Eos, Vol. 87, No. 20, 16 May 2006

# Altair Unmanned Aircraft System Achieves Demonstration Goals

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In the early morning of 15 November 2005, the unmanned Altair aircraft returned to Gray Butte Airfield, north of Los Angeles, Calif., after completing an 18.4-hour mission over the eastern Pacific Ocean. The flight was the last in a series undertaken by the U.S. National Oceanic and Atmospheric Administration (NOAA) in its Unmanned Aircraft System (UAS) Demonstration Project. The successful flight series has helped start the era of unmanned flights in service of environmental goals. Altair cruised at altitudes in the lower stratosphere (13 kilo-meters; ~43,000 feet), collecting atmospheric data with a 140-kilogram payload of both remote and in situ instruments.

NOAA has recognized that UAS technology will improve its ability to meet scientific and operational objectives in the coming years. Operating sensor payloads on a UAS fleet could play a crucial role in the detection and attribution of climate change, improvement of weather predictions, management of water resources, monitoring and evaluation of ecosystems and sanctuaries, and atmospheric and oceanic research. UAS platforms have the potential to carry instrument payloads to remote locations in a manner that could not otherwise be achieved with conventionally piloted aircraft.

NOAA initiated the demonstration project, which was a cooperative effort undertaken with General Atomics Aeronautical Systems, Inc. (GA-ASI, San Diego, Calif.) and NASA, as an effort to acquire experience with a key UAS platform and dedicated payload. As a partner with NOAA, NASA helped with project management, flight safety, and airspace coordination. NOAA provided the majority of funds to support the project. The success of this project will help NOAA and NASA identify the most useful objectives and strategies to pursue with UAS technology in the future.

## *Altair Platform and Payload*

Altair is a high-altitude long-endurance UAS, able to reach altitudes of 13–15 kilometers and stay aloft for more than 20 hours carrying a payload of at least 300 kilograms. Altair UAS technology is a seamless combination of an autonomous aircraft, redundant control systems, high-speed satellite and radio communication, and ground-based pilots and sensor operators.

The sole Altair aircraft has a 26-meter wingspan and an 11-meter fuselage length, and is made largely of composite materials (see Figures 1 and 2). Altair's rear-mounted turboprop engine provides a true airspeed of approximately 175 knots at a cruise altitude of 13 kilometers, which yields a 6600-kilometer range for a 20-hour flight. GA-ASI manufactured Altair, an extended-wing version of their Predator B UAS line, as part of NASA's Environmental Research Aircraft and Sensor Technology program.

The Altair payload as listed in Table 1 was integrated into the forward section of the Altair fuselage (see Figures 2 and 3), which also contains the satellite communications antenna. An external sampling probe was mounted on the starboard fuselage for the in situ instruments to obtain ambient air. Upper and lower fuselage areas were modified with openings to accommodate the viewing requirements of the remote instruments and the digital camera system (DCS). The electro-

*Fig. 1. The Altair in flight at three-kilometer altitude over the Channel Islands National Marine Sanctuary off the coast of California on 16 November 2005. The electro-optical infrared sensor protrudes below the forward fuselage. Original color image appears at the back of this volume.*

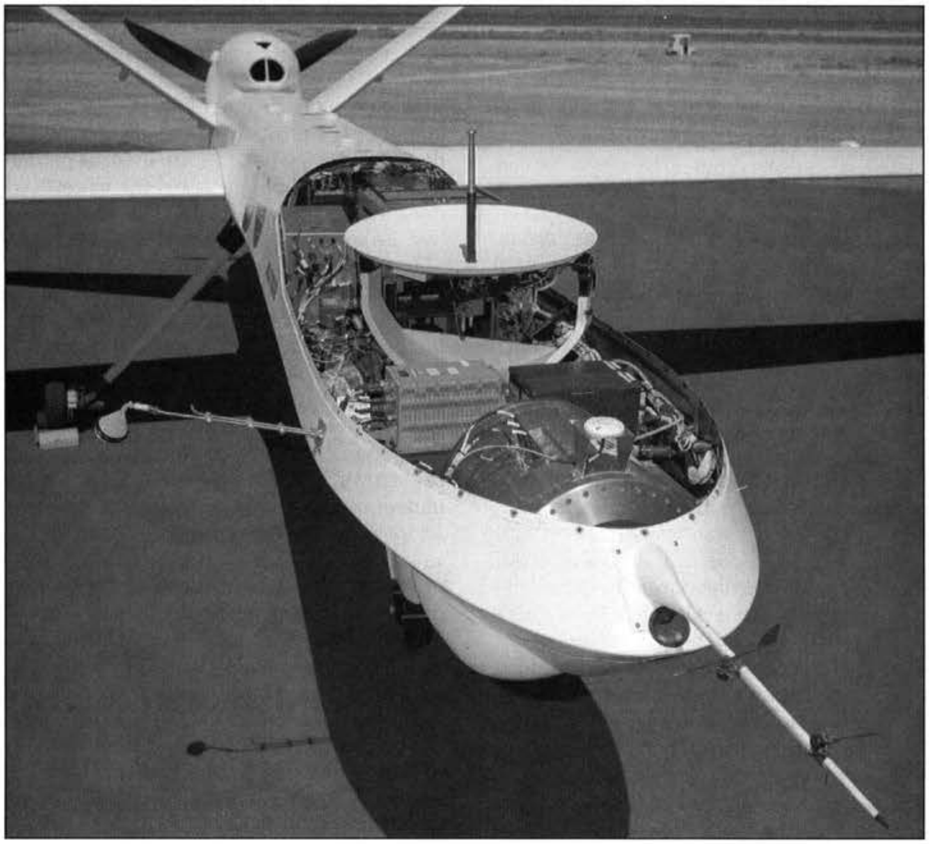

*Fig. 2. The Altair with its fuselage payload bay open at Gray Butte Airfield in April 2005. The sampling instruments are located inside the fuselage nose along with the gimbaled satellite antenna. The gas-sampling probe is visible on the left of the fuselage in this view. The small forward boom is used for sensing wind direction. The small opening at the tip of the nose is a camera port used by the pilots. Also visible above the rear fuselage is the engine intake and propeller. Original color image appears at the back of this volume.*

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aura.gsfc.nasa.gov/). The PMVS instrument was able to obtain signals from features of an atmospheric river on part of the May ocean flights. The ocean color sensor obtained substantial data at cruise altitudes and in a spiral descent and ascent over a calm ocean surface.

The DCS successfully mapped Anacapa Island (http://uav.noaa.gov/altair/data/anacapa_mosaic_sm.jpg) and coastal segments of two larger Channel Islands. The EO/IR sensor images were distributed as streaming video over the Internet during the flight to a pre-selected audience of interested users. Aggregations of California sea lions and northern elephant seals and approved fishing and diving activities were observed at several Channel Island locations. Large commercial ships were spotted and successfully identified by vessel type from up to 16.1 kilometers away. During flight, the REVEAL system created aircraft status displays and three-dimensional maps of the Altair location.

Altair operated in both restricted and controlled areas of the National Air Space (NAS). Obtaining permission for Altair flights from the U.S. Federal Aviation Administration (FAA) was an important success of this demonstration project because of the location and complexity of proposed flight plans. The FAA and its regional centers on the U.S. west coast were cooperative regarding flight plan approval and in-flight coordination with Altair. In August 2005, the FAA granted Altair the first 'experimental certificate' for a UAS, which provides increased freedom for Altair to operate in the NAS (http://www.ga.com/). The 'experimental' marking on Altair can be seen in Figure 1. The certification is notable recognition of the quality and reliability of Altair operations and encouragement for expanded development and use of UAS technology in the NAS.

### *The Way Forward*

With the Altair demonstration flights completed, work will focus on the interpretation and publication of the datasets. As a result of this project, NOAA has formally recognized the important role that Altair and related technology will play in NOAA's future by initiating a program to develop and direct UAS activities. A variety of UAS activities and collaborations are underway or planned. NOAA-planned Altair activities include a collaboration with NASA and the U.S. Forest Service on the Western States Fire Mission in 2006 and with NASA on the Aura Validation Experiment in 2007.

Additional ormation about the UAS program is available at http://uas.noaa.gov and http://www.uav.com/

### *Acknowledgments*

The success of this project depended on the skill and commitment of the pilots, engineers, managers, and support personnel at GA-ASI, and on the oversight provided by managerial, technical, and safety personnel at NASA Dryden Flight Research Center (Edwards, Calif.). Gregory Buoni, Kent Dunwoody, Geoff Dutton, Dale F. Hurst, Marian Klein, Alexander E. MacDonald, Fred L. Moore, David Nance, Samuel J. Oltmans, Eric A. Ray, Nicholas Trongale, and Brian Vasel made important contributions to this work. Photo credits: NASA Dryden Flight Research Center Public Affairs Office.

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# Reevaluating Hubbert's Prediction of U.S. Peak Oil

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In 1956, M. King Hubbert, chief consultant for the Shell Development Company's exploration and production research division, forecasted that U.S. oil production would peak in the early 1970s. He subsequently updated this prediction using newer data, but the predicted timing of peaking did not change significantly (see *Hubbert* [1982] for a review and references to earlier papers). In 1971, U.S. annual production of crude oil peaked at slightly more than three billion barrels (bbl).

Yet, Hubbert's model continues to be challenged by some. For instance, according to economist Michael Lynch, president of Strategic Energy and Economic Research, Inc., Winchester, Mass., it was only after Hubbert published his predictions "that the Hubbert curve came to be seen as explanatory in and of itself, that is, geology requires that production should follow such a curve" [*Lynch*, 2003].

This assertion is not supported by the geological literature. Long before Hubbert, geologists had pointed out that mining production follows a pattern of boom and bust: slow initial production preceding rapid growth as readily available resources are mined, followed by peak production and slow decline as remaining resources become more difficult to harvest. In 1889, geologist Edward Orton, after conducting a survey of the oil and gas resources in northwestern Ohio, warned that the local boom could not last long because "we are drawing upon a definite stock of this substance" [*Orton*, 1889].

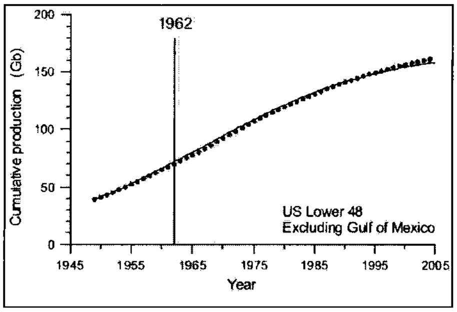

*Fig. 1. Cumulative oil production in the lower 48 states (dotted curve), excluding production from the Gulf of Mexico, compared with the predicted trend (solid curve) obtained in 1962 by Hubbert based on production data to the left of the vertical line.*

It has been long recognized that geologic constraints are not the sole factor driving the production cycle. *Hewett* [1929], for example, discussed the importance of technology, economics, and political factors, which may influence the precise nature of the production curve. The recent surge in oil prices has resulted in increased interest in what used to be considered unprofitable oil resources, and fields previously considered uneconomical are now being exploited. Nevertheless, the primary driver of the cycle of mining production is the limited availability of the resource being mined. Without understanding these concepts, there would have been no reason for Hubbert to consider peak production and subsequent decline; the U.S. data available at the time (1956) applied to the period of rapid growth and by themselves showed no sign of an impending peak.

Much of the criticism revolves around Hubbert adopting the logistic model or bell-shaped curve. Hubbert recognized that production need not be symmetric but espoused the logistic model, which yields a parabolic curve for production rate, $dQ/dt$, as a function of cumulative production, $Q$, because this symmetry was dictated by the U.S. oil production data, not because of some a priori assumptions. Stressing this point, *Hubbert* [1982] wrote that, "it is to be emphasized that the curve of $dQ/dt$ versus $Q$ does not have to be a parabola, but that a parabola is the simplest mathematical form that this curve can assume. We may accordingly

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Fig. 1.

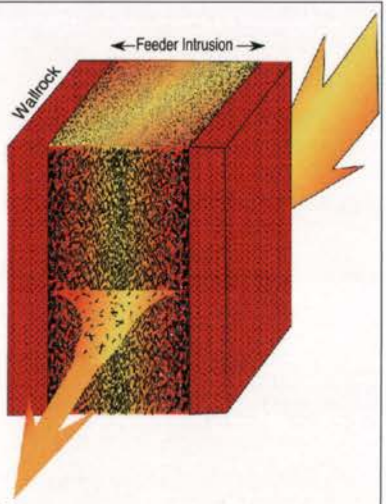

Fig. 2.

*Fig. 1. Photographs of the Kashele giant plagioclase basalt (a) in the field and (b) in a polished slab. (c) A composite photomicrograph (crossed polars) of a single plagioclase crystal. The scale is in inches.*

*Fig. 2. Schematic representation of how the large plagioclase crystals may have grown from magma batches that flushed through the feeder dike over time. These 'giant' plagioclase crystals may have grown within a zone containing 25 percent crystals that formed a 'chicken-wire network.'*

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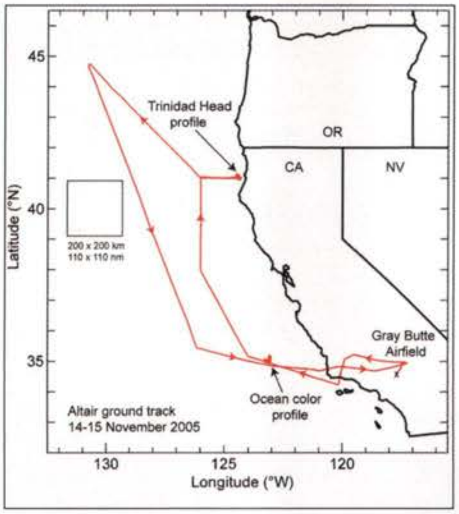

*Fig. 3. The Altair ground track for the 18.4-hour flight on 14–15 November 2005. Altair returned to Gray Butte early because of a fuel management concern. Landing fuel reserves indicated that the flight could have been extended by several hours. The two locations of the ascent and descent altitude profiles are also indicated.*