NASA Global Hawk: A Unique Capability for the Pursuit of Earth Science

J. Chris Naftel [a]

[a] NASA Dryden Flight Research Center, Edwards, CA 93505, USA – (chris.naftel@dfrc.nasa.gov)

For more than 2 years, the NASA Dryden Flight Research Center has been preparing for the receipt of two Advanced Concept Technology Demonstration Global Hawk air vehicles from the United States Air Force. NASA Dryden intends to establish a Global Hawk Project Office, which will be responsible for developing the infrastructure required to operate this unmanned aerial system and establishing a trained maintenance and operations team. The first flight of a NASA Global Hawk air vehicle is expected to occur in 2008. The NASA Global Hawk system can be used by a variety of customers, including U.S. Government agencies, civilian organizations, universities, and state governments. A combination of the vehicle's range, endurance, altitude, payload power, payload volume, and payload weight capabilities separates the Global Hawk unmanned aerial system from all other platforms available to the science community.

Keywords: Earth science, Global Hawk, High altitude long endurance, Remote sensing, Unmanned aerial system.

1. INTRODUCTION

Accurate global warming and ozone depletion measurements, better hurricane tracking and landfall prediction, improved weather forecasting, and comprehensive Earth observations are just some of the potential missions that a Global Hawk air vehicle (Northrup Grumman Corporation, Rancho Bernardo, California) could support. The ability of the Global Hawk air vehicle to autonomously fly long distances and remain aloft for extended periods of time means that measuring, monitoring, and observing remote locations of the Earth's surface are now possible. Heretofore, satellites have performed many of these missions, but satellites fly above the Earth's atmosphere, and despite a long endurance, they may not provide persistent observation over a specific area of interest. Satellites also cannot "reach out" and sample the characteristics of the environment. As the capabilities of unmanned aerial systems (UASs) continue to improve and operating costs decrease, these systems have the potential to perform certain functions that satellites cannot.

As a leader in flight research, operations, and safety, the NASA Dryden Flight Research Center (Edwards, California) has the responsibility to support the nation's scientific community by harnessing new capabilities. To this end, NASA Dryden is preparing to operate two Advanced Concept Technology Demonstration (ACTD) Global Hawk air vehicles, which may become available to NASA in the near future.

This report presents NASA Dryden's planning status for NASA operations of the Global Hawk system for Earth science missions. NASA Dryden plans to establish a Global Hawk Project Office and conduct operations from its facilities at Edwards Air Force Base (EAFB) in California. Initially, NASA Dryden intends to focus on line-of-sight flight operations using an existing United States Air Force (USAF) ground control station (GCS) for air vehicle command and control (C2). After the project team achieves operational proficiency during the initial flight series, NASA Dryden plans to conduct more demanding Global Hawk missions that meet the needs of the scientific community. In a parallel effort, a NASA GCS, which is similar to a Global Hawk Launch and Recovery Element (LRE), will be developed. After the NASA GCS is operational, NASA Dryden expects to be able to offer additional flexibility in scheduling missions.

2. THE NASA GLOBAL HAWK SYSTEM DESCRIPTION

This section contains a description of the assets required for the NASA Global Hawk system. These assets include the air vehicle, GCS, and communications architecture.

2.1 Air Vehicle

The Global Hawk system is the only available UAS with performance specifications suitable to meet some high altitude, long endurance science payload objectives. It has already demonstrated an endurance of more than 31 hours with the capability to take more than 1500 lb (680 kg) of payload to an altitude of 65,000 ft (20 km) while cruising at 350 knots. As such, it represents a major step forward in platform capabilities available for scientific research. The Global Hawk air vehicle has numerous existing payload compartments and the potential for adding wing pods. The air vehicle has the capacity to provide science payloads with substantial margins for payload mass, volume, and power in these payload spaces.

Two Global Hawk air vehicles, AV-1 and AV-6, are expected to be transferred to NASA. The AV-1 was the first air vehicle manufactured under the original Defense Advanced Research Projects Agency (DARPA) ACTD Program. It is a well-proven air vehicle that has flown more than 500 hours, including flights to and from Europe. The AV-6 was the sixth air vehicle manufactured and has flown less than 200 hours.

The air vehicles will require minimal modifications before they are ready to support science missions. A standardized payload interface panel will be installed in each payload space. This interface panel will provide power, 1553-based inertial navigation system (INS) data, and C2 signals to each payload. The panel provides the user with a simple, well documented, and functional plug-and-play interface to the vehicle that applies to all payload spaces.

Many payload options may be available to customers depending on their instrument and mission requirements. For example, modifications can be made to the air vehicle to accommodate optical windows, air sampling probes, exhaust ports, and the capability for a sensor to look upward, downward, or to the side of the air vehicle.

The addition of wing pods to the air vehicle could provide additional options for integrating payloads. The air vehicle wing was designed and fabricated with suitable hard points for wing pods, but the full implementation of wing pods requires mechanical and electrical modifications. Furthermore, integration and test efforts are necessary to demonstrate flight worthiness of the air vehicle with the wing pods attached. Enhanced capabilities provided by the additional payload accommodation, however, may justify this effort.

An intriguing aspect of having many payload bays is the possibility of allowing additional customers to "piggyback" on a primary customer's mission on a noninterference basis, if the piggyback customer has compatible mission requirements. Under this approach, the primary paying customer would control the Global Hawk's mission plan and flight schedule. The piggyback approach could potentially allow organizations such as high schools and universities the opportunity to design and fly payloads at a relatively low cost. This capability may give NASA a significant opportunity to allow the educational community to explore aspects of UAS-based high altitude atmospheric science and perform long-duration Earth science experiments.

2.2 Ground Control Station (GCS)

NASA Dryden plans to develop two GCSs. One GCS is to be located in a portable trailer and will be deployed to other locations to meet customer requirements. The other is to be installed inside an existing building at NASA Dryden. Each GCS will provide C2 for the air vehicles but not the payloads. The C2 for the payloads will be provided through a separate payload control station. The NASA GCS hardware and software will be nearly identical to the hardware and software installed in the LREs used in the USAF Global Hawk Program.

2.3 Communications Architecture

Although the Global Hawk air vehicle is an autonomous air vehicle, it requires two independent communication links between the GCS and air vehicle before the start of air vehicle operations. The baseline plan for NASA operations is to use the ultrahigh frequency line-of-sight system for the primary C2 link during line-of-sight operations, and use one of the two International Maritime Satellite Terminal (INMARSAT) systems (International Maritime Satellite Organization, a.k.a. Inmarsat Plc, London, United Kingdom) for the backup C2 link. For beyond line-of-sight operations (BLOS), one of the two INMARSAT systems installed on the air vehicles will be used for air vehicle C2 and the other INMARSAT system will be used for BLOS air traffic control voice communication.

An assessment is underway to investigate the feasibility of adding an Iridium communications system (Iridium Satellite, LLC, Bethesda, Maryland) to the air vehicle and the NASA GCS for air vehicle C2. The addition of an Iridium system to the communications architecture would add a second BLOS communications link for air vehicle C2 and add the capability to communicate with the air vehicle over the entire planet.

Communications with the payloads will occur through an independent communications link. In the near term NASA Dryden intends to achieve this capability through an Iridium communications link that will provide C2, status, and limited payload data telemetry. Additional options are being investigated that would offer wideband communications with the payloads. These options include both line-of-sight and BLOS systems.

3. THE NASA GLOBAL HAWK CONCEPT OF OPERATIONS

Most of the project staff will consist of NASA Dryden personnel supplemented with contract personnel. Project personnel will participate in training opportunities with the USAF on a noninterference basis. NASA plans to establish its own Global Hawk training program. For maintenance of the air vehicles, NASA Dryden intends to use its well-trained, highly experienced mechanic and technician workforce. All NASA sponsored Global Hawk flight operations will be conducted within the quality assurance framework already established by the USAF for the conduct of Global Hawk flights.

NASA Dryden plans to produce an "Experimenter's User Guide," which will include the payload certification requirements. Adhering to these requirements will enable a payload provider to efficiently develop a science payload package that will integrate seamlessly for use on the NASA Global Hawk system.

The sponsoring organization that provides the science payload for the NASA Global Hawk system must ensure that the payload conforms to specific size, weight, and electrical power consumption requirements. In addition, the payload instrumentation components must conform to the basic payload operational environment requirements, including pressure, temperature, vibration, and acceleration requirements. After all certifications and preintegration tests have been successfully completed, the payload is expected to be approved for integration and testing on the air vehicle itself.

Mission simulations will be conducted before the first flight. These simulations will provide training for the science payload mission operator in the payload control station for monitoring the payload and executing payload commands as appropriate. Payload operator procedures also will be tested for completeness during these simulations.

Integration of the experiment payload must conform to the NASA Dryden Airworthiness and Flight Safety Review Board (AFSRB) requirements. The AFSRB will conduct a review to verify that sufficient testing has been successfully completed before the first flight, and that the air vehicle along with the payload is ready to perform the mission. When flight approval has been obtained, one or more test flights will be conducted within the EAFB flight test range. Typically, the first flight is expected to last 4 to 6 hours and will be used primarily to verify that the instruments function as expected, the in-flight operating procedures associated with the payload are checked out, and the scientific project team becomes familiar with the standard Global Hawk flight test routine. For missions that take the Global Hawk vehicle beyond the EAFB range, NASA will apply for a Certificate of Authorization from the Federal Aviation Administration to operate in the national airspace.

4. CIVIL GLOBAL HAWK APPLICATIONS

A Global Hawk air vehicle that is available for non-DOD (Department of Defense) missions has many potential applications for the advancement of science, improvement of hurricane monitoring techniques, development of disaster support capabilities, and development of advanced UAS technologies. The remainder of this section discusses some of these potential applications.

4.1 Science Applications

The Global Hawk air vehicle has performance capabilities that could fill an important niche for the science community. This section discusses several examples of missions that a NASA Global Hawk vehicle could perform and the applicable sensors for these missions. These potential science missions were identified during a 2006 civil UAS capabilities assessment sponsored by the NASA Science Mission Directorate.

4.1.1 Coastal Ocean Observations

This suborbital mission could help scientists further understand coastal bloom compositions and the changes over time and space. In addition, the science data could help scientists quantify the submerged aquatic vegetation and coral reefs, measure estuarine conditions, and evaluate how nutrients are consumed and released into the coastal zone and their impact on the carbon cycle. The science data gathered could reduce the uncertainties in the fluxes and coastal sea dynamics by resolving horizontal and vertical resolution (improved spatial and temporal resolution) with multiple sensor integration.

4.1.2 Vegetation Structure, Composition, and Canopy Chemistry

This suborbital mission could help scientists improve the characterization of terrestrial biomass, leaf level chemistry, and canopy water content. The science data could provide three-dimensional vegetation structure and information on composition and chemistry. In addition, the observations may elucidate functional groups and physiological impacts on the carbon cycle.

4.1.3 Imaging Spectroscopy

The intent of this mission is to collect spectra as images to determine surface composition and change, water vapor, and sulfur dioxide (SO_2) in space and time. Specifically, this mission could measure:

- The composition and change at the surface-atmosphere interface.
- Accurate and precise three-dimensional water vapor for derivations based on a global positioning satellite (GPS).
- Three-dimensional sulfur dioxide and other phenomena distributions associated with active volcanoes.
- Earthquake fault optical spectroscopy properties, before and after an earthquake.

4.1.4 Topographic Mapping and Topographic Change with Light Detection and Ranging

The purpose of this mission is to generate high-resolution topographic mapping and topographic change detection of targeted ground areas (including those covered by vegetation) using light detection and ranging (LIDAR) measurements. All-terrain topographic change detection by repeat mapping complements interferometric synthetic aperture radar (SAR) measurements of sub-centimeter to decimeter surface levels (for example, observe decimeter to tens of meters of near-field surface deformation in the vicinity of ruptured faults and inflating volcanoes to understand earthquake and magmatic processes; observe decimeter to hundreds of meters of topographic change associated with landslides, volcanic eruptions and flows, coastal and fluvial erosion, and sediment redistribution). Targets of highest priority are narrow, long, quasi-linear features (such as fault zones and coastal zones) amenable to targeted mapping, or point features (such as volcanoes) amenable to monitoring by means of station keeping.

4.1.5 Weather Prediction: Supplementing Gaps in the Earth Observation System

The purpose of this mission is to supplement the Earth observation system required for weather prediction by gathering data in the areas where critical gaps currently exist. Many of these gaps within the Earth observation system are in remote areas of the globe including oceanic and Polar Regions. Thorough weather prediction depends on routine and frequent observations of key parameters. The Global Hawk vehicle could carry remote sensors that would allow monitoring of critical variables not observable by current methods, such as horizontal water vapor transport and radar reflectivity indicative of severe weather.

4.2 Hurricane Monitoring

Advancements are needed in the nation's hurricane prediction capabilities, especially in the areas of intensity and movement predictions. High altitude UASs, with the ability to fly above the hazards of a hurricane, may provide the data necessary to enable this advancement. The devastation of recent hurricane seasons and the prediction of similar hurricane activity during future seasons require that the best possible information be made available to decision-makers as they determine whether to implement mandatory evacuations and other costly actions to prepare for approaching hurricanes. The Global Hawk system is well suited to be a part of an aggressive program that applies new technology and science to make significant improvements in hurricane monitoring for future hurricane seasons.

Several operational and scientific issues must be addressed to improve hurricane intensity prediction: (1) cycle of eyewall replacement, (2) ocean interaction with the storm, and (3) hurricane environmental interaction (winds, temperature, and moisture structure of the air for an area that can be more than a thousand miles across). A sensor payload suite on a Global Hawk vehicle could address all three of these issues. The payload may include (but is not limited to):

- Drop sondes for persistent measurement of atmospheric temperature, moisture, pressure, and wind speed.
- Microwave scanners to continuously provide information about the inner rain bands, eyewall, and eye.
- Laser sounders to accurately measure the cloud cover.
- Step frequency microwave radiometers for sea surface wind determination.
- Ocean surface sondes to measure and report ocean surface temperature under the hurricane cloud canopy.

4.3 Disaster Support Applications

The NASA Global Hawk system could be used to develop and demonstrate advancements in disaster response techniques. The long range and long endurance capabilities of the Global Hawk system allow it to provide response to an area affected by a disaster anywhere on the planet. It could provide surveys of damaged areas, a vital communications link for first responders, and situational awareness for use in determining the optimal placement of disaster relief supplies.

4.4 Unmanned Aerial System Technology Development Applications

The NASA Global Hawk system is intended for use primarily in scientific research but also may be used to demonstrate key technologies that could enable the development of advanced UASs. These technologies include: improvements in multishift operations techniques, advancements in mission planning, demonstrations of communications networks, improvements in the national airspace access process, and improvements in operations techniques that may reduce operating costs.

5. SUMMARY

Scientists are eager for the opportunity to use the unique capabilities of a Global Hawk system for Earth observations. The United States Air Force Advanced Concept Technology Demonstration (ACTD) vehicles may possibly become available to the NASA Dryden Flight Research Center in the near future, and an extensive planning effort is underway to prepare for this opportunity. The expected concept of operations for NASA based Global Hawk missions has been described. The ACTD Global Hawk air vehicles are expected to be valuable additions to NASA Dryden's aircraft inventory, because they are particularly suited to satisfy the unique needs of a broad range of users in the science community.