

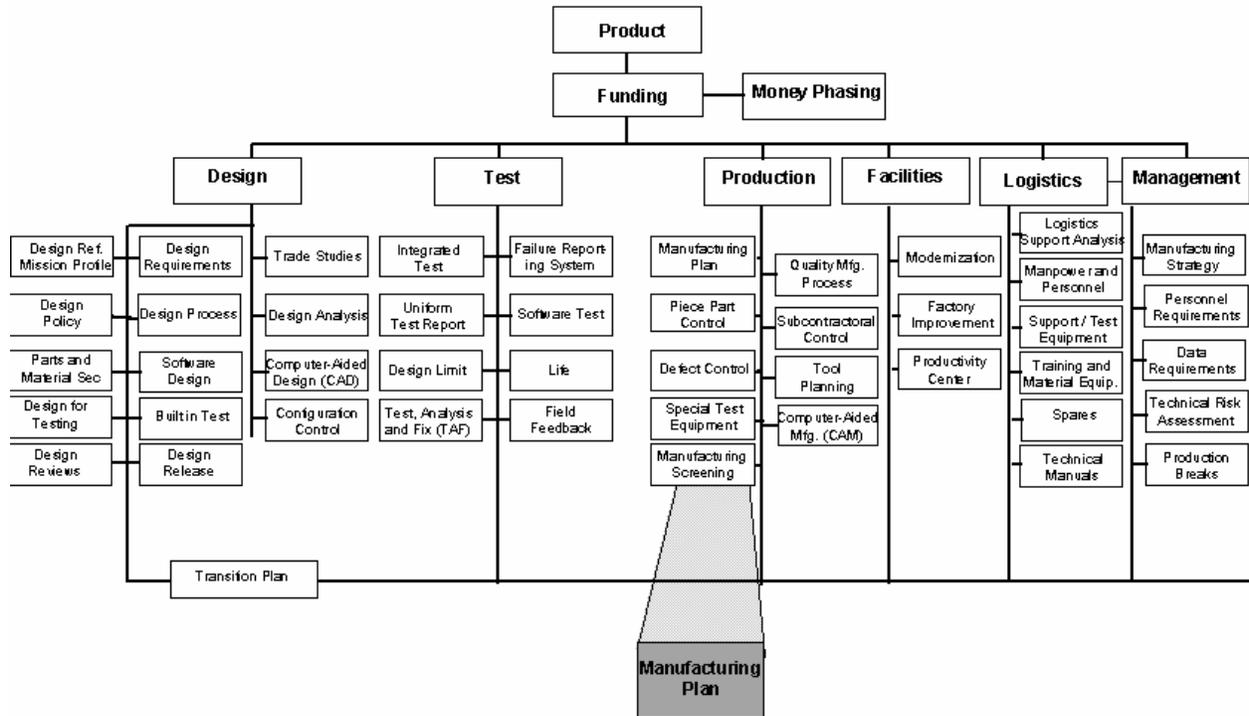
## **Chapter 5 -- Production**

### **A. -- Introduction for Production Critical Path Templates**

Solving the manufacturing portion of the equation is a major factor in reducing the risk of transition from development to production. The history of military procurements chronicle again and again the scenario of proven functional designs being introduced into the manufacturing process, only to complete that process as end products that cannot support their mission requirements.

The DSB task force investigated transition matters related to preparation for and management of the manufacturing process. More specifically, it dealt with issues in such areas as part quality and management; the cause and relation of workmanship defects; the vendor impact on quality, cost, and schedule; the recipes for successful transition to production; and the associated transition management techniques. The task force agreed that within industry today there exists the experience, wisdom, tools, and techniques to successfully manage the transition process. However, based on past transition experience, the issues outlined in this section represent those that have been especially troublesome and require special initiatives and discipline to manage effectively. Consequently, the implementation of the concepts, techniques, and procedures specified in this section will reduce significantly, the risk of transition from development to production.

### **B. -- Manufacturing Plan**



## Area of Risk

Involvement of production and manufacturing engineering only after the design process has been completed is a fundamental error and a major transition risk. Consequences of late involvement are (1) an extended development effort required for redesign and retest of the end item for compatibility with the processes and procedures necessary to produce the item, and (2) lower and inefficient rates of production due to excessive changes in the product configuration introduced on the factory floor. Increased acquisition costs and schedule delays are the result of this approach.

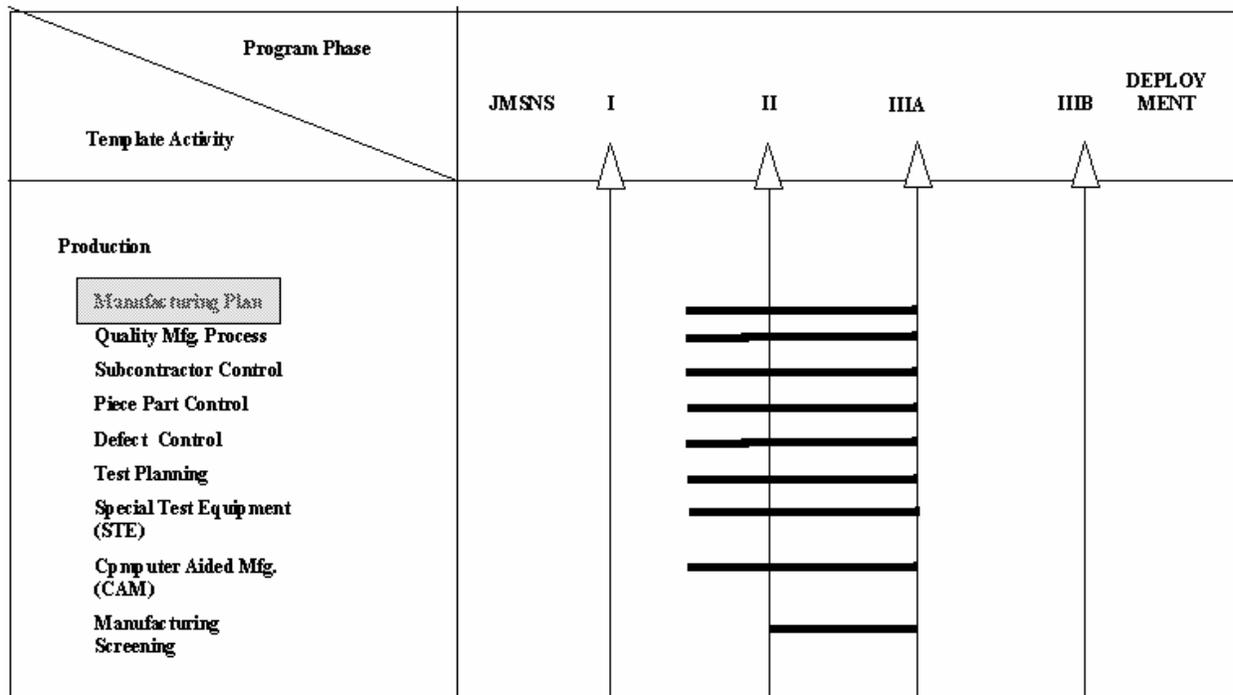
## Outline for Reducing Risk

- Documented early planning that focuses on the specifics of the fabrication practices and processes required to build the end item is initiated while the design is fluid and completed before the start of rate production. Documenting this process constitutes a manufacturing plan.
- The following represent the key elements of a manufacturing plan:
  - Master delivery schedule that identifies by each major subassembly the time spans, riced dates, and who is responsible.
  - Durable tooling requirements to meet increased production rates as the program progresses.
  - Special tools.

- Special test equipment.
- Assembly flowcharts.
- Test flowchart.
- Receiving inspection requirements and yield thresholds.
- Production yield thresholds.
- Producibility studies.
- Critical processes.
- Cost and schedule reports.
- Trend reports.
- Inspection requirements.
- Quality plan.
- Fabrication plans.
- Design release plan.
- Surge and mobilization planning.
- Critical and strategic materials.
- Labor relations.
- Manpower loading.
- Training.
- Training facility loading.
- Production facility loading and capacity.
- Machine loading.
- Capital investment planning.
- Make or buy criteria.
- Subcontractor and vendor delivery schedules.
- Government-furnished material demand dates.

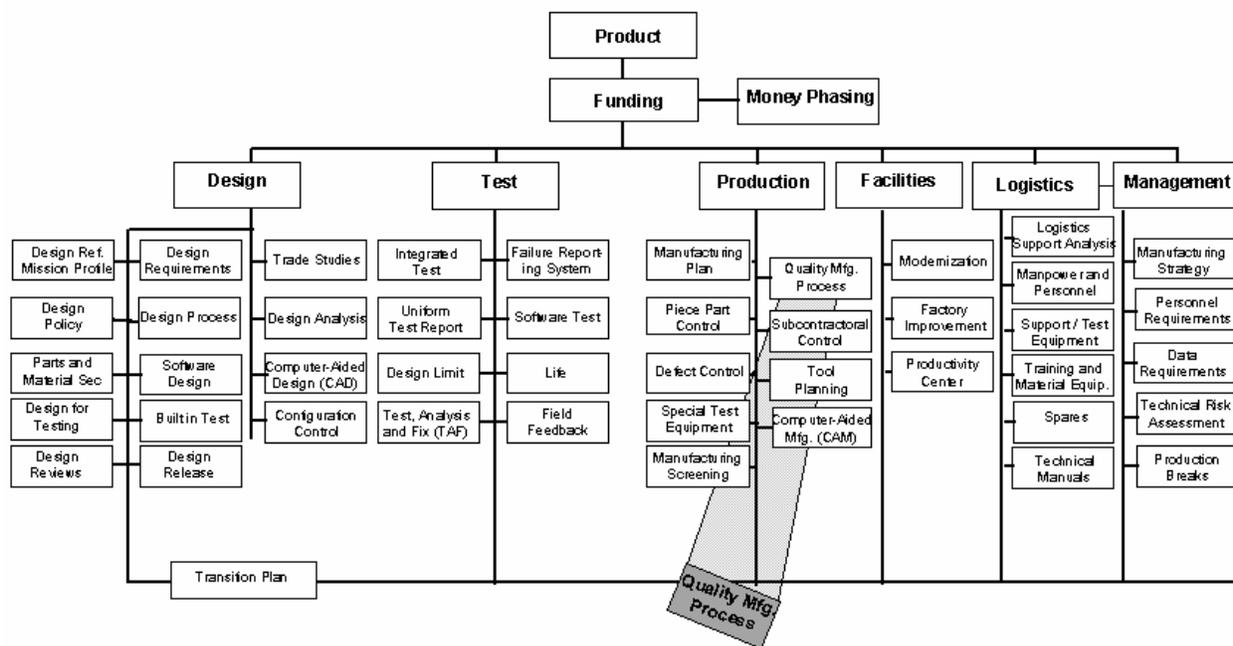
- Work measurement planning.
- Energy management audits.
- The following elements also may be considered when generating a manufacturing plan. They usually are influenced by unique aspects of the acquisition, capabilities of the contractor, or initiatives of the military procurement agency.
  - Project and functional personnel in manufacturing are collocated.
  - Engineering and manufacturing test equipment are built alike.
  - Assembly planning is verified before rate production.
  - Specify that a part of design engineers' time be spent on the factory floor.
  - Assembly, inspection, test, and rework are combined in unit work cells, when appropriate.
  - Development hardware is inspected by production line inspectors.
  - Production personnel participate in building development hardware.
- The overall manufacturing strategy developed earlier in the acquisition cycle is implemented by production planning activities.
- The manufacturing plan is verified and progress against the plan is monitored by a series of contractual and internal production readiness reviews.
  - Reviews include both prime contractor and subcontractor. It is the prime contractor's responsibility to ensure that production readiness reviews are conducted at the subcontractor's facility.
  - These reviews are staffed with knowledgeable personnel (that is, a mixture of manufacturing and design engineering people from outside the line organization doing the work).
  - The depth of these reviews is similar to that of the design reviews with participation by a similar level of qualified people in the areas of design and manufacturing engineering.

## **Timeline**



The manufacturing plan identifies the approach for effective fabrication of the product design. Manufacturing planning activities, concurrent with development activities, are essential.

### C. -- Quality Manufacturing Process



## **Area of Risk**

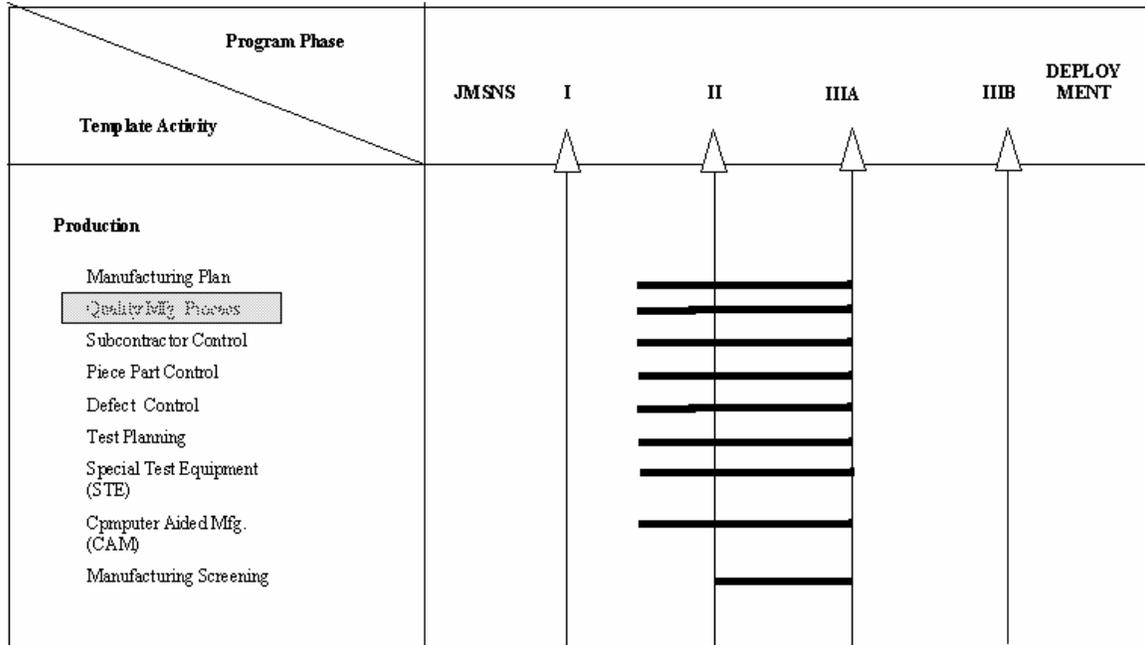
The introduction of a recently developed item to the production line brings new processes and procedures to the factory floor. Changes in hardware or workflow through the manufacturing facility increase the possibility of work stoppage during rate production. Failure to qualify the manufacturing process before rate production with the same emphasis as design qualification-to confirm the adequacy of the production planning, tool design, manufacturing process, and procedures-can result in increased unit costs, schedule slippage, and degraded product performance.

## **Outline for Reducing Risk**

- The work breakdown structure, production statement of work (as identified in the contract), and transition and production plans do not contain any conflicting approaches. Any discrepancies among these documents are identified and resolved before production is started.
- A single shift, 8-hour day, 5-day workweek operation is planned for all production schedules during initial startup. Subsequent manpower scheduling is adjusted to manufacturing capability and capacity consistent with rate production agreements.
- The drawing release system is controlled and disciplined.
  - Manufacturing has the necessary released drawings to start production.
  - No surge in engineering change proposal (ECP) traffic from design or producibility changes occurs.
  - “Block changes” to the production configuration are minimized. (A consistent configuration that does not need any block changes is an indication of low risk.)
- The manufacturing flow minimizes tooling changes and machine adjustments and ensures that alternate flow plans have been developed.
- A mechanism is established that ensures the delivery of critical, long lead time items 4 to 6 weeks before required.
- All new equipment or processes that will be used to produce the item are identified.
  - Qualified/trained personnel are assigned to operate the new equipment and processes.
  - “Hands on” training is accomplished with representative equipment and work instructions. (See Productivity Center template.)
- Hardware and other resources are allocated to “proof of design” models for data package validation, and to “proof of manufacturing” models for implementation prove-out and production equipment troubleshooting. Quantities of the “proof of” models are decided jointly by the customer and contractor depending on the nature and complexity of the program.

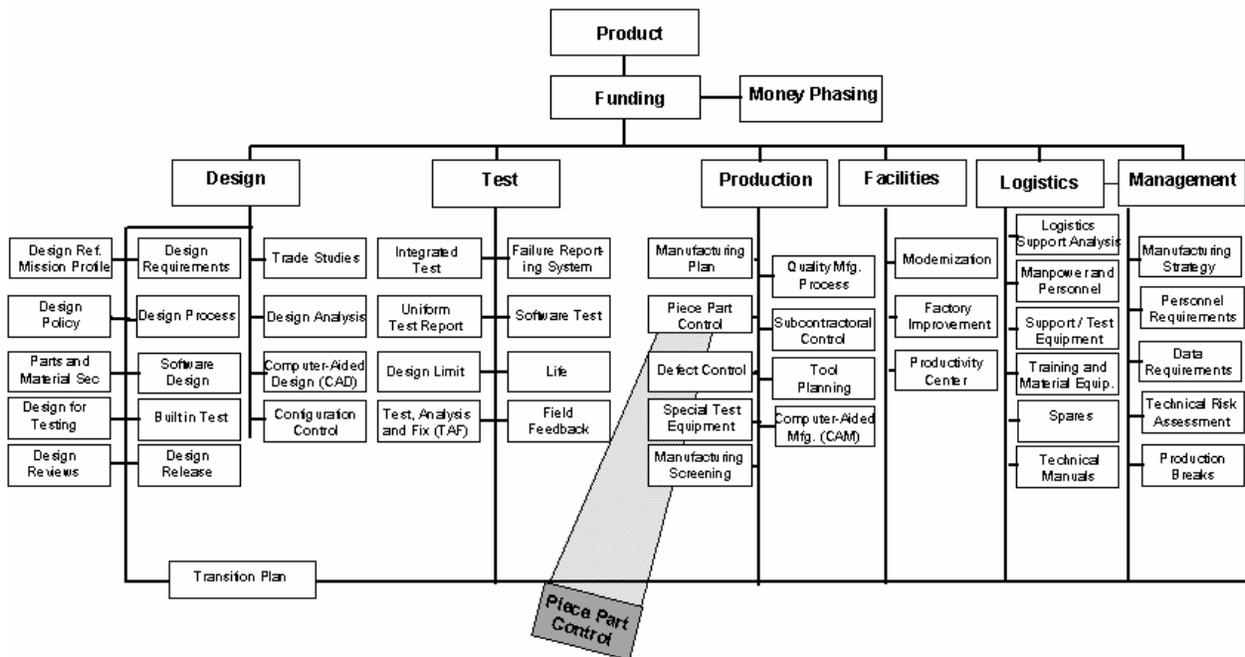
- The manufacturing process is qualified both at prime contractors and all major subcontractors.

## Timeline



The manufacturing process required to produce an item significantly influences the design approach and product configuration. Therefore, the manufacturing process is qualified with enough time for design or configuration changes to be introduced in the baseline product configuration before low rate production commences.

### D. -- Piece Part Control



## Area of Risk

Most military programs require MIL-STD parts in weapon and support systems. This practice has left much to be desired in its ability to ensure delivery of high quality, reliable parts to contractors. In self-protection, users must conduct intensive screening and inspection at their own facilities, to provide an acceptable product to the production line. Semiconductors in particular have played a major role in increasing the cost and risk of producing a reliable product, in some cases showing defect rates of 3 to 12 percent during user rescreening.

## Outline for Reducing Risk

- Receiving inspection is more effective than source inspection:
  - Suppliers tend to ship better quality products to customers performing receiving inspection rather than source inspection.
  - Receiving inspection costs typically are less than source inspection.
  - Typically, more lots per man-hour can be inspected at receiving than at source inspection.
- One hundred percent rescreening of semiconductors reduces risk and usually is cost-effective. Departures from 100 percent rescreening are appropriate, provided they are supported by sound technical and cost rationale. Factors influencing a departure might include the use of mature technology parts, demonstrated ability of the supplier to deliver consistently quality products, and test and failure cost data.

The following represents a minimal baseline program to be conducted at the user's facility:

- Perform particle induced noise (PIN) testing, at a minimum, on all hybrids and preferably on all semiconductors with cavities when used in critical applications.
- Perform electrical test at - 55" C, + 25YC, and + 125" C.

Typical costs (1982 dollars) for the above tests:

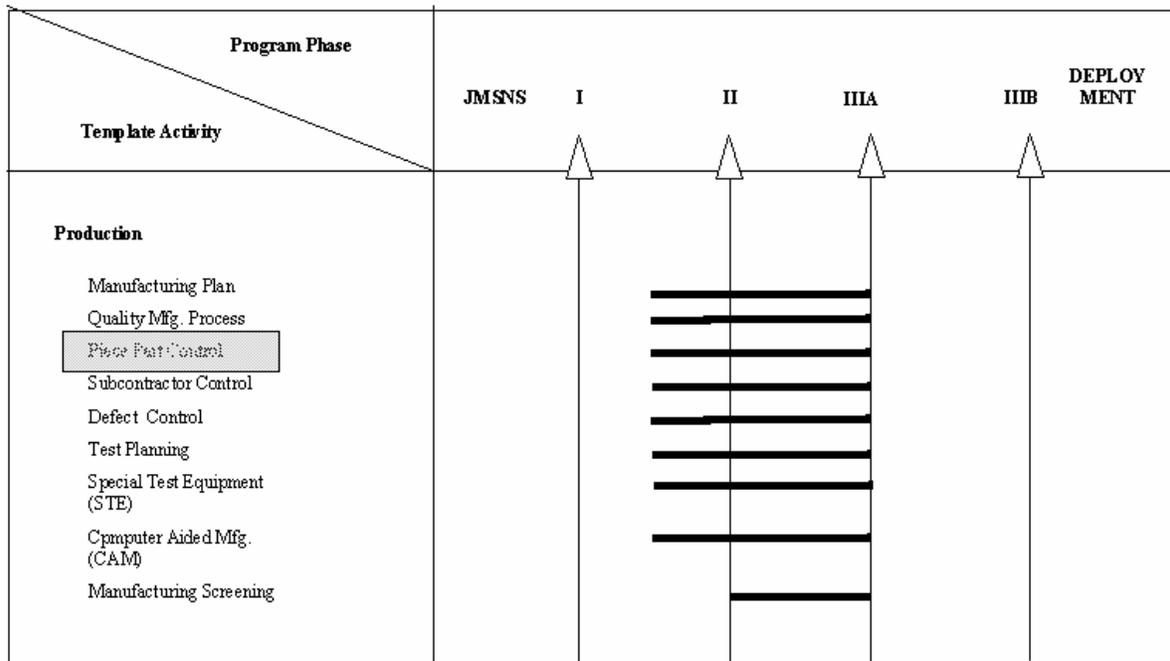
- Transistor/transistor logic (ITL) integrated circuits	\$ .68
- Complimentary metal oxide semiconductor (CMOS) logic integrated circuits	.81
- Linear integrated circuits	1.04
- Memories/microprocessors	1.45
- Transistors/diodes	.74

Typical costs (1982 dollars) for parts replacement if the defect is found at a higher level of assembly:

- Printed wiring assembly	\$ 50
- Line replaceable unit	500
- System	1 .500
- Field	15,000

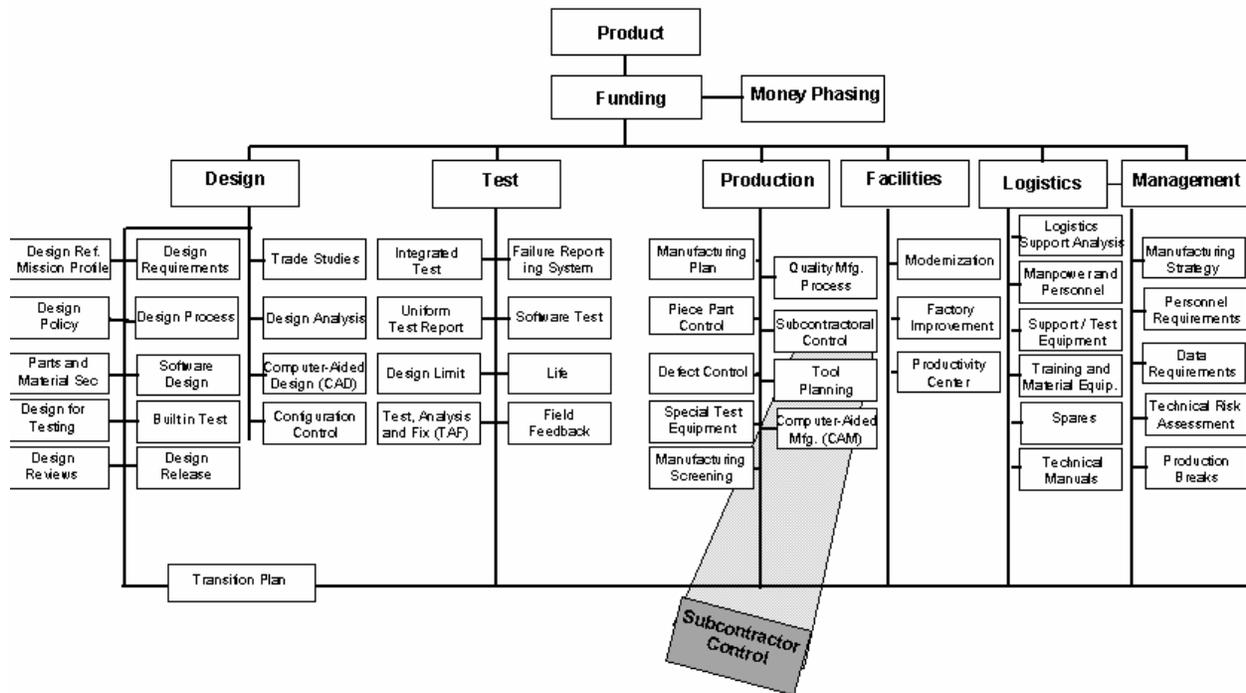
- Performing destructive physical analysis (DPA) at the user's facility also can detect faulty parts, can verify suppliers' processes, and is a good adjunct to the rescreening program.
- Small users can use an independent test laboratory to conduct rescreening if they lack the necessary test equipment. Costs to conduct this screening are similar to those quoted above.
- Receiving inspection and rescreening exert contractual leverage on part suppliers to improve overafl quality of the product and ultimately to reduce the cost of parts to the user.
- Pretin component leads and conduct a solderability test at incoming inspection.
- Piece part control includes provisions for screening of parts (especially mechanical and electrical components, as well as electronic devices), to ensure proper identification and use of standard items already in the Military Service logistics system.

## **Timeline**



A key element of parts control is an established policy that ensures that certain steps are taken early in the buildup of the first hardware items to control part quality (both electrical and mechanical).

**E. -- Subcontractor Control**



## Area of Risk

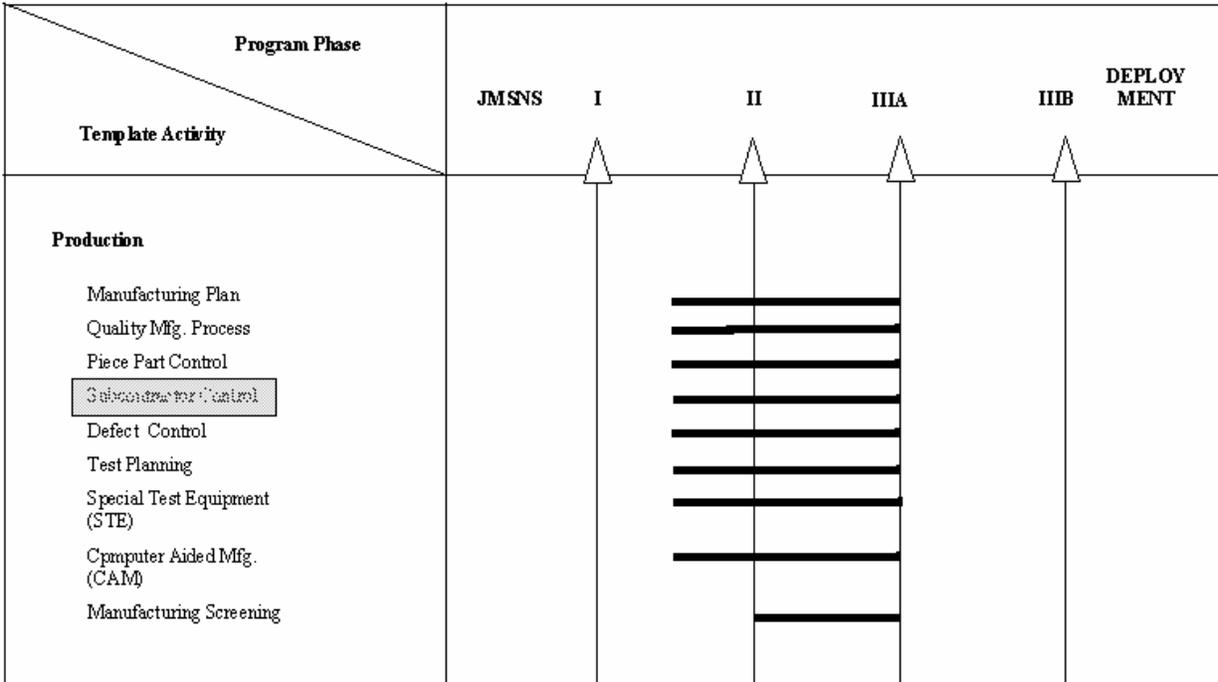
Over the years, the percentage of major weapon systems that are subcontracted has grown, reaching as much as 80 percent in some cases. Hence, reliance on subcontractors and upon the skills of prime contractors to manage their subcontractors and suppliers has increased. An informal poll of ten prime contractors averaging about ten major programs each resulted in statements that nearly half their programs were in schedule or cost trouble because of major subcontractor problems. Clearly, the effective management of subcontractors needs more emphasis within industry and in the Government's management of prime contractors if there is to be a smooth transition to production.

## Outline for Reducing Risk

- Request for proposals (RFPs) for prime contractors require responses from bidders with equitable emphasis on subcontractor management planning versus in-house management. Responses include the following:
  - Prime contractor's organization for managing subcontractors. .
  - Plans for onsite evaluation of potential subcontractors before source selection.
  - Tasks and associated payment plans to ensure that required up-front subcontractor activities are visible.
  - Plans for program reviews, vendor audits, and production readiness reviews.

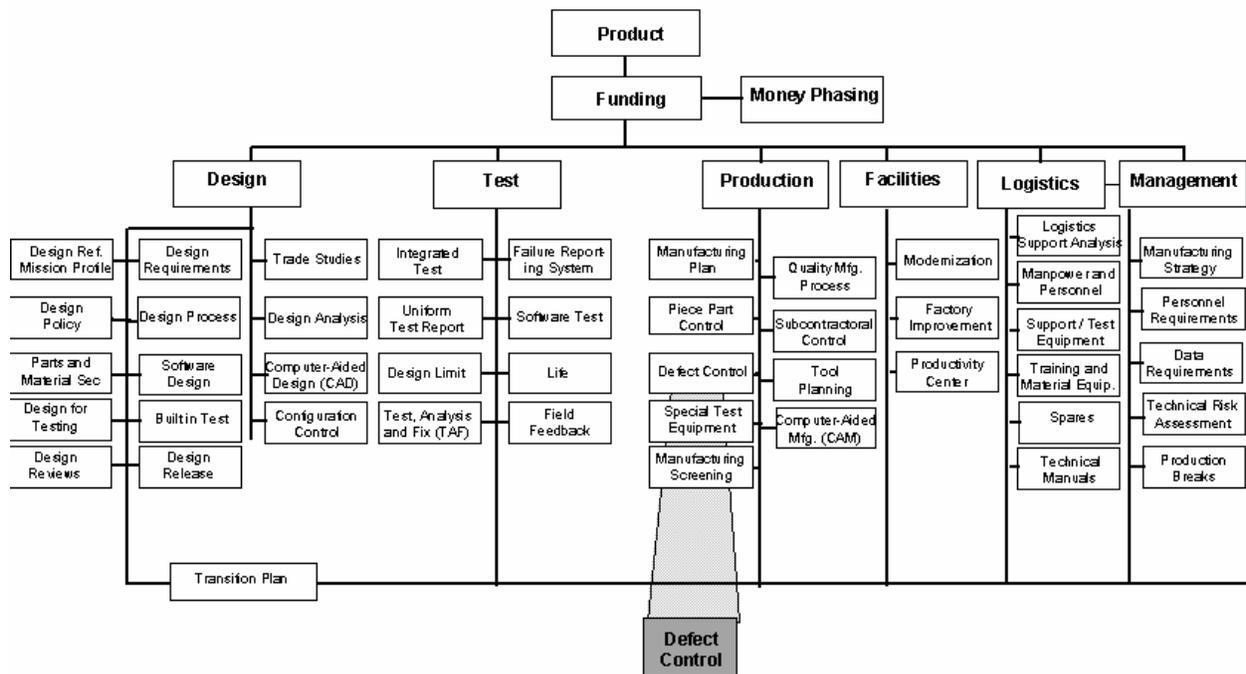
- Military program managers and prime contractors conduct vendor conferences that address the following:
  - Educate each subcontractor thoroughly on the requirements in his or her contract, as well as the key elements of the prime contract.
  - Communicate to the subcontractors what is required of them.
  - Provide an awareness of their role in the total weapon system acquisition.
  - Allocate resources to do the job right.
  - Recognize and (when appropriate) reward good performance.
- prime contractors establish resident interface at critical subcontractors before production start.
- prime contractors maintain a roster of “subcontractor assist” personnel for surprise problems.
- Budget for both resident and “subcontractor assist” teams to be available on demand with well-qualified technical, process, manufacturing, and procurement people.
- Proper funding is committed to conduct the above guidelines during the early design phases, to ensure adequate support to procurement. An estimate for an 80 percent subcontracted’ program amounts to 3 to 4 percent of full-scale engineering development costs.

## **Timeline**



Informal and formal program reviews are an essential ingredient of effective subcontractor control during the development process. The prime contractor shall, on a regular basis, evaluate the “real” progress made by the subcontractor through such reviews.

### F. -- Defect Control



## Area of Risk

High defect rates in a manufacturing process drive up production costs because of higher rework and scrap costs. Product quality is a function of the variability of defects, that is, the higher the number of defect types, the lower the quality and vice versa. Lack of an effective defect information and tracking system not only increases production costs but also degrades the product's performance in the field.

## Outline for Reducing Risk

- Types of assembly defects are identified in terms of specific data categories and priorities for corrective action. (See figure 5-1., which applies to electronic parts. Similar figures are derived for other categories of component parts.)

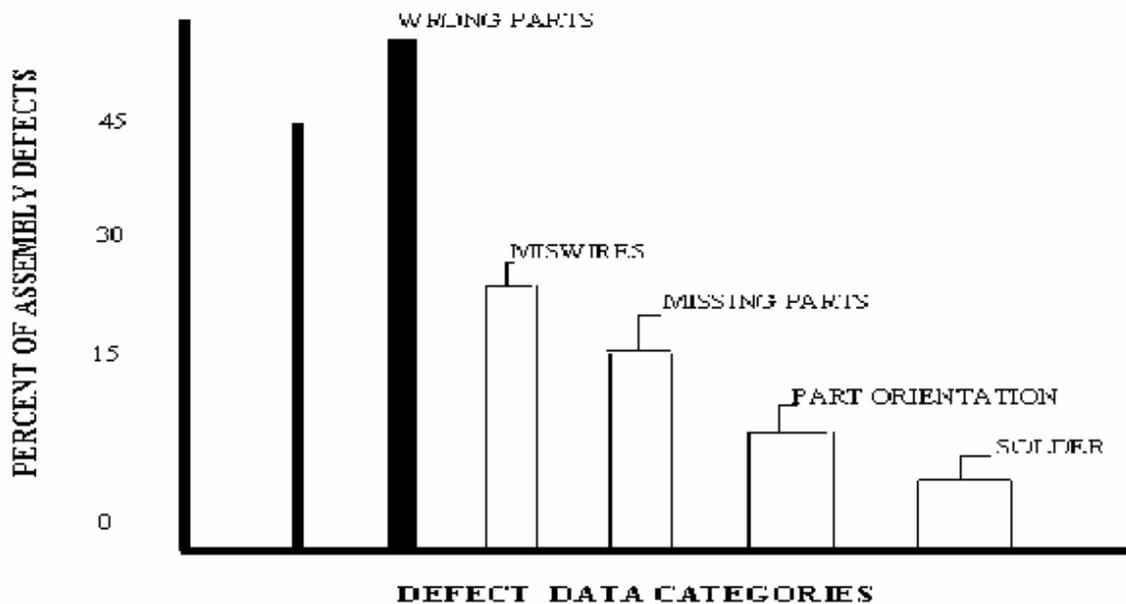


FIGURE 5-1. ASSEMBLY DEFECTS

Figure 5-1. -- Assembly Defects

- Effectiveness of a time-phased corrective action program is tracked (see figure 5-2)

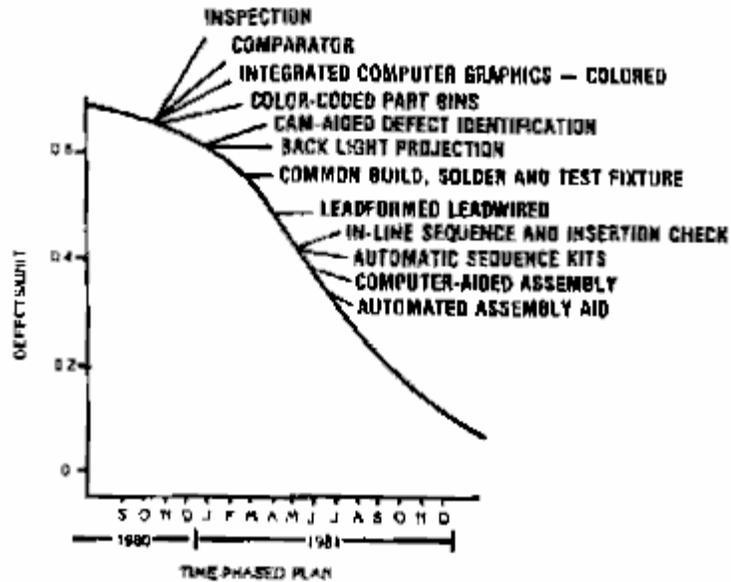


Figure 5-2. – Corrective Action Program

- Inspection and test yields and hardware throughputs are monitored continuously with predetermined action thresholds (see figure 5-3).

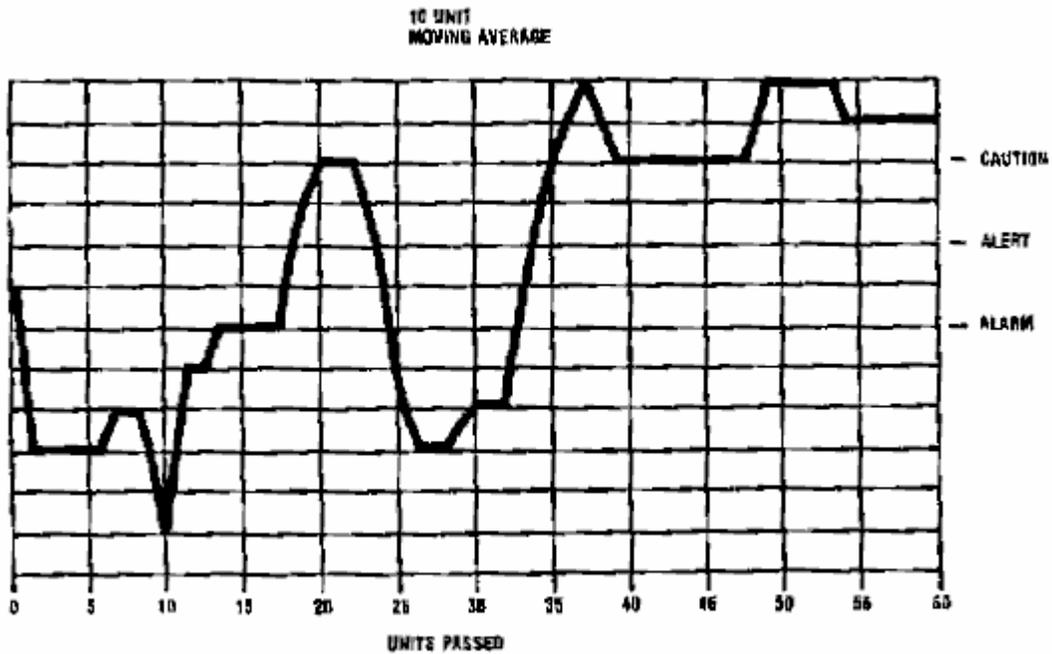


Figure 5-3. – Performance Threshold Tracking

- Caution threshold requires engineering action:
  - Seventy-two-hour maximum response time.

- Daily reporting to program management until caution thresholds are exceeded.
- Alert threshold requires functional-level management action:
  - Seventy-two-hour maximum response time.
  - Daily progress reports to program management until all thresholds are exceeded.
- Alarm threshold requires full-time team action:
  - Program manager constitutes team within 24 hours.
  - Action is implemented and reported to program management within 72 hours.
  - Daily reports to program management until thresholds are exceeded.
  - A feedback system to factory personnel and manufacturing supervisors is established.
- Factory policy adequately reflects the criticality of its defect information and tracking system.
- Critical Process yields are monitored and tracked to ensure consistency of performance (see-figure 5-4.)

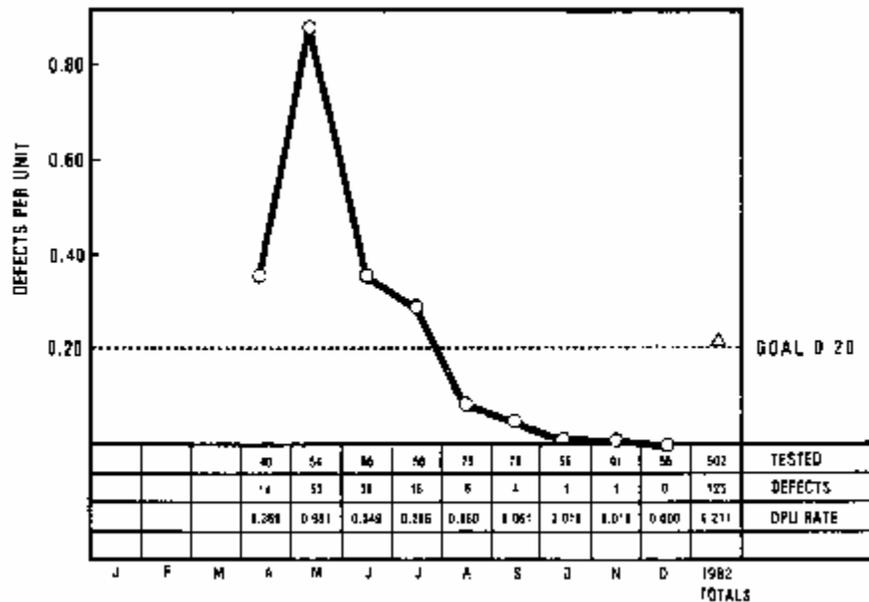
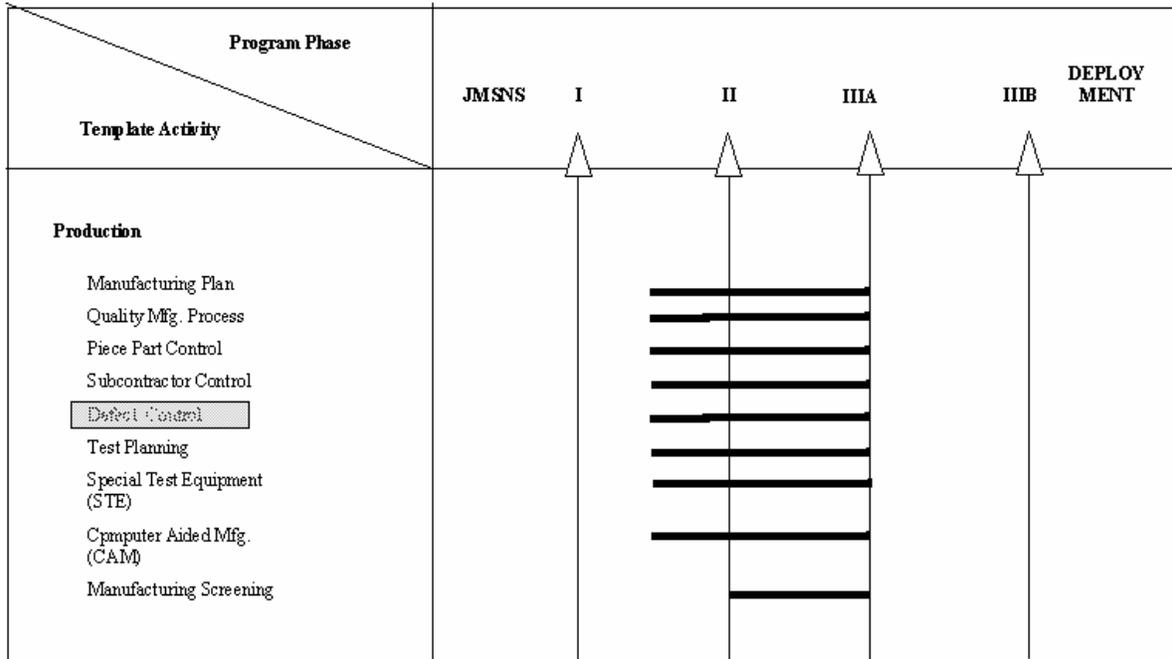


Figure 5-4. Production "Rate Test" Defects

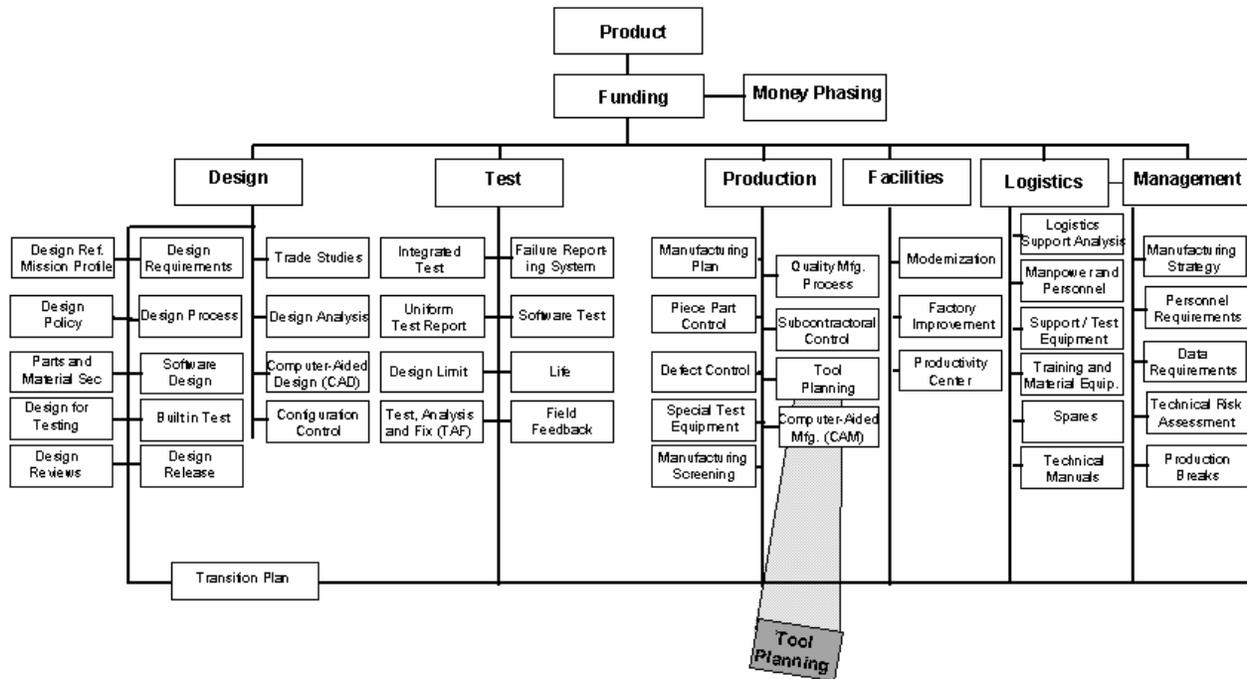
Figure 5-4. -- Production "Rate Test" Defects

### Timeline



A management commitment to defect “prevention” is the prime ingredient of a sound defect control program. A management policy on defect control is established during the development phase. This policy will require management involvement in the review of defect analyses and an emphasis on defect “prevention” that is flowed down to all subcontractors.

**G. -- Tool Planning**



## Area of Risk

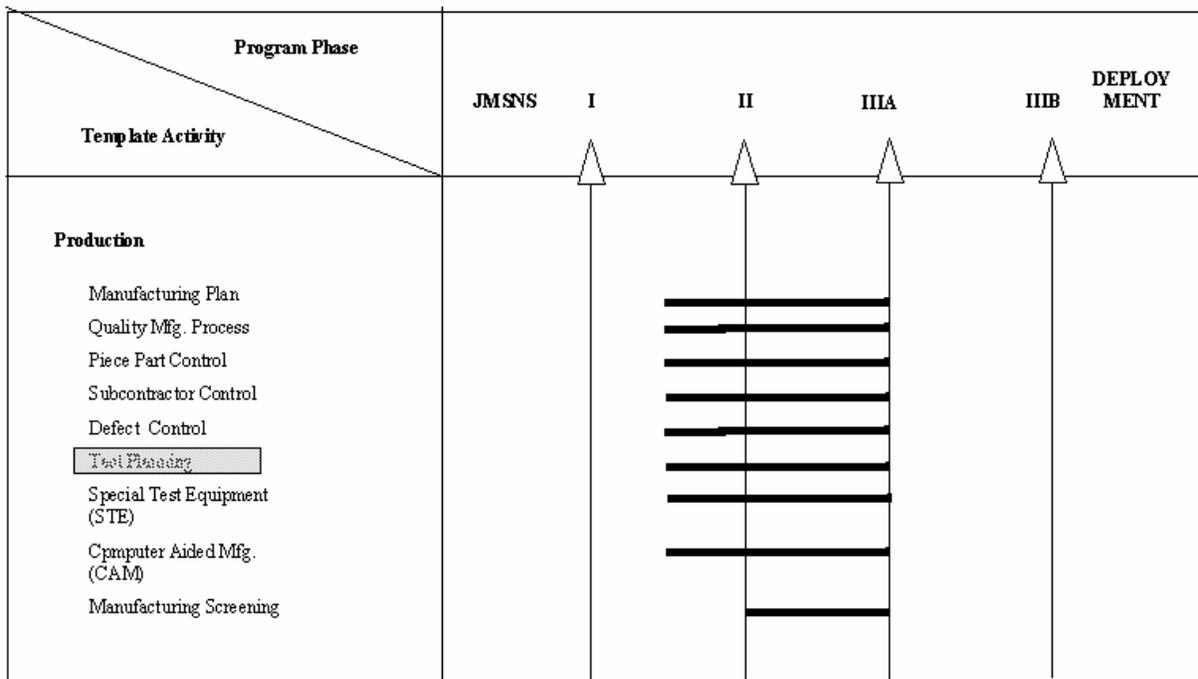
Tools are auxiliary devices and aids used to assist in the manufacturing and test processes. They range from special handling devices to ensure personnel and equipment safety, to equipment required for methods planning to achieve the designed quality, rate, and cost. The risks associated with improper tool planning and proofing affect cost, quality, and ability to meet schedules. Improper tools prevent workers from achieving desired production rates, fail to prevent or perhaps even contribute to errors in the build process, and cause more man-hours of labor to be expended in accomplishing a task than were planned.

## Outline for Reducing Risk

- A tooling philosophy is documented as a part of the early manufacturing planning process and concurrent with production design.
- A detailed tooling plan is developed that defines the types “hard” or “soft,” and quantities required for each manufacturing step and process.
- A requirement is included for a similar plan for each subcontractor and its implementation is disciplined.
- Each tool is proofed rigorously before its initiation into the manufacturing process to verify performance and compatibility with its specification.
- Strict tool configuration management is maintained.

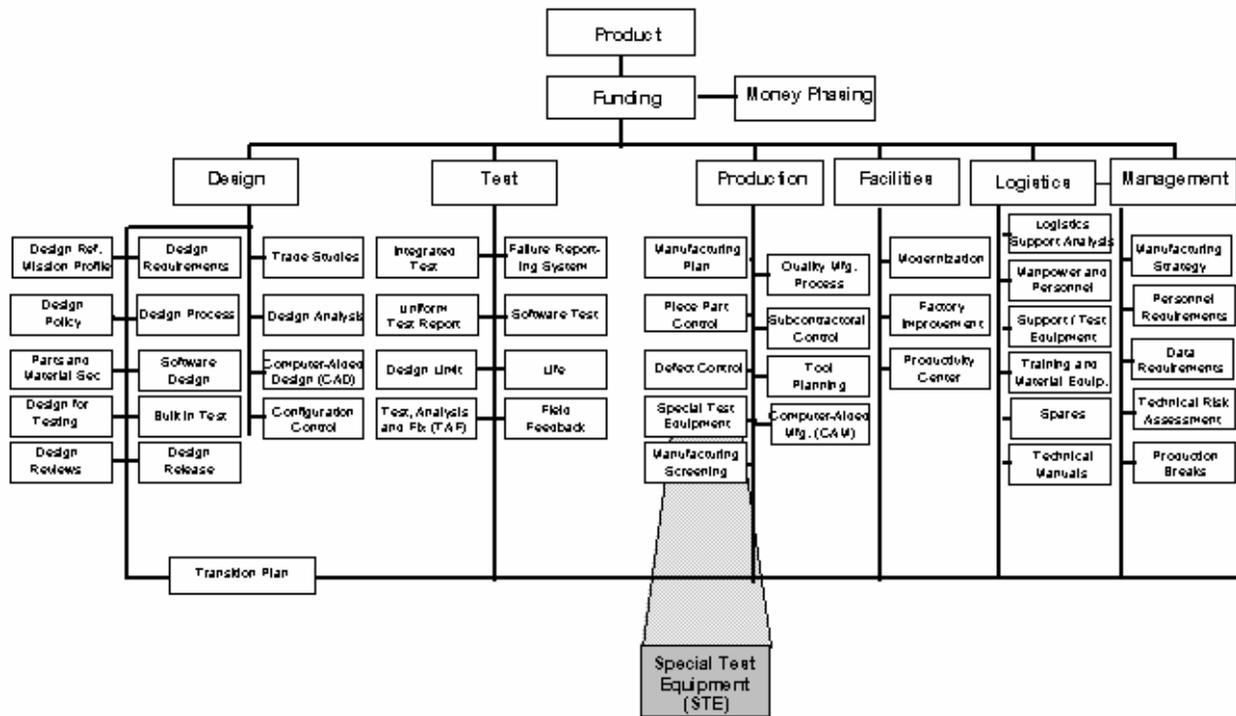
- An effective tooling inventory control system is established and maintained to facilitate continuous accountability and location control.
- A routine maintenance and calibration program is established and conducted to maintain tool serviceability.
- Manufacturing engineering and tool designers are collocated with design engineers when practical, and CAD/CAM systems are used in tool design and fabrication.

**Timeline**



Tool planning encompasses those activities associated with establishing a detailed comprehensive plan for the design, development, implementation, and certification of program tooling. Tool planning and design activities start early in the development phase.

**H. -- Special Test Equipment (STE)**



## Area of Risk

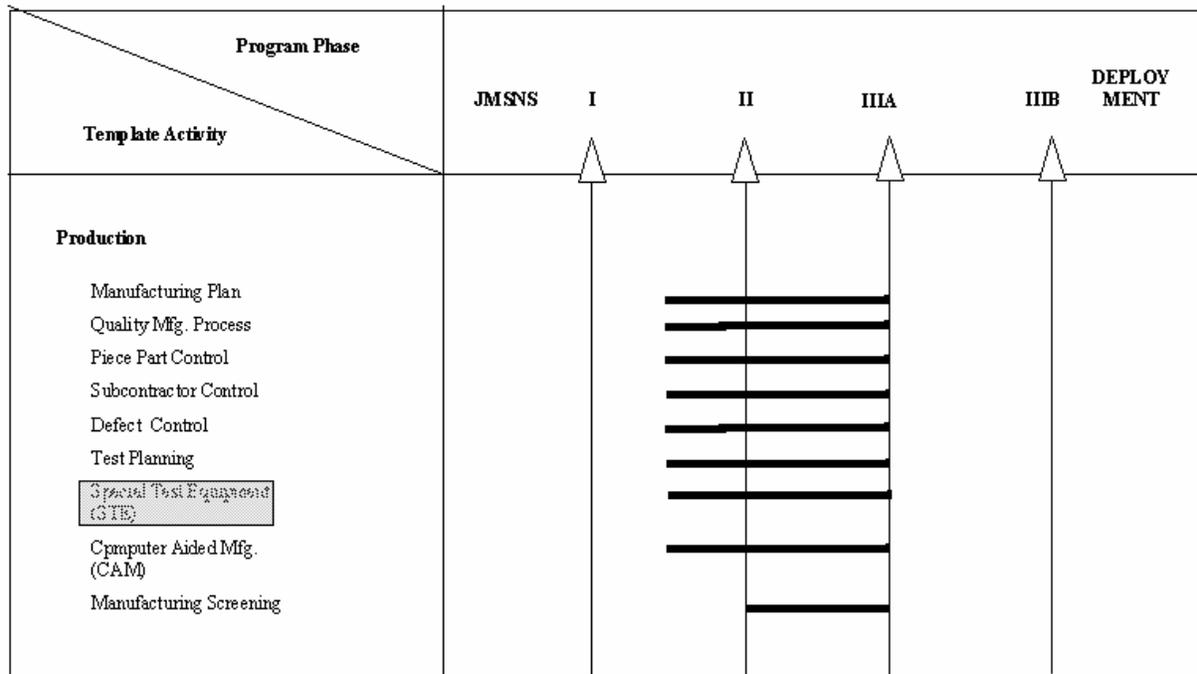
Special Test Equipment (STE) is a key element of the manufacturing process. It is STE that tests an article (or final product) for performance after it has completed in-process tests and inspections, final assembly, and final visual inspection. Late STE design activities and the lack of the availability of qualified STE on the factory floor create unique technical risks. These risks include inconsistent final test measurements (when compared to test procedures used during the successful development program), false alarm rates that result in needless troubleshooting and rework of production hardware, and poor tolerance funneling that causes either rejection of good hardware or the acceptance of hardware with inadequate performance. Program consequences in this situation are schedule delays, increased unit costs, and poor field performance of delivered hardware.

## Outline for Risk Reduction

- A thorough factory test plan is developed before detailed design of prime equipment.
- Adequate prime equipment designer input and concurrence on test requirements and test approach is required.
- Test equipment engineers and maintainability engineers participate in prime equipment design and partitioning, test point selection, built-in test design, and design for test and maintenance as well as function.
- Prime and STE systems design personnel are collocated when practical.

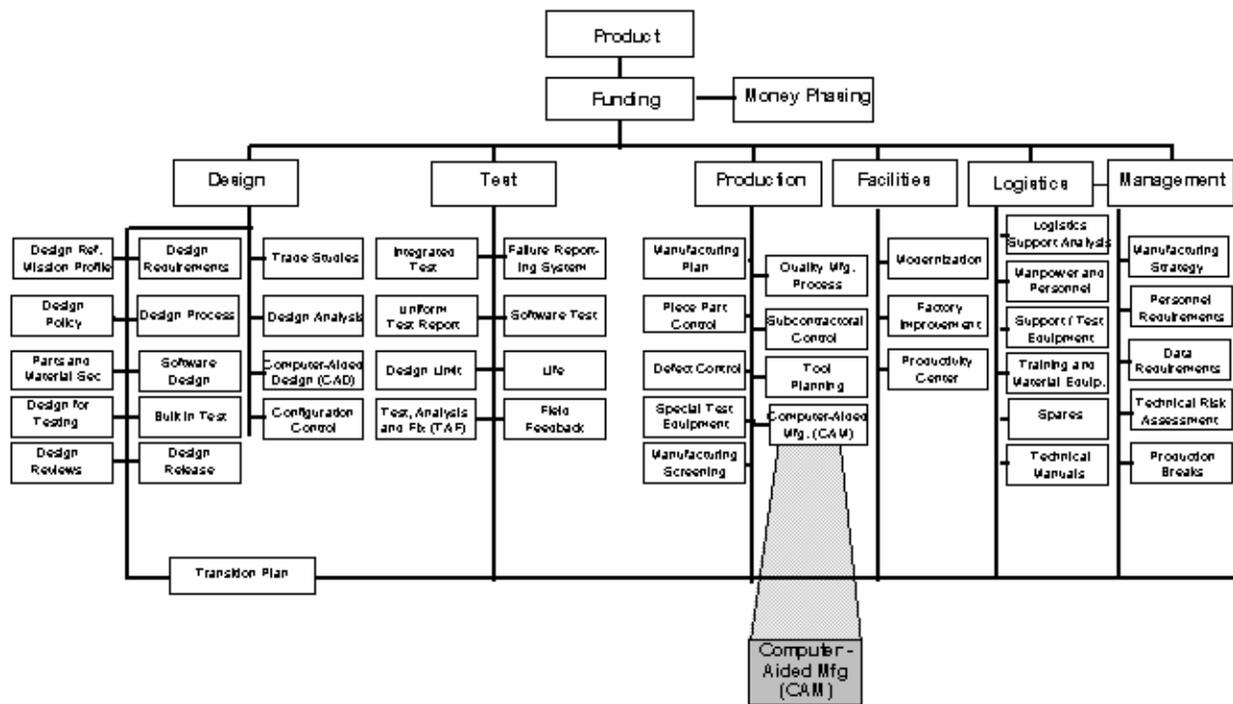
- The test approach for completeness of test is analyzed, and a feedback loop to correct test escapes is provided.
- Test tolerance strategy is employed to catch problems at the lowest level, but does not cause excessive rejection of an adequate product. Tolerance incompatibility with higher-level test is corrected.
- The capabilities of the prime equipment are understood and utilized fully to achieve simplifications in STE.
- Design strategies are used in test equipment that simplify tolerance changes and enable tests to be readily added and deleted. “Go/no go” tests are minimized.
- Manual intervention capability is provided in automated test equipment so that the equipment can be used while final software debugging is in process (this also can aid in debugging).
- Brassboard prime equipment is used, when appropriate, to begin debugging test equipment (this can enhance test equipment schedules).
- Prime equipment design personnel are assigned’ as part of the test equipment integration and verification effort.
- Adequate time is allotted for test equipment software debugging and compatibility verification.
- Government certification of factory test equipment is required, as well as re-certification if significant product and test equipment changes occur.
- A thorough and realistic rate analysis is performed to avoid shortages of test equipment (or overbuying). Considered in this analysis are the number of expected failures in prime and test equipment in various phases of the program, and equipment requirements to support qualification test, TAAF, engineering problem-solving, and overhaul and repair.
- Automated test techniques are used when rate requirements on the program warrant the investment.

## **Timeline**



STE should be designed, qualified, and used as early as possible to ensure a uniform final product test from development through production transition. The STE design should commence during the late phases of advanced development (that is, before Milestone II) and STE should be qualified before rate production.

### **I. -- Computer-Aided Manufacturing (CAM)**



## Area of Risk

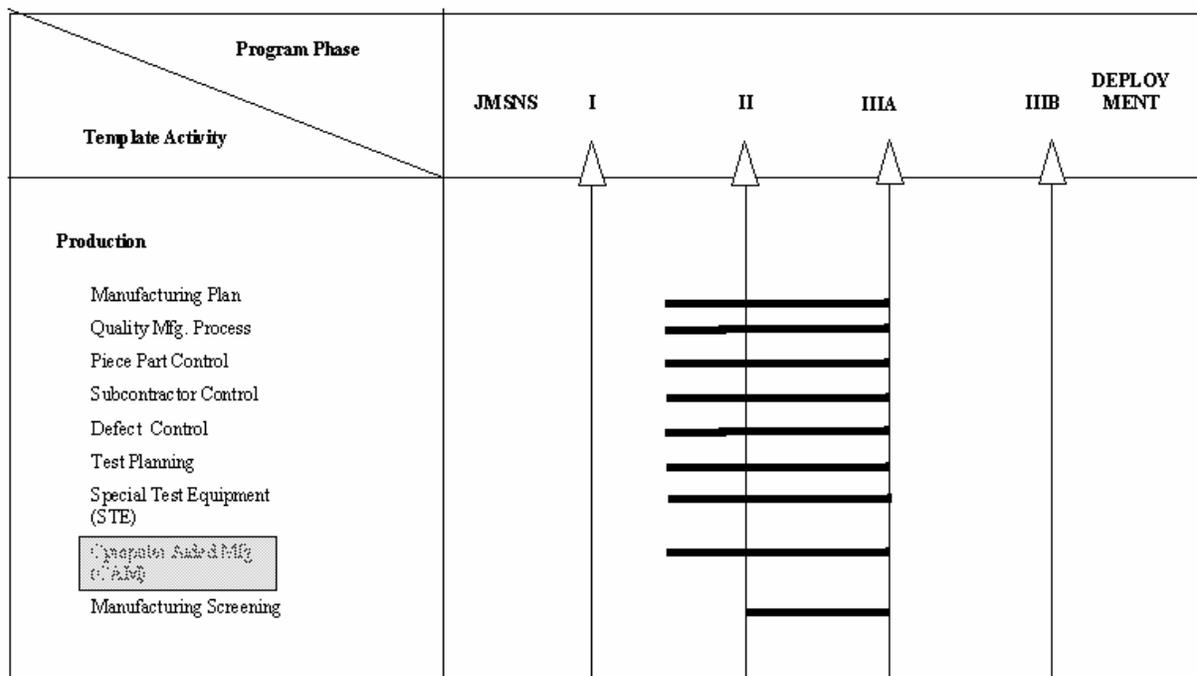
The transition of a qualified design to the manufacturing process historically has been accomplished via a “drawing package,” including not only drawings but also a large number of related documents, truly a massive amount of paperwork. Generation of this paper lengthens the period of transition, impedes rapid and accurate communication between the design and manufacturing functions during this highly volatile period, and introduces numerous errors via the drawing package. Even some facilities that have invested heavily in CAD continue to transfer their designs to the factory on paper. Once the drawing package is available, many production facilities continue to utilize outdated high risk manual operations both to duplicate the design (“build to print”) in rate production and to manage the manufacturing process.

## Outline for Reducing Risk

- The development of software tools for common use by industry is supported by the Department of Defense with appropriate resources and coordination efforts.
- A common data base between the design and manufacturing functions has inherent technical problems but has the highest potential payoff in product quality and productivity.
- Implementing automated manufacturing and control functions can reduce transition time by 50 percent.

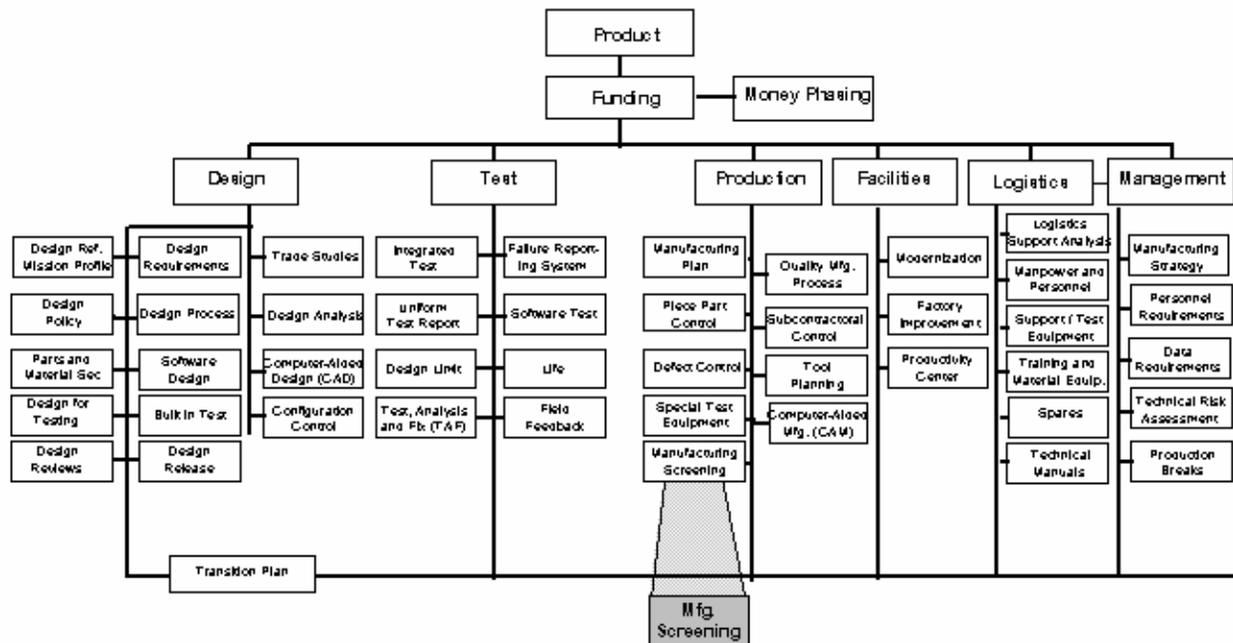
- Using computers to control manufacturing operations (fabrication, assembly, test, and inspection) and to collect shop floor data can increase productivity, can reduce required shop floor space, and can improve product quality.
- Use of computers to control material flow and maintain inventory and in-process data significantly reduces inventory investments and storage space.
- Tooling redesign occurs when product design changes. Using CAD reduces these design iterations. Therefore, using CAD for the product design and the additional use of CAD for tool design can reduce tooling costs by 50 percent.
- Top-down strategy for implementing CAM usually increases return on investment (as opposed to replacing in-kind capability, or bottom-up).
- Training and retraining plans to maintain employee morale and productivity are included in a company's strategy.
- See template on CAD.

### Timeline



Contractors using CAM integrated with CAD are experiencing improved productivity. With manufacturing personnel involved in the design process, a common CAD/CAM data base can be established resulting in reduced risk in the transition from development to production.

### J. -- Manufacturing Screening



## Area of Risk

Environmental stress screening (ESS) is a manufacturing process for stimulating parts and workmanship defects in electronic assemblies and units. Although ESS has been proven to reduce field failure rates by 20 to 90 percent (reducing life cycle costs) and to reduce in-plant failure rates by as much as 75 percent (reducing production costs), its use is still not accepted universally by many contractors as a standard part of their manufacturing process. When ESS also is performed during development, it helps to ensure that the electronics hardware performs on demand, that the most effective screening levels are determined before high rate production, and that possible part type and vendor problems are discovered early. Analysis of failures experienced on unscreened developmental systems has indicated that 60 percent are due to workmanship, 30 percent are due to bad parts, and only 10 percent are design problems. ESS should not be confused with environmental qualification testing (which is designed to demonstrate design maturity).

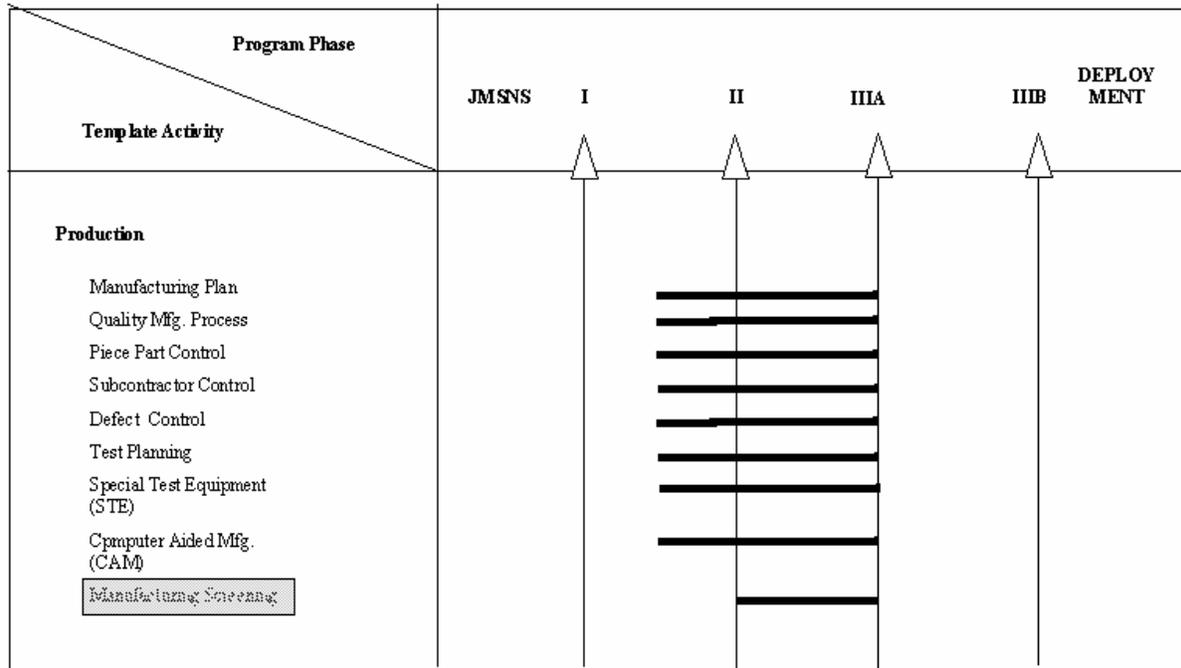
## Outline for Reducing Risk

- ESS procedures are established during development.
- Temperature cycling and random vibration are effective” environmental stress screens and are performed on 100 percent of electronic products (it is not done on a sampling basis).
- The predominant factors in temperature cycling are:
  - Rate of change of temperature.
  - Minimum and maximum range of temperature.

- Number of cycles.
- Level of assembly on which performed.
- The predominant factors in random vibration are:
  - Spectral density.
  - Lower and upper frequency limits.
  - Axis of stimulation.
  - Level of assembly.
  - Duration of screen.
- Random vibration stimulates more defects than fixed or swept sine vibration of similar levels of excitation.
- There are many technical and cost benefit tradeoffs to be made in designing an ESS program. A particularly useful document in making tradeoff decisions is the Environmental Stress Screening Guidelines for Assemblies. 1 A screening guidelines document for parts will be published by the IES in late 1985.
- Recommended starting conditions are:
  - Random Vibration
    - Spectral density: 6g rms
    - Frequency limits: 100-1000Hz 1
    - Axis: 3
    - Duration: 10 min.
  - Temperature Cycling:
    - Rate: 10° C/minute
    - Range: – 40° C to 60\* C
    - Number of cycles: 15 (last must be failure free)
    - Power: On (except cool down)
- For greatest return on investment, vigorous corrective actions are made to' adjust manufacturing process to minimize recurrence of defects.
- The ESS program is a dynamic one. Procedures are adjusted, as indicated by screening results, to maximize finding defects efficiently.
- Objective of ESS is not to find design defects, although such may be a by-product.

- Appropriate screening for manufacturing defects, as an acceptance test, is developed electrical and electronic products.

## Timeline



ESS techniques precipitate assembly and workmanship defects, such as poor soldering or weak wire bonds during the assembly process.

*Note:* Sponsored by the Institute of Environmental Sciences (IES), September 1984.

Next Section