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NASA's $14 BILLION DECISION

Who will ferry cargo to ISS next?

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Five aerospace teams are vying for up to $14 billion in NASA contracts to dramatically boost the amount of cargo delivered to and from the International Space Station. The competition pits industry stalwarts against relative newcomers, and traditional mission designs against daring innovation. Debra Werner looks at NASA's options and the potential payoffs to astronauts.

UPPING the station's upmass

The stakes for NASA's latest competition to deliver supplies to the International Space Station were laid bare in April, when a Russian Progress cargo ship spun out of control toward the end of its ride to space on a Soyuz rocket. More than 2,700 kilograms of cargo burned up in the atmosphere over the Pacific Ocean, forcing the six person crew to go without fresh produce until the next resupply flight, a SpaceX Dragon scheduled at press time to launch June 26, 2015. The failure came just six months after an American-built Cygnus cargo capsule was destroyed when its Antares launch vehicle exploded during liftoff from Wallops Island, Virginia.

Even when all goes right, the station crew must rely on a dwindling fleet of freighters. Europe's Automated Transfer Vehicle stopped flying in 2014; Japan's H-2 Transfer Vehicle is scheduled to deliver cargo once a year until it retires in 2019, and the space shuttle fleet flew its last mission in 2011. Nearly all supplies are delivered by Russian-government Progress ships, plus two kinds of commercial vehicles that NASA added to the mix after a 2008 competition: The SpaceX Dragon and Orbital ATK Cygnus capsules.

NASA wants to solve the dearth of delivery options by increasing the mass that can be delivered to the station, and it is in the closing weeks of a high-stakes indus-

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The competitors

Five companies are chasing the next cargo contract for the International Space Station

SpaceX Dragon

Observers say SpaceX is well positioned because of the seven Dragon missions flown to the station so far, including a demonstration mission. The existing Dragon includes a 14-cubic meter trunk that is jettisoned to dispose of trash in the atmosphere while the main capsule returns cargo to Earth. Here are more details of the current version:

Dimensions:
7.2 meters long, 3.7-meters diameter, including a disposable trunk

Maximum load:
3,310 kilograms up; 2,500 kilograms down plus 810 kilograms burned up in disposable trunk

Launch vehicle:
Falcon 9

Landing:
Ocean splashdown

Reusable?
Not yet, but SpaceX aspires to that

Boeing Crew Space Transportation-100 (CST-100)

Boeing argues NASA would save money by adding cargo to the CST-100's mission of carrying astronauts to the space station. Boeing hasn't spelled out the adjustments it would make for a cargo version, but it will on reentry land under parachutes at one of five sites in the U.S.

Dimensions:
5 meters long, 4.6-meter diameter

Maximum load:
Boeing won't comment, except to say CST-100 cargo version will carry at least 2,500 kilograms

Launch vehicle:
Atlas 5

Landing:
Touches down on land

Reusable?
Yes

Orbital ATK Enhanced Cygnus

After three flights to the station, Cygnus was sidelined last October when an Antares rocket exploded in a launch attempt from Virginia. While the company works on the Antares, it will get back to business in November by using an Atlas 5 to launch a new, larger version of Cygnus with updated electronics. Orbital ATK hasn't provided details of its bid for the new cargo contract, but here are details for Enhanced Cygnus:

Dimensions:
4.9 meters long, 3-meter diameter

Maximum load:
3,500 kilograms to and from space station

Launch vehicle:
Orbital ATK Antares; Atlas 5

Landing:
None, burns up on reentry

Sierra Nevada Dream Chaser

This is the only non-capsule design in the competition. The cargo version would ride to space shrouded by a rocket fairing, and after the mission its wings would deploy mechanically for a runway landing. Sierra Nevada says the exact deployment method is competition sensitive.

Dimensions:
10 meters long, 8-meter wingspan

Maximum load:
5,500 kilograms up; 1,750 kilograms down. Also can release 3,250 kilograms to burn up in the atmosphere.

Launch vehicle:
Atlas 5 or Europe's Ariane 5

Landing:
8,000-foot conventional runway

Reusable?
Yes

Lockheed Martin Jupiter and Exoliner

This is the only entirely new concept in the competition, although Lockheed Martin says it will rely on technologies proven on other missions. An orbiting Jupiter space tug would deliver disposable Exoliner containers to the station using a robotic arm.

Dimensions:
9.7 meters long, 4.4-meter diameter

Maximum load:
5,000 kilograms in a pressurized compartment; 1,500 kilograms in an unpressurized compartment

Launch vehicle:
Atlas 5

Landing:
None, used Exoliners burn up in the atmosphere; Jupiter remains in orbit

Source:
Aerospace America research

try competition for the right to do that. Dragon and Cygnus have carried 14,000 kilograms of cargo in six flights over the span of three years under the original 2008 contracts. Starting in 2018, NASA wants to send about that amount in a single year and possibly much more by upping the annual launch tempo to four to five flights. This desired annual upmass of 12,000 to 32,500 kilograms has made the Commercial Resupply Services-2 competition a coveted $14 billion prize that's likely to be split among multiple winners.

There could be added benefits to boosting the upmass.

"Launching more and more often over time should reduce costs and increase reliability since, as with anything in human experience, you will get more efficient and proficient over time," says Frank Slazer, Aerospace Industries Association vice president for space systems.

Vying for the CRS-2 contracts are two incumbents, SpaceX and Orbital ATK; Sierra Nevada Corp. with its winged lifting body Dream Chaser; Boeing with a modified version of its CST-100 capsule; and Lockheed Martin with Jupiter, a refuelable space tug that would stay in orbit for at least 12 years to grab newly launched cargo modules with its robotic arm, take on fuel for its hydrazine engines and ferry expendable cargo containers called Exoliners to the station.

NASA plans to announce the winner or winners in September, and as is typical in the closing weeks of a multibillion competition, the agency isn't saying much. Outside of NASA, there is plenty of discussion about the future cargo delivery contracts. Much of it centers on how many companies NASA will select – the agency won't say – and whether anyone can beat SpaceX, the pioneering leader of the "new space" startups that are happy to serve government customers, provided they get to do most things their way.

Last year, NASA chose proposed passenger versions of the SpaceX Dragon and the Boeing CST-100 to deliver astronauts to the space station under a separate Commercial Crew Services program, turning aside Dream Chaser, one of the current competitors.

"Most people assume SpaceX is a shoe-in," says Charles Miller, president of NextGen Space LLC, a space and public policy consulting firm in Arlington, Virginia. If that conventional wisdom proves correct, the remaining question becomes who else NASA might pick.

Why does SpaceX appear to have an edge? Not only is the company's Falcon 9 rocket far less expensive than its competitors, the company has more experience than anyone else delivering space station cargo, says Marco Cáceres, senior space analyst at Teal Group in Fairfax, Virginia. In the six commercial flights performed through May of this year, the SpaceX Dragon carried about 10,000 kilograms to the station (about the weight of a school bus) and brought back another 8,000 kilograms, according to NASA cargo manifests and press releases.

"If NASA's goal is to find a company that can transport cargo to station as reliably and cheaply as possible, SpaceX will be hard to beat," Cáceres says.

Daring architecture

If SpaceX leads on price and experience, Lockheed Martin hopes to win with innovation. It wants to sell NASA on the idea of using Jupiter to ferry Exoliners to the station. Each Exoliner would carry 5,000 kilograms in a pressurized compartment and 1,500 kilograms in an unpressurized compartment.

On the first mission, Jupiter and an Exoliner would be stacked inside the shroud of a United Launch Alliance Atlas 5. After release, Jupiter would fire, turn on hydrazine engines to whisk the container toward the space station, where the station would use its robotic arm to pull it to the airlock. Astronauts would unload supplies sent by NASA and fill Exoliner's pressurized and unpressurized compartments with waste materials, small satellites and science experiments. Jupiter would then maneuver the Exoliner to an elliptical or "racetrack" orbit that is slightly above or below the space station to keep Jupiter and Exoliner safely out of the station's path, but still close enough for cargo deliveries.

With Jupiter safely in orbit, Lockheed Martin would launch Exoliners on successive Atlas 5s, using the rocket's Centaur upper stage to rendezvous with Jupiter at an intermediate orbit well below the space station's. Lockheed Martin hasn't said exactly how Jupiter's robotic arm would ex-

change the old Exoliner and refueling modules for the new ones, except to say that the old Exoliner and refueling module never orbit freely. They would be placed on the Centaur, which would carry them back into the atmosphere to burn up. Jupiter would then tug the new Exoliner to the space station for another delivery. Lockheed Martin flight controllers would monitor the mission from the ground.

Lockheed Martin knows that this approach would be a new way of delivering supplies to the station. The company is trying to counter concerns about the additional rendezvous step by pointing to the spaceflight heritage of its components. Lockheed Martin engineers patterned Jupiter after their design for the Mars Atmosphere and Evolution probe that arrived in orbit around Mars last year. Lockheed Martin's partner, Italy's Thales Alenia Space, plans to model Exoliner on the pressurized cargo module the firm built for the Automated Transfer Vehicles that carried supplies to station from 2008 to 2014. Even the robotic arm looks familiar. Designed by Canada's MDA Corp., it will be modeled on robotic arms MDA supplied to the space shuttle and space station programs for 30 years, says Lockheed Martin's Tim Priser, the company's CRS-2 proposal manager.

Lockheed Martin refers to Jupiter and the Exoliners as multipurpose space vehicles, because in addition to delivering cargo to the station, they could in theory rendezvous with other satellites or carry cargo beyond low Earth orbit. Lockheed Martin has even suggested to NASA that it put a stationary bike or other exercise equipment in the pressurized section of an Exoliner and dock it to an Orion crew vehicle, which Lockheed Martin is also developing, so the astronauts could carry additional life-support equipment and get exercise during a long mission to deep space.

"Instead of just a simple FedEx machine that delivers cargo for station, this is something that looks like a habitat," Priser says.

Chasing the dream

Lockheed Martin isn't the only company arguing that its proposal has value beyond the station. Sierra Nevada says that its winged Dream Chaser Cargo System, the only contender that would land on runway, could be modified for Earth observation or scientific flights, to retrieve and repair satellites or to nudge the space station a little higher in orbit when necessary. Observers were surprised last year when NASA did not pick Dream Chaser as one of the commercial craft to carry astronauts to the station, given its resemblance to a space shuttle orbiter. The agency instead chose Boeing's CST-100 and SpaceX's Dragon capsules. Sierra Nevada hasn't given up on carrying astronauts and suggests that the cargo craft could be adapted for that purpose, too.

Sierra Nevada continues to work on the crew version of Dream Chaser with its own money and some from NASA. Over the last nine years, it has received $363.1 million from NASA. Regardless of how the cargo competition turns out, the firm plans to conduct a flight test of its original Dream Chaser design from California's Edwards Air Force Base by the end of the year.

Unlike the piloted version, the Dream Chaser Cargo System would fly to space and land on a runway autonomously. Its wings would deploy mechanically before the trip home. The crew version would have flown atop Atlas 5s without a shroud and with its wings deployed. In orbit, large solar arrays would provide power. Sierra Nevada would equip the Dream Chaser with an expendable cargo module designed to be ejected to burn up in the atmosphere with up to 3,250 kilograms of trash. In all, Dream Chaser could transport 5,500 kilograms to the station and bring 1,750 kilograms back to Earth for a runway landing.

Despite the crew competition setback, Sierra Nevada casts the runway landing as a key selling point. Dream Chaser would need no more than an 8,000-foot runway, typical of regional airports. It uses nontoxic propellants, which means a ground crew could unload cargo quickly.

"You need to get those experiments back in the hands of the researchers as soon as possible or the quality of the science starts to degrade," says Steve Lindsey, a veteran of five space shuttle missions who now runs Sierra Nevada's Space Exploration Systems unit.

"If NASA's goal is to find a company that can transport cargo to station as reliably and cheaply as possible, SpaceX will be hard to beat."

Marco Cáceres
Senior Space Analyst
at Teal Group

Expanded mission

Boeing hopes to sell NASA on the idea of buying CST-100 cargo flights on top of the work it's already doing on the crew version for NASA, which it says would lead to economies of scale and lower the vehicle's overall cost. At the end of a mission, onboard guidance, navigation and control software would calculate precisely when the spacecraft would need to begin its reentry to reach one of five U.S. landing sites. Thrusters would reduce its speed to start the process, and high in the atmosphere the blunt-cone capsule would reorient itself and use atmospheric drag to reduce its velocity. High-speed drogue parachutes would deploy, followed by three main Kevlar and nylon parachutes. The main chutes open in stages to gradually slow the capsule until it nears the ground and releases six airbags to reduce the force of impacts.

Boeing engineers designed CST-100 with astronauts in mind, and they made sure crews could climb on board shortly before takeoff and exit quickly when the capsule reached its destination. NASA could take advantage of that same design to move cargo quickly onto and off the spacecraft, Boeing says.

Quiet incumbents

SpaceX officials declined to discuss any plans to modify Dragon for NASA's CRS-2 competition, but observers don't expect the company to make significant changes to the current design or operations.

Dragons are launched on Falcon 9 rockets from Cape Canaveral. Outside the atmosphere, the Dragon jettisons a nose cap that covers the vehicle's space station docking hatch. Beneath the hatch, Dragon has an 11-cubic-meter pressurized cargo bay and a 14-cubic-meter unpressurized cargo hold known as Dragon's Trunk. When the spacecraft leaves the space station, the Trunk separates from the primary capsule and burns up on reentry, while the main capsule reenters and slows for landing with the help of two drogue parachutes and three main parachutes.

The existing Dragons can deliver and pick up a maximum of 3,310 kilograms of cargo. On the return trip, Dragon can bring home a maximum of 2,500 kilograms and dispose of the rest in Dragon's Trunk, according to the Commercial Resupply Services contract NASA awarded SpaceX in 2008.

Orbital ATK officials also declined to discuss their CRS-2 proposal but agreed to talk about Cygnus's ongoing space station delivery work. The cylindrical Cygnus spacecraft conducted three NASA cargo missions between September 2013 and July 2014, before the rocket failure in October 2014.

During its first three missions, Orbital ATK delivered 3,629 kilograms to the space station, about the weight of two F-150 pickup trucks. Orbital ATK does not bring cargo back to Earth. Instead, astronauts pack the capsule with the space station's trash, which burns up in the atmosphere. "We've taken away more cargo than we've delivered, which is a very valuable service to NASA," says Frank DeMauro, Orbital ATK vice president of human spaceflight systems.

He emphasizes this experience as an incumbent: "We have a very competitive and compelling offering based on what we've already shown is a very successful system."

Orbital ATK is in the process of upgrading Cygnus for five additional cargo missions it plans to perform for NASA under the original Commercial Resupply Services contract. Beginning in November, Orbital ATK will carry NASA cargo in the Enhanced Cygnus, which includes new radios and navigation sensors, improved solar arrays and a cargo module built by Italy's Thales Alenia Space to hold 3,500 kilograms compared with 2,300 kilograms for the initial Cygnus model. The November flight will be on an Atlas 5 from Cape Canaveral. Orbital ATK plans to purchase one or two Atlas flights while the company upgrades Antares and replaces its first-stage AJ26 engines due to concerns that their failure may have caused the October accident.

Much of Orbital ATK work focuses on integrating the spacecraft's hardware and software, but DeMauro keeps reminding his team that their ultimate goal is supplying astronauts. "The first chart I show in every all-hands meeting is a picture of the crew to remind everyone that those are the folks we are really working for," DeMauro says. "Our management is counting on us to succeed and NASA is counting on us to succeed, but no group of people are counting on us more than those crew members."