7 AEROSPACE AMERICA JULY-AUGUST 2012

July-August 2012

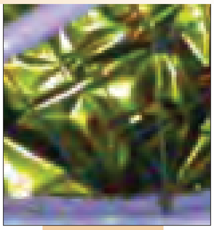
AEROSPACE AMERICA

The Dragon roars

Mars Science Laboratory: Going for a touchdown

A conversation with Norman R. Augustine

A PUBLICATION OF THE AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS



The Dragon roars

When the ships found Dragon, bobbing on Pacific waves off Baja Mexico,the scars of its journey were evident. Blackened and scorched, torn by parachute deployment, the spacecraft's polished white skin had been sacrificed to the demands of survival. Dragon had ripped down through the atmosphere from 230 miles up, fending off temperatures of 3,000 F in the battle between heat shield and white-hot blowtorch of reentry.

Superheated reentry shock plasma is a hungry beast, always seeking weakness and the chance to devour the structure of a spaceship. On each of my four shuttle reentries, I glanced up from checklists and instruments in half-amazement, half-fear. Outside, a neon orange-pink glow licked across our windows, then wrapped itself into a flashing, incandescent vortex in our wake. In a grim foreshadowing of Columbia, one of my orbiter crewmates watched the spray of fire outside and joked, "I wonder what color aluminum makes when it burns."

Dragon survived its own hypersonic ordeal, its blunt PICA heat shield battering at the atmosphere until drag finally slowed it below the peak heating zone. The ionized plume enveloping the capsule had cut off telemetry; on Earth we had to wait and watch, fascinated to see if the ship had come safely through the fire.

The Falcon 9 rocket's engines ignite on the SpaceX launch pad at Cape Canaveral Air Force Station on May 22. Credit: SpaceX.

A NASA airborne camera finally caught Dragon's infrared glow. When three parachutes billowed and slowed the spacecraft, it was all over except the rapid-fire popping of champagne corks at SpaceX headquarters in Hawthorne, California.

Dragon rests on the barge after being retrieved from the Pacific Ocean after splashdown. Credit: SpaceX.

Launching a new era

When Dragon slipped safely into the Pacific and recovery teams hoisted the capsule and its return cargo aboard a waiting barge, the SpaceX team could celebrate a remarkable achievement. The May 31 splashdown and recovery marked the end of a nearly perfect voyage to the ISS, notching a long list of accomplishments. The Dragon C2+ flight was the third consecutive successful launch of the company's Falcon 9 booster, which roared aloft on 854,000 lb of thrust in the predawn hours of May 22.

The mission's first launch attempt on May 19 was inauspicious. A predawn countdown led to a last-second pad shutdown when one of Falcon 9's engine purge valves stuck open, causing the number 5 combustion chamber pressure to exceed redline limits. Engineers replaced the valve, and three days later Falcon 9 lifted Dragon from Cape Canaveral's Launch Complex 40 on a brilliant pillar of flame reminiscent of Atlas or Saturn launches. A single Merlin engine on the second stage, also burning RP-1 and liquid oxygen, placed Dragon precisely onto its rendezvous trajectory.

Shortly after orbital insertion, Dragon deployed a pair of rectangular solar array wings. The solar arrays unfolded on fairings on the flanks of an unpressurized cylindrical trunk, the capsule's lower half. SpaceX founder and chief executive Elon Musk said the start of the cargo delivery demonstration flight was "like winning the Super Bowl."

The original Commercial Orbital Transportation System 2 (COTS 2) mission was to demonstrate Dragon orbital operations, including orbit adjustments, initial rendezvous maneuvers, communications with ISS, sensor operations, extended systems operation in the space environment, and tests of spacecraft avionics and software. The COTS 3 flight was to rehearse a safe approach to ISS, then close for proximity operations directly below the station. Once in a stable position just 10 m below the ISS, Dragon would demonstrate free drift (thrusters off) mode and await capture by the station crew. After berthing, cargo transfer would continue for about a week, followed by separation, deorbit, and recovery. NASA and SpaceX combined these objectives in the C2+ mission.

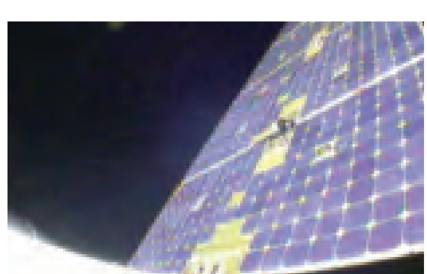
Impressive orbital debut

Many space observers and policy specialists were skeptical that SpaceX could pull off this ambitious agenda in a single mission. Software problems had delayed the launch repeatedly and led to several NASA reviews. Prior to launch, I gave SpaceX just 50/50 odds of a complete mission success. I thought the launch would succeed, but that the spacecraft was unlikely to make it all the way to the station. After all, Dragon had only flown once before, on a two-orbit flight in December 2010. That mission had not demonstrated any of the power, propulsion, and avionics capabilities needed for ISS rendezvous and berthing. For the C2+ flight, NASA had hedged its bets, loading Dragon with only 1,146 lb of nonessential cargo: food, clothing, batteries, laptops and computer gear, and 46 lb of NanoRack/CubeLabs science experiments and packaging.

From the ISS, Dragon can be seen on May 25 as the station's robotic arm moves it into place for attachment. Photo: NASA

But once in orbit, Dragon began demonstrating remarkable maturity. Eighteen Draco 90-lb thrusters conducted a series of orbit control and rendezvous burns, closing to within 1.6 mi. of the ISS while showing safe sensor, communications, and maneuvering capability.

On May 25, Dragon cautiously approached ISS along the R-bar, the imaginary line between the center of the Earth and the station. Expedition 31 crewmembers Don Pettit and Andre Kuipers monitored the spacecraft using a UHF communications link. From the ISS cupola, they spotted Dragon against Earth's spectacular landscapes by day, and tracked the capsule's flashing strobe light by night. Flying close formation just 33 ft beneath the station's Harmony module (Node 2), Dragon stabilized and went to free drift on command.



Two solar arrays power Dragon as it begins its travels. Credit: SpaceX.

Few situations give astronaut crews greater pause than a multiton vehicle drifting close to their own spacecraft. I had heard colleague Mike Foale describe firsthand the terrifying 1997 Progress collision with the Mir station, and had worked on the space shuttle during satellite retrievals and ISS docking operations. On STS-80 Columbia, my crew had deployed the Wake Shield 3 satellite; as that 4-ton spacecraft performed its separation maneuver, we sweated bullets as it glided by, barely 2 ft above our cabin windows.

Pettit and Kuipers took no chances with Dragon, which hovered in darkness, lit eerily by station work lights. A planned grapple in direct sunlight would have forced a wait for another half-orbit; during that time, Dragon's avionics and software might receive some false sensor input and initiate an automatic abort. The crew decided to move in immediately with Canadarm II. The pair closed the end effector snares over Dragon's grapple pin at 0956 EDT on May 25. "Houston, looks like we've got a Dragon by the tail," quipped Pettit. Two hours later, the astronauts swung the first private craft to visit ISS into berthing position against Harmony's Earth-facing port.

Completing the sweep

Aboard ISS, the 24-ft-tall, 12-ft-wide Dragon drew power and conditioned air from the station's systems as the crew unloaded the welcome cargo. Pettit reported no debris visible inside the pressurized volume, and observed that the internal environment looked inviting for future astronaut crews who might ride Dragon to orbit. The station crew packed Dragon for return with 1,455 lb of used equipment, scientific samples, and spacesuit hardware no longer needed aboard. Early on May 31, Pettit and Kuipers activated the ISS common berthing mechanism, unberthed Dragon, and released it into orbit.

The spacecraft performed a series of separation burns, departing safely from ISS, then positioning itself for deorbit. The capsule closed its guidance, navigation, and control systems compartment door, fired thrusters for reentry, then jettisoned the unpressurized trunk and solar arrays.

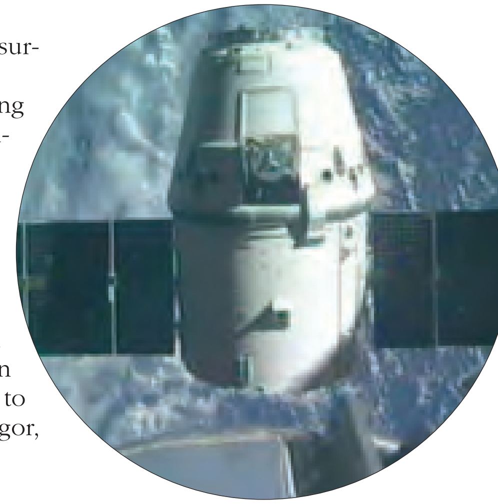
Dragon followed a guided, lifting reentry profile, targeting a splashdown point about 560 mi. southwest of Los Angeles. After deploying its trio of 116-ft main parachutes at about 10,000 ft, Dragon hit the water at 16-18 ft/sec, ending its voyage at 11:42 a.m. EDT. Recovery crews soon had the spacecraft on deck and on its way to the port of Los Angeles, to be trucked to SpaceX's McGregor, Texas, facility.

Six-year saga

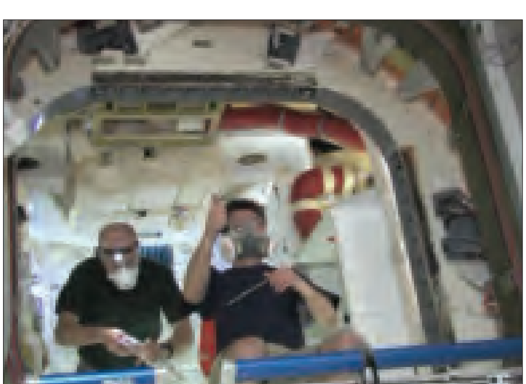
Dragon's return marked the first operational success of NASA's COTS program, inaugurated in 2006 under the Bush administration to supplant the space shuttle's massive cargo capacity to and from ISS. Commercial cargo services were to have been in place by 2009, but delays with SpaceX and Orbital Sciences' Antares/Cygnus vehicle left NASA with no domestic upmass capability. Even with shipments by Russia's Progress, ESA's ATV, and JAXA's HTV, NASA would still face an upmass shortfall of roughly 40 metric tons through 2015. The shuttle's retirement also cut off return of so-called downmass, so Dragon's recovery was doubly welcome.

"I just don't think it's going to take us very long to make the determination this was an extremely successful mission, and [SpaceX] should be well on the way to starting services," declared Alan Lindenmoyer, the manager of NASA's commercial cargo development program.

The $800-million COTS program, funding private development and testing milestones, is now materially closer to enabling regular cargo runs to ISS. SpaceX and NASA signed a $1.6-billion commercial resupply services contract in December 2008 for 12 flights to the station through 2015. Orbital Sciences will receive about $1.9 billion for eight cargo flights during the same interval. The flight rate is expected to be about three or four missions per year.



After six days at the ISS, Dragon departs for its return to Earth, carrying a load of cargo for NASA. It carries a high-tech, high-performance heat shield to protect it during the return through the atmosphere. All other cargo resupply vehicles burn up during reentry. Photo: NASA.



U.S. astronauts Don Pettit and Joe Acaba collect air samples from inside Dragon. As with all visiting cargo vehicles, the astronauts wear breathing and eye protection to guard against any stray material. Photo: NASA.

SpaceX plans the next Dragon flight, the first in its operational cargo runs, for late September. Orbital hopes to fly its first Antares booster from NASA Wallops in early autumn, with a Cygnus demonstration flight to ISS before the close of the year.

Boost for commercial crew

The Dragon success is widely perceived as a boost to NASA's execution of a crucial 2010 Obama administration policy shift that canceled the government's Ares I and Orion crew transport plan for ISS and replaced it with private, contract transportation. SpaceX has designed its Dragon from the ground up for astronaut transport. The dramatic C2+ success is a step toward what the company hopes is a contract to carry NASA crews to ISS.

NASA's commercial crew development (CCDev) program funds several other competitors to SpaceX, in a strategy to produce economical, safe crew transport. Those companies are Blue Origin, Boeing, and Sierra Nevada. NASA is predicting that, under current funding assumptions, the first astronauts may launch on a private vehicle to the station in 2017.

Major obstacles remain. To create a successful crew transport capability, private firms must demonstrate a reliable booster; ground egress and safety systems; a robust, flight-tested launch escape system; reliable, failure-tolerant avionics and life support systems; and a recovery system capable of landing a crew safely on land or sea. NASA may also want industry to provide an ISS crew lifeboat, which would remain docked at the station for up to six months to provide a means for rapid departure in case of emergency.

With Dragon, SpaceX is certainly closer than any of its competitors to meeting most of those requirements. But Sierra Nevada has begun aerodynamic flight tests of its Dream Chaser lifting body vehicle based on the old HL-20, and Boeing recently tested recovery parachutes for its CST-100, designed to launch atop the existing Atlas V. Blue Origin limits information about its orbital Space Vehicle, but in May the company completed a system requirements review, a milestone on the way to an ISS-capable vehicle. ATK, with its shuttle-booster-based Liberty rocket and capsule concept, is eager to compete in the next round of CCDev competition.

The biggest challenge NASA faces is how to fund all these competitors through preliminary design review, when the agency can assess the technical and cost performance of each firm and select a design for orbital transportation services. Congress gave NASA only half the CCDev funds the White House wanted this year, and the House of Representatives has again proposed cuts to this year's $800-million administration request.

Much attention in April followed a letter from Apollo commanders Neil Armstrong, Jim Lovell, and Gene Cernan backing a House appropriations bill that called for NASA to select a single private CCDev firm. The rationale was that a downselect would speed progress, restore to NASA the needed oversight of crew transport vehicle design, and better match the limited funding Congress is likely to provide through 2017.

Reaction came quickly from the Commercial Spaceflight Federation, which represents many of the 'new space' companies. Federation president and former astronaut Michael Lopez-Alegria stated that it was vital for Congress to preserve "competition in the program, as the vehicles are not sufficiently mature to enable NASA to confidently select a single vehicle at this time. The next phase of the program should also maintain the use of Space Act agreements, which require meaningful investment by the competing companies to augment NASA funding." In this election year, with the House opposing administration policy and a continuing budget resolution likely, the agency will probably see funding for CCDev again fall short.

Dragon lands in the Pacific. Credit: NASA/U.S. Navy.

Restoring a national capability

I have little doubt, based on the SpaceX success and continuing progress from the other CCDev partners, that private firms will meet the technical challenges of orbital flight. NASA is providing them with appropriate engineering and safety advice, based on its half-century of orbital flight experience. I do worry, however, about how long it will take the agency to realize a private crew transport capability.

We will be depending on Russia to meet our crew transport needs for at least another five years—longer, if the private firms experience a serious failure in flight testing, or if congressional funding fails to materialize. The presidential election may also lead to another space policy review, which could further slow progress in 2013.

These delays put the ISS, representing a $100-billion U.S. taxpayer investment, at heightened risk. With shuttle retirement, NASA lost its ability to mount an extensive orbital repair campaign to deal with an emergency at the outpost. We have neither the domestic crew transport nor a quick-response cargo system to get vital repair equipment and trained crews into orbit. Today, a serious orbital crisis could force NASA to abandon ISS.

With the current 2017 target for resuming U.S. crew launches, our government is taking a gamble: that the station will face no serious emergency until private firms eventually restore our human launch capability. The White House and Congress seem content to let the bet ride indefinitely.

Political leaders and technical managers should move now to protect our investment. Build on SpaceX's success, but go it one better: Accelerate the funding pace, let NASA decide on the right rocket, and advance the date when the U.S. can once again put its own citizens into space.

Thomas D. Jones
Skywalking1@gmail.com
www.AstronautTomJones.com