

Middeck Active Control Experiment (MACE) and MACE-II

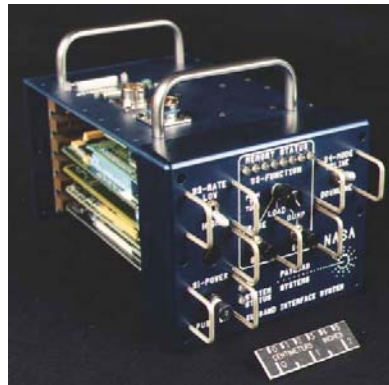
Description:

The Middeck Active Control Experiment is designed to study the closed-loop dynamics of a complex space platform with two independently articulating, two-axis-pointing payloads. Although the research task for which MACE was envisioned originally called for a payload bay design, the Payload Systems team determined that all of the experiment objectives could be accomplished at greatly reduced cost and with greater probability of success by adopting a middeck design instead. The resulting payload incorporated several completely novel features not previously seen in middeck payloads. For its first mission, MACE utilized nearly all the resources available in the middeck, including the entire power allocation available from the Middeck Utility Panel, and high-speed data up/downlink via a custom-designed Ku-Band Interface System (KIS).

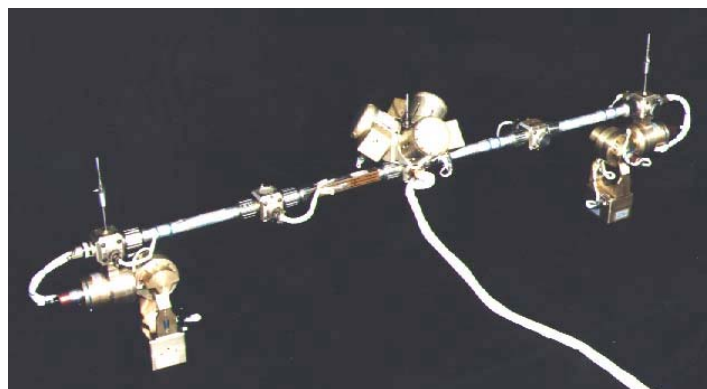
All experiment command, interface, and data recording functions are performed by the MACE Experiment Support Module (ESM). MACE also incorporates a Handheld Serial Terminal which is connected to the ESM via a thin umbilical and allows the crew to interact with the experiment from anywhere in the middeck.



MACE Experiment Support Module



Ku-Band Interface System
(side panel removed)



MACE Multibody Platform suspended on the ground. The MBP measures approximately 1.6 m from end to end.

The MACE test article consists of a tubular Multibody Platform (MBP) with an articulating pointing payload at each end, an active segment on one end, and a three-axis reaction wheel assembly in the center. Additional elements simulate the dynamics of large flexible solar array structures. The entire platform was loosely tethered in the middeck to simulate free-floating conditions.

During experiment operations, the payloads were commanded to point to specified coordinates while the active segment flexed. Or one payload was commanded to point while the other scanned and the active segment and reaction wheels acted to control or eliminate the payload disturbances. MACE data were downlinked via the KIS, and the ground team used the data to prepare measurement-based controllers. Meanwhile, prestored closed-loop tests were conducted to gather data on the effectiveness and accuracy of closed-loop controllers developed based on MBP performance on the ground. New control algorithms derived from the prestored closed-loop test data were then uplinked through the KIS and executed on the ESM and MBP. All data were recorded and analyzed postflight.

Payload Systems' Contribution:

Payload Systems (PSI) designed and fabricated all MACE components (ESM, HST, MBP, KIS). PSI was also responsible for functional and environmental testing of the hardware, as well as for the physical integration of the payload. Nineteen days of payload-specific crew training were conducted, with Payload Systems responsible for developing lesson plans and flight procedures. MACE was given clearance to transmit data and protocols through the orbiter Ku-band system, even though at the time this service was not offered to middeck payloads. Finally, despite its highly unusual complexity for a middeck payload, MACE cleared its Phase II Safety Review with no comments from the Safety Review Panel. Phase III was similarly completed without a single action item. All launch and delivery milestones were met as planned, including late access stowage of the MACE optical disks. All reviews, documentation, and crew training were completed on or ahead of schedule. Payload Systems supported mission operations with round-the-clock staffing of the Customer Support Room and Payload Operations Control Center.

For MACE-II, Payload Systems provided all hardware upgrades and carrier integration services at a small fraction of the cost of developing and integrating new flight systems.

Results:

MACE originally launched in March 1995, onboard STS-67. During the mission, MACE performed over 13 days of on-orbit operation and data collection, even though only 6 days had been originally scheduled. The crew remarked on several occasions their extreme satisfaction with the MACE experiment and hardware, and put in extra on-orbit time to obtain further data beyond what was called out in the flight plan. In addition, the KIS unit was used as the primary uplink path for electronic transfers after the PADM system failed several days into the flight.



MACE was launched for the second time on STS-106 / ISS-04/2a-2b as MACE-II, funded under a collaborative effort between the United States Air Force and MIT to test advanced control methodologies. MACE-II was the first experiment payload operated on ISS, where it successfully

completed all of its planned protocols before being returned to earth in late 2001. The crew again enthusiastically supported MACE operations, and MACE operations were included in the IMAX film, *Space Station*.



Publications:

Some examples of papers given by Payload Systems and its partners include:

Hoskins, W., Klynn, L., Miller, D.W., **de Luis, J.** "The MACE Active Member." Proc. of the Adaptive Structures, Actuators, and Material Conference, Alexandria VA, November 1991.

Jacques, R.N., Miller, D.W., **de Luis, J.** "Typical Section Problems for Structural Control Applications." *AIAA Journal of Guidance, Control and Dynamics*, October 1991.

Miller, D.W., **de Luis, J.**, Crawley, E.F. "Dynamics and Control of Multipayload Platforms: The Middeck Active Control Experiment (MACE)." 41st International Astronautical Federation Congress, Dresden, GDR, October 1990.

de Luis, J., Crawley, E.F. "Active Control Experimental Results on a Prototype Intelligent Structure." Presented at the 31st AIAA / ASME / ASCE / AHS Structures, Structural Dynamics and Materials Conference, Long Beach CA, April 1990.

For information on the IMAX film, *Space Station*, visit <http://www.imax.com/spacestation/>.

For more information on Payload Systems Inc., visit <http://www.payload.com> .

