transportation/ logistics

Building and maintaining the International Space Station (ISS) is a very complex task. An international fleet of space vehicles launches ISS components; rotates crews; provides logistical support; and replenishes propellant, items for science experiments, and other necessary supplies and equipment. The Space Shuttle must be used to deliver most ISS modules and major components.

All of these important deliveries sustain a constant supply line that is crucial to the development and maintenance of the International Space Station. The fleet is also responsible for returning experiment results to Earth and for removing trash and waste from the ISS.

Currently, transport vehicles are launched from two sites on Earth. In the future, the number of launch sites will increase to four or more. Future plans also include new commercial transports that will take over the role of U.S. ISS logistical support.

Soyuz

Roscosmos
Russia

Proton

H-II

JAXA
Japan

Ariane

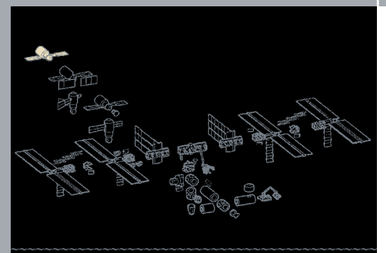
ESA
Europe

Shuttle

NASA
United States

	RUSSIA		JAPAN	EUROPE	U.S.
	Soyuz SL-4	Proton SL-12	H-II	Ariane 5	Space Shuttle
First launch	1957 1963 (Soyuz variant)	1965	1996	1996	1981
Launch site(s)	Baikonur Cosmodrome	Baikonur Cosmodrome	Tanegashima Space Center	Guiana Space Center	Kennedy Space Center
Launch performance payload capacity	7,150 kg (15,750 lb)	20,000 kg (44,000 lb)	16,500 kg (36,400 lb)	18,000 kg (39,700 lb)	18,600 kg (41,000 lb) 105,000 kg (230,000 lb), orbiter only
Return performance payload capacity	N/A	N/A	N/A	N/A	18,600 kg (41,000 lb) 105,000 kg (230,000 lb), orbiter only
Number of stages	2 + 4 strap-ons	4 + 6 strap-ons	2 + 2 strap-ons	2 + 2 strap-ons	1.5 + 2 strap-ons
Length	49.5 m (162 ft)	57 m (187 ft)	53 m (173 ft)	51 m (167 ft)	56.14 m (18.2 ft) 37.24 m (122.17 ft), orbiter only
Mass	310,000 kg (683,400 lb)	690,000 kg (1,521,200 lb)	570,000 kg (1,256,600 lb)	746,000 kg (1,644,600 lb)	2,040,000 kg (4,497,400 lb)
Launch thrust	6,000 kN (1,348,800 lbf)	9,000 kN (2,023,200 lbf)	5,600 kN (1,258,900 lbf)	11,400 kN (2,562,820 lbf)	34,677 kN (7,795,700 lbf)
Payload Examples	Soyuz Progress Pirs	Service Module Functional Cargo Block (FGB) Research Module (RM) Multipurpose Lab Module (MLM)	H-II Transfer Vehicle (HTV)	Ariane Automated Transfer Vehicle (ATV)	Shuttle Orbiter Nodes, U.S. Lab Columbus, JEM, Truss elements Airlock, SSRMS

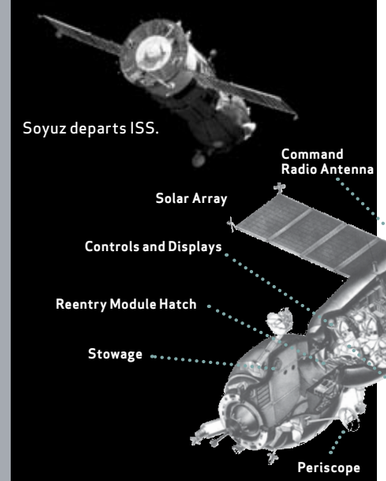
The largest U.S. and Russian launch vehicles are used to place elements of the ISS, crew, and cargo in orbit. Eventually, Japanese and European launch vehicles will support cargo delivery. Currently, only the U.S. Space Shuttle provides the capability to return significant payloads.

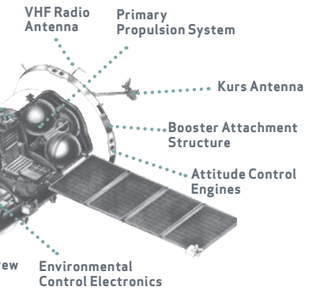


Soyuz

S.P. Korolev Rocket and Space Corporation Energia (RSC Energia)

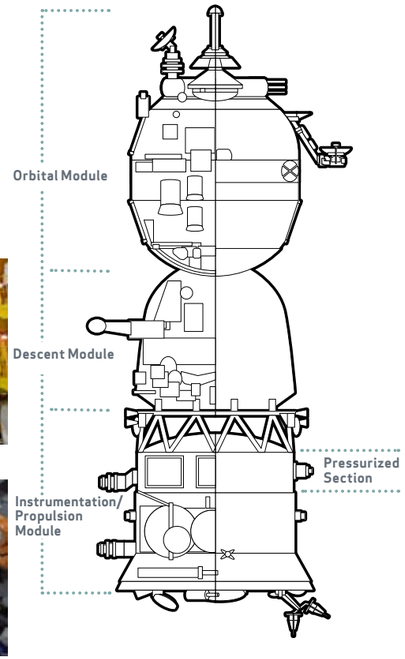
Soyuz spacecraft have been in use since the mid-1960s and have been upgraded periodically. Soyuz can support three suited crewmembers for up to 3 days. A nitrogen/oxygen atmosphere at sea level pressure is provided. The vehicle has an automatic docking system and may be piloted automatically or by a crewmember. The Soyuz TMA used for the ISS includes changes to accommodate larger and smaller crewmembers, an improved landing system, and digital electronic controls and displays.





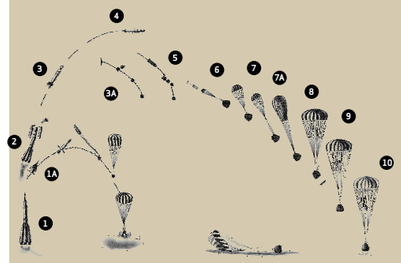

Soyuz being prepared for launch.


Soyuz descent module interior.



Launch mass	6,441 kg (14,200 lb)
Descent module	2,630 kg (5,800 lb)
Orbital module	1,179 kg (2,600 lb)
Instrumentation/ propulsion module	2,360 kg (5,200 lb)
Delivered payload (with three crewmembers)	30 kg (66 lb)
Returned payload	50 kg (110 lb)
Length	7 m (22.9 ft)
Maximum diameter	2.7 m (8.9 ft)
Diameter of habitable modules	2.2 m (7.2 ft)
Solar array span	10.7 m (35.1 ft)
Volume of orbital module	6.5 m^3 (229.5 ft^3)
Volume of descent module	4 m^3 (141.3 ft^3)
Descent G-loads	3–4 g
Final landing speed	2 m/s (6.6 ft/s)

Mission Sequence



Launch and Aborts

1. Launch
- 1A. Abort using escape rocket
2. Escape rocket jettison, nose shroud separation (160 seconds in full)
3. Staging (186 seconds)
- 3A. Abort by separation of Soyuz
4. Orbital velocity (526 seconds)

Return

5. Soyuz retrofire, orbital module separation, reentry module separation
6. Pilot parachute deploys
7. Drogue parachute deploys
- 7A. Main parachute reefed
8. Main parachute fully deployed
9. Reentry heatshield jettison
10. Landing, retro rocket firing

Progress

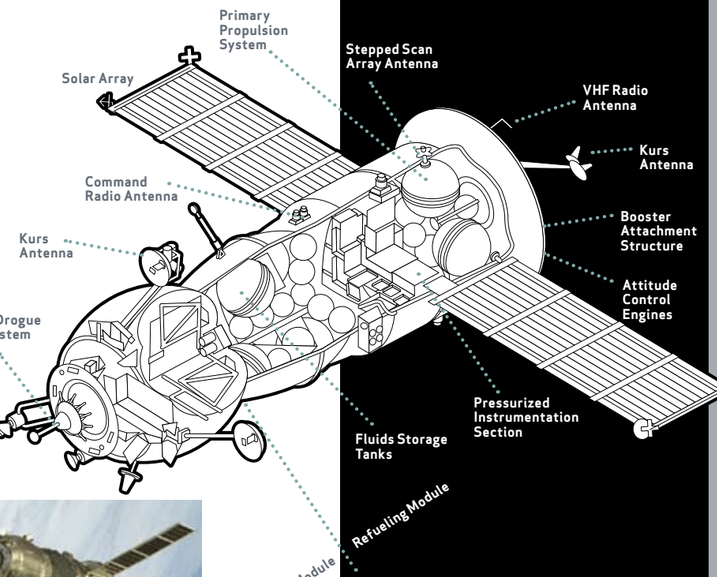
S.P. Korolev Rocket and Space Corporation Energia (RSC Energia)

Progress is a resupply vehicle used for cargo and propellant deliveries to the ISS. Once docked to the ISS, Progress engines can boost the ISS to higher altitudes and control the orientation of the ISS in space. Typically, three Progress vehicles bring supplies to the ISS each year. Progress is based upon the Soyuz design, and it can either work autonomously or can be flown remotely by crewmembers aboard the ISS. After a Progress vehicle is filled with trash from the ISS, and after undocking and deorbit, it is incinerated in Earth's atmosphere at the end of its mission.


Progress cargo module interior.


Progress prelaunch processing.

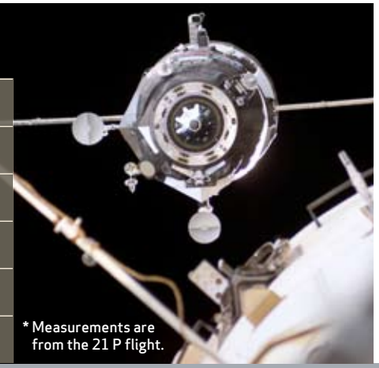

Progress prior to reentry.



Length	7.4 m (24.3 ft)
Maximum diameter	2.7 m (8.9 ft)
Span with solar arrays	10.6 m (34.8 ft)
Launch mass	7,150 kg (15,800 lb)
Cargo upload capacity	2,230–3,200 kg (4,915–7,055 lb)
Pressurized habitable volume	6.6 m^3 (233 ft^3)
Engine thrust	2,942 N (661 lbf)
Orbital life	6 mo

Cargo Load

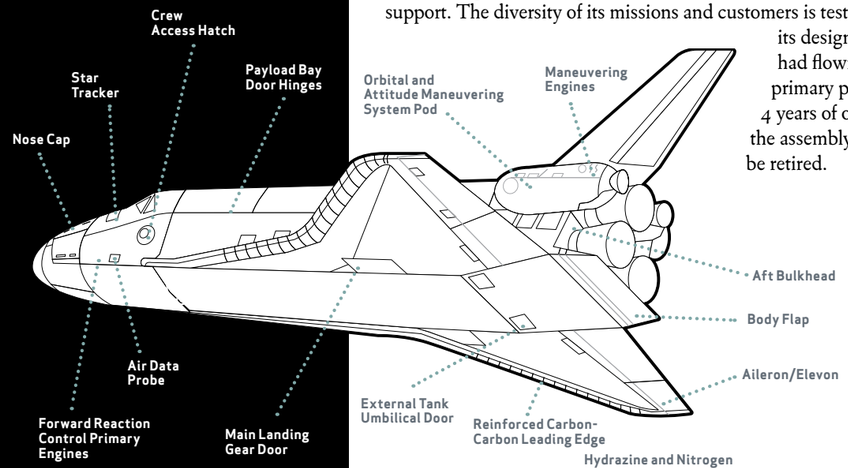
	MAXIMUM	TYPICAL*
Dry cargo such as bags	1,800 kg (3,968 lb)	1,070 kg (2,360 lb)
Water	420 kg (925 lb)	300 kg (660 lb)
Air	50 kg (110 lb)	47 kg (103 lb)
Refueling propellant	1,700 kg (3,748 lb)	870 kg (1,918 lb)
Reboost propellant	250 kg (550 lb)	250 kg (550 lb)
Waste capacity	2,000 kg (4,409 lb)	2,000 kg (4,409 lb)

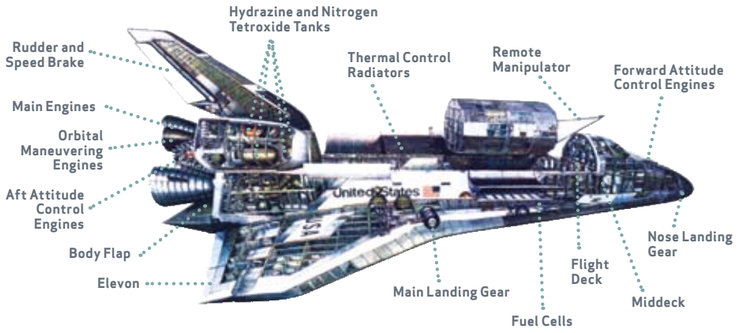

* Measurements are from the 21 P flight.

Space Shuttle Orbiter/ Discovery, Atlantis, Endeavour

NASA/Boeing/Rockwell

The U.S. Space Shuttle provides Earth-to-orbit and return capabilities and in-orbit support. The diversity of its missions and customers is testimony to the adaptability of its design. As of mid-2006, the Shuttle had flown 115 times. The Shuttle's primary purpose during the remaining 4 years of operation will be to complete the assembly of the ISS. By 2010, it will be retired.





Length	37.2 m (122.2 ft)
Height	17.3 m (56.7 ft)
Wingspan	23.8 m (78 ft)
Typical mass	104,000 kg (230,000 lb)
Cargo capacity	16,000 kg (35,000 lb) (typical launch and return to ISS)
Pressurized habitable volume	74 m^3 (2,625 ft^3)
Mission length	7–16 days, typical
Number of crew	7, typical
Atmosphere	oxygen-nitrogen
Cargo Bay	
Length	18.3 m (60 ft)
Diameter	4.6 m (15 ft)

The Shuttle approaches the ISS carrying the Multi-Purpose Logistics Module (MPLM).

Shuttle berthed at the U.S. Lab, PMA 2.

Multi-Purpose Logistics Module (MPLM)/Leonardo, Raffaelo, Donatello

NASA/Alcatel Alenia Space

The Italian-built Multi-Purpose Logistics Module (MPLM) serves as the International Space Station's "moving van" by carrying laboratory racks filled with equipment, experiments, and supplies to and from the Station aboard the Space Shuttle.

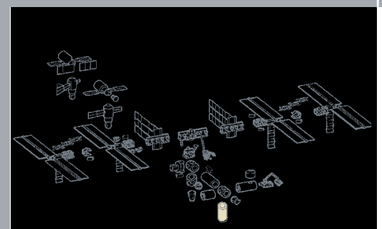
Mounted in the Shuttle's cargo bay for launch and landing, the modules are transferred to the Station using the Shuttle's robotic arm after the Shuttle has docked. While berthed to the Station, racks of equipment and stowage items are unloaded from the module, and racks and equipment may be reloaded to be transported back to Earth. The MPLM is then detached from the Station and positioned in the Shuttle's cargo bay for the trip home.

MPLM berthed at Node 1.

Stowage within MPLM.

MPLM interior during cargo transfers.

Length	6.6 m (21.7 ft)
Diameter	4.2 m (13.8 ft)
Mass (structure)	4,685 kg (10,329 lb)
Mass (payload)	9,400 kg (20,700 lb)
Racks	16, 5 active
Pressurized habitable volume	31 m^3 (1,095 ft^3)



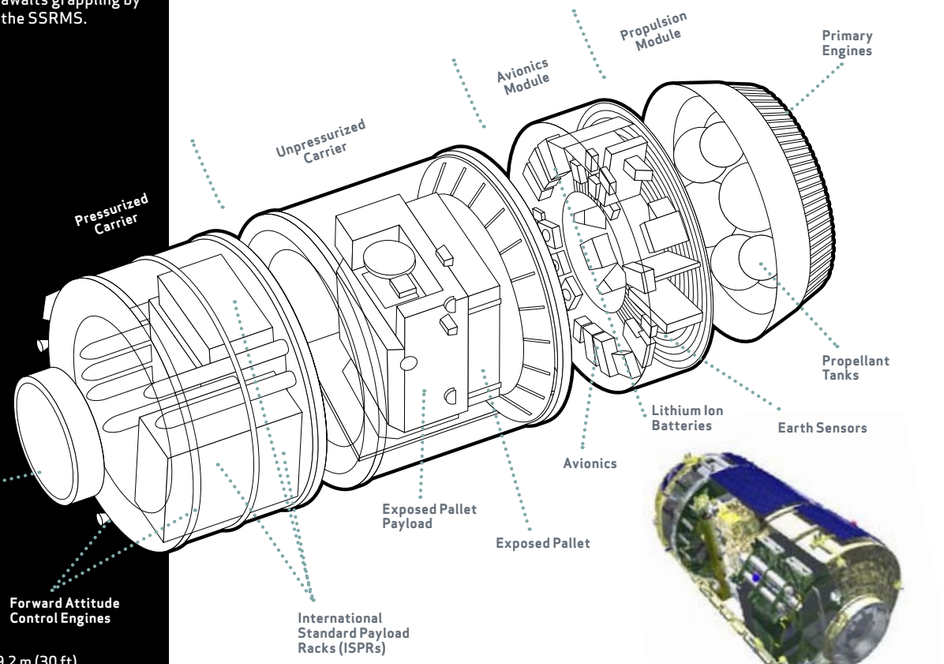
After rendezvous with the ISS, the HTV awaits grappling by the SSRMS.

Interior view of HTV pressurized carrier.

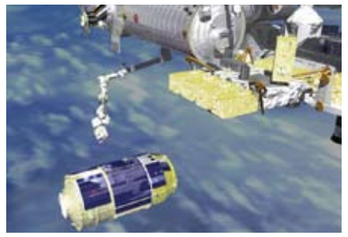
JAXA H-II Transfer Vehicle (HTV)

Japan Aerospace Exploration Agency (JAXA)/ Mitsubishi Heavy Industries, Ltd.

The H-II Transfer Vehicle is an autonomous logistical resupply vehicle designed to berth to the International Space Station using the Space Station Remote Manipulation System (SSRMS). HTV offers the capability to carry logistics materials in both its internal pressurized carrier as well as in an unpressurized carrier for exterior placement. It is launched on the H-II unmanned launch vehicle and can carry dry cargo, gas and water, and propellant. After fresh cargo is unloaded at the ISS, the HTV is loaded with trash and waste products; after unberthing and deorbit, it is incinerated during reentry.

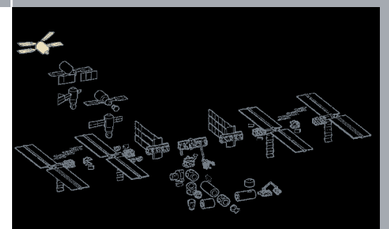


Length	9.2 m (30 ft)
Maximum diameter	4.4 m (14.4 ft)
Launch mass	16,500 kg (36,375 lb)
Cargo upload capacity	5,500 kg (12,125 lb)
Pressurized habitable volume	14 m^3 (495 ft^3)
Unpressurized volume	16 m^3 (565 ft^3)
Orbital life	6 mo



The HTV is berthed onto JEM by the Space Station RMS.

The HTV primary propulsion system performs rendezvous maneuvers.

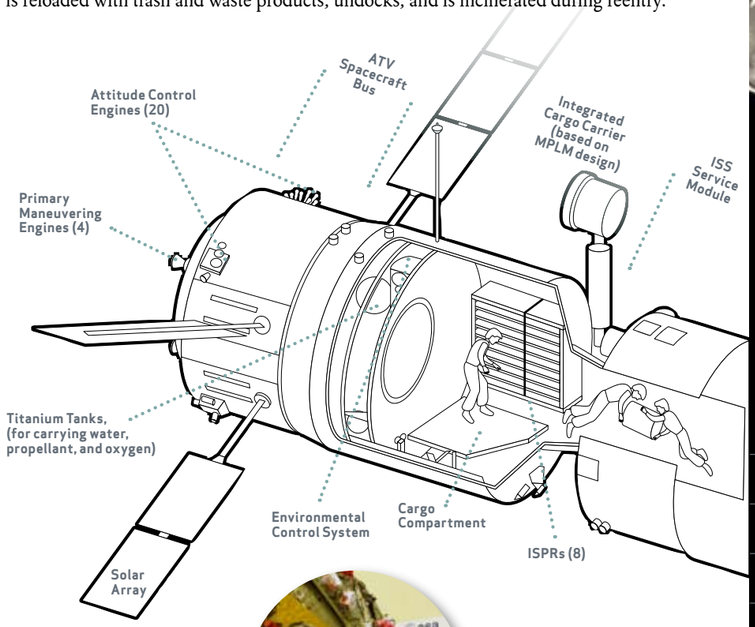


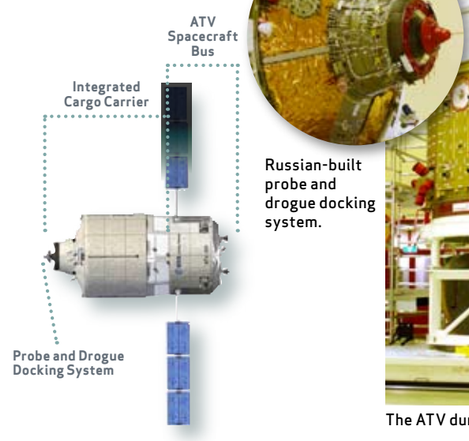
Artist's rendering shows the ATV approaching the ISS.

Automated Transfer Vehicle (ATV)

European Space Agency (ESA)/European Aeronautic Defence and Space Co. (EADS)

The European Space Agency Automated Transfer Vehicle is an autonomous logistical resupply vehicle designed to dock to the International Space Station and provide the crew with dry cargo, atmospheric gas, water, and propellant. After the cargo is unloaded, the ATV is reloaded with trash and waste products, undocks, and is incinerated during reentry.





Russian-built probe and drogue docking system.

The ATV during manufacture.

Length	10.3 m (33.8 ft)
Maximum diameter	4.5 m (14.8 ft)
Span across solar arrays	22.3 m (73.2 ft)
Launch mass	20,750 kg (45,746 lb)
Cargo upload capacity	7,667 kg (16,903 lb)
Engine thrust	1,960 N (441 lbf)
Orbital life	6 mo
Cargo Load	
Dry cargo such as bags	5,500 kg (12,125 lb)
Water	840 kg (1,852 lb)
Air (O_2, N_2)	100 kg (220 lb)
Refueling propellant	860 kg (1,896 lb)
Reboost propellant	4,700 kg (10,360 lb)
Waste capacity	6,500 kg (14,330 lb)

Crew Exploration Vehicle (CEV)/Orion

NASA has initiated the development of the Orion Crew Exploration Vehicle (CEV). The first Orion flights are planned for 2012–2014 and will support the ISS.

The CEV approaches the ISS.

Commercial Orbital Transportation Services (COTS)

NASA is seeking commercial providers of launch and return logistics services to support the ISS after the Space Shuttle is retired. The first COTS demonstration missions are planned for 2010.