Richard Branson and Burt Rutan walk around WK2.

Virgin Galactic has teamed with Scaled Composites to make commercial spaceflight a viable business. Their joint venture, The Spaceship Company, plans to build a fleet of commercial suborbital craft that will take paying customers on flights to the edge of space. As the technology for these vehicles advances, the number of passengers signing up for rides is also increasing. The company has overcome early setbacks, including a tragic accident, but is now on track to begin turning the dream of space tourism into reality.

by Leonard David
Contributing writer

There is real substance behind a phrase touted at Mojave Air and Space Port in California: "Imagination flies here." That is clearly true of this work-in-progress, the world's first commercial spaceline operation.

The change from fancy artwork and public relations handouts to actual aerospace hardware is evident within the hangars of Mojave-based Scaled Composites. Testing continues on the vehicles that will shape a projected suborbital space tourism market, drawing on the history-making WhiteKnight/SpaceShipOne launch system that enabled the first nongovernmental piloted rocket ship to fly to the edge of space in 2004—snagging a $10-million Ansari X Prize along the way.

Virgin Galactic is a company established and owned by U.K. billionaire Richard Branson and his Virgin Group, formed to make private space travel a reality. Virgin Galactic's intent is to own and operate privately built spaceships. Doing so will mean blending aviation, adventure, luxury travel, and cutting-edge design. And 2009 is the year when all these elements are to come together.

Business plan

How do you form a business around a hoped-for hunger by the public to fly to the edge of space?

Taking wing:

Liftoff

FOR PUBLIC SPACE TRAVEL

In July 2005, Branson and Burt Rutan, then head of Scaled Composites, announced the signing of their agreement to form The Spaceship Company—a business entity assigned the task of building a fleet of commercial suborbital spaceships and launch aircraft. Under license from Paul Allen's Mojave Aerospace Ventures—the Microsoft cofounder bankrolled the building of SpaceShipOne—The Spaceship Company adopted the "carefree reentry" concept and the "cantilevered-hybrid" rocket motor technology developed for the X-Prize-winning SpaceShipOne.

Jointly owned by Virgin and Scaled, The Spaceship Company will contract Scaled for the research, development, testing, and certification of SpaceShipTwo/WhiteKnightTwo (WK2). Through that partnership, Virgin Galactic has placed orders for five SpaceShipTwo vessels and two carrier planes, and it has options on more. The deal secures Virgin Galactic's exclusive use of the systems for the first 18 months of commercial passenger operations.

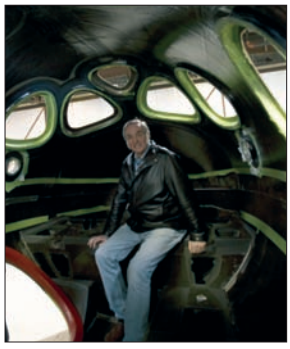
Following delivery of the Virgin Galactic ships, the company will supply flight hardware to additional commercial spaceline operators. A goal of the company, as flight hardware matures and is operated by these competing spacelines, is for many thousands of people each year to experience suborbital travel.

Initially, Virgin Galactic's spaceflights will operate from the Mojave Air and Space Port. That locale—also the home of Rutan and his Scaled Composites team, who masterminded SpaceShipOne—is where SpaceShipTwo is being built.

Following months of shakeout flights, the company will establish its headquarters and operate its spaceflights from Spaceport America, the world's first purpose-built commercial spaceport, now under construction in New Mexico. The business plan for the spaceline company also calls for using other potential spaceport locations around the world, with a view to expanding the enterprise.

Astronaut wings

For $200,000 a seat, Virgin Galactic will take passengers on a suborbital trajectory that propels them to around 360,000 ft. That fee also includes bonding and training.



Once released from WK2, the two-pilot/six-passenger SpaceShipTwo reaches its maximum speed some 30 sec into a boost phase that lasts around 90 sec. Over that time, the rocket burn gives an approximately 3-4-*g* kick in the pants to those on board.

The suborbital sojourn offers 4-5 min of microgravity. With faces pressed against large windows, customers get an on-high view of more than 1,000 mi. in any direction. It takes SpaceShipTwo about 30 min to glide to a touchdown. The *g* forces will build on reentry over a relatively short period of time, expected to peak very briefly at around 6-7 *g*s before quickly declining. During the flight, the spaceship hits a maximum speed of around 2,500 mph before gliding to a runway landing. From the tarmac takeoff to the spaceship's touchdown is roughly 2.5 hr. In taking the ride, customers will have shot by the internationally recognized border of space: 62.5 mi. above the Earth's surface.

Rollout ceremonies

With great fanfare WK2 was put on public display for the first time on July 28, 2008, at Scaled Composites. Parked in one of the company's hangars, still under construction and shrouded under black tarp, was SpaceShipTwo. Atop the craft, a sign read: "Coming soon…to a spaceport near you."

"The beauty of WhiteKnightTwo and SpaceShipTwo is that they can help change our relationship with space," Branson said at rollout ceremonies. "The other thing that I admire about the system is that it has the architecture that would someday be developed into a passenger-carrying vehicle able to take people from A to B around the planet…outside of the atmosphere, at near-orbital speeds."

WK2 is being billed as the world's largest all-carbon-composite aircraft in service. By contrast, the Boeing 787 uses composite materials for about 50% of its primary structure. A variety of WK2's component parts have been built using composite materials for the very first time. Purportedly, the control wires of the craft are carbon composite, a first in aviation and now a patented technology.

WK2 looks like a giant catamaran for the sky. It sports two individual fuselages, each including a cabin that replicates the interior of SpaceShipTwo. The aircraft is topped by a large, 140-ft stretch of wing—the longest single carbon composite aviation component ever fabricated. Sitting on a retractable quadricycle gear configuration, the vehicle is 78 ft long with a tail height of 25 ft.

Another important duty of WK2 is to serve as a training ground (albeit in the air) for prospective space travelers. The plane can supply stints in microgravity, ideal for acclimatizing next-in-line SpaceShipTwo flyers. Similarly, it will provide 6-7 *g*s to mimic the forces encountered during an actual suborbital flight.

Powering the large carrier plane are four PW308A turbofan engines built by Pratt & Whitney Canada (P&WC), based in Quebec.

According to John Saabas, executive vice president of P&WC, the WK2 program gives the firm an opportunity to amass high-altitude performance data for the PW308A turbofan. The fully certified engine—currently powering Raytheon's new Hawker 4000 super midsize business jet—has a demonstrated capability to fly at an altitude of up to 60,000 ft. Rated at 6,900 lb normal takeoff thrust and equipped with a full-authority digital engine control, the engine offers a combination of cruise thrust, fuel consumption, and power-to-weight ratio considered the best in its class, notes a company fact sheet on the engine.

Given WK2's maximum altitude of over 50,000 ft, its U.S. coast-to-coast range will allow SpaceShipTwo to be ferried on long-duration flights.

The Oshkosh factor

Will Whitehorn, president of Virgin Galactic, told *Aerospace America* in December that the Virgin Galactic customer base was still growing. "We're just under 290 customers, and we're holding just a shade under $40 million in deposit. It's grown a fair bit since the summer when we unveiled WhiteKnightTwo," he says. To help with ticket sales, Virgin Galactic has now appointed, trained, and qualified more than 100 "accredited space agents" in over 30 countries.

Whitehorn notes that as more of the WK2/SpaceShipTwo technology moves from

WhiteKnightTwo soared over the mountains on its successful maiden flight, on December 21, 2008.

artwork toward reality, this directly influences the number of people buying tickets and making reservations. "I call it the Oshkosh factor," he suggests, drawing from his experience in attending the yearly Experimental Aircraft Association's AirVenture show in Wisconsin, replete with homebuilts, antiques, ultralights, and rotorcraft. "They all say I'm going to buy it when I see it come to Oshkosh. In fact, that's one of our plans [for 2009], to take the WhiteKnightTwo to Oshkosh…make it there with the SpaceShipTwo underslung below it," he continues.

And you can take that Oshkosh factor to the bank. Some 40% of the first 290 customers who have actually paid money are pilots, Whitehorn observes.

Now on the Virgin Galactic agenda is development of what Whitehorn calls String Two and String Three—new lines of business beyond pay-per-view public space travel.

One key to those new business lines is the large, open architecture permitted by the twin fuselage placement on WK2. Within that open space, a multipurpose range of payloads can be cradled under the aircraft. The twin fuselage and central payload area are intended for easy access to WK2 and to the spaceship for passengers and crew. That design also aids operational efficiencies and turnaround times. WK2 is now projected to support up to four daily spaceflights and carry out both day and night-time operations, making use of advanced avionics.

"The payload carried by WhiteKnightTwo need not be SpaceShipTwo. It could be an unmanned rocket capable of launching from 50,000 ft a low-Earth-orbit satellite weighing up to 200 kg," says Whitehorn. "We're now talking to parties around the world who might be interested in building such a capability," he says, emphasizing that there has not been a launch vehicle that makes the economics of microsatellites that interesting.

One other idea now bubbling up for study is whether WK2 can act as a forest fire waterbomber. The aircraft could tote a massive carbon composite water tank, one that can be quickly replenished to stage repeat runs over roaring fires. Having the vehicle haul hefty amounts of cargo from point to point is another proposed use.

Change the paradigm

Another line of business, says Whitehorn, is to support suborbital science—using both WK2 and SpaceShipTwo to carry experiments, and even experimenters, to suborbital heights so they can conduct on-the-spot research.

WK2's twin fuselage placement enables the aircraft to carry a multipurpose range of payloads.

NASA has already begun surveying the use of privately operated suborbital vehicles, to help it carry out its space activities and even train its cadre of astronauts. The capability, if realized, could offer NASA a new mode of scientific research: human-tended suborbital investigations in which having a live person in the loop would increase the scientific return of flight experiments.

If NASA gives the green light, a pilot research program of suborbital flight operations could be implemented in 2010-2011. Given the capabilities of such spaceships, research tasks might involve astrophysics, heliophysics, planetary science, and Earth science, as well as the microgravity sciences.

A program office at NASA Ames has

The Mojave accident

The quest to create a commercial spaceline has not gone without incident.

On July 26, 2007, a rocket oxidizer cold-flow test for SpaceShipTwo's hybrid rocket motor at the Mojave Air and Space Port went awry. The mishap caused the death of three workers and serious injuries to three more. While similar systems had undergone numerous tests for SpaceShipOne's rocket motor, the accident rocked the Scaled team.

SpaceShipTwo, like SpaceShipOne, is expected to use a hybrid motor with nitrous oxide as an oxidizer and hydroxy-terminated polybutadiene (HTPB or rubber) as the fuel.

Since the accident, Scaled has implemented a variety of improvements to enhance the safety of the N_2O hybrid rocket motor. Those improvements and plans include:

- *Conducting increased compatibility testing between N_2O and any materials that contact it in the tank, and eliminating incompatible materials in the flow path.*
- *Revising cleaning procedures to further minimize the risk of contaminants in the system.*
- *Replacing the composite liner in the N_2O tank with a metal tank liner.*
- *Diluting N_2O vapor in the tank with nitrogen or another inert gas to decrease its volatility and/or act as a pressurant.*
- *Designing additional safety systems for the N_2O tank to minimize the danger due to tank overpressure; for example, a burst disk feature.*
- *Increasing the amount of testing during the development program to demonstrate that these design changes, and any improvements to system components, prevent the sequence of events that led to the accident.*

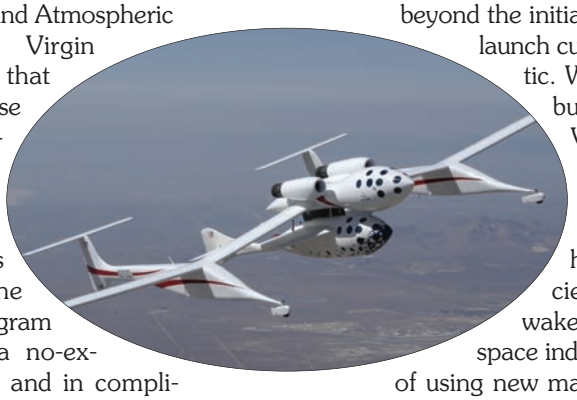
Last August it was announced that SpaceDev of Poway, Calif., had signed a multiyear contract with Scaled Composites to assist the company in the development of a production rocket motor for SpaceShipTwo. The contract, which runs through 2012, has an initial value of approximately $15 million for work to be primarily completed over the next two years.

Under the deal, SpaceDev will be the lead rocket motor team member for SpaceShipTwo and will collaborate with Scaled's internal design team to develop a production-ready hybrid rocket motor; provide engineering services to refine the design of the hybrid rocket motor being developed; and provide the development, manufacture, and integration of key rocket motor system components. Also, SpaceDev will be conducting ground tests on those motor components and will be working to assist Scaled in the full-scale rocket test program, both on the ground and during SpaceShipTwo flight tests.

SpaceShipTwo will offer plenty of viewing opportunities to its passengers.

been established for the use of emerging commercial suborbital vehicles for scientific research. The hope is to lower costs for traditional suborbital science and create a new way of doing business for NASA and the research community.

In a related development, last October the National Oceanic and Atmospheric Administration and Virgin Galactic announced that they will explore the use of WK2 and SpaceShipTwo for climate science and other relevant studies. Work conducted under this agreement during the vehicles' test flight program would be done on a no-exchange-of-funds basis and in compliance with all relevant FAA regulations. The first of these instruments focuses on studying greenhouse gases within the Earth's atmosphere, with data collected seen as a help in gauging findings from satellite-based atmospheric probing.



This newest endeavor will build on the success of the SpaceShipOne/WhiteKnight duo.

Whitehorn emphasizes that Virgin Galactic is busy looking into markets other than public space tourism. "What we're developing is a space launch system with multiple applications," he says, ways to enhance the likelihood of being profitable in the years to come.

At the moment, Whitehorn emphasizes, Virgin Galactic has based its entire business plan on space tourism, which he says is the only way being a smallsat launcher can become economically attractive in the future. Branson also notes that the system will be capable of launching small payloads and satellites at low cost.

"As far as science is concerned, this system offers tremendous potential to researchers who will be able to fly experiments much more often than before, helping to answer key questions about Earth's climate and the mysteries of the universe," said Branson at last July's rollout festivities.

"And for applied research, it is currently just too expensive to do most of the things in space from which industries like biotechnology could really benefit. The beauty of WhiteKnightTwo and SpaceShipTwo is that they can help change the paradigm of our relationship to space, achieving an era where space accessibility becomes a commercial and scientific norm rather than an exception."

Downsizing uncertainty

Rutan, now chief technology officer and chairman emeritus of Scaled Composites, is just as eager to convey both multifaceted uses of the launch system, but takes a poke at those who embrace conventional technology.

"I believe the vehicle will be developed and sold for a variety of launch applications beyond the initial requirements of our launch customer, Virgin Galactic. We have set up a new business jointly with Virgin, The Spaceship Company, to develop this vehicle, and we very much hope that its efficiency will herald a wake-up call to the aerospace industry on the necessity of using new materials and technologies in the future."

But putting more ring into that wake-up call depends on first testing WK2 and gaining confidence in its flying and handling attributes, and on evaluating SpaceShipTwo. Rutan is quick to note shakeouts of the launch system are critical to "downsizing the uncertainty."

While Rutan's aerospace designer talents were essential to the success of WhiteKnight and SpaceShipOne, he salutes the expertise of such people as Bob Morgan, Jim Tighe, Matt Stinemetze, and Pete Siebold, all part of the engineering team that has scoped out the new endeavor. Douglas Shane was appointed president of Scaled Composites last June to assume responsibility for the company's day-to-day operations.

Taking to the skies

WhiteKnightTwo made its maiden test flight on December 21, 2008, rolling down the runway and into the air at the Mojave Air and Space Port. On its first shakeout trek, the aircraft flew for an hour, carrying out a modest list of test objectives.

WhiteKnightTwo's flight was preceded by several weeks of taxi tests at the Mojave site.

"It's a great day here," said Stuart Witt, general manager of the spaceport. "We're out here welcoming the dawn of a new era."

As the backbone of Virgin Galactic's bid to establish spaceline operations, WhiteKnightTwo will undergo a series of flights prior to the attachment of SpaceShipTwo—followed by the two vehicles flying as one before drop tests of the rocket plane are initiated, a step that leads to solo powered flights of SpaceShipTwo.

"Today was just the beginning of an extensive flying program… soon to involve SpaceShipTwo as well… and a very exciting year now lies ahead for Virgin Galactic," Will Whitehorn, president of Virgin Galactic, told Aerospace America.

In related news, the New Mexico Spaceport Authority (NMSA) announced on December 15 that the state's Spaceport America had received its Record of Decision and license for vertical and horizontal launch operations from the Federal Aviation Administration's Office of Commercial Space Transportation.

"These two governmental approvals are the next steps along the road to a fully operational commercial spaceport," said NMSA Executive Director Steven Landeene. "We are on track to begin construction in the first quarter of 2009, and have our facility completed as quickly as possible," he said in a press statement.

Once the WhiteKnightTwo/SpaceShipTwo configuration has been fully tested at the Mojave spaceport, Virgin Galactic plans to home base its commercial operations at New Mexico's Spaceport America.

Vertical launch activity at Spaceport America is slated to increase in 2009. Also this year, construction is to start on the terminal and hangar structures to be used for Virgin Galactic operations—facilities that are to be completed by late 2010.

Scaled's lead engineer on the spaceline venture, Bob Morgan, sees the project as truly ground-breaking—it produced not only the design and construction of the world's first commercial space launch vehicle, but also a template for aviation in the future. Indeed, the challenges have been significant, he notes, from the full-span continuous composite wing structure to the all-composite control cable system in the aircraft.

Morgan sees WK2 as "the most innovative first stage of a space launch system ever developed."

Compared to the original WhiteKnight, WK2 is triple the launch weight, "allow[ing] so many more people to experience the edge of space and zero-gravity in our lifetime," says Morgan. He salutes the Rutan axiom of "fast and fun innovation" and the establishment of a Scaled culture "where salaried employees, vice presidents, and the CEO show up on a Sunday morning at 5 a.m. to mix epoxy paste to help technicians bond that wing span."

Just taking in an eyeful of WK2 does not tell you the whole story, says Morgan. "You don't see the thousands of lines of custom software and avionics developed and validated in our flight simulator. You won't see the fault tree analysis conducted on every system. You don't see the hundreds of joint tests and coupons that we took to structural failure to support the analysis," he says.

Razzle dazzle meets engineering

An atmosphere in which mystery meets show business envelops the building of the Virgin Galactic commercial spaceline hardware. On the one hand, there is the drama of that company and its eccentric, flamboyant leader, Branson—a magnet for the media attention needed to sell tickets. Then there is the nose-to-the-grindstone style of Scaled's engineers, who face tough challenges but must deliver safe, reliable, robust hardware. The two elements can be odd bedfellows.

While other companies are touting different concepts to gain a foothold in the personal spaceflight market, Virgin Galactic appears to have a clear lead.

"There are a lot of brilliant technical teams out there, but few that have navigated anything like the challenges of starting a business like this. That's where I see Virgin Galactic having an advantage over the competition," says Carissa Bryce Christensen, managing partner of Tauri Group, a technology consulting group in Alexandria, Va.

But like all such companies, she adds, Virgin Galactic also will face cost risk as it moves from developmental vehicles to operational services, and uncertain demand given the high introductory price of its service and the turbulent global economy.

"Virgin Galactic is, however, differentiated by business credentials that combine institutional experience and entrepreneurship. More than its excellent technical team, Virgin's deep pockets, successful experience in diverse consumer services, and leadership with a visionary, long-term perspective…will all be critical to its ability to succeed," Christensen believes.

With an eye toward months of testing still ahead, Whitehorn sums up the progress made to date:

"We've actually encountered no showstoppers at all. It's all going according to plan. We're looking at being able to put the SpaceShipTwo under the WhiteKnightTwo to begin its flight testing in the second half of this year," says Whitehorn. "There's no going back now."