SECONDARY PAYLOADS USING THE LCROSS ARCHITECTURE. T. L. Segura[1], A. S. Lo[1], H. Eller[1], D. Dailey[1], E. Drucker[1], J. Wehner[1], [1]Northrop Grumman Aerospace Systems, One Space Park, Redondo Beach, 90278 teresa.segura@ngc.com ; amy.lo@ngc.com .

Summary: 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.

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, launched in June 2009 and is mapping and characterizing the surface details of the moon, in preparation for human exploration [1]. 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.

One of the enabling features of LCROSS was 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.

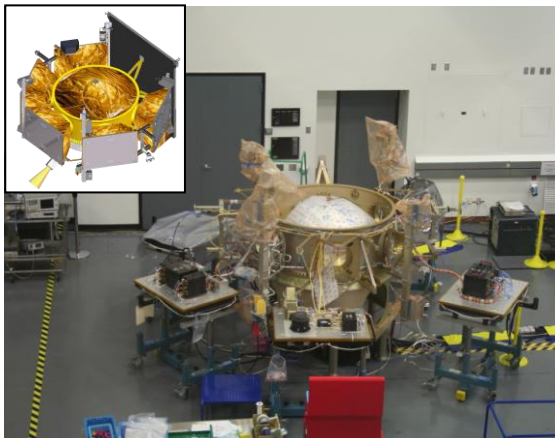

Figure 1: Photo of the "Flat-sat" view of LCROSS during integration. The upper left inset is the integrated LCROSS satellite in the assembled view.

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 in-

curred 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 opportunities [3]. In this paper we will show planned NASA missions along with possible future NASA launches and examples of secondary missions that could be accommodated. We will describe several mission architectures that could be accommodated by an ESPA-based structure.

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.

Conclusions: 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.

References: [1] Chin, G., et al., *Space Science Reviews*, Vol. 129, No. 4, April, 2007, pp 391-419. [2] Colaprete, A., et al., *Bulletin of the American Astronomical Society*, September, 2006, Vol. 38, p. 591. [3] MacNeal, B.E., Herrell, L.M., Aerospace Conference, March, 2008 IEEE , pp.1-14

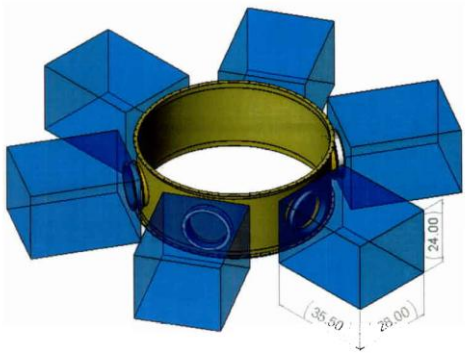

Figure 2: The ESPA payload volume envelope. Units shown are in inches. Figure from the ESPA users guide.