
NASA's Orion spacecraft will be using a Service Module built in Europe, based on ESA's Automated Transfer Vehicle technology

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## ESA's Service Module for Orion

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**ESA and NASA plan to send astronauts farther into space than ever before, in Orion spacecraft powered by European Automated Transfer Vehicle technology.**

When it blasts off atop the Space Launch System rocket in 2017, NASA's Orion spacecraft will be using a Service Module built in Europe, derived from ESA's Automated Transfer Vehicle (ATV). ATVs have been resupplying the International Space Station (ISS) since 2008. The fourth in the series, ATV *Albert Einstein,* is being readied for launch this year from Europe's Spaceport in French Guiana.

ATV is a versatile showcase of European space capability, performing many functions during a mission to the ISS. The space freighter is used to reboost the ISS and can even push the Station out of the way of space debris. While docked, ATV becomes an extra module for the astronauts, and at the end of its mission it takes waste materials away from the Station.

ESA and NASA signed an agreement last December for the provision of a Service Module for the Orion's Exploration Mission-1 in 2017. The agreement maps out a plan for ESA to fulfil its share of operational costs and additional supporting services for the ISS by providing the Orion Service Module and necessary elements of its design. The plan was given the go-ahead at ESA's Ministerial Council last November and allows European industry to capitalise ATV technology while significantly cutting research and production costs for NASA.

NASA plans to make a first unmanned test flight in 2017, meaning that ESA will have to deliver the first Service Module in 2016 – a tight schedule but the people behind ATV are used to delivering a model each year. The first Service Module will be delivered as part of ESA's contract for International Space Station utilisation, with an option for a second module to be exchanged in kind for other services still to be identified. Sending European astronauts on Orion is, of course, on the wishlist of the European space community.

## The flights

The first Orion flight will be Exploration Flight Test-1 in 2014, in which an uncrewed Orion will launch on a Delta IV heavy rocket and fly to an altitude of around 5700 km above Earth's surface, farther than a manned spacecraft has gone in 40 years. For Flight Test-1, the system will not include a Service Module, but only a structural test adapter built by Lockheed Martin that connects the capsule to the launcher. The main objective of this mission is to test the Crew Module at re-entry speeds representative of returns from beyond low-Earth orbit missions.

The first European Service Module will fly on Exploration Mission-1, the first flight of the Orion spacecraft on NASA's new Space Launch System (SLS). This mission will be an


↑ The NASA/ESA Orion Partnership news conference in Houston, 16 January 2013 (from left): William Gerstenmaier, NASA Associate Administrator for Human Exploration and Operations; Thomas Reiter, ESA Director of Human Spaceflight and Operations; Mark Geyer, Orion Program manager; and Bernardo Patti, ESA Manager of ISS Operations (NASA)

↑ The first Orion spacecraft in orbit attached to a Delta IV upper stage during Exploration Flight Test-1 (NASA)

uncrewed lunar flyby, returning to Earth's atmosphere at 11 km/s – the fastest reentry ever. Provided these missions go well, Exploration Mission-2 will then launch an Orion with a crew of four astronauts into space in 2021.

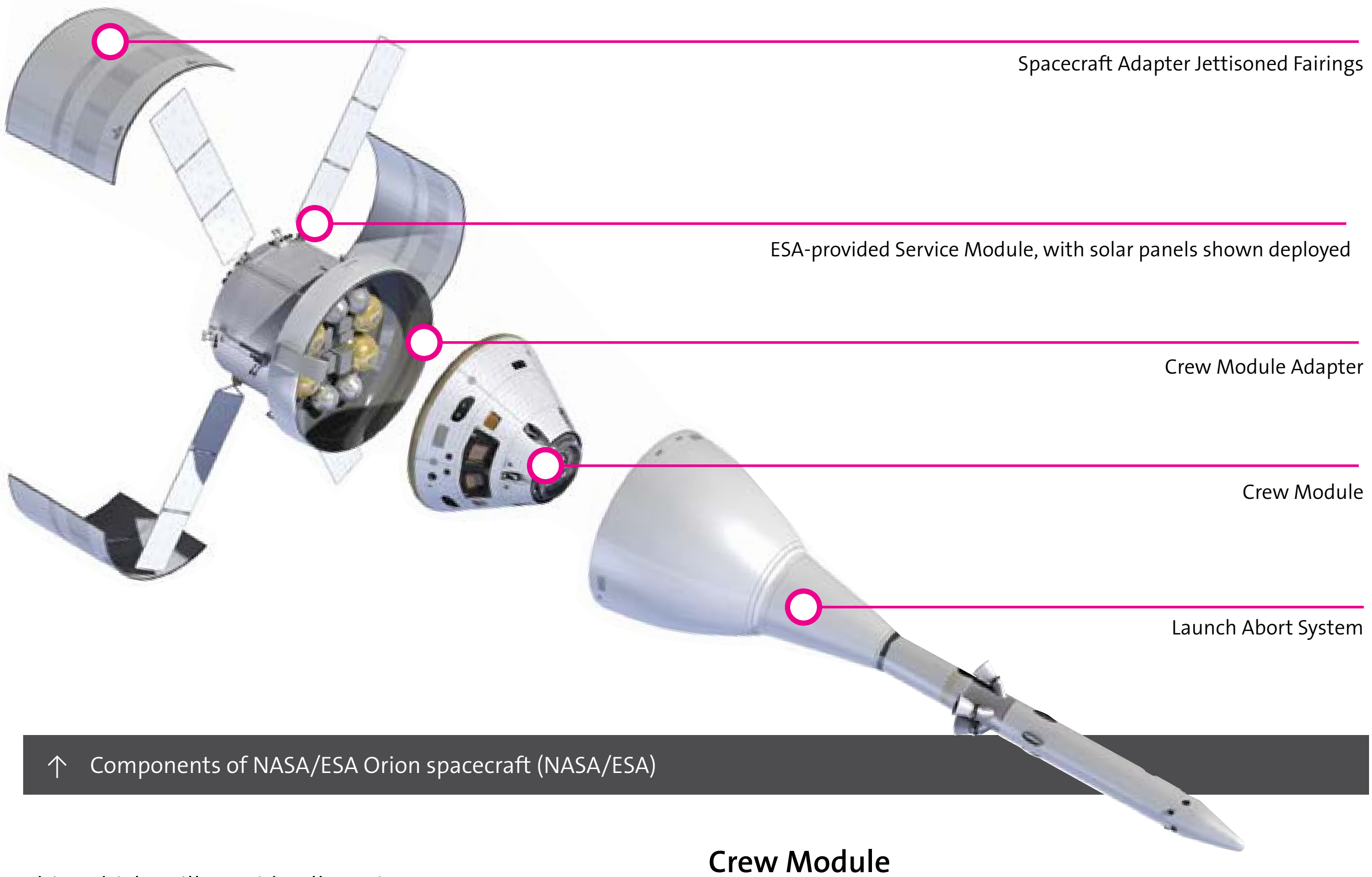
Thomas Reiter, ESA's Director of Human Spaceflight and Operations, said, "The cooperation with NASA in the critical path of a human-rated transportation system, which will take astronauts beyond low Earth orbit, opens a new page in the transatlantic relationship. It's a strong sign of trust and confidence in our capabilities, and an important contribution to the future of human exploration."

Nico Dettmann, Head of ESA's ATV Programme Department, said, "ATV has proven itself on three flawless missions to the Space Station and this agreement is further confirmation that Europe is building advanced, reliable spacecraft."

Dan Dumbacher, NASA's Deputy Associate Administrator for Exploration Systems Development, agrees: "It is a testament to the engineering progress made to date that we are ready to begin integrating designs of an ESA-built Service Module with Orion. Space has long been a frontier for international cooperation as we explore. This latest chapter builds on NASA's excellent relationship with ESA as a partner in the International Space Station, and helps us move forward in our plans to send humans farther into space than we've ever been before."

## The Orion vehicle

Orion is the name given to the Multi-Purpose Crew Vehicle, a crewed spacecraft that will transport up to four astronauts from Earth's surface to a nearby destination or staging point and bring the crew safely back to Earth at the end of a mission. Orion consists of a Crew Module, a Crew Module Adapter, a Service Module, a Spacecraft Adapter, Spacecraft Adapter Jettisoned Fairings and a Launch Abort System.




↑ Components of NASA/ESA Orion spacecraft (NASA/ESA)

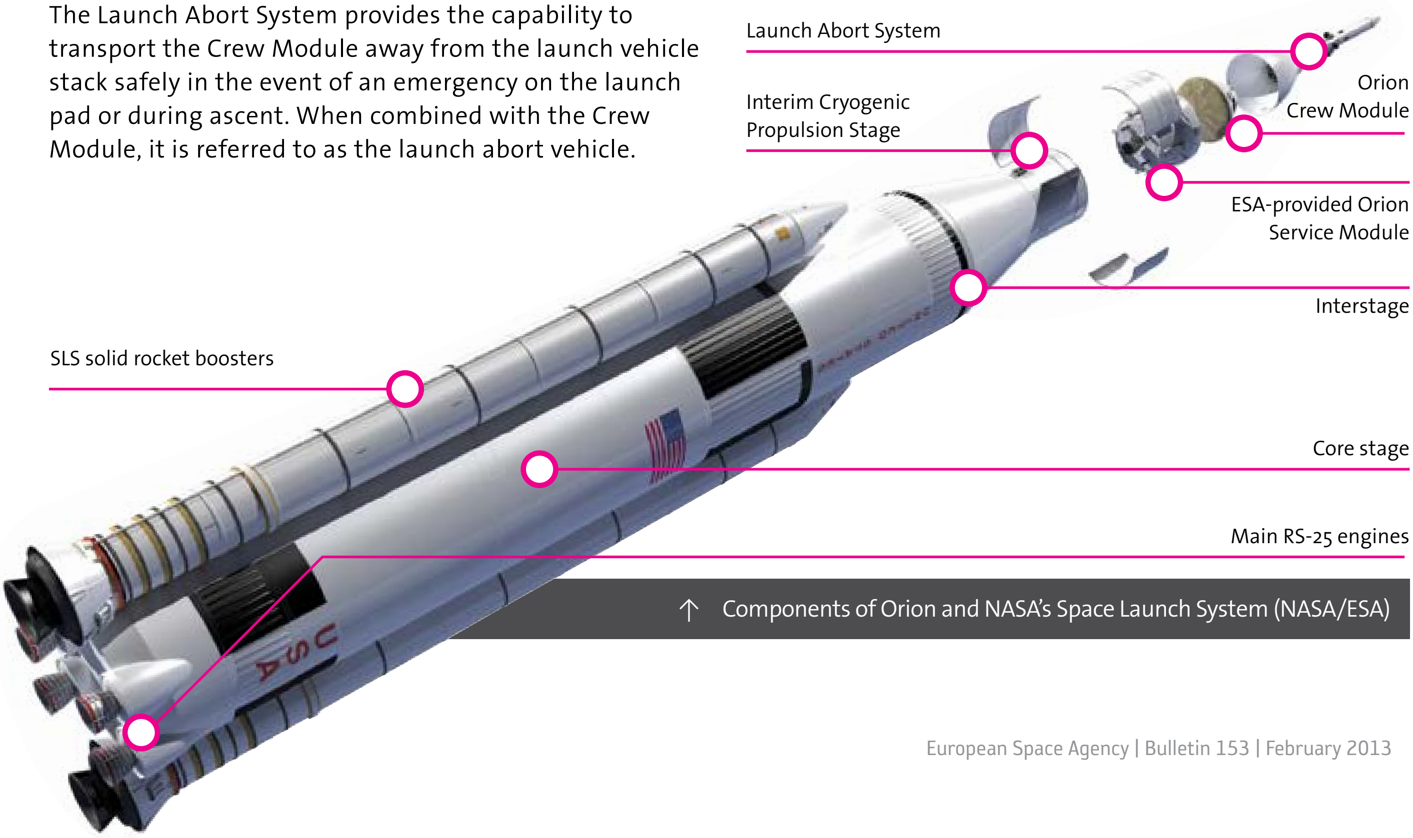
This vehicle will provide all services necessary to support a crew during all phases of a given mission, from launch operations to Earth entry, descent, landing and recovery (for shorter duration (1–21 days) missions or until a crew transfers to another space vehicle). Orion astronauts will wear launch, entry and abort (LEA) suits to protect them during these operations. The LEA suit does not provide any in-orbit extravehicular activity capability.

## Launch Abort System

The Launch Abort System provides the capability to transport the Crew Module away from the launch vehicle stack safely in the event of an emergency on the launch pad or during ascent. When combined with the Crew Module, it is referred to as the launch abort vehicle.

## Crew Module

The Crew Module is the command, control, communications and navigation centre for all in-space operations. This module supports up to four astronauts and consists of a closed, environmentally controlled cabin that provides the habitable volume. The cabin is enclosed by the backshell and heatshield, which protect it during reentry into Earth's atmosphere. The Crew Module is supported by the Service Module systems for most mission durations.




↑ Components of Orion and NASA's Space Launch System (NASA/ESA)

Pre-launch and post-landing crew access is through the side hatch on the starboard side of the Crew Module. The hatch opens outward to the left side for egress, and is sized for ingress and egress by crewmembers wearing a pressurised suit. During docked operations and in post-landing contingency scenarios, crew access is through the docking hatch. Egress aids are provided for post-landing emergency egress.

The Crew Module includes crew accommodation for eating, sleeping, hygiene and stowage of tools, hardware, supplies and cargo. Interfaces for pressure suits, communications, and biomedical data are provided for each astronaut. Interfaces for power, vehicle displays and controls, vehicle data and communications are also provided.

## Crew Module Adapter

This adaptor provides the structural, mechanical, electrical and fluid interface between the Crew Module and the Service Module. It houses communication equipment, sublimators for thermal heat rejection, and power and data control/interface electronics.

## Service Module

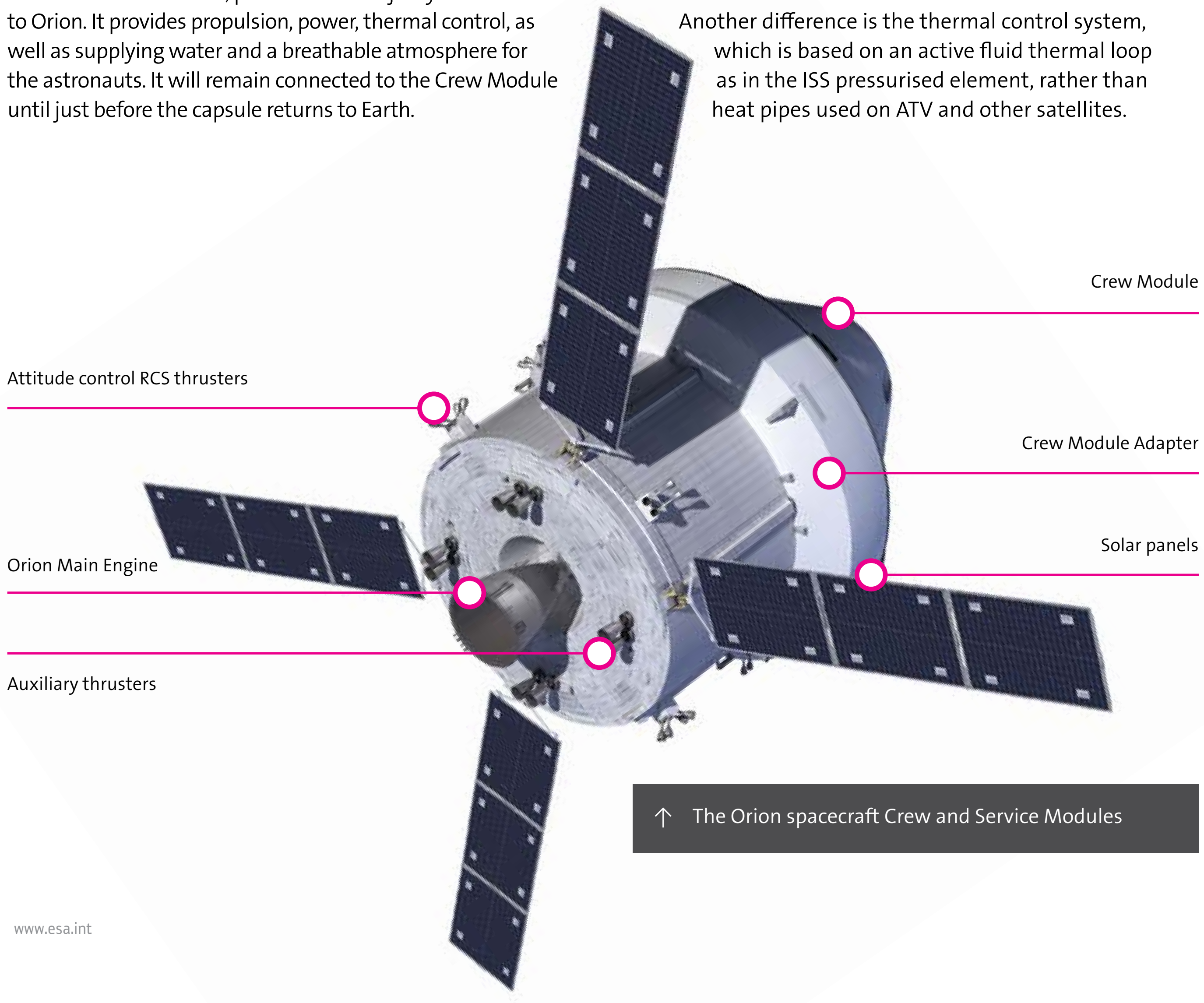
The European ATV-derived Service Module, sitting directly under the Crew Module, provides four major system functions to Orion. It provides propulsion, power, thermal control, as well as supplying water and a breathable atmosphere for the astronauts. It will remain connected to the Crew Module until just before the capsule returns to Earth.

The Service Module will be 2.7 m long and 4.5 m wide, similar to the present ATV but a quarter of the length. Although ATV's solar panel configuration will remain, they will get a significant upgrade. Slightly shorter and wider, the new solar panels for the Service Module will use gallium arsenide technology and supply more electricity, up to 11 kW – enough to power the energy needs of a typical household. These newer solar panels offer 30% efficiency converting solar energy, compared to ATV's current solar panels, which manage around 17%.

The Service Module houses the Orion Main Engine and engine thrust vector control, the reaction control system and auxiliary thrusters, and the fuel, oxidiser and pressurant tanks for the propulsion system. These provide the in-space propulsion capability for orbital transfer, attitude control and high-altitude ascent aborts.

The Main Engine is one of the main differences with the current ATV design, which does not have such an engine. The Orion Main Engine is an increased performance version of the rocket engine used by the Space Shuttle for its Orbital Manoeuvering System. This engine will supply around 26 kN of thrust in addition to eight smaller engines (compared to ATV's four). The smaller engines will supply a total of 490 N, enough to get Orion back to Earth if needed.

Another difference is the thermal control system, which is based on an active fluid thermal loop as in the ISS pressurised element, rather than heat pipes used on ATV and other satellites.




↑ The Orion spacecraft Crew and Service Modules

↑ Launch of Orion on the Space Launch System vehicle from Kennedy Space Center, Florida (NASA)

Additionally, thermal radiators surround the propulsion tanks and, like the Crew Module, the Service Module's passive thermal control design incorporates multi-layer insulation blankets, thermal coatings and micrometeoroid/orbital debris shielding.

The Service Module may provide additional volume and other resources for selected missions, for example by accommodating science, engineering demonstrations, development test objectives, or deployment of lunar infrastructure equipment during the cruise and lunar orbit phases of lunar missions. This volume provides electrical power distribution, network access for command and control interfaces, and structures and mechanisms.

## Spacecraft Adapter

The Spacecraft Adapter provides the interface to the launch vehicle during launch and ascent. This adapter attaches the aft end of the Service Module to the launch vehicle and includes the structural interface, separation mechanisms and umbilical connectors for communication between the launch vehicle and the Orion. When the launch vehicle burns out, the Orion spacecraft separates from the Spacecraft Adaptor.

## Spacecraft Adapter Jettisoned Fairings

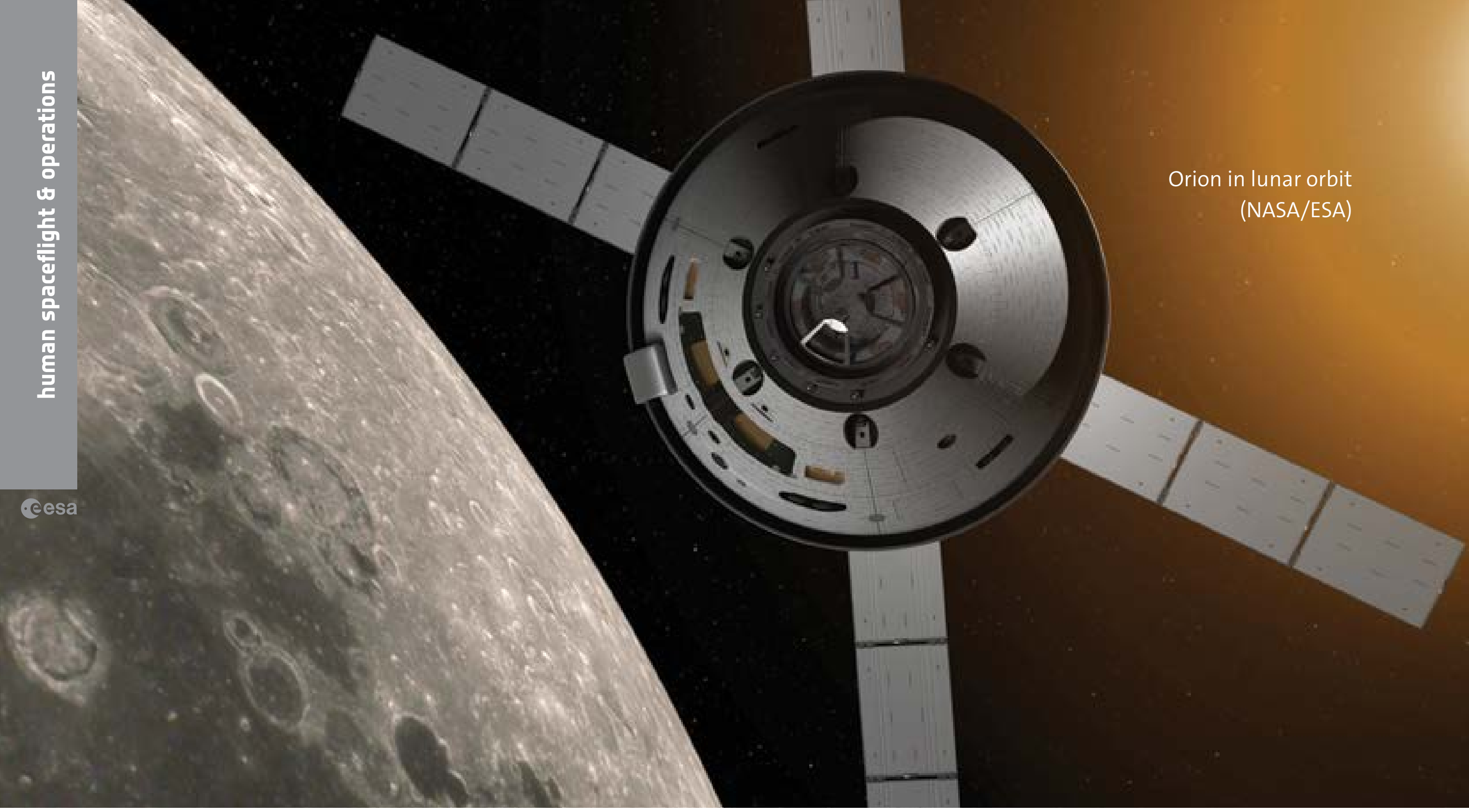
The Service Module is enclosed by three fairing panels, which protect the solar arrays, radiators and thrusters during launch and ascent. The fairings may be jettisoned during the ascent phase or following main engine cutoff of the launch vehicle.

## The missions

The official name of Orion is 'Multi-Purpose Crew Vehicle', meaning that the spacecraft can be used to complete different missions. A number of the possible mission descriptions, called Design Reference Missions, have been created to provide the context in which an ESA-provided Service Module and Spacecraft Adapter may be required to operate. Note that these plans are only intended to help define the Service Module's spaceflight capabilities; they may not necessarily represent missions that will actually be flown.

***1) Uncrewed beyond Earth orbit mission (lunar flyby)***
This mission uses a single SLS launch with an interim cryogenic propulsion stage and lunar Orion to go

↑ The Orion spacecraft in low Earth orbit (NASA/ESA)



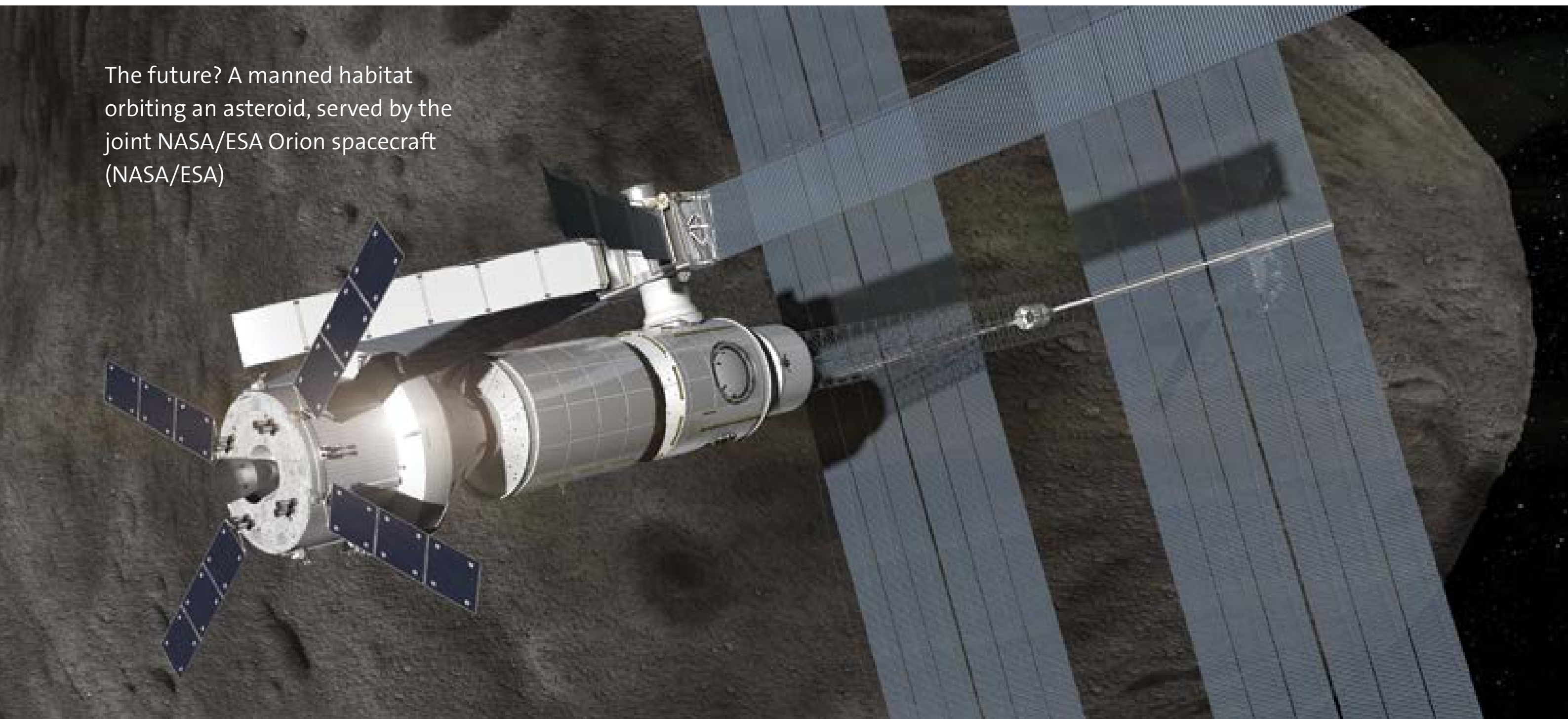
Orion in lunar orbit
(NASA/ESA)

beyond Earth orbit and test critical mission events as well as demonstrate spacecraft performance in relevant environments. The initial SLS configuration places an uncrewed Orion in low Earth orbit. The interim propulsion stage engine fires to raise its low Earth orbit, and again for a trans-lunar injection burn.

The trans-lunar injection manoeuvre puts the Orion on a free-return trajectory that is targeted for a lunar closest approach altitude of 100–200 km. The Orion performs a lunar flyby and then returns to Earth. The trajectory is designed to achieve a high-speed atmospheric entry to demonstrate the Orion entry, descent and landing systems. Orion's return velocity will be 11 km/s.

***2) Crewed beyond Earth orbit mission (lunar orbit)***
An SLS configuration with an interim cryogenic propulsion stage will be used to launch a crewed lunar Orion into low Earth orbit. The interim propulsion stage engine fires to raise its low Earth orbit, and again for a trans-lunar injection burn. When approaching a high lunar orbit, the Orion provides the lunar orbit insertion burn to put the spacecraft into an elliptical high altitude lunar orbit.

A high lunar orbit is used because the Orion is performing both the lunar orbit insertion and trans-Earth injection burns. The Orion's elliptical lunar orbit will be between 100–200 km at its lowest point and around 1000 km at its highest. The Orion will remain in lunar orbit for several



The future? A manned habitat orbiting an asteroid, served by the joint NASA/ESA Orion spacecraft (NASA/ESA) days and then will perform a trans-Earth injection burn to begin the return to Earth.

*3) Crewed lunar vicinity/lunar surface mission*

This mission could include a 'Lunar Surface Sortie', which lands four crewmembers on the surface of the Moon in the equatorial or polar regions and returns them to Earth. Two launch vehicle stacks are used in this scenario, the first SLS launch puts a Lunar Lander with a cryogenic propulsion stage into low Earth orbit, while the second SLS puts the manned Orion into low Earth orbit.

Instead of docking the Orion with the Lander around Earth (as was done in Apollo), this plan uses a dual lunar orbit rendezvous mission design that performs rendezvous, operations, docking and undocking in low lunar orbit. Just before separation of the Lander, the Orion is configured for uncrewed operations. In general, this preparation will not consist of any major powerdowns, since the Orion must be fully operational and fault-tolerant to ensure readiness for the initial separation burn from the Lunar Lander, possible emergency rendezvous or a normal return from the lunar surface. Things to be powered down include internal crew interfaces, displays, lighting, etc.). The crew prepares the spacecraft communications systems for remote commanding from the Lander or Earth, and stow equipment in preparation for the later return of the crew and cargo.

The crew transfers into the Lunar Lander and descends to the Moon's surface. The Lunar Lander would provide habitation for up to seven days duration on the surface. Deep-space extravehicular activity suits will be required for surface operations.

*4) ISS backup capability mission*

This mission provides an alternative means of delivering crewmembers and cargo to the ISS if other vehicles are unable to perform that function. Currently, this is just an analysis, awaiting decisions from the ISS partner agencies on whether this backup will be needed. Orion's design is optimised for exploration, but since this capability must be available if needed, assessments must be performed to determine the cost, schedule, and technical impact of implementing crew rotation and cargo delivery to the ISS.

Orion should support a crew for at least four active mission days, plus two more days as contingency. After orbit insertion, the Orion performs rendezvous, proximity operations and docking with the ISS. Orion will remain at the ISS in a quiescent mode for up to 210 days (which includes 30 days for contingency) and spend one day undocking and returning to Earth. Contingency days are intended to address cases such as a launch delay of the next crew, or delayed departure due to landing site conditions. ■

Main parachute test on the Orion Crew Module (NASA)