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Demonstrating Low Cost Access to Space for Small Satellites: Space Test Program-1 Mission

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DEMONSTRATING LOW COST ACCESS TO SPACE FOR SMALL SATELLITES: SPACE TEST PROGRAM-1 MISSION

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ABSTRACT

The DoD Space Test Program (STP) is charged with providing spaceflight to Research and Development (R&D) payloads from the Space Experiments Review Board (SERB) priority list. STP is dedicated to timely, cost-effective spaceflight opportunities. Often these opportunities result in innovative missions that maximize the amount of SERB payloads manifested per launch vehicle. In this spirit, STP has designed a multi-manifest mission that will deliver up to seven separate spacecraft to different earth orbits. This mission is called the Space Test Program–1 (STP-1). STP-1 is the most aggressive United States Department of Defense (DoD) multi-satellite R&D mission ever attempted.

This complex mission is a collaboration between the Air Force Space Command (AFSPC), the Air Force Research Laboratory (AFRL), and the Defense Advanced Research Projects Agency (DARPA). Other participants include the Naval Research Laboratory (NRL), the Naval Postgraduate School (NPS), United States Naval Academy (USNA) and the United States Air Force Academy (USAFA). This paper will briefly review the STP-1 mission payloads. The focus of this paper is to discuss the Evolved Expendable Launch Vehicle (EELV) Secondary Payload Adapter (ESPA) and challenges facing the first ESPA mission. STP is managing this mission utilizing a diverse Integrated Product Team (IPT). This IPT is working to overcome several unique challenges in balancing limited manpower resources with the requirement to manage all the separate STP-1 mission components.

INTRODUCTION

The goal of the STP since 1965 has been to fly as many DoD R&D payloads as possible. These R&D payloads are picked from the Space Experiments Review Board (SERB) priority list. The most practical way to approach this is to maximize the number of R&D payloads per launch. To put this simple concept into action and faced with limited number of launch opportunities, STP in partnership with the Air Force Research Laboratory (AFRL) developed the Evolved Expendable Launch Vehicle (EELV) Secondary Payload Adapter (ESPA). The ESPA ring is capable of providing transportation for up to six secondary payloads and a large primary payload (figure 1). The first ESPA mission is called the Space Test Program-1 (STP-1) and is scheduled to launch in March 2006. There are many challenges that face this program. Just as with any first time missions, STP is learning how to get multiple satellites to space using a single mission.

STP-1 MISSION

Since the mid-90s, the United States Air Force Space Command (AFSPC) has supported STP with a medium class launch vehicle every four years to fly DoD R&D payloads. This eliminates the need for STP to secure funding for these expensive vehicles, and allows the STP funding to be utilized for spacecraft acquisition, launch vehicle integration, and operations in partnership with R&D space programs.

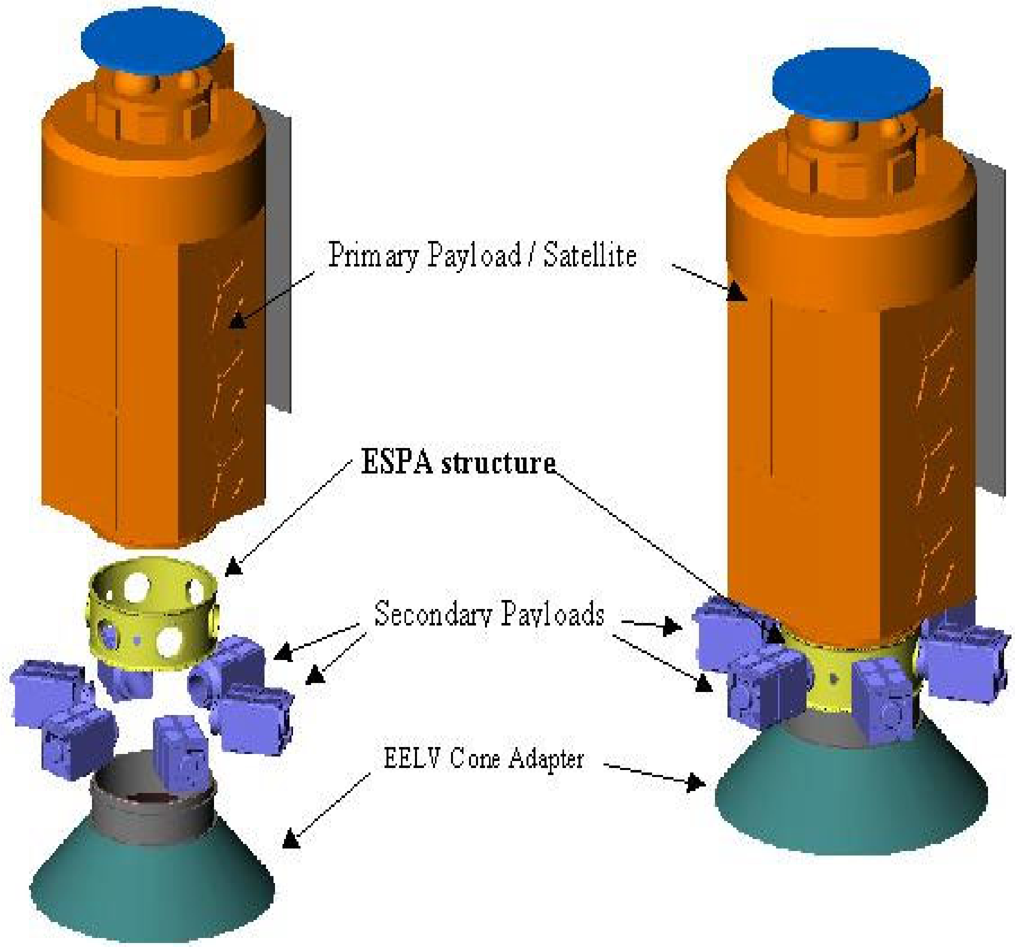

Figure 1. Example of Fully Loaded ESPA Stack

AFSPC will buy STP a Delta IV Medium variant (far left in Figure 2). Currently, the Delta IV-Medium vehicle is to be procured in 2004 with an initial launch capability by 2006. This rocket has the power and flexibility to allow the STP-1 mission to go to multiple Orbits. The current plan is to drop off the primary payload off first then a secondary payload at a Low Earth Orbit (600 kilometers at 46 degrees inclination). Next the rocket will perform an orbit and plane change and the remaining 3 secondaries will be dropped off in another LEO orbit (560 kilometers at 56.4 degrees inclination).

The key to this mission is the ESPA jointly developed by AFRL and STP. The ESPA has been specifically designed for the EELV. In an effort to lower cost for launching small satellites into space, the ESPA has a standard 15-inch interface and can accommodate up to six secondary spacecraft weighting up to 400 pounds each. Additional details about ESPA are discussed later in this paper. STP-1 will have the honor and challenge of flying the first ESPA.

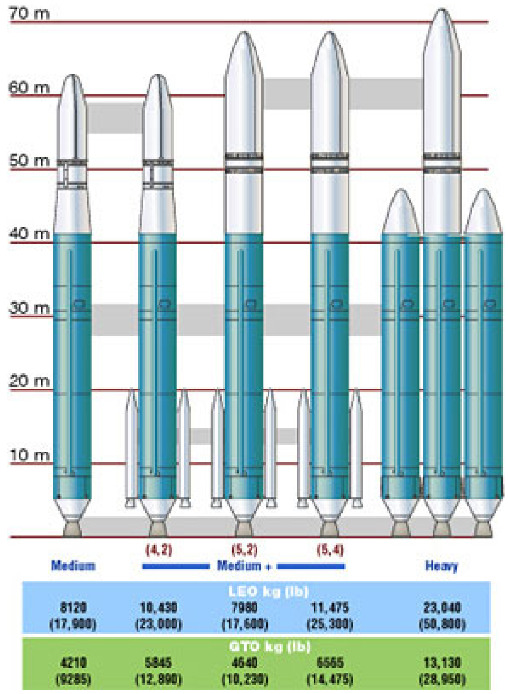

FIGURE 2. Delta IV-Medium/Heavy Vehicles

The STP-1 mission is currently made of four secondary payloads and a primary payload. The primary payload is Orbital Express. The secondary payloads are STPSat-1, NPSAT-1, FalconSat-3, and MidSTAR-1. These payloads are discussed in more detail later. Figure 3 shows the organization of the STP-1 team. The Mission Director has overall authority to add or remove payloads from the mission and to adjust the STP-1 funding levels. The STP-1 Mission Manager has the job of running the day-to-day activities of the mission and has the authority to move STP funding between payloads. The ESPA Integration Team is responsible for handling range issues, launch vehicle issues, ESPA issues, and integration issues in regards to getting the payloads on the ESPA for launch. Each payload has its own team that ensures the payload is built, tested, and delivered for launch. To round out the STP-1 organization there are contract and finance teams supporting the STP-1 mission.

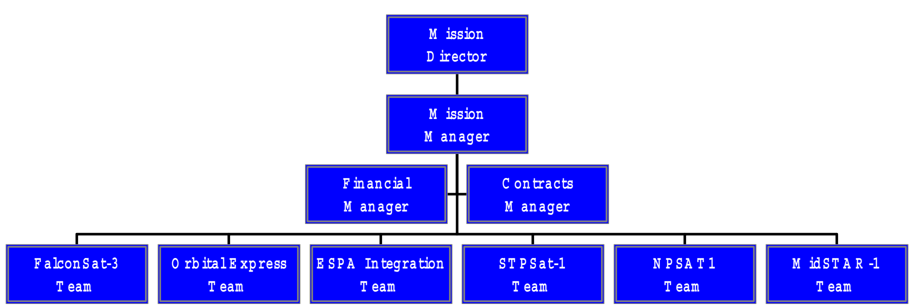

FIGURE 3. STP-1 Team Organization

PAYLOAD DESCRIPTION

Primary Payload

Orbital Express (OE), DARPA payload, will weight 1200 kg and is the primary payload for the STP-1 Mission. OE is an exciting concept that will demonstrate the ability of a satellite to autonomously service other satellites with fuel and instrument replacement. OE payload will consist of two satellites (shown in figure 4 sitting on top of the ESPA). The servicing satellite is called ASTRO (On-orbit Rendezvous, Docking, Fueling & Instrument Replacement). The satellite that ASTRO will service is called NEXTSat (Next Generation Satellite). In the future satellites will be built with servicing in mind to extend their useful life. Orbital Express ranked #5 at the 2002 DoD SERB.

EELV Secondary Payload Adapter

ESPA represents the fundamental belief that the secondary payload—given a reliable, standard interface—can utilize excess launch vehicle margin for access to space. ESPA itself is a 24 inches high aluminum ring with a diameter of 62.5 inches. The concept is that all DoD medium class EELVs can carry an ESPA as part of their payload stack. Then, based on an appropriate analysis and integration, a single small spacecraft or suite of small spacecraft can ride along when mission requirements dictate it. The Ariane community is very successful with a similar capability, the Ariane Structure for Auxiliary Payload (ASAP).

Secondary Payload—STPSat-1

The STPSat-1 spacecraft will be built with STP funds and the payload (space vehicle) will weight up to 170 kg. The STPSat-1 mission consists of one primary scientific experiment (SHIMMER) and two supplemental scientific experiments (CITRIS and MEPSI). SHIMMER is the Spatial Heterodyne Imager for Mesospheric Radicals. The others are the Computerized Ionospheric Tomography Receiver in Space (CITRIS), and the Micro-Electro-Mechanical (MEMS)-based PicoSat Inspector (MEPSI).

SHIMMER is a high-resolution ultraviolet spectrometer based on the new optical technique known as Spatial Heterodyne Spectroscopy (SHS). It will demonstrate that SHS facilitates the design of low mass, low power, low volume, and high throughput spectrometers for space-based remote sensing. SHIMMER will image the earth's limb at low latitudes, measuring the hydroxyl (OH) resonance fluorescence around 308nm. These long-term, global-scale measurements will contribute significantly to the small set of existing atmospheric OH observations. These will help to answer the numerous outstanding questions about the chemical and dynamic processes in the middle atmosphere, allowing better model validation and forecasting capabilities. SHIMMER was ranked #4 on the 2000 DoD SERB list.

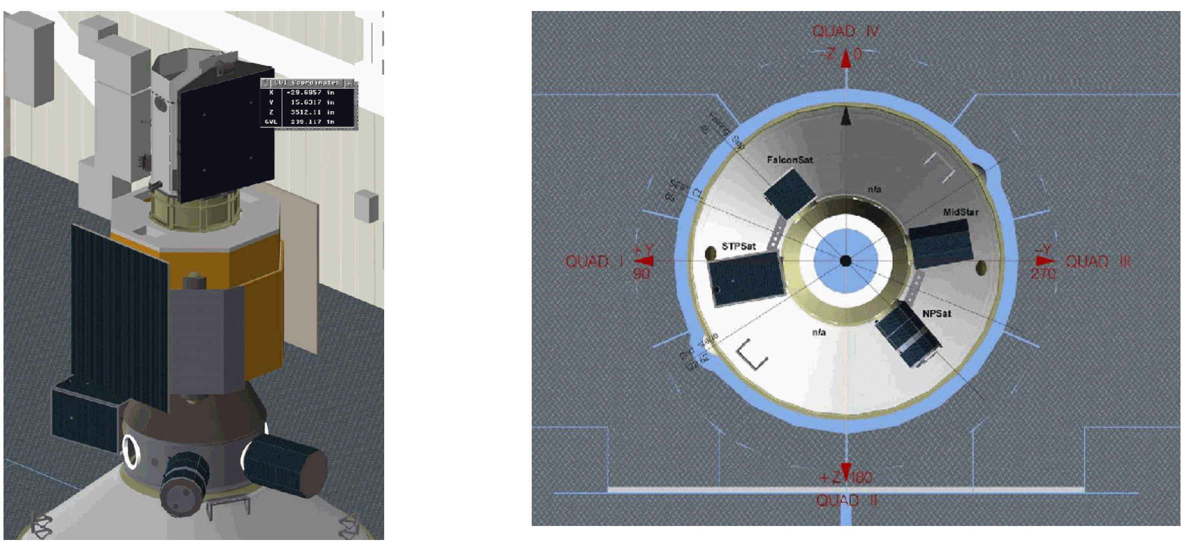

FIGURE 4. STP-1 Mission Payloads

The CITRIS system is a three-frequency receiver connected to an antenna located on the front (ram) or back (wake) of the STPSat-1 satellite. Transmissions from Coherent Electromagnetic Radio

Tomography (CERTO) beacons located on three other Low Earth Orbit satellites (like the one on NPSat1 outlined later) are detected by the CITRIS satellite to provide measurements of satellite-to-satellite Total Electron Count (TEC) and signal fluctuations. Occultation of the earth's ionosphere can be used to derive electron density profiles from the TEC measurements. The receiver will make both amplitude and phase measurements to provide scintillation data at Very High Frequency (VHF), Ultra High Frequency (UHF), and L-Band frequencies. CITRIS ranked #24 at the 2000 SERB.

The MEPSI payload will demonstrate an intelligent hardware "agent" which can enable autonomous satellite operations. Operationally, MEPSI will demonstrate the capability to store a miniature (<1kg) inspector agent that can be released upon command to conduct surveillance of the host vehicle for independent situational awareness. MEPSI was ranked #27 on the 2000 DoD SERB.

Secondary Payload—NPSAT1

NPSAT1 will weight up to 83 kg and will provide an educational tool for officer students at the Naval Postgraduate School in Space Systems Engineering and Operations. NPSat1 will demonstrate commercial, off-the-shelf technology in a spacecraft architecture as a means of decreasing development time, and increasing reliability in software development.

NPSAT1 will have two SERB experiments. First, a low-cost, commercial, visible imager (digital camera) will fly to enhance officer student education through integration, test, and flight operations. Second, the Naval Research Lab's CERTO experiment will fly as a piggyback. CERTO (Coherent Electromagnetic Radio Tomography) Sensors will provide measurements of the integrated electron density of the ionosphere in the satellite orbit plane in conjunction with the CITRIS system. CERTO ranked #25 at the 2000 SERB, NPSat1 ranked #29.

Secondary Payload—MidSTAR-1

MidSTAR-1 will weight up to 150 kg and will provide an educational experience for officer candidates at the United States Naval Academy. MidSTAR-1 will have two SERB experiments. ICSat (Internet Communications Satellite) will demonstrate transfer of files to and from spacecraft via TCP/IP Protocols at 1 Mbps and CFTP (Configurable Fault Tolerant Processor) will evaluate utility of a configurable fault tolerant processor in Earth-orbit radiation environment. ICSat ranked #39 and CFTP ranked #34 at the 2002 SERB.

Secondary Payload-FalconSat-3

FalconSat-3 will weight up to 45 kg and will provide an educational experience for officer candidates at the United States Air Force Academy. FalconSat-3 will have three SERB experiments.

FLAPS (Flat Plasma Spectrometer) will characterize non-maxwellian charged particle distributions on the formation, propagation, and decay of plasma bubbles. The data from FLAPS will be used to validate plasma models associated with DoD's C/NOFs Program (due to launch in FY 2005). FLAPS rank #31 in the DoD 2002 SERB.

PLANE (Plasma Anomalous Noise Environment) will characterize the plasma turbulence in the environment surrounding the space vehicle. PLANE will distinguish between turbulence in the ambient environment and variations in the plasma population co-moving with space vehicle. PLANE ranked #18 in the 2002 SERB.

MPACS (Micro Propulsion Attitude Control System) will experiment using micro-pulsed plasma thrusters (PPTs). MPACS ranked #36 in the 2002 SERB.

STP-1 CHALLENGES

Payload Funding

One of the biggest challenges facing DoD R&D programs in general is the funding stability. Funding instability has taken its toll on the STP-1 mission (originally called MLV-05). The team originally started with the 2000 DoD SERB based on timing (2000 kick-off, 2001 mission planning, 2002-2004 mission execution, and 2005 launch) and selected six payloads. Of the six original payloads only two payloads are still part of the STP-1 mission. The prime and three payloads have been replaced by a new prime and two new payloads early FY 2003. Payload funding has caused the STP-1 mission to slip the launch date by one year. Now scheduled to launch 31 March 2003.

STP Funding

As discussed earlier the spacecraft mission that was solid a few years earlier has collapsed leaving a void for STP to quickly fill. The STP team has been responsive to replacing spacecraft. However, it has driven up the cost of the mission due to replanning. In addition, this is the first integration of ESPA. STP must fund this integration and fund any unique Delta IV mission requirements. Each spacecraft is a unique, one of a kind, R&D class entity with all the associated variables.

Payload Maturity

The next challenge facing the STP-1 is payload maturity. The original payloads (STPSat-1 and NPSAT1) are at the critical design level. The new payloads (EO, MidSTAR-1, and FalconSat-3) are all at the preliminary design level. The Delta IV has requested inputs around three years prior to launch to handle the unique requirements of the mission. Because of the design maturity of the new payloads, the information provided to Delta IV is beyond their maturity level and they will have to design to the information they submit. This increases the risk of the program slipping.

Schedule

The schedule on the STP-1 mission has been compressed. Mission planning and execution originally planned to take 4 years (2001-2004) and now has been compressed to three years (2003-2005). The loss of a year for payload maturity has added increased program risk and also increased cost to STP-1. The original studies (orbit analysis, ops planning, etc.) for the mission have had to be redone. The STP-1 program has no schedule slack. In addition, each spacecraft program must stay on track and obtain required funding or risk slipping the entire mission or falling off the ride.

Payload Compatibility

Consideration must be taken into account how each spacecraft will be mounted and orientated on the ESPA. This is very important because an inadvertent deployment of a boom or antenna could damage another payload. Payloads may interact with each other for such factors as out gassing, battery life, deployment, and early operations issues. This requires planning to ensure that one payload will not damage another payloads instrumentation. For example, having the out gassing products of one payload coating the optics of another payload.

STP Personnel Resources

On large programs, STP staffs the program with a Mission Manager, Spacecraft Manager, Ops Manager, and Test Manager. The STP program will have Aerospace and a support contactor to help provide technical assistance to the program. Because to of the size of the STP-1 program and limited STP personnel resources, each payload has been assigned a Mission Manager. The voids in staffing are filled by the Mission Managers. To glue all these missions together STP has assigned a senior STP-1 ESPA Integration Manager and has contracted with the Boeing Company to support integration of all payloads. Since the payload programs are only one deep, the risk to the mission increases. To help overcome this STP-1 Mission Managers have been assigned to backup another STP-1 mission. This has increased their workload significantly over a normal STP mission. To complicate matters Aerospace support to STP has been reduced causing a reduction in the support provided to the STP-1 mission. The positive side, STP has hired a contractor as the OE Ops Manager and has one other contractor to help support STPSat-1.

Technical Risk

Technically, the risks of STP-1 are the most challenging seen by a DoD STP mission. The STP-1 mission will be the first flight of ESPA. From design to management to integration to execution, the team will be working in uncharted waters. Never has STP integrated a suite of such diverse spacecraft on a payload adapter on so large of a launch vehicle. The team is working to understand the environment that the axially mounted spacecraft will see during launch.

One of the most interesting technically challenging aspects of the mission design to date is the launch profile. The rocket will fly to a height of 600km at 47 degrees inclination and release Orbital Express and MidStar. Then it will move to 560km at 35.4 degrees inclination and release the remaining satellites. The effects of this lengthy deployment are being studied.

CONCLUSION

STP has been the single point of access to space for DoD research since 1965. STP continues to evolve using creativity and ingenuity to find new, reliable, low cost paths to space. The STP-1 Mission carries on this innovative approach that has turned science into operational national assets. The goal of the STP-1 mission is provide access to space for small R&D payloads using the ESPA.

The challenges facing the STP-1 team are great. STP-1 team is facing a compressed schedule, limited STP personnel resources, immature payloads, increase cost, and new technical frontiers. The payloads themselves are under significant pressure to maintain their schedules, funding and overcome their own technical issues associated with developing a new R&D payload. However, working and learning together the STP-1 team and their associated payload teams will demonstrate this new national capability in 2006.

ACKNOWLEDGEMENTS

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