

NASA Global Hawk: Project Overview and Future Plans

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Abstract – The National Aeronautics and Space Administration (NASA) Global Hawk Project became operational in 2009 and began support of Earth science in 2010. Thus far, the NASA Global Hawk has completed three Earth science campaigns and preparations are under way for two extensive multi-year campaigns. One of the most desired performance capabilities of the Global Hawk aircraft is very long endurance: the Global Hawk aircraft can remain airborne longer than almost all other jet-powered aircraft currently flying, and longer than all other aircraft available for airborne science use. This paper describes the NASA Global Hawk system, payload accommodations, concept of operations, and the scientific data-gathering campaigns.

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

1. INTRODUCTION

The National Aeronautics and Space Administration (NASA) Dryden Flight Research Center (DFRC) (Edwards, California, USA) has acquired three Advanced Concept Technology Demonstration (ACTD) RQ-4A Global Hawk (Northrop Grumman Corporation, Los Angeles, California, USA) aircraft from the United States Air Force (USAF). Two of these pre-production Global Hawk aircraft are being used to support NASA and the National Oceanic and Atmospheric Administration (NOAA) science customers as well as additional customers who require access to a high-altitude, long-endurance system. The DFRC and the Northrop Grumman Corporation (NGC) have entered into a five-year Space Act Agreement that includes the development and operation of the NASA Global Hawk system. The NGC is providing technical, engineering, maintenance, and operations support, as well as portions of the ground control station. The DFRC is providing facilities; flight approval responsibility; flight operations coordination; and maintenance, operations, and project staffing. The NGC and NASA share equal access to the NASA Global Hawk system for the duration of the Space Act Agreement.

2. NASA GLOBAL HAWK SYSTEM DESCRIPTION

The DFRC is located within Edwards Air Force Base (EAFB) and is 65 miles (105 km) northeast of Los Angeles, California, USA. It is from the DFRC facilities that the two Global Hawk unmanned aircraft are being operated. This section describes the aircraft, the DFRC facilities, and operational and payload-related features, including those features that are unique to the NASA Global Hawk system.

2.1 The NASA Global Hawk Aircraft

The three NASA ACTD Global Hawk aircraft are of the same geometry as the USAF RQ-4A (Block 10) air vehicles, and have similar performance characteristics. The Global Hawk aircraft provides a unique combination of high-altitude and

long-endurance performance capabilities that can meet many demanding payload and mission requirements: has demonstrated the capability to carry more than 1500 lb (680 kg) of payload to 65,000 ft (19.8 km) with mission endurance of over 30 hr and a total range in excess of 10,000 nm (18,518 km). With this total range capability, the aircraft can fly down range 2000 nm (3,700 km) from the operations base, remain on station for 18 hr, and return to the same operations base. In another operational example, the aircraft can fly from EAFB to the Arctic region, collect scientific data for over 5 hr, and return to EAFB.

The Global Hawk is a low-wing, long-range, long-endurance, single-engine unmanned jet aircraft that typically operates as a fully autonomous vehicle using a comprehensive pre-loaded mission plan. The execution of the mission plan begins when the aircraft is commanded to taxi to the runway and ends when the aircraft taxis off the runway at the completion of a mission.

The typical flight profile of the aircraft consists of a rapid climb to approximately 50,000 ft (15.3 km); a subsequent climb at a lower, steady rate as fuel is expended until the aircraft reaches its maximum operational altitude of 65,000 ft (20 km); and flight at maximum operational altitude until the aircraft returns to the operations base and descends for landing.

2.2 Ground Facilities

Both of the operational NASA Global Hawk aircraft reside in a hangar located within DFRC. A joint DFRC / NGC team maintains the aircraft, integrates the payloads, and conducts ground and flight operations. Within the same hangar, a dedicated payload work area is available for visiting customers. This customer workspace is climate- and access-controlled, and is available for all payload-related activities, including payload buildup, payload checkout, and payload operations. Before integration into the aircraft, the payload is connected to a payload test bench in the hangar for verification of power and data connections, and to verify that the payload is capable of providing health status through the Global Hawk payload communications system.

The Global Hawk Operations Center (GHOC) is located inside a building at DFRC. The GHOC is used to support all ground testing, training, and worldwide flight operations of the NASA Global Hawk aircraft. The GHOC consists of consoles used for the command and control (C2) of the aircraft, monitoring of the aircraft systems, Air Traffic Control (ATC) coordination, mission planning, and all payload-related C2 and data display functions.

The GHOC consists of three rooms: the Flight Operations Room (FOR), the Payload Operations Room (POR), and the Support Equipment Room (SER). The FOR has workstations for the pilot, co-pilot, mission director, GHOC operator, and a range safety officer. The POR has workstations for up to 14 customers. Each POR workstation is connected to the

aircraft payload network via Iridium (Iridium Communications Inc., Bethesda, Maryland, USA) Satcom communications links and a Ku Satcom communications link. The SER contains the racks of equipment that support the workstations located in the FOR and POR. The SER also serves as an observation area while missions are being conducted.

A combination pilot trainer and mission simulator is located at DFRC near the GHOC. The software and pilot interfaces are identical to the software and interfaces in the GHOC. This facility is used for pilot training in a realistic environment and when the GHOC itself is not available for training.

2.3 Communications Between the Global Hawk Operations Center and the Aircraft

Although the Global Hawk system consists of an autonomous aircraft that is fully capable of executing a pre-programmed mission plan, communication links are active between the DFRC Global Hawk Operations Center and the aircraft at all times during a mission. These links permit the pilot to send commands and receive system status information from the aircraft's mission computers, and to conduct two-way audio communications with Air Traffic Control via a radio on board the aircraft. Separate and fully independent communications links are used for command, control, and data communications with the payloads on board the aircraft.

The NASA Global Hawk is operated in two distinct regions: line-of-sight (LOS) and beyond line-of-sight (BLOS) of the ultra-high frequency (UHF) ground antennas located at DFRC. The communications link used for aircraft LOS C2 is a UHF-band link. The primary communications links used for aircraft BLOS C2 are a primary Iridium Satcom link and a redundant Iridium Satcom link. An Inmarsat (Inmarsat plc, London, England) Satcom link provides a backup aircraft C2 communications capability. The BLOS ATC bi-directional audio communications between the pilot, located in the GHOC, and the aircraft are conducted using the primary Iridium Satcom link and a redundant Iridium Satcom link. The aircraft has an onboard UHF/VHF radio set that is used to transmit and receive voice communications between the aircraft and ATC. The use of the Iridium system for aircraft C2 and ATC communications provides complete global coverage, including the north and south Polar Regions.

The NASA Global Hawk payload communications links are fully independent of the communications links used to operate the aircraft. Four dedicated Iridium Satcom communication links are used for continuous narrow-band communications between the GHOC and the payloads on the aircraft. This narrow-band communications capability allows customers to send payload commands from dedicated payload workstations in the Payload Operations Room of the GHOC and receive real-time status and low-rate data from their instruments throughout the duration of the mission. The flight crew uses two additional Iridium links to monitor power consumption by individual payloads, and to control features such as lasers and dropsonde dispensing. A wide-band Ku payload data telemetry link was added to the NASA Global Hawk system in 2010 and was utilized during the first two Earth science campaigns.

3. PAYLOAD ACCOMMODATIONS

The NASA Global Hawk aircraft can carry payloads having a total weight of up to 1500 lb (680 kg) in compartments of a total approximate volume of 336 ft³ (9.5 m³). Two types of

payload spaces are available: pressurized compartments, which are conditioned during the flight by the aircraft's environmental control system, and non-environmentally controlled compartments, which will experience the ambient temperature and pressure conditions present during a flight.

3.1 Payload Command, Control, and Communications System

The core element of the NASA Global Hawk payload capability is the new Global Hawk Payload Command, Control, and Communications (C3) system, which consists of the Airborne Payload C3 system (APCS) and the Ground Payload C3 system (GPCS). The C3 system, which was developed by the NASA Ames Research Center (Moffett Field, California, USA), enables every payload in the aircraft to be constantly monitored and controlled throughout the mission by payload principal investigators and controllers located in the GHOC.

The airborne and ground Global Hawk Payload C3 system is an integrated TCP/IP-based communications network. This system permits a payload operator, working at a payload workstation in the GHOC POR, to communicate with their airborne payload's instrument interface, similar to communicating with another IP address on a local wireless network.

When a payload is connected to the APCS on the aircraft, it has access to the complete functionality of the Global Hawk payload system, including: AC and DC electrical power; real-time communication with the ground payload workstation for command and control and global narrow-band data transmissions; real-time aircraft state and air data; access to APCS-based auxiliary data storage; access to GPS and IRIG-B data signals; and connectivity to a safety-interlock circuit.

3.2 Payload Integration

For payload integration into the aircraft, the NASA Global Hawk Project provides a single point of contact so that the process is consistent and efficient. The customer has two options for mounting a payload to the NASA Global Hawk air vehicle: payloads may be attached directly to mounting points in the payload bays; or mounted onto a pallet, which is then attached to mounting points in the payload bay. The modular feature of the payload pallets allows for sensor development, integration, checkout, and maintenance at the customer's facility before the payload or pallet is delivered to DFRC.

For electrical integration, the Global Hawk Project provides two cables to the customer for their payload. One cable connects the payload to the Experiment Interface Panel (EIP); the other cable connects the payload to an Ethernet switch. The EIP provides AC and DC power, a safety enable circuit, a GPS signal, and the aircraft state data. The Ethernet switch provides access to the aircraft data telemetry system and permits the customer to interact with their payload.

Payloads may require special viewing ports, external probes, hatches, radome fairings, new radomes, and other payload-specific accommodations. The DFRC and NGC teams provide assistance with the design, fabrication, and installation of all payload-specific systems.

4. MISSION PLANNING AND CONDUCT

Mission planning for unmanned aircraft is typically more complex and requires more lead time than does mission

planning for manned aircraft. This is especially true for flights outside of the EAFB restricted airspace in the National Airspace System (NAS). The Federal Aviation Administration (FAA) has developed a policy that allows unmanned aircraft to fly in the NAS through the issuance of a Certificate of Authorization or Waiver (COA), which is an approval process that requires a thorough review of the planned mission. The Global Hawk Project provides all coordination for flight clearances and the development of COAs.

Missions within the EAFB restricted airspace require coordination with EAFB airspace, airfield, and frequency management. There are typically no altitude or chase aircraft requirements for flying in this restricted airspace. Specific requirements are determined for each mission. The FAA regulations regarding unmanned aircraft do not apply in restricted airspace.

When conducting flights in the NAS, coordination with the FAA is required for all Global Hawk missions. For each COA application, DFRC develops and submits a detailed documentation package to the FAA. Included in the COA request are the flight profiles with the number and frequency of the planned flights.

The time required to gather and process the required information for the COA request, and to coordinate flight activities with the FAA, could be extensive. The amount of time needed depends on the location, altitude, and frequency of the specific flights. Missions that require coordination across multiple states and Air Route Traffic Control centers may require up to six months lead time to coordinate airspace usage with the FAA.

The NASA DFRC is responsible for all airworthiness and flight safety aspects of the NASA Global Hawk aircraft, and therefore also the flight approval process. The NASA Global Hawk Project Office coordinates the airworthiness process for a customer mission, including identification, categorization, and mitigation of specific risks and hazards that may exist.

Prior to a NASA Global Hawk mission, the customer team, and the NASA Global Hawk ground and flight operations team develop procedures covering pre-flight, flight, and post-flight. In addition, the combined team conducts mission rehearsals and simulations prior to flight.

On the day before a flight and the day of a flight, the ground operations team prepares the aircraft and the payload team completes pre-flight payload preparations. The flight operations team for the aircraft and the payload operations team occupy the GHOC approximately one hour before takeoff in order to complete pre-flight activities. The aircraft is towed to a staging area near the runway, where the final aircraft checkouts are completed and the engine is started. At this point, control of the aircraft is transferred from the ground operations team to the pilot in the GHOC. The pilot commands the aircraft to begin executing the mission plan. After landing, the ground operations team conducts post-flight activities and assists the payload team in gaining access to their instruments and sensors on board the aircraft. The FOR and POR are occupied throughout the mission by the flight crew and payload operations team.

5. COMPLETED GLOBAL HAWK SCIENCE CAMPAIGNS

After the initial checkout flights of the NASA Global Hawk were completed during October-November 2009, the aircraft was modified with the payload support infrastructure. These modifications were completed in March 2010 and the aircraft was ready for instrument integration and science data-gathering missions.

5.1 Global Hawk Pacific 2010

The Global Hawk Pacific 2010 campaign, or GloPac, was the first use of a Global Hawk for Earth science. The flights were designed to address various scientific objectives, including: 1) validation and scientific collaboration with NASA earth-monitoring satellites, principally the Aura satellite; 2) observations of stratospheric trace gases in the upper troposphere and lower stratosphere from the middle latitudes into the tropics; 3) sampling of polar stratospheric air and the break-up fragments of the air that move into the middle latitudes; 4) measurements of dust, smoke, and pollution that cross the Pacific Ocean from Asia and Siberia; and 5) measurements of streamers of moist air from the central tropical Pacific Ocean that move onto the West Coast of the United States (atmospheric rivers).

A combination of eleven remote sensing and in-situ instruments were integrated into the aircraft. A total of five missions were flown over the Pacific Ocean and the Arctic region during March-April 2010 and the flights ranged from 6 to 29 hours. All objectives were met during these missions and the Global Hawk aircraft was proven as a platform that is capable of supporting Earth science.

5.2 Genesis and Rapid Intensification Processes

Four months later, in August and September 2010, the Global Hawk aircraft was used in a study of tropical storms in the Gulf of Mexico and the eastern Atlantic Ocean. The autonomously-flown aircraft carried a suite of four instruments for the Genesis and Rapid Intensification Processes, or GRIP, mission. The objective for the Global Hawk aircraft was to demonstrate its ability to support severe storm research and gather data that will improve intensification forecast models.

Five missions were flown over severe storms, ranging from tropical depressions to a Category 5 hurricane. The most demanding mission was a 25-hour flight that studied Hurricane Karl as that storm intensified from Category 1 to Category 3. Twenty passes were made over Karl's eye in the Gulf of Mexico, some while the NASA DC-8 and WB-57 were also gathering data simultaneously at different altitudes.

5.3 Winter Storms Pacific and Atmospheric Rivers

During the winter of 2011, a series of flights were conducted over the Pacific and Arctic regions to demonstrate a new instrument on the Global Hawk aircraft: the Airborne Vertical Atmospheric Profiling System (AVAPS). The AVAPS, which was developed by the National Center of Atmospheric Research (NCAR) for NOAA, is capable of dispensing up to 90 instrumented dropwindsondes. Each dropwindsonde collects atmospheric data while descending from the aircraft and transmits the data back to the aircraft.

6. FUTURE GLOBAL HAWK SCIENCE CAMPAIGNS

In NASA's Earth System Science Pathfinder program, two Earth Venture proposals were selected in May 2010 from among those submitted, providing funding for airborne investigations that will be undertaken with the Global Hawks. The two Earth Venture projects that will utilize Global Hawk aircraft require flight operations from deployment locations. To support this requirement, a portable operations capability is being developed that includes a Global Hawk Mobile Operations Facility and Payload Operations Facility.

6.1 Hurricane and Severe Storm Sentinel

The first Earth Venture project is Hurricane and Severe Storm Sentinel, which will focus on the processes involved in hurricane intensity change. Two Global Hawk aircraft will be used during the 2012-2014 hurricane seasons in the Atlantic Ocean and Gulf of Mexico regions, with both aircraft being deployed from the NASA Wallops Flight Facility in Wallops Island, Virginia, USA.

6.2 Airborne Tropical Tropopause Experiment

The second Earth Venture project, the Airborne Tropical Tropopause Experiment, is designed to improve scientists' understanding of the processes that control the flow of atmospheric gases into the stratosphere. Mission flights are planned for 2012-2014 that will study chemical and physical processes at different times of the year using a Global Hawk aircraft operating from bases in and around the Pacific Ocean.

7. SUMMARY

The National Aeronautics and Space Administration (NASA) Global Hawk system became operational in 2009. A partnership between NASA and the Northrop Grumman Corporation (Los Angeles, California, USA) has been established. This partnership has enabled the rapid development of the NASA Global Hawk capability and provides customers with efficient payload integration options as well as streamlined mission preparations. Three Earth science campaigns have been completed and two multi-year campaigns will begin in 2012.