***Mars Atmosphere and Volatile EvolutioN (MAVEN)* Mission**

MAVEN's Lessons Learned
PI Forum #5, Academy Center for Excellence, KSC

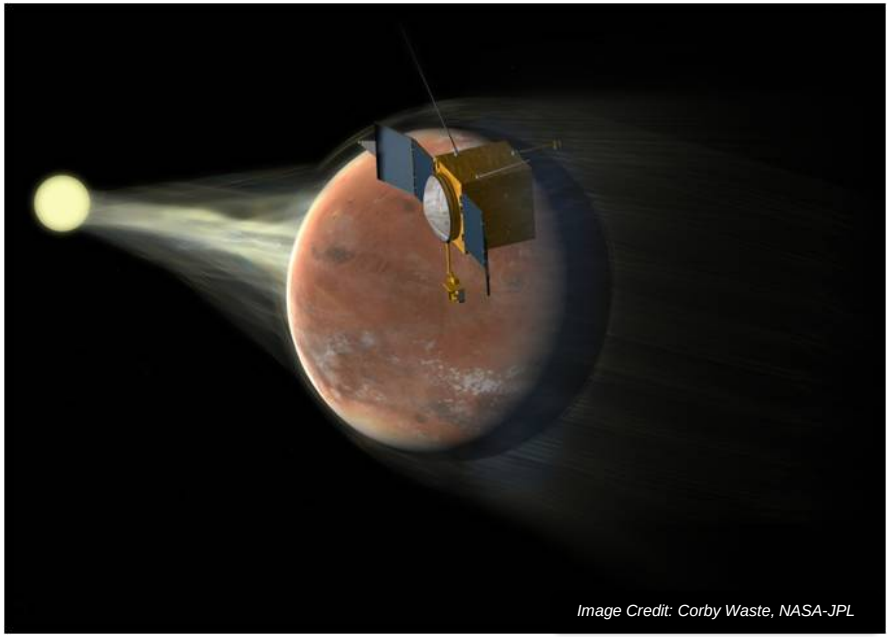
David F. Mitchell
Goddard Space Flight Center, Director of Flight Projects
MAVEN Project Manager (former)

March 16, 2016

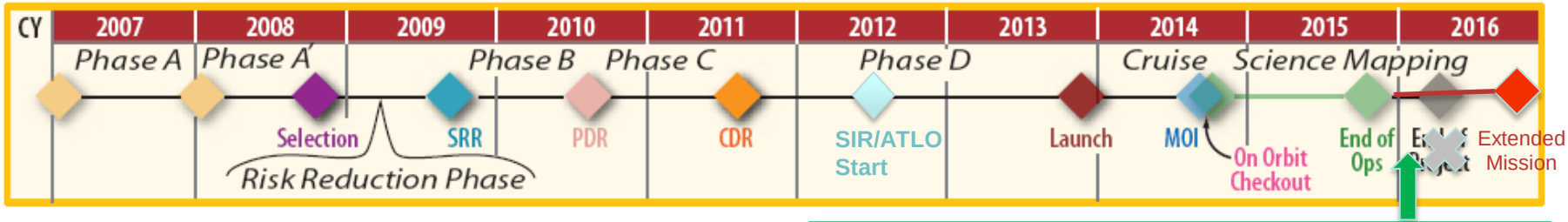
The MAVEN Project's Journey

MAVEN
Mars Atmosphere and Volatile Evolution Mission
CU/LASP • GSFC • UCB/SSL • LM • JPL

From Proposal Days…



… to Science at Mars

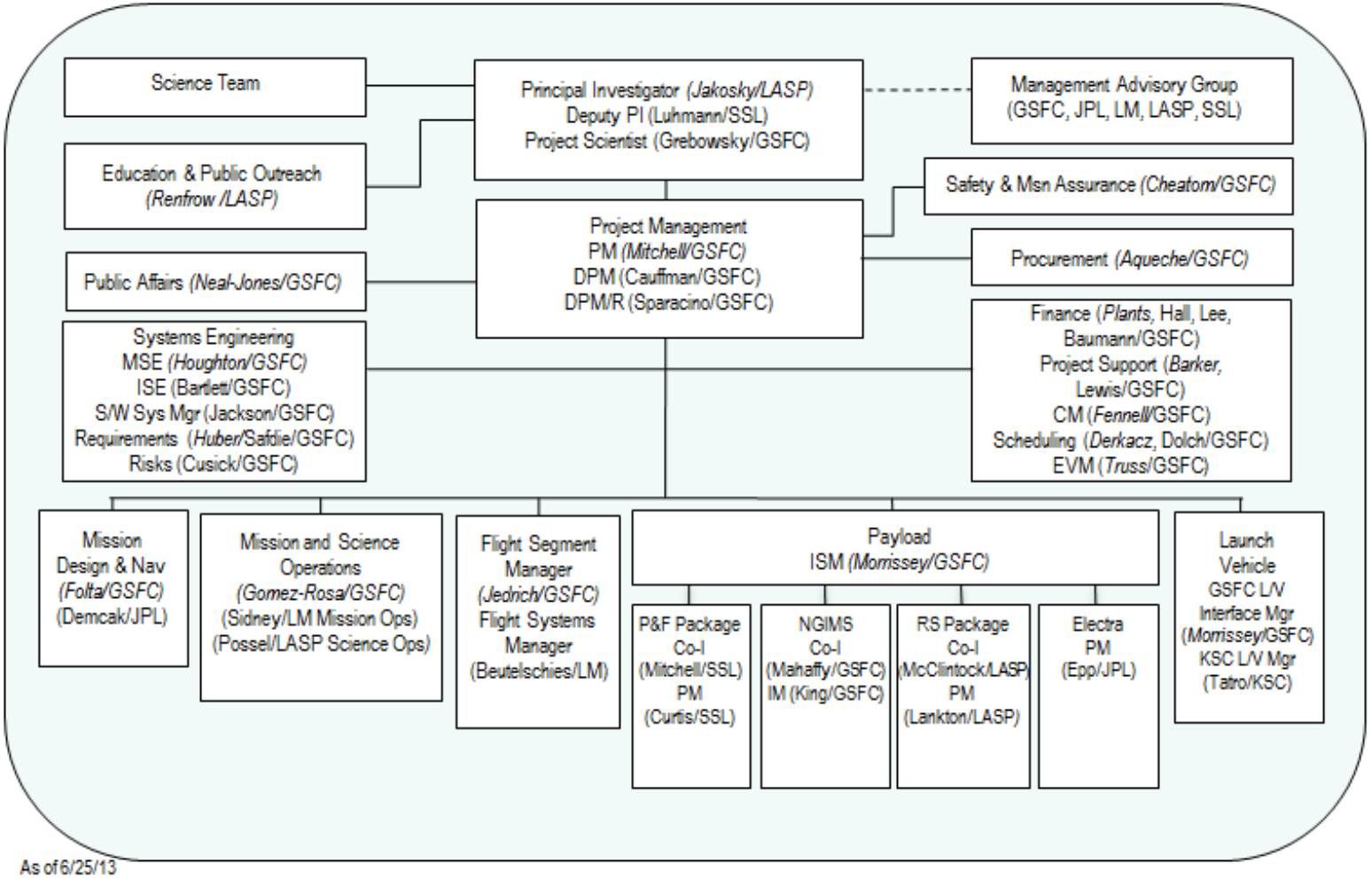


All major milestones, including launch, achieved on the schedule originally proposed in 2008 - and under budget!

Historical Perspective

- The concept which became MAVEN was hatched in 2003 by one scientist from the University of Colorado/Boulder (eventual Principal Investigator (PI)) and two scientists from the University of California/Berkeley
- The MAVEN PI asked Goddard to join the team in 2005. The MAVEN proposal was submitted in response to the NASA HQ Scout II Announcement of Opportunity (AO) in 2006
- MAVEN was one of 20 proposals Step-1 proposals. Two were selected for a more-detailed feasibility or Phase A study
- Following the competitive Phase A study, MAVEN was selected to move forward to flight in 2008
- After a 1-year “risk reduction phase”, MAVEN transitioned to a 4-year development phase for launch. MAVEN was confirmed in 2010
- MAVEN was included in the government shutdown in October 2013, less than 7 weeks from launch. Launch-preparation activities were restarted after 2 days
- MAVEN launched on November 18, 2013. This was the first day of its 3-week launch period, and it launched at the first opportunity at the start of its 2-hour firing window that day. MAVEN entered Mars orbit on September 21, 2014
- **MAVEN launched on schedule, under budget, and with the full technical capability that was intended**

Project Organization at Launch



As of 6/25/13
Leads are shown in Italics

- Project resides within GSFC's Flight Projects Directorate, Planetary Science Projects Division
- Support from GSFC internal organizations, as well as NASA HQ, Jet Propulsion Laboratory, Kennedy Space Center, and industry partners is key
- Note that MAVEN is a CU-LASP PI-led mission, with project management coming from GSFC

Major Partner Institutions

Cost Status

- MAVEN life-cycle cost (through primary mission)
  - Original AO cost cap, $475M (project-controlled costs only, including launch vehicle, FY06 dollars); “Mars Scout” mission, but same class as Discovery
  - LCC approved at confirmation was $671M (equivalent to AO cap; includes non-project-controlled costs, HQ-held reserves, tallied in real-year dollars)
  - LCC as most-recently revised, ~$603M, reflects substantial under-run
  - Science augmentation from reserves during Phase C/D, supported C/D/E activities

Project Management: Principles to Success

MAVEN
Mars Atmosphere and Volatile Evolution Mission
CU/LASP • GSFC • UCB/SSL • LM • JPL

1. Establish a clear and compelling vision
   - Create a clearly defined vision of the future that serves to inspire and motivate the project team which in turn provides an important first step in paving the road toward project success

2. Secure sustained support "from the top"
   - Develop effective working relationships with key stakeholders at all levels

3. Exercise strong leadership and management
   - Identify and develop other leaders and technical staff within the organization, define clear lines of authority and demand accountability

4. Facilitate wide open communication
   - Listen and share the good, the bad and the ugly

5. Develop a strong organization
   - Design and align culture, rewards, and structure

6. Manage risk/seek opportunities
   - Employ a continuous and evolving risk-management process
   - Look forward then exploit opportunities to reduce cost or schedule requirements through agile principles

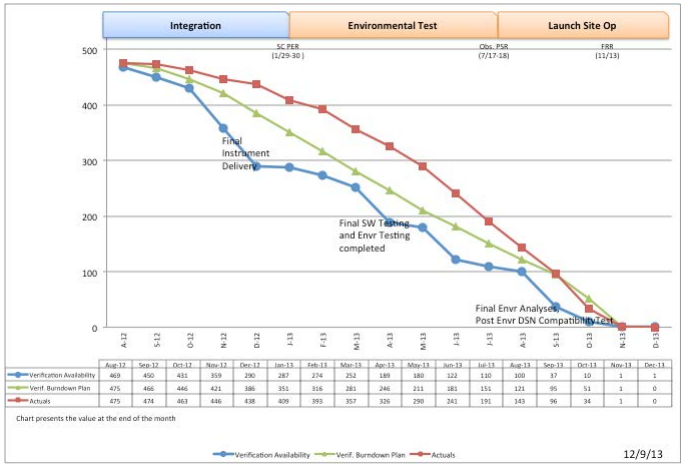
7. **Establish, maintain, and implement an executable baseline**
   - Develop clear, stable objectives/requirements from the outset; establish clean interfaces; track changes, implement corrective actions when necessary; and maintain effective configuration control

Nuggets from the MAVEN Journey

MAVEN
Mars Atmosphere and Volatile Evolution Mission
CU/LASP • GSFC • UCB/SSL • LM • JPL

- Rigorous tracking of metrics (cost, schedule, technical) is critical to keeping leadership aware of negative trends in order to react early

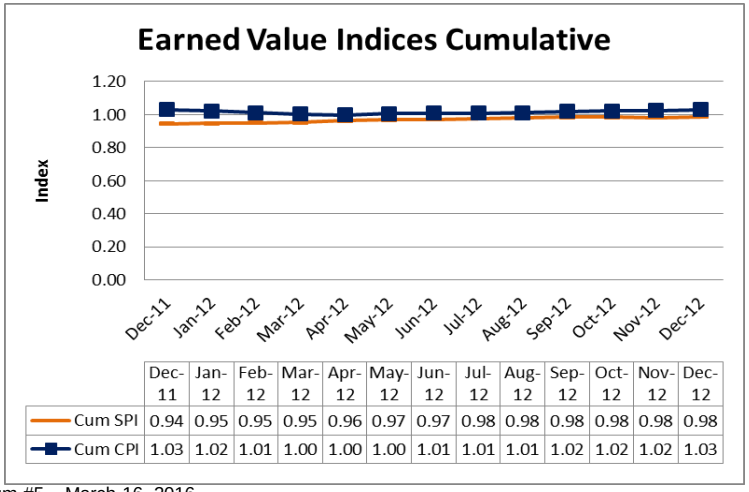
Verification Status (L1 & 2 Burndown)



1/31/13

	MAVEN Critical Milestones	Need Date
1	NGIMS FM ready for Environmental Testing (GSFC)	1/7/13
2	NGIMS Vibration Test Complete (GSFC)	2/7/13
3	Delivery of SWEA Paylaod to LM (SSL)	3/21/13
4	Deliver NGIMS Payload to LM (GSFC)	3/25/13
5	Flight TAME Controller Available to ATLO	2/1/13
6	C&DH #1 DTCI-U Flight Spare available to ATLO (LM)	2/3/13
7	Magnetics Swing Test (ATLO)	1/10/13
8	Begin S/C Modal Survey Test (ATLO)	2/4/13
9	Re-Install TAME (ATLO)	2/5/13
10	FSW Build 5.0 Available (LM)	3/18/13
11	Begin S/C Acoustics Test (ATLO)	2/8/13
12	Begin S/C Sine Vibe Test (ATLO)	2/27/13
13	Install SWEA to Spacecraft (ATLO)	3/28/13
14	Install NGIMS to Spacecraft (ATLO)	4/1/13
15	Begin ORT 1 Test (GDS)	4/17/13
16	Begin S/C EMI/EMC Test (ATLO)	4/19/13
17	S/C Self Test #7	4/25/13
18	Begin SVT/MOI (Off-Nominal) Tests (ATLO)	5/1/13
19	Lost in Time Test (LM)	5/3/13
20	Begin Thermal Vac Test (ATLO)	5/22/13
21	Power Performance Test (ATLO)	6/11/13
22	Begin ORT 2 Launch Nominal Test (GDS)	6/12/13
23	Payload Final Performance Test (ATLO)	6/21/13
24	Dry Spin Balance Test Complete (ATLO)	7/9/13

1 - Reviewing TAME PWB coupons to determine useability
2 - SWEA is diagnosing issues with high voltage discharges.SWEA was decoupled from the PFP package and to be shipped separately.
3 - DTCI Fabrication delayed
4 - EMI/EMC Test moved to accommodate NGIMS delivery
5 - FSW 5.0 delayed to accommodate additional changes



	Dec-11	Jan-12	Feb-12	Mar-12	Apr-12	May-12	Jun-12	Jul-12	Aug-12	Sep-12	Oct-12	Nov-12	Dec-12
Cum SPI	0.94	0.95	0.95	0.95	0.96	0.97	0.97	0.98	0.98	0.98	0.98	0.98	0.98
Cum CPI	1.03	1.02	1.01	1.00	1.00	1.00	1.01	1.01	1.01	1.02	1.02	1.02	1.03

Review	Review Held / Scheduled	Actions	Submitted	% Submitted	Closed	% Closed
RSS PER	4/10/12	5	5	100%	5	100%
PFP PER	5/22/12	7	7	100%	7	100%
NGIMS PER	10/15/12	2	2	100%	2	100%
Spacecraft PER	1/29/13	5	3	60%	3	60%
SIR	6/25/12	4	4	100%	4	100%
Electra HRCR (JPL Internal)	6/21/12	0	n/a	n/a	n/a	n/a
RSS PSR	10/24/12	1	1	100%	1	100%
PFP PSR	10/30/12	1	1	100%	1	100%
NGIMS PSR	TBD	TBD	-	-	-	-
Observatory PSR	7/16/13	TBD	-	-	-	-
MOS/GDS Peer Review	6/5/12	0	n/a	n/a	n/a	n/a
MOR	11/13/12	14	8	57%	6	43%
ORR/FOR	8/13/13	TBD	-	-	-	-
Totals		**39**	**31**	**79%**	**29**	**74%**

Schedule Specific Nuggets: Planning

- From Phase A, top-level schedules established key milestones (PDR, CDR, SIR, LRD, etc.) that all organizations could use for lower level planning and pricing purposes

- It is critically important to get out of the starting blocks quickly with proper project staffing. Brought the schedule lead, financial manager, and Earned Value Management (EVM) lead onboard at the beginning of the project to design a Work Breakdown Structure (WBS)-based schedule and EVM system – costs and schedule were monitored together

- Held early face-to-face meetings with organizations supplying schedule and EVM data to set expectations and assess institutional capabilities. This created a collaborative environment

Schedule Specific Nuggets: Resource-Loaded Schedules

MAVEN
Mars Atmosphere and Volatile Evolution Mission
CU/LASP • GSFC • UCB/SSL • LM • JPL

- Schedules and costs were understood, basically integrated, at the conclusion of Phase B and prior to the Integrated Baseline Review (IBR) for EVM (early in Phase C)
  - Caution: Resist pressure to develop resource-loaded schedules before plans are fully formed, as premature cost and schedule planning will create false expectations or require justifications for change to early drafts
- Integrated schedules and costs provided detailed planning and cost data by WBS
  - Project office – more accurate schedule assessments linked to cost information for use with risk assessment and budget planning
  - Product leads – ability to adjust schedule tasks if employees' hours were over-allocated or if more support was needed in certain areas
  - Facility managers (vibration tables, thermal vacuum chambers, etc.) – ability to make right resources available, in optimal schedule and quantity
- Integrated costs and schedules increased the likelihood that the project would complete **On Time and Below Cost**

Schedule Specific Nuggets: Integrated Baseline Reviews

- Early in Phase C, performed in-depth IBRs covering each major WBS cost account (e.g., spacecraft subsystem, instrument) to assess integrity of schedule and cost baseline and to examine risk
- All contracts greater than $20M were required to conduct an IBR within 6 months of confirmation. MAVEN mined this EVM tool for long-lasting benefit
  - Improved understanding by the project office and contractor counterparts of the work that lay ahead, the schedule, resource requirements and associated costs, and management tools to be used
  - Improved understanding and communication of the project's operating plans to key contractors
  - Helped to identify problem areas for early and more collaborative resolution

Schedule Specific Nuggets: Execution

- All schedules were reviewed 30, 60, and 90 days ahead
- During each shift of key integration and test events, the product lead met with the team, quality control representatives, and the scheduler to review planned and completed activities and status
- During mission integration and test (Lockheed called it ATLO, Assembly, Test and Launch Operations)
  - At the beginning and end of every shift, ATLO team reviewed the daily and hourly schedule to prepare and execute assignments
  - Daily schedule briefings were held. The team focused on tasks scheduled for the coming days and weeks. Problems were addressed, identifying workarounds to save schedule
- The project team acted with the mindset of **"schedule is king"** during every phase of the mission. The team had to, given the constrained planetary launch period

Nuggets from the MAVEN Journey

MAVEN
Mars Atmosphere and Volatile Evolution Mission
CU/LASP • GSFC • UCB/SSL • LM • JPL

- Stability of leadership through the project lifecycle is critical
- Push to get front line managers in the project office that have strong hardware development experience

- Maintain a sense of urgency throughout the project lifecycle even if your mission does not have a constrained planetary launch period. Time is money
- **Communicate, communicate, communicate** with the project office, the PI, partner institutions, program office and NASA HQ; regular face-to-face interactions are critical. You/your team have to be road warriors

- Transparency and openness with your team is critical. You want to hear about concerns early, not days before or after launch

Nuggets from the MAVEN Journey

- **Fight for sufficient cost reserves** at the outset of the mission (and sufficient up-front funding and carryout). These cost reserves will be needed to address many of the unknowns during development
  - Pressure to cut bid price during the competitive phase was rebuffed by the Principal Investigator and the Project Manager
  - Descoped two instruments shortly before final proposal submission to ensure proper reserves
  - Execution is much more efficient when the project remains green throughout development rather than going yellow or red

- **Resist requirements creep**, both in the science and engineering areas
  - A solid mission was proposed and we stuck to it even under pressure from various corners (e.g., add a camera, add a student instrument, add a “free” foreign instrument)

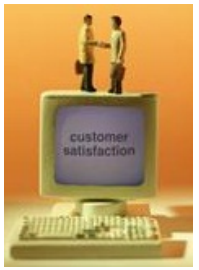
Nuggets from the MAVEN Journey

MAVEN
Mars Atmosphere and Volatile Evolution Mission
CU/LASP • GSFC • UCB/SSL • LM • JPL

- Transition into Phase CDE of a project is a large effort. For a planetary project, any loss of schedule is critical. In an effort to expedite the CDE proposal process, the spacecraft contractor opened the lower level internal subsystem reviews to the Project prior to submittal of the Phase CDE proposal. The result was a delivered proposal that contained no surprises

- Negotiate partner institution Phase C-E contracts before the Confirmation Review - MAVEN retired a significant cost growth risk and bounded the overall scope of effort

- The spacecraft contractor and Project Office personnel traveled extensively together to kickoff meetings at vendor facilities. These meetings set expectations on how we wanted the vendors to operate



- Heritage systems help but just as importantly you need the matching "heritage people" building the hardware (this isn't always possible)
  - In one case, a technician who built circuit boards for previous instruments retired and the replacement tech did not implement the correct high-voltage workmanship techniques because they hadn't been documented

Nuggets from the MAVEN Journey

- Spending money early to retire risk significantly reduced late surprises and overruns

- There was a large amount of interest from external parties that impacted "normal" work. **Be prepared for significant data requests, questions, audits.** Staff accordingly

- Brought the Joint Cost/Schedule Confidence Level (JCL) independent review team into the mix with the Project 6 months before the Preliminary Design Review (PDR). This was significant in relieving any disconnects in the run up to Mission PDR and Confirmation Review

Nuggets from the MAVEN Journey

- **The first lesson in planning is that you can't plan for everything.** We encountered plenty of issues on MAVEN that required us to assess the impacts and move forward with Plan B. Surprises along the way:
  - Two instruments were delivered months late, during the year of launch
  - Application of a new material in a heritage system (MetGlas) and impacts in I&T. Must fully evaluate new materials and their application prior to use
  - Sequestration, with imposition of a travel cap in FY12 that threatened MAVEN's approach to conducting business
  - FY14 furlough beginning 7 weeks before scheduled launch and how we preserved MAVEN's full launch period
  - Removal of an instrument at the launch site for rework back at Goddard (the "Cannot Duplicate Problem" that surfaced again during launch preparations at KSC, and forced a late, tough decision)
  - Comet Siding Spring – truly an "unknown unknown" when we bid the mission in 2008. This comet was discovered in January 2013 and drove a significant amount of analysis and mitigation planning and implementation for the October 2014 encounter
- Find opportunities to team build at frequent intervals and schedule in lessons learned opportunities during every phase of development

Want to follow MAVEN at Mars?

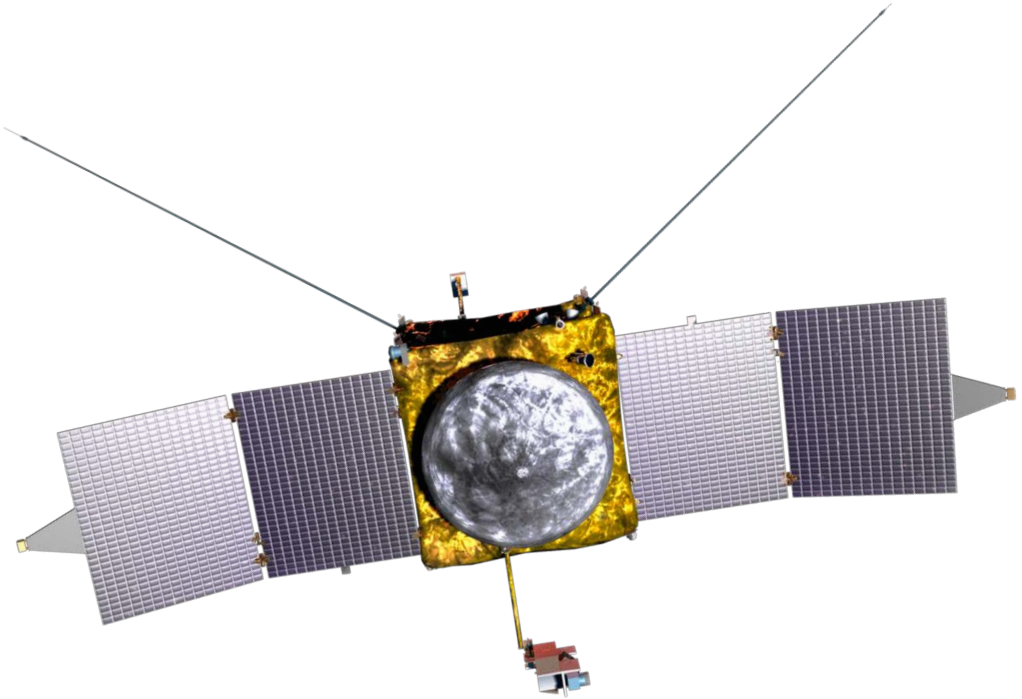
MAVEN
Mars Atmosphere and Volatile Evolution Mission
CU/LASP • GSFC • UCB/SSL • LM • JPL

We're on Facebook and Twitter: MAVEN2MARS

and on the web:

http://www.nasa.gov/maven

http://lasp.colorado.edu/maven




It is difficult to say what is impossible...
for the dream of YESTERDAY
is the hope of TODAY
and the reality of
TOMORROW.
- Robert H. Goddard (1882 - 1945)