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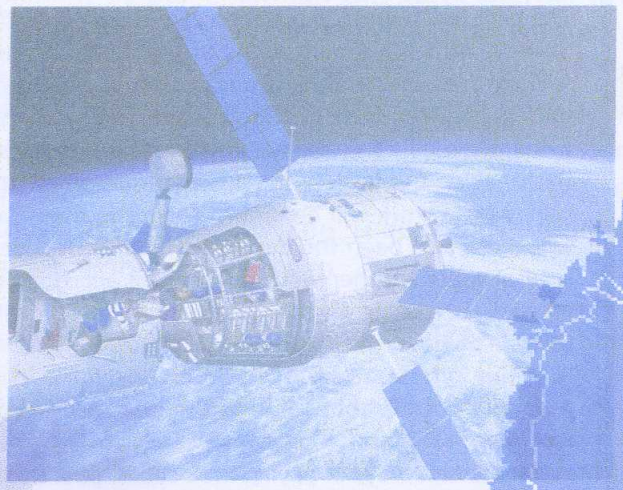

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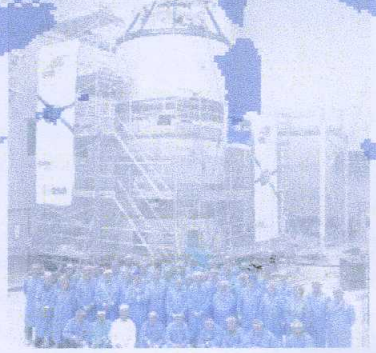

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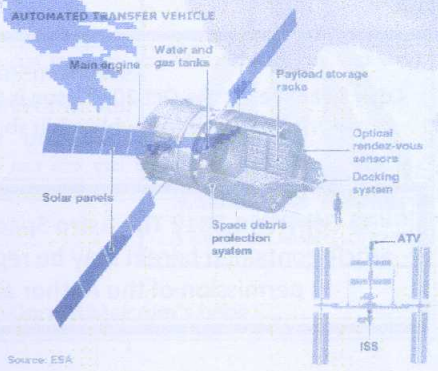

June 2012 issue 94

Italy and the Shuttle : 2 - Spacelab continued *by Umberto Cavallaro*

Flying the Italian Flag in Space

The Spacelab programme was unique for many reasons. First of all it represented the first European manned space project. The demarcation of obligations as specified in the two diplomatic MoUs (memoranda of understanding) signed by NASA and ESRO in 1973 left to the European partner the whole financial and industrial responsibility of defining, designing, developing, qualifying and delivering to NASA one prototype Engineering Model (EM), one Flight Unit (FU), ground engineering support for the first two flights and spares/documentation. NASA was to support the European effort, provide general managerial and technical information, monitor ESRO's technical progress, specify interfaces, develop the tunnel, operate Spacelab within the Shuttle Programme and procure a second Spacelab if the first met its design and price requirements.

On the cover below signed by the ESA astronauts Ulf Merbold, Ernst Messerschmid, Reinhard Furrer and Wubbo Ockels, the main contractors are listed, including: VFW-Fokker/ERNO (later MBB/ERNO; prime contractor), Aeritalia (Italy - later Thales Alenia Space - PM structure, Igloo, thermal Control), Matra (France - command/data management), British Aerospace (Pallet), AEG-Telefunken (electrical power system), British Aerospace (pallet structure), Dornier Systems (Germany - environmental control and life support system), Fokker (The Netherlands), SABCA (Belgium) and Kampsax (Denmark)

US-European co-operation on Spacelab was lengthy and complex. Problems of interfaces between Spacelab and the Shuttle had to be solved while schedules and technical features of the Shuttle were progressively changing. On one hand the American programme changed over time and its originally very ambitious scope was reduced, due to a severe limitation of American funds. On the other hand, the Spacelab programme demanded from Europe much more than initially foreseen and "the large number of interface modifications needed and the delivery to NASA of more hardware than initially foreseen, greatly contributed to this increase in expenditures". [1]

In US eyes, for the first time in the history of their space effort, the design and development of a major element of a manned space vehicle was entrusted to a foreign agency and to a group of countries which had never before built such a system. This choice respected however some of the traditional concerns of NASA in co-operation with foreign countries: the space laboratory had to be self-funded (by Europe), essentially separable from the Shuttle, even if it was an integral part of the post-Apollo programme as a whole, and it didn't require the transfer of highly advanced technical information.

This implied that US assistance would be "limited": if found necessary and appropriate, Europe would be allowed to buy existing American equipment as black boxes. Seen from the European side, it provided Europe with the systems development and management experience needed to move into the exclusive manned space flight arena. At the end, in terms of programme costs, ESA completed its part within 140% of its original estimate, NASA's development programme was completed within 169% of its original estimate, and the NASA follow-on procurement was only 25% of the first estimate, primarily because of reduced content and favourable dollar exchange rates.

As a result, Europe had a manned space system capability and the U.S. had a really versatile laboratory system, to use with its Space Shuttle, several years before it would have been possible if the United States had had to fund it on its own. And this is why the Spacelab programme was criticised in Europe as being a $1 billion gift to the U.S. Space Shuttle programme: "Europe's most expensive gift to the people of the United States since the statue of Liberty".[2]

However despite divergences and discussions during the negotiations of the agreements and their implementation, at the end of a decade of development, with the successful completion of the Spacelab 1 mission, all doubts and perplexities were removed. The Spacelab had demonstrated in a convincing fashion its ability as a useful tool capable of expanding the Shuttle's ability to conduct science on-orbit many fold or, better, capable of transforming the Shuttle into a first generation Space Station.[3]

Spacelab 1

SPACELAB 1, which flew in November 1983 on STS-9. was considered a sort of *verification flight test* (VFT) for the European-built Spacelab system, the primary objective being to verify the Spacelab system and subsystem performance capability and to demonstrate the ability to conduct advanced scientific research in space, with astronauts and payload specialists working in the Spacelab module and coordinating their efforts with scientists at the

1 HSR 21, p. 32 2 HSR #19, p. 35 3 HSR #21, p. 3-4

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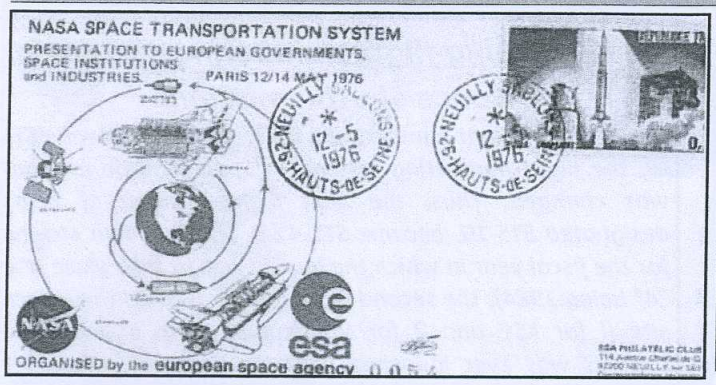
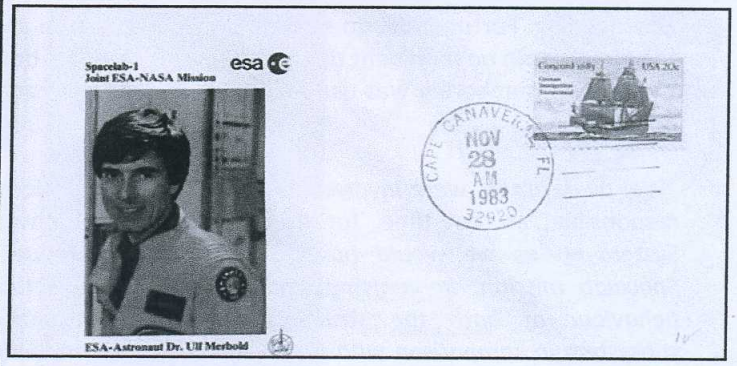




Payload Operations Control Center (POCC) located at the Johnson Space Center.

Seventy-two experiments in the joint ESA/NASA programme would test the Spacelab system and its onboard crew in a "Multidiscipline mission" with a large scientific programme. The chosen experiments fell in fact into five space disciplines: astronomy and solar physics, space plasma physics, atmospheric physics and Earth observations, life sciences, and materials science. There was something for everyone, including two experiments coming from Italy :
- Three-Dimensional Ballistocardiography in Weightlessness (prof. A. Scano - *Life Sciences*)
- Adhesion of Metals in an Ultra High Vacuum Facility (G. Ghersini, G. Grugni, F. Rossitto, P. Sona - *Materials Science*)

John W. Young, the veteran of five NASA space flights and one of the most experienced astronauts was chosen as the commander of the flight crew for the Spacelab 1 mission. He had flown two Gemini missions, made two trips to the Moon in Apollo, and had commanded the first Shuttle flight in April 1981. Assisting him as pilot would be Major Brewster H. Shaw, Jr., USAF, making his first space flight, although he was an experienced test pilot and flight instructor with 3500 flying hours in over 30 types of aircraft.

Drs. Robert A. R. Parker and Owen K. Garriott would be the Mission Specialists. Both had valuable Skylab programme experience, Parker as Program Scientist on the ground, and Garriott as Science Astronaut on the Skylab *3* mission. Garriott, a ham radio buff, would add special interest to the mission with his planned attempts to communicate to the ground with a small hand-held radio unit. Garriott and Young were prepared to perform any contingency EVA if required.

The five Payload Specialists selected by ESA and NASA in 1978 as candidates for this mission had been narrowed to two. Claude Nicollier, one of the early ESA candidates, was in training to become a Mission Specialist and would probably fly on a later mission. However, ESA had selected **Ulf Merbold** as its Payload Specialist for this mission. Wubbo Ockels would serve as a backup Payload Specialist and would be located in the JSC Payload Operations Control Center (POCC) during the mission to communicate with the onboard science crew. Dr. Byron K. Lichtenberg would be the NASA Payload Specialist, and Dr. Michael L. Lampton would be his backup, also playing a key support role in the POCC. This was certainly the most qualified, experienced, and trained flight crew ever selected for a space mission. The scientists had been intimately involved in the selection and preparation of the experiments and in the development and qualification of the basic Spacelab system.

At launch STS-9 was the most ambitious Space Shuttle mission to date, characterized by many "firsts":
- First flight of non-career astronauts (Payload Specialists Merbold and Lichtenberg)
- First flight on a NASA mission of a non-American (Merbold, a German)
- Longest Shuttle mission (planned for 9 days)
- Largest Shuttle crew (Commander, Pilot, two Mission Specialists, two Payload Specialists)
- Two shifts for 24-hour operations
- The heaviest payload to date
First operational use of the Tracking and Data Relay Satellite System

Experiments were already under way during lift-off as Lichtenberg and Merbold wore biomedical headgear to monitor their eye motions during the launch phase. Once in orbit, Lichtenberg activated the lymphocyte experiment and within 3 hours of take-off the crew was ready to open the airlock hatch and enter the Spacelab.

As in previous manned flights, half the crew experienced varying degrees of motion sickness, which was not discussed in the open press for reasons of privacy. In fact, some of the experiments would be expected to drive the subjects to the brink of nausea, so a high percentage of such problems in this mission would not have seemed unusual.

After a "very nominal" lift-off (as described by the NASA Launch Manager Al O'Hara) and a highly successful ten-days in space, the STS-9 mission experienced a thrilling conclusion. During orbiter orientation, four hours before re-entry, one of the flight control computers crashed when the RCS thrusters were fired. A few minutes later, a second crashed in a similar fashion.

Although the crew did not realize it at the time, leaking hydrazine fuel from two of *Columbia's* auxiliary power units had started a small fire that led to an explosion 15 minutes

after landing. Fortunately, no serious damage was done and the crew was in no imminent danger. It was also the last time the old STS numbering was used until STS-26 (see the panel opposite).

"We, as Aeritalia, were involved" – recalls Piero Messidoro, responsible, at that time, for the active Thermal Control System – *"as we would have been in any subsequent Spacelab mission, in verifying and monitoring the actual behaviour of both the structure and thermal control subsystem in comparison with the expectations. This activity was carried-out in real time in support of the European team following the mission in NASA. In addition we were requested to analyse and predict the behaviour of the above subsystems for the new missions especially in presence of changes in the basic configuration. Updated values of mass, centre of gravity, moment of inertia for the module structure as well as thermal dissipation for module and pallets thermal control due to the new payloads or to any hardware improvements were calculated and compared with the baseline. If acceptable they became reference points for mission follow-on and post flight analyses".*

Spacelab 3

According to the original plan, Spacelab 1 was scheduled for the 10th Shuttle mission, Spacelab 2 with the 14th and Spacelab 3 with the 20th, in April 1984. Due to problems with the TDRSS (Tracking and Data Relay Satellite System) and changes in DoD mission plans and, mainly, to the delay in finalizing the Instrument Pointing System essential for the mission's experiments of Spacelab 2, all the planning was completely revised: Spacelab 1 mission was flown on the 9th Shuttle flight, Spacelab 2 was postponed. and Spacelab 3 was scheduled for the seventeenth flight of Shuttle: mission STS 51A.

Spacelab 3 was planned to be the prototype of a NASA-dedicated Spacelab mission. Rather than containing experiments covering a broad range of disciplines as in Spacelab 1, the Spacelab 3 payload would focus on microgravity for most of its investigations, with the Orbiter in a gravity gradient attitude, its tail pointed toward the Earth, to provide the best stability possible. As many as 50 firings per hour of the vernier thrusters would minimize the impact on the Orbiter and its payload to less than one-thousandth of a g-load.

The confusing flight numbering system for Space Shuttle missions

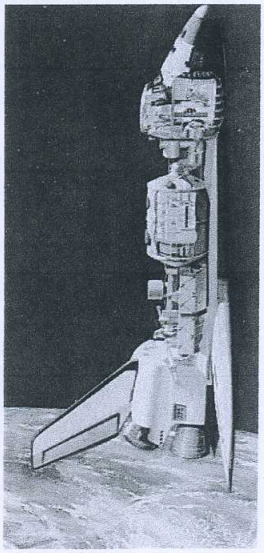
NASA shuttle flight numbers can be confusing. Following STS -9, the flight numbering system for Space Shuttle missions was changed. Thus, the next flight, instead of being designated STS-10, became STS 41-B, the first digit staying for the fiscal year in which the launch was to take place (the "4" being 1984); the second numeral represented the launch site (l for KSC and 2 for Vandenberg AFB, although no shuttles was ever launched from Vandenberg); the letter represented the order of launch assignment, e.g., "B" in STS-41B meant it was the second launch scheduled for fiscal year 1984.

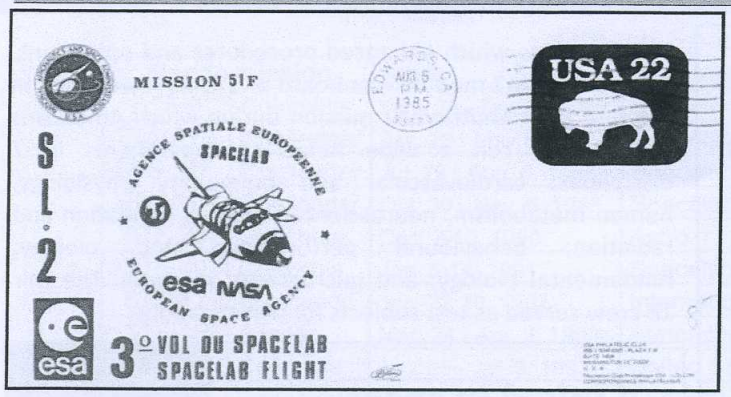
After the 1986 Challenger tragedy. NASA returned to the original easy-to-understand numbering system based on sequential flight numbers: the first mission when flights resumed after Challenger was the 26th shuttle and was numbered STS-26. Unfortunately, even the simple scheme became confused when NASA was forced to move flights around in the schedule. With STS numbers assigned 19 months in advance, the agency decided each flight would keep its number through all schedule changes.

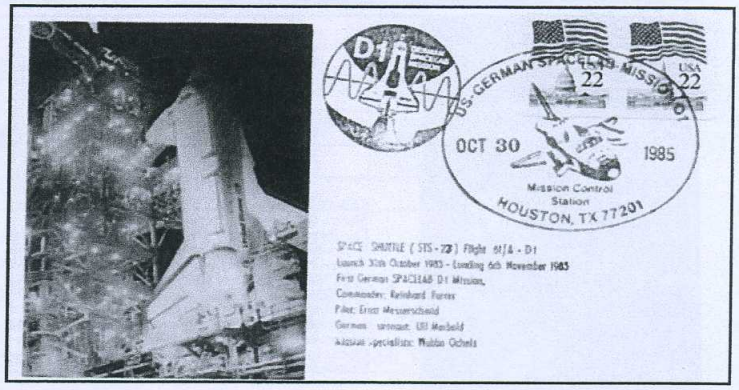
It turned out – according to several astronauts' NASA oral histories – that NASA administrator James Beggs suffered from triskaidekaphobia, the fear of the number 13 4. STS-41D was supposed to launch on April 13th, which in 1984 was a Friday, and Beggs simply wanted to avoid having an "STS-13" after what had happened with Apollo 13.

Spacelab 2

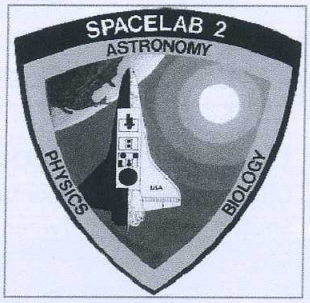
The laboratory module Spacelab-2 was the primary payload of mission STS-51-F, launched from Kennedy Space Center, Florida, on 29 July 1985, after the first launch attempt on 12 July 1985 was halted with the countdown at T-3 seconds – the main engine had already been ignited – when it was discovered a malfunction of a coolant valve in the number two SSME (Space Shuttle Main Engine). *"It was the longest 3 seconds I've ever experienced"* Commander Gordon Fullerton told reporters later.







The launch was rescheduled for July 29. Like the previous two Spacelab missions, Spacelab 2 was a verification test of the Spacelab system. This time, however, there was no laboratory module or habitable module, but pallets only, and the crew was confined to the Orbiter crew compartment.



The Spacelab 2 payload comprised 13 investigations mainly focusing on 3 scientific disciplines: astronomy, solar and plasma physics, and biology (as shown in the mission emblem), aiming at demonstrating to a variety of users the validity of the Spacelab pallet-only mode and the performance of the Instrument Pointing System. The flight marked in fact the first time the ESA Instrument Pointing System (IPS) was tested in orbit. This unique pointing instrument was designed with an accuracy of one arcsecond. Initially, some problems were experienced when it was commanded to track the Sun, but a series of software fixes were made and the problem was corrected. The IPS was fine-tuned in view of its planned use for observing Halley's Comet during the next year (a plan that would be cancelled following the *Challenger* disaster in January 1986).

Despite one of the three French-built Matra computers being totally out of service (so heightening the old confrontation with the US manager who, since the beginning, intended to use IBM machines), this was a very successful scientific mission. Almost 13 000 commands were transmitted to the Orbiter, exceeding any previous Shuttle flight by 50 %. Approximately 1.25 trillion bits of data were transmitted to the ground, requiring 230 miles of magnetic tape to store.

Spacelab D1

STS-61A was the 22nd Space Shuttle mission and was the first Spacelab flight entirely funded and controlled by one country: West Germany. Hence the name D1 (for Deutschland 1).

The mission marked the first utilization of the second Spacelab module LM2, purchased by NASA for its own use from ERNO, developed by former Aeritalia (now Thales Alenia Space) and integrated in Germany by ERNO.

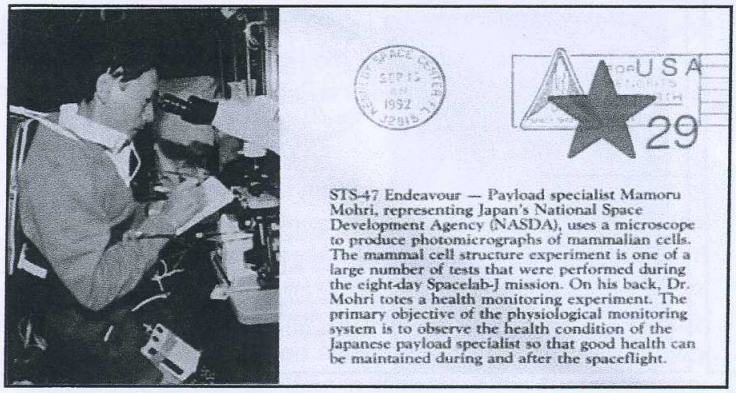
Germany reserved this mission, flown in October/November 1985, for use by its universities, industries and other research institutions. Germany wished to benefit as much as possible from the Spacelab project in which it had invested 55% of the European budget, sometimes blamed by the other European Partners who "did not like to leave too much control in German hands".

Payload operations and scientific research carried out during the seven-day mission were controlled from the German Space Operations Centre in Oberpfaffenhofen, Germany, near Munich, instead of the regular NASA Centre which only operated the Shuttle, and was responsible for overall safety and control functions throughout the flight.

The mission holds other records also, since it was the only shuttle flight to launch with a crew of eight, and still holds the record for the largest crew aboard any single spacecraft for the entire period from launch to landing. On board the Space Shuttle *Challenger,* in its last successful flight were in fact Henry Hartsfield, Steven Nagel, Bonnie Dunbar, James Buchli, Guion Bluford, Germans Ernst Messerschmid and Reinhard Furrer and ESA astronaut from the Netherlands Wubbo Ockels who became the second ESA astronaut and the first Dutch citizen in space (not the first Dutch-born astronaut, as he was preceded by naturalised American Lodewijk van den Berg, who flew into space five months earlier). More than 75 scientific experiments were completed in the areas of physiological sciences, materials science, biology and navigation.

22 Spacelab Missions

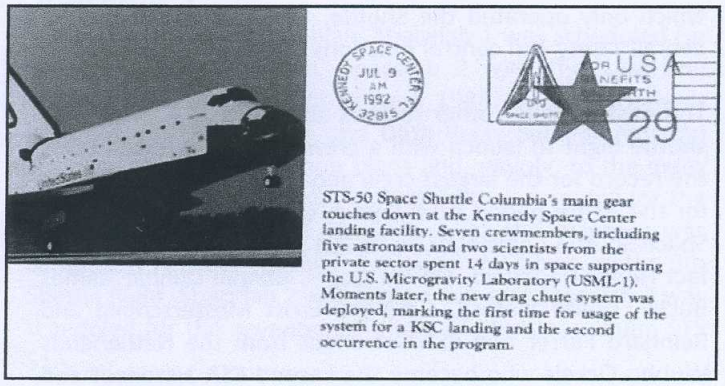
A similar mission, *Deutschland 2* (Spacelab-D2 or DLR-2), was planned in 1988, but after the *Challenger* disaster, was postponed until 1993 (STS-55) and became the first German human space flight after the German reunification.



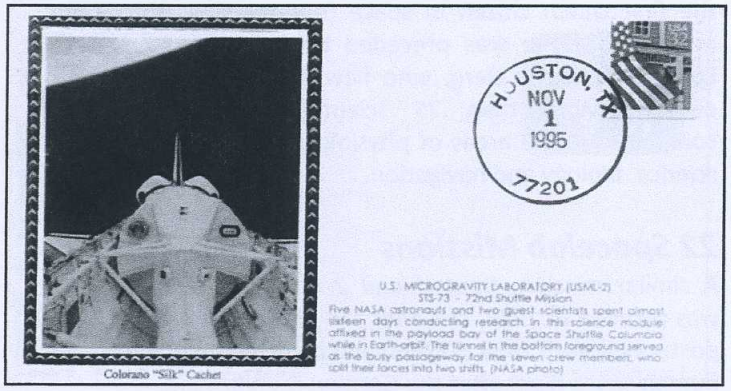
STS-47 Endeavour — Payload specialist Mamoru Mohri, representing Japan's National Space Development Agency (NASDA), uses a microscope to produce photomicrographs of mammalian cells. The mammal cell structure experiment is one of a large number of tests that were performed during the eight-day Spacelab-J mission. On his back, Dr. Mohri totes a health monitoring experiment. The primary objective of the physiological monitoring system is to observe the health condition of the Japanese payload specialist so that good health can be maintained during and after the spaceflight.

Even Japan, in 1992, funded its own Spacelab mission: Spacelab-J on STS-47 on materials science and 20 in life science, mainly sponsored by NASDA, the Japanese Space Agency. For the first time a Japanese astronaut – Mamoru Mohri – flew in space.

Obviously the United States has its own dedicated Spacelab missions. In particular the missions USML-1 (1992) and USML-2 (1995) were completely devoted to microgravity experiments. In both the mission the module LM1 was used, on-board *Columbia*.



STS-50 Space Shuttle Columbia's main gear touches down at the Kennedy Space Center landing facility. Seven crewmembers, including five astronauts and two scientists from the private sector spent 14 days in space supporting the U.S. Microgravity Laboratory (USML-1). Moments later, the new drag chute system was deployed, marking the first time for usage of the system for a KSC landing and the second occurrence in the program.



Top, a cover commemorating the mission USML-1 (STS-50): and above mission USML-2 (STS-73)

USML-1, taking advantage of the long-duration of the mission, Completed 31 microgravity experiments in five basic areas: fluid dynamics, crystal growth, combustion science, biological science, and technology demonstration provided new insights into the theoretical models in use.

The mission plan of USML-2, incorporated technical knowledge gained in the previous mission and ran 14 experiements which enhanced procedures and operations. A Spacelab LM2 module – onboard of STS-71 – was used in the first joint Shuttle/Mir mission during which Americans and Soviets run a wide range of experiments in 7 disciplines: cardiovascular and pulmonary physiology, human metabolism; neuroscience; hygiene, sanitation and radiation; behavioural performance and biology; fundamental biology; and microgravity research. The Mir 18 crew served as test subjects for investigations.

Different flight configurations

Different Spacelab configurations flew altogether in 22 Shuttle missions between November 1983 and April 1998. After that, the scientific experiments were run aboard the ISS, where modules derived from Spacelab exist. The list of the Spacelab missions is shown in the table *opposite top.*

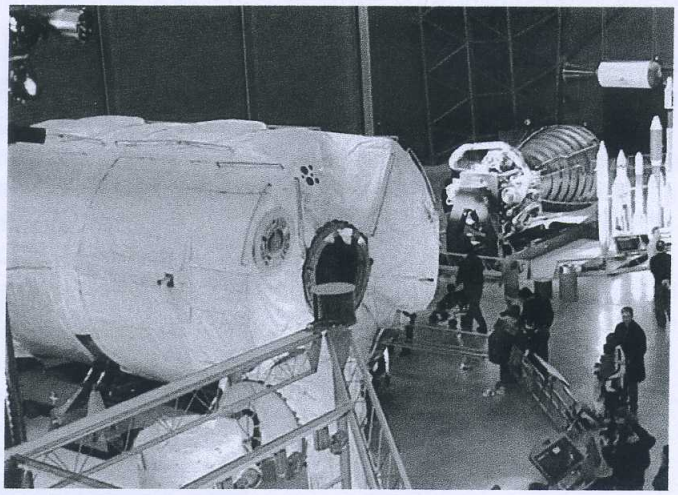
Flight configuration	Max. payload
	2,5 t
	5,5 t
	5,5 t
	7,5 t
	8,5 t
	9,1 t
	9,1 t
	9,1 t

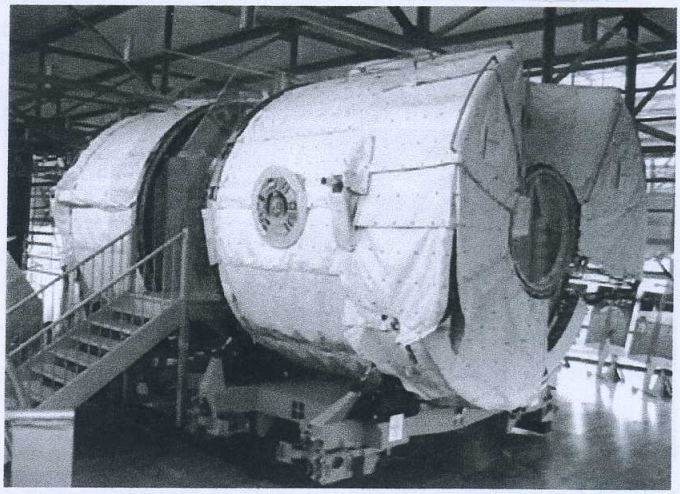
Space relics on show

Spacelab **LM1** has been on display, since December 2003, in the Space Science Exhibition Station at the Steven F. Udvar-Hazy Center in Chantilly, VA (USA), annex of the National Air & Space Museum at Dulles International Airport, Washington DC. Spacelab **LM2**, was returned to ESA in April 1999 and exhibited for ten years in the Bremenhalle at the Bremen Airport. In 2010 it was transferred to Building 4C of Astrium, near Bremen Airport.

Official Spacelab flights

Shuttle mission		dates	Spacelab Mission	Module
STS-9	Columbia	Nov. 28 - Dec. 8, 1983	Spacelab-1	LM1
STS-51B	Challenger	Apr. 29 - May 6, 1985	Spacelab-3	LM1
STS-51F	Challenger	Jul. 29 - Aug. 6, 1985	Spacelab-2	Igloo
STS-61A	Challenger	Oct. 30 - Nov. 6, 1985	Spacelab-D1	LM2
STS-35	Columbia	Dec. 2-10, 1990	Astro-1	Igloo
STS-40	Columbia	Jun. 5-14, 1991	Spacelab Life Sciences (SLS)-1	LM1
STS-42	Discovery	Jan. 22-30, 1992	International Microgravity Laboratory (IML)-1	LM2
STS-45	Atlantis	Mar. 24 - Apr. 2, 1992	Atmospheric Lab. for Applic. and Science (ATLAS)-1	Igloo
STS-50	Columbia	Jun. 25 - Jul. 9, 1992	United States Microgravity Laboratory (USML)-1	LM1
STS-47	Endeavour	Sep. 12-20, 1992	Spacelab-J	LM2
STS-56	Discovery	Apr. 8-17, 1993	ATLAS-2	Igloo
STS-55	Columbia	Apr. 26 - May 6, 1993	Spacelab D-2	LM1
STS-58	Columbia	Oct. 18 - Nov. 1, 1993	SLS-2	LM2
STS-65	Columbia	Jul. 8-23, 1994	IML-2	LM1
STS-66	Atlantis	Nov. 3-14, 1994	ATLAS-3	Igloo
STS-67	Endeavour	Mar. 2-18, 1995	Astro-2	Igloo
STS-71	Atlantis	Jun. 27 - Jul. 7, 1995	Spacelab-Mir	LM2
STS-73	Columbia	Oct. 20 - Nov. 5, 1995	USML-2	LM1
STS-78	Columbia	Jun. 20 - Jul. 7, 1996	Life and Microgravity Spacelab	LM2
STS-83	Columbia	Apr. 4-8, 1997	Microgravity Science Laboratory MSL-1	LM1
STS-94	Columbia	Jul. 7-17, 1997	Microgravity Science Laboratory MSL-1R	LM1
STS-90	Columbia	Apr. 17 - May 3, 1998	Neurolab	LM2





Above Spacelab LM1 in Chantilly, Virginia (USA) and right Spacelab LM2 in Bremen (Germany)

The Spacelab Pallet nicknamed "*Elvis*" was transferred to the Swiss Museum of Transport for permanent display on 5th March 2010. *Elvis*, was used during the eight-day STS-46 mission, 31 July—8 August 1992, when Italian Astronaut Franco Malerba was on board Shuttle *Atlantis* to deploy ESA's European Retrievable Carrier scientific mission (Eureca), and the joint NASA/ASI Tethered Satellite System (TSS-1).

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