so as to see and avoid other aircraft. Without a pilot on board to scan the sky, UASs do not have an on-board capability to directly "see" other aircraft. Consequently, the UAS must possess the capability to sense and avoid the object using on-board equipment, or do so with assistance of a human on the ground or in a chase aircraft, or by using other means, such as radar. Many UASs, particularly smaller models, will likely operate at altitudes below 18,000 feet, sharing airspace with other objects, such as gliders. Sensing and avoiding these other objects represents a particular challenge for UASs, since the other objects normally do not transmit an electronic signal to identify themselves and FAA cannot mandate that all aircraft or objects possess this capability so that UASs can operate safely. Many small UAS models do not have equipment to detect such signals and, in some cases, are too small to carry such equipment. The Aircraft Owners and Pilots Association,[12] in a 2006 survey of its membership, found that UASs' inability to see and avoid manned aircraft is a priority concern. Additionally, the experts we surveyed suggested, more frequently than any other alternative, conducting further work on detect, sense, and avoid technology as an interim step to facilitate UAS integration into the national airspace system while FAA develops a regulatory structure for routine UAS operations.

The effort to develop the Traffic Alert and Collision and Avoidance System (TCAS), used widely in manned aircraft to help prevent collisions, demonstrates the challenge of developing a detect, sense, and avoid capability for UASs. Although FAA, airlines, and several private-sector

[12]The Airline Owners and Pilots Association is a not-for-profit organization representing the interests of general aviation.

companies developed TCAS over a 13-year period, at a cost of more than $500 million, FAA officials point out that the designers did not intend for TCAS to act as the sole means of avoiding collisions and that the on board pilot still has the responsibility for seeing and avoiding other aircraft. FAA officials also point out that TCAS computes collision avoidance solutions based on characteristics of manned aircraft, and does not incorporate UASs' slower turn and climb rates in developing conflict solutions. Consequently, FAA officials and stakeholders we interviewed believe that developing the detect, sense, and avoid technology that UASs would need to operate routinely in the national airspace system poses an even greater challenge than TCAS did. FAA officials believe that an acceptable detect, sense, and avoid system for UASs could cost up to $2 billion to complete and is still many years away.

UASs Have Communications, Command, Control, and Physical Security Vulnerabilities

Ensuring uninterrupted command and control for a UAS is important because without it, the UAS could collide with another aircraft or, if it crashes to the earth, cause injury or property damage. The lack of protected radio frequency spectrum for UAS operations heightens the possibility that an operator could lose command and control of the UAS. Unlike manned aircraft, which use dedicated, protected radio frequencies, UASs currently use unprotected radio spectrum and, like any other wireless technology, remain vulnerable to unintentional or intentional interference. This remains a key security vulnerability for UASs, because in contrast to a manned aircraft where the pilot has direct, physical control of the aircraft, interruption of radio frequency, such as by jamming, can sever the UASs' only means of control. One of the experts we surveyed listed providing security and protected spectrum among the critical UAS integration technologies.

To address the potential interruption of command and control, UASs generally have pre-programmed maneuvers to follow if the command and control link becomes interrupted (called a "lost-link scenario") and a means for safe return to the ground if operators cannot reestablish the communications link before the UAS runs out of fuel. However, these procedures are not standardized across all types of UASs and, therefore, remain unpredictable to air traffic controllers. Predictability of UAS performance under a lost link scenario is particularly important for air traffic controllers who have responsibility for ensuring safe separation of aircraft in their airspace.

Ensuring continuity of UAS command and control also depends on the physical security provided to UASs. Presently, UAS operations in the national airspace are limited and take place under closely controlled conditions. However, this could change if UASs have routine access to the national airspace. One study identifies security as a significant issue that could be exacerbated with the proliferation of UASs. TSA notes that in 2004, terrorists flew a UAS over northern Israel.[13] One stakeholder questioned how we could prevent this from happening in the United States. UASs have the capability to deliver nuclear, biological, or chemical payloads, and can be launched undetected from virtually any site. In response to the events of September 11, 2001, entry doors to passenger airplane cockpits were hardened to prevent unauthorized entry. However, no similar security requirements exist to prevent unauthorized access to UAS ground control stations—the UAS equivalent of the cockpit. Security is a latent issue that could impede UAS developments even after all the other challenges have been addressed, according to one study.

UASs Have Shown a Lack of Reliability

Although DOD has obtained benefits from its UAS operations overseas, the agency notes in its Unmanned Systems Roadmap[14] that UAS reliability is a key factor in integrating UASs into the national airspace system.[15] Our analysis of information that DOD provided on 199 military UAS accidents, of varying degrees of severity, that occurred over 4½ years during operations Enduring Freedom and Iraqi Freedom, indicates that reliability continues to be a challenge. About 65 percent of the accidents resulted from materiel issues, such as failures of UAS components.[16]

Studies indicate that a number of factors could contribute to UAS reliability problems. Many UASs have been designed primarily as expendable or experimental vehicles, where factors such as cost, weight, function, and performance outweigh reliability concerns, according to a

[13]Transportation Security Administration, *Advisory – Security Information Regarding Remote Controlled Aircraft and Unmanned Aerial Vehicles* (Arlington, Va: Nov. 22, 2004).

[14]Department of Defense, *Unmanned Systems Roadmap 2007 – 2032*, (Washington, D.C.: Dec. 10, 2007). We did not evaluate the validity of information contained in the roadmap.

[15]DOD defines reliability as (1) the probability that an item will perform its intended function for a specified time under stated conditions or (2) the ability of a system and its parts to perform its mission without failure, degradation, or demand on the support system.

[16]DOD classifies accidents according to severity. The accident data that DOD provided included accidents in class A, B, C, and D. See appendix I for accident class definitions and further details on our methodology. We also determined that 17 percent of the accidents were due to human factors (i.e., issues associated with how humans interact with machines); 6 percent of the accidents were caused by environmental issues; and 12 percent of the accidents' causes were undetermined. We did not evaluate the validity of the accident information that DOD provided.

2004 study.[17] The Congressional Research Service reported in 2006 that the lack of reliability stems from the fact that UAS technology is still evolving, and, consequently, less redundancy is built into the operating system of UASs than of manned aircraft, and until redundant systems are perfected, accident rates are expected to remain high.[18] Reliability issues also stem from the nature of the components used in some UASs. A DOD report notes that there has been a tendency to design UASs at low cost using readily available materials that were not intended for use in an aviation environment. For example, one UAS used by DOD was equipped with a wooden propeller that could disintegrate in the rain.[19] A composite or metal propeller could cost two to three times more than a wooden propeller.

Human Factors Deficiencies in UAS Design Have Caused Accidents

UAS developers have not yet fully incorporated human factors engineering in their products. Such engineering incorporates what is known about people, their abilities, characteristics, and limitations in the design of the equipment they use, the environments in which they function, and the jobs they perform. According to researchers and agency officials we interviewed, technology in its early developmental stages typically lacks human factors considerations. Researchers noted that UASs, similar to any new technology, have been designed by engineers who focused on getting the technology to work, without considering human factors, such as ease of use by non-engineers. FAA officials noted that UASs today are at a similar stage as personal computers in their early years before newer, more user-friendly operating systems became standard. Studies indicate that human factors issues have contributed to military UAS accidents and DOD has indicated the need for further work in this area.[20] Our analysis of DOD's data on UAS accidents during Operation Enduring Freedom and Operation Iraqi Freedom showed that 17 percent were due to human factors issues.

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[17]The MITRE Corporation, 2004.

[18]Congressional Research Service, *Homeland Security: Unmanned Aerial Vehicles and Border Surveillance* (Washington, D.C.: 2006).

[19]A DOD official commented that wooden propeller damage is managed by adding treatments to the wood and by regular maintenance and inspection.

[20]Human factors, such as pilot error, have also been significant contributors to manned aircraft accidents.

Several human factors issues have yet to be resolved. For example, the number of UASs that a single ground-based pilot can safely operate remains undetermined, as some future scenarios envision a single pilot operating several UASs simultaneously. Other unresolved issues include how pilots or air traffic controllers respond to the lag in communication of information from the UAS, the skill set and medical qualifications required for UAS pilots,[21] and UAS pilot training requirements.[22]

The variety of ground control station designs across UASs is another human factors concern. For example, pilots of the Predator B UAS control the aircraft by using a stick and pedals, similar to the actions of pilots of manned aircraft. In contrast, pilots of the Global Hawk UAS use a keyboard and mouse to control the aircraft. Differences in UAS missions could require some variation among control station designs, but the extent to which regulations should require commonalities across all ground control stations awaits further research.

The transition from one crew to another while UASs are airborne serves as another human factors issue needing resolution. Because UASs have the capability of extended flight, one crew can hand off control to another during a mission. Several military UAS accidents have occurred during these handoffs, according to a 2005 research study.[23] The National Transportation Safety Board cited a similar issue in its report on the April 26, 2006, crash of CBP's Predator B UAS. According to the report, the pilot inadvertently cut off the UAS's fuel supply when he switched from a malfunctioning console to a functioning one.[24] When the switch was made, a lever on the second console remained in a position that would cut off the fuel supply if an operator used the console to control the aircraft. Although procedures required that the controls on the two consoles be matched prior to making such a switch, this procedure was not followed. CBP reports that it has taken action to address this issue and has also

[21]FAA currently requires that UAS pilots and observers have in their possession a current second class or higher airman medical certificate issued under chapter 14, Code of Federal Regulations part 67.

[22]Jason S. McCarley and Christopher D. Wickens, *Human Factors Implications of UAVs in the National Airspace* (Institute of Aviation, Aviation Human Factors Division, University of Illinois at Urbana-Champaign, 2005).

[23]McCarley and Wickens, 2005.

[24]The second console can be used to operate the Predator's camera or to control the aircraft.

addressed nearly all of the board's other recommendations stemming from this accident.

A remote pilot's lack of situational awareness serves as another human factors-related challenge for the safe operation of UASs. For example, FAA officials have noted that situational awareness remains a key factor for operators to detect and appropriately respond to turbulence. A pilot on board an aircraft can physically sense and assess the severity of turbulence being encountered, whereas a remote pilot cannot. A UAS could break apart and become a hazard to other aircraft or to persons or property on the ground if the pilot has no indication of turbulence or its severity. Even if a remote pilot had an awareness of the turbulence, the level of risk that the pilot might accept needs further study. Because a pilot does not risk his own safety when operating a UAS, the pilot may operate the UAS in situations unsuitable for the aircraft, such as flying through turbulence strong enough to destroy the UAS's airframe.

Although many experts and aviation stakeholders believe that the technical issues discussed above represent difficult challenges for UAS integration into the national airspace system, others do not. For example, DOD's Unmanned Systems Roadmap asserts that the technology for detecting and maneuvering to avoid objects does not present a major obstacle. Some experts responding to our survey expressed similar opinions. For example, one noted that technology needed to safely integrate UASs into the national airspace system exists today and that implementation should be the focus. Another said that FAA is too slow in adopting new technology and that sense and avoid techniques are available today that, when used in combination with a qualified pilot at the ground station's controls, would be sufficient to allow free access for larger UASs. However, FAA expects to continue its current practice of allowing UAS access to the national airspace system on a case-by-case basis, after a safety review, until technology, research, and regulations mature.

A Lack of Regulations Limits UAS Operations

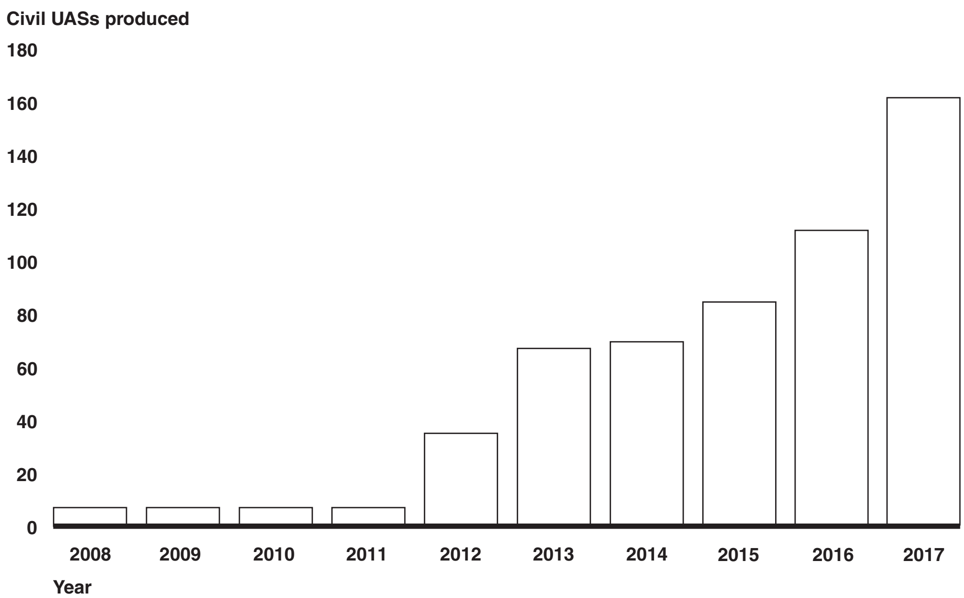
The U.S. Code of Federal Regulations[25] prescribes rules governing the operation of most aircraft in the national airspace system. However, these regulations were developed for manned aircraft. Minimum performance standards for UAS detect, sense, and avoid and communications,

[25]Part 91 of title 14.

command, and control capabilities, as well as regulations that incorporate these minimum standards, do not exist. Moreover, existing regulations may need changes or additions to address the unique characteristics of UASs. For example, because UASs do not need to be large or powerful enough to carry a pilot, they can be much smaller than any aircraft that today routinely operates in the national airspace system. Existing regulations were developed for aircraft large enough to carry a human.

The lack of a regulatory framework has limited the amount of UAS operations in the national airspace system, which has, in turn, contributed to a lack of operational data on UASs and a lack of airspace in which developers can test and evaluate their products. An industry forecast indicates that growth in a civil UAS market is not likely until regulations exist that allow UASs to operate routinely. The forecast assumes that such regulations would be in place by 2012, but notes that few civil-use UASs would be produced in the near term, with numbers increasing towards 2017. (See fig. 6.)

Figure 6: Forecast of Civil UASs Produced, 2008 through 2017



Source: Teal Group Corporation, 2008.

Studies indicate that the lack of regulations can affect liability risk of UAS operations, which can increase insurance costs. For example, without airworthiness standards, insurers would be even more concerned about the liability hazard of UASs crashing in a dense urban environment. The lack of regulations to govern access to airspace has also posed challenges for developers of civil UASs. Officials of associations representing UAS developers told us of difficulties in finding airspace in which to test and evaluate UASs. One of these officials noted that some manufacturers have their own test ranges, and some have access to restricted military airspace, but other UAS developers have not had this access. Additionally, because UAS operations in the national airspace have been limited, operational data is scarce. Having data on UAS operations is an important element in developing regulations.

Because UASs have never routinely operated in the national airspace system, the level of public acceptance is unknown. One researcher observed that as UASs expand into the non-defense sector, there will inevitably be public debate over the need for and motives behind such proliferation. One expert we surveyed commented that some individuals may raise privacy concerns about a small aircraft that is "spying" on them, whether operated by law enforcement officials or by private organizations, and raised the question of what federal agency would have the responsibility for addressing these privacy concerns. On the other hand, a study for JPDO noted that if UASs were increasingly used to produce public benefits in large-scale emergency response efforts, public acceptance could grow as the public notes the benefits that UASs can provide.[26]

Coordinating with Other Countries' Efforts to Integrate UASs Is a Key Task

As other countries work toward integrating UASs in their respective airspaces, FAA faces a challenge to work with the international community in developing harmonized standards and operational procedures so that UASs can seamlessly cross international borders and U.S. manufacturers can sell their products in the global marketplace. International bodies such as the European Organization for Civil Aviation Equipment (EUROCAE), and the European Organization for the Safety of Air Navigation (EUROCONTROL), as well as individual countries face challenges similar to those that the United States faces in integrating UASs into their respective airspaces.

EUROCAE formed a working group—WG-73—in 2006 to focus on UAS issues. The working group completed its first product in January 2007—a preliminary inventory of airworthiness certification and operational

[26]Unmanned Aerial Vehicle National Task Force, 2004.

approval items that need to be addressed. The working group also plans to develop a work plan that lays out work packages and timelines; a concept for UAS airworthiness certification and operational approval that will provide recommendations and a framework for safe UAS operations in non-segregated airspace;[27] requirements for command, control, and communications, as well as for sense and avoid systems; and a catalog of UAS-air traffic management incompatibility issues that need to be addressed.

EUROCONTROL has established a UAS Air Traffic Management Activity and is hosting workshops to seek feedback, suggestions, and advice from a broad range of aviation stakeholders on its approach to UAS integration into European airspace. The second workshop is scheduled for May 2008 and is open to all interested civil and military stakeholders, including air navigation service providers, UAS operators and manufacturers, regulators, as well as associations and professional bodies. EURCONTROL has also established an Operational Air Traffic Task Force that has developed high-level specifications for military UASs operating outside segregated airspace in a form suitable for European states to incorporate into their national regulations. The specifications state that UAS operations should not increase the risk to other airspace users, that air traffic management procedures should mirror those applicable to manned aircraft, and that the provision of air traffic services to UASs should be transparent to air traffic controllers.

Table 1 illustrates the variety of individual country efforts to integrate UASs into their respective airspaces. With the variety of ongoing efforts around the world, FAA and other countries face a challenge in harmonizing UAS standards and procedures.

[27] Non-segregated airspace is airspace that is available for all aircraft.

Table 1: Examples of UAS Integration Efforts in Other Countries

Country	UAS integration efforts
United Kingdom	"The Autonomous Systems Technology Related Airborne Evaluation and Assessment" project is focusing on the technologies, systems, facilities, and procedures that will allow UASs to operate safely and routinely in United Kingdom airspace. The project has received funding from the British government, industries, and universities and work has commenced to address topics such as communications, collision avoidance, operating rules and procedures, and integration with the operating environment.
Australia/New Zealand	An Australian aerospace firm has commissioned a program, Unmanned Aircraft Technology Applications Research, to organize efforts to address UAS issues. The program has, in turn, established an Australian/New Zealand working group to use demonstration programs to solve the critical issues currently inhibiting commercial UAS operations. The working group includes global, regional, and Australian UAS manufacturers and operators, researchers, military aviation, and an international insurance underwriter.
Japan	In 2004, a consortium of Japanese manufacturers and a government ministry completed formulation of safety guidelines for using unmanned helicopters for commercial purposes over unpopulated areas. This consortium became an association that includes additional manufacturers and individuals from universities and research agencies and plans to develop safety guidelines for UASs. Japan currently uses unmanned helicopters for pesticide spraying.
Canada	In 2007, Transport Canada issued the Final Report of its Unmanned Air Vehicle Working Group. The working group developed a plan to safely integrate unmanned air vehicles into the Canadian airspace system. The working group included representation from government, defense, and private-sector entities.
Germany	Germany has established a working group called "UAS-Deutschland" to facilitate the operation of UASs in German airspace. The working group is tasked with developing a national opinion concerning enabling the integration of UAS operations in non-segregated airspace and preparing for and fostering international harmonization. Another working group called "UAV DACH" has been established for German-speaking countries—Austria, Germany, the Netherlands, and Switzerland—to develop standards for national and international regulations for civil and military UAS flights. The group is also charged with finding solutions for UAS technical challenges such as sensing and avoiding other aircraft.

Source: FAA documents, Internet Web pages, a press release, and a UAS expert.

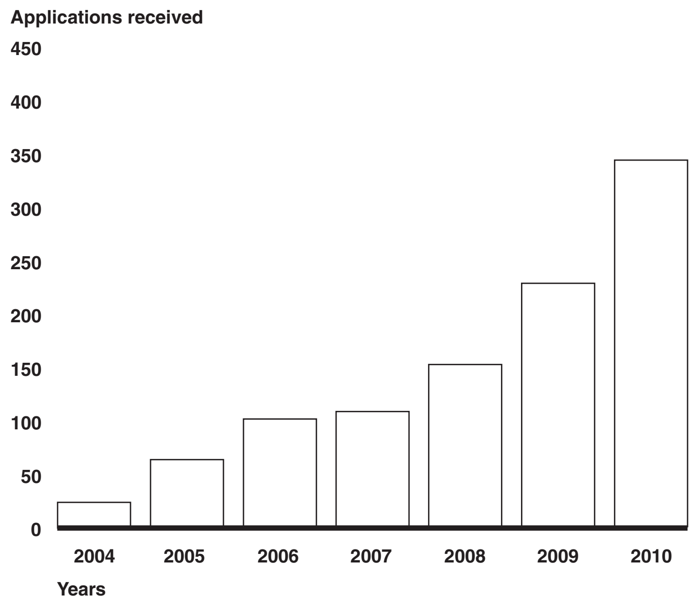
FAA Faces Increased Workload to Process COA and Special Airworthiness Certificate Applications for UAS Operations

FAA could face a workload challenge in conducting an increasing number of case-by-case safety reviews for proposed UAS operations in the national airspace system. FAA is already having difficulty in meeting its 60-calendar day goal for processing COAs, used for government requests to operate UASs. From December 2006 through January 2008, FAA's COA processing time averaged 66 calendar days.[28] FAA anticipates a substantial increase in requests for COAs, as well as for special airworthiness certificates, used by private-sector entities proposing UAS operations in the national

[28] FAA does not start calculating the processing time until officials have determined that the application is administratively correct and that the proposed UAS operation is feasible.

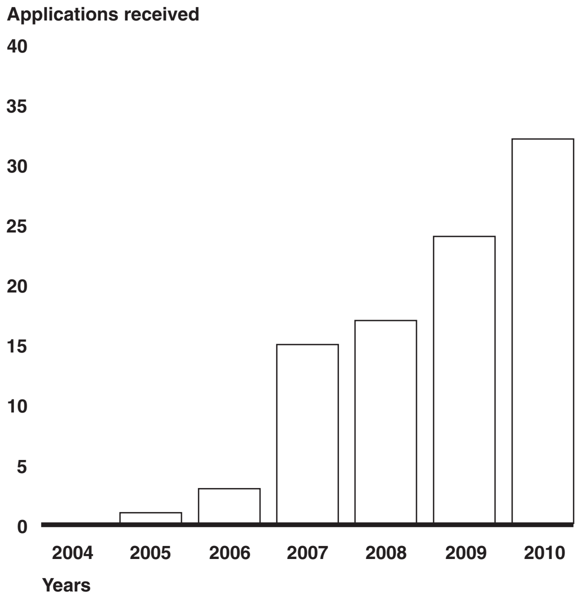
airspace system, by 2010. (See figs. 7 and 8.) Increased demand could result in even longer processing times for COAs.

Figure 7: Applications for Certificates of Waiver or Authorization, Received in Calendar Years 2004–2007, and Projected through 2010



Source: FAA.

Figure 8: Applications for Special Airworthiness Certificates, Received in Fiscal Years 2004–2007, and Projected through 2010



Source: FAA.

A lack of knowledge of the number of federally-owned or -leased UASs adds uncertainty to FAA's expected future workload. The number of COAs does not provide a count of federally-owned or -leased UASs because each COA reflects an authorization to operate a UAS, not the number of UASs owned or leased by an agency. According to FAA, an agency could have multiple copies of the same type of UAS whose operation is approved in a COA. Moreover, having multiple UASs of the same type could drive additional workload for FAA if the agency requests authorization to operate its UASs under different operating scenarios, each of which would require a separate COA. An agency could also have only one UAS, but more than one COA, if the agency required and received approval for the UAS to operate under different sets of conditions. GSA has responsibility for maintaining the inventory of federally-owned and -leased aircraft, but its regulations on reporting these aircraft have not been updated to require federal agencies to report UASs.

Coordination among Federal Agencies and Others Is Lacking

Coordinating the efforts of numerous federal agencies, academic institutions, and private-sector entities that have UAS expertise or a stake in routine access to the national airspace system is a challenge. As discussed above, several federal agencies are involved to varying degrees in UAS issues. Additionally, academic institutions have UAS expertise to contribute and UAS manufacturers have a stake in supplying the demand for UASs that routine access could create. FAA and experts referenced the Access-5 program that, in the past, served as an overarching coordinating body and provided a useful community forum. While some experts believe that Access-5's focus on high-altitude, long-endurance UASs is no longer appropriate, the program's institutional arrangements demonstrated how federal government and the private-sector resources could be combined to focus on a common goal.

Stakeholders and experts we surveyed believe that coordination and focus are lacking among the diverse entities working on UAS issues, and expressed concerns that the potential public and economic benefits of UASs could be delayed while FAA develops the safety regulations required to enable routine UASs operations in the national airspace system. They noted the numerous potential uses in public safety, law enforcement, weather forecasting, and national security, discussed previously, stating that these benefits will be delayed until standards are developed. Some also noted that economic benefits realized through industry growth and productivity gains in the commercial sector would also be delayed. Additionally, some experts believe that, at the current pace of progress, the United States would lose its leadership position and manufacturers would move to other countries where the regulatory climate is more receptive. However, as previously noted, an industry forecast indicates that the United States will account for about two-thirds of the worldwide UAS research and development in the coming decade.

Fully Addressing UAS Challenges Involves Several Agencies and Could Take a Decade or Longer

FAA and other agencies have roles in addressing technological, regulatory, and workload challenges, but no entity is in charge of coordinating these efforts. FAA and DOD are addressing some technological challenges, but TSA has not addressed the security implications of routine UAS operations. FAA is establishing a regulatory framework, but routine UAS access to the national airspace may not occur for over a decade. FAA is mitigating its expected increased workload by automating some of its COA processing steps. GSA is updating its federal aircraft reporting requirements to include UASs. Experts and stakeholders believe that an overarching entity could add focus to these diverse efforts and facilitate routine UAS access to the national airspace system.

Federal Agencies Are Addressing Some Technological Issues

FAA is addressing technological issues by sponsoring research and taking steps to address UAS vulnerabilities in communications, command, and control. DOD is taking steps toward improving UAS reliability and the extent of human factors consideration in UAS design. An FAA-sponsored federal advisory committee is developing technical standards for FAA to use in developing UAS regulations. Although TSA issued an advisory circular in 2004 on UAS security concerns, it has not addressed the security implications of routine UAS access in the national airspace system.

FAA Is Sponsoring Research on Detect, Sense, and Avoid Technologies and Other Topics

FAA has budgeted $4.7 million for fiscal years 2007 through 2009 for further UAS research on topics such as detect, sense, and avoid; command and control; and system safety management. NASA, FAA, and others have conducted tests to determine the capabilities of and potential improvements to detect, sense, and avoid technology. For example, in 2003, NASA installed radar on a manned aircraft that was equipped for optional control from the ground. The tests indicated that the radar detected intruding aircraft earlier than the onboard pilot, but also revealed the need for further work on the onboard sensing equipment to ensure adequate response time for the remote pilot. In another example, FAA and the Air Force Research Laboratory collaborated to execute flight tests for sense and avoid technology between October 2006 and January 2007. According to a summary of the lessons learned from these tests, the results showed some promise, but indicated that much work and technology maturation would need to occur before the tested system could be deemed ready for operational use.

FAA Has Begun to Address Radio Frequency Spectrum Allocation for UASs to Ensure Uninterrupted Communications, Command, and Control

Addressing the challenge of radio frequency allocation for UAS operations is moving forward, but may not be completed for several years. The International Telecommunication Union allocates radio frequency spectrum and deliberates such issues at periodic World Radiocommunication Conferences, the most recent of which was held in the fall of 2007. To obtain spectrum allocation for UASs, FAA has participated with the Department of Commerce in a national preparation process to place spectrum allocation decisions on the conference's future agenda. At the 2007 conference, delegates agreed to discuss at the next conference, in 2011, the spectrum requirements and possible regulatory actions, including spectrum allocations, needed to support the safe operation of UASs. The Department of Commerce and the Federal Communications Commission would jointly implement and manage the spectrum allocation decisions made at the 2011 conference, as these agencies manage, respectively, federal and non-federal use of frequency spectrum.[29]

DOD Is Working to Improve UAS Reliability and Incorporate Human Factors in UAS Design

DOD is urging manufacturers to increase UAS reliability while keeping costs low by using such practices as standard systems engineering, ensuring that replacement parts are readily available, and using redundant, fail-safe designs. DOD also notes in its Unmanned Systems Roadmap that, although UASs suffer accidents at one to two orders of magnitude greater than the rate incurred by manned military aircraft, accident rates have declined as operational experience increased. For some UASs, the accident rates have become similar to or lower than that of the manned F-16 fighter jet, according to the roadmap. According to a study by The MITRE Corporation, General Atomics designed the Predator B UAS with reliability in mind, and the Altair UAS, which is a modified version of the Predator, has, among other things, triple redundant avionics to increase reliability.

The Army has made some progress in limiting the variety of ground control station designs for unmanned aircraft—a human factors concern—by developing its "One System®," which involves a single ground control station capable of operating a variety of UASs. Further increasing standardization and interoperability across all unmanned systems is a continuing DOD goal.

A Federal Advisory Body Is Developing Technical Standards

The Radio Technical Commission for Aeronautics (RTCA), a federal advisory committee sponsored by FAA,[30] is establishing minimum performance standards for FAA to use in developing UAS regulations. RTCA established Special Committee 203 in October 2004 to develop such standards for UAS detect, sense, and avoid and for UAS communications, command, and control. Individuals from academia and the private sector serve on the committee without government compensation along with FAA, NASA, and DOD officials.

[29]The National Telecommunications and Information Administration of the Department of Commerce manages federal use of spectrum.

[30]RTCA is a private, not-for-profit corporation that develops consensus-based performance standards regarding communications, navigation, surveillance, and air traffic management system issues. RTCA serves as a federal advisory committee, and its recommendations are the basis for a number of FAA's policy, program, and regulatory decisions.

Special Committee 203 has begun assessing the technological and regulatory landscape as it pertains to UASs to determine the scope of its task. The committee published guidance materials to provide a framework for its standards development effort and to help UAS designers, manufacturers, installers, service providers, and users understand the breadth of operational concepts and systems being considered for integration into the national airspace system.[31] The committee anticipates that the guidance will be further refined and validated as the standards development process moves along.

According to a committee co-chair, the committee did not realize, at the outset, that developing technical standards for UASs would be a project of unprecedented complexity and scope for RTCA. RTCA's projects have been narrower in scope in the past, he said. Although the committee officials had previously estimated that the standards would be completed by 2011 or 2012, the completion date is now between 2017 and 2019. The additional time has been added to apply a data-driven, systems engineering approach that will require the collaborative efforts of FAA, DOD, and MITRE's Center for Advanced Aviation System Development.[32]

RTCA anticipates that reliability and human factors requirements will be integrated into its minimum performance standards. The guidance materials note that UASs must meet the same reliability as manned aircraft, and that reliability is an important component of safety; flight control systems; certification requirements for detect, sense, and avoid avionics; and for command and control systems such as the UAS's autopilot. According to RTCA officials, human factors will be an overarching consideration in standards development.

Security Implications of Routine UAS Access to the National Airspace System Have Not Been Addressed

Although UASs remain vulnerable to many of the same security risks as manned aircraft, little attention has been afforded to UAS security. In 2004, TSA issued an advisory that described possible terrorist interest in using UASs as weapons. The advisory noted the potential for UASs to carry explosives or disperse chemical or biological weapons. However, the advisory noted that there was no credible evidence to suggest that

[31] RTCA Special Committee 203, *Guidance Material and Considerations for Unmanned Aircraft Systems* (Washington, D.C.: 2007).

[32] MITRE's Center for Advanced Aviation System Development is a federally-funded research and development center that performs systems research and development work for FAA and other civil aviation authorities.

terrorist organizations plan to use UASs in the United States and advised operators to stay alert for UASs with unusual or unauthorized modifications or persons observed loitering in the vicinity of UAS operations, loading unusual cargo into a UAS, appearing to be under stress, showing identification that appeared to be altered, or asking detailed questions about UAS capabilities. In 2007, the agency advised model aircraft clubs to fly their aircraft only at chartered club facilities or at administered sites and to notify local authorities of scheduled flying events.

TSA considers these actions appropriate to address the security threat posed by UASs. According to TSA, the agency uses a threat based, risk management approach to prioritize risk, threats, and vulnerabilities in order to appropriately apply resources and implement security enhancements. TSA informed us that the agency continues to monitor threat information regarding UASs and has processes in place to act quickly to mitigate and respond to any identified vulnerabilities. While these actions may be appropriate for the low tempo of today's UAS operations, growth forecasts indicate that UASs could proliferate in the national airspace in the future. Such a proliferation could increase the risk of UASs being used by terrorists for attacks in the United States. A lack of analysis of security issues, while FAA develops the regulatory framework, could lead to further delays in allowing UASs routine access to the national airspace system.

FAA Is Establishing a Regulatory Framework, but Routine UAS Access to the National Airspace May Not Occur for a Decade or More

FAA has established a UAS program office and is reviewing the body of manned aviation regulations to determine the modifications needed to address UASs, but these modifications may not be completed until 2020. As an interim step, FAA has begun an effort to provide increased access to the national airspace system for small UASs. FAA is taking steps to develop data to use in developing standards, but has been slow to analyze the data that it has already collected. FAA is also coordinating with other countries to harmonize regulations.

FAA Has Created an Unmanned Aircraft Program Office to Ensure That UASs Operate Safely

In February 2006, FAA created the Unmanned Aircraft Program Office (UAPO) to develop policies and regulations to ensure that UASs operate safely in the national airspace system. With 19 staff, UAPO serves as FAA's focal point to coordinate efforts to address UAS technical and regulatory challenges and for outreach to other government agencies, the private sector, and other countries and international bodies working on UASs integration challenges. UAPO is developing a program plan to inform the aviation community of FAA's perspective on all that needs to be accomplished and the time frames required to create a regulatory framework that will ensure UAS safety and allow UASs to have routine access to the national airspace system. Although officials informed us that this plan was in progress in December 2006, as of March 2008 the plan was awaiting final approval for release. Issuing the program plan could provide industry and potential UAS users with a framework that describes FAA's vision and plans for integrating UASs into the national airspace system.

While RTCA is developing minimum performance standards for UASs, FAA has begun to review the existing body of regulations for manned aviation to determine what regulations need to be modified or whether new regulations are needed to address the unique characteristics of UASs. Some of the rules for manned aircraft may not apply to UASs. For example, the rule requiring that oxygen be on board for passenger use on all aircraft operating above 14,000 feet would not apply to a UAS. On the other hand, new standards may be needed. For example, while FAA has developed standards for manned airframe stress, no similar standard exists for UASs. UASs may require unique standards because, as mentioned previously in this report, a remote pilot cannot physically experience and judge the severity of turbulence that could potentially harm the airframe and cause an accident.

However, UASs may not receive routine access to the national airspace system until 2020. FAA's final step in developing UAS regulations must wait until the 2017 to 2019 time frame, after RTCA's Special Committee 203 develops minimum technical standards for UASs. FAA would then conduct a rulemaking to adopt the committee's standards, which would require an additional year, according to an FAA official.

As an interim effort to increase UAS access to the national airspace system, FAA began an effort in 2007 to establish regulations to incrementally allow small UASs to operate in the national airspace system, under low-risk conditions without undergoing the case-by-case approval process that is currently required. FAA has established a plan to publish a notice of proposed rulemaking by July 2009 and a final rule by 2010 or 2011. Although FAA has not reached any final decisions, FAA may limit these regulations to UASs weighing less than 30 pounds, operating within line of sight, and traveling at speeds less than 40 knots, according to an FAA official.[33] FAA is considering using a nontraditional certification

[33]DOD defines a small UAS as one that weighs less than 55 pounds, flies slower than 100 knots, and operates at altitudes below 1,000 feet.

approach that would allow applicants to register small UASs using a Web-based tool. FAA anticipates that, following the rulemaking, it will obtain data and experience with UAS operations that could lead to further gradual expansion of small UAS access to the national airspace system.

Allowing incremental access of certain UASs that pose low risks is consistent with pending legislation[34] and local government agencies and potential commercial operators have expressed much interest in operating small UASs. However, FAA recognizes that some small UASs may never have routine access to the national airspace system because their small size limits their ability to carry detect, sense, and avoid equipment. Additionally, FAA notes that, like all UASs, small UASs will require secure radio frequency spectrum for command and control, and this issue has not yet been resolved.

FAA Seeks Data on UAS Operations, but Progress Is Slow

The absence of a comprehensive database on UAS safety and reliability that could inform the standards and regulations development process hinders FAA's efforts to establish a regulatory framework for UASs. FAA has been working to leverage DOD's decades of experience with UASs. Collaboration between FAA and DOD could provide mutual benefits. DOD plans to spend over $7 billion in research, development, test, and evaluation funds for UASs between fiscal years 2007 and 2013. Data from these efforts could facilitate FAA's development of a regulatory framework to allow UASs to have routine access to the national airspace system. DOD would benefit from this access by being able to operate its UASs in the national airspace, without first obtaining a COA, as UASs transit from home bases to training areas or to overseas deployment. To this end, FAA and DOD finalized a memorandum of agreement in September 2007 that provides a formal mechanism for FAA to request, and DOD to provide, data on UAS operations to support safety studies. Through the memorandum, FAA will share the results of its studies with DOD and vice versa. FAA also participates with DOD on a joint integrated product team that is focusing on obtaining military UAS access to the national airspace system. According to DOD's Unmanned Systems Roadmap, the team's activities include modeling and simulation, technology development, acquisition, demonstrations, and flight tests.

While DOD's extensive experience with UAS operations and its accumulated data represent potentially rich sources of information on

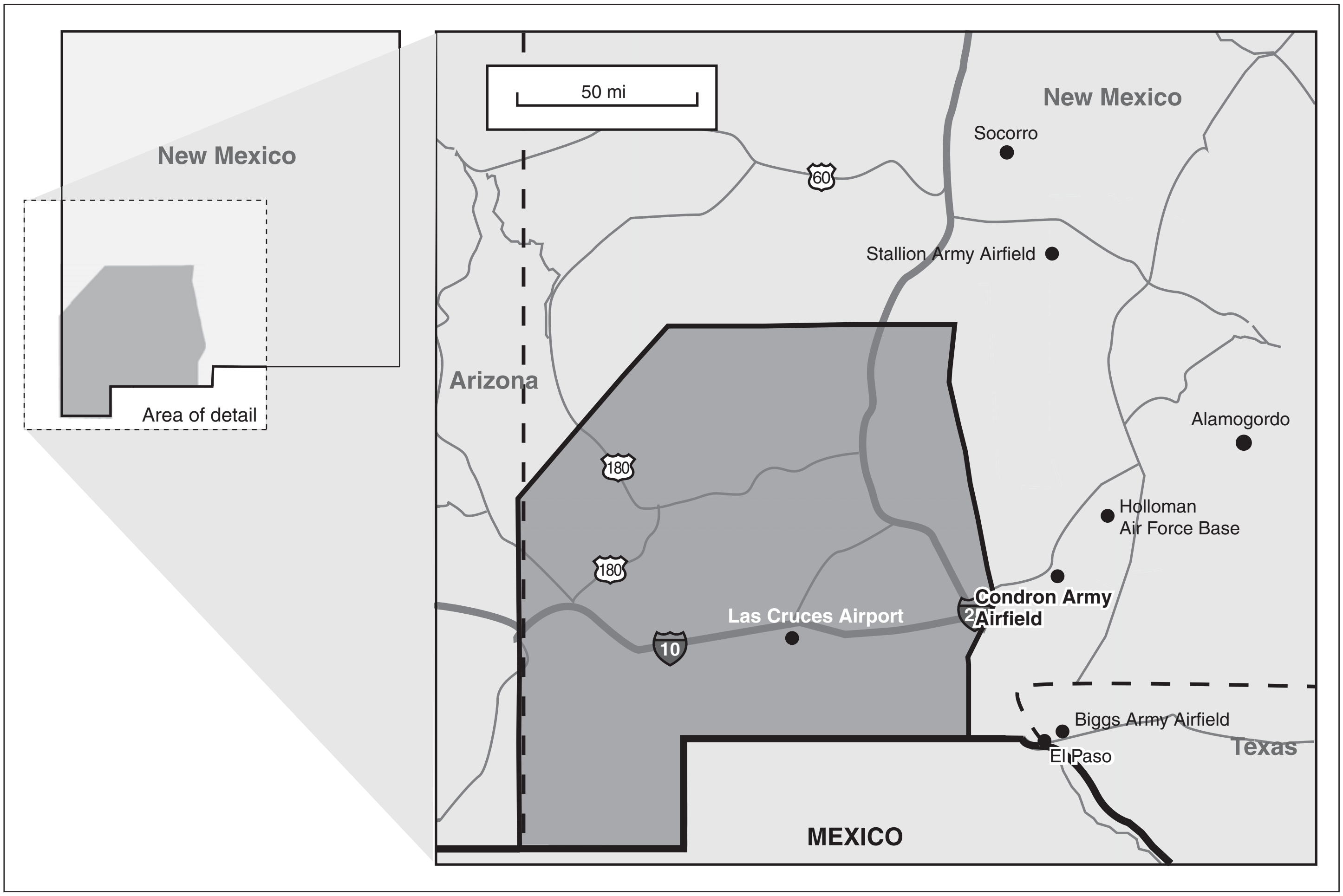
[34] H.R. 2881, § 322.

UAS operations, regulators should use such information with the understanding that it comes from a wartime operating environment. FAA and DOD officials acknowledge that military experience and operational data on UASs are not always directly transferable to operations in the national airspace system. The military's use of UASs is focused on mitigating the danger to troops. Safety and reliability risks that may be appropriate in a war zone to protect troops may not be acceptable in the national airspace system.

FAA's efforts to develop and analyze UAS operations data are a good start, but FAA has not yet analyzed the data that it has already collected. The COA requires the applicant to provide FAA with a variety of operational data, such as the number of flights conducted, the pilot duty time per flight, equipment malfunctions, and information on any accidents. FAA has been archiving this information as it is received, but has not analyzed it because of resource constraints, according to a UAPO official. Analyzing this data could add to the information available for developing standards.

As a vehicle for collecting data on UAS operations and to address the challenge that UAS developers have had in finding airspace for testing and evaluating their products, FAA has established a UAS test center at New Mexico State University in Las Cruces, New Mexico. FAA expects that UAS operations at the test center, which opened in the spring of 2008, will provide FAA with some of the data needed to develop standards and regulations for allowing routine UAS access to the national airspace system. The university will operate the 12,000 square mile test center, where UASs can operate at altitudes up to 18,000 feet. (See fig. 9.) The university has several years of experience in demonstrating, testing, and evaluating UAS technologies. The New Mexico environment has the advantage of a very low population density and a low volume of air traffic, and the test center is located over mostly undeveloped government-owned land. FAA will provide oversight of the test center operation by way of announced and unannounced visits, according to an FAA official.

Figure 9: UAS Test Center at New Mexico State University



Sources: GAO and FAA.

FAA Is Coordinating with Other Countries to Harmonize Regulations

To address the challenge of coordinating U.S. efforts with those of other countries, FAA is working with international aviation bodies and maintaining contact with other countries as they also work to overcome the challenges of integrating UASs into their respective airspaces. For example, the manager of FAA's UAPO serves as a vice chairman of EUROCAE's WG-73,[35] and FAA has established a collaborative effort with

[35]EUROCAE formed WG-73 in 2006 to focus on UAS issues.

EUROCONTROL to leverage mutual expertise and resources. FAA told us that the International Civil Aviation Organization (ICAO)[36] has formed a study group to identify changes needed in global standards and practices to address UAS issues. FAA has also established a memorandum of cooperation with the Netherlands' Civil Aviation Authority to work on UAS technology, hazards, and risks. FAA plans to contribute, subject to appropriations, $1 million during fiscal years 2007 through 2011, to provide the Netherlands with data and expertise, while the Netherlands plans to contribute €160,000 ($251,279).[37] FAA has received briefings on Japan's use of UASs for pesticide spraying and has collaborated with several countries to address UAS issues with ICAO.

FAA's efforts to work with the international community could facilitate mutual sharing of experiences and substantially increase the amount of information available to all countries. One stakeholder suggested Israel as a potential source of data, as that country has had extensive experience with UAS operations. An Israel Space Agency official, noting the growing importance of UASs in that country, stated that the numbers of unmanned aircraft in the Israel Air Force will outnumber manned aircraft within 20 years. The official also stated that in a recent conflict, Israel's UASs compiled more flying hours than manned aircraft.

FAA Is Mitigating Anticipated Workload Increase by Automating Some COA Processing Steps, and GSA Is Working to Develop an Inventory of Federal UASs

FAA has taken some actions to mitigate the workload challenge stemming from an anticipated increase in requests for COAs to operate UASs in the national airspace system. During the spring of 2007, FAA began to introduce more automation into its COA review process for UASs and has plans for increasing automation. For example, FAA established a Web-based COA application, which became mandatory for applicants' use on July 1, 2007. FAA officials believe that the Web-based process allows applicants to more easily determine the application's requirements, thereby eliminating rework and repeated reviews before FAA accepts the application. FAA also expects that the September 2007 memorandum of agreement with DOD will reduce the number of COA applications because it allows DOD to conduct certain operations with UASs weighing 20 pounds or less over military installations and in other specified airspace

[36]ICAO is the global forum for civil aviation. ICAO works to achieve its vision of safe, secure, and sustainable development of civil aviation through the cooperation of its member States.

[37]Based on conversion rate as of April 9, 2008.

without obtaining a COA.[38] Additionally, FAA is working to identify characteristics of routine COA applications, which FAA estimates constitute up to 80 percent of total COA applications, enabling agency staff to focus limited resources on non routine cases. Focusing less attention on routine cases is consistent with comments from three of our experts who noted the need for an expedited process for obtaining COAs and special airworthiness certificates. FAA officials also stated that because applicants are becoming more familiar with COA requirements, a higher percentage of applications do not need additional work and review.

Knowledge of the number of federally-owned or -leased UASs could help FAA to plan for future workload. Forecasters indicate that UASs operated by federal agencies could be a major component of UAS growth in the immediate future. Although the current number of federally-owned or -leased UASs is unknown, GSA is taking steps to obtain this information. In response to our requests for data on the number of federally-owned or -leased UASs, GSA sent letters to federal agencies in February 2008, clarifying that FAA defines a UAS as an aircraft and requesting agencies to report their UASs by March 31, 2008. GSA is also in the process of revising regulations to require federal agencies to include owned or leased UASs in their aircraft inventory reports. GSA expects to have its regulation updated by February 2009. GSA anticipates that the first public reporting of UASs will be in the fiscal year 2008 Federal Aviation Report, due by March 31, 2009. This report could add a degree of certainty to FAA's future workload requirements.

Experts and Stakeholders Believe an Overarching Entity Could Facilitate Efforts to Achieve Routine UAS Access to the National Airspace System

In addition to FAA, DOD, TSA, and GSA, other federal agencies, academia, and the private sector also have UAS expertise or a stake in obtaining routine UAS access to the national airspace system. For example, RTCA notes that developing standards will require collaboration with DOD's joint integrated product team and technical expertise from staff in MITRE's Center for Advanced Aviation System Development. DOD seeks expanded access to the national airspace and, as previously discussed, has extensive experience with operating its own UASs. Beyond DOD and FAA, other entities also have UAS expertise or a stake in achieving routine UAS access to the national airspace system. For example, DHS's CBP and Coast Guard need UAS access to the national airspace system to perform their

[38]Previously, UAS operations could occur without a COA only within DOD's restricted airspace or warning areas.

missions. Several academic institutions have been involved in developing UAS technology in areas such as vehicle design and detect, sense, and avoid capability. Additionally, the private sector has a stake in being ready to respond to the anticipated market that could emerge when FAA makes routine access available to most UASs. Although FAA's UAPO serves as a focal point within FAA, the office has no authority over other agencies' efforts.

Experts and stakeholders suggested that an overarching body might facilitate progress toward integrating UASs into the national airspace system. DOD, as the major user of UASs, is taking such an approach. DOD has recognized the need for coordination of UAS activities within its own sphere of influence, as each service has recognized the value of UASs for its respective missions. Consequently, DOD established an Unmanned Aircraft Systems Task Force to coordinate critical issues related to UAS acquisition and management within DOD. According to DOD, the task force will establish new teams or lead or coordinate existing Army, Navy, and Air Force teams to enhance operations, enable interdependencies, and streamline acquisitions. FAA is participating in a joint integrated product team that is part of this task force, and DOD has invited DHS to join the task force.

The European Defense Agency has also recognized the challenge of channeling diverse entities, as well as multiple nation-states, toward the common goal of UAS access to non-segregated airspace. In January 2008, the agency announced that it had awarded a contract to a consortium of defense and aerospace companies to develop a detailed roadmap for integrating, by 2015, UASs into European airspace. The project is intended to help European stakeholders such as airworthiness authorities, air traffic management bodies, procurement agencies, industry, and research institutes to develop a joint agenda for common European UAS activities. The consortium held its first workshop in February 2008 and has since prepared a roadmap outline based on the needs and requirements expressed by the stakeholders. The consortium has also identified as a baseline, key actions to be undertaken and key topics for further investigation. The consortium has invited stakeholders to discuss this common baseline at a second workshop, scheduled for May 2008.

Congress addressed a similar coordination challenge in 2003 when it passed legislation to create JPDO to plan for and coordinate a transformation of the nation's current air traffic control system to the next generation air transportation system (NextGen) by 2025. NextGen involves a complex mix of precision satellite navigation; digital, networked communications; an integrated weather system; layered, adaptive security; and more.

NextGen's coordination and planning challenges are similar to those posed by UASs. For example, as required for UAS integration, the expertise and technology required for NextGen resides in several federal agencies, academia, and the private sector. DOD has expertise in "network centric" systems, originally developed for the battlefield, which are being considered as a framework to provide all users of the national airspace system with a common view of that system. JPDO's responsibilities include coordinating goals, priorities, and research activities of several partner agencies, including DOD, FAA, the Department of Commerce, DHS, and NASA with aviation and aeronautical firms. Congress directed JPDO to prepare an integrated plan that would include, among other things, a national vision statement and a multiagency research and development roadmap for creating NextGen. The legislation called for the roadmap to identify obstacles, the research and development necessary to overcome them, and the roles of each agency, corporations, and universities.

Impact of Routine UAS Operations Is Unknown

The impact of routine UAS operations on the national airspace system and the environment depends on a number of factors and remains generally speculative. UAS impact will depend on factors such as the number of UASs purchased for civil uses and the altitudes and geographic locations where they are used. Stakeholders whom we interviewed provided a variety of perspectives on UASs' potential impact. One official told us that UASs that use airports will impact air traffic control, while the impact of small UASs that do not need to use airports is less clear. Officials also noted that the level of risk depends on factors such as the UAS's weight and horsepower. For example, a small, 2- or 3-pound UAS would pose little risk to aircraft or people on the ground, but UASs weighing more than 20 pounds could do significant damage to an aircraft. Officials also noted that a UAS used over a sparsely populated area would have less impact than UAS operations over densely populated areas.

Predictions of the impact of UASs on the national airspace system are speculative because there are few data upon which to base predictions. Predictions become even more speculative in view of RTCA's recent estimate that minimum standards for UASs—a prerequisite for routine UAS access to the national airspace system—will require about another 10 years to complete. One study notes that more needs to be known about the needs and capabilities of future UASs as well as the potential market, but concluded that their operations could have a significant and potentially disruptive impact on aviation by affecting capacity and introducing more complexity. In 2007, RTCA's Special Committee 203 reported similar concerns, indicating that UASs will create some unique challenges because they operate differently from typical manned aircraft. While manned aircraft generally go from one location to another, UASs may hover or circle in one location for a significant time. Additionally, UAS speed, maneuverability, climb rate and other performance characteristics may differ substantially from those of conventional aircraft. The committee believes that these characteristics could affect air traffic flow, air traffic controller workload, and departure and arrival procedures, among other things. Similarly, FAA officials noted that UASs pose airport safety and capacity questions that require further analysis.

Most of the experts stated that the impact of UAS's would be at least as significant as that of additional manned aircraft on airspace, airports, and air traffic control. For example, they predicted that, as with manned aircraft, UASs would add to the number of aircraft and, therefore, affect airspace and airport capacity and add to the workload of air traffic controllers. However, the experts also predicted that UASs could have a beneficial impact on the environment. The experts predicted that UASs could assume some missions currently performed by manned aircraft, but could perform these missions using engines that burn less fuel or produce less air pollution.

Conclusion

Although ensuring that UASs operate safely in the national airspace system is a new and complex challenge for FAA, the national airspace system should be prepared to accommodate them. Understanding the issues, trends, and influences of UASs will be critical in strategically planning for the future airspace system. FAA is making progress in addressing the challenges. Establishing a UAS test center to provide UAS developers with airspace in which to test, evaluate, and refine their aircraft designs, and initiating efforts to increase airspace access for small UASs are significant steps. Moving forward, issuing FAA's long-awaited program plan should benefit the aviation community by communicating FAA's strategy of how it plans to address the interactive complexities and unique properties of UASs and how it plans to leverage the resources of multiple entities that have expertise and experience in this area. FAA's efforts to accumulate and analyze data will be important to facilitate the regulatory development process. However, analyzing the data that it already has collected from recent UAS operations would further support decisions on the new regulations. FAA's new estimate that the regulatory framework is not likely to be completed until sometime near 2020—about 8 years later than the date assumed by the industry forecast cited in this report—could further delay the time frame when civil-use UAS production begins to increase. While TSA's risk assessment of UASs may be appropriate for today's UAS environment, a national airspace system that allows routine UAS access for all government and private UASs will require increased safeguards to protect against security vulnerabilities like those exposed in the events of September 11, 2001. Proactively assessing and addressing these issues will help ensure that the benefits of UASs are not further delayed pending resolution of security challenges. Additionally, it will be important for GSA to follow through and ensure that federal agencies report all of their owned or leased UASs, so that FAA has a more accurate basis for workload planning. It remains to be seen whether Europe will be successful in integrating UASs into its airspace by 2015, which is considerably sooner than the 2020 time frame expected in the United States. An overarching entity, modeled after JPDO and set up to coordinate federal, academic, and private-sector entities, could facilitate progress in moving toward UASs having routine access to our national airspace system.

Matter for Congressional Consideration

To coordinate and focus the efforts of federal agencies and harness the capabilities of the private sector so that the nation may obtain further benefits from UASs as soon as possible, Congress should consider creating an overarching body within FAA, as it did when it established JPDO, to coordinate federal, academic, and private-sector efforts in meeting the safety challenges of allowing routine UAS access to the national airspace system.

Recommendations for Executive Action

To obtain further benefits from UASs, we are recommending that the Secretary of Transportation direct the FAA Administrator to expedite efforts to ensure that UASs have routine access to the national airspace system by taking the following two actions:

1. Finalize and issue a UAS program plan to address the future of UASs.

2. Analyze the data FAA collects on UAS operations under its COAs and establish a process to analyze DOD data on its UAS research, development, and operations.

To ensure that appropriate UAS security controls are in place when civil-use UASs have routine access to the national airspace system, we are recommending that the Secretary of Homeland Security direct the TSA Administrator to examine the security implications of future, non-military UAS operations in the national airspace system and take any actions deemed appropriate.

Agency Comments

We provided a draft of this report to DOT, DHS, DOD, GSA, NASA, and the Department of Commerce. DOT agreed to consider our recommendations as it moves forward in addressing UASs and DHS agreed with our recommendation to it. GSA commented that, although our report contained no recommendations to the agency, it will continue to work with federal agencies to ensure that FAA has accurate information on the number of federally-owned or –leased UASs. DOT commented that the report would benefit from additional information on the impact of UASs on airports. We revised the report to include DOT's concern that the impact of UASs on safety and capacity at airports requires further study. DOT, DOD, and DHS provided technical comments, which we incorporated as appropriate. NASA and the Department of Commerce had no comments.

We are sending electronic copies of this report to FAA, DHS, DOD, GSA, NASA, the Department of Commerce, and interested congressional committees. We also will make electronic copies available to others upon request. In addition, the report will be available at no charge on the GAO Web site at http://www.gao.gov.

If you or your staff have any questions about this report, please contact me at (202) 512-2834 or dillinghamg@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff who made major contributions to this report are listed in appendix IV.

Gerald L. Dillingham, Ph.D.
Director, Physical Infrastructure Issues

Appendix I: Scope and Methods

Our objective was to assess the Federal Aviation Administration's (FAA) efforts to ensure that unmanned aircraft systems (UAS) are safely integrated into the national airspace system and the potential impact of UASs on the national airspace system and the environment after integration occurs. To meet this objective, we developed the following research questions: (1) What are the current and potential uses and benefits of UASs? (2) What challenges exist in operating UASs safely and routinely in the national airspace system? (3) What is the federal government's response to these challenges? and (4) Assuming that UASs have routine access to the national airspace system, how might they impact the system and the environment?

To address these questions, we surveyed the literature and also obtained and reviewed documents and interviewed officials of government, academic, and private-sector entities involved with UAS issues. We discussed current and future use of UASs with officials at FAA, Department of Defense (DOD), National Aeronautics and Space Administration (NASA), and Department of Homeland Security (DHS). We interviewed leaders of the Radio Technical Commission for Aeronautics' (RTCA) Special Committee 203, which is developing UAS standards, and met with officials from a federally-funded research and development center. We discussed potential use of UASs for cargo transport with the United Parcel Service and Federal Express. We also discussed our questions with officials of associations of UAS manufacturers and users of the national airspace system, specifically, the Air Transport Association; Aerospace Industries Association; Association for Unmanned Vehicle Systems International; Aircraft Owners and Pilots Association; Air Line Pilots Association, International; American Institute of Aeronautics and Astronautics; ASTM International, originally known as the American Society for Testing and Materials; Palm Bay Police Department; and Los Angeles Sheriff Department. We discussed UAS operations with officials and observed UAS operations at Fort Huachuca, Arizona, and met with DHS's Customs and Border Protection (CBP) officials in Arizona to discuss UAS use in border protection. Additionally, we obtained industry forecasts of UAS growth and interviewed a senior analyst involved in preparing Teal Group Corporation's UAS market profile and forecast. We also observed a demonstration of unmanned systems at Webster Field, St. Inigoes, Maryland.

To obtain additional information on the challenges that must be overcome before UASs can safely and routinely operate in the national airspace system, we leveraged information that was originally obtained and analyzed for a related GAO engagement.[1] For that engagement, we contacted the Army Combat Readiness Center, Naval Safety Center, and Air Force Safety Center to obtain data on each service's UAS accidents from October 2001 to April or May 2006, depending on when the services queried their databases. The services provided data on class A, B, C, and D accidents.[2] Using the descriptive information that the services provided for each accident, we determined whether human, materiel, environmental, or undetermined factors caused the accident and categorized each accordingly. We used the definitions of human, materiel, and environmental factors provided in Army Regulation 385-40, Accident Reporting and Records. We classified accidents as "undetermined" when descriptive information did not fall within one of the first three categories of factors. We discussed the results of our analysis with DOD officials and incorporated their comments as appropriate.

To obtain additional information on the federal response to the challenge of integrating UASs into the national airspace system and the impact that UASs might have on the system after they have routine access, we reviewed agency documents and interviewed officials of the General Services Administration and the Department of Commerce's National Telecommunications and Information Administration. We also obtained information from DHS's Transportation Security Administration.

[1]See GAO, *Unmanned Aircraft Systems: Advance Coordination and Increased Visibility Needed to Optimize Capabilities*, GAO-07-836 (Washington, D.C.: July 11, 2007). The data, although not used in this report, was obtained and analyzed using generally accepted government auditing standards.

[2]DOD classifies accidents in categories A, B, and C, based on the severity of resulting injury, occupational illness, or property damage. Property damage severity is generally expressed in terms of cost and is calculated as the sum of the costs associated with DOD property and non-DOD property that is damaged in a DOD accident. Class A accidents result in damages of $1 million or more, total loss of a DOD aircraft, or a fatality or permanent total disability. Class B accidents result in damages of $200,000 or more, but less than $1 million, a permanent partial disability, or hospitalization of three or more personnel. Class C accidents result in damages of $20,000 or more, but less than $200,000, a nonfatal injury that causes any loss of time from work beyond the day or shift on which it occurred, or a nonfatal occupational illness or disability that causes loss of time from work or disability at any time. Additionally, the services have varying classifications of less severe accidents. Only the Army provided accident data for Class D accidents, which the Army defines as those which result in property damage of $2,000 or more but less than $20,000, or a nonfatal injury that does not meet the criteria of a Class C accident.

Additionally, we surveyed 23 UAS experts, whose names were identified with the assistance of the National Academies. We asked the experts to provide, in narrative format, their views on the interim regulatory, technological, research, or other efforts that could be undertaken for UASs to operate, if not routinely, then to the maximum extent possible in the national airspace system while FAA develops the regulatory structure to enable all UASs to have routine access to the system. We also asked the experts to provide their predictions on how small and large UASs might impact the national airspace, airports, air traffic control, noise, and air quality, using a 7-point scale from large adverse impact to large beneficial impact, and asked that they explain their answers. Appendix II discusses how we developed and conducted the survey. The complete survey instrument appears as appendix III.

We conducted this performance audit from October 2006 to May 2008, in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Appendix II: Survey Methods

We administered a Web-based survey to gather the professional views of experts on the impact of UASs on the national airspace system and the actions needed to move toward safe and routine UAS operations. The structured survey questions ensured that all individuals had the opportunity to provide information in response to the same questions and enabled us to quantify the results.

We contracted with the National Academies to identify experts to participate in our survey. Using criteria to ensure adequate representation across the criteria that we had specified, the National Academies identified 26 experts. The criteria ensured that we achieved:

- balance in terms of the type of expertise (i.e., aircraft and avionics manufacturing officials, association representatives, engineers, academics, foreign civil aviation authorities, and researchers involved in aviation safety);
- balance of knowledge across relevant content areas (i.e., aviation regulations and safety, UAS technology, next generation air transportation system planning, airport operations, human factors, and international issues); and
- balance in representation of relevant organizations (i.e., academia, business, government, and professional organizations).

The survey responses represent the professional views of the experts. Their expertise can be derived from formal education, professional experience, or both. The experts were identified by the National Academies as individuals who are recognized by others who work in the same subject matter area as having knowledge that is greater in scope or depth than that of most people working in the area. The experts included researchers, consultants, vice presidents, directors, and professors who were associated with private sector firms, associations, or academic institutions involved with UASs. Some of the experts were retired federal officials.

We recognize that it is likely that no one individual possessed complete knowledge in each of the content areas addressed in the survey. However, through our selection criteria, we attempted to identify a set of individuals who, when their responses were considered in the aggregate, could be viewed as representing the breadth of knowledge in each of the areas addressed in the survey.

We identified the information to collect in our surveys based on our congressional request, Internet and literature searches, professional conferences we attended, background interviews, and through discussions with external expert advisors. A social science survey specialist collaborated with staff with subject matter expertise on the development of the surveys.

We pretested the survey to ensure that the questions appropriately addressed the topics, were clearly stated, easy to comprehend, unbiased, and did not place undue burden on respondents. We also evaluated the usability of the Web-based survey. Based on the pretest results, we made necessary changes to the survey prior to implementation.

We administered the Web-based survey during August and September 2007. We used email to inform the respondents of the survey administration, and provided them with the Web link for the survey and their log-in name and password. In the email message, we informed respondents that our report will not contain individual survey responses; instead, it may present the aggregated results of all participants. To maximize the response rate, we sent follow up email reminders and followed up by telephone as necessary to encourage survey participation.

The survey was sent to 26 experts; three did not respond, giving the survey a response rate of 89 percent.

The narrative responses in question 1 and the explanations for the closed-ended items in questions 2 and 3 were analyzed and coded into categories. A reviewer checked the resulting categories and coded responses and, where interpretations differed, agreement was reached between the initial coder and the reviewer. The coded results were tallied and provide the basis for our survey findings for these items. Because we did not report on aggregate responses to question 4, we did not perform content analysis on this question.

The number of responses reported for the closed-ended questions may vary by question because a number of experts responded “Don’t know” or “No basis to judge,” or did not answer specific questions.

The survey was administered via the Web and is reproduced as a graphic image in appendix III.

Appendix III: Survey of Experts on Unmanned Aircraft Systems

Survey of Experts on Unmanned Aircraft Systems

U.S. Government Accountability Office

Welcome to the U.S. Government Accountability Office's (GAO) Survey of Experts on Unmanned Aircraft Systems (UAS). GAO is conducting this survey as a part of our study on the future of UASs in the national airspace system which was requested by the Aviation Subcommittee of the House Committee on Transportation and Infrastructure. The purpose of the survey is to collect information on the impact of UASs on the national airspace sytem and the actions needed to move toward safe and routine UAS operations.

To begin, you will need the user name and password from the e-mail message we sent you. In addition, please click here to download important information that will help you complete the questionnaire.

The questionnaire will be available on the web for one week. During this time, you may log into the questionnaire to enter and edit information as often as you like. It will take between 30 and 45 minutes to complete the questionnaire.

You may bookmark this page to make it easier to start the questionnaire again.

If you want to print a blank questionnaire for reference, you will need the Adobe Acrobat Reader software to do this. If you do not already have this software, click on the Adobe icon to download the software.

If you want to print a blank questionnaire for reference, click here to download a copy. You will not be able to enter responses into this PDF file.

If you have questions, please contact: Ed Menoche (menochee@gao.gov) at 202-512-3420 or Teresa Spisak (spisakt@gao.gov) at 202-512-3952.

Click on the button below to start this questionnaire.

Start log in

Survey of Experts on Unmanned Aircraft Systems

U.S. Government Accountability Office

Click here to learn more about navigating, saving, and exiting the survey, copying and pasting text responses, and printing all your survey responses at one time.

Please be aware that you can print your responses to all the questions at one time using the link at the end of the survey.

Interim Efforts Until UAS Operations are Safe and Routine

1. **Our review of the literature and discussions with knowledgeable individuals indicates that it could be at least four years before a technological and regulatory framework exists to permit UASs to operate safely and routinely in the national airspace system. By safe, we mean that UASs operate at a level of safety equivalent to manned aircraft. By routine, we mean that they operate within existing regulations without the case-by-case review that exists today.**

   In your opinion, between now and when UASs can operate safely and routinely in the national airspace system, what regulatory, technological, research, or other efforts could be undertaken for UASs to operate, if not routinely, then to the maximum extent possible in the national airspace system?

Impact of *Smaller* UASs Once They Are Safely and Routinely Operating in the National Airspace System

2. **In the future, when *smaller* UASs are *safely and routinely* operating, how do you think they will impact the following areas?**
(Choose one answer for each row.)

	Large adverse impact	Moderate adverse impact	Limited adverse impact	Neither adverse nor beneficial impact	Limited beneficial impact	Moderate beneficial impact	Large beneficial impact	Don't know/No basis to judge
2a. Airspace								

Please explain your answer.

	Large adverse impact	Moderate adverse impact	Limited adverse impact	Neither adverse nor beneficial impact	Limited beneficial impact	Moderate beneficial impact	Large beneficial impact	Don't know/No basis to judge
2b. Airports								

Please explain your answer.

	Large adverse impact	Moderate adverse impact	Limited adverse impact	Neither adverse nor beneficial impact	Limited beneficial impact	Moderate beneficial impact	Large beneficial impact	Don't know/No basis to judge
2c. Air traffic control								

Please explain your answer.

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		Large adverse impact	Moderate adverse impact	Limited adverse impact	Neither adverse nor beneficial impact	Limited beneficial impact	Moderate beneficial impact	Large beneficial impact	Don't know/No basis to judge
2d.	Environmental noise								

Please explain your answer.

		Large adverse impact	Moderate adverse impact	Limited adverse impact	Neither adverse nor beneficial impact	Limited beneficial impact	Moderate beneficial impact	Large beneficial impact	Don't know/No basis to judge
2e.	Air quality								

Please explain your answer.

If there are other areas that would be impacted by *smaller* UASs, list them in the space below and explain their expected impact.

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Survey of Experts on Unmanned Aircraft Systems Page 5 of 12

Impact of *Larger* UASs Once They Are Safely and Routinely Operating in the National Airspace System

3. **In the future, when *larger* UASs are *safely and routinely* operating, how do you think they will impact the following areas?**
(Choose one answer for each row.)

	Large adverse impact	Moderate adverse impact	Limited adverse impact	Neither adverse nor beneficial impact	Limited beneficial impact	Moderate beneficial impact	Large beneficial impact	Don't know/No basis to judge
3a. Airspace	○	○	○	○	○	○	○	○

Please explain your answer.

	Large adverse impact	Moderate adverse impact	Limited adverse impact	Neither adverse nor beneficial impact	Limited beneficial impact	Moderate beneficial impact	Large beneficial impact	Don't know/No basis to judge
3b. Airports	○	○	○	○	○	○	○	○

Please explain your answer.

	Large adverse impact	Moderate adverse impact	Limited adverse impact	Neither adverse nor beneficial impact	Limited beneficial impact	Moderate beneficial impact	Large beneficial impact	Don't know/No basis to judge
3c. Air traffic control	○	○	○	○	○	○	○	○

Please explain your answer.

8/2/2007

	Large adverse impact	Moderate adverse impact	Limited adverse impact	Neither adverse nor beneficial impact	Limited beneficial impact	Moderate beneficial impact	Large beneficial impact	Don't know/No basis to judge
3d. Environmental noise								

Please explain your answer.

	Large adverse impact	Moderate adverse impact	Limited adverse impact	Neither adverse nor beneficial impact	Limited beneficial impact	Moderate beneficial impact	Large beneficial impact	Don't know/No basis to judge
3e. Air quality								

Please explain your answer.

If there are other areas that would be impacted by *larger* UASs, list them in the space below and explain their expected impact.

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Other Countries' UAS Efforts

4. **To your knowledge, what regulatory, technological, research, or other approaches to integrating UASs that are used by other countries are potentially transferable to the United States?**

Additional Observations or Comments

5. **Please provide any additional observations or comments you may have on the safe and routine operation of UASs in the national airspace system.**

Submit Your Completed Questionnaire

6. **Are you ready to submit your completed questionnaire for the first phase of the survey to GAO now?**
   (Check one.)
   1. ○ Yes, I have completed the questionnaire
   2. ◉ No, the questionnaire is not yet complete

7. **Would you like to print all of your answers?**
   (Check one.)
   1. ○ Yes (**Click here to go to** Get a Copy of Your Responses)
   2. ○ No (Click on the "Save responses and close" button below to send your answers to GAO)

Get a Copy of Your Responses

Click here to get a copy of your responses. Once you open the copy of your responses, scroll to the end of the document and click on "Print".

Click on "Save responses and close" below to send your answers to GAO.

Thank you for your participation in the first survey on unmanned aircraft systems. We will recontact you soon to complete the second phase of the survey.

Print this page

Save Responses and Close

Close this page

Survey of Experts on Unmanned Aircraft Systems Page 12 of 12

Questionnaire Programming Language - Version 5.0
U.S. Government Accountability Office

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Please do not use the "Enter" key on your keyboard to navigate through the survey.

To read to the bottom of a section: Use the scroll bar on the right side of the screen.

To move from section to section: Use the menu bar on the left side of the screen. Do not use the "Enter" key on your keyboard to navigate through the survey.

To exit: Click on the "Save responses and Close" button at the bottom of the screen. Always use the "Save responses and Close" button to close the survey. If you do not, you will lose all the information that you have entered on the screen of the survey where you improperly exited the program.

To change your answers: To change an answer marked with a "button" (circle), click on another answer. To change what is in a text box, click in the box, delete, and type over. Note: You cannot use your browser's Back button to back up and make changes. Use the "Previous section" button or click on a side caption in the left margin instead. You can change an answer, even after logging off, by logging on again.

To skip nonapplicable questions: If the response you wish to choose has a highlighted link next to it, instead of clicking on the circle, you should click on the highlighted link. The circle to the left of the response will be automatically filled in and you will be taken to the next applicable part of the survey.

To copy and paste text responses: To use the same text responses for more than one question you can copy and paste your responses. To do this, first highlight the text and then press Ctrl-C. Second, left-click one time in the box where you want to paste the text response and press Ctrl-V.

To print all your responses at one time: When you are finished providing responses for each program, you are provided a link to view and print your responses for that program. You also have the option of printing each page as you complete the survey

Suggestion: Print this section to have it for future reference.

Click here to close this window.

Print

Definition of smaller unmanned aircraft systems

Page 1 of 1

For purposes of this survey, we are defining smaller UASs as those similar to model aircraft, which have traditionally been covered under FAA's Advisory Circular for Model Aircraft Operation (AC 91-57). We are focusing on the size dimension because, to a great extent, size is associated with the UAS capabilities, such as range and type of operations, that may have varied impacts on the national airspace system.

Click here to close this page.

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Definition of safe and routine | Page 1 of 1

By safe, we mean that UASs operate at a level of safety equivalent to manned aircraft. By routine, we mean that they operate within existing regulations without the case-by-case review that exists today.

Click here to close this page.

8/2/2007

Definition of larger unmanned aircraft systems

For purposes of this survey, larger UASs include all UASs not covered by our small UAS definition. We define smaller UASs as those similar to model aircraft, which have traditionally been covered under FAA's Advisory Circular for Model Aircraft Operation (AC 91-57) We are focusing on the size dimension because, to a great extent, size is associated with the UAS capabilities, such as range and type of operations, that may have varied impacts on the national airspace system.

Click here to close this page.

Appendix IV: GAO Contact and Staff Acknowledgments

GAO Contact

Gerald L. Dillingham, Ph.D., (202) 512-2834 or dillinghamg@gao.gov

Staff Acknowledgements

In addition to the contact named above, Teresa Spisak, Assistant Director; Edmond Menoche, Senior Analyst; Colin Fallon; Jim Geibel; Evan Gilman; David Hooper; Jamie Khanna; Patty Lentini; Josh Ormond; Manhav Panwar; and Larry Thomas made significant contributions to this report.

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