MAVEN

Development and Implementation of the MAVEN Mission: PI Lessons Learned

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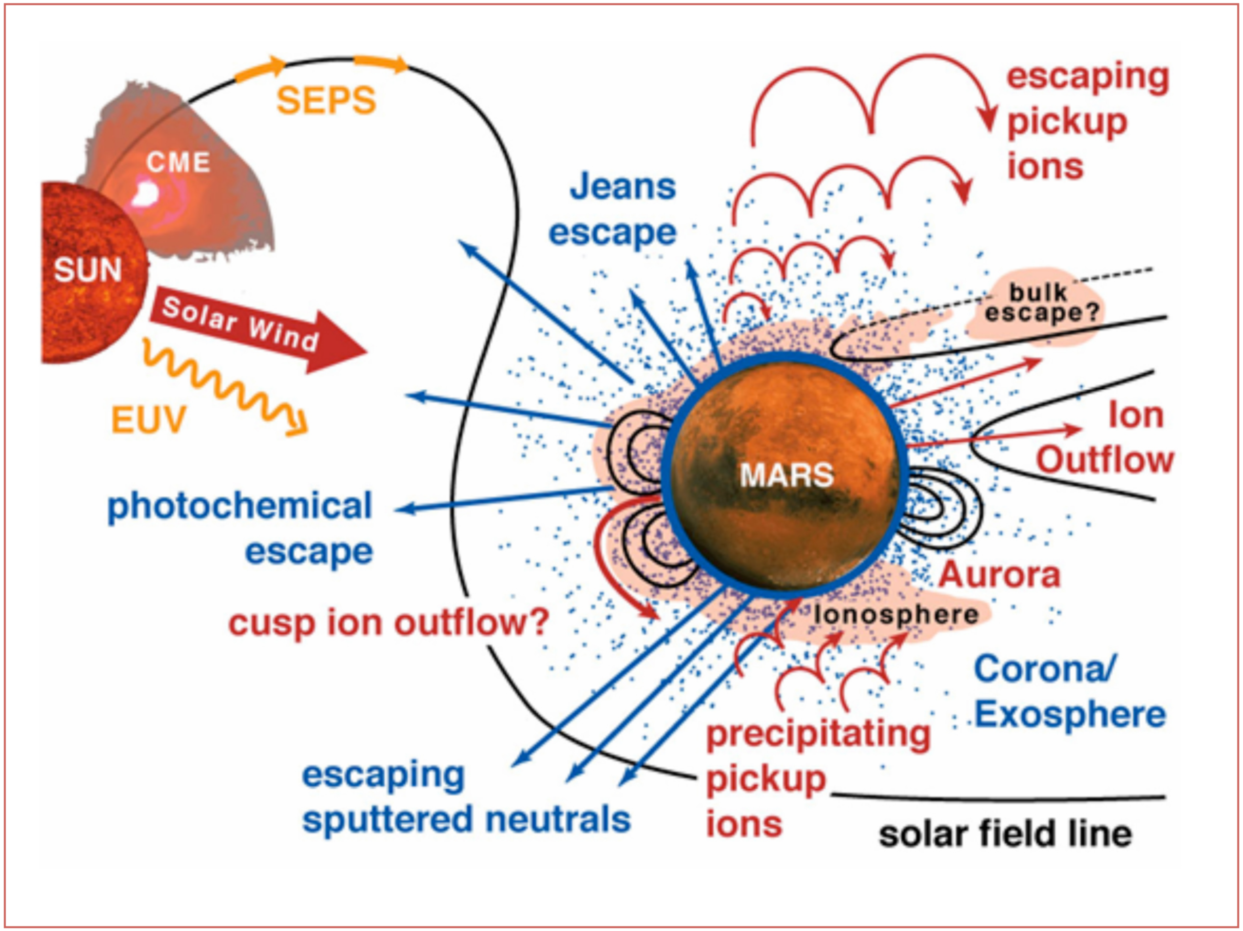
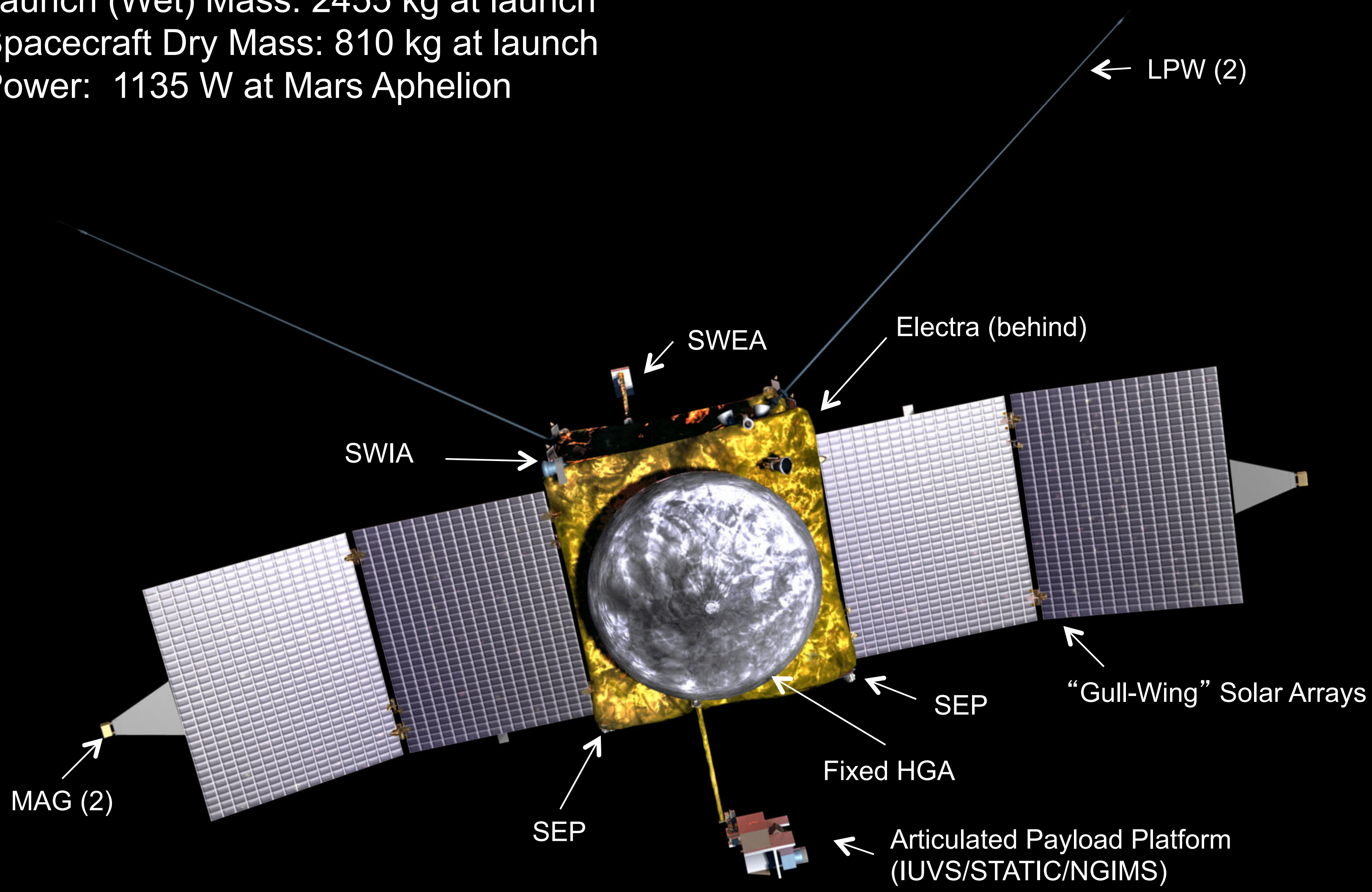
MAVEN Will Allow Us to Understand Escape of Atmospheric Gases to Space

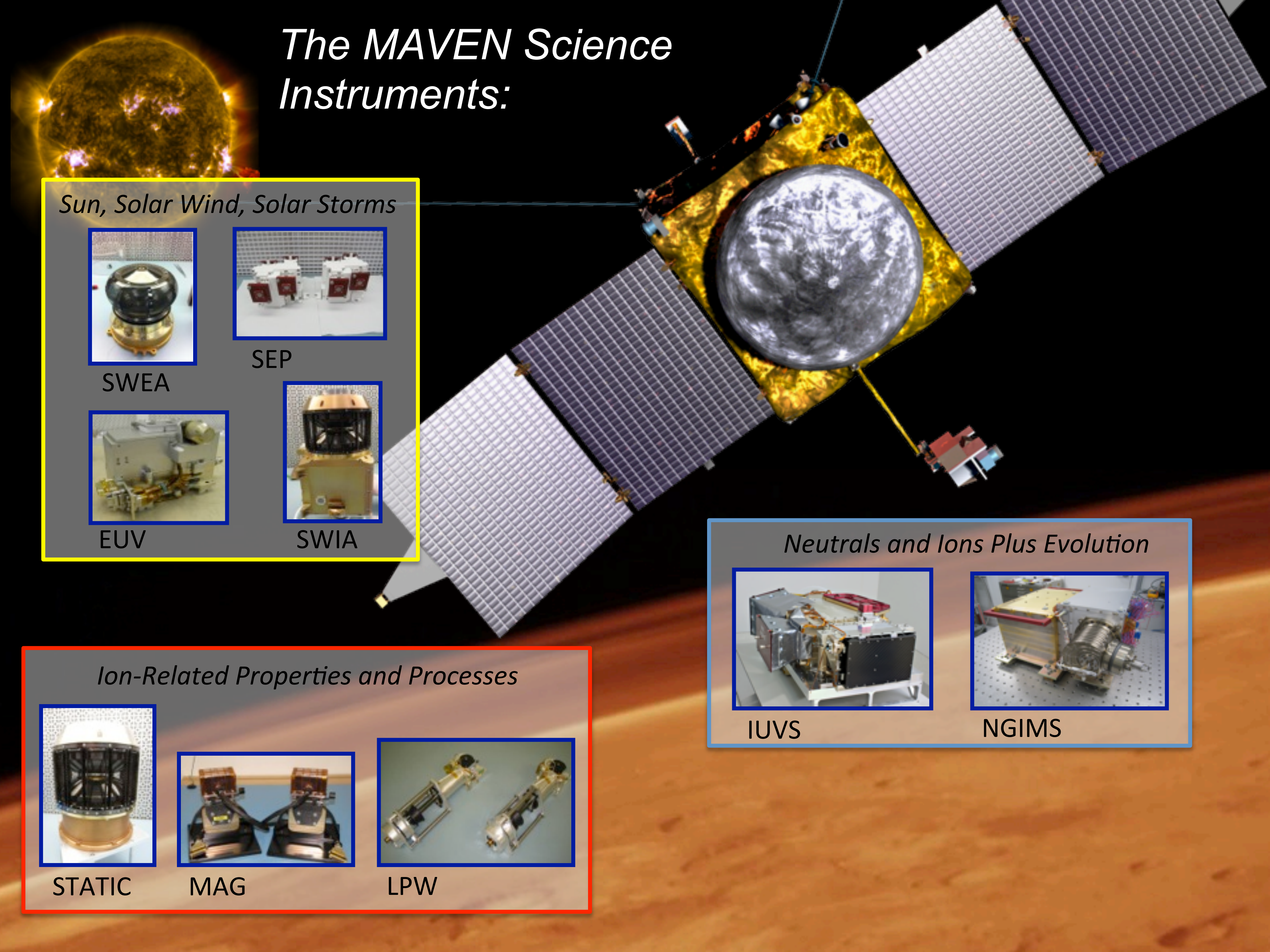


- Measure energetic drivers from the Sun, response of upper atmosphere and ionosphere, and resulting escape to space
- Understand the key processes involved, allowing extrapolation to loss over Mars history

The MAVEN Spacecraft

- Launch (Wet) Mass: 2455 kg at launch
- Spacecraft Dry Mass: 810 kg at launch
- Power: 1135 W at Mars Aphelion

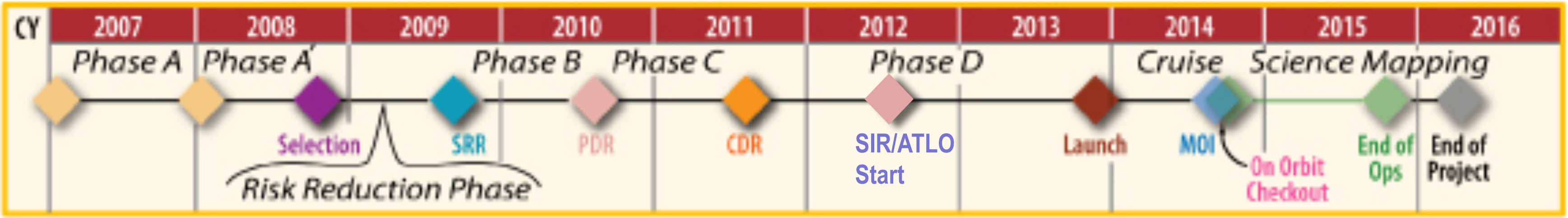




The MAVEN Science Instruments:
Sun, Solar Wind, Solar Storms
SWEA
SEP
EUV
SWIA
Neutrals and Ions Plus Evolution
IUVS
NGIMS
Ion-Related Properties and Processes
STATIC
MAG
LPW

MAVEN Cost And Schedule

- MAVEN key milestones
  - Step-1 proposal submission, August 2006
  - Selection for competitive Step-2/Phase A, January 2007
  - Selection for development for flight, September 2008
  - Launch, November 2013; Mars Orbit Insertion, September 2014
  - End of primary mission operations, November 2015
  - Original "End of project" (end of data analysis and archiving through primary mission), April 2016
- 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



Science Has To Be The Driver

- There's incredible pressure from all corners on major decisions that can/will drive the project:
  - Pressure to fly a particular instrument
  - Competitive pressure and desire to win the program at any cost
  - Need for institutions to win the program to stay solvent
  - Different perspectives within the team on the science to be carried out
- Decisions have to balance multiple factors
  - Science
  - Technical risk
  - Cost and schedule
- Ultimately, you're flying a science mission, and you have to stay true to the science
- Examples
  - Decision not to descope to "minimum acceptable mission" late in Phase A in order to be more cost competitive
  - Decision to descope an instrument from my own institution and to descope my lab director
  - Decision to not add camera that would have enhanced perceived value while not contributing substantially to MAVEN science

Balance More Science Against Cost/Schedule/Risk

- You can always enhance science by
  - Adding or enhancing an instrument
  - Increasing scope or duration of mission
  - Augmenting other factors
- These types of enhancements *will* increase cost or risk
- You have to balance the increase in science against the increase in cost/risk
- NASA HQ is perceived as being inconsistent on this issue – they often are seen as selecting the most science, but they don't want to risk cost overruns
- Examples
  - Decision in Phase A to descope two instruments, delete one year of science ops, and cut two data-analysis Co-Is in order to maintain reserves
  - Decision not to add "free" foreign instrument that would have enhanced science but at expense of cost and risk
  - Real value in identifying a mission in our original proposal that was within scope of available resources and then doing what it takes to stay there; balance against perception that we could have done more science
  - Comment from Associate Administrator about "just don't overrun the budget".

PI Is The Only One Looking Across Entire Mission

- Project Manager and his staff really understand the engineering, but are not experts in the science; this is especially the case early in development (Phase A, B), when many key decisions are made
- Engineering decisions can ripple back to science in subtle ways
- PI (or his/her designee) is the only person who looks across entire project and understands the potential impact of decisions on science
  - Includes obvious issue of technical impact that can affect science results
  - Also includes more-subtle issues of cost and schedule impact that can reduce ability to respond to later problems elsewhere
  - Requires strong presence of PI or of other science representation in all aspects of the project
- Examples
  - We descoped instruments that were not having any problems in and of themselves to address reserves issue in Phase A, because they were the most cost-effective descopes (dollar savings versus science lost)
  - We simplified planned instrument ops very early by negotiation between PI and s/c ops lead, in a way that had essentially no impact on science; ability to do this with only a small impact on science was not obvious to the engineering/ops team and was facilitated by discussion between only two people

Beware Of Changing Requirements

- Changes in requirements in mid-stream
  - Requirements changes of any kind increase cost – work that needs to be done over, impact on schedule, retesting, etc.
- Science/engineering creep
  - Adding instrument or changing instrument design
  - Changing observing sequences
- Dance with the partner you brought to the dance
- Examples
  - Change that could have been implemented in comm system to increase data rate; we kept the data rate at values originally proposed (doing this made a strong statement to the team on resource allocation and requirements creep)
  - Decision to not implement a change in our “zone alerts” in response to an RFA (Request for Action) from the Standing Review Board; it might have been easier to implement than to fight, but we deemed it unnecessary and pushed back
  - Balance this against changes that truly are necessary – such as decision to switch from Delta II (which we really had outgrown) to EELV (Atlas V) during Phase A.

Value Of Working Closely With The PM

- PI and PM need to be working together
  - Can’t try to exert different philosophies on the team or provide contradictory direction
  - PI is not the PM; each has a different job, although they are inextricably intertwined
- Examples
  - PM really runs the day-to-day operations during development. As PI, my largest regular interaction was with the PM
  - PM (and DPM) felt free to argue with me on issues (usually in private); that went both ways

Ask Us Over a Drink About Stories Related To:

- “Do over” on Phase A due to conflict of interest identified during CSR review
- Government shut-down seven weeks before launch
- Major unknown risk from the Comet Siding Spring close approach to Mars (and MAVEN) four weeks after spacecraft arrival at Mars

Perspective On Being P.I.

- The PI is the only person who watches across the entire project, including science
- PI has ultimate responsibility for balancing cost, risk, schedule, and science; you can always increase science at the expense of the other factors, but this is a dangerous path
- There is no single approach to defining the PI role; each PI has to invent it from scratch. I had to figure out for myself what role I should play during each new phase of the project, and it has changed again (not gotten easier) during Phase E
- Being PI has dominated my life for more than a decade, in ways I could never have imagined
- One colleague told me that a flight project is like a marathon and you can't treat it as a series of 100-m dashes; at the same time, you have to do exactly that in order to hit each milestone as it comes up

P.I. Lessons Learned

- The mission has to be driven by the science goals, and has to address fundamental science.
- Getting selected for Phase A is largely about combination of science and technical implementation. Getting selected for flight is about low risk (cost, schedule, technical, science).
- Good communications is absolutely essential; this requires in-person interactions (i.e., lots of travel)
- Real heritage and absence of technology development are valuable in keeping cost risk down
- Resist requirements creep, on both science and engineering – it will drive up cost and have a major hit on schedule; if you have a good mission to begin with, go with it.
- Being able to define and implement a space mission is an incredible responsibility and commitment, but it's also an incredible opportunity!