BMP SYSTEMS ENGINEERING MODEL

USING

CONCURRENT ENGINEERING METHODS

10 YEARS OF ACQUISITION REFORM

REV 4.1

BMP

SYSTEMS ENGINEERING MODEL

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SECTION ONE

SYSTEMS ENGINEERING MODEL BACKGROUND

1.1 Best Manufacturing Practices (BMP) Program

The Best Manufacturing Practices (BMP) Program was established by the Navy in 1985 with the mission to collect, analyze and disseminate information on proven techniques used by the government and industry throughout the acquisition, development and field support process. Typically, this information is obtained via on-site surveys of a company's production lines and through meetings with development and production managers and personnel. The BMP Program has four main products: Best Practices Survey Reports, the Program Manager's Workstation (PMWS), WEB and Virtual Office services, and Systems Engineering work for Program Managers.

SURVEY REPORTS: After completion of a BMP survey, a report is developed which identifies best practices used by that company in design, test, manufacturing, and support of their products. The survey report is then distributed throughout the BMP user community. In addition, potential industry-wide problems are also documented (with the company's permission) and shared in an effort to encourage cooperation in solving these problems. One measure of the success of this program is the quantity and quality of design and manufacturing information shared between companies.

PMWS: After several years of successful BMP Program operation, it was determined that an improved and automated methodology was needed to collect, analyze and disseminate program and engineering process information. From this vision, the concept of a "Workstation" was pursued; and, since the information that was to be made available would be extremely valuable to Program Managers, the system was named Program Manager's Workstation (PMWS).

WEB SERVICES: The BMPCOE has a very capable web services group specializing in large database and back office support using CORBA, JAVA, and other effective technologies. The web-based virtual office, one of our top products, enables teams to work together from any web connection. These Virtual Offices are fully encrypted and utilize a self-managing architecture to significantly reduce costs.

SYSTEMS ENGINEERING: Our systems engineering support includs detailed metallurgical and material properties studies; hardware failure analysis; pedigree program development; and risk management. The Systems Engineering model is used heavily by this group in its support to Program Managers. The Systems Engineering Model represents the best of DoD and commercial practices, and is proving successful on military and commercial programs alike. Central to the PMWS expert systems, the model consists of a flowchart and supporting narratives that guide the user through all the critical technical processes. The flowchart shows key activities in the engineering process, as well as principal tools and guidance which the PMWS provides to assist the user. The narratives provide amplifying information on the flowchart's engineering process activities.

1.2 PMWS Philosophy - Workload Reduction

The Program Manager's Workstation (PMWS) is the pseudonym for a series of interrelated software environments and knowledge based packages designed to provide timely acquisition and engineering information to the user. Workload reduction is a top priority of the PMWS.

Typical project management programs, based on cost and schedule, used the graphical power of the computer to show the user numerous items on the screen at once. The power of these programs to display and "scroll" through data is enormous, and the graphical interface makes it very easy for the user to manipulate the data. However, these programs do little to reduce the workload on an already overworked manager/engineer. In fact, studies have shown that displaying large amounts of data tends to confuse the user instead of focusing on the critical items needing his attention. Rather than display large amounts of data, or even the entire critical path, the PMWS typically shows the user the one to five most critical items that should be addressed NOW!

1.3 Unique PMWS Capabilities

The PMWS is unique among existing program management "tools" and is meant to fill a long standing deficiency. Other tools (e.g., Microsoft Project) center mainly on cost and schedule indicators/relationships (typically, CDRL, WBS, or DoD 5000 oriented) and attempt to manage an acquisition based on their current (and sometimes projected) status. There are many good programs of this type on the market today and the PMWS is not attempting to duplicate their functions. While these tools do facilitate organizational plans and coordination, despite their use we continue to find acquisition programs failing during development and the transition to production.

1.4 Focus on Engineering Process

PMWS tools are centered on the engineering process itself, and therefore, are very process oriented. If all engineering processes are understood, proper, and under control, the results will be as good as the state-of-the-art will allow.

Cost and schedule are **downstream indicators** of technical problems (sometimes far downstream). This is why PMWS tools manage technical and process risks, so that engineering problems are surfaced and given visibility at the earliest possible point. In this way they can be addressed and mitigated before cost and schedule problems are indicated.

For example, if the risk management (TRIMS) portion of the PMWS indicates that your program has/is incurring a risk due to a Design Reference Mission Profile not being conducted; the user can go directly to the knowledge base (i.e., KnowHow and BMP Database) and get FULL details on why a Design Reference Mission Profile is needed and how to develop one, including metrics and examples. The PMWS will identify such problems early in the design process. However, non-technical (e.g., cost, schedule) tools will not expose the problem until well into the operational test and evaluation process. This is a typical example of how the PMWS can work for you.

The PMWS is a dynamic new tool that will:

(1) give you rapid access to the information you need to manage your program
(2) provide technical risk assessment for your specific program requirements
(3) show you successful industry solutions to reduce technical risk and improve quality and productivity.

The PMWS is a series of expert systems and decision assistance tools. It provides **knowledge**, **insight**, **experience**, and **communication** as an extensive network of information and software resources which are easily accessible through your PC.

1.5 Technology Transfer Nationwide

The automated, computerized, communication link connecting all BMP Program participants, including the network of PMWS users, is called, appropriately enough, BMPnet. Currently, BMPnet is used to facilitate communication between DoD components, Department of Commerce (DOC), Department of Energy (DOE), Federal Aviation Administration (FAA), DoD Centers of Excellence, and commercial companies. Program Managers can now communicate with each other and gain from each other's experience simply and easily when solving problems.

Other activities of the BMP Program include developing and publishing technical manuals and guideline documents, producing instructional videos, and working with the Navy/DoD Technical Centers of Excellence.

During the development of the PMWS, several BMPnet prototype testbeds were established to evaluate different system implementation concepts and designs. The one design, which we named BMPnet, proved very flexible and was established as an initial BMP system host during that study phase.

1.6 Systems Engineering Model

The Systems Engineering Model was developed as part of the PMWS to improve the collection, analysis, and distribution of engineering process information. The Systems Engineering Model includes of a flowchart that describes key engineering process activities, as well as their locations, interfaces, and timing with respect to other activities in the acquisition process. In addition, the flowchart blocks are keyed to assist the user to rapidly access a supporting narrative description, specific electronic tools, and related guidance items from PMWS.

Two significant additions were made in this version of the Systems Engineering Model. They are the Technology Maturation Loop and the Process Maturation Loop. These loops describe events that require repetitive processes, rendering traditional program management schedule tools ineffective. Section Four contains additional narrative for these loops (block numbers 61 and 72 respectively) as well as a separate discussion in Section Five.

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SECTION TWO

BEST MANUFACTURING PRACTICES CENTER OF EXCELLENCE (BMPCOE) SYSTEMS ENGINEERING MODEL

2.1 Acquisition Reform

The Systems Engineering Model is a direct outgrowth of the PMWS expert systems. It contains the results of the best of DoD and commercial practices. The application of the flowchart contained within the model is proving successful on military and commercial programs alike. It is compliant with the DoD 5000 series, NAVSO P-6071, DoD 4245.7-M, and NAVSO P-3679. It is invaluable for helping individuals involved at any point in the acquisition process, including the application of Non-Developmental Item (NDI), now that they are not omitting any critical technical processes.

The flowchart, used with PMWS, identifies specific PMWS template topics much as an electronic consultant. Intelligent search routines improve access to automated information by up to 95%. PMWS is a stand-alone system and can be run on any PC or network under Windows.

The flowchart contains blocks that show key engineering process activities. These blocks are in sequence to show their location, interfaces, and timing with respect to other activities and the overall acquisition process. Under the blocks, in a black background, are additional tools and guidance items that directly support that block. Information on these and other related items is easily accessed on a computer by activating the powerful search option at the bottom of the computer screen. In addition, each block in the flowchart has a supporting narrative description of its role in the acquisition process. These narratives can be selected by number from the main flowchart menu screen. A copy of the flowchart is in Section 3.0 and copies of the narratives are contained in Section 4.0 of this document.

2.2 Point of Contact Information

For PMWS or BMPnet technical assistance, call the help desk at (301) 403-8179. For additional information on the BMP Program, contact the BMP Center of Excellence at (301) 403-8100.

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SECTION THREE

BMPCOE
SYSTEMS ENGINEERING MODEL FLOWCHART

3.1 Introduction

This section is intended to familiarize the user with the Systems Engineering Model Flowchart. The flowchart process blocks use identification numbers on the LEFT and RIGHT sides of the process blocks to identify initial applications, as well as specific critical inputs. The numbers on the LEFT of the block indicate the initial application of that process. The numbers on the RIGHT of the block indicate a previously referenced process with specific critical inputs needed for that block. In addition to the identification numbers and for the user's convenience, PMWS template Name/Topics are identified below the process blocks. These Name/Topics can be found in the PMWS and provide specific topics and tools that can help you effectively conduct the applications.

As an example, Figure 1 on page 3-2 has been extracted from the actual flowchart. This example will familiarize you with the process block numbering system described above.

The following narrative describes how the numbering system is used to identify process blocks in the flowchart.

- Block numbers 42 through 47 have numbers on the upper LEFT. That indicates this is the first time you have seen this activity, and introduces a new process application.

- Three other blocks (Generate Final Spec Tree, Generate Detail Hardware Level Breakdown, and Update LCC/Logistics Analysis) have no numbers on the upper LEFT. That indicates that you have previously seen this activity.

- Block 44 (Draft Software User's Manual) has a number on the upper LEFT, indicating this is the first time you have seen this activity. This block also has numbers on the upper RIGHT, indicating previously referenced processes with specific critical inputs needed to conclude this activity.

- Five blocks (Perform Human Factors Analysis, Perform ID/T Analysis, Generate Final Spec Tree, Update LCC/Logistics Analysis, and Establish Supplier Requirements) identify specific PMWS Template topics and tools in obverse (black on white printing) that can help you.

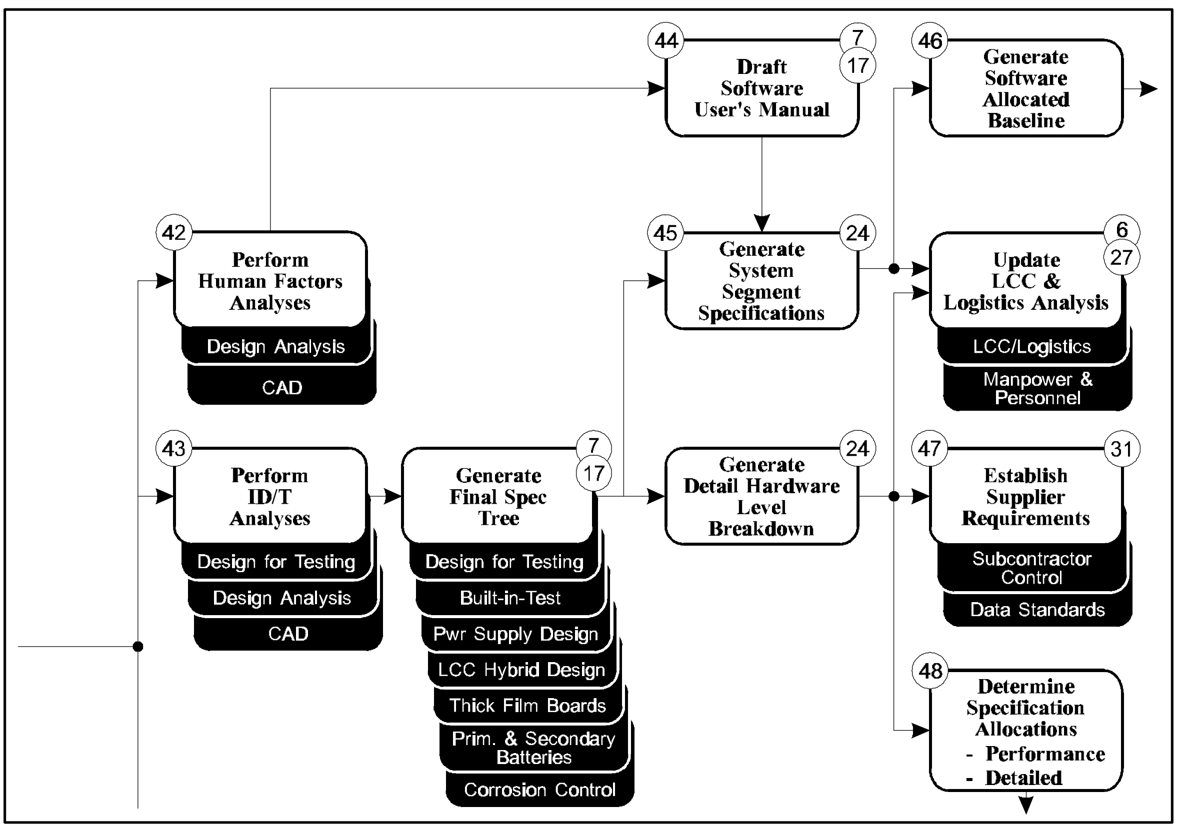
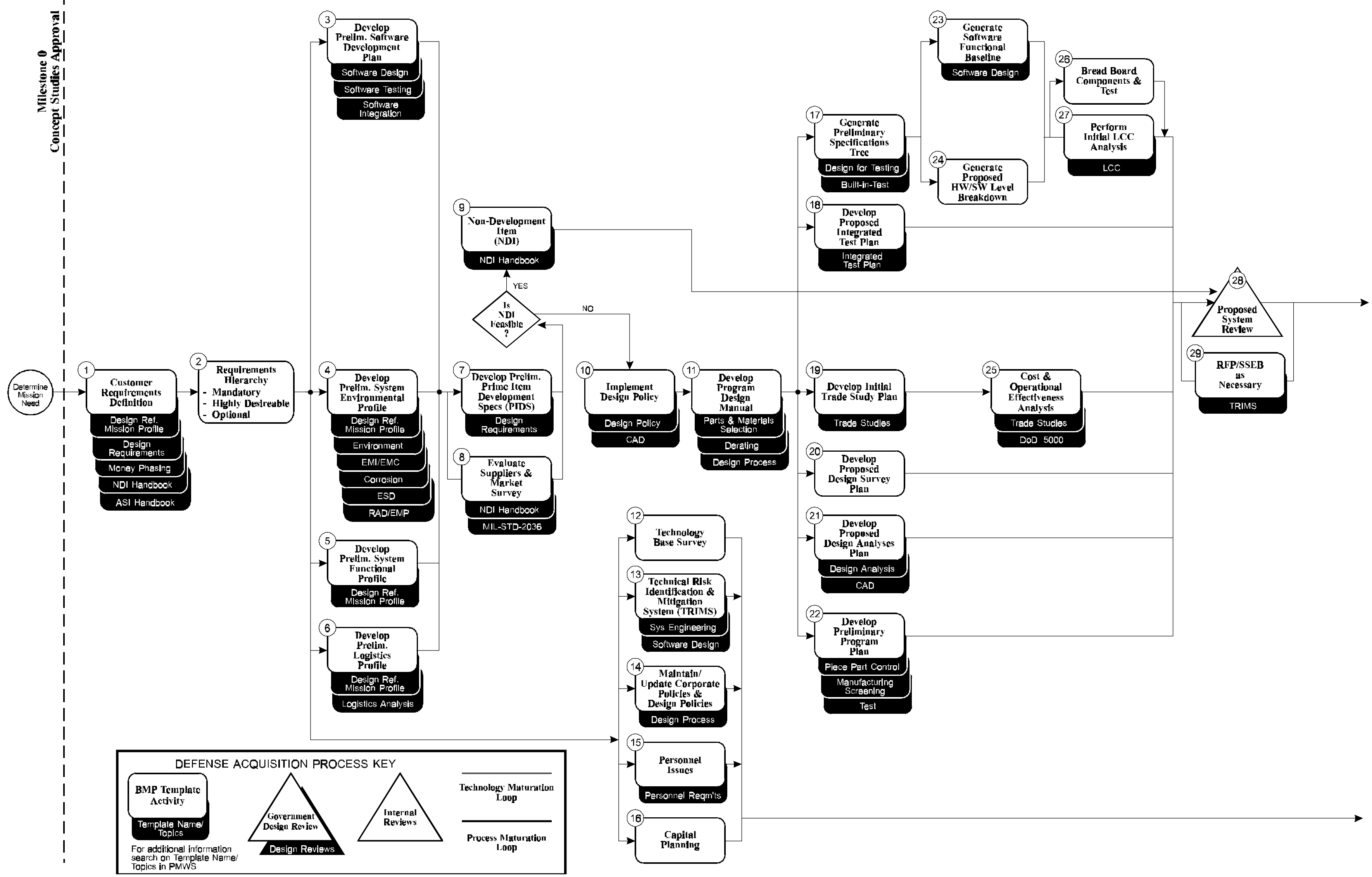


Figure 1 - Sample Process Block Identification

3.2 Flowchart

The following pages contain the complete Systems Engineering Model Flowchart.

Phase 0: Concept Exploration



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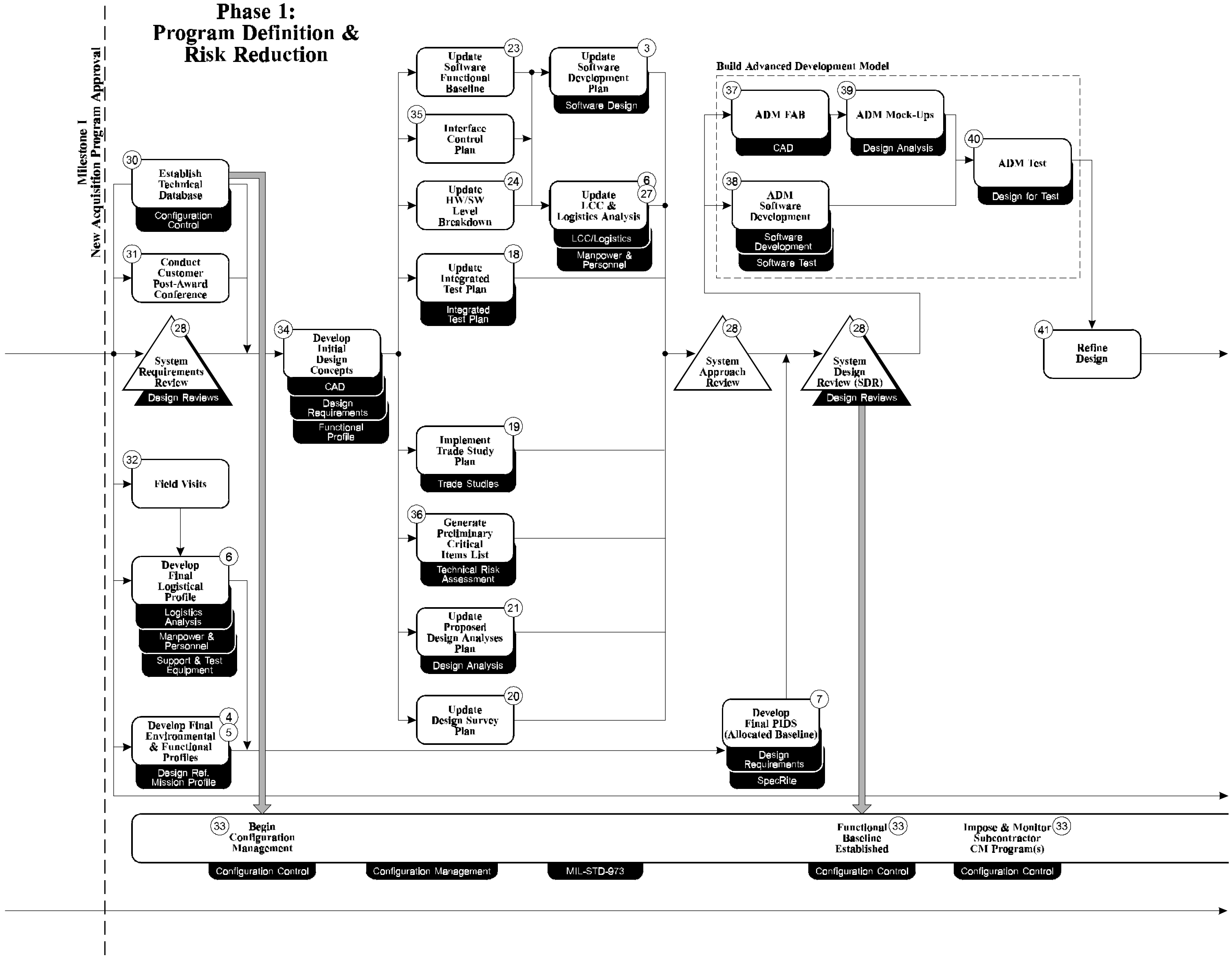
Phase 1: Program Definition & Risk Reduction



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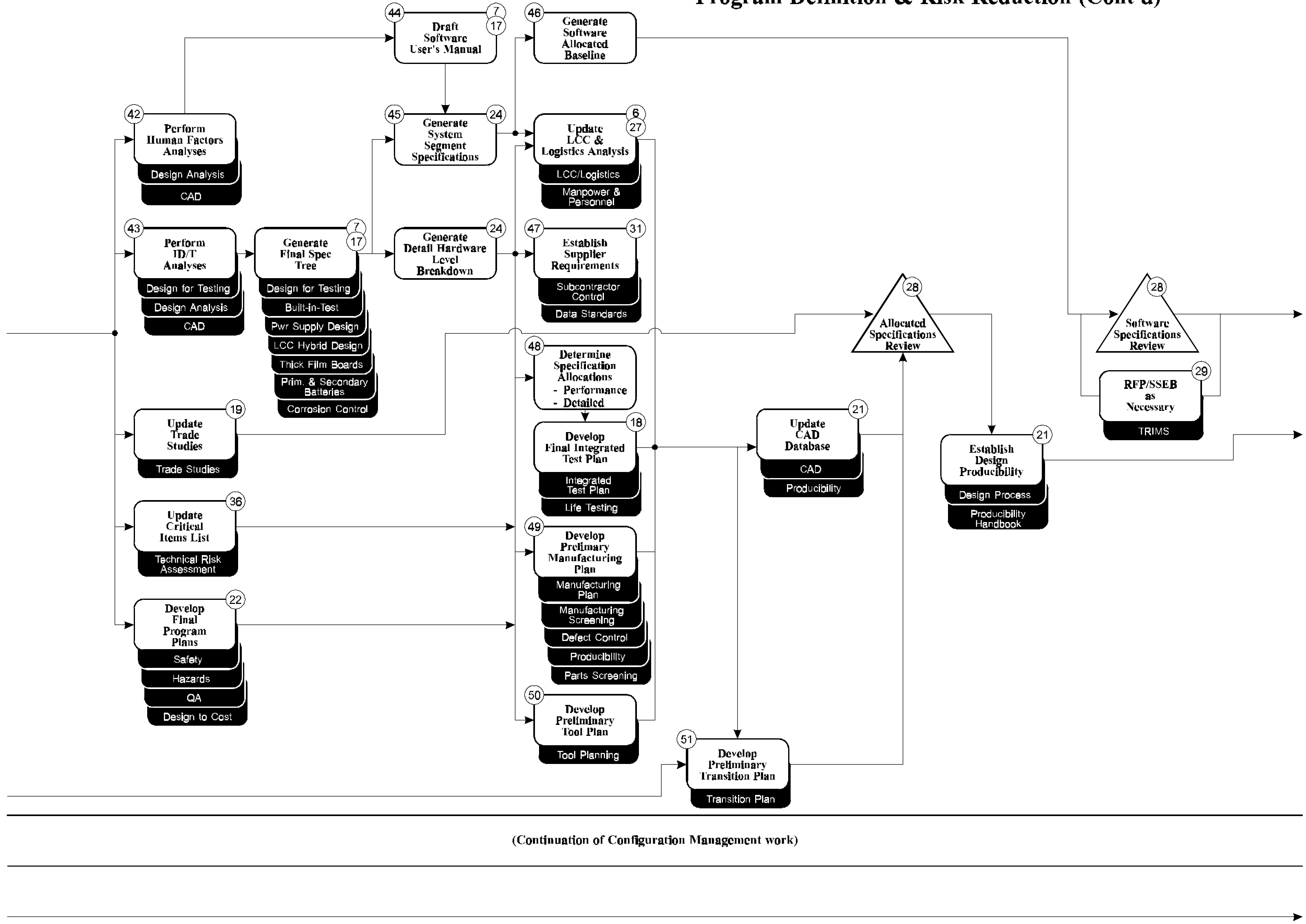
Phase 1:
Program Definition & Risk Reduction (Cont'd)



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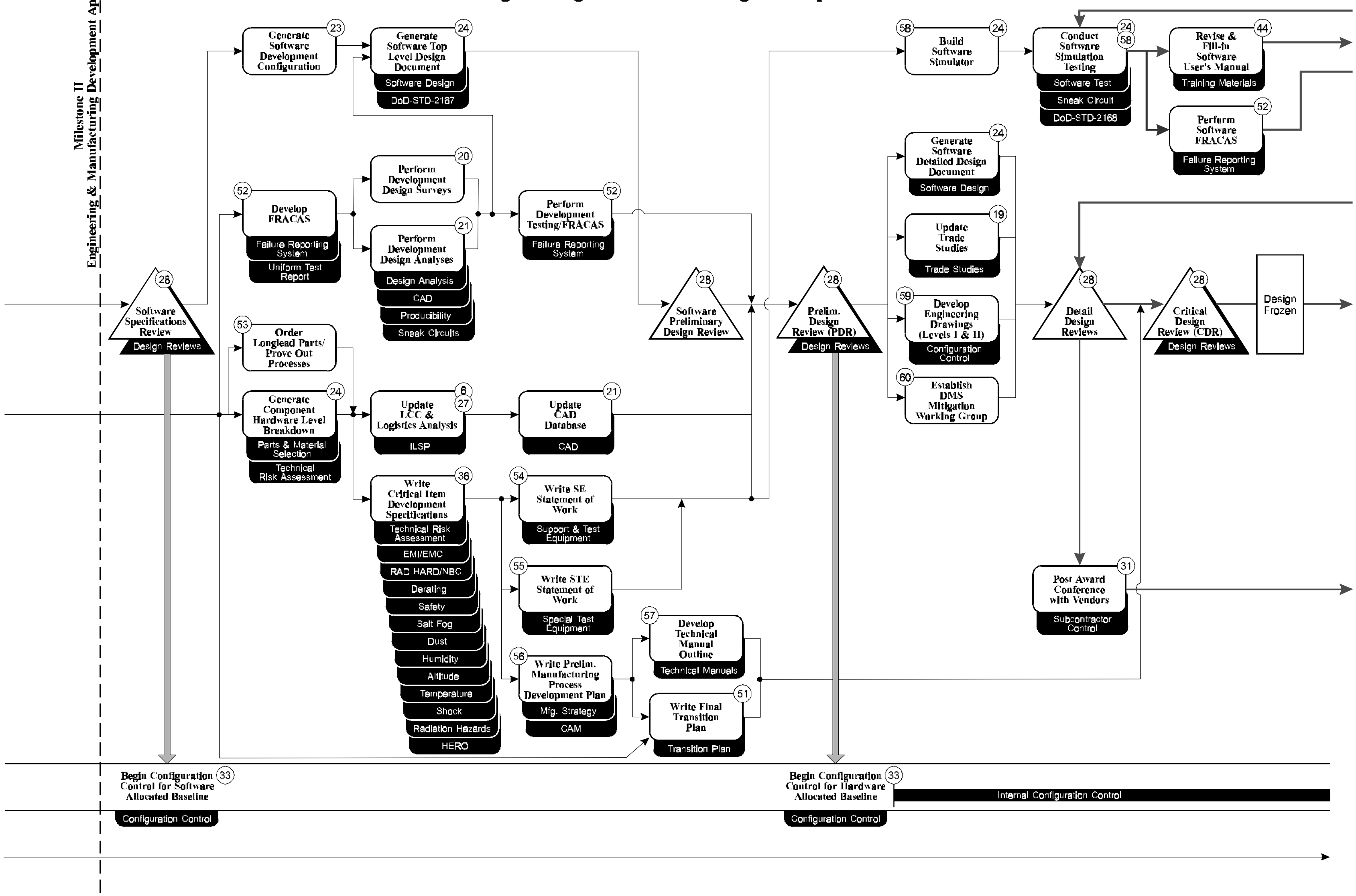
Phase 2:
Engineering & Manufacturing Development



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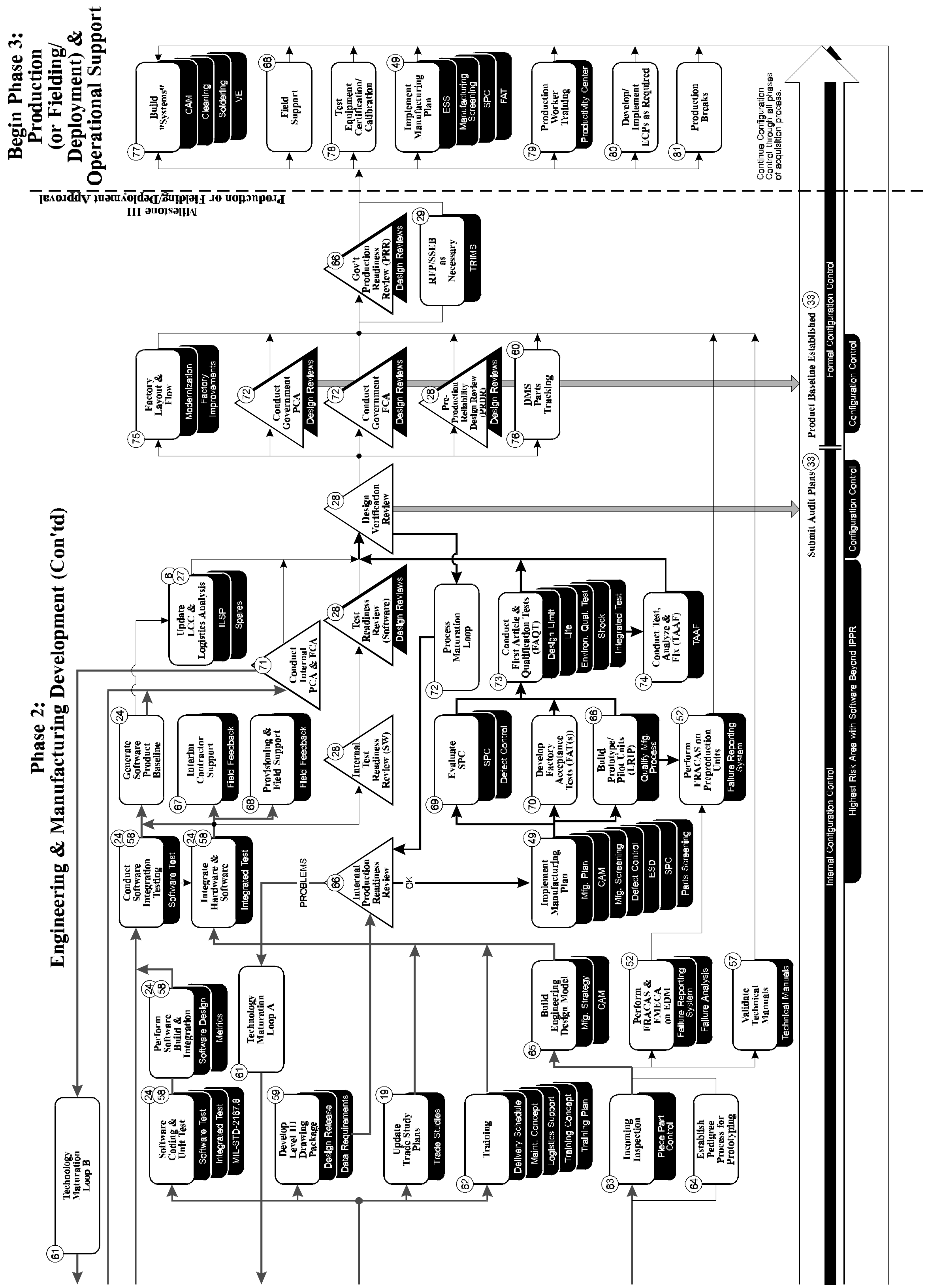
Phase 2:
Engineering & Manufacturing Development (Con'td)
Begin Phase 3:
Production
(or Fielding/
Deployment) &
Operational Support
Milestone III
Production or Fielding/Deployment Approval
Technology Maturation Loop B
Software Coding & Unit Test
Software Test
Integrated Test
MIL-STD-2167/8
Perform Software Build & Integration
Software Design
Metrics
Technology Maturation Loop A
Develop Level III Drawing Package
Design Release
Data Requirements
Update Trade Study Plans
Trade Studies
Training
Delivery Schedule
Maint. Concept
Logistics Support
Training Concept
Training Plan
Incoming Inspection
Piece Part Control
Establish Pedigree Process for Prototyping
Build Engineering Design Model
Mfg. Strategy
CAM
Perform FRACAS & FMECA on EDM
Failure Reporting System
Failure Analysis
Validate Technical Manuals
Technical Manuals
Conduct Software Integration Testing
Integrate Hardware & Software
Internal Production Readiness Review
PROBLEMS
OK
Implement Manufacturing Plan
Mfg. Plan
Mfg. Screening
Defect Control
ESD
SPC
Parts Screening
Generate Software Product Baseline
Interim Contractor Support
Field Feedback
Provisioning & Field Support
Internal Test Readiness Review (SW)
Evaluate SPC
Develop Factory Acceptance Tests (FAT(s))
Build Prototype/Pilot Units (LRIP)
Qualify Mfg. Process
Perform FRACAS on Preproduction Units
Update LCC & Logistics Analysis
ILSP
Spares
Conduct Internal PCA & FCA
Test Readiness Review (Software)
Design Reviews
Process Maturation Loop
Conduct First Article & Qualification Tests (FAQT)
Design Limit
Life
Environ. Qual. Test
Shock
Integrated Test
Conduct Test, Analyze & Fix (TAAF)
TAAF
Design Verification Review
Factory Layout & Flow
Modernization
Factory Improvements
Conduct Government PCA
Conduct Government FCA
Pre-Production Reliability Design Review (PRDR)
DMS Parts Tracking
Gov't Production Readiness Review (PRR)
RFP/SSEB as Necessary
TRIMS
Build "Systems"
Cleaning
Soldering
VE
Field Support
Test Equipment Certification/ Calibration
Implement Manufacturing Plan
Manufacturing Screening
FAT
Production Worker Training
Productivity Center
Develop/ Implement ECPs as Required
Production Breaks
Continue Configuration Control through all phases of acquisition process.
Submit Audit Plans
Product Baseline Established
Formal Configuration Control
Configuration Control
Internal Configuration Control
Highest Risk Area with Software Beyond IPPR

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SECTION FOUR

FLOWCHART SUPPORTING NARRATIVES

4.1 Narratives

The following narratives provide additional information on each block in the Systems Engineering Model Flowchart. They are numbered as they appear in the flowchart. When the Systems Engineering Model is installed on your Personal Computer (PC), you can access the narratives simply by selecting the corresponding block number and title in the main flowchart menu.

1. Customer Requirements Definition

These three areas - design reference mission profile, design requirements, and funding are basic responsibilities of the customer and must be derived from a determination of mission need. Failure to adequately define the design mission profile, adequately state design requirements, or provide sufficient up front funding will adversely affect the program for its entire life cycle.

2. Requirements Hierarchy

Requirements are not all equal and the establishment of a hierarchy from the outset is critical for effective design, trade, and cost studies. All requirements should be assigned to one of three categories: Mandatory, Highly Desirable, and Optional.

3. Software Development Plan

The Software Development Plan includes the development and testing of software. The software test plan is generated as part of the software development plan and is completed prior to the start of coding. Design and test disciplines are inputs to the software test plan.

The software test planning activity includes plans for the building, use, and maintenance of a software simulator and produces data that allows completion of the software user's manual. The performance of software coding, unit test, software build, and software and software/hardware integration testing is described in the software development plan. Software development is integrated with prime equipment development as practical.

4. System Environmental Profile

MIL-SPEC environments are reviewed, analyzed, and tailored to describe the system's production, operation, and support environments versus time. The minimum operating and non-operating requirements addressed are: temperature, vibration, Electromagnetic Interference/Electromagnetic Pulse (EMI/EMP), Electrostatic Discharge (ESD), humidity, altitude, salt spray/fog, Nuclear, Biological, Chemical (NBC), sand/dust, Foreign Object Damage (FOD), and production contaminants. Analyses should also qualify environmental differences between new requirements and similarly deployed in-service equipment.

5. System Functional Profile

Describes prime equipment functional requirements (addressing both operational and production requirements) versus time (both mission and life cycle). First or Second Level Functional flow block diagrams are normally developed to give project management personnel an overall functional perspective.

6. Logistics Profile

Developed to represent a system's total life cycle logistical environment. Special attention is paid to both operator-related and maintenance-related human factors and maintainability needs. Addresses, at least:

- Definition and analysis of Operability and Supportability (O&S), e.g., available manpower skills, best maintenance concept, trouble report system.
- Development of a design constraints/goals list following O&S analysis, field observations and comparison with similarly deployed systems.
- Development of an ILS Plan.
- Development of a Military Manpower/Hardware Integration Program (HARDMAN) Plan.

7. Prime Item Development Specifications (PIDS), Allocated Baseline

Converts environmental, logistical, and functional profile requirements (including in-house production needs) into a prime item development specification. Should address electrical, mechanical, and software requirements; operating and non-operating environments, support constraints and production needs. These requirements should then be allocated to each subassembly.

8. Supplier Evaluation/Market Surveillance

Suppliers must be evaluated in terms of financial stability and history of delivering quality products and services. The market must be surveyed to see what the current technical base has "off-the-shelf" and what it can be expected to develop and produce. This evaluation should identify a list of potential suppliers to engineering.

9. Non-Development Item (NDI)

A Non-Development Item covers material available from a wide variety of sources with little or no development effort required by the Government. NDIs include:

- Any item of supply that is available in the commercial marketplace.
- Any previously developed item of supply that is in use by a department or agency of the U.S., a state or local government, or a foreign government with which the U.S. has a mutual defense cooperation agreement.

- Any item of supply described above that requires only minor modification in order to meet the requirements of the contracting agency.

- Any item of supply that is currently being produced that does not meet the requirements of the items described above solely because the item is not yet in use or is not yet available in the commercial marketplace.

The application of NDI to an acquisition should be viewed as a matter of degree rather than an all or nothing proposition. As the extent of NDI utilized in an acquisition increases, development cost and time are reduced. Many NDI opportunities require modifying an existing item (e.g., ruggedize, militarize) and incorporating NDIs into larger elements of a system.

A predominant use of NDI is related to the insertion of NDI at subsystem, equipment, component, and piece part levels in major developmental programs. These opportunities should be explored as part of system engineering and system integration processes. The use of NDI in satisfying approved operational requirements could involve a combination of items (e.g. commercial, individual or joint service, foreign, or standard DoD) coupled with and integrated into a significant developmental effort.
The major benefits of NDI acquisitions are:

- Quick response to operational needs.

- Elimination or reduction of research and development costs.

- Application of state-of-the-art technology to current requirements.

- Reduction of technical, cost, and schedule risks.

10. Design Policy

A corporate statement supported by controlled engineering manuals, procedures, and guidelines. This Design Policy should be visible and followed with check points to validate compliance, and tailored to a specific project or product area.

11. Program Design Manual

A program design manual, developed and introduced to the design team before the start of design, should address such issues as producibility guidelines/standards, parts selection and derating, testability guidelines, and other design requirements for compliance. The manual should be approved by management, and should be part of each designer's required documentation. Compliance with the manual is verified and documented at each design review.

12. Technology Base Survey

An important early study is of the capabilities of the U.S. industrial bases vers product requirements. Will special custom tooling need to be made? Who has done this before and with what variability. Is there adequate availability of raw materials. How mature are the technologies needed to build your product and how many single source suppliers will you have? These and other similar issues need to be resolved and used as input to the trade studies process.

13. Technical Risk Identification and Mitigation System (TRIMS)

TRIMS is one of the PMWS suite of tools. TRIMS currently supports risk management in three (3) separate functional areas: Systems Engineering, Software Development and Circuit Testability. In addition to a technical risk management system, TRIMS will also "rollup" several risk assessments into higher level reports. It is also an excellent action item tracking system.

14. Corporate Policies and Design Policies

Corporate policies and procedures are the heart of a continuous process improvement program; unless a process is baselined and tracked, it is impossible to know whether or not you are improving or declining. Also, without clear policies and procedures, employees do not know what is expected of them, or how to get ahead.

The design process, supported by design policies, describes all the actions taken that culminate in a set of drawings or a database from which a model can be constructed for testing to verify specification compliance. Design criteria are developed and proven before EMD, and may be updated and refined as experience is gained during development. Production design occurs concurrently with the other elements of the design process.

15. Personnel Issues

Despite the automation in factories today, people still design and assemble the lion's share of any product. Companies must know how to identify and retain their key personnel, as well as allow a path for all ideas to flow freely upward from the workforce. Typical management channels have proven ineffective in this area.

16. Capital Planning

Capital planning is critical if an organization is to remain competitive. Capturing and maintaining a business base is more than just a statement on a business plan demanding "15% growth." Markets must be analyzed and proper investments made to penetrate or maintain your business base.

17. Specifications Tree

Based on PIDS, a complete set of specifications including system, hardware/software interfaces, reliability/failure rate, testing, and functional requirements are developed down to the Shop-Replaceable Assembly (SRA) level. BIT allocations/requirements are defined at each level.

18. Integrated Test Plan (ITP)

A complete ITP is developed and maintained, addressing, for example, all development, qualification, and acceptance testing to be performed by the company, subcontractors, and the government, Development Test and Evaluation (DT&E) and Operational Test and Evaluation (OT&E), support equipment/special test equipment evaluation, and acceptance testing. The ITP also identifies critical test resources and schedule constraints, missing and redundant test efforts, and documents use of similarity of design to justify lack of testing. This plan requires government approval and calls for as much government participation in testing as is practical.

19. Trade Study Plan

A broad spectrum of trade studies is initiated during concept exploration. These trade studies continue into engineering and manufacturing development as a logical approach to selecting the best design, once the mission profile and design requirements have been specified. The final selection and fine tuning of the design approach must consider such factors as producibility, operational suitability, performance, obsolescence, cost, risk, schedule, alternatives, and technology assessments.

20. Design Surveys

Surveys include Stress/Strength, Worst Case Tolerance, Thermal, and Vibration. Surveys are scheduled, performed, and the results stored and checked against program Design Manual criteria to ensure compliance with program requirements. Surveys are scheduled to allow time for interpretation and proof of correction; surveys are redone to verify corrective action or when there is a significant test parameter change.

21. Design Analyses

Required analyses: Stress/Strength, Worst Case Tolerance, Sneak Circuit, FMECA/FMEA, Thermal, Logistics, System Safety, and Integrated Diagnostics & Testability (ID/T). Others (e.g. Fault Tree, mass properties) are performed as needed. All results are documented and maintained throughout the program's life. The results are checked against the program's Design Manual criteria to ensure compliance with program requirements. Analyses are scheduled and performed to support the design effort and agenda of design reviews. Computer-Aided Design/Computer-Aided Engineering tools are used to perform analyses whenever possible. Design updates will be documented using CAD/CAE when possible.

22. Program Plans

Plans (e.g. safety, reliability, testability, human factors, compatibility assessment) address performance parameters which are proven during System Qualification Testing. Items on the list address specific system needs and may show up as deliverable data items. Project management decides which plans will be developed and maintains written justification for excluding any plan. Plans are released and government-approved as part of the Transition Plan.

23. Generate Software Functional Baseline

Formal Configuration Management (CM), which includes Software Functional Baselines (FBLs), is mandated by the customer after customer-approved baselines are established. For example, formal CM begins at contract award for any existing system specifications called out in the contract. However, the system specifications may not always be provided with the contract; occasionally, the contractor is required to develop or update this specification. These specifications and the system-segment specifications, if any, constitute the Functional Baseline (FBL).

The FBL is approved documentation describing a system's or item's functional characteristics and the verification required to demonstrate the achievement of those specified functional characteristics. FBLs shall be initially entered into the Government's configuration status accounting information system, by means of a Government-approved Engineering Release Records (ERR) system.

24. Level Breakdowns for Hardware and Software (HW/SW)

Various HW/SW level breakdowns are developed at different stages in the design process to give project management personnel top-down and bottom-up perspectives on how the system physically comes together. Each level breakdown must reflect agreement among design, production and manufacturing, software, and logistics disciplines; plus reflect contract requirements and specifications as they are understood by the contractor and the government at that time. Component level breakdowns serve as the basis for writing critical item development specifications. Functional, allocated, and product baselines are generated to provide inputs to the life cycle cost analysis and configuration control mechanism.

25. Cost and Operational Effectiveness Analysis

A Cost and Operational Effectiveness Analysis provides assistance in determining the relative importance of alternatives. It does this by providing a solid framework for evaluating the alternatives, and by highlighting the implications of alternative choices. In that regard, it is essential to:

- Compare equal-cost or equal-effectiveness alternatives.
- Show the absolute values of measures by making the facts available and visible for each alternative.
- Never use schemes in which several measures of effectiveness are weighted and combined into an overall score.
- Use ratios only where appropriate. Ratios may ignore sufficiency and mask important differences.
- Point out dominance relationships.
- Identify the more effective alternatives that are roughly equivalent in cost, and the less costly alternatives that are about equal in effectiveness.
- For alternatives with comparable costs and effectiveness, identify those that are weaker with regard to the more important (or more frequent) objectives, and those that incur risks without producing compensating benefits.

- Highlight factors that may help in ranking the remaining alternatives.

- Reexamine the base case alternative in light of the new insights. It may well be better than was first perceived, or it may have turned out to be such a poor choice as to make otherwise unattractive alternatives quite appealing.

26. Bread Board Components and Test

Bread board hardware is the first implementation of the design concept in hardware. The intent of this early hardware is to prove the feasibility of the conceptual design. Form and fit considerations are not addressed, only function. The components are usually commercial grade, or whatever is available to perform the function. The completed bread board is tested in-house and at various facilities to demonstrate feasibility.

27. Life Cycle Cost (LCC) Analysis

Life Cycle Cost (LCC) Analysis is a tool used to incorporate design, operation, and support cost impacts into the design process. In addition, all modernization activities will be checked with LCC.

LCC is also an analysis tool that is used to view a product and its support system from an economic standpoint during the design process. LCC analyses address the following items:

- Research
- Development
- Production
- Operation
- Maintenance
- Phase Out
- Modernization

LCC tradeoffs are traceable back to customer requirements via interplay between the specifications tree, level breakdown, and LCC analyses.

The LCC process is repeated whenever any of the factors affecting product design or support change.

28. Reviews

Internal and government required reviews are scheduled for hardware and software; government required reviews are conducted per MIL-STD 1521. Agendas include all company and government concerns. A review should NOT be scheduled before the activities supporting its objectives have been completed. Technical issues are presented in a manner that match the audience's technical expertise and fosters understanding. All disciplines that play a role in the transition to production should have input to the reviews.

29. Request For Proposal (RFP) and Source Selection Board (SSEB)

A Request For Proposals (RFP) is prepared and sent to industry so the buyer can determine which company's approach represents the best value to them (or with only a single supplier, it details what the buyer can expect). A Source Selection Evaluation Board (SSEB) is established which develops a plan to evaluate the proposals submitted to the buyer(s) in response to the RFP.

30. Technical Database

A technical database is established at the time of contract award and maintained by configuration and data management personnel. It contains such information as MIL-SPECS, PIDS and Spec Tree (and related profiles), data deliverables, program memos/reports, information for design reviews and PRR. All relevant items are included in the database when available and updated when appropriate. Database information should all be current prior to each internal and government required design review.

31. Post Award Conferences

There are two types of post award conferences:

- A customer conference follows the proposed system review. The purpose is to discuss technical and funding/provisioning issues, schedule field visits, and agree on program schedule.

- A supplier (subcontractor) conference follows a detail design review. The purpose is to verify all appropriate contract requirements, inform/remind suppliers of incoming inspection policy, introduce suppliers to individual points of contact in the company, and discuss quick reaction capabilities.

32. Field Visits

Field visits are conducted to gain first hand experience about how and where the system will be used and maintained and to identify operational constraints. At least one visit should be conducted; if radically different deployment sites exist, each should be visited. Field visits should occur early enough to impact logistics profile requirements and PIDS.

33. Configuration Management

As customer-approved baselines are established, the scope of configuration control increases. Upon establishment of the product baseline, formal configuration control, including configuration audits, requires customer approval. Prior to this, the only changes requiring customer approval are those affecting approved specifications. The Configuration Control Board (CCB) integrates all functional areas to effectively evaluate proposed change impact and approve or disapprove changes.

34. Design Concepts

Design concepts identify all reasonable system alternatives (architectures and support methodologies) that may satisfy the mission need and include recommendations to the program office. The program manager then selects those alternatives or concepts which meet cost, risk, schedule, and readiness objectives. Since the use of Computer Aided Design (CAD) technology is a significant factor in reducing the risk in development projects, the use of CAD technology should be encouraged.

A design concept will evolve into the design process that includes continuous trade-offs.

35. Interfaces

Shortly after the architecture of a product is chosen, the interfaces within and outside the product must start to be finalized and put under configuration control.

36. Critical Items List

A critical items list is developed and continuously maintained. The list must include: any item of high technical risk with no work around, any item with a schedule delivery risk, all sole source items, all high-failure-rate items (connectors and cables are automatically listed), Critical Item Development Specifications, and all Safety-of-Flight material. Trade studies and lessons learned are incorporated to ensure all critical items are identified at appropriate stages for consideration by program management.

37. Advanced Development Model (ADM) Fabrication

Advanced Development Model fabrication provides the first time the product team can determine what was right and what was wrong from their modeling and simulation efforts.

38. Advanced Development Model (ADM) Software Development

Today, software development represents an ever-increasing part of the development process. CASE tools must be chosen and evaluated for the full scale development process. Key Factors at this time include:

- What exception conditions, violation limits, and capacity limits have been taken into account?
- What modifications are needed as a result of preliminary prototype testing?
- What percentage of the software can be reused from earlier systems?
- How many standard and off-the-shelf software components are estimated for the final system?

39. Advanced Development Model (ADM) Mock-ups

Mock-ups are an important part of early development to review ergonomics and equipment placement.

40. ADM Tests

Tests of an ADM have different goals than tests later in development. ADM tests should validate design assumptions and tools as well as the product itself.

41. Refine Design

Information gathered from the ADM development and test process is used to further refine the design.

42. Human Factors Analyses

Incidental to the ILS program, the Logistics Analysis and manpower requirements must be determined early in the Program Definition & Risk Reduction phase. These analyses affect the system design while also providing accurate information for use in planning manpower availabilities and skill levels. The analysis incorporates human engineering design criteria, principles, and practices to successfully integrate the human into the system, subsystem, equipment, and facility. They permit optimum compatibility between human performance and system or equipment requirements for checkout, operation, maintenance, or control. The results are also helpful to establish user procedures and avoid excessive, or inappropriate manpower or skill problems.

43. Integrated Diagnostics/Testability (ID/T)

Achievement of Diagnostic and Testability features results from early and clear requirements definition to the designer. This effort specifically screens the design and looks for cost-effective use of BIT, ATE, and manual testing. Effective analyses will ensure that assembly, integration, acceptance, performance, diagnostics, and maintenance testing are all considered within this scope. This effort also ensures that producibility is included in the design process, utilizing proven manufacturing processes.

44. Draft Software User's Manual

Coding and related software development activities should be focused on top-level requirements. Begun after human factors analysis, a draft SW user's manual is completed prior to the start of coding, deriving elements from PIDS, Spec Tree, and system segment specifications. The manual provides other disciplines with insight into software requirements, the efforts being made to meet them, and how these efforts relate to their own activities.

45. System Segment Specifications

Just as the Spec Tree and associated requirements must be developed down to the lowest replaceable assembly level, so must the H/W and S/W breakdowns flow continuously down to the piece-part or code levels. This event identifies the requirement for each segment specification to be developed fully, reflect agreement with other segment specifications, as well as agreement among the various disciplines incorporated within the segment specification. This event represents one formal stage in completing the total system design.

46. Software Allocated Baseline

The Software Allocated Baseline is the initially approved documentation describing the software's functional, interoperability, and interface characteristics. These characteristics are allocated from a system or higher level configuration item, interface requirements with interfacing configuration items, additional design constraints, and the verification required to demonstrate the achievement of those specified characteristics.

47. Supplier/Subcontractor Requirements

All specifications, SOW, etc., for goods and services are established and documented, reflecting all requirements necessarily imposed either by the prime contract or company policy. One dedicated specifications group is used to ensure completeness and consistency of specifications, procurement packages, technical interfaces and imposed requirements.

48. Determine Specification Allocations

A review must be conducted to determine how the design or product will be tested and proven to meet customer needs. The goal is to use as high a level of performance specifications as possible to allow the contractor maximum flexibility in achieving the desired goal. However, many times it is hard to impossible to test a requirement through a performance test; these requirements should be specified using a detailed specification. This specification should call out any critical processes that must be followed, special materials to be used, and assemble techniques needed to ensure product integrity.

49. Manufacturing Plan

All actions required to produce, test, and deliver acceptable systems on schedule and at minimum cost should have been defined in the manufacturing plan. Hence, the materials, fabrication flow, time in process, tools, test equipment, plant facilities, and personnel skills are described and integrated into a complete sequence and schedule of events. It is essential that both prime contractor activities and subcontractor activities be included in the sequence and schedule of events.

Additional aspects to be incorporated into the Manufacturing Plan include the extent of computer-aided-manufacturing, electro-static discharge protection, environmental stress screening, subcontractor and factory acceptance and qualification testing, and provisions for statistical process controls. Early recognition and selection from these options will permit orderly assignment of responsibilities and the evolution of a best manufacturing strategy, with low risk and costs.

50. Tool Plan

A tool plan identifies program tooling requirements, including a tool inventory control system, and integrates the design and control of tooling with the prime equipment development. Its objective is to ensure adequate tool planning and control throughout the design and production phases. The tool plan is separate from the manufacturing plan but is integrated into and updated with the Transition Plan.

51. Transition Plan

The Transition Plan (from development to production) is developed as part of the program plan and serves as a guideline to reflect an integrated corporate strategy for the program. It begins following contract award, implemented during Engineering and Manufacturing Development (EMD), and is not complete until approved by upper management and reviewed by the government. The plan may use DoD manual 4245.7-M and will contain mechanisms to allow evaluation of the program's progress and compliance with the plan.

52. Failure Reporting Analysis and Corrective Action System (FRACAS)

The main objective of a closed-loop FRACAS is to document failures, analyze their cause, determine corrective actions, and disseminate the data. Timely dissemination of accurate failure information is necessary for remedial actions to be taken to prevent failure recurrence. FRACAS is complete only when "all failures have been identified and corrected;" no failures may be considered random, and all failures are reported, analyzed and corrected.

53. Long Lead Parts/Prove Out Process

While many program managers understand the need to order long lead parts and materials, very few understand the need to prove out "long lead" processes so that they will be mature at production time.

54. Support Equipment (SE) SOW

The objective of this activity is to ensure support equipment planning and development requirements will be defined concurrent with design requirements and communicated to suppliers.

This activity ensures that SE planning and development activities are defined and communicated to suppliers together with system requirements. Additionally, such timely definition enables system design and user communities to reassess the design where negative SE impacts emerge.

55. Special Test Equipment (STE) SOW

The objective of this activity is to ensure special test equipment planning and development requirements will be defined concurrent with design requirements and communicated to suppliers.

This activity ensures that STE planning and development activities are defined and communicated to suppliers together with system requirements. Additionally, such timely definition enables system design and user communities to reassess the design where negative STE impacts emerge.

56. Manufacturing Process Development Plan

The goal of this plan is to determine the best manufacturing strategy (i.e., one that provides low manufacturing risk and lower costs) by achieving a balance between proven manufacturing processes and newer techniques. Critical manufacturing processes are identified and agreed upon by engineering and manufacturing personnel who are ideally collocated during development. No manufacturing should take place until processes developed for the program are mature enough to support it.

The following major items are considered in support of the Manufacturing Process Development Plan:

- Schedule
- Budget
- Hardware Utilization Mix
- Capital Procurement
- Risk Management Plan
- Manufacturing Plan/Strategy
- Make/Buy Plan (Including updates)
- Transition to Production Plan (Including updates)
- Manufacturing Technology Capabilities Assessment
- Subcontract Management Plan
- Test Equipment Approach/Goals
- Major Subcontractor Selection

57. Technical Manuals

A complete set of technical manuals is developed concurrent with HW/SW development. Ideally, manufacturing process development is integrated with technical manual development. Responsibilities for technical manuals are outlined in the Integrated Logistics Support (ILS) plan and maintenance tasks are identified via Logistics Analysis. Outlines are submitted to the government for review and comments prior to final publication; interim versions are available for training course development.

58. Software Simulator

A simulator is built, used, and maintained throughout the program's life for software simulation testing. A software top-level design document is completed prior to, and includes a plan for the simulator build. The simulator is completed before software simulation testing can begin.

Software simulators should be considered and requirements developed during the planning and requirements phase to effect a significant item of risk reduction during test implementation, especially for large systems. This will ensure that applicable metrics, standards, and responsibilities for their implementation are assigned in a timely manner. Simulators also provide potential benefits by defining integration issues, and can identify the probability and impact of unwanted latent paths or timing which may be considered for sneak circuit analysis.

59. Engineering Drawings (Level I & II)

A complete technical documentation package may be a contract deliverable for hardware to be purchased by the government. It allows any qualified manufacturer to build the hardware. Development of product drawings and associated lists begins after:

- Conceptual and developmental design drawings and associated lists have completed detail design reviews.
- The critical design review is completed.

60. Establish Diminishing Manufacturing Sources (DMS) Mitigation Working Group

A top problem today is parts obsolescence. Currently the U.S. parts base is turning over in as little as 24 months. This means that if you take more then 24 months from CDR to production you may have to redesign just due to parts obsolescence problems. There are many ways to deal with this problem; two critical activities are the establishment of a parts tracking database and rules for the rapid insertion of new technologies (e.g., what level of regression testing). An important task of this working group between the PDR and CDR is to review the design for vulnerability to parts obsolescence. Certain design philosophies (e.g., use of FPGAs instead of ASICs) are much less susceptible to parts obsolescence. Associated issues include parts derating, 100% parts re-screening of commercial and plastics parts for the military environment, and Environmental Stress Screening (ESS).

61. Technology Maturation Loop

While most acquisition and development time lines are drawn as linear events progressing from left to right, in reality this is not how the process actually works. At a high level the time lines look serial or sequential, but actually have two "loops" where traditional program management tools and techniques are not effective. The first of these we call the Technology Maturation Loop. During this time a series of some 10 to 12 hardware and software events are repeated in an iterative manner to mature the design. Many factors affect the length of time spent in this loop including technology maturity, contractor experience, and design analysis tools used. During these maturation loops it is EXTREMELY hard if not impossible to predict schedule with high reliability. See discussion at end of Section Four entitled *"Accurate Schedule Reporting Through Tiered Milestone Dating"*

62. Training

Training consists of the processes, procedures, techniques, training devices, and equipment used to train civilian, active duty, and reserve military personnel to operate and support equipment. A training plan should be developed to identify a schedule for the life cycle manpower, personnel, and training requirements associated with planning the introduction of new equipment, systems, or subsystems. This includes equipment maintenance and manning requirements, a training concept for instructors, individual and crew training (both initial and continuation), and on-the-job training. Training shall also address logistics support planning for the training site, curriculum, training materials, technical training equipment, technical manuals, special tools and test equipment, spare parts, training device acquisitions and installations.

63. Incoming Inspection

An effective parts control program requires that feedback techniques be established which notify suppliers of defective parts and require corrective action on the part of the vendor. In addition, visibility of incoming and assembly yield rates must be continuously maintained to identify poor suppliers and to develop more effective incoming and vendor screens. Early detection of parts problems is the key to a low risk transition to rate production.

64. Establish Pedigree Process

Today due to the heavy use of statistics (6 Sigma, etc.) in the design and production process the ability to build one high quality prototype (or Golden Round) has been lost. A key part of this process is documenting the pedigree of all parts and assemblies. This detailed documentation and tracking of all parts and assemblies allows test engineering to know (or know they don't know) the quality of the Unit Under Test (UUT). This process also provides feedback to the assemblers at times when (for example a lot of squibs showed 40% failure rate) you don't want to use an item from this lot in your test round. Without a strong pedigree process you will not even know if your parts came from this lot! A good pedigree process insures traceability and documentation at all levels covering the four main categories of MAN, METHODS, MACHINE, and MATERIALS.

65. Engineering Design Model (EDM)

Because the design process involves all the disciplines of the integrated product team, the use of uniform and standard practices improves the resulting schedule realism and accuracy of the design. Construction of the Engineering Design Model (EDM) is one such formal stage in validating the design with manufacturing disciplines. The EDM serves to proof the design on manufacturing models with feedback of the results to engineering. This step augments similar engineering information flow from design review findings. Sometimes this run of units is extended prior to a production award into prototypes and a Low Rate Initial Production (LRIP).

66. Production Readiness Review (PRR)

Production Readiness Review (PRR) is intended to determine the completion status of specific activities required for production go-ahead decisions. PRR occurs incrementally during EMD addressing all areas of concern in the manufacturing plan. Early stages are devoted to gross level manufacturing concerns and progress to a more detailed level as the design matures. There is no upper limit to the number of incremental PRRs; PRR schedules relate to major design milestones, but are not specifically related to other design reviews. Subcontractors and suppliers are included in PRRs. A PRR is complete when both the contractor and government have verified that all activities required to support a production go-ahead decision have been completed.

67. Interim Contractor Support

When funded by the government, interim contractor support is intended to ensure equipment supportability and continued FRACAS activity until the prime equipment and its spares are fully integrated into the government inventory. Contractor engineering teams provide independent engineering analysis of field data and are required to provide details of all failures.

68. Provisioning and Field Support

While numerous logistics studies and analysis many have been conducted, provisioning is the first step to supporting an operational system. Very few systems today are "throw away" so field support is important. Field support should not only be used to ensure customer satisfaction but also as feedback to the design and production process.

69. Statistical Process Control (SPC)

Statistical Process Control (SPC) takes on many forms. It is important that it be tailored to the particular product in question. Use SPC for process monitoring, problem solving, and communication. Teach basic SPC techniques to all: check sheets, histograms, Pareto analysis, cause and effect analysis, and control charts. Teach advanced SPC techniques to engineers and operators: multivariate charts, design of experiments, and capability charts.

70. Factory Acceptance Tests

Once the design has matured, Factory Acceptance Tests are developed to ensure that each unit performs as the test units did.

71. Physical Configuration Audit (PCA)/Functional Configuration Audit (FCA)

These audits will verify that configuration items have been developed satisfactorily and that they achieve the performance and specified functional characteristics. In addition, configuration items will be technically examined to assure that the "As Built" configuration items conform to the technical documentation that defines them. The design package cannot be released to production until the audits have been successfully conducted.

72. Process Maturation Loop

While most acquisition and development time lines are drawn as liner events progressing from left to right in time, in reality this is not how the process actually works. The high level process looks serial but actually has two "loops" where traditional program management tools and techniques are not effective. This "loop" is similar to the Technology Maturtion Loop discussed during the design phase, except now instead of maturing the design it is the production process that matures or "stabilizes" resulting in low variability. During this time a series of approximatelly 12 events are repeated in an iterative manner to mature the process. This is the second place where traditional program management tools and techniques are not effective. During these maturation loops it is EXTREMELY hard if not impossible to predict schedule with high reliability. See discussion at end of Section Four entitled *"Accurate Schedule Reporting Through Tiered Milestone*

73. First Article & Qualification Test (FAQT)

These tests address environmental and life test requirements, as documented in PIDS and the integrated test plan. The purpose is to measure actual hardware and software configuration items performance for compliance with PIDS, software requirements, and interface requirements specifications. Testing occurs on preproduction hardware. Test results are documented in a format that facilitates government interpretation and certification.

74. Test, Analyze, and Fix (TAAF)

Test, Analyze, and Fix (TAAF) is a planned process in which development items are tested under actual or simulated mission profile environments to disclose design deficiencies and to provide engineering information on failure modes and mechanisms. The purpose of TAAF is to provide a basis for early incorporation of corrective actions and verification of their effectiveness in improving equipment reliability.

75. Factory Layout and Flow

Factory improvement does not just mean updating the equipment in the factory. It involves striving to achieve an integrated and supportive mix of layout, material flow, inventory control and flow, manufacturing processes, maintenance, and plant control. An organization must be able to assess the value-added of the technology before investing capital.

76. DMS Parts Tracking

Identification and prevention of parts obsolescence requires a dynamic, proactive process. Examination of the design prior to the Production Readiness Review provides a timely opportunity to ensure that the design reflects parts and materials that will be available throughout production and supportable in use. At this point, parts and materials at risk of obsolescence need to be identified and replaced. DMS is a producibility issue and, therefore, a design term rather than a problem that simply materializes during production and support.

77. Build Systems

The actual building of the system is what all the design efforts were about. The goal now is to meet production schedules, constantly reduce costs, cycle time, and variability.

78. Test Equipment Certification/Calibration

It is important that test equipment have the accuracy, precision, and repeatability to measure the critical aspects of the product and its performance.

79. Production Worker Training

Training programs should be in effect which satisfy current and future needs of both employer and employee. Personnel training is a critical ingredient in ensuring the stability of the manufacturing operation. A "hands on" training program should be in place for factory personnel. This training should be accomplished "off-line" using the same equipment, procedures, and work instructions that will be required on the factory floor. Work force stability should be tracked. Personnel turnover and level, and quantity and level of training should be readily accessible and tracked. The introduction of new equipment or personnel on the product line without successful completion of "hands on" training should never occur.

80. Develop and Implement Engineering Change Proposals (ECPs) as Required

The need for an Engineering Change Proposal (ECP) occurs whenever there is a problem or an opportunity for improvement. An ECP generates an alteration to a product's attributes or its associated design. An ECP can also be used to change the released configuration documentation of a product. Effecting an engineering change may involve modification of the product, product information and associated interfacing items. Changes to released documentation must be evaluated for the effect on users of the released information who may have begun ordering material, designing tooling, planning manufacturing, coding software or producing parts. ECPs are classified as Class I or Class II depending on the extent of the impact.

81. Production Breaks

Production breaks can unavoidably be caused by project justification delays or funding problems. This normally results in either a slowdown or a temporary shutdown of production. Production delays always result in overall project cost increases. The primary reasons production breaks increase costs are:

- Skilled employees must be paid from funded projects or be released from employment in order for any company to remain profitable.
- The additional costs to train replacement workers.
- Inflation.
- Job instability affects personal security and motivation.
- Floor space and expensive machinery are valuable resources that cannot remain idle.
- Loss of established vendors.
- A production restart effort means the lessons learned originally must be learned again.
- Ultimately, the overall cost to produce each unit increase.

SECTION FIVE

ACCURATE PROGRAM SCHEDULE REPORTING THROUGH TIERED MILESTONE DATING

A major problem facing program managers today is meeting schedules. Developing and maintaining schedules are very important aspects of an acquisition program. So why do military acquisition programs have such difficulty in meeting schedules? To answer this, we must realize that the problem is multi-faceted. DoD and GAO have identified a variety of contributors. One key element is the lack of validated models to predict future events.

Schedule overruns seem to mount on top of previous schedule overruns, and soon senior decision makers have no faith in the promises of their program managers. Since schedules are actually predictions, then we must look at the methods we use to predict future events.

The ability to accurately predict an outcome is based on two factors: (1) an understanding of the process, and (2) the ability to consistently follow this process. The Navy's Best Manufacturing Practices Center of Excellence (BMPCOE) has been developing and maintaining a systems engineering model, and developing process control tools (e.g., the Technical Risk Identification and Mitigation System [TRIMS]) for some time. While these tools have proven to be effective for instilling repeatability into the systems engineering process, schedule overrun problems still persist.

When the BMPCOE started out to study schedule overrun problems, we first reviewed the acquisition process being used. In this case, the baseline is the DoD 5000 acquisition process. Figure 2 shows an overview of a basic DoD acquisition timeline.

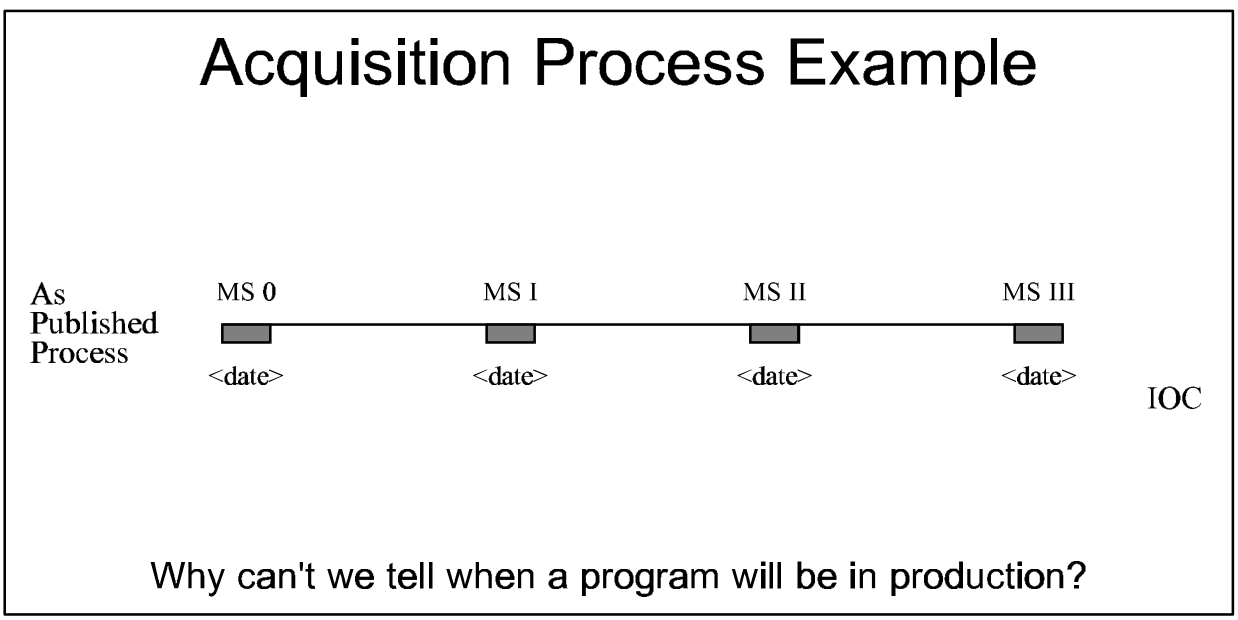

Figure 2 - A Linear Assumption of the Acquisition Process

This acquisition process, as published, is basically linear and divided into phases that depict the maturation of a system as time progresses. While there are many iterative processes involved, the basic process at the top level is still depicted (and managed) as though it were linear. To further illustrate this belief is the fact that we typically publish an IOC for a program almost at Day 1! Herein is where the problem lies: the process at the top level is not linear.

There are two critical points that occur during a DoD acquisition program's life. These points are best described as maturation loops as shown in Figure 3. The loops represent: (1) the design maturation process where modeling and simulation tools do not exist, are poorly characterized, or were not used; and (2) the production maturation process where the design differs from the norm and processes and tooling must be tailored. The activities within these loops are NOT manageable with traditional program management disciplines and tools. In fact, they exist because modeling is not possible for the potentially millions of interactions that are taking place. These two breakpoints render it is almost impossible to accurately predict an IOC early in a state-of-the-art development program.

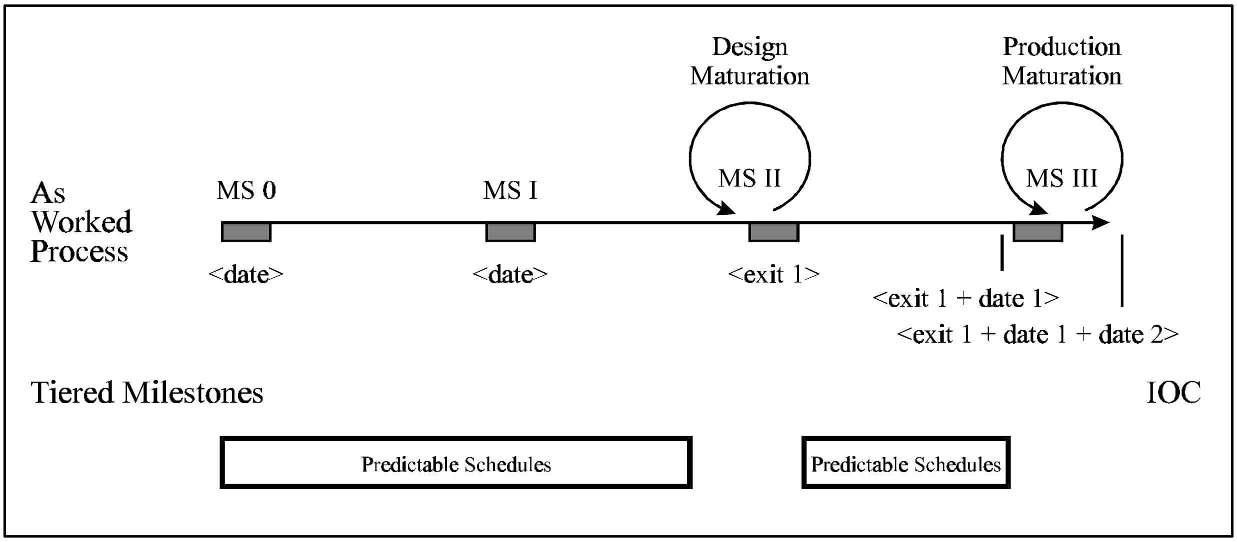

Figure 3 – You Cannot Mandate Technological Breakthroughs

The comment has been made "why don't we see these loops in commercial programs"? In point of fact we do. Many purely commercial programs have built dozens of prototypes to get a design correct. The lack of these maturation loops in a commercial program is typically because they are not pushing state-of-the-art concepts. Most commercial programs, while producing a new product, are based on very mature technology.

Consequently, two very different processes and tools are needed to manage a DoD acquisition program. First, the typical program management processes and tools are needed; second, a method for managing activities within the maturation loops must be established. The typical program management tools and techniques are well known, so we will focus on the maturation loops.

Since we are maturing technology, the following adage is the governing principle:

"You cannot mandate a technological breakthrough."

This statement is not to be taken lightly. Most everyone, when asked if they agree with this statement, will publicly state that they do. Yet technological breakthroughs are exactly what we expect during these maturation loops, and we expect them on schedule! These two desires are diametrically opposed, hence, program managers are constantly overrunning their predicted schedules.

So what does the process really look like and how should it work? The process, shown in Figure 3, is representative of how the acquisition process really works, and is based on what we call relative (or tiered) milestone dating. Even though the tools and techniques do not exist to accurately predict when a program will exit a maturation loop, the periods before, between, and after these loops are VERY predictable based on proven program management methods. It is in those periods that a program manager should be held responsible for maintaining a program within schedule. Therefore, an IOC should not be published as a distinct date but rather as an equation (e.g., Early in a program I cannot predict exactly when I will pass MS3, but I do know that it will be X days after a distinct technical event is achieved.).

Inside the maturation loops, the process is quite simple (e.g., How much money do you want to spend and how fast?). Since we cannot mandate a technological breakthrough, what can we do instead?

A. Bring ALL design analysis tools to bear.
B. While exit points cannot be determined by date, specific technical exit criteria should be established.
C. While exact exit dates cannot be determined at entry, increased funding does typically shorten the "loop" duration.

There is a second issue with regard to accurately predicting schedules and that is time itself. To use an example from aviation lets look at the concept of navigation using an Inertial Navigation System (INS). This system keeps track of where the aircraft is by keeping track of each and every turn and change in speed. Consequently, with no external inputs it can tell you where you are as long as it knows where you started (you can equate good requirements, or more importantly an allocated baseline to the starting point). But there is a problem: no machine is perfect, and as the aircraft travels along over time very slight errors are introduced into the calculation of the aircraft's position. On a short flight this is not a big problem, your actual position will not vary much from the displayed position. But on longer flights these small errors accumulate and build over time until the aircraft can actually be many miles from the displayed position.

This same process applies to acquisition programs and their schedules. The further out one goes on a predicated schedule the less and less accurate it becomes. It is rarely possible to develop accurate plans more then one or two major steps ahead in an acquisition process (typically 18 months to a maximum of 2 years); beyond this point plans are vague, non-specific and hence schedules are nothing more then guesses. In fact this desire to predict IOC on day one, and the subsequent attempts to meet it (based on vague planning and lots of technical unknowns) actually lengthen schedules!

In conclusion,

Tiered Milestone Dating

- DoD acquisition process is not linear as published
- You cannot mandate technological breakthroughs: Different skills and metrics needed to “manage” R&D and Production Maturation Loops
- We must define and understand entry and exit criteria for “Loops”
- Strong use of modeling and simulation can shorten “Loops”
- “Loops” shortened by use of “Evolved Capability” and true P^3I
- Digital systems design approach (hardware and software not separate)
- Schedules depicting events more than 18-24 months in advance are merely guesses

Results: More accurate reporting