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Space-bound Payloads, for the 1980s and 1990s

As Space Shuttle development began at Marshall in the 1970's, planners at the Center were studying ways to use the proposed new vehicle's capabilities for scientific research. The ninth flight of the Shuttle carried a multiconfiguration spaceborne scientific laboratory called Spacelab into orbit. Early studies at the Marshall Center had called for development of a versatile, reusable, laboratory facility. This facility would fit inside the payload bay of the Shuttle orbiter and provide scientists with workbench space, power, computer support, and racks and storage for a scientist's own experiment equipment.

In 1970, the Marshall Center requested proposals from industry for the preliminary design of a research and applications module as a way to provide versatile laboratory facilities for Earth-orbital research and applications work. In 1971, the Marshall Center began in-house studies on a laboratory called the Sortie Can, later renamed the Sortie Lab. The Sortie concept for Spacelab included a combination of habitable modules in which scientists could conduct investigations, and unpressurized pallets for instruments requiring direct exposure to space.

In 1972, NASA began negotiations with the European Space Research Organization, the forerunner to the European Space Agency (ESA). This ultimately led to an agreement between NASA and ESA under which ESA assumed responsibility for funding, developing, and building Spacelab. Under the arrangement, Marshall did the feasibility and preliminary design work during the Sortie studies, and ESA did the engineering design and hardware development based on Marshall requirements. Marshall, however, retained responsibility for technical and programmatic monitoring of Spacelab development activities in Europe, which involved 50 manufacturing firms in 10 European countries.

In addition to its program management responsibilities, Marshall was assigned responsibility for building related Spacelab flight components, including an optical window for scientific observations, and development of a pressurized transfer tunnel for passage of crew and equipment between the orbiter cabin and the laboratory module.

Marshall also had responsibility for Spacelab's command and data management subsystem and its high data rate multiplexer and high data rate recorder. In addition, a software development facility was established to develop and verify programs for the Spacelab experiment components. Other responsibilities ranged from the development of ground support equipment to sophisticated scientific instruments.

Spacelab also required engineers and other specialists at Marshall to perform systems analyses, design and develop integration hardware, oversee assembly and checkout, plan the flight timeline, conduct simulation and training exercises, and provide real-time support for the missions. Marshall's payload crew training complex became a training site for Spacelab mission specialists from the astronaut corps and payload specialists from the scientific community. Prior to the establishment of a new Spacelab Mission Operations Control Center facility at Marshall, Marshall mission managers monitored, controlled, and directed experiments aboard Spacelab from a Payload Operations Control Center at the Johnson Space Center.

Early Spacelab Missions

The primary purpose of the first Spacelab mission, launched on November 28, 1983, was to demonstrate the scientific capability of the laboratory and check the thousands of structural, mechanical, and electronic parts making up the laboratory. During the 10-day mission, the science crew conducted more than 70 separate investigations in life sciences,

Payload Specialist Dr. Ulf Merbold installs a sample into the Materials Science Double Rack during the Spacelab 1 mission launched on November 28, 1983. Spacelab was the first flight for payload specialists, who were career scientists from outside the astronaut corps. Marshall Space Flight Center was responsible for Spacelab development and control.

atmospheric physics, Earth observations, astronomy, solar physics, space plasma physics, and materials science and technology. Two additional Spacelab missions were flown in 1985. The primary purpose of the mission launched April 29, 1985, was to conduct materials science experiments in a stable low-gravity environment and to conduct research in life sciences, fluid mechanics, atmospheric science, and astronomy. The mission was also used to evaluate two crystal growth furnaces, a life support and housing facility for small animals, and two types of apparatus for the study of fluids. Another 7-day Spacelab mission, launched on July 29, 1985, served as a laboratory and observatory for investigations in solar physics, atmospheric physics, plasma physics, high-energy astrophysics, infrared astronomy, technology research, and life sciences. In addition to Spacelab missions 1, 2, and 3, Spacelab hardware and systems flew on the Spacelab D1 mission, and several partial payload missions were launched in the 1983–1985 time period.

Spacelab and Astrophysics

NASA launched Astro–1 on December 2, 1990. The astrophysics mission aboard *Columbia* (STS–35) represented the first Spacelab mission controlled from NASA's new Spacelab Mission Operations at Marshall. It was also the first Spacelab dedicated to a single scientific discipline. In fact, four of the seven astronauts on board were astronomers. Managed by Marshall, Astro–1 telescopes examined the ultraviolet and x-ray emissions from stars and galaxies. Specific targets included Supernova 1987a, the nearby supergiant star Betelgeuse, and others. In all, 135 deep space targets were examined during the 394 observations.

Five years after Astro–1, NASA launched STS–67 carrying the Astro–2 mission, mounted on a Spacelab pallet in the Shuttle cargo bay. Devoted to astronomy, the mission was designed to observe energetic objects in space in the ultraviolet portion of the electromagnetic spectrum.

Spacelab and Atmospheric Science

Planet Earth was the subject of three Spacelab missions in 1992, 1993, and 1994 as part of the Atmospheric Laboratory for Applications and Science (ATLAS) program. All three missions were mounted on a Spacelab pallet mounted in the Shuttle cargo bay. ATLAS–1 was launched in March 1992 aboard *Atlantis* (STS–45). The Marshall-managed instrument package was designed to take a detailed scientific "snapshot" of Earth's atmosphere. This international collaboration between the U.S., France, Germany, Belgium, the U.K., Switzerland, the Netherlands and Japan involved 12 instruments designed to provide investigations in four fields—atmospheric science, solar science, space plasma physics, and ultraviolet astronomy. The second ATLAS mission was launched aboard *Discovery* in April 1993 and was designed to take measurements of Earth's atmosphere to compare with readings from satellites and other ATLAS flights. Scientists were particularly interested in collecting data on the relationship between the Sun's energy output and Earth's middle atmosphere and how these factors affect the Earth's ozone layer. ATLAS–3 was launched on *Atlantis* (STS–66) in November 1994, once again to provide scientists with new insights into how human activities are changing the Earth's environment.

Spacelab and Microgravity

The 1990's marked a decade of Marshall-managed microgravity related Spacelab missions. For example, in September 1992, Japan's National Space Development Agency shared joint sponsorship with NASA in the American-Japanese Spacelab-J mission. That series of microgravity investigations included 24 materials science experiments and 19 life science experiments.

Multiple Spacelab missions were also flown as part of the International Microgravity (IML), United States Microgravity Laboratory (USML), and United States Microgavity Payload (USMP) series. On IML–1 in January 1992, astronauts conducted life sciences and microgravity processing experiments developed by scientists from NASA, the European Space Agency, the Canadian Space Agency, the French National Center for Space Studies, the German Space Agency and the National Space Development Agency of Japan. In all more than 220 scientists from 14 countries participated in the investigations. On IML–2 in July 1994, Shuttle astronauts divided into two teams and worked around the clock to perform more than 80 experiments aboard Spacelab. Using furnaces and facilities aboard the Spacelab module, the investigators produced a variety of material structures from crystals, metal alloys, and other substances. They also studied fluid processes not readily observable on the ground due to the influence of Earth's gravity.

USML–1, launched in the summer of 1992, included experiments in crystal growth, fluid dynamics, and combustion science. USML–2 in the fall of 1995 focused on microgravity research into fluid flows—investigations with direct applications on Earth for the manufacture of high-tech crystals, metals, alloys, and ceramics.

USMP missions flew in October 1992, March 1995, February 1996 and November 1997. These missions advanced American expertise in low-gravity research. In addition, some low-gravity experiments requiring direct exposure to space were controlled remotely by ground-based scientists during the mission.

Spacelab and Preparations for the *International Space Station*

The Life and Microgravity Spacelab mission aboard *Columbia* in 1996 focused on research intended to set the stage for the forthcoming *International Space Station*. In July 1997, after an abbreviated mission in April, NASA launched the Microgravity Science Laboratory with the focus on experiments inside the Spacelab module and in the Shuttle's middeck area. The mission focused on new ways to conduct experiments in space and on opportunities to develop procedures that might eventually be used on board the *International Space Station.*

Other Marshall Payloads

America's Space Shuttle transportation system was designed to serve as a "space truck"—a reliable and reusable means for ferrying satellites, space probes, scientific experiments, supplies, and humans to and from Earth orbit.

Marshall-provided payloads have often occupied the Shuttle's cargo bays. Many of those Marshall-managed experiments have taken place in the cargo bay or in the Shuttle middeck. As part of the second flight of the *Columbia* (STS–2) mission in November 1981, the orbiter carried the Induced Environment Contamination Monitor, the first major Marshall-managed Shuttle payload. The payload was designed to measure the environment in and around the cargo bay. STS–2 also carried another Marshall project, the Nighttime/Daytime Optical Survey of Lightning. The project was intended to provide atmospheric researchers with valuable insights into lightning and thunderstorms as observed from Earth orbit.

Columbia's third flight in March 1982 marked the first flight of the Monodisperse Latex Reactor materials processing experiments. Developed by scientists from Lehigh University and the Marshall Center, the experiment produced extremely uniform latex spheres that became the first commercial products manufactured in space and made available to the commercial market as laboratory calibration.

Columbia flew its fourth flight in the summer of 1982 and featured NASA's first joint Shuttle endeavor with industry. The Continuous Flow Electrophoresis System (CFES) was conducted as a joint endeavor arrangement pioneered and managed by the Marshall Center, NASA, and private enterprise. Orbital tests of the CFES (developed by McDonnell Douglas) involved the separation of biological materials such as blood cells and enzymes.

The Materials Experiment Assembly flight hardware was carried aboard *Challenger* on STS–7. The project represented one of the first cooperative international research projects to be conducted aboard a Space Shuttle. The experiments included the "Vapor Growth of Alloy-Type Semiconductor Crystals," "Liquid Phase Miscibility Gap Materials," and "Containerless Processing of Glass Forming Melts."

Orbiter *Discovery* was the focal point for several experiments in April 1985 leading to important insights toward new medical treatments. The investigations included the Protein Crystal Growth Experiment designed to produce large uniform crystals for pharmaceutical development. The mission also included the Phase Partitioning Experiment for separating biological materials.

The summer of 1984 marked the first time the Marshall Center had overall management responsibility for a major Shuttle payload: the Solar Array Flight Experiment. Deployed from the orbiter's cargo bay, the 102-foot long array was designed to convert the Sun's energy into electricity to study a new source of additional electrical power for future Space Shuttle missions.

In late 1985 Space Shuttle mission 61–B focused on a pair of space walks by two *Atlantis* astronauts who demonstrated advanced orbital construction techniques in the spacecraft's cargo bay. One technique was called the Experimental Assembly of Structures EVA (extravehicular activity). The other was called the Assembly Concept for Construction of Erectable Space Structures.

The summer of 1992 featured the first Tethered Satellite System (TSS–1) mission. This was a joint NASA/Italian Space Agency effort on STS–46. This "satellite on a string" experiment was designed to study the electrodynamics of a tether system in the electrically charged portion of Earth's atmosphere as a potential source of spacecraft power. During TSS deployment, however, the satellite reached a maximum distance of only 840 feet from the orbiter rather than the planned 12.5 miles because of a jammed tether line. Four years later, NASA and the Italian Space Agency re-flew the Tethered Satellite System aboard *Columbia* on STS–75. This time the tether abruptly snapped just short of full deployment with the satellite 12.8 miles from the orbiter. Although the satellite could not be retrieved and broke up as it re-entered the Earth's atmosphere, considerable amounts of useful information were gained from the experiment despite the mishap.

Payload Boosters

The Space Shuttle operates in low-Earth orbit. Some payloads, however, are intended for higher orbits, while others are propelled out of Earth's gravitational influence altogether in order to embark on interplanetary voyages. In 1977, Marshall assumed responsibility for overseeing the development of several new propulsion elements needed to give certain Shuttle payloads the necessary post-deployment boost. One of these elements was the Inertial Upper Stage, (IUS) a U.S. Air Force-developed rocket. Acting as NASA's management and coordination Center on the project, Marshall provided the Agency's design and operational requirements to the Air Force and participated in the development of two IUS configurations for NASA. Marshall also provided substantial input into the design and development of Orbital Science Corporation's Transfer Orbit Stage (TOS), intended to broaden the variety of payloads that could be placed into orbit from the Shuttle.

In late 1986, NASA announced that it had selected the IUS to carry probes to Jupiter, Venus and the Sun. NASA also announced that the Marshall Center would manage the IUS and the payload-to-IUS integration for the planetary missions. NASA selected the upper stage, built by Boeing Aerospace under Air Force contract, for three planetary missions—Galileo, Magellan, and Ulysses. These missions would be the first to employ an IUS to carry payloads to other bodies in the solar system. On May 4, 1989, the Space Shuttle *Atlantis* crew successfully deployed the Magellan spacecraft for its rendezvous with Venus using the IUS stage during the first day of the STS–30 mission. On October 18, 1989, the STS–34 crew aboard *Atlantis* used the Marshall-managed IUS to boost the Galileo spacecraft toward a rendezvous with Jupiter. Approximately 1 year later, on October 6, 1990, the STS–41 crew used an IUS to send the Ulysses probe on its 5-year journey to explore the Polar Regions of the Sun. By 1995, the IUS had also been used to launch more than a half dozen Tracking and Data Relay Satellites.

In September 1992, the Mars Observer Spacecraft was launched aboard a Titan III rocket. Marshall/ Orbital Science Corporation's TOS rocket booster then injected the spacecraft into a Mars-bound journey for an 11-month journey to the Red Planet. Unfortunately, contact with the spacecraft was abruptly broken approximately 1 year later during a critical Mars insertion maneuver meaning that the spacecraft was irretrievably lost. In September 1993, the crew of *Discovery* deployed the Advanced Communications Technology Satellite. Shortly thereafter, the satellite was boosted to geosynchronous orbit by an attached Transfer Orbit Stage. This marked the first time a TOS had flown aboard a Space Shuttle.