

# Computers in engineering

## FEA helps SpaceShipOne soar

On October 4, 2004, a private, manned, prototype spacecraft called SpaceShipOne (SS1) made its second trip into space within two weeks to win the \$10 million Ansari X PRIZE. The X PRIZE was awarded by the **Ansari X PRIZE Foundation**, a non-profit educational organization headquartered in St. Louis, MO.

SS1 was designed and built by **Scaled Composites** and funded by Paul Allen, the co-founder of **Microsoft**, with the goal of creating the first privately funded, reusable space vehicle. Allen's company, **Mojave Aerospace Ventures**, owns the technology.

Even before proving itself to the world at large by winning the X PRIZE, SS1 took a large step towards Allen's primary goal when it grabbed the imagination of Sir Richard Branson, the British entrepreneur responsible for **Virgin Airlines**, who ordered five commercial versions of SS1 to equip the world's first commercial space tourism program.

SS1 does not resemble anything NASA has flown, and nor does it behave like any predecessor craft. It flies in three different modes, taking off like a rocket, righting itself upon re-entry into the atmosphere, and landing softly, like an airplane. Both SS1 and its launching airplane, **White Knight**, have several small windows rather than a single large window. SS1's pilots do not wear cumbersome space suits—to protect the pilot, the SS1 cabin was designed with a safety factor of 3, unlike the usual aircraft safety factor of 1.5.

Burt Rutan, founder and owner of Scaled Composites, developed a revolutionary hinged rear for the craft that lifts the tail and wings of SS1 so that it behaves like a badminton shuttlecock, which always descends with its feathers up, no matter how it is hit. The lifted rear makes sure the craft re-enters the atmosphere in the correct orientation to the ground, ready for a soft landing. SS1 has three different control systems for the three different



*SpaceShipOne, here being carried by its mothership, White Knight, won the \$10 million X PRIZE for being the first private manned spacecraft to reach 100 km altitude twice within two weeks. (Image courtesy of Scaled Composites.)*

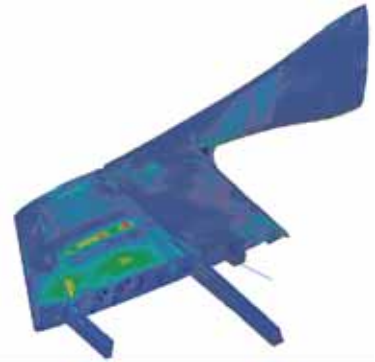
modes in which it flies—one for subsonic flight, one for supersonic flight, and another consisting of cold gas thrusters for attitude control in space.

As might be expected in such a complex structure, simulation played a big part in the design of SS1. Scaled Composites uses a number of simulation tools, and has used COSMOS FEA software from **SRAC** for composite analysis for about 15 years. SRAC is a division of **SolidWorks**, a wholly owned subsidiary of **Dassault Systemes**.

In the specific case of SS1, which is built primarily of bidirectional carbon cloth, Structural Analyst Dan Kreigh used COSMOS to perform static, buckling, and some nonlinear analyses for the fuselage, wings, and tail.

The analysis process starts when Rutan or another engineer creates a CAD model of the structure. That model is then simplified in the CAD program for IGES (initial graphics exchange specification) import into COSMOS. "The goal," said Kreigh, "is to create immediately meshable geometry from the imported CAD geometry."

After importing the geometry, the engineers often perform basic calculations by hand on paper or spreadsheet to establish a baseline structure for the COSMOS FEA model. Hand calculations typically include basic spar size and panel buckling. Once a baseline structure is defined in COSMOS, load cases are defined and applied. The



*COSMOS FEA software was a key simulation tool in the successful development of SS1 by Scaled Composites.*

structure is then optimized through many runs.

A structure often has multiple load paths through it. For example, SS1 has a front and aft spar that creates an indeterminate structure, which means that as one spar is made stiffer, more load may be carried by it while relieving the stress in the second spar. In effect, according to Kreigh, COSMOS allows engineers to design optimum load paths through any structure.

"We can define spar cap elements in multiple ways," he said. "In the case of the SpaceShipOne COSMOS model, we modeled spar caps as short, non-tapered beam elements with different cross sections down the length of a wing. Doing this requires that each beam element be assigned its own real constant set, which defines the spar cross-section properties."

Because all those data can cause a bookkeeping nightmare, Kreigh created a spreadsheet that required only root and tip spar properties.

"The spreadsheet can calculate all the other real constant sets between those two points," he said. Data from the spreadsheet are very easy to read into COSMOS because of its text data input and output capability. "Even though it takes a day or two to create the spreadsheet, it saves a huge amount of time in the long run as new load cases pop up, or as the vehicle changes weight—which requires very

## Briefs

**PTC** has announced that the Defense Advanced Research Projects Agency (**DARPA**) has selected PTC as the prime contractor for a research project to deliver 3-D Integrated Circuit (3DIC) design management capabilities. PTC will use the proceeds from this funded research project to enhance Windchill, Pro/ENGINEER, and InterComm. DARPA plans to use these solutions along with other advanced IC solutions to improve the performance of next-generation military electronics.

The Belgian Federal Government has agreed to co-finance the continuing development of LMS Virtual.Lab for Aerospace, a dedicated virtual simulation suite for aircraft and space system development. The software, developed by **LMS International**, offers an integrated solution to simulate component and full aircraft performance such as the structural integrity of airframe designs, the dynamic performance of landing gear, and the vibro-acoustic comfort of the aircraft cabin.

**HMS Software** has received a \$1.5 million follow-on order for software and services from **Lockheed Martin Aeronautics** (LM Aero). LM Aero now has an additional 1100 software licenses as it continues to roll out the HMS Enterprise Manufacturing Information Suite across its manufacturing facilities. The additional software licenses support LM Aero's Electronic Work Instruction Project to develop and distribute digital manufacturing information to shop-floor workers.

**Mercury Computer Systems** has shipped conduction-cooled multicomputer systems to **Northrop Grumman** Electronic Systems Sector for the synthetic aperture radar (SAR) systems onboard the F/A-22 Raptor fighter. SAR systems create images of the ground from aerial or space-borne platforms. Unlike traditional optical or infrared imaging, accurate images can be created by SAR systems at night, in poor weather, and low visibility. U.S. and Allied aircraft across all service branches are currently being upgraded to include SAR technology.

quick re-sizing of the spar caps."

Kreigh said that Scaled Composites also uses COSMOS for "large composite layup schedules such as required for fuselage and wing skins." This technique produces definitions for the number of composite plies, fiber orientation, and sandwich core thickness. "We used COSMOS to model the complete SpaceShipOne airframe, including tail, wing, feather, fuselage, crew cabin, and part of the rocket motor." Applicable load cases were then applied to those structures.

"We have three basic parameters for composites analysis—strength, deflection, and stability or buckling," Kreigh said. "Each of them has independent limits, and we need to balance the three to get the best structure."

He reported that he found nonlinear analysis important for the windows of SS1. "The windows bulge out under cabin pressure, so we needed to really understand the pressure on the edges of the window to prevent any real problems," he said. "The windows are made in two layers. The inner window takes the air load, while the outer one protects against anything that might hit it. The results of our analyses led to SpaceShipOne having many small windows."

## Global simulation a reality

**NASA** has unveiled its newest supercomputer at the agency's **Ames Research Center** in California. The "Columbia" is one of the world's most powerful supercomputing systems. Columbia was named to honor the crew of the Space Shuttle Columbia, lost February 1, 2003.

"This amazing new supercomputer system dramatically increases NASA's capabilities and revolutionizes our capacity for conducting scientific research and engineering design," said NASA Ames Research Center Director Scott Hubbard. "It will be one of the fastest, largest, and most productive supercomputers in the world, providing an estimated tenfold increase in NASA's supercomputing capacity. It is already having a major impact on NASA's science, aeronautics, and exploration programs, in addition to playing a critical role in preparing the

Kreigh also used COSMOS for the landing-gear booms and wing panels on the mothership, White Knight, from which SS1 launches. The crew cabins for both craft are structurally identical. Because the White Knight cockpit environment was so similar to that of SS1, pilots practiced flying simulated SpaceShipOne landing approaches in White Knight by adjusting the glide path with large wing spoilers. Identical structural cabins also saved cost.

The software was used for weight optimization as well. "The COSMOS model proved its value again when we were uncertain about being able to make the required 100-km altitude for the last two X PRIZE flights," said Kreigh. "Every extra pound of structural weight subtracts more than 100 feet of altitude, so we studied areas where structure could be trimmed—resulting in another 6 to 8 pounds of weight reduction."

In all, Kreigh said, "COSMOS played an indispensable role in the success of our SpaceShipOne program, which ultimately resulted in the first private manned spacecraft, the first two private space pilots, and winning the \$10 million X PRIZE."

*David Alexander*

Space Shuttle for return to safe flight next year."

Comprised of an integrated cluster of 20 interconnected **SGI** Altix 512-processor systems, for a total of 10,240 **Intel** Itanium 2 processors, Columbia was built and installed at the NASA Advanced Supercomputing facility at Ames in less than 120 days.

"The Columbia system is a tremendous development for NASA and the nation. Simulation of the evolution of the Earth and planetary ecosystems with high fidelity has been beyond the reach of Earth scientists for decades," said Ghassem Asrar, NASA's Deputy Associate Administrator, Science Mission Directorate. "With Columbia, scientists are already seeing dramatic improvements in the fidelity of simulations in such areas as hurricane track prediction, global ocean circulation, prediction of large-scale structures in



**The Columbia supercomputer was a team effort by SGI and Intel working with NASA scientists and engineers that delivered a tenfold increase in computing power within 120 days.**

the universe, and the physics of supernova detonations.”

Columbia provides an integrated computing, visualization, and data storage environment to help NASA meet its mission goals and the Vision for Space Exploration. The new system builds upon the highly successful collaboration between NASA, SGI, and

Intel that developed the world’s first 512-processor Linux server, named “Kalpana,” after Columbia astronaut and Ames alumna Kalpana Chawla.

“With SGI and Intel, we set out to revitalize NASA’s computing capabilities, and the Columbia system has done so in a spectacular way,” said Walt Brooks, chief of NASA’s Advanced Supercomputing Division. “Not only were scientists doing real Earth and space analysis during the system build, but within days of the full installation, we achieved a Linpack benchmark rating of 42.7 teraflops on 16 nodes with an 88% efficiency rating, exceeding the current best reported number by a significant margin.”

NASA chose to deploy PBS Pro workload management software from **Altair Engineering** on Columbia. The software was developed to optimize the utilization of computing environments—including Linux clusters, distributed servers, and workstations—by intelligently scheduling and managing computational workload.

The almost instant productivity of the Columbia supercomputer architecture and technology has made the system available to a broad spectrum of NASA-sponsored scientists. Feedback from scientists is extremely positive. Columbia already is enabling scientists to conduct research and analyze complex data much faster in a variety of scientific disciplines. The research and analysis ranges from providing more accurate hurricane predictions, to climate change, galaxy formation, black holes, and supernovas.

Thanks to the Columbia supercomputer, NASA scientists have already developed an improved global circulation model. Initial results from this new model predict when a hurricane is expected to hit land five days in advance, three days sooner than current methods, thereby helping reduce the potential impact on life and property.

*David Alexander*

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