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"THE PATRIOT PAC-3 MISSILE PROGRAM - AN AFFORDABLE INTEGRATION APPROACH"

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Abstract

The affordable PAC-3 system upgrade approach is based on innovative, joint consolidation and integration of existing industry and government assets. Through the integrated use of a network of geographically dispersed simulation, hardware-in-the-loop, and test facilities, the PAC-3 missile design and performance is being analyzed and verified prior to first missile flight. This process begins with the thorough and rigorous testing of missile components. It then continues with the use of integrated simulations which is a key activity to verify and predict PATRIOT system performance with PAC-3 upgrades. The process is culminated with system level and flight testing conducted at White Sands Missile Range, New Mexico.

During the Gulf War, the PATRIOT air defense system made its now-famous battlefield debut against Tactical Ballistic Missiles (TBMs). Through a succession of improvements and modifications to refocus its mission on missile defense, PATRIOT helped defend coalition forces and Israeli territory from Iraqi Scud missile attacks. Despite this success, we realized that we needed to improve lethality (ability to destroy hard TBM warheads), radar detection range, defended area (footprint) and automatic recording of battle data. Improvements to the Engagement Control Station (ECS), radar, missile and launcher were planned to counter the TBM threat. Not only would a new state-of-the-art Hit-to-Kill (HTK) technology advanced missile need to be developed, but it needed to be quickly and affordably integrated into the existing PATRIOT system. To minimize cost, the current government and industry team missile integration test assets had to be maximized. Key performance drivers include: sufficient radar detection range to allow time to establish and filter a track of the threat TBM, and rapidly calculate fire solution and launch with sufficient time of flight to kill the target missile above the keepout region; alignment of the missile's and radar's reference frames to guide the missile to an error basket (in endgame, sufficient detection range is required to provide time to establish an accurate track and for track filters to converge and to determine a intercept trajectory for the PAC-3 missile to fly into the threat TBM); determination of the target's profile is required to steer the PAC-3 missile to impact with the most vulnerable part of the threat missile's warhead.

The PAC-3 missile evolved from the highly successful FLAGE missile technology program which in May 1987 intercepted and destroyed a LANCE missile through body-to-body contact. This program was re-designated the Extended Range Interceptor (ERINT) program and entered an advanced demonstration program in 1987. This phase of the program culminated in 1994 with three successful intercepts and the ERINT missile was chosen as the PATRIOT PAC-3 missile. The Defense Acquisition Board (DAB) approved entry into Engineering Manufacturing Development (EMD) in May 1994 (Figure 1).

The PATRIOT PAC-3 system will be organized like the current PATRIOT system and will exhibit a balance of system component requirements to achieve stressing Hit-to-Kill capability. The current system is normally organized into a Battalion structure with up to six Firing Batteries per Battalion. PATRIOT Battalions can be further included in Air Defense Brigades. Each Firing Battery consists of a Phased Array Radar Set (RS), an Engagement Control Station (ECS), and Launcher Station (LS). The primary element of the Firing Battery (Fire Unit) is the ECS, which interfaces with the RS and the LS. The number of LSs per Firing Battery is normally eight with four "certified round" missiles in each canister and four canisters per launcher. When the PAC-3 system is

fielded, a typical firing unit will have four PAC-3 launchers with eight PAC-3

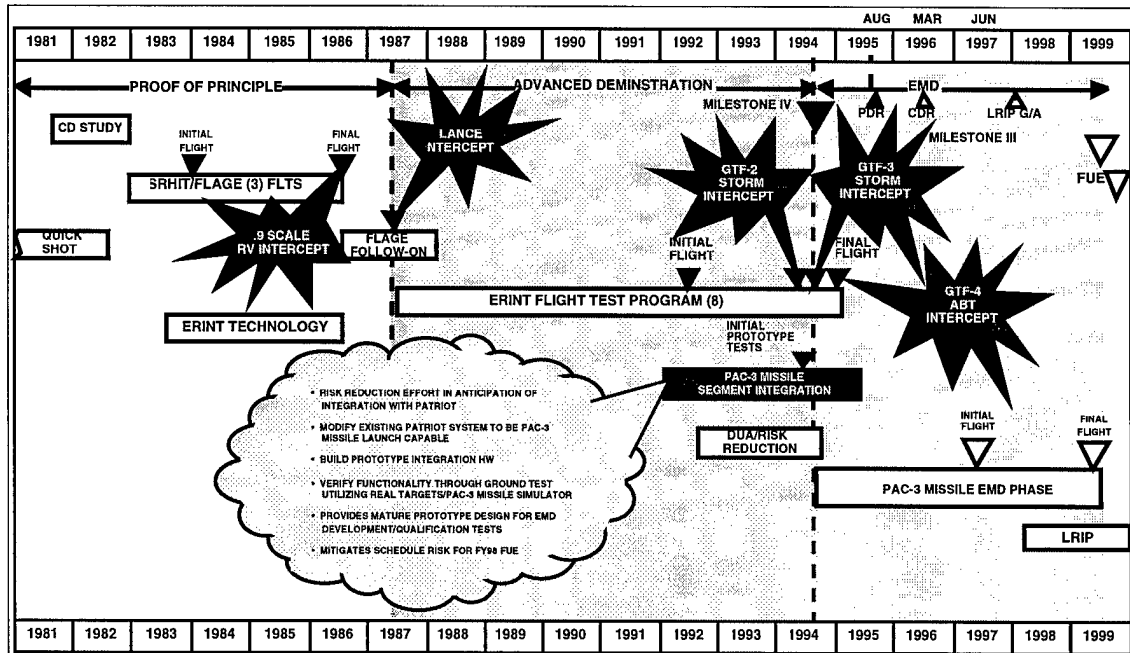ring Lethality Enhancer (LE) is deployed near intercept to further increase single-

Figure 1. PAC-3 Program History

missiles and four PAC-2 launchers with four PAC-2 missiles. The multi-function Phased Array Radar serves as the eyes of the Firing Battery. It detects and identifies aerial targets. Within the PATRIOT Battalion, the Information Coordination Central (ICC) and Firing Batteries are netted together. The ICC, the nerve center of the Battalion, performs the tactical command and coordination functions. It can control fires of up to six firing batteries and interfaces with higher echelons. The Communications Relay Group (CRG) provides a radio relay communication facility for the PATRIOT Battalion.

The PAC-3 missile is a high velocity, Hit-to-Kill, surface-to-air missile capable of intercepting and destroying tactical missile and air breathing threats set forth in the PAC-3 Operational Requirements Document. The PAC-3 missile provides the range, accuracy, and lethality necessary to effectively defend against tactical missiles with nuclear, conventional high explosive, biological, and chemical warheads. Although interceptor to target body contact generates a high destructive energy level against theater ballistic missiles, a two

shot probability of kill against air breathing threats. The PAC-3 missile uses a solid propellant rocket motor, aerodynamic vane controls, Attitude Control Motors (ACM), and inertial guidance to navigate to an intercept point specified by its ground based Fire Solution Computer (FSC) prior to launch. Inertial alignment and target trajectory data can be updated by the ground radar, if required, during missile flyout by means of a Radio Frequency Data Link (RFDL) on board the missile. Shortly before arrival at the intercept point, the missile's on-board Ka-band radar homing seeker acquires the target, the missile's rate of spin is increased, and terminal homing guidance is accomplished to eliminate miss distance. The control necessary for HTK is provided by the agile, lightweight, missile airframe, fast response aerodynamic vanes and ACMs which effectively control the missile's rotational inertia. The ACMs are small, short duration (impulse) solid propellant thrusters located in the missile's forebody forward of the missile center of gravity.

The PAC-3 missile ground equipment includes the Fire Solution Computer (FSC), the Enhanced Launcher

Electronics System (ELES) and the canister. The Fire Solution Computer's purpose is to compute the target track file and issue fire instructions to the PAC-3 missile. The FSC consists of three high speed processor cards and one executive processor card. There are three open slots in the Optical Disk Peripheral Control Unit (ODPCU) back plane to provide space for future growth. The circuit cards and wiring harness are mounted in the ODPCU. The FSC interfaces with the Enhanced Weapons Control Computer (EWCC) and all FSC functions are transparent to the ECS operator. The launching station upgrade to the PAC-3 requires replacing the existing Launcher Electronics Module (LEM) and Launcher Missile Round (LMRD) with an Enhanced Launcher Electronics System (ELES) and a Launching Station Diagnostics Unit (LSDU) / Junction Box (JB). These two units provide the following

moisture controlled shipping container for the missiles and is stackable (Figure 2).

The PAC-3 missile evolved from the initial ERINT design to the current Critical Design Review (CDR) design (Figure 3). Improvements were derived from analysis of the demonstration validation flight tests and risk resolution analysis. Major design changes included change of the radome material from quartz duroid to ceramic or composite; upgrade of the seeker with addition of a 5th CPU, improved gimbal, and 20% reduction of parts; redesigned master frequency generator, and elimination of potentiometers; addition of Ada software to the guidance processing unit; addition of an RFDL; change from tungsten to steel fragments in the lethality enhancer; improvements to the solid rocket motor tactical safe arm fuze, ignition safety device and external insulation; and
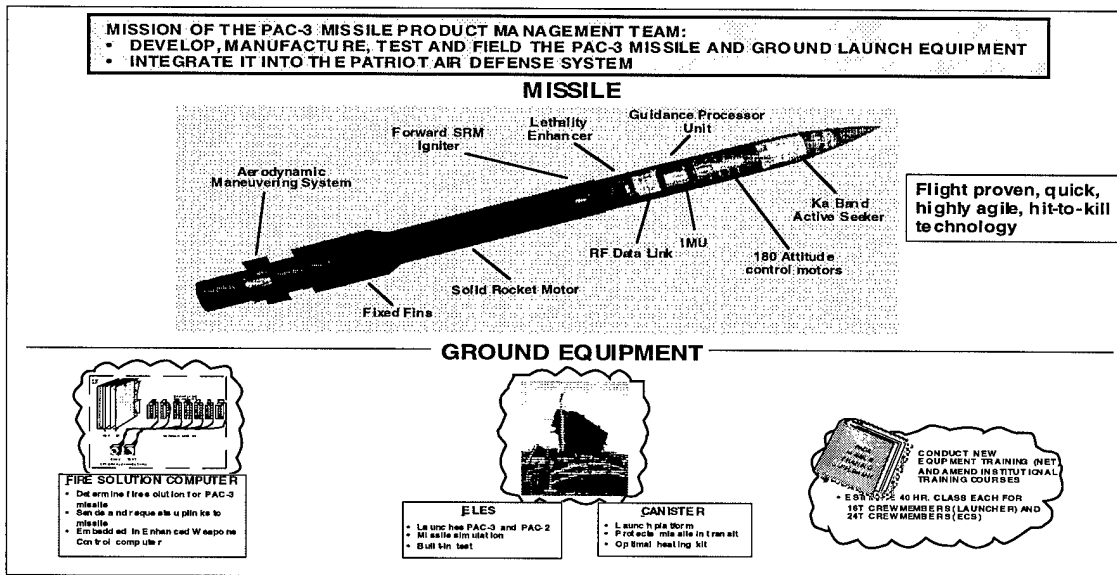

Figure 2. PAC-3 Missile Products

capabilities; (1) the ability to launch all PATRIOT missile types; (2) enhanced reliability/availability/maintainability with a single control panel; (3) easy configuration; (4) integrated launch simulation functions; (5) modular design; and (6) elimination of obsolete components. The four-pack canister consists of four graphite epoxy composite tubes each with a blow off front cover. It provides a

improvement of fins from stainless steel to acoustic titanium. The technical baseline of the PAC-3 missile design began in 1994. The PAC-3 missile System Requirements Review (SRR) which established the missile system performance requirements was conducted in April 1994. The prime item development specification was approved at the Preliminary Design Review in August 1995. A successful CDR was completed in March 1996. Ground

testing is underway and will lead to the first flight test scheduled for early 1997. A major milestone decision is scheduled for September 1997 for approval to enter low rate initial production. The first unit will be equipped with the PAC-3 missile in July 1999.

The affordable PAC-3 system upgrade approach is based on innovative, joint consolidation and integration of existing industry and government assets. Through the integrated use of a network of geographically dispersed simulation, hardware-in-the-loop, and test facilities, the PAC-3 system design and performance is being analyzed and verified prior to first missile flight. This process begins with the thorough and rigorous testing of missile components at facilities such as Rockwell International's Anechoic Chamber, the Vought System's wind tunnel facility, and the MICOM and Vought Systems hardware-in-the-loop. Missile components being tested include: The PAC-3 seeker, an active Ka-Band, coherent, range-gated

data required to guide the missile with sufficient accuracy to provide body-to-body contact. The seeker uses state-of-the-art technology. It consists of the radome housing and the seeker electronics. The seeker electronics consists of several subsystems including a Master Frequency Generator (MFG), Transmitter, Antenna, Gimbal and associated electronics, Microwave Receiver Unit (MRU), Intermediate Frequency Processor (IFP), Digital Processor (DP), Low Voltage Power Supply (LVPS) and Seeker Structure. The weight of the seeker section is 28.68 kg and the length is 1057.1mm. The seeker has been fabricated at the Rockwell Tactical Systems Division in Anaheim, CA and is currently being tested in the Duluth, GA production plant.

The Attitude Control Section provides the supporting structure for the thermal (Pyro) battery and 180 radially installed Attitude Control Motors (ACMs). The ACS is 355.67 mm in length and its shell structure material is 7050 aluminum
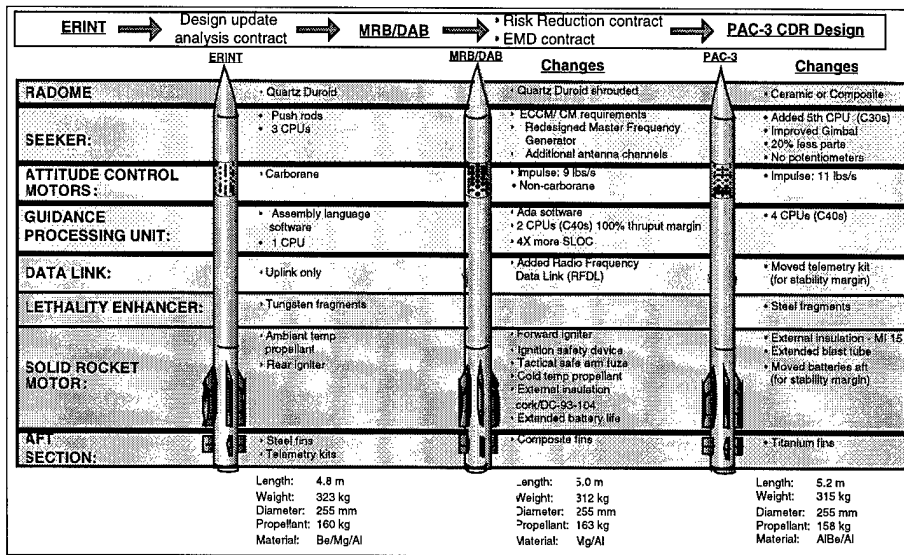

Figure 3. Evolution of PAC-3 Missile Design

pulse Doppler radar capable of operation in high acceleration environments. The PAC-3 seeker includes a monopulse antenna mounted on a two-axis gimbal platform. The seeker's high power transmitter assembly utilizes a Traveling Wave Tube (TWT) power amplifier. The seeker provides the capability for the missile to lock-on to a target and then provide the

alloy. Bulkheads at each end of the section support the two shells in a concentric position, and the ACMs are mounted in 10 rings of 18 ACMs per ring. Each ACM is spaced 20 degrees apart with the rings clocked 10 degrees apart. A rubber shock mount supports the inboard end of the ACM against the inner housing, and a spring washer supports the outboard end of the

ACM against the outer housing. The Motor Firing Circuit (MFC)/Flexspring Assembly and thermal battery are supported between phenolic retainer plates in the core of the ACS inner housing. The MFC Electronics Assembly is mounted to the end of the ACS aft bulkhead, and converts logic-level commands from the Guidance Processor Unit (GPU) to current pulses required to initiate the ACMs. The MFC receives 10 Rank and 18 File optically-coupled drive command signals from the GPU, and generates 8-ampere nominal current into one of the 180 selected ACMs. The MFC receives motor firing commands from the GPU, processes the command, and then fires a specified ACM at a time computed by the GPU. The major MFC subassemblies include the circuit card and flexprint. The circuit card contains five hybrid firing circuits and four connectors. The inner core provides support for the wrap-around flexsprings which have 180 coaxial pin sockets for the ACMs.

The ACM consists of a graphite / epoxy case overwrapped on a stainless steel cone, aft pole piece assembly, pryotechnic initiator, and solid propellant grain. The metallic cone functions both as the forward pole piece and as an inner liner. The propellant is class 1.3 Hydroxyl-Terminated Polybutadience (HTPB) formulation. The steelraft pole piece functions both as an inner liner and support structure for the motor nozzle.

The Mid-Section consists of a structure (graphite-epoxy outer skin with aluminum forward bulkhead and guidance equipment support shelf with exterior ablative coating) that houses the Inertial Measurement Unit (IMU), the Guidance Processor Unit (GPU), the Radio Frequency Data Link (RFDL), and the Telemetry / Flight Termination System (TM/FTS). The IMU measures vehicle angular rate and linear acceleration in a body-mounted strapdown mode, by providing three axis angular rate, compensated angle increment, three axis acceleration, and compensated linear velocity increment data in a digital format. The GPU is the central data processor of the PAC-3 missile and is responsible for navigation, based on data received from the IMU and Seeker, generation of guidance commands to the

ACMs and Aerodynamic Maneuvering System (AMS), autopilot, generation of arm and fire commands to the SAF, execution of Built-in-Test (BIT), accumulation of GPU and missile status, and target data processing from the RFDL uplink. The C-Band RFDL on the PAC-3 missile consists of transmit / receive electronics, processing / interface electronics, and four antenna arrays which cover the circumference of the missile. The missile receives, via the RFDL, alignment information, target data updates, aimpoint refinement updates, and command destruct messages from the ground-based PATRIOT radar. The RFDL responds to valid uplink messages with one of three downlink message formats (standard length, extended length, and Super Barker). The Telemetry / Flight Termination System (TM/FTS) is inserted as required to gather selected missile performance data or transmission to a ground receiver and provides the capability to receive a ground command to destroy the missile when fired in a test range environment.

To further increase the kill probability against air breathing threats (not used against TBM engagement), a low fragment expansion velocity Lethality Enhancer (LE) is included in the PAC-3 missile configuration. The LE design integrates the function of the Safe Arm Fuze (SAF) so that it provides redundant simultaneous signals for LE activation and flight termination activation. The LE is made up of structure, explosive, steel fragments, detonator/key-locks, transfer leads, booster ring, SAF and Flight Safety Switches (FSS) and will be installed within the Mid-Section assembly. It is an explosive assembly designed to increase the probability of target kill by increasing the lethality of Hit-to-Kill and the probability of hitting the aim point. Detonation of the main explosive charge, LE-1, generates a radial pattern of 24 cycloids (fragments) with a low expansion velocity, effectively increasing the diameter of the Hit-to-Kill missile. The 95-gram cycloids are arranged in two concentric rings around the circumference of the midsection of the missile. The small quantity of LE-1 is designed such that the

two rings of cycloids are given different radial velocities. The main charge consists of approximately 330 grams of LE-1 and is detonated by a Booster Ring through four explosive ports in the core assembly located around the inside diameter of the main charge. The Booster Ring is detonated by either of two output ports from the SAF, one per channel. The SAF also detonates the Command Destruct (CD) ordnance by two explosive output ports, one per channel.

The Solid Rocket Motor (SRM) includes the insulated case, the aluminized HTPB propellant, the nozzle/blast tube assembly, and the forward end mounted igniter. Its case is constructed with a high strength graphite/epoxy composite that includes integral wound titanium fin lugs, and the forward and aft skirts, and must provide adequate structural stiffness to satisfy both autopilot and bending load requirements during flight. Internal insulation provides thermal protection to the case during motor burning. Titanium fin lugs are used to attach the four fixed fins. The forward skirts provide the structural interface to the Mid Section Assembly and the aft skirts to the same for the AMS. Two aluminized HTPB propellants have been selected as the baseline which is bonded to the insulated case as the propellant cures after casting. These propellants have been qualified on other programs and have a hazard classification of 1.3. The baseline design is a dual grain configuration that includes longitudinal slots. These slots, along with the propellant burning rate, control the thrust profile. The longitudinal slots also provide stress relief of the propellant gain to meet low temperature storage and operating requirements. The nozzle assembly consists of the aft closure, blast tube, and exit cone. A titanium structural shell is used on the aft closure, blast tube, and exit cone to minimize weight. A four-dimensional carbon/carbon composite is used as the throat insert which also requires a carbon phenolic backup insulation to protect the titanium shell and control the temperature in the AMS. A removable threaded exit cone is required to permit installation of the missile components around the blast tube. The rocket motor is ignited through the use

of a forward mounted $BKNO_3$ igniter. An Ignition Safety Device (ISD) and initiator assembly will be mounted on the forward end of the SRM and will allow for rocket motor initiation following a signal from the ELES. The ISD has independent circuits (enable, arm, and fire) and provides electrical power to the initiator which fires the SRM igniter. The four fixed fins provide aerodynamic lift and stability to the missile. The fins are attached to the SRM case fin lugs. The fins are fabricated from a titanium material overcoated with Acusil for thermal protection. The mounting holes are machined after curing. The exterior of the motor case is protected from aerodynamic heating by the heat shield which is Acusil II exterior insulation.

The aft section receives digital fin commands from the GPU and processes the commands to position the four control surfaces providing aerodynamic control of the missile. Feedback is provided to the GPU indicating aft section status. The aft section also houses the batteries which provide power for missile electronics, control surface actuators and the seeker.

The design analysis and verification process continues with the use of integrated simulations which is a key activity to verify and predict PATRIOT system performance with PAC-3 upgrades. The PAC-3 program has been selected as a lead program for streamlining acquisition by the Department of the Army. One key element of the acquisition streamlining is the use of simulation to augment expensive flight testing. The PATRIOT Project Office will make heavy use of simulation tools, both digital and hardware-in-the-loop (HWIL), to evaluate the PAC-3 system performance. Figure 4 depicts the general methodology that will be used to demonstrate compliance with all system performance related requirements. As shown, the digital simulations will be used to demonstrate compliance over the entire engagement zone and under all specified environments. The HWIL simulations will be used in a complementary manner to verify performance and explore the "edge of the envelope" over selected regions of

the engagement zone and the corresponding environments. The HWIL simulations will provide data that will be used to validate the digital simulations. The flight tests will provide data for the validation of the digital and HWIL simulations, as well as, demonstrate system performance at selected locations throughout the engagement envelope under specific engagement conditions. Additionally, data collected from a number of ground tests will be used to validate portions of the digital and HWIL simulations. These tests include component tests as described above, environmental tests, captive carry tests, and sled and gun lethality tests.

The PAC-3 simulations used to demonstrate compliance with the system performance related requirements are shown in Figure 5. The upper portion and the bar across the middle of the figure show the functions that the PATRIOT system performs during an engagement. The lower portion of the figure shows a bar for each simulation used in demonstrating performance related requirements. The bar for each simulation spans the functions that it simulates. In the case of the HWIL

and the Multi-Function Simulation (MFSIM). The HWIL simulations are the Flight Mission Simulator (FMS), the Guidance Test and Simulation Facility (GTSF), and the MICOM Millimeterwave Simulator System-2 (MSS-2). Additionally, an interface is being developed to connect the FMS and MSS-2 facilities, in non-realtime, to provide an end-to-end HWIL capability.

Figure 6 shows the PAC-3 missile integration test assets available to Vought Systems, Raytheon and the Government. Significant overlap exists between the HWIL simulations. While it is desirable to develop one facility that addresses each portion of the problem in high fidelity, the reality is that such a facility is impractical for this program, hence each of the HWIL simulations focuses on the evaluation of a different aspect of the engagement process. The FMS focus is on tracking and processing multiple targets and missiles, the GTSF is on integration of the PAC-3 computers and software into the PATRIOT System, and the MICOM MSS-2 is on high fidelity miss distance measurement and realistic RF scene
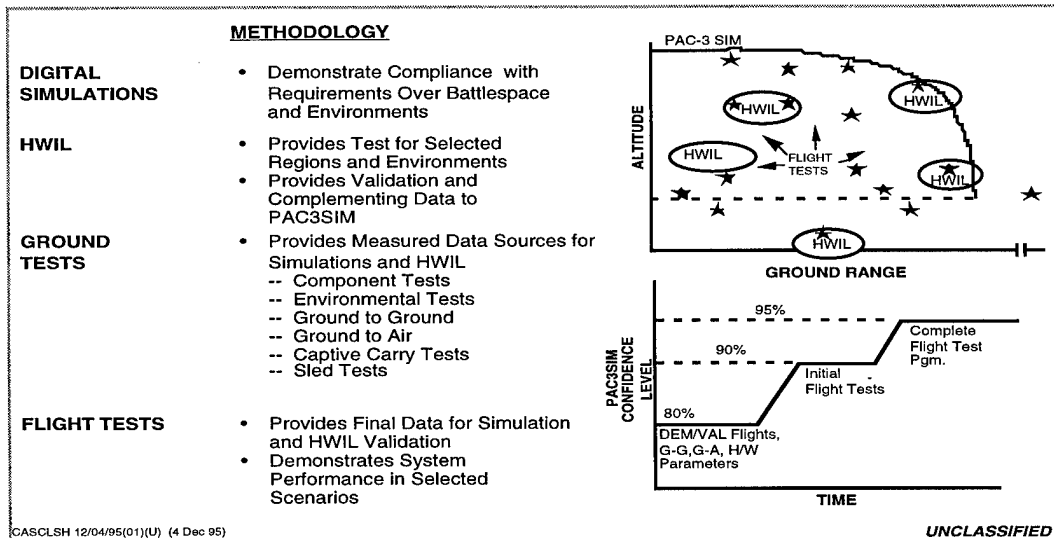

Figure 4. PAC-3 Performance Evaluation Methodology

simulations, the functions that are not simulated, but contain the system hardware, are indicated by the dark gray shading. The simulation suite consists of two solely digital and three HWIL simulations. The digital simulations include the PAC-3 Simulation (PAC3SIM)

presentation. The resulting overlap of data from the HWIL simulations and digital simulations allows for extensive consistency checking to be done to minimize the risk of errors creeping into the system undetected. The sharing of data and common software

among the digital and HWIL simulations is shown in Figure 7.

An executive summary of each of the simulations shown in Figure 7 follows. A top level discussion of the components that comprise the simulation, and how the PPO will use it in the PAC-3 upgrade program is presented.

The PAC3SIM digital simulation developed and used at the US Army Missile Command, is the tool used to demonstrate compliance with the majority of the system performance related requirements. The PAC3SIM is an end-to-end simulation which simulates all aspects of a PAC-3 engagement with the PAC-3 missile from emplacement through lethality assessment. The PAC3SIM simulates one-on-one engagements at a high level of fidelity (six-degree-of-freedom). The PAC3SIM includes high fidelity simulations of the PATRIOT Radar

that no reliability failures are encountered. The simulation is then run over the engagement zone to determine the area defended on the ground for the required Pk with intercepts above the keepout altitude.

The Multi-Function Simulation (MFSIM) also developed by the US Army Missile Command, will be the tool used to demonstrate compliance with traffic handling and multi-function requirements. The MFSIM simulates many targets on one fire unit, with potentially many missiles in flight. The MFSIM simulates, in great detail, the scheduling and utilization of the PATRIOT radar resources. The simulation models the target kinematics, missile flight, and target track errors at a fidelity that is sufficient to properly drive the scheduling and utilization of the radar resources. The MFSIM supports a number of activities, such as development of search patterns, evaluation of raid timing and
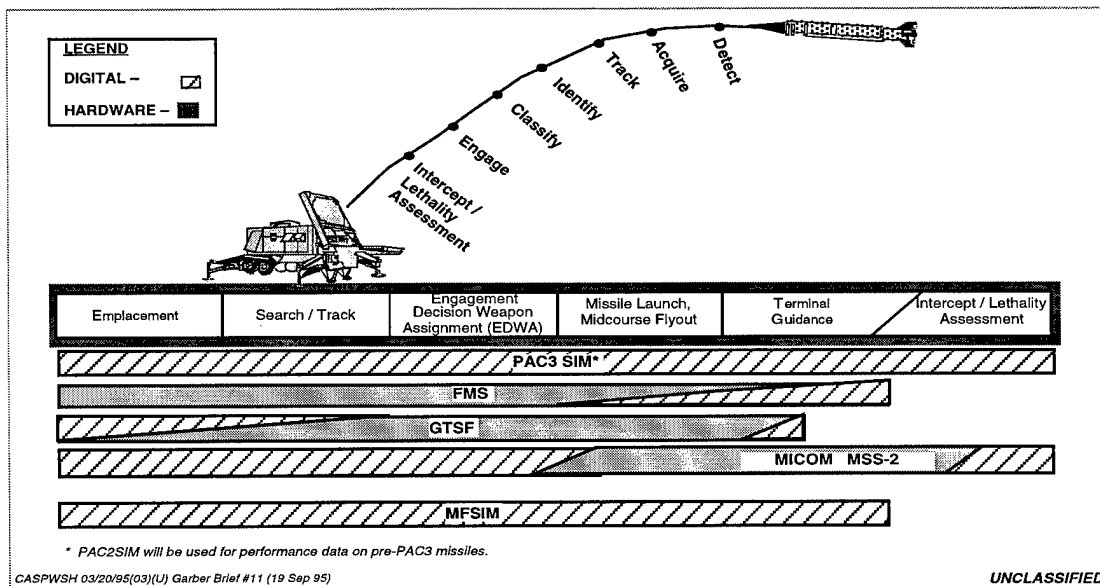

Figure 5. PAC-3 Models & Simulations

(PASS), the PAC-3 Missile (SSS), non-TBM threat lethality (ELEGS), and TBM lethality (PEELS). The PAC3SIM supports a variety of activities including development and evaluation, pre-flight predictions, and post-flight reconstruction. The major focus of PAC3SIM is the assessment of PAC-3 system performance when engaging a threat with the PAC-3 missile. The most meaningful output of the PAC3SIM is the probability of kill, given

defense deployment on radar loading, and establishment of time-power budgets. The focus of the MFSIM is to verify compliance with the requirements for numbers of targets in track, the search volume required to support the defended area, and engagement of targets.

The Flight Mission Simulator (FMS) located at Raytheon Corporation, Bedford, Massachusetts, is a many targets on one radar HWIL for the PATRIOT radar.

The FMS is a piece of equipment that is non-intrusively hooked up to a fully functioning radar and ECS. The FMS consists of a junction box that connects it to return that will occur. Radar timing, frequency, and trigger information are picked off to allow the return to be injected into the radar just behind the antenna at
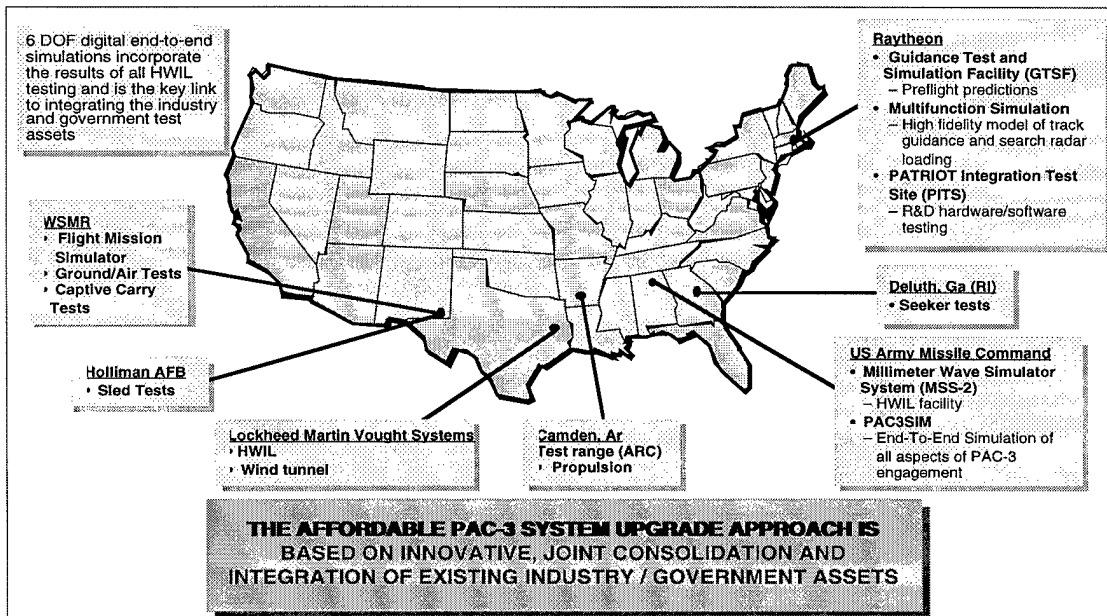

Figure 6. Missile Integration Assets

the ECS and radar, a control computer, a scenario and environment generator, a missile simulation computer, and RF waveform generation equipment. The FMS listens to the Radar Action Messages (RAM) being sent from the ECS to the radar, and combines that information with threat raid scenario to determine the radar

the correct time. The returns can include simulated skin tracks, ECM, digital downlink, and Track-Via-Missile (TVM) in the case of pre-PAC-3 (all basic, PAC-2, GEM, SOJC, etc.) missiles. The signals are injected into the main beam, sidelobe canceler, and TVM channels of the radar. The FMS is used to stress load the actual
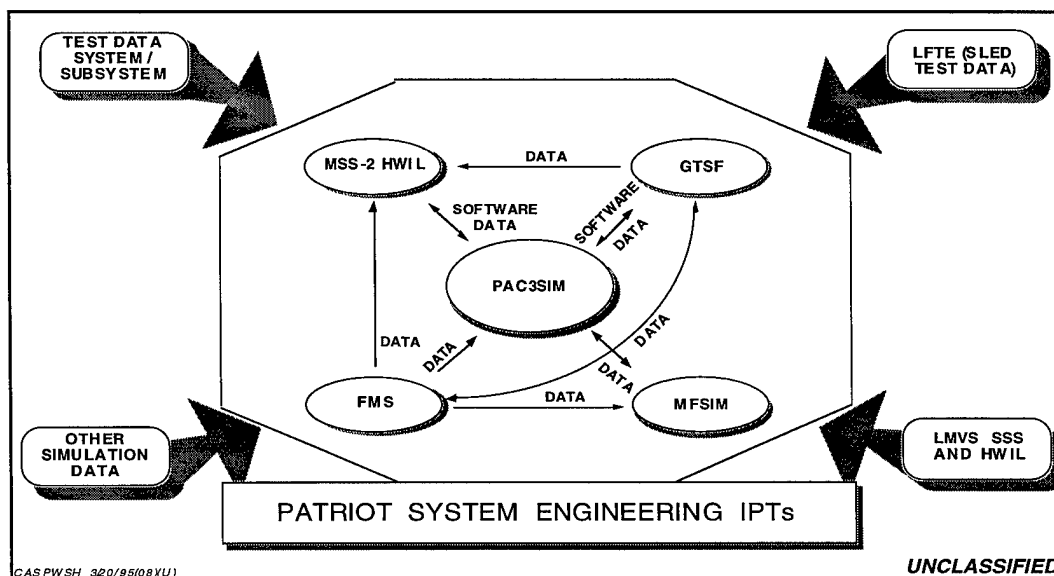

Figure 7. Simulation Interconnectivity

PATRIOT tactical ground system to verify proper operation, to provide data to support validation of the MFSIM and PASS component of PAC3SIM, to load the system during search track tests and serve as the front end of the end-to-end HWIL. The FMS allows the radar and ECS to function fully, so that FMS and real targets can be tracked at the same time (the PATRIOT system cannot distinguish the FMS targets from the real targets). A mobile version of the FMS is being developed which can be used in conjunction with operational tests. A capability to make the FMS DIS compatible is being studied.

The Guidance Test and Simulation Facility (GTSF) also located at Raytheon, has a dual role in the PAC-3 program. The GTSF HWIL facility will be used to verify the proper integration of the PAC-3 system computers and software. It will also maintain its original role of being a complete HWIL facility for the PAC-2 system with pre-PAC-3 missiles. In the role of the HWIL facility for the pre-PAC-3 missiles, the GTSF contains hardware elements of the PATRIOT system required to close the guidance loop. The missile forebody is mounted in a three axis motion table with the RF target source at the other end of the Anechoic Chamber. The portions of the radar system that are required to provide the digital uplink/downlink functions and process the TVM channels are present. The Expanded Weapons Control Computer (EWCC) is fully functioning and directs the simulated radar search, the Engagement Decision and Weapon Assignment (EDWA), and the missile guidance functions. Only the search and track actions of the radar are digitally simulated. In the role of verifying that the PAC-3 missile components and software are properly integrated into the PATRIOT system, the GTSF is the only facility that will have tactically configured computers and software in the system operating within a single HWIL facility. The ground system will be as described above with the Fire Solution Computer (FSC) installed in the EWCC. The missile will consist of all of the missile electronics with the exception of the RF portion of the seeker. The target scene will be digitally injected into the seeker, which provides significantly more flexibility than a point source at the end of the chamber. The uses of the GTSF, in this capacity, will be to verify proper system integration, to ensure that the integrated system performs properly in off-nominal conditions, to conduct pre-flight software verification and predictions, and post-flight reconstruction. It will also serve to aid verification of other HWIL/simulations.

The MICOM MSS-2 facility located at the Research Development and Engineering Center, US Army Missile Command, is a high fidelity HWIL facility to test the guidance capability of the PAC-3 missile. The facility is the HWIL miss distance measurement tool. The MSS-2 has the capability to model extremely complex RF scenes, including the range and angle extent of the target, clutter, ECM, multipath, and multiple targets. The PAC-3 seeker is mounted in a very agile three axis rotating motion table. The ground system will be simulated with digital models similar to PAC3SIM. The MSS-2 facility will be used for pre-flight predictions and post-flight reconstruction, ECCM and guidance algorithm development, development of data for PAC3SIM validation, and as the backend of the end-to-end HWIL required to meet program exit criteria. The focus of the MSS-2 facility will be exploration of the regions near the "edge of the envelope," and evaluating the missile response to the varying RF environments.

The design, analysis and verification process is culminated with system level and flight testing, conducted at White Sands Missile Range, New Mexico.

The PAC-3 missile product management focuses on planning and problem resolution through the Integrated Product Team (IPT) to minimize development time and maximize concurrent engineering and system engineering. Effective internal and external communications to other IPTs and cognizant Government agencies is key. Earned value is managed at the IPT level. Risk management is based on technical performance assessment and cost reduction.

The disciplined implementation of these principles is key to meeting the challenges of the PAC-3 missile program. Government expertise and support is implemented through the extensive participation of the PAC-3 Product Office and the six Vought Systems IPTs which run the PAC-3 industry program (Figure 8). Technical issues and decisions are coordinated through the System Integration Team. Managerial issues are resolved by the Program Management Team, of which the DCMC and the Product Manager are members. Earned Value Status, the monitoring of 27 Technical Performance Measurements, Critical Path Analysis, and surveillance activity are the primary ways in which the Program Management Team monitors IPT progress.

An indication of the success of the PAC-3 IPTs was the highly successful series of Critical Design Reviews (CDRs) that were conducted from December 1995 to March 1996. The Government evaluation team (Figure 9) included the PATRIOT Project Office, PATRIOT Seeker Advisory Group, PEO-Missile Defense, US Army Missile Command, Space and Strategic Defense Command, US Army Air Defense School, Training and Doctrine Command,

Systems Analysis Agency, Test and Evaluation Command, Ballistic Missile Defense Organization and Office of the Secretary of Defense. Detailed reviews of the following areas were conducted: system integration; command launch systems; seeker; missile; and missile segment. After 9,000 manhours of evaluating drawings, documentation and presentations, the CDR resulted in only 15 action items, all of which have been closed.

A remaining area of design activity is the guidance navigation control algorithm development. The PAC-3 missile team has utilized a design / simulation /refine /test /refine approach to control algorithm development effort. Careful modeling of integrated subsystems coupled with disciplined algorithm development, verified by windtunnel and ultimately flight testing, develop confidence for consistent, successful Hit-to-Kill intercepts.

The ultimate system integration test will be a combination of the Raytheon ground-to-pole test with the Vought Systems captive carry program. The Radar, ECS and launcher system are exercised to track and simulate an engagement with a "target" RV mounted on
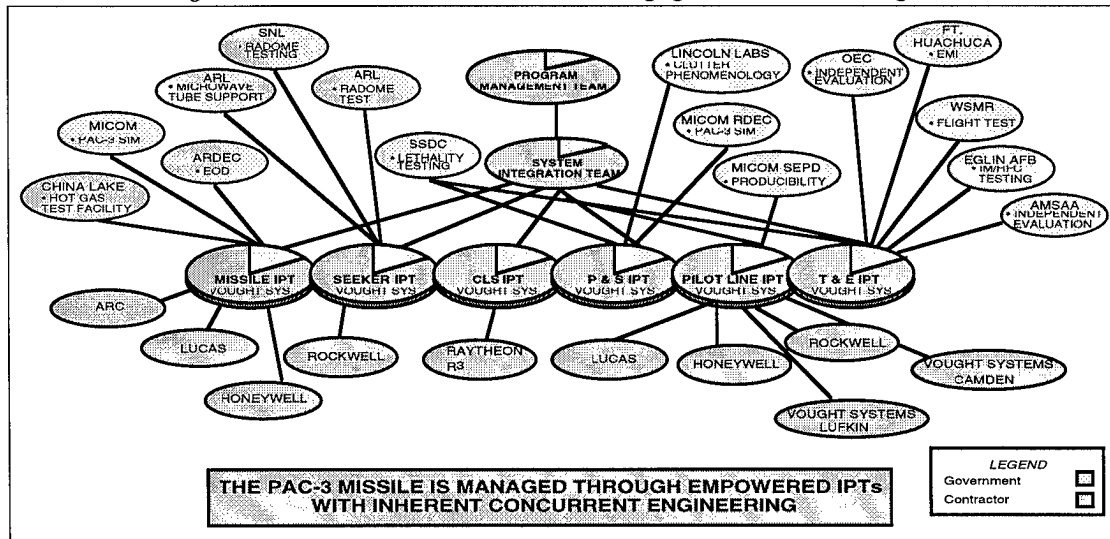
Figure 8. Contractor Government Team Organization

White Sands Missile Range, the Applied Research Laboratory, the Anti-Tactical Missile Panel, Operational Test and Evaluation Command, Test and Experimentation Command, Army Material

a pole. In captive carry, the PAC-3 seeker and GPU are mounted in a C130 aircraft to track a target in flight.

The Flight Test Program will begin with two control test flights (CTF)

scheduled for March and May 1997. The purpose of the CTFs is to checkout the

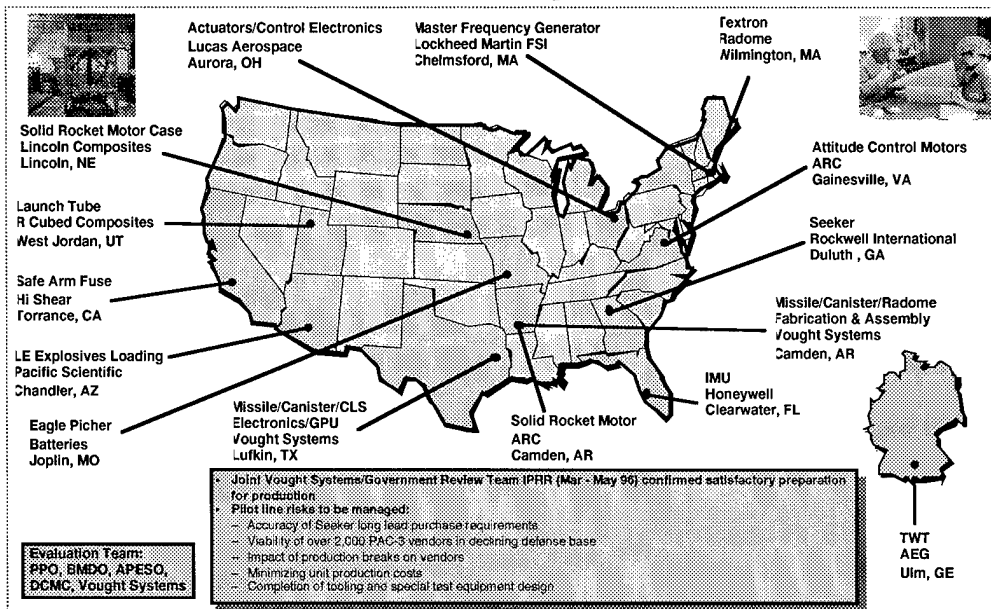The IPRR established an early baseline of production related issues that could impact

Figure 9. PAC-3 Missile Contractors

aerodynamic and structural control of the missile. These flights will be followed by a series of ten Guided Test Flights from August 1997 through October 1998. These tests will demonstrate both high and low altitude intercepts of TBMs, engagement of Air Breathing Targets (ABTs) and low altitude cruise missiles. The flight test program will conclude with a series of Operational Test flights in February through April 1999.

A joint Vought Systems / Government Review Team Initial Production Readiness Review (IPPR) conducted from March to May, 1996, confirmed satisfactory preparation for production. The IPRR consisted of a formal examination of contractor's operations to determine adequacy of production planning, processes, and control; existence of suitable production facilities; design stability; and early identification of potential problems.

milestone approval. All reviews were conducted on-site at contractor facilities.

Affordable development of Hit-to-Kill interceptor systems requires maximum integration of industry and Government assets. An Integrated Product Team approach is essential. Effective continuous communication and earned value management systems are key. Consolidated digital simulations must be the link between widespread hardware-in-the-loop, captive carry, wind tunnel and the ground test facilities. A high fidelity pilot line must be established to minimize risks in transition from design to production. Cooperation of all industry and Government participants has resulted in the program meeting all objectives while preparing for flight testing and production.