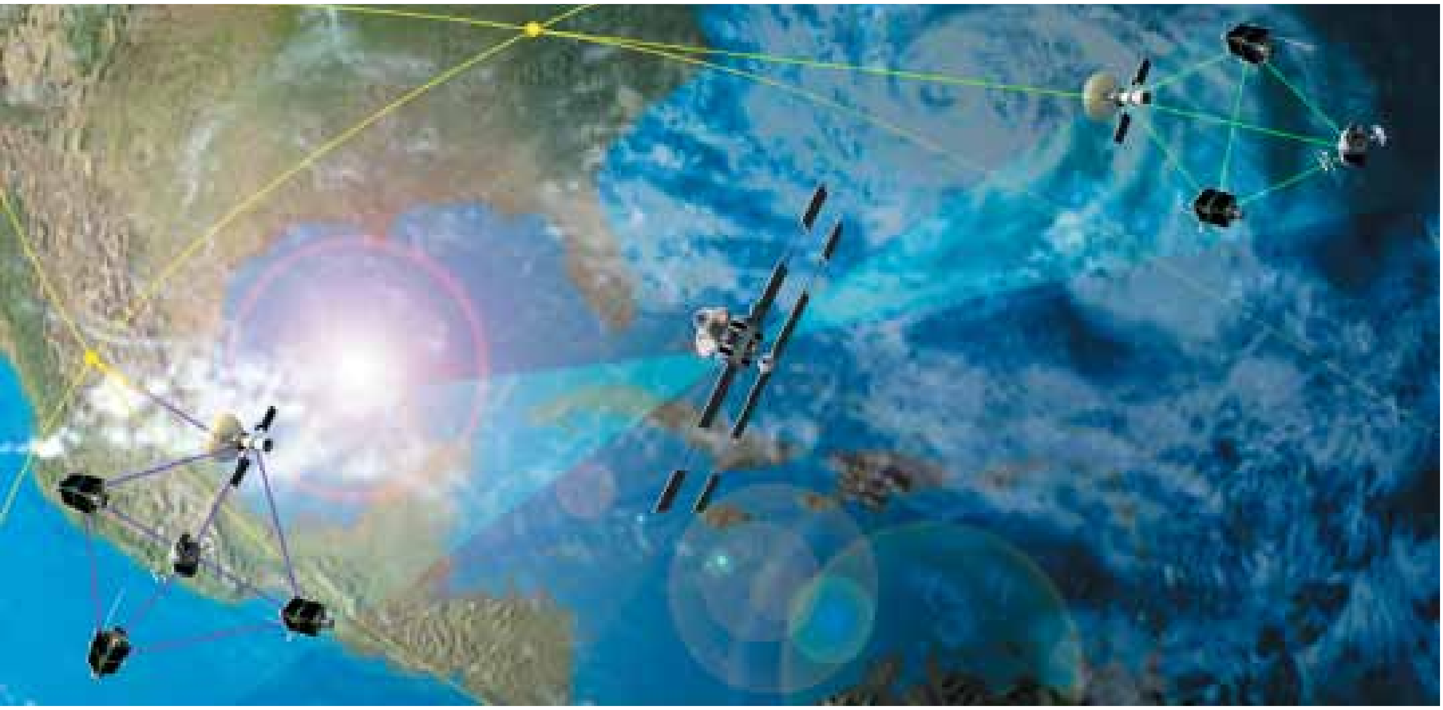
Game Changers

By **Michael C. Sirak,** Senior Editor

These are exciting times for those engaged in cutting-edge aerospace work. The Air Force and cooperative government agencies are engaged in an unusually large number of high-profile research efforts aimed at pushing the limits of the aerospace art.

Out on the frontiers of aerospace, next generation technologies are coming into view.



DARPA illustrations

Above and left: A DARPA artist's conception of System F-6.

For example, revolutionary technological advances likely are coming soon in the critical field of hypersonics.

Under current plans, the Air Force and its government and industry partners by year's end will conduct a maiden flight test of the X-51A Scramjet Engine Demonstrator-WaveRider over the Pacific. This hypersonic system features a supersonic combustion ramjet engine that burns jet fuel and is designed to operate at more than six times the speed of sound.

The X-51A could pave the way for new types of ultrafast-striking missiles that could reach targets much more quickly than can today's cruise missiles. It would also advance the technology base for aircraft and reusable space-access vehicles. These are potentially powered by a combination of high-Mach-capable scramjets and either rockets or turbine engines.

"I view hypersonics as one of the last great untapped frontiers in aeronautics," said Robert A. Mercier, deputy for technology in the Air Force Research Laboratory's Aerospace Propulsion Division at Wright-Patterson AFB, Ohio. Indeed, mastering the scramjet would go far toward eliminating distance as a barrier to operations.

The Fastest Ever

Also this year, the AFRL and Lockheed Martin have flown the Advanced Composite Cargo Aircraft, an experimental platform meant to prove out new manufacturing technologies that could be critical in the design of a next generation tactical airlifter.

The prototyping and manufacturing processes used in ACCA hold the promise of slashing the cost and time needed to field a new transport, said Barth Shenk, ACCA flight demonstrator program manager and air mobility technologies lead at AFRL's Air Vehicles Directorate at Wright-Patterson.

Moreover, the Defense Advanced Research Projects Agency expects by the end of the year to fly the first Hypersonic Technology Vehicle developed under its Falcon hypersonic technology research program. This vehicle, designated HTV-2, is a composite aeroshell meant to validate the materials and navigation, guidance, and control technologies for a future unmanned hypersonic cruise vehicle that could blaze through the atmosphere to deliver weapons at a point on the other side of the globe.

It is thought that HTV-2, if successful in flight, would be the fastest vehicle ever flown from the ground, said Steven H. Walker, deputy director of DARPA's Tactical Technology Office and program manager for Falcon.

"We have never built or flown a vehicle like this, so it will be interesting to see history being made," he said.

Early next decade will be important milestones for two additional projects that have the potential of a huge impact. In the case of the DARPA-Air Force Integrated Sensor Is Structure (ISIS) program, huge is no exaggeration. Both organizations aim to demonstrate the technologies in a scaled model starting in late 2012 that could lead to a helium-filled airship so large it could fit USS *Ronald Reagan* (CVN-76), the largest US aircraft carrier, inside its massive belly.

Perched on station for up to 10 years in the stratosphere at altitudes around 70,000 feet, this airship's massive radar would be able to discern individual soldiers from 186 miles out and otherwise hard-to-detect slow-moving cruise missiles from 373 miles distance, said Timothy Clark, a DARPA program manager who leads the airship project. Its radar could see under foliage. Such capabilities do not exist today.

The DARPA-led System F6 satellite technology program, known formally as the Future, Fast, Flexible, Fractionated, Free-Flying Spacecraft United by Information Exchange initiative, also seeks to conduct a demonstration beginning in 2012, this time on-orbit.

Under System F6, DARPA aims to break the current mold of designing large, monolithic satellites and replace them with so-called fractionated architectures in which nodes of the satellite are placed on modules that are physically separated but connected via wireless links to provide the same capability as the monolithic counterpart.

Such an approach offers advantages in flexibility and robustness, said Paul Eremenko, a DARPA program manager who is leading F6. However, it also offers far-reaching implications in enabling smaller aerospace companies to be viable players in the satellite arena, whereas today that is much more difficult.

What's What

"I think that this is probably by far the most exciting program in DOD today ... in terms of the potential impact on the way we acquire, the way we develop spacecraft, and the structure of the aerospace industry," Eremenko said. "This program has the potential to have ramifications beyond any single technology because it is an architectural paradigm change."

■ **X-51A.** The X-51A is scheduled to fly for the first time in late October off the coast of southern California. Three additional flight tests are planned in 2010. A B-52 test aircraft flying from Edwards AFB, Calif., will carry the X-51A and its host Army Tactical Missile System rocket booster aloft and release them over the Point Mugu test range heading west.

The ATACMS booster will propel the X-51A to speeds more than Mach 4.5. The X-51A will separate from the booster and, if all goes according to plan, its HyTech scramjet will ignite when the vehicle reaches speeds around Mach 4.8. The scramjet will then accelerate the vehicle to speeds greater than Mach 6 and propel it for about five minutes until its fuel runs out. The expendable vehicle will splash down in the ocean; the test articles will not be recovered.

"This will be a very significant advance," said AFRL's Mercier of the time that the scramjet will run and valuable flight data are collected. By comparison, he said each of NASA's two successful flights of scramjet-powered X-43A Hyper-X air vehicles in March and November 2004 collected just 10 seconds' worth of engine data.

For each successive X-51A flight, the goal will be to achieve the maximum speed, said Mercier. The vehicle's design limits its top speed to Mach 6.5.

Success in the flights would show that scramjets have strike "missile application, definitely," explained Mercier. It would also establish a cornerstone for building the technology base to enable larger, sustained-use scramjets in reusable aircraft and space-access systems, he said.

AFRL believes that a scramjet 10 times the size of the X-51A's engine is necessary to power a long-range strike missile carrying a significant weapon payload or as part of a combined-cycle propulsion system, such as coupled with a high-speed turbine engine, in unmanned strike or reconnaissance aircraft.

For larger strike and reconnaissance platforms and for space-access vehicles, a scramjet on the order of 100 times larger than the X-51A's engine is envisioned, Mercier said.

While the X-51A design could be spun off into a weapon, Mercier said he doesn't think it would be the best configuration for a weapon.

AFRL is teamed with DARPA, NASA, and industry partners Boeing and Pratt & Whitney Rocketdyne on the X-51A.

■ **Falcon's HTV-2.** DARPA is building two identical HTV-2 air vehicles for flight testing. The first test is slated for December and the second about a half year later, said DARPA's Walker.

Each expendable vehicle will be launched atop a Minotaur IV Lite booster stack from Vandenberg AFB, Calif., toward the Kwajalein Atoll, said Walker.

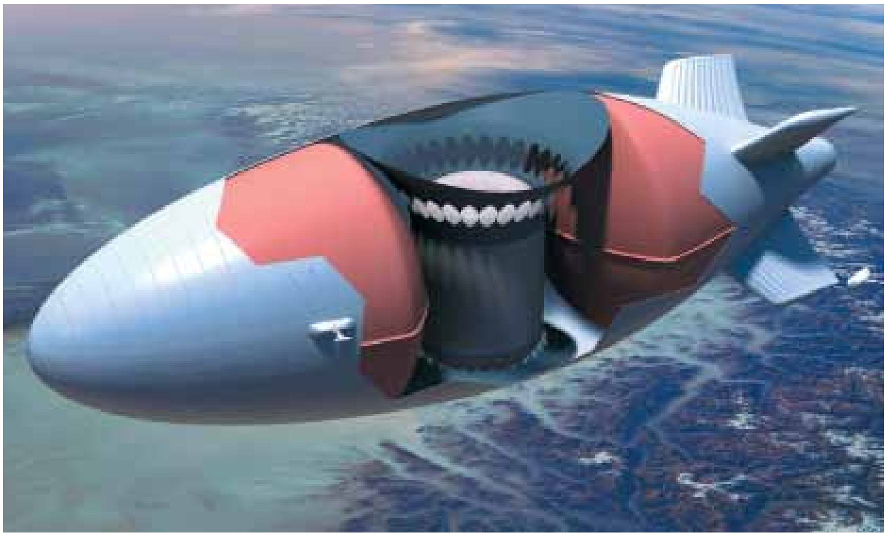
These unpowered glide vehicles will reach speeds of Mach 15 and Mach 20 and soar in the atmosphere at altitudes between 150,000 feet and 200,000 feet.

"The goal has been from Day 1 to simulate long-duration hypersonic flight," explained Walker.

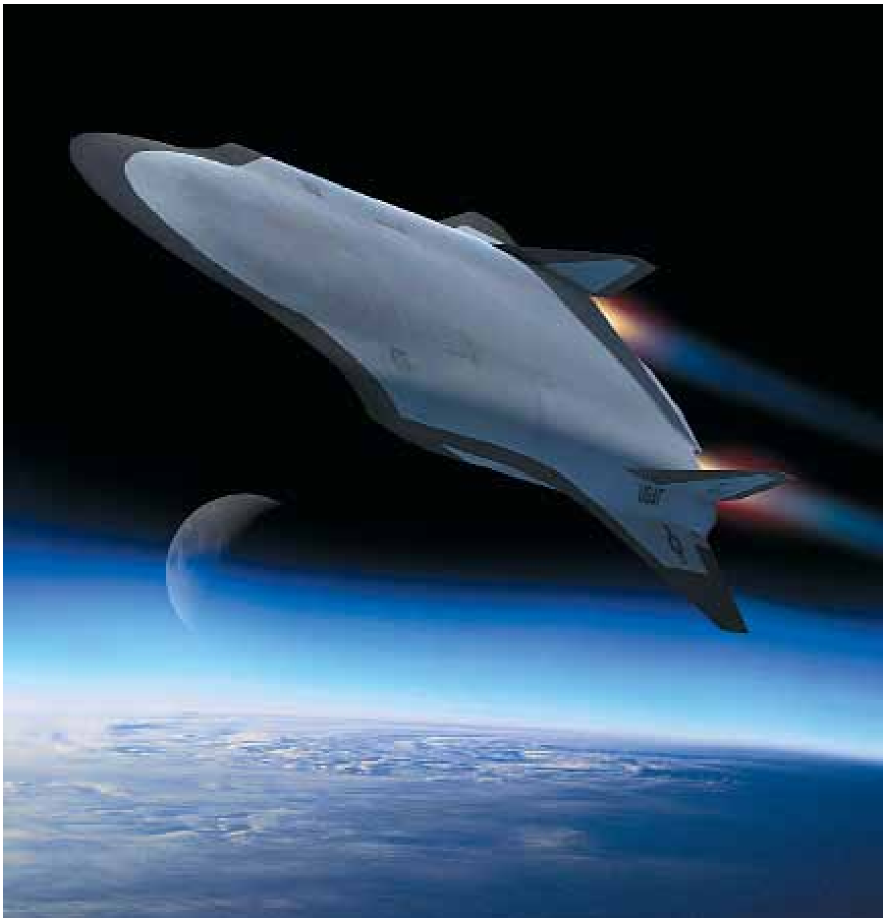
The flights are meant to validate the thermal management and navigation, guidance, and control systems, and assess how well the vehicles handle. HTV-2A will fly essentially straight downrange, while HTV-2B will travel along more of a curved trajectory to test the vehicle's ability to maneuver significantly cross range, said Walker.

These flights will also make history, he noted.

DARPA illustration



A conception of the DARPA-USAF Integrated Sensor Is Structure (ISIS) airship.



Conceptions of the Hypersonic Cruise Vehicle envisioned as part of DARPA's Falcon program (above) and the Hypersonic Technology Vehicle-2 (right).

DARPA illustrations

"This HTV-2 will be, we believe, the farthest and fastest vehicle ever flown" for a vehicle taking off from the ground, said Walker. "It is going to go 4,000 nautical miles in the atmosphere at Mach 15 to Mach 20."

The fruits of Falcon will transition to the Air Force in 2010. Already, in June, the service announced its intent to task Lockheed Martin to modify the HTV-2 design into one that can accommodate a weapon. The Air Force wants to test this modified air vehicle in flight in 2012.

This work will fall under USAF's Payload Delivery Vehicle project, which fixes to demonstrate the warhead shroud component of the service's Conventional Strike Missile concept. CSM calls for launching a non-nuclear weapons payload on top of a Minotaur booster stack from coastal US bases such as Vandenberg, in order to strike extremely time-sensitive targets within an hour of launch when other military options are not available. An example of this target set would be an enemy's long-range missile being fueled on the launchpad with a launch imminent.

Under Falcon, DARPA has also been maturing scramjet engine technologies. The agency, together with the Air Force, wanted to commence in Fiscal 2009 the development of a reusable test bed demonstration aircraft called the Blackswift. About the size of the Have Blue experimental aircraft, this would be used to validate a combined-cycle propulsion system comprising a high-speed turbine engine and the scramjet DARPA has been developing.

Enter ISIS

However, Congress essentially killed this idea by severely cutting the $120 million funding request for it to just $10 million. With that limited funding in hand, DARPA started this year a project called Mode Transition, or MOTR, with which it intends to demonstrate the combined-cycle propulsion envisioned for Blackswift in ground tests around 2011 to 2012.

■ **ISIS.** The ISIS airship, perched in the stratosphere, would enable unprecedented overhead search, tracking, and fire-control functions with an exceedingly large radar system in both the X-band and UHF-band that is fitted to a cylinder inside the airship.

The UHF radar will enable both volume searches for air targets, including otherwise hard-to-detect, slow-moving cruise missiles, and will penetrate foliage to be able to track dismounted soldiers. The X-band provides higher resolution tracking for fire control.

The airship fits in with the Air Force's layered sensing approach under which "you want to put the right sensor

Lockheed Martin photo

The Advanced Composite Cargo Aircraft on its first flight June 2.

at the right place at the right time to get the right data," said Mark Longbrake of the AFRL's Sensor Directorate at Wright-Patterson.

"We recognize that one sensor can't do everything and one platform can't do everything," he continued. So, "we look at ISIS as a node in that layered sensing construct that can provide a great capability" in terms of air moving target indication and ground moving target indication, he said.

DARPA plans to conduct the one-year ISIS flight demonstration starting in late 2012, said the agency's Clark. The vehicle will be launched from its hangar at Lockheed Martin's facility in Akron, Ohio, and then will fly down into the Florida Keys area where radar performance will be assessed against ground, water, and air targets, he said. Lockheed Martin is the lead contractor; Raytheon supplies the radar.

The demonstration aircraft will be roughly one-third the size of the notional operational variant—the one that could fit the carrier *Reagan.* This means the demonstrator will be about 460 feet long and 197 feet high.

Its X-band array will be about 1,067 square feet, roughly half the size of a highway billboard, and its UHF antenna will be about 5,813 square feet, for full 360-degree coverage. On an operational ISIS airship, the radar arrays would cover approximately 65,000 square feet, the size of a 15-story building, according to DARPA.

Clark said ISIS will feature an advanced hull material that is one-quarter of the weight of contemporary hull materials and has about 10 times the life of current material, as well as very lightweight radar arrays, and fuel cells and solar arrays for power.

Fractionated Space

The airship is designed to stay aloft the entire time of its service life and not come down to the surface and then return to the stratosphere. At the end of the demonstration, the airship will still have "significant lifetime" left and will be transitioned to the Air Force, Clark explained. He said the service was still determining exactly how it would exercise the system.

Clark asserted that the ISIS would be a very affordable system. Estimates are that it would cost just $30 million a year in operations and maintenance, including all of the data analysis, the data links, and software improvements. That equals out to about $3,000 per flight hour, he said.

Alone, one ISIS positioned near Iraq could have watched over one of the former no-fly zones there, he noted.

ISIS leverages some technology from the Missile Defense Agency's High Altitude Airship, also designed to operate in the stratosphere.

■ **System F6.** System F6 is designed to help break the paradigm of monolithic satellite design—that is, planning to put all of a satellite's components on the same spacecraft bus, connected via wires. In its place, DARPA is advancing the concept of fractionated space architectures in which a satellite's nodes (e.g., sensors, power source, communications downlinks, processors) can be physically separated into modules that are connected in function via wireless links so that they create the same capability as their monolithic counterpart, if not more.

"What we have here is essentially the capability of creating a virtual satellite," said DARPA's Eremenko.

Fractionated architectures offer satellite designers and operators flexibility not possible with monolithic systems, Eremenko said. Nodes can be deployed incrementally to offer partial functionality until the complete capability is on orbit or to upgrade the virtual system once on orbit as technology advances. Eventually this approach could even enable wireless resupply of a satellite network's power, Eremenko said.

Launching nodes separately prevents one launch failure from causing the loss of an entire new space system and overcomes the lift limits of launch vehicles that today's largest monolithic satellites are steadily approaching.

Fractionated nodes allow for more robust on-orbit systems since nodes could be repopulated more easily than large satellites if lost due to collisions with debris or an enemy act. Nodes are more survivable on orbit because they can be spread out to avoid debris or an adversary's anti-satellite activities, said Eremenko.

But it's System F6's influence on the space industry that could have the greatest impact of all, he said.

"This has the potential to do for the space industry what modular computing and the Internet did for the computer industry," he said. By breaking the large satellites down into smaller pieces that can be networked on orbit, "you reduce the barrier to entry" for smaller companies and universities in today's oligopolic industry, said Eremenko.

To foster this, DARPA is developing an F6 developer's package to allow for easy entry into fractionated design, as well as a layer of software known as middleware that acts as a "universal translator" to tie modules with different software seamlessly into the fractionated network.

Another innovation of System F6 is the focus on designing the space system's software before the module's hardware is fabricated, said Owen Brown, DARPA program manager, who led System F6 at its inception.

DARPA plans to conduct an on-orbit demonstration in low Earth orbit

USAF photo by Mike Cassidy

An X-51A Scramjet Engine Demonstrator-WaveRider hangs from the wing of a B-52 at Edwards AFB, Calif.

with four modules starting in 2012, said Eremenko. Notionally, there will be two infrastructure modules that provide basic mission-independent functionality (e.g., terrestrial communication downlinks, computing, and data storage).

There will also be a payload module carrying some yet-to-be-determined military-useful package. The fourth module will be provided by another military agency to demonstrate the ability of an outside source using the developer's kit to participate in the fractionated architecture.

Dramatically Fast

The demo is slated for about eight months, after which there will be a residual capability.

Eremenko said fractionated architectures are just as applicable to satellites in geosynchronous orbits as they are to LEO. They also fit the Air Force's Operationally Responsive Space concept of operations, which the service is currently working to address via small satellites that can be placed in orbit on short notice compared to traditional satellites.

System F6 represents a midterm approach to ORS, he said. In fact, it overcomes the limits of the current approach which is constrained by what one can fit on the small satellites.

■ **ACCA.** The composite aircraft's maiden flight took place June 2 in Palmdale, Calif., an impressive feat, considering that the program started only about 25 months before that, said AFRL's Shenk.

"That is dramatically fast," he said. "If you had to build a lot of tooling for metal parts, there is no way you would make that kind of timetable." Further, this was accomplished for the comparatively affordable investment of $50 million, he said.

ACCA is a Dornier 328J aircraft with its mid/aft fuselage and empennage fitted with an advanced composite structure that reduced the number of parts for those sections from 3,000 to 300 and the number of mechanical fasteners from 30,000 to approximately 4,000. Lockheed Martin is the prime industry partner.

"We are compressing the time and the cost by probably over 50 percent of what you would expect in a metallic airplane," said Shenk of the results. Compared to a metallic airplane of its size class, ACCA is also "about 20 percent lighter," although it can carry heavier loads, he said.

ACCA was modified to have the attributes of a tactical transport such as a cargo door and a fuselage wide enough to accommodate pallets. It was meant to be a realistic cargo aircraft design in order to validate the tools and manufacturing processes, including rapid prototyping and out-of-autoclave curing of large composite structures, that could be used to build a future transport to replace the C-130 Hercules family.

The Air Force has an emerging requirement for a future speedy, short takeoff and landing transport, which it calls provisionally the Joint Future Theater Lift platform, that can take off from air strips 2,000 feet long or less.

Shenk said the work on ACCA has raised the knowledge baseline in industry in preparation for developing and building a future airlifter program.

Shenk anticipates that the ACCA flight-test phase will last about one year. Thereafter, ACCA may be used as a testbed aircraft for other technologies such as cargo-handling systems, sensors, and subsystems, said Shenk.

"The aircraft has good endurance and volume and it's not too expensive to operate," he said. ■