

Secondary Payloads Using the LCROSS Architecture

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Abstract

The Lunar CRater Observation and Sensing Satellite (LCROSS) is a secondary payload mission that was selected to launch with the Lunar Reconnaissance Orbiter (LRO) when that mission was upgraded from a Delta II to an Atlas launch vehicle. The LCROSS spacecraft employs the EELV Secondary Payload Adaptor (ESPA) ring as the primary structure, ensuring compatibility with both the Centaur upper stage and the LRO spacecraft. In this novel approach the ESPA ring, which was originally designed to hold up to 6 small satellites weighing 205 kg each, supports the LCROSS spacecraft subsystems on panels mounted to each adaptor fitting. This ESPA ring architecture affords low-cost access to space through reduced spacecraft costs and by enabling two capable missions for the cost of a single launch. The modular subsystem panel approach also provides flexibility in performing integration and in adapting the design to new missions. This paper describes our approach for leveraging the extra lift capability of the new generation of EELVs to enable the use of a secondary mission at well below the cost of an independently launched mission. We discuss the design of the LCROSS mission, and use the LCROSS architecture to illustrate a variety of planetary and astronomical missions that are compatible with being a secondary payload. Despite being labeled a secondary mission, provides the potential for high value science missions at a fraction of the cost of the traditional mission approach.

I. Introduction: LCROSS

With the expected flat budget facing NASA, the US needs an innovative, inexpensive and rapidly implementable way to increase the number of payloads launched per year. The secondary mission architecture being demonstrated with the LRO/LCROSS launch is an approach that promises to increase the number of NASA missions at an affordable cost. LRO, the Lunar Reconnaissance Orbiter, is a mission planned for an early 2009 launch to map and characterize the surface details of the moon, in preparation for human exploration¹. LRO was originally intended to go in a Delta II launch vehicle, but was upgraded to an Atlas V launch vehicle. This significantly increases launch capability. NASA saw the opportunity for a co-manifested payload and, following a competitive process, the Lunar CRater Observation and Sensing Satellite (LCROSS), was selected as the secondary payload.² LCROSS was required to meet a 27 month, ATP to launch, schedule, and to have minimal impact to LRO development and launch.

The LCROSS mission will to make the first definitive measurements of water ice in the permanently shadowed craters at the poles of the moon by impacting the lunar surface with the spent Centaur upper stage and the LCROSS spacecraft itself. The plumes will be observed in space and also on Earth. Following launch, the LCROSS bus will guide the Centaur upper stage in a 3 month journey to lunar impact. The LCROSS bus separates from the Centaur 8 hrs before impact so that it can observe the Centaur's impact plume prior to its own impact. Impact velocity will be 2.5 km/sec, and targeting accuracy will be <2 km. The initial impact of the Centaur upper stage, about 4 minutes before the impact of the LCROSS bus, will create an extensive ejecta cloud, and the LCROSS bus will fly through the plume and perform spectroscopic analyses to detect the presence of water ice or hydrated water. It will transmit this spectroscopic data from the on-board sensors to Earth before its own secondary impact. Both impacts will be observed by amateur and professional telescopes at Earth, including the Hubble Space Telescope. Missions in orbit around the moon are also planning observations.

One of the enabling features of LCROSS is its innovative use of the EELV Secondary Payload Adaptor (ESPA) ring (see next section), which was originally designed to carry six separate small satellites. For the LCROSS mission, the ESPA ring became the shepherding spacecraft's primary structure with the payload and spacecraft subsystems are bolted to each of the six ports. This enabled LCROSS to be designed to carry the LRO spacecraft without developing a new structure. Figure 1 shows LCROSS in the "flat-sat" configuration used during integration and testing. In the figure, the ESPA ring is shown in gold; the panels are oriented with out-facing panels down to facilitate integration and testing. The panels are then bolted onto the spacecraft at the panel attachment points, and the integrated LCROSS is shown in upper left Figure 1. LCROSS shares the same avionics suite as LRO, and while the LCROSS spacecraft does not require the capabilities of the LRO avionics, the reduced cost of a second unit and leverage of the LRO testing process made it the logical choice. For future missions, the same avionics can provide higher capability than is needed by the LCROSS mission.

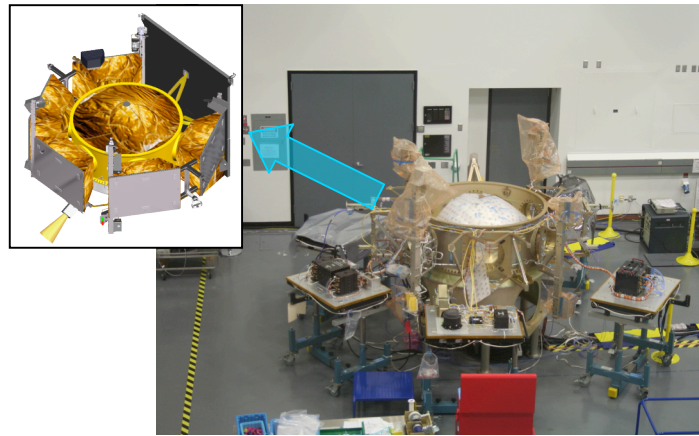


Figure 1: Photo of the "Flat-sat" view of LCROSS during integration. The upper left inset is the integrated LCROSS satellite in the assembled view.

II. The ESPA

The EELV Secondary Payload Adaptor (the ESPA) is a joint development between the Space Test Program of the Department of Defense (DoD) and the Space Vehicles directorate of the Air Force Research Laboratory (AFRL). The industry partner chosen to develop the ESPA was CSA engineering.³ The ESPA was designed not to interfere with the primary payload and consists of a 104 kg ring, which is 0.6 m tall. The diameter of the ESPA can be varied to suit the EELV. Inside the fairing, the bottom of the ESPA is mounted to the EELV Standard Interface Plane, a 1.58 m bolt circle. The primary payload adaptor cone is mounted on top of the ESPA, which mimics the configuration of the Standard Interface Plane.⁴

The six ports on the ESPA were designed to accommodate 6 small satellite payloads, with masses of up to 205 kg and a volume limitation of 0.61 m x 0.71 m x 0.97 m, mounted on the outside of the ring as shown in Figure 2. The first ESPA launch was aboard an Atlas V rocket, on March 8th, 2007 for the Space Test Program (STP) 1 mission. It carried 6 small research satellites, including the two Orbital Express satellites. The cost of the ESPA ring itself is approximately \$250,000.

The ESPA is already changing military and commercial launches, and with the launch of LRO, the ESPA will increase the number of NASA payloads launched as well. The ESPA enables the launch of small missions, and LCROSS will demonstrate that the ESPA can also provide larger secondary missions with significant payload masses and volumes.

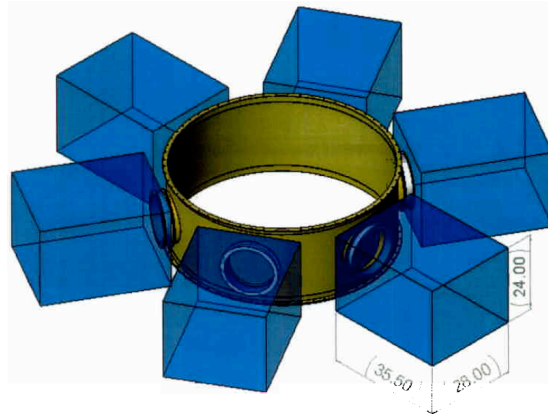


Figure 2: The ESPA payload volume envelope. Units shown are in inches. Figure from the ESPA users guide.

III. Secondary and Co-Manifested Launches

With the planned phase out of Delta II's, missions originally scheduled for a Delta II launch are being upgraded to EELVs. The expanded capacity of EELVs means co-manifested payloads can be accommodated with very little impact to the primary mission. While the primary mission or its sponsoring organization has already incurred a full launch cost, a secondary mission can be added for only a small additional integration cost, and, if necessary, strap-ons at \$7-8M to provide additional mass margin to both missions.

A sustained program to identify and mate primary missions with suitable secondary missions would be very valuable. Currently a NASA working is examining the feasibility and working out potential accommodation and integration issues for some of these opportunities⁵. Table 1 lists planned and possible future NASA launches and examples of secondary missions that could be accommodated.

Primary Mission	Example Secondary Mission
Mars Scout	Mars Comm Relays
Juno	Jovian Moon Impactor
EJSM	Asteroid Lander
Lunar Sample Return	Lunar Comm Relay or Earth Observer
Comet Sample Return	Main Belt Comet Lander

Table 1: Future planned NASA mission and example secondary missions

LCROSS has developed a simple interface between the primary and the secondary that runs all of the primary payload's launch umbilicals along the external surface of the LCROSS bus. This approach never intermingles the primary spacecraft's umbilical with the secondary payload's and allows the secondary spacecraft to be launched unpowered if desired so there is no possibility of electrical interaction with the primary spacecraft.

Since the EELV core stage is always launched fully fueled for slosh mitigation reasons, nearly half of all launches in the next five years can accommodate a LCROSS sized secondary mission without any increase in launch vehicle capability. Also launches manifested on an Atlas 401 or 501 may be upgraded to an Atlas 551, resulting in a 100% increase in life capacity for only ~50% increase in launch cost. Thus launching two missions on the larger launch vehicle demonstrates more cost efficiency than two separate launches on the smaller EELV. Launching two payloads per launch significantly improves the average cost per launch without inconveniencing the primary payload. In addition to the EELV, the LCROSS ESPAsat spacecraft can also be launched as a secondary spacecraft on the Falcon 9 or as a primary payload on a Taurus II. Compatibility with multiple launch vehicles provides flexibility in managing launch manifests and response to contingency situations.

Figure 3 shows the Atlas fairing volume, with LCROSS and a generic primary payload on top. Larger existing payload fairings can also provide launch volume to accommodate the addition of a secondary spacecraft and mission on the launch at low total overall cost.

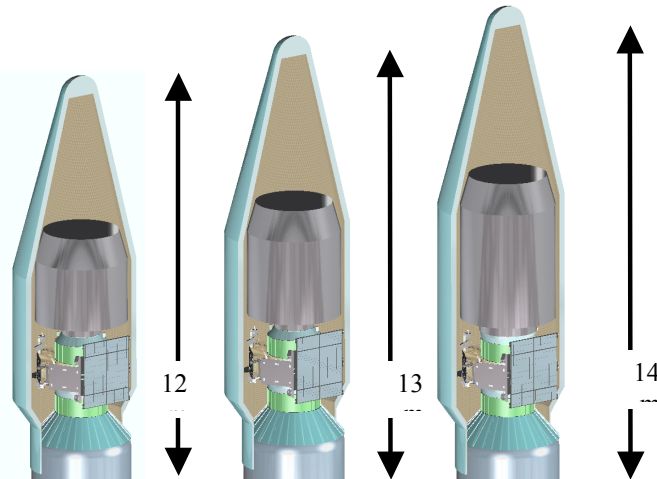


Figure 3: Atlas payload fairing height. Shown with LCROSS and generic primary indicated by grey cylinder.

IV. Example LCROSS-Derived Secondary / Co-Manifested Missions

LCROSS has dedicated one of six panel modules (the R6 panel) for the payload. A wide range of sensor or manipulator payloads can be supported on this panel module or can be mounted directly to the standard ESPA port. In addition to the P6 panel location around the perimeter, the ESPAsat can support large and heavy payloads inside the ESPA ring, either below or above the ESPAsat’s propulsion tank. A conceptual isolation system for a centrally mounted “deck” would be used where payload architectures demand tight operational jitter environments.

The five example missions below are examples of the mission capability that can be addressed by the LCROSS-derived architecture. These notional missions are meant to illustrate the flexibility of the LCROSS platform, and are not fully fleshed out mission concepts at this writing.

A. Asteroid Orbiter/Lander

Figure 4 shows an Asteroid Orbiter/Lander derived from the LCROSS concept. LCROSS has a large fuel capability, because it is designed to perform trajectory correction maneuvers while attached to the Centaur upper stage. Without the need to control an upper stage, the LCROSS configuration can deliver three to six times the delta-V required by the LCROSS mission. The LCROSS ESPAsat already has a 6 Degrees of Freedom propulsive system enabling rendezvous and soft landing on a low-mass body such as an asteroid. This concept take advantage of the heritage high data rate communication system design capability which will fly on LRO, but not LCROSS. This Ka based communication allows a data rate of 100 Mbps compared to the LCROSS maximum of 1 Mbps.

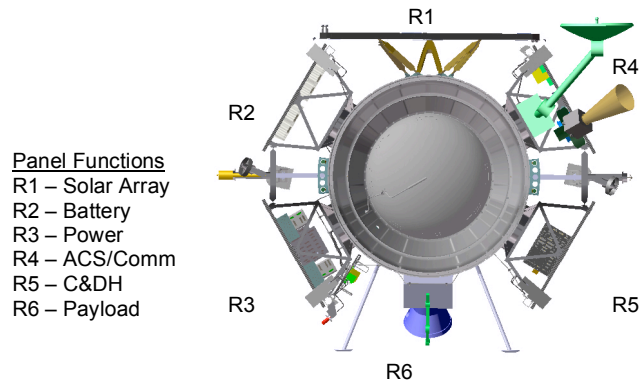


Figure 4: Asteroid Orbiter/Lander Configuration

B. Earth Observation Platform

The secondary payload mission architecture can also serve to deliver Earth-orbiting missions. Figure 5 shows an Earth Observation or weather monitoring system with a nadir platform for Earth observation. The dynamically isolated observation platform provides a low-cost approach to achieve high pointing stability. This isolated platform can also be used to mount and isolate all of the elements that introduce system jitter and the mission instrument accommodated on the ESPA ring. For most earth observation missions, A reaction wheel module is also included at the Zenith end of the spacecraft mounted on the inside of an adaptor section. This wheel based pointing will allow significant flexibility in operations and saves propellant over the LCROSS thruster-only based pointing system. The addition of a Solar Array Drive Assembly (SADA) also allows persistent spacecraft pointing while the solar arrays track the sun.

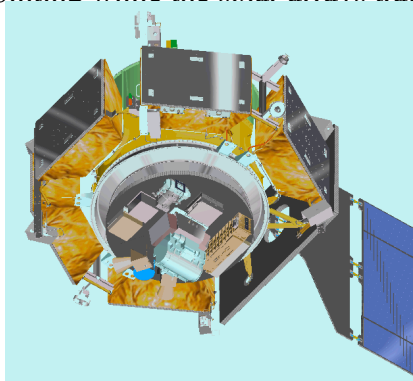


Figure 5: Earth Observation or Planetary Weather Monitor

C. Small Space Telescope

Figure 6 shows an innovative way of accommodating a small space telescope where the primary optic occupies the central volume of the spacecraft. A 1.1 m primary optic can be accommodated inside the ESPA central volume. The concept shown here uses two stacked ESPA rings as the light baffle inside the ESPA central volume. A deployable baffle is lighter and could be used to eliminate the need for an additional ESPA ring. This concept uses two stacked ESPA rings for the structure. If the launch vehicle has enough room to accommodate it, this is a growth path to a larger secondary bus, to facilitate a more capable mission.

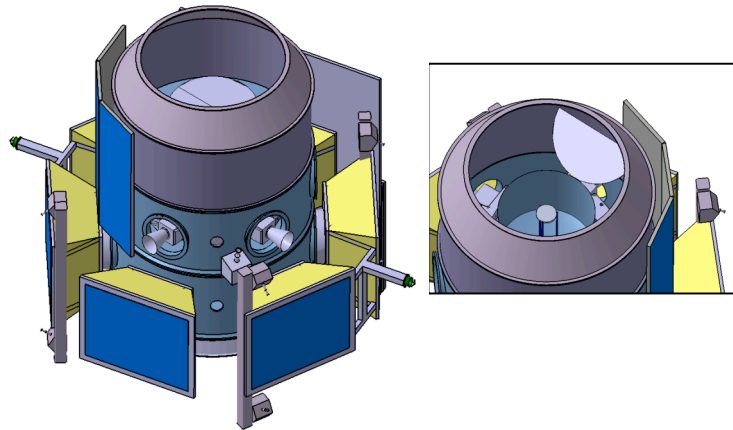


Figure 6: Small Space Telescope

D. Deployable Antenna

Figure 7 shows the accommodation of a large Perimeter Truss Reflector (PTR) for either high periodic gain in LEO or continuous communication coverage in GEO or around other solar system bodies. The PTR provides lightweight, low volume stowage and we have considered a number of ESPA-based concepts employing PTR for sensing or communications.

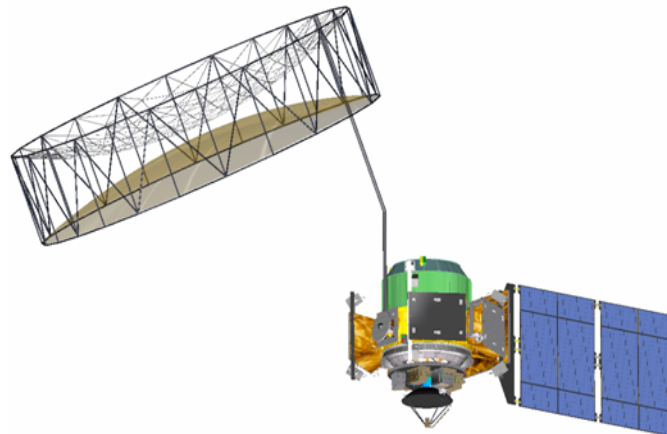


Figure 7: Deployable Radar Antenna

A low-cost GEO insertion capability may be integrated into an LCROSS derived ESPAsat. Many of the rideshare launches may only be LEO or GTO launches, requiring a significant amount of delta V to bring the secondary spacecraft on station. This GEO transfer capability allows GTO to GEO to become a valid operational orbit choice and can support many of the other mission configurations shown.

V. Conclusion

The LCROSS program demonstrates an innovative use of the ESPA ring technology that enables a secondary mission to gain rapid, low-cost access to space with significant payload capability. The modular subsystem provides simple, flexible integration and rapid reconfiguration for new payloads and missions. As a secondary, the ESPAsat avoids the costs of a single independent launch and incurs only integration and possibly additional strap-on booster costs for launch. It can also be used to launch secondary missions that require payload masses and volumes that cannot be accommodated by a small sat.

Because the ESPAsat can support different payloads and configurations in its modules, a variety of secondary missions (planetary, astronomical, and earth-orbiting studies) can be developed and launched at minimal costs. Mission capabilities can also extend beyond NASA science missions to military and other government needs. The next steps will be to identify future launches, determine which types of secondary missions can complement the primary mission, and formulate mating and rideshare strategies. Although the accommodation and integration plans are still in development, the LCROSS-derived ESPAsat, due to its cost-effective approach and flexibility in accommodating launches, has the potential to dramatically increase the scope and value of NASA and other government missions.

Acknowledgments

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