High-Altitude Surveillance

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GeoIntelligence

When Per Lindstrand flew his *Stratoquest* to an altitude of 65,000 feet, he set the world record for the greatest height ever reached by a human in a hot-air balloon. His flight also piqued the interest of military and intelligence officials seeking near-space technology solutions that could provide persistent surveillance in an operational theater.

What if the military could deploy unmanned lighter-than-air systems in the Earth's atmosphere between 60,000 and 200,000 feet – well above an aircraft's upper limit of 60,000 feet and well below the greater than 100,000,000-foot orbits of geosynchronous satellites? For how long could such systems hover over a single area and continuously provide communications and high-resolution information products? How large would the imagery footprint be at different altitudes – 500 miles wide, 1,000 miles? Wouldn't the time and hardware costs of deploying near-space, high-altitude platforms be significantly less expensive than launching satellites? What if this technology could be developed largely in the private sector?

Seeking answers to such questions is exactly the task that Project Alpha has undertaken. Headed by Lt. Col. Kevin Frisbie, Project Alpha is the futures investigative arm of the U.S. Joint Forces Command (USJFCOM) Joint Experimentation Directorate (J9) and is charged with quickly identifying and examining promising innovations and civil-sector technologies that have transformational potential to the military (see "Project Alpha Promotes Jointness" sidebar). One of the topic areas being assessed by Project Alpha involves advanced high-altitude platforms – including lighter-than-air systems (balloons), high-altitude unmanned aerial vehicles (UAVs), and hybrid systems. Known as the HALL (High Altitude, Long Loiter) program, Project Alpha's evaluation of these platforms and technologies, as well as its assessment methodology, are of active interest to USJFCOM and Department of Defense (DoD) transformation activities.

GLOSSARY

- **AHAB:** Advanced High-Altitude Aerobody
- **DoD:** Department of Defense
- **FAA:** Federal Aviation Administration
- **HALL:** High Altitude, Long Loiter
- **ICAO:** International Civil Aviation Organization
- **NASA:** National Aeronautics and Space Administration
- **UAV:** Unmanned Aerial Vehicle
- **ULDB:** Ultra-Long Duration Balloon
- **USJFCOM:** U.S. Joint Forces Command

Stay and Stare

A key element of the military's interest in high-altitude-capable balloons and other platforms stems from the fact that orbital mechanics deny satellites the ability to hover – except at an altitude of 22,300 miles above the equatorial belt (geostationary). Inexpensive, unmanned lighter-than-air systems, on the other hand, are being developed that will offer sustained operations in the Earth's stratosphere 10-30 miles above the surface. These systems are said to be high-altitude and long-loiter capable. In other words, the platforms will be able to stay and stare, or station-keep.

Station-keeping refers to the ability of a HALL platform to maintain an visual footprint for long periods of time, or in some cases, to maneuver to sustain the same stratospheric location (within 2-500 kilometers). Station-keeping effectiveness is not measured in the minutes or hours of a satellite pass, but in terms of the weeks, months, and years that the system is "on-station." Stratospheric fields of view also provide large footprints – a 60,000-foot altitude results in a 520-mile-diameter footprint – yielding wide coverage from a few balloons (see Figure 1).

In addition, because HALL platforms would operate in the stratosphere, they would encounter little to no traffic. The Federal Aviation Administration/International Civil Aviation Organization (FAA/ICAO) airspace ceiling is 60,000 feet; thus, the platforms would not interfere with air traffic or with NASA (National Aeronautics and Space Administration) operations. Lying above the jet stream, the area is also characterized by light winds and a marked decrease in weather effects.

"This combination of high-altitude flight and station-keeping technologies potentially provide responsiveness and persistence," stated Lt. Col. Frisbie, noting that HALL technologies are well-suited to Joint Forces concepts of persistent surveillance and continuous communications.

The constellations of satellites currently in use do not continuously cover every place on the globe. An incredible number of traditional satellites would be required to provide that level of surveillance, whereas a station-keeping metric of days/weeks/months for a HALL vehicle really puts meaning into the term "persistence."

The cost to launch a HALL platform versus a satellite is also significantly less. Projected costs for HALL vehicle operations vary from $1,000 to $50 million – a fraction of the price to launch orbiting bodies or fleets of aircraft.


PROJECT ALPHA PROMOTES JOINTNESS

"Project Alpha Promotes Jointness" sidebar (Click to enlarge)

Trucks in Space

Currently, HALL platforms are being designed independent of payload. "One could think of them as trucks," said Gary Trinkle, the project leader for Project Alpha's investigations of HALL technologies. "The trucks don't care what goes in the payload bed . . . mass and power requirements are all the platform cares about," he elaborated.

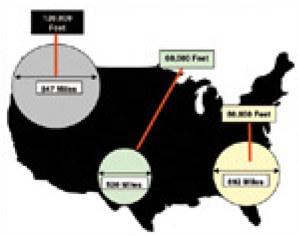

Figure 1 (Click to enlarge). Stratospheric HALL platforms can provide persistent surveillance over large areas. The higher the vehicle is deployed, the larger the diameter of its footprint. (Courtesy of Project Alpha)

During its research, Project Alpha discovered more than 300 worldwide efforts (open-source searches) adapting HALL technology for civilian uses, mostly in the fields of communications and geolocation. The technology is of particular interest to the international cell-phone industry. Like most tactical communications systems, civil-sector wireless technologies rely on line of sight. A HALL platform could provide the equivalent of a 20-mile-high cell tower.

With wireless communications providers showing great interest in HALL platforms, the U.S. military stands to benefit from the technology advances that the commercial-sector is driving. Indeed, the U.S. Army already uses tethered balloons, which it reels in for equipment updates and component swap-out to support various operations. But what greater flexibility could be provided if DoD could shed the tether and have a balloon in place for months or even years while maintaining the ability to update technology needs?

Free-Floaters, Steered -Floaters, UAVs

The benefits afforded to DoD and military operations by HALL platforms depends on the type of vehicle, where it will be deployed, and for what purposes. In particular, HALL platforms are able to achieve persistence in one of three ways: as free-floaters, steered-floaters, or high-altitude maneuvering systems, including balloons, UAVs, and hybrids.

Category 1. Free-floaters are the most rudimentary platforms and are inexpensive. They can be deployed with minimal expense and manpower when they are planned with stratospheric wind-condition forecasts. Persistence is achieved by sending a stratospheric balloon up as needed. Before a balloon bursts or drifts out of its useful perimeter, it is feasible to launch another free-floater to replace it. The payload from a burst balloon can be either blown up or brought back to Earth on a parachute or paraglider. Free-floaters can travel as high as 160,000 feet, carry as much as 8,000 pounds, and stay afloat for as long as 700 days. No single platform, however, has achieved all of these parameters in one mission.

Although stratospheric balloons are not maneuverable and are not capable of achieving powered station-keeping, they achieve persistence nonetheless. For example, if coalition forces had launched, as Trinkle describes, "Four to 12 of these platforms with a surveillance system every day for use in Iraqi Freedom, U.S. military command could have had continuous coverage of the entire country for the duration of the conflict."

Space Data Corporation's SkySite is an example of a free-floater that has been test launched and is being developed for use by the telecommunications industry. The U.S. Patent and Trademark Office has granted Chandler, Arizona-based Space Data a broad utility patent for using this technology to provide ubiquitous wireless service to cell phones, pagers, and telemetry devices. The platform will be able to provide clear, strong wireless signals from an altitude of 100,000 feet. From that height, a single SkySite can provide service to an area the size of Oklahoma.

The unique aspect of Space Data's system is that the company developed the technology to enable the creation of an entire constellation of SkySites by controlling the altitude and the relative position of each vehicle. A constellation of only 70 SkySites could provide ubiquitous service to the entire continental United States.

A SkySite balloon costs less than $100 and carries a payload worth $400 to $500. The payloads carry light beacons and phone numbers, and have been recently outfitted with GPS technology for tracking. Payload sensors are parachuted to Earth when the balloons burst. Good tracking and labeling has resulted in 95 percent of sensors being returned.

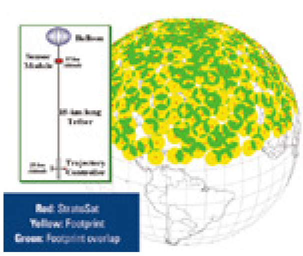

Figure 2 (Click to enlarge). Global Aerospace's StratoSat tethers a

Category 2. Because free-floating HALLs could be characterized as "drifting on the wind," they must be continually replenished to ensure persistent coverage. A more sophisticated approach envisions using a constellation of long-duration, steered platforms to ensure coverage. These platforms still generally drift with the wind, but they can be controlled with a small degree of precision by a steering mechanism. Thus, although steered-floaters are capable of station-keeping, their accuracy is insufficient for effective persistence, thereby requiring deployment in large numbers.

Sponsored by the NASA Institute of Advanced Concepts, Global Aerospace Corporation of Altadena, California, developed StratoSat – an example of a Category 2 HALL vehicle. StratoSats use superpressure ULDBs (Ultra-Long Duration Balloons), which were developed by NASA and are manufactured by Raven Industries, that float at 115,000 feet. On a 15-kilometer tether beneath the balloon is an aerobody-like device, known as the StratoSail, that takes advantage of denser air at lower altitudes of 65,000 feet to provide trajectory control to trajectory control device 15 kilometers below a stratospheric ballon. The device enables the HALL to be steered using the denser air at lower altitudes. A constellation of StratoSats with overlapping footprints would be necessary to provide global persistence. (Courtesy of Global Aerospace)

steer the balloon. The StratoSail can also contain sensors for imaging, positioning, and communications to provide surveillance that can cover an area the size of Kansas. A constellation of StratoSats would be required for persistent coverage (see Figure 2).

Another example of a steered-floater is *Pufferfish,* an oversized spherical balloon produced by Techsphere Systems International of Atlanta, Georgia, and demonstrated on June 28, 2004 near Washington, D.C. This vehicle is powered by as many as four propellers, with a rudder system at the back for steering. Thin-film solar cells, turbodiesel engines, and backup generators enable the craft to rise and descend. *Pufferfish* can cover an area the size of the state of Virginia, but it has only plus or minus 200 kilometer station-keeping accuracy. Two or three balloons would be required for certain coverage of the state.

Category 3. Even more sophisticated, persistent, and responsive HALL options being developed involve stratospheric platforms that are able to maneuver through a combination of floating and flying. The high-altitude maneuvering systems – comprising airships, aerodynamic balloon bodies, UAVs, and hybrid systems – are thus capable of station-keeping over specified points. They have low mass, are highly aerodynamic, and are designed to fly in low-air-density conditions that do not support traditional flight.

"Hall Specifications" sidebar (Click to enlarge)

Helios is an example of a Category 3 HALL system. Developed by AeroVironment of Monrovia, California, in cooperation with NASA's Environmental Research Aircraft and Sensor Technology program, Helios is a large, solar-electric, flexible-wing stratospheric satellite. It has 12 small engines across its wingspan. The wing flexes in the wind like that of a bird. Helios has been tested to 96,000 feet and has been involved in demonstrations using a variety of payloads designed for stratospheric altitudes.

Lockheed Martin of Bethesda, Maryland, is also developing an advanced-concept demonstration satellite for the Missile Defense Agency and U.S. Army for station-keeping use. Lockheed Martin's craft is a dirigible designed with three or four propellers and control surfaces to facilitate high-altitude flight. This concept craft is projected for its first flight demonstration in two or three years.

In addition, the Physical Science Lab at New Mexico State University is designing the Advanced High-Altitude Aerobody (AHAB). This superpressure balloon incorporates wing-like devices to give it a sleek aerodynamic shape. AHAB is designed to offset the effects of light winds by using a porpoising technique as necessary, trading altitude for horizontal motion. The craft is made up of a series of individual cells, and helium is pumped between cells to effect movement.

Many more HALL platforms are in various stages of development. The "HALL Specifications" sidebar on page 31 overviews the technical specifications for systems mentioned here as well as several others.

Operational Hurdles

Despite many successful HALL vehicle prototypes, several hurdles still must be overcome for the platforms to achieve operational functionality. For instance, a possible downside to the HALL technology occurs when a balloon transits the troposphere. A craft designed for 30-80-knot winds in near space may not be able to traverse the winds of the jet stream, which can be as fast as 250 knots.

Fortunately, NASA has been working with launch technology for quite some time. One potentially suitable application comes from the ULDB program at Wallops Island, Virginia. NASA launches the large, 1,000-foot-diameter ULDBs in semi-inflated state. Such launches, however, require a wide-open facility because the balloons' deployments are dependent on catching the wind. Another option would be to sea-launch ULDBs from the fan tail of a large ship. A third option is to have the balloon shot ballistically in a missile. At a predetermined trajectory point, the projectile releases the balloon, which self-inflates and deploys (see Figure 3). Current proposals even consider launching a rocket to Mars to deploy a balloon with research instrumentation at the fringes of the Martian atmosphere.

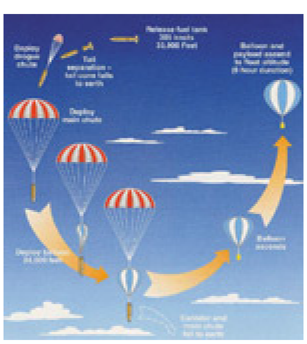

Figure 3 (Click to enlarge). Because a HALL platform designed for the 30-80-knot winds in near space may not be able to

The Project Alpha team found that there are varying degrees of launch planning and preparation required with use of the HALL platforms. Flight safety is another major consideration. It is critical to coordinate with FAA/ICAO airspace control facilities when HALL systems will transit the troposphere. Debris from HALL platforms at the end of a mission could also be an issue.

Other technological enablers for HALL systems include on-going advancements in solar film/batteries, regenerative fuel cells, and size and weight of materials, sensors, and communications equipment.

Supporting Transformation

With the technology advancing quickly and private-sector interest high, Project Alpha envisions that HALL platforms will become complementary to satellite technology. It will be possible to add data collected from balloons to other data to obtain a complete operational picture. This enhanced information will increase the U.S. warfighter's chances of distinguishing combatants from noncombatants and assist commanders in better understanding a situation and the surrounding environment.

traverse the 250-knot winds of the jet stream, engineers are pursuing options to deploy balloons ballistically. (Courtesy of NASA)

Joint Forces is interested in HALL technology to support a number of mission areas, including anti- and counter-terrorism surveillance; tracking of high-value assets or targets; missile defense and missile warning; battlefield command, control, communications, computers, intelligence, surveillance and reconnaissance; natural-disaster response and emergency communications; homeland security; border control; and monitoring of illegal crops. The technology can also support transformation.

Transformation is the process of changing form, nature, or function. Within the U.S. military, transformation requires adaptation of our military forces to changes in the mission-set; revision in the nature of our (military) culture and doctrine that supports those forces; and streamlining of our warfighting functions to more effectively meet the complexities of the new threats challenging our nation in the new millennium.

The U.S. military has a long tradition of experimentation. From the fleet problems of the U.S. Navy in the 1930s that birthed the concepts for the use of aircraft carriers, to the Army's famous Louisiana Maneuvers of 1941 that developed the doctrine for combined arms air/ground operations – experimentation has been at the forefront in the evolution of military affairs.

And so it is today, in the midst of information-age warfare and challenges from a new kind of adversary – one that claims ideas rather than a state – our military must adapt its methods to think, plan, and respond to those that would bring harm to us. As in times past, America's innovation and ingenuity will rise to the test.

Mary Ann Stewart is principal of Mary Ann Stewart Engineering, LLC and a member of the Geospatial Information & Technology Association's Annual Program Conference Committee. U.S. Air Force Lt. Col. Kevin Frisbie is military director of Project Alpha for the U.S. Joint Forces Command Joint Experimentation Directorate. Gary Trinkle is a senior military space analyst. This article stems from Lt. Col. Frisbie's participation in the Homeland Security Plenary Panel held at the Geospatial Information & Technology Association's Annual Conference, April 25-28, 2004. He was accompanied by Christian Grant, a Project Alpha project manager. They toured the exhibit hall, attended speaker presentations about technical issues, and took time to collaborate on this article. The views expressed are those of the authors and do not necessarily reflect the position of the Department of Defense or U.S. Joint Forces Command.