Development of the Aerial Vehicle Synthetic Aperture Radar (UAVSAR) for the Global Hawk

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Abstract - **The Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR) instrument is a pod-based L-band polarimetric synthetic aperture radar (SAR), specifically designed to acquire airborne repeat track SAR data for differential interferometric measurements. This instrument is currently installed on the NASA Gulfstream-III (G-III) aircraft with precision real-time Global Positioning System (GPS) and a sensor-controlled flight management system for precision repeat-pass data acquisitions. UAVSAR has conducted engineering and preliminary science data flights since October 2007 on the G-III. We are porting the UAVSAR to the Global Hawk Unmanned Airborne Vehicle (UAV) to enable long duration/long range data campaigns. We plan to install two radar pods (each with its own active array antenna) under the wings of the Global Hawk to enable the generation of precision topographic maps and single pass polarimetric-interferometry (SPI) providing vertical structure of ice and vegetation. Global Hawk's range of ~ 8000 nm will enable regional surveys with far fewer sorties as well as measurements of remote locations without the need for long and complicated deployments.**

I. INTRODUCTION

The 2003 NASA Earth Science Enterprise strategic plan‡ recommended an observational program that includes both airborne and spaceborne capabilities where scientists can have earth deformation measurements on an hourly basis with global access, objectives best supported by a spaceborne high-orbit (e.g. geosynchronous) constellation of repeat-pass interferometric (RPI) SAR satellites. The recommended first step in this observational program is a low-earth-orbit deformation satellite with a repeat period of roughly one week, hence the proposed Decadal Mission for Deformation, Ecosystem System and Dynamics of Ice (DESDynI). The sub-orbital radar program enters the Earth Science Enterprise plan as a key supplemental capability, providing repeat-pass measurements at time scales much smaller than one week, potentially as short as twenty minutes. The Uninhabited Aerial Vehicle Synthetic Aperture Radar (UAVSAR) instrument is a new, pod-based L-band polarimetric synthetic aperture radar (SAR), specifically designed to acquire airborne repeat track SAR data for differential interferometric measurements [1]. This instrument is currently installed on the NASA Gulfstream-III (G-III) aircraft with precision real-time Global Positioning System (GPS) and a sensor-controlled flight management system, allowing us to constrain a flight path to within a 10 m diameter tube about the desired flight track [2]. The porting of UAVSAR to the Global Hawk UAV will enable long duration/long range data campaigns. The Global Hawk endurance of nearly a day will enable long loiter time over dynamic targets such as volcanoes and earthquake-prone regions for pre-event signature studies or post-event scientific and hazard management activities. The Global Hawk range on the order of 8000 nm will enable data collection of distant areas of interest such as Greenland and Antarctica without complicated campaign deployments. In addition, the two radar pods, each equipped with an active array antenna, will enable high precision topographic map generation and single pass polarimetric-interferometry (SPI) for vegetation structure measurements. Global Hawk is an ideal platform for performing mapping and regional science using the UAVSAR instrument.

‡ http://science.hq.nasa.gov/strategy/ESE_Strategy2003.pdf

Phase 1 of the UAVSAR port to Global Hawk, being funded by the NASA Earth Science Technology Office (ESTO), consists of the implementation of SPI. Aircraft and instrument modifications will take place over the next 15 months and flight testing is currently scheduled to occur in September 2011. The RPI implementation of UAVSAR on Global Hawk is currently not funded.

II. INSTRUMENT CHARACTERISTICS

Table 1 lists key radar operational parameters for UAVSAR onboard the Global Hawk (GH). The two radar antennas have a physical separation of 2.8 m, resulting in an effective antenna baseline of 5.6 m because we alternate the transmitting antennas (ping-pong mode). Although the GH is capable of flying at higher altitudes, the present NASA GH configuration is able to maintain constant altitude at altitudes less than or equal to 13.7 km (45,000 ft). This is slightly higher than the typical G-III cruising altitude of 12.5 km (41,000 ft). The GH will be flying at ~180 m/s, 15% slower than the typical cruising speed of the G-III (~215 m/s). The GH's long flight duration of 22 hours will allow us to achieve a nominal flight range of 14,500 km, in comparison to the G-III's nominal flight range of ~ 6,300 km (3400 nm). We expect that the relative height accuracy of the digital elevation model (DEM) generated by SPI to be on the order of a few meters depending on the terrain variation.

Table 1. Key radar operational parameters for UAVSAR implementation on the Global Hawk platform.

Parameter	Value
Frequency	L-Band 1217.5 to 1297.5 MHz
Polarization	Full Quad-Polarization
Resolution	1.67 m Range, 0.8 m Azimuth
Range Swath	22 km (13.2 miles)
Look Angle	25º - 65º
Antenna Baseline	5.6 m
Platform	Global Hawk
Nominal Altitude	13.7 km (45,000 ft)
Nominal Ground Speed	180 m/s (330 knots)
Nominal Flight Duration	22 hours
Nominal Flight Range	14,500 km (7800 nm)

III. IMPLEMENTATION PLAN

Implementation of single pass polarimetric-interferometry with UAVSAR instrument onboard the Global Hawk platform encompasses interfacing the two existing UAVSAR pods to the Global Hawk airframe, modifying radar control and timing to synchronize the two radar pods, ground and flight testing, and modifying the UAVSAR ground processor to generate polarimetric-interferometric data products.

Figure 1 is an artist's rendering of the UAVSAR pods under the Global Hawk wings. The two pods will be mounted symmetrically on the existing hard points under the wings. One of the radar pods will be the master pod, which is a complete radar. The other pod will be a slave pod where it contains an active array antenna and the motion measurement subsystem (the inertial navigation unit and the real-time differential Global Positioning Satellite receiver unit) to track the precise location and attitude of the slave antenna. The master pod will provide power, radar timing, transmit chirp, and frequency up/down-conversion for the slave pod. The digitized raw radar data will be routed to the data recorder, will reside in the fuselage of the GH. An onboard processor is also planned to be located in the fuselage.

The technical effort involved in radar modification includes: 1) development of radar control software to remotely operate the radar and monitor instrument status via the Iridium satellite modem link; 2) addition of two receive channels to the master pod to receive data from the slave antenna; 3) modification of radar control and timing to command two antennas and 4 receive channels; 4) development of cable harnesses between the two radar pods and between the master pod and the fuselage equipment; 5) modification of the ground data processor to handle polarimetric-interferometric data; 6) Ground and flight testing and instrument calibration. JPL is responsible for all radar modification tasks.

The technical effort involved in aircraft modification includes: 1) design, fabrication, and installation of the wing mounting hardware; 2) redesign of the pod nose cone and tail cone to reduce flutter; 3) aerodynamic, flutter, and flight control system assessments; 4) ground vibration tests and weight and balance of the aircraft with and without the pods attached; 5) flight approval process, and 5) preparation and conduct of the flight tests within the Edwards Air Force Base range. All above efforts will be conducted by Northrop Grumman or NASA Dryden.

Figure 1. Artist's rendering of the UAVSAR pods under the Global Hawk wings

IV. OPERATIONAL CONCEPT

The radar operator on the ground communicates with the radar via the Iridium satellite modem link, which operates at 2400 bps. There is also a Ku-band satellite link that offers a much higher downlink data rate (~3 Mbps), which if cost permits, will be a practical means for transmitting onboard processed imagery down to the ground terminal.

The operational flow of the UAVSAR onboard the GH is as follows:

- Generate a flight plan file that contains the flight lines to be flown, the radar instrument parameters, a waypoint file for the GH, and a script for the GH remote pilot.
- Before takeoff, load flight plan information via the Radar Operator Workstation (on the ground) to the Automatic Radar Controller (on the GH) and waypoint to the platform Flight Management System.
- Load a hard disk on the GH to collect data during flight.

- The GH takes off and flies to selected sites to acquire data over selected flight lines.
- Radar operator monitors radar via Iridium satellite link to insure proper instrument operation.
- Return GH to base, recover radar data disk, and complete orderly shutdown of radar.
- Transfer data to JPL for processing and analysis.

A typical GH flight can last 22 hours. One single flight from Wallops Island will provide about 16 hours of data acquisition time in Greenland. This will allow us to image the glaciers along the entire coastline of Greenland (blue flight lines in Figure 2) and half the coastline in an offset flight path (red flight lines in Figure 2).

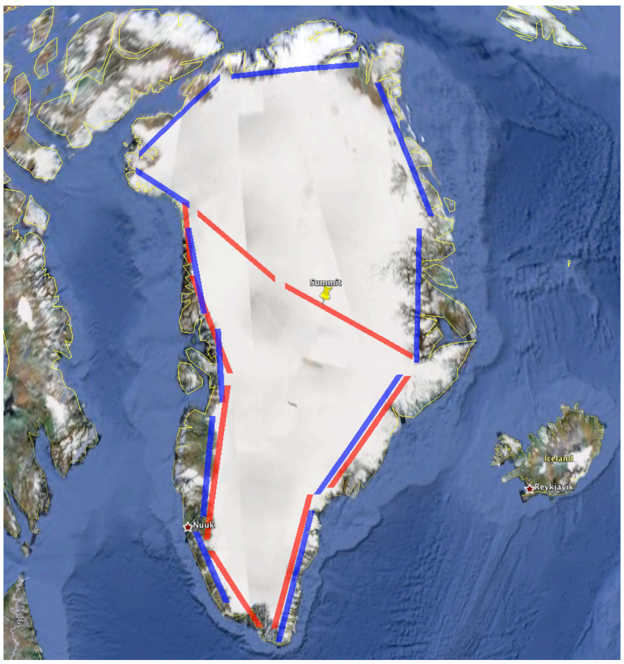

Figure 2. Example UAVSAR-GH flight plan where we are able to acquire data over the entire coastline of Greenland 1.5 times during a single 22-hour GH flight.

V. DEVELOPMENT STATUS

Technical effort involved in radar modification is well underway. We have completed initial development of radar control software for remote instrument operation, additional hardware as well as much of the control and timing capability associated with the dual-antenna operation. Laboratory testing is well underway. This summer we will be focusing on the electrical interfaces and mechanical accommodation of the two radar pods and fuselage equipment. Aircraft modification effort is just underway because of a delay in getting Northrop Grumman on contract. We expect to begin integrating the radar with the GH in spring 2011, conduct ground tests in summer 2011, and flight tests in September 2011.

VI. FUTURE PLANS

One of the highest priority upgrades for the UAVSAR on GH configuration will be the implementation of precision platform auto-pilot, which will enable the support of repeat-pass interferometry for rapid response of natural hazards such as earthquake, volcano eruption, and post-fire debris flow. Other potential upgrades include the installation of a UHF radar front-end or a Ka-band radar front-end in the slave pod (that replaces the current L-band antenna) to enable simultaneous dual-frequency operation for a variety of science applications that are currently not possible with the single frequency L-band radar.

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