SPACE TEST PROGRAM ACTIVITIES AND LESSONS LEARNED

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Abstract

The Space Test Program (STP) was established in 1966 to provide space flight for Department of Defense (DOD) space experiments which had no other means of space flight. This paper discusses STP's capabilities and achievements as a provider of space services. STP is now part of a new organization with expanded capabilities to include on-orbit support, launch operations and planning, and sub-orbital launches. With extensive experience acquiring, launching, and operating small satellites, lessons learned from recent missions are presented.

Introduction

The Space Test Program (STP) serves the research and development community by providing unique and valuable space flight opportunities for advanced Department of Defense (DOD)-sponsored experiments that do not have their own funds for space flight. In addition to providing flight opportunities, STP also funds the spacecraft and launch vehicle integration, and one year of the data retrieval costs.

STP is a tri-Service (Army, Navy, and Air Force) program under the executive management of the Director of Space Programs, Office of the Assistant Secretary of the Air Force-Acquisition (SAF/AQS). The actual planning and execution of the various space flight missions is done by the Air Force's Space Test and Small Launch Vehicle Programs Office, Space and Missile Systems Center (SMC/CUL), located at Los Angeles Air Force Base, California.

STP Experiments

As a space services organization for the DOD research and development community, STP flies experiments from many different agencies, but all experiments must have some degree of military relevance. These range from experiments whose resulting scientific data potentially affect future military systems or operations, to experiments that provide major inputs to current significant DOD systems.

A non-DOD experimenter must obtain sponsorship from a DOD organization. Again, military relevance is the key to success in securing sponsorship. Both the experimenter and sponsor share the responsibility for experiment funding, development, fabrication, qualification testing, and post-flight data reduction and analysis.

Members of the DOD research and development community, or research institutions that support DOD, can benefit from STP if they are involved in:

* Proving a new concept to accomplish a military mission in space.

* Testing or demonstrating space hardware before it is required for the development of an operational DOD system.

* Researching and collecting data in the space environment that is useful in the performance of a military mission.

The military, in turn, benefits from the scientific data, new or improved satellite systems, or better ways to conduct military operations in space resulting from these experiments.

Achievements

In its first 25 years, STP played a significant role in the development of military space systems. Since its inception in 1966, STP has flown over 250 experiments on over 75 missions directly benefiting scientific research and many operational satellite programs.

For example, STP flew the Spacecraft Charging At High Altitudes (SCATHA) experiment to measure the charge on spacecraft surfaces and conditions of plasma surrounding the spacecraft. SCATHA has provided a data base for analyzing anomalies that have occurred in military spacecraft such as the Defense Satellite Communications System (DSCS) and the Defense Support Program (DSP).

Often, technology proven through STP experiments evolves into a new realm of capabilities. The knowledge gained from STP experiments on radiation belts, satellite charging, and rubidium atomic clocks contributed to the creation of the Navigation System using Timing Ranging/Global Positioning System (NAVSTAR/GPS), which provides precise navigation information to a variety of military and civilian users.

The STP Lincoln Experimental Satellites 8 and 9 (LES 8/9) proved that two satellites could cross link at extremely high frequencies, making possible the U.S. Navy's Fleet Satellite Communications (FLTSATCOM) System. FLTSATCOM provides high priority command and control (C^2) communications for land, sea, and air-based users. The U.S. Air Force Satellite Communications (AFSATCOM) system, which provides C^2 communication for U.S. global nuclear forces, is carried aboard FLTSATCOM satellites.

Space Flight Modes

STP employs a variety of free-flying spacecraft, Space Shuttle-attached carriers, and piggybacks on operational satellites to fly experiment payloads weighing from a few pounds to several tons.

For experiments with unique orbital requirements, STP funds, develops, integrates, and launches its own sophisticated free-flying spacecraft.

The Space Test Experiments Platform (STEP) is intended to be STP's primary flight mode. It is an adaptable small satellite bus developed to provide quick-response space flight for STP experiments. The STEP bus is designed for launch on the Air Force Small Launch Vehicle (Pegasus) and is envisioned as a "pick-up truck" using low-cost, off-the-shelf hardware for experiments of 1 to 3 years' duration. Two STEP missions per year are expected beginning FY 93.

For experiments that exceed STEP's capabilities, STP flies a medium launch vehicle (MLV) class satellite every four years. A recent example is the Combined Release and Radiation Experiments Satellite (CRRES). Our next MLV class mission is scheduled for a 1995 flight.

STP also flies experiments as secondary payloads on spacecraft of various agencies, including NASA and DOD. For example, the Ionospheric Current Systems and Aurora (ICSA) experiment, a magnetometer designed to measure in situ variations of the magnetic field associated with auroral activity, flew on a Defense Meteorological Satellite Program (DMSP) spacecraft.

The Quick-Response Shuttle Payloads (QRSPs) comprise a class of STP payloads that includes Space Shuttle middeck and aft flight deck locker experiments, and certain simple cargo bay experiments using Get Away Special (GAS) canisters and Hitchhiker opportunities. As part of the QRSP Program, astronauts have taken photographs of aurora and clouds using STP's space-qualified camera equipment.

Air Force Small Launch Vehicle

In addition to STP activities, SMC/CUL manages the Air Force Small Launch Vehicle (SLV) contract, which is currently for the Pegasus launch vehicle. The SLV will provide access to space for STEP and other small spacecraft.

STP Part of a New Organization

In July of this year, SMC/CUL became part of a new organization, the Space Experiments Program (SMC/CU), which is to be the Space and Missile Center's focal point for development test and evaluation (DT&E) of "one-of-a-kind" research and development systems. The mission of the organization is to provide safe and cost effective military DT&E flight opportunities and support for R&D.

STP and the SLV programs are managed by the Space Test and Small Launch Vehicle Programs Office (SMC/CUL). Besides SMC/CUL, other divisions in SMC/CU include:

* Re-entry Systems Launch Program (formerly part of the Ballistic Missile Office, Norton AFB, CA). This directorate provides sub-orbital launch capabilities, and testing and evaluation to support missions. Coming on line in 1994 is the capability to provide inexpensive space launch using Minuteman II assets.

* Test Integration and Launch Directorate (formerly 6595 Test and Evaluation Group, Vandenberg AFB, CA). They will perform government validation and verification for program activities by assisting in the early identification of test objectives, critical issues, and methods to assure a safe, reliable test program. This directorate also has the launch operations responsibility for any DT&E tests and for our Minuteman assets, and can provide test analysis and requirements traceability capabilities.

* Space Test and Evaluation Directorate (formerly Consolidated Space Test Center, Onizuka AFB, CA). They will provide management, planning, design, development, procurement, operation, and maintenance support for on-orbit satellite operations.

* The Customer Service Office is newly formed and is located at Los Angeles AFB, CA to function as the front door to all new customers of this new organization. This directorate will also provide initial planning and long-range infrastructure planning for the Space Experiments Program. Parties interested in SMC/CU services should contact Capt Don Johnson, SMC/CUC, P.O. Box 92960, Los Angeles AFB, CA 90009-2960, (310) 363-2504.

Small Satellite Experience

STP has been flying small satellites from its inception. Our recent history includes five small spacecraft (less than 300 pounds) flown since 1986, all of which are still operational. Another small satellite is scheduled for launch in 1993. The payloads range from geo-magnetic mapping to store-and-forward communications to space based radar calibration.

The environment for building small satellites is very demanding. Schedules are short, budgets are small, requirements are big and expectations long. Managing a small satellite effort requires attention to detail, technical competence, and a close working relationship with an innovative spacecraft builder who will quickly find solutions to unique problems.

Yet rewards abound. It is possible to see a space system progress from conception to successful operations in two years or less! Smaller spacecraft have equivalent subsystems to large ones, but are generally simpler, so a single manager can "get their arms around" the entire satellite, its payload, spacecraft subsystems, and operations. Small satellites can provide large rewards for a small number of dollars as well as operational independence to the payload user.

Lessons learned from our recent small satellite activities are broken into four categories:

* Spacecraft Planning
* Development
* Integration and Test
* Operations

Spacecraft Planning

When selecting a spacecraft contractor, look for an organization which is responsive and willing to assume inner company risks to assure a quality product in a short period of time. With typically short schedules, answers to questions and solutions to problems cannot be hindered waiting for paper work or by simple lack of action.

Competence and experience with space systems is important, but beware of exaggerated claims to unproven capabilities. While an organization may claim unique capabilities and experience, be certain of real capabilities and the ability to continually improve a product. One successful spacecraft under their belt does not guarantee another. New programs bring on new people. Different spacecraft and payloads ensure new and different problems. Past successes does not always guarantee successful future products.

Plan for an excellent product at a fair price. When negotiating a contract be prepared to verify all proposed facts, including performance capabilities, cost estimates, and performance criteria. Then be prepared to pay a reasonable price with rewards for good performance. Nickel and diming a contractor and frequent cost changes can only detract from useful progress.

Be cautious about being oversold on previously flown spacecraft hardware. We accepted a claim on a deployable boom without sufficient verification and test. The results were an improper deployment and degraded on-orbit performance. Plan up front to verify and test all hardware and subsystems.

Clearly define requirements and stick to them. After the baseline requirements and design have been defined, there is always a temptation to add enhancements--and sometimes completely new payloads. The question should be asked: Does this addition help achieve a requirement, and if so, is it worth the schedule and budget risk?

Lastly, a small satellite program manager must surround himself or herself with experts. Even though we can "get our arms around" a small satellite in a general sense, it is not reasonable to expect one person to be an expert in all areas. We frequently go to our experts for advice on specific problems, and for general oversight in their area of expertise.

Development Phase

The ability to solve problems quickly and cheaply is paramount. We have been very fortunate with our contractors' talents in this regard. We have worked closely as a team, recognized problems early, and everyone works for quick and inexpensive solutions. Most small spacecraft programs are on a fixed budget and even mild cost over-runs could mean the cancellation of a program. Unfortunately, we have been involved in programs that were never completed for this very reason.

Work with the contractor to develop a highly motivated work team. "Let-someone-else-fix-it" attitudes and clock watching workers have no place in small satellite building. Keep enthusiasm high, remember that people make the product, and reward those people and teams who perform well.

Keep focused on the objective. Frequently ask, "Is the product what was planned? Are we achieving a system that will meet the payload users expectations?" Remember that the spacecraft is to be designed to support the payload, the payload is not designed to support the contractor's spacecraft.

Audit the program in phases -- don't wait until a disaster happens. We have found "hands-on" evaluations of performance to be most effective. Be where the action is, mingle with the engineers, be aware of alternatives and pursue them if they show promise. Cancel unproductive activities early. And again, reward a good product.

Ensure that each subsystem has been thoroughly designed and tested before integration, including:

* Attitude Control
* Power System
* Payload Interface and Control
* TT&C
* Software
* Payload

Execute the plan with thoroughness during development. Leave no questions unanswered. Don't let the schedule impair the need for development testing. Remember if it doesn't work here, it won't work on orbit.

Integration & Environmental Test

There is no forgiveness for bad work after launch. Integration and testing validate the space system and finalize the design. It is the last chance to find and fix faults in the system. Small satellites tend to be single string--we have a tendency to reduce or eliminate redundancies to keep it light, simple, and small. This makes testing even more critical. Those single strings must work. Testing exceeds all other activities in importance.

Some guidelines based on our experience:

* Every subsystem should be functionally tested during integration and during environmental tests.

* Insist on thorough test plans and procedures, and in advance for appropriate review (use your experts). Failure and re-test criteria should be well established. Isolate intermittents regardless of the time it takes. Accept no compromises during testing. Get that "warm fuzzy" that everything will work.

* Take nothing for granted--if in doubt, retest.

* Final functional test should be in a "fly alone" mode operated by RF link only with no Ground Support Equipment (GSE) attachments.

* Quality Assurance (QA) oversight by a party independent of the spacecraft contractor should be present for all development, integration, and test activities. Non-biased oversite is essential to ensure quality at every level.

We failed to perform the final functional test by RF link on one spacecraft. The GSE flipped a bit that allowed a particular subsystem to operate, but without the GSE connected, the subsystem was inoperable. The fault could easily have been fixed if we had only tried it once by RF link. Again, the schedule, budget, and contractor eagerness to finish the product cost us the operation of this subsystem. Fortunately, in this case, the subsystem was redundant and the spacecraft is performing well.

Operations

We have operated our spacecraft successfully with PC based ground stations providing direct spacecraft control and data ground link transfer. These ground stations should be simple, user friendly, and with built-in automatic anomaly alerts. This type of system works especially well if the data transfer rates are low and spacecraft control is simple.

With the dedicated autonomous ground station it is easy to maintain a close link to the payload user and the spacecraft operator. When feasible, we have turned the ground station over to the user and let them collect spacecraft data and control on-orbit operations. The user, like no one else, will concentrate on successful operations and collection of data. Avoid creating or promoting a bureaucracy for spacecraft operations.

Conclusion

While the suggestions in this paper may seem obvious and perhaps unoriginal, in the heat of trying to meet schedules and cost, we don't always do the obvious. Because sponsors and funding sources are very intolerant of failures, it is vital to apply these lessons learned to ensure success.

The small, low-cost satellite business isn't for the faint of heart, but it can be exciting and full-filling. We are positive about future prospects for small satellites and expect that STP will continue to successfully utilize them to meet the requirements of our customers.