LPD 17 ON THE SHIPBUILDING FRONTIER: INTEGRATED PRODUCT & PROCESS DEVELOPMENT

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Abstract

In the April 1996 words of Secretary of the Navy Dalton, "LPD 17 is a first. The Navy is on the frontier of a new way of doing things through teaming with our Industry partners and streamlining the administration and acquisition processes." Truly, in the months since that prophetic statement, the LPD 17 program has crossed the shipbuilding frontier and through its Integrated Product Process Development (IPPD) tools has developed its innovative acquisition strategy - a strategy that has application to many other programs as well. The LPD 17, the first amphibious ship designed for the 21st Century, is on the leading edge of new product and process innovations in Naval shipbuilding.

This paper provides a synopsis of the IPPD strategy as implemented by the LPD 17 Government and Industry Team. Components of IPPD will be addressed in terms of goals, people, processes, and tools. In addition, it details the steps in establishing the baseline for IPPD implementation and relates specific examples of early successes. Written by members of the LPD 17 team, it concludes by offering process examples that may enable this edition of IPPD to enhance other applications and programs.

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Abbreviations/Definitions

3-D	Three Dimensional
AAAV	Advanced Amphibious Assault Vehicle
ACAT	Acquisition Category
AEM/S	Advanced Enclosed Mast/Sensor System
AIM	Asset and Information Management
AIR	Action Item Request
C^4I	Command, Control, Communication, Computers and Intelligence
CAD	Computer Aided Design
CAE	Computer Aided Engineering

CAM	Computer Aided Manufacturing
CCB	Change Control Board
CCT	Change Control Team
CEO	Chief Executive Officer
CET	Cost Engineering Team
CFE	Contractor Furnished Equipment
COMOPTEVFOR	Commander, Operational Test and Evaluation Force
CPT	Cross Product Team
CTT	Combined Test Team
DFO	Design For Ownership
DIT	Design Integration Testing
EBRR	Event Based Readiness Reviews
ECS	Engineering Control System
FMR	Field Modification Request
FSC	Full Service Contractor
GD/BIW	General Dynamics/Bath Iron Works
GFE	Government Furnished Equipment
GFI	Government Furnished Information
GFM	Government Furnished Material
IDEF	Integrated Definition Process Modeling Method
ILS	Integrated Logistics Support
IMP	Integrated Management Plan
IPDE	Integrated Product Data Environment
IPPD	Integrated Product and Process Development
IPT	Integrated Product Team
ISDP	Integrated Ship Design and Production
ISEA	In-Service Engineering Agents
LBTE	Land Based Test Environment
LCAC	Landing Craft Air Cushion
LCU	Landing Craft Utility
MIRWS	Master Integrated Resource and Work Schedule
MOA	Memorandum of Agreement
NAVSEA	Naval Sea Systems Command
NTN	National Test Network
OPNAV	Chief of Naval Operations Staff
OSD	Office of the Secretary of Defense
O&S	Operating and Support
OT	Ownership Team
PECP	Preliminary Engineering Change Proposal
PEO	Program Executive Officer
PMS	Planned Maintenance Schedule
PMT	Program Management Team
PRR	Production Readiness Review
PTS	Procurement Technical Specification
QFD	Quality Function Deployment
RCS	Radar Communication System
RHIB	Rigid Hull Inflatable Boat
SDM	Ship Design Manager
SSDG	Ships Service Diesel Generator
SSES	Ship Signal Exploitation Space
SWAN	Shipboard Wide Area Network
TLPG	Top Level Program Goals
TOC	Total Ownership Cost
TSET	Total Ship Engineering Team
VFI	Vendor Furnished Information
WBS	Work Breakdown Structure

Introduction

As the 20th Century comes to a close, few industries are undergoing as many challenges as the United States Naval Shipbuilding industry. Among these formidable challenges shaping shipbuilding are threat, fiscal conservancy, technology leaps, and manpower trends. The Cold War victory ended the main superpower threat while replacing it with the potential for dozens of hot spots and minor conflicts, necessitating doing more with fewer ships. The requisite need to divert military financial resources to other programs and to better manage available resources created a demand for new acquisition techniques. The explosion of technological advancements directed improved management techniques and integrated information systems to maximize efficiencies and to "Engineer once, use many." Finally, more sophisticated technology requires a corresponding increase in fully qualified Sailors and Marines. Unfortunately, the pool of available fiscal resources within the Navy infrastructure continues to diminish as Operating and Support (O&S) budgets continue to decline.

Given these challenges, the collective Naval shipbuilding community needed to change and change it did. However, the LPD 17 program was caught in the middle of this transitory, revolutionary effort. Conceived in the Cold War 1980s and begun in 1988, the LPD 17 program became both a tool of these changes and sometimes a victim. No longer could a prolonged learning curve be afforded. The program would have to plan, design, and produce a combat-ready ship and in the words of the Assistant Commandant of the Marine Corps, General Neal, "Get it right the first time."

Modifications to acquisition guidance created the first hurdle as the program survived dramatic swings in budgetary priorities, legislative direction, and acquisition

policy within a two-year time span. Employing the modifications, LPD 17's Request for Proposal allowed the potential Full Service Contractors' to initiate smarter, more effective solutions to overall program requirements. For example, only the Military Standards that addressed technical specifications where Industry did not have direct commercial equivalents were retained. These changes required variation and transformation from traditional processes.

Concern for costs also dominated much of the LPD 17 planning. Total Ownership Cost (TOC) combines the research and development, design and traditional ship construction costs with life cycle operating and support costs. Figure 1 depicts the relative relationship of initial design, acquisition, and operating and support costs as viewed from a TOC perspective. The LPD 17 TOC perspective quickly led to the program tenet to target program cost drivers. The LPD 17 program will consider paying a premium in acquisition, within budget constraints, to obtain significant savings during the 40-year life of each ship of the class.

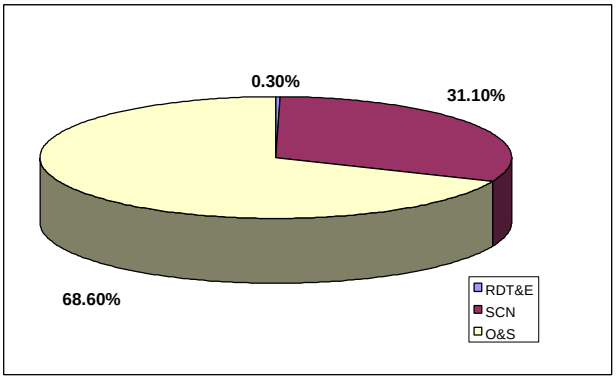

Figure 1: LPD 17 TOC Breakout

The changing military threat also entered into the LPD 17 equation. With no other superpowers on the horizon for the moment, the ship required warfare capable, mission flexible, technically adaptable, and affordability supportable to be the right tool for the 21st Century expeditionary warriors (see Figure 2). Forward presence and missions of state required new focus even as designers patterned the ship to accomplish the traditional tasks of transporting and landing Marine Corps assault forces where needed. In some cases the multi-faceted missions facing LPD 17 created potential design dichotomies. For example, the proposed Advanced Enclosed Mast/Sensor System (AEM/S) design conflicted with traditional signal flag display while the need for reduced radar cross section signature conflicts with traditional methods to accommodate ship's boats. Above all, new technology has to be warrior friendly while still supporting the goal of delivering a combat ready ship for the Navy-Marine Corps team.

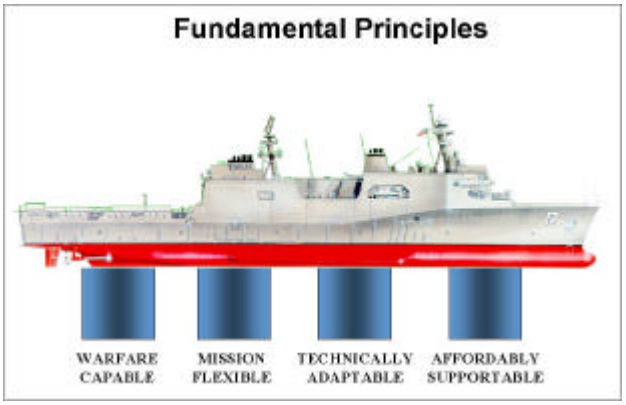

Figure 2: LPD 17 Fundamental Principles

Building LPD 17 right the first time also requires a sustained dialogue with the ship's ultimate owners, the Sailors and Marines. Ideas, suggestions and recommendations from the operators, maintainers, trainers, and testers need to be solicited to ensure the process stays on track. Product development will not be successful if the customer is not satisfied with the LPD 17 end product.

Finally, the LPD 17 Program quickly recognized the value of cooperating and collaborating with Industry. By challenging the best minds and most experienced experts from an Industry team, shared technologies and innovative efficiencies would more likely be integrated into the process. Industrial solutions, often proven effective in the world of profit and loss, could be made directly applicable to LPD 17. Industrial teaming was not only encouraged, but became a practical necessity. The Full Service Contractor recognized this and created the Avondale Alliance, a team of proven shipbuilders from Avondale and Bath Iron Works, of combat systems artisans from Raytheon, and of seasoned computer aided engineering system integrators from Intergraph. Partnering with these experts in an IPPD approach also enabled the Government to evolve from detailed direction and guidance to overall strategic management.

In the April 1996 words of Secretary of the Navy Dalton, "LPD 17 is a first. The Navy is on the frontier of a new way of doing things through teaming with our Industry

partners and streamlining the administration and acquisition processes." The resulting management approach developed to meet the challenges "on the frontier" and to realize advantages of progressive attributes is IPPD. It is best defined in terms of goals, people, process and tools. With these baselines, IPPD's emphasis on product and process is not only starting to achieve victories in the LPD 17 program, but is also demonstrating potential application to other programs that will lead to complimentary benefits.

Goals

Satisfy Customer Requirements

Who is LPD 17's customer? Before the customer can be satisfied and a goal accomplished the customer must be defined from the many opinions. Since the LPD 17 is an ACAT 1D program, the various entities within the Office of Secretary of Defense may think they are customers. The Avondale Alliance may think that the Naval Sea Systems Command is the customer since they are the contract authority for the ship. In reality, OSD, OPNAV, Fleet Commanders, Sailors, Marines, taxpayers, and NAVSEA are all customers and must all be satisfied.

Reduce Total Ownership Costs

Reducing Total Ownership Costs is a prevailing goal, a continuing focal point for TEAM 17. At Milestone II, the LPD 17 program performed a structured analysis of TOC drivers. The principal Operational and Support cost drivers are manpower and maintenance. (See Figure 3) These two cost drivers are being researched and all aspects of technology and ownership processes are being assessed to reduce the impact on TOC for this ship program.

As a result of these studies the LPD 17 program proposed that a 20% reduction in O&S could be achieved by the 12 ships of the class over their 40-year life cycle compared to traditional amphibious ship programs.

Post contract award, the Avondale Alliance indicated that they would strive to surpass the Navy's Operational and Support savings goal. Through IPPD, TEAM 17 has been given top-level reduction goals that are being allocated within the ship product structure.

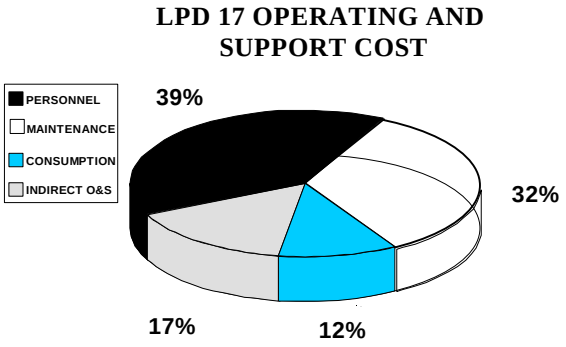

Figure 3: LPD 17 Operating & Support Costs

Reduced Cycle Time

Time is money, and excessive processing times and built-in delays must be avoided. Therefore acquisition reform and re-engineering of procurement processes necessitates the reduction of cycle time throughout an integrated, concurrent engineering environment. For LPD 17 the reduced cycle time goal is being applied to such relevant processes as the contract change process, ship production process, the total ship testing process, logistic processes, shipboard maintenance processes; and, of course Government decision making processes.

Reduced Program Rework

One of the basic tenets of IPPD and concurrent engineering is reduced rework. The time to eliminate the conflicts, errors and establish the proper production processes is during the product development phase. The ultimate goal is to eliminate all production rework. This should eliminate the traditional steep learning curves for follow-on ships, which have been typical of historical shipbuilding programs.

Total Ship System Integration

The total ship integration process goal is a paradigm shift within ship acquisition processes. Traditionally ships were viewed as platforms where combat/mission systems would be installed with minimal emphasis on total ship integration. The LPD 17 business model is significantly different. The LPD 17 will not enter into the production phase until the required level of total ship systems integration is achieved. This includes integration of all

ship systems with all C4I and functionalities (from ship control to combat system control, from the Engineering Control System to C4I, from CFE to GFE). This requires that total ship information management be taken to a level unsurpassed in surface ship acquisition and be fully transferable to the ship's future owner, its crew.

Long Term Relationship

Among the critical goals of the LPD 17 program, a long-term relationship within TEAM 17 is an overarching principle. The value of continuity and stability within a program that will exist for 50 years cannot be over-emphasized. The strategy includes maintaining a long-term relationship with the Avondale Alliance given satisfactory performance (achieving TOC reduction and programmatic performance). This includes two additional negotiated contracts for the remaining 9 ships of the Class. Subsequent negotiated contracts for Planning Yard responsibilities, and various life cycle support tasks are planned.

People

People are the most important resource in an IPPD organization. IPPD thrives in a team environment and for LPD 17 the foundation for team building was an effective organizational model, proper training, and co-location. The initial confusion of the team is minimized when all team members start with a common understanding of what the team is to accomplish, of where each member fits into the scheme, and of how easy interaction will be. This is a continuous process that must be sustained as the program progresses.

The integration of multi-functional, multi-talented personnel is critical to the success of the IPPD organization. The Government in the RFP required the IPPD team to be composed of persons possessing the appropriate disciplines, specialties and functions from both the Government and Contractor and major subcontractors/vendors. The Government also specified that it would co-locate its members of TEAM 17 (representatives from NAVSEA 01,02,03,317,PEO TAD, SPAWAR, SUPSHIPs, and other Government activities) at a mutually agreed upon Contractor site. Co-located means "sharing the same floor, walls, and overhead with no intervening walls."

The Avondale Alliance, composed of representatives from Avondale Industries, Bath Iron Works, Hughes Aircraft Company (now Raytheon) and Intergraph, proposed an IPPD structure that was different from the Governments notional concept (Figure 4) in the RFP. The Alliance submitted an IPPD proposal that was based on a tiering structure. Figure 5 is a graphical representation of the Alliance proposed IPPD team.

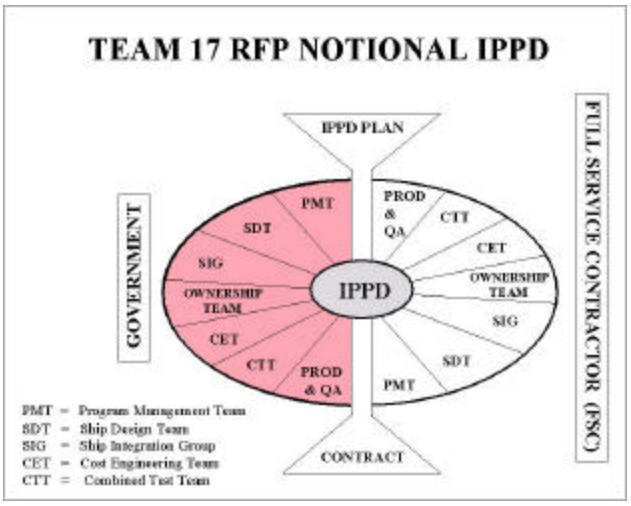

Figure 4: TEAM 17 RFP Notional IPPD

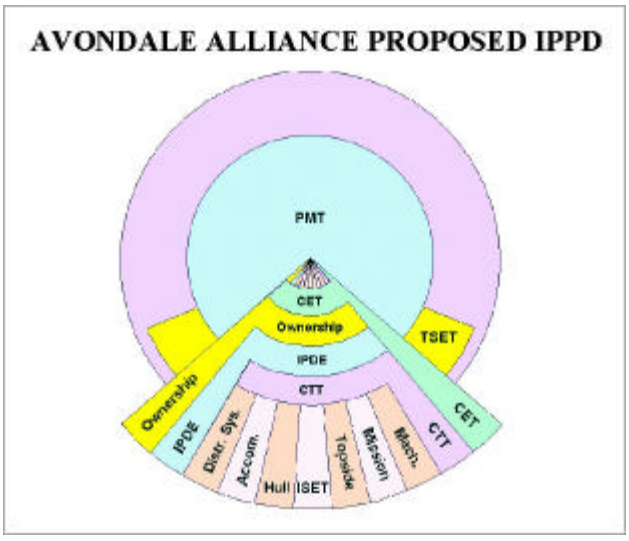

Figure 5: Avondale Alliance Proposed IPPD

Working together in a process-developing environment, the organizational differences were resolved. The Alliance proposed a structure to focus on LPD 17

program attributes and to allow work to be accomplished efficiently. At the core of the IPPD organization was the Program Management Team (PMT), co-led by the Avondale and Navy Program Managers, consisting of representatives from each of the Alliance members companies. This structure, in turn, was supported by seven Integrated Product Teams (IPTs), each responsible for a specific set of related products, systems, sub-systems and components for the life of the ship. These seven IPTs were:

- Integrated Ship Electronics Team (ISET)
- Distributive Systems Team
- Accommodations Team
- Hull Team
- Topside Team
- Mission Team
- Machinery Team

In addition to the seven product oriented IPTs, the Alliance proposed four Cross Product Teams (CPTs) that cross all program activities. These four CPTs were:

- Ownership Team (OT)
- Total Ship Engineering Team (TSET)
- Integrated Product Data Environment (IPDE)
- Combined Test Team (CTT)

Each CPT had representation within each of the IPTs. The TSET coordinates technical issues across all program activities. This proposed IPPD structure would provide program direction and performance monitoring of efforts to achieve life cycle cost reduction. [Note: the Design For Ownership (DFO) group is an important part of the OT organization. The DFO group provides the teams with input from the warriors, operators, maintainers, and trainers.]

Training

Proper and continuous training of personnel is a key step in the IPPD start-up process. When bringing together personnel to form a team from different organizations, with different backgrounds, cultures and practices, it is essential to provide up front training on how this team is going to work and ensure that their goals and objectives are clearly defined. For LPD 17, the Government required the Contractor to provide IPPD training to the Government/ Contractor team (TEAM 17). As a result, TEAM 17 embarked on an unprecedented three-phase ten-week team-training program at the beginning of the contract execution period. This team training consisted of:

- Establishing Top Level Program Goals
- Developing Cross Product and Product Team Charters
- Issuing a TEAM 17 contract baseline
- Identification of TEAM 17 key processes
- Issuance of an Integrated Management Plan development and deployment plan
- Issuance of a Master Resource and Work Schedule development and deployment plan
- Issuance of an Integrated Product Data Environment development and deployment plan
- Issuance of TEAM 17 Total Ownership Cost model development and deployment plan
- Development of TEAM 17 rules/team behavior
- An IPPD team building workshop
- Development of TEAM 17 self assessment process
- Development of TEAM 17 accession process for new members

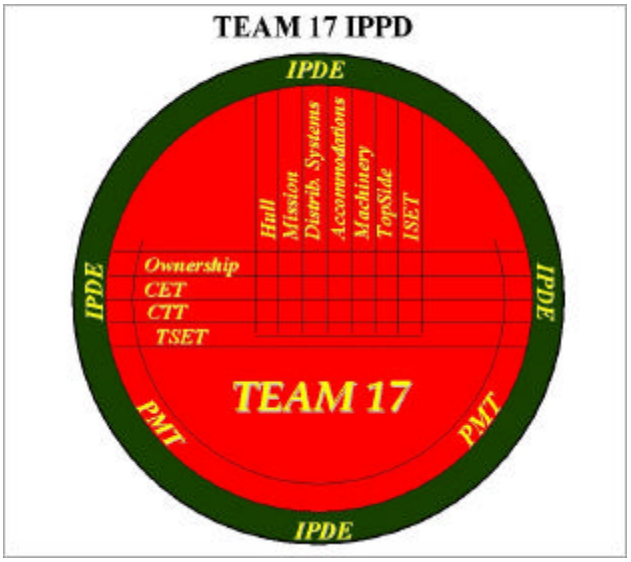

Figure 6: TEAM 17 IPPD

At the conclusion of the first four weeks of training, team members approved an IPPD organization that included one additional CPT, the Cost Engineering Team (CET). This organization relies on the IPTs (Hull, Machinery, Topside, etc.) as the single point of product development. All requirements (DFO, contract, production, testing, integration, logistics, IPDE, TOC, etc.) are the overarching input to the detail design process for the

seven product teams. Figure 6 is a graphic representation of the integration of the IPTs and CPTs.

This training period was also critical in establishing a mutual understanding of how TEAM 17 could achieve many of the contract requirements. For instance, the team members developed a working comprehension of the LPD 17 concurrent engineering process that would be used from contract award to ship delivery (see Figure 7).

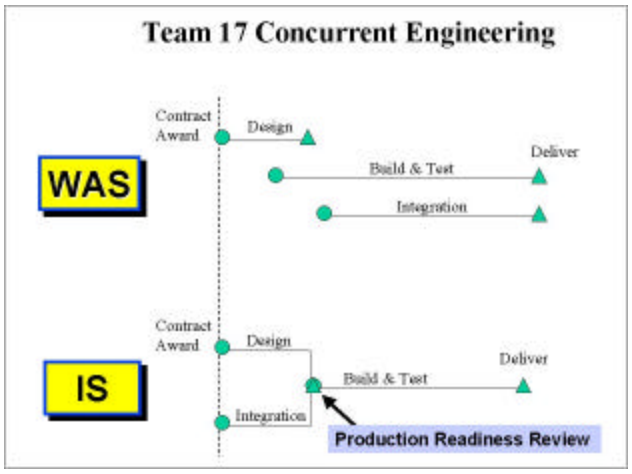

Figure 7: Concurrent Engineering

To provide overarching guidance to the team during the initial phase, a set of Top Level Program Goals (TLPG) was also established. These goals allowed the program to focus on the end product as well as the process.

As the training continued it moved to the builder's site. There, cross-functional focus groups were established for each TLPG to originate a charter, an action plan and prescribed metrics. Made up of cross-functional team members of TEAM 17, their collective efforts produced tangible and intangible results. For instance, for each goal, the focus group's mission was to monitor each of the goals that were used for the first award fee assessment. All seven product IPTs and CPTs developed charters from which they identified mission, roles, responsibilities, mission statement and membership. The charters assist in keeping focused on these boundaries and provide new members with an understanding of their teams.

Each of the product IPTs supporting the TSET are populated with members from the other CPTs, (CTT, OT, and IPDE). In addition, the membership includes production, logistics, and engineering disciplines up front. The CET serves as the Cost Engineering Team for TOC. They manage the TOC baseline and the impact of contract changes.

Intangible, these sessions cemented the team-building infrastructure. Every shipbuilding endeavor faces start up challenges of key elements getting to know each other, and it may be months into the evolution before the process really starts to click. For LPD 17 and within the IPPD dynamic, this ten-week period of working together to develop process structure within an atmosphere of equality was invaluable.

New member indoctrination remains a vital part of IPPD. As is the nature of ship detail design and construction, there are distinct phases which the program will progress through. TEAM 17 evolves based on the detail design, life cycle planning, logistic support, total ship testing and construction schedules. In order to keep the momentum and a consistent approach during these transitions, new members must be brought onboard and come up to speed quickly. New member indoctrination consists of a set of key references that outlines the products from the initial IPPD training activities, contract products which the member is responsible for, a brief overview of the design to date, and a basic understanding of the product development process and IPPD.

Co-Location

IPPD is a process that capitalizes on rapid, daily communications to meet many of the initial challenges of this new way of doing business. Co-location is one venue that has facilitated the administration of this Government-Industry interface. Traditionally, the Full Service Contractor (FSC) would formally draft and forward questions about the ship specifications to the Program Office. Typically, after 45 days or so the Program Office would respond in a letter. More time would elapse in many cases, as the contractor requested additional clarification via successive cycles of letter writing. The Program Office would respond to each cycle, each taking about 30 days before the issue was finally resolved. Until, of course, the actual production team encountered further questions or requested a change for improvement. Then the process might start all over again, culminating in a Change Request that would involve more time and money.

In past naval shipbuilding, the above back and forth efforts might consist of over hundreds of letters in the first two years of a major shipbuilding program. For LPD 17 and IPPD, no Navy program office letters were generated in the first eight months. In fact day-to-day and face-to-face interaction have completely eliminated previous cycle time delays. Decisions are made and solutions obtained within days instead of the historic months that often slowed traditional programs. If the decisions warrant a contract change, then the program office Change Control Board meets and the FSC is requested to provide a proposal to amend the contract.

Process

IPPD is not a single process, but instead melds a series of processes into an effective management undertaking. Process ingredients of IPDD include product development, risk management, design for ownership, TOC reduction, life cycle support, design integration testing and a variety of management processes.

Product Development Process

Product development is a balancing act between acquisition and life cycle cost, schedule and risk. Concurrent engineering through the IPPD process is the method to accomplish the balancing act. Figure 8 depicts TEAM 17's approach to concurrent engineering. IDEF (Integration Definition for Functional Modeling) was used to map this process. The product development process includes 6 distinct milestones, which leads through Production Readiness Review and into the final testing phase of the ship. The LPD 17 concurrent engineering process has many input requirements. Some of these requirements include:

- Functional and performance requirements of the ship specifications
- Contract requirements to reduce total ownership costs
- Integration with the design for ownership process
- Integrated Product Data Environment requirements
- Alignment with the Master Integrated Resource and Work Schedule
- Compatibility with LPD 17 class ships being built at two different shipyards
- Integration of engineering and logistics requirements.

The LPD 17 total ship development process is composed of six overarching Design processes (see Figure 8):

- Define product requirements
- Define ship systems
- Develop transition design
- Develop detail ship configuration
- Extract production design
- Production, testing and support of ship delivery

During the Define Product Requirements phase, the following were reviewed for determination of detail design requirements:

- Allocation of TOC reduction goals
- Establishment of the IPDE product structure
- Support of the detailed MIRWS process by all IPTs
- Issuance of allocated requirements by within the product structure

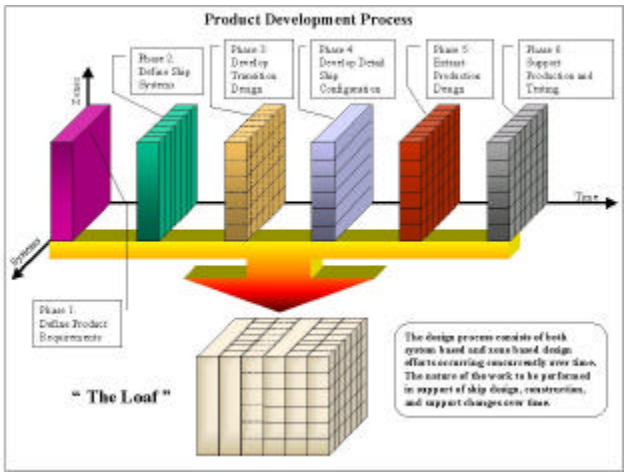

Figure 8: LPD 17 Production Development Process

The LPD 17 detail design allocated requirements will be continually updated throughout each detail design process and are updated to reflect the latest ship configuration using requirement management software. During the Define Ship Systems phase, the following types of activities are planned:

- Review and de-conflict allocated requirements
- Perform engineering analyses and trades (TOC, DFO, supportability, performance, etc.)
- Develop preliminary configurations including integration of electronic systems data
- Define procurement activities
- Perform top level test planning

- Develop production plan

During the Develop Transition Design phase, the system-based design previously completed is now "transitioned" into a spatially based design within the product data model. The general focus of activities includes:

- Develop arrangement configuration
- Perform transition design analyses and trades (TOC, DFO, performance, etc.)
- Initial population of 3D product model
- Perform subsystem design
- Perform supportability analyses
- Release transition design configuration
- Assess achievement to TOC reduction goals

During the Develop Detail Ship Configuration phase, the finalization of the detail design is the principal focus. The following activities are planned:

- Continued development of the 3D product model
- Electronic system implementation and detailed planning
- Interference checking of the 3D product model
- Bill of material development including attributes
- Generation of test procedures
- Finalization of product plan
- Validation of detail design
- Generation of logistic support products and life cycle support data
- Development of attribute information to allow data extraction
- Assess achievement to TOC reduction goals

During the Extract Production Design phase, the LPD 17 will be gearing up for the contract required Production Readiness Review. This phase will highlight extraction of production data from the product model for development of documentation necessary for fabrication, logistics support, construction, and testing to support delivery of a mission ready ship. Each IPT will be responsible for extraction of production drawings from the product model for it's area of responsibility.

The last phase of the LPD 17 product development process will be production, testing and support of ship delivery by the various product teams. The activities of the teams include validation of the as-built configuration (functional description, location, quality, component characteristics, the product model), verification that logistics data are consistent, support the pre-commissioning crew process and training, support the Combined Test Team (CTT) in the total ship test program, and support the product process to clarify questions and document solved problems.

Risk Management Process

Risk management is an integral part of all up-front planning activities. Risk assessment, mitigation plans and implementations of necessary mitigation measures are all part of the management process. A comprehensive risk mitigation program has been developed as part of the program Integrated Management Plan and will be assessed quarterly by the PMT.

Design for Ownership Process

Design for Ownership has been a key tenet of the LPD 17 program since its inception. The DFO process brings the operator, maintainer and trainer into the design process early in order to incorporate their requirements up front to minimize rework. At the same time it seeks to provide a ship which will satisfy the customer, the US Navy throughout the 40-year life of the ship. Numerous DFO workshops and conferences have been held to discuss various aspects of the ship design. These workshops have included:

- Expeditionary warfare workshop
- Missions and capability
- Manning requirements
- C4I requirements
- Habitability requirements
- Maintenance requirements
- Training requirements
- Combat cargo requirements
- Pre-commissioning requirements
- Mixed gender crew and troop requirements
- Aviation requirements

In addition, the program will utilize virtual mockups to gain useful operator feedback as the design progresses. The virtual crew concept will allow all stakeholders to review the product in process and participate in product development. All this effort is meant to ensure that the customer has a product, which will serve the needs into the 21st century. The LPD 17 War Room at the Expeditionary Warfare Training Group in Little Creek, Virginia maintains the database of DFO issues and is the conduit for input from Navy and Marine Corps amphibious forces.

TOC Reduction Process

TOC reduction is also a key tenet. In today's environment, the Navy cannot afford to operate as in the past. TOC reduction includes a focus on all cost drivers. This includes creating tools, policies, and systems that modernize the manning approach, improve maintenance, streamline the logistics approach, etc. - at all times seeking to find better ways to perform task at less cost. The contract requires the Avondale Alliance to pursue TOC avoidance as a key component in all program activities. The TOC process is integrated with the total ship development process and is a component of all team activities.

In order for TOC inputs to be most effective, TEAM 17 has developed a front end process as part of the detail design. Each high-level design activity is identified in MIRWS, such as Procurement Technical Specification (PTS) development, system development, 3-D modeling, etc. A kick off meeting is held for each of these activities and representatives from all CPTs, production, and DFO attend. Each team member is to bring lessons learned and examples of TOC opportunities. At the end of each kick off meeting, if TOC savings will result from a change to the contract, then an Action Item Request (AIR) is submitted and TOC savings are also identified to update the TOC baseline. If the proposed change is found to be technically acceptable, then it is forwarded to the PMS 317 Change Control Board (CCB).

Life Cycle Support Processes

LPD 17's acquisition process is not limited to acquisition processes. The IPPD promotes the mapping of processes to support the program in post-delivery and throughout the life cycle. The Avondale Alliance will participate with the Government to determine the most affordable and practicable means to support the LPD 17 Class throughout its lifetime. The LPD 17 contract contains a contract line item option for Avondale to perform life cycle support planning. This option will be exercised in the near term contingent on acceptable performance under the detail design and construction contract line item.

Design Integration Testing

Integral with the Total Ship Integration process goal is using a tool to reach this objective. A Design Integration Testing (DIT) process is required for the LPD 17 program. The use of DIT will be performed through a Land Based Test Environment (LBTE), which consists of a FSC test and integration facility as well as a National Test Network (NTN). The principle purpose of DIT is to test GFE to GFE, GFE to CFE, and CFE to CFE software interfaces with contractor furnished systems in a developmental test framework vice production test. For example, testing the Engineering Control System (ECS) principle interfaces with the Shipboard Wide Area Network (SWAN) will occur among several development sites located across the continental United States. The ultimate goal of DIT effort is to eliminate costly rework that can occur during production, testing and just before delivery of the ship.

Management Processes

IPPD not only envelops design and building processes, but also provides management with the tools to guide these processes to product. These involve the creation of the Government detachment at Avondale, MIRWS, the change process, award fee and the overall IPDE process.

LPD 17 Detachment

The creation of the NAVSEA LPD 17 Detachment at Avondale, LA has brought forward a revolutionary process to program management. This detachment has consolidated technical authority, legal authority, contract authority, various aspects of financial authority and program management authority directly to the FSC execution site. This capability facilitates prompt resolution of issues/actions required by the Navy. This detachment has various processes built in where its on-site authority is defined with Memorandums of Agreement (MOA). With an empowered Government detachment on site, many of the aggressive program goals are achievable.

MIRWS Process

The Government and the Avondale Alliance have agreed to jointly utilize the Master Integrated Work Schedule (MIRWS) as the single tool to manage program activities. MIRWS contains high level activities and is based on various predecessor and successor logic connections linking schedules, resources, and event sequencing.

Within MIRWS, Event Based Readiness Reviews (EBRR) and key milestones are identified and assessed. Each key event has a list of exit criteria. The LPD 17 program has no quarterly reviews as part of the management approach. The EBRRs also are used as a management tool to demonstrate completion of previously defined exit criteria for each Contract Milestone and corresponding key events. Their overall purpose is to minimize engineering rework associated with premature starts of downstream activities, provide logical checkpoints of metrics, and obtain program buy in by effected team members before initiation of those downstream activities.

Change Control Process

The LPD 17 program is aggressively attacking the Change Control Process. A common theme among previous acquisition programs is the inordinately long process to adjudicate changes, often becoming a weak link in the contract execution process. This was a key factor in determining that an on site Government team was a necessity. The change control process is as follows:

- Begins with an idea or proposed change brought forward by the product IPTs.
- The idea is formulated as an Action Item Request and can initiate a study or change. Studies are used to pursue ideas that require further development before the appropriate contract change can be formulated.
- An AIR needs to get agreement from CPTs reps on the product IPTs and both the Alliance and Government leaders before it is considered by the CCB.
- Once the change is approved by the CCB, it begins the Field Modification Request (FMR) process where the change is scoped in more detail for technical impact and pricing.
- The joint technical scoping and pricing process involves a joint Government/Alliance co-located Change Control Team (CCT). The performance metrics for the change process on LPD 17 are currently aggressive and will become even more aggressive in the future.
- Once approved the change or AIR is implemented into the LPD 17 contract quickly in order to limit change costs.

Award Fee Process

A key performance incentive for TEAM 17 is the award fee provision. The Avondale Alliance and the Government have jointly developed award fee criteria. TEAM 17 members collaborate and provide input to the Government Award Fee Evaluators. The various award fee criteria being developed on the LPD 17 program are highly integrative amongst themselves. This has been a conscious effort as the program works towards achievement of key program goals.

A final contract performance incentive is available as an added inducement above and beyond the Award Fee for the FSC to design and build a trouble free ship capable of uninterrupted exceptional performance. The incentive period shall commence at ship delivery and conclude two years later. The incentive pool is composed of unearned Award Fee. Up to $10M per ship will be available.

IPDE Process

The IPDE process is the fundamental backbone for almost all key processes for this program. The IPDE infrastructure and functionality are essential to the success of the many key processes discussed. IPDE provides the tools, which the team needs to accomplish detail design, total ship systems integration, production, testing, logistics and life cycle support processes for the LPD 17 program.

Tools

Integrated Master Plan (IMP)

The IMP reflects the Avondale Alliance's integrated approach for detail design, total ship systems integration, construction, testing, logistics, delivery and life cycle support planning of the LPD 17 lead ship and up to two follow ships. The IMP includes the following plans:

- IMP Executive Summary
- Integrated Product and Process Development (IPPD)
- Integrated Product Data Environment (IPDE)
- Contract Data Management
- Subcontractor Management
- Quality Assurance Program
- Operation Security Program
- Detail Design

- Total Ship Systems Integration
- Hardware Development and Management
- Total Ship Software Development
- Software Process Improvement
- RCS/SSES Implementation
- Survivability Systems Engineering
- Environmental and Hazardous Material Management
- Reliability and Maintainability Program
- Human Systems Engineering and System Safety
- Production of LPD 17
- Test and Evaluation
- Standardization
- Configuration Management
- Integrated Logistics Support
- Manpower Optimization
- Shipboard Facilities Maintenance Improvement
- Life Cycle Support Management
- Class Maintenance/Modernization
- Life Cycle Cost Estimating Program
- Technical Manual Integration

Master Integrated Resource and Work Schedule (MIRWS)

MIRWS is an event-based, integrated scheduling system that depicts and interrelates all activities required for the performance of the contract. Welcom's "Open Plan Professional" project management software has been adopted by the Avondale Alliance as one of the core tools within the MIRWS system. The software has a Microsoft Windows-style interface that allows users to view their data in:

- Network logic
- Gantt Charts
- Histograms
- Resource Learning curves
- Spreadsheet
- Hierarchical structured views

MIRWS contains all team interfaces and key activities such as product design, process design, test, build, contract deliverables, and other related events that are required to complete the program. The predecessors and successors for each of these events may be identified in order to facilitate a critical path analysis for the program. MIRWS links the Work Breakdown Structure (WBS) to the product model structure. MIRWS events are based on a product-based WBS that reflects the team structure and allows the collection of metrics that are accurate and predictive (process-focused). Each element in the WBS is detailed in work packages that describe the activities, establish intermediate milestones, and identify deliverable items required for the team product. Events are defined in the work packages, and they are time-phased in conjunction with the program schedule. Associated resources are allocated to the events to yield a time-phased budget.

An immediate benefit of MIRWS was realized during the first months of contract execution. Production teams are normally driven by timelines, but the MIRWS forced an all encompassing perspective. Events and activities contributing to a product had to be sequenced and structured, necessitating a logical, common sense approach to product development. Potential production problems and resource shortfalls were identified months before they would have been in a traditional program providing the requisite time to resolve and correct.

Integrated Product Data Environment (IPDE)

The IMP and the MIRWS are maintained as part of the common data environment called the Integrated Product Data Environment (IPDE). The IPDE is an open architecture information system that supports the delivery of integrated acquisition, engineering, and logistics products for the LPD 17 Class life cycle. The IPDE's phased implementation includes the integration of a product model database, associated support data products such as drawings, technical manuals, GFI, training materials, and program execution information such as plans, schedules, software deliverables, and procedures in order to satisfy the information requirements for both the Navy and the Avondale Alliance. Figure 9 illustrates the concept.

The IPDE provides the capability to concurrently develop, capture, update and re-use data in electronic form in a fashion that leads to data integrity, efficiency, and configuration control throughout the life cycle of the ship. Figure 9 depicts the relationship between the product model data (Level I) and the other major components of the IPDE. Support data such as Vendor Furnished Information (VFI), GFI and other technical documentation (Level II) are integrated with the ship product model description.

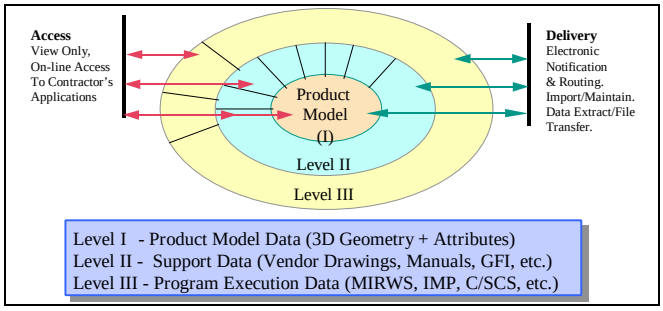

Figure 9: Integrated Product Data Environment

The Alliance is developing an IPDE based Configuration Management Program which has the capability to manage and control the physical, functional, and data requirements of each ship throughout its life cycle. Integration objectives are met through the utilization of a three-dimensional product model. Data and data products are integrated and managed within AIM following predetermined revision and approval processes. The AIM system provides the core functionality to manage data to LPD 17 processes (see Figure 10). All IPPD team members have the ability to generate and/or use information contained in the IPDE. Two of the key software tools forming the IPDE are:

- AIM (Asset and Information Management). Intergraph's AIM system is based on an object-oriented approach for the definition and management of product information. Office documents, bill-of-material information, CAD/CAM/CAE files, desktop publisher data, raster images, and paper documents are modeled as objects. AIM stores product definition information in a logically centralized repository based upon an underlying Oracle® relational database management system. Users gain access to product definition information via a web browser interface.
- ISDP (Integrated Ship Design and Production). Intergraph's ISDP software package uses several shipbuilding specific CAD/CAM modules that work together in creating models by providing 3-D structural modeling, routing and modeling of piping and electrical systems, and generation of mold loft information for production.

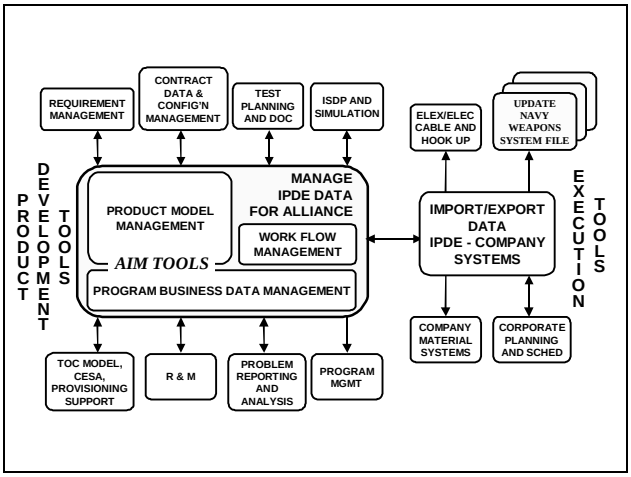

Figure 10: FSC IPDE Functional Architecture

Metrics

TEAM 17, utilizes metrics at the IPT, CPT, and PMT levels as a tool to gauge process and product effectiveness. All of the metrics are aligned to the TLPGs. However, our belief is metrics are meaningful only if the team believes in them. Thus individual metrics vary at each level. Team "buy-in" is achieved in many ways. For example, to validate and bring focus to the Program Manager's metrics effort, the team utilized a technique called Quality Function Deployment (QFD) to understand the various Program Managers' expectations and desires. The QFD process is systematic and structured. It ensures that trade-offs between product characteristics are prioritized based on the priority of customer needs. QFD also helps the team focus on the specific tools and techniques that will produce the greatest payoff. QFD helped us link the various Program Managers' desires into the business, engineering, and production processes.

These objectives are being transformed into eleven program metrics until PRR. These established metrics will be reassessed for their post-PRR applicability. New and/or modified metrics will be developed as required to support the post-PRR phase. These metrics are in final design and prototyping stage, where deployment is imminent.

Results to Date

Pre-Contract Acquisition Strategy

Early in the acquisition process, IPPD characteristics were applied to the older methods of acquiring ships and systems.

TEAM 17 developed an innovative acquisition strategy that for the first time in a major naval ship program blends shipbuilding and a total ship systems integrator in the same contract. The result was a FSC – two shipbuilding firms, a ships systems integrator, and an IPDE systems developer. Most previous shipbuilding programs separated the entities contractually with the Navy managing the interface. The LPD 17 acquisition strategy requires the Full Service Contractor to manage these interactions while the Navy management team focuses on top level strategic direction.

There are several advantages to this strategy. First the program office can itself be spared the work-intensive efforts of refereeing between the prime contractor and its sub-contractor integrators – Government talent can be dedicated to key decision-making and top level management issues. This process also recognizes the value of concurrent engineering where design and integration occur simultaneously. The new working relationships between prime, sub-contractor and Government team incorporate efficiencies and facilitate process execution that will ensure successful integration.

Process integration is also enhanced by the unique LPD 17 strategy: one FSC, one plan and one design, with shared management teams, schedules and data elements.

The LPD 17 program approved acquisition strategy also envisions a long-term relationship with the Full Service Contractor. "Full Service" does not just apply to the first ship construction contract, but continues through subsequent construction under two separate contracts for follow-on ships. Further, the acquisition strategy anticipates the FSC will be tasked with life-cycle support and planning yard responsibilities for the entire class for the duration of the LPD 17's lifetime.

The results of this new pre-contract acquisition strategy will be forthcoming as the program evolves.

Fleet Input

Another indication of IPPD success is the sustained and continuous dialog with the future owners of LPD 17. Traditional shipbuilding programs have relied upon periodic interaction with Sailors and Marines, but this was sometimes not early enough to make a difference. In other instances, not all-relevant information was accessible or incorporated in the design. Finally, by the time the pre-commissioning crew arrived to take delivery of the ship and make recommendations, the cost of change was exorbitant

Fleet and Marine Corps personnel are constant sources of ideas, suggestions and recommendations for LPD 17. Reflecting the aspect of IPPD that the ship is being designed for the owners: individuals, individual ships, and commands have been provided an opportunity to impact design and planning. The forum for Design for Ownership has been a series of 27 conferences and workshops and an interactive issues database on the LPD 17 Home Page (lpd17.nswc.navy.mil). This forum provides a device for input as well as feedback from the Program Office to the interested Sailors and Marines.

Maintaining a viewpoint of working side by side with the owners, LPD 17 designers have cooperated with COMOPTEVFOR and the President of Board of Inspection and Survey to take an early, detailed look at the ship. In two Early Operational Assessments, a team from Commander Operational Test and Evaluation Force reviewed drawings and simulations of the ship. They provided a wide variety of useful comments and recommendations. The direct participation by the Fleet and Marine Corps will continue. Most recently a "Virtual crew" of operator, maintainer and trainer experts is being employed for real-time support.

Fleet input has also brought port engineers and experienced warfighters face to face with the Avondale Alliance. These sessions serve as constant reminders that the ultimate goal for the LPD 17 Class is to serve the Naval Expeditionary Warfare forces.

Manning Reductions to Date

No facet of LPD 17 attracts more attention than the eventual crew size. Each Sailor represents a significant cost investment that when multiplied by 12 ships and by 40 years becomes a significant cost. Given an annual price tag of about $50K each, every crew member

deducted from the final crew reflects $24M in Total Ownership Cost avoidance.

IPPD has been a factor in addressing crew size. Advancing technologies, innovative efficiencies, and close examination of manning criteria have already led to reductions. From a planned size of 450, the LPD 17's crew size has been reduced below 400 while efforts continue to reduce manning further. The guidance principle for this effort is to reduce shipboard workload before people are removed.

TEAM 17 is providing feedback to the Navy manning activities to reexamine manning models and processes. Workload paradigms may need to be revised to incorporate increased shipboard training emphasis. Procedures and doctrine may also need to be changed as traditional and routine functions are performed smarter and more efficiently. New initiatives from Navy testing and evaluation on Smart Ship and GATOR 17 are also expected to provide manning conservation recommendations.

Remaining billets and watch stations are under scrutiny for potential removal and future cost avoidance. Recently 24 watch stations were identified that could be candidates for removal if Wireless communications supplemented the need for sound powered phone talkers, and computers replaced manual damage control plotting. However, these watch stations do not represent immediate savings. Each Sailor in a watch station must also have associated reductions in maintenance and workload, in own unit support tasks, and routine watch standing chores. Only when there are savings in all areas, may a billet be reduced.

Fleet and Marine Corps involvement remains mandatory to ensure that the ship tactical operations are not compromised. The LPD 17 IPPD theme in manning is "Do No Harm"; combat readiness remains a priority over cost.

TOC Savers

To date, 31 TOC initiatives have been incorporated into the contract baseline. The number of ongoing TOC related efforts increases daily. High leverage items executed or under study include:

- Manning reduction to 400 persons (assuming $50K/Person), the cost avoidance is $1.2 billion.
- SSDG transient load requirements change – under loading of Ship Service Diesel Generators causes excessive and early wear. LPD 17 type, number, and transient load of generators will expand SSDG mean time between overhauls and reduce maintenance.
- SPS 67/64 radar substitution with SPS 73 – the SPS 73 is less expensive to maintain and requires one technician instead of two.
- Titanium piping in sea water systems – extends lifetime of piping and overall replacement costs
- Paint coating systems and corrosion control systems – reduce maintenance and manpower intensive preservation through longer lasting paints, more efficient application and disposal, the incorporation of corrosion inhibitors and the elimination of corrosion-friendly designs could yield a significant savings manpower, consumables, etc.
- Self-cleaning filters on Main Propulsion Diesel Engines.
- Oily Water Separator – replacement of planned 50GPM with a 10GPM system will satisfy requirements while saving in space, weight, and reduce TOC.
- Machinery fresh water cooling system self-cleaning strainers.

Not all TOC reductions are so readily apparent. Some in fact may not necessarily equate to a reduction in acquisition costs. An example is the AEM/S system. This system may increase acquisition costs but in addition to radar cross section reduction benefits, the system provides the ability for ship's company to conduct maintenance during all weather conditions while reducing exposure to the elements for sophisticated electronic systems – benefits whose long-term cost savings may far outstrip acquisition costs. The decision point is anticipated in the fall of 1998.

Future Challenges

IPPD is not a stagnant concept. It is expected to grow and evolve as TEAM 17 becomes more practiced in its evolution. IPPD will also mature as it is implemented to meet future challenges.

Grow the Team

TEAM 17 will change and evolve as a function of time. As new team members are brought on board they require the requisite training. As TEAM 17 matures new teams will be chartered and some teams will be retired. The program still must maintain the virtual crew process. The purpose will be to ensure that the ship as delivered meets all customer expectations. The appropriate team awards and recognition program must be in place and practiced.

Successful Production Readiness Review (PRR)

The PRR is less than 18 months away. The PRR is planned to be a PEO review, along with the Avondale Alliance CEOs of LPD 17's readiness to begin production. The exit criteria will be focused on completion of product development attributes prior to production start.

Program Performance Measurement

The LPD 17 program must assess its progress so that the Alliance/Government program managers of TEAM 17 can clearly determine where management focus must be applied. The hardest challenge is measuring what is important for overall effective program management. Currently TEAM 17 is establishing the initial set of program metrics. These program metrics are being designed and will be tools for the PMT. As the program matures the metrics will be tailored to the significant characteristics of the program at that particular time.

Long Term Relationship

A long-term relationship between the Government and the Avondale Alliance is a key factor in the LPD 17 program ability to perform to planned expectations. The long-term vision of the LPD 17 program is being refined. Many questions still remain with regard to the roles of the FSC and the Navy infrastructure to achieve a best value life cycle support plan for the class.

Elimination of GFE

Where it makes sense the elimination of GFE should be undertaken. If traditional Government furnished system is in full rate production and the risk to the program is low, the benefits of converting this traditional GFE equipment as contractor furnished should be evaluated on follow ships. This challenge is complicated by various internal and political forces. However, the potential benefits are significant and these efforts should be pursued.

Life Cycle Support Processes

The Operational and Support processes of the LPD 17 program represent approximately two-thirds of the Total Ownership Costs. The development of these O&S processes is currently underway. Many decisions remain regarding which part of the Government/Industry team will perform which function. These decisions are further complicated by the various ongoing reviews of outsourcing, review of core Government functions, etc.

Conclusion

TEAM 17 has a long way to go before the first ship is delivered, and certainly a long way to go before the last ship is decommissioned around the year 2050. IPPD will remain not only a valuable tool, but also an evolving, constantly improving implement for reshaping the shipbuilding frontier. Implementing IPPD has been challenging and exciting and we will continue to learn and to share our lessons as Integrated Product and Process Development and LPD 17 unfold.

Acknowledgements

The authors would like to thank the many TEAM 17 members past and present that have contributed to the evolution of the SAN ANTONIO Class.

Biographies

Howard Fireman - *Mr. Fireman began his career with NAVSEA in 1977. He has held various assignments in NAVSEA 03 including Hull Systems Engineer and a Senior Ship Design Manager position until 1994. In 1994, he was reassigned as the LPD 17 Acquisition Program Manager in PMS 317. He currently resides in New Orleans, LA as the Acquisition Program Manager in NAVSEA LPD 17 detachment. Mr. Fireman holds both a BSE and MSE degree in Naval Architecture and Marine Engineering from the University of Michigan. In 1993, he completed an MS degree from Johns Hopkins University in Technical Management and the DSMC Program Manager course. He has received numerous professional achievement awards including Navy Superior Civilian Service Award, Navy Meritorious Civilian Service Award, DC Council Architect of the year under Age 35 and ASE Professional Achievement Award for Engineer under Age 30.*

Marianne Nutting - *Ms. Nutting began her career as an EIT in the Preliminary Design Division at NAVSEA in 1989. She was a Project Naval Architect on the LX feasibility studies, MCS(X) feasibility studies and the COBB/R Low Endurance Fisheries Research Vessel COR development for NOAA. In July 1993 she moved to PMS 380 Security Assistance Program Office where she was the case manager for the ship transfer of the LST 1179 USS BARNSTABLE COUNTY and ship reactivation/transfer of four Ocean Going Minesweepers (MSO) to the Taiwan Navy. She moved to the LPD 17 program in January 1995 and is currently the NAVSEA Deputy Ship Design Manager for LPD 17. She currently resides in New Orleans, LA as an "on-site" member of the Total Ship Engineering Team that manages the seven design product IPTs for detail design effort. Ms. Nutting graduated from Virginia Tech with a BS in Civil Engineering and she has received ASE's Dr. James A. Lisnyk Award and the Navy Meritorious Civilian Service Award.*

Thomas M. Rivers - *Mr. Rivers is a Systems Engineer in the Surface Ship Design and Systems Engineering Group of the Naval Sea Systems Command. He obtained his BS degree in civil engineering from the University of Maryland. In 1983, Mr. Rivers began his career in NAVSEA as an engineer in the Structural Branch of the Design Division at Philadelphia Naval Shipyard. Mr. Rivers assumed his current position in 1991 and is currently the LPD 17 Hull Systems Engineer. He currently resides in New Orleans, LA as the "on- site" co-leader of the Hull IPT, the Accommodations IPT, and the Large TOC Reduction TLPG Working Group. He is also the Affordability Through Commonality (ATC) Project's LPD 17 liaison. Mr. Rivers is a member of ASCE, ASE and ASNE and a past recipient of the ASE Professional Achievement Award. His professional achievement awards include the Navy Superior Civilian Service Award and the Navy Meritorious Civilian Service Award.*

Gary Carlile - *Gary Carlile is the Program Manager for the TRW LPD 17 Ship Acquisition Support Project. He is responsible for managing all TRW contractor support services for the acquisition of the LPD 17 program. Prior to joining TRW, he was the LPD 17 program resource sponsor in OPNAV, N85, and was responsible for drafting the Mission Needs Statement and successfully guiding the program through the Milestone zero decision process. During his 22 year Naval career, he served on three LPD class ships. Mr. Carlile has an Analytical Management degree from the U.S. Naval Academy and a Masters degree in Education and Training from Old Dominion University.*

CAPT Kendall King USN (Ret) - *CAPT King is a Senior Analyst with American Systems Corporation supporting LPD 17 as part of the Design For Ownership Team. He manages the LPD 17 issues database and facilitates the DFO-waterfront interface through the LPD 17 War Room. During his 25 year Naval career, CAPT King served on 8 afloat commands including as pre-commissioning operations officer on USS WASP (LHD 1) and as commanding officer of USS FRESNO (LST 1182). He has earned graduate degrees in Education, Business and Management Information Systems and recently was honored with the Surface Navy Association's Literary Award (Honorable Mention) for co-authoring "Amphibious Redux" in the June 1997 Proceedings.*