NASA/TM-2009-214647

NASA Global Hawk: A New Tool for Earth Science Research

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May 2009

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National Aeronautics and
Space Administration

Dryden Flight Research Center
Edwards, California 93523-0273

May 2009

Available from:

NASA Center for AeroSpace Information
7115 Standard Drive
Hanover, MD 21076-1320
(301) 621-0390

ABSTRACT

Scientists have eagerly anticipated the performance capability of the National Aeronautics and Space Administration (NASA) Global Hawk for over a decade. In 2009 this capability becomes operational. 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 first scientific data-gathering mission: Global Hawk Pacific 2009.

NOMENCLATURE

ACTD	Advanced Concept Technology Demonstration
APCS	airborne payload C3 system
ATC	air traffic control
BLOS	beyond line of sight
C2	command and control
C3	command, control, and communications
COA	certificate of authorization
DFRC	Dryden Flight Research Center
EAFB	Edwards Air Force Base
EIP	experiment interface panel
FAA	Federal Aviation Administration
FOR	flight operations room
GHOC	Global Hawk Operations Center
GPCS	ground payload C3 system
GPS	global positioning system
HALE	high altitude long endurance
LOS	line of sight
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NGC	Northrop Grumman Corporation
NOAA	National Oceanic and Atmospheric Administration
nm	nautical miles
POR	payload operations room
Satcom	satellite communications
SER	support equipment room

UAS	unmanned aerial system
UHF	ultra high frequency
USAF	United States Air Force
VHF	very high frequency

INTRODUCTION

The National Aeronautics and Space Administration (NASA) Dryden Flight Research Center (DFRC) (Edwards, California) acquired two Advanced Concept Technology Demonstration (ACTD) RQ-4A Global Hawk (Northrop Grumman Corporation, Los Angeles, California) aircraft from the United States Air Force (USAF). 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 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 will share equal access to the NASA Global Hawk system.

NASA GLOBAL HAWK SYSTEM DESCRIPTION

The DFRC is located within Edwards Air Force Base (EAFB) and is 65 miles northeast of Los Angeles, California. 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.

The NASA Global Hawk Aircraft

The NASA ACTD Global Hawk aircraft have the same geometry and similar performance characteristics as the USAF RQ-4A (Block 10) air vehicles. 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. The Global Hawk aircraft has demonstrated the capability to carry more than 1,500 lb of payload to 65,000 ft with mission endurance of over 31 hr and a total range in excess of 11,000 nm. With this total range capability, the aircraft can fly down range 2,000 nm from the operations base, remain on station for 20 hr, and return to the same operations base. For example, the aircraft can fly from EAFB to the Arctic region, collect scientific data for over 7 hr, and return to EAFB.

The Global Hawk is a mid-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 onto the runway and ends when the aircraft rolls to a stop after touchdown.

The typical flight profile of the aircraft consists of a rapid climb to approximately 55,000 ft; a subsequent climb at a lower, steady rate as fuel is expended until the aircraft reaches its maximum operational altitude of 65,000 ft; and flight at maximum operational altitude until the aircraft returns to the operations base and descends for landing.

Ground Facilities

Both of the 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 operations. Within the same hangar, a dedicated payload work area is available for visiting customers. This customer workspace is both climate and access controlled, and is available for all payload-related activities, including payload buildup and payload checkout. 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 within 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, flight support engineer, 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 an Iridium (Bethesda, Maryland) satellite communications (Satcom) 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 when the GHOC itself is not available for training.

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 GHOC 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 ATC via radios 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 International Maritime Satellite Terminal 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 a 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 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 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 payload data telemetry link will be added to the NASA Global Hawk system in the near future.

PAYLOAD ACCOMMODATIONS

The NASA Global Hawk aircraft can carry payloads with a total weight of up to 1,500 lb in compartments with a total approximate volume of 336 ft^3. Two types of payload spaces are available: pressurized compartments, which are conditioned during the flight by the environmental control system of the aircraft, and non-environmentally controlled compartments, which will experience the ambient temperature and pressure conditions present during a flight.

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 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 instrument interface, which is similar to communicating with another IP address on a local wireless network.

When a payload is connected to the APCS on the aircraft, it will have 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 narrowband 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.

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 convenient for the customer. The customer has two options for mounting a payload to the NASA Global Hawk aircraft: 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/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.

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

MISSION PLANNING AND CONDUCT

Mission planning for unmanned aircraft is typically more complex and requires longer lead-time than does mission planning for manned aircraft, especially 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 (COA), which is a waiver 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 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 will develop and submit 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 will depend 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 flight safety aspects of the NASA Global Hawk aircraft, and therefore also the flight approval process. The NASA Global Hawk project office will coordinate 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 will develop procedures covering pre-flight, flight, and post-flight. In addition, the combined team will conduct mission rehearsals and simulations prior to flight.

On the day of the flight, the ground operations team will prepare the aircraft and the payload team will complete pre-flight payload preparations. The flight operations team for the aircraft and payload will occupy the GHOC several hours before takeoff in order to conduct 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 will conduct post-flight activities and assist the payload team in gaining access to their instruments and sensors on board the aircraft. The FOR and POR will be occupied throughout the mission.

GLOBAL HAWK PACIFIC 2009

The initial scientific campaign utilizing the NASA Global Hawk system has been designated Global Hawk Pacific 2009 (GloPac). GloPac flights will begin and end at EAFB, and are expected to encompass the entire offshore Pacific region and the USA-controlled Arctic region. A total of six flights, ranging from 12 to 30 hr in duration will be flown. GloPac flights are currently planned for June-July 2009.

Scientific Objectives

The GloPac flights are 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 mid-latitudes into the tropics,
3. Sampling of polar stratospheric air and the break-up fragments of the air that move into the mid-latitudes,
4. Measurements of dust, smoke, and pollution that cross the Pacific from Asia and Siberia,
5. Measurements of streamers of moist air from the central tropical Pacific that move onto the west coast of the United States (atmospheric rivers).

Scientific Instruments

The scientific payload suite for the GloPac missions consists of a combination of in situ and remote-sensing instruments. The majority of these instruments have flown on other airborne platforms, most notably the NASA ER-2 (Lockheed Martin Corporation, Bethesda, Maryland) research aircraft. The twelve GloPac instruments include:

1. Airborne Compact Atmospheric Mapper (ACAM),
2. Autonomous Modular Sensor (AMS),
3. Cloud Physics LIDAR (CPL),
4. Meteorological Measurement Systems (MMS),
5. Microwave Temperature Profiler (MTP),
6. Miniature Visual Imaging System (MVis),
7. Nuclei Mode Aerosol Size Spectrometer (NMASS),
8. Focused Cavity Aerosol Spectrometer (FCAS),
9. Global Hawk UAS Ozone Photometer (Ozone),
10. UAS Chromatograph for Atmospheric Trace Species (UCATS),
11. Ultra-High Sensitivity Aerosol Spectrometer (UHSAS),
12. UAS Laser Hygrometer (ULH).

Science teams from the NASA Ames Research Center (Moffett Field, California), NASA Goddard Space Flight Center (Greenbelt, Maryland), NASA Jet Propulsion Laboratory (Pasadena, California), NOAA Earth System Research Laboratory (Boulder, Colorado), the University of Denver, and Droplet Measurement Technologies (Boulder, Colorado) are providing these instruments.

Mission Description

The final flight path for a specific GloPac flight will not be chosen until several days prior to flight. Nominally, baseline flight paths will be determined 48 hr prior to flight and coordinated with the appropriate FAA organization. It is expected that the project will fly one flight per week during the campaign for a total of six flights.

Additionally, there will be other meteorological, volcanic, and climactic phenomena that will be of interest for investigation during the GloPac flights. Sampling of these phenomena will be requested in real time as deviations from the filed flight plan or modifications to the 48-hr coordinated flight track. The modifications will be determined 6-12 hr prior to flight using short-term meteorological forecasts. Long-range meteorological forecasts (greater than 12 hr) are too inaccurate to adequately specify the location of these phenomena.

In addition to the standard flight conditions flown by Global Hawk aircraft to date, a new flight condition, known as a vertical profile, will be used during GloPac missions. A vertical profile is a straight-ahead descent from maximum cruise altitude (greater than 55,000 ft, down to 43,000 ft, and then a climb back up to the current maximum cruise altitude. The aircraft will remain at 43,000 ft altitude up to 15 minutes to accommodate payload sampling. The vertical profiles will be coordinated with ATC, in real time, to avoid any potential conflict with other air traffic. Approximately 3-5 vertical profiles per flight will be requested.

SUMMARY

The National Aeronautics and Space Administration (NASA) Global Hawk system will become operational in 2009. A partnership between NASA and the Northrop Grumman Corporation (Los Angeles, California) 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. Flight operations are scheduled to begin in Spring 2009 and initial customer flights in June 2009.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
01-05-2009	Technical Memorandum	

4. TITLE AND SUBTITLE
NASA Global Hawk: A New Tool For Earth Science Research

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
J. Chris Naftel

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
NASA Dryden Flight Research Center
P.O. Box 273
Edwards, California 93523-0273

8. PERFORMING ORGANIZATION REPORT NUMBER
H-2951

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
Washington, DC 20546-0001

10. SPONSORING/MONITOR'S ACRONYM(S)
NASA

11. SPONSORING/MONITORING REPORT NUMBER
NASA/TM-2009-214647

12. DISTRIBUTION/AVAILABILITY STATEMENT
Unclassified -- Unlimited
Subject Category 43 Availability: NASA CASI (301) 621-0390 Distribution: Standard

13. SUPPLEMENTARY NOTES
Naftel, NASA Dryden Flight Research Center. Also presented at the 33rd International Symposium on Remote Sensing of Environment, Stresa, Italy, May 4-8, 2009.

14. ABSTRACT
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15. SUBJECT TERMS
Earth science, Global Hawk, High altitude, Long endurance, Remote sensing, Unmanned aerial system

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19b. NAME OF RESPONSIBLE PERSON
					STI Help Desk (email:help@sti.nasa.gov)
					19b. TELEPHONE NUMBER *(Include area code)*
U	U	U	UU	13	(301) 621-0390

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39-18