CRS Orb-1 Mission

# Mission Overview

## Overview

Under the Commercial Resupply Services (CRS) contract with NASA, Orbital will provide approximately 20 metric tons of cargo to the International Space Station over the course of eight missions. Orb-1 is the first of those missions.

The Orb-1 mission builds on the successful Commercial Orbital Transportation Services (COTS) demonstration mission conducted from September 18 to October 23, 2013. The Orb-1 flight will carry substantially more cargo (1465 kg vs. 700 kg) than the COTS mission, including several time-sensitive payloads and Cygnus' first powered payload, the Commercial Generic Bioprocessing Apparatus (CGBA) from Bioserve.

# *Mission Overview, Cont.*


## Antares®

The configuration of the Antares launch vehicle for the Orb-1 Mission is much the same as the two previous Antares flights with a CASTOR 30B second stage motor instead of the CASTOR 30 used previously. The first stage includes a core that contains the tanks for the liquid oxygen and kerosene, the first stage avionics, and two AJ26 rocket engines. The second stage consists of the CASTOR® 30B solid rocket motor, an avionics section containing the flight computer and guidance/navigation/control functions, an interstage that connects the solid rocket motor to the first stage, the Cygnus spacecraft, and a fairing that encloses and protects the Cygnus spacecraft during ascent.

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# *Mission Overview, Cont.*


## Cygnus™

The Cygnus spacecraft is composed of two elements, the Service Module (SM) and the Pressurized Cargo Module (PCM). The SM provides the propulsion, power, guidance, navigation and control, and other “housekeeping” services for the duration of the mission. The PCM carries cargo and payloads to the ISS and uses a passive Common Berthing Mechanism (CBM) as the mechanical interface to the ISS. Cygnus will also be used to remove disposal items from the ISS upon its departure.

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# *Mission Overview, Cont.*

## Mission Operations

During the Orb-1 mission, Cygnus will perform a series of maneuvers to catch up and rendezvous with the ISS, and perform grapple/berthing operations. Cygnus will be monitored and controlled by Orbital personnel from Orbital's Mission Control Center in Dulles, Virginia (MCC-D) in continuous coordination with NASA personnel at Johnson Space Center's (JSC) Mission Control Center in Houston, Texas (MCC-H). Japanese Space Agency (JAXA) flight controllers will also support Cygnus rendezvous, berthing and departure operations by operating their PROX systems on the ISS, which provides near continuous command and data exchange between Cygnus and the ISS.

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# Mission Highlights

During the Orb-1 mission, Cygnus must successfully perform a series of tasks to demonstrate key technical and safety capabilities of the system prior to capture and berthing with the ISS.

*Day 1 (Launch):* Orbital's Antares rocket will launch the Cygnus spacecraft into orbit from the Wallops Flight Facility. After separation from Antares, Cygnus will deploy its solar arrays and prepare its propulsion system for maneuvers. As Cygnus orbits the Earth, it increases its altitude, moving closer to the space station. Cygnus systems will be subject to a series of tests to determine their readiness for rendezvous and berthing with the ISS.

*Day 2:* Cygnus will continue its ascent toward the ISS.

*Day 3:* NASA will provide a "Go" for Cygnus to berth with the station. Cygnus will approach to within 12 m (39.4 ft.) and stop below the ISS autonomously. Cygnus will then be commanded to "free drift" by the astronauts, then captured by the station's robotic arm and subsequently attached to the station. This will require extreme precision as both Cygnus and station will be orbiting the Earth every 90 minutes, travelling in formation at approximately 28164 kph (17,500 mph).

*Day 4 to Day 45:* Astronauts will open Cygnus' hatch, unload the payloads and cargo and fill Cygnus with disposal cargo.

*Day 46:* After it has completed its mission at the ISS, Cygnus will be detached from the station and guided to a destructive reentry over the South Pacific Ocean.

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# Mission Description

After launch from the Wallops Flight Facility, Cygnus will begin its journey to the space station. Just over 10 minutes after launch, Cygnus will reach its preliminary orbit, deploy its solar arrays and begin a carefully choreographed series of engine firings to reach the station.

For its final day of approach to the station, Cygnus will perform an engine burn that will bring it to a Joint Target Reference Point (JTRP or "Jay-trip") at 4 km (2.5 miles) below the station. Once achieving the JTRP, a go/no-go poll is performed by the Mission Control Houston team to allow Cygnus to perform a set of thruster firings (burns), ADV 1 and 2, that will bring it to within 1.5 km (0.9 miles) of the station. A second go/no-go will take place from Mission Control Houston after the completion of ADV-2, and then Cygnus will perform another series of burns referred to as "approach initiation" to move from 1.5 km (0.9 miles) below to a position of 250 m (820 ft.) directly below the ISS.

After a "go" from MCC Houston, the Cygnus flight control team in Dulles, Virginia will then command the spacecraft to approach the station from its hold position. It will move from 250 m (820 ft.) below the station to a position 30 m (98 ft.) from the station and will automatically hold at that point.

After another go/no-go poll of the NASA and Orbital flight control teams is completed, Cygnus will proceed to the 12 m (36 ft.) hold position, which is the capture point. A final go/no-go is performed, and the Mission Control Houston team will notify the ISS crew they are "go" to capture Cygnus. At that point, Expedition 37 crew member Mike Hopkins will use the station's robotic arm, which measures 17.6 m (57.7 ft.) long, to reach out and grapple the Cygnus spacecraft, and with the help of fellow crew member Koichi Wakata, guide Cygnus to the bottom, Earth-facing side of the Harmony node, where it will be attached to the station. If the rendezvous and Cygnus testing runs long, Mission Control could elect to leave Cygnus grappled to the station's arm overnight before berthing it the next day.

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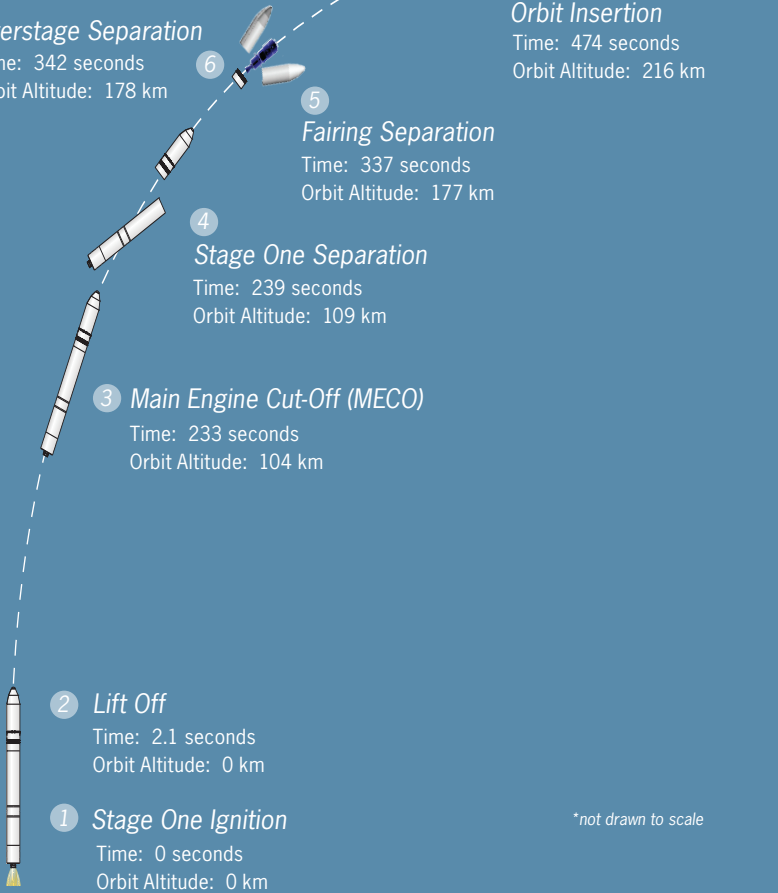
# Antares Ascent Profile

*Mission Parameters:*
Orbit Altitude: 210 km x 298 km
Inclination: 51.64°



*Payload Separation*
Time: 594 seconds
Orbit Altitude: 215 km

9

*Stage Two Ignition*
Time: 346 seconds
Orbit Altitude: 180 km

7

8

*Stage Two Burnout/ Orbit Insertion*
Time: 474 seconds
Orbit Altitude: 216 km

*Interstage Separation*
Time: 342 seconds
Orbit Altitude: 178 km

6

5

*Fairing Separation*
Time: 337 seconds
Orbit Altitude: 177 km

4

*Stage One Separation*
Time: 239 seconds
Orbit Altitude: 109 km

3 *Main Engine Cut-Off (MECO)*
Time: 233 seconds
Orbit Altitude: 104 km

2 *Lift Off*
Time: 2.1 seconds
Orbit Altitude: 0 km

1 *Stage One Ignition*
Time: 0 seconds
Orbit Altitude: 0 km

**not drawn to scale*

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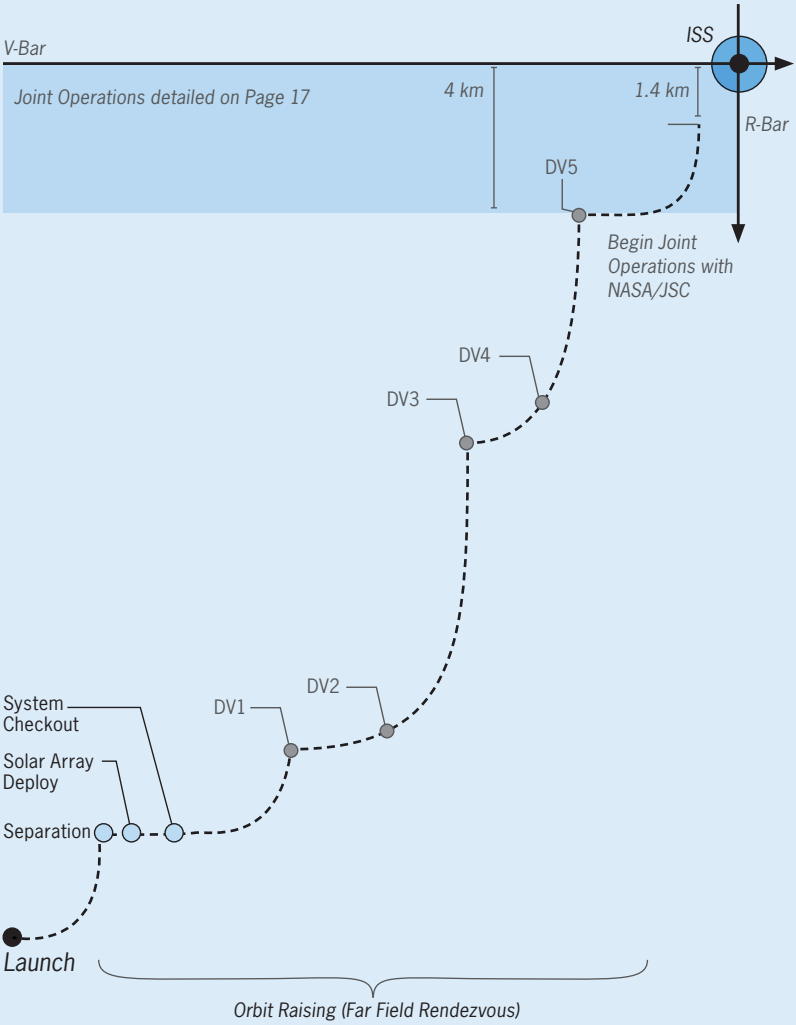
# Cygnus Mission Profile

## Phasing Operations - ~2 days Launch to 4 km of ISS



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# Cygnus Mission Timeline

## Phasing Operations - ~2 days Launch to 4 km beneath ISS

| *Event* | *Description* |
|---|---|
| Launch | Launch from Wallops |
| Separation | Cygnus separation from Antares stage 2 |
| Solar Array Deploy | Cygnus deploys its solar arrays |
| Delta V1 - Delta V5 | Series of thruster burns to raise orbit from separation altitude, ~215 km (~134 miles) to 4 km (2.5 miles) below ISS |

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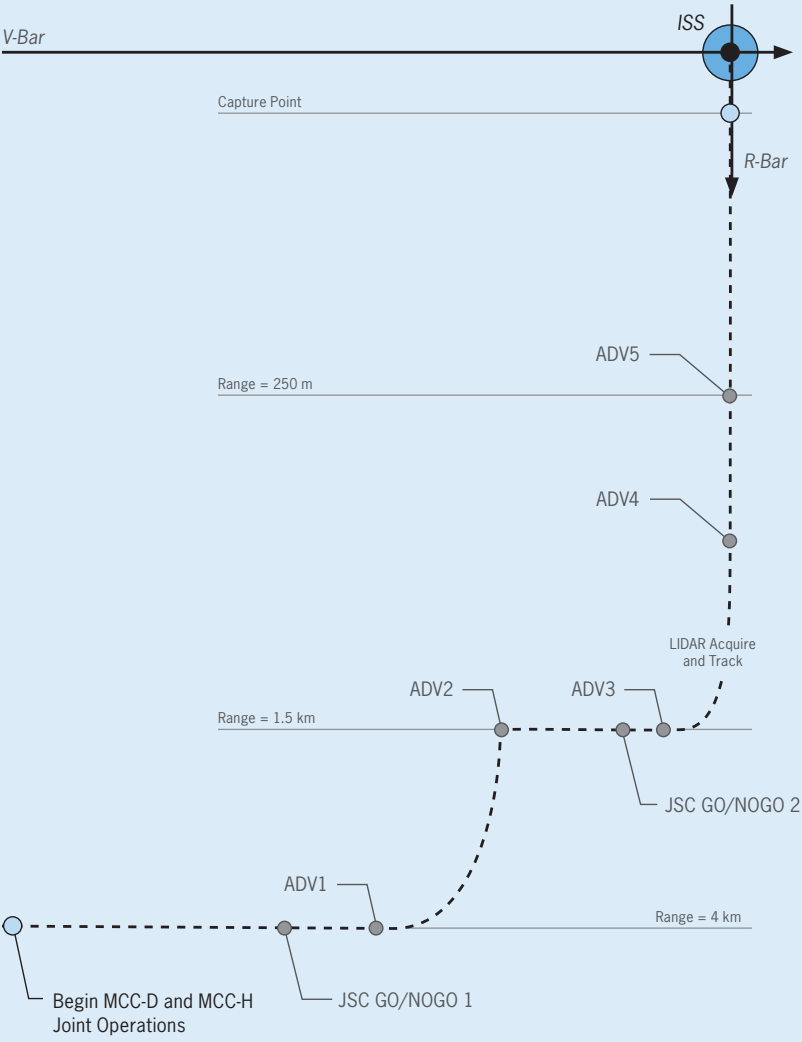
# Cygnus Mission Profile

## Joint Operations (JOPS) Final Approach and Berth with ISS



CRS Orb-1 Mission

# Mission Profile Timeline

## JOPS Final Approach and Berth with ISS

| *Event* | *Description* |
|---|---|
| ○ Joint Target Reference Point | Start Joint Operations with NASA |
| ● ADV 1 | Thruster burns to change orbit altitude from ~4 km (2.5 miles) below ISS to ~1.5 km (.9 mile) below the ISS |
| ● ADV 2 | |
| ● ADV 3 | Thruster burns to intercept R-bar, ascend to 250 m (820 ft.) below ISS and hold autonomously |
| ● ADV 4 | |
| ● ADV 5 | Thruster burn to ascend up the R-bar toward the station |
| ○ Capture | ISS crew maneuvers ISS robotic arm and captures Cygnus |

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# Post Berthing Activities

The crew will open the hatch between Cygnus and the station the day following the rendezvous and berthing. The crew will spend about 25 hours over the following weeks unloading the cargo. On this mission, Cygnus will transport 1465 kg (3,217 lb.) of cargo and will remove approximately 1300 kg (2,866 lb.) of disposal cargo.

Cygnus will spend up to 43 days attached to the space station, at which point the crew will detach it from Harmony, maneuver it out to the release point and then will ungrapple the vehicle. Cygnus will perform a series of engine burns that will place it on a trajectory to take it away from the vicinity of the ISS. Mission Control in Houston will then confirm that Cygnus is on a safe path away from the complex.

Approximately two days after Cygnus leaves the station, it will conduct its deorbit burn, which will last approximately seven minutes. It will take about 30 minutes for Cygnus to re-enter the Earth's atmosphere and burn up over the South Pacific Ocean.

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# Cygnus Cargo Manifest

| *Bag Title* | *Bag Mass (kg)* |
|---|---|
| ***INITIAL LOAD*** | |
| *M-02 Bag, BOBs* (10)* | *56.17* |
| *M-02 Bag, BOBs (10)* | *52.58* |
| *M-02 Bag, ECLSS/CHeCS* | *42.52* |
| *M-02 Bag, BOBs (10)* | *52.65* |
| *M-02 Bag, BOBs (8)* | *45.39* |
| *M02 Bag, Crew Provisions/Crew* | *75.31* |
| *M02 Bag, Crew Suitcases* | *42.23* |
| *M02 Bag, EVA/Stabilization Frames* | *40.72* |
| *M02 Bag, QDM/Hygiene* | *30.78* |
| *M01 Bag, PCS/Photo/TV/BOBs* | *78.39* |
| *M01 Bag, CLPA/Slosh* | *66.05* |
| *M-02 Bag, LHA/BPA/ORU ASSY* | *35.34* |
| *M-02 Bag, Nanoracks/BCAT/Crew* | *49.79* |
| *M03 Bag, ARED Flywheels/AIB* | *144.56* |
| *M-01 Bag, MSG Hardware* | *74.15* |
| *RCTB, DBL, ITCS/Kapton Tape* | *22.23* |
| *RCTB, TPL, Crew Provisions* | *23.41* |
| *RCTB, DBL, BOBs (4)* | *22.1* |
| *RCTB, TPL, BOBs (7)* | *36.47* |
| *Total Initial Load* | *990.84* |
| ***LATE LOAD*** | |
| *HEM-02 Bag, BASS/ECLSS/CCS* | *27.02* |
| *M-02 Bag, CHECS/Payloads* | *36.81* |
| *M-02 Bag, CUBESAT 1 of 2* | *78.46* |
| *M-02 Bag, CUBESAT 2 of 2* | *74.24* |
| *M-03 Bag, ISEV/NANORACKS* | *159.61* |
| *LD45FR Plastazote covered with nomex* | *0.98* |
| *LD45FR Plastazote covered with nomex* | *0.98* |
| *LD45FR Plastazote covered with nomex* | *3.54* |
| *Lightweight Locker, Ant Habitat* | *12.93* |
| *CGBA, ISS Locker* | *30.16* |
| *Double Cold Bag/NANARACK 9/38* | *24.91* |
| *Double Cold Bag/NANARACK 9* | *25.21* |
| *Total Late Load* | *474.85* |
| *TOTAL PAYLOADS AND CARGO* | *1465.69* |

**BOB – NASA shorthand for food rations*

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# Orb-1 Payloads

On the Orb-1 mission, Cygnus will be carrying a number of important science and technology payloads to the ISS. The following list illustrates some of the science payloads flying on Cygnus:

- NLP Vaccine-21 (Antibiotic Effectiveness in Space – 1) – Is aimed at using a spaceflight antibiotic effectiveness model to help address drug-resistance issues on Earth. Specifically, this study is designed to identify what phenotypic and transcriptomic changes permit bacterial survival under normally inhibitory concentrations of antibiotics.

- BCAT-KP (Binary Colloidal Alloy Test – Kinetics Platform) – Focuses on a fundamental understanding of the underlying physics that will enable formulation of commercial products with enhanced performance and stability.

- BASS-2 (Burning and Suppression of Solids 2) – Studies how the unique space environment affects a material's burning behavior, yielding results used in combustion models and predictions with implications to firefighting strategies in spacecraft and performance-based material selection.

- NanoRacks Module 9 S/N 1008, 1010, & 1011 – Consist of suites of student spaceflight experiments in areas such as enzyme activity in microgravity, DNA mutation rate, cell regeneration, and oil bubble formation.

- NanoRacks Module 38 (NanoRacks Mission Discovery ISS Biomedical Experiments) – Examines petri dish growth utilizing the NanoRacks Microscopes Facility.

- Commercial Generic Bioprocessing Apparatus Science Insert – 06: Ants in Space (CSI-06) compares behavior differences in groups of ants living in normal gravity and microgravity conditions. It measures how the interactions among ants in a group depend on the number of ants in a given area.

- Story Time from Space – Consists of crewmembers videotaping themselves reading children's books, and completing simple demonstrations that accompany the science, technology, engineering, and math concepts in the books.

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# Orb-1 Payloads

In addition to these scientific payloads, the following technology payloads are included on Orb-1:

- SPHERES-Slosh (Synchronized Position, Hold, Engage, Reorient, Experimental Satellites – Slosh) – Uses small robotic satellites on the ISS to examine how liquids move inside containers in microgravity.
- NanoRacks CubeSat Deployers (NRCSDs) & CubeSats – Involves economical small satellite launching platforms and multiple CubeSat-based investigations (Dove (28), ArduSat-2, LituanicaSat-1, SkyCube, UAPSat-1, and LitSat-1).
- NanoRacks Module 39 (NanoRacks ArduLab-1) – Is a technical demonstration of the ArduLab microcontroller board system for use with the NanoRacks modular experiment system.

*It should be noted that the 33 CubeSats will be transported to the ISS for deployment from the NanoRacks CubeSat Deployers. Among the CubeSats are 28 Dove Nanosatellites.*

*Additional payload details can be found at www.nasa.gov/iss-science.*