# 18th Annual AIAA/USU Conference on Small Satellites
# Space Test Program-1 (STP-1)--First of its kind!

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ABSTRACT: The Space Test Program's inaugural, "self-named" mission, STP-1, is a "first of its kind" program launching seven distinctly different satellites containing 11 separate Satellite Experiment Review Board (SERB) experiments to two different orbits. There are several "firsts" for the DoD Space Test program on this mission including: First EELV, First Integrating Contractor, First launch of the EELV Secondary Payload Adapter (ESPA), First dual orbit mission, and many others. All of these items are being accomplished in order to pave the way for future multiple "ESPA-class" satellite missions. The key with this mission is to set the stage for future small satellite launches...making access to space easier and more commonplace for the small satellite community.

The STP-1 mission includes an 1,800 kg "prime" satellite, Orbital Express, mated to the top of the ESPA ring holding five sub-400 lb "small" satellites, STPSat-1, FalconSAT-3, MidSTAR-1, NPSAT1 and CFESat. All of these satellites, or the experiments that they are carrying, were ranked from #4 to #39 on the 2000-2002 versions of the SERB and have significant military relevance. This mission has progressed significantly since its inception 2 years ago and many things are on the horizon very soon shooting for a September 2006 launch.

## INTRODUCTION:

The DoD Space Test Program is the "front door" to space for small satellites with displayed military relevance and is run out of the Space and Missile Systems Center, Detachment 12 located at Kirtland AFB, New Mexico. The organization, commanded by Colonel "Mouse" Neumeister is the "one-stop shop" for military small satellite missions including the mission planning and design, launch vehicle acquisition and on-orbit operations. The three different divisions of Det 12 accomplish these tasks and the Space Test Program, headed by Col Richard White is the lead for the STP-1 mission. This "self-titled" Atlas V Evolved Expendable Launch Vehicle (EELV) mission is a "first of its kind" rideshare/auxiliary mission for the Space Test Program (STP). The first ever EELV launch, the first ever use of the EELV Secondary Payload Adapter (ESPA), the first multi-orbit "small" satellite mission for STP and the highest number of SERB payloads ever on a single mission makes STP-1 a pathfinder to the future of military space missions.

This paper will detail the mission overview, satellite composition, mission progress to-date, major upcoming events and actions, and future plans for the Space Test Program on EELV missions.

## STP-1 MISSION

### *SERB Payloads and Manifest Changes*

The initial STP-1 mission was created from the 2000 Space Experiments Review Board (SERB), but the mission has undergone several remanifesting actions that have replaced 5 of the 6 satellites on the mission. The current satellite composition is listed in Table 1 with the ranking of the SERB experiments associated with the different satellites.

**Table 1. SERB Payload composition**

| Satellite | SERB Ranking |
|---|---|
| Orbital Express | #5 |
| STPSat-1 | |
| - SHIMMER | #4 |
| - MEPSI | #27 |
| - CITRIS | #24 |
| CFESat | #2 |
| FalconSAT-3 | |
| - FLAPS | #31 |
| - MPACS | #18 |
| - PLANE | #36 |
| NPSAT1 | #29 |
| - CFTP | #34 |

| Satellite | SERB Ranking |
|---|---|
| MidSTAR-1 | |
| - ICSAT | #39 |
| - CFTP | #34 |

The SERB payload rankings for the 11 experiments on the STP-1 mission are from the 2000 and 2002 SERB lists. The 2002 SERB listing was used to remanifest the payload composition when the initial primary satellite was dropped due to funding issues and several ESPA satellites were changed out for miscellaneous other reasons. These are the specifics of the many changes to the STP-1 payload composition, launch vehicle and projected launch date (changes in **BOLD**):

**Jan 01** - Prime SV: IOMI
ESPA SVs: TechSAT-21 (3)
STPSat-1
NPSAT1
LV: Delta IV (Mar 05)

**Jun 02** - Integrating Contractor (Boeing) ATP

**Dec 02** - Prime SV: **Orbital Express**
ESPA SVs: STPSat-1
NPSAT1
**FalconSAT-3 or LTWAR**
**MidSTAR-1 or CFE**
LV: Delta IV **(Mar 06)**

**Feb 03** - Prime SV: Orbital Express
ESPA SVs: STPSat-1
NPSAT1
**FalconSAT-3**
**MidSTAR-1**
LV: Delta IV (Mar 06)

**Jul 03** - Prime SV: Orbital Express
ESPA SVs: STPSat-1
NPSAT1
FalconSAT-3
MidSTAR-1
**LV: Atlas V (Oct 06)**

**Aug 03** - Prime SV: Orbital Express
ESPA SVs: STPSat-1
NPSAT1
FalconSAT-3
MidSTAR-1
**LV: Atlas V (Oct 06) MLV or HLV??**

And the CURRENT configuration is…

**Nov 03** - Prime SV: Orbital Express
ESPA SVs: STPSat-1
NPSAT1
FalconSAT-3
MidSTAR-1
**CFESat**
**LV: Atlas V (Sep 06) MLV!**

No major changes since November 2003!!

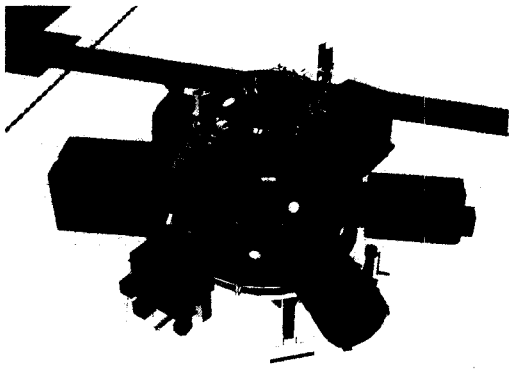

**Figure 1. Computer-generated picture of ESPA, Booster Adapter, and five ESPA satellites (clockwise from top: CFESat, MidSTAR-1, NPSAT1, FalconSAT-3, and STPSat-1)**

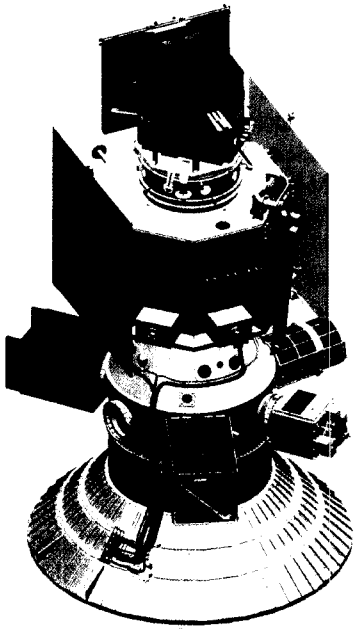

**Figure 2. Computer-generated picture of Integrated Payload Stack (IPS)**

To say the least, the STP-1 mission has undergone several significant changes that have had severe

impact to the overall mission. The Det 12 team has done a remarkable job keeping the mission moving forward while trying to minimize the schedule and cost impact. At this point, the program office has a good handle on the mission specifics, has a Special Study in work with Lockheed Martin and the Atlas V team to define the launch environments and proceed towards a launch vehicle contract.

### *STP-1 Launch Specifics*

The current launch date for STP-1 is 1 Sep 2006 from Launch Complex-41 at Cape Canaveral AFS, Florida. The specific launch window still TBD. The launch profile includes two orbits to deploy the six different satellites (both "firsts for the STP program office and the Atlas V launch vehicle). The "prime" payload, Orbital Express, and one of the ESPA satellites, MidSTAR-1, will be deployed in the first orbit at 492 km and a 46° inclination. After two more centaur burns, the remaining ESPA payloads, STPSat-1, NPSAT1, CFESat and FalconSAT-3, will be inserted in the second orbit at 560 km and an inclination of 35.4°. Operations for these six satellites will be coordinated through five different ground control centers; another significant coordination obstacle the STP-1 team must hurdle. Two satellites, Orbital Express and STPSat-1, will be controlled out of the Range Control Center (RSC) at Kirtland AFB operated by Det 12/VO. The other four satellites, CFESat, NPSAT1, FalconSAT-3, and MidSTAR-1, will be operated out of control centers located at Los Alamos National Labs in New Mexico, the Naval Post-Graduate School in California, the US Air Force Academy in Colorado, and the US Naval Academy in Maryland, respectively.

### *STP-1 "Firsts"*

The STP-1 mission is chalked full of things that the Space Test Program office has NEVER done before. This mission is easily the most significant and challenging mission for the Det 12 program office since its inception. Several significant processes are being developed and tested in order to get this mission done along with new hardware being designed, built and tested that will make future launches of multiple "small" satellites more commonplace.

Two processes that will be key to the successful integration and on-orbit operations of this mission are the role of the Integrating Contractor and the STP-1 Integrated Operations Plan needed for this mission.

The Integrating Contractor (Boeing) contract was a first for the STP program office once it was determined that the program office did not have the manpower to accomplish this task on their own. The contract was awarded over a year after the mission was first manifested and it has been modified several times over the past two years as new items, determined to be a part of the integrating contractor responsibilities, were added to the original contract. This process has been very involving for the program office and the complete advantages and disadvantages of this set-up are yet to be determined. A more in depth analysis of this process is currently being done by the Plans and Programs office of the Space Test Program (STX) as they design the STP-2 mission.

The Integrated Operations Plan for the STP-1 mission must deal with the many aspects of deploying six satellites into two orbits in a matter of a couple hours. The coordination among multiple satellite control centers along with having multiple satellites being controlled from the same center can be logistical nightmares. All the questions and concerns of over 12 agencies involved in the STP-1 mission must be addressed by this plan, contingency operations must be in place and the processes need to be practiced in order to ensure successful deployment and operations of all satellites on the mission. The Integrating Contractor, the STP program office and the satellite communities are currently developing this plan.
Many hardware items have been designed, built or modified in order to complete this mission including the ESPA ring, separation systems, Booster Adapter, lifting fixtures and many other smaller MGSE items. All of these items will be vital to the mission and will make future missions of this nature much easier. Most of the hardware designed and utilized on the STP-1 mission will not be one-time use items, but will be reused on STP-2 and further down the line. As we progress in this mission we are also finding ways to modify existing equipment to make the integration process easier. These items are being recorded for future viability determinations.

## THE STP-1 SATELLITES

### *Orbital Express*

Orbital Express is the "prime" satellite on the STP-1 IPS and is the largest in size and mass. This satellite consisted of two independently developed structures, NEXTSat and ASTRO, that will be combined for launch but will operate as two separate satellites on-

orbit. The combined structure stands approximately 8 feet high with a mass of 1,800 kgs. This $100M+ DARPA Program will demonstrate cost effective methods using industry wide standards for autonomous satellite servicing including fully autonomous rendezvous and proximity operations. It will also demonstrate soft capture and mating, fluid and Orbit Replaceable Unit (ORU) transfers, robotic arm demonstrations and complex ground infrastructures for on-orbit operations. This satellite system, termed Orbital Express Demonstration System (OEDS), could prove significant technologies that could increase on-orbit life of vital satellite systems for the military or civilian communities.

The Orbital Express Demonstration System is past the Critical Design Review (CDR) level. The NEXTSat CDR was accomplished in July '03 and the combined ASTRO/OE CDR was completed in Dec '03. The satellite designers are currently developing the CCAFS integration and flight operations requirements along with the specific testing schedule for the individual components and any reviewing any requirements for integrated testing.

The next major event this satellite is the first set of NEXTSat flight unit testing beginning in Feb '05.

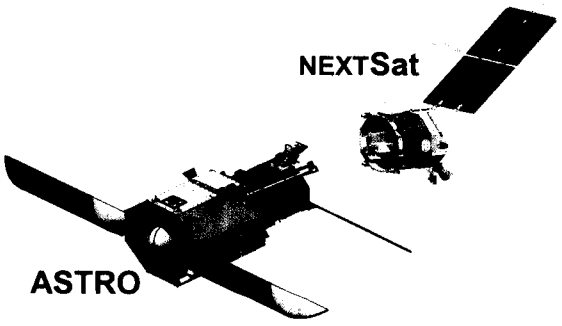


**Figure 3. Orbital Express**

***STPSat-1***

The STPSat-1 satellite is being built via a contract owned by the Space Test Program with the purpose of launching as many SERB payloads on one platform as feasibly possible. The satellite bus will contain the following SERB payloads: SHIMMER (#4 on 2000 SERB), Spatial Heterodyne Imager for Mesospheric Radicals Link, CITRIS (#24 on the 2000 SERB),Computerized Ionospheric Tomography Receiver In Space, and MEPSI (#27on the 2000 SERB), Micro Electromechanical-based Pico Sat Inspector. The primary experiment, SHIMMER, built by the Naval Research Lab, is composed of a Chemical & Biological Agent Detection sensor and middle atmosphere weather assessment and forecast capability sensor that can be vital to in-field military forces.

The STPSat-1 satellite is past CDR level in system design and the flight structure was subjected to vibration testing in May '04. Space Vehicle integration and test will commence in Jan '05 after the payloads have been delivered and spacecraft-level integration and test is complete.

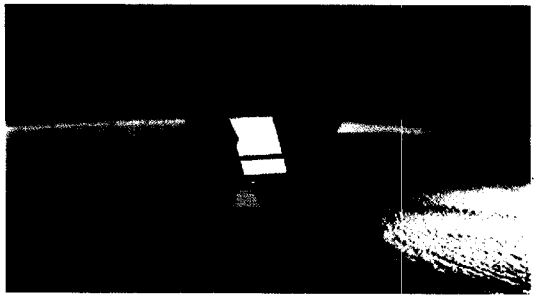

**Figure 4. STPSat-1**

***CFESat***

The Cibola Flight Experiment, (CFE) built/procured by Los Alamos National Labs (LANL) in Los Alamos, New Mexico is another very interesting small satellite with significant experimental sensors and capabilities. The satellite bus is on contract to be built by Surrey Space Technologies Limited (SSTL). The entire experiment was rated #2 on the 2000 SERB and has many functions including: on-orbit validation of commercial S-RAM-based FPGA for on-orbit processing, single-platform geolocation, and multi-mission RF demonstration utilizing reconfigurable computing. In other words, this experiment will be able to detect, geolocate, & characterize VHF/UHF signals around the world along with being adaptable to re-configure on-orbit to address new missions--a very useful tool for the military unit engaged in a moving enemy. This flight demonstration will raise the test readiness level to 7-8 for these FPGA devices, thus, lowering the risk for use by future near Earth space missions.

CFESat is the "newest addition" to the STP-1 Integrated Payload Stack (IPS) and the CFE team is currently finalizing the interface control requirements for SSTL in addition to reviewing initial satellite bus

designs. The Preliminary Design Review (PDR) is scheduled for July '04 with the Critical Design Review (CDR) to be held in November of 2004. SSTL will delivery CFESat to LANL for payload integration in November 2005.[1]

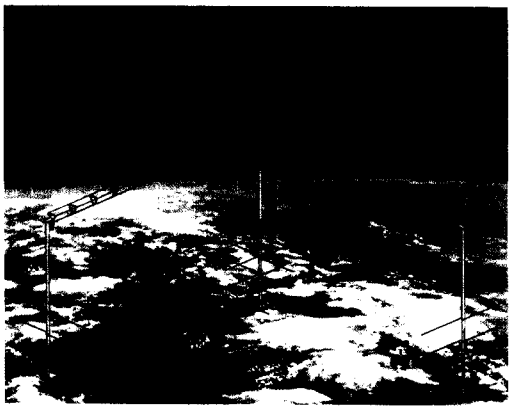

**Figure 5. CFESat**

series of tests to Qualification levels at the Air Force Research Labs in Albuquerque, NM. The actual Flight Model will be built in the Spring of 2005.[2,3]

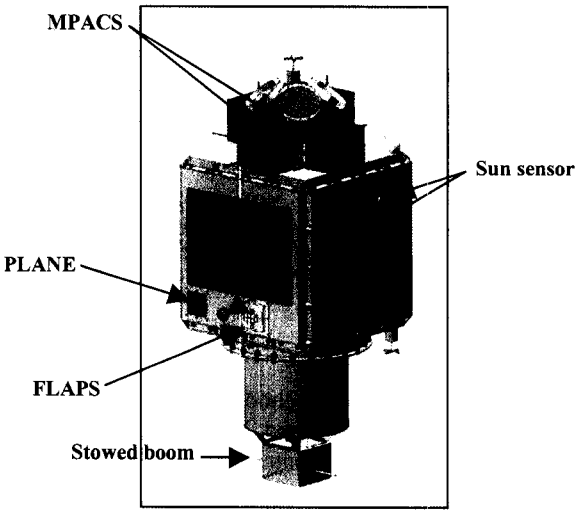


**Figure 6. FalconSAT-3**

***FalconSAT-3***

The FalconSAT-3 satellite is being built by US Air Force Academy (USAFA) cadets and is the third in the FalconSAT line of space vehicles. The purpose of the space program at USAFA is to "establish and sustain a cadre of space professionals" by providing an opportunity for USAFA cadets to "learn space by doing space." The main drive is to develop and validate subsystem designs and operational procedures for future FalconSAT missions throughout this cycle. The FalconSAT-3 satellite contains the following three SERB experiments:

1.) Micro Propulsion Attitude Control System (MPACS) (#18 on the 2002 SERB)
   - Develop and demonstrate micro-thrusters
2.) Flat Plasma Spectometer (FLAPS) (#31 on the 2002 SERB)
   - Characterize ionosphere plasma bubbles
3.) Plasma Local Anomalous Noise Environment (PLANE) (#36 on the 2002 SERB)
   - Characterize plasma turbulence in the environment surrounding spacecraft

The FalconSAT-3 program completed their Critical Design Review (CDR) in Oct '03 and completed testing of their System Engineering Model #2 (SEM2) in Jan '04. The next major milestone for this program is a testing plan for the FalconSAT-3 Qual Model (QM) in the Fall of 2004. The QM will use Flight-quality avionics (a 2nd set) and will undergo a

***MidSTAR-1***

The MidSTAR-1 satellite is the fourth in a line of space vehicles being designed and built by US Naval Academy (USNA) Midshipmen. Similar to the USAFA goals, the USNA space program seeks to educate First Class Midshipmen (Seniors) in the Astronautics curriculum of the Aerospace Engineering Major in spacecraft design, systems engineering, program management techniques, cost, scheduling, flight certification, safety procedures, and spacecraft testing. The sole purpose of the MidSTAR-1 (Midshipmen Space Technology Applications Research) program is to integrate, test, launch, and operate a space vehicle to support the following two SERB experiments:

1.) Internet Communications Satellite (ICSat) (#39 on the 2002 SERB)
   - Move data via RF link using TCP/IP
2.) Configurable Fault Tolerant Processor (CFTP) (#34 on the 2002 SERB)
   - Evaluate triple-redundant fault tolerate processor design using COTS technology

The MidSTAR-1 program recently completed their CDR in Apr '04 and plan to accomplish flight unit testing starting in Apr '05.

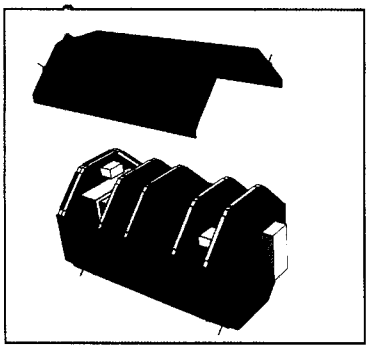

**Figure 7. MidSTAR-1**

*NPSAT1*

The Naval Postgraduate School (NPS) in Monterey, California is designing and testing the NPSAT1 satellite for the STP-1 mission. This space vehicle is a spacecraft architecture and technology demonstration for NPS hoping to provide a "Microsat" class spacecraft through hands-on education for NPS officer students. The program hopes to demonstrate COTS technology (a PC-compatible command and data handling subsystem along with the Linux operating system) in spacecraft architecture as a means of decreasing development time, and increasing reliability in software development, as well as providing a platform for space flight experiments. The NPSAT1 satellite was rated #29 on the 2002 SERB list and contains two additional SERB payloads, CERTO beacon that was rated #25 on the 2000 SERB and #24 on the 2001 SERB and another NPS experiment, CFTP, which is also being flown on MidSTAR-1.

The NPSAT1 program completed their CDR in Feb '03 and is planning Engineering Design Unit (EDU) structural testing in late 2004 followed by flight qualification testing in late 2005. The EDU testing was originally planned for earlier, but the recent switch in separation systems (Lightband to StarSys) in May '04 delayed that testing until a separation system was available for use.[4, 5]

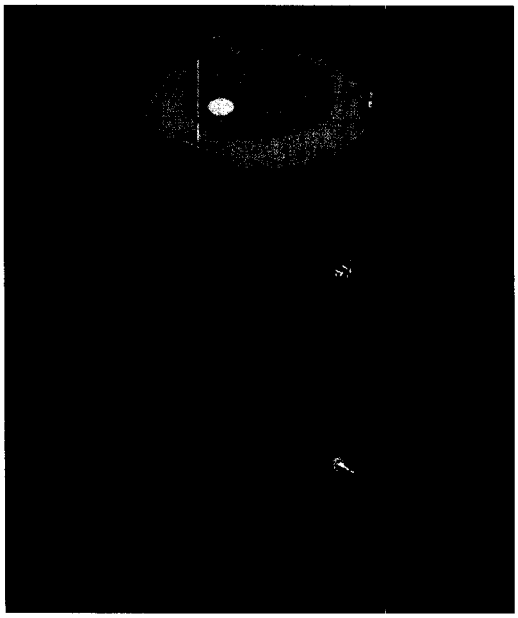

**Figure 8. NPSAT1**

## MISSION PROGRESS

*Atlas V (EELV)*

Since the launch vehicle change in July '03, the STP program office and SMC/EV in Los Angeles, CA have been hard at work trying to catch the program up to where they were before the switch without much, if any, schedule delay. A Special Study contract was initiated in Dec '03 and will be completed in Sep '04. This nine-month effort by Lockheed Martin (Atlas V), the STP program Office and SMC/EV will set the stage for getting the STP-1 mission requirements defined and coordinating the many aspects of a multi-satellite payload on this "first-of-its-kind" mission.

The contract establishing the 2-year Standard Services for the Atlas V EELV rocket assigning a specific rocket to the mission was completed by the EELV Program Office in Los Angeles, CA. and the formal "signing party" for the contract was held on 10 June 2004. The 24-month standard services contract will commence on time for an Integration Initial Launch Capability (ILC) of 1 Sep 06. The actual launch date will be selected around L-1 year in coordination with the Eastern Range launch schedule. By the time the actual Small Satellite Conference is held, the STP program office should be well on its way to planning the integration and flight specifics for this mission.

### *Coupled Loads Results*

One of the major concerns for the STP-1 mission is the flight environments (static loads, vibration, shock) that the ESPA-class payloads would be subjected to in a horizontal position relative to the vehicle flight direction. This has been one of the major obstacles in the mission design. The ESPA-class payloads have been designing, building and testing their Qualification models to be able to withstand certain "estimated" launch environments. The STP program office was quite conservative in setting these testing levels because we did not want any of the ESPA satellites to "under-design" their spacecraft, progress down the road to building their bus and then get "updated" environment levels to where they would have to redesign part or all of their spacecraft.

The launch vehicle switch caught us in the middle of figuring out what the estimated environments might be on a Delta IV rocket. With the switch to a different rocket, many of the studies and work to this effort had to be reaccomplished. This would not normally be a big deal, outside of monetary cost, but with the ESPA satellites progressing towards the build/test phase it presented a couple different problems. Some satellites needed to delay tests until Atlas launch environment info was available which increased the cost to the different programs in by extending the monthly "standing army" costs and requiring revisions of schedules and testing accommodations. The first major milestone once the Atlas V Special Study commenced was the completion of the initial coupled loads analysis. With those results in, the Integrating Contractor, STP Program Office, Lockheed Martin (LMA), and Aerospace are trying to develop a coordinated testing plan to satisfy all launch requirements and ensure a successful mission for each and every one of the satellites involved.

## UPCOMING STP-1 EVENTS

### *Atlas V items*

The Atlas V Special Study is approaching its Midterm Review Mtg (29 Jun 04) and the study is progressing well. Many items have been uncovered as areas for further review and study, but with the teamwork involved in this study, each item has been worked as needed and no "show-stoppers" have been discovered.

The Special Study will conclude in September '04 with a complete outbrief and test report on the following topics:

1.) Preliminary Design Load Cycle
2.) Performance/Control and LV Margin Analysis
3.) Integrated Payload Stack Mission Support plan
4.) Draft LV ICD development
5.) Payload fairing and LV Adapter design
6.) Electrical interface design
7.) LV Mission integration schedule
8.) LV Dynamic environments
9.) Mission-specific requirements
10.) Program Management Plan

### *Separation System progress*

The separation mechanism for the ESPA payloads is also of significant importance in order to complete the various satellite missions and is also a high priority due to its lack of flight experience and qualification. The STP-1 mission will be the first mission to flight-test both the Planetary Systems Corp (PSC) developed "Lightband" separation system and the StarSys Research Company's CBOD mechanism. Both systems look to be able to do the job of separating an ESPA payload from the ESPA interface while on-orbit, but neither is completely "flight-qualified" by STP standards. The Integrating Contractor is currently developing a testing plan and schedule to get both of these systems to a minimum "flight qualification" level by mid-2005 in preparation for the ESPA satellite separation and electrical interface tests.

### *Integrated Operations Plan*

The other major obstacle that is of significant importance for the STP-1 team will be the process of integrating of seven different payloads at Cape Canaveral, the launch countdown mission rules/launch commit criteria, the on-orbit deployment/hand-off or all seven satellites, and early orbit operations for these missions. Three of the seven satellites will be operated out of the Research, Development, Test and Evaluation Support Complex (RSC) at Kirtland AFB, NM. The other four satellites will be operated from individual control centers at the USAFA, USNA, LANL, and NPS located across the United States. Plans are currently being developed for this HUGE coordination task and developing the launch and on-orbit procedures to make this mission a success for every part of the STP-1 team.

## FUTURE STP PLANS

### *The "Pathfinder" mission*

The STP-1 mission is a "pathfinder" mission not only for STP-2 (currently planning on an estimated 2010 launch), but also for all small satellites that want to take advantage of excess margin on future EELV launches. Several future EELV missions have expressed a willingness to work with the small satellite communities and utilize all of the capability of the EELV rocket.

### *STP-1 Benefits for Small Satellites*

Another key outcome of this mission will be a measurement of the actual flight environments. The STP-1 mission, as a first-of-its-kind mission, is scheduled to be heavily instrumented to record "actual" flight environments. This data will be downloaded and analyzed in determining some basic "design-to" requirements for future ESPA-class satellites. This should significantly decrease the SV design/redesign costs because the expected launch environments will be known and there will not have to be any satellite redesign when the estimated launch environments are "updated."

STP-1 is breaking the ground for the small satellite community on larger launch vehicles and even opening the door for small satellites to occupy a complete medium launch vehicle manifest. The EELV Secondary Payload Adapter (ESPA) will prove the technology of multiple small satellite deployment in the same orbit among other vital items associated with multiple launch vehicle payloads.

## CONCLUSION

Taken together, each of the STP-1 milestone events, truly makes this mission the "first of its kind" and a watershed event for the world of small satellites. The next year for this program holds many vital milestones including satellite and hardware build, satellite flight unit testing, separation system procurement and qualification, flight operations development, and mission success criteria definition to name a few. When we talk next year hopefully the news will be all good and we will be near completion of many of the most vital milestones. Talk to you then!


### *Acknowledgements*

The DoD Space Test Program (STP), which falls under the Space and Missile Systems Center (SMC) headquartered in Los Angeles, CA., has a wide variety of platforms to host space research and development experiments including Small Class Spacecraft, Medium Class Spacecraft, the Space Shuttle, and Piggyback on other spacecraft. STP provides spaceflight for qualified DoD-sponsored experiments at no charge to the experimenter, via the DoD-Space Experiments Review Board (DOD-SERB). STP also provides services to other experimenters on a reimbursable basis.

This medium launch vehicle multi-satellite program has been successful to this date due to the undying efforts and teamwork of the Det 12/STP Mission Managers, Aerospace personnel (located at Kirtland AFB and LA AFB), the Boeing Integrating Contractor personnel, Lockheed Martin Atlas personnel and SMC/EV. Management support at all these locations has given the team the money and tools to get the job done on the "first-of-a-kind" mission. The satellite communities at Boeing Phantomworks/DARPA (OE), AeroAstro (STPSat-1), LANL and SSTL (CFESat), USNA (MidSTAR-1, USAFA (FalconSAT-3), and NPS (NPSAT1) have put significant effort into ensuring the future success of not only their satellites on STP-1, but the mission as a whole. I have to thank all these communities for keeping the communications lines open and always pushing forward towards integration and launch.

I also received significant contributions for the specifics of this paper from Lisa Berenberg and Riaz Musani of the Aerospace Corporation located at Kirtland AFB, NM. Additional information, outside the references listed below, was received from Melissa Wright, SRS Technologies and Michael LaGrassa, Aerospace Corporation. Thank you to all who helped me collect this information.


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