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"Free Launch with Manageable Risk: Challenges of Integrating Dual Spacecraft"

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Background

- In 2006 a new type of launch opportunity became available for the Exploration Systems Mission Directorate (ESMD)
- When the Lunar Reconnaissance Orbiter (LRO) was re-manifested from a Delta II to an EELV class vehicle, approximately 1450 kg of flight lift mass performance became available
- ESMD recognized a quick opportunity to take advantage of this windfall to advertise, evaluate, and select an secondary mission for Lunar exploration



Background Cont.

- The mission selected, the Lunar Crater Observation and Sensing Satellite (LCROSS), chose to include the spent second stage rocket body as 2/3 of their spacecraft mass and take that element into uncharted territory
- LCROSS designated a Class D risk category
- This is a view of the launch integration process from the rocket side of the interface



Past Experience

- Two separate spacecraft – DPAF
 - Calipso/Cloudsat
 - Jason/Timed
- Typical Secondaries
 - Small less than 100kg side hangers
- Multiple spacecraft
 - Themis – built and integrated as a “single” spacecraft (5)
- Multiple in line separate spacecraft
 - None



Procurement of a “Secondary” Spacecraft

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- Since the launch date for LRO was set and the LRO spacecraft was already in development and launch vehicle selection underway, the launch integration timeline became very constrained for a new mission



Procurement Phase - Mission

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- Same program runs both projects within ESMD
- Quick decision to go forth and do this
- AO issued and responses due back quickly
- Knowledgeable people doing dedicated quick turnaround work in same location
- Checks and balances
- Teamwork
- Sticking to process
- After downselects and orals, the LCROSS mission was selected and rapidly approved by HQ and turned on



Procurement Phase - LV

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- Since the LV procurement was already underway, an addendum was added to the RFP
- It was decided that instead of re-starting, the new mission would be added as a full mission unique to the LRO procurement and deemed a LRO secondary
- Rebids were quickly received and evaluated and selection made and approved and given authority to proceed



The Mission

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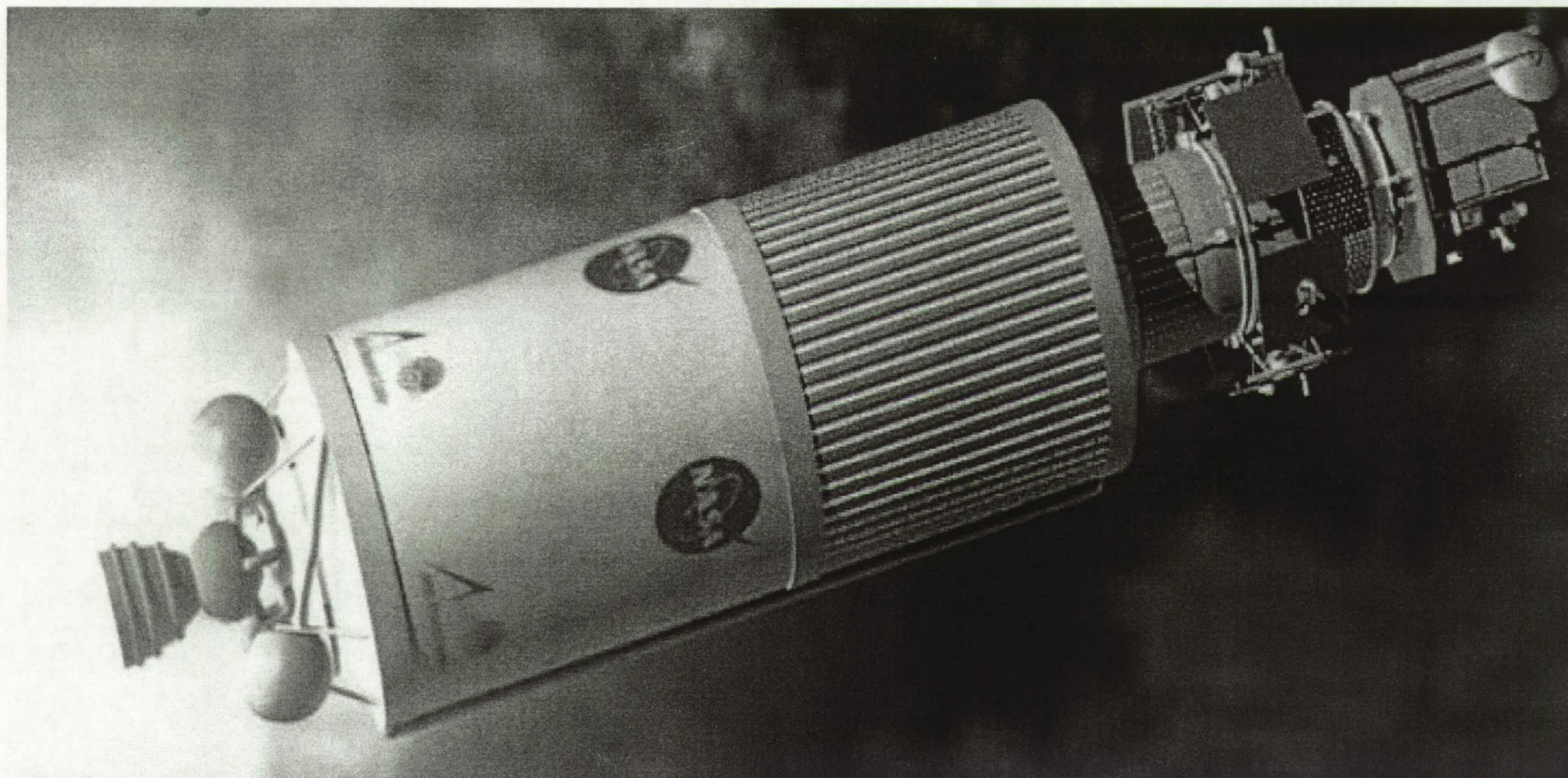
- LRO will be launched on a Lunar arrival trajectory and separated to go into orbit, perform checkout, and it's primary mission (1 year)
- The LV will handover control of the mission after inserting the LCROSS s/c into it's Lunar swing by mission then go "inert"
- LCROSS will spend approx 120 days doing orbital refinement waiting for LRO to be activated
- LCROSS will then target the spent rocket stage into a Lunar south pole crater and follow it in shortly after for a second impact



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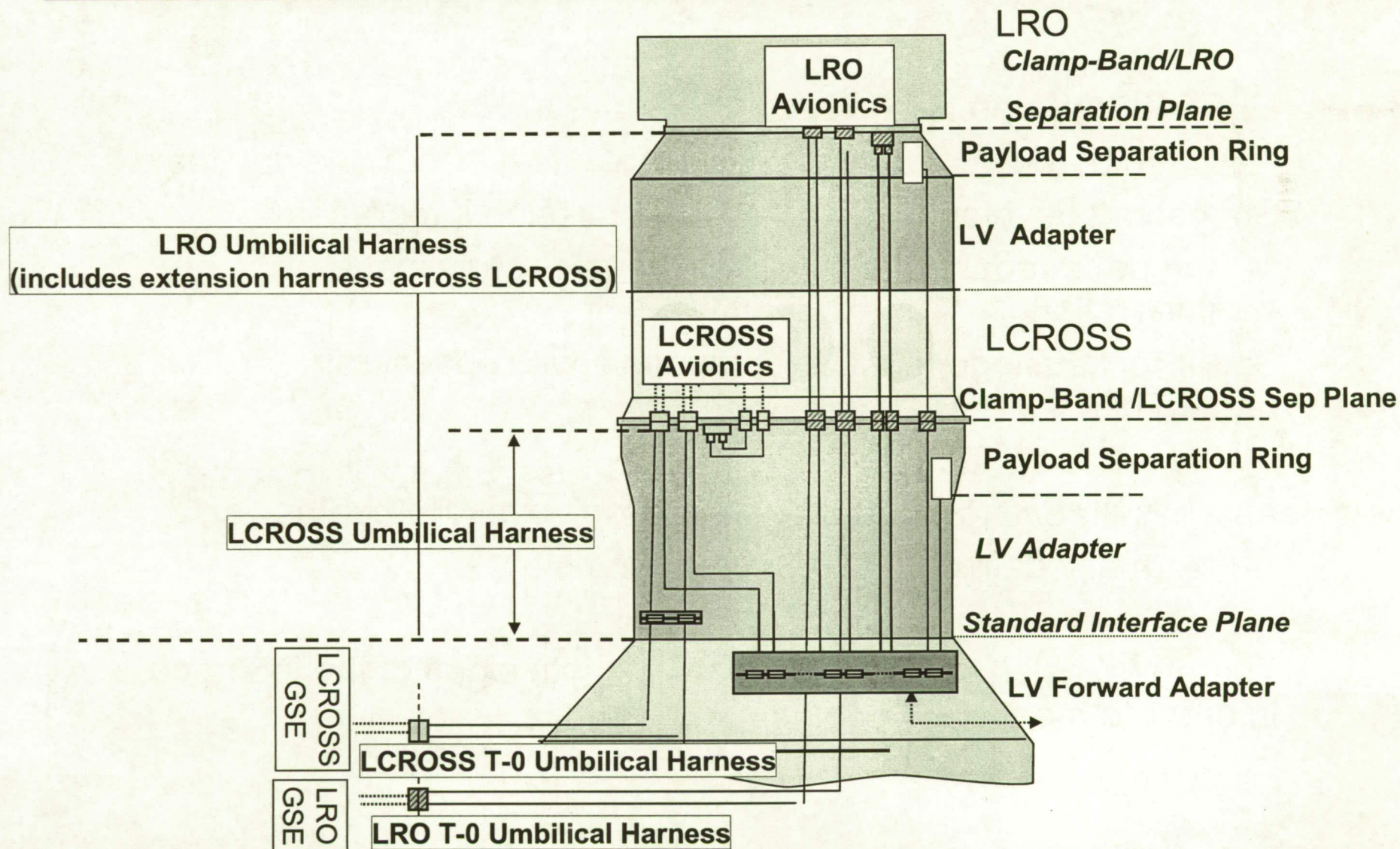
LRO-LCROSS

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SC/LV Configuration





Requirements Definition Phase

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- LCROSS mission will be about 120 days
 - State of rocket body not really known after about one day max
- Spacecraft developed in parallel with mission integration
 - Interface requirements will evolve over early stage of integration
- Spent rocket stage must be compatible with spacecraft requirement
 - Never designed to do this
- As a result, S/C to LV ICD definition took over 15 months
 - Normally defined in about 3-6 months
- Therefore, risk had to be accepted on both sides of the interface in order to meet the primary schedule



Secondary Spacecraft Risk

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- The primary had to accept risk of having a secondary inserted into their mission
- The secondary S/C had risk with the LV 2/3 of their S/C mass not being under their control
- The LV had risk of S/C using their rocket for something it was not designed to do



Examples of Individual Risks

Aka: The devil is in the details



Thermal

- LV detailed thermal model
 - Integrated thermal analyses
 - LCROSS mission profile requirements
 - Definition of long duration thermal environment
 - Effect of this environment of the LV parts
 - Effect on S/C power budget
 - Thermal coatings of LV parts
-
- Risk: The LV hardware will be out of thermal qual and function as designed – Very low



Electrical Connectors

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- Large connectors must separate without binding
- Small connectors must separate and conduct the separation commands to the LV sep system from LCROSS
- Risk: Once the thermal environment was defined, the connectors were within thermal qual but no margin
 - This was acceptable risk for a class D mission but a risk reduction test was successfully performed for the large connectors – Very low
 - The small ordnance connector were never used in this manner so they were qualified for full thermal range – Very low



Loads

- Since the secondary is in line with the primary, the “stack” loads must be evaluated as a single S/C
- Each S/C had different testing requirements so loads model verification was different
- Risk: Final loads verification could have residual risk for primary acceptance - Low
 - $DUF > 1.0$



Trajectories

- The LRO targets provide for a launch opportunity 3 days every two weeks
 - Initial target set CY 2008 is 18 targets
- LCROSS constrained for these target sets
 - Targets are incrementally developed
- LV sequential analyses must make certain to encompass/bound all targets
- Risk: That a later target will not be bounded for LCROSS and cause a redo of LV analyses or acceptance of some performance risk – Low to moderate for schedule



Contamination

- Since the LRO S/C is very contamination sensitive, all items for thermal had to be approved by LRO
- The operational procedures for stacking and pad ops had to be worked in detail early for contamination control
- Prohibited substance on LV side of connectors
- Risk: LRO contamination and science degradation – Very low



Rocket Body State

- The rocket at handover to LCROSS must be definitized
 - Tank pressures and probably of disturbance
 - State of avionics and graceful shut
 - Commodities on board that can contaminate the science
 - Water, H₂, O₂
 - Tank frequencies for LCROSS control
- Risk: That the LCROSS S/C can not control the full configuration
 - Low



How are we going to do this????

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- Stick to all parties standard practices for the defined requirements including defining what a Class D spacecraft really is:
 - LSP
 - LV
 - LCROSS and contractor
 - LRO
- Oh yes, the COST I mentioned in my title??
 - The added launch integration cost of this “secondary” is about 15-18% the cost of the base ride...

NOT FREE BUT NOT BAD!!!



The way ahead

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- Solar Dynamics Observatory (SDO) – Atlas V 401, ~700 kg of unused lift mass
- LDCM – Atlas V 401, thousands of kgs margin, Earth polar
- Juno – Atlas V 551 – no margin
- Discovery – Grail mission selected, going to the Moon, LV TBD
- Mars Scout – In mission selection



Lessons learned in parallel development

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- Having a single program have authority of both S/C is very beneficial
- Start early for both the mission selection and getting defined requirements into the rocket selection
- Review policies early for ease of integration
 - Example: Separation of primary first
 - Classification of spacecraft and testing requirements



Conclusions – Opinions?

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- Multiple manifesting is doable and we must do it if we are going to utilize our Nation's full space lift capability
- BUT the spacecraft community needs to work together early to make this happen
- Past policies may need to be modified to utilize the lift mass
- Let's go and explore the universe together!!