Galactic

Speed brakes, similar to these red surfaces deployed on White Knight Two, will be used to help slow SpaceShipTwo during its gliding descent through the atmosphere.

GUY NORRIS/MOJAVE, CALIF.

With its sharp-nosed fuselage and sweeping, feathering tails, Virgin Galactic's SpaceShipTwo (SS2) makes for an imposing sight as it comes together in the Scaled Composites facility at Mojave, Calif.

Measuring 60 ft. in overall length, the 42-ft.-span clipped delta-wing vehicle merges the proportions of a business jet with the sci-fi look of a Star Wars fighter. Yet there is nothing illusionary about this project or its suborbital ambitions as Scaled workers begin to close up the wing skins and complete the systems installation on the SS2.

The composite vehicle is on track for rollout in December, and shortly after will be carried aloft beneath the capacious 140-ft.-span wing of the White Knight Two (WK2) mothership for captive-carry tests. Glide flights in 2010 will then lead to initial powered flights to space before culminating in the start of commercial services, widely expected later in 2011.

To reach this point, the project has weathered development issues—including a 2007 propulsion system test accident at Mojave—but Virgin Galactic President Will Whitehorn now believes most of the biggest hurdles are behind it. "The big one now is to make sure the spaceship will work properly, but there's nothing I can see at the moment that's a showstopper," he says.

With a rather unique support base of $40 million in deposits representing $60 million in total income from 300 suborbital adventurers, the project's financial footing remains firm despite the global economic gloom. "These are the kinds of customers who are not much affected by that, and sales this month are better than they were a year ago. Regardless of what's happening in the economy, success or failure is in the hands of the people in the project," says Whitehorn.

Yet for all the headline-grabbing plans for space tourism, a key element of Virgin Galactic's business plan is to quickly develop the baseline WK2/SS2 architecture into a delivery system for cargo and science payloads at a fraction of current prices. "We've got the basis for a really good business in three areas—payloads, science in space and space tourism. These are all symbiotic and not mutually exclusive," says Whitehorn, who notes that low-Earth-orbit launch costs of less than $3 million could be achieved, versus the $28-30 million typical of today.

Longer-term ambitions to develop the launcher business were boosted in July when Abu Dhabi-based investment group Aabar committed to buy a 32% stake in Virgin Galactic for $280 million. The deal includes plans to commit a further $100 million to develop a satellite launch capability for the system and the creation of a spaceport in Abu Dhabi.

"This new investment allows us to bring forward the satellite work," says Whitehorn. In addition, Virgin Galactic aims to pursue a recently issued NASA request for proposals for a suborbital science program. "We will go to 110 km. [68 mi.]

MARK GREENBERG

Quest

Virgin leading the charge as a billion-dollar space tourism industry gets off the ground, with XCOR, others to follow. Scientists may outnumber rich thrill-seekers in suborbital seats.

with SS2 for space tourists and up to 140 km. for space experiments such as microgravity," he says.

Space tourists remain the key enabler to both continuing development of the spaceship and launcher combination, as well as to building the economies of scale, which will help bring launch frequencies up and costs down. "We're still getting sign-ups, and we'd like to be at around the 600 level by the time we begin operations," says Whitehorn. Initial flight tempo will be around one per week, gradually increasing to around one per day. The first passengers will gain space-farer status on reaching an altitude of 100 km. and are each paying $200,000 for the experience. "But after the first few years we will start bringing prices down," says Whitehorn, who alludes to the similar gradual reduction in cost over time for luxury items such as flat-screen TVs.

The SS2 is sized to take up to six passengers and two crew, and has a 90-in.-dia. fuselage to provide sufficient room for maneuvering for several minutes in zero-g, as well as for sizable science experiments. The vehicle is more than double the size of SS1, the pioneering Scaled Composites-built craft with capacity for a single pilot and two passengers. SS1 sparked the space tourism market into life when it claimed the $10-million Ansari X Prize in 2004 by reaching 100-km. altitude twice in a two-week period with the equivalent of three people on board.

The decision to go for a much larger vehicle than SS1 was made in December 2004 following the X Prize, when "we figured we should be designing vehicles like this using the '747' approach rather than the 'Concorde' approach," says Whitehorn. "SS1 would have been the little Concorde, with room for only one or two passengers. That was Concorde's big downfall; it had no real range beyond London to New York and no room for cargo, so it was doomed. But Boeing designed the 747 in such a way as it could be versatile and do so much more."

A production facility for five SS2s and as many as three WK2s is currently being established at Mojave under the auspices of The Spaceship Co. (TSC), an entity set up in 2005 by Scaled Composites founder Burt Rutan and Virgin President Richard Branson. TSC is jointly owned by majority shareholder Virgin Group and Scaled (now part of Northrop Grumman). "We will start making the initial vehicles during the test program," says Whitehorn, who adds that the final production tally of WK2s remains undecided, "depending on what we do with the first aircraft." The facility is set up to deliver the first batch of vehicles exclusively to Virgin Galactic, but will then be open to additional sales to other customers.

SpaceShipTwo has all the unique design features that might be expected in "an aircraft that goes Mach 3 and folds in half," says SS2 chief project engineer Jim Tighe, referring to the "feathering" wing reentry mechanism. Unlike the mid-wing-configured SS1, which pioneered the feathering device, SS2 makes use of a more conventional low wing to allow a larger fuselage with better viewing.

SS2, also dubbed Model 339 by Scaled, is assembled complete-

MIKE MILLS

Although SpaceShipTwo has been kept under wraps, this image shows cabin assembly well advanced with the nose section nearing completion.

ly from composite material, apart from one section of fiber-glass skin to accommodate expansion around the oxidizer tank for the hybrid Scaled/Sierra Nevada rocket motor (RM2).

"We've used more pre-preg than we did in the past, and a lot more high-temperature tools," says Tighe. The cabin section is assembled into a complete pressure vessel from sections and reinforced with longerons and three offset vertical frames.

Systems and control runs are located in channels running fore and aft along the base of the cabin, while seats will be aligned to "get the passengers' heads as close to the windows as possible for the boost phase," he adds. The cabin has three large windows on either side measuring 17 in. across, plus six 13-in.-dia. windows in the crown. As with the WK2 design, the cockpit has four 21-in. windows plus a smaller center transparency for maximum situational awareness.

Aft of the 12-ft.-long cabin, a pressure bulkhead separates the compartment from the oxidizer tank; the RM2 rocket unit is housed at the rear within a composite-skin section. The main valve bulkhead between the oxidizer tank and the rocket incorporates the injector, valve, slosh baffle and igniter components. The single-use rocket engine will be detached from the bulkhead and replaced after every flight, says Tighe.

Initial tests of the RM2—the largest hybrid rocket of its kind in the world—were completed earlier this summer. Work included controlling pressurization within the system using helium, as well as testing various solid-fuel alternatives. Although hydroxy-terminated polybutadiene, or synthetic rubber, was used in earlier engines, the later tests have included paraffin and asphalt-based materials. Exact details of the final choice remain closely held; however, Whitehorn says the final fuel will follow the "rubber-based approach."

The cabin, which was static-tested in a water tank while being dynamically twisted and bent with hydraulic rams, is pressurized using bleed air from an air-cycle machine while attached to WK2. "Then when we separate, we're like a submarine. SS1 was a submarine all the way from takeoff, but we had humidity issues with that," says Tighe. The self-contained atmosphere in SS2 will be supplied with bottled oxygen, heated by body warmth from the occupants and dried by a desiccation system to prevent window condensation.

The wing has a leading-edge sweep angle of 55 deg. and is built up around two main spars, forward and aft, as well as a series of deep ribs to stabilize the wing skins. The leading edge, as well as the associated thermal protection system, is attached to shear webs that also support environmental, control and other systems. The trailing edge and booms support eight flight-control surfaces: two rudders, two horizontals, two elevons and two speedbrakes. For maneuvering outside the atmosphere, SS2 is fitted with a cold-gas reaction control system, with nozzles in the nose for pitch and yaw, and in the wing tips for roll thrust.

To make more use of the wing as a torsion box, Scaled designed the forward section of the tail booms forming the feathering mechanism to lock farther forward than on SS1. The feather section, consisting of the tail booms and "feather flaps," rotate around four large metallic hinges that are wound onto the composite rear spar. Two main pneumatic 625-psi. actuators, with a 9.5-in. bore and 31-in. stroke, change the position of the feather, which extends the forward section of each tail boom downward below the pivot axis when deployed.

The manual flight-control systems of both SS2 and WK2 will also make use of patented hybrid composite-steel flight-control cables designed to more closely match the coefficient of expansion of the control runs during the prolonged "cold soak" periods at high cruise altitude. On WK1, the conventional steel cables contracted so much that considerable pilot input was needed for relatively small control-surface deflections at altitude. However, at lower altitudes and warmer temperatures, the controls became very slack as the cables expanded.

MARK GREENBERG

Identical to the SS2's interior, the inside of WK2 provides ample room for maneuver. Test pilot Pete Siebold (right) prepares for a flight with Richard Branson (left) and project engineer Bob Morgan.

Composite cables, made from wound and cured carbon filaments, provide more consistent tension from start to finish, says Tighe. "Our goal is that the pre-load you put into the cables is pretty much what you get in flight." Control runs, requiring up to 150-ft.-long cables, command roll and pitch and feed into a mixer to combine both for elevon input.

The gravity-assisted, spring-deployed main undercarriage is custom-made by Scaled and resembles that of the North American P-51. The three-piece gear door is similar to the Beech Staggerwing design with the spring-loaded door mechanism tied to the motion of the trunnion. One door is fixed to the gear leg's half fork, the mid-section to the leg, and the lower section is attached to the mid-piece above it. The nose gear is the familiar Scaled skid.

The cabin and forward fuselage of the SS2 are structurally identical to the two fuselages hanging beneath the 140-ft.-span wing of the WK2. Powered by four Pratt & Whitney Canada PW308A turbofans, this distinctive mothership has notched up more than 60 hr. since its first flight in December 2008.

The novel twin-fuselage concept emerged after early studies of a scaled-up WK1 revealed potential problems for crew and passenger evacuation. "WK2 is designed for the same launch conditions as WK1, but it is three times as big. The early layouts were very similar to WK1, but there were challenges because of the scaling effects and the need for more room in the cabin. It meant we were effectively putting a business jet cabin on top of another, and that meant egress became a problem," says WK2 project engineer Bob Morgan.

The alternate twin-boom layout creates "very little or no drag" and provides options for payload growth as well as additional capacity for training flights and science missions. "Burt [Rutan] usually likes asymmetric designs, but I was thinking during the Space X prize how cool it would be for others to view the launch, or for it to be used as a means of space training for weightlessness or positive g," Morgan adds. Each 78-ft.-long fuselage can carry up to eight people, but only the right-hand boom contains a cockpit.

Two continuous composite primary spars run tip-to-tip through the wing. The spars are similar to the continuous 110-ft.-span I-beam spar developed for the GlobalFlyer, a record-breaking, single-engine aircraft flown around the world by adventurer Steve Fossett in 2005. Resembling a flattened "W" in profile, the wing is kinked with dihedral outboard of the booms and anhedral inboard to provide adequate ground clearance for the SS2, which will be suspended in the 46-ft. clear span between the fuselages.

The trailing edge at the center of the span is currently being cut away to enable a large mounting pylon to be attached to hold the spaceship. The pylon will be attached to the shear webs rather than the spars to provide maximum separation between the attachments, and to avoid the potential for fuel leaks with the wet wing. Each fuselage is attached to the wing via a cradle support, which is fixed to the shear webs with four large bolts.

The wing is a derivative of the GlobalFlyer design, but with a slightly thicker cross section designed for lower pitching moments. Configured with a high degree of inverse camber, the natural laminar-flow wing is designed to carry the SS2 up to release altitudes of around 50,000 ft. "To handle the torsion loads, the skins are four to five times thicker than they need to be for conventional flight," says Morgan.

The WK2 has a maximum takeoff weight of 65,000 lb., of which roughly 8,000 lb. will be fuel. This is designed to give it a ferry range of more than 2,550 mi., making it capable of reaching Hawaii from the U.S. West Coast as part of eventual long-term plans to enable the vehicle to transit to operating bases in Australasia. Aside from New Mexico and Abu Dhabi, other potential bases are being looked at in Asia, Scotland, Spain and Sweden. Maximum WK2 design payload is 35,000 lb., providing considerable margin for growth to take larger payloads than the 30,000-lb. loaded SS2, while maximum landing weight is 48,000 lb.

Flight tests completed envelope expansion to 53,000-ft. maximum altitude, 180 KIAS and Mach 0.65, says Scaled test pilot Pete Siebold. Changes have been made to the gearing of the ailerons and to the rudder horn balances to improve handling issues discovered on the early flights, but "now we're really pleased with how the aircraft is flying," he says. Upcoming tests will focus on basic aerodynamic qualities of the WK2/SS2 together and to "check that they fly together as expected. We will then slowly expand the envelope and introduce a pilot into the spaceship before commencing the glide tests."

Rocket Ride

GUY NORRIS/MOJAVE, CALIF.

Scaled Composites is using a fixed-base engineering development simulator to perfect the cockpit designs of White Knight Two (WK2) and SpaceShipTwo (SS2), as well as to train pilots for emergencies and other "off-nominal" procedures.

THIERRY BOCCON-GIBOD

"This is a living simulator," says avionics group engineer and software designer Terry Agold. "We've used it as an engineering tool and to determine the cockpit layout from a human factors and systems standpoint, and the follow-on will be for flight training in which it will be linked to the ground station."

Imagery derived from satellite and 3D terrain databases is projected on a wraparound screen and coordinated with aircraft position and orientation. The simulator can be used to represent WK2 or SS2 with a quick center-console change (see photo).

This AVIATION WEEK editor was invited to fly the simulator in SS2 mode with feather activation and locking handles replacing the WK2's engine throttles. The simulation began with the spaceship at release altitude around 50,000 ft., with the most immediate visual impression being the proximity of the two WK2 fuselages on either side. At release, the spaceship was trimmed 18 deg. nose-up using the electric servo horizontal stabilizers and the rocket ignited for the Mach 3.5 boost to space.

As I caught a momentary glance through the upper cockpit window of WK2 sliding quickly behind, SS2 accelerated rapidly to around 2,600 mph. Initial net g-force for the climb is expected to be around 3.5. Using guidance cues on the primary flight display to stay on track, I glanced out to see blue sky quickly turning to the blackness of space. After less than 2 min., the rocket burned out and we continued to soar toward our apogee at more than 370,000 ft. from where the Mexico-to-Oregon coastline was visible.

Agold asked me to deploy the feather device by pulling an activation handle, and then to lock it using a bulky handle made for gloved hands. He then activated the reaction control system, which was linked to the movements of the control yoke. Using this to reposition the spacecraft for the return leg through more than 4 min. of what would be weightlessness, we then began our descent. Thanks to the feather device, this is essentially a hands-off procedure with the craft swaying gently from side to side.

As we passed deeper into the atmosphere, the g-forces peaked briefly at around 6.5 before dropping back to a sustained 1.5. The feather device was stowed, resulting in a sharp nose-down motion for the final glide. Despite guidance cues, I misjudged the approach to Mojave and was forced to divert to the welcoming expanse of the lakebed at nearby Edwards AFB for a dubiously hard landing.

Deep Field

SpaceShipTwo is only one among many private spacecraft in development

FRANK MORRING, JR./WASHINGTON and GUY NORRIS/MOJAVE, CALIF.

On the cusp of what could be a major new aerospace industry, a handful of brash startups are vying with The Spaceship Co. to develop their own vehicles for personal spaceflight.

XCOR Aerospace, Blue Origin, Armadillo Aerospace and Masten Space Systems are not exactly household names today, but the visionaries working for them believe that in the near future their companies could become the spacecraft equivalents of Boeing and Airbus.

Just down the road from the Scaled Composites plant where The Spaceship Co. is building its first SpaceShipTwo, XCOR Aerospace is starting a second phase of tests of the 5K18 rocket engine which is earmarked to power its Lynx suborbital spacecraft.

As many as four liquid oxygen/kerosene-fueled 5K18 engines will be used on the vehicle, which is designed to reach suborbital altitude in a single-stage, rocket-powered flight from a conventional runway. The vehicle will glide back to land at the same runway used for takeoff, but will retain some fuel for a rocket-powered go-around in the case of a missed approach.

The initial test phase demonstrated the basic cooling design and the ability of the engine to run continuously at thermal equilibrium. Next steps will include installation of the cryogenically adapted fuel piston pump, all the tests to date having used pressure-fed fuel. XCOR views the pump as a key enabling technology as it allows for a lighter-weight airframe design without the need for strengthened, pressurized fuel tanks.

Vehicle work is focused on refining the high-speed aerodynamic lines as well as completing a full-scale engineering model of the pressurized cabin. The Lynx is designed to be just over 24 ft. in span and around 28 ft. long, and is configured with a cranked-arrow delta wing with tip-mounted vertical stabilizers and rudders. Lynx also has large trailing-edge elevons and a reaction control system (RCS).

First flight is still provisionally planned for 2010, with suborbital flights following within two years. Initial services will be provided by the Mk. 1 vehicle now being developed to reach an apogee of 38 mi. (61 km. or 200,000 ft.) and a maximum speed of Mach 2 during a powered ascent from a runway takeoff. A second, more capable variant Lynx Mk. 2 with more thermal protection and a lighter structure will be able to reach an altitude of 68 mi.

XCOR is marketing rides on the Lynx

through a company called Rocketship Tours and recently completed a beta test of its customer experience with the group. Ticket agents and representatives attended training seminars at a luxury resort near Phoenix and underwent hypoxia training in the Arizona State University altitude chamber before flying high- and low-g maneuvers in a Pitts S-2 aerobatic aircraft.

Within the age group most likely to use his space vehicles, John Carmack probably is better known as a game developer than a personal spaceflight entrepreneur. Carmack has used the money he earned creating computer games like DOOM and Quake to finance Armadillo Aerospace's ongoing bid to win prize money in the NASA-backed Northrop Grumman Lunar Lander Challenge that is intended to push planetary lander technology.

Armadillo already has captured the $350,000 "level one" prize for maneuvering and sequential flight with its small, radio-controlled LOX/ethanol craft (Carmack flies them with a gamer's joystick), and is working with partners on LOX/methane engine technology. The company has said it wants to scale up its vertical takeoff and landing vehicles for space tourism, quoting a seat-of-the-pants price of $100,000 a ride to the edge of space—half the cost of a Virgin Galactic ticket (*AW&ST* Nov. 3, 2008, p. 20).

Also playing in the vertical takeoff and landing arena is Masten Space Systems Inc., another Mojave, Calif., outfit. The company has entered the lunar lander challenge competitions in the past, and hopes to develop the same sort of capability for which Armadillo is aiming. This summer its engineers have been working on aluminum combustion chambers for their rocket engines, an example of the sort of innovation and flexibility that is sometimes seen at the low-cost end of the personal spaceflight community.

At the other end of that scale is Blue Origin, set up by Amazon.com founder Jeff Bezos in the suburbs of Seattle and in Culbertson County, Tex., to develop a large-scale vertical takeoff and landing vehicle dubbed New Shepard. The company flew a testbed version of its vehicle in 2007, and has remained publicly mum since then. However, there have been hints that Blue, as it is known in personal spaceflight circles, may have some new word this fall on its work and plans.

XCOR AEROSPACE/MIKE MASSEE

Tests of XCOR Aerospace's liquid oxygen/kerosene Lynx 5K18 rocket engine are taking place at Mojave, Calif.

"Though the economic downturn has caused some belt-tightening, a lot of these companies have investment in hand to proceed with their programs, and as we've seen with Virgin, it hasn't kept new investment from coming in," says John Gedmark, executive director of the Commercial Spaceflight Federation, which counts among its members Armadillo, Blue Origin, Masten, XCOR and Virgin Galactic. "That's a reflection of the fact that this is a long-term endeavor."

Gedmark's federation, which has mounted a "Next Step In Space" campaign to push for more investment in commercial space, is also working to develop new markets for its members' vehicles. One involves using vehicles developed for personal spaceflight to conduct research in the upper atmosphere.

"There's been growing interest from the space community, and we think flying scientists and researchers will be a huge market," Gedmark says. "It'll be an entirely different revenue stream, and when we go to conferences to talk to scientists we've been floored at the amount of interest."

One of the most vocal scientists on the issue is Alan Stern, who became interested in using suborbital piloted vehicles for scientific research when he was associate administrator for science at NASA in 2007-08. Since then he has worked as a consultant to Blue Origin and Virgin Galactic to help them develop the market.

"Tourists typically buy tickets one at a time, and research agencies are likely to buy significant numbers of seats, so there are bigger sales," Stern says.

Stern, who is also working with the Commercial Spaceflight Federation, has formed a Suborbital Applications Researchers Group (SARG) that is planning a conference of researchers in February 2010 to discuss potential uses of suborbital vehicles.

"They go to a really interesting place in the atmosphere, where you can do space research, upper atmospheric research, ionospheric research, auroral research," Stern says. "They've got some phenomenal capabilities that are different from what the robotic suborbital vehicles do."

Although researchers would use the same vehicles as space tourists, Stern says they should fly on separate flights to avoid interference in the 3 or 4 min. of microgravity and even shorter exposure to the space environment.

While the SARG has reported to a U.S. National Research Council panel studying suborbital research, Stern says the interest is not limited to the U.S. Abu Dhabi, which has bought a share in Virgin Galactic that will help the company develop the capability to launch small satellites as well, is looking for access to space for its scientific community, he says, and there are likely to be others.

"At these prices, I like to say that every country on Earth can afford to have a space research program with human payload specialists flying," Stern says. "There are 194 nations on Earth. Countries like Aruba can afford to have their own astronauts doing space research, education, public outreach, things that inspire kids."

Tourist Plan

Personal spaceflight infrastructure keeps pace with vehicle development

FRANK MORRING, JR./WASHINGTON and GUY NORRIS/LOS ANGELES

URS/FOSTER & PARTNERS CONCEPT

Work is underway on this futuristic spaceport in New Mexico where Virgin Galactic plans to launch tourists and researchers to the edge of space.

When the emerging private human spaceflight industry finally takes to the skies and beyond, there will be a network of spaceports to serve its vehicles and—in the U.S., at least—regulations to make their risky sorties as safe as possible.

Locales across the U.S. and elsewhere in the world have set up spaceports in hopes of getting in on the ground floor of an industry that theoretically has no upper limits. The U.S. already has seven nonfederal spaceports and eight more in the works (plus the Sea Launch Odyssey floating launch pad whose home port is Long Beach, Calif.). There are plans to fly space tourists from Scotland, the Swedish Arctic and Abu Dhabi.

Spaceport America, as the Virgin Galactic launch site near Truth or Consequences, N.M., is called, will compete with spaceports in Alaska, California, Oklahoma, Texas and Virginia already licensed by the FAA. "This groundbreaking ceremony is an important step toward our goal of being at the forefront of a vibrant new, commercial space industry," said New Mexico Gov. Bill Richardson at its June 19 kickoff to constituents, who voted an increase in sales tax to fund the project.

Economists in New Mexico estimate the facility, set for completion in 2011, will have a $300-million annual payroll after five years of operations and employ 2,300 workers. Futron Corp. estimates annual revenues for the desert launch site of $1 billion by 2020.

According to FAA Associate Administrator for Commercial Space Transportation George C. Nield, there should be plenty of business in the years to come.

"About half a dozen companies right now are designing and starting to test vehicles that can take people up to the edge of space," Nield says. "Whereas today NASA's having a pretty good year if they launch the space shuttle five or six times per year, I see an excellent probability that within the next five years we'll see several companies that are flying their vehicles several times a week on suborbital space tourism launches. That'll mean hundreds of launches every year, carrying thousands of people up to the edge of space to personally experience space travel."

Nield's office will license those flights, and ensure that the passengers sign informed consent waivers asserting they understand the risk. Acting under the Commercial Space Launch Amendments Act of 2004, the FAA Office of Commercial Space Transportation is responsible both for ensuring public safety during commercial launch and—an increasingly important role with the rise of space tourism—reentry, and for encouraging and promoting private spaceflight.

"We feel like we're ready to go," Nield says. "We've got the regulations in place. People know what the rules are; what needs to be done."

Will Whitehorn, the president of Virgin Galactic, says his company has helped pave the way with the FAA on deciding how to deal with the unusual flight profile of SpaceShipTwo, which transitions between the conventionally governed zones of atmosphere and space.

"It shares a bit of everything, and perhaps the X-15 came closest," Whitehorn says. "The lovely thing about this project is, despite claims that we're not in a race with anyone apart from safety, we are the world's first commercial space launch system that's using parameters that are based on general aviation-type safety standards, not the experimental standards of NASA and the European Space Agency. We're not going to be certified but it will be built to those standards."

As traffic begins to reach the levels Nield expects, the FAA will have to modify its air traffic control procedures to handle flights that pass through the atmosphere into space and return again. After the Columbia space shuttle accident, the FAA commercial space office started putting a team in the FAA command center to deconflict returning orbiters from commercial traffic. It has also developed notification procedures to keep air traffic clear of flight tests for spacecraft, and is working with the multi-agency NextGen air traffic control development effort to meld space traffic into the air traffic, in part by using the satellite-based Automatic Dependent Surveillance-Broadcast (ADS-B) technology (*AW&ST* Apr. 27, p. 36).

"That would be a good candidate for use on some of these vehicles, and the questions are under what conditions does that work," Nield says.

The commercial space office also licenses the U.S. companies—SpaceX and Orbital Sciences Corp. so far—that are positioning themselves to provide cargo and crew transportation services to the International Space Station. And the international role is likely to expand as suborbital tourist flights that return to their starting points evolve into point-to-point transportation across international borders. Nield says it will be important to develop international standards along the lines of regulations already in place in the U.S. so space transportation can follow the lead of the air transport industry.