3RD SPACE EXPLORATION CONFERENCE & EXHIBIT

Looking for Lunar Water on a Budget

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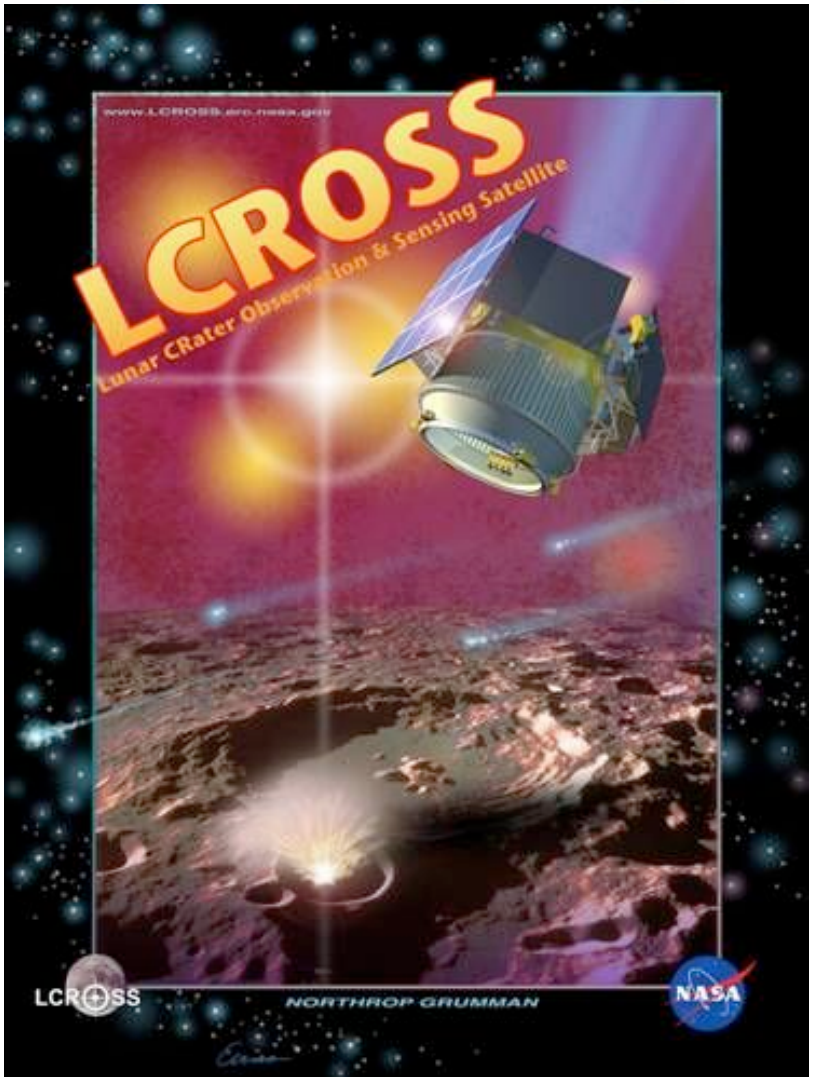
LCROSS: A Mission of Opportunity

- When LRO moved from a Delta-II rocket to an Atlas-V, 1000Kg of up-mass became available
- In January, 2006, ESMD announced a “small secondary payload” opportunity to be launched with LRO in 2008
  - *“Given schedule & cost constraints, NASA encourages concepts that have history and heritage… concepts that leverage existing hardware, have high TRL components or that are well studied and documented will be more attractive than concepts that do not”*
- In April, 2006, ESMD selected LCROSS from (19) proposals!

It's about the water…

If permanently-shadowed lunar polar craters contain water ice in sufficient quantities, it could be converted to rocket fuel and breathable oxygen, making possible a lunar base for returning astronauts



The LCROSS Mission Recipe

Step 1: Hitch a ride to the Moon

(Thanks LRO)

Step 2: Part with LRO, *but hang onto that rocket!*

(we'll use it later)

Step 3: Tug it around the earth

Step 4: Point it toward our crater

Step 5: Let go!

Step 6: Slow-down & watch what kicks-up

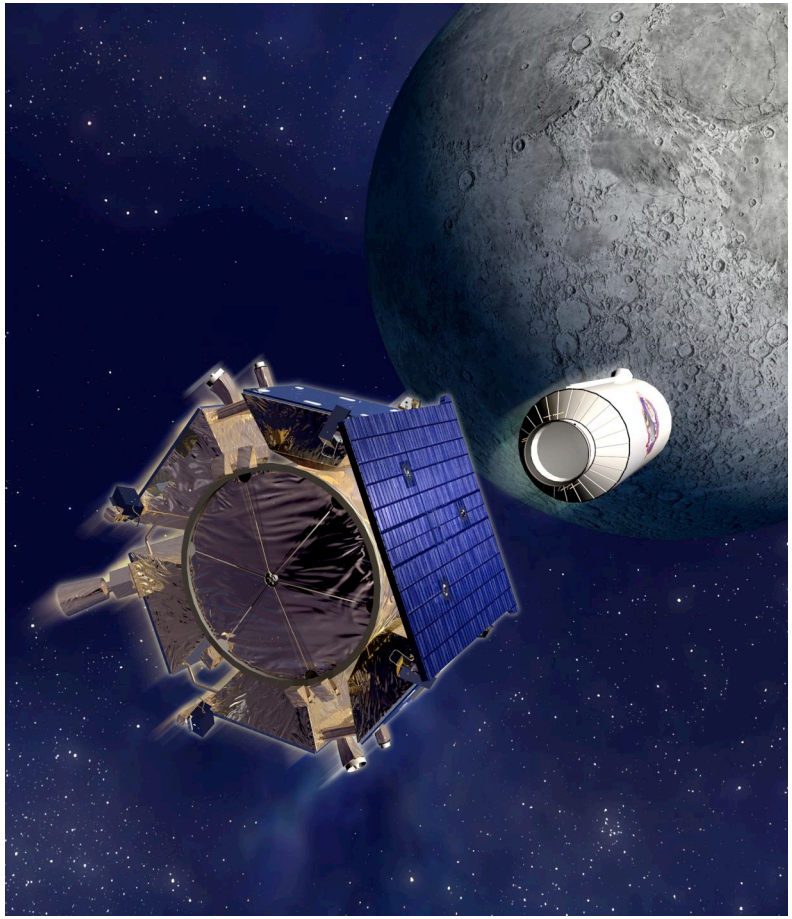
Step 7: Send pics & data back to Earth

Step 8: Say good-bye

(Taste regolith!)

OK. But there's some fine print…

- We have to fit within 1000Kg wet mass…
- We have to design and build the spacecraft in only 30 months!
- We have a cost-cap of $79M, including reserves…
- … and we can't levy any requirements on LRO…

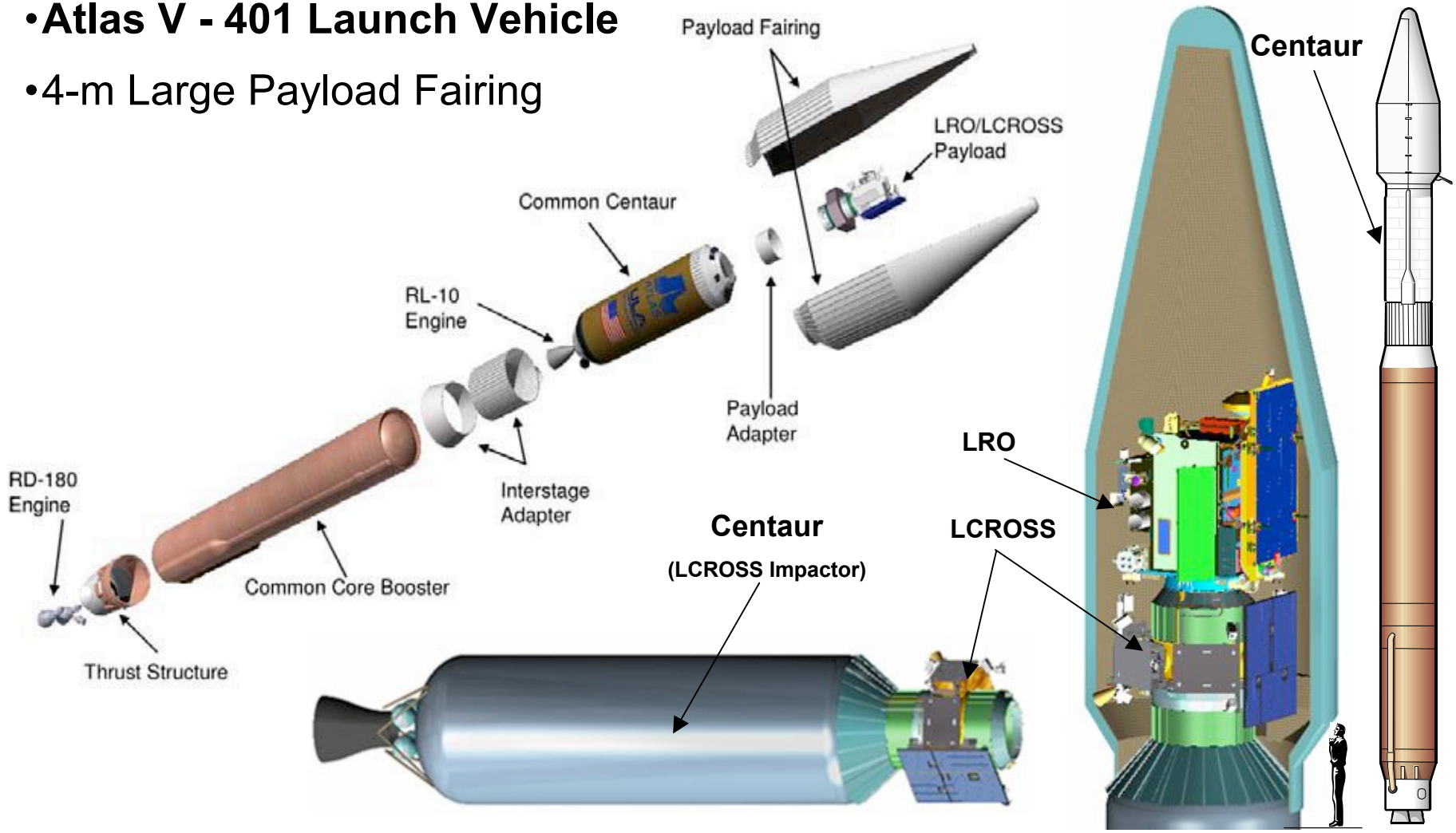


- But, the good news is that we are <u>Class D mission</u> (per NPR 8705.4) which states, *"Medium or significant risk of not achieving mission success is permitted."*

- ***… of course every mission is Class A on launch day***

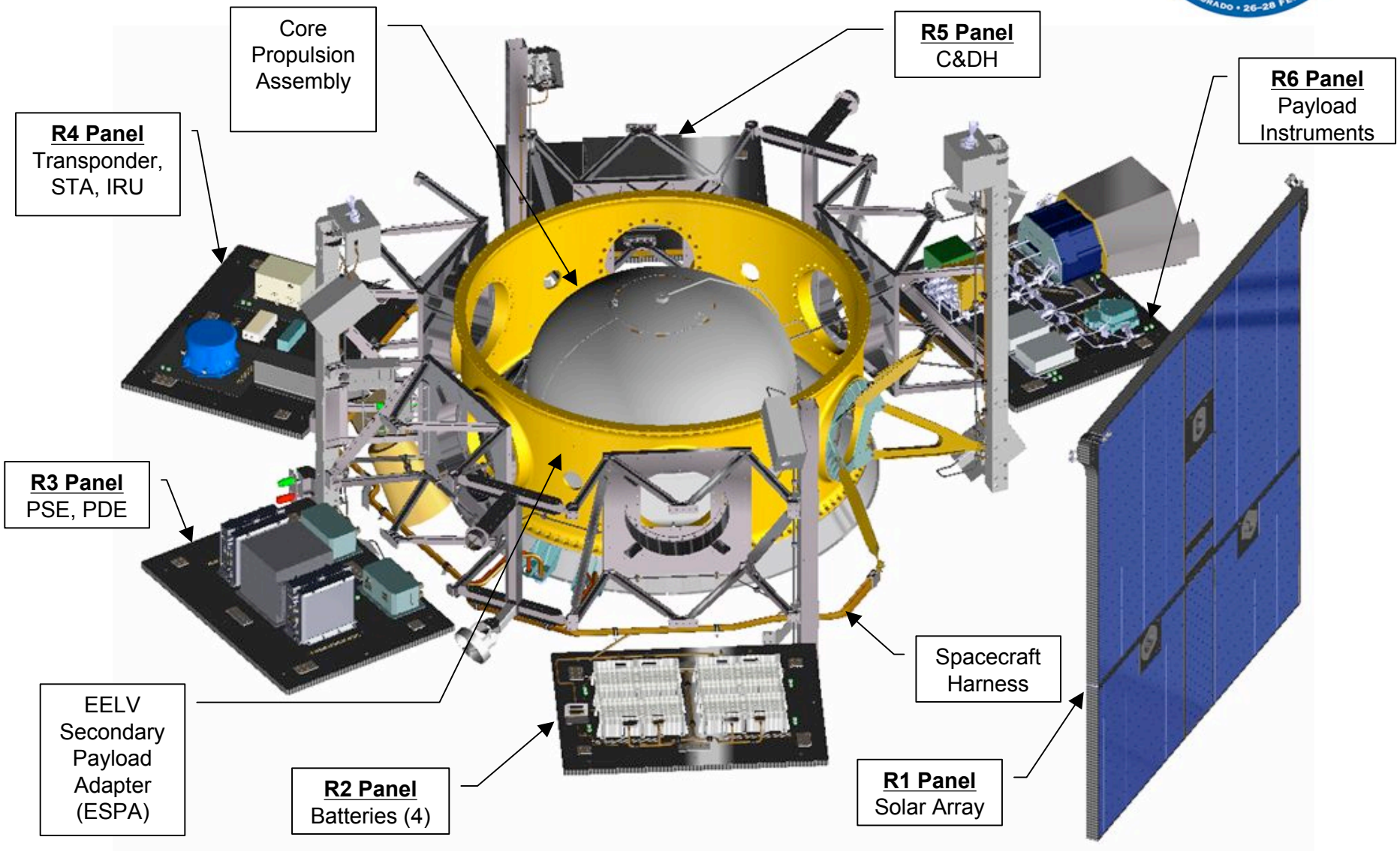
The Launch Stack

- **Atlas V - 401 Launch Vehicle**
- 4-m Large Payload Fairing



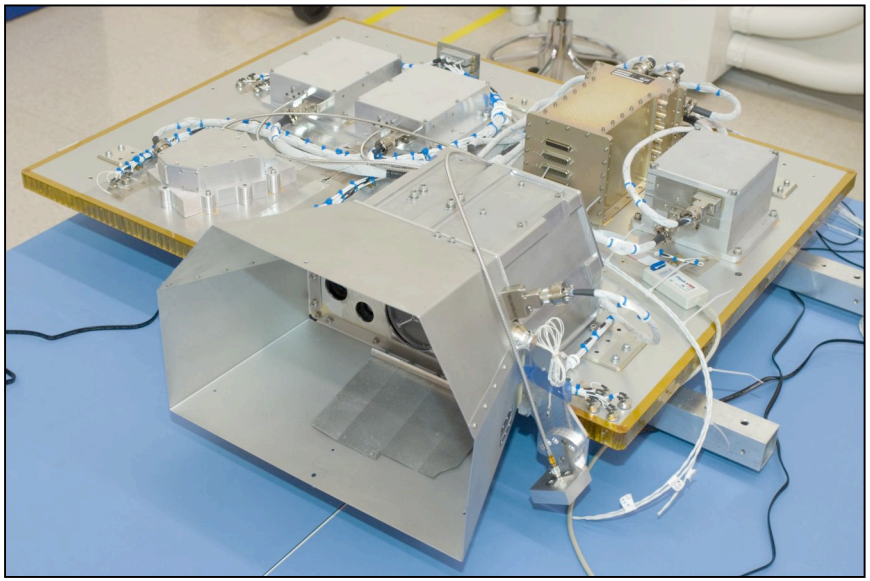
Atlas V 401

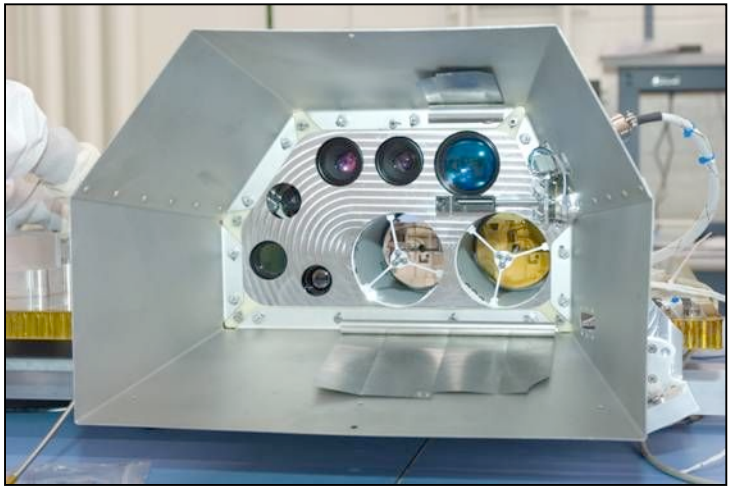
The Spacecraft



The Payload Instruments

- The Instruments:
  - (9) instruments make-up a robust measurement suite
    - Near & Mid IR spectrometry
    - IR & Visible cameras
- The Purpose:
  - Water-ice / Water-vapor detection & concentration
  - Ejecta grain properties
  - Crater and general imagery
- The Heritage:
  - Proven, existing instruments
    - Spaceflight / Space-proven
    - Military / Airborne applications
    - Ocean Floor exploration
    - Industrial monitoring applications
    - Motor sports applications





The Project Team

NASA-Ames:
- Project Management
- Systems Engineering
- Risk Management
- S&MA
- Mission Science
- Mission Design (Lead)
- Payload Development, Integration & Test
- Mission Operations
- Science Operations
- Launch Site Lead

Northrop-Grumman:
- Spacecraft Design, Development, Integration & Test
- Avionics Build, Integration & Test
- Flight Software
- Launch Site Integration Support
- Mission Operations Technical (Back Room) Support

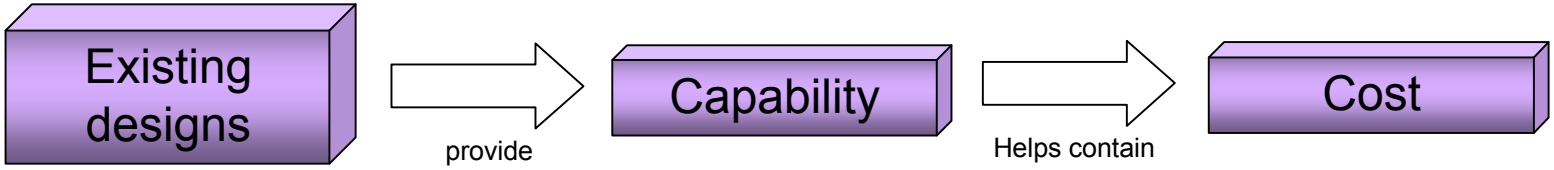
JPL:
- Mission Design – Navigation & Orbit Determination
- DSN

GSFC:
- Mission Design – Flight Dynamics
- LRO Interactions

KSC / ULA:
- Launch Services
- Atlas V - 401

How will LCROSS fit in the box?

- The LCROSS Mission is a Capability-driven, Design-to-Cost project [1]
  - "Capability-driven" = cost and schedule constrained

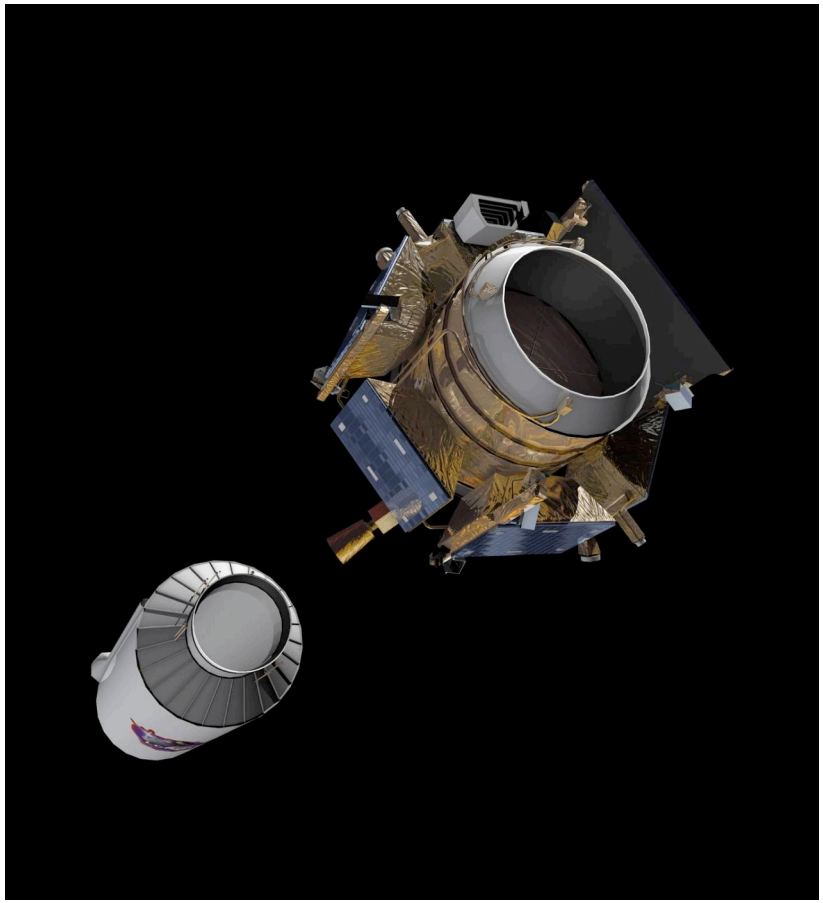


- *Ideal* Capability-driven projects require few modifications
- *Real* Capability-driven projects:
  - Need some modifications, leading to some uncertainty, and requiring reserves
  - Cost containment requires de-scope alternatives and willingness to accept higher risk

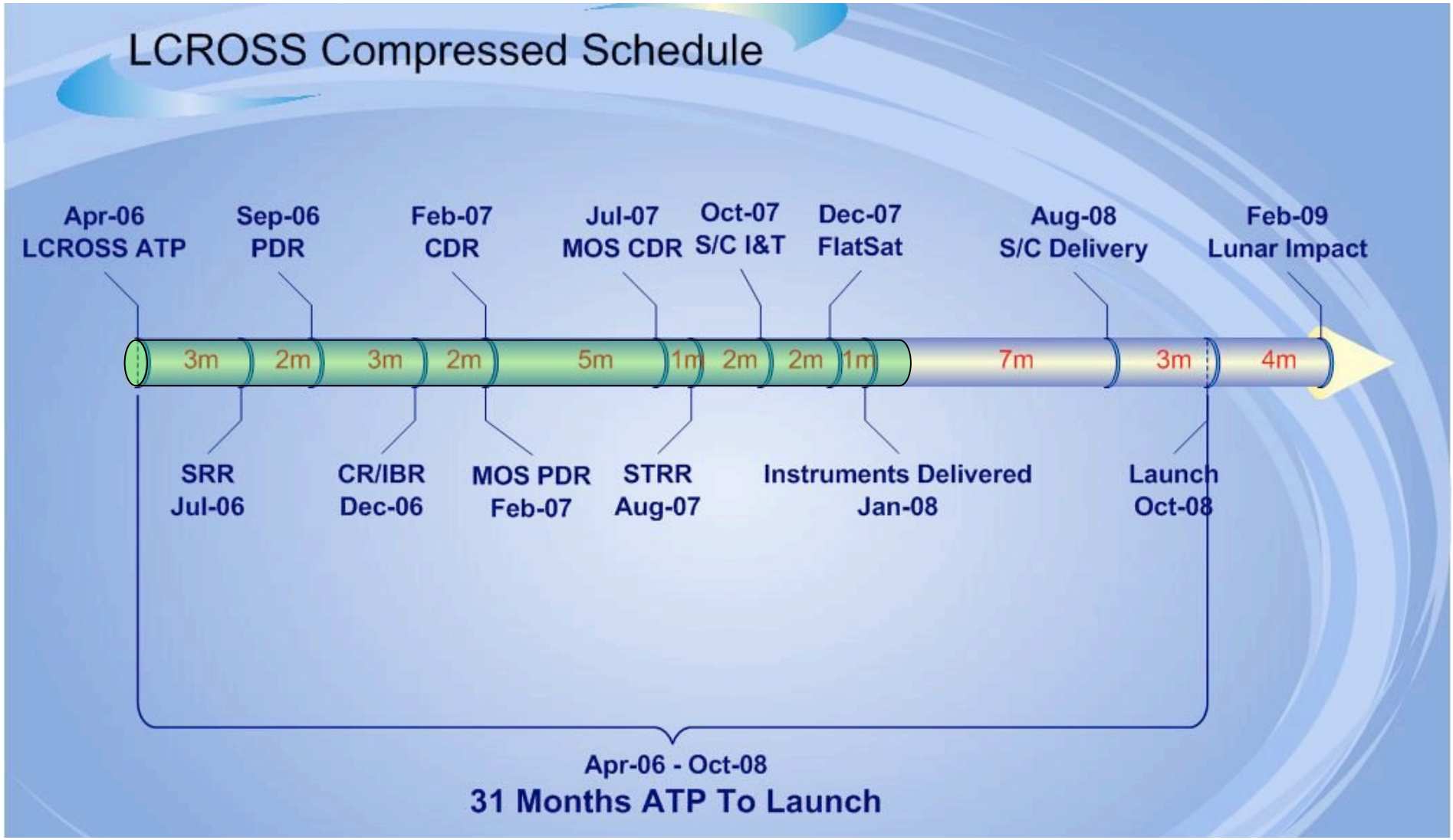
[1] "How to Plan and Manage Reserves Effectively", Kenneth Atkins, JPL
2004 IEEE Aerospace Conference Proceedings

LCROSS: A *Real* Capability-driven Project

- LCROSS trying to remain a “glue” mission – one which integrates (glues) existing hardware together into a working S/C system
  - LCROSS is leveraging the LRO avionics design, acquisition, and V&V of those components
  - LCROSS is acquiring flight-proven or ruggedized COTS payload instruments
  - LCROSS S/C is a low-complexity S/C, designed around a fundamentally simple bus-structure: The ESPA ring
  - LCROSS utilizes flight HW proven on other missions (star tracker, transponder, MIMU, CSS, batteries, antennae, thrusters, prop tank, etc)



The LCROSS Schedule

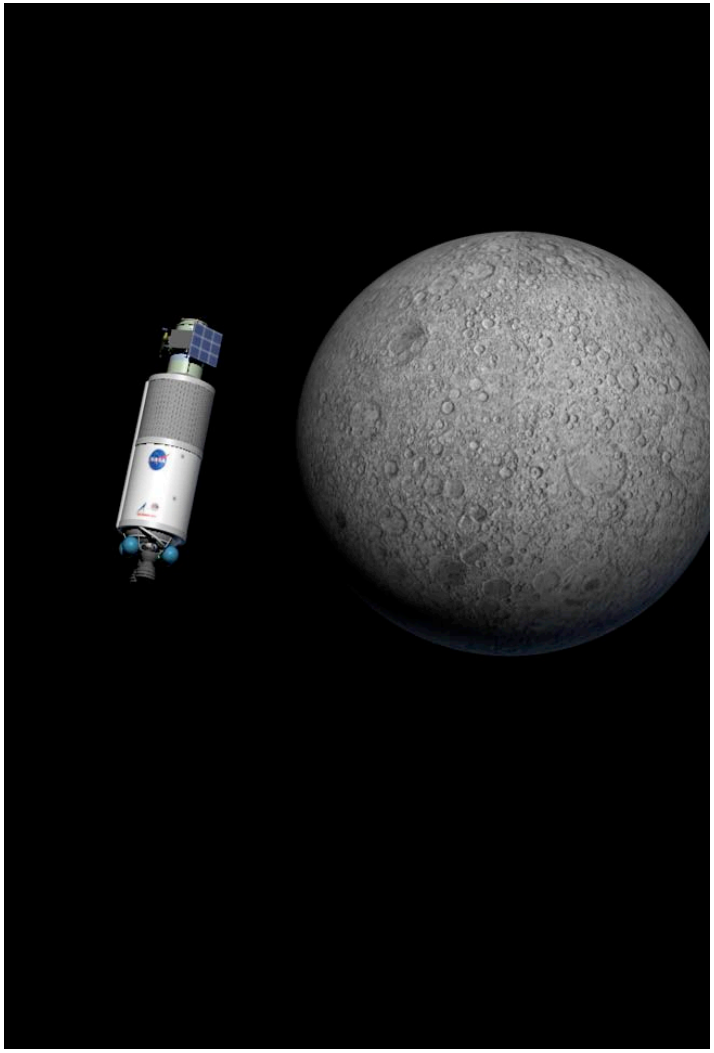


So How Does LCROSS Handle Risk?

- **LCROSS cannot afford to *avoid/eliminate* risk – it is too costly**
  - Risk is managed as a resource, like schedule slack, cost reserves, or technical margin
- **Real partnering between NASA and Northrop-Grumman**
  - Establish common ground; What does success mean to each?
- **Get through design phase swiftly**
  - To keep risk in check, keep the design simple (Design-to-cost)
- **Made extensive use of commercial components for payload instruments**
  - Resist temptation of levying "improvement" requirements - it costs money and time
- **Employ affordable "acceptance" test program and margins**
  - Minimal testing in TC, vibe, and TV checks for design robustness and workmanship
- **Minimize use of Engineering Test Units (ETUs)**
  - *Although having them enables improved schedule reflowing possibilities*
- **Make use of Contractor best practices**
  - Moving an accomplished contractor off their standard processes grows cost/time

Some Project Approaches

- As a Class D mission, LCROSS can tolerate elevated risk levels, but this still requires understanding our risk position
- LCROSS has established a culture of risk understanding and management
  - Technical people *do consider programmatics* in their reasoning
  - Programmatic people *do consider technical issues* in their reasoning
  - While ITAs exist for a purpose, having everyone operate on the cost/schedule/technical plane, makes for fast & effective solutions to problems
- LCROSS tries to apply an even-handed sensibility to risk-based decisions
  - It's too easy to get lost in driving-down risk by way of additional testing or analysis
  - We try to think holistically about risk, evaluating each risk against other systemic risks to help decide when residual risk should be accepted



Opportunity: The Flipside of Risk

- LCROSS has been "opportunistic" when confronting risk or issues
  - There have been many cases where a problem/issue was turned-into an opportunity for the team

Issue: Upon discovery that the 1553 bus could not handle the required payload instrument data rates, the Payload team was confronted with creating a "black-box" to process all the payload instrument signals

Opportunity: Have all instruments work to RS-422, and use the existing Ecliptic DHU to process not just the vis cams, *but all instruments*

Result: We have a cleaner instrument interface, requiring fewer vendor mods (most can handle RS-422), and is already flight proven

Issue: The LRO S/C thruster projects into the LCROSS adapter volume indeterminately, holding-up the critical design layout for the LCROSS instrument tripod within that volume

Opportunity: Move instruments off the tripod within the adapter, and place on panel R6, collocated with instrument electronics

Result: This not only allowed the LCROSS design to move forward, but ended-up being a simpler design, requiring fewer HW elements, less installation labor, and overall lower residual risk due to simplicity

Closing Thoughts…

- Missions like LCROSS should not be considered as stand-alone, but as part of a portfolio.
  - A handful of risk-tolerant, cheaper missions, can tolerate some failures while still returning more mission for the dollar
  - The mission of LCROSS is proving to be so engaging and interesting to the public, that its Class D construct is challenging for the stakeholders

- The importance of the good working relationship between the LRO Project and the LCROSS Project cannot be understated
  - LRO and LCROSS have shared mutual discoveries and resolutions, benefiting both Projects
  - NASA wins by getting more mission "bang for the [invested] buck"

- **LCROSS is currently carrying about a calendar month of schedule slack, and 20+% reserve on cost-to-go…**

LCROSS will be a smashing success !

(http://lcross.arc.nasa.gov/)