Department of the Navy
NAVSO P-6071 March 1986

Best Practices

How to Avoid Surprises in the World's Most Complicated Technical Process

The Transition From Development to Production

Preface

As follow-on to the efforts of the Defense Science Board Task Force on the Transition from Development to Production which culminated in Department of Defense Directive 4245.7, this manual attempts to enhance the enlightenment of both government and industry by identifying specific practices in current use and their potentially adverse consequences in terms of cost, schedule, performance, and readiness. It then describes proven best practices which avoid or alleviate these consequences, and provides enough background information to understand their rationale. Enlightenment follows better understanding. I would expect that all three Services recognize the substance and value of these practices and subscribe to their use. New and improved practices are continually being found which further reduce the technical risk associated with military weapon system acquisition programs. I urge users, government and industry alike, to bring forward any developments which ought to be acknowledged in future revisions.

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Transition from Development to Production

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Introduction
Why Should You Read This?

Weapon system design, test, and production constitute the world's most complicated technical process.

Most new weapon systems waste operators' time and taxpayers' money with excessive maintenance and logistics support, while reducing the readiness of our Nation's defenses. This says that project managers, and the hierarchy of management above them, clear to the top – government and contractor alike – don't understand and properly manage the technical process of weapon system procurement.

If you're a project manger, no doubt you disagree. You have been taught to believe that by following government and corporate project administration policy to the letter, your project will succeed and you will be a hero.

The sad truth is that you may be right, because that policy measures success in terms of "on time and within budget" rather than performance in service. The existing material acquisition process focuses on administrative issues: cost and schedule. Its milestone decision points are unrelated to the industrial processes and the transition between development and production in the factory. It does not account for, and has no method of evaluating, technical risk at these milestones. Concurrency is looked upon unfavorably. Insufficient funding early in design allows programs to proceed beyond the point of affordable action to correct shortfalls.

You're in Trouble and Don't Know it

Congressional actions, new DoD policies, and public opinion are beginning to demand performance in service, yet government and corporate policies don't help you to get there from here.

So if you are managing your project in the "good old time-tested, business as usual" way, your project is headed for disaster. It may take you with it.

Most acquisition mangers seem to recognize that there is a risk associated with the transition from development to production, but perhaps do not know the magnitude or the origin, because the transition is not a discrete event but a process composed of three elements: design, test, and production. Many programs simply cannot succeed in production despite the fact that they've passed the required milestone review. These programs can't succeed for technical reasons, not withstanding what is perceived as prior management success related to DoD acquisition policy. A poorly designed product cannot be properly tested or produced. In the test program, there will be far more failures than should be expected. Manufacturing problems will overwhelm production schedules and costs. The best evidence of this is the "hidden factory syndrome" with its needlessly high redesign/rework costs.

The Industrial Processes of Design, Test, and Production are Poorly Understood

The industrial processes of design, test, and production are poorly understood both by the government, which contracts for them, and by industry as a whole, which developed them. That is, some contractors are knowledgeable in, and make good use of, certain processes, but no contractor chooses to use them all. As a result, various technical issues in design, test, or production degrade performance and readiness in service, not the management issues.

Performance and readiness in service don't improve except by retrofit – clearly, problems are predestined before the product leaves the factory. These problems, at levels of technical detail not normally visible to project managers, are eliminated only when the product is changed. They usually come as surprises to the project manger – government or contractor – who has focused on administration and has accepted the reassurances of his staff without understanding the technical issues and their consequences.

Government and contractor project managers sincerely want to do a good job – all that's needed are proper tools. DoD Directive 4245.7 dated 19 January 1984, in its TRANSITION DOCUMENT "Transition from Development to Production," defines the proper tools, or "templates." The topics they address constitute the "critical path" for a successful material acquisition program. To ignore any one of them would be foolhardy. This is not inconsistent with project management policy – the project manager should have enough familiarity with the technical issues in the industrial processes of design, test, and production to manage them as closely as the administrative issues.

You have No Control of Acquisition Strategy

There are two approaches to the material acquisition process. The current approach is defined in DoD 5000-series documents and dutifully implemented by project managers. These documents and the requirements that they spell out are important in that they establish a management grid which the various participants in the acquisition process must follow. But they don't describe the industrial process, nor do they provide intelligence on the management and control of those technical activities and their related details that can either make or break a project. What has evolved as today's acquisition strategy hardly recognizes the importance of development and production, much less utilizes the vast resources of development and production data in any decision process.

Current DoD systems acquisition policies don't account for the fact that systems acquisition is concerned basically and primarily with an industrial process. Its structure, organization, and operation bear no similarity whatsoever to the systems acquisition process as it is conventionally described. It is a technical process focused on the design, test, and production of a product. It will either fail or falter if these processes are not performed in a disciplined manner, because the design, test, and production processes are a continuum of interrelated and interdependent disciplines. A failure to perform well in one area will result in failure to do well in all areas. When this happens – as it does all too often – a high-risk program results whose equipment is fielded late and at far greater cost than planned.

Among the characteristics of the current approach are the following:

- Control of acquisition strategy by Congress, not the project manager
- Blind reliance on military standards and specifications
- Focus on cost and schedule to support management decisions
- Management by milestone-driven administrative process
- Little or no technical assessment factored into management decisions
- Ignorance of the industrial processes of design, test and production

But You Can Take Control with Best Practices

The alternative approach requires that project managers understand the technical and industrial processes involved, in terms of proven best practices. They manger, report, and base their project decisions on the technical progress of their projects to the same degree as the administrative. It requires them to understand the consequences of the current approach, in relation to the industrial processes involved, in order to manage their project to ensure successful performance in service in spite of current DoD acquisition policy.

DoD 4245.7-M associated with DoD Directive 4245.7 provides an overview of the critical path templates. These areas of risk may not be very convincing, particularly to first-time project managers. In its abbreviated form, DoD 4245.7-M isn't able to convey enough to the program manager and the contractor to understand the consequences of current approaches and the benefits of best practices. The program manager must have no doubt where he was erred, and how he can recover. Something needs to make clear what must be done to reduce the technical risk in a material acquisition program and to ensure performance in service with confidence.

This book does that. It is intended for program mangers and their superiors, both government and contractor. This management level is usually concerned with the administrative process – cost and schedule – and is frequently ill-prepared to manage the technical process, depending instead on staff assistance for the technical details. In today's material acquisition environment, in which even the Congress is showing concern for technical risk, this is an unsatisfactory situation. Management will be held accountable for striking a balance between administrative and technical risk in every program decision, and a general understanding of the technical disciplines becomes an essential requirement.

This aid identifies the proper requirements for requests for proposals and contracts. It is a road map through the industrial processes involved in the full-scale development and production phases of a program, supporting program reviews and formal design reviews.

Although written at a technical policy level for maximum value to program management, it also contains data and information applicable to the design and production engineering functions, as well as engineering support organizations such as reliability engineering. It should therefore be required reading for everyone associated with the technical issues of defense systems acquisition, and should be understood by those responsible for the current administrative processes as well.

Watch Out for the Traps

Each template in DoD 4245.7-M is addressed in this manual. For each template, certain elements are currently being approached in a manner which emphasizes the administrative process and disregards best practices utilizing the disciplined technical process – a manner which results in high risk. This manual refers to these approaches, standard ways of doing business in today's defense systems acquisition environment, as "traps" since they represent potential danger to program success. Although traps may not appear to be inherently dangerous, they become problems when they are sprung. There are indicators, or "alarms," both subtle and obvious, which alert the project manager to the fact that he is caught. On the other hand, the dangers of a trap can be avoided if he knows how to "escape." The project manager will immediately relate to the traps discussed in this manual because with few exceptions he will find them in his project.

Four traps have been identified for each template. Though many more could be identified, these four are deemed the most significant. If a project manager avoids these through best practices, his project risk will be reduced to acceptable limits insofar as that template is concerned. Each trap has technical characteristics which would indicate that the danger has not been avoided – that the project has sprung a trap. These are the alarms, encountered too often in our current approach to defense systems acquisition. They contribute directly to unacceptable project risk, and their existence is evidence that the trap is having a negative effect on the project. The consequences of being caught in the trap are predictable from the experience of many projects and from the application of common sense.

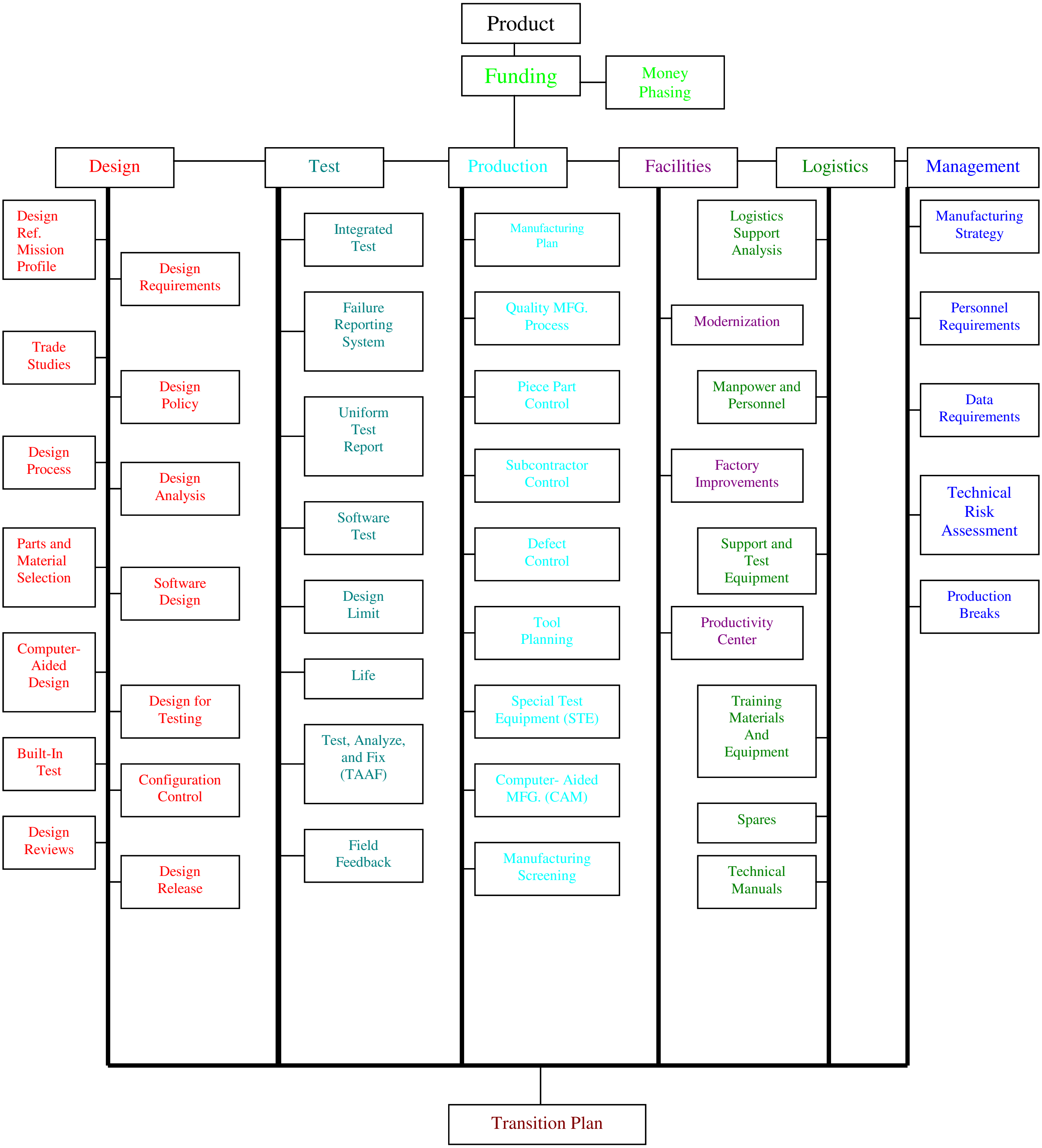
How to Avoid Getting Caught

The best approach to material acquisition is the use of best practices from the beginning, through careful attention to the system specification and the contract, and effective management of the technical process during design, test, and production. The more likely situation finds the project loaded with traps. The earlier they are escaped, the greater likelihood of successful performance in service.

The impact of escapes on cost and schedule vary from one trap to the next. The best practice in one instance may cost more, while in another instance the best practice is better use of resources, at a net cost saving. Increased cost in design or test may be offset in production as a result of lower reject rates and reduced rework, which will improve delivery schedules.

The benefits of avoiding or escaping traps in the material acquisition process are not necessarily the converse of the consequences of entrapment. For example, assigning production engineers to work directly with design engineers at the beginning of the design process helps to avoid redesign for producibility after production start, as well as high rework levels (the hidden factory). At the same time, however, the design may take advantage of new production technology which has the potential of significantly improving performance. Best practices will always improve performance in service, and will do so at reduced life cycle cost.

Performance in Service is Your Responsibility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How to Use This Book
This Book is a Tool!

For each critical path template identified in DoD 4245.7-M, there is a corresponding section in this manual which includes traps, charts for each trap comparing the benefits of best practices to the consequences of the most commonly used current approach, narrative summaries, and checklists.

Each trap is only a trap if the best practice is not observed. Other approaches incur varying degrees of greater risk. Four traps have been identified for each template. More could be identified for many templates, but these four are deemed the most significant. If a project manager (government or contractor) selects the best practice for all of these, his project's overall risk will be reduced to a minimum.

The wrong approach to each trap has telltale early-warning signs which result from its use. These are called "alarms," because they contribute directly to unacceptable project consequences, and their existence is evidence that the wrong approach has been taken. The specific actions to reap the benefits of best practices are termed "escapes" to call attention to the opportunities to reduce program risk. While these escapes are best included in solicitations and evaluated in source selection, it is seldom too late to make the switch, although changes usually become more costly as the project progresses.

The templates are grouped by function, and each topic is described by four elements:
1. The TRAPS, accompanied by a brief definition of the topic.
2. A two-page COMPARISON CHART comparing the consequences of current approaches to the benefits of best practices for each trap, and including both the alarms indicative of being trapped and the escapes by means of best practices.
3. A SUMMARY which briefly discusses current and best practices.
4. A CHECKLIST to aid both the project manger who wants to take advantage of best practices and the reviewing authority who wants to ask the right questions.

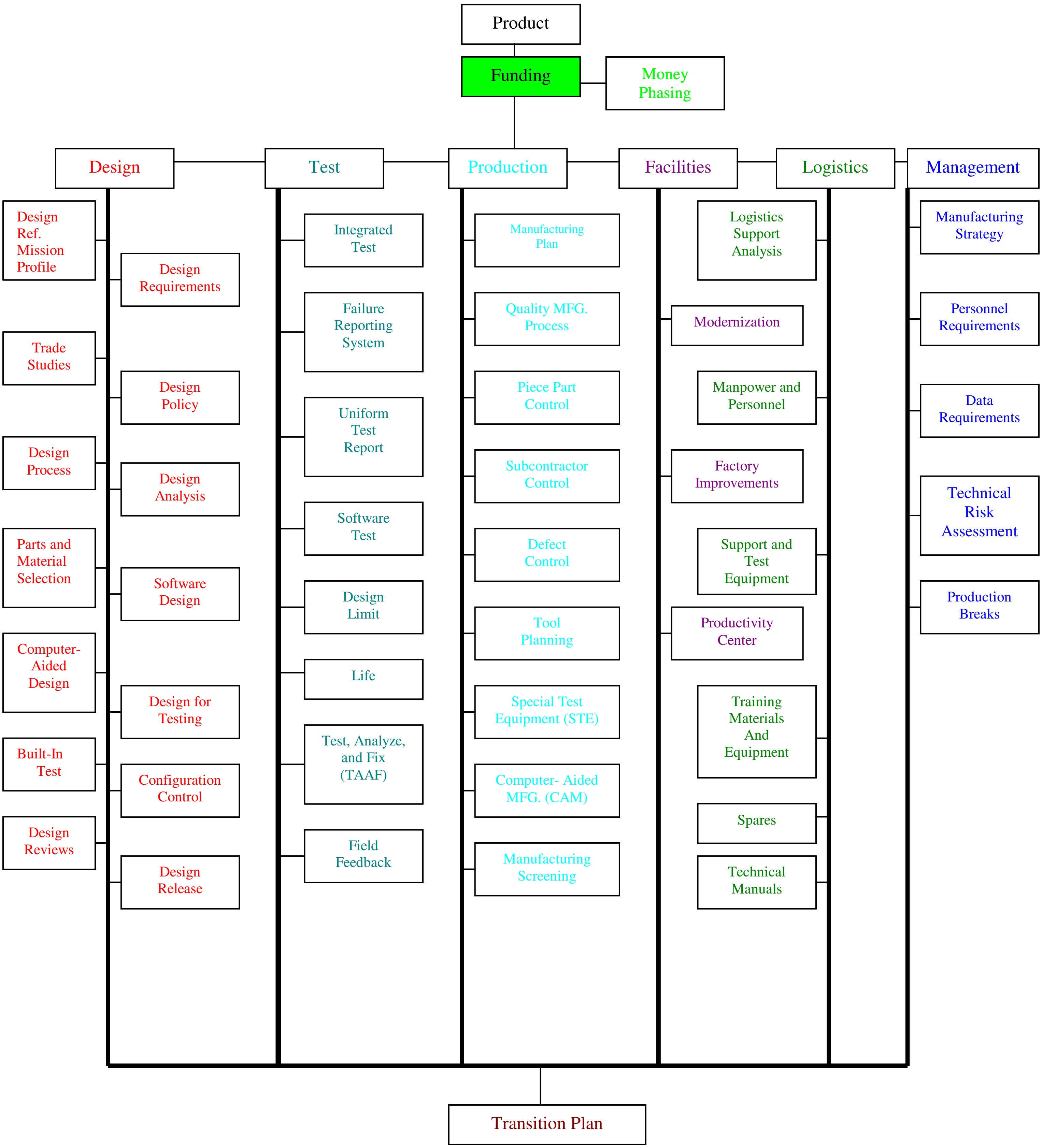
The manual illustrates that many of the approaches commonly used in past and current defense systems acquisition programs are not best practices – they led or will lead to high risk, poor operational readiness, and high support cost in service use. The manual should first be reviewed thoroughly to understand the interpretation of the current defense systems acquisition process with respect to risk. The format of the manual has been designed to make this review easy and fast, by providing instant focus on critical issues. The first-time reader should scan the traps on the first page of each section. Each subsection becomes increasingly explanatory, and he need read only far as he finds necessary.

Defense systems project mangers should then conduct in-depth reviews of the contract requirements and contractor policies and practices with regard to the requirements, to determine in which traps they are ensnared, using the manual as a checklist. Plans to escape these traps will depend upon what stage each project is in, as well as the availability of resources which may be required. In many instances, it will be discovered that escapes can be affected with little or no additional resources – save perhaps time, for which there will be more than ample paycheck later on – simply by learning the proper technical issues to address at design reviews and other milestone decision points, and summoning the courage to say “NO!”

Do not wait until formal project meetings to investigate these issues. Ad hoc government-contractor meetings, onsite technical audits, and temporary onsite government engineering teams to assist the contractor in corrective actions can often result in project salvage in time to escape a trap prior to a crucial decision point. This manual will serve as overall guidance, but it will require supplementation and standards, non-government technical staff support, expert government technical support from among its many engineering centers and research laboratories, and a strong experience base within the government project office’s technical staff. Onsite engineering action on a continuing basis by a well-informed government project office has been found a most valuable asset to reducing project risk.

On the contractor’s part, the manual outlines a model industrial process. It was not conceived by the government, but by key industry representatives who identified the best practices for reducing technical risk that are being used in industry today. It should be pointed out that no one contractor utilizes all of the best practices described. Rather, these best practices are scattered throughout the defense contractor community and their outstanding results in a particular template area have been discovered or highlighted during onsite program reviews. Thus, DoD 4245.7-M and this manual are unique in bringing together for the first time a compendium of best practices distilled from the entire defense systems acquisition community, both government and industry. To ensure competitive position and certify minimal technical risk in their products, defense contractors would be well advised to investigate the feasibility of changes in both corporate organizational structure and technical policy; and capital investment in new engineering and manufacturing tools such as CAD/CAM, automatic parts screening, and automatic assembly and test

The Rest is Up to You



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FUNDING
Money Phasing

Overview: Government and industry project managers realize the importance of adequate and timely funding to project success. However, few appreciate fully the complexity of the defense authorization and appropriation process; or possess sufficient knowledge of DoD Planning, Programming, and Budgeting System (PPBS); or understand the relationship between the PPBS and DoD acquisition process. As a result, many projects begin with inadequate allocation of Research, Development, Test, and Evaluation (RDT&E) funding for the initial design and engineering efforts. This is further aggravated as early production monies are unavailable to support tooling, long lead materials, production line startup, etc. It is vital that project managers ensure that the need for early funding is strongly communicated to the budget process.

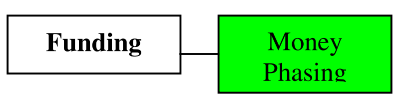
Traps!

1. Project manager has complied with PPBS to obtain funding

2. Technical problems are accepted as grounds for budget increases

3. Project is sufficiently funded

4. Production funds are available at Milestone III



Money Phasing

Benefits

Funding decisions will be based on sound technical inputs	Funding resources will be available for technical problem solutions	Early design and test efforts will be fully funded	Concurrency (engineering versus manufacturing) in transitioning from design to production will be well-managed

Escapes

Prepared technical tradeoffs with specific project impact, to influence PPBS decisions	Prepare alternative solutions to technical problems with different cost options Never assume at project briefings that the audience possesses technical understanding	Provide technical justification to restructure project funds into a realistic funding profile	Obtain properly phased buildup of production funds during RDT&E phase down

Best Practices

TRAPS

1. Project manager has compiled with PPBS to obtain funding	2. Technical problems are accepted as grounds for budget increases	3. Project is sufficiently funded	4. Production funds are available at Milestone III

Current Approach

Alarms

Technical "issues" are not adequately presented to justify funding requirements	Project managers believe that major decisions are made by people with sufficient technical background	Funding profile is skewed as described in DoD 4245.7-M	Procurement of long lead items, tooling, and proof of manufacturing models is started late

Consequences

Funding decisions are based primarily on cost, schedule, and bureaucratic considerations	Project's status may be in jeopardy	Project is initiated with inadequate design effort due to poor allocation of funds	Production start-up problems are magnified

Money Phasing

Summary: Undoubtedly, there is no one involved in the acquisition of defense systems who does not know that the DoD Planning, Programming, and Budgeting System (PPBS) is the framework within which the Secretary of Defense and the Service secretaries make decisions regarding weapon system development and production. Whereas the acquisition process proceeds in phases, each of which could involve anywhere from part of a single budget cycle to several full cycles, the PPBS runs on a tightly structured schedule from initial planning through congressional enactment to budget execution. PPBS decisions are not based on particular project needs but rather on the higher-level need for balancing all DoD programs within financial limits established by Congress, Office of Management and Budget (OMB), and Office of the Secretary of Defense (OSD) for both a particular fiscal year and the overall Five Year Defense Plan (FYDP).

Needless to say, it does not take an alert government project manager very long to discover that he always will be plagued by two constant dilemmas. One is a lack of a roadmap through an acquisition process which has not been integrated with the PPBS; the second is the fact that the authors of and watchdogs over both the acquisition process and the PPBS are generally those with non-technical backgrounds (e.g., comptrollers, lawyers, accountants). In other words, a government project manager, together with his prime and subcontractor team, is asked to traverse an uncharted acquisition path through innumerable technical traps and pitfalls and, while enroute, be subject to reviews by personnel not qualified for their review assignment, using guidelines which are irrelevant to the predominately technical reasons causing cost, schedule, and performance to go awry.

How does a project manager navigate safely through these *technical* traps and pitfalls since the acquisition process is known for its *management* orientation and the PPBS for its *fiscal* orientation? Given that he has surrounded himself with a competent staff and established an effective working relationship with his contractor, the project manager should begin by understanding thoroughly the acquisition process and the PPBS, and their strengths and weaknesses … "know your enemy," so to speak. In the process, he should note the following quotes from two major DoD policy directives:

a. DoD Directive 5000.1: "Estimate and budget realistically, and fund adequately, procurement (research, development, and production), logistics, and manpower for major systems."

b. DoD Instruction 5000.2 Enclosure (3): "*Funding Implications*. Discuss affordability, including the level of funding the component is willing to commit to satisfy the need. When a concept has been selected, provide gross estimates of total RDT&E cost, total procurement cost, unit cost, and life cycle cost."

Note the general guidance on budgeting and affordability. In the first quote there is no definition of "realistically" or "adequately" nor is there any guidance, general or specific, in this key policy directive which would help a project manager prepare a funding plan for less-than-major systems. In the second quote, which comes from the format for the Justification for Major System New Start (JMSNS), gross estimates of total RDT&E and procurement funds are requested but how these gross estimates are obtained is not specified in these major system acquisition procedures – nor should they be at this early stage of the life cycle. Reviewing the contents of DoD Directive 5000.1, DoD Instruction 5000.2, and other key directives from a funding standpoint leads to several observations, including the following:

a. Major system acquisition procedures published by OSD are by definition broad in scope. The Services must tailor the procedures to particular system needs.

b. Less-than-major system acquisition procedures are governed by all policies and regulations in the Defense Acquisition Regulatory System (DARS) except for the unique business demands of major system acquisitions which are covered by DoD Directive 5000.1 and DoD Instruction 5000.2. Here again, the DARS contain broad procedures which must be tailored to specific project needs.

c. The DoD 5000 series instructions are management-oriented, not technical-oriented.

d. The DoD 7000 series instructions and other key publications, such as the Navy Comptroller Manual, are fiscal-oriented, not technical-oriented.

From these observations, two important conclusions can be made:

a. The DoD acquisition process and the PPBS, with their attendant directives/instructions, are not guilty of any blatant sins of commission because their broad guidelines are fairly sterile; however,

b. They are guilty of sins of omission because of a failure to emphasize properly the importance of technical discipline in the acquisition process.

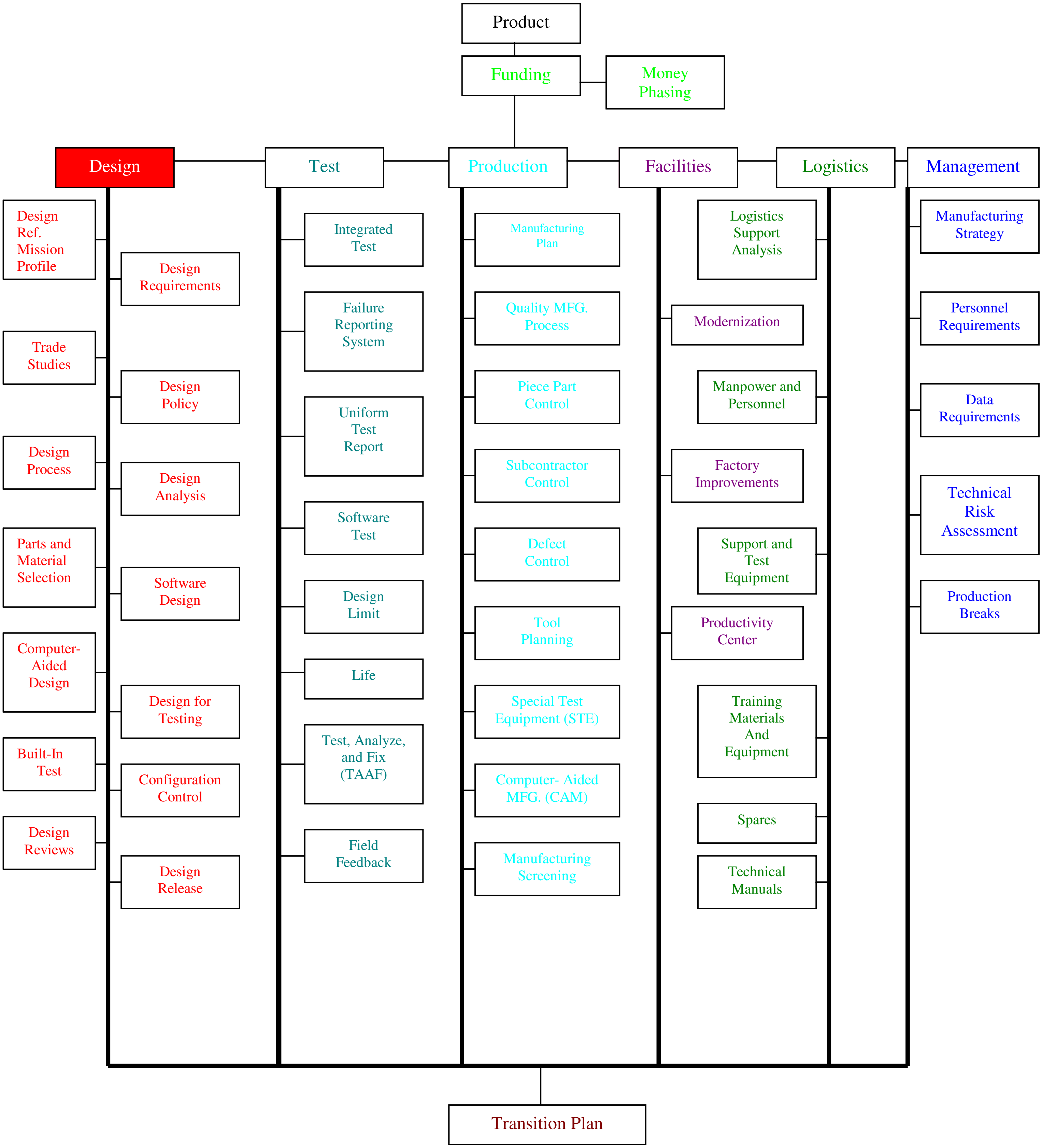
The second conclusion is the direct result of an acquisition process (and a PPBS) for which the "drivers" too often have been cost and schedule at the expense of technical performance. As an aside, a case could be made for operational performance as a "driver" during development, which is counter-productive to technical performance and, consequently, counter-productive to operational performance during and after production. Elimination of these sins of omission can only occur by an increased awareness of good technical practices during design, test, and manufacturing, coupled with the courage and conviction to implement these practices in a timely fashion.

Since an operationally effective weapon system can best be affordable by a sound design during the early phase of development, RDT&E funding can have much higher payoff than any other appropriation. For most projects, it can generally be demonstrated how a well-structured, technically sound development effort can cost no more RDT&E dollars than a poorly structured program without technical discipline.

Money Phasing

Checklist

- ✓ Have technical justifications been prepared to influence PPBS decisions?
- ✓ Have alternative solutions to technical problems been prepared with different cost options?
- ✓ Are project briefings structured to enlighten non-technical decision-makers?
- ✓ Is DoD 4245.7-M used as a predominant directive for compliance and funding profile?
- ✓ Are programs with highest potential fully funded?
- ✓ Do critical early design and engineering activities receive adequate funding?
- ✓ Are production funds available during FSD for tooling and long lead item procurement?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Design Limit
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Field Feedback
Manufacturing Plan
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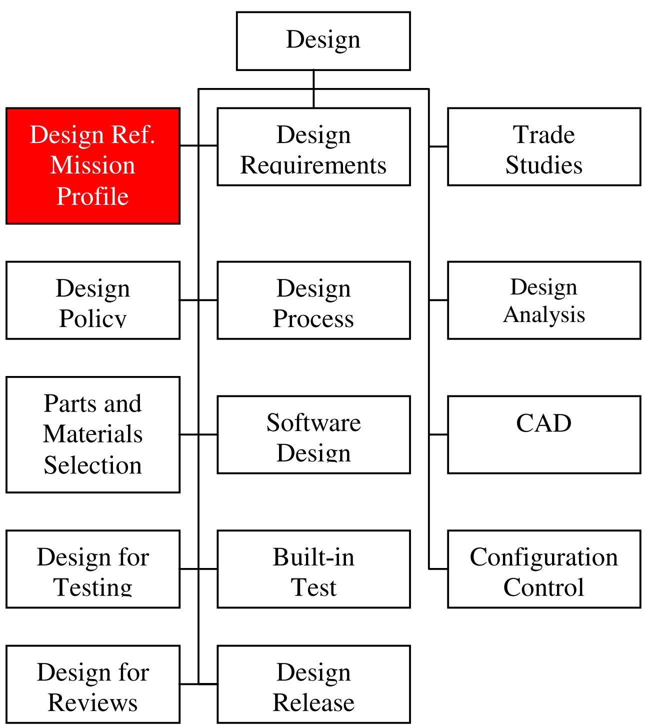
DESIGN
Design Reference Mission Profile

Overview: Mission functional and environmental profiles are often inadequately defined in design engineering terms. As a result, the design product is not compatible with all life cycle use conditions.

Traps!

1. Military Specification environments are used
2. The contractor interprets system performance requirements
3. Mission profile emphasizes tactical mission
4. Operational requirements define the mission profile



Design Reference Mission Profile

Benefits

Design to specification correlates to actual use conditions	Conservative design margins are established	Equipment failures in the field are reduced	System design meets all life cycle functional and environmental criteria

Escapes

Tailor military specification environments in the request for proposal and the contract to describe live cycle profile environments	Government and contractor concur on complete design life cycle system profiles	Ensure that the mission profile includes a comprehensive listing of all functions expected in every potential mission Ensure that the mission profile defines the total envelope of environments to which the system will be exposed	Government provides mission functional and environmental profiles in request for proposal Contractor establishes system functional and environmental profiles and includes them in the design requirements

Best Practices

TRAPS

1. Military specification environments are used	2. The contractor interprets system performance requirements	3. Mission profile emphasizes tactical mission	4. Operational requirements define the mission profile

Current Approach

Alarms

Approximate or generalized environmental limits and cycle times are accepted	Government does not provide enough information for complete mission profile definition Government accepts contractor "design to" margins	Tactical mission ignores transportation, storage, training, maintenance, etc.	Operational requirements do not define full functional and environmental profiles Contractor uses operational requirements instead of mission profile to derive system requirements

Consequences

Overstressed design conditions with high failure rates due to wrong design margin	Design engineers forced to make assumptions concerning functional and environmental criteria	Design fails to recognize some significant failure modes	System designed to an incomplete set of requirements

Design Reference Mission Profile

Summary: Although the need for a new system is specific and justified by the DoD 5000 series of directives, no specific guidance is available that addresses in-depth requirements for a mission profile. A statement of system need is generally proposed relative to (1) a weakness in countering a new enemy threat or (2) a perceived inability to counter an enemy threat. Mission profiles are addressed only in the arguments stated in the threat response requirements, and often contain incomplete information from the design engineering viewpoint. Therefore, it is left for the contractor to determine the specific attributes of system performance that are requirements. Many conditions of system/subsystem overstress have occurred in the field. Those incidents often have been traced to inadequate design margins or to the inability of the design to meet all operational requirements in the full range of field environments.

Accurate and complete specification of a mission profile is the solution to this problem. Mission profile definition supports the entire acquisition process (e.g., design definition, stress analysis, test design, logistic support analysis). The degree to which the specified mission profile corresponds to service use conditions and operations establishes the ability of the product to perform its intended missions in all operational scenarios. Adequate mission profile definition is essential in assuring rapid progress toward design maturity as determined by service use, not development and operational testing.

Mission profiles include both functional and environmental profiles. An environmental mission profile shows on a time scale the significant environmental parameters including their levels and duration that are expected to occur during the life of the weapon system. It defines the total envelope of environments in which the weapon system must perform, including conditions of storage, handling, transportation, and operational use. A functional mission profile shows on a time scale all the functions that must be performed by the system to accomplish the intended mission(s). Both functional and environmental profiles are the government's responsibility.

Functional and environmental mission profiles are used in preparation of the system specification, or otherwise included in the request for proposal. It is the contractor's responsibility to use these profiles to establish the *system* functional and environmental profiles that become the basis for the design requirements for the component parts of the system. Any updates to the mission profile must be communicated to the contractor for use in changing the design requirements as necessary to meet the new tactical need.

Mission profiles, when used in a logical and thorough fashion, greatly enhance mission effectiveness and timeliness of system deployment. The lack of top-down, integrated, and disciplined approach has impeded the effectiveness of the mission profile technique. The use of the mission profile as a system integration tool, and as an efficient means of assuring compatibility of the design requirements with tactical mission requirements, ensure effective systems development.

Design Reference Mission Profile

Checklist

- ✓ Have mission functional and environmental profiles been prepared by the government and included in the request for proposals?
- ✓ Has the contractor used detailed mission functional and environmental profiles to establish requirements and design margins for the system and its component parts?
- ✓ Are mission functional and environmental profiles updated as test data warrants?
- ✓ Have design life cycle system profiles been developed by the contractor and agreed to by the government?

Design Requirements

Overview: The designation of detailed requirements is singularly important in the discussion of design activities. An iterative requirement setting process starts with concept formulation and with trade studies, using refined mission/environmental profiles, and results in firm requirements necessary for the Full-Scale Development (FSD) Request For Proposals (RFP).

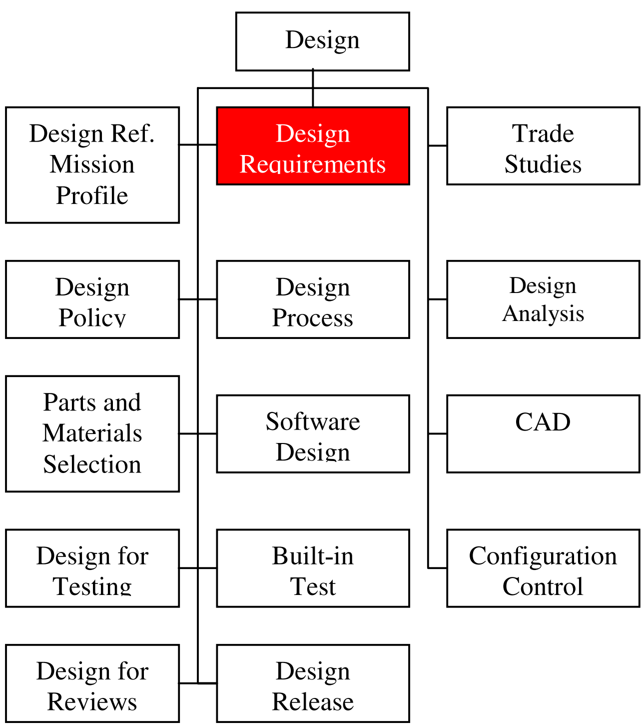
Traps!

1. Operational requirements are stated as design requirements

2. Management policy stresses program and delivery schedules

3. Latest technical developments are used as basis for design requirements

4. Detailed design requirements evolve with design effort



Design Requirements

Benefits

Design engineer has a common baseline	Design requirements properly allocated and verified	Engineering balance is achieved between proven technology and state-of-the-art advances	Known/mature design placed in production

Escapes

Specify detailed design requirements in RFP; use Inherent Availability (A_i), not (A_o) Use mission profile requirements as basis for design requirements Translate operational, maintenance, and training requirements into measurable design requirements	Both government and contractor agree that requirements have been allocated and verified accurately to the lowest technical level	Evaluate state-of-the-art advances with associated risks before implementation	Freeze design requirements at Milestone II

Best Practices

TRAPS

1. Operational requirements are stated as design requirements	2. Management policy stresses program and delivery schedules	3. Latest technical developments are used as basis for design requirements	4. Detailed design requirements evolve with design effort

Current Approach

Alarms

Operational Availability (A_o) is used as a design requirement Operational requirements are tactically oriented, not design oriented Operational requirements emphasize performance at expense of other disciplines	Program schedule pressure precludes flow down of design requirements to lowest technical level Operational needs not verified during design Next program phase used to resolve difficulties	State-of-the-art capability drives design instead of operational requirement	Design engineers confused as to what the requirements are Schedule slips from lack of engineering process Incomplete data package for production

Consequences

Design may not meet operational requirements	A quantum increase in engineering changes	Possibility of system being overdesigned	Design changes continue into production

Design Requirements

Summary: The system specification in the definitized contract for full-scale development is the foundation for the design, test, and manufacture of a weapon system. The clear expression of requirements in the contract is an essential objective of the government and the contractor in communicating the needs for a project. To ensure that this is met, requests for proposals must be explicit in transmitting project intent and philosophy, and in establishing underlying objectives, particularly with respect to the priority and relative weighting of full-scale development requirements. Project schedules established in the requests for proposals must realistically reflect the time required to achieve the objectives intended for the project. The timing of program phases must accurately acknowledge the time required for each specific activity if early development of mature systems is expected.

Cost studies have shown that a significant portion of development costs results from poor or premature decisions made at higher levels of design. It is important that requirements be delineated in both quantitative and qualitative terms of progressively lower levels of details as the product development cycle unfolds. Although it is true that any new system contains resources developed and/or used in older systems, beware of means dictating requirements. Requirements should always precede functional or physical means, which should then be designed or selected to satisfy the requirements.

The design requirements for full-scale development must be specifically defined to meet the mission profile, beginning with factory acceptance and extending throughout the life of the system. These requirements include a complete definition of the total range of environments to which the weapon system will be exposed, including conditions of storage, maintenance, transportation, and operational use. The system specification must define the total envelope of external environments, and the contractor must augment these as required to define his system's internal environmental conditions that become the design criteria for the component parts of the system. Operational requirements, from which design requirements are derived, are of no direct value to system designers. It is the responsibility of the government to specify the design requirements which will satisfy the operational requirement.

Design requirements include a full and explicit statement of quantitative performance requirements. In addition to the more obvious requirements for system performance levels, this set of parameters includes structural static and dynamic requirements, weight, reliability, maintainability, and unit production cost. To ensure affordability, specified levels of reliability and maintainability must be consistent with realistic expectations of achievement within the limits of existing technology. The requirements must be defined in terms relevant to the contractor (e.g., mean time between failures and mean time to repair) and should all or for growth during the project.

When the achievement of specific quantitative system requirements is conditional upon the performance of a set of predefined tasks, the contract must establish the requirements for development of approved program plans for the accomplishment of these tasks. This will be the case in such disciplines as a structural analysis, weight control, stress analysis and derating criteria, systems safety, corrosion prevention, parts standardization, and similar activities. The contract clarifies the government's intention with respect to the conduct of these programs, and the specific requirements for each are tailored to the needs of the weapon system development project. It is appropriate for the system specification to be as explicit (and as lengthy) as necessary to ensure an unambiguous explanation of these requirements.

At each level in the contractual hierarchy, a significant fraction of the development and production funding (often greater than 50 percent) is expended in the form of procurement from suppliers. It is essential to the achievement of satisfactory design that the project management philosophy and project objectives are adhered to at all levels in the contractual process. Detailed instructions and requirements should flow down from each procurement level to the next to whatever degree is necessary to ensure this top-to-bottom consistency. The requirement for flow down is an integral part of the basic prime contract.

Besides the more obvious performance and reliability requirements, there is the additional demand of producibility: it must be economically feasible to manufacture a quality product at a specified rate and to deliver end items capable of achieving the performance and reliability inherent in the design. This design requirement is not always well understood and historically has taken a back seat to more popular objective of high performance. The results of this neglect have ranged from factory rework rates in excess of 50 percent to suspension of government acceptance of end items pending major redesign for producibility. A strong producibility emphasis early in design will minimize the time and cost required for successful transmission to production.

Producibility considerations require inclusion of the following requirements in the system specification and in its execution by the contractor:

a. Design engineers have manufacturing knowledge or experience

b. Design policy includes producibility

c. Manufacturing engineers are involved early in the design process

d. Engineering is involved in developing the manufacturing plan

e. Detailed design documents require review by manufacturing

f. Released engineering documents require sign-off by manufacturing

Requirements of joint engineering/manufacturing participation throughout the full-scale development phase are among the most critical to ensuring that the risk attributable to transmission from development to production is minimized.

Design Requirements

Checklist

- ✓ Have mission needs been interpreted and specified as measurable design parameters?
- ✓ Have system design requirements been specified for, allocated to, and understood by each responsible design engineer?
- ✓ Have relevant design requirements been flowed down to subcontractors?
- ✓ Have detailed design requirements been specified in the RFP?
- ✓ Is Inherent Availability (A_i) used as a design requirement?
- ✓ Have design requirements been frozen at Milestone II?

Trade Studies

Overview: A broad spectrum of trade studies is initiated during the concept exploration phase. These trade studies continue on into Full-Scale Development (FSD) 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 producibiliy and operational suitability as well as performance, cost, and schedule.

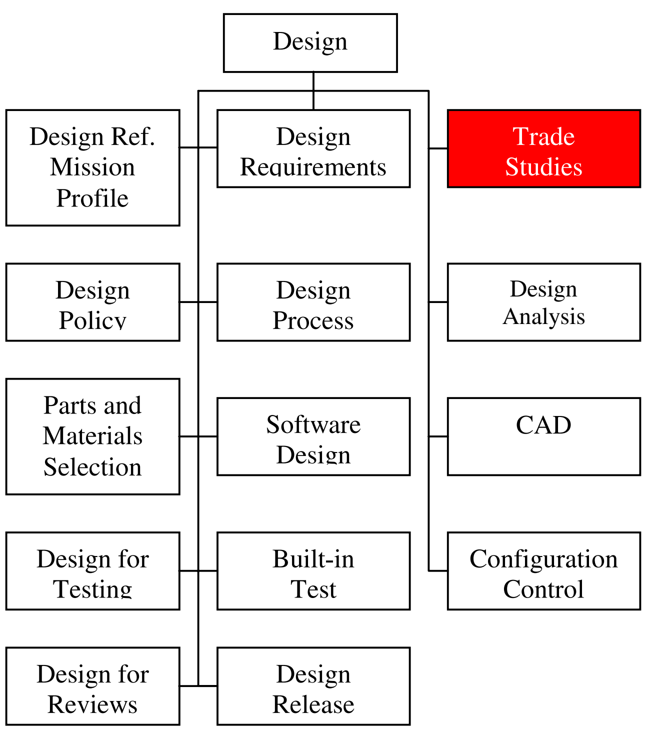
Traps!

1. Conducted as a single event on performance requirements

2. New technology is the answer

3. Timing and depth of studies are flexible

4. Producibility will be considered at start of production contract



Trade Studies

Benefits

Best design approach is identified	New technology used only when beneficial	Reduction of repetitive design efforts	Final design concept selected can be efficiently produced

Escapes

Verify that trade studies are part of the corporate design policy and process Ensure that design tradeoff studies continue throughout full-scale development	Use detailed trade studies to identify relative risks of all options associated with new technology	Ensure that trade study procedures establish a specific schedule, identify individuals responsible, and define proper level of reporting	Conduct a trade study for each design concept to assess its producibility

Best Practices

TRAPS

1. Conducted as a single event on performance requirements	2. New technology is the answer	3. Timing and depth of studies are flexible	4. Producibility will be considered at start of production contract

Current Approach

Alarms

Lack of business exists between effectiveness issues and suitability	New technology is used without trade studies being conducted	Trade studies are not completed prior to Critical Design Review (CDR) Neither government nor contractor personnel fully understand the process	Trade studies during design do not consider alternative manufacturing processes

Consequences

Design surprises will surface during tests	Concepts untested in the production environment may cause severe cost and schedule problems	Wrong alternative selection could compromise mission effectiveness	Costly redesign for producibility

Trade Studies

Summary: Too frequently in the past, trade studies have been performed on design alternatives to meet specific performance or reliability requirements only when a problem was identified, not to review and optimize all design areas for the purpose of avoiding problems.

The current DoD definition of trade studies is the "evaluation of concepts, policies, techniques, methods, and systems in terms of their costs and effectiveness to determine preferred employments of the several forces and development of projects, postures, and strategies which optimize the attainment of U.S. objectives in potential or actual conflict." In theory this sounds rather all-inclusive. Because a strong emphasis is placed on mission requirements, however, the studies typically do not include total system technical issues in practice. No specific guidelines or checklists are used to ensure completeness of the tradeoffs performed. These studies are initiated by the procuring agency and there is significant concern over their ability to technically analyze and evaluate complex, sophisticated projects effectively. In addition, the studies are performed generally during FSD as a singular event, and in many cases are not available totally to the contractor prior to the start of hardware design. The unfortunate consequence in many instances is that the selected alternative is inadequate for the perceived need, resulting in compromised mission readiness and effectiveness.

Best practice in FSD requires that current definition be interpreted as a study of design and production alternatives culminating in a selection that best balances the need against what is achievable realistically. Considerations to be included are mission effectiveness, cost comparisons, producibility, advantages/disadvantages, and project risk in terms of schedule, cost, and technical issues. Further, these FSD studies should extend and augment the tradeoff studies conducted during the conceptual phase by the government and concept-phase contractor personnel. Until the critical design review, the contractor is responsible for continuing tradeoffs at the detailed design level to assure as "fine-tuned" a design as possible. These subsequent studies are continual and iterative as the design develops and matures. All potential program or design selection options thus will have been exercised throughout the process to assure the timely deployment of a system that meets the mission requirements.

Trade Studies

Checklist

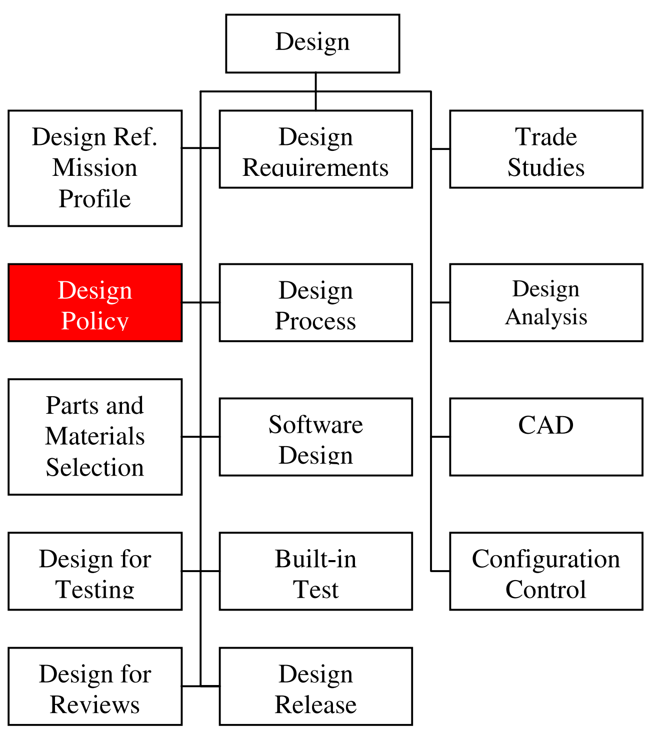
- ✓ Does the contractor's corporate design policy include trade studies?
- ✓ Are trade studies iterative from concept through FSD?
- ✓ Have trade study results identified the risk associated with new technologies?
- ✓ Do trade study procedures establish specific schedules, identify responsible individuals, and define levels of reporting?
- ✓ Has the producibiliy of each design alternative been considered in a separate trade study?

Design Policy

Overview: The implementation of best practices in engineering design is the responsibility of contractors. The existence or absence of documented corporate policies, backed up by controlled design engineering manuals to the necessary degree of detail, has a direct bearing on the degree of product risk associated with material acquisition. Many contractors do not have such corporate policies, and where these policies do exist, they often lack substantive direction regarding best design practices.

Traps!

1. MIL-STDs are used as design policy
2. Low cost design policy is implemented
3. New design policy is generated for each project
4. Design policy guidelines are established after contract award



Design Policy

Benefits

A framework for a disciplined design approach will be established	Design deficiencies will be identified and corrected prior to test phase	Design iterations will be minimized	Disciplined application of proven design principles and practices will be ensured

Escapes

Document a specific corporate policy Identify and formally implement both industry and government proven guidelines for all facets of design	Use latest design standards and engineering practices Assess depth of design analysis at periodic design reviews	Implement proven design policy with minor changes from lessons learned	Submit design guide-lines as part of the source selection pro-cess before contract award Specify detailed eng-ineering surveillance to ensure compliance in the contract

Best Practices

TRAPS

1. MIL-STDs are used as design policy	2. Low cost design policy is implemented	3. New design policy is generated for each project	4. Design policy guidelines are established after contract award

Current Approach

Alarms

No corporate design policy exists, or policy is not implemented below management level MIL-STDs and MIL-SPECs used in lieu of corporate design policy	Superficial design analysis and trade studies are dictated by cost	Lessons learned relative to design policies or practices on past projects are not documented	Design policy is not included during source selection Uniformity in design policy between prime and subcontractors is lacking

Consequences

Inconsistent and inadequate design policies degrade product	Redesign is excessive due to early test failures. Time and cost are increased because of the re-design necessary during production	Cost-effective corporate policies may not be recognized or implemented	Considerable redesign and fixes may be required in FSD

Design Policy

Summary: In most military acquisition contracts, there are no provisions for the contractor to implement his own design policy. When this situation exists, there is a relatively high risk that recognized good design principles and practices will not be used and the product will be deficient in performance, and will take longer and cost more to produce.

An obvious solution requires that each contractor submit detailed, working, corporate design policy for consideration in source selection. Many contractors already have established a corporate design policy which includes lessons learned on state-of-the-art materials and techniques. By doing so, these contractors demonstrate confidence that cost-effective design practices will be applied consistently.

A design policy is a statement supported by controlled engineering manuals, procedures, or guidelines, that attempts to reduce the risk in the design process by implementing fundamental design principles and practices. These design policies set the right climate to encourage good design practices. They should be visible and followed, with checkpoints to validate compliance, and tailored to a specific project or product area.

Guidelines that aid the design process do exist. These guidelines include requirements documents issued by both the government and the contractor, such as requirements allocation, component derating, design analyses, tradeoff analyses, testability requirements, parts control policy, training programs, etc. However, these guidelines are not consistent throughout industry, nor are they uniformly implemented for similar projects. Both government and industry agree on the importance of the design effort and the necessity to apply certain disciplines in this process.

It is generally acknowledged that systematic implementation of proven design principles and practices can lead to significant advances in equipment reliability without excessive added cost. The need exists for a more disciplined application of the policies, procedures, and techniques that are already established and general known throughout government and industry.

Lack of industry and government attention to design policy ignores the importance of setting the right climate for implementing fundamental design disciplines. Engineering integrity gives way to other considerations of a regular basis. Products are designed in an undisciplined approach with the risk that they will require considerable redesign and fixes after they get into the field.

Design Policy

Checklist

- ✓ Does a corporate design policy exist?
- ✓ Have lessons learned been reflected in the design policy or guidelines?
- ✓ Is there a separate design policy for different types of products?
- ✓ Do detailed design guidelines of standards exist, based on corporate policy?
- ✓ Have the salient design standards been passed on to subcontractors?
- ✓ Are the appropriate personnel aware of the design policy guidelines and standards?
- ✓ Is the design process treated in the design policy guidelines and standards?
- ✓ Were the design policy guidelines and standards considered during source selection?

Design Process

Overview: The engineering design activities that are necessary for product development are often treated as a discrete functional activity, with little or no involvement of the other plant functions (e.g., manufacturing or production engineering). Particular projects often are compartmentalized within a multiproject organization. This approach to product development stresses performance and gives little attention to producibility considerations. As a result, the product's design meets performance specifications at the completion of development, but does not allow for the limitations of manufacturing processes and procedures found on the factory floor. Hence, the apparently mature product configuration does not survive rate production without performance degradation, and significant redesign is required for efficient production.

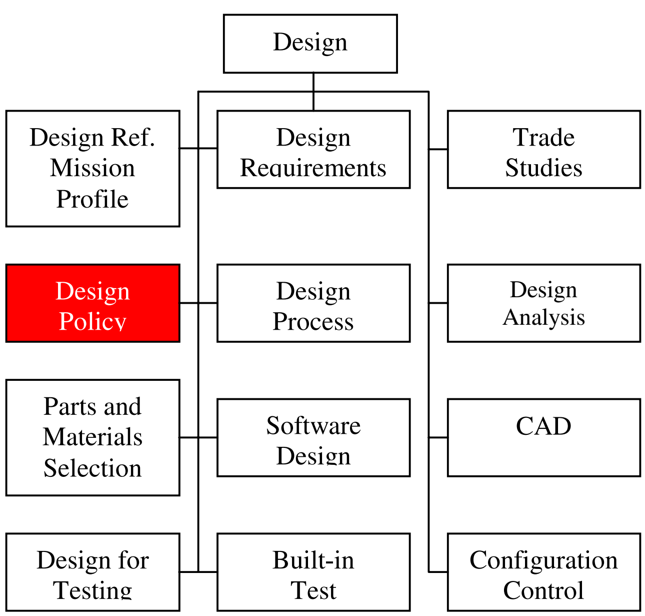
Traps!

1. Producibility studies are performed at the completion of FSD

2. Manufacturing process are proven during low rate production

3. Latest technological processes are used

4. The design is dictate by design engineering



Design Process

Benefits

Design will be producible	Production perturbations will be minimized	Potential production risks will be identified and minimized	Good Level III technical data package will be delivered at the end of FSD

Escapes

Include producibility reviews as part of the design process in contractor policy Team of specialists evaluate new processes and materials during design evolution	Use proof of manufacturing models prior to production	Use proven manu-facturing processes whenever possible Use tradeoff studies to justify the production risk of new technology	Collocate design and manufacturing engineering during product development Conduct production readiness reviews incrementally

Best Practices

TRAPS

1. Producibility studies are performed at the completion of FSD	2. Manufacturing processes are proven during low rate production	3. Latest technological processes are used	4. The design is dictated by design engineering

Current Approach

Alarms

Producibility issues are not identified during CDR Redesign for producibility is scheduled after FSD	Unanticipated tooling redesign is required for rate production	Parts material inventory require-ments are increased Yield rates are abnormally low	Volume of engineering changes is excessive Volume of material review board actions is high

Consequences

Fabrication is labor intensive	Costly schedule delays are caused by need for new manu-facturing processes and equipment	Learning curve is poor	Initial production units require retrofits

Design Process

Summary: The fist step in the design process is to review the requirements. After the design requirements have been review for completeness and clarity, ideas are formulated on how to meet the cited requirements. Here, producibility is considered as part of the design criteria to be evaluated for cost-effectiveness and ease of manufacture versus the degree of compliance with the functional requirements. Preliminary analyses should be made to tentatively select components, configuration, materials, and processes without locking onto the design of any tentative selections. These initial selections merely provide a basis for the designer to evaluate the concept. With a number of possibilities to consider, analysis is required to choose the approach that shows the greatest promise. As a minimum, analyses should be made of the risk involved in design alternatives, function versus cost, schedule versus cost, and components versus manufacturing capability.

Producibiliy is an engineering function directed toward achieving a design which is compatible with the realities of the manufacturing capability of a contractor. More specifically, producibility is a measure of the relative ease of manufacturing a product. Producibility often is identified as one of the items to be covered in a design review but is not discussed as one of the major cost drivers in the transition from development to production. Several DoD directives and MIL-STDs discuss the topic of production design but provide very little direction or guidance. Producibility, as a subset of production design, is usually not a major concern during the review activity. As a result, it is not given sufficient attention to impact the design process in the early development phases.

It should be recognized that the producibility effort must be performed by a team of specialists from across the project and supporting functions. One individual cannot possibly accomplish the total producibility effort without assistance from other functional areas. Considering the number of new processes and materials that are being developed, materials specialists should be brought into the areas of manufacturing, test and evaluation, and the design process. People from the various disciplines are necessary so that detailed interaction can occur between the product designers and the personnel who have specific knowledge of the available manufacturing technologies and their relevant costs.

Very often proof of manufacturing models are not provided or required, which results in tooling and process problems not being totally resolved prior to production. As a consequence, many producibility-type issues are not discovered until production, and depending upon the severity of these problems, rate production may be severely impacted. Retooling, new equipment, considerable redesign, exotics manufacturing processes, and the like are often require – at great additional expense and time – to allow for production quantities.

The achievement of production phase objectives usually requires the use of the most efficient, shop-proven processes for material transformation. These two process descriptors, “efficient” and “shop-proven,” often tend to be mutually exclusive. New processes and approaches to manufacturing, such as computer-aided manufacturing, often do not have extensive shop experience. The challenge is to maintain maximum efficiency of manufacture within the risk levels deemed acceptable for the specific project. It is important to recognize that advanced manufacturing technology generally brings certain levels of risk to a program along with the potential benefits of improved efficiency.

A contractor design policy should be established which specifically outlines the considerations to be implemented during the production design process. Management participation in design and producibility reviews is critical to its success. Collocation of design engineers, production engineers, and the producibility function greatly encourages cooperation and participation in early reviews of the design to ensure its eventual producibility at rate. Producibility must be confirmed prior to the production decision to ensure that a stable, mature design is transitioned to the factory. In addition, it is mandatory for low risk that proof of manufacturing models be required and that all processes be proofed to ensure that the design is indeed consistent with production processes and capabilities.

Design Process

Checklist

- ✓ Does the contractor's corporate policy include producibility as part of design reviews?
- ✓ Are manufacturing and producibility personnel involved in the design process?
- ✓ Are proof of manufacturing models required prior to production?
- ✓ Are proven manufacturing processes being used whenever possible, with trade studies performed to justify the use of new technology?
- ✓ Are design and manufacturing engineers collocated during development?
- ✓ Are production readiness reviews planned incrementally?

Design Analysis

Overview: As the design process progresses, analytical techniques guide the continuing effort to arrive at a mature design. While the design process concerns the actual additions, deletions, and changes to the design embodied on drawings and in engineering test models, design analysis evaluates the ability of the design to meet performance specifications at low risk. Those analyses oriented to the reduction of design risk include, but are not limited to, stress and stress/strength, worst case tolerance, sneak circuit, failure models and effects, and thermal analyses.

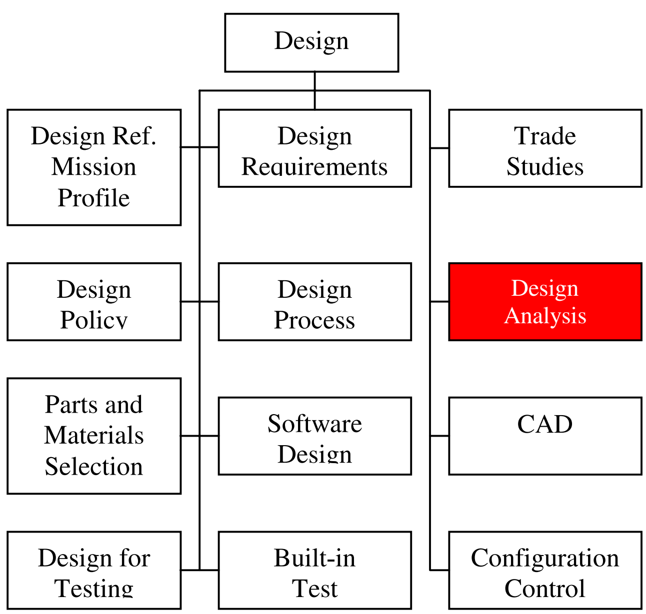
Traps!

1. Design analyses are conducted when problems occur

2. Design analyses results are required as contract data items

3. Design analyses are performed by support functions

4. Design analyses are cost drivers



Design Analysis

Benefits

Fewer recurring problems will exist during production and operational testing	A design that satisfies requirements will be released early	Technical design risk will be reduced	Significant cost savings will be realized through the coordinated use of design analyses and tests

Escapes

Conduct iterative design analyses to assure compliance with design requirements during the design process	Ensure that corporate standards identify design analysis as an integral part of the design process	Design engineers participate in and use results of design analyses to finalize the design	Maximize the use of design analysis Ensure that design analysis results influence both hardware design and test design

Best Practices

TRAPS

1. Design analyses are conducted when problems occur	2. Design analyses results are required as contract data items	3. Design analyses are performed by support function	4. Design analyses are cost drivers

Current Approach

Alarms

Design analyses are not provided at design reviews Design problems (detectable by analysis) occur during prototype testing	Analyses are conducted after design is completed Analytical results are used to show contract compliance Design is not changed to conform to analytical results	Design engineers are not active members of the analysis team Analysis recommen-dations are not implemented in the design	Achievement of design maturity is planned through the use of extensive testing

Consequences

System requires extensive engineering changes and increased logistics support	Testing may require additional prototypes	Design analysis fails to control the design process	Recurring failures lengthen the test program

Design Analysis

Summary: Inadequate risk-oriented design analyses probably cause more schedule, cost, and performance problems than any other project element. There is a lack of understanding of the nature of these analyses, and even what the various terms mean (e.g., worst case analysis, sneak circuit analysis, and thermal stress analysis). In addition, risk-oriented design analyses are generally a design engineering option, and often are accomplished by engineering support function rather than the design engineers themselves.

The solution to this problem begins with the requirement that the contractor establish and maintain detailed corporate technical policies specifying the risk-oriented design analyses which are require as a part of the design effort. The responsibility for design analysis lies with the designer, as a necessary adjunct to the design process. A design which has not been subjected to continual and complete risk-oriented analysis is not ready for release. Design release prior to completion of design analyses carries a high risk of design faults which, at best, will impede the test program by frequent failure, and at worst, will go undetected until deployment in the operational environment.

Risk-oriented analyses, such as thermal stress analysis, Failure Modes and Effects Analysis (FMEA), or sneak circuit analysis may require the support of other engineering personnel having specialized knowledge of those disciplines, but the prime responsibility remains with the design engineer. Corporate policy not only defines the necessary analyses but also assigns the participating support engineering organizations and makes provisions for implementation. These provisions include adequate time and resources, and methods for measurement of compliance.

Evidence of the effectiveness of Computer-Aided Engineering (CAE) is so overwhelming that contractors are moving rapidly toward the use of such CAE techniques as common technical databases which are available to designers through local terminals. CAE analysis tools which aid in locating and eliminating risk-oriented design problems, while reducing the requirement for the designer to be an expert in the risk-oriented design analysis disciplines, are improving both the accuracy and thoroughness of the analyses and giving the designer greater control of the design process.

Enforcement of thorough design analyses (and mature designs) is aided by the understanding that design reviews will include detailed evaluation of design risk as well as performance. Typical design reviews are so oriented towards performance requirements that design risk is not considered. Best practice requires that design reviews devote the time necessary to evaluate the results of the risk-oriented design analyses. The extra time necessary to complete this evaluation will be more than recovered in the test program and the trouble free transition to rate production.

Design Analysis

Checklist

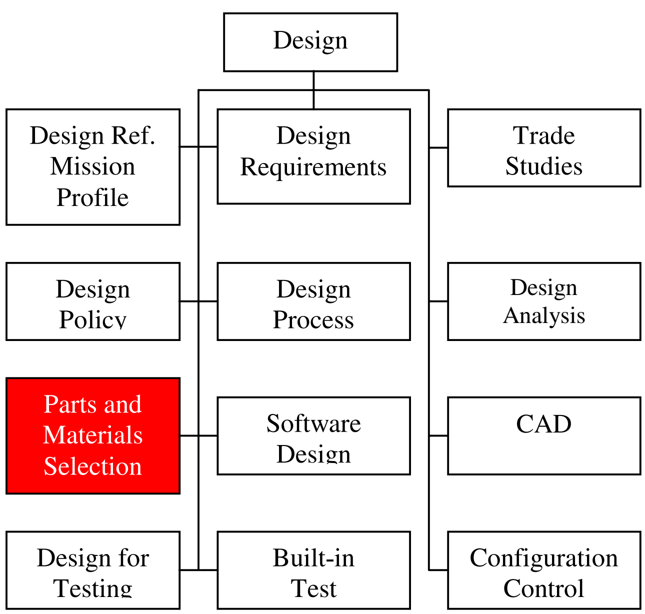
- ✓ Has continuous design analysis throughout the design process been specified?
- ✓ Do the contractor's corporate standards identify design analysis as an integral part of the design process?
- ✓ Are design engineers required to participate in and use the results of design analyses?
- ✓ Has proper balance been achieved between design analysis and testing?

Parts and Materials Selection

Overview: In attempting to maximize the performance of military weapon systems, design engineers often apply parts and materials too close to maximum rated stress levels, and they may also specify nonstandard parts. The uncontrolled use of these techniques leads to high risk during testing and operational use, decreases operational readiness, and increases logistics support systems complexity.

Traps!

1. Approved Parts List (APL) developed during FSD
2. Engineers use their own derating criteria
3. Thermal design is verified by early performance tests
4. Thermal derating compliance is verified by thermal analysis



Parts and Materials Selection

Benefits

Technical risk will be minimized at program start	Product line will have the benefit of corporate experience	Fewer problems will occur during development testing	Reduced stress levels in design will enhance operational life

Escapes

Issue APL at the start of FSD	Contractor establishes design policy on parts and materials derating that all engineers are required to use Government reviews and approves contractor derating criteria prior to contractor award	Use conservative thermal derating criteria Ensure that thermal analysis results cause appropriate design changes	Perform thermal surveys to measure part operating temperatures Compared measured temperatures to derating criteria and use results in analytical models

Best Practices

TRAPS

1. Approved Parts List (APL) developed during FSD	2. Engineers use their own derating criteria	3. Thermal design is verified by early performance tests	4. Thermal derating compliance is verified by thermal analysis

Current Approach

Alarms

Lack of standardization is indicated by design reviews	Obsolete and outdated derating criteria are used	Numerous design deficiencies are revealed during testing	Thermal analysis data is often inaccurate Thermal models may be unrealistic

Consequences

Proliferation of nonstandard parts causes increased maintenance burden	Design engineering approach is nonuniform	Extensive product redesign is required late in FSD	Project decisions are based on inaccurate information

Parts and Materials Selection

Summary: During the design process, specific parts and materials are selected and configured to meet specified requirements and to achieve desired objectives. The primary requirements concern performance, reliability, and maintainability, with the objective of meeting these requirements on schedule and within budget. Formal engineering education aims at the design process from a performance point of view. When parts and materials selection becomes a consideration, design engineers are not so well educated. Cost, schedule, and performance risks increase as a result.

To ensure the uniform application of parts and materials by all design engineers, an Approved Parts List (APL) must be issued at the start of Full-Scale Development (FSD). In addition to providing design engineers a baseline from which to select parts and materials, the APL also serves to introduce discipline into the design process since the use of any nonstandard parts or materials requires engineering justification prior to approval.

Results in recent pioneering defense systems acquisition programs have proven that specified derating criteria (fixed upper limits on allowable stresses affecting operating life) support low-risk design engineering. These criteria, invoked in government contract specifications and corporate engineering design policy, assist design engineers in making proper parts and materials selection and application decisions. At the same time, engineering design policy must require proven design solutions such as standard circuits and mechanical designs: techniques for designing for production assembly, test, and inspection and other successful techniques for reducing design risk.

To assure that the contractor's derating criteria in his corporate engineering design policy are kept up-to-date with government and industry standards, the government should review and approve the contractor's derating criteria prior to contract award.

One of the most critical factors to consider when determining the proper application of electronic parts is thermal stress, since one of the most common causes of electronic part failures is thermal overstress. The use of conservative thermal stress derating criteria provides an effective means of reducing part failure rates. In order to determine part thermal stress levels, the design engineer cannot wait until thermal overstress failures occur during testing, since the cost and schedule impact of redesign may be unacceptable. Therefore, it is critical that thermal stress analyses are performed on the design as soon as is practical. Equally important is the feedback of the results of the analysis into the design to effect design changes, not simply the reporting of the result to meet a contract data requirement, as has been done so often in the past. The thermal analysis must be continuously updated as part of the overall design effort.

As working models are constructed, the thermal analysis results should be confirmed by thermal survey measurements and the measured temperatures compared to derating criteria, as well as fed back into the analytical models.

Parts and Materials Selection

Checklist

- ✓ Will an Approved Parts List (APL) be issued at the start of FSD?
- ✓ Does the contractor have an established set of derating criteria that all engineers must use?
- ✓ Will the contractor's derating criteria be approved by the Government prior to contract award?
- ✓ Will part operating temperatures be determined by thermal survey measurements?
- ✓ Are the results of thermal analyses and thermal survey measurements being used in the design process?

Software Design

Overview: Modern weapon systems have become increasingly dependent upon software for their operation. The impact of software is accentuated by the fact that no cost-effective procedure exists for eliminating failures, or even accurately measuring the failure rate due to software when married to hardware in an operational scenario. Therefore, it is essential that software design practices follow a disciplined process similar to proven hardware design practices. Tradeoff analyses can disclose significant life cycle cost savings through proper and clear allocation of hardware and software roles, and can minimize the difficulty of isolating and correcting design problems.

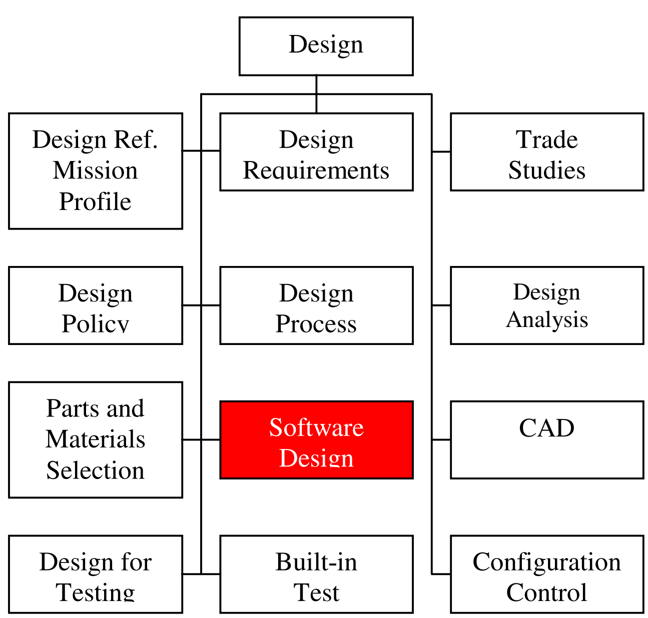
Traps!

1. Functional requirements are allocated either to hardware or to software

2. Programming is conducted in parallel with product design

3. Users manuals are scheduled for delivery with system software

4. Software progress reviews are a part of the periodic project reviews



Software Design

Benefits

Software design will meet requirements and hardware/ software integration will be smooth	Efficient software will meet customer requirements	Software will be user friendly for operators and maintainers	Software errors will be minimized

Escapes

Assign hardware/ software allocations after preliminary design tradeoffs are completed	Schedule programming to start at customer acceptance of product design specification	Schedule completion of draft users manual outline before programming begins	Conduct frequent separate software inspections as informal reviews on each software module Conduct reviews with a small team of experts

Best Practices

TRAPS

1. Functional requirements are allocated either to hardware or to software	2. Programming is conducted in parallel with product design	3. Users manuals are scheduled for delivery with system software	4. Software progress reviews are a part of the periodic project reviews

Current Approach

Alarms

Hardware/software interfaces are not defined clearly	Top-down design is not completed Product design specification is scheduled for delivery several months after programming is started	Outline of users manual is not prepared during product design phase Changes in draft users manual are not reflected by software	Reports of walk-throughs at detailed design and coding level are not available Software reviews are conducted without customer participation

Consequences

Isolation and correction of design problems are difficult	Inefficient code and interface problems are encountered	Software is difficult to use and maintain	Both design and coding errors may not be identified

Software Design

Summary: Successful software design involves defining what job the software is to perform, writing a design specification which describes in clear terms the solution to performing the job, allocating tasks for detail design and coding, and measuring progress.

A requirements document describes accurately and in detail what the government's problem is. In some cases, this is done during proposal efforts before contract award and, in others, the government has defined requirements in only sketchy terms and the first phase of the contract will involve a significant analysis effort. The requirements document should state what the problem is, not how to solve it.

The design specification is the contractor's solution, chosen from alternatives offered by the design team, on how he is going to solve the customer's problem. The design specifications, (which is the product baseline), should show the solution in terms of a functional description of what the system will do, and also in terms of how the system is structured to perform its functions.

After the design specification is written and accepted by the customer, actual programming can begin. Top-down design allocates the work into modules for detailed design, with allocation of module design to specific individuals. The module design must live within the company manual that defines standard practices, procedures, and conventions for detailed design and coding. The unit development folder has been used by many companies to provide:

a. An orderly and consistent approach to developing each software unit.

b. A uniform collection vehicle for all unit documentation and code.

c. Discipline in establishing and achieving development milestones.

d. Improved management and control over the detailed design and coding phase.

As the design and coding phases progress, frequent informal reviews (programmers like to call them walk-throughs) should be conducted with a small team of experts to ensure that the detailed design and coding are consistent with the design specification, and to uncover potential interface problems among modules. As coding proceeds, changes in the detailed design often will be found necessary or desirable. As long as these changes do not affect the baseline design and are in accordance with the company standard practices, procedures, and conventions, making these changes is the responsibility of the programmer.

Module testing is a concurrent process with module development. Each module should run flawlessly before attempting to combine it with other modules. Proper interface definition in the design specification will avoid interface problems between modules and with the hardware. Since almost all software will require maintenance after acceptance and delivery, good documentation will enable software maintainers to perform their tasks efficiently in the operational use of the software. Maintenance involves finding and correcting bugs not previously identified, making improvements in the delivered software, and providing enhancements to the system. Definition of the contents of user manuals and design of test plans should be completed as a part of the design phase before programming. These documents provide guidance for the detailed design effort so that the user will have programs that are "user friendly," and the test team will be able to measure the ability of the system to do what the customer wants it to do.

Software Design

Checklist

- ✓ Are hardware/software allocations assigned soon after preliminary design tradeoffs are completed?
- ✓ Are hardware/software interfaces clearly defined?
- ✓ Is software programming scheduled to start when the product design specification is accepted by the government?
- ✓ Is the draft of the users manual outline scheduled for completion before the start of programming?
- ✓ Are frequent separate inspections conducted as informal reviews on each software module?
- ✓ Are reports available for walk-throughs at the detailed design and coding level?
- ✓ Are software reviews conducted with government participation?

Computer-Aided Design (CAD)

Overview: Many design tools and analysis techniques that will facilitate the design process are not used and do not have meaningful impact on the product. Through the use of Computer-Aided Design (CAD) equipment, a full slate of design tools that facilitate the design process, and at the same time yield a producible product, is available. The use of such equipment decreases the length and cost of reliability development testing, decreases the cost for tooling and test equipment, eliminates redesign efforts for producibility, and ultimately reduces the risk during the transition from development to production.

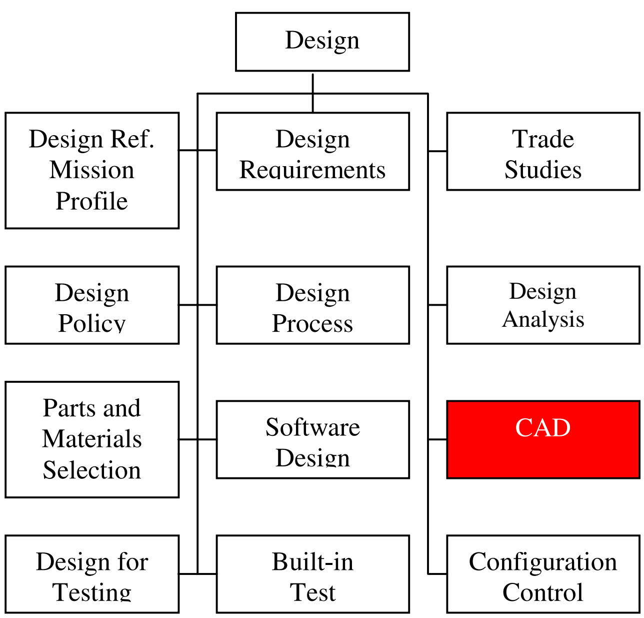
Traps!

1. CAD use is considered optional

2. CAD is used as an interactive graphical tool

3. CAD is considered an individual program requirement

4. CAD simulation and design analysis are performed using a design database



Computer-Aided Design (CAD)

Benefits

Design time will be reduced four-to-one	Design process will be enhanced and design changes will be fewer	Design process will be improved through the phase in of CAD	Design effort will be optimum for a mature product

Escapes

Dictate use of CAD by design policy Use detailed CAD data to facilitate design reviews	Provide workstations which have a comprehensive engineering analysis capability Make adequate CAD facilities and databases available to the designer	Orient CAD to support all product lines Include CAD as part of a corporate modernization strategy	Include corporate experience on parts and materials in a common database Integrate design engineering with all other plant functions through the use of a common database

Best Practices

TRAPS

1. CAD use is considered optional	2. CAD is used as an interactive graphic tool	3. CAD is considered an individual program requirement	4. CAD simulation and design analysis are performed using a design database

Current Approach

Alarms

CAD implementation is not supported by formal plans	Workstations have only a solid modeling capability Workstations are used primarily to facilitate the drafting process	CAD is perceived as too costly for general use Corporate database is not established or used There is no integrated employee CAD training program	Full menu of available parts and materials is not available Tooling considera-tions are not included in the design process Design release and configuration control are not implemented in CAD system

Consequences

Design process is less rigorous and more time consuming	Inefficient use of a major capital investment	Lessons learned on non-CAD programs not readily available	CAD capabilities not fully used

Computer-Aided Design (CAD)

Summary: Most DoD programs acquiring electronic systems have depended on contractor definition of the Computer-Aided Design (CAD) systems that facilitate product design and development. Independent definition of basic requirements has allowed use or nonuse of CAD as a tool to achieve these requirements. In many cases, CAD systems are considered as a “tool “ for simplifying the design task without recognizing the full benefits provided by CAD to introduce discipline throughout the plant operation. Technical discipline throughout the design process ensures success in complex development projects.

Since the use of adequate CAD technology is a significant factor in reducing the risk in development projects, particularly as those projects make the transition from development into production, the use of CAD technology should be encouraged. Therefore, it is recommended that CAD capability be recognized as a factor in source selection. Companies with a definite corporate policy with regard to CAD/CAM, and those companies that have proven capability in effective use of this technology should be ranked higher. As a general rule, the use of CAD systems should not be considered project-unique requirements and contractually funded. Although some product-peculiar CAD activities may occasionally be appropriate, CAD activities should be oriented to support all of the factory’s product lines.

What constitutes a good CAD system? CAD systems vary widely and range from stand-alone “personal” terminals to complex, interactive systems that require the use of complex and expensive host computer systems for data manipulation. An optimum CAD capability would provide each design engineer with a simple stand-alone terminal and provide an interactive terminal with a more comprehensive graphics team analysis capability for every for to six design engineers

The software used with these CAD terminals has paramount importance of the effectiveness and efficiency of the design control achieved through the use of CAD. Integrate CAD/CAM software architecture for multiple access and control, coupled with a common database, greatly improves system effectiveness and facilitates the design-to-production transition. The software that should be evident in a good CAD system include special analyses such as stress, vibration, thermal, noise, and weight. In addition, the CAD system should permit simulation modeling using finite element analysis and solids modeling. Such a system can cut the design/drafting process time by factors of four or five. The scope and thoroughness of these analyses are limited only by the programs available in the computer system.

The software package should be used in conjunction with a CAD/CAM database that includes (as a minimum):

a. design specifications including mission profile, performance limits and requirements, and reliability requirements

b. design standards and rules that support company policies

c. verified libraries of preferred electronic parts with both performance and physical characteristics, including tolerances

d. preferred mechanical parts

e. previously manufactured and qualified assemblies

f. materials, processes, and finishes

g. manufacturing processes, standards, and rules

h. design data including analytical results

i. manufacturing data, including:
   - design release status
   - test status
   - test and failure analysis
   - manufacturing yield and trend analysis

j. tool design

k. control of design release and configuration

Corporate policy that defines CAD technology as an integrated part of an overall factory modernization strategy is a low risk, effective approach to the development and use of CAD technology. Approaches that use computer-assisted technology (CAD, CAE, and CAM) in a piecemeal or "band aid" approach without careful consideration to the total plant-wide picture can be guaranteed a most difficult and costly system phase in from a lack of hardware and software compatibility. In addition, continuous and aggressive corporate involvement is required to enhance CAD capabilities. These enhancements are necessary to provide new analysis tools for manufacturing processes and updates of parts data information as high technology parts become available.

Once the CAD system is "on-line," it will be design engineer's effective use of his new design tool that will determine the benefit of the CAD system. The design engineer must, therefore, be made aware of the full capability of his CAD system. A formal training program for all users of CAD should be implemented. Such a training program should be integrated with other plant operations that are introducing computer-assist capability. This training program will ensure acceptance of the "new way of doing business," and ensure full use of the CAD system's features that may not be apparent from system documentation.

Computer-Aided Design (CAD)

Checklist

- ✓ Is CAD use dictated by corporate policy?
- ✓ Are individual alphanumeric terminals available for each design engineer?
- ✓ Are interactive graphics terminals provided for groups of engineers?
- ✓ Does a formalized training program exist for introducing engineers to CAD?
- ✓ Is a common and up-to-date database available containing parts and materials information as well as design engineering information?
- ✓ Is CAD oriented to support all product lines?
- ✓ Is CAD included in overall corporate modernization strategy?

Design for Testing

Overview: To provide for efficient and economic manufacture, consideration must be given to providing the proper test and inspection capabilities in the basic equipment design. Past development projects have neglected to consider the need for production and field test capabilities during the early design phase. Attempting to add these capabilities later has proven difficult and costly, especially in those cases where production has been initiated.

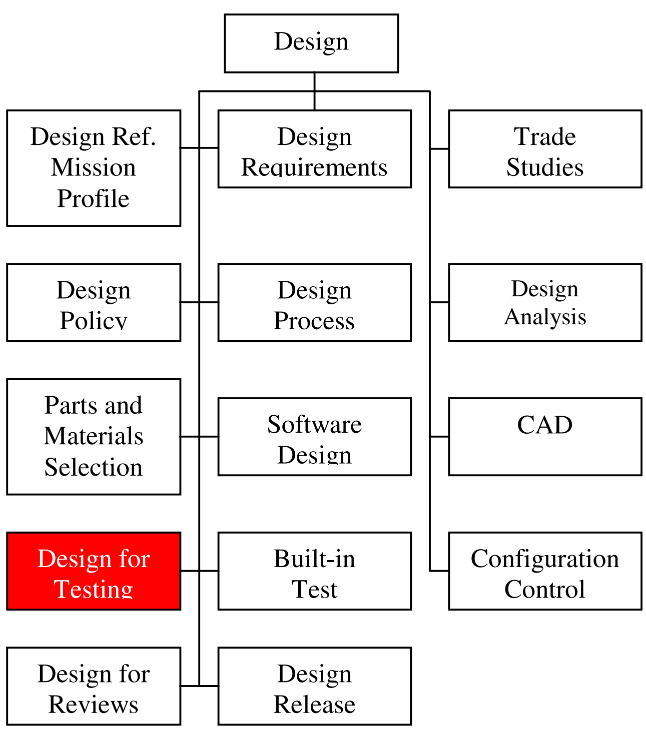
Traps!

1. Production test requirements are defined after design release

2. Specification contains operational test and maintenance requirements

3. Testing of performance parameters is emphasized in design

4. Design efforts are concentrated on the prime system



Design for Testing

Benefits

Design will permit efficient production testing	Spares burden will be reduced	Acceptance test capabilities will enhance rate production	Compatible ATE will be used in production and initial operational testing

Escapes

Establish corporate design policy on design for testing Production testing personnel coordinate with designer during trade studies and design reviews	Detail testability, maintainability, and supportability requirements clearly to designer Perform trade studies for cost-effective use of BIT, ATE, and manual testing	Establish production test guidelines prior to full-scale development	Select/develop ATE concurrent with prime system in time for FSD testing

Best Practices

TRAPS

1. Testing of performance parameters is emphasized in design	2. Specification contains operational test and maintenance requirements	3. Testing of performance parameters is emphasized in design	4. Design efforts are concentrated on the prime system

Current Approach

Alarms

Add on test circuitry is required	Requirements such as Operational Availability (A_o) and Mean Time To Repair (MTTR) are not translated into quantified testability design requirements Break out cables are required for fault isolation at operational level	Product is designed for performance testing and not for production acceptance and maintenance testing	ATE selection/design is not considered until end of FSD

Consequences

Test throughput cannot support rate production	Availability is degraded by marginal testing capabilities	Product is difficult to test with minimum effort and costs	ATE is not compatible with prime system and not available for deployment

Design for Testing

Summary: Built-In Test (BIT) and production testing are two major test areas that must be considered from the start of the design effort. Otherwise, these and other testing considerations can negatively impact both manufacturing and life cycle costs. The contractor should develop and implement a corporate policy relative to an integrated design for testing effort.

Design for testing addresses the needs to: (1) collect data, during the developmental process, of particular performance characteristics; (2) enable efficient and economic production by providing ready access to and measurement of appropriate acceptance parameters; and (3) enable rapid and accurate assessment of the status of the product to the lowest repairable element when deployed. These objectives can all be achieved, but only if they are fully recognized from the beginning of the design process. It is natural for engineers to concentrate upon the functional design characteristics, measuring performance parameters during development to the detriment of the product's suitability for test and inspection of acceptance parameters during production. This trap can be avoided if a set of specific guidelines is promulgated before design is initiated. These guidelines are based upon a written corporate policy reflecting up-to-date manufacturing, test, and inspection processes and equipment. The design for testability is approached in a systematic fashion no different than other design aspects. Balanced integrated requirements are identified, a plan developed, audits and reviews conducted, and demonstrations performed.

Frequently the availability of a test asset is ignored and the capability built-in test is overlooked when designing for test. With very high-speed integrated circuitry, the only means of test is self-test. Testability and inspectability designed for automatic equipment facilitate production. When production problems are minimized (through proper design for test, fault isolation, and inspection) maintainability problems are minimized as well. A design that is easily and completely testable and inspectable without disassembly, adjustments, special environmental conditioning, or external equipment or stimuli for monitoring of responses, is amenable to economic production. When one major system element is required to stimulate another during test, or when there is little functional modularity within the design, complexities increase. So do production and support costs.

A testability mentality must be established within the design activity. Just as reliability must be designed in, so must testability and inspectability. All designs should be guided by a strong test philosophy. Test measurements, with tolerances, should be specified to ensure interchangeability of subassemblies. Test specifications should identify what to measure and the required results.

As an integral part of the design process, testability design concepts should include: (1) physical and electrical partitioning, (2) Unit Under Test and Automatic Test Equipment (ATE) compatibility, (3) initialization, (4) test control and access, (5) parts selection, (6) system-level and item-level BIT, and (7) distributed BIT.

ATE is necessary for both operational testing and production acceptance testing. Therefore, the design tradeoffs between BIT, ATE, and manual testing must be done early so that the ATE is selected and designed concurrently with the prime equipment. The ATE should be tested with the prime equipment during FSD for compatibility and should be available for production testing. The Joint Service Automation Testing (AT) Acquisition Planning Guide[1] presents fundamentals of ATE design.

Involving knowledgeable manufacturing engineers familiar with the available and planned test and inspection processes and equipment is critical to designing prime hardware for economic production. This involvement must begin in the very early phase of design and is intimately associated with producibility. Proof Of Manufacturer (POM) models provide the basis for the evaluation of the maturity of manufacturing.

Testability and inspectability are such important aspects of manufacturing that it is absolutely essential to have POM systems/units available to verify production test and inspection equipment and methods. These same POM assets also are available to the manufacturing activity during the production effort and are an invaluable to "proofing" proposed changes in test or inspection before the formal commitment is made. Even if used only for the purpose of ensuring that the appropriate provisions have been made in the design for production test and inspection, POM models are cost-effective and will reduce life cycle costs.

Use of developmental test equipment for production generally perpetuates the desire to monitor performance parameters, continuing the data collection process. Data collection should be reserved for development and for troubleshooting. The production process should not be encumbered with making performance measurements on the product. Properly thought out acceptance criteria expressed in terms amenable to automatic test equipment should be the standard. Acceptance test requirements frequently are warmed-over performance requirement statements, thus carrying unnecessary measurements throughout the production run. Acceptance testing should be a check of the workmanship of the manufacturing process, not a proof of design or a requalification exercise.

A common trap is to assume that ingenuity in the design of manufacturing test and inspection equipment can compensate for deficiencies in the testability and inspectability of prime hardware. In fact, not much can be done to "add on" testability and inspectability if provisions for them were not in the original design. No amount of break out boxes, cables, and extender cards can compensate for poor testability design. The question of quantity is sometimes asked to determine whether the design should accommodate automatic testing and inspection. More frequently it is asked to guide manufacturing personnel in the type of equipment to be selected, rather than to influence prime hardware design.

A design that is fully maintainable is quite likely highly producible. If fault isolation needs are met, if access to signal flow is provided, if modularity of function is provided, if knowledge of proper performance can be determined without introducing external stimuli or monitoring requirements, and if alignments and adjustments are minimized, the maintainability needs regarding testing and inspection will have been met. These are the same objectives to be met in production.

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[1]Joint Service Automation Testing
(AT) Acquisition Planning Guide
NAVMAT P9404/DARCOMP 700-19
AFLCP 800-38/AFSCP 800-38/NAVMC 2719
19 March 1981

Design for Testing

Checklist

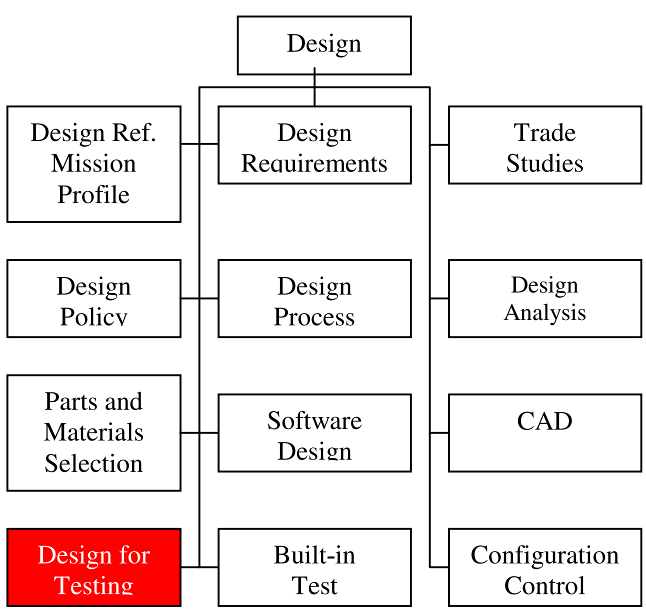
- ✓ Is corporate policy for design-for-testing in effect?
- ✓ Are manufacturing/producibility personnel involved in trade studies and design reviews?
- ✓ Have production test guidelines been established prior to full-scale development?
- ✓ Have trade studies been done during design to establish relative levels of BIT/ATE/manual testing?
- ✓ Is automatic test equipment being selected/designed concurrently with the prime system?

Built-in Test (BIT)

Overview: The continuing increase in complexity of military systems has imposed additional operational, maintenance, and logistics burdens on our military organizations. Unfortunately, these organizations are concurrently experiencing a reduction of both manning and skill levels of operators and maintenance personnel. The result is a more critical requirement that Built-In Test (BIT) monitoring and fault isolation capabilities be incorporated as integral features of system design. Consideration also must be given to the use of BIT as part of the manufacturing process, to verify proper functioning at various levels of assembly. BIT is therefore a significant factor in the initial design plans and tradeoff analyses and must be evaluated in subsequent design reviews.

Traps!

1. BIT design follows detailed design
2. BIT is required to isolate faults to a single replaceable item
3. Integration of BIT with production test needs is considered at the start of the production phase
4. BIT design is done independently



Built-In Test (BIT)

Benefits

BIT design will be properly integrated into initial system design	Balance among BIT, automatic test equip-ment, and manual testing will be proper	BIT will be designed properly for factory, operational, and depot test needs	BIT design will be fully coordinated

Escapes

Include BIT in design plan Include field and pro-duction test needs in detailed trade studies Identify subcontrac-tor/vendor BIT requirements early	Base BIT design philosophy on realistic requirements Perform detailed tradeoff analyses in accordance with the Joint Services BIT Design Guide	Involve production test and integration personnel in initial BIT design and tradeoff efforts	Specify and coordinate BIT interfaces and requirements before design Include BIT in coordinated design reviews

Best Practices

TRAPS

1. BIT design follows detailed design	2. BIT is required to isolate faults to a single replaceable item	3. Integration of BIT with production test needs is considered at the start of the production phase	4. BIT design is done independently

Current Approach

Alarms

BIT requirements/ constraints are not integrated into design effort	Operational and production testing requirements are unrealistic Cost, volume, power, and weight are not considered to be constraints in BIT design	BIT redesign is required by production test needs BIT is not available during prototype integration	Tradeoffs are not done for total test requirements

Consequences

BIT design is less effective and more costly	System overdesigned for BIT function	BIT is marginal for factory testing	BIT design does not adequately support operational and maintenance needs

Built-In Test (BIT)

Summary: The traps identified are associated with "too little and too late" consideration of BIT requirements relative to initial system design. A significant amount of analysis and tradeoffs must be done before a cost-effective BIT design approach can be detailed. As presented in the Joint Services BIT Design Guide[1], the operational and maintenance requirements of performance monitoring (failure direction) and fault localization, using tradeoff relationships with cost, weight, and volume, to determine the type and depth of BIT needed. Included in this would be the consideration as to whether the requirement would be better filled via automatic test equipment, manual test techniques, or mixes of the three approaches. The operational and maintenance BIT requirements then must be coordinate with Integrated Logistics Support (ILS) and production test personnel.

The BIT design concept can be taken too far, ending up with an expensive, impractical, product if the requirement is to isolate to a single replaceable item for a large system. Tradeoff analysis should be used to justify or reject such an approach. The obvious advantages of isolating to a single replaceable item are (1) reduced diagnostics time and (2) reduced occurrences of "no trouble found" removals.

Built-in test function should be planned early in the program for maximum effectiveness in both field operation and production integration and test. The "real" field maintenance environment should be determined, not an imagined or "should be" scenario. Trade studies should be performed to determine the most effective BIT parameters for the system. Ultimate production test needs will have a significant impact on BIT philosophy and should be determined early in the project development phases.

A detailed BIT approach should be developed prior to design start. This should included not only prime contractor BIT design, but also subcontractor and major vendor considerations, since BIT concepts can have a major impact on design approach. Failure to take these positive steps early in the program will result in a BIT philosophy which evolves piecemeal, rather than a well understood design concept which drives the conceptual and detail designs.

It is critical to effective BIT design to involve test and production discipline in trade studies to determine optimum approaches. Often, ultimate production cost can be prohibitive if the needs of integration and test functions are not considered. Test engineering personnel can analyze production steps and assist in choosing optimum BIT for production testability. A thorough testability analysis should be performed at this time to guide the system design. This integrated BIT design approach will assist the design engineer in selecting techniques which are best for both field supportability and production test efficiency.

A single point responsibility for BIT design at the system level is a key factor. Tracking implementation of the BIT plan as it evolves will ensure that redesigns are not necessary and that BIT "works" for successful evaluation testing of the total design. The Joint

Services BIT Design Guide[1] presents the fundamentals of BIT, provides an overview of the different approaches available to the designer and acquisition manager, and discusses standardized methods for evaluation of these different approaches. This guide is an invaluable tool for the personnel responsible for test, maintainability, reliability, and logistics support for present and future systems.

One of the prime objectives of the BIT design guide is to provide acquisition managers with guidelines for selection of analytical techniques, specification of BIT requirements, and for determining why BIT should be specified at all. The guide also gives guidance to designers responsible for translating BIT requirements into integral features of equipment design. The guide aids the designer in evaluating alternative BIT concepts and configurations, in choosing the preferred alternative, and in verifying the adequacy of choice.

Designers should receive adequate training in the latest BIT technology. Use of both manufacturing and test personnel to critique the design will allow production transition without redesign, and prevent an integration/test scheme which is “tacked on.” This approach will minimize schedule slips which are inevitable when BIT requirements are redefined late in the design cycle.

The early evaluation of BIT design is essential. The detail design reviews of the system should include a thorough review of the conformance of the design to the BIT plan by senior designers as well as test, production, and field personnel. This should be followed by structured verification in the initial system integration and early measurement in the use environment by end item users. This should prevent marginal BIT design and should ensure efficient production and field test capabilities.

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[1] Joint Services Built-in Test
(BIT) Design Guide
NAVMAT P9405/DARCOMP 34-1
AFLCP 800-39/AFSCP 800-39/NAVMC 2721
19 March 1981

Built-In Test (BIT)

Checklist

- ✓ Have BIT design requirements been based on a realistic scenario?
- ✓ Does BIT design reflect ILS and manufacturing test considerations?
- ✓ Have iterative tradeoff analyses been performed in accordance with the Joint Services BIT Design Guide?
- ✓ Have BIT design details been identified and included as part of initial design efforts?
- ✓ Have BIT requirements been passed on to subcontractors and vendors?
- ✓ Is BIT included in design reviews?
- ✓ Have production test and integration personnel been involved in initial BIT design and tradeoff efforts?

Configuration Control

Overview: The concept of a smooth transition from development into production requires that the design be frozen and documented at a point in time, and from then on, that the "configuration" be carefully controlled and documented. Only then can the final planning for production, installation, maintenance, and logistics be completed. Configuration control must be maintained throughout the life cycle of the equipment to avoid degraded operational availability and higher support costs.

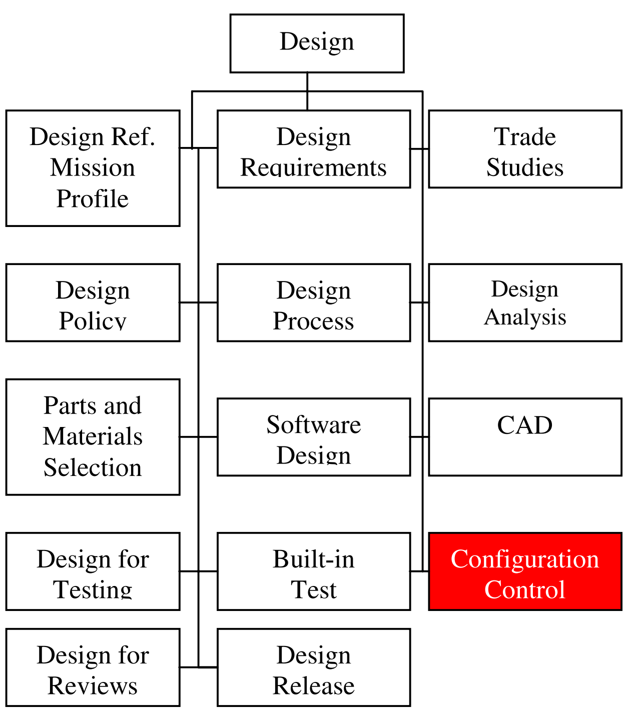
Traps!

1. Configuration control MIL-STD is applied directly

2. Configuration control is ended with delivery

3. Improvement changes are expedited

4. Level of control is dictated by schedule



Configuration Control

Benefits

Product baseline will be known	Maintenance and sparing will be facilitated	Design integrity will be maintained	Change control board will be strong

Escapes

Tailor plan to complexity of configuration item Flow control down to subcontractors Ensure management emphasis and corporate policy	Include information feedback from field activities in status accounting system	Establish a quality assurance change verification system Define baseline design using configuration audits	Project manager delegate full authority Use technical qualified personnel throughout

Best Practices

TRAPS

1. Configuration control MIL-STD is applied directly	2. Configuration control is ended with delivery	3. Improvement changes are expedited	4. Level of control is dictated by schedule

Current Approach

Alarms

Plans are boilerplate Subcontractors are left alone Requirements are not tailored	There is no formal field feedback Maintenance manuals do not correspond to hardware in the field	Stock purging is substituted for parts control Prints are red-lined	Configuration control function is staffed by administrative personnel Discipline is not ingrained in the designers

Consequences

Product is controlled by chance	Retrofit kits do not match configuration	As-built configuration does not match the design configuration	Excessive retrofit/ rework is required

Configuration Control

Summary: In too many military acquisition programs, neither the user nor the contractor really understands the concept of configuration control throughout the life cycle and their resulting efforts are too little and too late to achieve control. The results can be disastrous relative to operational maintenance, sparing, field modifications, and production. The application of configuration control on any project is essential. For effective utilization, it should be tailored to fit the nature of the project. It is critical that corporate policy recognizes the importance of proper configuration management in the development of a new project, and to emphasize the need to generate an adequate plan of implementation.

The configuration management plan must be streamlined, yet it must adequately encompass the entire life cycle, recognizing the requirements and complexity of the configuration item(s) and subsystems. At a minimum, it must establish the mode of operation and interface relationship among subcontractor, contractor, and customer. It also must manage the specification tree, engineering release, and drawing disciplines, and be responsible for revision to contract plans, including associated equipment and government-furnished equipment. Generating boilerplate policies or invoking MIL-SPECs as a direct substitute leads to overly simplified or overly complex approaches to managing the project early in development phase.

Proper staffing and delegation of authority also are critical to success. Staffing configuration management organizations primarily with administrators lacking good technical background, or using the discipline as a training ground for new or transient personnel, job shoppers, etc., results in weak configuration control.

The application of configuration management, the responsibility of the program manger, is normally delegated with sufficient authority to a separate configuration management organization. In cases where the configuration management organization is subordinate to either engineering or manufacturing, its function becomes less objective and more subjective in nature. Decisions of a controversial nature tend to be strongly influenced by the wishes of the activity to which it is subordinate. These decisions are often based upon what is best suited to satisfy the short-term cost or schedule requirements. Such an approach is not conducive to a sound configuration management policy for the overall life cycle of the project.

Configuration management is a discipline that organizes and implements, in a systematic fashion, the process of documenting and controlling configuration. Its antitheses are chaos, confusion, crisis, and adverse cost impact. The designer must understand this at the outset of design. Training courses to emphasize and demonstrate configuration control are helpful. Whenever configuration management is perceived to be a roadblock, and methods are improvised to bypass this function to satisfy schedule requirements, this is an early warning that design integrity has been compromised.

The use of red-lined prints, advance release information, and prerelease documentation to procure, fabricate, and install parts, assemblies, and systems virtually ensures that substantial redesign effort will shortly follow. Premature, unauthorized, unidentified, and uncoordinated “improvement changes” introduced during the transition from development to production are often the root of spares identification and field maintenance problems once the configuration item goes into service. These are also symptomatic of insufficient or inefficient configuration control.

Purging stock of unusable parts without issuing new part numbers is shirking responsibility by engineering. Such delegation of configuration is neither wise nor cost-effective. Failure to assign new part numbers with each configuration change will invariably result in installing the wrong item in a higher assembly, where rework and reidentification are more costly.

Specifically selected “critical” structural or functional detail parts, subassemblies, and assemblies which require special attention and control through design, manufacture, test, and delivery, are subjected to added controls and annotated as Designated Parts (DPs). DPs require specific serial number identification with in the item and a systematic capability to track the DP through manufacture, procurement, inspection, storage, spares, and test history. Over the life of a project, this approach becomes most cost-effective.

Typical indicators of effective configuration management are strong change control boards and status accounting reporting systems that invoke timely feedback requirements from the production facility and from field service activities. These ongoing functions avoid the costly efforts required to continuously submit retrofit kits which are not compatible item(s) being modified.

Configuration Control

Checklist

- ✓ Have configuration control procedures been tailored to product complexity?
- ✓ Are configuration control requirements flowed down to all subcontractors?
- ✓ Does the status accounting system allow for information feedback from the field?
- ✓ Have functional and physical configuration audits been conducted?
- ✓ Has a quality assurance change verification system been established?
- ✓ Are technically qualified personnel involved in configuration management?
- ✓ Has full authority been delegated by the project manager?

Design Reviews

Overview: Although most defense contracts require formal design reviews, the reviews themselves often become a forum for providing an overview of the overall hardware design, rather than an in-depth technical assessment of design maturity. Design reviews must be performed by technically competent personnel in order to review design analysis results and design maturity, and to assess the technical risk of proceeding to the next phase of the development process.

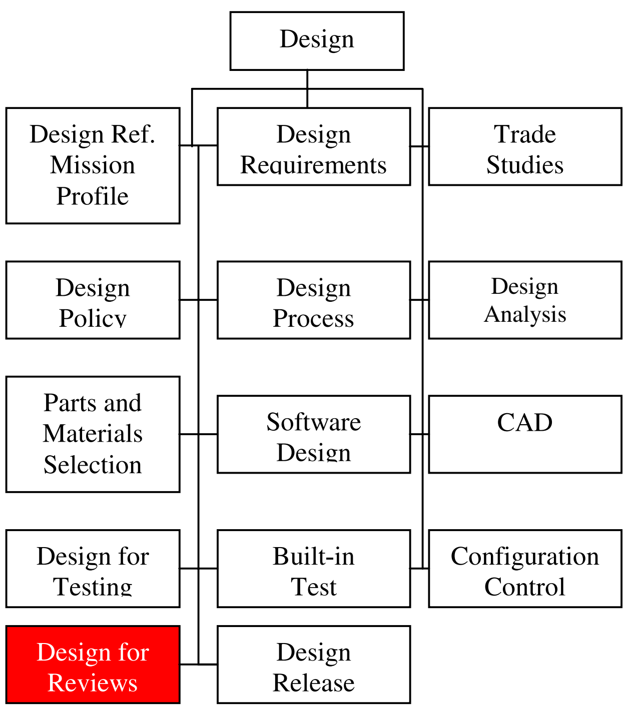
Traps!

1. Project review format is used

2. Review is keyed to project milestones

3. Review is focused on the design

4. Design reviews are held informally



Design Reviews

Benefits

Technical balance will be maintained between management and design	Design maturity will be known	The design will fulfill all specified requirements	Design baseline will be certified

Escapes

Establish both internal contractor and contractor/government reviews via corporate policy	Establish technical design review schedule based on design progress	Ensure that review team's total experience base is greater than the product design team's experience Evaluate alternative design approaches for all disciplines	Establish a formal corporate design review policy with procedures for documenting results and action items

Best Practices

TRAPS

1. Project review format is used	2. Review is keyed to project milestones	3. Review is focused on the design	4. Design reviews are held informally

Current Approach

Alarms

Review is staffed with management people Review is conducted in accordance with a master schedule	Review is success-oriented, not a technical evaluation Risk is not identified or assessed	Analyses, assumptions, and processes are not reviewed Tradeoff studies, underlying data, and risk assessments are not presented	Design review actions are not reported to management Formal report with appropriate action items is not prepared

Consequences

Management status is reviewed instead of design progress	Design deficiencies are not identified	Design is not influenced by all analytical activities	Total system requirements are not met

Design Reviews

Summary: Although design reviews are recognized as being important to verify design before production, the lack of depth of reviews is alarming. The cause of these inadequate reviews must be shared by both the contractors and the government. Contractually, the government rarely requires the contractor to do a comprehensive technical review and the contractor doesn't do so unless required to, even though it may be cost-effective from his point of view. Even when the right words are used, the end results depend largely on corporate policy to allocate sufficient resources to perform a detailed analysis of the design and associated processes.

The objective of all design reviews, both internal contractor and contractor/government, is to ensure that the design will fulfill its requirements.

The government and contractor both recognize that design reviews represent the "front line" of readiness for the transition to production. The review should be conducted by non-project, impartial, objective senior technical experts at the contractor and subcontractor alike. Many design reviews fail in meeting objectives. They often lack specific plans and discipline in requirements, criteria in execution, and depth in review. They tend to concentrate on the performance characteristics of the design at the expense of manufacturing, quality, test, and support. The main trap to be avoided is conducting a design review as a mini-project review. Some design reviews degrade to the point of familiarizing people with an overview of the hardware design. Little depth or breadth of the design is reviewed and minimum contribution to design in maturity is realized. A design review that rationalizes acceptance of risks because correction would compromise schedule or cost is almost worst than no review at all.

Internal contractor design reviews should be conducted to validate the design at each step of the process before a commitment is made to the next phase or design stage.

Sound design reviews identify technical risks in performance, test, manufacturing, producibility, and use. Internal contractor design reviews are mandatory at every key design and development milestone. The soundness of the review is evidence by the topics to be reviews. Some typically forgotten topics are:

- Product safety
- Component applications
- Materials
- Mission profile to detail requirements analysis
- Manufacturing and inspection processes and plans
- Tooling and test equipment
- High risk technology to manufacture and use
- Reliability and maintainability
- Test equipment and special equipment
- Built-in test

- Producibility and inspectability
- Subcontractor design
- Design margin analysis results
- Production readiness
- Software design walk-through

The government/contractor design reviews also play an important role in ensuring a mature design. The technical competence of the reviewers (both government and contractor) must be equal to or greater than that of the designer. “Observers” are not a proper part of the design review. Team ownership of the product design can be enhanced by functional area review leaders. In order to ensure positive contributions and sound action items, the preparation by the reviewers should be very detailed in the technologies and disciplines to be reviewed. The most basic customer/contractor reviews are:

- System Requirement Review
- Preliminary Design Review (PDR)
- Critical Design Review (CDR)
- Functional Configuration Audit
- Physical Configuration Audit
- Production Readiness Review

The design review process is critical to reducing program risk. It provides the discipline necessary to ensure timely identification of problems and their solutions. It is an efficient way to evaluate the maturity of the design, find areas needing correction, spot high technology risks, look at the producibility and design margins, and evaluate the manufacturing and quality aspects of the design. The independence and competence of the reviewers is essential. Maintaining the dual review categories and providing necessary visibility of the results will help to ensure a low risk program, which will transition a mature design into production.

Design Reviews

Checklist

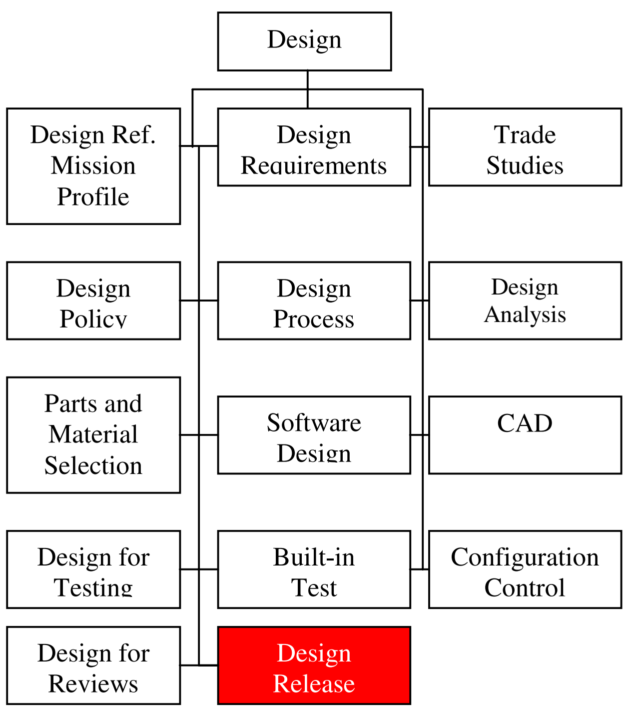
- ✓ Does the contractor have a corporate policy identifying procedures for internal reviews as well as customer required reviews?
- ✓ Is emphasis being placed on technical interchange meetings between contractor and customer rather than large-scale reviews?
- ✓ Are reviews being done by qualified technical experts who can challenge the design and assess risks?
- ✓ Are technical design review schedules established based on design progress?

Design Release

Overview: Integral to the development process are the facts that at some point, creative design must cease, and the design must then by released to manufacturing. Only then can the baseline design be identified; a detailed design review take place; a configuration audit be performed; and correct documentation for producibility, system operation, maintenance, and sparing evolve.

Traps!

1. Design release points are pre-established
2. Pre-release drawings are used
3. Drawing release is on schedule
4. Drawings are approved for release by design engineering



Design Release

Benefits

Design release systems and manufacturing build will be compatible	Solution of surprise problems can be expedited	Long lead time items will be available when needed	All disciplines will have influenced the design

Escapes

Release design when technical risk judged acceptable Engineering schedules design releases with manufacturing and purchasing	Invoke management system for control of pre-released drawings	Schedule critical drawing releases to match manufacturing cycle	Require concurrent review by all disciplines

Best Practices

TRAPS

1. Design release points are pre-established	2. Pre-release drawings are used	3. Drawing release is on schedule	4. Drawings are approved for release by design engineering

Current Approach

Alarms

Release schedule is derived from previous programs Manufacturing is setting release schedules	Drawings are issued with "TBD" requirements "Red-line" drawings are used by manufacturing	Releases are not compatible with purchasing and manufacturing requirements	The "ilities" are bypassed during design development or scheduled too late in approval cycle

Consequences

"Can't build to" documentation is released	Configuration control is lost	Manufacturing schedule is slipped	Multiple revisions occur after drawing release, increasing rework

Design Release

Summary: Design release is related closely to other design activities such as design reviews, production design, and configuration control. Designs may be released which are incomplete, inaccurate, or premature. When this happens, it obviously causes problems downstream for all activities involved with the hardware or the design documentation. Designs frequently are released early for scheduling or other reasons, and get-well actions are lengthy and not always satisfactory.

Design release is driven most often by previous project production accomplishments that have little or no application to the current effort. Setting up release schedules by "back planning" from manufacturing schedules often requires engineering to meet unrealistic dates, and thus to deviate from standard procedures, permitting inferior-quality documentation to reach users. By using uniform practices and procedures concerning technical requirements and evaluating current manufacturing capability, more realistic design release dates can be established. Formal drawing release negotiations should be conducted at the functional management level since this responsibility is too critical to be delegated. Any changes or adjustments to schedule should be made by concerted effort of affected disciplines, on a normal or emergency basis as required, and as specified in standard procedures.

There is seldom time permitted for interface between disciplines when emergencies arise, so that schedule and cost impacts are not examined. The flexibility of an "in-series approval cycle" delays data flow, and detracts from time allotted to review documentation prior to release. If disciplines are not adequately involved in design development, their inputs in the last phase of design release will be ignored.

By organizing formal negotiations for design release between engineering, manufacturing, and purchasing, schedules can be prioritized by mutual agreement and in accordance with manufacturing and procurement requirements. A project team made up of representatives of affected function integrates milestones and conducts surveys of design progress, and allows for schedule adjustments to cover contingencies.

Expedited and advanced releases, used extensively as catch-up devices, generally create a need for second- and third-generation efforts and clog the design release pipeline. The same is true for "early-issue" specifications burdened with "TBD" passages and requirements. Manufacturing unreported "work-arounds," (i.e., fixing problems by red-lining, and reviewing blueprints without engineering support), slide a large workload into inappropriate time frames and disturb product integrity. Similarly, engineering changes not transmitted in a timely manner to manufacturing can play havoc with operational schedules. To correct this recurring condition, the design should be validated in stages, using experienced personnel from technical and production disciplines to ensure that the design is adequate, complete, and on schedule (or adjusted schedule) when released. Proofing the design on manufacturing models and providing the results to engineering ensures that the documentation maintains its integrity. The same type of information flow is required to incorporate the findings of design reviews.

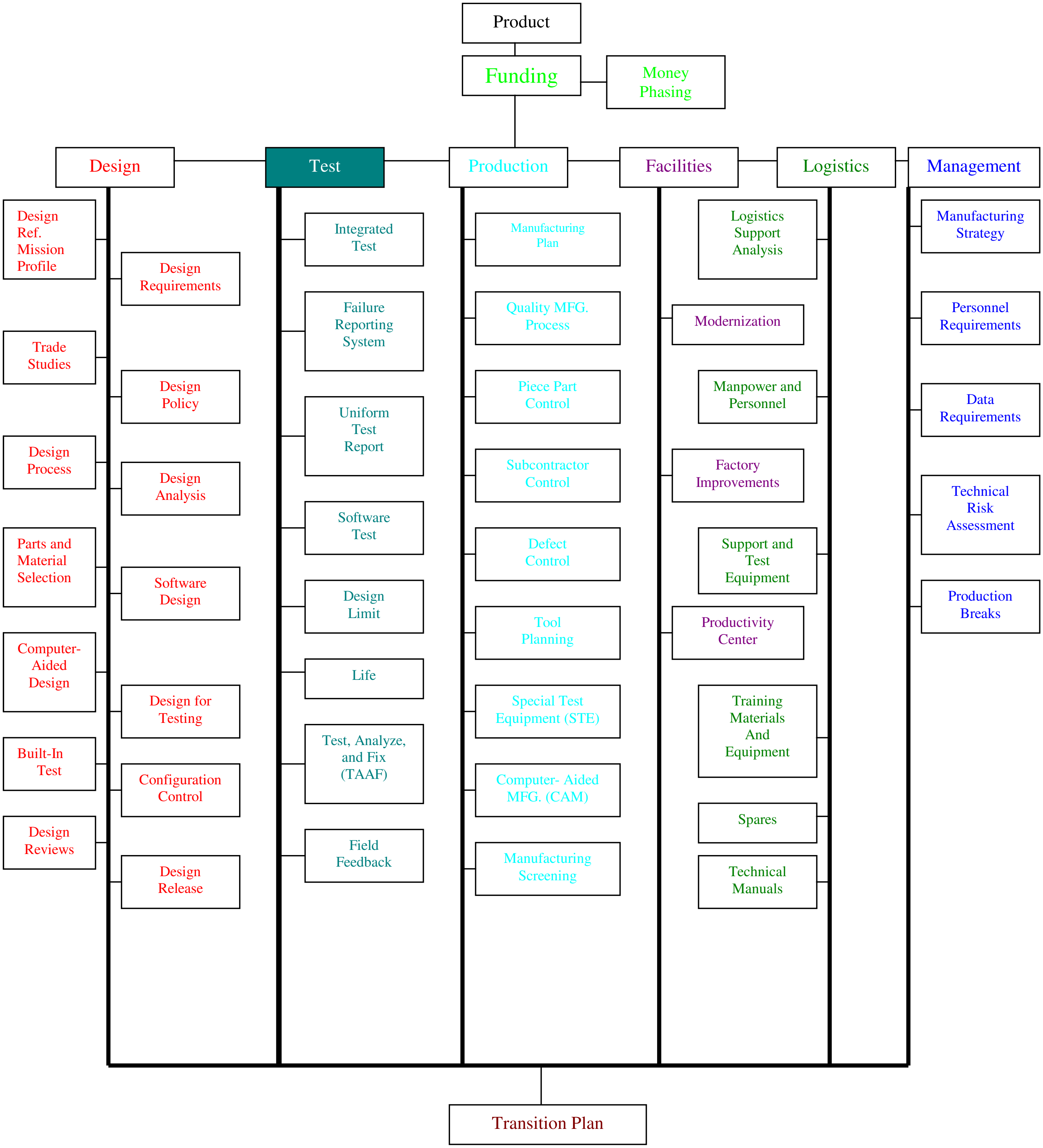
Counting drawing releases does not provide a measure of design progress versus schedule versus budget used. In the same vein, excessive changes immediately after initial design release may seem more important than they are. Minor corrections often are required at this point, and without a concise analysis of the nature of the changes is meaningless. The practice of only auditing when directed by the government (or imposed by any customer) does not permit a reasonable estimate of the status of design release activity.

Measurements for technical performance should be a planned policy, done in concert with scheduled configuration reviews to determine compliance with contractual and company requirements.

Design Release

Checklist

- ✓ Has engineering scheduled design releases with manufacturing and purchasing?
- ✓ Has technical risk been judged to be acceptable prior to design release?
- ✓ Does the management system control pre-released drawings?
- ✓ Have critical drawings been identified?
- ✓ Is the release of critical drawings properly scheduled to meet requirements?
- ✓ Does the design release process require concurrent review by all disciplines?



Product
Funding
Money Phasing
Design
Test
Production
Facilities
Logistics
Management
Design Ref. Mission Profile
Design Requirements
Trade Studies
Design Policy
Design Process
Design Analysis
Parts and Material Selection
Software Design
Computer-Aided Design
Design for Testing
Built-In Test
Configuration Control
Design Reviews
Design Release
Integrated Test
Failure Reporting System
Uniform Test Report
Software Test
Design Limit
Life
Test, Analyze, and Fix (TAAF)
Field Feedback
Manufacturing Plan
Quality MFG. Process
Piece Part Control
Subcontractor Control
Defect Control
Tool Planning
Special Test Equipment (STE)
Computer- Aided MFG. (CAM)
Manufacturing Screening
Logistics Support Analysis
Modernization
Manpower and Personnel
Factory Improvements
Support and Test Equipment
Productivity Center
Training Materials And Equipment
Spares
Technical Manuals
Manufacturing Strategy
Personnel Requirements
Data Requirements
Technical Risk Assessment
Production Breaks
Transition Plan

TEST
Integrated Test

Overview: During the development of a weapon system, a large number of tests are conducted by subcontractors, the prime contractor, and the government. To assure that these tests are properly time phased, that adequate resources (e.g., test articles, test facilities, funding manpower) are available, and that duplicative or redundant testing is eliminated, a properly integrated test program is required. Previous efforts at test program integration have resulted in top level documents which did not adequately address the entire test program. Such efforts have not produced viable management documents which actually control the total test program.

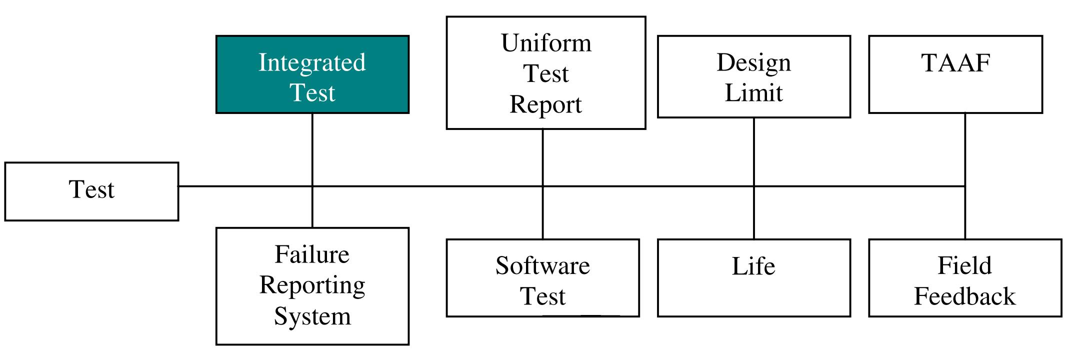
Traps!

1. Test and Evaluation Master Plan (TEMP) is prepared using DoD Directive 5000.3 guidelines

2. Development testing is independently performed by contractor

3. Test program is planned to support major milestone reviews

4. Individual test plans are submitted for government approval



Integrated Test

Benefits

ITP will identify duplicate or missing test activities and ensure proper test sequencing	Coordinated test program between contractor and government will provide early identification of deficiencies	Sufficient time will be available to obtain technical data to satisfy project requirements	Test facilities and resources will be used efficiently

Escapes

Contractor prepare an Integrated Test Plan (ITP) addressing all contractor and subcontractor tests	Provide contractual arrangements for at least some government participation in contractor weapon systems testing	Base test schedules on engineering considerations with sufficient time provided for redesign/ retest	Ensure that test program objectives are satisfied by planning for required integration of individual tests

Best Practices

TRAPS

1. Test and Evaluation Master Plan (TEMP) is prepared using DoD Directive 5000.3 guidelines	2. Developmental testing is independently performed by contractor	3. Test program is planned to support major milestone reviews	4. Individual test plans are submitted for government approval

Current Approach

Alarms

Contractor and subcontractor tests are not identified	No provisions are made for government personnel to participate in contractor weapon systems testing	Time is insufficient for redesign or retest of identified problems Milestone reviews are supported by unrealistic projections of limited test data	Integrated test plan is not required Overall test program is not reviewed for duplicate or missing test activities

Consequences

Visibility of overall test planning is lacking	Systems integration, human engineering, and interface problems are not recognized until OT&E	Milestone review decisions are based on limited technical information	Schedule, resource, or test adequacy shortfalls are risked

Integrated Test

Summary: Because testing is a major cost and schedule driver, adequate planning is essential long before the start of any testing. Test planning between subcontractors, the prime contractor, and the government should start with program initiation. To ensure a successful integrated test program, close coordination is required between the government, the prime contractor, and all subcontractors.

DoD Directive 5000.3 requires the preparation of a Test and Evaluation Master Plan (TEMP). The TEMP is a broad plan relating test objectives to required system characteristics and critical issues, and is a top level document used at major milestone reviews to assess the adequacy of planned test and evaluation. The TEMP normally covers only government-required tests, and does not provide a sufficient level of detail to identify contractor and subcontractor tests. In an attempt to control the test program at the contractor and subcontractor level, contracts may contain requirements for the submittal of individual test plans for government approval. If an integrated test plan is not required, these individual test plans may not be reviewed for duplicate or missing test activities resulting in an inefficient and costly test program.

The prime contractor should be responsible for the preparation and updating of an Integrated Test Plan (ITP). To develop an efficient and well-coordinated integrated test program, the prime contractor and all subcontractors should jointly participate in the preparation of the ITP. The ITP should include all developmental tests to be performed by the prime contractor and all subcontractors at both the system and subsystem levels. The ITP should be a detailed working-level document which will aid in identifying risk as well as duplicate or missing test activities, and will provide for the most efficient use of test facilities and test resources. In developing the ITP, the purpose and time phasing of each individual test should be carefully examined. Unnecessary tests should be eliminated and test schedules should be adjusted to provided sufficient time for retest, should failure occur. The proper sequencing of tests is necessary to ensure completion of required lower-level subcontractor tests prior to the start of prime contractor tests.

During Development Test and Evaluation (DT&E), the contractor and the government normally conduct separate, dedicated tests,. In many instances these separate test periods result in redundant testing, testing which is not user oriented, lack of continuity in the contractor's development program, and a lack of cooperation between contractor and government personnel. In order to increase the efficiency of DT&E, the government should participate in some of the contractor's testing. This will help eliminate redundant testing, reduce the length of DT&E phases, provide more user-oriented test results, and result in a more mature system for Operational Test and Evaluation (OT&E).

Most test schedules are planned to support the major milestone reviews that occur during the development of a weapon system. The tests are planned to provide positive (successful) test results for presentation at the milestone reviews, in order to obtain approval for the project to proceed to the next milestone. This leads to a test philosophy in which passing tests is the main objective of the test program, rather than considering the engineering need for the test or the technical information provided by the test results. As a result of this philosophy, test schedules tend to be success-oriented, many times resulting in schedule slippage due to the need for retest or a lack of test assets.

As test programs progress, many tests will disclose a need for redesign and retest. In some instances, only a minor correction and verification test will be required. In other cases, the corrective actions many be extensive and require significant retest. If test schedules have not allowed sufficient time for redesign and retest, changes and retesting may be delayed until production equipment is available. If the changes prove incorrect and additional redesign is required, production units have to be retrofitted and a large number of Engineering Change Proposals (ECPs) may be required during the early phases of the production program. Also due to the sequential nature of some tests, the performance of certain tests may be delayed until production, possibly resulting in additional ECPs.

Test schedules should be properly phased primarily on the basis of engineering considerations, rather than strictly milestone-oriented. The purpose or objective of each test should be considered as well as the interrelation of various tests with each other. Since the start of certain tests may be dependent upon the completion of others, critical tests should be identified and provisions made for schedule slippage due to needed redesign and retest. In certain cases, critical test schedules can be accelerated by providing more test assets or additional test facilities. This strategy can provide significant leverage to reduce the overall development test schedule. Milestone reviews can then be planned on the basis of realistic test schedules. More engineer-oriented test results showing design strengths and weaknesses should be presented at design reviews. The review should discuss design weaknesses and how they have been or will be corrected. The overall success of a carefully integrated test program will result in a minimum of resources applied to testing and the elimination of a costly ECP or retrofit program during production.

Integrated Test

Checklist

- ✓ Is the prime contractor required to prepare an integrated test plan?
- ✓ Do test schedules allow time for redesign and retest?
- ✓ Are contingency resources available for unforeseen test problems?
- ✓ Has the integration of individual tests been considered?
- ✓ Have contractual arrangements been made for government participation in contractor weapon systems tests?

Failure Reporting System

Overview: MIL-STD-785B and MIL-STD-781C require Failure Reporting, Analysis, and Corrective Action Systems (FRACAS). The implementation of these requirements, in many instances, has been poorly managed, not properly defined, and undisciplined. The flow down of requirements from prime contractor to subcontractors has not been uniform, analysis of all failures has not been required, the timely close out of failure reports has been overlooked, and systems for alerting higher management to problem areas have been missing.

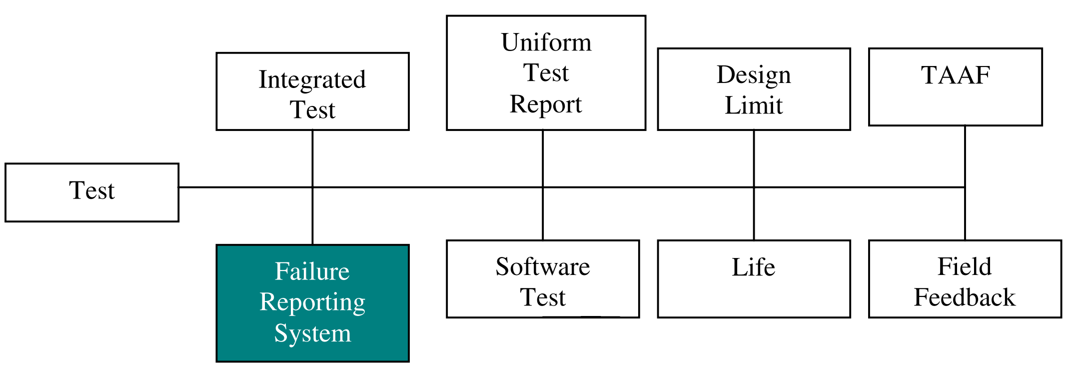
Traps!

1. Failure reporting system is required at the start of Full-Scale Development (FSD)

2. Failure review board is established

3. Cost-effective failure analysis is based on frequency of occurrences

4. All failures are required to be closed out



Failure Reporting System

Benefits

Elimination of failure modes at the subsystem level will result in decreased system level test times	Failure review board will make technically sound recommen-dations that can be promptly accepted	Design weaknesses will be eliminated early	Corrective actions will be timely and effective

Escapes

Ensure at post-award conference that the required failure reporting systems include GFE and are a requirement in all subcontracts	Contractor and government review and approve failure review board membership to ensure adequate representation	Analyze all failures to identify failure cause and corrective actions, as necessary	Close out all failures within 30 days Verify corrective actions or reopen failure reports

Best Practices

TRAPS

1. Failure reporting system is required at the start of Full-Scale Development (FSD)	2. Failure review board is established	3. Cost-effective failure analysis is based on frequency of occurrences	4. All failures are required to be closed out

Current Approach

Alarms

Failure reporting system requirements are not imposed on subcontractors Government-furnished equipment is exempted from failure reporting system	Technical experts from each functional area are not included on failure review board Failure review board is composed entirely of junior members	Failure are classified as random and are not analyzed Failure analysis is only required when repetitive failures occur	No specific time limit is established for failure close-out Verification of corrective actions as part of close-out criteria is not required

Consequences

Failures occurring during FSD continue into production	Failure review board recommendations are improper	Design weaknesses are surfaced during operational testing or use	Ineffective corrective actions and delays in implementing corrective actions

Failure Reporting System

Summary: The MIL-STD definition of a Failure Reporting, Analysis, and Corrective Action System (FRACAS) is “a closed-loop system for initiating reports, analyzing failures, and feeding back corrective actions into the design, manufacturing, and test processes.” The primary objective of a closed-loop FRACAS is to document failures, analyze the cause of failures, determine corrective action, and disseminate the data. The timely dissemination of accurate failure information is necessary so that remedial actions may be taken promptly to prevent the recurrence of the failure.

A number of pitfalls exist in the world of FRACAS. Typically, there is a lack of detailed procedures at the working level; a lack of integrated feedback of anomalies, problems, and failures; and a definite lack of discipline. Most of these problems exist even though detailed instructions appear in applicable military standards on how a FRACAS should be implemented. Total compliance with MIL-STD requirements often is hampered because the requirements are not tailored to a particular project. Most FRACAS problems can be alleviated through proper planning which describes the management procedures for controlling failure report initiation, failure analysis, and the feedback of corrective actions into the design, manufacturing, and test processes.

An atmosphere of openness and encouragement needs to be fostered so that all problems are surfaced at the lowest levels of hardware at the earliest possible time. Early implementation of a FRACAS is important because corrective action options and flexibility are greatest during design evolution. The earlier that failure causes are identified, the easier it is to implement corrective actions. As the design matures, corrective action still can be identified, but the options become limited and implementation becomes more difficult.

A FRACAS will be effective only if the input data in reports documenting failures are accurate. Essential inputs should document all conditions surrounding a failure to facilitate cause determination. The failed item should be identified when a failure occurs and all pertinent information about the failure should be documented on the report form. Each reported failure should then be verified and analyzed to the extent necessary to identify the cause of failure and any contributing factors. Failure analysis can range from a simple investigation of circumstances surrounding the failure to a sophisticated laboratory analysis of the failed hardware. The level of analysis should be sufficient to provide an understanding of the cause of failure so that logically-derived corrective actions can be developed. Failure data that is collected in a FRACAS is useful only when aggregated for purposeful evaluation. A failure data system should be designed to collect, store, and retrieve failure information and to provide the means for displaying the data in a meaningful form. The outputs of a failure data system should be tailored to provide summaries and special reports for both management and engineering personnel. The failure summary is a useful output of a failure data system should provide information that automatically alerts management when failure reports are open longer than 30 days.

After a corrective action is implemented, it should be monitored to ensure that the failure cause has been removed and that no new problems have been introduced. If the corrective action proves ineffective, then the failure report should be reopened until an effective corrective action is developed.

Failure Reporting System

Checklist

- ✓ Have uniform requirements been imposed on subcontractors, prime contractors, and government activities?
- ✓ Will all failures be reported?
- ✓ Will all failures be analyzed to sufficient depth to identify failure cause and necessary corrective actions?
- ✓ Will all failure analysis reports be closed out within 30 days of failure occurrence or rationale provided for any extensions?
- ✓ Will corporate management be automatically alerted to failures exceeding close-out criteria?
- ✓ Has failure review board membership been reviewed and approved by both contractor and government?

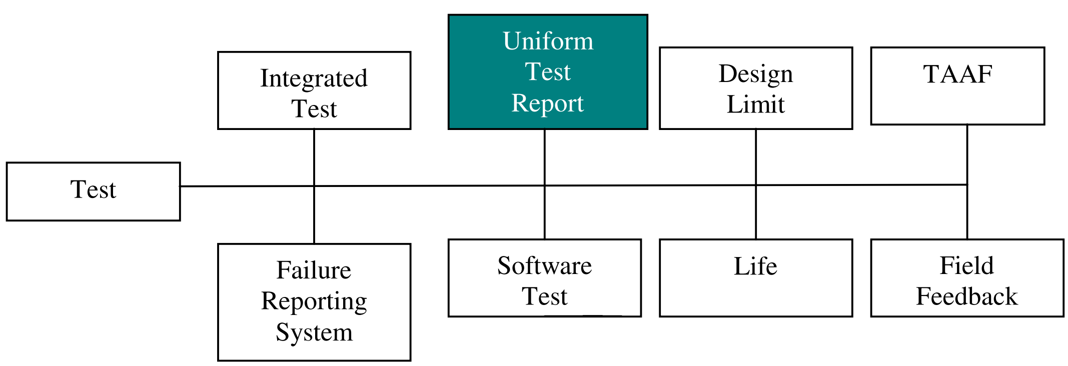
Uniform Test Report

Overview: Separate reliability development tests using Test, Analyze, and Fix (TAAF) methodology are normally performed for failure mode identification and elimination. During these tests, all results are reported in a format which provides to acquisition managers visibility into actual versus predicted reliability growth.

Results from other tests being performed during the development and transition phases are usually reported in different formats. This change in format increases risk by preventing an overall assessment of design maturity by acquisition managers when that is the only form of information provided.

Traps!

1. Test report format is left to contractor
2. Subcontractor test results are required by the prime contractor
3. Test data submission is a contractual requirement
4. Government test results are used to measure achievement of project objectives



Uniform Test Report

Benefits

Both engineers and management will be able to assess overall design maturity	Problems in subcontractor's design, manufacturing, and test areas are detected earlier in the project	Design maturity and readiness for production can be assessed earlier in the project	Field test results will measure achievement of project objectives

Escapes

All test data must be analyzed and displayed in a consistent manner Test results must show progress relative to specifications	Test reporting requirements/format are flowed down to all subcontractors, as appropriate	Test results, separately and collectively, must show trend and growth history	Present all test results using the same basis of evaluation

Best Practices

TRAPS

1. Test report format is left to contractor	2. Subcontractor test results are required by the prime contractor	3. Test data submission is a contractual requirement	4. Government test results are used to measure achievement of project objectives

Current Approach

Alarms

Relationships between test results and design requirements are not identified	Subcontractor raw data sheets are submitted as required	Specific test data are presented as an entity There is no growth indication or measure of life required	Field test results are not evaluated against contract requirements

Consequences

Test program progress and/or problems are often camouflaged	Management lacks visibility of status of overall test program	Excessive time required to interpret test results	Lack of correlation exists between government and contractor test results

Uniform Test Report

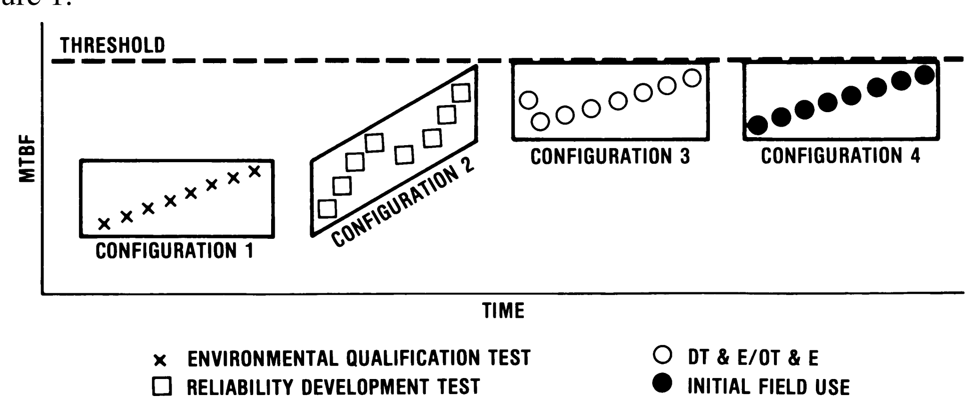
Summary: During FSD, a variety of tests are performed to assess progress in meeting design requirements. The results of each test are presented individually and an assessment is made concerning the achievement of the objectives of the particular test under review. Normally, the format used to present these results at the project management level does not provide an indication of progress being made toward achieving overall reliability program requirements. These results presented only indicate the success or failure in passing a particular test.

To provide reliability trend analysis for management visibility, it is essential that all test data be analyzed and displayed in a consistent manner. Therefore, a key function to be specified by contract is a reporting format which will drive the collection of life and reliability data during all subsequent testing, including DT&E/OT&E testing. The inclusion of reliability development (TAAF) tests and other life measuring tests in the project is essential to project risk reduction. Critical subcontractor equipment should be included and test results should be reported to project management.

All test data must be collected in the specified format and analyzed to determine reliability growth. This is difficult is some cases due to widely varying environments, but trend data will be valuable at transition, particularly when compared to prior programs. As better techniques of data analysis are developed, steady reliability growth (or a lack of it) can be assessed.

High confidence in the transition readiness of the system will be aided by an adequate data collection system to measure performance and current reliability levels. The contractor's Failure Reporting and Corrective Action System (FRACAS) is important, but a field data collection system designed for measurement of reliability as well as performance is also necessary. Consideration of this need during the planning stages will ensure that an adequate system is ready during field evaluation tests. Continuous measurement of reliability growth will add to confidence in fielding a system with low transition risk.

Improved management visibility will be provided when all test results are reported using a TAAF-type format. The plotted results can be used to assess reliability design maturity and readiness for transition from development to production. An example format is show in Figure 1.



Uniform Test Report

Checklist

- ✓ Do contracts require test data to be presented in a consistent format and related to design requirements?
- ✓ Are contractor requirements relative to format flowed down to subcontractors?
- ✓ Does the test data submission include trend data and history of performance?
- ✓ Will all test results, including field operations, be reported using the same basis for evaluation?

Software Test

Overview: In a typical software development project, approximately 20 to 30 percent of the elapsed time is involved in the integration and test phase. Module-level testing during the code and debug phase can take a significant portion of the programming schedule. As weapon systems become more complex, the software becomes extremely difficult to adequately test. An overriding factor relative to both test and design is that no technique exists to thoroughly test the software throughout its transition from separate modules to a system integrated with the hardware. The best approach is thorough testing at each of the early stages of design and coding to reduce the probability of errors escaping and surfacing during system field use.

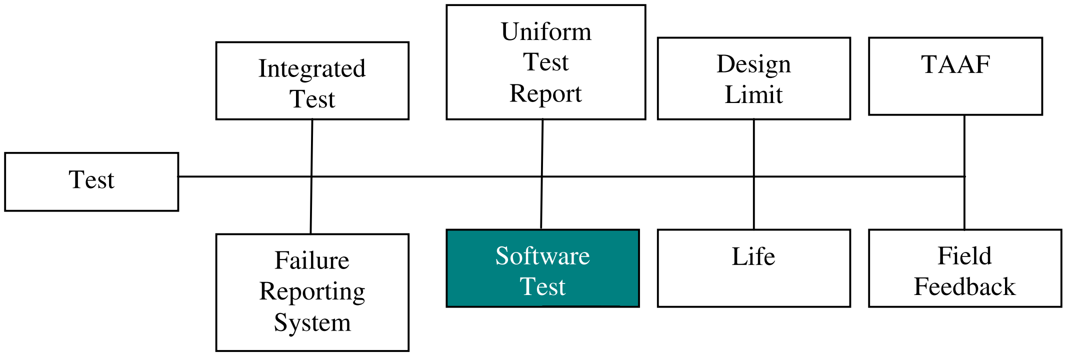
Traps!

1. Software test plan review is conducted as part of the code review

2. System test team is comprised of representatives from software design and programming

3. Verification and validation are performed as part of integration and test phase

4. Software is tested in accordance with DoD-STD-1679A



Software Test

Benefits

Test plans, system design, and coding will be consistent	System test team will unearth software problems which can be corrected prior to acceptance test	System design and coding will be adequately verified and validated	Software errors will be detected during initial design coding

Escapes

Develop and review test plan before coding starts	Include system users on test team Use programmers as observers and consultants but not as test participants	Require verification and validation as continuing effort from the requirements phase through design and coding phases	Establish a comprehensive program of internal review and testing for all phases of design and coding using operational personnel to review

Best Practices

TRAPS

1. Software test plan review is conducted as part of the code review	2. System test team is comprised of representatives from software design and programming	3. Verification and validation are performed as part of integration and test phase	4. Software is tested in accordance with DoD-STD-1679A

Current Approach

Alarms

Test planning is done with or after coding, resulting in a tendency to "track" the code	User/customer representatives are not on the test team Software designers and programmers are evaluating their own efforts	Verification and validation are not performed for requirements in product design phase	Design and coding walk-through and tests at module and subsystem levels are not required Software is considered error-free if no failures occur during DoD-STD-1679A stress test

Consequences

Errors and oversights in the code tend to get projected into tests Tests are less reliable	Software test is incomplete and lacks objectivity	Portions of code are not adequately tested Design is not complete	Many design and coding errors escape testing process

Software Test

Summary: With the technology explosion in solid state microelectronics, functional complexity of both hardware and software components of a system has increased proportionally. More severe and complex functional requirements are imposed, which increase the problems associated with the design, coding, and testing of the associated software. As with hardware, the later software problems are detected in the development cycle, the more costly is the associated correction. For example, the cost of correcting a software design error after the system is operational is 100 times greater than an error corrected during design.

The obvious approach that has evolved over many years combines a formalized, intensive design effort (including verification and validation of requirements, test plans, and coding) with testing at each stage from module coding to software/hardware integration. Unfortunately, even when such an approach is properly implemented there is no assurance that all design and coding errors have been eliminated since no techniques currently exist to exercise the software completely with all combinations and permutations of the logic and data which would be experienced throughout operational use. Recognition of this situation prevents the Military Services from specifying a designed software "reliability" (such as a maximum number of failures per 1,000 lines of code). Rather, the Military Services require that recognized design and test practices be followed vigorously and documented throughout the software development phases.

As the complexity of systems increases, it becomes more imperative that the user (i.e., operational experienced personnel) provides guidance during the early design planning and test phases of the software. In this way, the system will be designed and tested to requirements which are representative of field usage.

Major integrated software/hardware systems should be tested exhaustively in a total system test bed. Actual operational exercises can then be simulated with the system under test. This test method will detect most of the software and software/hardware problems prior to fielding the system.

Software Test

Checklist

- ✓ Are test plans developed before coding starts?
- ✓ Are system users (i.e., operational personnel) on the test team?
- ✓ Are programmers used as observers and consultants, but not as test participants?
- ✓ Is system-level testing evaluated by a test team, not the software designers and programmers?
- ✓ Is verification and validation required as a continuing effort from the requirements phase through design and coding phases?
- ✓ Is a comprehensive program of review and testing required for all phases of design and coding?
- ✓ Are design and coding walk-throughs required at the module and subsystem levels?

Design Limit

Overview: Design limit tests ensure that system or subsystem designs meet performance requirements when exposed to environmental conditions expected at the extremes of the operating envelope – the "worst case" environments of the mission profile. In the past, test environments have not been representative of the actual operating environment, resulting in poor performance during operational use. To remedy this situation, design limit test conditions simulate the worst case environments of the mission profile.

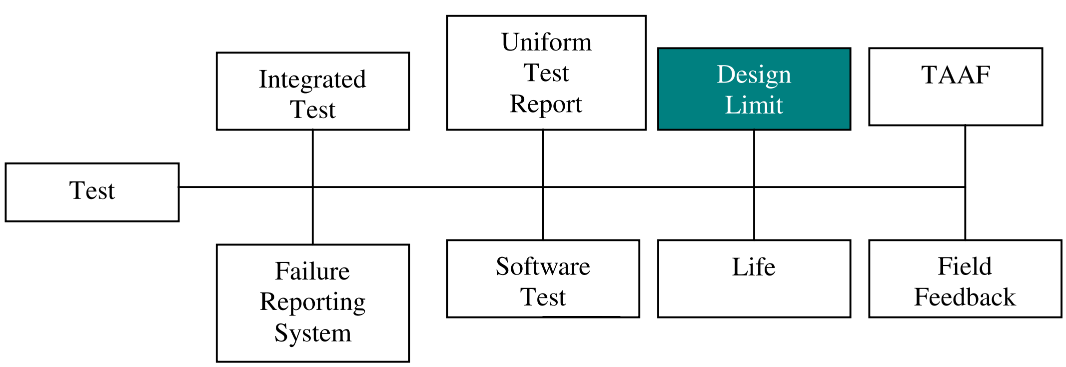
Traps!

1. Qualification of MIL-STD and MIL-SPEC environments is required

2. Test environments are specified at the weapon system level

3. Design limit qualification tests are based on mission profile stress levels

4. Qualification by similarity with proven in-service equipment is used



Design Limit

Benefits

Equipment will be properly designed for operational environments	Test environments will be representative of subsystem operating environments	Equipment will survive the extremes of the life cycle environment	Suitability of equipment for use in new operating environments will be verified

Escapes

Use operational mission profile environments to develop test environmental profiles Modify test environments as operational data becomes available	Allocate weapon system mission profiles to the subsystem level and confirm by measurement	Use worst case environmental conditions of the system and subsystem life cycle profiles for design limit qualification tests	Quantify environmental differences to identify the need for additional tests

Best Practices

TRAPS

1. Qualification to MIL-STD and MIL-SPEC environments is required	2. Test environments are specified at the weapon system level	3. Design limit qualification tests are based on mission profile stress level	4. Qualification by similarity with proven in-service equipment is used

Current Approach

Alarms

Mission profile environments are not specified	The same test environments are applied uniformly to all subsystems	Simulated mission profile environments do not consider worst case life cycle profile	Comparison is not made between previous qualification test requirements and new operating environments

Consequences

Overstress failures occur in operational use	Amplification or isolation factors cause increased failures or overdesign of subsystems	Failures occur due to inadequate design margins	Design is not qualified for new operating environments

Design Limit

Summary: Design limit tests are those tests performed to ensure that a weapon system will provide adequate performance characteristics when exposed to environmental conditions expected at the extremes of the operating envelope. Many past development programs have attempted to satisfy these requirements by promoting MIL-STD or MIL-SPEC tests which did not duplicate actual operational environments, resulting in poor performance and excessive failures during field operations.

Mission profile data is essential to sound design limit testing of systems and subsystems. Early in the project, studies to determine the "real" mission profile and subsequent "worst case" environments must be performed. Care must be taken to allocate the overall worst case system mission profile environments to all subsystems. Some subsystems will see either increased stress due to amplification factors and cooling problems or decreased stress due to shock and vibration isolation or efficient cooling systems. Subsystem test environments must be adjusted accordingly to ensure that proper test levels are used. The contractor should be required to develop test environments using measured environmental data, where possible. Contractual arrangements should be made for the modification of test environments as additional data becomes available.

The overall test plan should integrate design limit with other planned testing. Design limit testing should be planned at multiple levels from parts through critical assemblies to subsystems to the system level. This will give a complete view of potential problems and allow data comparison from several sources. This planning will also increase test efficiency. Testing can be minimized using this approach, and a design proven at many levels will result. Integration of test results may often show problems which otherwise would be obscured by lack of data until field deployment. The field environment is a complex combination of environments. The best design limit test will result if these combined environments are simulated.

Many of these design limit tests are viewed as a hurdle which must be "passed" and as such, the test program becomes a success-oriented exercise. This in turn leads to unrealistic test schedules with little attention paid to the engineering information provided by the test results. Design engineers should be provided feedback concerning the results of their design efforts so that future designs may benefit from the knowledge gained or current designs improved. The objective is to establish knowledge of the design, not simply to pass the test.

All failure incidents are important and should be analyzed in detail, regardless of when they occurred. They may be symptoms of a future serious deficiency. Early analysis should prove otherwise or result in changes to prevent possible recurrence. High confidence, not test completion, is the goal of successful testing and the program should be structured to create this atmosphere. Verified effective corrective action is an intrinsic part of the qualification process. Redesign for all detected problems, and trend analysis to ensure effectiveness in later contractor and field testing, is necessary.

For subsystems which are being designed for multiple-use applications, tests must be designed to simulate worst case conditions. If a subsystem has been previously qualified, the environments previously used must be compared with those expected in the new application. Any case result in a more severe environment should require additional (delta) qualification testing to the more severe environment.

Design Limit

Checklist

- ✓ Are operational mission profile environments used to develop test environmental profiles?
- ✓ Have weapon system mission profiles been allocated to subsystems?
- ✓ Has the need for additional tests of in-service equipment been considered for new applications?
- ✓ Are worst case life cycle environmental conditions used for design limit qualification tests?

Life

Overview: During the development of a weapon system, tests and analyses are performed to assess the effects of long-term exposure to various portions of the mission profile. Tests are used to ensure that the design will not fail prematurely due to metal fatigue, component aging, or other problems caused by long-term environmental effects. In many cases these tests have been ineffective due to delays in starting the test, lack of feedback into the design process, or a lack of understanding of scaling or acceleration factors.

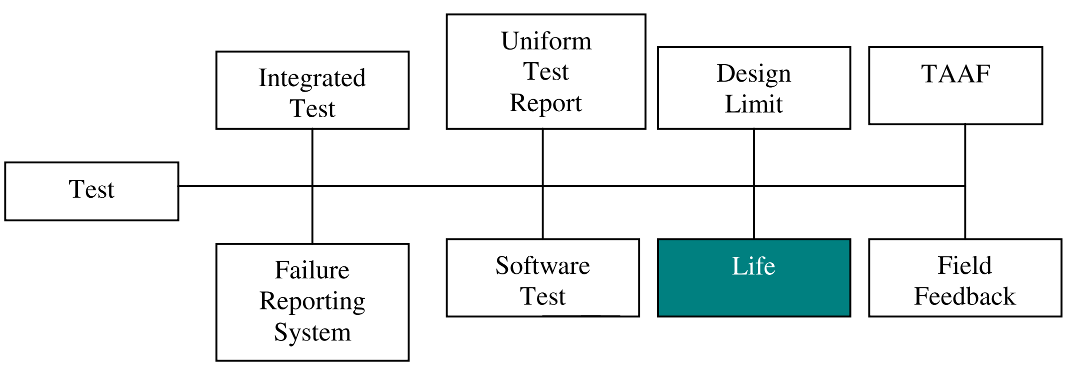
Traps!

1. General MIL-SPEC test environments are specified for life testing

2. Life test is performed in production phase

3. Analyses of life characteristics planned using available data

4. Accelerated life testing is used to the maximum extent possible



Life

Benefits

Maintenance and support planning will be more accurate	Design will be optimum for mission needs	Cost-effective approach to estimating life by analyses and testing will be developed	Weapon system aging characteristics will be realistically simulated

Escapes

Base life test environments on mission environmental profiles	Schedule adequate life test no later than FSD, to establish life characteristics prior to final design release	Analyze aging characteristics data from all possible sources to identify risk areas and develop a comprehensive life test program	Use only proven, well-understood accelerated testing techniques

Best Practices

TRAPS

1. General MIL-SPEC test environments are specified for life testing	2. Life test is performed in production phase	3. Analyses of life characteristics planned using available data	4. Accelerated life testing is used to the maximum extent possible

Current Approach

Alarms

Test engineers have not compared MIL-SPEC environments to mission profile environments	Life test resources are limited due to production commitments Design is frozen for production before life test results are available	Only in-house data is used All potential failure mechanisms are not considered	Unverified acceleration factors are used to shorten the life test program

Consequences

Inaccurate assessment is made of life characteristics resulting in unexpected failure mechanisms during operational use	Identification of life characteristics is inadequate or untimely	Results of analytical efforts are inadequate to plan a cost-effective life test program	Unrealistic life projections resulting in either overdesign or underdesign

Life

Summary: Life testing is often misapplied during the acquisition process with verification usually too late to impact the design. The ability of the product to withstand long-term exposure to the operating environment is essential. One solution to the problem of life and life testing is an early recognition of the requirement with required test activities described in an integrated test plan. The integration will allow the design and test process to be closely aligned such that feedback of test results and projection of long-term performance can be efficiently made.

The structuring of a life test program follows the same basic fundamentals used to structure other environmental test programs. The test environments must be based on expected mission environmental profiles, rather than blindly applied MIL-STD or MIL-SPEC environments. Life tests should be scheduled for completion during the full-scale development phase, in order to establish life characteristics and allow the implementation of design changes prior to final design release. In the past, life tests have often been planned too late to influence the design, resulting in poor life characteristics or expensive and time-consuming retrofit programs.

Life tests can be time-consuming and costly. To achieve maximum benefit (impact on design of the life testing effort), detailed analyses must be made of life characteristics concurrent with the initial design. Aging failure data must be collected and analyzed on components and like equipment from all possible sources. These analyses will help identify design risk and form the basis for planning life tests.

Ignoring life characteristics until test results are available could require extensive redesign and project delays. Therefore, in order to ensure that life characteristics are considered early in the design phase, field or corporate experience on similar items should be used to project life characteristics and to determine the initial equipment design. This technique should aid in minimizing design changes resulting from life testing and provide for shortened test schedules.

A commonly used technique, to provide the designer with early life test results, is accelerated life testing. However, in an attempt to shorten life tests, some projects have used unverified acceleration factors, resulting in unrealistic projections of equipment life. This could result in overdesign if the test was too stringent, or undersign if the test was too benign. If accelerated testing is being considered, only proven, well understood techniques should be used.

Life

Checklist

- ✓ Are life test environments based on mission environmental profiles?
- ✓ If accelerated testing is planned, will proven accelerated testing techniques be used?
- ✓ Are life tests started in FSD as soon as representative equipment is available and will they be completed during FSD?
- ✓ Are detailed analyses made during initial design effort on the life characteristics of the components and subsystems?
- ✓ Have analyses and tests been budgeted and planned?
- ✓ Are procedures in place to feed back results of life tests efforts to the design program?

Test, Analyze, and Fix (TAAF)

Overview: Many past development contracts have not included reliability development testing (Test, Analyze, and Fix [TAAF] methodology), instead relying on a reliability qualification test to demonstrate a numerical MTBF requirement. This approach has been ineffective in providing weapon systems with acceptable field reliabilities. Reliability development (TAAF) testing using simulated mission profile environments and emphasizing reliability growth has proven to be a more effective use of limited test resources, and has reduced the risk of transitioning systems from development to production.

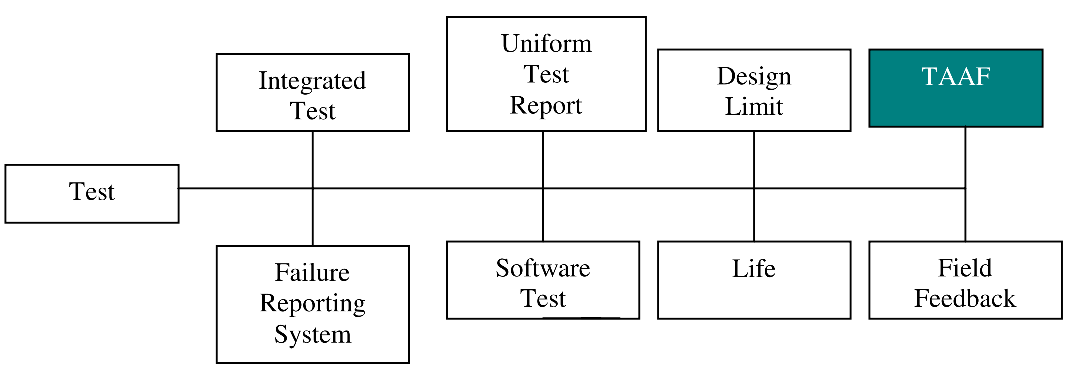
Traps!

1. Reliability qualification (demonstration) test is required

2. Design changes are implemented during low rate initial production

3. Reliability development (TAAF) test is planned as a separate entity

4. Reliability development testing is performed during FSD



Test, Analyze, and Fix (TAAF)

Benefits

Design weaknesses will be eliminated prior to production	Fixes will be identified and tested during reliability development testing	Reliability development test will be more efficient	Problems associated with initial operational use will be corrected prior to full production

Escapes

Implement the TAAF concept during FSD to ensure the early incorporation of corrective action	Evaluate candidate design changes using design engineering fundamentals Use reliability development test to verify that design changes preclude failure recurrence	Implement a closed loop failure reporting, analysis, and corrective action system for all development tests Ensure that corrective actions from all tests are implemented in the reliability development test hardware	Implement a field reporting system for development testing and early operational use, with resultant failure analysis and corrective action

Best Practices

TRAPS

1. Reliability qualification (demonstration) test is required	2. Design changes are implemented during low rate initial production	3. Reliability development (TAAF) test is planned as a separate entity	4. Reliability development testing is performed during FSD

Current Approach

Alarms

Reliability development (TAAF) test is not planned during FSD	Verification of design changes prior to low rate initial production is not permitted by schedule	TAAF concept is not being applied to all development testing during FSD Only design changes affecting functional performance are considered	No provisions are made to continue TAAF process during early operational use

Consequences

Production is initiated with an unsatisfactory design	Costly ECP and retrofit programs with additional design changes are required	Major design changes are required during reliability development test	Corrective actions for early field-related failures do not impact production

Test, Analyze, and Fix (TAAF)

Summary: The Reliability Development Test (RDT) is a planned Test, Analyze, and Fix (TAAF) 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 RDT is to provide a basis for early incorporation of corrective actions and verification of their effectiveness in improving the reliability of equipment.

The RDT by itself, however, is not the most efficient or economical means of achieving acceptable reliability. Proper emphasis must be placed on design fundamentals such as derating, stress analysis, thermal analysis, and failure mode and effects analyses so that a potential for reliability is designed into the equipment prior to the start of RDT. Reliability growths will then result when positive changes are made to the design to correct problems identified during test.

The RDT is conducted under controlled conditions with simulated operational mission and environmental profiles to determine design and manufacturing process weaknesses. The RDT emphasizes reliability growth rather than a numerical measurement. Unlike the RDT, the Reliability Qualification (demonstration) Test (RQT) is not designed for reliability growth and has proven to be ineffective for improving equipment reliability. The RQT normally is performed too late to provide major impact on the design effort, and if corrective actions are required, they seldom are incorporated and verified before production because of the need to meet delivery schedule commitments.

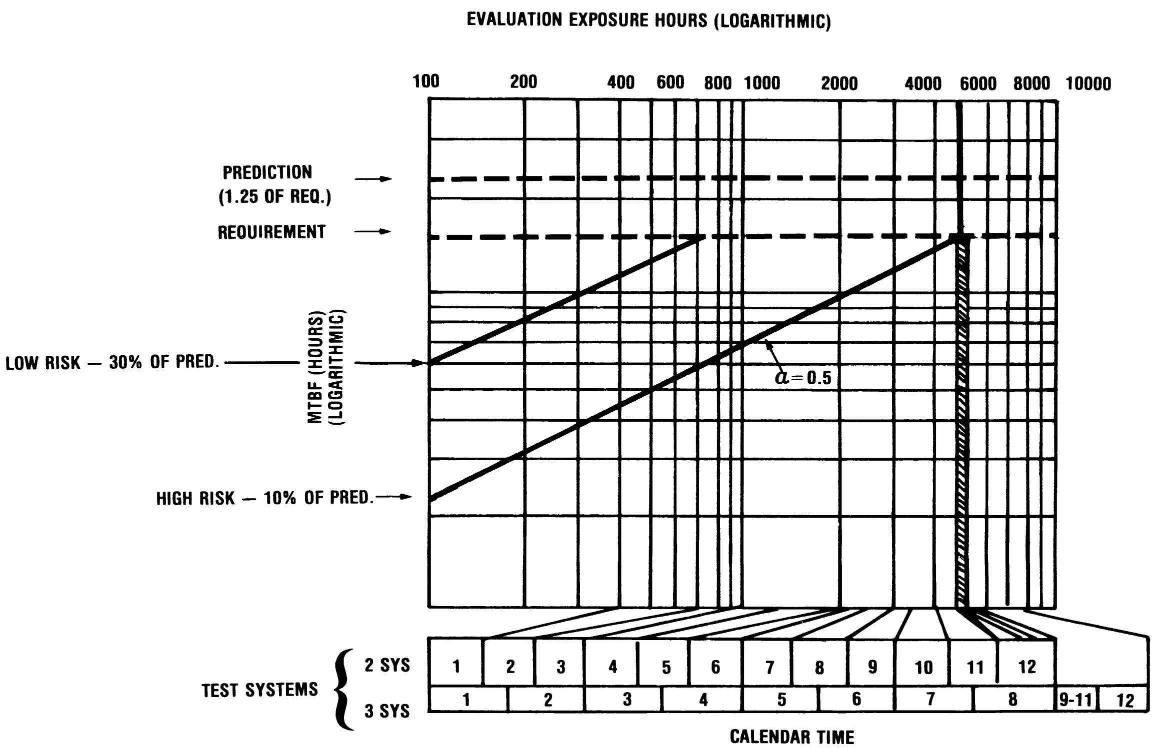
The RDT, using the TAAF process, is a key requirement to achieving acceptable system reliability. The RDT, however, must be tailored to the needs of the specific project and must be integrated with other development test activities to provide for the more efficient use of test resources. For example, the temperature and vibration portions of the design limit qualification tests could be used for the initial portion of the RDT. Corrective actions developed as a result of other tests should be incorporated in the RDT test units to verify their effectiveness and to prevent unnecessary duplication of failure analyses and corrective action efforts.

The efficient use of test resources also requires that reliability growth test emphasis be placed on those equipment that will have the most impact on system and mission reliability. Selection of equipment for RDT should be based on consideration of reliability allocation and prediction, state-of-the-art, equipment similarities, and complexity. RDTs should be performed on subsystems of low (predicted) reliability. High (predicted) reliability subsystems not selected for RDT should be evaluated during the system-level development testing. If any of these subsystems exhibit problems during the system development tests, then suitable corrective action can be identified and incorporated to preclude the recurrence of the problems, or additional RDTs can be considered.

The RDT must be monitored and kept flexible to allow for changes as the reliability database grows. When reliability data indicates that further testing will produce only insignificant changes in reliability, the RDT should be terminated. Early termination of one subsystem RDT will permit test resources to be applied to other subsystems where additional testing is expected to provide significant reliability improvement.

Reliability growth during RDT is the result of an iterative design process. Equipment is tested to identify failure sources and further design effort is spent to correct the identified problems. The rate at which reliability will grow during this process is dependent on how rapidly the failure sources are detected and how well the redesign effort solves the identified problems without introducing new problems. It is essential, therefore, that periodic reliability growth assessments be made and compared with the planned reliability growth values. These periodic assessments will provide visibility of achievements and will identify deficiencies in time to affect system design.

Prior to initiation of an RDT, the design reliability should have advanced to such a stage that the predicted MTBF is at least 1.25 times the required MTBF. To estimate the amount of time for conducting the RDT, a plot of MTBF versus time can be constructed on log-log paper. An initial starting MTBF estimate for a low risk project of 30 percent of the predicated MTBF may be used with lower values for higher risk projects (as low as ten percent in some cases). A growth slope of 0.5 or less should be used, with lower slopes for less aggressive reliability projects. Figure 1 shows examples for both low risk and high risk projects. To monitor satisfactory progress, the actual growth curve should be compared to the ideal 0.5 slope and additional emphasis placed on failure analysis, corrective actions, etc., for significantly lower-growth slopes.



Test, Analyze, and Fix (TAAF)

Checklist

- ✓ Are reliability development tests using the TAAF concept planned for FSD?
- ✓ Will design changes be verified during reliability development testing?
- ✓ Will the TAAF process include early operational use?
- ✓ Is a field reporting system planned, which includes development tests and early operational use?

Field Feedback

Overview: Early feedback of problems occurring during initial use of weapon systems is essential for the elimination of unforeseen design and manufacturing defects usually encountered during the transition from low-rate production processes and tooling to full-rate processes and tooling. Feedback concerning field problems, however, is often slow and inadequate, and failed parts may not be returned for analysis in a timely manner. Complete and accurate reporting of operating times and environments, along with detailed descriptions of failures and possible causes, is needed but is normally not available from military data reporting systems since the systems are designed for maintenance data and not reliability data. While steps are being taken to improve the military systems, contractor personnel frequently must be used for data collection efforts.

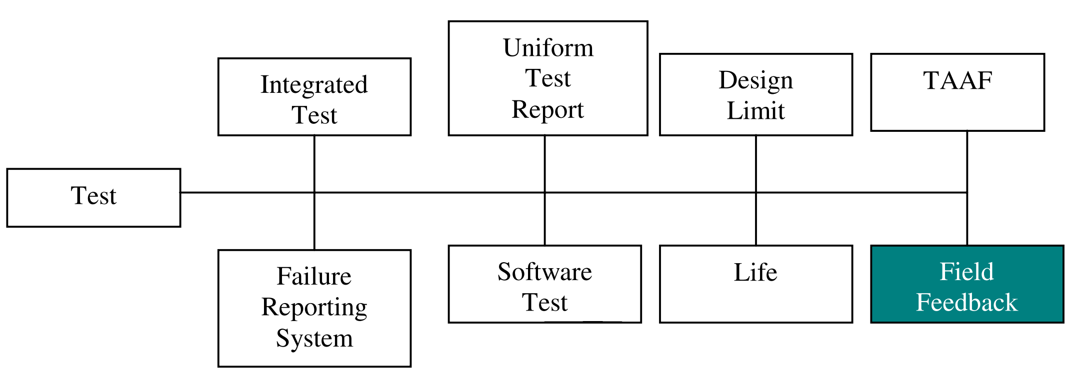
Traps!

1. Provisions for contractor support during deployment are contained in contract

2. Contractor is required to analyze failures of all returned equipment

3. Government is solely responsible for repair of failed parts

4. Standard military data collection systems are used



Field Feedback

Benefits

Ability to evaluate the system on a real-time basis	Detailed and timely information will be available concerning field problems	No-cost product improvements will be introduced	System problems in the field will be accurately assessed

Escapes

Ensure that the contract requires a contractor engineering team during initial deployments	Onsite contractor engineering team provide information on the details of each failure Prime contractor retain responsibility for analysis, corrective action, and close-out	For commercial items, conduct tradeoff on government versus commercial repair Contractor responsible for repair for the first three years after Initial Operational Capability (IOC) Consider a transition period to government responsibility three to five years after IOC	Require the contractor to analyze field data independently for an engineering assessment of field problems

Best Practices

TRAPS

1. Provisions for contractor support during deployment are contained in contract	2. Contractor is required to analyze failures of all returned equipment	3. Government is solely responsible for repair of failed parts	4. Standard military data collection systems are used

Current Approach

Alarms

Contract statement of work provisions for: • maintenance support • training manual updates • classroom training on system operation and maintenance	Failed parts are not returned in a timely manner Failed parts are not identified for proper failure analysis	Planned activity to evaluate the capability of designated government repair facilities is lacking	Contractor developed data is not used to supplement the military data system

Consequences

Design and manufacturing problems are accepted as routine by maintenance personnel	Correctable problems persist longer than necessary	Decrease in Operational Availability (A_o) is experienced	Assessment of field problems is logistics support-oriented

Field Feedback

Summary: Early field feedback during early deployment of a weapon system is critical in evaluating the hardware in an operational environment so that expeditious corrective action can be provided.

Many past attempts to provide contractor support have resulted in maintenance-oriented contractual arrangements, which often result in field repairs made to meet operational requirements. As a result, problems which do not appear to have a severe maintenance impact may go unreported and therefore uncorrected by the manufacturer.

Major systems contracts should include provisions for onsite engineering teams during early deployment, not only at the contractor's facility (initial training/test sites), but at remote sites used during initial military use. Subcontractors of critical items should also be included. These teams foster positive reliability trends early in the deployment phase, and a corresponding decrease in spares consumption throughout the life cycle.

When government repair activities are used to make repairs during field operations, data on failures experienced, repairs accomplished, and changes made are not normally communicated to the prime or responsible subcontractor. This severely hampers traceability and maintenance of configuration control disciplines necessary for reliability improvement.

Engineering analysis of early deployment problems enhances early solution, and can provide the opportunity to identify potential problems and those that might otherwise go unreported. Should the analysis prove to be too complex for the field, technical inputs can be made to the prime and/or related subcontractor, avoiding delays and identifying the tasks so it may be appropriately dispositioned. Field representatives should be retained after initial operation to improve the accuracy and quantity of failure reports and corrective actions.

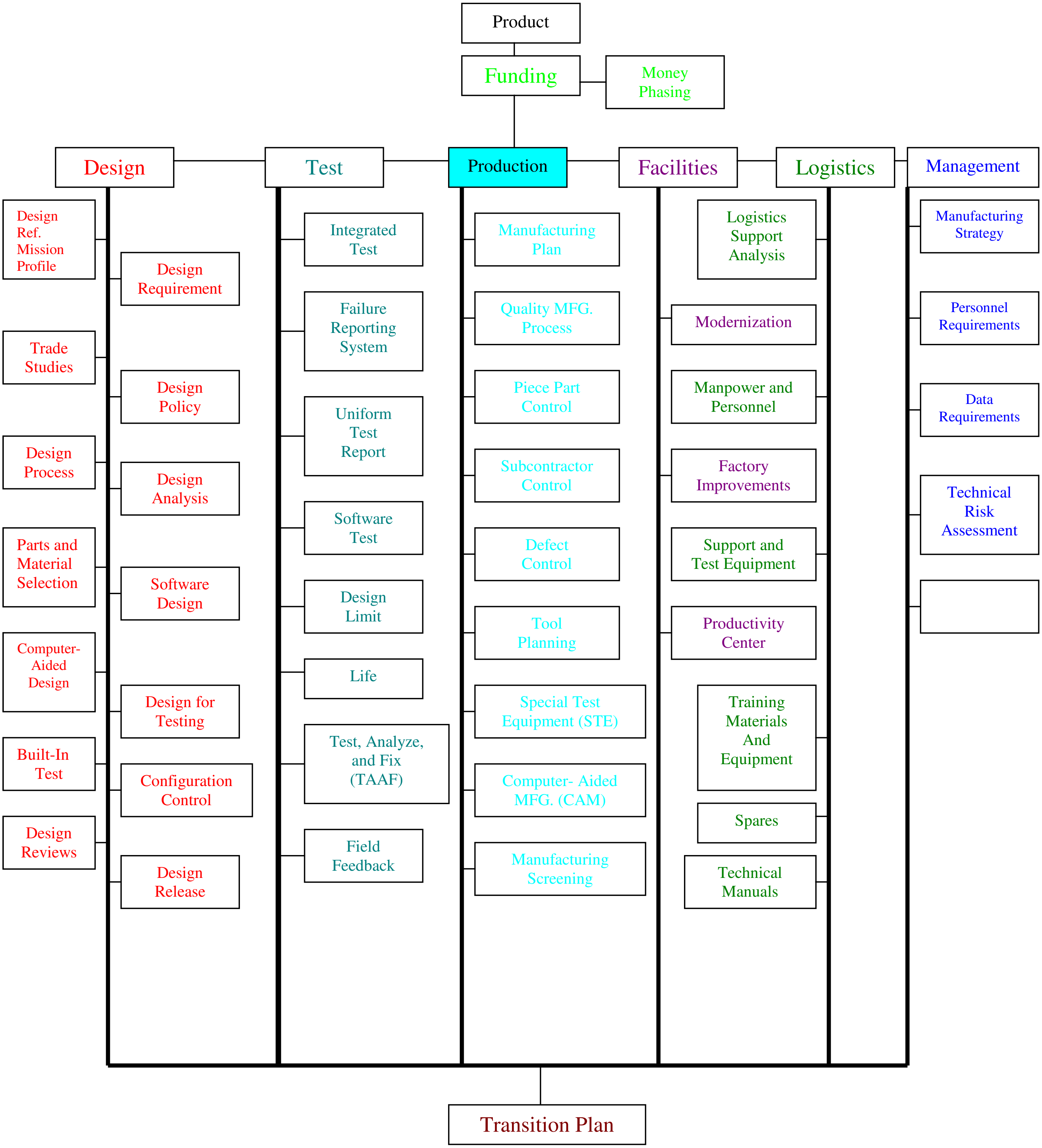
An efficient reporting and corrective action system needs to be established as soon as field operation commences. As a minimum, it should specify procedures for the control and handling of returned/failed hardware, and for the investigation of complaints concerning deficiencies, warranty claims, and associated reports received from the customer.

Field service reports by contractors should not be limited to failures and discrepancies. They should include incorporated improvement changes, alternative maintenance techniques applied, customer comments, and other field environments and stresses, that are not readily known to the contractor or the military acquisition manager. They should also evaluate how well the system works in the field, and to determine what problems justify corrective actions.

Field Feedback

Checklist

- ✓ Have contracts been written to provide appropriate onsite contractor engineering teams?
- ✓ Will contractor engineering teams be required to provide details of each failure?
- ✓ Does the prime contractor have responsibility for failure analysis, corrective action, and closeout?
- ✓ Do contractor engineering teams provide an independent engineering analysis of field data?

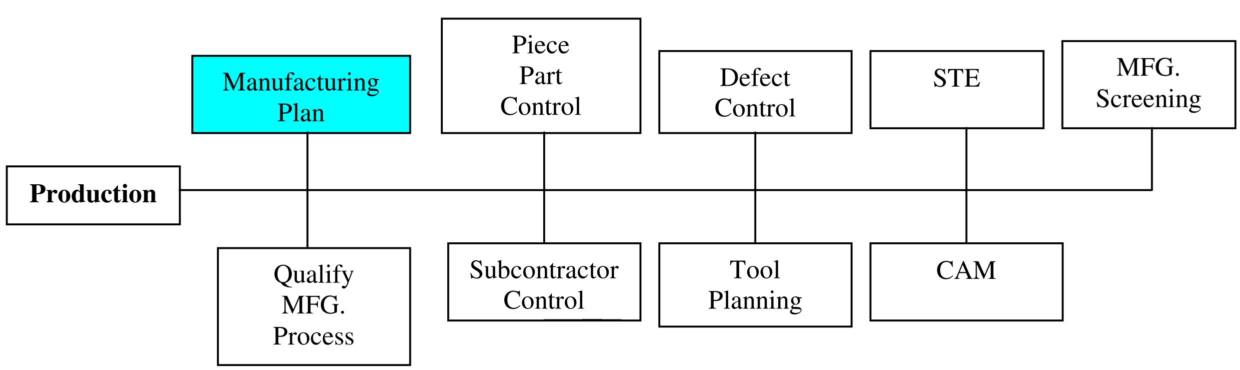

Product
Funding
Money Phasing
Design
Test
Production
Facilities
Logistics
Management
Design Ref. Mission Profile
Design Requirement
Trade Studies
Design Policy
Design Process
Design Analysis
Parts and Material Selection
Software Design
Computer-Aided Design
Design for Testing
Built-In Test
Configuration Control
Design Reviews
Design Release
Integrated Test
Failure Reporting System
Uniform Test Report
Software Test
Design Limit
Life
Test, Analyze, and Fix (TAAF)
Field Feedback
Manufacturing Plan
Quality MFG. Process
Piece Part Control
Subcontractor Control
Defect Control
Tool Planning
Special Test Equipment (STE)
Computer- Aided MFG. (CAM)
Manufacturing Screening
Logistics Support Analysis
Modernization
Manpower and Personnel
Factory Improvements
Support and Test Equipment
Productivity Center
Training Materials And Equipment
Spares
Technical Manuals
Manufacturing Strategy
Personnel Requirements
Data Requirements
Technical Risk Assessment
Transition Plan

PRODUCTION
Manufacturing Plan

Overview: DoD Directive 5000.34 Paragraph 5, requires that production engineering and planning be accomplished throughout FSD. MIL-STD-1528 states that manufacturing plans shall be prepared when required by the contract and shall be sufficiently comprehensive to (1) ascertain with a high degree of confidence that the contractor has adequately evaluated and planned for production, (2) verify conformance to the principles in this standard, and (3) monitor the contractual effort to ensure the timely effective execution of the production program.

Traps!

1. Producibility issues are addressed after Defense Systems Acquisition Review Council (DSARC) Milestone IIIA
2. Manufacturing plan is a contract data item requirement
3. Manufacturing plan is based on mature production yield rates
4. Engineering is ended when production starts



Manufacturing Plan

Benefits

Acceleration to planned manufacturing rate will be achievable	Product will be delivered on time	Production rate requirements will be compatible with plant capacity	Manufacturing problems will be solved on the factory floor

Escapes

Establish producibility analysis requirements in the FSD contract Complete manufacturing process qualification during FSD	Ensure that the design concept is compatible with factory procedures and capabilities Address manufacturing considerations during design evaluation Update the manufacturing plan continuously	Plan manufacturing based on separate yield rates for low rate initial production, production ramp-up, and mature production	Establish a joint manufacturing/ engineering support team on the factory floor Establish a fast-reacting production center for off-line correction of problems

Best Practices

TRAPS

1. Producibility issues are addressed after Defense Systems Acquisition Review Council (DSARC) Milestone IIIA	2. Manufacturing plan is a contract data item requirement	3. Manufacturing plan is based on mature production yield rates	4. Engineering is ended when production starts

Current Approach

Alarms

Long lead material commitment precludes producibility redesign Hardware configuration changes are required for producibility	Manufacturing engineering tasks are not undertaken during development "Hands on" production people are not involved in the design process	Master phasing schedule is not used in initial production planning	Sustaining engineering support on the factory floor is low Plans call for the rapid phase out of engineering support when production starts

Consequences

Six- to twelve-month production gap is likely	Redesign is required to achieve rate production	Production ramp-up and yield rates are optimistic	Start-up problems continue late into production

Manufacturing Plan

Summary: The manufacturing plan identifies the approach for duplicating a product configuration in a cost-effective manner. It is based on the results of detailed planning and analysis activities that have been conducted to define the optimum approach for product manufacture. Therefore, all actions that are required to produce, test, and delivered acceptable systems on schedule and at minimum cost should have been defined in the manufacturing plan. Hence, the materials, fabrication flow, time in process, tolls, 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 are included in the sequence and schedule of events.

A manufacturing plan is usually submitted as a contract data requirement at the end of the FSD contract, or early in Low Rate Initial Production (LRIP). Such an approach encourages late planning for product manufacture and precludes tradeoffs between manufacturing process alternatives and product design configurations. This late planning causes many “surprise” product redesigns for producibility. Manufacturing planning concurrent with the product redesign process will preclude most product redesign efforts for producibility considerations that would otherwise be revealed after LRIP begins.

Manufacturing planning activities that should be accomplished before LRIP include:

- Estimate manufacturing resource requirements
- Schedule definition
- Personnel requirements
- Make or buy decisions
- Facilities

These five areas at a minimum should be addressed in the manufacturing plan.

The manufacturing processes and procedures translate into requirements for tooling, capital equipment, and plant facilities. Accurate definition of those requirements demands a detailed translation of a product’s physical and functional characteristics into a set of manufacturing processes and procedures. Both design and manufacturing engineering involvement during FSD is essential in accomplishing this translation. Since the product design configuration has a direct influence on the manufacturing processes and procedures, determination of manufacturing resource requirements should be accomplished early in FSD with a firm commitment to the availability of those resources before the product design configuration is frozen.

The schedule presented in the manufacturing plan should provide assurance that the necessary resources will be available when needed, that no resources will be overloaded or expended during execution of any manufacturing tasks, and that product delivery dates are indeed achievable. The details of the entire project schedule should be the top level planning baseline. Lower tier schedules should be developed for all manufacturing activities, with special attention to those having potential impact on the product delivery schedule (in terms of either quantity of time). Some examples of areas that may impact product delivery schedule are: engineering release; material procurement; tool design, fabrication, and prove-out; test equipment (particularly software related) prove-out; and capital equipment procurement. Examination of the schedule of manufacturing activities, and the schedules for material procurement and delivery of subcontracted items, coupled with the use of a manufacturing flow diagram (also included in the manufacturing plan) displaying both material quantities and schedules, are useful in determining if the manufacturing approach is low risk in terms of schedule.

The number of personnel, the specific skill types, and the ability of the contractor to meet these requirements should be defined. Personnel plans should be consistent with the planned personnel loadings to ensure that adequate skill types and quantities are available and maintained. The stability of the current work force, the contractor's ability to attract and retain personnel in the specific skill types necessary for product fabrication, and the types of training and certification programs used to maintain work skill levels, should be readily assessable using the information presented in the manufacturing plan, and information obtained through onsite surveys.

A make or buy plan establishes the distribution of effort between the prime contractor and subcontractors. The percentage of weapon system components that are subcontracted can be as high as 80 percent. The make or buy approach used in product manufacture can have a tremendous impact in cost schedule risk. Therefore, the make or buy plan should be addressed in sufficient depth for evaluation. The impact of in-plant loadings on the prime contractor's overhead rates should be visible in the make or buy selection of the manufacturing plan. Specific attention should be given to the make or buy decisions since there may be differences between overall contractor goals in structuring make or buy decisions and the goal which the government might consider appropriate for the specific project.

The facility includes all plant and capital equipment necessary to accomplish product manufacture. Therefore, a facility plan should be addressed in the manufacturing plan. The planning approach should show the material flow within the plant from the stock room to the shipping dock. In-process storage time represents a significant cost burden to the manufacturing operation. Analysis should be provided to determine that in-process storage and material transit time will be maintained at a minimum level. For batch manufacturing operations (i.e., more than one product type is manufactured on the product line), analysis should be evident that ensures that sufficient plant capacity exists to sustain the product at the required production rates, given the projected demands of all other projects using the production line. Finally, plant requirements including power, special test and handling equipment, clean rooms, and storage and handling of hazardous or explosive material should be identified. Analysis should be presented indicating that all plant requirements necessary for product manufacture are accommodated.

Manufacturing Plan

Checklist

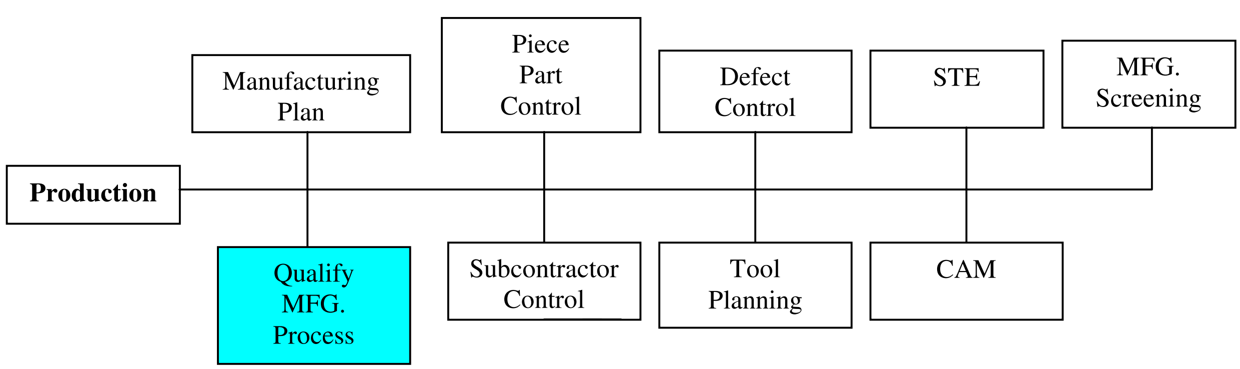
- ✓ Is the design concept compatible with factory procedures and capabilities?
- ✓ Are design engineers aware of manufacturing consideration during the development evolution?
- ✓ Is the manufacturing plan kept up-to-date?
- ✓ Are production people involved in the design process?
- ✓ Are producibility analyses requirements established during the FSD contract?
- ✓ Is manufacturing planning based on separate yield rates for low rate initial production, production ramp-up, and mature production?
- ✓ Is a master phasing schedule used during initial production planning?
- ✓ Is a joint manufacturing/engineering support team available for solving problems on the factory floor?
- ✓ Is a fast-reacting productivity center available for off-line correction of problems?

Qualify Manufacturing Process

Overview: One primary requirement of a successful production project is a manufacturing process that has been qualified before production is commenced. However, the techniques in establishing a successful manufacturing operation are perhaps the least understood area in industry. Government and industry must ensure that the process is capable of sustained production in terms of product performance, quality, volume, and cost.

Traps!

1. Primary objective of FSD is hardware for test and evaluation
2. Processes/procedures needed for product manufacture already exist on the factory floor
3. New technology/materials are used to reduce unit cost
4. Plans for experienced factory personnel to be assigned to the project



Qualify Manufacturing Process

Benefits

Optimum production rate ramp-up will be likely	Manufacturing methods will be qualified before rate production	Balance will be achieved in use of new technology	"Certified" factory personnel will be used

Escapes

Require a complete design development disclosure at the end of low rate initial production	Require proof of manufacturing processes and procedures Assess the consequences of design changes on proven manufacturing methods	Planned phase in of new technology/ materials should allow time for validating suitability prior to implementation	Introduce new product line to factory workers with "hands on" training project Provide formal training program

Best Practices

TRAPS

1. Primary objective of FSD is hardware for test and evaluation	2. Processes/ procedures needed for product manufacture already exist on the factory floor	3. New technology/ materials are used to reduce unit cost	4. Plans call for experienced factory personnel to be assigned to the project

Current Approach

Alarms

FSD is completed without manufacturing processes being identified Technical data package is incomplete at final Production Readiness Review (PRR)	Producibility analysis not used to identify manufacturing methods and procedures Adequacy of plant capacity has not been considered	Schedule planning does not provide for validating the suitability of new processes	Employee turnover rate is high A side variance in production quantities is required by contract

Consequences

Qualified product baseline is an unknown	"Surprise" process, procedure, and tooling problems likely	Increased activity in rework and test	Product unfamiliarity causes excessive workmanship errors

Quality Manufacturing Process

Summary: DoD Directive 5000.34, requires that production engineering and planning be accomplished throughout FSD. However, there is little technical guidance to ensure the maturity of the contractor's manufacturing process. Indeed, any focus on "getting ready" for production involves attention to ensuring that the Technical Data Package (TDP) is clean and conforms to MIL-STD-1000 (Level III) documentation. The actual process for ensuring the manufacturing operation and product documentation is "ready" for production consists of a Production Readiness Review (PRR) per DoD Instruction 5000.38, or similar internal review. Although the PRR is a good comprehensive review, the approach tends to be milestone-driven in the sense that the emphasis is on passing a review that normally occurs after the product baseline is established.

The manufacturing process required to produce an item influences the design approach, the technology used, and the product configuration. Therefore, the manufacturing process must be a qualified in a time frame that allows for design and configuration changes to be introduced in the product baseline before initial production. Normal project pressures caused many acquisition mangers to consider the primary objective of FSD to be the delivery of hardware for test and evaluation. As a result, the processes and procedures needed to fabricate, test, and inspect the product, and the required design documentation, often receive little attention until a production decision has been reached.

The qualification of the manufacturing process must be given the same visibility as design performance qualification. The procedures used in qualifying the manufacturing process must ensure the adequacy of the production planning, tool design, assembly methods, finishing processes, and personnel training before rate production. For example, the manufacturing flow diagram illustrated in the manufacturing plan should be checked for accuracy. Any changes in product configuration or manufacturing processes, planned tooling and equipment, or procedures should be reflected in an updated flow diagram. Any known problem areas should have "strategies" developed in terms of alternative flow plans. Work breakdown structures should be developed and checked for any conflicting approaches or approaches that are not compatible with factory operations. The established drawing release system should ensure that all necessary drawings have been released to manufacturing. All long lead material items should be identified and any critical long lead material should be highlighted. The contractor's purchasing department should provide positive assurance that those materials will be received six weeks prior to the established need date. "Proof of manufacturing" models should be used to establish that processes and procedures are compatible with the design configuration. Essential to qualifying the manufacturing process is the early application of resources so that the product design and manufacturing processes are compatible with each other at the time of government test and evaluation. Therefore, during the fabrication of the development hardware, qualified manufacturing processes and procedures should be used to the maximum degree possible.

In addition, a configuration control mechanism should be established that will ensure that both the production baseline and the production process are controlled and disciplined. A configuration control mechanism that addresses only the production baseline affords little protection from the introduction of new processes and procedures or design changes that degrade product performance. Repeatability of product is one of the toughest areas of manufacturing. Lack of product repeatability often can be directly traced to undisciplined control of the product baseline or manufacturing procedure/process documentation.

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 of personnel 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.

The qualification of the manufacturing process at both prime contractors and all major subcontractors is essential. Properly planned, staffed, and executed PRRs are valid tools for assessing the depth of production engineering and planning activities that have been completed. Some key indicators at these reviews that will ensure that the manufacturing process is qualified, or at least going in the right direction, include:

a. A low number of waivers and deviations on the parts and materials that are built per process specification. The low number of Engineering Change Proposals (ECPs) ensures a mature design and mature manufacturing processes, such that product integrity is measurable. The maximum control exists when block changes can be introduced and resulting process changes can be requalified and fully evaluated using "proof of manufacturing" models.

b. The existence of a "hands on" personnel training program with a mechanism in place for personnel recertification.

c. Successful functional, physical, and configuration audits. Such audits add confidence and credibility to the maturity of both design and the manufacturing process.

d. Adequate time and dollars to perform production trial runs to verify that skills have been acquired through training, that process instructions are useable and accurate, that capacity predictions are validated, and most important, that the process is in "statistical control" and is stable.

e. The existence of a periodic production test program. This test program will ensure that the production units are being built to the product baseline and inherent performance and quality are being maintained. A sample "off-line" unit subjected to an environmental test sequence, consistent with the product specification, is normally sufficient. With proper test planning and resources, long-term “life” effects also can be evaluated using this test program.

f. A single shift, eight-hour day, five-day workweek operation is planned for all production schedules, particularly during initial production.

g. For batch manufacturing operations, line capacity can handle increases in production rate requirements anticipated on other projects now using the factory. All anticipated production line throughput problems are identified.

Qualify Manufacturing Process

Checklist

- ✓ Is an internal manufacturing qualification plan documented?
- ✓ Are manufacturing processes qualified at the prime contractor and major subcontractors?
- ✓ What positive assurance is there that critical long lead material will be available when needed?
- ✓ Have manufacturing processes/procedures used in the fabrication of FSD hardware been qualified to the maximum degree practicable?
- ✓ Does configuration control ensure both hardware and manufacturing process control?
- ✓ Does a "hands on" personnel training program exist?
- ✓ Is there work force stability?
- ✓ Is a single shift, five-day workweek operation planned, particularly for Low Rate Initial Production (LRIP)?
- ✓ Did the PRR indicate a stable design and manufacturing process?
- ✓ What is the contractor's plan for implementing new technology?

Piece Part Control

Overview: Most military projects require the use of MIL-STD parts in weapon and support systems. This policy, although better than using commercial parts, leaves much to be desired in its ability to ensure delivery of high quality and reliable parts. Consequently, MIL-STD parts require additional user controls. MIL-STD semiconductors have been particularly troublesome in recent acquisition programs.

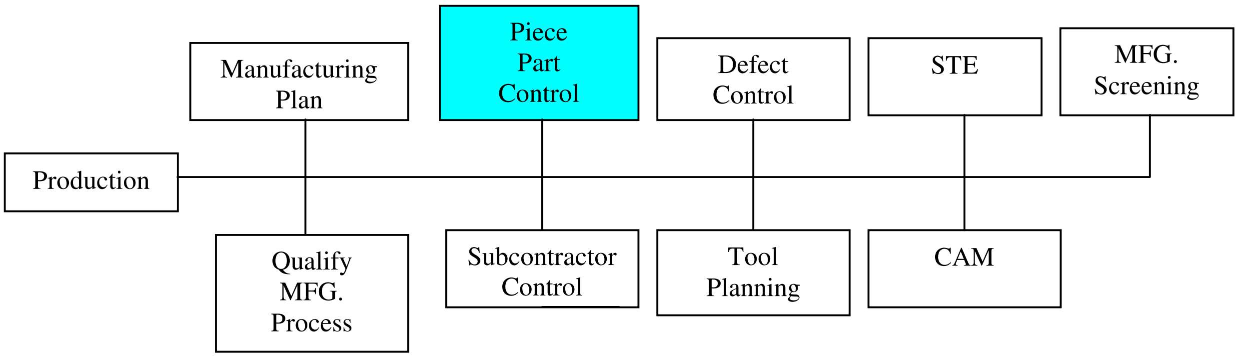
Traps!

1. Parts control program is initiated with rare production

2. Source inspection is relied upon for parts control

3. MIL-STD parts are used

4. Additional part inventory is maintained to ensure on time product delivery



Piece Part Control

Benefits

Engineers can concentrate on solving design problems	The "build" process will be started with known good parts	Unit cost will be reduced	Supplier part quality will be improved dramatically

Escapes

Require a formal parts control program during FSD Flow down requirements to subcontractors Parts application and derating criteria are addressed during design reviews	Require receiving inspection at the contractor's facility	Require 100 percent environmental stress rescreening for semi-conductors and Integrated Circuits (ICs) Require Particle Induced Noise Detection (PIND) testing on hybrids and selected cavity devices Require Destructive Physical Analysis (DPA)	Initiate aggressive incoming inspection program Maintain yield records on suppliers Monitor supplier performance by yield

Best Practices

TRAPS

1. Parts control program is initiated with rate production	2. Source inspection is relied upon for parts control	3. MIL-STD parts are used	4. Additional part inventory is maintained to ensure on time product delivery

Current Approach

Alarms

Excessive time spent troubleshooting initial design concepts Excessive part failures during development	Inspectors are not assigned full time to the vendors plant No plan to rotate source inspectors is implemented High reject rate is experienced during product fabrication	MIL-STD parts are not rescreened Lot sample screening is used	Part usage is increased due to part quality problems Bad parts are not returned to supplier Contractor has no contractual recourse to vendor

Consequences

More extensive design effort	Approximately 12 percent more parts are needed	Yield at card-level test is poor	Program cost is increased due to higher parts inventory requirement

Piece Part Control

Summary: Implementing a sound parts control program requires more than policy directive such as DoD Directive 4120.19 or plans to use "MIL-STD" parts. Although MIL-STD parts may provide some level of device control, blind dependence on them to ensure system reliability will prove disappointing. Until adequate control programs are set up with vendors to ensure adequate source controls, the assumption that procurement of parts to military standards automatically ensures good parts will remain faulty. Also, cost savings are feasible by establishing controls for all parts suppliers at the earlier possible time; such controls are not available through current standard parts programs (e.g., Defense Electronics Supply Center).

A key element of parts control is an established corporate policy which ensures that certain steps are taken to control part quality, (both electrical and mechanical), independent of government contract requirements. When this policy is well defined and imposed on subcontractors, the most effective parts control measures have been initiated.

Any attempt to delay adequate parts control planning until rate production will add significant risk to the project. The parts that will ultimately be used in production designs should be qualified and assessed during FSD. During FSD the critical parameters that need to be measured, and the identification of which parts will require rescreening at incoming inspection, must be identified. This will help ensure that FSD is successful and set the stage for significant production cost savings. Savings in purchased parts quantities of up to 12 percent have been noted. Reduced rework and repair results in additional cost savings, which is the principal benefit of electronic parts rescreening.

Although the exact rescreen to perform will vary with part type, 100 percent environmental stress rescreening on electronic and semiconductor piece parts has been found to be economical. Digital Integrated Circuit (IC) devices benefit most from performance testing at temperature, while diodes and transistors can sometime be effectively tested at room temperature. Particle Induced Noise Detection (PIND) testing on cavity devices (MIL-STD 883, Method 2020) and solderability tests on leaded devices are strongly encouraged. Destructive Physical Analysis (DPA) is also recommended to identify process characteristic changes in the manufacture of electronic piece parts that could affect part performance and reliability.

An effective parts rescreening 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. Ignoring these essential measurement and feedback techniques will lead to unexpected surprises and significant cost and schedule overruns in rate production. Developing an adequate testing and screening program at the vendor's facility should be pursued; however, parts rescreening at incoming inspection currently provides the best approach to solving the technical risk associated with piece part control.

Piece Part Control

Checklist

- ✓ Is corporate policy in place on piece part control?
- ✓ Is a formal parts control program required during FSD?
- ✓ Have piece part control requirements been flowed down to subcontractors?
- ✓ Is 100 percent environmental stress rescreening of semiconductors and ICs being done?
- ✓ Are piece part suppliers aware "up front" that their parts are subject to rescreening?
- ✓ Are poor suppliers identified on the basis of poor yield rates at incoming inspection and product assembly?
- ✓ Is there contractual recourse for returning bad parts to suppliers?

Subcontractor Control

Overview: As the complexity of weapons system increased, the percentage of major weapon systems which are subcontracted also has increased. Today, subcontractors are a critical member of the system development team. Unfortunately, the guidance provided in the Defense Acquisition Regulations (DAR), DoD instructions, and MIL-STDs leaves much to interpretation and emphasizes the cost and schedule aspects of subcontractor management in lieu of technical performance. The wide interpretation of specifications and standards often leads to poor communication, and creates inadvertent adversarial relationships. An informal poll of ten prime contractors averaging about ten major projects has resulted in statements that nearly half their projects experienced cost or schedule problems from inadequate problems form inadequate subcontractor control.

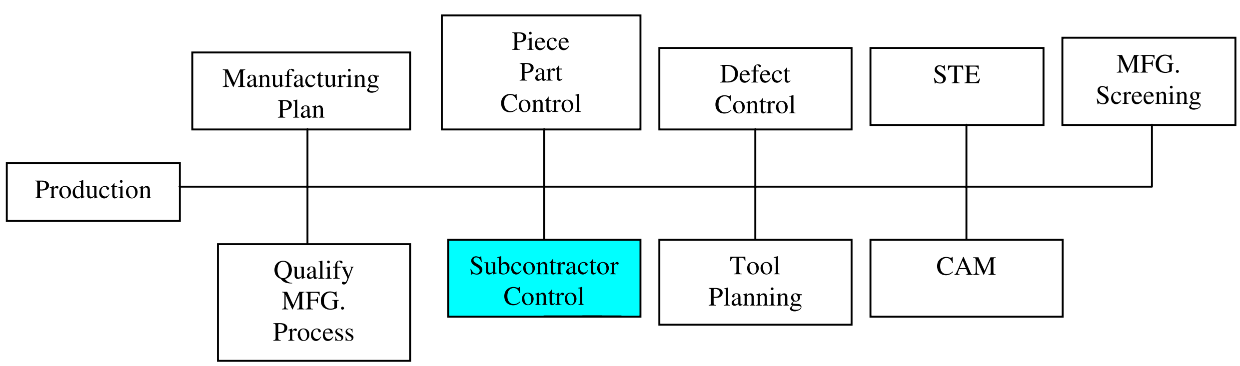
Traps!

1. Cost and schedule are monitored by prime contractor

2. Applicable MIL-SPECs are invoked by the contract

3. "Hands off" attitude is exhibited toward subcontractors

4. Prime contract awards based on low cost, provide incentive to accept low bid subcontractors



Subcontractor Control

Benefits

Prime contractor will know his subcontractor's product maturity	Subcontractors will understand technical product requirements	A team effort will be established with government, prime contractor, and subcontractor	Subcontractors meet schedule and cost requirements

Escapes

Establish scheduled design reviews with subcontractors Have prime contractor provide a technical assistance team as necessary	Use dedicated specification group to ensure completeness and consistency of specifications, procurement packages, technical interfaces, and flow down requirements	Government/prime contractors jointly conduct vendor conferences with subcontractors Assign an individual in prime contractor organization responsibility for each subcontractor	Assign equal weight to technical performance, cost, and schedule Evaluate subcontractor's capabilities prior to contract award

Best Practices

TRAPS

1. Cost and schedule are monitored by prime contractor	2. Applicable MIL-SPECs are invoked by the contract	3. "Hands off" attitude is exhibited toward subcontractors	4. Prime contract awards based on low cost, provide incentive to accept low bid subcontractors

Current Approach

Alarms

Technical problems are identified late or not at all Critical processes/ procedures and plans are not validated by prime contractor Prime contractor has no stated policy on subcontractor control	Procurement specifications and Contract Data Requirements Lists (CDRLs) are applied to the subcontractors without tailoring Procurement packages do not reflect detailed technical requirements	Requirements are waived to meet prime contractor schedule, and verbal instructions are issued to correct deficiencies Excessive proprietary data rights are allowed Configuration of qualified hardware not known by prime contractor	Cost and schedule are the only criteria stressed in source selection Subcontractor past performance is not considered or has been marginal

Consequences

Difficult to determine technical progress	Subcontractors do not understand "real" requirements	Prime contractor is not in control of subcontractor's end products	Subcontractors have difficulty in meeting project commitments

Subcontractor Control

Summary: The practice of applying MIL-STD-490 without the interpretation of generalities and options offers little guidance to subcontractors, and does not allow for the effective administration of state-of-the-art acquisition programs. When reviews are restricted to the formal DoD type, technical problems often go unnoticed and hidden costs are incurred. The situation becomes critical during source selection, when a subcontractor of unknown technical ability is selected upon basis of cost.

Subcontractors, when reviewing contract requirements, often are left to their own interpretation of specifications and "boilerplate" requirements. The interfaces that do not occur with the prime contractor and the government often are uncoordinated and do not provide the necessary leadership or adequately address the technical issues. Monitoring the subcontractor only using predetermined milestones permits many design/test/manufacturing operations to go unnoticed until a critical delivery schedule is slipped. Often, the prime contractor's schedule adversely affects the technical performance for the hardware delivered by subcontractors.

Good communication between the government, the prime contractor, and subcontractors is a key ingredient in effective subcontractor control. Specifications (including statement of work and CDRLs) should be prepared by a dedicated group to ensure consistency and completeness. A multidiscipline onsite evaluation team should ensure that the chosen subcontractor can perform adequately to the agreement. The evaluation team should include representatives from quality, material, technical, and configuration management, as a minimum.

After the subcontractors have been determined, the government and the prime contractor should conduct vendor conferences tailored to educating each subcontractor thoroughly on his contract as well as the key technical elements contained in the prime contract. The vendor conference should provide an awareness of each subcontractor's role in the total weapon system acquisition and identify specifically what will be required of each subcontractor. The prime contractor should provide to each subcontractor a "subcontractor assist" person who will work jointly with the subcontractor in solving any "surprise" problems.

In addition, the prime contractor should have an authoritative and centralized data administration organization for the processing and handling of subcontractor data to account for all actions require and completed. A point of contact must be established for each item subcontracted, and for major/critical subcontracts. An onsite representative must be required for effective monitoring of the subcontractor's daily operation. Periodic internal reviews should cover technical/manufacturing/test progress (or lack thereof) using accumulated data, part of which is in response to flow down of reliability development testing requirements (TAAF) from prime contractor to subcontractor.

During the contract period, data transmittals require close monitoring. Uncoordinated decision making and failure in maintaining timely responses to and from the subcontractor are the result of inattention to data management. This area of subcontractor control is especially important in tracking corrective action requests, and in validating critical processes and plans necessary for all activities to maintain schedule. Also, accepting proprietary rights claims without fully investigating their validity reduces the effectiveness of data management, and should be avoided.

Informal technical and project level reviews are an essential ingredient of effective subcontractor control. The prime contractor should, on a regular basis, evaluate the “real” progress made by the subcontractor through such reviews. Other techniques that should be considered include configuration readiness reviews, review of design/manufacturing/ test processes before qualification, and the requirement to use Test Requirements Documents (TRDs) to detail the procedures for product test. Finally, all project schedule changes should be coordinated between both the prime and subcontractors before firm changes to project commitments are made.

Subcontractor Control

Checklist

- ✓ Is there a dedicated group in charge of subcontractor specification preparation?
- ✓ Does an onsite review team review subcontractor's facilities and capabilities?
- ✓ Have subcontractor/vendor conferences been conducted?
- ✓ Do technical assistance teams exist?
- ✓ Does the prime contractor have an individual assigned for monitoring each subcontractor?
- ✓ Are changes in project requirements coordinated with subcontractors before commitment?

Defect Control

Overview: Quality assurance programs often emphasize inspection as ensuring that a "good" product is delivered to the customer. However, this emphasis on inspection does not give attention to activities that are necessary to minimize defect recurrence. Those activities that minimize defect recurrence also control factors that drive up production costs (e.g., rework/repair activities and material scrap).

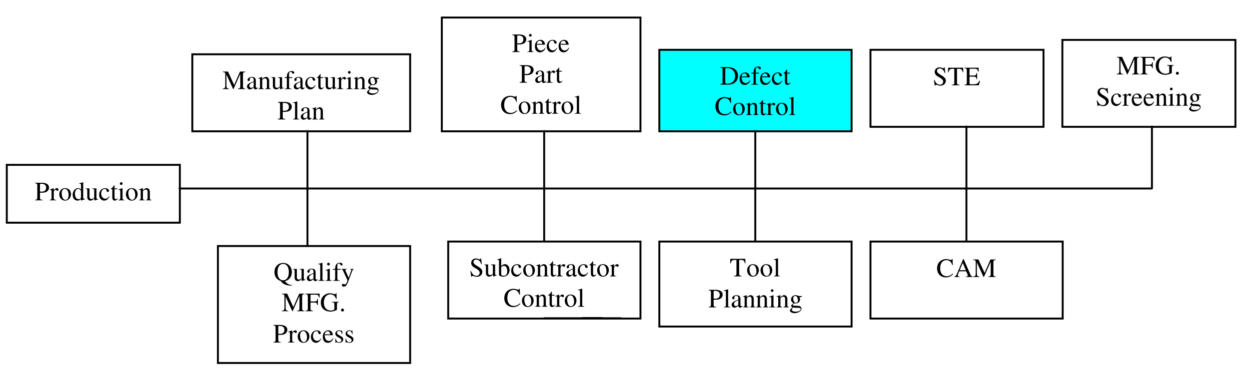
Traps!

1. Defect control program is based on MIL-Q-9858A

2. Production delays are avoided through the use of waivers and "use as is" disposition

3. Statistical analysis is required for yield/defect rates

4. Quality data system is manual



Defect Control

Benefits

A disciplined method will ensure manufacturing process control	Hardware performance will be consistent	Process control will be effective	Mechanism for defect prevention will be efficient

Escapes

Implement defect prevention plan that identifies the needed production equipment, trains personnel, and controls the manufacturing process	Corrective action team ensure that attention is focused on solving the causes of defects	Trigger corrective action team involvement by yield/defect rate thresholds Post current yield data on the factory floor	Implement automated reporting system that reports accurate and current status

Best Practices

TRAPS

1. Defect control program is based on MIL-Q-9858A	2. Production delays are avoided through the use of waivers and "use as is" disposition	3. Statistical analysis is required for yield/ defect rates	4. Quality data system is manual

Current Approach

Alarms

Defect control is the responsibility of the product assurance function Detection, nor prevention of defects, is emphasized	Volume of Request For Waiver (RFW) submissions is high Trends in first-pass test yields at product acceptance are decreasing Use as is dispositions used to expedite production	Yield/defect rates are calculated using cumulative data Daily control charts are not evident on the factory floor	Time lag in problem identification is excessive Data gaps are evident

Consequences

Hardware is continually repaired	Marginal hardware is fielded	Identification of problem areas on the factory floor is late	Old data is used in an attempt to control the manufacturing process

Defect Control

Summary: Most companies boast of a good quality inspection system. Indeed, quality assurance programs do require many inspections throughout the build cycle. However, inspections merely identify that defects are present, and repair actions on defective hardware involve either a "paper action" (i.e., "used as is," Material Review Board [MRB] disposition, or Request for Waiver [RFW] submission) or physical repair of the defect and resubmission for inspection. Some characteristics of ineffective attempts at preventing defects include (1) management indications that a majority of the problems are "worker caused," (2) a heavy volume of data review to determine causes of poor yields, or (3) strong management reaction to each incident on the factory floor. These approaches virtually eliminate the ability to maintain timely process control, and ensure high incidence of rework/repair that results in higher production costs and increased process times.

Some companies do strive for prevention of defects by monitoring yields and trends on the production lines. The approach is valid, but is ineffective when there is an overemphasis on the statistics involved with monitoring defects. In many instances no formal defect control system exists, or else it is unregulated or undisciplined. In those situations there will be a lack of concise historical data, poor feedback as to the effectiveness of corrective action taken previously, and a lack of emphasis on the cause of defects.

An extensive volume of data is generated on the factory floor during production. Data typically includes test results, inspection reports, and material discrepancy reports. Analysis of this data and the identification of meaningful trends is essential in identifying the causes creating discrepant hardware. A manual system of data recording and analysis is time consuming and is an inefficient tool in the identification of problem areas on the manufacturing line. Gaps in the data can be anticipated, and the susceptibility of manual analysis to human error can give late and inaccurate yield or defect trends.

An ineffective defect control program can be characterized in several ways. First, there exists a high incidence of rework and scrap. A review of MRB activity will document the level of rework and scrap. A cursory review of the scrap rate may indicate a low level, but a more thorough review of discrepant a hardware, including "use as is" dispositions and the volume of RFW submissions, will give the total picture. A continuous high rate of defect types (i.e., workmanship, part, etc.) without any evidence of decreasing trends is indicative of out-of-control process. Excessive emphasis on the statistical implications of defect or yield rate data, especially in terms of confidence level, is an indication of an ineffective approach to preventive defect control. Such an approach reduces the sensitivity to identifying process problems and underestimates the significance of those problem areas that are identified. A tour of the factory floor is a method to get a quick indication of the adequacy of the defect control program. Lack of visible indications of trends at workstations, and indications that workers are not aware of the types of problems being experienced on the floor and the efforts being undertaken to correct those problems, are symptomatic of difficulty in maintaining preventive defect control.

A management commitment to defect “prevention” is the prime ingredient of a sound defect control program. A management policy on defect control should be evident. The policy should require that management be involved in the review of defect analyses and that the emphasis on defect “prevention” is flowed down to all subcontractors. A management commitment to defect control must be enhanced by a corrective action program committed to defect control. Defect trend information should be obvious on the factory floor. A corrective action team must be established to ensure adequate attention to the causes of defects. Team members should be technical and management personnel familiar with the product being manufactured. The extent of team member’s involvement should be triggered by predetermined corrective action thresholds.

For the corrective action team to function efficiently, the volume of inspection data generated on the factory floor must be quickly reduced to identify trends. Such trend information can identify problem areas that are most critical. An automated real time defect reporting/tracking system is highly recommended to enhance timely identification of problem areas and verification of effectiveness of action taken to correct problems. Such a defect tracking system should correlate defects to (1) location and environment, (2) time in cycle, (3) test step, (4) point in the manufacturing process (as identified on a manufacturing flow diagram), (5) next assembly, (6) symptom description, and (7) similar defects observed in the assembly. In addition, yield and defect thresholds should be set so as to provide meaningful assessment of progress or degradation from the result of corrective action.

There are several good indicators when an effective defect control program is functioning. First, visible and meaningful information is posted on the factory floor. There is a distinct sensitivity to trends, versus waiting for statistical “proof” that a problem exists. Predetermined corrective action thresholds have been established and action is being taken based on those thresholds. The corrective action team receives concise data and is able to identify critical areas that need immediate action.

Defect Control

Checklist

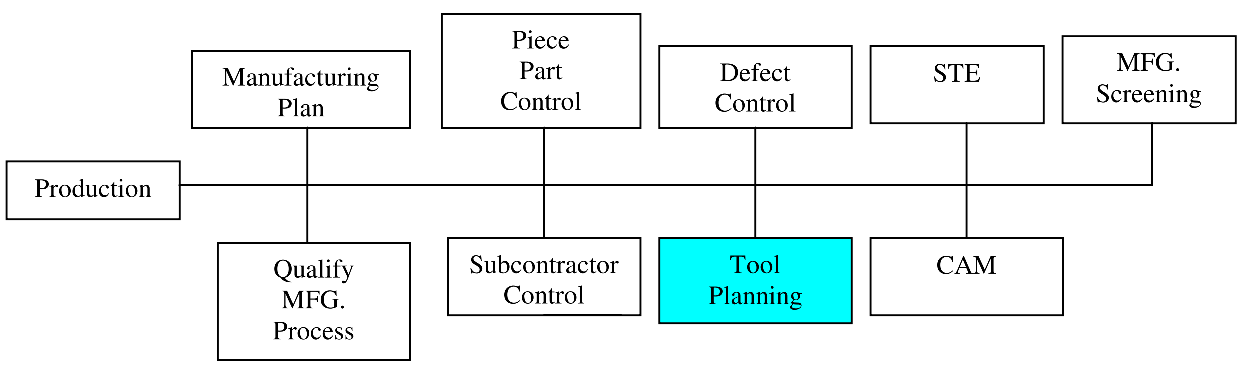
- ✓ Is there a corporate policy on defect prevention?
- ✓ Have corrective action teams been established?
- ✓ Is required corrective action team action defined by yield thresholds?
- ✓ Is management involved on critical/unsolved problems?
- ✓ Are there predetermined time limits on determining appropriate preventive actions?
- ✓ Is automatic data analysis/trend charting capability being used?
- ✓ Do subcontractors have an aggressive defect control program?
- ✓ Is effectiveness of each corrective action monitored?
- ✓ Is visible and meaningful yield/defect information posted on the factory floor?

Tool Planning

Overview: The need for tool planning is not generally understood. Therefore, it is considered of secondary importance to the other aspects of product development. Tools range from special handling devices (to ensure personnel and equipment safety) to equipment required for implementing methods planning (to achieve the desired quality, rate, and cost). Improper tool planning and proofing affect cost, quality, and ability to meet schedule.

Traps!

1. Tool plan is addressed in the manufacturing plan
2. Tool development is an independent project function
3. Configuration control for tooling is required
4. Existing tools are used on new product designs



Tool Planning

Benefits

The necessary tooling will be available when production begins	Tooling will support rate production requirements	A disciplined configuration control program will ensure tool compatibility	Existing tools will be qualified for the new product design

Escapes

Develop comprehensive tool plan before product design is frozen Develop and proof the necessary tools during FSD	Communicate the impact of tool design on product configuration to design and manufacturing Involve a tool designer with the design evolution during FSD	Manufacturing engineering check that tools are compatible with product configuration Include tool reviews and audits in design reviews	Proof tools using proof of manufacturing models

Best Practices

TRAPS

1. Tool plan is addressed in the manufacturing plan	2. Tool development is an independent project function	3. Configuration control for tooling is required	4. Existing tools are used on new product designs

Current Approach

Alarms

A one- or two-paragraph discussion on tooling is contained in the manufacturing plan Special tools are not considered The influence of tooling on design producibility is not considered	Tools are proofed after product design has been qualified Hard tooling forces changes to the qualified design configuration	Tooling configuration is emphasized after problems occur Manufacturing and design engineering are not part of the configuration control board for tooling	Damage is observed during product assembly or test Assembly of the product is extremely difficult

Consequences

High tooling costs are likely	Phase out of soft tooling is late	Tool inventory is not sufficient to sustain production rate requirement	Higher factory skill levels are required to manufacture the product

Tool Planning

Summary: Tool planning encompasses those activities associated with establishing a detailed, comprehensive plan for the design, development, implementation, and prove-in of program tooling based upon a visible corporate policy and structured around a documented practice. Tooling is of greater significance to the success of a production project than many prime item designers are aware. Production tooling is conceived and designed by a phase developmental approach just as is prime hardware. Evidence that one phase is completed prior to the beginning of the next phase should be one of the basic understandings. There are four fundamental phases in tooling design, namely: (1) conceptual design development, review, and approval; (2) preliminary design development, review, and approval; (3) detailed design development, review, and approval; and (4) fabrication, tool tryout, and acceptance. A phased development approach ensures that all interested parties are adequately informed and have an early and continuous opportunity to influence the design to ensure that the production tooling (1) will support the prime hardware at production rates; (2) is consistent with other program objectives such as production test; and (3) is producible. It is important to note that production tooling design is not a series task with the design of prime hardware. Key manufacturing personnel can provide vitally-needed input to prime equipment design in the conceptual phase.

Thus, there is an interaction between the prime equipment and the tooling required to produce it. A common pitfall is to ignore the synergism of that interaction.

To ensure that the tooling philosophy and practices are uniformly applied throughout the project, a firm requirement for plans, reviews, and demonstrations must be included in each subcontractor's statement of work. A strong working relationship must be established so that complete visibility is maintained of the subcontractor's tooling efforts. Adequate, timely audits and reviews must be planned, and responsibility for them must be left solely to a purchasing organization. The success of transitioning to production and maintaining efficient production rates depends heavily upon the individual successes of the subcontractors involved. One subcontractor failure can cause the entire project to fail.

The importance of Proof of Manufacturing (POM) models to the tooling endeavor cannot be overemphasized. Each tool must be rigorously proven in prior to its incorporation into the manufacturing process. This proving-in process verifies its performance and compatibility with the specifications controlling it. Since tooling includes those devices, fixtures, aids, etc., which are required to form, shape, fabricate, assemble, hold, or handle, the prime equipment, or any part of it, it is obvious that tooling has a great impact on cost, quality, and rate. This point alone justifies collocating manufacturing engineers and tool designers with prime equipment design personnel. It is not the intrinsic cost of the tools that is so important (although for most projects, tooling is not an insignificant budget item) but the leverage that good tooling wields in terms of production man-hours and product quality – the greatest cost drivers of all!

Using POM models to ensure that the tooling is compatible with the prime equipment is one significant way to reduce risk. Since POM models are defined to be "functionally operational systems produced by hard tooling, complete planning, and production test equipment," they are the ultimate proof of the ability to produce at project rate, quality, and cost objectives. Earlier "prove-ins" of tooling use prime equipment produced on soft tooling. These earlier models cannot satisfy the needs of POM models. Many a project has suffered severely from this illusion. Establishing and maintaining strict configuration control of the tooling is important so that there is complete harmony between the tooling configuration and the prime equipment configuration. The change control system must apply to both tooling and prime hardware, otherwise items will be produced with obsolete tooling, delays in introducing changes will occur, and configuration accounting will become unmanageable – in essence, configuration control will be lost.

A vital adjunct to configuration control is inventory control. Each tool needs to be accounted for by location and responsible individual. This is simply stated, but cannot be left to chance that it is accomplished. An established routine for maintenance and periodic calibration is also necessary to ensure and maintain tool serviceability. A tool that is out of calibration or has subtle flaws is worse than a tool out of commission.

Tool Planning

Checklist

- ✓ Is a comprehensive tool plan documented?
- ✓ Does the tool development and proofing occur concurrent with product development?
- ✓ Have “hard” and “soft” tools been defined?
- ✓ What is the phase out plan for “soft” tooling?”
- ✓ Is there a configuration control mechanism for tooling design?
- ✓ Does a tool inventory control system exist?
- ✓ Is a tool designer involved with the product before the product configuration is “frozen”?

Special Test Equipment (STE)

Overview: During FSD there is often neither the time nor the dollars available to address the issue of special test equipment. As a result, the Special Test Equipment (STE) required to support a weapon system is not addressed until the start of production. STE requirements address the needs of every project in two major areas: (1) product acceptance at the manufacturing facility, and (2) system support at the depot or intermediate maintenance levels.

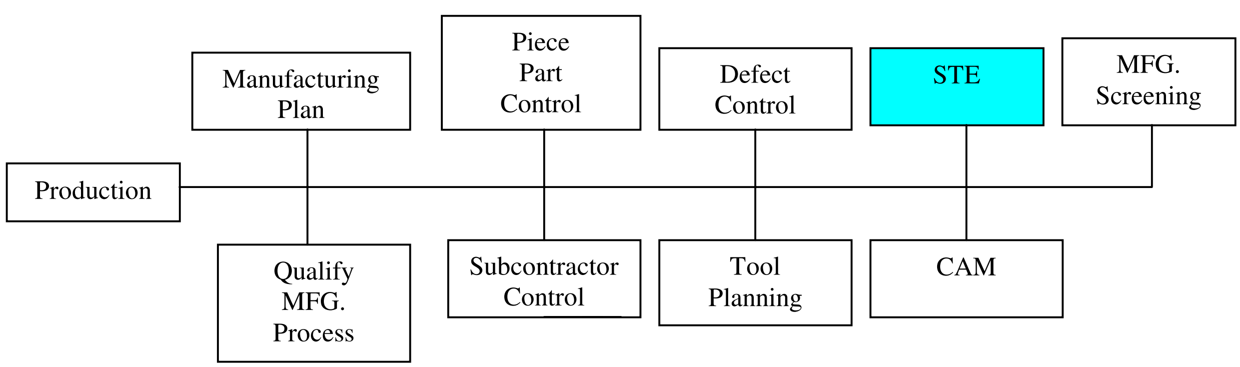
Traps!

1. Product performance is the primary design objective during FSD

2. Development test equipment is used during product fabrication/test

3. "Off-the-shelf" equipment is not adequate

4. Production test requirements are best addressed after Milestone III



Special Test Equipment (STE)

Benefits

STE will be available when needed and will be compatible with the design	STE will be sufficient for product manufacture and field maintenance support	Mix of contractor and government investment in test equipment will be optimized	STE will be certified before rate production

Escapes

Ensure that STE requirements are defined concurrent with design requirements Communicate STE requirements to subcontractor and vendors	Complete STE development in FSD Proof STE and make available in sufficient types and quantities to support program requirements	Identify STE versus "off-the-shelf" technical issues during FSD List commercial test equipment options and make available to the government	Ensure that both production and field test requirements are used to determine STE requirement Determine that STE "on-line" can sustain production rate changes when field returns are considered Ensure configuration change compatibility with STE and its ability to perform required tests

Best Practices

TRAPS

1. Product performance is the primary design objective during FSD	2. Development test equipment is used during product fabrication/test	3. "Off-the-shelf" equipment is not adequate	4. Production test requirements are addressed after Milestone III

Current Approach

Alarms

STE requirements are not defined in FSD STE development is scheduled for completion during low rate initial production	Slow production rate ramp-up is experienced Engineering analysis is often required to interpret test results Personnel with high technical skill levels must operate the test equipment	Tradeoffs between the capabilities of commercially-available test equipment and STE are not considered Equipment available on the factory floor is overlooked	Configuration changes are made on a proven design to accommodate testability

Consequences

Testing is incomplete on delivered hardware	Product testing is expensive and time-consuming	Unnecessary investment in STE increases acquisition and support cost	Product test before delivery is inadequate

Special Test Equipment (STE)

Summary: A common problem in weapon system acquisition programs is the definition of Special Test Equipment (STE) requirements too late to incorporate an efficient interface between the system, STE, and subcontractor-supplied subsystems. When the STE considerations are ignored until the design is well-established, efficient module and test point partitioning, and a well-thought out tradeoff between automation and BIT is not incorporated into the product design. The acquisition manager then is faced with one of two alternatives: (1) proceed with the design "as is," ignoring well-founded test requirements; or (2) undertake a redesign effort that alters a proven system configuration to accommodate STE requirements that should have been addressed during FSD. Either choice leads to increased cost, schedule slippage, and risk of degradation of system performance in production hardware.

An STE approach should consider tradeoffs between the use of "off-the-shelf" test equipment and STE. These tradeoffs most efficiently can be assessed when the product design remains fluid. STE development should include a tradeoff analysis to determine what test functions only can be accomplished using STE. "Off-the-shelf" test equipment that can accommodate any necessary test functions also should be identified in the tradeoff analysis. Optimum use of "off-the-shelf" test equipment optimizes the balance between contractor's capital investment and the government's investment in STE development. Failure to consider these tradeoffs results in needless increases in system acquisition cost.

A thorough factory test plan should be developed before the design of the system is completed. In addition, a realistic production-rate analysis need to be completed to avoid test equipment shortages (or overbuying). Such an analysis should include yield estimates that can be expected in various phases of product development and production including potential field returns. The factory test plan and the production-rate analysis should be major inputs in the test requirements definition. Design engineering should concur on the test requirements and test approach *before* the design configuration is frozen.

Specific engineering tasks that are conducted during STE development include a test tolerance funneling scheme that reveals problems at the lowest functional level, but does not cause excessive rejection at final acceptance. STE engineering should also (1) use design strategies that simplify modification to tolerance limits and enable tests to be readily added and deleted, (2) provide for a manual intervention capability in automated test equipment so that manual test equipment can be used if software problems do occur, and (3) provide for adequate test equipment engineering and maintainability engineering input to the system design and include optimum functional partitioning for ease of test.

Today's state-of-the-art test equipment requires software programming. Adequate time should be afforded for test equipment software debugging and compatibility verification. The use of a "proof of design" model to assist in software debugging, test equipment compatibility, and accuracy is encouraged. A collocated engineering team (STE engineering and system engineering) enhances tradeoff analysis, facilitates analysis of the test approaches for completeness, and improves the efficiency of communication necessary to correct any test escapes inadvertently generated from performance-oriented design changes.

Management decisions will be needed to determine the capital investment needed to accommodate these new requirements. In batch manufacturing operations, the test equipment hardware already exists on the factory floor. The use of such test equipment, therefore, requires a minimum investment; only costs for software programming peculiar to the item being tested are normally incurred. When the test operation on the factory floor is made efficient, production costs are lowered and rapid return on the investment in test equipment (STE or “off-the-shelf”) is realized. Therefore, the maximum use of test equipment available on the factory floor should be used. When test requirements are determined, a list of “off-the-shelf” equipment that can meet those requirements should be developed. That list, when compared to the inventory of test equipment on the factory floor, will identify areas where capital investment by the contractor, or the development of STE (requiring additional investment by the government) is warranted. The same list of test equipment also is useful to the government in planning for logistic support requirements. Test requirement definition and STE tradeoff analysis should be completed early while the design is fluid and compatibility between the system and STE can be optimized. An STE plan should be established that allows for integration of STE activities, with both the design and manufacturing planning activities (particularly tooling design activities) being executed concurrently.

Just as the weapon system requires attention to design discipline, so does the development of STE. The definition of sound test requirements is essential. Requirements for STE development should be addressed in the contract statement of work for both the prime contractor and all subcontractors. Just as weapon system development requires careful attention to a discipline design process, so does the development of special test equipment. STE should be designed, qualified, and used as early as possible to ensure a uniform final test from development through production transition. STE development should commence concurrent with weapon system development, and qualified STE should be used during the final product test on all deliverable hardware.

Special Test Equipment (STE)

Checklist

- ✓ Has STE been designed and qualified before the product design is frozen?
- ✓ Are STE requirements defined from a factory test plan?
- ✓ Is the STE plan integrated with both product and tooling designs?
- ✓ Do design reviews and audits include STE issues?
- ✓ Are STE quantities and efficiencies compatible with anticipated production yields?
- ✓ Has STE been designed and validated in time to test the deliverable product?
- ✓ Does field use support and maintenance drive STE requirements?
- ✓ Are STE requirements specified to the lowest level of assembly and flowed to the higher levels with appropriate consideration of tolerances?
- ✓ Are STE requirements flowed down to all subcontractors?

Computer-Aided Manufacturing (CAM)

Overview: The annual rate of productivity improvement in the United States recently has been lower than any other major industrial country of the Western World. This can be attributed largely to the fact that our manufacturing plants are operating with tools and processes that have not kept pace with emerging technology. Contractors using Computer-Aided Manufacturing (CAM) integrated with Computer-Aided Design (CAD) are experiencing phenomenal productivity increases.

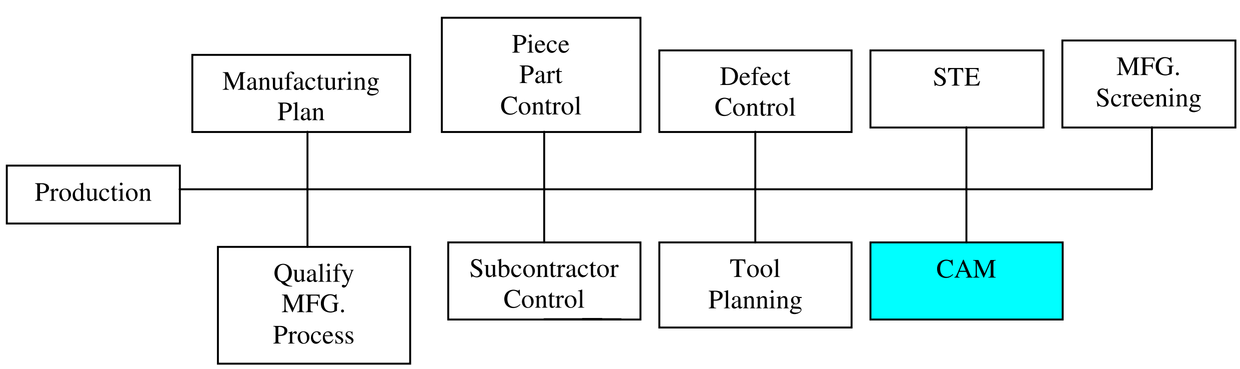
Traps!

1. CAM is used on a project application basis

2. CAM is applied to fix discrete production line problems

3. CAM is represented primarily by numeric control machine tools

4. CAD and CAM are considered to be independent functions



Computer-Aided Manufacturing (CAM)

Benefits

Introduction of CAM in the factory will be smooth	Increased production will result in savings to both government and contractor	Integrated plant modernization will evolve	Higher quality, lower cost product will result

Escapes

Apply CAM consistent with future plant objectives Involve joint manufacturing and engineering team to define and standardize critical processes	Develop database which includes design data, tooling data, and manufacturing engineering data Provide corporate assistance in material control, process planning, automated manufacturing, and test	Use computers to assist in production control from inventory control to the programming of machine tools	Utilize a common database in both engineering and manufacturing operations Include as a minimum, geometric and other product definitions in the database

Best Practices

TRAPS

1. CAM is used on a project application basis	2. CAM is applied to fix discrete production line problems	3. CAM is represented primarily by numeric control machine tools	4. CAD and CAM are considered to be independent functions

Current Approach

Alarms

No corporate policy on CAM is in place Tendency to overinvest in CAM is evident	No central database for design and manufacturing engineering has been created Difficulty in integrating computer-assisted functions (including CAD) is being experienced	CAM is perceived as a costly program with a long-term return on investment	Capital investment, long-term dedication, and technical support required for a CAD/CAM system are not recognized by corporate executives

Consequences

Implementation of CAM is inefficient	Increase in productivity for a high capital investment is minimal	Total capability of CAM is not realized	Competitive position in military market is jeopardized

Computer-Aided Manufacturing (CAM)

Summary: Unsuccessful or costly attempts at introducing Computer-Aided Manufacturing (CAM) at some facilities have contributed to slow introduction of CAM on the factory floor. Characteristics that are indicative of a high risk approach to introducing CAM include: (1) the lack of a well-defined corporate objective, (2) the weak translation of the corporate objective to an integrated plan for implementing CAM, (3) the use of CAM as a "fix" for discrete production line problems, (4) failure to consider the CAD interface, (5) failure to consider total factory requirements in terms of database development (i.e., requirements for inventory control, cost accounting, purchasing, etc., are often not considered), and (6) the lack of a comprehensive retraining program for personnel. These characteristics have basically one root cause: an ill-defined policy and plan for implementing CAM.

When manufacturing personnel are involved in the design process, the transition to production tends to be low risk. Corporate policies, therefore, should provide for the integration of CAM and CAD. The corporate policy should identify the design and manufacturing capability that is desired within the next five years, and these requirements should be translated into an implementation plan that addresses the requirements of all departments associated with the manufacturing operation. Remember, the factory is much more than tools and machinery. To keep a factory running smoothly, for example, parts must arrive on schedule, in specified quantities, and will be utilized at a projected rate. As the factory operation becomes more automated and efficient, real-time monitoring of those parameters is essential for precluding parts shortages that will virtually stop the production line. In addition, production engineering and quality control will require real-time monitoring of yield information on critical process and test points on the production line. Clearly, the use of computers to control the manufacturing operation (fabrication and assembly) and the use of computers to collect the data that maintain an optimum level of factory productivity are essential objectives in CAM implementation. A top-down strategy for implementing CAM will normally decrease the time required to achieve a return on the investment in CAM, as opposed to an uncoordinated or bottom-up approach.

When manufacturing personnel are involved in the design process, the transition to production is achieved readily. The use of a common CAD/CAM database will make this involvement more automatic. A CAM database when integrated with a CAD database provides for the maximum exchange of data between design engineering, manufacturing engineering, and the tool design shop. The use of such a database by design engineers identifies the manufacturing process limitations that must influence product design decisions. Also, the use of the design data for tool and test equipment design and the automation of test is a significant aid in the preparation for production. An integrated CAD/CAM database efficiently provides the necessary design data to reduce the tooling design and product design iterations. Tooling costs in some cases can be reduced by 50 percent, when an integrated database is used.

When computer-assisted equipment or automated factory equipment is implemented on the factory floor, personnel often become concerned about job security. These concerns can be eliminated through the use of a visible formal retraining program for employees. The use of an apparatus lab for off-line hands on training, coupled with classroom instruction, not only ensures that qualified personnel will operate the new equipment, but also serves as an employee motivation tool and relieves some of the uncertainty of an employee's future when state-of-the-art equipment is being introduced.

On the factory floor, maximum use of computers should be made to reduce the number of manual operations used in the manufacturing process. Some areas of manual operation that make effective use of computers include:

a. Control of fabrication, assembly, test, and inspection functions

b. Collection and analysis of shop floor data

c. Collection and analysis of test data

d. Parts kitting, material flow, and inventory control

e. Configuration management

Computer-Aided Manufacturing (CAM)

Checklist

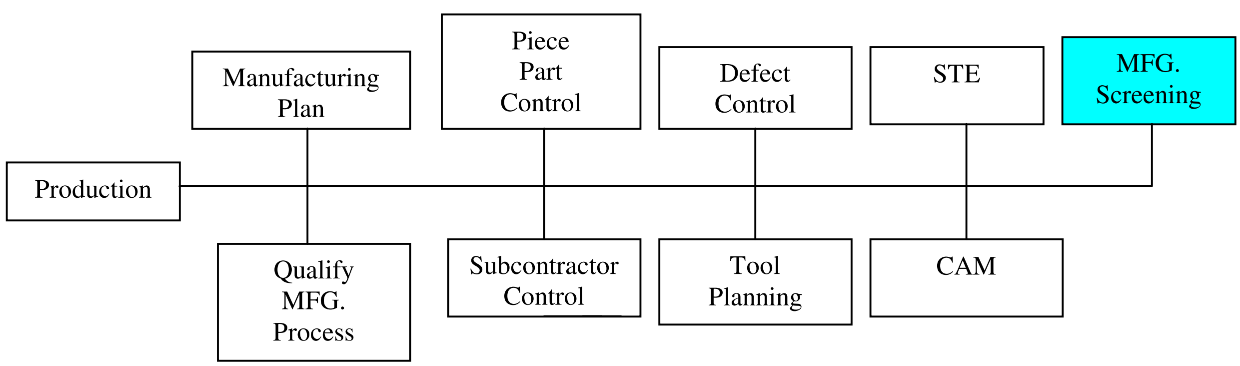
- ✓ Does a corporate policy exist on the phase in of CAM and other factory modernization initiatives?
- ✓ Does an integrated implementation plan ensure a top-down strategy for introducing CAM?
- ✓ Does a common database exist that includes the entire plant operation?
- ✓ Is reduction of manual operations emphasized?

Manufacturing Screening

Overview: During manufacturing, 100 percent of all electrical assemblies should be stressed to reveal workmanship defects before product acceptance. Vendor problems, as well as in-house manufacturing problems, can be identified from the use of Environmental Stress Screening (ESS) techniques. ESS is often misapplied or confused with the environmental envelope in which the product must successfully function.

Traps!

1. ESS is required for production
2. Manufacturing ESS levels do not exceed design qualification levels
3. Environmental stress screens are standardized
4. Manufacturing defects are eliminated by ESS



Manufacturing Screening

Benefits

Engineering can concentrate on design problems during development	Effectiveness of ESS screen will be optimized	Defects will be detected at lowest level of assembly	Reduction in in-plant failure rates will approach 75 percent

Escapes

Design ESS program during development Conduct ESS on development hardware	Conduct ESS in accordance with DoD 4245.7-M	Adjust screens based on results to maximize finding defects	Take vigorous corrective action to adjust the manufacturing process to minimize recurring defects

Best Practices

TRAPS

1. ESS is required for production	2. Manufacturing ESS levels do not exceed design qualification levels	3. Environmental stress screens are standardized	4. Manufacturing defects are eliminated by ESS

Current Approach

Alarms

ESS is not conducted during FSD Excessive quality problems are found during development	Design and ESS requirements are perceived to be compatible	Yield during FSD is approximately 100 percent Temperature cycling and random vibration regimes are not being tailored	Corrective action includes only the repair of defective hardware

Consequences

Design and quality problems unduly impact the design phase	Workmanship defects escape detection	First pass yield at acceptance test shows no improvement	Causes of defects remain uncorrected

Manufacturing Screening

Summary: Environmental Stress Screening (ESS) is often considered an "add on" requirement introduced during production. As a result, design engineering often considers the temperature and vibration techniques of ESS to be environments that will "break" the hardware. Consideration of ESS during the development phase precludes any concerns that ESS techniques will overstress the design.

ESS limits may exceed the limits of the environmental envelope required for product performance. Qualification testing assesses design maturity and the ability of the hardware to function in its environmental envelope. In contrast, ESS stresses the hardware in a nondestructive manner to stimulate parts and workmanship defects in electronic assemblies. Therefore, the ESS temperature and vibration limits may be significantly different than the qualification test environments. Power should be applied to the hardware to the maximum extent practical. Power should not be applied when the hardware is exposed to temperature outside the hardware's operating limits.

A common misconception is that ESS is a rigid program with standardized technical requirements that must be executed only at the highest practical assembly level. Practice dictates a dynamic program that allows for intelligent tailoring of temperature limits, number of temperature cycles, temperature rate-of-change, etc., and the level of assembly where best applied in the manufacturing process.

Burn in testing and environmental stress screening are sometimes considered identical. Burn in tests require operating the hardware at elevated temperatures for an extended period of time (typically, over 100 hours). ESS uses a combination of temperature cycling and random vibration, and a reduced test duration. Burn in tests primarily precipitate parts of semiconductor defects; ESS techniques primarily precipitate assembly and workmanship defects such as poor soldering or weak wire bonds.

Temperature cycling and random vibration are the most efficient environmental stress screens. ESS requirements should be tailored during the design process, and any necessary tradeoffs between the most effective screening limits and ESS compatibility with the design should be completed during FSD. It is key to remember that manufacturing screening is not intended to damage the hardware; it is intended to stimulate parts and workmanship defects.

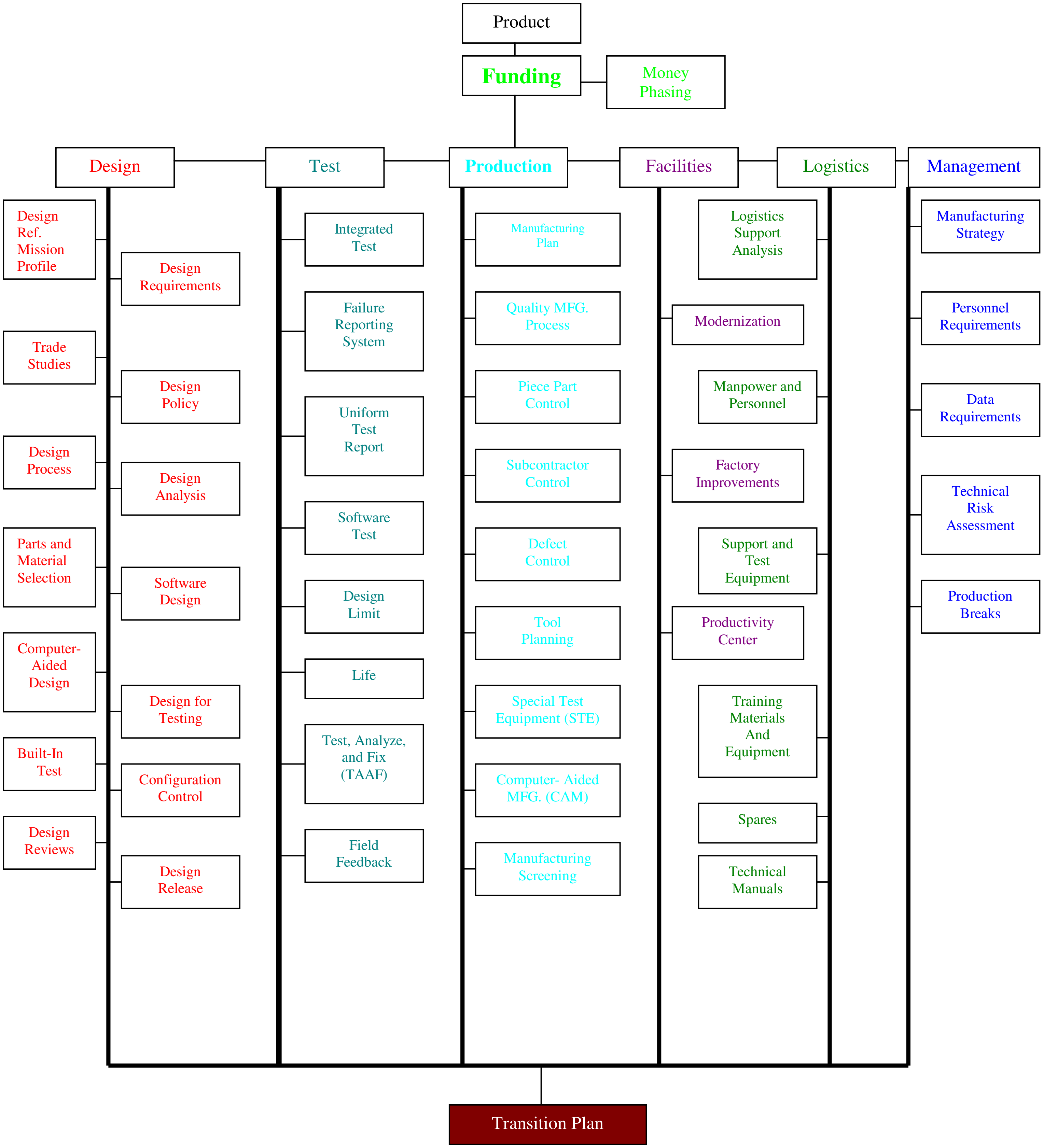
Effective use of ESS requires flexibility. ESS techniques at the highest practical level of assembly, using a combination of temperature cycling and random vibration, is an excellent starting point. The number of cycles depends on the complexity of the hardware. The temperature rate of change is another key parameter. A 10° to 15°C/min temperature rate of change is most effective in precipitating assembly and workmanship defects. A random vibration regime that includes 6g rms at frequencies between 100 to 1000 Hz for a 10-minute total duration on three axes is recommended. Power should be applied to the hardware for maximum effectiveness. The combination of parameters, including their levels, chosen for ESS in a particular application should be proofed during development and adjusted as appropriate during production. Further technical guidance on using ESS techniques can be found in DoD 4245.7-M.

Depending on the nature of defects found, it may be cost-effective to introduce ESS techniques at other points in the manufacturing process (e.g., after the circuit card soldering is completed). One purpose of ESS at this point in the manufacturing process is to reduce expensive rework at the higher assembly levels.

Manufacturing Screening

Checklist

- ✓ Is ESS considered a standard manufacturing process?
- ✓ Are subcontractors required to implement ESS?
- ✓ Have ESS requirements been tailored and proofed during development?
- ✓ Is ESS conducted in accordance with DoD 4245.7-M?
- ✓ Is ESS done on 100 percent of the electronics hardware delivered?
- ✓ Are manufacturing processes/procedures corrected based on ESS results?
- ✓ Have ESS screens been adjusted to maximize finding defects?

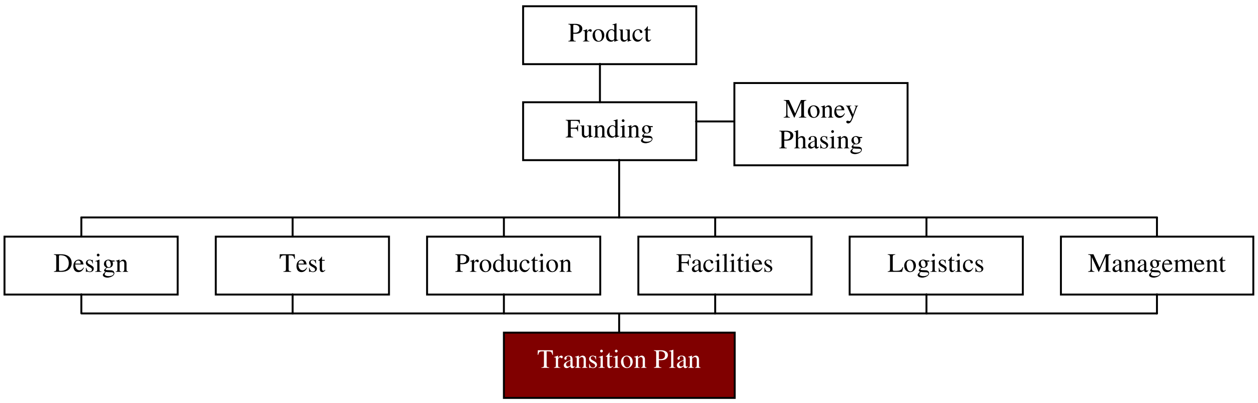

Product
Funding
Money Phasing
Design
Test
Production
Facilities
Logistics
Management
Design Ref. Mission Profile
Design Requirements
Trade Studies
Design Policy
Design Process
Design Analysis
Parts and Material Selection
Software Design
Computer-Aided Design
Design for Testing
Built-In Test
Configuration Control
Design Reviews
Design Release
Integrated Test
Failure Reporting System
Uniform Test Report
Software Test
Design Limit
Life
Test, Analyze, and Fix (TAAF)
Field Feedback
Manufacturing Plan
Quality MFG. Process
Piece Part Control
Subcontractor Control
Defect Control
Tool Planning
Special Test Equipment (STE)
Computer- Aided MFG. (CAM)
Manufacturing Screening
Modernization
Factory Improvements
Productivity Center
Logistics Support Analysis
Manpower and Personnel
Support and Test Equipment
Training Materials And Equipment
Spares
Technical Manuals
Manufacturing Strategy
Personnel Requirements
Data Requirements
Technical Risk Assessment
Production Breaks
Transition Plan

TRANSITION PLAN
Transition Plan

Overview: The application of the principles briefly discussed in the templates for design, test, and manufacturing is necessary for the successful accomplishment of the engineering tasks on schedule. Integrated with and pervading this effort are the activities presented within the templates for facilities, logistics, and management. The scope and interactions for this multidiscipline approach to risk reduction during development and production are significant. A transition plan (DoD 4245.7-M) is necessary to identify the timing and application of the different disciplines, the risk-driving interrelationships, and particularly how and when execution of the plan is to be evaluated. To be effective, the transition plan should be available at the start of engineering development and updated regularly until full production occurs.

Traps!

1. Transition plan is reviewed and approved by government at Milestone III
2. Transition plan is internally developed and approved by contractor
3. Transition plan is required by contract
4. Contractor is planning for an 80 percent learning curve



Transition Plan

Benefits

All transition activities will be identified and managed	Corporate resources will be available to support the transition plan	Perturbations during production start up will be minimized	Learning process will not be required

Escapes

Contractor should prepare and use a transition plan during early FSD	Review and approve transition plan at corporate level	Reflect an integrated corporate strategy in the transition plan: • collocation of manufacturing and design team • make or buy decisions • capital investment considerations • personnel recruiting and retention	Contractor should define and fully implement a transition plan

Best Practices

TRAPS

1. Transition plan is reviewed and approved by government at Milestone III	2. Transition plan is internally developed and approved by contractor	3. Transition plan is required by contract	4. Contractor is planning for an 80 percent learning curve

Current Approach

Alarms

Contractor fails to generate and use the transition plan prior to production start up	Transition plan is developed and approved only by the contractor project office	Manufacturing plan is presented as a transition plan Primarily production processes and equipment are addressed by transition plan	Contractor expects to achieve the 80 percent learning curve by improving worker skills

Consequences

Much of the benefit of transition planning is lost	Transition plan may be limited in scope	The government pays for a transition plan but doesn't get one	Process is extremely slow and costly

Transition Plan

Summary: Management of a major weapon system from development to production requires the effective administration and coordination of a multitude of activities. Large financial commitments are made during this time, based on detailed planning of these activities. Past efforts at coordinating and integrating these activities, in order to minimize cost and shorten development schedules, have failed to consider critical elements needed to provide a smooth transition from development to production. These past integration efforts have failed to recognize that transition from development to production is not an event with a readily identifiable starting point in the acquisition process. Transition planning must be considered throughout all phases of the acquisition process including design, test, and initial production.

Recognizing that one of the end objectives of all development projects is the efficient and economical rate production of the item under development, planning for this objective must be considered throughout all project phases. A transition plan – which is a comprehensive management plan describing all production-related activities (including management, personnel, and facilities) that must be accomplished during design, test, and low rate initial production – is needed to ensure a smooth transition from development to full rate production.

In order to be effective, a transition plan should be prepared and in use by the contractor during the early phases of Full-Scale Development (FSD), since it is during this phase of a project that many tradeoffs are made which can eventually have a significant impact on production processes, procedures, and facilities. A transition planning team should consist of representatives from all involved organizations. A typical planning team might be organized as follows:

- Manufacturing operations, team leader
- Facilities
- Engineering (design and test)
- Quality assurance
- Materials
- Finance
- Fabrication, planning, and tooling
- Human resources
- Configuration management
- Industrial engineering
- Operations control
- Manufacturing engineering
- Manufacturing planning

Although the contractor project office will be responsible for developing and updating the transition plan, the plan must have corporate level review, approval, and support, in order to ensure the availability of corporate resources for implementing the plan. The plan should reflect an integrated corporate strategy covering such items as collocation of the design and manufacturing team, make or buy decisions, capital investment considerations, and personnel recruiting and retention.

As part of the design process, many tradeoffs and design iterations are made which will have an impact on manufacturing. The transition plan should include provisions to ensure that manufacturing personnel will participate in this decision-making process, to properly influence the design, and to ensure that the final design is capable of being economically produced at the desired rates and with adequate quality.

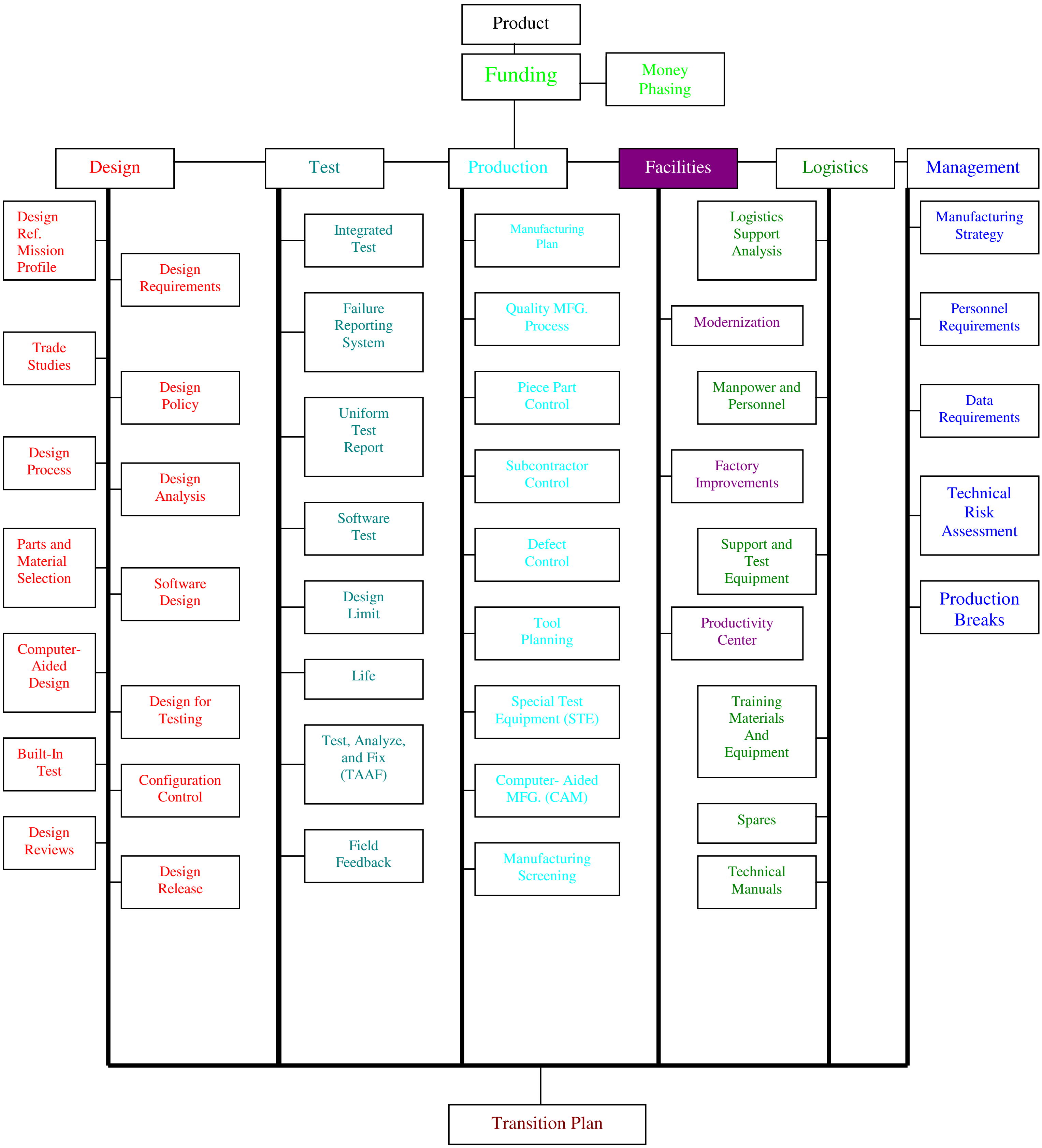
During FSD there are many time-consuming, production-related activities which must be planned and initiated well in advance of production. The need for additional capital equipment or plant facilities, for example, could require significant time and resources to ensure their availability prior to production start. Fabrication of special tooling and test equipment, or the procurement of long lead materials also might require special consideration. These activities often are documented in other planning documents such as manufacturing plans, make or buy plans, personnel plans, facilities plans, etc. The transition plan should be the one overall planning document which integrates and coordinates these separate plans and provides milestones for their implementation.

At the initiation of production, contractors have traditionally planned for a learning curve, or gradual reduction in man-hours required to manufacture the product, by improved worker skills, producibility changes, improved tooling and test equipment, etc. A typical learning curve of 80 percent might be planned, which means that the time required to manufacture the second system is 20 percent less than the first, the time required to manufacture the fourth system is 20 percent less than the second, the eighth system is 20 percent less than the fourth, and so on. If the contractor has a well defined and fully implemented transition plan, the various improvements which cause the learning curve to occur will have been implemented before the initiation of production. This should, in effect, eliminate the learning curve. That is, the man-hours required to manufacture the product should be close to their minimum at the start of production.

Transition Plan

Checklist

- ✓ Is the contractor required to have a transition plan? Is it funded?
- ✓ Has the contractor implemented a well-defined transition plan during early full-scale development?
- ✓ Does the contractor's transition plan reflect an integrated corporate strategy concerning such activities as:
  - Collocation of the manufacturing and design team
  - Make or buy decisions
  - Capital investment decisions
  - Personnel recruiting and retention?
- ✓ Does the contractor's transition plan have corporate-level approval?
- ✓ Does the contractor's transition plan present details on how and when the execution of the plan is to be evaluated?



Product
Funding
Money Phasing
Design
Test
Production
Facilities
Logistics
Management
Design Ref. Mission Profile
Design Requirements
Trade Studies
Design Policy
Design Process
Design Analysis
Parts and Material Selection
Software Design
Computer-Aided Design
Design for Testing
Built-In Test
Configuration Control
Design Reviews
Design Release
Integrated Test
Failure Reporting System
Uniform Test Report
Software Test
Design Limit
Life
Test, Analyze, and Fix (TAAF)
Field Feedback
Manufacturing Plan
Quality MFG. Process
Piece Part Control
Subcontractor Control
Defect Control
Tool Planning
Special Test Equipment (STE)
Computer- Aided MFG. (CAM)
Manufacturing Screening
Logistics Support Analysis
Modernization
Manpower and Personnel
Factory Improvements
Support and Test Equipment
Productivity Center
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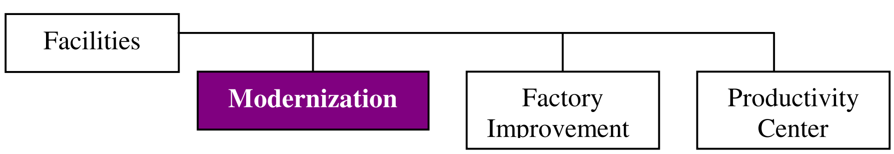
Technical Manuals
Manufacturing Strategy
Personnel Requirements
Data Requirements
Technical Risk Assessment
Production Breaks
Transition Plan

FACILITIES
Modernization

Overview: The production of more sophisticated weapon systems directly translates into the requirement for modern state-of-the-art manufacturing equipment on the factory floor. Factory modernization is essential to cost-effective production of today's sophisticated weapon systems.

Traps!

1. Cost-plus contract is used after Milestone III
2. Two-year Return On Investment (ROI) is planned
3. Corporate policy on plant modernization is in place
4. New capital equipment is installed



Modernization

Benefits

Contract will be structured to encourage factory modernization	Capital investment tradeoffs will be based on long-term benefits	Modernization program will decrease production cost and increase profit	Production yields will improve and rework activity will decrease

Escapes

Structure contracts to increase profits as production costs decrease Use cost-plus-incentive or fixed price contract arrangements to the maximum degree practicable	Consider in ROI decisions the beneficial dollar impact on other manufacturing operations (i.e., higher total throughput, improved material handling, higher quality acceptance ratio)	Document aggressive, long-term corporate policy Make technical levels aware of long-term corporate objectives Establish modernization as a team effort including all functional departments	Take a systems approach to plant modernization Assess impact on plant functions (e.g., do a plant layout analysis, determine change in work loading and unloading)

Best Practices

TRAPS

1. Cost-plus contract is used after Milestone III	2. Two-year Return On Investment (ROI) is planned	3. Corporate policy on plant modernization is in place	4. New capital equipment is installed

Current Approach

Alarms

Profit is a fixed percentage of production cost	Only immediate problems are solved by quick-fix attempts at modernization	Interface problems are created in the factory by plant modernization New equipment is purchased that has too little capability for its intended function	There is no implementation plan that addresses the phase in of new equipment New equipment utilization is adversely affected by unbalanced work flow New equipment is not tailored to specific manufacturing processes

Consequences

Long-range factory modernization plans are deterred	There is no appreciable change in productivity or the cost to produce	Modernization cost is high, with minimal increase in productivity	ROI on plant modernization is slow

Modernization

Summary: In the commercial sector, the amount of profits is generally directly proportional to the reduction of overall production costs. Hence, any cost reduction effort including factory modernization is considered favorably by corporate management.

On government products, profits are considered as a fixed percentage of the cost to produce. Therefore, any factory modernization effort that reduces production costs also reduces company profit. Hence, a disincentive to modernize facilities associated with government products exists.

Where modernization efforts have been introduced, those efforts have been typically limited to “quick-fix” improvements implemented in an unplanned, “piecemeal” fashion. Emphasis has been on immediate or near-term payback, as opposed to longer term benefits such as (1) the future ability to compete or (2) the advance manufacturing capability that ensures the capability to produce a future generation of product. This approach frequently leads to problems in later integration of discrete modernization tasks into an efficient total manufacturing operation. Those integration problems compound the difficulty in convincing corporate management of the benefits accrued by investing in factory modernization.

An aggressive long-range company policy and objectives statement leads to the integration of factory automation technology and improved management system capability. The use of semiautomatic equipment, particularly in electronics manufacturing, has proven essential in reducing transition risk. Indeed, in some instances 200 percent improvement in defect rates has been achieved. Corporate attitude is a key element in encouraging factory modernization.

The long-term benefits should be considered along with the cost of equipment, proofing, and direct increases in productivity. Long-term objectives should involve increasing use of automated methods in conjunction with the growing application of computer-controlled manufacturing. Those long-term benefits can best be analyzed if a corporate policy exists that establishes the capability and mix of product that is desired within the next five to ten years. This corporate long-range plan should be flowed down to the appropriate technical levels, so that an integrated modernization plan can be developed. Also, in any modernization effort, the contractor long-range policy should include flow down to all subcontractors. The proposed improvements should be consistent with the contractor’s long-range strategic objectives. A thorough analysis should be performed on any proposed improvements, and those improvements must be validated before implementation on the factory floor. This approach results in a workable modernization plan that increases productivity, and allows for an integrated and coordinated factory. Modernization incentives then can be compared to the technical merit intelligently assessed. The upfront cost associated with some state-of-the-art manufacturing equipment precludes the use of a short-term Return On Investment (ROI) strategy without a careful look at those long-term benefits that are consistent with corporate long-range planning.

The government also can encourage modernization. Why modernize? From the government's perspective, increased productivity reduces the cost to produce. The funding profile also is quite attractive. The government prefers contractor funding but the contractor's investments may be guaranteed by the government when appropriate. As a result of the government's Industrial Modernization Incentive Program (IMIP), both the contractor and the government share in the cost savings. The overall objective of the program is an increase in the rate of modernization.

Modernization

Checklist

- ✓ Is there a corporate long-term strategy for plant modernization?
- ✓ Does integrated modernization planning correlate with corporate long-term objectives?
- ✓ Does the decision making process address more than a short-term ROI?
- ✓ Do profit incentives encourage modernization?
- ✓ Are cost-plus-incentive or fixed price contract arrangements appropriate for this procurement?

Factory Improvements

Overview: In-plant failures from manual errors in assembly and test contribute to excessive rework and repair costs. The use of semiautomatic equipment in electronics manufacturing and the use of state-of-the-art equipment can provide, at a minimum, worker aids that will prevent many common workmanship errors.

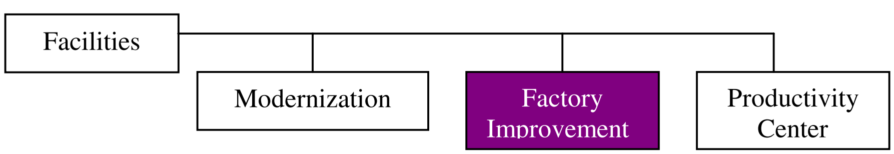
Traps!

1. Factory improvements to increase production rate are not justified

2. Only the assembly line is impacted by factory improvements

3. Existing factory facilities are considered adequate

4. Production requirements can be met by a highly skilled work force



Factory Improvements

Benefits

The manufacturing operation will be efficient and productive	Manufacturing paper work will be minimized	New equipment and processes will be introduced with low risk	Employee relations will be better and productivity will be improved

Escapes

Verify that at least the following improve-ments are in use: • computer-assisted parts kitting • semiautomatic circuit board • optical comparators • wave soldering	Use terminals in lieu of paper at work-stations, automated shoploading and per-formance reporting, with access to a common CAD/CAM database Use on-line down-loading of product configuration changes	Perform a detailed cost/productivity analysis comparing new equipment and processes to the capabilities of existing facilities	Seek worker advice on problem areas and solutions to factory problems Improve the skills of personnel by providing "hands on" experience before new equipment is used on the factory floor

Best Practices

TRAPS

1. Factory improve-ments to increase production rate are not justified	2. Only the assembly line is impacted by factory improvements	3. Existing factory facilities are considered adequate	4. Production require-ments can be met by a highly skilled work force

Current Approach

Alarms

Kits for electronic assemblies are prepared manually Process/configuration control is made difficult by excessive in-process paper work	Manual schedule/ planning system causes assembly line delays Configuration control system response is sluggish compared to factory floor Product assembly ceases to accommo-date equipment repro-gramming for the next scheduled assembly	Productivity remains constant No improvement is shown in yields Personnel turnover is high	Inconsistencies in yield attributable to human error are limiting productivity gains Lengthy training period is required for new production line worker

Consequences

"Hidden factory" is generated	Return on investment may not be realized	Ability to compete in the military market place is gradually lost	Production rate is highly worker-dependent

Factory Improvements

Summary: Circuit board and semiconductor device technology has increased to the point where manual operations in component insertion, soldering, and test have become increasingly difficult for the assembly line worker. Even with good work instructions, errors often do occur and are not identified until a rework and repair operation is necessary. Some test operations on circuits that contain software are prohibitively time consuming when performed manually. Unfortunately, the production rates on military hardware, such as missiles and tactical computers, often are not considered sufficient to justify the introduction of automatic assembly equipment. Therefore, we remain content with manufacturing state-of-the-art electronics using the processes and procedures that are obsolete. Production rate should be a basis for determining the degree of factory automation; but is not an excuse for *not* taking the steps necessary to ensure efficient product manufacture.

Changes on the factory floor are often considered as discrete, isolated events that only impact the assembly line worker. With the introduction of any assembly aid or semi-automated equipment, consideration must be given to the other plant operations that are likely to have an increased workload. For example, consider a plant operation that introduces a fully automated production line but has not considered upgrading the materials and yield tracking capability from a manual method of operation. In such a case, it will not take long for spot material shortages to appear and the availability of yield information will be obsolete before it can effectively be used. The result should be obvious! Any anticipated gain in productivity, reduced production costs, or improved production rate will not be achieved. In fact, it may appear that it was more cost-effective to fabricate electronic assemblies using manual techniques.

The type of facility involved in the manufacture of the end item product should be consistent with an accurate assessment of current manufacturing operations, the ability to perform the job, the knowledge and implementation of technology improvement projects (along with the necessary capital investments), and the necessity to reduce production costs and sustain production efficiency and product quality.

On low rate production lines, assembly aids for manual component insertion, the use of optical comparators for visual inspection of circuit cards, and programmable cable assembly equipment is cost-effective. A semi-automated transport system that provides controlled material flow for peak production efficiency also should be used.

The decision to introduce automated insertion equipment should be based on the anticipated production rate for a family of product types. Cost analysis comparing manual operations to the use of semi-automated equipment should be conducted using the number of component insertions per month for the family of product types. The results of the cost tradeoff should be a predominant factor in the decision to use automated insertion equipment.

Some degree of programmable test equipment is critical to the efficient testing of today's electronics circuit cards and assemblies. As a minimum, in-circuit test equipment that verifies the integrity of circuit assemblies before soldering, and programmable functional test equipment should be evident.

As assembly aids and automation are introduced on the factory floor, other areas for facilities improvement should be considered. For example, a material and process control system can accurately provide for the location of the components within the plant, the status of the operations completed on subassemblies currently "in-process," and routing directions for the balance of the process. Methods based on a manual process prohibit timely responses to project changes, inhibit different functional areas from accomplishing more discrete and finite scheduling tasks, and above all, cause excessive schedule delays within the manufacturing cycle.

Utilization of computers to support manufacturing processes, using a common design and manufacturing database should be considered as facilities improvements are made. Also, computer graphics capability can reduce the drafting tasks by 10 to 40 percent over the standard drafting board approach with the added advantage of enhanced accuracy and quality.

Current blueprint control systems are another candidate for computer assistance. Manual blueprint control systems require considerable lead time. Drawing revisions take too long because the system is technically antiquated resulting in operators using obsolete information. On-line computer access at key operator stations affords the capability of working with the latest drawing revisions. Many delays in completion of product fabrication can be attributed to the complexity of the planning paper that must travel with it. Using computerized technology can reduce the typical factory paper work such as planning sheets, routing sheets, work loaders, assembly instructions, and quality control documents.

Automated test and tracking techniques should be developed as part of the facilities improvement effort. Such test and tracking techniques can monitor where key parts are located through the manufacturing process and provide a real-time status of work-in-process assemblies. It can record test results and perform statistical tolerance analysis. Tracking techniques also provide for the location and progress of the processed item against the commitment baseline.

Factory Improvements

Checklist

- ✓ Are the following evident: computer-assisted parts kitting, semiautomatic circuit board assembly, optical comparators, and wave solder capability?
- ✓ Is the contractor using terminals in lieu of paper at workstations, automated shoploading, and performance reporting, with access to a common CAD/CAM database?
- ✓ Are detailed cost/productivity analyses performed to compare new equipment and processes to the capabilities of existing facilities?
- ✓ Does the contractor seek worker advice on problem areas and solutions to factory problems?
- ✓ Are personnel skills being improved by providing "hands on" experience before new equipment is used on the factory floor?

Productivity Center

Overview: Increases in plant productivity provide the potential for lower costs for product manufacture, and enhance a contractor's competitive position in the market place. The introduction of new manufacturing equipment and processes on the factory floor has the potential for dramatic increases in productivity. However, costly disruptions on the production line, as new manufacturing techniques are introduced in the factory, often reduce or eliminate anticipated gains in productivity. "Off-line" evaluation of new manufacturing techniques, and "off-line" worker retraining will significantly reduce those costly disruptions. A productivity center provides such an "off-line" capability.

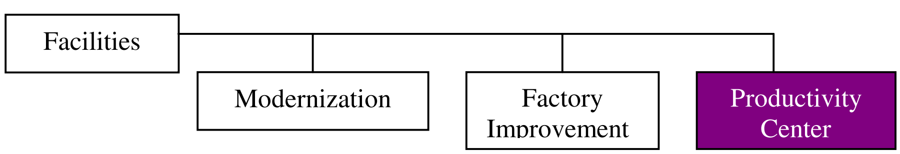
Traps!

1. Productivity is improved by introduction of new technology equipment

2. Operators are trained for specific projects

3. Individual skills are improved by formal classroom training

4. Operators are trained "on-the-job"



Productivity Center

Benefits

Introduction of new equipment on the factory floor will be smooth	Off-line operator training and certification will be comprehensive	Trainees will not be released to production tasks until skill levels meet production standards	Operators will receive rapid training and qualification without loss of production

Escapes

Proof the capabilities of new hardware and software off-line	Use an "off-line" productivity center for operator training and retraining	Integrate classroom training and hands on experience through the use of a productivity center	Train production personnel using "proof of manufac-turing" models in an off-line productivity center

Best Practices

TRAPS

1. Productivity is improved by introduction of new technology equipment	2. Operators are trained for specific projects	3. Individual skills are improved by formal classroom training	4. Operators are trained "on-the-job"

Current Approach

Alarms

New equipment is installed directly on the production line No plans are made for proofing new equipment	A uniform corporate training program is lacking Centralized, off-line training facilities don't exist	Little or no "hands on" training is included in the formal training program	Operators are only trained on the factory floor

Consequences

Potential for start-up problems is high	Skill levels vary from project to project	Newly trained operators sustain high error rates	Higher production reject rates occur during the training period

Productivity Center

Summary: Industry and government are being challenged with competition throughout the world. In order to meet this challenge, we must have continuous improvement in people, technology, information systems, and capital expenditures. The productivity center is a way for an organization to concentrate resources to effectively meet this challenge. Unfortunately, the use of productivity centers often lacks specific guidelines and procedures. Productivity centers often are considered at the start of the production phase, and in some instance are considered an option of the individual project manager. In other cases, the training of people and certification of equipment, tools, and processes is the sole financial burden of the individual project. Such an approach can lead to late or inadequate personnel training and manufacturing process qualification, and contribute to unfamiliarity with new equipment and processes until the equipment is first introduced to the factory floor.

One of the main goals of a productivity center should be to increase the quality and amount of work output from each individual. Such increased productivity is influenced by multiple factors including: the technology and its effective application; the information and information systems people work with; timely integration and application of resources to the job; training and retraining consistent with new and existing manufacturing processes and procedures; and finally, the commitment by people to do the job right – the first time. The hypothesis is that individuals in a self-motivating environment, if given adequate tools and provided with adequate training, will perform in a competent manner. To increase productivity will then be to continue to find better ways of doing assigned tasks.

The efforts of the productivity center must be supported by corporate policy and implemented independent of specific project requirements. Formal guidelines and indices of measurement are essential to a good productivity center. A closed-loop management effort that involves all levels of the organization contributes to individual support for the productivity center and will enhance worker motivation and the number of creative ideas generated in the productivity center environment. Some areas that can effectively be explored in a productivity center include:

a. Development of training modules in new or changed manufacturing processes that will be applied in different manufacturing and engineering organization learning centers. A measure of the impact on the delivered product is necessary before implementing changes and training people in the new production process.

b. Research and development of new processes and approaches that will implement advance design technology. The objective is to have manufacturing processes ready to produce advance design approaches.

c. Establishment of guidelines and procedures which yield higher productivity by all functions in the design and manufacturing cycle.

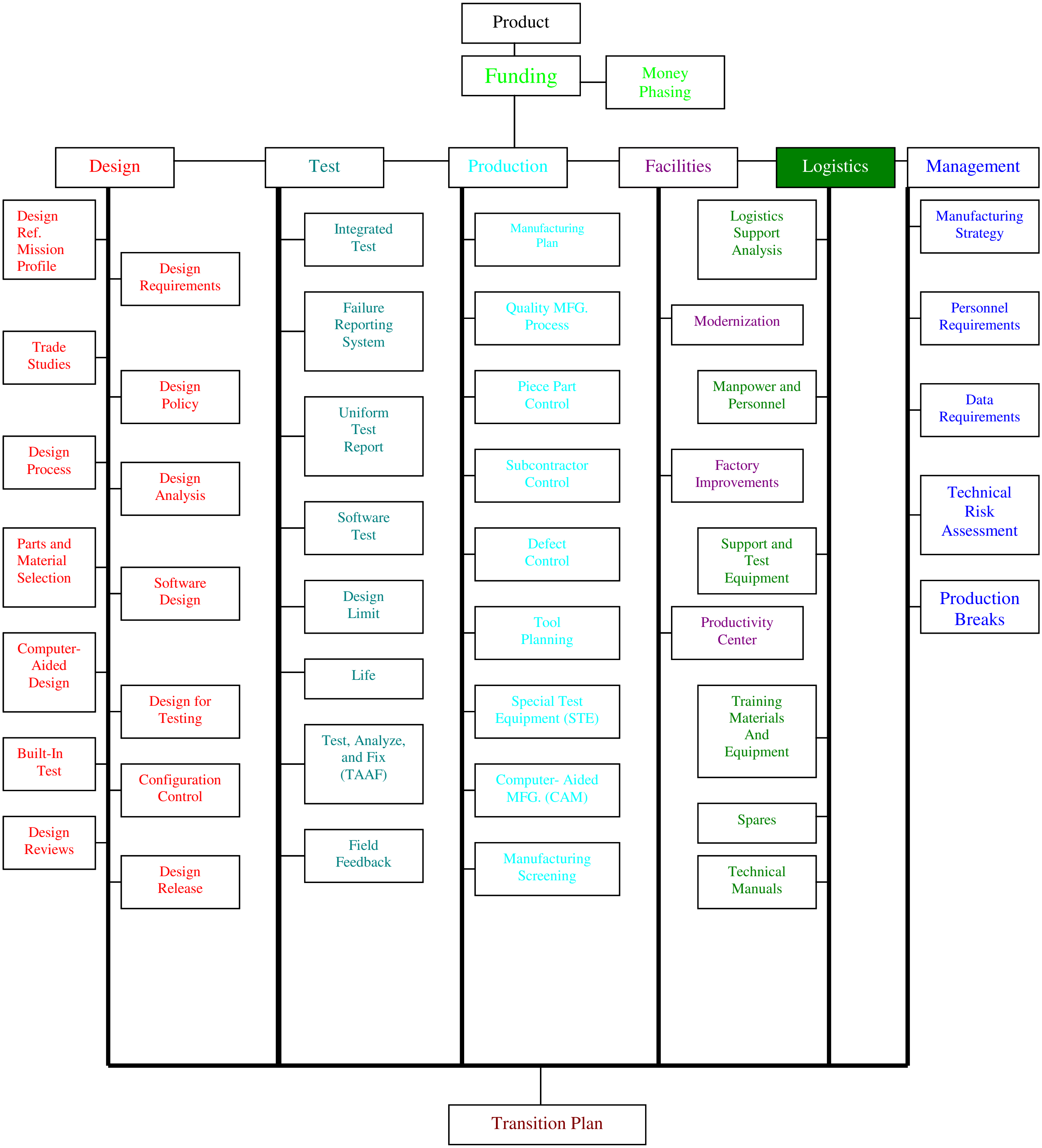
d. Development of optimum methods of accomplishing existing work tasks through direct worker involvement off-line. This approach is based on full teamwork and provides each worker with the opportunity to participate in establishing goals and improvements. The anticipated result is increased worker productivity because of the sense of worker ownership towards the team goals.

e. Worker training using both classrooms and "hands on" experience. Such a training and recertification program should include:
   - General product orientation and end item use
   - The manufacturing facility and the individual's role in it
   - Computer-aided design and manufacturing
   - Management information systems
   - New or changed manufacturing equipment, processes, or techniques tailored to a particular product application

Productivity Center

Checklist

- ✓ Is planning for proofing of new equipment completed?
- ✓ Are the capabilities of new equipment and software proofed off-line?
- ✓ Is an “off-line” productivity center available for operator training and retraining?
- ✓ Are classroom training and hands on experience integrated through the use of a productivity center?
- ✓ Is “hands on” training included in formal training programs?
- ✓ Are production personnel trained using proof of manufacturing models in an off-line productivity center?



Product
Funding
Money Phasing
Design
Test
Production
Facilities
Logistics
Management
Design Ref. Mission Profile
Design Requirements
Trade Studies
Design Policy
Design Process
Design Analysis
Parts and Material Selection
Software Design
Computer-Aided Design
Design for Testing
Built-In Test
Configuration Control
Design Reviews
Design Release
Integrated Test
Failure Reporting System
Uniform Test Report
Software Test
Design Limit
Life
Test, Analyze, and Fix (TAAF)
Field Feedback
Manufacturing Plan
Quality MFG. Process
Piece Part Control
Subcontractor Control
Defect Control
Tool Planning
Special Test Equipment (STE)
Computer- Aided MFG. (CAM)
Manufacturing Screening
Modernization
Factory Improvements
Productivity Center
Logistics Support Analysis
Manpower and Personnel
Support and Test Equipment
Training Materials And Equipment
Spares
Technical Manuals
Manufacturing Strategy
Personnel Requirements
Data Requirements
Technical Risk Assessment
Production Breaks
Transition Plan

LOGISTICS
Logistics Support Analysis

Overview: The Logistics Support Analysis (LSA) program is established and maintained as part of the ILS program throughout the life cycle of the system and equipment. The primary objectives of the LSA are: (a) to define readiness and support related performance parameters for integration into the systems engineering process; (b) to affect the design of the weapon and weapon support system as an initial part of the design analysis and design review processes; and (c) to provide accurate weapon system support requirements information for use in acquiring operational phase resources. An effective LSA program will assist in achieving the best balance between cost, schedule, performance, and supportability characteristics of the weapon system.

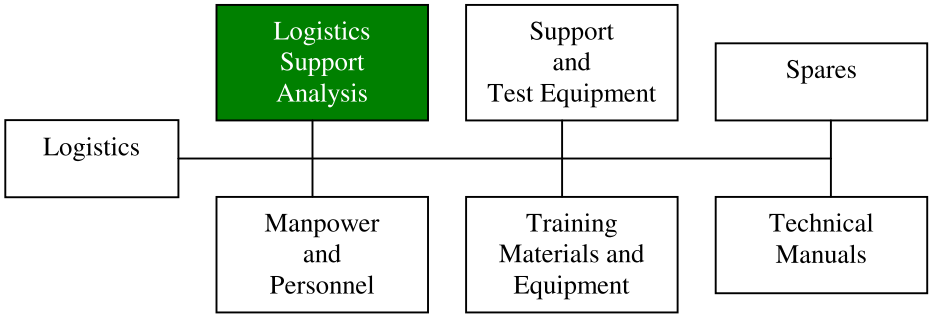
Traps!

1. LSA is required to establish a logistics support program

2. Contractor is given responsibility to develop the LSA program

3. LSA is funded as a data item

4. Logistics related design parameters are established after other performance parameters



Logistics Support Analysis

Benefits

Problems are minimized before operational use	LSA represents conditions that the system will encounter operationally	The LSA impacts design to cause changes before the design is finalized	Management assessment & control can be established & maintained over all technical performance parameters including those affecting readiness and support

Escapes

All engineering groups including design, production, and logistics, coordinate to identify and resolve potential problems during initial design	Customer is involved with developing LSA input data as a team effort	LSA is a continuous engineering process throughout the project The LSA identifies and resolves potential problems during design	LSA is treated in the same manner, and at the same time, as other engineering design analytical efforts LSA is used to determine & assess design requirements, constraints, & design features

Best Practices

TRAPS

1. LSA is required to establish a logistics support program	2. Contractor is given responsibility to develop the LSA program	3. LSA is funded as a data item	4. Logistics related design parameters are established after other performance parameters

Current Approach

Alarms

LSA is considered a subset of maintainability LSA is considered as a data item and the basis for setting up the logistics system	Customer is not involved with furnishing data for the LSA program Assumptions used in LSA are made primarily by contractor engineers	LSA is not staffed as a continuous process Major LSA milestones are shown as data submittals Project management and the customer only review the LSA when submitted	LSA is considered to be the way to assess & report on the consequences of the design; a reportive process only LSA does not result in development of parameters that are included in system & development specifications LSA results are not, or cannot be, used in the design control process

Consequences

Maintenance, logistics, and cost problems are transferred to the field	LSA doesn't reflect actual operational conditions thus resulting in wrong supportability & design to requirements	Many potential problems are not resolved due to lack of action between submittals	Readiness and support characteristics of the design are no in balance with other performance features

Logistics Support Analysis

Summary: Conflicting requirements for high Operational Availability (A_o) and for low Life Cycle Cost (LCC) force us into tradeoffs during design. The Logistics Support Analysis (LSA) can facilitate better design by defining A_o and LCC related design requirements and identifying when those requirements are not being met.

Like any design analysis, the LSA is an iterative process to inject and manage system support criteria during the design process. Alternative hardware designs are evaluated, quantitatively and qualitatively, relative to their impact on operational readiness/ availability and on meeting logistics support specifications. Design tradeoffs are made using the results of the design analyses including the LSA. Like drawings, parts lists, and production specifications, the LSA Record (LSAR) provides the necessary logistics resource data.

The systems engineering approach necessary for effective tradeoff efforts during the design phase must be based on specified requirements as well as clearly defined concepts of operation, maintenance, and support. Of particular importance, the LSA assists in developing (1) the maintenance concept (e.g., organizational level repair as compared to removal and replacement), (2) the extent of Built-In Test (BIT) design requirements and associated impact on maintainability and reliability specifications, and (3) special supply support requirements associated with a specified Ao.

When a designer fully understands all the design requirements and constraints, there are fewer false starts. To facilitate this understanding the design engineer should have available to him, all analytical feedback on his design. The LSA is part of that feedback mechanism.

The LSA, when treated as an integral part of the systems engineering process, provides both the designers and management with the tools to affect the design to achieve a balance between cost, schedule, performance, and supportability.

Logistics System Analysis

Checklist

- ✓ Is the LSA effort continuously providing timely design, management, and control information?
- ✓ Does the effort start with the initial design?
- ✓ Is LSA integrated into the design analysis and design review processes?
- ✓ Are the engineering analyses coordinated (tradeoff analyses) to achieve a cost-effective impact on design as early as possible?
- ✓ Does the LSA provide quantitative parameters used in the system and design specifications?

Manpower and Personnel

Overview: Manpower and personnel skill requirements and constraints must be determined early in the conceptual phase. Logistics Support Analysis (LSA) studies need to examine not only the technologies to be employed, but also the availability of manpower during the deployment and operation phase. System design specification requirements should reflect the results of the LSA studies in quantitative as well as qualitative terms. Designs that result in excessive manpower requirements or inappropriate skill levels may adversely affect overall weapon system availability. Costly redesign, and/or damaging redistribution and training of personnel from other weapon systems, may have to be used to correct manpower/skill caused problems.

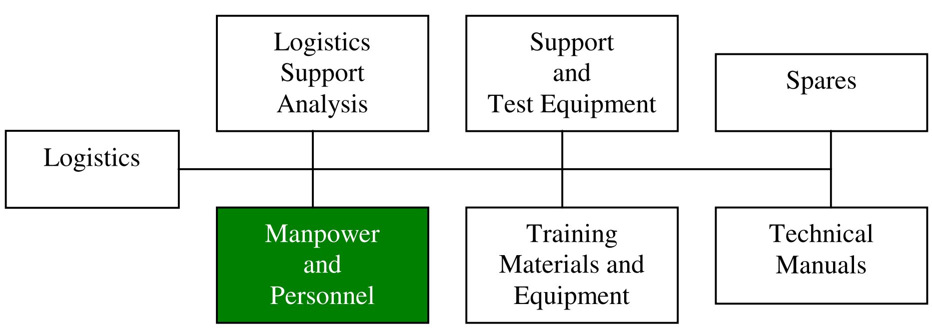
Traps!

1. Manpower and skill level requirements are derived from the LSA task analysis results

2. Manpower and skill analyses are based on experience from previous systems

3. Manpower planning is based on current manpower availabilities and skill levels

4. Published manpower space and overhead costs are used for design and support studies



Manpower and Personnel

Benefits

Manpower and skill level constraints on the design are known, and the resultant design demands only available manpower and permits timely training of personnel	Unique manpower support requirements will be identified early	Manpower needs and skill levels will be compatible with equipment complexity	Realistic manpower costs will be utilized in design and support analyses

Escapes

Perform formal manpower and skill level analyses as part of the pre-conceptual phase Make manpower and skill level parameters part of the system and development specifications	Analyses of prior projects are tailored to current project needs Unique aspects of each new design are analyzed for unusual support requirements	Manpower and skill requirements are based on formal analysis using current and projected equipment design features Manpower and skill limitations are considered in equipment design	Analyses based on "real costs" including cost to train or replace experienced personnel

Best Practices

TRAPS

1. Manpower and skill level requirements are derived from the LSA task analysis results	2. Manpower and skill analyses are based on experience from previous systems	3. Manpower planning is based on current manpower availabilities and skill levels	4. Published manpower space and overhead costs are used for design and support studies

Current Approach

Alarms

Specifications reflect no constraints on manpower or skill levels necessary to operate and maintain the weapon system (to include support and test equipment)	Contractor analysis relies only on published data from other projects Manpower analysis efforts do not reflect a consideration of peculiar system design features or future manpower availabilities	Analyses fail to consider equipment complexity and the need for changes in skill and training requirements	Design and support analyses use existing data that are not properly evaluated for currency and completeness

Consequences

Studies and analyses assume current manpower and skill level availabilities	Manpower and skill needs are not accurately defined by the analyses	Mismatch of skill requirements and availability	Design and support decisions are based on inadequate cost analysis

Manpower and Personnel

Summary: Support manpower availability and personnel skill requirements often are not considered during the early stages of development. This leads to costly redesign, impact on other weapon system staffing, increased training requirements, increased technical manual cost, and reduced weapon system availability.

During the conceptual and validation phases of a project, a multitude of studies are performed concerning the design of the weapon system under development. Early support analyses during this phase often are hardware-oriented and do not consider manpower and skill requirements. The contractor as part of trade studies and logistics support analyses, should develop predicted manpower and skill requirements based on previous experience with comparable systems adjusted for any new or unique requirements for the weapon system alternatives proposed.

When Request For Proposals (RFPs) for FSD are issued, they should indicate the priority placed on manpower availability and skill level requirements and include these factors in the source selecting criteria. The RFP should provide detailed descriptions of current and projected manpower and skill needs, including specific information on current maintenance and operator performance and realistic manpower costs on similar fielded systems.

During FSD, the contractor should be allowed to observe or participate in organizational and intermediate (field) maintenance activities. Data gathered during field maintenance should then be used to supplement predicted maintenance parameters being used by the contractor, adding realism to the analytical studies being performed. Any unusual support requirements should become readily apparent. Then appropriate design changes can be made to minimize these requirements or changes in support planning can be made prior to field use to provide for unusual manpower or skill requirements. Design reviews held during FSD should address manpower and skill limitations in relation to design complexity. Any shortfalls should be highlighted.

One of the many factors which must be considered during design and support analyses is logistics support personnel costs. Existing data from other projects are often used in performing these analyses without verifying the currency or completeness of such data. In addition, the need for training or replacing experienced personnel is often overlooked. In performing logistics support and personnel cost analyses, all cost elements must be considered, including the costs to train or replace experienced personnel.

Manpower and Personnel

Checklist

- ✓ Will logistics support personnel analyses be performed before the conceptual phase?
- ✓ Will logistics support personnel analyses consider the unique aspect of each new design and be updated to include data from field observations?
- ✓ Will logistics support personnel requirements be based on formal analysis, taking into account equipment complexity and the availability of manpower?
- ✓ Will logistics support personnel skill limitations be addressed during formal design reviews?
- ✓ Will design and support analyses be based on “real costs,” including costs to train or replace experienced personnel as well as billet costs?

Support and Test Equipment

Overview: The ability to satisfactory operate and maintain a new weapon system is dependent on the availability of adequate support and test equipment, appropriate technical manuals, and trained personnel. The technical manuals and training are dependent on the support and test equipment design configuration, while the support and test equipment design itself is dependent on the weapon system design being supported. A successful support and test equipment acquisition balances concurrent development for low technical risk prime items with delayed development and interim contractor support for high risk items. Such support and test equipment efforts result in the maintenance of high operational readiness of weapon systems.

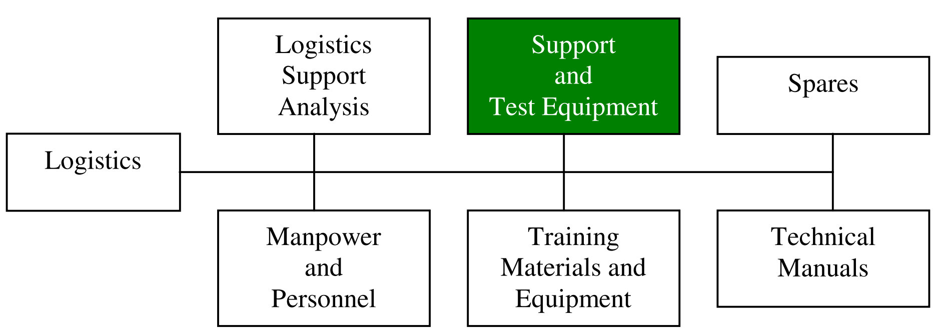
Traps!

1. Identify support and test equipment acquisition timing and requirements after the concept phase

2. Software provides test flexibility for adapting to design changes

3. Existing support and test equipment is selected for use with new weapon systems

4. Requirements for support and test equipment are minimized through extensive use of Built-In Test (BIT)



Support and Test Equipment

Benefits

Support & test equipment developed and deployed consistent with operational demands and technical risk	Software development costs will be minimized	Support & test equipment will be deployed with new weapon system that itself is reliable, supported, & cost-effective to produce	Test capability properly balanced between support & test equipment and BIT

Escapes

Support & test equipment acquisition planning is part of the overall system requirements determination process and takes into account the need to define the operational environment, examine technologies & concepts that support the employment strategies, & assess prime item technical risks	Software development is based on a stable design of the prime equipment	Government-furnished support & test equipment selections are made only after an analysis of the equipment's readiness & support characteristics Analysis is made relative to new system's deployment, operation, & support environment, not current employment environment	Optimize A_o by performing tradeoff analyses between BIT and support & test equipment

Best Practices

TRAPS

1. Identify support & test equipment acquisition timing and requirements after the concept phase	2. Software provides test flexibility for adapting to design changes	3. Existing support & test equipment is selected for use with new weapon systems	4. Requirements for support & test equipment are minimized through extensive use of Built-In Test (BIT)

Current Approach

Alarms

Support & test equipment planning is done without an assessment of system deployment scenarios or regard to prime item technical risk Contractor support is not considered in development of overall support & test equipment acquisition strategy	Intensive software development is completed before design maturity Software design limits the flexibility of the support & test equipment	Government-furnished support & test equipment is always selected over recommendations to use new equipment Existing support & test equipment is not scrutinized with the same level of concern as recommendations for new equipment	BIT is seen as a support equipment panacea in reducing the need for all STE BIT is not viewed as adding to the complexity of the prime equipment and the off-equipment test equipment requirements

Consequences

Readiness & support of the prime item is affected by lack of inadequate operation and maintenance capability, and orderly transition out of contractor support	Excessive software rework	Support & test equipment is selected that will not be reliable enough, or represents technologies that'll be out-of-date, & unsupportable during the time the new system is deployed & operated	Savings in test equipment more than offset by additional resources required to implement BIT

Support and Test Equipment

Summary: Support and test equipment includes all equipment required to operate and maintain a weapon system. This includes associated multi-use end items, ground handling and maintenance equipment, tools, metrology and calibration equipment, communications resources, test equipment, and automatic test equipment, with diagnostic software. It also requires the support for the support and test equipment.

One of the challenges in the development of modern weapon systems is the fielding of systems which are supportable in a cost-effective manner. Adequate support and test equipment is a key ingredient to successful deployment of a weapon system. Traditionally, support and test equipment was frequently the last item to consider in the acquisition process and was given only limited attention.

Modern weapon systems have reached levels of complexity that demand concurrent planning of both prime equipment and support and test equipment development. The planning for development of support and test equipment early in the system development cycle will provide project payoffs including a significant reduction in life cycle cost and gains in system readiness.

Key decisions are essential early in the development cycle to define testability of the system. Support and test equipment concepts and design requirements (based on use studies) are essential to the development of the overall weapon system support strategy. This strategy takes into consideration the employment scenarios; the on-board testing/repair technologies/off-equipment repair concepts needed to support the employment scenarios; and the technical risk (design volatility potential) for the various parts of the weapon system. Tradeoff analyses between BIT, BITE, and test equipment will not only reduce system downtime in the least costly way, but also are required to define precisely the system and support and test equipment requirements. In addition, early planning can help to eliminate costly and complex interfaces by making available practical early design techniques that can optimize the testability of a circuit, component, or system without reducing performance.

Support and Test Equipment

Checklist

- ✓ Is support and test equipment planning initiated along with planning for the prime equipment?
- ✓ Is the development of support and test equipment an integral part of the prime equipment development?
- ✓ Is software development for support and test equipment scheduled to occur after the prime equipment design is stabilized?
- ✓ Will the same design, test, and production disciplines be used for both the prime and support and test equipment?
- ✓ Are design reviews scheduled for support and test equipment development?
- ✓ Are tradeoff analyses conducted between BIT and support and test equipment?
- ✓ Are recommendations for the use of existing support and test equipment examined with the same scrutiny as recommendations for new support and test equipment?

Training Materials and Equipment

Overview: As weapon system complexity grows, operator and maintenance personnel training also becomes increasingly complex. Training equipment, such as simulators, can be more complex and costly than the hardware they support. Program schedules often reflect the development of training materials and equipment before the prime equipment design is stable. This premature development often results in inaccuracies in technical manual content and costly redesign of the training equipment. Adequate planning that takes into consideration technical risk (design volatility) and examines interim measures during the design volatile stage will result in overall training effectiveness and efficiency.

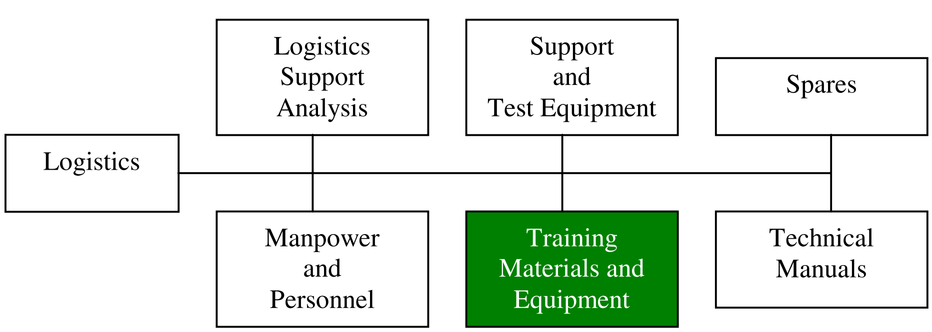
Traps!

1. Training materials and equipment design start early in the development program

2. Effective training courses are developed by offsite training professionals

3. Training requirements are addressed after design completion

4. Contractor develops training materials and equipment based on initial training used for Test and Evaluation (T&E) personnel



Training Materials and Equipment

Benefits

Training materials & equipment will be compatible with deployed systems	Training course material supports prime system training	Adequate training materials & equipment are available for start of training course	Training material & equipment are compatible with maintenance concepts and skill levels of students

Escapes

Initiate development of training material & equipment concurrent with prime equipment design release and with consideration to technical risk	The LSA task analysis (Task 401 of MIL-STD-1388-1A) is used to develop the training course material Computer-aided configuration control techniques are used to ensure consistency between the prime equipment & training materials/equipment	Ensure that training materials & equipment development are addressed at design reviews Training requirements are established early in the design process	Contractor provided with user skill levels and with training materials & equipment requirements derived from current training programs of comparable systems Considerations given to incorporation of on-the-job training capabilities in the prime equipment design

Best Practices

TRAPS

1. Training materials & equipment design start early in the development program	2. Effective training courses are developed by offsite training professionals	3. Training requirements are addressed after design completion	4. Contractor develops training materials & equipment based on initial training used for Test & Evaluation (T&E) personnel

Current Approach

Alarms

Training materials & equipment are designed before system design is stabilized	Training vendors are used who are remote from the system design and are not involved in design change analysis Technical course content is determined by the vendor	Training planning and course development have low program visibility Training equipment development planning and execution linked to system and support & test equipment development	Contractor does not recognize differences in duties, skill levels, and equipment configuration between T&E and deployment equipment

Consequences

Costly redesigns and modifications	Inadequate or inaccurate development of training course material	Training materials & equipment require extensive modifications	Training requirements are not adequately addressed for field use

Training Materials and Equipment

Summary: In order to accelerate operator and maintenance personnel training, many projects require the delivery of instructional materials and courses before design maturity is established and training/support and test equipment are available. The resulting inaccuracies in course technical content and lack of available equipment delay operator and maintenance personnel training or result in inadequately trained personnel. Additionally, if the equipment delivery schedules require the early initiation of equipment design for technically risky systems development, costly redesign or modification may be required due to configuration changes in the prime equipment.

To ensure that training equipment and materials are adequate when delivered, development should not be initiated until prime and support and test equipment design stability is ensured. In addition, realistic schedules need to be developed. Training requirements should be established early in the design process. During the development phase, the contractor must provide some manner of training for Test and Evaluation (T&E) personnel. As development progresses, efforts are sometimes made to modify these early training programs for use by operational personnel. It should be recognized that such programs may not be suitable due to differences in skill levels between T&E and operational personnel and changes to the equipment resulting from the T&E phase. To aid these development efforts, contractors should be provided with clear descriptions of user personnel qualifications and current training programs used on comparable systems. To ensure that adequate progress is being made during the development phase, training materials and equipment should be included as part of regularly scheduled design reviews.

Frequently, equipment such as simulators can be more complex and costly than the hardware they support. In order to reduce the need for such complex and costly equipment, consideration should be given to incorporating an on-the-job training capability in both the prime and support and test equipment. This factor should be included in trade studies made during the early design phase and then implemented during FSD. Often, built-in training features can be incorporated in the prime or support equipment with little impact on the cost or complexity. This is particularly true for computer based, bused systems with automatic maintenance test programming.

The use of Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM) techniques is rapidly expanding throughout the defense industry. During design and development of training materials and equipment, computer-aided techniques should use the information contained in the CAD/CAM databases to ensure consistency between training material and equipment and the configuration of the system they support.

Training Materials and Equipment

Checklist

- ✓ Will training material and equipment development be initiated concurrent with prime and support and test equipment design stabilization?
- ✓ Will LSA task analysis (Task 401 of MIL-STD-1388-1A) be used to develop training course material?
- ✓ Will computer-aided configuration management techniques be used to ensure consistency between the prime equipment, support and test equipment, and the training materials and equipment?
- ✓ Will training material and equipment development be addressed at design reviews?
- ✓ Has the contractor been provided with training requirements (user skill levels, training material, and equipment requirements) early in the design process?
- ✓ Will the prime and support and test equipment design consider the incorporation of on-the-job training capabilities?

Spares

Overview: In fielding new weapon systems, the Military Services have experienced both quality and quantity problems with the spare parts. Poor design quality and poor manufacturing quality have produced spares with unexpectedly low reliabilities and result in increased parts demands. This overdemand combined with underbuying of critical spares has led to some significant impacts on availability, mission success probability, and sustainability for new systems. Spare parts requirements, like support and test equipment, are dependent on deployment and operation scenarios, and the configuration of the design. Use rates also drive spare parts needs. Technical risk (volatility of design) is an important factor in the purchase of spares. Supply support planning is an integral part of the overall logistics planning, and provides the mechanism for organizing, directing, and controlling the spares effort.

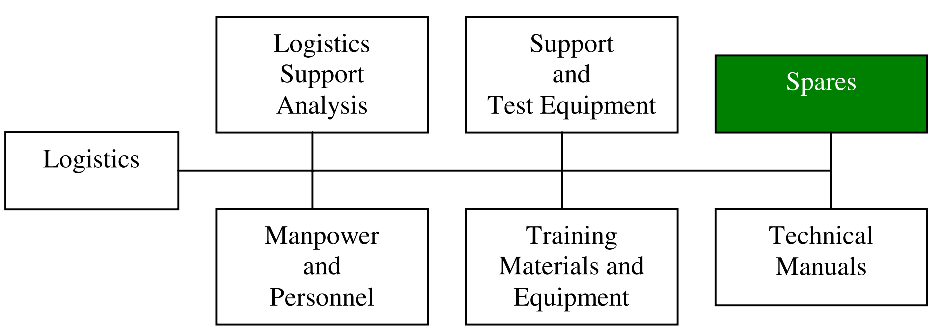
Traps!

1. Spares are provisioned during the development phase

2. Initial spares procured competitively

3. Sparing allowances are determined by funding availability and fill rate objectives

4. The government assumes spares support responsibility upon completion of the first production contract



Spares

Benefits

Spares support responsive to operational commitments	Weapon system operational availability levels maintained	Improved operational availability within cost constraints	Smooth transition of sparing responsibility

Escapes

Spares are provisioned using stable design information Spares demand factors are based on proven sparing models and verified by test results	Spares are manufactured using proven hardware quality and manufacturing standards Vendors selected from current qualified bidders list	Spares selection process is optimized by considering additional factors such as operational availability, system performance, and supply system characteristics Evaluate combining spares procurement with production to reduce unit cost Consider economic order quantity purchase during initial sparing	Verified spares documentation is delivered to the government at a specified time Transition to government spares support planned on a phased subsystem by subsystem basis

Best Practices

TRAPS

1. Spares are provisioned during the development phase	2. Initial spares procured competitively	3. Sparing allowances are determined by funding availability and fill rate objectives	4. The government assumes spares support responsibility upon completion of the first production contract

Current Approach

Alarms

Design immaturity, as indicated by high rate of ECPs, is not taken into account Incomplete/inadequate engineering data is used to derive sparing requirements	Spares are procured by part number without reference to the specifications Spares procured from vendors who have yet to demonstrate the capability	Spares provisioning is based only on past experience and cost factors alone Sparing decisions are affected by fill rate goals as opposed to operational availability goals	Spares planning does not provide for the orderly transition from contractor to government

Consequences

Spares not compatible with fielded hardware requirements	Increased maintenance burden due to low spares reliability	Critical item spares shortages develop	Gaps created in spares availability

Spares

Summary: The consideration of spares availability for the operational phase rarely impacts system design during the development phase. However, the development and operational scenarios drive maintenance, support and test equipment, and sparing requirements. Operational Availability (A_o) is impacted by prime and support and test equipment spares availability, while the need for spares is a direct result of component reliability. Quality of design and manufacture are part of that reliability picture.

Once the system is designed to minimize failures, there are several approaches used to ensure supply support objectives are met:

(1) The spares, or replacement items, have at least the same quality and reliability as contained in the original equipment.

(2) The spares stock at both the organizational and intermediate maintenance levels is based on the results of analyses as to the relative mission critically for each replaceable item.

Considerable progress has been made in recent years toward acquisition of spares with satisfactory quality and reliability. This has been done by properly including in the spares acquisition specifications and drawings the risk reduction techniques and quality manufacturing standards used for the prime hardware. For example, the tailored incoming inspection and environmental stress screening provisions determined during the system FSD should be used, as appropriate, for spares acquisition.

Another factor that can be significant relative to spares quality is degradation due to storage or the dormant reliability factor. Many materials and devices degrade during storage life. The cost-effective approach of buying all spares needed until phase out while a production line is running is no longer valid for these cases. Studies must be made to determine how much storage time (degradation) is tolerable.

Having sufficient spares at each level of maintenance while minimizing inventory costs is one of the most difficult challenges in supply support. The issues of which items to spare and the quantity to spare are always complicated by limited funds and changing environments. To handle this complexity, the Services have or are developing modeling techniques to assist in highlighting spares requirements based on operational demands in peacetime and under war plan taskings. The integrated efforts of war planners, users, designers, manufacturers, and commodity managers are necessary to provide the requisite operational availability with constrained funds.

Spares

Checklist

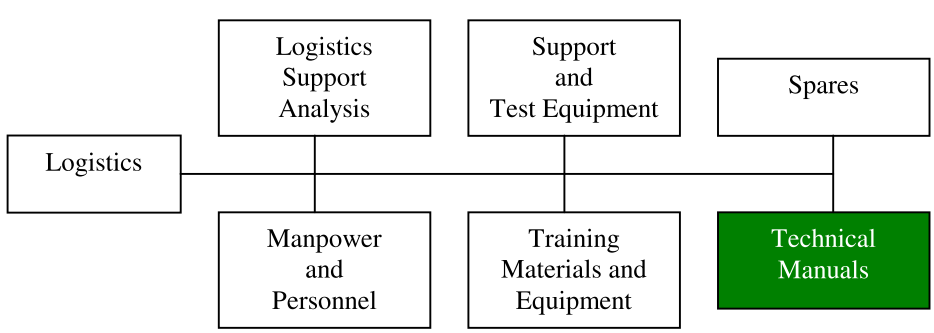
- ✓ Has a spares acquisition strategy been developed early in FSD?
- ✓ Have appropriate quality manufacturing standards and risk reduction techniques been included in spares acquisition documents?
- ✓ Are the sparing allowances at both organizational and intermediate maintenance based on optimizing A_o?
- ✓ Have plans been made for spares procurement and manufacturing options to sustain the system until phase out?

Technical Manuals

Overview: The technical manuals preparation process needs to ensure consistency with the as-built configuration, and readability comprehension by the ultimate user. The technical manual process involves translating engineering work and design analyses (including logistics support analysis) into an operations and maintenance information system. Technical manuals must reflect the design of both the prime items and support equipment and are becoming embedded in both as more items become computer/ microcomputer controlled. With the ability to change equipment operations via software changes, there is a real need to closely tie the design/design change process to the technical manual preparation and change process. The use of CAD/CAM databases in the technical manual process provides this link. Their use improves both accuracy and preparation efficiency.

Traps!

1. Technical manuals prepared using word-processing techniques
2. Contract requires delivery of technical manuals for initial training courses
3. Government review and approval of final technical manuals is required by contract
4. Technical manuals are written using the full-scale development logistics support analysis results



Technical Manuals

Benefits

Increased productivity and reduction in errors	Consistency between training courses and technical manuals	Complete and accurate technical manuals are available when needed	Technical manual accuracy is improved

Escapes

Provide for information transfer between CAD/CAM & technical manual databases to ensure consistency with as-built hardware Investigate the latest automation techniques for reviewing (i.e., readability analysis) and transmission (i.e., electronic mail) of technical manuals	Require the delivery of interim manuals for training course development prior to the start of initial training Provide in-process reviews comparable to hardware assessments	Require the submission of draft manuals for verification and validation using equipment specified in the contract, prior to preparation and publication of final manuals	Link the design/ design change databases to the technical manual preparation process via a constantly updated logistics support analysis database Provide management control mechanisms to ensure all databases are consistent with the current configuration

Best Practices

TRAPS

1. Technical manuals prepared using work-processing techniques	2. Contract requires delivery of technical manuals for initial training courses	3. Government review and approval of final technical manuals is required by contract	4. Technical manuals are written using the full-scale development logistics support analysis results

Current Approach

Alarms

No use made of corporate CAD/CAM databases or advanced automated reviewing techniques during preparation of technical manuals Configuration control of technical manuals is not equal to that exercised over the hardware	Delivery of technical manuals scheduled concurrent with start of training course; no other deliveries required	Contract does not require the submission of draft manuals for review prior to submission of final manuals	The logistics support analysis database reflects the full-scale development configuration, but lags or doesn't portray production configuration Technical manual configuration control doesn't parallel design configuration control

Consequences

Errors in technical and non-technical content introduced during preparation	Much of the training course is not relevant to the actual skills which must be learned	Publication of final manuals delayed causing major problems in repair & maintenance	Technical manual information does not accurately reflect the as-built configuration

Technical Manuals

Summary: Information used in the preparation of technical manuals is usually extracted manually from a variety of sources at high cost, low productivity, and high error rate. Despite the growing use of automation in the design and production of modern weapon systems, technical manuals are mostly prepared using only word processing techniques and equipment.

Modern defense contractors are, however, making increasing use of Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM) techniques during design and production. Much of the information developed during weapon system design and analysis is contained in the CAD/CAM databases such as schematics, wiring diagrams, engineering drawings, mechanical and electrical tolerances, parts lists, task analyses, etc. This data can be used directly in technical manual preparation. Integration technical manual preparation with CAD/CAM/LSA databases will provide reduced errors in the completed manuals, an accurate reflection of the as-built hardware, and increased productivity in preparation of the manuals.

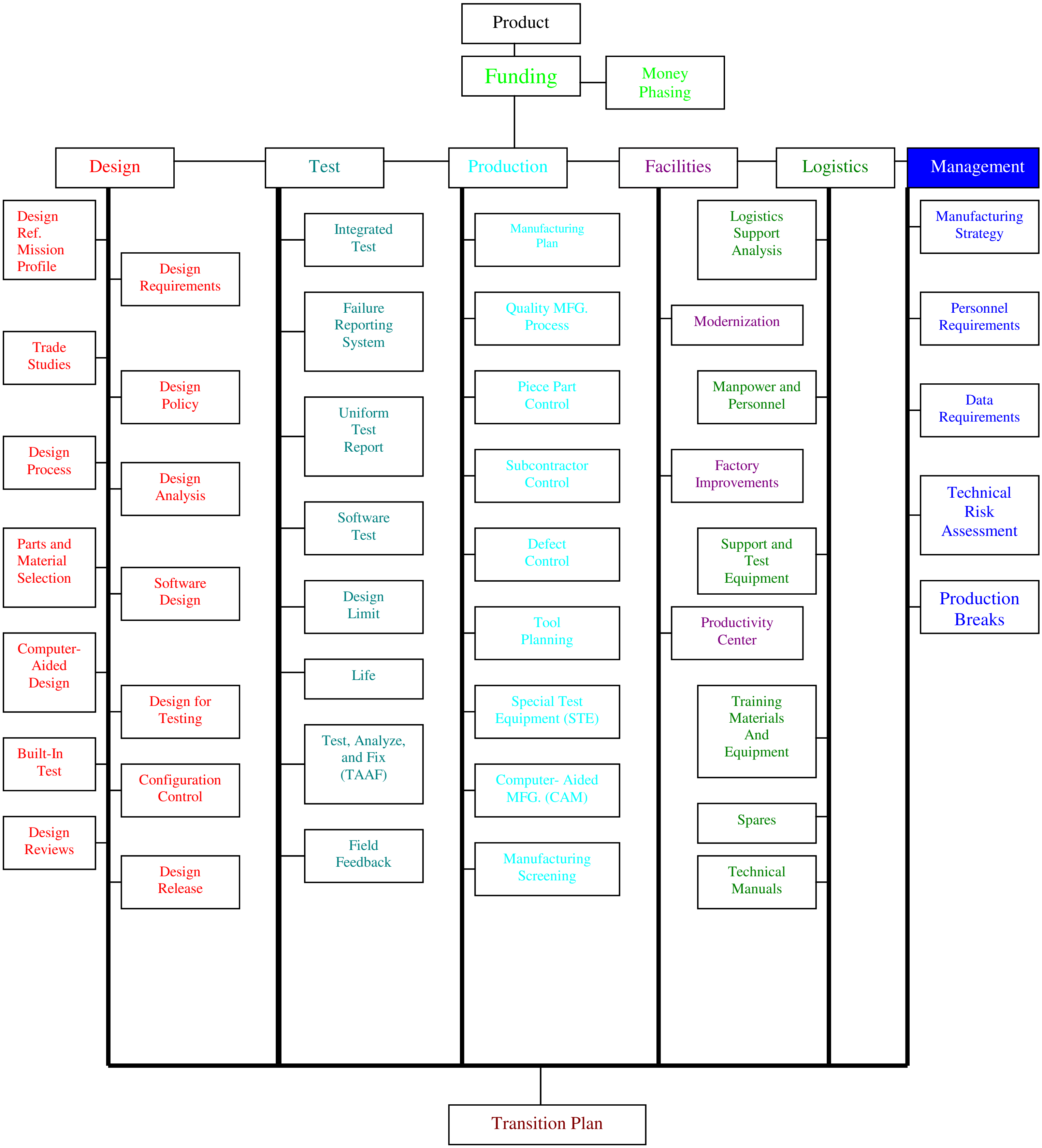
During the development of technical manuals, close coordination must be maintained between the contractor and the government. As the design progresses and draft manuals are developed, user inputs must be provided by the government to ensure that the manuals are adequate for their intended use. Government and contractor responsibilities for verification and validation of the draft manuals must be clearly delineated in the ILS plan. To ensure that the manuals are consistent with the production configuration, the contract must designate the equipment that the manuals will be verified against (i.e., first pilot production model, first production models, etc.). The contract also should clearly specify the level of reading comprehensive required and the methods to be used to verify this.

The end use of technical manuals must be carefully considered when developing milestone schedules for their preparation and delivery. Interim manuals needed to support test programs or for the development of training courses should be included in milestone schedule planning. Test programs could be significantly impacted if the technical manuals did not reflect the hardware configuration under test. Erroneous test results could be obtained if the equipment was not operated as designed and test schedules could be delayed if improper repair procedures were used. In addition, interim training manuals are needed to aid in the development of training courses and to eliminate inaccuracies in technical content of the training courses.

Technical Manuals

Checklist

- ✓ Does the ILS plan outline government and contractor responsibilities for technical manuals?
- ✓ Will the contract require the submission of draft manuals for verification and validation prior to the publication of the final manuals?
- ✓ Will the delivery of interim manuals be required for training course development?
- ✓ Will computer-aided techniques be used to ensure the accuracy of the technical manuals?
- ✓ Does the LSA database reflect the most current configuration?


Product
Funding
Money Phasing
Design
Test
Production
Facilities
Logistics
Management
Design Ref. Mission Profile
Design Requirements
Trade Studies
Design Policy
Design Process
Design Analysis
Parts and Material Selection
Software Design
Computer-Aided Design
Design for Testing
Built-In Test
Configuration Control
Design Reviews
Design Release
Integrated Test
Failure Reporting System
Uniform Test Report
Software Test
Design Limit
Life
Test, Analyze, and Fix (TAAF)
Field Feedback
Manufacturing Plan
Quality MFG. Process
Piece Part Control
Subcontractor Control
Defect Control
Tool Planning
Special Test Equipment (STE)
Computer- Aided MFG. (CAM)
Manufacturing Screening
Logistics Support Analysis
Modernization
Manpower and Personnel
Factory Improvements
Support and Test Equipment
Productivity Center
Training Materials And Equipment
Spares
Technical Manuals
Manufacturing Strategy
Personnel Requirements
Data Requirements
Technical Risk Assessment
Production Breaks
Transition Plan

MANAGEMENT
Manufacturing Strategy

Overview: Manufacturing strategies provide the long-term framework for developing superior manufacturing capabilities that can enhance a company's competitive position. High quality, low cost production only can be developed through a disciplined approach of acquiring knowledge and resources on critical and emerging manufacturing technologies. Sufficient resources for this long-term learning process only will be available if manufacturing is an integral part of the corporate strategy and business plans.

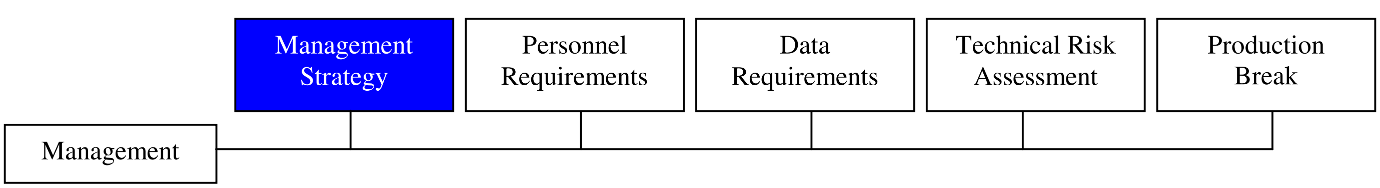
Traps!

1. Superior manufacturing capability is easily accomplished with sufficient investment of capital

2. Manufacturing strategy requires a minimum of advanced planning

3. Producibility studies are performed at the completion of FSD

4. Manufacturing strategies are developed as the design becomes mature



Manufacturing Strategy

Benefits

Critical manufacturing processes and equipment are available for production start-up	Manufacturing is flexible to meet changing requirements	Design will be producible	Contractor will be able to meet his production commitments

Escapes

Critical manufacturing technologies are identified and developed concurrently with equipment design Manufacturing technology requirements drive the funding rather than the reverse	Anticipate potential of new manufacturing technologies and acquire expertise before implications are apparent	Include producibility reviews as part of the design process in contractor policy Team of specialists evaluate new processes and materials during design evolution	Develop and refine a manufacturing strategy, as specified by DoD Directive 4245.6, during the conceptual phase and include in solicitations for FSD

Best Practices

TRAPS

1. Superior manufacturing capability is easily accomplished with sufficient investment of capital	2. Manufacturing strategy requires a minimum of advanced planning	3. Producibility studies are performed at the completion of FSD	4. Manufacturing strategies are developed as the design becomes mature

Current Approach

Alarms

Critical manufacturing equipment will be purchased from outside vendors Development of critical manufacturing technologies is dependent on funding availability	Product technology advances are regarded as the key to competitive position Long range planning does not exist for new production facilities and equipment	Producibility issues are not identified during CDR Redesign for producibility is scheduled after FSD	Manufacturing strategy not included as part of the initial acquisition strategy Contractor's production and transition planning documents aren't consistent with government manufacturing strategy

Consequences

Critical equipment and processes do not meet production requirements	Manufacturing is unprepared for changes in technology	Fabrication is labor intensive	Inadequate manufacturing capability

Manufacturing Strategy

Summary: Manufacturing today is facing formidable challenges in the national and international marketplace caused in large part by rapidly changing technologies. Technological advances are requiring major reorganization of the manufacturing function including facility modernization, high levels of automation, and the ability to quickly implement new technologies. This influx of change has placed manufacturing into a major role in the overall corporate strategy. A corporate strategy of developing superior manufacturing capability is a major step towards enhancing the corporation's competitive position through increased productivity and quality. Unfortunately, large capital investment alone cannot immediately correct problems caused by years of neglect. Developing superior manufacturing requires a disciplined approach covering many years.

Most successful companies are formed initially around a unique or superior product design. This initial start has resulted in many companies, especially in the high-tech areas, considering design and marketing as the company's primary functions. Since the United States had superior manufacturing capabilities in the 1950s and 1960s, corporate management could systematically neglect manufacturing and still be successful. Manufacturing was treated as a service organization and considered in the negative terms of poor quality, low productivity, high wage rates, etc., and not expected to make a positive contribution to a company's success. Recent U.S. failures in the international marketplace, however, have shown the critical error of this corporate philosophy. Many high quality and low cost products are now successful even though more sophisticated products may be available.

Manufacturing strategies are the framework for accomplishing the long-term corporate goals for the manufacturing function. This framework helps to focus the corporation's goals for manufacturing and provides plans for integrating the necessary functions and resources into a coordinated effort to improve production. Communication of this strategy sets the right climate for teamwork and long-term planning that is necessary in developing manufacturing capabilities. The strategy should be well known throughout the company with regularly scheduled reviews to monitor progress on obtaining these goals.

Implementing manufacturing strategies should result in major changes throughout the organization. Improved communication between manufacturing and design engineers can result in designs that are more producible with higher levels of quality. By identifying and anticipating manufacturing technologies of the future, manufacturing will beat their competition in utilizing advances in manufacturing and be prepared with engineering expertise and equipment. Long-range strategic plans allow sufficient emphasis to be placed on specific areas of high technology manufacturing systems or product goals such as high quality and low cost.

Lack of a manufacturing strategy ignores the long-term process necessary to develop superior manufacturing capabilities. Strategic position gives way to short-term solutions resulting in considerable risk when the product design transitions to the production phase.

Risks of poor quality, low reliability, and late deliveries are common with costly fixes necessary to meet production schedules.

Manufacturing Strategy

Checklist

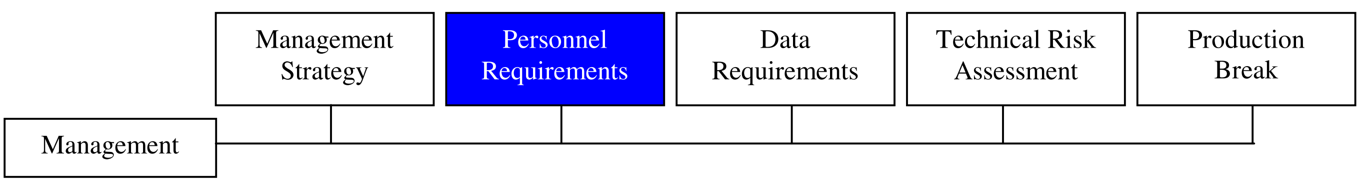
- ✓ Will a manufacturing strategy be developed during the conceptual phase and included in solicitations for FSD?
- ✓ Does the manufacturing strategy correlate with long-range corporate objectives and factory modernization?
- ✓ Are critical manufacturing technologies identified and expertise acquired early for their development?
- ✓ Is production planning information updated regularly?
- ✓ Do the manufacturing and design functions interactively develop both product and manufacturing processes?

Personnel Requirements

Overview: The implementation of technical discipline begins with a "right attitude" towards key issues for transition, such as high quality products and the singular importance of personnel. To obtain qualified personnel at all levels of endeavor, management must establish policy and implement training and motivational programs.

Traps!

1. Policy directive state that people are our most important resource
2. Work force is mature
3. Employee turnover rate is constant
4. Contractor receives incentive awards



Personnel Requirements

Benefits

The work force will produce high quality products	Work force stability will be maintained	Attitude of "teamwork" will pervade the factory floor	Employees will be motivated to continue outstanding performance

Escapes

Corporate policy directives require specific personnel training and motivational programs	Establish training and promotional programs which satisfy employer and employee current and future needs	Establish mandatory, formal technical training program for new employees Establish personnel management policy that matches employee skills with the job	Establish corporate policy to share incentive awards with all contributors

Best Practices

TRAPS

1. Policy directives state that people are our most important resource	2. Work force is mature	3. Employee turnover rate is constant	4. Contractor receives incentive awards

Current Approach

Alarms

No evidence exists of policy implementation at working levels	Career progressions and promotional opportunities are not clearly defined No advanced planning exists for replacing workers nearing retirement	New personnel are observed on the factory floor during each plant visit High incidence of workmanship errors is occurring	No financial benefit to workers is apparent No individual recognition of workers is given

Consequences

Lack of motivation and low morale exist	Unexpected retirements or transfer of critical personnel could quickly dilute the experience base	Poor employee morale exists to the extent that slower than anticipated deliveries are likely	Employee enthusiasm toward future efforts is lacking

Personnel Requirements

Summary: The key theme pervading this manual is the need for technical discipline during the acquisition process in order to follow a low risk path from concept formulation to production. However, this discipline only can be carried out when there are people of integrity at all levels using sound judgment and a well-planned approach to the management of technical risk. Therefore, the issue of "personnel requirements" should address both the recruitment and retention of a team of experienced DoD and industrial project managers supported by qualified technical personnel.

Selection of project managers should be based on their acquisition experience and leadership ability. An effective government/industry working relationship requires the organization to remain stable to provide for continuity of management.

Corporate policy directives should be implemented down to the working levels, requiring specific recruitment, training, and retention programs. Career paths for project managers and their key staff personnel should be clearly defined within a framework of effective organizational management practices on a year-round basis. Formal training programs must supplement on-the-job training to keep personnel current in the latest management techniques.

The hiring and training of competent people is essential whether discussing technical support personnel or those in project management. Line management must be involved in the selection and training of the technical staff as well as the planning of their career paths.

The employee turnover rate is an effective indicator of employee morale. Formal training programs for new employees and management policies for matching employee skills with the job are good management practices to follow to maintain teamwork throughout the acquisition cycle and to retain experienced personnel.

In contracts that receive incentive awards, it has been demonstrated that sharing these incentives with all contributors is important for employees to remain motivated to continue their outstanding performance.

Management policy that is sensitive to the adage "people are our most important resource" is the cornerstone of any project for reducing risk in transitioning from development to production.

Personnel Requirements

Checklist

- ✓ Are corporate-level personnel policy directives established? Are they current?
- ✓ Are personnel management staffs adequately manned with competent people?
- ✓ Have clearly defined organizations been established with the necessary span of control and levels of authority for effective management?
- ✓ Have career progressions been defined so that every employee understands his/her promotion opportunities?
- ✓ Are training programs in effect which satisfy employer and employee current and future needs?
- ✓ Are tours stable for key personnel, avoiding transfer of critical personnel at principal project milestones?
- ✓ Are project managers assigned to only one major project?
- ✓ Has a matrix management concept, coupled with as much collocation of key functional support personnel as possible, been established?
- ✓ Are line managers involved in the recruitment, training, and retention of key technical personnel, rather than leaving total responsibility for such tasks to the personnel support organization?

Data Requirements

Overview: Technical data is essential both for ensuring that the system being procured meets all technical requirements, and for providing needed reprocurement information. The proliferation of unnecessary data requirements, however, has caused a staggering increase in data costs, sometimes ranging as high as 20 to 50 percent of the total contract price. Stringent defense budgets and escalating equipment costs require reassessment of current procurement practices to eliminate the procurement of unneeded technical data and to ensure the adequacy of delivered data.

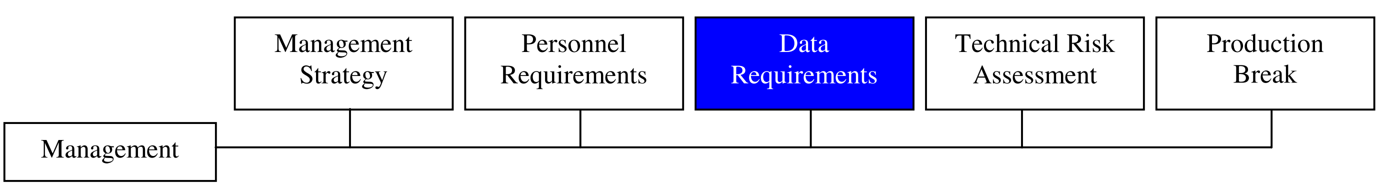
Traps!

1. Technical data requirements are established by government functional departments

2. Contract Data Requirements List (CDRL) reviews are used to monitor contractor performance

3. Subcontractor data requirements are defined by prime contractor

4. Level III drawings are ordered for second source procurement



Data Requirements

Benefits

Essential data will be obtained at minimum cost	Assessing technical progress and solving design and manufacturing problems will involve joint governmental/industry participation	Adequate subcontractor data will be available for project control and support	Second source production ramp-up will be smooth

Escapes

Conduct an independent review to ensure the procurement of minimum technical data, consistent with project needs	Conduct monthly technical progress reviews Onsite technical representatives review test procedures and witness tests	Ensure that the prime contractor flows down all technical data requirements to subcontractors	Independent review activity verify the suitability of drawings for second source procurement Investigate claims of proprietary data and consider the procurement of rights in data

Best Practices

TRAPS

1. Technical data requirements are established by government functional departments	2. Contract Data Requirements List (CDRL) reviews are used to monitor contractor performance	3. Subcontractor data requirements are defined by prime contractor	4. Level III drawings are ordered for second source procurement

Current Approach

Alarms

Government format is used extensively when contractor format will suffice Technical data requirements are not reviewed for duplication	Documentation CDRL reviews are emphasized by project office to monitor technical process Test reports are used to confirm specification compliance	Subcontractor reports do not contain any technical depth Supplemental provisioning data are inadequate	Critical manufacturing processes are declared proprietary Manufacturing processes and test procedures are incomplete

Consequences

Technical data costs up to 50 percent of the total contract price	Assessment of technical progress is late and possibly inaccurate	Insufficient data is available to control subcontractor performance	Production delays are costly and production yields are low

Data Requirements

Summary: In an attempt to control contractors, the government has continually increased the variety and amounts of technical data required by contract. Reports to monitor design analysis efforts, program plans to document contractor implementation of contract requirements, test plans, test result reports, logistics support data, engineering data packages – the list seems endless. Recent studies of the growth in technical data requirements have estimated that technical data may make up from 20 to 50 percent of the total cost of a contract.

To reduce the amount and cost of technical data, an independent review should be made of data requirements for duplication and proper program phasing. The need for the data should be justified. In many cases detailed military requirements are stated for technical content and format. Existing contractor data format should be considered, if it provides the information needed, rather than requiring unique and expensive format changes.

In the computer and support equipment areas, where commercial equipment meeting government needs is available, adequate technical data often exists in the form of commercial manuals. If adequate, this data should be accepted for use, without extensive restructuring into military format.

In many cases technical data, in the form of progress or test reports, are used to monitor technical progress. Since these reports normally follow the work performed by 30 to 90 days, any assessment or control of technical progress is lost. To provide real time monitoring and reduce data requirements, technical progress should be monitored through the use of onsite technical representatives or the performance of monthly progress reviews. To ensure that adequate substantiating data is available for monthly progress reviews, it may be necessary to include contract requirements for certain technical data. However, cost savings may be realized by allowing the contractor to retain the data for the onsite reviews, rather than require delivery of the data to the government.

Adequate technical data in the form of engineering drawings, specifications, and standards often are required for competitive reprocurement or the procurement of spare and repair parts. To ensure the adequacy of the data, an independent review activity should be used to verify the suitability and completeness of the data for its intended use. Contractor claims of proprietary data should be thoroughly investigated. If the contractor's claims are verified and the data is required for competitive reprocurement, the procurement of the proprietary data should be considered.

When Requests For Proposals (RFPs) are issued, consideration should be given to requiring alternate proposals from the contractor to reduce the volume of data required or to reduce the cost of the data by the use of contractor report format.

Data Requirements

Checklist

- ✓ Has an independent review been made to ensure only the procurement of minimum technical data?
- ✓ Are monthly technical progress reviews planned?
- ✓ Will onsite technical representatives be used to review test procedures and witness tests?
- ✓ Is the prime contractor required to flow down technical data requirements to his subcontractors?
- ✓ Will drawings planned for second source procurement be reviewed by an independent activity to determine their completeness and accuracy?
- ✓ Have contractor claims of proprietary data been investigated?

Technical Risk Assessment

Overview: In an effort to deal with project cost growth, the Department of Defense (DoD) has superimposed an increasingly complex network of management controls. Recent initiatives have resulted in management techniques geared to tracking and predicting budget and schedule performance. Project decisions are made after cost and schedule impacts have been carefully considered, but the impacts of cost and schedule decisions on technical risk and vice versa are not well understood. The tendency is to measure technical performance after the fact and not use predictions and up-to-the-minute impact data to make decisions. It is this lack of technical balance that continues to stifle improvement in DoD management systems and weapon systems. Consequently, the requirement to develop a technical risk assessment and reporting system cannot be overstated.

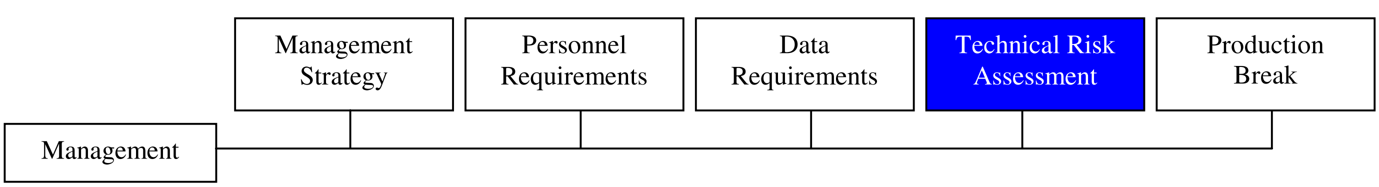
Traps!

1. Contractor claims to have a technical risk assessment and reporting system

2. Project design, test, and manufacturing engineers know the technical problems

3. Top level requirements are contained in the end item specification

4. Development and manufacturing test results are good technical risk indicators



Technical Risk Assessment

Benefits

Technical factors which impact cost and schedule will be predictable and manageable	Corporate resources will be available for timely resolution of technical problems	Technical risks will be minimized because the initial design is based on the top level requirements	Technical, cost, and schedule indicators will be used for risk management

Escapes

Contractor augment Cost/Schedule Control System Criteria (C/SCSC) with a technical risk assessment system	Provide formal reports to all levels of management on technical status, problems, corrective actions, and impact	Ensure the allocation of top level requirements to all levels of design and test	Develop a compre-hensive list of technic-al risk indicators from design and test activ-ities, for risk manage-ment during FSD and early production

Best Practices

TRAPS

1. Contractor claims to have a technical risk assessment and reporting system	2. Project design, test, and manufacturing engineers know the technical problems	3. Top level requirements are contained in the end item specification	4. Development and manufacturing test results are good tech-nical risk indicators

Current Approach

Alarms

Contractor meets government C/SCSC	Technical problems are formally reported only at the project management level	Top level require-ments have not been interpreted and passed on to in-house engi-neers (design and test) or subcontractors	The only indicators used for risk manage-ment are test results Unanticipated design and manufacturing problems surface during tests

Consequences

Time delay occurs in recognizing technical factors driving cost and schedule	Engineers hope to solve technical problems before management is alerted	Many detailed technical issues are not considered during development	Significant project cost and schedule impact occurs due to unrecognized technical risk

Technical Risk Assessment

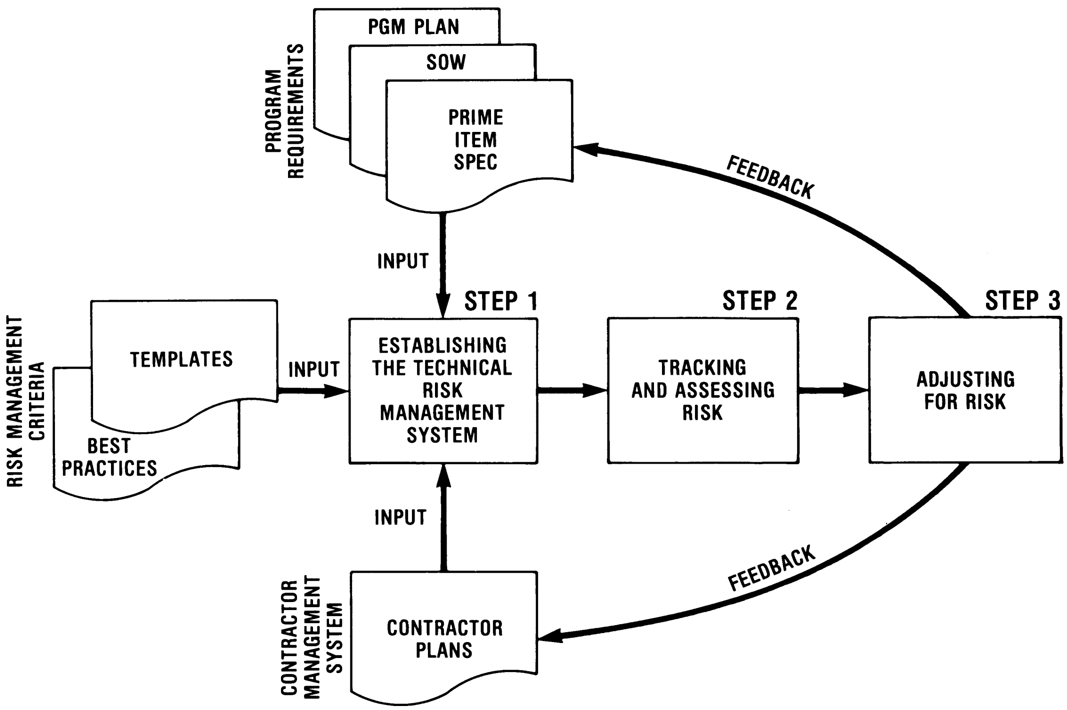
Summary: The key to improving our development programs lies in our ability to bring technical balance to the management process. High technology weapon development projects represent very challenging engineering and management projects. They are challenging, not because of the budgets involved – a state highway improvement program could easily be more expensive. They are challenging, not because of the schedule requirements – the milestones used to build an office complex are more detailed and more stringent. They are challenging primarily because of the technical risk inherent in the high performance designs required to meet most threats. The challenge follows from the need to stretch existing technology to its limits and to push new technology into designs early. However, when we look at the management techniques that are used today, technical risk is treated superficially, if at all. The focus of most risk analysis methods to date has been on the use of statistical techniques for evaluating financial risks. These methods depend on the accuracy of the probability functions that are assumed, and are generally not valid for unique one-of-a-kind development projects. We depend on sophisticated systems to control, monitor, and advise of performance against the cost and time schedules. We have no method in place to perform these same functions for technical risk inherent in the development of an advanced, highly integrated, complex weapon system.

A technical risk assessment system should provide management at all levels with (1) a discipline system for early identification of technical uncertainties, (2) a tool for instantaneous assessment of current project status, and (3) early key indicators of potential success or failure.

The system also provides the basis for taking action to control risk and for measuring the effectiveness of that action. Technical problems are highlighted before they become critical and plans are developed to manage project risks. The system could trigger restructuring of test plans, reallocation of system level requirements, or reallocation of program assets. It is even possible that the technical risk assessment system will reveal technical requirements which cannot be met within existing technology and resource limitations. There are three basic steps in the process of developing and applying a technical risk assessment system:

- Establish the technical risk management system
- Track and assess risk
- Adjust for risk

The first step includes the planning aspects of the process, with emphasis on the methods, parameters, procedures, and responsibilities for carrying out the system. Secondly, data are collected and integrated as necessary to identify, track, and assess risks by periodic reporting throughout the course of the project. The final step focuses on risk adjustment through execution of corrective actions aimed at reducing the impact of risks through elimination or monitoring. As illustrated in Figure 1, the technical risk assessment system is somewhat iterative through "feedback loops" to the project requirements and contractor plans.



Technical Risk Assessment

Checklist

- ✓ Does the contractor have a specific technical risk assessment and reporting program?
- ✓ Are periodic formal reports provided to all levels of management on the technical status, problems, corrective actions, and subsequent project impact?
- ✓ Have technical risk indicators been generated for design, test, manufacturing, cost, and management?
- ✓ Does each technical risk indicator have a projection of where it should be during its phase of the project?
- ✓ Have all top level technical requirements been allocated to the lowest design and test levels for both the prime and subcontractors?

Production Breaks

Overview: Production breaks are considered to include not only complete shutdown of a production line (i.e., breaks in production for varying durations of time) but also reduction in the delivery rate (i.e., project stretch-out) from a previously established level of rate production. Decisions requiring a production break often are made under the delusion that dollars will be saved. Unfortunately, such decisions actually present major risks in terms of increased acquisition and support costs.

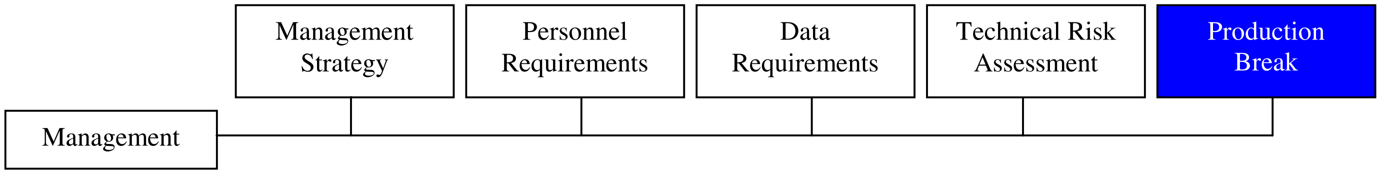
Traps!

1. Current budget environment is forcing funding cuts

2. Production break is used to save the government money

3. Delivery schedule stretch-out is forced by configuration changes

4. Short production breaks do not impact project restart



Production Breaks

Benefits

Best effort will have been expended to maintain project stability	Cost of production break will be kept to a minimum	Minimum stretch-out of delivery schedule will occur	Start-up problems will be minimized

Escapes

Authorize stretch-out or production break only after all options for sustained funding are exhausted	Fund contractor to retain key personnel, vendors, and facilities, to maximum possible extent	Group configuration changes into major block changes	Retain key technical personnel by sustaining a minimum level of effort Procure long lead material to facilitate production restart

Best Practices

TRAPS

1. Current budget environment is forcing funding cuts	2. Production break is used to save the government money	3. Delivery schedule stretch-out is forced by configuration changes	4. Short production breaks do not impact project restart

Current Approach

Alarms

Reprogramming activities are extensive Contractor is reassigning key personnel to other contracts	Contractor is projecting increased costs due to a loss of learning and increase in inflation	New product configuration is costing more per unit New tooling, processes, and procedures are impeding production rate ramp-up	Experienced assembly and fabrication personnel, and key engineering and manufacturing personnel are being reassigned Facilities are encroached upon by healthy projects

Consequences

Increase in technical and schedule risk	Restart costs are high	Increase in acquisition cost	Stage is set for major impact on cost, schedule, and technical risk

Production Breaks

Summary: Contracts awarded by the Department of Defense traditionally have covered the time period to the next project milestone decision point, at which each project must justify its continuation into the next phase. Funding, on the other hand, has been subject to the annual DoD and Congressional budget review and appropriation processes, as well as reprogramming options within the procuring department. One result of this paradox is that projects in rate production have, on short notice, been deprived of sufficient funding to sustain planned production levels. Traditional reaction to this dilemma has been to stretch-out the delivery schedule – sometimes reducing the production level to the "misery rate" which barely keeps the line going – or temporarily shut down production entirely, which puts a discrete break or gap in the delivery schedule. There have been other reasons for rescheduling production as well, among them suspension for time to implement design changes, to synchronize delivery rates with availability of "holes" in aircraft, ships, tanks, et al.

Project delays result in overall project cost increases, if due only to inflation. But much more significant effects of production gaps and stretch-outs on both cost and reliability are due to loss of learning. Learning includes many factors: optimization of repetitive tasks, effective problem recognition and solution, optimization of production flow, improvements in assembly and automated fabrication tooling, automated test equipment, optimized procedures and processes, and other intangibles which simply result from familiarity with the job. While not a learning factor per se, the reduced unit cost of increased quantities of purchased parts can be merged into the learning curve in terms of the effect of overall unit cost of continuous production. Consider for a moment what can happen when manufacturing is temporarily interrupted.

Employees must either be paid from funded projects or be released from employment in order for any company to long retain profitable. A stretch-out or a production break, although temporary, means reassignment of key personnel in both engineering and manufacturing positions to other projects which are funded, and layoff or dismissal of surplus production workers. The negative effects are twofold: psychological and practical. Job instability affects personal security, one of the most basic in the hierarchy of motivational needs. Even temporary reassignments may be interpreted as a less challenging alternative and a negative influence on motivation. But the big loss is in experience: the daily hands on practice which maintains expertise and efficiency. The "learning curve" is not an abstract concept – it has been quantified by many studies in terms of cost and time. Learning is a fragile commodity, easily and quickly lost through disuse.

Floor space and expensive machinery are, after employees, industry's next most valuable resources. These too cannot be allowed to remain idle for long. Not only are they of potential value to other projects in the same facility, but also they add to the overhead burden charged to the funded project. Production breaks, if lengthy, can only result in facility rearrangements, breakup of smoothly-running production flow, and loss of floor space for the affected project.

Production breaks have a domino effect on vendors, especially the smaller companies. The relatively small percentage of a project's components purchased from a small vendor may represent a relatively large percentage of that vendor's capacity, and either he must find other customers or face bankruptcy. When production is scheduled to resume, that vendor may no longer be a viable source, and in a worst case situation, product redesign may be necessary to accommodate the loss.

The end result of a production gap is a significant restart effort. The lessons learned originally must be learned again. Vendor relations must be reestablished, personnel must be hired or reassigned and retrained, machinery and manufacturing processes must be debugged and fine tuned, and administrative and production management procedures must be worked out again. The same problems and rejects experienced the first time around will be experienced all over again, to a degree depending on the length of the break. Not only does the production break increase the overall project cost, but also the equivalent unit cost will be achieved only at some higher order quantity than would have been the case had production continued uninterrupted.

One well-documented case history involving multiple breaks clearly illustrates the consequences. During the first four months, the program lost assembly and fabrication personnel. In the next three months, the loss overtook key personnel responsible for developing improvements through changes to methods, tools, design, facilities, and vendors. Past the eighth month, vendors and facilities were lost and key project personnel were reassigned. Within a year, major facility rearrangements would have been forced by corporate demands for other projects and initiatives.

The net results of a total of 16 months (in two breaks) included a $23 million increase in recurring costs, the effects of 16 months of inflation, and a 75 percent increase in the number of units produced before the unit cost has decreased to the value it would have been without breaks. What doesn't show are the effects on unit quality during the restart and learning periods following the breaks. The government also was required to devote a disproportionate level of attention to this project to ensure that an acceptable reliability threshold was not breached.

Production breaks are not a viable means to reduce costs, whether initiated by the government or by the contractor. True multiyear contracting with vendor flow down is the ultimate answer. This will permit sustained production across fiscal years and Congresses through project completion. In the meantime, avoid production breaks and stretch-outs by all possible alternatives.

Production Breaks

Checklist

- ✓ Have production stretch-outs and breaks been avoided or authorized only after all options for sustained funding were exhausted?
- ✓ Has the Contractor been funded to retain key personnel, vendors, and facilities to the maximum possible extent?
- ✓ Have configuration changes been grouped into major block changes?
- ✓ Will long lead material procurement be sustained, to ease production restart?