FEATURE ARTICLE

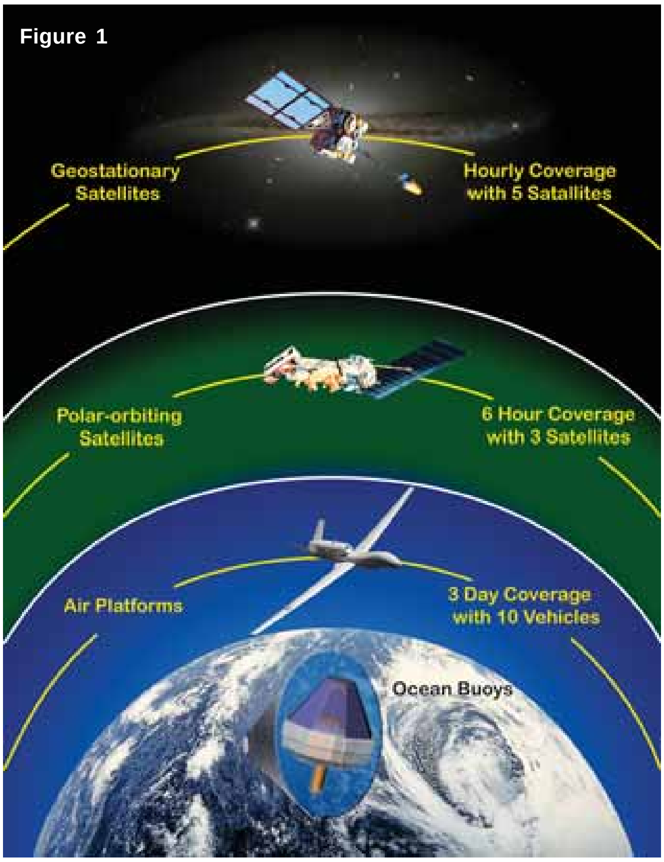
Environmental Scientific Applications For UAS

Sara Summers, National Oceanic and Atmospheric Administration
Randal Albertson, NASA Dryden Flight Research Center
Elizabeth Weatherhead, University of Colorado

The United States (U.S.) science community has identified a critical data gap in existing observing system between satellite, manned aircraft, and surface (land and ocean) systems, and recognizes the tremendous potential that Unmanned Aircraft Systems (UAS) have to fill this gap. The application of UAS to address environmental issues could revolutionize our ability to monitor the global environment and understand key processes in weather, climate change and ocean systems. UAS present a unique opportunity to improve scientific research that could yield tremendous national societal benefits, such as improved forecasting of severe weather events and preparedness for climate changes impacts by complementing and/or augmenting existing observational methodologies. Key national experts have requested a national initiative to accelerate the development of critical UAS technologies in the U.S., particularly for environmental monitoring. «Many scientists feel that we have hit a brick wall in terms of our ability to gather enough data to make meaningful statements about vast remote regions where the climate, and hence wildlife and vegetation, are changing, and that UAS can break down that wall if pursued aggressively enough.» (Wiscombe, CAUAS Symposium, http://cauas.colorado.edu)

U.S.Government agencies, academic communities, industries and the international community at large are pursuing opportunities to operate a range of UAS with scientific instruments on board, to take measurements to improve understanding of global weather, climate change, oceans and ecosystems. These data collected on a routine basis could play a critical role in improving our understanding of fundamental earth system processes in addition to enhancing weather and climate forecasts including hurricane intensity forecasts and fire weather forecasts, particularly in remote regions such as the Arctic and vast oceans expanses.

Figure 1



Global Earth Observations

Comprehensive Earth observations require multiple vantage points, each providing a unique and necessary perspective for understanding and predicting Earth systems. For over five decades, the three pillars of scientific Earth observation have been surface, satellite, and manned aircraft (*Figure 1*). Surface observations provide good temporal coverage and high accuracy but poor spatial coverage, especially for parameters such as temperature, pressure, humidity, clouds and soil moisture. Satellite observations provide unequalled spatial coverage but often with inadequate resolution or unknown accuracy.

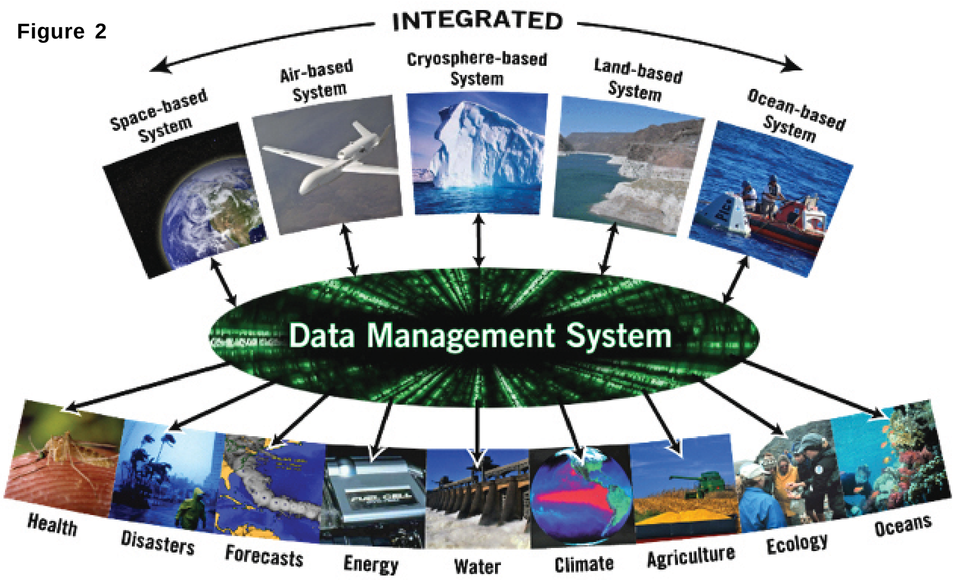
Manned aircraft provide observations at small scales not possible with satellites, and spatial interpolation not possible with surface sites. Such observations have provided a critical missing link between satellite and surface observations and have allowed us to learn how atmospheric properties vary over multiple spatial and temporal scales.

Over the five decades that Earth scientists have been using manned aircraft and satellites, it has become clear that these platforms have certain limitations which cannot be overcome except at prohibitive expense, if at all. In the case of satellites, these limitations concern spatial precision, accuracy, sampling, resolution, and the inability to measure certain parameters accurately and reliably, including surface inversions, wind speed, trace troposphere chemical concentrations and the composition of organic aerosols. In the case of manned platforms, the potential loss of life of the pilot restricts manned aircraft from flying into dangerous situations, such as volcanic plumes, chemical releases,hurricane situations or wild fires, or flying for long periods in remote areas, such as over Arctic sea ice.

Global Earth Observation System of Systems

The efforts of the U.S. science community links to the broader international effort that has been the focal point for coordinating environmental monitoring around the globe, the Global Earth Observation System of Systems (GEOSS) *(Figure 2)*, the primary goal being to develop an integrated system that will enable the global-scale scientific community to focus on broader global issues such as climate change, emission and transportation of pollutants, the health of the Earth's oceans and extreme weather impacts around the world.

Figure 2



needs of the US on a routine basis.

Airspace Access

The Federal Aviation Administration (FAA) is responsible for regulating aircraft operations and certification within the U.S. National Airspace System (NAS) out to 12 nm offshore from the surface to 60,000ft. Military controlled airspace (restricted and warning areas) is exempt from FAA regulations and subject to military regulations. Additionally, the FAA is authorized to provide air traffic services in some international airspace per International Civil Aviation Organization (ICAO); this oversight extends over most the Pacific and much of the Atlantic Ocean. FAA also provides air worthiness for civil aircraft flying in international airspace.

The science communities within U.S. government organizations (federal, state & local) are currently working with the FAA to develop Certificates of Authorization (COAs) and improve the processes. The FAA is supportive of the efforts of the scientific community to operate UAS in the NAS and actively collaborates with science platform operators to establish reasonable and responsive criteria for flights. Requirements that must be met in order for a COA to be approved by FAA include:
- See and Avoid;
- Operational Risk Management;
- Frequency Spectrum Approval;
- Airworthiness;
- Aircraft Qualifications.

Currently, each UAS mission is considered by FAA on a case by case basis, with line of sight being common criteria for approval. As safety records and technological capabilities are developed, policies may be developed, particular for use of small UAS and use of UAS in very remote areas.

UAS Technology Development in Support of Airspace Safety

Major technological challenges must be addressed to safely and routinely operate UAS in the national airspace. These challenges cut across agencies and include reliable communication for controlling an aircraft and the ability to detect and avoid obstacles, including other aircraft, in the air and on the ground. New technologies are required to safely manage the increasingly crowded airspace. Many of these technologies are likely to come from investments in UAS. The technology to facilitate safe and routine access to the national airspace comparable to manned aviation does not yet exist and requires accelerated investment in research and development.

UAS Technology Development in Support of Science

Much of the UAS development over the past several decades has been from the Department of Defense. The U.S. has the unique opportunity at this time to leverage the expertise and technologies in the U.S., including the returning servicemen who are trained to use UAS, to address and operate critical, non-military applications. As a leader in UAS technologies, the U.S. is in a key position to implement these technologies for scientific and other civilian applications. To move forward efficiently, a focused organization comprised of government, academia, and industry is needed to achieve these objectives. An initial meeting of these three groups or stakeholders took place in Boulder, Colorado on October 1-3, 2008. The meeting summary is available at http://cauas.colorado.edu. The group of high level experts that gathered immediately recognized the appropriate fit of UAS technologies to outstanding environmental issues, and determined that climate change, disaster response and homeland security were the three most critical civilian applications where UAS should be initially developed within the range of civilian applications. Even with this strong endorsement, there are considerable obstacles related to safety, technology and airspace access that will need to be addressed in order for UAS to serve the

Science Applications

Unmanned vehicles are proving themselves in initial attempts at civilian applications to be valuable in a variety

Figure 3a

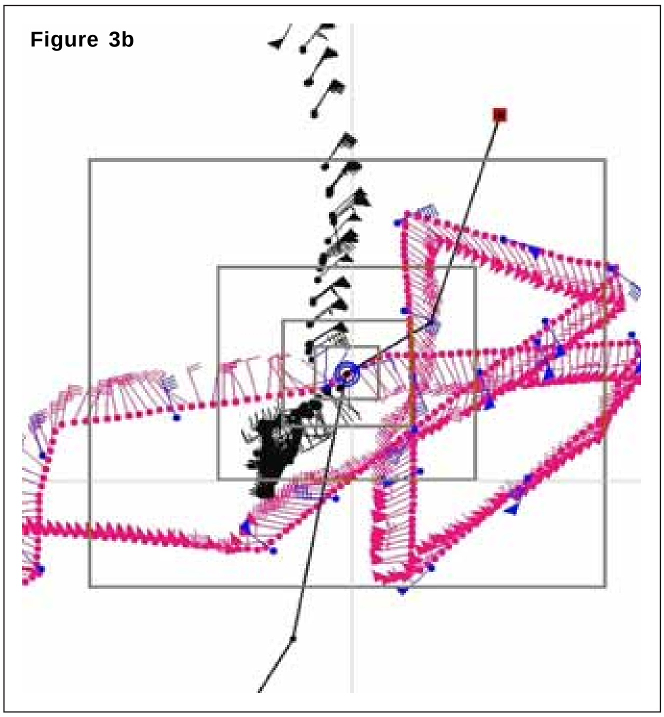


Figure 3b

of applications. Unmanned vehicles have gone far over the Arctic Ocean, flying low enough to take detailed measurements of the Arctic Ice that could not be taken with manned aircraft. AAI Corporation's Aerosonde (*Figure3a)* was launched from Wallops Island, Virginia, USA, into hurricane Noel in November 2007. The Aerosonde obtained critical wind measurements at low levels in the hurricane environment (*Figure 3b*) that could not have been gathered any other way. The near-surface UAS observations (particularly information on wind speed) were reported in real time to NOAA's National Hurricane Center (NHC). These flights were conducted as a NASA/NOAA joint effort in collaboration with AAI, and demonstrate the potential for UAS to bring tremendous results while maintaining safety in the air and on the ground. As another example, NASA worked with the US Forest Service in 2006 and 2007 for the Western States Fire Missions, and flew extended missions, including two emergency response missions, over most of the western US. This demonstrated the benefit of long endurance flights (many in excess of 20 hours), with multi-agency sensors, to monitor wild fires from the Canadian to Mexican borders and distribute relevant information in near real time to fire fighting decision makers. The FAA was very accommodating and allowed useful Ikhana flight in the NAS throughout the western US.

The 2007 mission results helped save property and possibly lives during the southern California fires last fall. Additionally UAS are successfully being used to support homeland security, assisting in border patrol missions, keeping our agents both safe and effective in their duties. NOAA's 2008 UAS plans include conducting an expanded demo during a hurricane deploying from Barbados in conjunction with NASA, AAI and partners in the region. One of NHC's main operational requirements is to accurately report the maximum surface wind of the storm in their advisories to better inform and warn the public.

US Agency support of UAS

Several agencies within the US are actively engaged in UAS efforts to support their mission goals. These include NOAA, NASA, NSF, DOE and DHS, all of whom are actively collaborating in their UAS efforts, while addressing their individual priorities. NOAA, NASA and DOE have held a number of workshops to address common goals and criteria for moving forward. NOAA and DHS are developing joint projects. NOAA and NASA are active partners on a number of UAS issues, particularly when focused on HALE platforms and their applications to environmental measurements.

Leveraging the Aeronautics Research investment and experience in UAS, including the Environmental Research Aircraft and Sensor Technology (ERAST) and ACCESS 5 Programs, NASA science is looking to adapt proven UAS platforms to investigate new earth observation techniques. Leading concepts being explored include long range high altitude transects for atmospheric chemistry and radiation measurements, as well as diurnal and other long endurance measurements. Boundary layer missions over the ocean, arctic and remote forests to measure ocean/atmosphere mixing, ice, as well as carbon fluxes. Hurricane research is also looking to benefit from a UAS that can loiter and track events complementing satellite coverage. Most missions are of interest to multiple agencies and institutions. Interagency collaborative efforts include being a signatory in a «Memorandum of Understanding with NOAA and the Department of Energy Concerning Unmanned Aircraft Systems for Global Observing System Science Research.» Other interagency efforts include having an in-place liaison in FAA's Unmanned Aircraft Program office as well as hosting a NOAA officer within Dryden's UAS project offices. NASA also maintains continuous discussions with academia and other government agencies regarding UAS enabled science and technology transfer.

NOAA's UAS Geographic Testbed Regions

The National Oceanic and Atmospheric Administration (NOAA) is a United States Federal agency whose mission is «to understand and predict change in the Earth's

Figure 4

environment and conserve and manage coastal and marine resources to meet the United State's economic, social and environment needs.» NOAA plays several distinct roles within the United States Department of Commerce among which is to enhancing economic security and national safety through the prediction and research of weather and climate-related events and information service. One of the most important resources today is information. Improved data and observations hold the key to saving lives, property and resources. NOAA supplies its customers with this information pertaining to the state of the oceans, atmosphere and our natural resources. The production of weather warnings through the National Weather Service, are some of the more visible products that NOAA produces, but NOAA's information products extend to climate, ecosystems and commerce, national coastal and marine environments.

To support information services in critical areas where observations are inadequate, NOAA has proposed three UAS testbed regions (*Figure 4*) for testing of UAS platforms for science missions, in partnership with agencies, academic institutions and industry.

1. A base in Alaska addresses issues related to the fate of the Arctic Ocean ice, monitor coastal erosion, ecosystems, marine mammals, forest fires. There is agreement that the Arctic Ocean's sea is retreating and likely will continue to retreat, however the rate of retreat is not well known at this time. Some models predict a rapid collapse (2015 to 2040) of the summer ice cover, which would likely have strong impact on Arctic ecosystems, indigenous peoples' way of life and transportation throughout the Northern Hemisphere.
   NOAA scientists believe that an intensive research and observing program over the Arctic Ocean combined with existing satellites and the observations from the International Polar Year can significantly reduce the prediction uncertainty and allow for appropriate planning for the resulting effects.
2. A base in the Gulf Region can deploy UAS during hurricane season (such as in the hurricane Noel mission in the previous section), to monitor hurricane cyclogenesis and the evolution of a tropical storm system over a week prior to landfall, and to collect hurricane data to improve the track and intensity forecasts, providing coastal residents with a greater lead time for evacuation. In addition, observations will be taken for harmful alga blooms that cause red tides and coastal erosion.
3. A base in the Pacific will support detection of Central Pacific storms and a variety of other critical needs. The base will support forecasting of flash floods that result from heavy snow and rainfall to the California coast; water resources management; and monitoring of the North West Hawaiian Islands National Monument, the largest marine conservation area in the world encompassing nearly 140,000 square miles. Other applications in the Pacific Ocean include typhoon development, ghost nets monitoring, fisheries assessments and enforcement, and protection of marine sanctuaries.
   NOAA plans to use the «Malolo One» in the spring of 2008 to search for marine debris in the Pacific.

NOAA continues to work with her partners in the science community and to explore new potential collaborations.