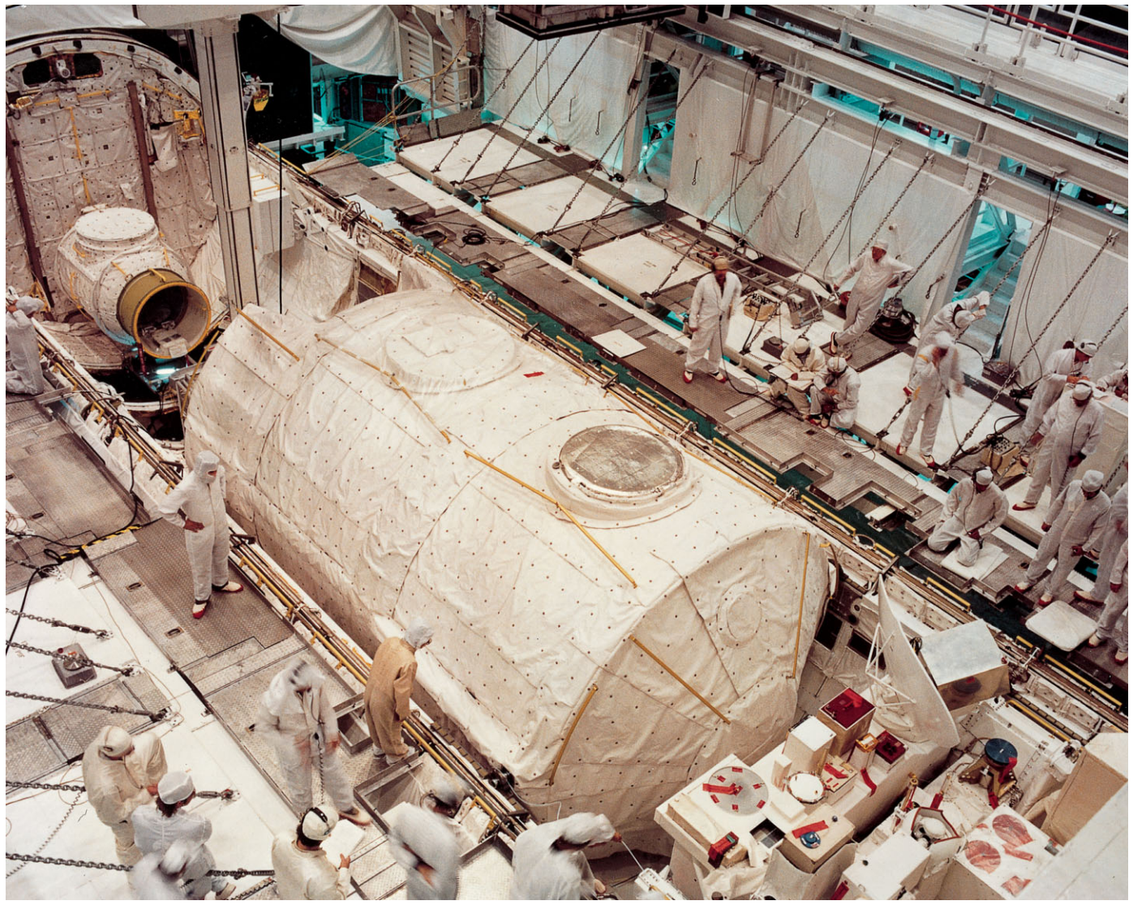
Spacelab

Achievements: principal scientific manned module for US Space Shuttle; major contributions to space sciences research and applications; first European manned space project; 22 missions
Launch dates: see table
Launch vehicle/site: US Space Shuttle, Kennedy Space Center, Florida
Launch mass: typically 10 t (Spacelab-1 totalled 8145 kg Pressure Module and 3386 kg Pallet; including experiments totalling 1392 kg)
Orbits: typically 300 km altitude, inclinations 28-57°
Principal contractors: VFW-Fokker/ERNO (later MBB/ERNO; prime), Aeritalia (PM structure, Igloo, thermal control), Matra (command/data management), Dornier (IPS, ECLSS), British Aerospace (Pallet)

Spacelab was an integral element of NASA's Space Shuttle programme and provided ESA/ESRO with a unique opportunity for developing a manned space capability. The 22 missions made outstanding contributions to astronomy, life sciences, atmospheric physics, Earth observation and materials science under microgravity – advances that stemmed from this crucial European contribution. Spacelab essentially comprised two types of payload carrier: a pressurised manned laboratory module and unpressurised external pallets. Its flexibility allowed it to accommodate both multi-disciplinary experiments and complements devoted to a single scientific or applications theme. The Pressure Module (PM) hosted the experiments equipment, data processing and electrical power equipment, an environmental control system and crew control stations. The crew of up to six researchers relied on the Shuttle Orbiter for living quarters, communications and data transmissions.

Europe was invited in 1969 to participate in the post-Apollo programme, ultimately deciding at the Ministerial Meeting of the European Space Conference in Brussels on 20 December 1972 to entrust ESRO with developing a modular, general-purpose laboratory.

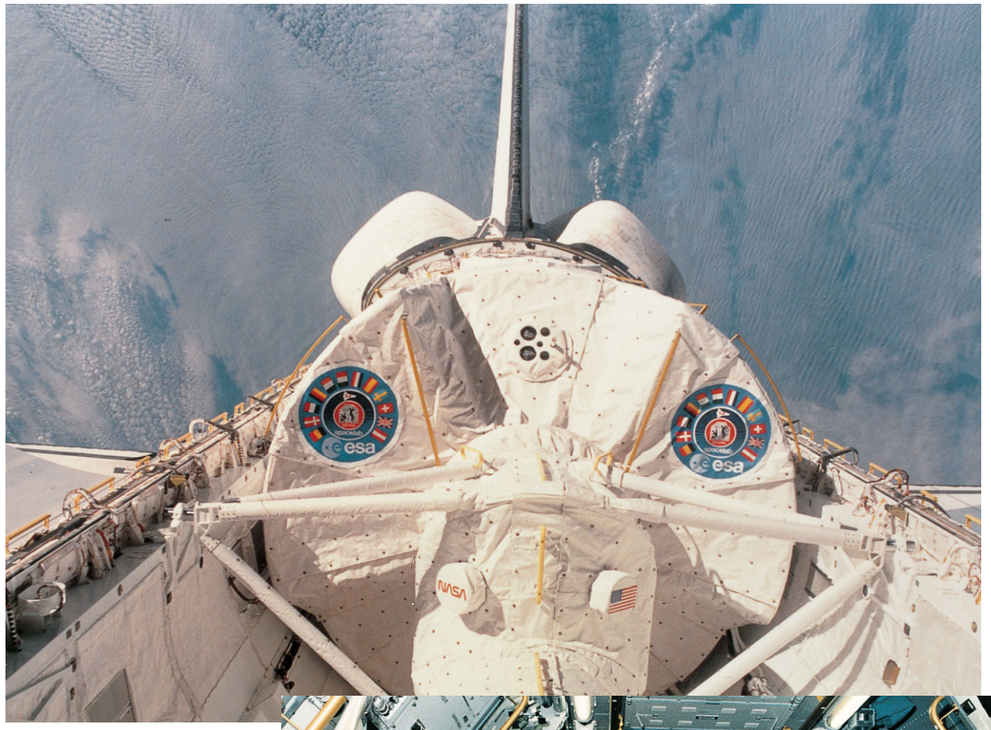
Spacelab was an integral part of the Space Transportation System. Shown is the Spacelab-1 configuration, flown in 1983.



The Memorandum of Understanding was signed with NASA on 24 September 1973, giving Europe the responsibility for funding, designing and building Spacelab. Europe agreed to deliver free of charge the Engineering Model and the first Flight Unit, plus ground support equipment, in return for a shared first mission. NASA would purchase any further equipment. The consortium headed by VFW-Fokker/ERNO (later MBB/ERNO) was awarded the 6-year ECU180 million Phase C/D contract in June 1974. Spacelab Flight Unit I, in Spacelab-1 configuration, was formally accepted by NASA in February 1982, comprising a Pressure Module, five Pallets, an Igloo, an Instrument Pointing System, plus support equipment. NASA bought a second set from ESA for about ECU200 million.

The maiden mission was designed to prove Spacelab's capabilities across numerous disciplines. Half the payload was allocated to ESA's First Spacelab Payload (FSLP). The representative configuration was the PM plus one Pallet with a total of 70 experiments. The mission required not only more experiment hardware than any previous ESA flight, but also more experimenters: 100 investigators interested in atmospheric physics, Earth observation, space plasma physics,

Inserting Spacelab-1 into the Shuttle Orbiter's cargo bay. The tunnel from the Orbiter's cabin has yet to be connected (top left).



Spacelab-1 in orbit: the debut of Europe's manned space laboratory. (NASA)

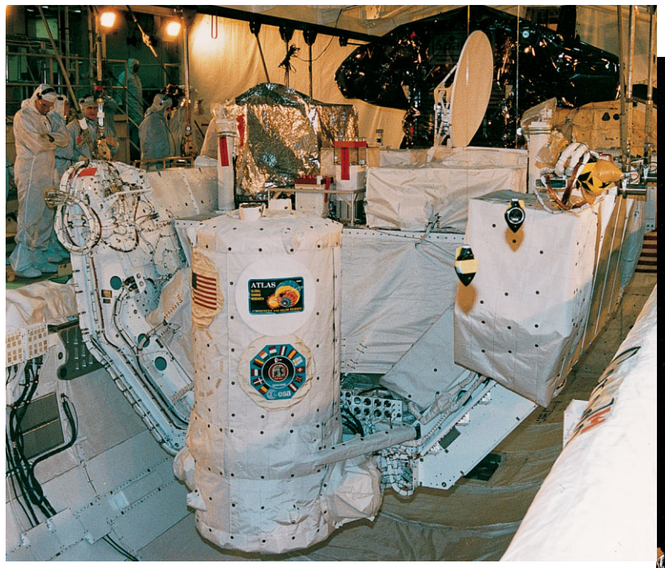
ESA astronaut Wubbo Ockels at work during the Spacelab-D1 mission.

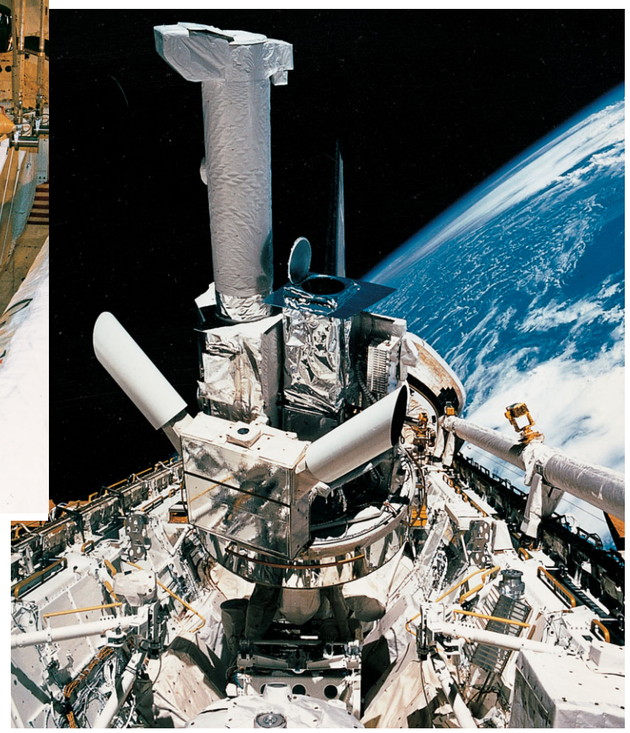
life sciences, materials science, astronomy, solar physics and technology. It also included the first European astronaut, Ulf Merbold, selected by ESA in 1977 along with Wubbo Ockels and Claude Nicollier as the agency's first astronaut corps. The mission was a resounding success, demonstrating Spacelab's far-reaching capabilities. Spacelab went on to prove itself as an unsurpassed asset. In the first eight PM missions alone, 387 experiments involved 323 Principal Investigators from 148 institutes in 26 countries. Spacelab flew its last mission in 1998 – a quarter of a century after Europe began the project – as scientists prepared for the advent of the International Space Station.

Spacelab Missions

STS Orbiter	*Launch Duration*	*Orbit Inc Altitude*	*Mission*	*Configuration*	*Discipline*	*European Astronaut*
STS-9 *Columbia*	28 Nov 83 10 d	57° 250 km	SL-01 FSLP	LM + 1P	Multi-discipline	U. Merbold
STS-51B *Challenger*	29 Apr 85 7 d	57° 360 km	SL-03	LM + MPESS	Materials Science	
STS-51F *Challenger*	29 Jul 85 8 d	50° 320 km	SL-02	IG + 3P + IPS	Solar Astronomy	
STS-61A *Challenger*	30 Oct 85 7 d	57° 330 km	SL-D1	LM + MPESS	Materials/ Life Sciences	W. Ockels E. Messerschmid R. Furrer
STS-35 *Columbia*	2 Dec 90 9 d	28° 350 km	Astro-1	IG + 2P + IPS	Astronomy	
STS-40 *Columbia*	5 Jun 91 9 d	39° 300 km	SLS-01	LM	Life Sciences	
STS-42 *Discovery*	22 Jan 92 8 d	57° 300 km	IML-01	LM	Materials/ Life Sciences	U. Merbold
STS-45 *Atlantis*	24 Mar 92 9 d	57° 300 km	Atlas-1	IG + 2P	Atmos. Physics Solar Astron.	D. Frimout
STS-50 *Columbia*	25 Jun 92 14 d	28° 300 km	USML-01	LM/EDO	Materials Science	
STS-47 *Endeavour*	12 Sep 92 8 d	57° 300 km	SL-J	LM	Materials/ Life Sciences	
STS-56 *Discovery*	8 Apr 93 9 d	57° 300 km	Atlas-2	IG + 1P	Atmospheric Physics	
STS-55 *Columbia*	26 Apr 93 10 d	28° 300 km	SL-D2	LM + USS	Multi-discipline	M. Schlegel U. Walter
STS-58 *Columbia*	18 Oct 93 14 d	39° 280 km	SLS-02	LM/EDO	Life Sciences	
STS-65 *Columbia*	8 Jul 94 15 d	28° 300 km	IML-02	LM/EDO	Materials/ Life Sciences	
STS-66 *Atlantis*	3 Nov 94 11 d	57° 300 km	Atlas-3	IG + 1P	Atmospheric Physics	J-F. Clervoy
STS-67 *Endeavour*	2 Mar 95 17 d	28° 350 km	Astro-2	IG + 2P EDO	Astronomy	
STS-71 *Atlantis*	27 Jun 95 10 d	52° 300 km	SL-Mir	LM		
STS-73 *Columbia*	20 Oct 95 16 d	39° 300 km	USML-02	LM/EDO	Materials Science	
STS-78 *Columbia*	20 Jun 96 17 d	39° 280 km	LMS	LM/EDO	Materials/ Life Sciences	J-J. Favier
STS-83 *Columbia*	4 Apr 97 4 d	28° 300 km	MSL-01	LM/EDO	Materials Science	
STS-94 *Columbia*	1 Jul 97 16 d	28° 300 km	MSL-01R	LM/EDO	Materials Science	
STS-90 *Columbia*	17 Apr 98 16 d	39° 280 km	Neurolab	LM/EDO	Life Sciences	

Atlas: Atmospheric Laboratory for Applications and Science. EDO: Extended Duration Orbiter. IG: Igloo. IML: International Microgravity Laboratory. LM: Long Module. LMS: Life and Microgravity Spacelab. MPESS: Mission Peculiar Experiment Support Structure. MSL: Microgravity Sciences Laboratory. P: Pallet. SL: Spacelab. SLS: Spacelab Life Sciences. USML: US Microgravity Laboratory.





The Atlas Spacelab missions did not include a Pressure Module, but instead housed the avionics in an Igloo (foreground) for controlling the payloads on the two Pallets. (NASA)

The Astro-1 mission was the first to employ the Instrument Pointing System, using the high-precision pointing capabilities for detailed observations of the Sun.

Pressure Module (PM)

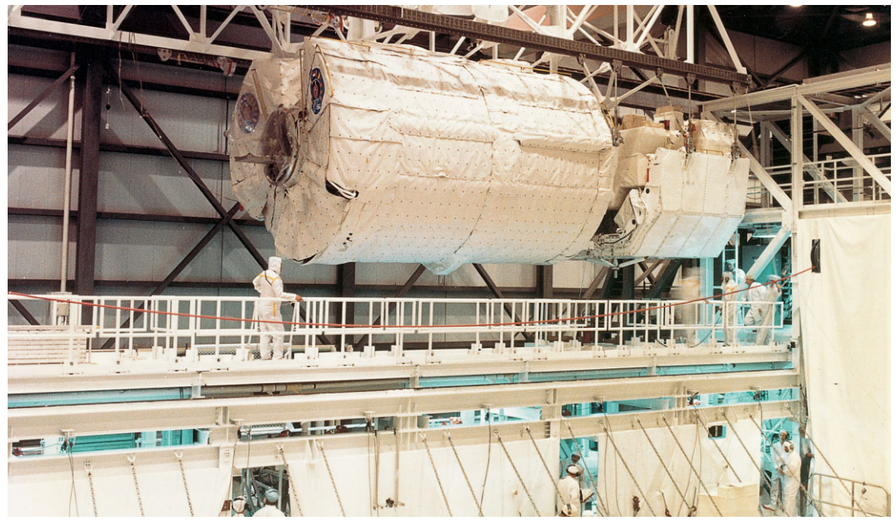
The 75 m³ PM was Spacelab's principal element, providing scientist-astronauts with a comfortable working environment. The 4.1 m-diameter, 7 m-long module was basically a 1.6-3.5 mm-thick aluminium cylinder with conical end pieces. The main segments could be unbolted for ground processing. The experiment racks were integrated outside the PM and then rolled with the floor into place along the PM side support beams. The racks held standard 48.3 cm-wide laboratory trays; the Double Rack had a 1.75 m³/580 kg capacity. The PM could carry the equivalent of 20 Single Racks, although two DRs were reserved each mission for avionics and equipment storage. The roof and floor offered storage space. The roof included two 1.3 m-diameter apertures: a window in the forward one and a scientific airlock aft for exposing experiments to space.

Pallets and Igloo

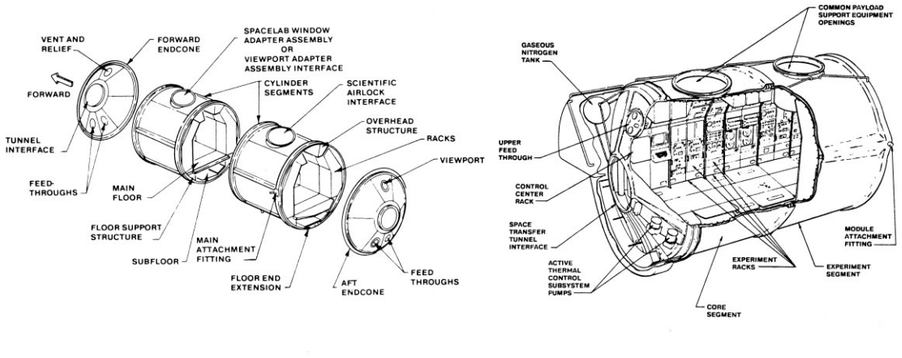
Experiments requiring direct exposure to space were carried on U-shaped Pallets that could be fully integrated before being inserted into the Shuttle's cargo bay. These proved to be so useful that non-Spacelab missions also used the Pallets; indeed, they continued in service for the International Space Station. Each 725 kg, 3 m-long 4 m-wide aluminium Pallet could hold a 3 t payload. Experiments were normally controlled via the PM, but on non-PM missions the pressurised 640 kg, 2.4 m-high 1.1 m-diameter cylindrical Igloo accommodated the avionics.

Instrument Pointing System (IPS)

Three Spacelab missions carried IPS to provide precision control and pointing of astronomical telescopes: the arcsec accuracy for a 2 t payload was 0.4 lateral/11.2 roll under star tracker control, and 0.5/41.0 in Sun mode. The 1.18 t IPS carried all inertial sensors, data and power electronics and the dedicated software for control via the Spacelab computers. It could route 1.25 kW to the payload and provided a 16 Mbit/s data rate.



Transferring the assembled Spacelab-1 to Space Shuttle Columbia. This assembly has been displayed in the Udvar-Hazy Center annex of the National Air & Space Museum at Dulles International Airport, Washington DC, since December 2003 (http://www.nasm.si.edu/udvarhazy/). The second set, flown on the final mission, can be seen at Bremen Airport (D).



Configuration: Spacelab comprised several elements that could be mixed-and-matched according to mission requirements. The Pressure Module accommodated experiments in a shirtsleeve environment, external experiments were mounted on Pallets, the Instrument Pointing System provided precision pointing for large telescopes, and the Igloo housed avionics when the PM was absent (6 out of 22 missions). See the separate sections for descriptions of each.

Attitude/orbit control: provided by Space Shuttle Orbiter.

Life support: a joint effort with the Orbiter to maintain a 1-bar atmosphere at 18-27°C and 30-70% humidity. Orbiter cabin air was drawn in through the linking tunnel, cleaned with lithium hydroxide and charcoal, cooled by heat exchangers and blown into the module through roof diffusers.

Power/thermal system: Spacelab was powered by the Space Shuttle's fuel cells at 28 Vdc, limited to 8 kW by the thermal control system. Experiments and avionics were mounted on cold plates linked to the Orbiter's cooling system. Cooling air was also forced up inside the experiment racks and drawn off. The whole module carried an external jacket of 39 layers of Dacron and goldised Kapton completed by an outer layer of Teflon-coated beta cloth.

Communications/data: data were usually transmitted in realtime through NASA's relay satellite system at up to 50 Mbit/s via the Orbiter's Ku-band system. When the realtime link was unavailable, a High Data Rate Recorder provided 32 Mbit/s storage. Spacelab's systems and experiments were controlled by three IBM AP-101SL computers (originally Matra 125/MS 64 kbit).