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## Spacecraft

European astronauts have travelled to the ISS in two types of spacecraft: the American Space Shuttle and the Russian Soyuz. They have been resupplied on board the station by payload in the Italian-built Multi-Purpose Logistics Modules (MPLM) carried aboard Shuttles and also by a variety of unmanned vehicles – the Russian Progress, the European ATV, the Japanese HTV, and the SpaceX commercial Dragon spacecraft.<sup>7</sup>

Each type of flight to the ISS uses a different code:

R:	Russian Roscosmos flight
A:	USA NASA flight
E:	European ESA flight
J:	Japanese JAXA flight
A/R:	Joint USA/Russian flight (financed by USA, built by Russia)
J/A:	Joint Japanese/USA flight
UF:	Utilisation flight
LF:	Logistics flight
ULF:	Utilisation/Logistics flight
S:	Crew delivery flight on Soyuz
P:	Cargo delivery flight on Progress
ATV:	Cargo delivery flight on ESA Automated Transfer Vehicle
HTV:	Cargo delivery flight on JAXA H-II Transfer Vehicle
SpX:	Cargo delivery flight on SpaceX Dragon.

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<sup>7</sup>Orbital Science's Cygnus first flew to the ISS in September 2013 and is thus outside the scope of this book.

### SPACE SHUTTLE

The Space Transportation System (STS) was developed by NASA as the next generation of spacecraft after the successful Apollo, ASTP and Skylab programmes. ASTP was a joint mission in 1975 where an Apollo spacecraft docked with a Soviet Soyuz in a foreshadowing of international projects such as Shuttle-Mir and ISS. The Skylab station was made by modifying a third stage of a Saturn V rocket to serve as an orbital laboratory and solar telescope, and a succession of crews were delivered in the last three Apollo capsules to fly. STS was to revolutionise space travel with a reusable ‘space plane’ that would launch on the back of a booster, operate in low Earth orbit, and glide back to a runway landing. It was to be a multi-purpose spacecraft that would fulfil all of America’s space requirements, such as deploying civilian and military satellites, conducting microgravity science experiments, making solar, terrestrial and astronomical observations, and ultimately assembling and servicing the Freedom Space Station.

While it did not achieve the hoped for cost savings associated with reusability and frequent flights, the Shuttle was the workhorse of the American human spaceflight programme for thirty years: 1981 to 2011.

The Shuttle consisted of the Orbiter Vehicle (OV), the External Tank (ET), and the Solid Rocket Boosters (SRB). Together these components were called the ‘stack’. It was launched vertically from the Kennedy Space Center in Florida. Between them the twin SRBs contributed 80% of the thrust at liftoff, with the remainder being supplied by the cluster of three SSMEs that drew liquid oxygen and liquid hydrogen from the ET. The SRBs were jettisoned after 126 seconds and the OV/ET continued to accelerate. Approximately 8 minutes after launch, the SSMEs shut down, and shortly after that the ET was jettisoned and left to re-enter the atmosphere. The OV then fired smaller rocket engines to adopt a stable orbit.

Five OVs were built and flown in space. Columbia (OV-102), Challenger (OV-099), Discovery (OV-103), Atlantis (OV-104) and Endeavour (OV-105). Enterprise (OV-101) was a test vehicle that carried out free-flight tests prior to the inaugural spaceflight by Columbia. Enterprise was not rebuilt for spaceflight. Challenger was an engineering test vehicle that was rebuilt for spaceflight. Columbia and Challenger never visited the ISS. Challenger was destroyed during a launch accident in 1986 and Columbia was lost during re-entry in 2003. The other three orbiters delivered European astronauts to the station on eight occasions, starting with Endeavour’s STS-100 mission which delivered Umberto Guidoni in April 2001, making him the first European to visit the station.

Endeavour also delivered Philippe Perrin during the STS-111 mission in June 2002 and Roberto Vittori on STS-134 in May 2011. STS-134 was Endeavour’s last visit to the ISS and its final flight.

Thomas Reiter became the first long-duration crewmember of the ISS when he was launched on Discovery’s STS-121 mission and joined Expedition 13. Both of Christer Fuglesang’s missions to the station (STS-116 and STS-128) started and finished on board Discovery. Reiter also returned to Earth on STS-116.

Finally, on the STS-122 mission Atlantis played a major European role when it delivered the ESA Columbus module to the ISS along with two ESA astronauts, Hans Schlegel and Léopold Eyharts; the latter joined the Expedition 16 station crew.

In total, 12 Shuttle missions delivered Italian-built Multi-Purpose Logistics Modules (MPLM) to the station between 2001 and 2011.



Space Shuttle Discovery, STS-128. (NASA)

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### SOYUZ

The Soyuz manned spacecraft has been operational in many guises since 1967 and is still the mainstay of human spaceflight to the ISS. Developed by the Soviet Union after the Vostok/Voskhod spacecraft, the Soyuz could be said to be the equivalent of NASA's Apollo spacecraft because it also carried three people to orbit. Although unmanned variants made circumlunar flights, it was never used to fly a crew into lunar orbit. However it has been used for Earth orbital operations, the ASTP docking, and ferrying cosmonauts to and from the Salyut, Mir, and ISS space stations.

The Soyuz spacecraft is launched on the eponymous rocket from the Baikonur Cosmodrome in Kazakhstan and consists of three parts:

- The Orbital Module that provides accommodation for the crew during their mission.
- The Descent Module that carries the crew into orbit and returns them to Earth.
- The Service Module that contains the instruments and engines and has solar panels attached.

### PROGRESS

Progress is an unmanned version of Soyuz and shares its architecture and design. It is a cargo freighter and has been used to deliver supplies to the Salyut, Mir, and ISS space stations. The Descent Module of the Soyuz was replaced with an unpressurised propellant and refuelling compartment. It can deliver up to 2,230 kg of cargo to the ISS, to which it docks automatically.

The Progress engines can be used to boost the ISS orbit. The entire craft burns up on re-entering the atmosphere, taking away trash from the station.

### ATV

The Automated Transfer Vehicle is ESA's unmanned cargo spacecraft, five of which were launched to the ISS between 2008 and 2014. The design was based on the MPLM module, fitted with a propulsion system. It docked automatically with the Russian section of the ISS and could deliver up to 7,667 kg of cargo.

The ATV's engines could be used to boost the ISS orbit. It would burn up on re-entry, taking away trash from the station.

### H-II

The H-II Transfer Vehicle is JAXA's unmanned cargo spacecraft. The design consists of four parts:

- The Pressurised Logistics Carrier (PLC) that contains the Common Berthing Mechanism to mate with the ISS and enable station crew to gain access.



The Soyuz TMA-7 'crew taxi'. (Wikipedia)

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A Progress freighter approaching the ISS. (NASA)



ATV-2 'Johannes Kepler'. (ESA)

- The Unpressurised Logistics Carrier (UPLC) that contains the Exposed Pallet which can be transferred to the exterior of the ISS by robotic arm.
- The Avionics Module.
- The Propulsion Module.



An HTV grappled by Canadarm2. (NASA)



A Dragon capsule grappled by Canadarm2. (NASA)

The HTV has a payload of 6,000 kg, including 5,200 kg carried in the PLC. An HTV doesn't dock automatically, it approaches the ISS and is grappled by the station's robot arm and berthed by the ISS crew. It burns up on re-entry, taking away trash from the station. Five vehicles were launched between 2009 and 2015, with plans for more at the time of writing.

## **DRAGON**

The Dragon spacecraft was developed by SpaceX as part of NASA's Commercial Resupply Services (CRS) programme where commercial companies design, build, and operate vehicles under contract.<sup>8</sup> This was a departure from the previous model where the government, via NASA, own the spacecraft.

The design consists of two parts:

- The blunt-cone pressurised ballistic capsule that can return to Earth and is re-usable.
- The unpressurised cargo-carrier trunk section that is equipped with two solar arrays.

The Dragon approaches the ISS and is grappled by the station's robot arm and berthed by the ISS crew. It can deliver up to 3,310 kg of cargo. In a valuable service, it can also return cargo to Earth. A total of eight were launched to the ISS between 2010 and 2015; all successful apart from the last one which was lost when the launch vehicle failed. At the time of writing it is intended to resume Dragon flights in 2016.

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<sup>8</sup>In 2008 SpaceX and Orbital Sciences were awarded contracts for 12 and 8 resupply missions to the ISS respectively.



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