# PISCES—PRECISION INTEGRATED STRIKE CONCEPT EVALUATION SUITE

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## ABSTRACT

This paper describes the initial development and demonstration of the Precision Integrated Strike Concept Evaluation Suite (PISCES). PISCES was initiated in early 1994 as an internal research and development project to create a virtual operating environment for demonstrating and evaluating Naval strike warfare capabilities using distributed interactive simulation. The overall focus of PISCES is concept evaluation and demonstration of advanced precision strike weapons launched from submarine and surface platforms, and delivered by tactical aircraft. The initial phase of PISCES development involved identifying available modeling and simulation capabilities at the Applied Physics Laboratory that could support a modest, yet relevant, concept demonstration. In the initial phase, six participants were connected over a secure fiber optic cable network. Existing software applications from each participant were modified to make use of the distributed interactive simulation protocols. A strike scenario was crafted to highlight specific advanced features of a planned future cruise missile weapon system and an unmanned aerial vehicle (UAV). Participant actions were shown against the backdrop of this strike scenario and the associated strike plan. Various forms of information were passed between participants over the secure local area network, including data messages between strike assets in the form of protocol data units (PDUs). Key aspects of the concept demonstration were incorporation of a prototype capability to show a command and control node exercising dynamic control of cruise missiles after launch, and the use of a model to show utility of an endurance UAV for providing tactical targeting and surveillance information. Other accomplishments of the first phase of PISCES are described in the paper. Progress made during the second phase of the project is also discussed.

## AUTHOR(S) BIOGRAPHY

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## INTRODUCTION

### Background

The Persian Gulf War saw standoff precision strike weapons used in greater numbers than in any previous armed conflict of such short duration. Two weapons employed for the first time, the Tomahawk Land Attack Missile (TLAM) and the Standoff Land Attack Missile, were used to strike targets where pin-point accuracy was required or where risk to manned aircraft was high. From both perspectives the successful employment of these weapons has subsequently spurred the continued development of standoff precision strike weapons, despite a reduction in overall defense spending.

The pressure on the military-industrial complex to do more with less has led to new approaches in acquiring weapon systems for the operational forces. The rapid pace of technology development, particularly computer- processor and display systems, has resulted in a shift from a more costly and time consuming approach of using militarized hardware to readily available commercial off-the-shelf hardware. Opportunities for placing evolving system prototypes in the hands of the operational user have been pursued to demonstrate system utility as justification for further development and to satisfy, in some measure, a current operational need. Military exercises are being conceived where advanced technology and concepts of operation can be demonstrated. Technology demonstrations often occur against the backdrop of a training exercise in which live forces and military systems are used to provide a stressful real-world environment. However, the extent to which operational forces can be employed is often limited by availability of resources.

A partial solution to the resource shortfall is being provided through the increasing use of models and simulations throughout the system acquisition cycle. We see, for example, the use of modeling and simulation (M&S) in simulation-based design and evaluation in the service's advanced strike aircraft development program [1]. However, the most prevalent use of M&S is in the training area where advanced distributed simulation is being applied to create a virtual environment in which synthetic entities are used to supplement the live forces in the exercise. The Navy is pursuing the use of M&S in training through the Battle Force Tactical Training (BFTT) program.

The use of models and simulations to demonstrate system utility and to supplement the training environment has considerable appeal. For one thing, it allows capabilities that have been developed independently over a period of time within the military-industrial complex to be effectively combined in a simulation environment. Remote locations can be linked together over local and wide area networks to simulate the participation of a particular system or entity. As new systems are conceived, early prototypes can be inserted into this environment to prove system concepts, remove weaknesses before the design is finalized, and reveal where other improvements might be needed. This approach also has the benefit of involving the user early in the development process to ensure system usability and to get a head start on structuring training and defining employment doctrines.

It is against this backdrop of precision strike weapon development, of reduced military budgets, and of the wider use of modeling and simulation technologies that the Precision Integrated Strike Concept Evaluation Suite (PISCES) project was undertaken.

### Objectives of PISCES

The PISCES project was initiated in 1994 as an internally funded research and development effort. The objective was to assemble a distributed simulation environment for strike warfare capable of demonstrating and evaluating the employment of advanced precision strike weapons. The scope of weapons to be included are those that are launched from surface ships and submarines, as well as delivered by tactical aircraft. The initial phase was limited to an advanced version of TLAM that is now under development by the Navy. The objectives of PISCES in Phase 1 were to:

(1) connect a few classified facilities, i.e., participants, over a secure local area net
(2) develop a scenario that highlights the new features of the advanced TLAM

(3) demonstrate participant interactions within the context of the scenario, and
(4) identify a distributed simulation exercise that would allow future interaction with other participants external to the local PISCES environment.

In general, this initial effort was focused on integrating existing capability. New software development was driven by those requirements associated with implementing the demonstration scenario.

The following sections discuss the capabilities demonstrated by the PISCES project. Each participant is identified and the local network connectivity is described. The scenario used for the demonstration is explained. We then provide a discussion of lessons learned. Two of the more important lessons are concerned with the importance of the demonstration scenario to focus developments, and the use of a relatively small number of PDUs to exchange information between participants. The final section summarizes Phase 1 accomplishments and gives an overview of activities for Phase 2 of the project this year.

## PISCES PARTICIPANTS

The approach taken to implement a PISCES environment builds on the M&S capability developed over the years of support to the Cruise Missiles Project. These activities have required a broad systems view of the Tomahawk Weapon System (TWS) and an understanding of all the elements essential to weapon system employment. Among these elements are mission planning, weapons control and the missile itself. With the development of a system upgrade comes the additional element of strike management, i.e., the ability to monitor and control missiles after launch. Other related elements include UAVs for surveillance and targeting as well as command, control and communication systems required for effective employment.

Six classified facilities were connected over a secure fiber optic cable network to create a distributed simulation environment within JHU/APL. Each facility reflects a particular element of the strike process involving TWS employment. The role of each facility, i.e., strike participant, is summarized below.

### Command and Ground Truth Monitoring

During execution of the strike demonstration scenario, a conference room setting is required to monitor progress and maintain ground truth. Exercise data is viewed and logged for subsequent playback and analysis. In addition to providing a central site for controlling participant interactions, a location is needed for observers to monitor the scenario in progress and to otherwise provide an area for briefing visitors. These functions are provided by the

**Warfare Analysis Laboratory (WAL).** These same viewport capabilities were used effectively in the recent Kernel Blitz training exercise.

### Mission Planning

The employment of TLAM requires that mission data be prepared in advance of strike execution. These data are used by TLAM to fly the intended route, perform necessary maneuvers to maintain altitude with respect to variable terrain and to execute the terminal maneuver to the target. Such simulated mission data, including target models and command information, were to be provided by the

**Mission Planning Development Laboratory (MPDL)**, representing mission planning as it might occur afloat in a Navy battle group. These capabilities were not fully implemented for the initial demonstration. During the scenario the MPDL was tasked for and provided imagery of the target area complex.

**Strike Management**

A future upgrade to the TWS will allow TLAM to be controlled after launch. Missile health and status information will be sent to a strike coordinator via a satellite data link. A message may be sent by the strike coordinator to a particular missile in flight to modify the mission being executed. This decision might be made, for example, using battle damage indications (BDI) provided by a previous missile. Preparation of the TLAM strike package, rehearsal of anticipated outcomes, and real-time management of the missiles after launch are functions of the strike coordinator. The strike coordinator was physically

located in the **Command and Control Systems Laboratory (CCSL)** for the demonstration. In the demonstration scenario, strike coordination was performed on one of the surface ship launch platforms.

**Submarine TLAM Launch**

TLAM can be launched from submarines as well as surface ships. A virtual launch environment is

provided by the **Submarine Combat Information Laboratory (SCIL)** which is a physical mockup of a submarine control room. In addition, SCIL supplements the strike scenario with other strike entities generated by ORBIS (Object-oriented Rule-Based Interactive System), an expert-system simulation tool. This capability has been used in the past in distributed simulation exercises of undersea warfare for the ARPA Maritime Simulation Demonstration. In that case the SCIL was a functioning node on the Defense Simulation Internet (DSI). The DSI capability was not used for the initial PISCES development; SCIL executed the launch of a TLAM using a hypothetical engagement plan for the assigned submarine missions.

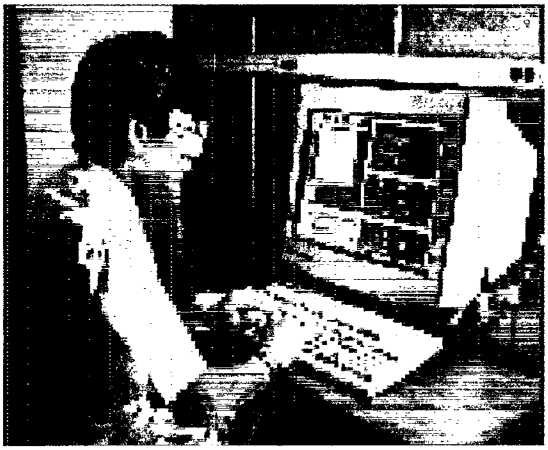
**TLAM Flight and Visualization**

After launch the TLAM flies a preplanned route to the target by executing terrain following maneuvers. An upgraded version of TLAM will have the ability to communicate with the strike coordinator during flight via a satellite data link. The Tomahawk upgrade also adds a forward-looking sensor for terminal guidance and transmits images to the strike coordinator for battle damage indications.

The **Digital Engineering Laboratory for Tomahawk Analysis (DELTA)** facility provides visualization of missiles after launch as well as a simulated seeker output during terminal flight. A missile community model simulates missile ground truth and communications. The simulation of one missile is handed off to a separate high fidelity model for terminal phase processing.

### Target Area Surveillance

Surveillance of the target area is performed by a high altitude endurance UAV. The UAV is on station before the execution of the strike and monitors the progress of the strike as TLAMs impact their intended targets. A simulation of the UAV is



provided by the **Aeronautics Classified Computing Facility (ACCF).** During the strike scenario an image of the target area after TLAM impact is sent by the UAV platform.

## NETWORK CONNECTIVITY

A primary task in establishing PISCES was putting a local area network (LAN) in place to support the exchange of information among participants. This included supplementing an existing fiber optic cable backbone with additional secure cable runs and adopting a communication protocol standard. These two aspects are discussed below.

### Secure LAN

Initially, none of the participants were connected on a LAN. The first step was to install fiber optic cable with sufficient fiber strands to allow various forms of information to be exchanged. This process was made somewhat easier by an existing fiber optic cable backbone between two patch panels located in buildings at either end of JHU/APL. Four of the participants were connected into one patch panel and the remaining two participants into the other panel. Available network repeaters were installed in each facility creating a ring topology for the demonstration project.

The ring LAN was used to pass simulation data between participants. In addition, the Multicast Backbone, or MBONE, was installed at each node to allow participants to communicate by voice over the LAN using ethernet protocols.

Other forms of information were passed from some participants in a point-to-point connection to the WAL. In four of the five facilities, a color video camera was installed, which, along with voice communication provided by MBONE, allowed each site to give remote presentations. Live video from each node was passed to the WAL and displayed in one quadrant of a large screen display. As a remote presentation was given, the small display in the appropriate quadrant was also displayed by itself on an adjacent large screen display. This adjacent larger display tended to focus attention on the briefing being given.

For two participant workstations, the high resolution color displays were passed over the LAN and displayed on 37-inch monitors in the WAL. These were the strike coordinator's workstation in CCSL showing the evolution of the strike and various control windows, and a workstation in DELTA showing visualizations of TLAM broaching water after launch, and during midcourse flight to the target. These displays supplemented the ground truth information provided to observers located in the WAL.

### Participant Interoperability

Interoperability on the LAN was achieved by adopting the Distributed Interactive Simulation (DIS) protocols for communicating simulation data between various participants. Six Protocol Data Units (PDUs) were implemented to support the execution of the demonstration scenario (discussed in the next section). The PDUs and their data items are shown (see Table 1). We used VR-Link, a product of MäK Technologies, Inc., to implement the PDUs. Other software packages, also from MäK, were installed in the WAL to record PDUs and to display three dimensional views of the virtual world represented by the PDU traffic. MäK's Data Logger and Stealth packages allowed the exercise to be played back and viewed as part of post-exercise evaluation.

**Table 1**
**DIS PDUs Employed**

| PDU | DATA ITEM |
|---|---|
| Entity State | Missile State |
| | Platform State |
| | Initial State |
| | UAV State |
| Signal | Missile Health and Status |
| | Mission Modification |
| | UAV Status |
| | BDI Data |
| Fire | BDI Image |
| Detonate | Missile Launch |
| Start/Resume | Missile Impact |
| Stop/Freeze | - |
| | - |

## STRIKE COORDINATION

A centerpiece of the PISCES project is the strike management prototype [2]. The strike management prototype offers a view of several real-time command and control capabilities in anticipation of the Navy's advanced Tomahawk cruise missile capability. It serves as an example of a central node from which these advanced cruise missiles could be monitored and controlled (i.e., managed). A geographic display and strike summary display are two of the strike management displays available in the prototype. Using these (and other displays and capabilities) the strike management prototype supports:

(1) previewing the strike plan
(2) monitoring strike progress
(3) controlling missiles in flight
(4) assessing strike effectiveness

Strike management principally deals with ensuring the strike plan is successfully executed. This includes preparing assets to carry out the strike (e.g., developing a missile communications plan) as well as monitoring and controlling assets once the strike is executed.

Two distinct aspects of strike preview allow the strike coordinator to prepare for strike execution. The first aspect is strike review. A detailed review of the strike plan allows the opportunity to evaluate the plan in light of the latest tactical information. This review would include examination of selected routes, their proximity to known threat locations and other operationally significant information, such as enemy and own force locations. Other important aspects to be reviewed include timing considerations, effects of environmental conditions and overall target coverage including the alternatives and options provided by flex sets. (A flex set is the collection of missions pre-stored on the missile. A missile can only be commanded to execute one of the other missions in its flex set, provided it has not passed the last flex point common to the two missions.) The second aspect of strike preview is strike rehearsal. Strike rehearsal prepares the strike coordinator for strike execution through a realistic representation of expected strike progress. Strike rehearsal includes practicing potential responses to positive and negative strike indications, as well as imagery recognition to support strike assessment.

The prototype provides basic capabilities to support the strike coordinator's review and rehearsal of the strike plan. The strike coordinator can select a preview speed (e.g., 10 times faster than real time) and play the strike forward in time, pausing and resuming at will. A timeline display allows the strike coordinator to examine timing relationships in the strike. In addition, the strike coordinator can confirm aimpoint coverage, including the expected levels of damage, missiles available to be flexed to each aimpoint, and available backup missiles. The strike coordinator can impose casualties that require an action in response to deviations from the nominal plan. A typical casualty is a missile failure, and the usual response is to flex a missile or order the launch of a backup missile to ensure adequate aimpoint coverage. The rehearsal capability also includes the presentation of simulated seeker imagery for appropriate missiles. This helps the strike coordinator recognize the target image expected from the missile during actual execution. The strike coordinator can also rehearse potential response to positive indications, such as an image showing adequate target damage. Potential actions might be to flex subsequent missiles away from the adequately damaged aimpoint to other aimpoints (provided an alternate mission is still available), or to influence tasking for restrike planning. Flexing based on positive indications was practiced during the PISCES Phase 1 experiment. The timing for this flex was critical, and the ability to rehearse in advance of execution proved invaluable.

In the future Tomahawk cruise missile system, monitoring and control of the strike will be provided through the two-way communications. The missiles can send data messages to the strike coordinator via a satellite communications channel, which allow the position and status of the missiles to be monitored in real-time throughout the strike. The strike coordinator can send information to the missiles (e.g., flex commands) via this same channel, to control missiles after launch.

The prototype provides a number of monitoring and control capabilities. The prototype automates the tracking of the missiles on the geographic and summary displays. Since Tomahawk missions are preplanned, it is easy for the prototype to dead reckon the missiles along their routes, and update the tracks as missile health and status messages are received. The prototype provides an information window for the missile accessed (or any other object on the display) using a simple point-and-click action.

The prototype provides strike control (i.e., flexing missiles, launching backup missiles) through two modes of control. In positive control the prototype computes the available recovery actions and presents them to the strike coordinator in ranked order. The prototype automatically computes recovery options when it detects an aimpoint that is not adequately covered (e.g., due to a missile failure). The system will take no action, however, until the strike coordinator selects and approves a recovery option. The second mode of control is manual control. As the name implies, in this mode flex and backup launch actions must be manually set up by the strike coordinator. The prototype performs some rudimentary checking, for example, only allowing missiles to be redirected to alternate missions that are still in the flex set. (Missions are automatically removed from the flex set when the missile passes the last flex point leading to the alternate route). Once a manual option is executed, the prototype automatically generates and transmits all necessary flex messages and backup launch orders.

With the satellite data link and the imaging seeker, missiles will be capable of providing important information in the terminal area; information that can provide a strong indication of the outcome of the strike. The strike coordinator can make an initial assessment of strike success based on the terminal data messages and images from the missiles. The prototype supports strike assessment through the collection and display of data and imagery. The prototype receives the terminal messages, and displays a color-coded indication of success based on the message contents. In addition images are received and made available for further review. Any available pre-strike images are provided along with the actual received images to support a "before and after" comparison. With the simple click of a button, the strike coordinator makes a qualitative damage assessment ("sufficient" or "insufficient") for each aimpoint. Taken collectively, these aimpoint damage assessments provide an initial assessment of overall strike effectiveness.

## DEMONSTRATION SCENARIO

A hypothetical cruise missile scenario was prepared to highlight the planned new features of the Tomahawk cruise missile. Developing the scenario early in the project helped to identify the PDUs needed to transfer simulation data between participants. It also allowed specific roles for each participant to be defined and their part in the demonstration to be scripted against the time-line of the scenario. The following sections provide an overview of the strike plan and discuss details for the timing and execution of the strike with the advanced Tomahawk cruise missile.

### Strike Plan Overview

The UN Secretary General, in consultation with the President of the United States and other world leaders, has decided that a military strike, code name OPERATION JOINT EFFORT, should be carried out against Zamfir, the capital city of Zamfiria. The objective of JOINT EFFORT is to cripple Zamfiria's capacity to engage in further hostile action. The targets selected for Tomahawk cruise missile strikes are:

- the Ministry of Defense (MoD) command and control headquarters
- the major weapons fabrication facility at Amal Abo
- the hydro-electric plant supplying the power grid for Zamfir and Amal Abo
- an aircraft hangar at Zamfir International Airport which holds recent shipment of critical war materials

Attacks against the command and control headquarters and hydro-electric plant are intended to severely restrict the enemy's ability to counter the strike. The MoD is the critical node in the enemy's highly centralized command and control structure. Disrupting the command and control functions will inhibit a coordinated response from the Zamfirians. The hydro-electric plant supplies primary power for the surface to air missile systems and anti-air artillery emplacements that might be used to threaten incoming cruise missiles. These two targets need to be neutralized only for the duration of the strike.

Strikes against the Amal Abo facility and the airport hanger, which are the high priority targets, are intended to severely cripple Zamfir's weapons production capacity. The materials awaiting transport from the airport are critical weapons production ingredients. Once these resources are destroyed Zamfir would be unable to threaten other countries until they restore their production capabilities. A UN trade and technology embargo will prevent Zamfir from rapidly re-establishing such capability, but their current capability must be destroyed by force. All of these targets will be struck by Tomahawk cruise missiles from US ships and submarines from the carrier battle group operating in international waters off the coast of Zamfir.

**Plan Coordination Details**

The strike plan consists of eight Tomahawk missiles launched from two surface ships and one submarine to strike five aimpoints on the four target complexes. The hydro-electric plant and MoD will be hit first followed closely by strikes on the weapons production facility and the airport. Figure 1 shows a geographic view of the area with missions and targets annotated. Figure 2 is a strike summary display for the strike plan. In Figure 2 time increases from left to right. Each bar represents the duration of flight for the missile indicated at the far left. The mission is indicated by a three character label (e.g., AM1) corresponding to a route on Figure 1. The aimpoint is indicated to the far right of each bar.

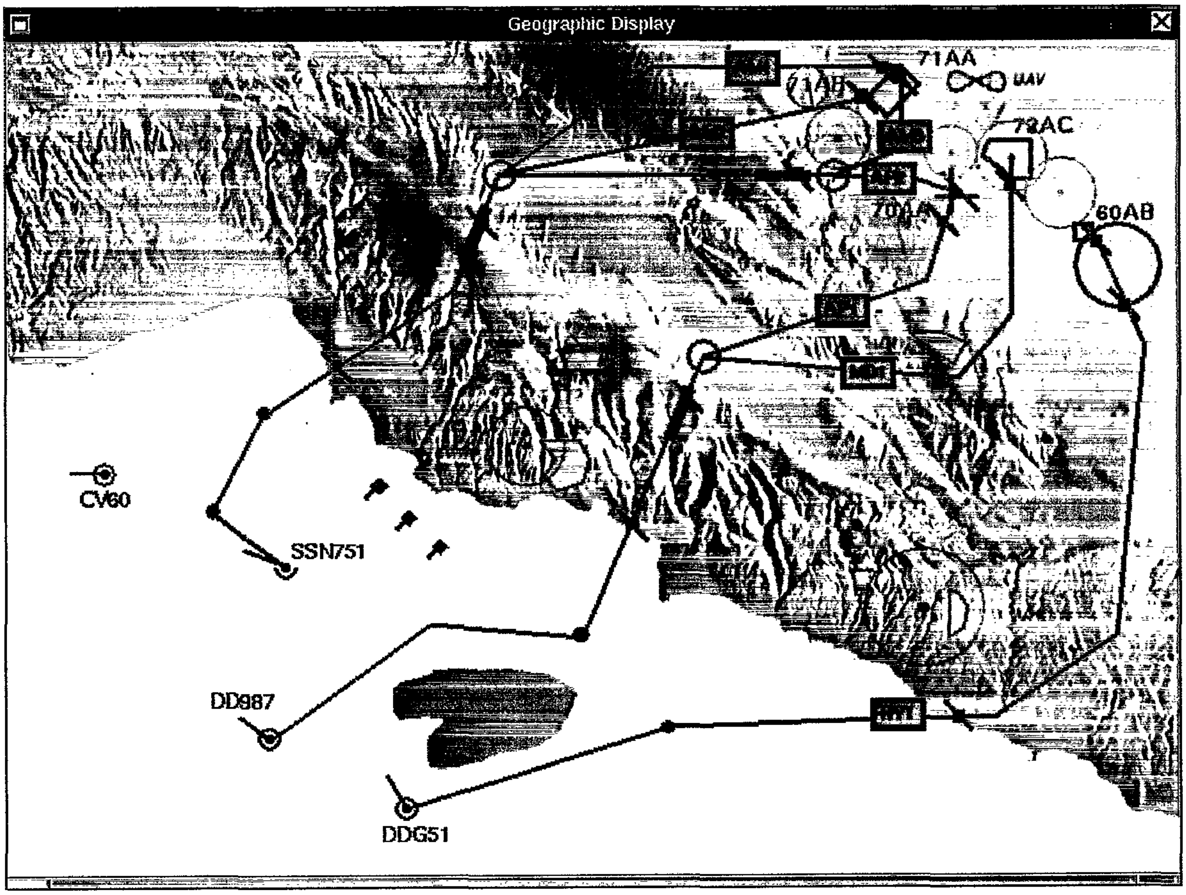



**Figure 1 Geographic Area for Strike Scenario**

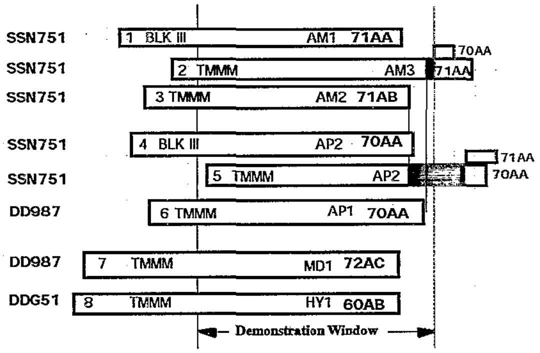



**Figure 2 Strike Plan Timeline**

Two of the eight Tomahawks are Block III missiles which fly to their intended targets using preplanned missions that cannot be redirected after launch. These missiles will be the first missiles into the Amal Abo facility and the airport. The remaining six missiles are Tomahawk Multi-Mission Missiles (TMMMs) which have the capability of communicating with the strike coordinator after they have been launched. These missiles can be redirected in flight via flexing to alternate aimpoints associated with the preplanned missions loaded into the missile before launch.

To achieve the plan, additional mission planning is required. Missions already existed for most of the aimpoints in the strike plan. Others missions were planned on the aircraft carrier in response to emergent tasking. Originally, there were no pre-planned missions to the airport hangar. (Without the weapons material, the hangar was not a Tomahawk target.) The carrier was tasked with planning two missions to the hangar. The tasking dictated one of these missions (AP2) as a modification of mission AM3, an existing mission to Amal Abo. The other mission (AP1) was planned by branching off of an existing mission to the Ministry of Defense (MD1).

The first missile in the strike (Missile 8) launched at 3:45 am local time will temporarily interrupt electrical power generation capability by hitting the on-line generator at the hydro-electric plant. At about the same time the plant is struck, the second missile (Missile 7) will hit the communications center at the MoD. This will effectively isolate the headquarters from field commands. By the time communications are restored, the strike will be over.

Amal Abo and the airport hangar are the highest priority targets. Three missiles are sent to each of these target complexes. The first two missiles into each complex are scheduled to arrive in short succession, the third missile follows some distance behind. The first missile into each complex is a Block III missile. The second missile is a TMMM that transmits a status message containing a single frame of imagery to the strike coordinator for damage indication. Based on the image, the strike coordinator may send an in-flight mission modification message to the trailing missile (also a TMMM) to flex to the other target complex. The trailing missiles may also send an image providing additional damage indications. This tactic exploits unique capabilities of the TMMM.

Multiple missions (a flex set) are loaded into selected TMMM prior to launch. The trailing missiles to Amal Abo and the airport will contain a flex set consisting of missions AM3 and AP2 (Refer to Figure 1). The trailing missile to Amal Abo (Missile 2 using AM3 as a primary mission) will have Mission AP2 as a secondary mission. Conversely, the trailing missile to the airport (Missile 5 using AP2 as a primary mission) will have mission AM3 as a secondary mission. The common portion of these missions has a flex point relatively close to the target complexes, so the trailing missiles need not lag too far behind.

Missile arrival times, aimpoint dispersion and run-in headings are coordinated to achieve required levels of damage and provide imagery. The airport hangar is hit first by Missile 4, followed closely by Missile 6. Imagery from Missile 6 arrives in enough time to make an initial damage assessment and flex Missile 5 to Amal Abo, if necessary (See Figure 2). That is, if the airport is sufficiently damaged, the trailing missile is redirected to the weapons production facility - a higher priority target. Likewise, if the imagery of Amal Abo from Missile 3 indicates adequate damage, and the imagery of the airport indicates insufficient damage, the trailing missile to Amal Abo (Missile 2) may be redirected to the airport. The shaded area on the time bar in Figure 2 (which extends from the time the video is received until the flex time) represents the time available to the strike coordinator to make a flex decision based on assessment from the video image. The bars above Missiles 2 and 5 show the time of flight if the missile is flexed to its alternate aimpoint.

Prior to the initiation of the strike, an endurance UAV will be tasked to overfly Zamfir and monitor the progress of the strike. Using its onboard imaging sensor it provides images of the target area. This information is used by the task force commander to assess battle damage and decide whether restrikes are necessary.

**Participant Presentations**

The scenario illustrated in Figures 1 and 2 provided a context for demonstrating distributed simulation with Tomahawk strike elements. Each participant had an opportunity to explain their role and system capabilities via remote briefings to the WAL during the demonstration window time period shown in Figure 2, beginning with the SCIL (launch of Missile 5 from the submarine). Each briefing was displayed on the large screen displays in the WAL.

The presentation sequence in the demonstration was carefully chosen to fit the scenario events. A 20 minute introduction of the PISCES project which included an overview of the scenario, was given during the initial launch phase of the strike. After seven of the eight missiles were launched, the SCIL provided an overview of their participation, concluding with the launch of Missile 5. Immediately, a visualization of a TLAM broaching water was displayed in the WAL, accompanied by a remote briefing from DELTA. During the subsequent missile fly-out phase the following participant presentations and events occurred:

- CCSL, i.e., strike coordinator, verbally tasked MPDL, i.e., mission planner, for target area imagery
- MPDL gave their vignette and transmitted imagery to CCSL
- ACCF, i.e., UAV, gave their vignette and transmitted imagery to WAL
- TLAM midcourse visualization was shown in WAL and discussed from DELTA
- strike coordinator's display was shown in WAL and discussed from CCSL

Finally, two vignettes were closely aligned to arrival of TLAMs in the target area. The concluding DELTA presentation discussed the terminal area seeker showing the seeker view for Missile 3 prior to impact. The BDI image for Missile 3 sent to the strike coordinator initiated the CCSL vignette, which included a real-time discussion of those actions taken to flex Missile 5 to the alternate target.

The amount of time for each vignette was tightly controlled. A timer was used to ensure that each remote briefing began and ended at the correct time. When viewed in the WAL, the effect was a coherent series of remote briefings without significant gaps from one presentation to the next. The demonstration scripted in this manner lasted about 45 minutes, starting with the launch of Missile 5 and ending before impact of Missiles 2 and 5.

## OBSERVATIONS AND LESSONS

Phase 1 of the PISCES project provided a learning experience for the development team. The constraints of time and the availability of resources influenced every task to be accomplished. Emphasis was placed on identifying and adapting existing simulations to the demonstration scenario. In this regard the scenario became a driver for the tasks to be accomplished. Other lessons learned from the project are listed in Table 2 and discussed below. Two high fidelity simulations did not execute in real-time on SGI computers. One simulated the terminal phase of a Tomahawk mission performing seeker correlations with stored target templates. The other provided a flight visualization for the Tomahawk missile in launch and in mid-course flight. In both cases the simulations were run before the demonstration and the visual data was stored for playback at real-time rates during the demonstration. The issue of simulation/model fidelity versus computational horsepower is one that must be addressed as activities move beyond demonstration into system concept test and evaluation and operational exercise support using virtual entities in a training environment.

**Table 2**
**PISCES Lessons**

| | |
|---|---|
| 1. | The demonstration scenario helped to focus development tasks. |
| 2. | Operational compromises were required to incorporate high fidelity simulations. |
| 3. | Implementing a small number of the DIS PDU types satisfied most information exchange requirements. |
| 4. | Phased testing during PDU development and demonstration rehearsal was aided by voice coordination provided by MBONE. |
| 5. | Network performance/operation was dependent on number of participants and types of data transmitted. |

For purposes of the demonstration only 6 of the 27 PDU types available in DIS message set were implemented. This number proved adequate for the demonstration with the entity state and signal PDU used most frequently. Some information elements requiring transmission with a signal PDU were not implemented due to the press of time. These were deferred to the next phase. Testing for PDU transmission and receipt was performed in a phased manner. This worked well since it only required those participants to be on the network who used the information contained in the particular PDU under test.

The use of MBONE was useful in dress rehearsals for the demonstration, even though it required recalibration of voice levels each time the scenario was practiced. MBONE required participants to exercise discipline in its use as there was a tendency to talk when it was not warranted.

As preparations for the demonstration were being completed though a sequence of rehearsals which involved bringing additional participants on-line, network problems began to occur. The network would not support all participants on-line each with MBONE activated. The ring network topology using local repeater units could not reliably support the network traffic. Because of this recurring problem, the demonstration was recorded on video tape in stages with no more than three or four participants on-line at any one time. The repeaters were subsequently replaced with a router which transformed the network into a star topology with the router at the center. Network testing with this configuration has proven to be completely reliable.

## CLOSING REMARKS

### Summary

The initial phase of the PISCES project established a baseline distributed simulation environment within APL for demonstrating and evaluating advanced precision strike system concepts. The objectives identified for Phase 1 were achieved. Six classified facilities were connected over a secure fiber optic cable network. Participant interactions were demonstrated against the backdrop of a hypothetical strike scenario designed to highlight the new features of an advanced Tomahawk cruise missile. Efforts on the first phase of PISCES culminated in the preparation of a demonstration tape. Phase 2 activities are being performed under a second year of internal research and development funding. Opportunities for applying the evolving PISCES capability in a training or demonstration exercise with other organizations are being pursued.

### Phase 2

An APL thrust area for modeling and simulation has been established to develop a virtual operating environment for exploring and resolving critical issues associated with advanced distributed simulation applications in command, control, communications, computers and intelligence (C4I). The second phase of PISCES is one subproject focusing on strike management C4I issues and concepts for employment of advanced precision strike weapons. Activities under this year's internal research and development support include:

- developing a satellite-link simulation for cruise missile communication
- implementing a precision weapon forward control capability
- demonstrating external connectivity with the Virtual Interactive Target [3]
- establishing interfaces with tactical equipment, e.g., the Joint Maritime Command Information System (JMCIS)
- incorporating a sensor model for the endurance UAV
- expanding the demonstration scenario to include reactive threats, e.g., surface-to-air missile sites and ballistic missile launchers

### Future Opportunities

Opportunities for applying PISCES in a training or demonstration exercise with other organizations are being pursued. For example, during Kernel Blitz the simulated entities injected by Battle Force Tactical Training (BFTT) were received and viewed in the WAL. This information was subsequently passed over the APL LAN and displayed on a JMCIS terminal in CCSL. A future task might establish a virtual shooter to refine strike coordination/launch coordination concepts in a BFTT training evolution. Still another application of PISCES might involve the demonstration of Tomahawk cruise missile employment in a simulated Joint exercise environment involving the coordinated use of several precision strike weapons.

## REFERENCES

[1] *JAST Plan Envisions ASTOVL Prototype*, Aviation Week and Space Technology, February 28, 1994

[2] LoPresto, Mark, et al, *Operator Support Concepts for Tomahawk Strike Management*, APL Technical Digest, Volume 16, Number 2, April-June 1995

[3] DiNova, Kay, Ron DeFranco, Peter Storch, *The Virtual Interactive Target in DIS*, 12th DIS Workshop, IST-CF-95-01.1, March 1995