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FEATURE

Memories of SpaceShipOne

Liz Nickels

Last July, as it flew past Pluto, NASA's space probe contained a small but significant piece of space history: a small carbon fiber piece of SpaceShipOne. Liz Nickels looks back at the groundbreaking composite commercial spacecraft eleven years on.

On its own, it only went as far as suborbital flight; but a three inch piece of SpaceShipOne met the outer limits of the solar system this month. The component was part of a group of eight other mementos on board the New Horizons probe, as it made its historic fly past Pluto, coming away with the clearest pictures ever taken of the dwarf planet. The autoclaved carbon fiber piece, part of the pilot seat made from preimpregnated carbon fabric and LTM 45 epoxy, represented the wide range of the reinforced plastic materials used to build the innovative craft.

In keeping with the tradition of space mementos, the SpaceShipOne piece includes a message about its significance. Side one reads, 'to commemorate its historic role in the advancement of spaceflight, this piece of SpaceShipOne is being flown on another historic spacecraft: New Horizons. New Horizons is Earth's first mission to Pluto, the farthest known planet in our solar system.' Side two reads: 'SpaceShipOne was Earth's first privately funded manned spacecraft. SpaceShipOne flew from the United States of America in 2004.'

The carbon fiber piece was developed by Cory Bird, current vice president and general manager of Scaled Composites LLC, the company that created SpaceShipOne. Scaled Composites is an aerospace and specialty composites development company located in Mojave, California. Founded in 1982 by Burt Rutan, the company focuses on air vehicle design, tooling and manufacturing, specialty composite structure design, analysis and fabrication, and developmental flight tests of air and space vehicles.

'SpaceShipOne is part of a historic moment in spaceflight, as more private companies work to bring space access to everyone,' said Kevin Mickey, president of Scaled Composites. 'We are honored to have been recognized for this by having this piece of SpaceShipOne's pilot seat on New Horizons, which has the potential to change the way we think about our solar system.'

Prize-winning craft

In October 2004, SpaceShipOne became the first private manned spacecraft to exceed an altitude of 328,000 ft twice in a 14-day period, winning the US$10 million Ansari X-Prize.

The Ansari XPRIZE spaceflight competition challenged aerospace enthusiasts from around the world to build a reliable, reusable, privately-financed, manned spaceship capable of carrying three people 62 miles (100 km) above the Earth's surface twice within two weeks. Twenty-six teams from seven countries competed for the prize, investing more than US$100 million in aggregate for research and development.

SpaceShipOne shown underneath White Knight during flight 15P. Photo courtesy Jim Campbell/Aero-News Network and Scaled Composites, LLC.

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SpaceShipOne ignites its engine after being released by the White Knight mothership. Video capture courtesy Vulcan Productions/Discovery Channel.

SpaceShipTwo and WhiteKnightTwo in their new home, Virgin Galactic Gateway to Space. Photo courtesy Mark Greenberg.

The US$10 million Ansari XPRIZE was modeled on the US$25,000 Orteig Prize, won by Charles Lindbergh in 1927. Lindbergh's plane was built by Ryan Aircraft, a future Northrop Grumman company, which, coincidentally, later was to take over Scaled Composites.

Scaled Composites' then vice president Mike Melvill piloted the spacecraft up to a height of 100 km–the highest altitude ever reached by a non-government-financed craft. At this height, a state close to weightlessness occurs and the pilot can see the blackness of space and the blue line of the atmosphere above the curved surface of the earth.

The company's concept of building a craft to fly into space dates back to April 1996. According to Scaled Composites, Burt Rutan started the conceptual design of the Tier One space launch system in 1997 and some of the concepts for the Tier One launch aircraft were worked out in Rutan's Proteus high-altitude, multi-mission aircraft which first flew on 26 July 1998. The full development program began in May 2001. The entire project cost less than US$40 million – much less than a government-sponsored program, according to the company. US$20 million came from philanthropist and Microsoft co-founder Paul G Allen, also founder and chairman of Vulcan Inc, which developed some of the motor technology of the craft.

Two stage flight

The Tier One vehicle consists of two stages: the White Knight carrier-launch aircraft, and the SpaceShipOne spaceplane. The plan would be for the White Knight to carry SpaceShipOne suspended beneath to a point 65 km from the airport base, and release it at 15 km altitude at 215 kph. SpaceShipOne would fire its rocket engine and go into an 84 degree climb, and after a 65 to 80 second burn, the engine would shut down, and the spacecraft continue on a ballistic ascent to 110 km altitude. This would be followed by re-entry into the atmosphere, and a glide landing.

SpaceShipOne is an air-launched rocket-powered aircraft with suborbital flight capability that uses a hybrid rocket motor. The design features a 'feathering' atmospheric re-entry system where the rear half of the wing and the twin tail booms folded upward along a hinge running the length of the wing, increasing drag while remaining stable.

Scaled Composites manufactured many of the ship's composite components. Many exterior and interior parts of SpaceShipOne are made with fiber reinforced plastic (FRP), including LTM 45EL prepreg supplied by UK-based Advanced Composites Group. The fuselage is made of a monocoque structure made of carbon fiber reinforced epoxy with a Nomex honeycomb core. The wings are also used carbon/epoxy skins, built up over structural ribs. The leading edge of the wings and the belly of the rocketplane use a red ablative material, which would be reapplied before each mission.

In the interior, the nitrous oxidizer tank and fuel casing (the largest components of the hybrid motor) are made of composites and designed by Scaled Composites. Aft of the horizontal stabilizer, where the heating is less, glass fiber is used as a radio-transparent skin material. The tank has a composite liner and the fuel casing is fabricated using a high-temperature composite insulator with a graphite and epoxy structure. In a few high-temperature areas, a phenolic resin is used instead of epoxy on the outer face sheet because it has better heat tolerance.

SpaceShipOne, having served its purpose of testing technologies required for safe, affordable suborbital passenger spaceflight, was retired after winning the Ansari X Prize and now hangs in the National Air and Space Museum in Washington, D.C.

SpaceShipTwo

Following the success of SpaceShipOne, Scaled Composites signed an agreement with Sir Richard Branson, founder of Virgin Galactic, to form a new company to build a fleet of commercial sub-orbital spaceships and launch aircraft. The new company owned the designs of the SpaceShipTwo and White Knight Two (WK2) launch systems in development at Scaled Composites.

SpaceShipTwo is a 60 ft long (18.3 m) spacecraft again made with carbon fiber composites to ensure high strength and weight savings. Powered by a hybrid rocket motor, the design is based in part on technology developed for the first-generation SpaceShipOne. SpaceShipTwo and White Knight Two are, respectively, roughly twice the size of the first-generation SpaceShipOne and mother ship White Knight. Construction of the carbon fiber spacecraft, which was expected to orbit above 50 000 ft (16 km) above earth, began in 2007. SpaceShipTwo (SS2), now rechristened Virgin Space Ship (VSS) Enterprise, was, according to Virgin, the world's largest, all-carbon composite aircraft.

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Close up of SpaceShipTwo during successful rocket-powered flight. Photo courtesy Scaled Composites, LLC.

WhiteKnightTwo is powered by four Pratt and Whitney PW308A engines which are amongst the most powerful, economic and efficient engines available. The WK2 mothership was designed to be capable of lifting other payload and launching it into space.

Unfortunately tragedy soon struck when an explosion occurred during an oxidizer flow test at the Mojave Air and Space Port, killing three workers and seriously injuring three more. 'It should go without saying that we were completely surprised by this accident, as we had conducted numerous tests, without incident, on similar systems including the SpaceShipOne rocket motor,' said the company at the time. 'The body of knowledge about nitrous oxide (N_2O) used as a rocket motor oxidizer did not indicate to us even the possibility of such an event. However, because this serious and unanticipated accident had occurred, we had to look back at what had happened and where we go from there.' The craft again ran into problems in October 2014 when it suffered an in-flight breakup during a powered flight test, resulting in a crash killing one pilot and injuring the other.

Despite this, the companies have continued to develop the craft with the aim to begin commercial flights for the public in the very near future for a mere US$200,000. The duration of the flights will be approximately 2.5 hours, though only a few minutes of that will be in space. Virgin Galactic is now well on the way to becoming the world's first commercial space line with 370 customer deposits totalling US$50 million.

SpaceShipOne's children

SpaceShipOne gave a boost, not just to the space industry, but to other private developers too. Two more examples of innovative composite craft include Space X's Dragon spacecraft and Falcon rocket, a two-stage rocket designed and manufactured by SpaceX for the safe and reliable transport of satellites and the Dragon into orbit. SpaceX decided to improve the performance of its Falcon rocket and Dragon capsule by adopting advanced composite materials, recognizing that composites could significantly improve performance by improving the strength-to-weight ratio of the materials used to construct its spacecraft. This is according to Siemens, which supplied the company with its Fibersim software to design and manufacture a variety of composite parts on both the Falcon rocket and the Dragon capsule. Fibersim was used to develop production fiber placement diagrams and laser projection files. It was also used to assist with actual fiber placement for the spacecraft's thermal protection system, including the heat shield, exterior panels, insulating layers on the rocket and spacecraft, and several panels around the nose cone and engines.

TenCate Advanced Composites also provided SpaceX with advanced composites for the Falcon 9 rocket. These include high temperature prepregs for spacecraft structures to bulk molding compounds used in compression molded components.

'SpaceX continues to set the bar higher and higher. They truly demonstrate the power of innovation and teamwork,' said Joe Morris, president of TenCate Advanced Composites at the time. 'We are proud and honored to be able to support SpaceX on all of their key platforms with our advanced composite materials.'

While the Dragon's pressure vessel was built with aluminum, its thermal protection system's carrier structures and its primary heat shield are made from bismaleimide (BMI) prepregs. It also features a heat-shield ablator made of lightweight epoxy-impregnated carbon foam.

In 2010, Orbital ATK developed the Pegasus and Minotaur-C rockets, selected to launch two NASA scientific satellites. Both feature composite fairings. The Pegasus payload fairing consists of two composite shell halves, a nose cap integral to a shell half, and a separation system. Each shell half is composed of a cylinder and ogive sections. The two halves are held together with a base

Space X's Dragon spacecraft. Photo courtesy SpaceX.

Space X's Falcon rocket. Photo courtesy SpaceX.

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Orbital ATK's Pegasus rocket. Photo courtesy of Orbital ATK.

frangible joint, two titanium straps along the cylinder and a retention boltin the nose.

Private spacecraft development has now met the mainstream. In 2011 NASA was given a five year US$5.9 billion government grant to encourage private companies to build, launch and operate their own spacecraft to benefit NASA and other entities. (This news also helped readers come to terms with the government's other admission – that there would be no more moon landings in the near future.)

'The next era of space exploration won't wait, and so we can't wait for Congress to do its job and give our space program the funding it needs,' said president Barack Obama at the time. 'That's why my Administration will be pressing forward, in partnership with [..] the private sector, to create jobs and make sure America continues to lead the world in exploration and discovery.'

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