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AFOTEC's Space Test Initiative: Transforming Operational Testing and Evaluation of Space System Capabilities

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Historically, the value of the operational test and evaluation (OT&E) data has been limited during the acquisition and deployment of space systems because OT&E occurs late in the process, after the satellite is orbiting in space and the ground stations are fielded, well after key acquisition decisions, investments, and critical launch decisions have already been made. This article presents the U.S. Air Force Operational Test and Evaluation Center's Space Test Initiative. The Space Test Initiative delivers an OT&E model that better fits the National Security Space system's acquisition model outlined in NSS 03-01 and delivers better value to both the acquisition and operational decision makers by moving OT&E well before launch.

Key words: Acquisition strategy; integrated testing; investment; OT&E test anatomy; space acquisition; system of systems evaluation.

The U.S. Air Force Operational Test and Evaluation Center (AFOTEC) is responsible for the operational testing and evaluation (OT&E) of all Acquisition Category I and II weapon system programs as well as those on Director of Operational Test and Evaluation oversight, acquired by the Air Force and often our Joint partners, to determine operational effectiveness, suitability, and degree of mission capability in the system's intended operational environment. Since AFOTEC's inception in 1974 and the creation of Air Force Space Command in 1982, OT&E of space systems has occurred after satellites are on orbit and ground stations are fielded. Therefore, AFOTEC could not fully meet its responsibility to provide independent OT&E data to key decision makers in a timely manner with regard to the acquisition and deployment decisions of space systems because the tests occurred after the decisions were already made.

The need for fully informed decisions regarding these increasingly expensive, yet indispensible capabilities is crucial in today's environment of constrained resources. For more than 20 years, AFOTEC and the other service operational test agencies (OTAs) conducted OT&E of space and other high-tech, limited-quantity systems using a model more appropriate for military systems with large-scale production decisions. Using an OT&E model that does not match the system's acquisition strategy renders the results of OT&E largely irrelevant. AFOTEC's "Space Test Initiative" delivers an OT&E model that better fits the National Security Space (NSS) system's acquisition model outlined in NSS 03-01 (DoD 2004) and provides fact-based decision quality data to decision makers in time to support their key space system acquisition decisions.

Figure 1 further illustrates the issue. In a traditional acquisition program governed by Department of Defense Directive (DoDD) 5000.1 (DoD 2003), expenditures are relatively small in the research and development and investment phases compared to the cost of production and system operation. For these traditional acquisitions, operational testing (OT) occurs just before the major investment or production decision and provides data to inform those decisions adequately.

However, most of the investment for space systems occurs early in the program, most often without a major production decision. In the current space OT&E

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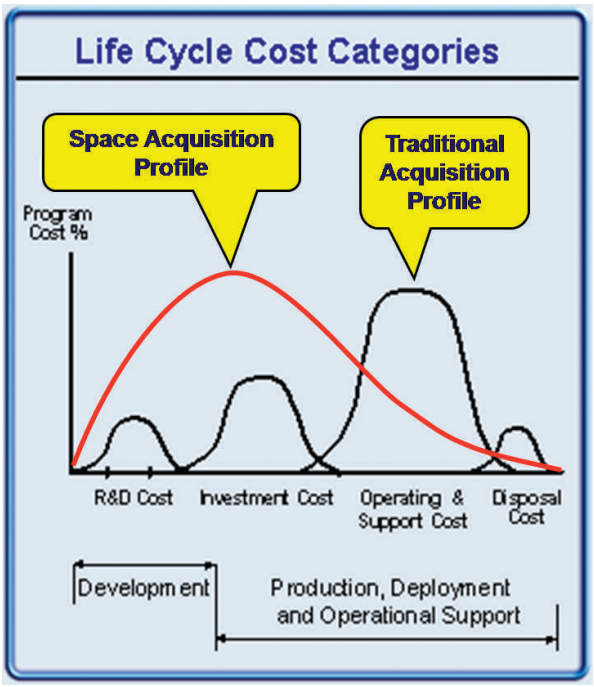

Figure 1. Department of Defense Directive 5000.1 versus National Security Space 03-01 life cycle costs

model, OT&E takes place at the same point in the acquisition cycle as with the DoDD 5000.1 (DoD 2003) programs. However, by this point in NSS 03-01 (DoD 2004) programs, most of the investment has been made, most of the key acquisition decisions have been made, and the critical operational decision to launch the satellite has been made and executed. The ground station and associated software often lag in deployment, making timely post-launch OT&E difficult, if not impossible. Making these key decisions before the execution of OT&E severely limits the value of OT&E.

AFOTEC's Space Test Initiative provides an OT&E model that better fits the space systems acquisition model, delivering better value to both the acquisition and operational decision makers by moving OT&E activity well before launch. The three key tenets of the Space Test Initiative are:

- early and continuous integrated testing involvement throughout the life cycle of the system,
- agile analysis and reporting,
- focus on system-of-system evaluations.

Space test anatomy

AFOTEC's OT&E guide provides an "Anatomy of an OT&E" that describes OT&E activities associated with each phase of a typical acquisition program. The anatomy is built on the DoDD 5000.1 acquisition model, which did not fit well for space system acquisition. In order to guide the OT activities of space systems, a NSS 03-01-focused OT&E anatomy needed development. In July 2008, AFOTEC hosted an Air Force Space Summit at Kirtland Air Force Base, New Mexico, where space acquisition, operations, and testing experts from across the Air Force gathered to build a new test anatomy. After the summit, event organizers socialized the ideas to the broader space acquisition and testing community both inside and outside the Air Force. This action included the other Service OTAs, the Joint Staff, Undersecretary of Defense (Acquisition, Technology, and Logistics), the national intelligence community, and the Director of OT&E. Comments received during that socialization resulted in slight modifications to the summit's model. In this article, we will walk through the resulting anatomy in a phased approach.

The activities shown in orange at the top of the anatomy *(Figure 2)* are conducted by the acquisition community. Those shown in light blue are conducted by the developmental test (DT) community. The grey region with the activities highlighted in yellow are integrated test activities, conducted by both the DT and OT communities. Finally, the blue boxes near the bottom of the anatomy are activities led by the OT community.

Beginning at the left of the anatomy, early in the acquisition process, the acquisition community receives strategic guidance or a description of the operational mission need. The acquisition community begins development of the initial Functional Solution Analysis or system concepts to address the operational mission need.

During the pre-Key Decision Point (KDP)-A period, the integrated test (IT) community begins development of an early involvement strategy. The early involvement strategy tailors this generic model to the specifics of the program, taking into consideration the required decisions, development, testing activities, etc. In addition, during this early phase the group responsible for building operational requirements forms the Integrated Concept Team. Members of the DT and OT communities also form the Integrated Test Team (ITT) and develop the ITT charter.

As the Integrated Concept Team develops the Functional Solution Analysis and the draft Initial Capabilities Document, the IT community is involved in the early reviews of the proposed concepts to generate a Concept Assessment Report. The report provides input to the concept decision, focused on the degree to which the system concept meets the mission needs stated in the strategic guidance.

While the acquisition community moves into the solution definition phase, the IT community partici-

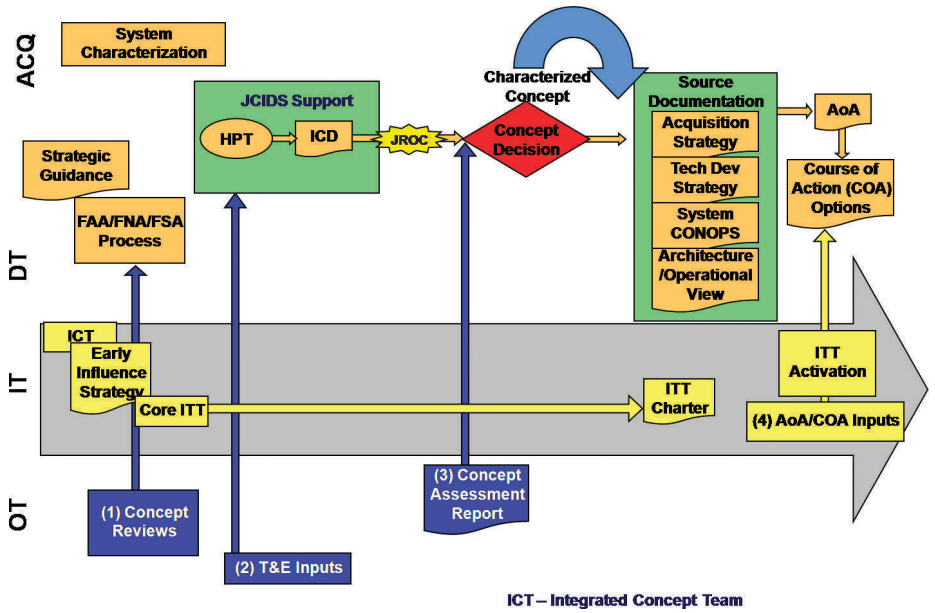

Figure 2. Pre-Key Decision Point-A activities

pates in the analysis of alternatives (AoA) and course of action (COA) development processes. The participation of the ITT in the AoA provides candidate evaluation criteria, potential measures of effectiveness and suitability, and operational scenarios for each alternative being considered. As the acquisition community develops the AoA and COA, the ITT develops the first test and evaluation strategy by melding DT and OT objectives.

The ITT's participation in the AoA/COA culminates in an operational assessment (OA). The resulting OA report informs the KDP-A, Concept Approval, decision. The OA report provides information on the degree of potential operational effectiveness and suitability, highlights any disconnects between the alternatives and the operational mission need, and identifies any potential testing issues of the AoA's alternatives and the COA's acquisition strategies. The OA report does not advocate or recommend an alternative.

Post-KDP-A to KDP-B, concept development phase

Throughout the KDP-A to KDP-B concept development phase *(Figure 3)*, the acquisition community refines the acquisition concept and matures both the technology and functional capabilities of the system. Meanwhile, the ITT continues to refine the test and evaluation strategy and builds the integrated test plan.

During the concept development phase, as the acquisition community translates the operational requirements into a set of technical requirements to serve as the basis of the Request for Proposals, the ITT evaluates the Capability Development Document/Technical Requirements Document traceability (see *Figure 4*). The look by the ITT at traceability focuses on the translation of operational requirements into the technical requirements that will ultimately serve as the basis for the system design. Throughout the system requirements review and system design review process, the technical maturation and functional development process generates concepts and prototypes. The ITT conducts OAs on these prototypes to evaluate their potential operational effectiveness, suitability, and degree to which they will meet the operational mission need, and to highlight any other operational issues noted during early testing.

The IT planning process culminates in the publication of the initial version of the Test and Evaluation Master Plan describing the integrated test approach. Finally, the IT community conducts an OA to assess the system's concept just before KDP-B to inform the KDP-B decision with an operationally focused evaluation of the system concept (see *Figure 5*).

Post-KDP-B to KDP-C, preliminary design phase

In the KDP-B to KDP-C preliminary design phase *(Figure 6)*, the acquisition community refines the system design through a series of design reviews and technology demonstrations. The IT community further refines their IT planning documents, wrapping up the preliminary design phase with a Test and Evaluation Master Plan update and an initial OT&E

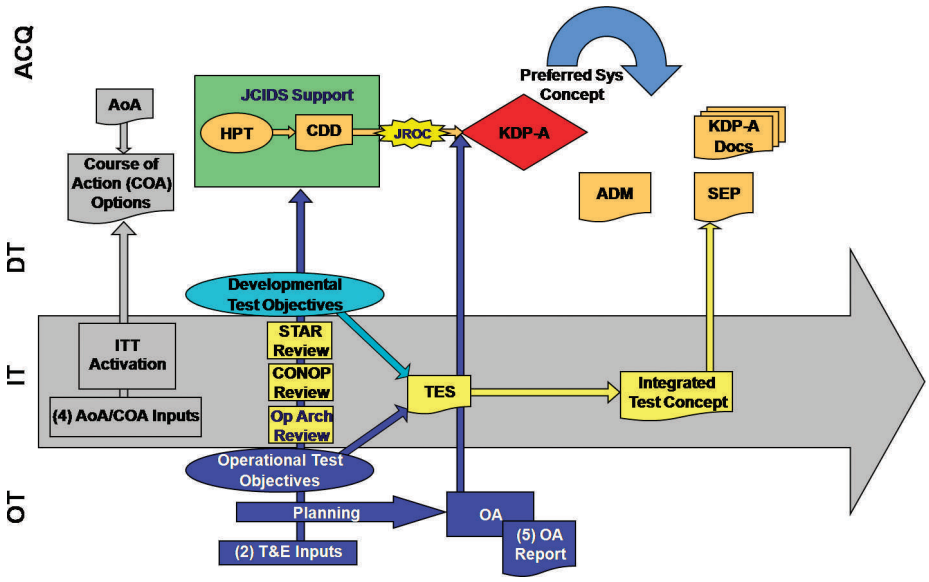

Figure 3. Key Decision Point-A activities

plan that fleshes out the details of how OT objectives will be addressed by traditional dedicated DT testing activities, such as laboratory and chamber testing.

During the preliminary design phase, developers conduct technical demonstrations to evaluate increments or components of the proposed system. The ITT is involved to provide status reports to the system program office on the potential operational effectiveness, suitability, the degree to which they will meet the operational mission need, and any other noted operational issues. In addition, these status reports begin to form an assessment of the system-of-system interfaces required for the system to operate successfully within its operational architecture.

In conjunction with the preliminary design review, the OTA conducts an OA to aggregate the information gathered through the preliminary design review stage to inform the KDP-C, Final Design Entry, decision on the potential operational effectiveness, suitability, and degree to which they will meet the operational mission need. Additionally, if the acquisition authority decides during this timeframe to allow the contractor to procure long lead items, part of the OA evaluates the operational aspects of those system components.

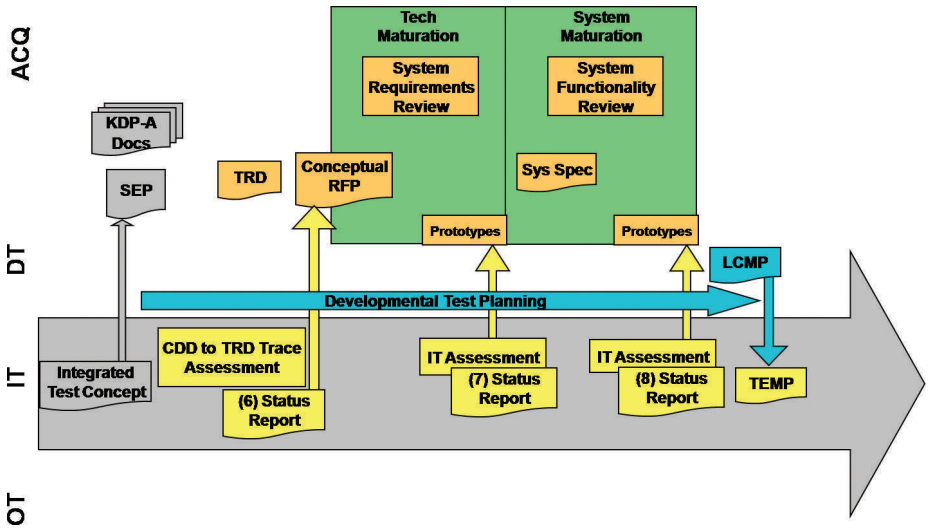

Figure 4. Key Decision Point (KDP)-A to KDP-B activities

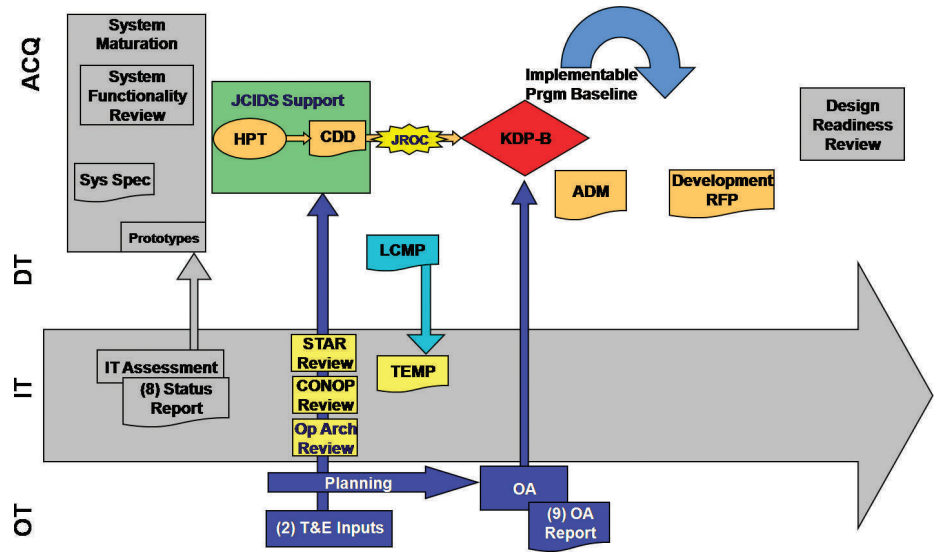

Figure 5. Key Decision Point-B activities

KDP-C to build approval, final design phase

In the final design phase *(Figure 7)*, the acquisition community refines the system design and conducts a series of risk-reduction tests, building up from component tests to subsystems to operational system tests. The IT community is involved with all testing activities. ITT participation is collaborative, and the generated status reports foster open communication between testers and developers as the system design is finalized.

At the conclusion of the critical design review, the OT&E community produces an Operational Assessment Report providing information on the potential operational effectiveness, suitability, and degree to which the proposed design will meet the operational mission need. The critical design review and Design Assessment Report inform the Build Approval decision.

System production to OT&E phase I

After Build Approval, the acquisition community produces the system and conducts a series of test activities, building up from the component to subsystem to full operational system testing. During the system production to OT&E phase I period *(Figure 8)*,

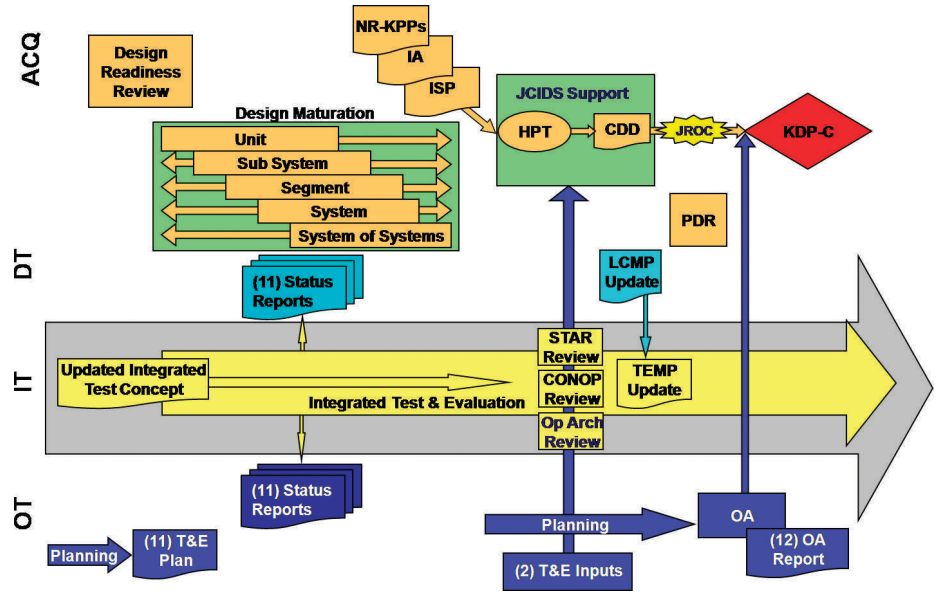

Figure 6. Key Decision Point (KDP)-B to KDP-C activities

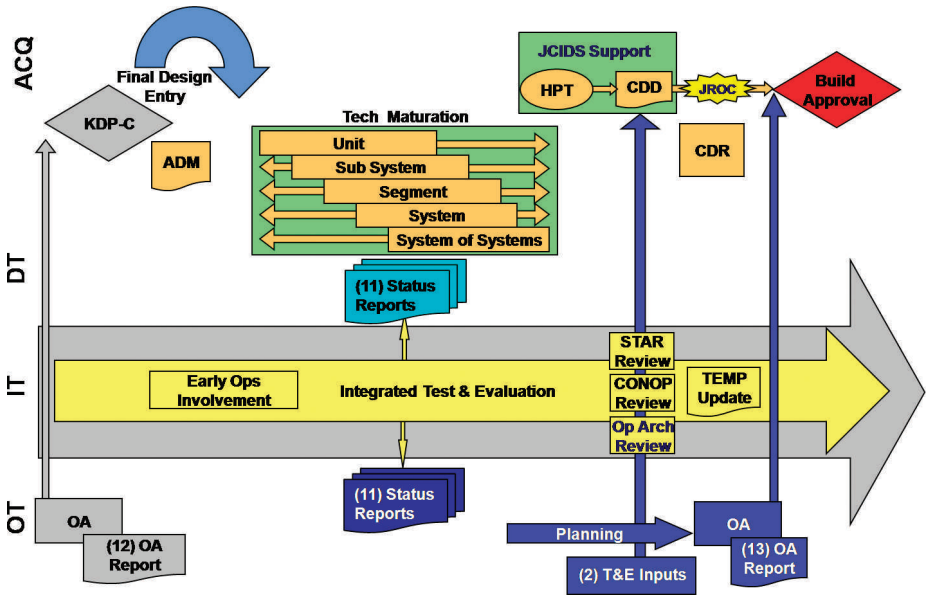

Figure 7. Key Decision Point-C to build approval activities

the ITT participates in the testing, taking full advantage of planned DT events to inject OT test measures and scenarios and gather information to fulfill OT&E test objectives. Status reports informing developers on how the system production is progressing, from both the adherence of the development to specification and the operational community's assessment of meeting operational requirements, keep the lines of communication open between the operational and developmental communities.

The system production period culminates in an OT&E Phase I, with its associated Program Element Officer certification and Test Readiness Review processes. The OT&E Phase I puts the system in as near an operational environment as can be replicated on the ground to support OT&E to inform the Consent to Ship decision. The Phase I OT&E takes into consideration the results of integrated testing, as well as the status of the system-of-systems required to provide mission capability to the warfighter. For example, this report may highlight that the satellite is ready for launch, but the ground segment will not be completed for another 2 years, enabling a conscious decision to delay satellite preparation for launch until the right time to optimize value to the warfighter.

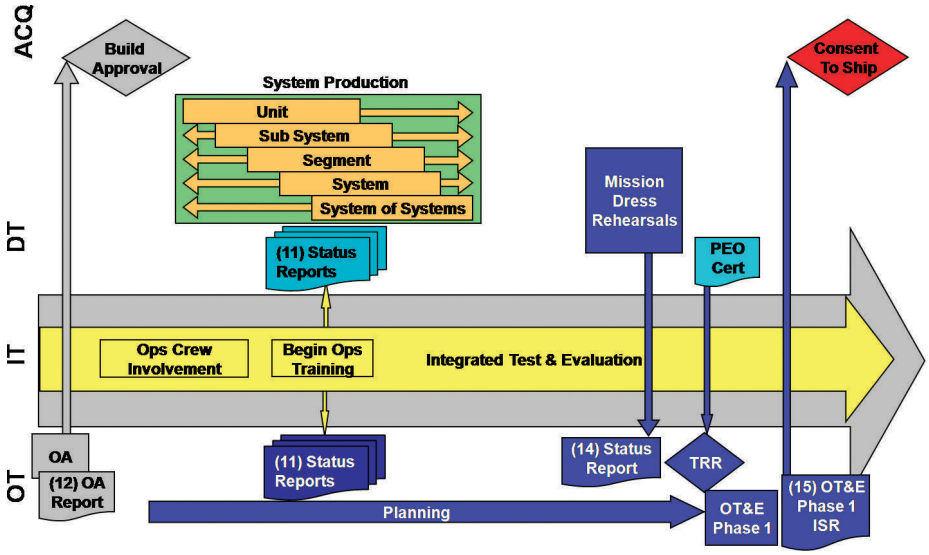

Figure 8. System production to operational test and evaluation Phase 1 activities

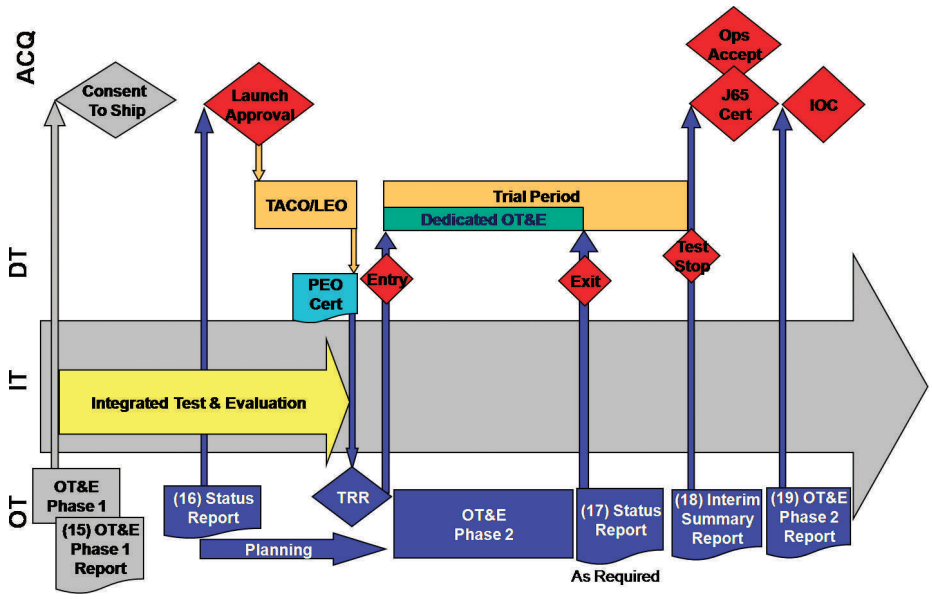

Figure 9. Launch and early orbit operations

Launch range compatibility testing

After deciding to ship the satellite from the manufacturing facility, the system is moved to the launch range, mated with the booster, and final integration and communication testing occurs. Again, integrated testing will inject OT test measures and scenarios into the DT-centric checkout events to provide an operational impact to any technical issues identified during compatibility testing. Integrated testing, documented in a Status Report, informs decision-making at the launch go/no-go decision point.

Launch and early orbit operations, OT&E phase II

After launch and during test and checkout, early orbit operations, and sensor checkout, the operational testing community participates to the greatest extent possible to inject operationally realistic scenarios, backgrounds, and procedures *(Figure 9)*. At the conclusion of the test and checkout period, the Program Element Officer certifies the system is ready to enter OT&E Phase II, the final 10 percent checkout of the operational capability of the system. OT&E Phase II takes a final look at whether the system made its ride to orbit successfully, if the performance reported throughout early integrated testing bears out in the operational environment of space, and that the system-of-system environments represent the true operational architecture and operate as expected.

AFOTEC conducts OT&E Phase II in conjunction with the users' operational trial period to facilitate delivering mission capability to the warfighter. At the conclusion of the OT&E Phase II and exit from the trial period, AFOTEC generates a status report to identify the hard-hitting, show-stopping issues found during this final stage of operational testing. The status report informs the *Operational Acceptance Decision*.

Depending on the program, the interim summary report, an approximately 20-page document that begins to draw conclusions and ratings, informs decisions such as the USSTRATCOM/J65 certification decision. Finally, AFOTEC publishes the OT&E report to provide full details on the results of the analyses. This report informs the Director of OT&E's Report to Congress, Initial Operational Capability decisions, future system upgrade decisions, etc.

Wayahead

To develop the next level of detail and implement the Space Test Initiative, a number of actions are required and in most cases are already in works. These actions include:

Understand/include detailed DT activities. The developmental test activities associated with the design development and maturation phases and system production cycles need further definition and inclusion in this model.

Define necessary policy. Current DoD, Air Force, Air Force Space Command, and AFOTEC policy does not speak to conducting space operational testing in the manner described in the Space Test Initiative. Therefore, AFOTEC initiated a policy crosswalk to determine what is in existing policy and what must be written to allow and direct the Space T&E Anatomy.

AFOTEC, in conjunction with the Air Staff, will draft the necessary policy documentation for incorporation into the current regulations.

Identify and define underlying test and evaluation processes. AFOTEC will define the processes required to execute this Space T&E Anatomy, include details on organizational roles and responsibilities, and entrance/exit criteria for each phase.

Identify and define test personnel resources. The number of personnel required to execute the Space Test Initiative, along with the required skill sets, will be defined. It is likely that AFOTEC will not have, or be able to increase, their personnel pool to provide the technical expertise necessary to execute the Space Test Initiative, particularly the early engineering-focused activities. Therefore, we must build agreements among the members of the integrated test and development community to share personnel resources.

Define capabilities and gaps in test infrastructure. Execution of the initiative's OT&E Phase I test infrastructure requires improvement in order to emulate an operationally realistic test space environment on the ground. For example, OT&E Phase I will have to use vacuum chambers that provide the capability to connect operational communication and command and control links.

Select a long-term candidate program to define cost/benefit. While AFOTEC Detachment 4 intends to apply this concept to all future space OT&E programs, they will select a pilot program to demonstrate and define the cost and benefits of this new approach. In addition, AFOTEC will use the pilot program to refine the concept, adding lessons learned as we execute these ideas from beginning to end on a space program.

Identify and define required contract changes. Most current space acquisition programs, particularly those initiated during the acquisition reform era, provide limited opportunity for government participation or insight into most development activities, or provide for test community access to developmental testing data. We require future contracts be written to allow the integrated test activities, as the ability to implement the Space Test Initiative depends on access to developmental data for analysis.

Space Test Initiative benefits

AFOTEC's Space Test Initiative provides the basis for knowledge-based acquisition and operational decisions throughout the life cycle of our national security space systems. It provides early operational involvement that will deliver a number of benefits, including: (a) ensuring the warfighter receives needed mission capabilities, (b) providing early clarity and continued update of operational requirements, (c) influencing early and continual development and refinement of the Concept of Operations, (d) ensuring frequent reviews of threat documents to ensure the system design addresses current threats, (e) highlighting program shortfalls and benefits throughout the development process when they can be addressed most efficiently and inexpensively, (f) enabling the user to understand and accept acquisition risks and adjust their mission requirements and plans accordingly, and (g) addressing and correcting systemic suitability issues early in the program development.

Other applications

Although AFOTEC's initiative focuses on space systems with its satellite-specific activities of Consent to Ship, Launch, and Early Orbit Operations, the model can be applied to other high-tech, small-quantity programs, such as one-of-a-kind command and control and information systems. Information systems can also benefit from the model of early testing since these programs are similarly front-loaded on investment with relatively little expense on production, operations, and maintenance once fielded. Like most space programs, no two information system programs are the same and few follow the DoDD 5000.1 template exactly. Unlike space programs, however, the DoD does not field information systems at one time (launch). Instead, DoD fields information systems in increments of capability. The fielding difference drives a requirement to test sooner and more often than space programs. However, the Space Test Initiative offers a model for information systems because the fundamental principles apply: (a) early and continuous integrated test involvement throughout the system's life cycle, (b) agile analysis and reporting, and (c) focus on system-of-systems evaluations. If a flexible, agile test approach is not used, the warfighter faces the dilemma of fielding capabilities before testing.

Summary

AFOTEC's proposed Space T&E Anatomy provides a model for testing systems governed by NSS 03-01. It identifies early test, evaluation, and reporting activities to inform acquisition and operational decisions, providing a roadmap for early program influence. The anatomy also provides an overarching model for each individual program's tailored implementation, as no two NSS programs (or DoDD 5000.1 programs for that matter) follow the standard NSS 03-01 model.

The benefit of the AFOTEC Space Test Initiative will be better space warfighting systems acquired through early, continuous integrated testing involve-

ment, providing inputs to the requirements processes to ensure the system addresses the mission capability gap and informing early program decisions when changes are less costly. The initiative focuses the majority of the OT&E effort, conceptually 90 percent of the OT&E community's time, on pre-launch to inform the key Consent to Ship decision. With early and continuous involvement, we will ensure that leaders make conscious, fact-based decisions to send satellites into orbit and field new ground stations when the complete system-of-systems required to deliver warfighting capability is in place. ❑

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