Orbiting Planet Mercury: Engineering Innovations—Guest Editors' Introduction

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ABSTRACT

This issue of the Johns Hopkins APL Technical Digest *comes at the end of the MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) mission—which flew the only spacecraft ever to orbit the planet Mercury, the Sun's closest neighbor. This compilation offers a culminating report highlighting the mission's applied innovations in engineering and operations. It is a retrospective on how the integrated system of systems performed and how it was operated in Mercury's hostile environment, managing risk to extend the mission's life to more than four times that required to achieve full mission success.*

In the early morning hours of 3 August 2004, the MErcury Surface, Space ENvironment, GEochemistry, and Ranging (MESSENGER) spacecraft was launched aboard a Boeing Delta II-Heavy rocket from the Kennedy Space Center on a journey to become the first spacecraft to orbit the innermost planet of our solar system. After a circuitous 6.6-year journey involving six planetary flybys—one of Earth, two of Venus, and three of Mercury—on 17 March 2011 EDT (18 March UTC) MESSENGER's thrusters were fired to slow the spacecraft so it would be captured into orbit about Mercury.

The baseline MESSENGER mission plan called for 1 year of orbital science data collection; however, efficiencies resulting from rigorous trajectory planning and propellant management allowed mission operations to continue for more than 4 years. The spacecraft and its subsystems performed nominally, and all seven science instruments that comprised its payload operated throughout. Orbital science data planning and acquisition, although exceptionally complicated, were greatly facilitated through the use of a software system developed at the Johns Hopkins University Applied Physics Laboratory (APL), SciBox,[1,2] to automatically schedule integrated instrument operations and associated spacecraft pointing for the entire payload. As a result, data were collected at every opportunity, using an automated planning and replanning process to ensure optimal results.

MESSENGER's final contact with NASA's Deep Space Network occurred on 30 April 2015, during which all high-priority data remaining on the spacecraft's solid-state recorder were downlinked. With its propellant exhausted, the spacecraft's orbital trajectory took it behind the planet (relative to Earth) for a final time. The operations team had projected that the spacecraft would impact the planet's surface at 3:26 p.m. EDT. When no signal was observed by 3:40 p.m., the time the spacecraft would have emerged from occultation had it not impacted, MESSENGER's principal investigator announced the end of the mission. For MESSENGER team scientists, engineers, and operations staff gathered in the Mission Operations Center, the celebration was one of great enthusiasm with a twinge of sadness.

The mission spanned more than a decade, with the bulk of the data acquired during the more than 4 years in orbit, using MESSENGER's seven science instruments and a radio science experiment. The result was a total data volume exceeding 10 TB. All of the formatted raw data, calibrated data, and derived data products, along with ancillary engineering data collected throughout the mission, now reside in NASA's Planetary Data System archive—in the public domain—inviting colleagues and aspiring space scientists to seek new findings. Each data set is thoroughly documented, so the measurements may be understood and their use facilitated for generations of new investigators.

The scientific justification for MESSENGER as well as the objectives and goals of the mission are spelled out in a special volume of *Space Science Reviews* (Volume 131, 2007), published three years after launch. Papers in that special issue laid out the unanswered science questions that compelled the mission and described the science instruments designed to acquire the data to answer those questions. Another paper in that volume gave an overview of the spacecraft and its subsystems designed to safely and accurately get the science instruments into position to make the observations and get the data into the hands of the science team, so those data could be analyzed, discoveries could be made, and results could be published. Because of the required trajectory, including orbit insertion and maintenance, and operational constraints in hostile thermal and radiation environments, the design of the instruments and the design of the spacecraft were quite challenging and required technological advancements in many areas. The papers in that special volume collectively provide an excellent summary of the numerous innovations in implementation that contributed to NASA's fund of knowledge.

This special issue of the *Johns Hopkins APL Technical Digest* comes at the end of MESSENGER's odyssey and offers a culminating report highlighting the mission's technological innovations and their performance. It describes the journey. Did MESSENGER handle known challenges as planned? How did it handle unexpected challenges? Was risk well managed under difficult circumstances? It is a story of the execution by the engineering and operations teams that led to the success of MESSENGER.

Although this publication focuses on engineering and operations and addresses related questions, it should be emphasized that the MESSENGER mission fundamentally changed our understanding of the planet Mercury. A new book, *Mercury: The View After MESSENGER* (Cambridge University Press, in press), written by members of the MESSENGER science team, offers a comprehensive view of the innermost planet as we now understand it after the MESSENGER mission.

The MESSENGER mission was the seventh in NASA's Discovery Program, sponsored by the agency's Planetary Science Division and managed by the Marshall Space Flight Center, Huntsville, Alabama. The principal investigator is Sean C. Solomon, former department director at the Carnegie Institution of Washington and currently Director of the Lamont-Doherty Earth Observatory, Columbia University. MESSENGER was developed, managed, and operated by APL.

Such an aggressive Discovery-class mission could be successfully executed only by an outstanding team of scientists, engineers, and supporting staff operating under strong leadership with outstanding NASA oversight and support. We thank our NASA sponsors who empowered APL as the MESSENGER primary implementing institution. We thank the entire MESSENGER team for their innovative ideas, relentless drive, commitment to integrity, and dedication to the interest of the sponsor and greater science community. We especially offer our sincere appreciation to Sean Solomon, who led the mission with vision, wisdom, tireless effort, and the grace to trust his experts combined with the perceptiveness to know just where to poke holes. Finally, we thank the authors, contributors, peer reviewers, and editors of this special issue.

More can be learned about the mission, its team, and the results obtained by visiting the MESSENGER website at http://messenger.jhuapl.edu. All science and engineering data acquired throughout the mission, as well as higher-level data products produced by the team, can be accessed through NASA's Planetary Data System archive at http://pds.nasa.gov.

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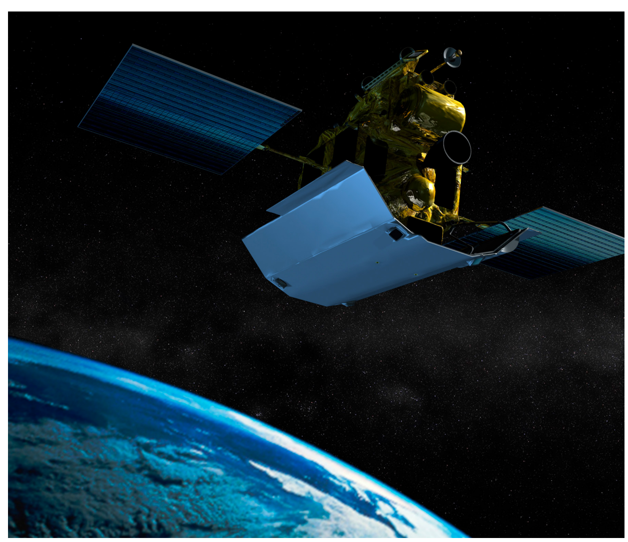

Artist's rendering of the MESSENGER spacecraft as it leaves Earth.

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