PSI Hierarchy Of Models

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OVERVIEW OF THE HIERARCHY

PSI's modeling and simulation environment provides for the development of a hierarchy of independent models. The underlying architecture requires that models follow the physical boundaries of environments, platforms and equipment as illustrated in Figure 1. To understand this approach, consider that a simulation of military operations must represent the environment in which entities operate. An example is the Western Pacific area with its islands and mainlands in a large ocean environment. Based upon experience with such large areas, visualization is best accomplished with a global model, where one can zoom in from outer-space, looking at radio connectivity of far out geo-stationary satellites, and then zoom into an area showing streets around an inlet containing ships moving in a harbor, for examples see [1]. This is the 3D Globe interface that PSI has developed for its simulations over the past five years.

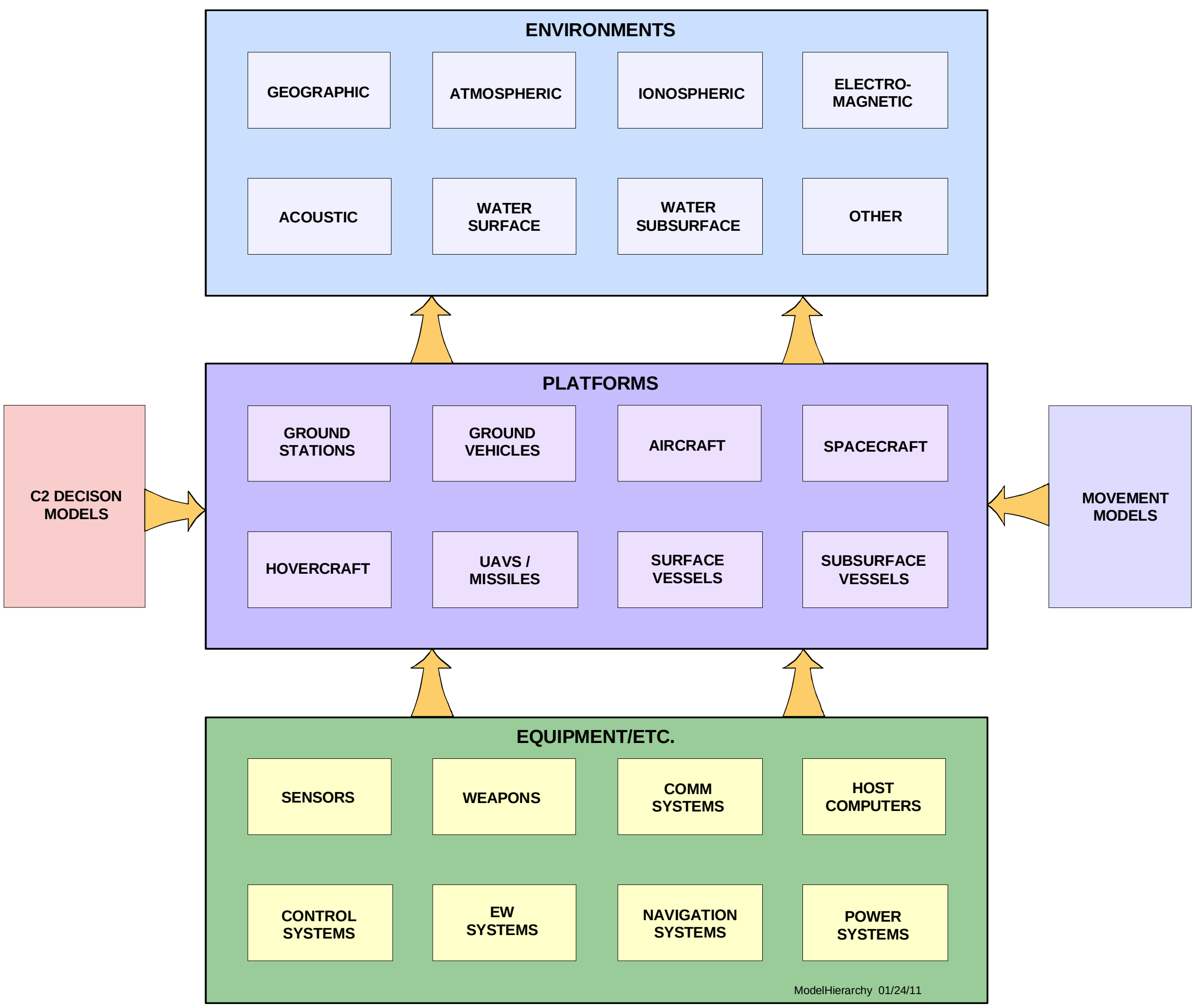

Figure 1. An illustration of PSI's Hierarchy of models.

ENVIRONMENT MODELS

The globe may contain various overlays to visually represent complex geographic environments, such as land-water boundaries, political boundaries, terrain, foliage, road networks, etc. Simulations use the WGS-84 spheroid representation of the earth, providing for resolution of object positions in (LAT, LON, ALT) or earth (X, Y, Z) coordinates from different databases down to 1.1 cm. (only certain engineering databases come close to this degree of accuracy). This includes special translation of terrain elevation data into a 3D representation.

Environment databases are used to affect platform or equipment models, e.g., supporting radio or visible spectrum propagation models from HF to Optical bands. To perform accurate propagation path loss predictions affected by terrain, one uses the DTED level commensurate with the required level of accuracy. If the models and databases are not carefully designed, prediction of large numbers of propagation paths for moving platforms becomes a major factor in simulation speed. Since 1982, PSI has worked to ensure that its propagation models are extremely fast while maintaining maximum accuracy, leading to (RELX, RELY, RELZ) space.

Models include HF, VHF, UHF, through optical, using Time-Of-Day, Sun spots, ionospheric layers, Line-Of-Sight (LOS), refraction, single and double knife edge diffraction, and scattering due to terrain, foliage, buildings, etc. as they apply to the different frequency bands.

PLATFORM MODELS

Platforms operate on the ground, in water, in the air and in space, typically interacting with each other through their environments. A platform may be a large ground complex, a fast moving aircraft, a ship, a very small moving ground vehicle, or a person, etc. As an example, aircraft platforms may be identified with tail numbers and types (e.g., F15-E). All platforms may contain C2 decision models that take in messages or events from other models, and based upon their current state produce messages or events for other models. Moving platforms contain movement models. For example, satellite platforms follow specific orbits as prescribed by design and supported by measured data, see examples in [2]. Aircraft platforms follow specified flight paths, but can change flight paths based upon decisions made by C2 models. Platforms are modeled using 6 degrees of freedom so that signal reception, affected by directional antenna patterns and polarization, also depends upon platform orientation. Radios or sensors residing on one platform may interact with other platforms through various types of emissions into their environments.

EQUIPMENT MODELS

Various types of equipment models may be incorporated into a platform. Some of these are provided below for examples. There are many more than those listed below. Equipment may be placed upon platforms interactively, including equipment type and model number to check for compatibility.

Host Computers

Host computers send and receive messages to and from one or more communication systems. Hosts may generate multiple messages based upon incoming messages, thus forming message strings. Hosts may generate events that are sent to a C2 system based upon messages received. Hosts may also generate messages based upon events received from a C2 system. When messages are sent and received they are time-stamped and recorded for both immediate and subsequent analysis. This provides for measures of latency so that one can determine if response time and throughput requirements have been met. It allows the modeling of delays within a communication system to be modeled directly, protocol layer by protocol layer, along physical lines.

Communication Systems

Many communication systems are used to support C2ISR requirements. Connectivity, capacity, and latency are the primary communication effects of interest. Connectivity can be measured in different ways, but typically it is measured on a link basis in terms of probability of communications (PCOM). PCOM measures the probability that a destination can receive the desired information within a given time increment. Capacity is a measure of the quantity of information that can be transferred over a link. There are many ways to specify capacity. For Point-To-Point communications, the capacity for each link may be specified. For shared media the capacity is usually a local density measure for all links. Since time critical information quickly loses its value, network delay for getting information between various locations may adversely affect mission effectiveness and may render distant systems useless.

Sensors

Various types of sensors may be modeled. Sensors supporting Signals Intelligence (SIGINT), Imagery Intelligence (IMINT), and Measurement And Signatures Intelligence (MASINT) collection require different characteristics to represent their capabilities. The difference in requirements for supporting different sensor types warrants separate models for each. The focus on sensors will depend upon the scenarios selected. The attributes used to characterize sensors can expand or change as additional resolution is added. The characterization and resolution are also influenced by measures of merit required by the analyses. For example, when targets are detected, one may want to generate an event or message that causes a follow on action. These messages and events may be recorded for immediate output or for future reference, such as when tracing causes of failure. As specific sensors are identified, additional characteristics may be required to more accurately represent a sensor.

Red Emitters

Red emitters are required to provide opportunities for detection. Red emitters need not be modeled in the same detail as blue communication systems to provide for detection. However, event threads and message strings may be defined to provide realism concerning the order and timing of transmissions. The criticality of the messages may then be established based on their mission role. This provides greater accuracy of traffic representation than simply generating random messages at the transmitter, since traffic is typically highly correlated with event threads. An example is timing of sensor data fusion at higher levels involving the determination of threat entity relationships and their intent.

Radars

Radars provide the ability to detect and track platforms. Types include pulse, continuous wave, and pulse Doppler radars. Each requires slightly different characteristics, e.g., continuous wave radars make use of two antennas. Vulnerability of platforms to radars is a function of their cross section. Radar Cross Sections (RCS) may produce radically different results for incident angles that are only a few degrees off. An RCS may be implemented similar to an antenna pattern but a single value representing the worst case RCS value may be used in many cases.

Jammers

Different jamming techniques are used to efficiently radiate RF energy to drive down the Signal-to-Noise-Ratio (SNR) at targeted RF receivers, lowering the probability of detection and reception of desired signals. These techniques may deny communications as well as sensor detections and processing of RF signals. Jammer models include broadband, sweep, and pulse jammers.

Weapon Systems

Weapon systems may be modeled at various resolutions. One is typically focused on representing the impact of the weapon system on various platforms based on the platform type, flight path, and flight time within the weapon's range. Characteristic sets of parameters for each weapon type can used to specify their capabilities. This allows one or two basic models to support the representation of multiple weapon types. Weapons typically ride on a platform that may contain sensors, C2 and communication systems, and may be limited by fuel and PNT receptions. Weapon platforms may be launched from moving host platforms.

When modeling a weapon system, e.g., a red IADS, one may model the system sensors, the C2 centers, and the weapon launchers as well as the weapons. The sensors, launchers, and weapons may contain their own C2 models. The weapons ride on platforms with movement models and may be limited by fuel. They may have their own sensors, POS-NAV, and communication systems commensurate with their level of sophistication.

C2 DECISION MODELS

C2 Systems make decisions based upon information at the time. These are modeled as decision and state tables that may change based upon events. When a given event occurs, elements in the tables may change depending upon the state of the current table. New events may be generated based upon incoming events and the current state. These models are incorporated into platforms, with each platform storing its own decision and state tables. Events may be sent to Host computers that generate messages into a communication system. One or more messages may correspond to a specific event.

MOVEMENT MODELS

Platform movement may be predetermined, e.g., a specified movement path, or may change based upon inputs to the movement model. Thus platform movements may be nonstationary. By nonstationary movement we imply that the platform path is unpredictable, i.e., movement may depend upon events. Examples include fast moving aircraft or missiles that make turns based upon messages or events that occur along the flight path. Movement models may interact with some of the equipment models listed below through a platform's C2 model.

TAXONOMY OF MODELS

PSI has completed over one hundred projects for its clients worldwide. Most of these projects have been aimed at the design and evaluation of complex systems, principally for the military, leading to a huge library of models. The following charts contain a taxonomy of models that PSI has developed over the years. Included are models currently in development to support additional projects. These tables are not meant to be exhaustive, but to provide a classification of models in the library.

ENVIRONMENT MODELS			
	WIRELESS LINKS		
		RF PROPAGATION	
			HF
			VHF
			UHF
		OPTICAL LOS	
	WIRED LINKS		
		CABLE	
		FIBER	
	GEOGRAPHIC		
		TERRAIN	
		FOLIAGE	
		ROADS	
		BODIES OF WATER	
		TOWNS	
	ATMOSPHERIC		
		WEATHER	
			TEMPURATURE
			PRESSURE
			RAIN/SNOW/HAIL
			FOG
			WIND
		SMOKE	
		PARTICULATES	

PLATFORM MODELS		
	GROUND	
		FIXED
		MOVING
	AIR & SPACE	
		SATELLITE
		FIXED WING
		MISSILE
		ROTARY WING
	NAVAL	
		SURFACE

EQUIPMENT MODELS			
	COMMUNICATION EQUIPMENT		
		TRAFFIC GENERATORS	
			VOICE
			DATA
		SWITCHES	
			CIRCUIT
			PACKET
			ATM
		ROUTERS	
		HUBS	
		LANS	
		RADIOS	
		ANTENNAS	
		JAMMERS	
	COMPUTER EQUIPMENT		
		TERMINALS	
		WORKSTATIONS	
		SERVERS	
		MASS STORAGE	
	SENSORS		
		ACCOUSTIC	
		RADAR	
		OPTICAL	
	WEAPONS		
		SMART BOMBS	
		SMART MISSILES	

C2 DECISION MODELS	
	LEADERS
	UNITS
	COMPUTER DECISION PROCESSES

MOVEMENT MODELS	
	(X, Y, Z) SPACE
	(LAT, LON, ALTITUDE) SPACE
	(REL X, REL Y, REL Z) SPACE

REFERENCES

[1] Placement of Sensing and Communications Platforms for Enhanced C4ISR Operations, Final Report, SPAWAR, San Diego, Contract #: N00039-08-C-0037, Dec 09.

[2] A Day Without Space (DWOS) - Initial Analysis, Final Report, Global Cyberspace Information Center, Langley AFB, Contract #: FA8750-07-D-0027, Apr 10.