Space Capabilities in Joint Training

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ABSTRACT

The vision for DMO is to enable warfighters to train, mission rehearse, and operate in large Composite/Joint/Combined Force packages with horizontal and vertical integration in a distributed full-spectrum Live-Virtual-Constructive battlespace. Space assets are force multipliers across the spectrum of conflict and must be integrated into deliberate and crisis action planning, as well as operations planning, combat operations, and time sensitive targeting (TST) to ensure timeliness of effects. To fully exploit the air, space, and information realms across the full spectrum of engagement, warfighters should understand how the synergistic application of space based systems, air platforms, and C4I can achieve rapid dominance in all three arenas, and victory over adversaries.

A DMO-Space architecture is currently being implemented that will provide the ability to both train the space crews in a dynamic battlespace and realistically assess the impact of degraded space effects on warfighting capabilities. DMO-Space will also provide a capability to perform trades of space systems with terrestrial alternatives and future space concepts.

This paper will discuss the successes and challenges experienced in the development of a standard-based GPS jamming capability to support both distributed operational and tactical training events. The culmination of this effort is a GPS Jamming federation demonstration which implements the updated FOM and interoperability standards necessary for implementation of a real-time, high-fidelity, GPS jamming capability. Discussion will include the impact of both JNTC and DMT training needs on battlespace fidelity and content as well as the rationale for the design decisions that were made in defining the GPS Jamming federation and associated Federation Agreements/Standards. The paper will conclude with a discussion of the potential for use of other space capabilities to support enhanced warfighter training.

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INTRODUCTION

Per Gen Chilton's correspondence to Chief of Staff of the Air Force (CSAF), dated 2 Mar 10, "space operators need simulators (supported by good models of the space environment, current and future satellites, and current and future threat capabilities) to train with for the inevitable fight we will have one day in the space domain." On 4 Mar 10, CSAF concurred with Gen Chilton acknowledging the "need to take actions to bring space modeling and simulation (M&S) to the degree of fidelity that we typically expect in the air domain."

Distributed Mission Operations (DMO) is a CSAF - directed readiness initiative to train warfighters as they would expect to fight; maintain combat readiness at home or deployed; and conduct mission rehearsal in an environment as operationally realistic as necessary.[1]

This paper discusses Air Force Space Command's (AFSPC) approach for establishing a DMO-Space (DMO-S) capability to both train space crews and enhance battlespace fidelity through the integration of space modeling capabilities into the operational and tactical training environment.

BACKGROUND

The Services, in accordance with DOD Directives, will integrate space capabilities and applications into all facets of their strategy, doctrine, education, training, exercises, and operations of United States (US) military forces.[1] DMO is the Air Force venue that supports training transformation. Support to the Joint National Training Center (JNTC), and DMO-S, is the essential component that will provide the integrated employment of space capabilities in joint training and exercises.

The DMO-S is an evolving concept that will link training for space forces with providing inputs for end-user training and exercises. This is a main tenet of Training Transformation (T2), supporting the Joint Force Commander's requirements for missile warning, battlespace awareness, and communications while training space force core competencies. DMO-S will train and exercise the space activities that contribute to force enhancement, space control, space support and force application. DMO-S will exercise the space operations training continuum beginning with the console operator at an AFSPC operational unit and ending with the warfighter in theater. A Space Command and Control (C2) integrated training system is required to provide a virtual, global, synthetic battlefield in which space forces, fully integrated with other US and allied forces, can both train and rehearse missions in a way which will provide predictive confidence in our capabilities to support national defense as well as deter a potential enemy. This system will ensure individual and collective skills training, employing a distributed environment that permits stand-alone training or training with other Space C2 nodes/centers as well as other space, joint, or international operations centers. The training system will support both routine and unpredictable activities and thus be a major enabler of mission readiness by providing timely training for unknown situations.

The Distributed Mission Operation Center–Space (DMOC-S), located within the Space Innovation and Development Center (SIDC), will be the focal point for the development, scheduling, and execution of DMO-S training exercise and mission rehearsal activity for AFSPC weapon systems. The DMOC-S will provide a scheduling and control capability to DMO-S assets to assure unit, inter-unit, and joint training and exercise needs are met in accordance with AFSPC established priorities and procedures. This includes training internal to AFSPC forces, and the interface to other DMO domains to provide space assets to the warfighter. The DMOC-S will coordinate intra- and inter-domain requirements with the DMOC. DMO-S

[1] IRD, Distributed Mission Operations, 20 Feb 03
[2] JP 3-14, Joint Doctrine for Space Operations, Aug 02

mission rehearsal can support Joint Force Air Component Commander (JFACCs) as they prepare or rehearse courses of action for aerospace forces.

AFSPC M&S Overview

AFSPC provides forces to support the space superiority mission. AFSPC, in conjunction with other Major Commands (MAJCOMs), must provide a realistic test and training environment across the air, space, and cyberspace operational domains to adequately prepare space control warfighters for combat. AFSPC currently tests and trains space control capabilities in a primarily live environment. This live environment alone does not provide a realistic combat environment due to security constraints in target and threat presentation. AFSPC requires an integrated Live Virtual Constructive (LVC) environment in which to test and train current and future space control capabilities. Therefore, AFSPC and Joint Forces space control units will use the Space Control Live, Virtual and Constructive Training Environment (SC-LVC-TE) for training and maintaining operational proficiency. The primary focus of the SC-LVC-TE is to enhance realism and the combat training value of live training by adding virtual and constructive entities (models, simulators and simulations) as dynamic targets and threats, providing training and testing opportunities that would otherwise be unavailable. In order to provide training and testing opportunities, AFSPC has the Space Innovation and Development Center (SIDC) that is the premier innovator, integrators and operational testers of air, space and cyberspace power to the warfighter.

SIDC

The SIDC is continually expanding their capability to support the JNTC with an array of simulation tools and trainers which provide high fidelity solutions for support both operational and tactical training. Below are brief descriptions of some of these capabilities:

Automated Scripter Simulator Exercise Trainer (ASSET)

Asset is a Windows-based application developed by the NRO that allows the operator to script friendly and enemy force movements, and then simulate the collection and dissemination of Signal Intelligence (SIGINT) and Imagery Intelligence (IMINT) based on the script. It transforms intelligence events into messages of a standard protocol & allows chronologically based injection of messages directly into tactical data processors or through the Integrated Broadcast System (IBS-S). Beginning with ASSET version 4.0, it can receive protocol data units (PDUs) from exercise generators and quickly converts these inputs into United States Message Text Format (USMTFs) used by intelligence systems throughout the DoD to provide situation awareness to exercise operators during scripted events.

Communications Effects Simulator (CES)

Using the OPNET/Joint Communications Simulation System (JCSS) models, the CES provides a comprehensive modeling and simulation of communications effects on networks. By simulating the communications effects of existing or planned networks that support Warfighter operations, JCSS helps to quantify risks and identify Command, Control, Communications and Computers (C4) deficiencies prior to exchange. OPNET/NETWARS provides a graphical User Interface (GUI) environment that allows all aspects of the space communications network to be modeled and allows “what-if” scenarios to be created, thereby enhancing exercises for warfighters. The High-Level Architecture (HLA) Module supports building and running a federation of many simulators, each modeling some aspect of a composite system. The OPNET-HLA interface provides the various simulators (federates) the necessary mechanisms to share a common object representation (for persistent elements), to exchange messages (interactions), and to maintain appropriate time synchronization.

Missile Defense Space Tool (MDST)

MDST is a software product created by the Missile Defense Agency to support Theater Missile Defense (TMD) and National Missile Defense (NMD) exercises, wargames, tests, and integration events. MDST provides real-time interactive software that simulates current and future space-based launch detection in a networked simulation environment. MDST is extremely flexible in the stand-alone mode and has an internal threat generator that is used to build missile launches. An operator can enter a launch and impact point in the simulation, assigns a missile type to the launch, and assigns a name to the threat. The threat generator automatically checks the launch to impact point range limit and generates a missile flight profile for the threat type and points entered. An MDST operator can enter as many launches as necessary to support an exercise or training event and can initiate the launches based on a time schedule provided by the supported unit.

Joint Communication Simulation System (JCSS)

Developed by OPNET Technologies for DISA, JCSS is a software application for analyzing defense-related network communications. The JCSS project is part of DoD's vision for achieving information superiority by optimizing military communications in realistic warfighter scenarios. The objectives for the JCSS software environment include simulating major theaters of war involving thousands of communications nodes, conducting communications burden analysis, contingency planning analysis, and evaluating emerging technologies in full Joint Task Force warfighting scenarios.

National Wargaming System - Next Generation (NWARS-NG)

NWARS-NG supports military exercises and experiments by simulating the collection and reporting functions of national satellite intelligence systems. It accepts Distributed Interactive Simulation (DIS) or HLA data from exercise generators, processes the data to reflect national systems satellite capabilities, and produces IMINT and Electronic Intelligence (ELINT) reports for dissemination to event participants via real-world tactical broadcasts or via networks simulating the dissemination of reports via Radiant Ether for further integration with warfighters at all echelons. In addition, it employs a Radiant Mercury multi-level security system to sanitize data before dissemination to exercise players. The NWARS-NG development is sponsored by the NRO as a warfighter training and exercise support tool. It is designed to enhance the training of warfighters on the integration of NRO satellite capabilities and limitations during the conduct of military operations.

Space Based Infrared System (SIBRS) Missile Warning Simulator (SMWS)

The SMWS is developed by Northrop Grumman (NG) and provides a simulation capability that leverages the SBIRS baseline software combined with a DIS interface to facilitate MCS crew participation during DMO events. A missile laydown is received by the SMWS via the SIDC STEN in the form of DIS Protocol Data Units (PDUs) and is turned into a "walking dot" pattern for the crew to analyze. If the "walking dots" are determined to be a missile launch, the crew then performs their missile warning procedures to release a USMTF message which is disseminated to the Air Operations Center for warning notification to the areas at risk. In addition, they then perform First Detect First Reporting (FDFR) using voice communications per the standard operating procedures.

Space Systems Generator (SSG)

SSG provides a space order of battle through a DIS or HLA interface to stimulate DMO exercise and training events. The SSG is developed and maintained by the SIDC Federation Development Team and leverages the AFSPC/A9 Simplified General Perturbations Satellite Orbit Model 4 (SGP4). It uses the NORAD catalogue and provides the operator with the health and status of the satellites. In addition, the operator can create or modify satellites, perform Delt-V maneuvers and responds dynamically to Detonations by creating satellite debris, simulating a breakup.

GPS Environment Generator (GEG)

Creates a machine-to-machine interface in the DIS environment by which distributed exercise simulations and players can receive realistic navigational accuracies and damage assessment reports in real-time. GPS Environment Generator (GEG) leverages the Global Positioning System (GPS) Interface and Navigation Tool (GIANT) 4.2 model to predict GPS navigation accuracy when GPS guided aircraft and munitions are employed in/out of an electronic combat jamming environment. The various factors GEG uses in its calculations to determine GPS accuracy include the geometry of the GPS constellation, the type of GPS receiver being used, the location of the receiver or body masking, the type of inertial navigation system employed as a backup, the type of jammer emitting and terrain masking. An aircraft or munition requests navigational accuracy from the GEG and it calculates the navigational accuracy and provide that information back to the entity requesting the data. Data supplied by the GEG includes Circular Error Probable, horizontal/vertical position error, horizontal/vertical velocity error and the 4th lowest J/S for P(Y) code on L1/L2 frequency. The entity then uses the accuracy data provided by GEG in course correction and damage assessment.

DMO-SPACE PROGRAM

Conceptual Model of the Mission Space (CMMS)

The CMMS program established the foundation for the initial DMO-S HLA-based training federation from which future training capabilities evolve. As part of this aggressive initiative, Northrop Grumman was tasked to work with both DMO and Joint Forces Command (JFCOM) teams to define and demonstrate a DMO-S training capability which was compatible in both training architectures.

The scope of this effort was to develop and validate a Federation Object Model (FOM) for the mission space. The mission space consisted of SBIRS and Phased Array Radar (PAVE PAWS), Perimeter Acquisition Radar Attack Characterization System (PARCS), FPS-85 and Ballistic Missile Early Warning System (BMEWS) as ground-based sensors (ref Figure 1). The focus was on integration AFSPC systems to demonstrate the ability to accomplish Mission Essential Tasks (METs). The METs that were addressed under this program included:

- Plan, integrate, synchronize, and execute tailored space support for theater warfighters
- Provide intelligence summaries, global situation awareness, and immediate threat analysis
- Receive, maintain, integrate, and display data from all sources and disseminate data to users at all levels in a timely manner
- Transmit alert, warning, and execution orders
- Determine and assess the nature and impact of critical events
- Assess friendly and non-friendly force and resource status
- Develop/evaluate/select courses of action
- Integrate space operations into theater terrestrial operations

Figure 1. DMO-Space Operational View

This FOM development effort was divided into two phases that are aligned with the Federation Development and Execution Process (FEDEP) described in the HLA FEDEP Model 1.5 dated 8 Dec 99. The FEDEP's top down, systems engineering based methodology was very conducive to the training operations driven requirements specified by AFSPC. Figure 2 illustrates the end-to-end traceability of the FEDEP as applied to DMO-Space. A brief review of the tailored FEDEP steps that were executed for DMO-S is provided below.

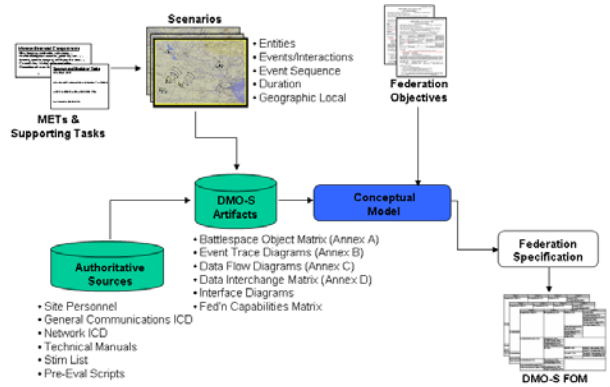

Figure 2. Requirements Traceability

FEDEP Step 1: Define Federation Objectives

During this step in the process we focused on achieving a clear understanding of customer needs and establishing program scope. The fact that AFSPC provided a list of specific METs that were accompanied by their respective supporting and enabling tasks, greatly simplified this effort. The dual applicability of this DMO-S training federation for both JNTC and DMO use required that some compromises be made to ensure training needs were addressed. During this effort, mission objectives and accompanying operational scenarios were developed as a means to further refine task requirements. Beyond federation objectives, other outputs of this assessment with customer and user community included federate composition, critical events, capability/fidelity needs, potential constraints, potential risks, and feasibility concerns, and measurable objectives.

FEDEP Step 2: Develop Federation Conceptual Model

The purpose of this step is to develop an appropriate representation of the real world domain that applies to the federation problem space and to develop the federation scenario. This effort was initiated through the development of 32 detailed scenarios (4/MET) which were accepted by our customer as representative of AFSPC training scenarios.

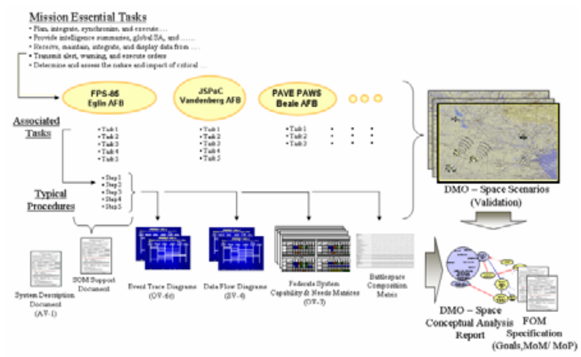

Figure 3. Conceptual Analysis

These scenarios were decomposed via Systems Engineering practices (e.g. Event Trace, Data Flow Diagrams) into a list of battlespace objects and specific intra and inter-team training capabilities. This information was then utilized in the development of a conceptual model which documented these capabilities and their required level of battlespace representation. Early agreement on fidelity of training was critical to confirming customer expectations and keeping costs under control. Figure 3 illustrates the conceptual analysis phase.

FEDEP Step 3: Design Federation

The purpose of this step of the FEDEP was to identify, evaluate, and select all federation participants (federate systems), allocate required functionality to those federates, and develop a detailed plan for federation development and implementation. Conceptual model development provided the necessary inputs for creation of the Federation Plan. This plan included which federate system was playing in the federation, which integration tools would be used and what the test approach was. Also during this step, the NG team focused on the following things in designing the federation:

- Defined what the training and system limitations were for the federates participating in the federation.
- Performed a trade-off study to evaluate options for communications systems, battlespace presentation, federation agreements content (ex. HLA RTI, DDM scheme, Enumerations), and FOM validation approach.

FEDEP Step 4: Develop Federation

The purpose of this step is to develop the FOM, modify federates if necessary, and prepare the federation for integration and test (database development, security procedure implementation, etc.). The DMO-S FOM is RPR-FOM v2.0 based with modification implemented as necessary to maintain compliance with both DMO and JNTC systems. Based on the outputs from FEDEP step 3, the NG team developed the DMO-S FOM by adding in the necessary Objects and Interactions needed in the federation from the Simulation Object Models (SOMs) of the space federates playing in the DMO-S scenarios. In order for space federates to play in a federation they need to abide by certain federation agreements. These agreements were developed by using the FOM specification developed in the previous FEDEP steps, and in order to maintain compliance with JNTC systems, JFCOM agreements were taken into consideration. These agreements included things such as which DeadReckconing Algorithms federates have to use, coordinate systems, time management, heartbeating and timeouts, units, HLA Run Time Infrastructure (RTI) mode, RTI rid file configuration, Data Distribution Management (DDM), network connectivity, etc… NG also developed a Test Plan and Procedures during this step to validate the Federation Plan.

FEDEP Step 5: I&T Federation

The purpose of this step of the FEDEP is to plan the federation execution, establish all required interconnectivity between federates, and test the federation prior to execution. The tailored we executed is illustrated in Figure 4.

The on-site validation was achieved at NG's Orlando facility using a combination of existing and surrogate Space systems. Distributed validation was much more challenging due to our proximity to JFCOM, and the SIDC at Schriever AFB, CO.

Our distributed systems validation challenge was overcome by leveraging JFCOM's Joint Distributed Integration Facility (JDIF) in Orlando, FL as our DMO-S I&T node. The joint training nature of the DMO-S program met the JDIF requirement for supporting joint training initiatives. The benefits of JDIF sponsorship include access to facility resources (e.g. staff, systems, etc), and Joint Training and Experimentation Network (JTEN) connectivity.

This connectivity afforded us the ability to test with both JFCOM's Technical Innovation and Development Branch (TDIB) and the SIDC lab. The final test event was a missile defense scenario which demonstrated that the correct bi-directional flow of data (e.g. entities, interactions, communications) was occurring to facilitate distributed training.

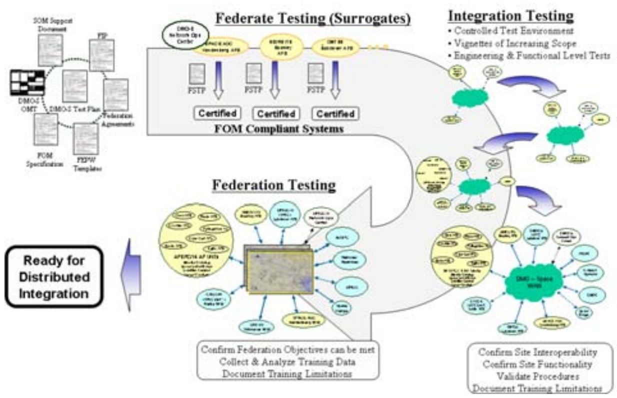

Figure 4. I&T Methodology

This methodology is shown in figure 4 and was successfully executed to develop the FOM, Federation Agreements, and test artifacts necessary to validate a distributed Missile Warning training capability for AFSPC.

COUNTER SPACE

Overview

Counterspace is categorized into 3 areas:

- Defensive Counterspace (DCS): Detect, characterize and locate source of an attack
- Offensive Counterspace (OCS): Degrade / destroy adversary Counterspace and SSA capabilities
- Degrade/destroy enemy space capabilities and gray supporting space capabilities for the duration and location required

Currently, most of the Counter Space training that is conducted today in exercises and mission rehearsal events is "white carded" or performed as a White Cell function. There are two systems, however, that are used to provide modeling and simulation in some of the events to support Counter Space training in a distributed environment. One of those systems is the Threat Emulator operated by MDAs exercise support facility during major exercises to represent an ASAT launch against Blue Force space-based assets. The Threat Emulator models a rocket launch and simulates a foreign country's hostile intent against a Blue Force satellite. The training audience sees the indications and warning of the space launch vehicle and proceeds to take action as directed by JFCC Space. Another system that has been employed during the Advanced Concepts Events sponsored by AFRL's Directed Energy Division (Kirtland AFB) is the Space Systems Generator (SSG) developed by the DMOC-S at the Space Innovation & Development Center in Colorado Springs, Colorado. The SSG models Red, Blue or Gray satellite constellations and publishes the Space Order of Battle in the DIS or HLA environment, stimulating the training audience who then responds accordingly. During the ACE events, the SSG models Delta-V maneuvering of satellites and can simulate space-based assets involved in defensive and offensive Counter Space operations. The NORAD Space Catalogue is used as well as the ability to create or modify satellites to provide for Counter Space distributed training. The SSG has recently been selected for integration with the JSpOC Mission System for providing space M&S stimulus to the JSpOC and USSTRATCOM exercise and mission rehearsal events.

GPS Jamming Focus

The main focus in counter space was to bring GPS Jamming capabilities to joint distributed and tactical training exercises. This capability provided to the exercise battlespace a GPS and space environment that focused on providing realistic navigational accuracies and damage assessment reports in real time to the systems/platforms. Also, the focus of the GPS Jamming capability solution was to implement it in phases, where phase 1 was jamming of long range weapons, phase 2 was jamming short range weapons and the final phase was jamming aircrafts. Each phase in this solution used a standards based approach, so that the solution could be easily implemented into systems/platforms and integrated into the battlespace exercise with limited interoperability issues.

TRAINING DOMAIN APPLICABILITY

Based on initial discussions with the TDIB team, it was clear that a high fidelity GPS jamming capability had applicability in both the operational and tactical training domains. Our primary contacts for training requirements and validation of a standards-based GPS jamming capability are the TDIB and Combat Air Force (CAF) DMO leadership.

Combat Air Force Distributed Mission Operations

The purpose of the DMO Program is to allow United States Air Force (USAF) warfighters to train in the full spectrum of team combat skills. DMO supports inter-team and intra-team composite force training for warfighters located in geographically separate locations. Mirroring current doctrine, the DMO System provides warfighters the ability to train as a team, while supporting the enhancement of individual proficiency.

The Combat Air Force (CAF) DMO program was initiated in 1999 and is the foundation for revolutionizing training for the USAF. This global, distributed, virtual-constructive training solution provides in excess of 1200 distributed training events which facilitate 10000 training hours per year. CAF DMO training systems (ex. F-15C, E-3, F-16CJ, JSTARS, B-1, F-22) are comprised of high fidelity man-in-the-loop virtual cockpits for training pilots, weapon system officers, and Command, Control, Intelligence, Surveillance and Reconnaissance (C2ISR) crew stations, and training support systems (ex Environment Generators, Threat Stations). The primary focus of this training capability is tactical training.

GPS JAMMING

Operational Needs

The first thing that must be identified before bringing the capability to an exercise is the "specific" operational training need. The following operational needs were identified to justify the implementation of a GPS Jamming capability in training:

- Numerous General Officer requests for an improved GPS Jamming capability at ACC's Requirements Training Review Board (RTRB).

- The GPS Jamming capability was briefed at the Terminal Fury (TF) 08 Initial Planning Conference (IPC). The briefing was given to the TF 08 Executive Leadership and the Modeling and Simulation Group. The outcome of the brief was that there was a need for the capability in the exercise. It was also suggested by the TF leadership that it could be used in Talisman Saber Exercises.

- In PACOM operational training exercises such as Northern Edge, the GPS jamming capability is being trained by "white carding." Therefore, it was specifically requested by exercise planners to make it more real-time by having it simulated.

- In the CAF-DMO, the Bomber Group such as the B-2, B-1 and B-52 have identified that there is significant training value in injecting GPS Jamming affects on weapons and aircrafts during tactical training exercises.

- The GPS Jamming Capability was briefed to the ACC EW DMO Users group, where it generated a lot of interest and it was decided that requirements and scenarios needed to be defined before it can be integrated into CAF-DMO Exercises.

Description of GPS Jamming Solution

The GPS Jamming solution involves the GEG, SSG, MAK VR-Forces, DIS to HLA Gateway and Jammers. The GEG and the SSG provided the GPS Environment to the battlespace, the MAK VR-Forces was the Computer Generated Forces (CGF) that takes in the GPS Jamming effects and the Jammers provided the jamming effects on the weapons and aircrafts. A scenario was created in conjunction with Joint Forces Command (JFCOM), whereby in the battlespace you would have a group of four ship aircrafts, targets, Jammers and the GEG and SSG systems providing the GPS environment. If no jamming was going on in the scenario, the weapons fired by the aircrafts would hit the target, but if jamming was going on the weapons would miss the targets.

Standards-Based Focus for Weapons Jamming

The Standard Based approach for weapons jamming calls for the following:

- Space Systems generate a realistic GPS and Space environment to provide a GPS Jamming capability.

- Simulation Entities that can perform jamming.

- Entities capable of consuming the GPS jamming data provided by the Space Systems that interferes with the delivery of weapons.

In a realistic GPS environment, the SSG contributes to the environment by generating the simulated space systems and sensors and publishes a Space Orbit (OB). The SSG publishes entity location information on designed satellites to provide "truth" data to the realistic GPS environment. To provide the "truth" data the SSG extracts the indentifying information (satellite NORAD number) and earth centered inertial (ECI) position and velocity vectors for each satellite in the environment. The GEG consumes the data produced by the SSG, and factors in platforms, munitions, terrain and effects of potential jamming for targets areas and routes. It then predicts the GPS Navigation Accuracy, Circular Error Probable and Horizontal/Vertical Position Error when GPS/INS guided munitions are employed in or out of an electronic combat jamming environment. The GEG will receive jammer information in the form of Entity States (location, vector, status) and Transmit or Electromagnetic Emissions PDUs (emissions parametrices) to condition the laydown of countermeasures. As the characteristics of the electronic combat environment change, the GEG continually calculates the GPS environment, of which the jammer parametrices contribute, providing each of the weapons systems that query GEG. The System /Platform will need to publish a tracked munition (Entity State and Weapon Fire) for the GPS Guided munition and would need to continuously query (Data Query PDU) the GEG for GPS Jamming data once it fires the weapon. Once the GPS Jamming data is consumed by the Platform/Systems it is up to the weapon system to decide how to model the navigational error data.

Standards-Based Focus for Aircraft Jamming

The Standard Based approach for aircraft jamming calls for the following:

- Space Systems generate a realistic GPS and Space environment to provide a GPS Jamming capability.
- Simulation Entities that can perform jamming.
- Entities capable of consuming the GPS jamming data provided by the Space Systems that interferes with the aircraft navigation systems.

This phase involves simulating the impact of jamming within the aircrafts model. For each GPS enabled flight flown by a platform/system, the GEG will be consulted to determine whether the GPS guidance system of the aircraft is jammed and how this jamming will affect its flight plan.

Interoperability Requirements

In order to implement a Standard-Based GPS Jamming solution for weapons and aircrafts in a Computer Generated Forces (CGF) the following interoperability requirements had to be implemented:

- The CGF simulates an aircraft and a target entity.
- The CGF simulated aircraft uses its internal algorithms to model how the munition will target a stationary entity.
- A tracked munition entity is created by the CGF, and the CGF would send out the initial Entity State PDU for the munition. Within the CGFs munition logic, a destination location is maintained. Each simulation frame, the CGF steers the munition (within the specified maneuverability limits) towards this destination. The CGF would initially set the destination point of the munition as the position of the target entity.
- Immediately following the creation of the munition, the CGF would send a DataQuery PDU to the GEG with the Entity ID of the munition as the Originating Entity.
- The "Receiving Entity ID" is the Weapon Systems ID that is in the Data PDU “Entity ID” field of the missile.
- In the DataQuery PDU, the IDs are reversed, so the Munition Entity ID would be the Originating Entity and the GEG ID would be the Receiving ID.
- The CGF would listen for a Data PDU from the GEG; in the Data PDU the CGF receives the Munition Entity ID will be listed as the Receiving Entity.
- The CGF shall not directly update any PDU field with the destination point. Rather, the "Destination Point" should be held internally by the CGF, and would be used by the guidance algorithm when determining the next position of the missile. With each simulation tick, the new munition position would be calculated using the internal destination point, and that location would be published in the Entity State PDU for the munition.
- For each simulation frame, the CGF should steer the munition towards its specified destination. Entity State PDUs should be published with the munition location when appropriate. (Heartbeat and dead-reckon threshold exceeded).
- Periodically, (every 5 seconds) the CGF shall send a new query to the GEG. The new offsets received would cause a new destination location to be calculated for the munition. When the munition impacts either an entity or the terrain

surface, a detonation PDU would be published that includes the actual point of impact of the munition, and damage would be assigned to entities in CGF appropriately.

- The GEG does not calculate a new position (or offset), it is the CGF responsibility to use the CEP and the horizontal and vertical positional error values to determine how to perturb it's entities position (e.g., based on the error information, always take the next step to be along the direction of travel but to the right [as opposed to the left] of the current position).

The below tables defines the FixedDatum Record for Data and DataQuery PDUs. The DataQuery is used by the weapon system/platform to query data from the GEG and the Data PDU has the GPS Jamming effects data that is sent to the requesting system/platform.

Table 1.0 Fixed Datum Record for Data/Data Query PDU

Fixed Datum Value (32 Bit Unsigned Integer)	Fixed Datum Value (32 Bit Float)
300000	Horizontal Error Probable (m)
300001	Horizontal Position Error (m)
300002	Vertical Position Error (m)
300003	Horizontal Velocity Error (m/s)
300004	Vertical Velocity Error (m/s)
300005	4th Lowest J/S for P(Y) code on L1 frequency (dB)
300006	4th Lowest J/S for P(Y) code on L2 frequency (dB)

Horizontal Error Probable (m): This is the circular horizontal sigma error derived from the covariance matrix of position error and converted to a circular error probable in the user's horizontal plane…in other words, this is the horizontal error of the platform [in meters].

Horizontal/Vertical Position Errors (m): The position errors for a given GPS-equipped platform are computed from the contribution of two sources—a combination of the pseudo range errors from each of the satellites the platform is tracking and a geometric error based on their locations and the INS "drift" errors.

Horizontal/Vertical Velocity Errors (m/s): These values are used if the platform is concerned about rate of change of velocity errors or their magnitude of contribution to the overall position. The only impact velocity error has on a weapon is at handoff, and this is actually the velocity error of the launch platform. Until the weapon acquires full State 5 GPS, the launcher's handoff velocity error affects the weapon's position error as a function of the weapon's time of fall without GPS after launch. Upon GPS acquisition by the weapon, all handoff errors are forgiven.

The 4th lowest J/S for P(Y) code on the L1 and L2 frequencies: This is the 4th lowest jammer to signal ratio for the for the P(Y) code on the specified frequency (L1=1575.42 MHz or L2=1227.6 MHz). Now you can interpret this value to give you a feel for the level of jamming being seen by the requesting platform at the requested time such that if the 4th lowest J/S value is less than the tracking threshold for the GPS receiver being modeled in the GEG, then you are fairly confident that it can track at least 4 satellites and form a GPS solution. If the value is higher than the receiver's threshold, then you may at best be able to track 3 satellites (but that is not guaranteed). For the Data Query PDU, the values for the enumerations in the FixedDatum Record need to be set to zero since they are not required by the GEG.

Modifications to JFCOM Models

Based on the standardized solution, one of the first JFCOM CGFs to be modified was the AWSIM model. The modification involved 3 phases where they used the weapons standardized solution requirements to do GPS Jamming on Cruise Missiles. This solution was validated in a test facility at the JDIF. These changes were also validated during Spiral 3.1 Integration and Test at the JFCOM facility in Suffolk, Va. The AWSIM model still needs to implement the remaining phases of the GPS Jamming capability that includes jamming on close range weapons and on aircrafts.

LESSONS LEARNED

Interface with Stakeholders:

Constant communications and interface with the stakeholders in developing the GPS Jamming capability helped resolve interoperability issues and concerns quickly and easily.

Integration and Testing using a Testbed:

Creating and using a local testbed with the necessary federates and tools provided the Northrop Grumman team easy access and the ability to provide a standardized proof of concept quickly to the users.

Standards-based Solutions:

A GPS Jamming capability had been demonstrated in the past as a stand-alone capability. Acceptance of this stove-piped approach was limited by organizations since interoperability in other training solutions was not evident. Presentation of our GPS Jamming capability leverage the same GFE systems but include formal standards/requirements necessary for implementation in existing training solutions. This approach has allowed us to work efficiently with the joint community to demonstrate the applicability of this capability in training.

CONCLUSION

A standards-based GPS Jamming capability was demonstrated at the JDIF in early 2009. We are currently working with JFCOM and CAF DMO leadership to integrate this capability to enhance their respective Operational and Tactical training capability. With a GPS Jamming capability defined for use by organizations to support training, we have begun to focus on other areas of training.

A primary focus is the development of a standards-based solution for Anti-Satellite (ASAT) training. An ASAT training capability is currently provided to the JSpOC during Rapid Tiger events, space scrimmage and most major exercise events. The tools and methods used during these events are centered around "white carding" white cell functions with some use of rocket launch modeling by the Threat Emulator (MDA) simulating a direct ascent ASAT and Delta-V maneuvering by the SSG simulating co-orbital ASAT and direct ascent ASAT during the ACEs. The next increment in SSG development will provide dynamic updates to the ISSA and JMS in the coming year. This will then provide a capability in the JSpOC and USSTRATCOM to model and simulate new foreign launches, direct ascent and co-orbital ASATs. Once validated, these DMO-S capabilities will be available for use in other training federations.

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