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Increased Government Involvement in Developmental Test and Other Lessons Learned from Responsive Space

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Recent legislation recognizes the value of increased emphasis on systems engineering in the acquisition process. Of particular interest to the acquisition community are the major reductions in government developmental test and evaluation resources over the past decade. This is particularly true regarding drastic cuts in the developmental test workforce resulting in much testing being accomplished with little government oversight or involvement. Potential remedies prescribed by the Weapon Systems Acquisition Reform Act (WSARA) of 2009 and changes to DODI 5000.02 are expected to reinvigorate Department of Defense systems engineering in general and specifically, developmental testing. These include the establishment of senior defense positions to provide oversight, additional reporting requirements, increases in the size and more attention to development of the systems engineering workforce.

Space assets generally require significantly more rigorous testing than other DoD systems because they must work perfectly the first time since there is no economically feasible method for repair or adjustment of on orbit space assets. Significantly reducing time to plan and execute the testing of space assets coupled with the demand for high fidelity testing generate one of the largest challenges to meeting demands for responsive space.

The Space Development and Test Wing (SDTW) at Kirtland Air Force Base has a long history of successfully launching and operating research and development (R&D) satellites which by nature have short acquisition cycles. SDTW also works closely with the recently created Operationally Responsive Space (ORS) office which is focused on fielding operational satellites in very short time frames. This makes the SDTW a perfect setting for developing test methods and examining and improving the testing process. The Space Development and Test Wing began the process of increasing government involvement and oversight into developmental test in 2007. Although there were initial growing pains, the SDTW model has proved to work exceptionally well in the responsive space arena. Some of the lessons learned at SDTW are potentially applicable to larger, more monolithic programs and may suggest ways to improve test processes for other space systems developers as well as provide insight into successfully increasing government involvement in developmental testing.

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I. Introduction

The Weapon Systems Acquisition Reform Act (WSARA) of 2009 (WSARA) was signed by the President on May 22, 2009 (Public Law 111-23). It was soon followed by a Directive-Type Memorandum (DTM) 09-027, Implementation of the Weapon Systems Acquisition Refrom Act of 2009. DTM 09-027 was signed by the Under Secretary of Defense (USD) for Acquisition, Technology and Logistics (AT&L) on 4 Dec 2009, instutionalizing WSARA, amending acquisition policy in Department of Defense (DoD) Instruction (DoDI) 5000.2, the Defense Acquisition Guidebook and the Defense Federal Acquisition Regulation Supplement (DFARS). WSARA statuatory direction was effective upon signing of the document. Implementation of acquisition policy and process changes such as changes to Milestone A and B certification processes is accomplished on new programs as they come up for review while a retroactive certification process is underway for older programs.

II. Senior Oversight

WSARA recognizes the importance of Systems Engineering (SE) and Developmental Test (DT) to weapon systems acquisition and creates the positions of Director of Developmental Test and Evaluation (DDT&E) and Director of Systems Engineering to be appointed by the Secretary of Defense. Both are supervised by the USD AT&L. The design is to force/ensure a cooperative and synergistic relationship between the two offices fostering joint coordination and resulting in joint DT&E and SE guidance. The Directors are required to present the Joint Report on DT&E and SE Activities annually to Congress.

A. Director of Developmental Test and Evaluation

The DDT&E may be dual hatted as the Director of the Department of Defense Test Resources Management Center (TRMC). The Director is tasked with development of DT&E policies and guidance and approving the Developmental Test and Evaluation (DT&E) portion of the Test and Evaluation Strategy (TES) and/or the Test and Evaluation Master Plan (TEMP) for Major Defense Acquisition Programs (MDAPs) instead of the USD (AT&L). The DDT&E is the principal advisor to the Secretary of Defense and the USD AT&L on developmental test and evaluation in DoD.

A major role of the DDT&E is to "provide advocacy, oversight, and guidance to elements of the acquisition workforce responsible for developmental test and evaluation" and to "periodically review the organizations and capabilities of the military departments with respect to developmental test and evaluation and identify needed changes" [1]

B. Director of Systems Engineering

The Director of SE (DSE) is charged with developing systems engineering policies and guidance and approval of the Systems Master Engineering Plan (SEP) for MDAPs. This was previously accomplished by the Deputy USD for Acquisition and Technology. The DSE is the principal advisor to the Secretary of Defense and the USD (AT&L) on systems engineering and development planning in DoD.

The DSE is required to "provide advocacy, oversight, and guidance to elements of the acquisition workforce responsible for systems engineering, development planning, and lifecycle management and sustainability functions' and to "periodically review the organizations and capabilities of the military departments with respect to systems engineering, development planning, and lifecycle management and sustainability, and identify needed changes or improvements to such organizations and capabilities." [2]

III. Improving of the Developmental Test and Systems Engineering Workforce

In addition to assigning workforce development roles and responsibilities to the DDT&E and the DSE, there are other important changes. One benefit to the DT&E and SE communities is the increased emphasis on effectively managing, resourcing, and training the DT and SE workforce. WSARA requires Component Acquisition Executives (CAEs) of MDAPs to appropriately resource DT&E and SE organizations, and report to the Directors within 180 days that they have done so. Also, the DDT&E and the DSE are required to report on the extent to which each military department requires additional authorities or resources are to attract, develop, retain, and reward developmental test and evaluation personnel and systems engineers with appropriate levels of hands-on experience and technical and expertise to meet the needs of the military department or Defense Agency. Also, to implement WSARA, the Pentagon plans to beef up its acquisition personnel by hiring 20,000 new acquisition personnel. Eleven thousand of these new positions will be former contracted positions converted to civilian jobs. This expansion, with an intended completion date of 2015, represents a 15 percent increase in acquisition personnel.[3]

IV. Increased Governmental Involvement in Developmental Test and Evaluation

In the 1990s there was a large push to rely heavily on contractor support to complete the majority of government acquisition processes including testing and evaluation. This method unfortunately had two major negative side-effects. The first is it reduced the acquisition and testing expertise and knowledge within government personnel. This is commonly referred to as the "acquisition gap" and has been a topic of concern in government acquisition for many years. The second was a general degradation in the testing fidelity and rigor of new weapons systems. In an effort to overcome these problems more emphasis has to be made to improve in-house government knowledge in systems engineering and particularly expertise in developmental test. This involves not only becoming more involved in test and evaluation of new systems but leading and taking responsibility for such testing. The Space Test Operation Squadron (STOS) as the lead test organization of the Space Development and Test Wing (SDTW) has made major significant progress in returning to in-house test expertise that was historically enjoyed by the government.

There are many benefits connected with government personnel leading test and evaluation efforts of new systems. First of all it restores the natural incentive to plan and execute thorough yet timely test activities. Government test personnel are motivated to create effective test plans that ring out the systems capabilities every cognizant that these systems will be used by their fellow brothers in arms and never wanting to send a defective or dangerous product to the field. On the other hand, in-house government test personnel are also motivated to keep schedules and cost to a minimum and therefore are incentivized to compress test schedules as much as possible without sacrificing test fidelity and rigor. Unfortunately, relying on contractor testing does not usually produce these types of natural positive incentives since the contractor and their employees can often earn more with less effective control over cost and schedule, and increasing test fidelity usually only spells more work with little to no direct reward for the contractor. In fact, if the manufacturing contractor is also the testing contractor there is often a conflict of interest since rigorous testing may reveal flaws in the system they provided which will negatively impact their award fee and reputation. These factors make in imperative that the government develop the ability to conduct developmental test and evaluation activities in house rather than relying on contractors to run testing the very system they produced.

The STOS demonstrated this concept recently during the development of a R&D satellite. Early on in the program it was observed that the ground system (GS) contractor's testing strategy was severely lacking in detail, fidelity and rigor and as a result some of the early tests conducted did not produce the information and documentation that was expected. As a result, the government Test Integrated Product Team (TIPT) lead started to review the contractors test plans and documents in more detail and began requesting more information, organization and structure to their test methods and products. When testing issues continued, the TIPT assumed testing roles, such as system acceptance testing (SAT), that had historically been left to the contractor. As a result the SAT tests were conducted at a much higher fidelity and multiple days of redundant testing were trimmed saving the government both time and money.

Another benefit involved in improving government test expertise is an increased level of situational awareness, oversight and thereby control of testing. When testing is left to the contractor to plan and conduct, the government typically loses a significan amount of oversight and situational awareness regarding the test objectives and the extent and depth of what gets tested on each sub-system or component. The government becomes nothing more than a program manager of the test and not a true "tester." Without good situational awareness and oversight the government inherently loses control over the design and effectiveness/efficiency of the test. Having government personnel leading and planning test efforts allows them to design and tailor test objectives and procedures to efficiently and effectively evaluate the areas of the system considered most crucial and save time and money by reducing unnecessary testing on less important or critical components.

The government-led TIPT for the R&D satellite previously discussed took control of test events such as Factory Compatibility Test (FCT) and many other similar end-to-end tests. They developed test plans and ran the tests. The TIPT methodically moved from objective development within the test plan to procedure writing, focusing on the most critical and important aspect of the system for evaluation. The tests were executed more efficiently and with more rigor, thoroughly wringing out the system yet still finishing early, saving cost and schedule. For example, despite encountering significant system problems that halted testing multiple times, the system's FCT was completed a day and half early. The test reports identified many critical deficiencies, many of which absolutely had to be fixed before launch. Without government personnel leading this test effort it would have undoubtedly taken longer, focused on the wrong system components and lacked general test fidelity. It's conceivable that many of the launch critical deficiencies may not have been found at all, potentially jeopardizing the entire mission.

The government also benefits from growing in house testing expertise by reducing "standing army" cost and enhancing testing flexibility. Even though the contractor is still usually intimately involved in developmental testing, when the test is led by government personnel it saves the government money in the form of overhead costs. Allowing the government testers to act as test directors and managers reduces the contractor's personnel costs both before and during testing. This is especially important when there are test delays or halts that force the majority of the test team to stand around waiting for the issue to be resolved. The fewer contractors standing around doing nothing the more cost efficient it is for the government. Using government personnel to run testing also allows additional schedule flexibility since changing, adding or rescheduling test events doesn't require modifying or adjusting contracts or at least rests less heavily on such activities. A good illustration of this is when a major test didn't go as hoped and many deficiencies were documented preventing the government from accepting the system at that time. As a result, additional work and testing on the system was required but in order to get the contractor on contract to support additional test activities required a contract extension that took weeks to push through the system. In the meantime the government members of the TIPT were able to prepare all of the test documentation and planning to avoid additional testing delays since the contractor was on "stop work." This level of flexibility proved to be invaluable in keeping the program on schedule and preventing additional delays, and would have been impossible if the TIPT had not been leading the test activities at that point and intimately familiar with the system testing to that point.

In order to leverage these results and multiply their effect the Space Development and Test Wing and specifically the STOS has followed this pattern for all test programs and has taken on Responsible Test Organization (RTO) responsibilities throughout the wing. STOS has increased the level of government personnel involvement and responsibility in developmental test and evaluation (DT&E) of new systems. Immediately after receiving a request to support system develoment, STOS creates a TIPT and officially documents roles and responsibilities of each participating organization within a TIPT charter which is signed at the wing level. STOS then leads TIPT to produce the over arching test strategy and documents in a Test and Evaluation Strategy (TES) and/or a Test and Evaluation Master Plan (TEMP). These are used and updated throughout the program to guide through the test activities and phases. For each major test event, the TIPT establishes the test objectives together as a working group to design an efficient and effective test focused on the primary test purposes. The test plan is then designed around these objectives and the test procedures are derived from and mapped to the established objectives. The tests are then directed by the TIPT lead (acting as Test Director) and executed by members of the TIPT usually either by users or the manufacturing contractors. At the conclusion of each test STOS generates an immediate Quick-look Report and later a Final Test Report to document the results of each test. Lessons learned from each test are also documented and applied to future tests both for the current program and for other programs throughout the Wing. Government test experts lead the TIPT For all of these test events and focus on rigorous yet efficient and timely testing. The test expertise developed by government personnel through this process enables them to offer important test advice to the Program/Project Office (PO) on many occasions regarding contract requirements and deliverables from the contractor. They are able to evaluate the contractor's test approach and deliverable for content and usefulness and offered recommended changes to the PO. They have identified multiple problems with the testing contractor's test plans, procedures, deliverables such as requirements verification traceability matrix (RVTM) and test reports regarding accuracy, validity, content and completeness.

STOS is currently in the process of using this test expertise and "lessons learned" to even further standardize test policies and methods. All test documentation is being standardized for format, content and structure to allow simple reuse without duplication of effort and to reduce confusion and improve organization and understanding. Testing guidelines and a database of "lessons learned" and best practices are also being developed based on the testing expertise gained through leading test events.

V. Standardization

Government leadership in Developmental Test at SDTW has resulted in major gains in efficiency due to standardization. Space acquisition systems encounter significant difficulties compared to terrestrial acquisition systems as a result of three main factors: 1. The harsh and extreme environment in which they operate including solar radiation, lack of oxygen, zero gravity, extreme temperature cycles and other space debris and radiation; 2. The small number of operational units built for each program, many are one of a kind and even the largest programs rarely have more then 20 to 30 satellites per constellation; 3. Since there is no economically feasible method for repairing orbiting space assets they must work the first and every subsequent time without maintenance or physical intervention.

As a result of these factors space systems generally require much more rigorous and thorough developmental testing than non-space systems. However, there has been a recent emphasis by the DoD to accelerate and shorten space acquisition cycles to meet urgent DoD goals and needs. This schedule compression makes executing rigorous and thorough testing on new space systems especially difficult. Space acquisition experts have concluded that one of the best methods for meeting the aggressive acquisition schedules is to standardize the new systems as much as possible, specifically the hardware, software, interfaces and support equipment. In order to maintain rigorous testing in short space acquisition programs the benefits of this standardization must be leveraged.[4,5,6]

The Space Development & Test Wing (SDTW) performs testing for many Research and Development (R&D) satellites which by nature have short acquisition cycles. The SDTW also works closely with the recently created Operationally Responsive Space (ORS) office which is primarily focused on rapidly producing and fielding operational satellites. This makes the SDTW the perfect setting for analyzing methods designed to expedite the testing process without sacrificing fidelity. Engineers at the SDTW have conducted an analysis of test methods within the Wing to work toward understanding and resolving the challenges of rapid testing required by compressed development schedules. The analysis indicated that the key to accomplishing high-quality testing in a limited timeframe is to leverage standardized equipment and hardware, software, test strategy and the documentation and by seeking opportunities to combine test activities.

VI. Standardizing the Equipment and Hardware

Recent ORS and R&D space programs under development and test at SDTW have made significant efforts to standardize common equipment; this standardization has successfully reduced system acquisition timelines. Testing of these compressed-schedule systems must leverage standardized equipment in order to proportionately reduce testing timelines. This concept has been implemented on both ground system (GS) and space vehicle (SV) systems within the SDTW.

C. Standard Ground System

The Multi-Mission Satellite Operation Center (MMSOC) Ground System Architecture (GSA) is an example of how leveraging of standardized equipment can be used to shorten GS testing timelines without losing fidelity or test rigor. The MMSOC GSA system was designed as a standard core command and control (C2) system to be used on all future satellites that will be built or fly out of the SDTW or Satellite Operations Center (SOC) 11 at Schriever AFB. The MMSOC GSA Strategic Intent document describes the advantages and efficiencies of such a system.

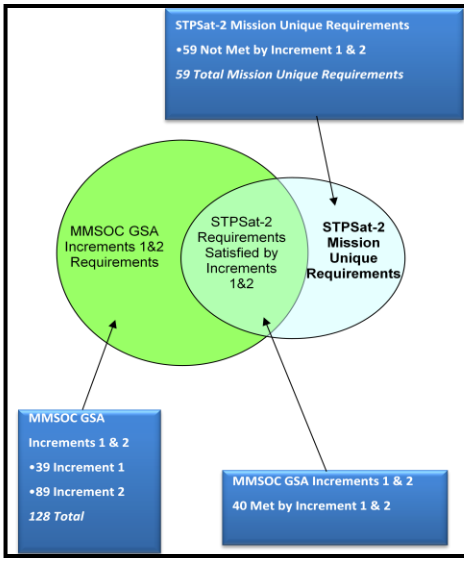
> "The MMSOC GSA will consolidate satellite operations by providing an agile and flexible overarching ground system enterprise. Additionally, a tailor-able standard user interface will provide commonality across multiple missions which will minimize cost and time investments. This flexibility and responsiveness is the key enabler to achieve the capability. The MMSOC GSA is designed to support multiple types of satellites. Because the satellites this ground system will operate are varied, it will not be built as an optimized (or stove pipe) system. To enable the MMSOC GSA to have the flexibility to operate many different satellite missions and payloads, internal and external interface standards must be established. These standards will be published for the satellite developers and manufacturers, developers of [Telemetry, Tracking and Command] TT&C tools, and external agencies that will interface with the MMSOC GSA. By establishing, publishing, and applying interface standards the MMSOC GSA will be able to rapidly integrate new satellites, increase capability through hardware and/or software upgrades, and expose and publish data and services to other users... The standard interface will minimize the impact of satellite specific implementation, allow the MMSOC GSA to follow a spiral development path, and enable more rapid integration of new or improved capabilities."
>
> "The MMSOC GSA will provide a defined standard interface for satellites and external users. With these standard interfaces, the MMSOC GSA is a net-centric satellite operations system, providing rapid integration of new satellites… [and] provides for rapid expansion of system capability through hardware and/or software upgrades. The design of MMSOC GSA enables rapid capability expansion to support joint or interagency operations. The MMSOC GSA, as an ORS enabler, will follow the ORS procurement process. This process allows for rapid acquisition of systems in order to support warfighter needs…"
>
> "The MMSOC vision provides a collaborative environment where warfighters and developers can rapidly and cost-effectively introduce new space capabilities to the fight."
>
> "ORS provides the capacity to respond to unexpected loss or degradation of selected capabilities, and to provide timely availability of tailored or new capabilities. Currently, the MMSOC GSA has been designated as a primary satellite operations capability for the ORS satellites and/or payloads. It has been designated as the ground system for ORS Sat-1, and Space Test Program (STP) Sat 2."[7]

This description emphasizes the concept that use of standardized GS equipment, hardware, software and interfaces will shorten the development schedule of future satellite programs. The advantages and efficiencies obtained through a common core ground system must also be leveraged by the test community to reduce testing timelines. This is currently being demonstrated in the testing strategy of both satellite programs identified in the Strategic Intent document, STPSat-2 and ORS-1.

MMSOC GSA provides the common core ground system for both satellites. The core consists of a majority of the requisite GS hardware and a platform for Command and Control (C2) software, such that new satellite programs could simply develop and install necessary mission unique hardware and software and be ready to launch in a very short time period. Since the core functionalities that are generally common among most satellites are met by the core MMSOC GSA system, new satellite systems can save testing time by referencing the MMSOC GSA test results rather than duplicating them. Since many of the system requirements are met by the core system, the results from previous MMSOC GSA testing can be applied to "buy off" on the mission unique GS requirements.

The STPSat-2 program will be the first satellite to fly on the MMSOC GSA system with ORS-1 to follow. Both programs are developed in parallel, which afforded the opportunity to directly identify requirements overlap. During the Preliminary Design Review (PDR) it was shown that of the 99 total STPSat-2 GS requirements (found in the Ground Specification Document[8]), 40 requirements overlapped with MMSOC GSA requirements. This meant that test results from MMSOC GSA acceptance testing could be directly used to verify 40 STPSat-2 requirements, leaving only 59 mission unique requirements to be verified through STPSat-2 testing. Assuming a relatively even distribution of requirement verification work load, this equates to a reduction in testing effort by more than 40%. By estimating the total amount of time required to test the 59 STPSat-2 Mission Unique (MU) GS requirements as being close to 6020 contractor man hours[9], the overlapping requirements saved the STPSat-2 program over 4080 man hours. This estimate doesn't include government employee man hours saved. Figure 1 illustrates the requirements overlap between MMSOC GSA and STPSat-2 MU GS. The resulting time and man hours saved could be redirected to focus on accomplishing mission unique hardware and software testing and accelerate the overall test schedule for STPSat-2.

The ORS-1 Program Office and their Responsible Test Organization (RTO), SDTW Space Test Operations Squadron, will also leverage MMSOC GSA testing and operations to reduce ORS-1 GS testing similar to that of STPSat-2. ORS-1 will be able to directly reference test results from MMSOC GSA testing to buy off the core capabilities of the GS, allowing ORS-1 testers to focus on the mission unique portion of the ORS-1 GS. Additionally, since ORS-1 will launch after STPSat-2, the successful test results and operational performance of the STPSat-2 can be leveraged by the ORS-1 RTO to reduce risk and improve confidence. In this regard, ORS-1 can essentially treat MMSOC GSA as Government Furnished Equipment (GFE), drastically diminishing the amount of testing required. By leveraging the test results of MMSOC GSA and applying them to other satellite programs the testing schedule can be accelerated without sacrificing testing rigor or fidelity.



# of Requirements	Mission Unique Requirement Areas
11	Data Processing
11	Data Exchange
9	Automatic Retransmission
7	Mission Planning
5	CCSDS
5	Routing Telemetry to SPEX Area
3	Payload Test Center
2	Trending
2	Display
1	Automatic Command to Restart Transmission
1	SPEX Archival Processing
1	Memory Management

Figure 1: MMSOC GSA and STPSAat-2 MUS Requirements Overlap[10]

In addition to MMSOC GSA, ORS-1 will leverage testing and operations of other portions of the GS that were accomplished on prior satellite programs. The ORS-1 satellite will downlink information through ground terminals referred to as Common Data Links (CDL). One of the 2 ground CDL units that will be used for ORS-1 is currently in use at the National Air and Space Intelligence Center (NASIC) at Wright-Patterson Air Force Base for Tactical Satellite #3 (TacSat-3) contacts. The only difference in downlink configuration between ORS-1 and TacSat-3 are the types of files being downloaded. This similarity will reduce the amount of testing required for the CDL ground equipment, since it is already being used operationally. ORS-1 CDL testing will consist of a simple installation and checkout at the site, along with flowing data through the system during an End-to-End (N2N) test, essentially allowing the CDL to be treated as an off-the-shelf component that has already been operationally tested. Additionally the use of the CDL was demonstrated prior to TacSat-3 launch by its predecessor TacSat-2. ORS-1 operational use of the CDL will leverage test results from both heritage systems to "buy down" risk and improve confidence without extending the testing timeline. This process will save ORS-1 numerous testing hours without compromising test rigor.

D. Standard Spacecraft Bus

Similar results can be obtained for spacecraft testing as well. A Standard Interface Vehicle (SIV) or "standard bus" was developed for use on STPSat-2. The objective of the program is to develop multiple space vehicles with a standard payload-to-spacecraft interface that is applicable for all SIV missions. In other words, the concept is to create a common bus that has standard interfaces so that all future Satellite Test Program satellites can be built around the same bus structure. Reusing a standard bus structure with standard interfaces will reduce development time and cost for future STP satellites. Additionally, use of standard interfaces can be used to reduce testing timelines. For example, the bus structure of STPSat-2 (SIV-1), was subjected to qualification testing, which is much more rigorous than prototype testing, and similar to most live fire testing, ultimately rendering the test article unflight worthy. The second SIV (SIV-2) will serve as the spacecraft bus of STPSat-3. Since SIV-2 has an identical physical structure to SIV-1, the results from SIV-1 qualification tests can be reused to qualify SIV-2 without requiring a retest. SIV-2 will only have to undergo prototype testing which will save time since a qualification test article will not need to be manufactured and tested at qualification levels again. Since the prototype test article will not have to undergo qualification testing it will still be considered flight worthy and another physical structure will not need to be manufactured for use on the operational satellite. This will save both manufacturing and testing man hours that otherwise would have to be duplicated for SIV-2. Leveraging the similarities between SIV-1 and SIV-2 allowed the test schedule for STPSat-3 to be accelerated without reducing test fidelity.

Another way spacecraft bus standardization maximizes test efficiency is by reducing time and effort in test procedure development. The interface test procedures produced during SIV-1 testing can be reused in full with SIV-2 since the interfaces are all standard. Authoring, editing, checking and correcting the test procedures to achieve their final state represent a significant amount of time which does not have to be duplicated as a result of taking advantage of standard interfaces. See Figure 2 for an illustration depicting GS and SV standardization programs.

Another excellent example of improving test efficiency on space vehicles is found in the ORS-1 and TacSat-3 relationship[11]. The ORS-1 satellite will be built on a bus that is nearly identical to the TacSat-3 bus. ORS-1 will reuse many TacSat-3 features with only minor modifications including: the Global Positioning System (GPS) receiver, Power Control Electronics, Battery, Solar Arrays, Command and Data Handling (C&DH) (99.9% Heritage), Power supply, TAM, PPT's, fault management plan, flight software (FSW), Guidance, Navigation and Control (GN&C), hardware (HW) status, collection algorithms, collections operations, guidance algorithms, Telemetry, Tracking and Commanding (TT&C) internal interfaces, C&DH external interfaces, thermal design requirements, temperature design limits, mechanical requirements, and bus structure[12]. All of these similarities have enabled the ORS-1 to be acquired, integrated and tested with unprecedented rapidity. Many of these similarities have also been leveraged to accelerate the testing schedule. The ORS-1 program has leveraged thousands of hours of TacSat-3 since early 2008, including an independent Integration and Test (I&T) cycle at AFRL and stress testing scenarios. Furthermore, TacSat-3 performance requirements that were verified during testing could be used on ORS-1. The thermal and mechanical stress analyses performed on TacSat-3 were reused saving testing and preparation time required for such activities. Many of the spacecraft bus test plans and procedures were reused, saving even more time and effort. Testing was further accelerated by reusing many of the test resources used for TacSat-3, such as the FlatSat simulator (a computer system with the satellite flight software installed used to mimic satellite reactions responses and interaction) and the Electronic Ground System Equipment

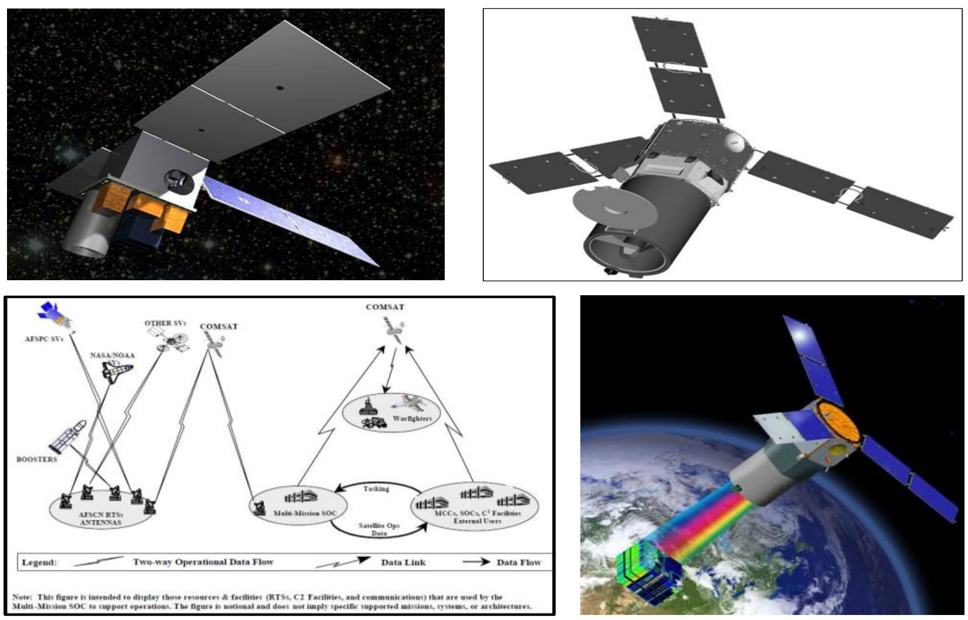


Figure 2: Standardized GS and SV programs.
(Top left: STPSat-2, Top Right ORS-1, Bottom Left: MMSOC GSA CONOPS, Bottom Right: TacSat-3)

(EGSE). Many of the models and simulations developed for TacSat-3 such as Finite Element Models (FEM) and Matlab/Simulink models were reused on ORS-1 with only minor modifications. Moreover, ORS was able to use the operational status and performance of TacSat-3 on orbit to "buy down" risk and increase confidence on components such as: solar array deployment and release mechanisms, launch vehicle separation, power system performance, GN&C pointing modes, bus components, and C&DH software. Finally, ORS-1 used lessons learned from TacSat-3 development and testing to improve efficiency, especially regarding flight software code generation and analysis. All of these methods used to reduce test time while maintaining test rigor prove the concept is feasible. Furthermore, additional time savings can be achieved when these concepts are more deliberately applied on future satellite systems additional cost and schedule savings can be achieved.

VII. Standardization of Test Strategy and Documentation

Besides standardizing system hardware and test equipment, making documentation standard among multiple systems can contribute to reducing test duration. Standardizing test strategy shortens the initial test planning process by building off of the planning and lessons learned during earlier programs. ORS-1 has used test strategy and processes from earlier missions such as STPSat-2 and TacSat-3, with adjustments based on lessons learned to build a test strategy in a very short period of time. The STPSat-2 program used test plans, test checklists, and even Test Readiness Review (TRR) slides from previous programs, such as TacSat-3 and C/NOFS to expedite the test planning process. Another example is the hypersonic Conventional Strike Missile (CSM) program, which has reused much of the strategy and documentation from the precursor Defense Advanced Research Projects Agency (DARPA) program called Hypersonic Test Vehicle #2 (HTV-2), dramatically shortening the timeline to develop these items from scratch. Documents such as the Preliminary Requirements Document and Environmental Assessment, which are necessary for using the Reagan Test Site (RTS) and Vandenberg launch facility, can be very extensive and time consuming to author; the ability to leverage these documents from similar, previous programs can save a substantial amount of time and effort. As mentioned previously, ORS-1, STPSat-2 and SIV-2 have all leveraged test plans and procedures to facilitate test efficiency.

In addition to using test documentation from other programs, ORS-1 testers were able to use lessons learned from previous programs to streamline the coordination and staffing process to get signatures and approval of test documentation, which saved months of rework and resubmission.

VIII. Combining Test Events

Another method for accelerating testing timelines of satellite programs is to combine test activities with other events. One method of doing this is to combine Developmental Testing (DT) events with Operational Testing (OT). This concept has been well established throughout the DoD testing community and is often referred to as integrated testing. This concept was applied wherever possible within ORS-1 and STPSat-2 by allowing the eventual users to conduct developmental tests and N2N tests. However, the unique nature of space acquisition programs makes it difficult to combine DT and OT effectively, especially for R&D programs that may or may not include significant OT efforts. Testing activities can also be combined with training events. STPSat-2 proved this concept by combining testing events such as Command and Telemetry Verification and Validation (CMD&TLM V&V) and User Acceptance Test with training events such as a rehearsal and a readiness event. Additionally, the DT&E test cases that normally would have been conducted by the developing contractors will be conducted by the operators, combining testing and training opportunities. Combining DT activities with other DT events, OT, and training activities can contribute to reducing testing timelines without reducing test fidelity.

IX. Conclusion

From the examples discussed above there are certain conclusions that can be drawn to apply these methods and concepts generally to future rapid space acquisition programs. The first is that standardization of equipment can significantly decrease testing requirements and should therefore be sought out and leveraged during test planning wherever possible. In many of the examples discussed, these efficiencies were found after the fact or were a natural result of standardization for rapid development purposes that happen to have application in test. However, to truly maximize the potential efficiencies achieved by testing overlap and reuse, they should be sought out and planned for during the initial design and development stages. Equipment and hardware standardization need to be actively pursued in order to benefit not only development schedules but test schedules as well. One important objective here is to minimize the number of modifications and changes made between future and heritage systems, however minor. The more identical the systems or subsystems are, the more testing results from past programs can be directly applied to verification of future systems. This can lead to eliminating some testing altogether. Unfortunately, even seemingly minor changes and modifications to a component may force the entire subsystem or system to be retested in full, negating the effect of leveraging the heritage system. Along these lines, when modifications are necessary (some almost always are, by definition of a "new system," otherwise it would just be a new instantiation of an old system), efforts should be made to confine the changes to specific subsystems or components to reduce the number of components that must be retested and to reduce the number changes necessary to system level integrated tests. To facilitate this process, the test documentation, such as common/core plans and procedures, should also be modularized as much as possible so testing of each subsystem or component can be separated into sections or test cases such that required modification of one section will not affect other sections or cases.

Implementing these concepts will require the testing community to be involved in the acquisition development process early. They will need to focus on finding opportunities to use the testing from heritage systems to streamline their testing strategy. The goal of minimizing test schedules by leveraging heritage system testing should be incorporated in the design process and should be a driving factor in design modification decisions. By actively seeking and planning for test reuse and leveraging, it should be possible to improve testing efficiency even beyond what has been demonstrated in MMSOC, ORS-1, STPSat-2 and SIV-2.

As these systems become more and more standardized it would prove beneficial for the test organizations to invest in standardized testing equipment. This would almost certainly appear as an additional cost up front, but will improve test efficiency for future programs that will not have to design develop, pay for and implement the use of new test equipment. Creating a standard set of test equipment such as EGSE, satellite models and simulators, etc. would facilitate rapid test planning and execution. This would also alleviate contractors' responsibilities to develop test equipment that is satisfactory to the government and would reduce the amount of proprietary limitations that hamper sharing of test data between programs.

Sharing of test data is another way to improve test efficiency. If standard data bases and share points specific to rapid R&D / ORS satellite testing, were created from which future programs could draw test results, operational performance, test documentation, lessons learned, test plans and procedures, etc. from past programs, it would significantly shorten the testing timelines and improve efficiency of future test programs. This database would need to be well organized, rigorously maintained, easily searchable and widely publicized in order for it to be effectively utilized, however, if this could be accomplished, countless duplicative hours and dollars could be eliminated. The next step beyond creating a testing database would be to continue to expand and formalize a standardized set of documentation templates specific to rapid satellite testing that would facilitate efficient and effective test reporting that could be streamlined to cover the essential needs of the program. Efforts would be made to trim the unnecessary or redundant information; allowing testers to focus on accomplishing the required testing in a timely manner rather than focusing on superfluous documentation. To some extent SDTW/STOS has been working to this end; however, increased formality and development of official templates is still expedient. Along these same lines, an efficient method for obtaining signatures and buy in from leadership on important test documents should be established to streamline the documentation process and reduce the time spent on coordinating and staffing test documents. This starts with early staffing of documentation but establishing strong Integrated Test Teams (ITT) with the appropriate personal (preferably with Colonel level support) to make high level test decisions on the spot would also serve to expedite the process. Ideally, previous agreement and acceptance would already have been established within the ITT and the staffing process would become merely an effort to formalize the decisions.

By implementing these methods, testing timelines can be significantly reduced while maintaining test rigor and fidelity. The basic concepts that have been proven by these GS and SV programs can be further developed and adapted to increase the level of efficiency yielded through their implementation. If the testing of rapid acquisition space programs is expected to keep pace with the ever decreasing development timelines and resources, then these concepts must be further developed and implemented on future programs.

The test expertise developed by government personnel through this process enables them to offer important test advice to the Program/Project Office (PO) on many occasions regarding contract requirements and deliverables from the contractor. They are able to evaluate the contractor's test approach and deliverable for content and usefulness and offered recommended changes to the PO. They have identified multiple problems with the testing contractor's test plans, procedures, deliverables such as requirements verification traceability matrix (RVTM) and test reports regarding accuracy, validity, content and completeness.

There are a multitude of benefits associated with improving the in-house test expertise of government personnel and the STOS has provided an example or template of how to re-grow this capability within Space Command and throughout the entire DoD acquisition community.

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