SPY-1D(V) MODELS AND SIMULATIONS SUPPORT OPERATIONAL TESTING IN THE CORNFIELD

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Introduction

Accredited models and simulations make land-based testing of the SPY-1 radar family more credible than ever before. This model and simulation credibility is achieved through a verification, validation, and accreditation process that ensures the proper use of high fidelity, thoroughly understood models and simulations. The development and application of this accreditation process in support of the recent SPY-1D(V) radar test are described below. Organizations involved with modeling and simulation in the operational test and evaluation arena may find some useful ideas in this description. This article focuses on the managerial, rather than the technical, aspect of this process.

In 1994, the Navy had an acquisition strategy decision to make. The decision was important because the AEGIS SPY radar system is completely integrated into the AEGIS ship and it takes five years to build a ship. Two options were presented:

(i) option 1: produce a single SPY-1D(V) radar and install in a new construction DDG 51-class ship.

(ii) option 2: use the land-based test site to test operationally the engineering development model of the SPY-1D(V) radar.

The first option would cause the interruption of SPY-1D radar production and create a unique operational ship for the sole purpose of at-sea testing to support a low-rate initial production acquisition decision. This option would have the advantage of testing in the operational environment, but the disadvantage of delaying fleet introduction of SPY-1D(V) radars for up to five years and incurring additional costs for creating a unique asset and having two SPY-1D(V) production starts. The second option called for land-based testing to support a low-rate initial production acquisition decision without interfering with current radar/ship production. This option had the advantage of making the acquisition decision in 1996 vice 2003-plus, but the disadvantage of testing in a land-based operating environment.

The key to the SPY-1D(V) strategy decision was a determination that land-based testing was adequate to support a low-rate initial production decision. This land-based testing was planned for the Navy's

Combat System Engineering Development Site (CSEDS) in Moorestown, New Jersey. Due to its land-locked location, CSEDS' characteristics are vastly different from any shipboard environment, and those differences had to be assessed. The CSEDS facility is 50 miles from the Atlantic Ocean in a location that prohibits low-flying aircraft and severely restricts chaff and electronic jamming activities. Any test scenarios involving fixed wing aircraft, helicopters, chaff, and jamming must be conducted in areas that do not interfere with commercial airways, nearby subdivisions, or local farm animals. Site characteristics bear little resemblance to the at-sea operating environment of dynamic sea clutter, multipath low elevation propagation, and pitching and yawing conditions a radar will operate in when installed in a Navy ship. The testing methods for SPY-1D(V)'s new capabilities were all adversely impacted by CSEDS' site limitations.

To help make the test adequacy determination, the Assistant Secretary of the Navy (Reseach, Development, and Acquisition) (ASN(RDA)) commissioned an independent advisory committee to investigate the SPY-1D(V)'s capabilities and CSEDS characteristics. This independent committee assessed risk mitigation, technical risks, and test adequacy. The committee concluded that, with the use of models and simulations (M&S), the radar could be tested well enough to support the low-rate initial production decision. Based in part on this conclusion, ASN (RDA) chose the second option and signed an Acquisition Decision Memorandum authorizing land-based operational testing at CSEDS.

ASN(RDA)'s decision complemented the growing trend within the Department of Defense (DOD) to find alternatives for the ever-increasing costs and rapidly shrinking resources associated with test and evaluation requirements, particularly requirements associated with field tests. One alternative is the use of M&S. DOD has moved toward M&S as a way to cut expenses in both developmental and operational testing. Real-world assets such as very small targets, aircraft services, and missile firings are becoming increasingly scarce and expensive. Some acquisition programs have been using M&S for years and have established methodologies for conducting verification and validation (V&V).

The following discussion addresses the verification, validation, and accreditation of the SPY-1D(V) program models and simulations and how this process enhanced the realism and credibility of an operational radar test conducted in a New Jersey cornfield.

The Verification, Validation, and Accreditation (VV&A) Process

To the Navy's independent test agency, Commander, Operational Test and Evaluation Force (COMOPTEVFOR), the idea of using M&S instead of actual field operations to validate at-sea systems' performance was a departure from traditionally accepted testing methodology. To the COMOPTEVFOR staff who experienced and well understood at-sea realities, the modeling of them for operational applications had little credibility because CSEDS is land-locked.

COMOPTEVFOR supported the move towards M&S by developing a command concept and procedure that outlined how M&S fits into operational testing. This concept involves a process called verification, validation, and accreditation (VV&A). This idea calls for a program executive office (PEO) to V&V all the M&S it requires to perform necessary developmental and engineering tests. The V&V process should satisfy PEO that the selected M&S functions as expected. When PEO is satisfied, it formally accepts the M&S for use in developmental testing. This formal acceptance is called certification, and is the measure of the program office's confidence in its model. After certification, PEO directs the model's use in the developmental test strategy. If the M&S will be used in an operational test, COMOPTEVFOR must accredit the M&S for a specific purpose within that test. Accreditation is the COMOPTEVFOR formal acceptance of the validated M&S. COMOPTEVFOR always considers certification a prerequisite to accreditation.

Step 1: The Simulation Management Plan (SMP)

Neither PEO Surface Combatants-AEGIS Program (SC-AP) nor COMOPTEVFOR possessed the experience or the infrastructure to support any of the new M&S initiatives, including VV&A. Some of the basic concepts were there, such as certification and accreditation, but few of the real world mechanics. Those mechanics had to be created.

The first step was finding a working M&S organization. The Tomahawk Cruise Missile Program had been using M&S for years and possessed practical experience, which it willingly shared. PEO SC-AP and COMOPTEVFOR staff members had to master the Tomahawk methodology, the COMOPTEVFOR VV&A instruction, PEO and COMOPTEVFOR goals, and the time and financial constraints on the entire process. Once all these elements were digested, PEO and COMOPTEVFOR staff jointly authored a

VV&A plan. This VV&A plan was called the SPY-1D(V) Radar System DT/OT Simulation Management Plan (SMP).

The First SMP Component: The Goals

The establishment of goals by each participating office is the first component of the SMP. Once established, each office must clearly understand the goals of all other offices and jointly design a framework that will mutually support the achievement of all goals.

COMOPTEVFOR's primary goal was being able to accredit those models that supported its mission - the operational test. In this case, seven models/simulations/simulators/stimulations were required. Accreditation was only given after a thorough review of the V&V process to determine the fidelity of each model in supporting operational testing. Prior to accreditation, the following required documents for each model were reviewed:

(i) a Simulation Validation Plan (SVP).

(ii) a Simulation Validation Report (SVR).

(iii) a Simulation Version Description Document (SVDD).

(iv) PEO certification.

These documents are discussed at length below. There is no requirement that any model must exactly replicate the real world; in other words, no model is expected to be a "perfect" empirical representation.

Alternately, one of PEO's major goals was the accreditation of its M&S. Accreditation meant that the SPY-1D(V) M&S was credible enough to conduct the test strategy outlined in ASN(RDA)'s Acquisition Decision Memorandum. Accreditation also meant that an outside activity reinforced PEO's reputation for enforcing standards. Since certification was a prerequisite to accreditation, the SMP outlined PEO's certification requirements as well.

The Second SMP Component: The V&V Method

The other major component in the SMP is the actual V&V execution framework. The preferred, overarching theoretical concept of V&V calls for a disinterested third party to accomplish validation. This type of validation is known as independent V&V, or IV&V. For the SPY-1D(V), there was neither the time nor the money to contract such a party to IV&V all seven required M&S. Instead, the SMP authorized an internal V&V method. This meant that the M&S developers would validate their own models with PEO and COMOPTEVFOR oversight. The credibility risk to the program in using this method instead of IV&V would have to be mitigated.

Again, in the interest of time and money, the SMP did not require new data collection. In other words, for certain models the developers were not tasked to acquire new empirical data to support V&V. New collection and analysis of atmospheric propagation, sea clutter, or live missile telemetry data was impractical. This information already existed in several places and could be used at significant time and cost savings.

The Third SMP Component: Credibility

Finally, both PEO SC-AP and COMOPTEVFOR agreed that ruthless self-discipline must be maintained to reduce risk and ensure credibility since IV&V would not be used. All VV&A procedures, results, and discussions would be open to outside agencies' inspection. This openness philosophy was the cornerstone of the entire effort's success.

The Fourth SMP Component: The Framework

The SMP provided the organizational structure to achieve the goals and execute the V&V method. This structure consisted of the Simulation Management Board (SMB) and the Simulation Control Panel (SCP). The SMP required the use of the SMB and SCP and provided an executive summary of their functions. The SMP also described each board's membership and its role in accomplishing both certification and accreditation.

<u>Step 2: The Simulation Control Panel (SCP)</u>

The SCP provided the working technical oversight of the V&V process. The panel was mainly composed of technical personnel who well understood their respective M&S, as well as AEGIS combat system technical representatives. Part of the SCP's function was to promote a technical exchange.

The SCP: Its Membership

The SCP's chairman was the SPY-1D(V) program manager's assistant. The co-chairman was the COMOPTEVFOR operational test director for the SPY radar program. These two individuals directed the oversight process. It is important to note that both co-chairmen had to be in agreement for any item to pass SCP. Other members included technical representatives from the three companies who developed the M&S, namely, Lockheed-Martin (Government Electronic Systems) Corporation, Technology Service Corporation, and Systems Engineering Group. Additionally, the Naval Surface Warfare Center and AEGIS Technical Representative provided technical support to the PEO chairman, and the Center for Naval Analyses supported the COMOPTEVFOR co-chairman..

The SCP: Its Function

As previously mentioned, the SCP's charter was to perform the working level oversight of the V&V process. To do that, the membership devoted a good deal of time and effort to understanding and defining the seven M&S. When the SCP leadership believed they achieved a sufficient understanding of each M&S, it asked the developer to propose a V&V plan based on its assets and the data available. When a proposal was submitted, the membership discussed it at length and selected the actual process the developer would use to validate the M&S. Most of the early meetings centered around selecting the proper V&V method. Sometimes these discussions were rather frank and resulted in some strong disagreements, but fortunately, the SMP did not require unanimity. When the co-chairmen accepted the validation proposal, the Simulation Validation Plan (SVP) was written. The SCP met frequently to monitor validation progress. Sometimes, the SCP had to change V&V procedures because the developer found a better way or discovered the current method wasn't working as planned. The SCP membership carefully reviewed validation progress and early results to ensure SMP objectives were met. As V&V progressed, the developers began to write the Simulation Validation Report (SVR) and the Simulation Version Description Document (SVDD).

The Simulation Validation Plan (SVP)

The SVP Groundwork

The SMP required a separate SVP for each M&S. As noted above, early SCP meetings centered around determining which V&V method to employ for each M&S. Several questions had to be answered, or at least addressed, during those determinations in order to author the SVP. Some of these questions were:

- Is the M&S a model? A model is defined as a physical, mathematical, or otherwise logical representation of a system entity, phemonenon, or process.

- Is the M&S a simulation? A simulation is defined as a method for implementing a model over time, or where real world and conceptual systems are reproduced by a model.

- For what purpose will the M&S be used?

- What are the capabilities and limitations of the M&S?

- What value will the M&S add to the operational test?

- How will the M&S's use impact the operational tester's ability to formulate conclusions?

- How does the model interoperate with the other six models?

- What options exist within the time/money/data constraints to V&V each model?

In practice, some of these questions were answered after the SVP was approved, and the interoperability issue was never completely addressed. The SCP intended the V&V process to be flexible. When a better way was found, the process was altered and sometimes an answer changed too. When the SCP had sufficient information, it addressed requirements for the SVP.

Two SVP Requirements

The SMP mandated that at least one of three possible methods must be used in the V&V process. The first SVP requirement was the selection of the right method based on the SCP's understanding of the M&S. The three methods were:

(i) a model-to-real world comparison.

(ii) a model-to-model comparison.

(iii) a code analysis.

For SPY-1D(V), a model-to-real world example was the simulation that represented small radar cross-section targets. This simulation was used because no real world targets existed. The developer attached a physical sphere to a balloon and launched it into the air. This sphere had a known cross-section which fluctuated in the real environment. The SPY-1D(V) radar tracked the sphere as it floated away. The SPY-1D(V) also tracked a target simulation constructed with the same cross-section. Unlike the sphere, however, the target simulation possessed no cross-section fluctuating capability. The sphere's cross-section as observed by the radar was compared to the simulation's cross-section as observed by the radar. Results determined the corrective action necessary to improve the simulation.

A model-to-model example was the sea clutter simulation. This simulation was used because CSEDS is a long way from the ocean. The simulation was actually a composite of two M&S, a mathematical model and a hardware generator. The mathematical model represented the sea clutter phenonemon. The generator implemented the model into the system such that the radar can observe the sea clutter. The validation of the generator's implementation ability compared the mathematical model with the generator's simulation. The results initiated a plan of action.

The second requirement stipulated that the known capabilities and limitations of the M&S be stated. Every SVP included a list of the known capabilities and limitations of its model to preclude future misunderstandings. The unforeseen benefit of this requirement was the discovery that the "known" capabilities and limitations listed in the SVP were not necessarily the same ones revealed later during V&V.

As V&V progressed, the SCP began to author the next two required documents, the Simulation Validation Report and the Simulation Version Desciption Document.

The Simulation Validation Report (SVR)

The SVR was the written report of results achieved during V&V. It contained an executive summary and a technical analysis section. The SVR included the validation details, such as:

(i) a description of the actual validation procedure,

(ii) a discussion of why that procedure differed from the one outlined in the SVP, and

(iii) a list of capabilities and limitations confirmed by the V&V process. An explanatory note was added where the SVP and SVR lists differed.

The Simulation Version Description Document (SVDD)

The SVDD briefly described the computer program configuration management that supported the M&S. This SMP requirement was met chiefly through a related, non-accreditation event called a COMOPTEVFOR Software Quicklook. A Software Quicklook provided COMOPTEVFOR with a basic understanding of a developer's software management program. PEO had encouraged the conduct of a

Software Quicklook to promote COMOPTEVFOR's understanding in configuration management issues. A thorough review of the Quicklook confirmed that the prime developer followed accepted software configuration management procedures and increased COMOPTEVFOR's confidence in the M&S. Since the Quicklook is not a VV&A requirement, it did not eliminate the accreditation requirement for an SVDD. However, using Quicklook data, the SCP could streamline the document.

Now V&V was complete. The SCP had written an SVP and the developers had executed it. The approved SVR contained an executive summary and the technical results. The SVDD was complete. The co-chairmen agreed to move the VV&A process forward. The next step was to convene the Simulation Management Board.

Step 3: The Simulation Management Board (SMB)

The SMB's purpose was to recommend certification to the PEO certifying officer. To do that, it evaluated the SVRs provided by the SCP. The SMB was a four-member board, chaired by the SPY-1D(V) program manager. The voting members were the chairman, the PEO SC-AP models and simulation division head, and an AEGIS Technical Representative senior staff member. The COMOPTEVFOR Assistant Chief of Staff for Surface Warfare acted as the single nonvoting, advisory member. The SMB acted to satisfy itself that the V&V had been rigorously executed. The COMOPTEVFOR advisory member was consulted for the accreditation authority's perspective on the V&V results. When the vote was unanimous, the board forwarded a certification recommendation to proper authority at PEO. When the vote was not unanimous, the board returned the product to the SCP for additional work.

The SMB/SCP was intended to be an open process. Interested parties from the Director, Operational Test and Evaluation and the Institute for Defense Analyses had a standing invitation to attend either board. This invitation was extended for two purposes. One, without specific DOD guidance the SPY-1D(V) joint VV&A effort was somewhat "experimental." Agencies closer to DOD might be able to provide additional perspectives on the future evolution of M&S policy. Two, the demonstration of the rigorous, disciplined process should be witnessed and not merely advertised.

Step 4: Certification and Accreditation

The SMB chairman briefed the certifying authority on the results and recommendations of the SMB. This authority certified the recommended M&S when convinced that the SMB had applied the requisite tough examination required by the SMP tenet of self-discipline. An official letter of certification was sent to the accreditation authority after PEO's internal administration had been completed.

The OPTEVFOR operational test director briefed the accrediting officer on the certification letter. The brief included a synopsis of the technical details from each SVR, including capabilities and limitations, the intended use of the M&S in the operational test, and whether the ability to draw conclusions was affected. The brief also discussed how well COMOPTEVFOR requirements had been met and then provided recommendetions. COMOPTEVFOR accredited the M&S when convinced that the PEO/COMOPTEVFOR/developer working team had satisfactorily executed its charter.

The operational test director was now able to complete the test plan, obtain its approval from appropriate authority, and conduct the operational test. Afterwards, the data analysis, final report, and test results briefings relied heavily upon the VV&A effort.

FUTURE CHALLENGES

The successful achievement of certification and accreditation for the operational test did not mean the end of the SPY-1D(V) VV&A process. As expected, the subsequent briefings provided to PEO SC-AP, COMOPTEVFOR, and the Director, Operational Test and Evaluation resulted in feedback. Thus, some new challenges arose:

- expand existing databases by collecting new empirical real world data
- refine M&S fidelity, such as the sea clutter mathematical model more closely approximating real sea clutter
- increase the capabilities of essential M&S, such as incorporting a fluctuating radar cross-section behavior in the simulated targets
- overcome certain limitations, such as the sea clutter generator's inability to implement fully the sea clutter model
- improve the VV&A process
- investigate new M&S that will add value to future developmental and operational tests.

Lessons Learned

The reality of the VV&A process is its functioning was not nearly as clean or linear as outlined above. In some cases, an SVP and its SVR were written concurrently. For example, a validation procedure was discovered to be impractical halfway through and another method had to be implemented. In other cases, a model's V&V had an unexpected result. Once, a model intended for use was found to have an undesired less-realistic effect when compared to other industry models. This model was ultimately discarded and a substitute selected. For reasons like these, the SCP was educational for all its members.

Lessons were learned throughout the course of this VV&A process. A brief description and solution follow for three of these lessons:

(1) The SCP was originally constructed as a voting body, similar in makeup to the SMB. But, a simple majority vote consisting of the three developers and/or a supporting organization could theoretically override either PEO or COMOPTEVFOR desires at this level. The SMP had obligated both PEO chairman and COMOPTEVFOR co-chairman to support mutually the common goals it contained. For either individual to proceed without the complete concurrence of the other was self-defeating, regardless of developers' positions. So in practice, voting was irrelevant and ultimately eliminated; a simple agreement between chair and co-chair moved the SCP forward.

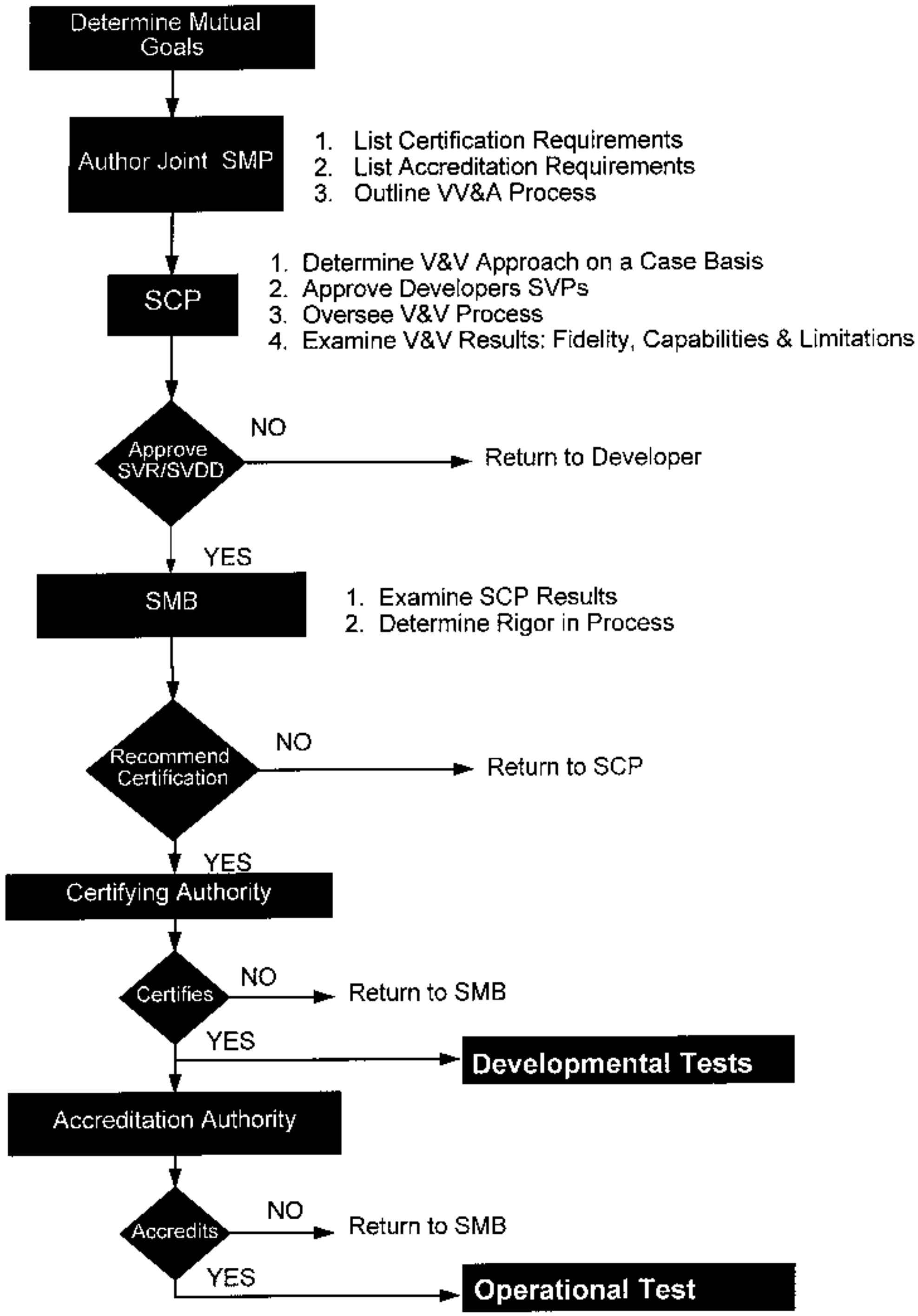
(2) There was only one SCP for all seven M&S. The Tomahawk Program's original concept of one SCP per model was good but considered impractical for SPY-1D(V) because of the time and money constraints. So, each SCP meeting addressed all the concerns and problems associated with each M&S. As test time drew near, with much left to do, this "do-everything-at-SCP-meeting" approach failed. The SCP could not efficiently handle all the requirements of SVR development for seven models. SVP writing turned out to be much more challenging and controversial than anticipated. The SCP eventually became so inundated it would have had to stay in session permanently. The solution was to break up the SCP into smaller teams that each dealt with a subset of SVRs. This allowed the available expertise to focus more completely and exactly than before. One team's membership consisted of two Lockheed-Martin

experts, and the Naval Surface Warfare Center and Center for Naval Analyses representatives. Another team included an AEGIS Technical Representative staffer, a Lockheed-Martin engineer, and an OPTEVFOR analyst. PEO and OPTEVFOR had representation on each team. When a team had a viable product to present, the formal SCP was convened.

(3) The honesty and integrity of all the participants in the V&V process was absolutely vital to its credibility. The co-chairing offices hid nothing from external observers, including some rather high-spirited controversies. One developer immediately revealed a model's limitation, newly discovered during V&V, that impacted unfavorably on its use. The supporting activities involved themselves in problem solving, not just problem noting.

Conclusion

The net result of this rather involved process had several positive elements. All parties learned that a model's legacy is not sacrosanct. Preexisting, unknown capabilities and limitations were uncovered that led to a more precise use of the M&S and a more accurate interpretation of test data. A high degree of confidence in the capabilities as well as the limitations of the M&S was achieved. PEO and its developers gained fresh insight about their M&S and how to improve them. COMOPTEVFOR authored an operational test plan that realistically and fairly tested the radar at CSEDS. ASN(RDA)'s acquisition strategy worked as intended, and the Navy saved a lot of time and money. Common sense and teamwork made this process viable and successful. DOD will see more of these efforts in future programs as the program office/developer/operational tester combination works smarter to place the best technology available in the hands of the warfighter.


Determine Mutual Goals
Author Joint SMP
1. List Certification Requirements
2. List Accreditation Requirements
3. Outline VV&A Process
SCP
1. Determine V&V Approach on a Case Basis
2. Approve Developers SVPs
3. Oversee V&V Process
4. Examine V&V Results: Fidelity, Capabilities & Limitations
Approve SVR/SVDD
NO
Return to Developer
YES
SMB
1. Examine SCP Results
2. Determine Rigor in Process
Recommend Certification
NO
Return to SCP
YES
Certifying Authority
Certifies
NO
Return to SMB
YES
Developmental Tests
Accreditation Authority
Accredits
NO
Return to SMB
YES
Operational Test