SCIBOX AND OBSERVATION PLANNING FOR MESSENGER'S EXTENDED MISSION AT MERCURY. Teck H. Choo[1], Mark E. Perry[1], Robert J. Steele[1], Hari Nair[1], Lillian Nguyen[1], Joseph F. Skura, Michael Lucks[1], Peter D. Bedini[1], Sean C. Solomon[2], and the MESSENGER Team. [1]The Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723 (Teck.Choo@jhuapl.edu); [2]Department of Terrestrial Magnetism, Carnegie Institution of Washington, Washington, DC 20015.

Introduction: In March 2012, the MESSENGER spacecraft [1] will complete its primary science mission [2]. Remaining propellant will be sufficient for MESSENGER to continue orbital operations for at least one additional Earth year, and NASA formally extended the MESSENGER mission to March 2013.

Although all of the original science goals for MESSENGER are expected to be achieved or exceeded by the end of the primary mission, the extended mission provides additional opportunities to advance our understanding of Mercury substantially beyond what will be achieved by the end of the primary mission. The extended mission will provide improved spatial resolution through changes in mission design and observing strategies, increased signal-to-noise ratio by doubling the total observing time and increasing the proportion of time at lower altitude, better accuracy for the higher-order structure of Mercury's gravity and internal magnetic fields, additional high-resolution observations of hundreds of new targets, and a special opportunity to observe the Mercury system during a time of greater solar activity.

The SciBox planning system: As with the primary mission, the MESSENGER team will use the SciBox software [3-4] to plan extended mission observations. SciBox is a mission simulation and command-generation system that models instrument and spacecraft performance with high fidelity, applies spacecraft and observing constraints, analyzes science investigation opportunities for each investigation and measurement requirement, determines a complete set of observations optimized for the entire mission, and generates the attitude profile and commands for upload to the spacecraft. SciBox can complete the simulation of a realistic, specific orbital operations scenario within a few hours. Rapid execution, coupled with the extensive set of evaluation tools and reports that accompany each SciBox run, allows the science team to assess many alternative observing plans.

During the weekly planning cycle, SciBox generates all the commands for all the instruments, all the commands for spacecraft attitude control, and some of the commands for the on-board data recorder, communication system, and solar panels. Because it develops complete plans so quickly, SciBox can use the latest predictions in spacecraft position, the actual Deep Space Network ground station schedule, the current spacecraft clock drift coefficient, and the status of the recently downlinked observations to minimize errors due to latency. The SciBox algorithms and results are vetted and verified before operational use, so the week-

3rd Solar day	**4th Solar day**
G&C Sun-line crossing	G&C Sun-line crossing
PA antenna protection	PA antenna protection
Orbit correction maneuver	Orbit correction maneuver
Eclipse power management	Eclipse power management
UVVS exosphere campaign	UVVS exosphere campaign
High-gain antenna downlink	High-gain antenna downlink
UVVS polar scan	UVVS polar scan
MDIS thermal calibration	MDIS thermal calibration
Priority 1 targeted obs.	Priority 1 targeted obs.
UVVS day side limb scan	UVVS day side limb scan
MLA nadir obs.	MLA off-nadir obs.
Priority 2 targeted obs.	MLA nadir observation
MASC star calibration	Priority 2 targeted obs.
XRS star calibration	MASC star calibration
MDIS limb imaging	XRS star calibration
Priority 3 targeted obs.	MDIS limb imaging
MASC southern grid campaign	Priority 3 targeted obs.
XRS and VIRS mapping	MASC southern grid campaign
FIPS magnetosphere obs.	XRS and VIRS mapping
EPS field aligned particle obs.	FIPS magnetosphere obs.
Priority 4 targeted obs.	EPS field aligned particle obs.
MDIS 3-color high-res. map	MDIS north-polar monitoring
MDIS north-polar monitoring	MDIS med.-incident stereo pair
MDIS high-incident map	Priority 4 targeted obs.
UVVS exosphere scan	UVVS exosphere scan
GRS nadir observation	GRS nadir observation
UVVS exosphere stare	UVVS exosphere stare
VIRS dark calibration	VIRS dark calibration
MDIS albedo map	UVVS night shadow obs.
UVVS night shadow obs.	UVVS night column obs.
UVVS night column obs.	MAG measurements
MAG measurements	GRS ride along obs.
GRS ride along obs.	NS measurements
NS measurements	EPS ride along obs.
EPS ride along obs.	FIPS ride along obs.
FIPS ride along obs.	MLA ride along obs.
MLA ride along obs.	MDIS-NAC high-res. strip
MDIS-NAC high-res. strip	RS low-gain antenna tracking
RS low-gain antenna tracking	

Figure 1. Extended mission observation types listed in order of priority. Engineering activities are highlighted in gray. Science activities that are new to the extended mission are highlighted in yellow. Using separate priorities for the two Mercury solar days smoothes data volume and reduces observing conflicts.

ly operations are extremely efficient; the only required manual operations are to spot check the resulting commands and verify objectives by examining the reports.

Extended mission simulation and planning: Once the extended mission was approved by NASA, the SciBox development team worked with the science team to implement elements that are new to the extended mission. Some of the new elements include an orbit period of eight rather than twelve hours, new observation objectives and geometries, and revised priorities. An overarching and essential requirement for the architecture of the SciBox planning system is flexibility: SciBox must be able to accommodate the many types of changes that are inherent in any mission. SciBox contains many modularized components that are readily modified or reused to meet new requirements. Parts of SciBox that remain unchanged include all of the spacecraft- and instrument-state simulators, interfaces to mission operations and data processing systems, commanding systems, and constraint-validation modules. Some of the specific instrument-observation modules, which contain many parameters, are also being reused without change or modified to accomplish the new extended mission observations by parameter adjustment only. Other measurement objectives that called for new observing geometries usually required development of a new SciBox module.

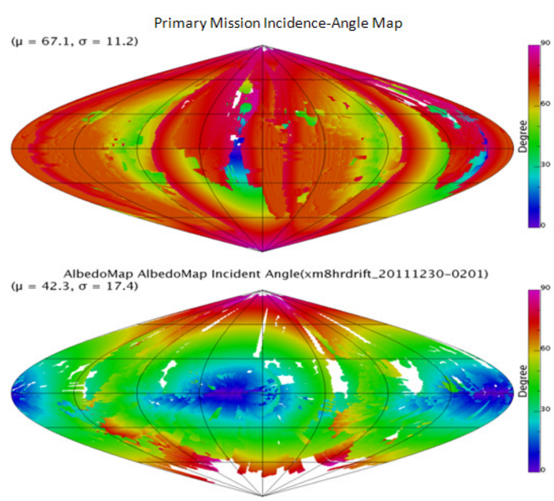

Figure 2. A comparison of expected monochrome imaging coverage by incidence angle for the primary mission (top) and for the extended mission (bottom).

Modules for the new extended mission measurement operation were developed and adjusted incrementally. After incorporating and verifying the observation scenarios, the major effort involved resolution of conflicts and improvement in observation sets by adjusting parameters. Within three months, the bulk of this work was completed, and the full extended-mission observing plan received preliminary approval from the science team. The resulting scheduling priority for all extended-mission science measurement objectives is illustrated in Figure 1. These priorities may yet be adjusted as necessary to accommodate new observing requests, modified spacecraft constraints, or a desire to evaluate additional options for optimizing the overall set of observations.

A sample of a science investigation report comparing the expected monochrome image coverage by incidence angle between the primary and extended missions is shown in Figure 2. During the primary mission, the global monochrome imaging campaign was designed to image Mercury at an average incidence angle of 68°. The extended-mission measurement campaign is designed to minimize the incidence angle, and the average angle is approximately 30°.

Summary: The SciBox planning system has enabled rapid development of a complete, fully integrated observing plan for MESSENGER's extended mission. The observing plan, which leaves no unallocated time throughout the 12-month extended mission, meets the requirements defined by the science team. SciBox also provides a mechanism for adjusting the observing plan to accommodate new strategies and observations or to respond to mission changes.

References: [1] Leary J. C. et al. (2007) *Space Sci. Rev.*, *131*, 187-217. [2] Solomon S. C. et al. (2007) *Space Sci. Rev.*, *131*, 3-39. [3] Anderson, B. J. et al. (2011) *LPS, 42,* 1862. [4] Choo, T. H., et al. (2011) *LCPM 9,*.