# PARTS ON DEMAND

## EVALUATION OF APPROACHES TO ACHIEVE FLEXIBLE MANUFACTURING SYSTEMS FOR NAVY PARTS ON DEMAND

### VOLUME I



**SCIENCE APPLICATIONS, INC.**

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## EVALUATION OF APPROACHES TO ACHIEVE FLEXIBLE MANUFACTURING SYSTEMS FOR NAVY PARTS ON DEMAND

## VOLUME I

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## EXECUTIVE SUMMARY

### Background

Procurement of spare parts for critical U.S. Navy weapons systems has become a cost and readiness driver because the manufacturing base to support their production has silently eroded. However, advanced manufacturing technology capabilities can be exploited to restore and vitalize spare parts production. These are the main findings that come from a nine-month's study which assessed the magnitude of the spare parts supply problem and the potential benefits to be derived from developing new methods for manufacturing replacement parts only when and if needed.

The scope of this study, sponsored by the Office of Naval Research and the Naval Supply Systems Command, focused on reducing spare part supply and procurement problems by using a "Parts-on-Demand" (POD) system that was defined by the study in these terms: "a concept using advanced manufacturing technology to produce parts as needed and to reduce cost and production lead time in small batch production." The solution approach is based on using advanced manufacturing technologies capable of reducing cost and production lead time for low volume manufacturing. A major national program, using the concept of POD, is recommended to advance design, fabrication, test, and assembly technology for low volume production.

The Navy POD program objectives were developed to foster a transition to very flexible manufacturing by encouraging both changes 1) in vendor's manufacturing technology to support low volume production and 2) in military supply system policy and practices to more effectively employ its benefits. The emphasis of this study was on the technological issues involved and the role the Navy can play in stimulating research and development needed to advance manufacturing technology to support flexible manufacturing systems to produce low volume replenishment parts. POD, however, is not to be imagined as a stand-alone system and will certainly not work in isolation. It must be gradually integrated into the current supply and procurement system, and modifications in policy and practice will be required for its effective implementation.

## Study Results

During the conduct of this study the state of the art in manufacturing technology was assessed to determine the extent to which the industrial base and commercial flexible manufacturing systems (FMS) could economically handle military specific requirements for a wide range of spares and replacement parts. It was found that current systems are not designed for the low volume of spares needed over the extended lifetime of weapon systems in peacetime nor are they capable of fabricating small quantities of parts in a short time for reasonable cost for surge/mobilization requirements. Diminishing sources of supply, long lead times and increasing procurement and holding costs for spares and parts are elements which contribute to the Navy problem. Four generic manufacturing areas for development were included in the study to provide a comprehensive solution: machined parts production, electronic products, near net shape formation, and precision assembly tasks.

The proof of principle for one aspect of parts on demand was developed under this project with data from the National Bureau of Standards. NBS demonstrated the capabilities of an adaptive machining cell to produce mechanical parts at their Automated Manufacturing Research Facility (AMRF). The demonstration compared costs and production times for different technologies to produce an oil flinger, a critical part needed by the Battleship Modernization Program. Similar demonstrations are recommended to provide empirical data about state of the art in advanced forming, processing and assembly technologies for mechanical, electrical and electronic parts needed to support military weapon systems.

## Major Findings and Conclusions

The study effort forms the basis for a major comprehensive program with the objective to improve spare parts availability with commuensurate enhancement of cost and readiness posture of military systems. The payoff comes from a progressive strengthening of the U.S. industrial base and a proliferation of U.S. capability in low volume batch manufacturing.

The major findings of the study were twofold:

- Determination of the dimensions of the problem which is needed to bound the program recommendations

- Determination of the POD impact potential and adaptation of commercial manufacturing technology required to address the supply problem areas

- Specific findings of the study effort show the dimensions of the problem to be large and costly.

The logistics issues addressed in this study derive from part availability needed to support lifetime requirements and sustain weapon systems for ships and aircraft in the Fleet. Long lead times, diminshed sources of supply, and out-of-production systems have resulted in increasing holding and procurement costs and a large stagnant inventory.

On the basis of data analyzed in this study, it was calculated that over 65% of the spare part inventory stagnent. The value of the inventory is about $10 billion of which about $7.5 billion is for insurance items and about $6.6 billion represents dormant parts, 8% of which have not been ordered in years. The Navy holding costs are calcuated at $2 billion yearly. The annual procurement costs, based on Federal Budget Trends itemized in FY84 Annual Report to Congress, is $3.5 billion for the Navy and $15 billion for DoD. The line items of interest to the POD program include about 61% mechanical parts, 25% electrical parts and 14% electronics. ASO alone manages 240,000 parts, of which about half are in the Mark 0 category which is most likely to contain POD candidate parts. In addition, there is likely to be 10 times that many items in an airplane that do not have stock numbers and do not get counted in the 240,000. (See Reference 1 for details of logistic cost estimates.)

- Pod Impact Potential Ascertained.

A key finding of this study was the determination of potential benefits to be derived from developing advanced methods for manufacturing parts when needed. The

Navy can play a major role in stimulating R&D needed to advance manufacturing technology and to support the development of flexible manufacturing systems to produce low volume replenishment parts. Commercial operations are not designed for the low volume of spares needed over the extended lifetime of weapon systems nor are they capable of fabricating small quantities of parts in a short time for reasonable cost to meet surge/mobilization requirements. The POD program is designed to improve manufacturing capabilities, support R&D to transform the technology into viable working systems needed to sustain military operations, and provide an impetus for advancing industrial productivity in general. The penalties paid by the military for out-of-production items and critical low volume spares and replacement parts will be reduced and the production flexibility of the industrial base will be increased if automated technology is pushed to provide the needed capability.

Even if each workpiece going through the system is unique, a POD system can be designed to use the same equipment for different tasks and to change quickly from one operation to another. This will require, however, using advanced microcomputer technology and machine interface hardware with high level language software. It will further require the dvelopment of a comprehensive manufacturing database where part specifications are stored and recalled as needed as well as providing for input requirements to be automatically checked against available machine capacity and operating limits. Sophisticated sensors and control logic will also be needed to maintain machine reliability and part specification accuracy.

**Recommendations**

A successful POD Program is dependent upon acceleration of efforts and an ongoing commitment to a long term effort. Implementation of the following recommendations requires the development of a program plan with well defined decision points.

(1) It is recommended that the major tasks identified in the implementation plan for mechanical and electronics projects be funded for FY84 and FY85. The proof of principle for parts on demand needs to be demonstrated on a

wider test basis and current requirements for out-of-production parts and obsolete integrated circuits necessitate the immediate development of POD systems. The pilot manufacturing programs developed by this study will provide a wedge for efficient POD Program development and are summarized in Figures 32 and 33 of this report.

(2) Development efforts in Parts-on-Demand requires the integration of a broad spectrum of technologies. A consortium of universities, industry, and government needs to be established and R&D efforts focused on POD objectives. It is recommended that the U.S. Navy play a key role in putting this team together.

(3) A major national program is justified not only on basis of immediate gain to the military community, but in its spin-off to the economy as a whole. It is recommended that key projects and initiatives which support generic enabling technologies such as generative process planning be started at once. The survey made by this study identifed eight specific technologies that need to be developed to attain the economies and flexibility needed by POD for low volume, small batch operations. Other key technologies include expert systems, sensor/system integration, smart material handling, machine fixturing, inspection systems, tool control and near net shape techniques.

(4) Technology transfer to second and lower tier industries is an essential step that needs to be accomplished in order to exploit the successes of the POD program. These tiers have been neglected in the past and are the areas where the silent erosion has been most costly. It is recommended that immediate technology transfer actions and plans be implemented to strengthen this segment of the industrial base.

The recommendations of this study are based on a recognition of the magnitude of the spare parts problem and its solution through POD. A long range development program will be required to effectively deal with the current supply problems and the development of new technology to improve batch manufacturing. The technology alternatives and risks need to be quantified and validated through technology and economic demonstrations designed to analyze cost impacts and benefits. An active technology transfer program such as that proposed by NBS to utilize high impact manufacturing improvement opportunities (HIMIO) will be an important interface to stimulate POD applications.

## INTRODUCTION

Under Modification P000001 to contract N00014-82-C-0845, Science Applications, Inc. (SAI) performed a comprehensive evaluation of approaches to achieve flexible manufacturing systems for the Navy Parts on Demand (POD) Program. SAI responsibilities under this contract were to perform six related tasks and provide a final report documenting their findings. The six tasks covered the following areas:

- Project planning and definition
- Survey and analysis of Navy parts
- Survey and analysis of manufacturing technologies
- Economic and operations analysis
- Long range R&D planning recommendations
- Near term implementation plans

These tasks required the development of a project work plan to focus efforts; the establishment of selection criteria to identify POD parts; an assessment of key technologies to support POD system development; the identification of candidate support organizations and centers of excellence capable of advancing automated technology; an analysis of the current logistics supply system; the development of an R&D investment strategy and approach for long-range R&D planning; and the recommendation of near-term implementation plans.

In discharging these responsibilities SAI drew on its industrial and government contract and staff expertise in the areas of Navy supply systems, economic and operations analysis, and advanced manufacturing technologies/systems and programmable automation equipment. The major project objective was the development of R&D plans to improve future logistics system capability to produce low volume spares and replacement parts to meet peacetime readiness and wartime sustainability requirements. The goal was focused on how the Naval Supply Systems Command could best use state of the art and ongoing research efforts of industry, Navy facilities, universities and non-profit R&D centers to advance the technology. This report is the documentation of these efforts. It includes a definition of the problem and a summation of study results by project task. The appendicies contain details of activities covered by various tasks of the project as outlined in the project workplan as well as additional deliverables which were requested by the client to accelerate efforts and to focus attention on the investment strategy and funding justifications for the NAVSUP Porgram. These specific deliverables included detailed program plans and inputs for POM 86 and were considered within the scope of effort for the project but required a reallocation of resources so as not to exceed the level of effort planned for performance of work under this contract.

The major deliverables produced by this project include the following items:

- Project Workplan
- POD Parts Selection Criteria
- Assessment of State-of-the-Art Capabilities
- Survey of Candidate Centers of Excellence
- Methodology for Selection and Economic Analysis
- Analysis of Cost Benefits
- Selection Criteria for POD Investment Analysis
- Recommended POD Projects for Navy Logistics R&D Program Plan
- POA&M Draft and Conceptual POD Program Network
- Preliminary Dictionary Sort for POD System Planning Schedule
- Near-term Implementation Recommendations for Mechanical and Electronic POD Programs

## PROBLEM DEFINITION

This portion of the report discusses the background to the study effort and the approach used to meld existing and evolving technologies with current and projected supply system practices.

### Spare Parts Are Recognized as an Increasingly Costly and Readiness Critical Element

All branches of the U.S. military are reporting increased problems with the availability and costs of spare parts. Peacetime readiness and wartime sustainability are seriously impacted by the availability of spare parts to support weapon systems. Part availability is aggravated when weapons systems use is extended beyond predicted life cycle and replenishment parts to support these systems are no longer in production. The need for an accelerated program of logistics R&D and for new initiatives and improved practices in spare parts procurement is being stressed at the highest levels of the Department of Defense.[2]

### Diminished Sources and Changing Technology Impact Spare Part Availability

A major portion of part unavailability can be attributed to the diminished industrial base in this country, particularly in the lower tier industries.[3] Materials, machines, and processing methods have changed, been replaced or improved and frequently the original vendor no longer exists, particularly for mechanical and electro-mechanical parts that support weapon systems procured in the 1940's, 50's and 60's.

Part unavailability also results from the rapid pace of technology, particularly in electronics. In the integrated circuit (IC) area, the technology advances so rapidly that many ICs are abandoned and replaced by new, higher technology ICs long before the full potential of the old design has been reached. Since DoD now provides only about 4 percent of the microelectronics market, it, consequently, has much less market clout than previously. Significant supply problems also exist in such areas as casting, forgings, electrical connectors, and precision metal parts--items used in almost all weapon systems.

**Present Naval Supply System Practices Concentrate on Holding Large Inventories of Spare Parts**

Faced with the problem of spare parts unavailability, the Services have bought items determined to be critical either as a deliberate action, or, when the end of production is announced by the vendor, with a buyout for insurance purposes. Unfortunately, since the government has little leverage with these low volume purchases, this drives up both procurement and holding costs. Many vendors are no longer willing to serve this market, preferring instead the higher volume civilian sector. If a vendor can be found to produce the item, the unit cost per part is very high.

In a recent survey of 15,000 frequently purchased spare parts, the Pentagon's Inspector General found that prices on 65 percent of the items surveyed had increased at least 50 percent between 1980 and 1982.[4] About 75 percent of the parts held in inventory are insurance items, and only about 15 to 20 percent of these items are ever needed.

Total inventory value of parts identified as relevant to this study amounts to about $10 billion for the Navy. DoD expenditures for spare parts is estimated at $15 billion every year, and within the Navy, about $3.5 billion is spent annually. Further, it requires approximately 20 percent of the acquisition cost to hold items in inventory each year.

**A Technology Approach to Problem Solution Is Now Available Through Evolving Manufacturing Advances**

At the same time that an awareness of the logistics problems is taking place, modern manufacturing systems are evolving and increasingly giving attention to low volume production, lines that produce less than 10,000 parts per year. Automated procedures have traditionally focused on mass production to achieve economies of scale, sacrificing flexibility for volume. The military concern, however, is with the flexible systems that can produce small lots, variable batches, or even one-of-a-kind runs, lines capable of being easily redirected and not tied to hard automation, dedicated machines, or high volume production.

The evolution of flexible manufacturing systems has progressed in fairly well defined increments over the past few decades. Conventional machine tools were operated manually up to the time of Henry Ford when the focus of industry turned to developing mass production technology to take advantage of relative cost differentials and economies of scale based on increasing the production rate. Mechanical automation and dedicated machines were developed and used effectively for high-volume lines with few model changes. The advantages of hard automation increase as production rate, model inflexibility and production simplicity go up. Expensive machines are amortized over the life of production, usually many years.

In the late 1960's soft automation was introduced which added flexibility and capability to penetrate the economies of scale at lower production rates. This is still a form of mechanical automation, but uses numerical control (NC) or computers to give the mechanisms the ability to be retooled in the time it takes to change the instructions.

Robotics is a form of soft automation that uses the same concept of computer control rather than moving cams or mechanical stops. It introduces additional flexibility by using mechanisms capable of complex motion like the human arm and hand. Industrial robot systems and flexible manufacturing use machining centers with robots and machine tools working in cooperation. Other examples include robotic welding centers and light assembly equipment.

The focus in the 1980's is on systematic integration of computer-aided technology which capitalizes upon improved information handling and manufacturing processing capabilities. The use of computer-aided systems is a key area for developing a parts-on-demand system as is the use of group technology which provides economies based on the total number of parts produced, not on the individual production run size.

**POD Program Approach to Problem Solution Has Been Put Forward by the Navy as an Effective Response**

The Naval Supply Systems Command (NAVSUP) was assigned SYSCOM leadership responsibility in three key areas which address these problems. The scope of their charter has been expanded to include the leadership role in low-volume manufacturing, for Navy logistics R&D and IR&D, and for developing manufacturing technology in subcontractor and vendor tiers of the industrial base.

The Navy Parts-on-Demand Program was established to support the development of manufacturing systems to produce a constantly changing mix of parts using advanced flexible, low volume, automated manufacturing technology. Design and development aspects of POD systems will focus on Navy spare/replacement part requirements. Technology to be assessed includes hardware technology which improves metal removal and forming methods, assembly and inspection system advances, and software technology to improve selection criteria for assigning parts to fabrication systems, planning and scheduling methods, design (redesign, adapting, replicating, or simulating) techniques for creating and recreating parts, and economic analyses. The initial analysis indicates that the solution is equally weighted between managing information and creating new integrated manufacturing facilities to produce parts on demand. As such, the same issues are equally important in reducing procurement and holding costs as well as providing replacement parts as needed.

# POD TECHNICAL APPROACH
# BY PROJECT TASKS

This section of the report summarizes efforts and results achieved under this contract. It describes specific activities addressing parts on demand (POD) program definition, logistic issues and supply problems, state of the art in manufacturing technology, POD program risks and payoff assessments, and R&D plans, strategy, and recommended projects for POD program development.

## Task 0 - Program Definition

Program definition was based on a preliminary assessment of the state of the art in manufacturing technology particularly as it applies to programmable batch manufacturing and the spare parts supply problems. Initial activities focused on the development of a work plan to establish POD objectives and scope and to structure the technical approach for SAI project task activities. This resulted in both a refinement of the concept definition for parts on demand and program goals needed to develop future systems responsive to military requirements.

- **Participating Agencies Helped Focus POD Strategy**

Planning meetings involved input from numerous agencies since the supply problems being addressed are pervasive throughout the military community. Participants in this effort included over 25 Navy organizations and groups and 100 individual representatives. Key participants at these meetings came from ONR (contracting agency), NAVSUP (funding agency and project coordinator), CSDL (technical monitoring and oversight review), NBS (collaboration and advice), and SAI (prime contractor). Other contributors included OASD, NAVMAT, NAVSEA, NAVAIR, NAVELEX, DTNSRDC, ASO, SPCC, NRL, NSWC, NSRDC, NSES, NOSC, NAC, the Aegis Shipbuilding Project Management team, and the Battleship Modernization Project team.

The study objectives were established to develop both long-term R&D strategy and near-term implementation plans. The parts-on-demand concept is based on using advanced manufacturing technology to produce parts as needed. POD was defined to mean that for a required spare or repairable finished part, an advanced flexible manufacturing system would be capable of producing the part to specification within an established time frame. Discussions included functional and design specification goals, data base and timeframe requirements, and various POD systems to interface with the current procurement system as well as more diverse facilities that could handle the type of POD parts needed, which range from simple parts to complex assemblies.

- **POD Program Scope and Goals Derive from Near-Term Development Opportunities and Incremental Implementation Strategy**

Future POD systems will not only be using current technology more efficiently, but will be based on systems designed to extend the leading edge of technology derived from such successes as reducing inventory level by manufacturing parts "just in time". Three goals were established for the SAI project to assure that the POD program scope allowed a convergence of Navy needs and state of the art:

- Identify a select group of critical mechanical and electrical/electronic parts needed for repair or replacement within the Navy and select candidate parts for near-, medium-, and long-term projects.

- Match parts and technology based on readiness, performance and economic benefit to the Navy during both peacetime and surge periods.

- Recommend an R&D strategy and plans for near-term demonstration and implementation to catalize POD efforts and long-range plans for implementation decisions.

Th POD program plan that was developed is designed to use a broad technical approach because the sources of the problem are widespread. It is primarily based on the technology issues and applying appropriate commercial technology developments to logistics problems. Evolving computer-aided technologies, particularly in the information handling and manufacturing processing areas, have been identified for high payoff potential. The broad and incremental aspects of the recommended program are summarized below.

- Identify available commercial capabilities and developments appropriate for parts manufacturing, technology advances necessary to complement commercial developments, and appropriate interface with other government programs.

- Identify a set of early demonstration programs focusing on highest payoff areas and using adaptations of commercial capability.

- Identify non-technology changes and programs required to maximize value of POD program initiatives.

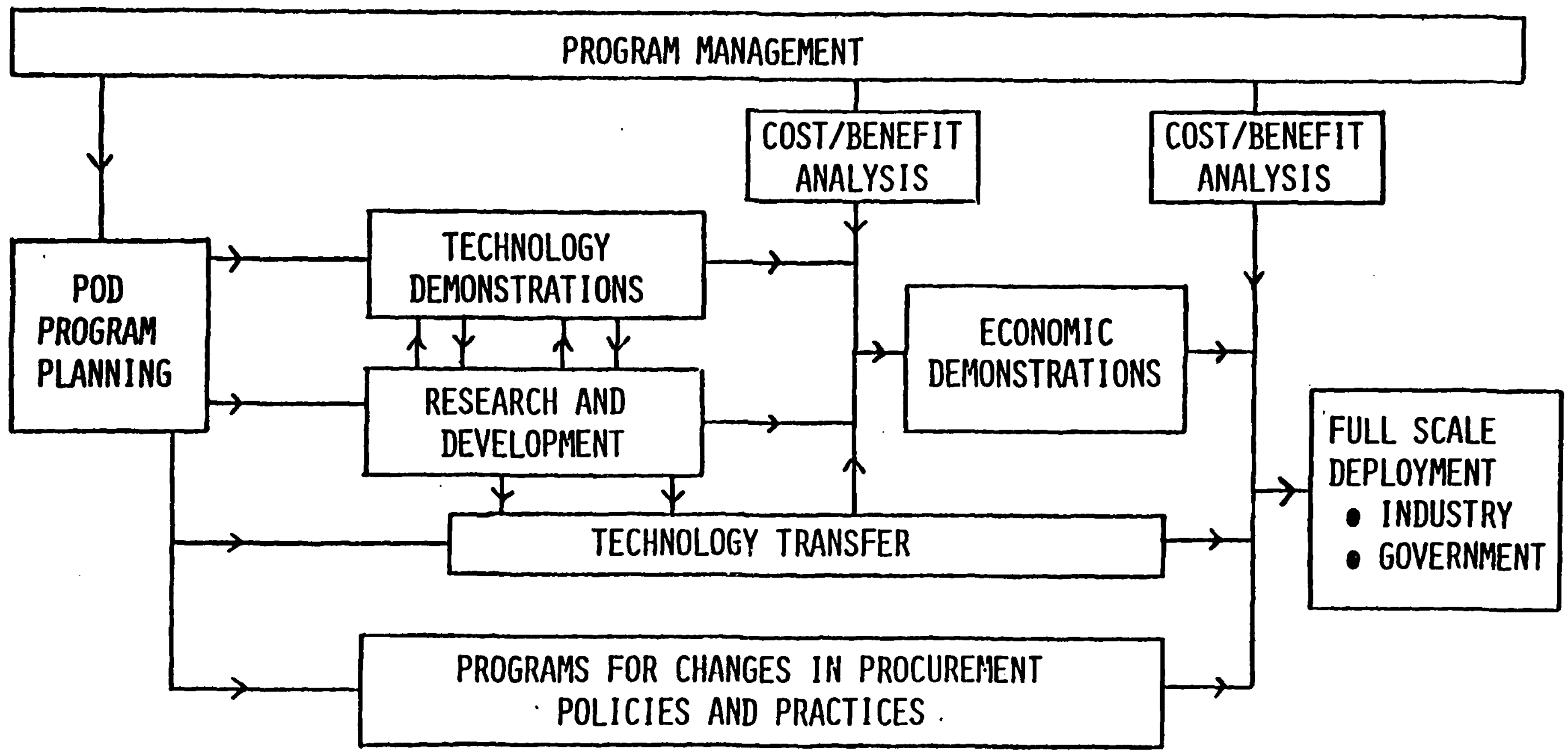
- Based on successful technology demonstrations, design and develop POD systems for economic demonstrations.

- Transfer technology to industrial base and DoD spare part suppliers.

- Develop full scale implementation requirements and make deployment decisions for POD systems.

Figure 1 provides an overview of the POD program plan developed to manage and coordinate the major elements leading to implementation decisions. Program planning activities initiate the process and overall program management is needed to monitor operations throughout the process. The technology assessment aspects require that R&D and best commercial practices are integrated and analyzed and that cost/benefit analyses are performed both before and after economic demonstrations. These analyses will be used to make sure that productive projects are funded and unproductive projects pruned throughout the process. A key element in the development process is feedback derived from an active technology transfer program.

Figure 1 POD Program Overview



Appendix A provides a copy of the Project Workplan which was developed and a summary of the planning meetings and activities carried out under this task.

**Task 1. Survey and Analysis of Navy Parts/Supply System**

Under this task SAI reviewed and analyzed the current Navy logistics system and data base so as to determine spare part issues and problem areas and to identify readiness, performance and demand requirements for a parts-on-demand system. This task was used to help define what constitutes suitable parts and technical data requirements to implement POD, and efforts focused on quantitative validation and statistical sampling of parts appropriate for POD manufacturing.

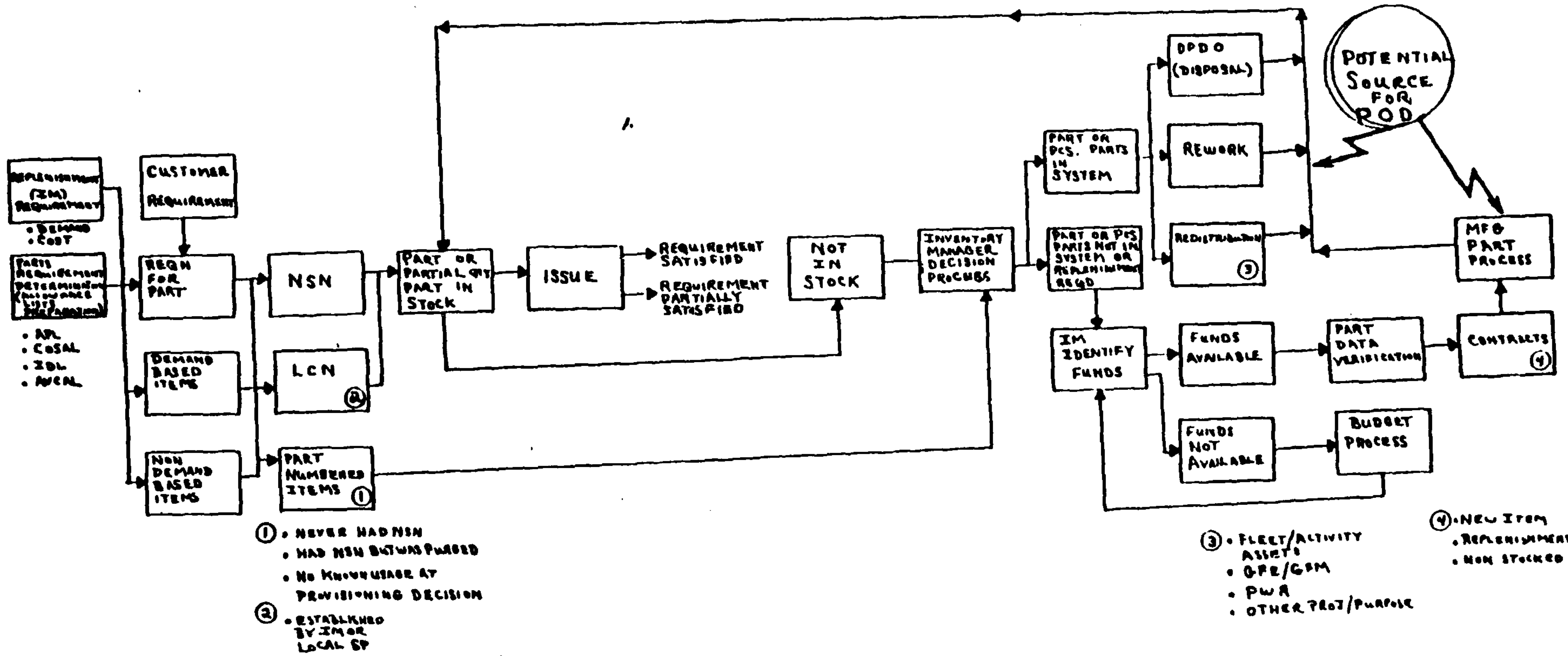
The major source of information came from staff at the Inventory Control Points (ICP) and supply centers. Other data sources included Navy Management Data List (NMDL), Shipyard Management Information System (SYMIS), Repairable Management Data System (RMDS), Serialized Line Item Tracking System (SLIT), Closed Loop Aeronautical Maintenance Program (CLAMP), CASREP reports and NMCS/PMCS.

The current procurement system was assessed to allow reliable estimates to be made on how many parts might be candidates, how often they are ordered, how much they cost, how long the lead times are, and so on. Road maps of the procurement system before and after POD were developed to help structure the gathering of information. These road maps illustrated the flow of information, identified decision points in the process, and clarified the potential role of POD in the process. Figure 2 illustrates a simplified schematic of the basic supply system flow.

- **Stock Analysis Reveals that Many Items Have a Low Turnover**

SAI prepared a questionnaire, collected computer data and made site visits to the Naval Supply System Command, Naval Aviation Supply Office (ASO), and Naval Ship Parts Control Center (SPCC) to study stock turnover. The ASO and SPCC were visited several times to assess inventory records, demand and non-demand based requirements, CASREP reports, stock status reports, order rates, stock levels and

Figure 2 Basic Supply System Flow to Potential Source for POD



requisition processing requirements. It was learned that many thousands of part numbers are carried as insurance items in low quantity and low order rates, and that thousands of other items without stock numbers are ordered each year in low quantities. Thus the amount of ordering activity in small quantities may be larger than previously thought. Trip reports and questionnaire responses from ASO and SPCC are included in Appendix B.

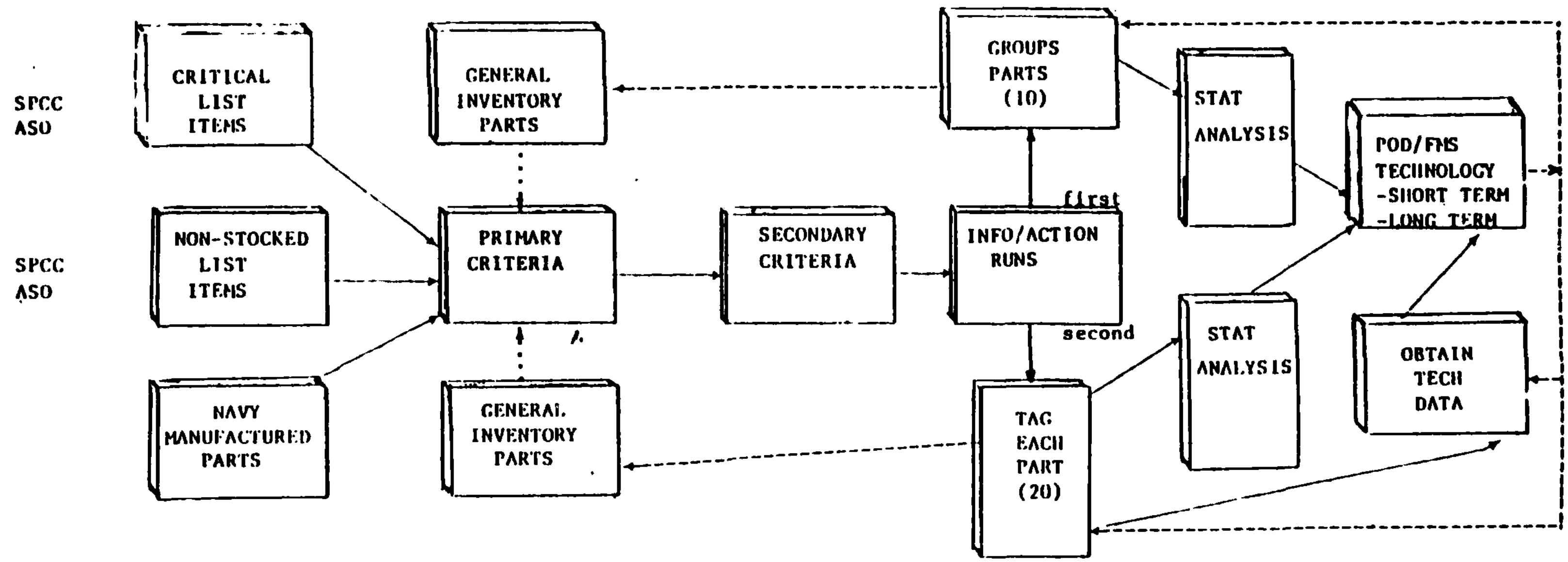
- **Selection of Parts Appropriate for POD Required Development of Sampling Methodology**

The methodology developed for the POD parts selection process is illustrated in Figure 3. The criteria for selection evolved from the review and analysis of material collected from the supply centers, the selection of appropriate federal groups and classes within the inventory, and the determination of the manufacturing requirements of selected parts. The objective of the methodology used was to foucs the range of parts for consideration while maintaining a wide mix of federal groups/classes. Appendix B contains a list of consumable and repairable types considered as potential POD items from 15 groups and 30 classes of the Federal Supply Classification (FSC). These covered weapons, fire control equipment, aircraft components and accessories, ship and marine equipment, engines, turbines, components and accessories, transmission equipment, pumps and compressors, detection equipment, electrical and electronic components, and instruments and laboratory equipment.

Appendix B illustrates the selection procedure used for part sampling. About 30 percent of Navy managed items are handled by the ICPs and form the baseline of the sample; candidate parts were also categorized based on definable areas of the inventory which would have measurable impact if changed. The following items were included in the sample:

- Mark Zero Items - Low demand insurance items which represent about three-fourths of the Navy managed inventory (See Appendix B for further description).

## Figure 3 POD Parts Selection Process




LEGEND:

- ———————— Primary Data Flow
- - - - - - - - - Feed Back for More or Different Data
- ................ General Inventory Parts Review

- Stock No.
- PLT
- Demand
- Item Stats
- Etc.
- Cost

- **Parts Characterization Analysis Identified POD Data Requirements and Problem Areas**

The final step in this task was to obtain the technical data packages for selected parts and analyze the current data availability and format. The results of this effort were used to determine part requirements for POD systems, identify problem areas, and provide data for the economic and operational analysis task.

A list of eight specific candidate spare parts recommended for POD by SPCC which represent items for which the original manufacturing source had gone out of business is also included in Appendix B. The available specifications were reviewed and evaluted as to feasibility for POD using current technology at NBS's Automated Manufacturing Research Facility (AMRF). This review found that major problem areas were based on the technical data and drawings which were incomplete and/or difficult to read.

It was determined that a first priority for manufacturing POD parts and assemblies will be the establishment of minimum technical data requirements, to include the most useful format, essential tolerances and geometry, a materials list, and process, assembly and inspection steps.

**Task 2-Survey and Analysis of Manufacturing Technology**

Under this task SAI reviewed the state of the art in key emerging and evolving technology areas appropriate for the development of POD systems. Candidate organizations with R&D and manufacturing capability were identified and related military and industrial R&D efforts reviewed. The resulting assessment highlighted the generic enabling technologies and cross-cutting R&D projects required to focus current state of the art for POD system development.

- **Computer-Aided Systems Identified as Key Enabling Technology**

Concurrent with the survey and analysis of supply part requirements, SAI assessed key generic technologies for a Parts-on-Demand facility, particularly state of the art in computer-aided technology. A preliminary assessment of POD plant requirements was made and used to generate several conceptual manufacturing flow

- High Mission Criticality - Items designated Not Mission Capable or Partially Mission Capable Supply (NMCS/PMCS).

- Diminished Source of Supply - Items for which manufacturing source has been reduced, limited, or lost.

- Non-Stocked Items - Items not provisioned or stocked which are managed by demand, supplied by spot buys, and which may generate Navy Inventory Control Numbers (NICN).

Random samples of data were extracted from the Master Data File (MDF) and screened using the primary critera to identify families of parts for POD application:

- Part is a Navy managed item
- Part is mechanical, electrical, electronic item (this excludes fuel, etc.)
- Part is a repairable item.

The secondary criteria was used during a second screen which determined the following:

- Part has a significant stock piling penalty (high cost, shelf life, size, long lead time)
- Part has a low failure rate (a measure of low turnover)
- Part has low or no storage criteria
- Part requires relatively high degree of manufacturing (complexity, tolerance, material).

The sampling process, sample size and limits, decomposition procedures, and controlled and uncontrolled factors are described in more detail in Appendix B.

diagrams. Figure 4 illustrates control and processing requirements for a POD manufacturing operation. Other flow diagrams represented specific requirements for machining, material handling, and circuit card facilities.

Further analysis highlighted key tradeoff between inefficient but versatile systems. Some of the key plant design options included:

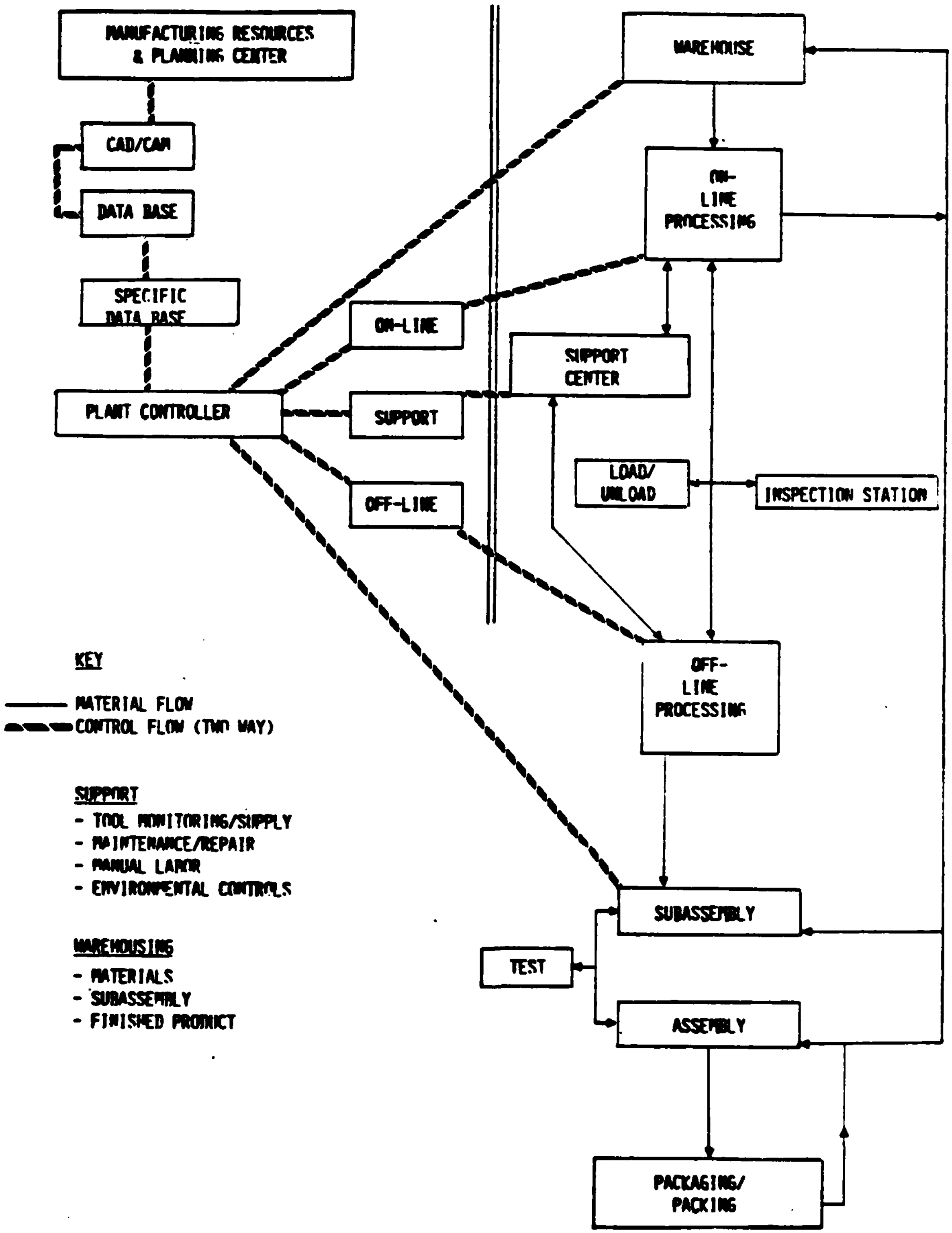
- Design plant as grouping of manageable units for group technology manfacturing
- Provide physical and administrative control over all material in system
- Provide straight-through flow with provision for buffers as required
- Provide random access to all materials stored at point of use
- Provide tool management system which will monitor and replace worn tools
- Design major processing units for assembly, subassembly and parts
- Provide inspection system for work in process and finished products
- Provide ability to expand incrementally without disrupting facility arrangement or interrupting major flows
- Design and standardize interchangeable equipment for group technology manufacturing.

Key areas for engineering development efforts are based on improving plant control and monitoring systems to provide real-time data processing, instructions, and interaction so that the POD system will be able to balance the work load of a constantly changing mix of parts. It was determined that computer-aided design to provide direct design capability, computer-aided process planning to maximize on-line and off-line part flow routing, computer-aided control of timed manufacturing and assembly operations, and computer-aided monitoring and diagnostic systems to expedite material handling, tool control, and in-process test and inspection operations are needed to support a POD manufacturing operation.

- **Specific Technologies Assessed for POD Impact and Research Requirements**

In order to address the specific problem of spare parts and low volume, batch production requirements of the military, a survey of technologies and their impact on

Figure 4 Parts on Demand Manufacturing Flow Diagram



POD systems was conducted. The following technologies were identified as necessary to attain the economies and flexibility needed for POD.

- Generative Process Planning. A generative process planning capability will allow a POD system to generate and evaluate alternative machines, processing procedures, material and part flow routing. This will be based on knowledge of the product's basic physical characteristics and geometric information. A POD system must be able to be reconfigured to suit rapidly changing manufacturing requirements. In the near term, computer-aided process planning systems need to be developed based on POD database and network requirements. A key goal is to reduce unproductive machine setup and waiting time. Graphic tools can be used for workstation selection, sequence, program operations, and selections of raw material blanks, tools/holders, end effector/grippers, probes, and lubricants. In the mid-term attention needs to be given to integrating the production functions with inventory transfer, and inspection requirements.

- Expert Systems. Computer driven process planning and generative process planning can use artificial intelligence and expert systems developed to manage the complexity and flexibility required of POD systems. The expert system needs to be based on a well defined knowledge base of production domain facts and heuristics associated with low volume, flexible manufacturing. The power of the system lies in specific knowledge of the problem domain and the most powerful and efficient system is one with the most knowledge.

- Sensor Systems. The development and integration of sensor systems into a POD facility can provide orientation and monitoring information of on-line production and inspection systems, material handling, assembly, and process control. In the near term these systems can be used to reduce skilled operator requirements or obtain higher equipment output. Longer term goals are to develop systems which couple vision, tactile, acoustics, proximity or other sensors with computers to allow decision making based on external data rather than preprogrammed directions.

- Smart Material Handling. Improved material handling systems and warehouse procedures are needed to provide loading/unloading, transportation, bin picking, part recognition and orientation, and random access capabilities. Another goal that has been identified is the development of feedback mechanisms to determine the impact of material handling on quality of the part produced.

- Machining Fixtures. The determination of machining fixtures and work holding requirements for a POD system will be based on design and knowledge of critical surfaces. Work holding fixtures are required to provide proper alignment, accommodate lead in and torque requirements of the equipment, and minimize part damage due to shock, acceleration, and finishing operations. Near term research should include development of programmable jigs and fixtures for multipurpose operations and programmable parts feeders.

- Inspection Systems. An integrated POD inspection system must have the equipment to perform a number of duties that are planned, in-process, and timed operations. Specifically it will be used to maintain quality control by measuring the part in relation to its design specifications. Inspections will be made on incoming parts and raw materials, in-process parts, and finished products. Testing measures the function and performance of the product, critical for military end items. Both contact and noncontact inspection methods need to be evaluated, but emphasis will be on noncontact inspection which can speed the process in a POD system by avoiding the need to reposition the part and eliminate wear on mechanical probes (such as programmed coordinate measuring machines-CMM). In-process inspection points need to be determined

- Tool Control. A sophisticated adaptive control system and related tool monitoring capability will be largely dependent upon developing appropriate sensors. Reliable tool wear sensors and diagnostic devices need to be developed to predict failure just before it occurs rather than identifying a component that has failed. Troubleshooting procedures will use sensory data, perhaps embedded in fixtures, to determine the source of difficulty. The system can then self-compensate or self-adjust by calling for appropriate off-line information. The long term goal is a tool control, tool changing and replacement system with the ability to self-diagnose problems.

- Near Net Shape. Near net shape techniques have been applied in industry for some time. These include use of powder metals in dies with hot isostatic presses, rotary forging (both hot and cold), investment casting, and hammer forging. Other techniques such as a laser sculpting and implosion techniques are not yet in use but are currently under development. Each of the technologies mentioned above have their own advantages and disadvantages when viewed from a Parts on Demand system in which very small batches are to be manufactured. The research and development project summaries listed in Figure 5 are examples of the technology assessment needed to determine the advantages and disadvantages of this technology for small batch production.

- **Engineering R&D Identified as Critical Components of an Integrated POD System**

An assessment was then made of high priority items for early attention in the development of a POD program. Active R&D programs were reviewed under this task and key centers of excellence and intellectual resources in commercial, academic, and governmental institutions were identified. Appendix C contains lists of organizations that were reviewed.

On the basis of ongoing programs and specific requirements of a POD system, an initial assessment was made of critical components relevant to the development of POD facilities. It was determined that based on a detailed architecture of the current system and the development of a POD manufacturing database, conceptual POD systems should be designed and fabrication and assembly equipment integrated using

**Figure 5. Sample Technology Assessment: Advantages, Disadvantages and R&D Requirements for Near-Net-Shape Forming**

| Technology | Advantages | Disadvantages | Research and Development for Parts on Demand |
|---|---|---|---|
| Powder Metallurgy | • More durable<br>• Unique materials<br>• Stronger materials<br>• No storage of stock shapes | • Expensive dies<br>• Needs special press | • Develop programmable die<br>• CAD/CAM for die design |
| Hot and Cold Hammer Forging | • NC machine<br>• Material saved<br>• Reduced machining<br>• Stronger | • Shapes presently limited to axially symmetrical | • Application to small batch production.<br>• Investigate inner surface forming |
| Investment Casting | • Can produce odd shapes<br>• Reduced machining | • Expensive dies<br>• Long lead times | • CAD/CAM for die design<br>• Develop flexible dies |
| Advanced Techniques, Laser Sculpting, Implosion Forming | • Flexible | • Limited Application | • Develop basic methods |

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standardized modules and multipurpose centers for mechanical, electrical and electronic parts manufacturing. Advanced manufacturing systems should be tested and centralized control systems for planning and production management defined and developed. State-of-the-art in computer-aided machine tools, advanced sensor technology, advanced material handling, off-line programming, on-line and in-process test and inspection, electronic emulation and powder metallurgy should be integrated into CAD/CAM/CAT systems appropriate for military specific POD requirements.

## Task 3 - Economic and Operations Analysis

Under this task SAI analyzed the supply system problems and costs and compared actual production costs for a specific candidate mechanical part, using various technology alternatives. POD proof of principle was tested at the National Bureau of Standards, Automated Manufacturing Research Facility. A methodology was also developed to rank POD projects for review to include as broad a range of parts and technologies as possible within the scope of effort.

- **Logistic Issues Categorized and Problem Areas Analyzed**

The source of the logistic issues can be categorized into three areas: 1) parts requirement shortfall, 2) continued upheaval in the U.S. industrial base, and 3) government procurement practices.

One of today's prime logistics problems is the demonstrated shortfall of the present logistics system to satisfy spare part requirements efficiently. Unpredictable requirements are inherent in the system and cause increased lead times and high cost. Unplanned life extensions and administration difficulties also contribute to the unpredictability of part requirements.

In the second category we are witnessing a prolonged upheaval in the industrial arena. The smokestack industries such as steel are eroding and provide us with graphic evidence of a severe loss of capacity. The high technology industries, on the other hand, are rapidly evolving and providing an increasing variety of consumer goods (such as video games) that are not necessarily well attuned to defense needs.

Under the third category the military support base has been further weakened by government procurement practices and regulations that until recently have provided no incentives for modernization. Uneven funding and short-term contracts have contributed to the overall erosion of the industrial base, particularly in the lower tiers of the subcontactor base.

The result in many situations is that parts are not being manufactured as needed. The evidence of this is seen in the excessive costs of insurance items in stock, or dependence on obsolete processes for the manufacture of such parts as small-scale integrated circuits and our overall lack of a cohesive database on the specification and design of the parts in our inventory. We find that parts are made in too large a lot size for effective inventory logistics. This often leads to long ordering and production lead times as well as inventory turnovers that are much longer than best commercial practice. This increases the chances of stock outages and ultimately reduces the availability of critical weapon systems. Furthermore, the parts manufacturing base has very little startup, surge, or mobilization capacity. The subcontractor base is limited and unfortunately requires longer lead times that desirable particularly for new or surge systems. Furthermore there is an unavoidable reliance on choke point suppliers of critical equipment such as forgings for landing gears for fighter aircraft.

- **Spare Parts Availability and System Readiness Assessed**

Some of the specific problem areas examined during this study are illustrated in the following series of charts. One measure of weapon system availability or readiness is illustrated by the analysis summarized in Figure 6. In this study, SAI analyzed requisition response time based on a survey of twenty weapon systems and the percentage of requisitions which were filled on the first request. From 1981 to 1983, 60% or more of the requests were filled on the first request for 14 of the systems and less than 60% for six of the systems. However, the majority of the cases examined were below the 85% goal established by the military. Figure 7 graphically shows this softfall based on 1983 data for the first four systems which were examined in detail. Additional analysis in this area is recommended to focus on out-of-production weapon systems; however, since the inventory is not categorized according to weapon systems, data pertaining to parts of interest is difficult to compile.

Stock turnover is a reasonable measure of system readiness under the current way of doing business even though we expect low stock turnover because of the large range of spares. It indicates areas where potential savings can be realized using POD systems. Initial investigation shows that once a POD system is in place, spares can be

Figure 6 Readiness Performance Based on Weapon System Availability

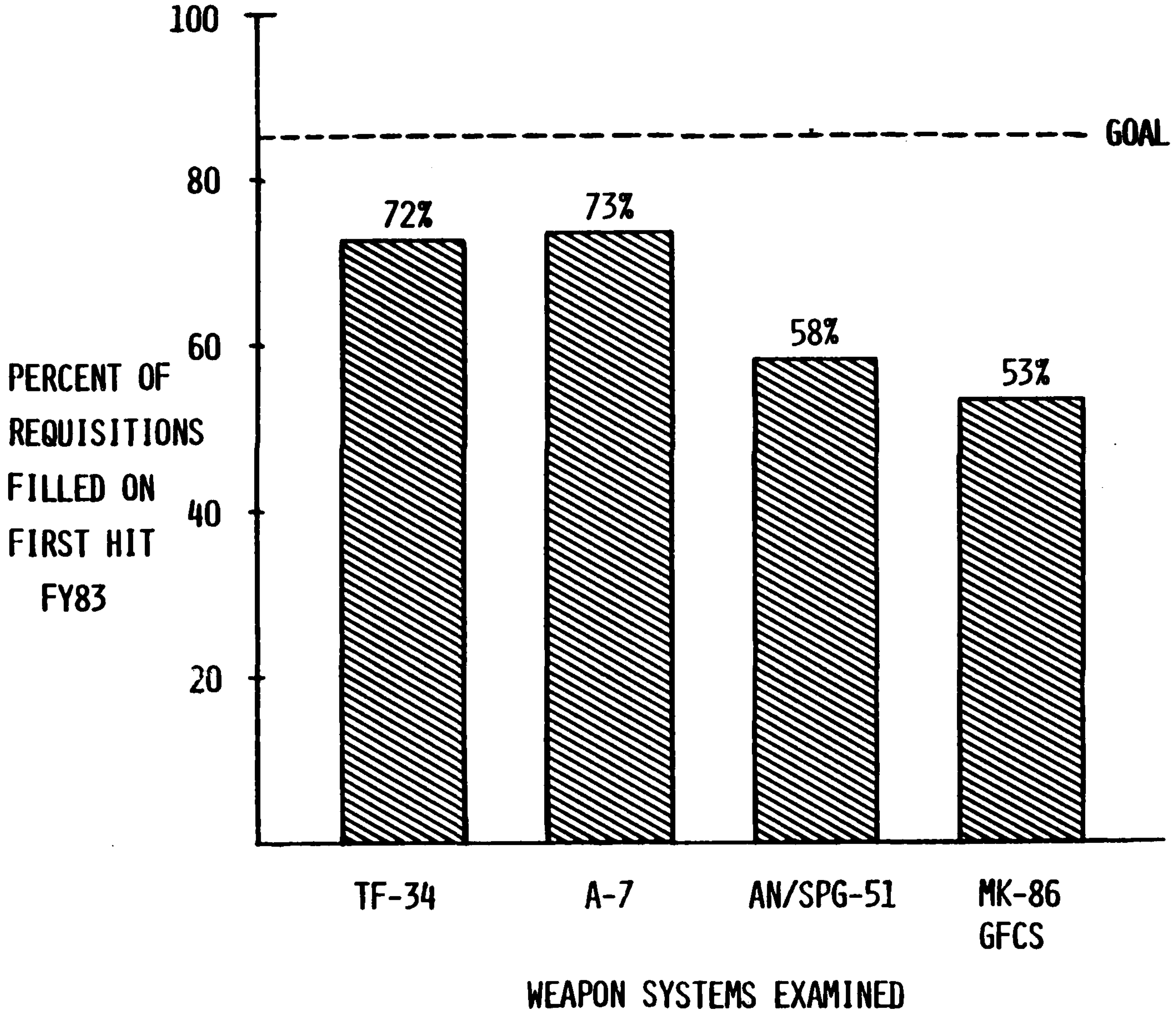
| WEAPON SYSTEM | FY8 AVG REQNS/MO | FY8 AVG REQNS FILL (1) | FY82 | FY83 | REMARKS (2) |
|---|---|---|---|---|---|
| TF-34- | 1496 | | 1806 | 1795 | AVG REQ/MO INC. |
| | | 79% | 76% | 72% | % REQ FILL DEC |
| | | | | | 92% 1R-8%2 R |
| A-7 | 5070 | | 5164 | 4670 | AVG REQ/MO DEC |
| | | 80% | 77% | 73% | % REQ FILL DEC |
| | | | | | 57% 1R-43% 2R |
| AN/SPG-51 | 691 | | 742 | 594 | AVG REQ/MO DEC |
| | | 65% | 58% | 58% | % REQ FILL DEC |
| | | | | | 45%1H-55% 7G/7H |
| MK 86 GFCS | 508 | | 529 | 445 | AVG REQ/MO DEC |
| | | 44% | 50% | 53% | % REQ FILL INC |
| | | | | | 18% 1H-82% 7G/7H |

NOTE: (1) % REQUISITIONS FILLED OF 20 WPNS SYSTEM SURVEYED

| | DEC | INC | |
|---|---|---|---|
| > 60% | 8 | 6 | 14 |
| < 60% | 2 | 4 | 6 |
| | 10 | 10 | |

(2) CONSUMABLES = 1R, 1H REPAIRABLES = 2R, 7G, 7H

Figure 7 Requisition Response for Selected Weapon Systems FY83



produced more readily which allows for a smaller inventory which will turnover faster and contributes to a reduction in holding costs. POD provides an alternative way to produce the insurance items and costs would be incurred only if the part is actually needed.

- **Magnitude of the Problem and Savings Projections Calculated**

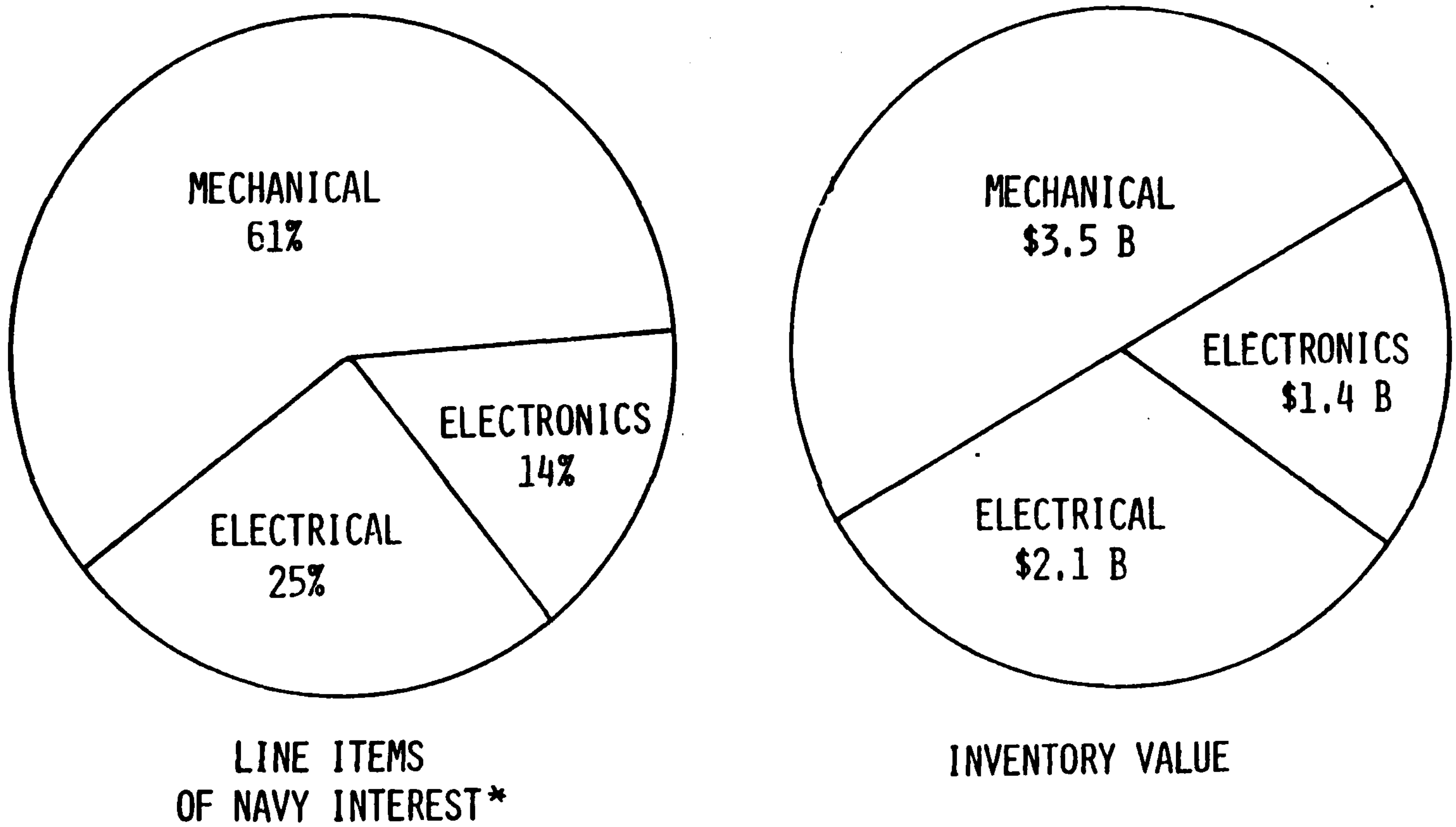
An assessment of the logistics problem for spare parts was based on the inventory items of interest which included about 850,000 mechanical, electrical, and electronic parts used by the Navy (not all Navy managed). Figure 8 shows the percentage breakout and estimated inventory value of these items, about $7 billion. In FY83 procurement costs for spares was about $3.5 billion, inventory was valued at $10 billion, and holding costs were estimated to be $2 billion. The steadily escalating procurement costs for secondary items and spare parts are shown in Figure 9. The projections are based on a conservative 3% increase in costs.

Figures 10 and 11 indicate some of the price disparities which received considerable publicity during the time of this study. The multiplier between the initial cost and replacement cost of recent studies is shown in the first chart and the estimated effects in parts logistics are shown in the second chart. The range of the multiplier depends upon the type of part, how it is produced and how it is stocked. If good parts are discarded in replacing a subassembly, the multiplier can be one to two orders of magnitude higher. Despite all this, it should be remembered that the cost of not having the part is even higher.

- **Logistic System Cost Analysis Was Based on Inventory Data and Holding and Ordering Cost Calculations**

The major logistics system elements of interest are those which impact part availability and therefore costs and lead times associated with current procurement and inventory practices were examined. Using data obtained from ASO and SPCC of selected spare parts of interest (mechanical, electrical and electronic parts), the value of the inventory and average lead times of the current inventory (October 1982) were

Figure 8 Dimensions of Logistics Problem — Inventory Areas of Interest to POD




* MECHANICAL (520,000), ELECTRICAL (210,000), ELECTRONIC (120,000)
EXCLUDES CONSUMABLES, FUEL, ETC.

Figure 9 Annual Secondary Items/Spare Parts Costs

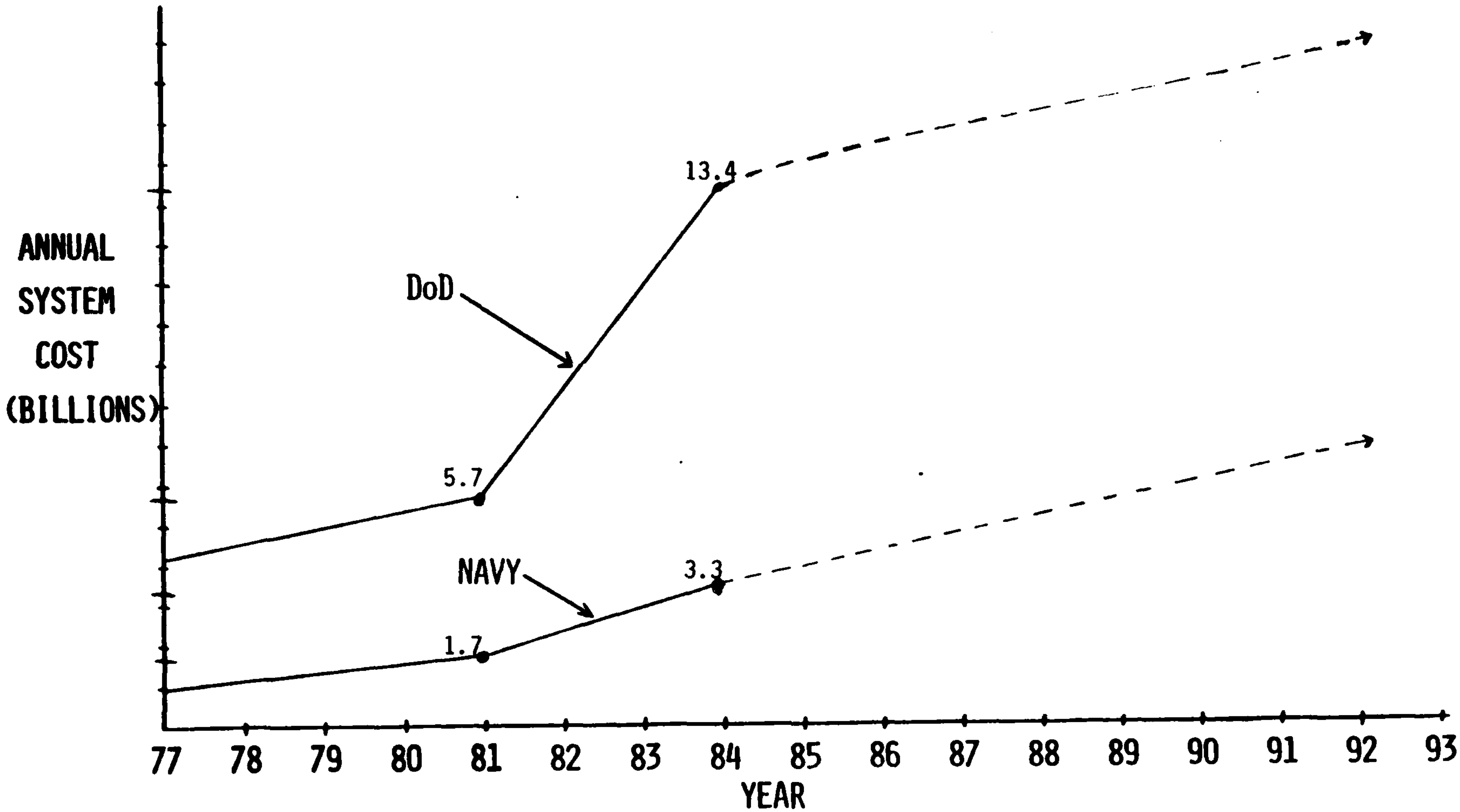


Figure 10 Reported Multipliers in Recent Studies

| PART DESCRIPTION | INITIAL COST | REPLACEMENT COST | MULTIPLIER (M) |
|---|---|---|---|
| USAF BOLT | $0.67 | $17.59 | 26 |
| ROLLS-ROYCE ENGINE RING ASSEMBLY | $3.70 | $54.75 | 15 |
| USN DIODES | $0.4 | $110.00 | 2750 |
| USN LAMPS | $0.17 | $44.00 | 259 |
| CIRCUIT CARD ASSEMBLIES | $170.00 | $2,470.00 | |

Figure 11 Multiplier Effect in Parts Logistics

| | ESTIMATED M |
|---|---|
| • LOW PRODUCTION VOLUME | 30% |
| • NO INCENTIVE TO ECONOMIZE (NAVY, CONTRACTOR) | 100% |
| • UNECONOMIC BUYING LOT SIZE | 50% |
| • ORDER ADMINISTRATION COSTS PER PART | 20% |
| • REDESIGN, QUALIFICATION OF NEW SOURCE ETC. | 50% |
| • STOCKAGE | 100% |
| • OVERORDERING (WASTE) RANGE | 100-10000% |
| • INDIVIDUAL HANDLING COSTS | 50% |
| • TRANSPORTATION TO INTERMEDIATE POINTS | 20% |

RANGE OF MULTIIPLIER = 25-2528; DEPENDS ON TYPE OF PART, HOW PRODUCED AND STOCKED

- IF GOOD PARTS ARE DISCARDED IN REPLACING A SUB ASSEMBLY THE MULTIPLIER CAN BE ONE TO TWO ORDERS OF MAGNITUDE HIGHER

- DESPITE ALL THIS - THE COST OF NOT HAVING THE PART IS EVEN HIGHER!

calculated for consumables and repairables (Appendix D). These figures were used as a baseline to determine the magnitude of the problem and represent the major items in inventory which are of interest to the POD program. The value of this inventory is about $3.2B and about 80% of the line items are held in inventory because they have supply source problems or require long lead time to acquire.

The next step in this part of the cost analysis task was to calculate holding and ordering costs for definable areas of the inventory which would have some measurable impact if changed. Random samples of data taken from the Master Data File (MDF) and the Cyclic Stock Status Reports and ordering and holding cost calculations were compared to unit price replacement costs. For example, the yearly holding cost for a cylinder and piston which would cost about $10,500 to replace is about $3,000. This cost is derived from calculating the following percentage of unit replacement price:

- Storage cost: 1%
- Obsolescence rate: 17%
- Procurement time preference rate: 10%

The order cost breakout for this same item amounts to about $11,000 based on quarterly demand forecasts, cost to reorder, and lead time demands. Figure 12 summarizes the cost calculations made on this example. Appendix D describes this cost analysis procedure and formual used for this analysis.

- **Case Study and Production Demonstration of Diminished Source Part for Battleship Modernization Program**

As part of this task an analysis was made of the cost to produce a sample part by flexible manufacturing and comparing four machining technology alternatives:

- Manual production
- NC tools without CAD
- NC tools with CAD
- FMS using NC tools and CAD

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**Figure 12 Sample - Cost Analysis Worksheet**

| NSN | | | NOMENCLATURE |
|---|---|---|---|
| FSC | NATO | NIIN | |
| 2810 | 01 | 0233173 | CYLINDER AND PISTON |

REPLACEMENT UNIT PRICE $10,496.17

HOLDING COST:

| | | |
|---|---|---|
| $10496.17 x .01 = | $ 104.96 | |
| $10496.17 x .17 = | $1,784.34 | |
| $10496.17 x .10 = | $1,049.61 | |
| TOTAL HOLDING COST | | $2,938.91 |

ORDERING COST:

$$\frac{309.89 \times (41.25 \times 4)}{\sqrt{\dfrac{8 \times (309.89) \times 25.563}{.28 \times 10{,}496.17}}} = \frac{51131.85}{4.64} = \$11,019.79$$

TOTAL YEARLY ..................................$13,958.70

* SEE APPENDIX D FOR FORMULA & BREAKOUT OF ANALYSIS

The National Bureau of Standards (NBS) was asked to demonstrate how a candidate part of relative complexity could be produced using standard general purpose machines set up in their experimental FMS laboratory. The demonstration used a part required by a recently recommissioned WW II battleship, an oil flinger governor for a steam turbine engine which was not in inventory or available from a current source of supply.

NBS was provided the specification requirements and available technical data background by the Navy. Personnel at the Ship Parts Control Center (SPCC) indicated that the oil flinger had originally been made in the late 1930's or early 1940's prior to the establishment of current item record files at SPCC in 1963. The only buy recorded by the SPCC is in June 1981 when a single oil flinger was purchased from the Northern Ordnance Division of FMC Corporation at a cost of $1240.44. Since that time inventory control management of this part has been assigned to Defense Supply Construction (DSC) whose records show it as a non-stocked item with no demand records to date and a value of $80.53 based on the original piece part cost.

NBS first produced an experimental copy of the oil flinger in their Automated Manufacturing Research Facility (AMRF). The replica was made because the specified steel was not in stock for the actual replacement part and because the technical data package for producing the part had to be developed, the part geometry redesigned, and the production process recreated.

The test results obtained from NBS were used to compute the costs based only on factors integral to the machining functions required. These costs are summarized in Figure 13 where CAD with NC represents the current state of the art and actual NBS costs associated with the production of the oil flinger. Appendix D contains detailed worksheets of inputs and assumptions used to make these calculations and cost comparisons with alternative techniques.

Subsequently, the proper steel was obtained by NBS and four oil flingers were produced to satisfy the Navy's requirements. The test results at NBS proved state-of-the-art capability of currently available NC and CAD equipment in a flexible

Figure 13 Cost Comparison of Four Alternative Production Techniques-Oil Flinger Case Study

| Technology Options | Oil Flinger Part: Production Costs 1/First Unit w/o data ($) | 2/First Unit w/data ($) | 3/Additional units ($) |
|---|---|---|---|
| Totally Manual | 1203 | 923 | 800 |
| Manual with NC | 2962 | 2682 | 335 |
| *CAD with NC | 2811 | 2682 | 335 |
| Future CAD/FMS | 1458 | 763 | 253 |

* This line represents the actual level of current technology and the costs incurred by NBS in production of the oil flinger. The other techniques were computed using inputs and assumptions described in Appendix D, Cost Analysis of Case Studies B and C. (Line numbers referenced below refer to worksheet anlaysis)

Notes:

1. Pilot part produced without technical data package. Part geometry requirements and production process developed (Line 37).

2. Pilot part produced using stored data. Illustrates effect of storing design and processing information for future runs (Line 49).

3. Marginal cost of producing an additional unit (Line 28).

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manufacturing system to produce parts economically down to units of six. Figure 14 graphically compares production time and Figure 15 compares cost per unit produced. The production time includes the number of hours that the equipment is tied up for tooling set up and production as well as manhour and computer time requirements. The costs involved in production include labor, machining and transport equipment, and computer and software usage.

- **Economic Methodology Developed for POD Investment Analysis**

The methodology developed for an economic analysis of program investments for Parts on Demand R&D includes evaluation procedures for both short term and longer run portions of the program. An economic analysis of investment opportunities for the POD program requires that the following steps be followed to determine the scope and limitations of the program and cost tradeoffs.

- A clear statement of the operational objectives of the POD R&D program (including the subsequent implementation of the concepts) and the time frame to be considered.

- An evaluation of the natural path of development of the affected areas in the absence of government R&D investment.

- Estimates of the incremental R&D investment sums to be expended (including indirect expenditures on IR&D and policy studies).

- Determination of those cost factors likely to be affected by a POD development program, preferably broken down by the various portions of the program (i.e., a cost model).

- An estimation of absolute costs (or, if necessary, relative cost differentials) for the areas to be influenced. Also cost differentials and measures of cost effectiveness such as discounted present value must be computed. These cost estimates (and model specification) must be based upon

Figure 14 Minimum Production Time Comparison for Several Technologies Producing "Oil Flinger" (Case Study B)

ALT 1: MANUAL
ALT 2: NC no CAD
ALT 3: NC with CAD
ALT 4: FMS includes NC and C

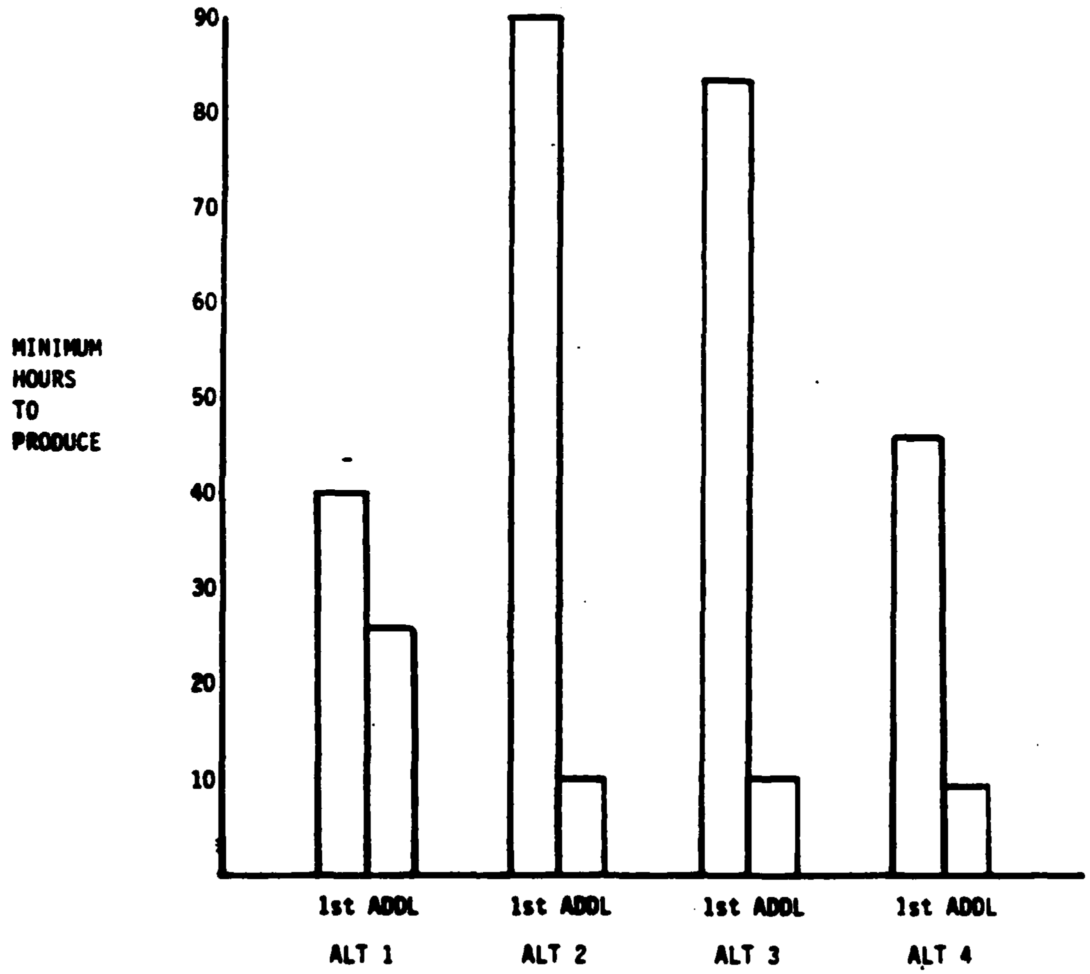
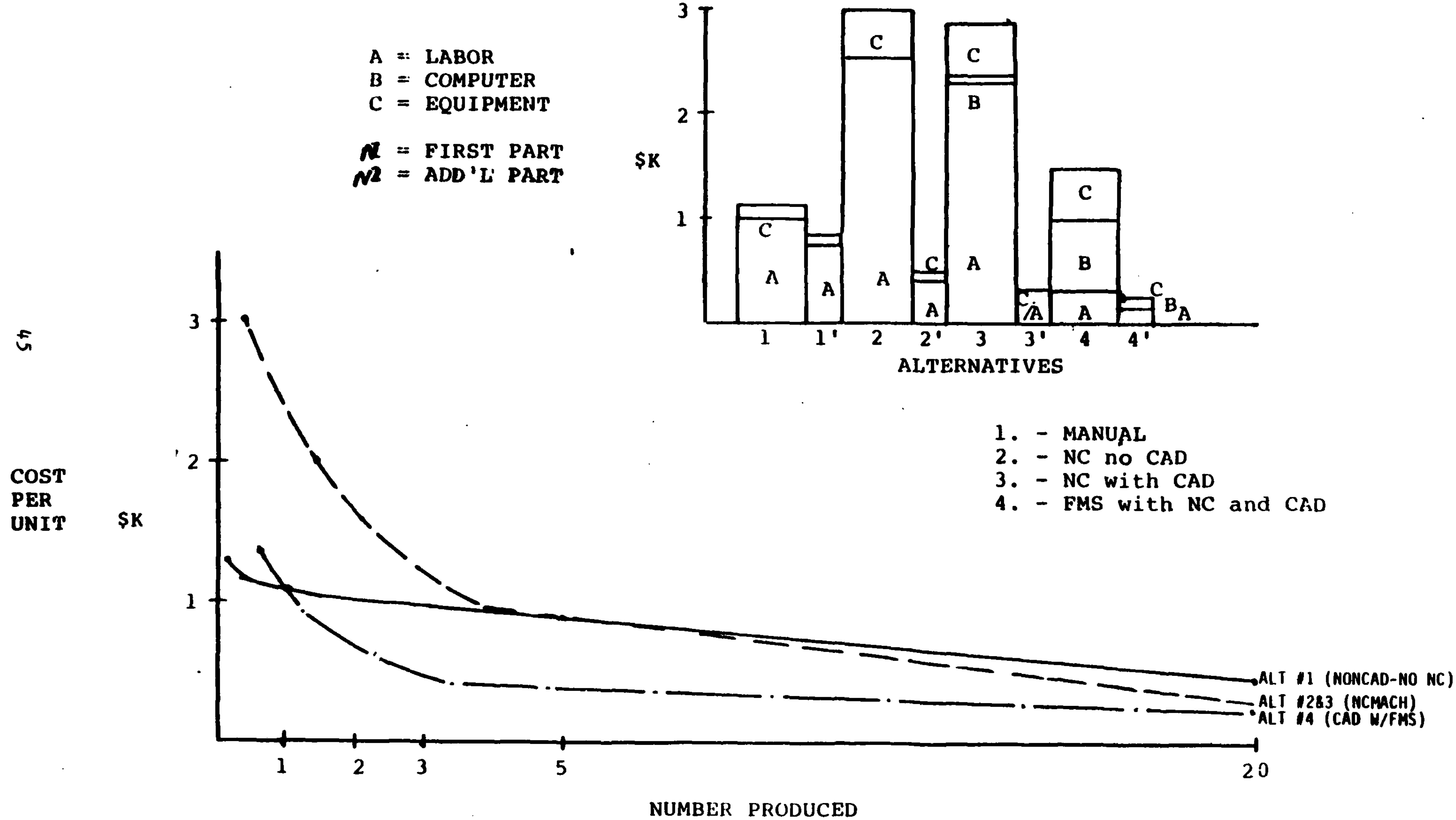


Figure 15 Cost vs Units Produced for "Oil Flinger" Produced Using Four Different Technologies (Case Study B)



engineering evaluations of supply system data on sample parts drawn from the supply system, along with data on results of part and ongoing demonstrations of POD technology.

- Determination of suitable measures of readiness and surge capacity (including measures of mobile logistic force effectiveness).
- An evaluation of effects of POD on readiness and range capacity. These estimates would be based on the same data as the cost estimates.
- Evalute the trade-offs of cost vs the other measures of effectiveness.
- Formulate principal conclusions.
- Identify the sensitivity of the conclusions to the key data and assumptions.
- Formulate recommendations.

Since the objective of the POD program is to speed up the incorporation of new technology into those portions of the civilian market that supply DoD, the numerous projects that will make up the whole program will also need to be evaluated by a similar procedure using more specific and relevant data and assumptions. It is difficult at this point to identify the milestones and decision points required to carry this program from concept formulation to concept validation and implementation. However, the POD investment program can, in general, be assessed and evaluated based on DODI 5000.2 procedures for the development of a coordinated R&D program as summarized in Figure 16. These considerations, however, must be modified somewhat since the POD program is not designed to lead to the procurement of a special item (e.g., weapon system), but rather to speed up the incorporation of new technology into the DoD industrial base. The class of payoff areas are similar in scope to those of the Navy Federal Computer project which is developing a wide range of standard computers and regulations to ensure proper use.

# Figure 16 System Approval Considerations

| MILESTONES | | 0 | | I | | II | | III |
|---|---|---|---|---|---|---|---|---|
| PHASE → | CONCEPT FORMULATION | | CONCEPT FORMULATION | | CONCEPT VALIDATION | | FULL SCALE DEVELOPMENT | |
| | Prepare Justification for Major Systems New Start<br>• Identify elements of Defense Guidance to which system responds<br>• Describe role of system in mission area<br>• Describe Alternatives to be considered in concept exploration<br>• Describe System Policy Improvements<br>• Discuss maturity of technology planned<br>• Discuss manufacturing processes and risks<br>• Discuss Affordability<br>• Discuss Contraints<br>• Provide Acquisition Strategy | APPROVE JMSNSs | Prepare System Concept Paper (SCP)<br>• Describe Systems<br>• Provide History of Project Actions/ Decisions<br>• Describe Mission area and role of systems<br>• Define operational concept<br>• Describe Inadequacies of System<br>• Discuss Alternatives<br>• Describe selected alternatives (affordability, readiness, standardization, sustainability, manpower)<br>• Identify key areas of technological, risk<br>• Discuss general strategy for entire program<br>• Discuss specific strategy for proceeding to next milestones<br>• Identify and discuss issues<br>• Identify decisions needed.<br>• MIP | APPROVE SCP | Prepare Decision Coordination Paper (DCP)<br>• Describe Systems<br>• Update history of Project Actions/ Decisions<br>• Refine Mission area and role<br>• Describe inadequacies of system<br>• Discuss Alternatives, reasons for non-selection<br>• Update Operational concept<br>• Update and describe selected alternatives (affordability, readiness, standardization, sustainability, manpower)<br>• Discuss T&E results showing all significant risks resolved<br>• Verify technology in hand, only engineering effort remains<br>• Acquisition strategy<br>– Discuss general acquisition strategy<br>– Discuss detail strategy for proceeding to next milestone<br>– Program structure<br>– Verify future cost and schedule<br>– Discuss cost control<br>• Identify and Discuss key Issues | APPROVE DCP I | Prepare Decision Coordination Paper (DCP)<br>• Update DCP I<br>• Refine Cost and Schedule<br>• Identify MILCON<br>• Prepare Training Plan<br>• Firm up Industrial Base<br>• Engineering Development Models (Delivery/Test)<br>• MIP<br><br>• Identify decisions needed<br>• Prepare MIP<br>• Conduct Developmental Testing<br>• Identify Industrial Base<br>– Lead time<br>– Production buildup<br>– Production rate<br>– Surge | APPROVE DCP II |

R&D Titles → RESEARCH EXPLORATORY DEVELOPMENT ← ADVANCED DEVELOPMENT → | ← ENGINEERING DEVELOPMENT

Figure 17, therefore, takes the evaluation one step further and shows the various investment and policy implementation areas that would be affected by a POD investment plan grouped according to the investment area and according to various proposed investment stages such as implementation and deployment. The legend identifies the investment requirements with an "X" indicating a payoff cell for ultimate implementation and deployment. Some areas marked with an I or P might be dropped from further consideration based on preliminary analyses; conversely other investment techniques, areas, or cells can be added along the way.

The economic models to be developed to determine cost and logistic effectiveness will investigate potential technology improvements across the many areas identified in this study. Life cycle costs and other logistic factors can then be used to evaluate particular parts produced through a POD facility compared to a base line facility. The cost categories and cost determinants listed in Figure 18 exemplify typical cost considerations for a single part that needs to be included in an economic model for program analysis. A more complete discussion of the POD Program economic analysis requirements is contained in Appendix D.

## Figure 17 Parts on Demand Investment and Implementation Program Milestones

| ACQUISITION MILESTONES | 0 | | | | I | | | II | | | | | | | | III | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | CONCEPT FORMULATION | | | | CONCEPT VALIDATION | | | FULL SCALE DEVELOPMENT | | | | | | | | IMPLEMENTATION/DEPLOYMENT | | | | | | |
| INVESTMENT AREAS | IR&D | OTHER R&D | INDUSTRY TECH. DEMO | MLF TECH DEMO | INDUSTRY DEMO | MLF DEMO | STANDARDS FORMULATION | GOCO DEV & TEST | GOGO DEV & TEST | STDS DEV & TEST | ICP DEV | PROC POLICY/ STDS FORMUL INC | SEL RFP | REQ RQMT | MLF OPERS TEST | STDS PROM | POLICY IMPLEM INC | SEL RFP | REQ RQMT | ICP DATA BASE | GOGO | COCO |
| 1. MACHINING OF MECH. PARTS | I | I | I | I | I | I | I | I | I | | | | | | I | P | | | | | XO/P | XO/P |
| 2. ASSEMBLY OF MECH PARTS | I | I | I | I | I | I | I | I | I | | | P | P | P | I | P | P | P | P | | XO/P | XO/P |
| 3. ASSEMBLY OF ELECTRO MECH PART | I | I | I | I | I | I | I | I | I | | | P | P | P | I | P | P | P | P | | XO/P | XO/P |
| 4. MANUFACTURE OF ICS AND/OR PWBA | I | I | I | I | I | I | I | I | I | P | P | P | P | P | I | P | P | P | P | | XO/P | XO/P |
| 5. PRODUCTION OF MECH PARTS TO NEAR NET SHAPE | I | I | I | I | I | I | I | I | I | | | P | P | P | I | P | P | P | P | | XO/P | XO/P |
| SUPPLY SYSTEM (ICP) USAGE, DATA STORAGE & USAGE | | I | | | | | I | | | | I | P | P | P | P | | P | P | P | X I/P | O/P | |
| CERTIFICATION & QUALIFICATIONS APPROACHES | | I | | I | I | I | | I | I | I | I | P | P | P | | P | P | P | P | | X/P | X P |
| POD STANDARDS FOR DATA & H/W | | I | | | | | I | I | I | I | I | P | P | P | I | P | P | P | P | X P | XO/P | XO/P |

LEGEND

I = R&D INVESTMENT REQUIRED
P = DOD/NAVY POLICY CHANGE REQUIRED
MLF = MOBILE LOGISTICS FORCE
O = OTHER EXPENDITURES REQUIRED
X = PAYOFF CELLS

Figure 18 Life Cycle Cost Elements

| COST CATEGORIES | COST DETERMINANTS |
|---|---|
| Ordering Cost Extension | Beginning Inventory |
| Storage Cost Extension | New Demand |
| Marginal Product Cost Extension | Backorders |
| Setup Cost Extension | Discount Factor |
| Design Investment Extension | Order Size |
| Design Conversion Extension | Ordering Cost |
| Design Maintenance Extension | Response Time |
| Design Facility Investment Extension | Storage Cost |
| | Marginal Product Cost |
| Design Facility Maintenance | Setup Cost per Order |
| Allocation Design Facility | Product Design Investment |
| Product Facility Investment Extension | Design Conversion |
| | Product Sites Added |
| Product Facility Maintenance Extension | Design Maintenance |
| | Design Facility Investment |
| | Design Sites Added |
| | Design Facility Maintenance |
| | Design Facility Allocation % |
| | Product Facility Investment |
| | # Added Product Sites |
| | Product Facility Maintenance |
| | Product Facility Allocation % |

**Task 4 - Long Range R&D Planning**

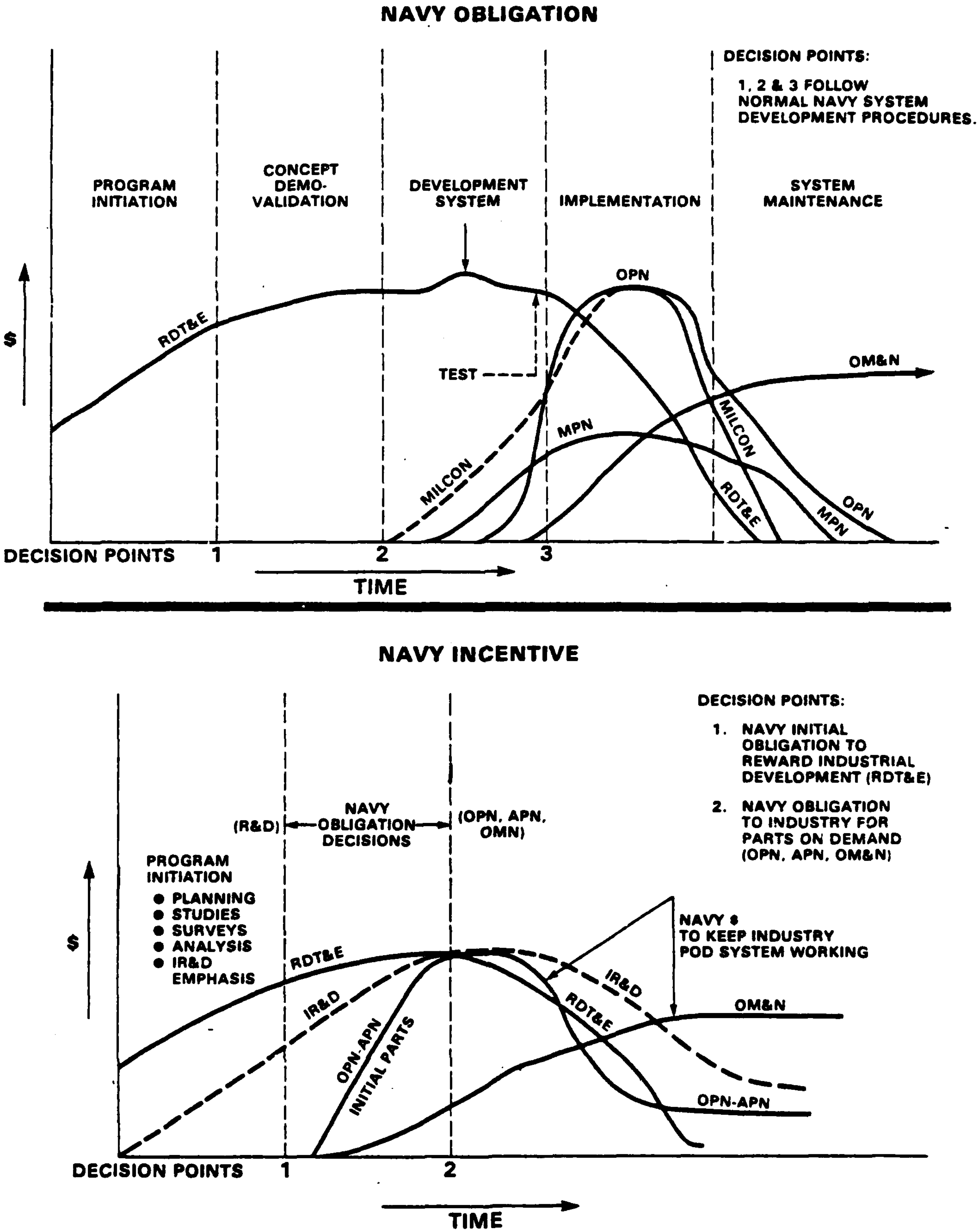
Under this task and client direction for acceleration of project efforts, SAI developed an initial investment plan for POD program development. It was provided in the form of input to the Navy Logistics R&D Program Plan for "Low Volume Automated Manufacturing/Parts on Demand," and briefing material for program justification. In addition, a draft of major actions, milestones (POA&M), and conceptual POD program networks were developed and a dictionary sort for a POD system planning schedule format was generated. The basic elements required for a full scale POD Program Management Plan (PMP) were briefly discussed with NAVSUP during this period. A conceptual comparison of Navy obligation versus Navy incentive plan for POD was also developed under this task.

- **The Basic Program Strategy Is Based on an Incremental Approach to Research and Development**

The performance milestones and key technology development recommendations were identified under this task. Early technology demonstrations and prototype production lines were selected based on operational and technical capability of existing, off-the-shelf technology to produce parts on demand. Organizations with in-place facilities which had been identified during the study were suggested to evaluate and prove the effectiveness of adapting advanced equipment to test the POD concept. Sample parts to be fabricated and key processes to be analyzed were suggested to refine the process and basic data requirements for POD systems. The results of the recommended demonstration would then be used as the basis for long-range R&D projects to focus on areas that need to be funded to push the technology.

It was recommended that economic demonstrations be designed to put promising POD production systems in an industrial setting. Not only would these demonstrations be used to test operational requirements and economics involved, but would also serve as part of the technology transfer plan to stimulate hands-on experience and training in new technologies for Navy suppliers of spare parts. This supplier base could gradually be expanded to include primary, secondary and tertiary tiers of the industrial vendor base. Parallel demonstrations in Navy organic facilities such as the Naval Aircraft Rework Facilities (NARFS) and shipyards were also recommended to provide opportunities to determine the development path to be taken in eventual deployment decisions, i.e., the Navy's obligation to develop POD facilities versus providing industrial incentives to improve capabilities of the industrial base. Figure 19 compares these two development paths and illustrates the critical decision points relative to time and cost.

Figure 19 POD Development Decisions - Navy Obligations vs Navy Incentive




# POD DEVELOPMENT

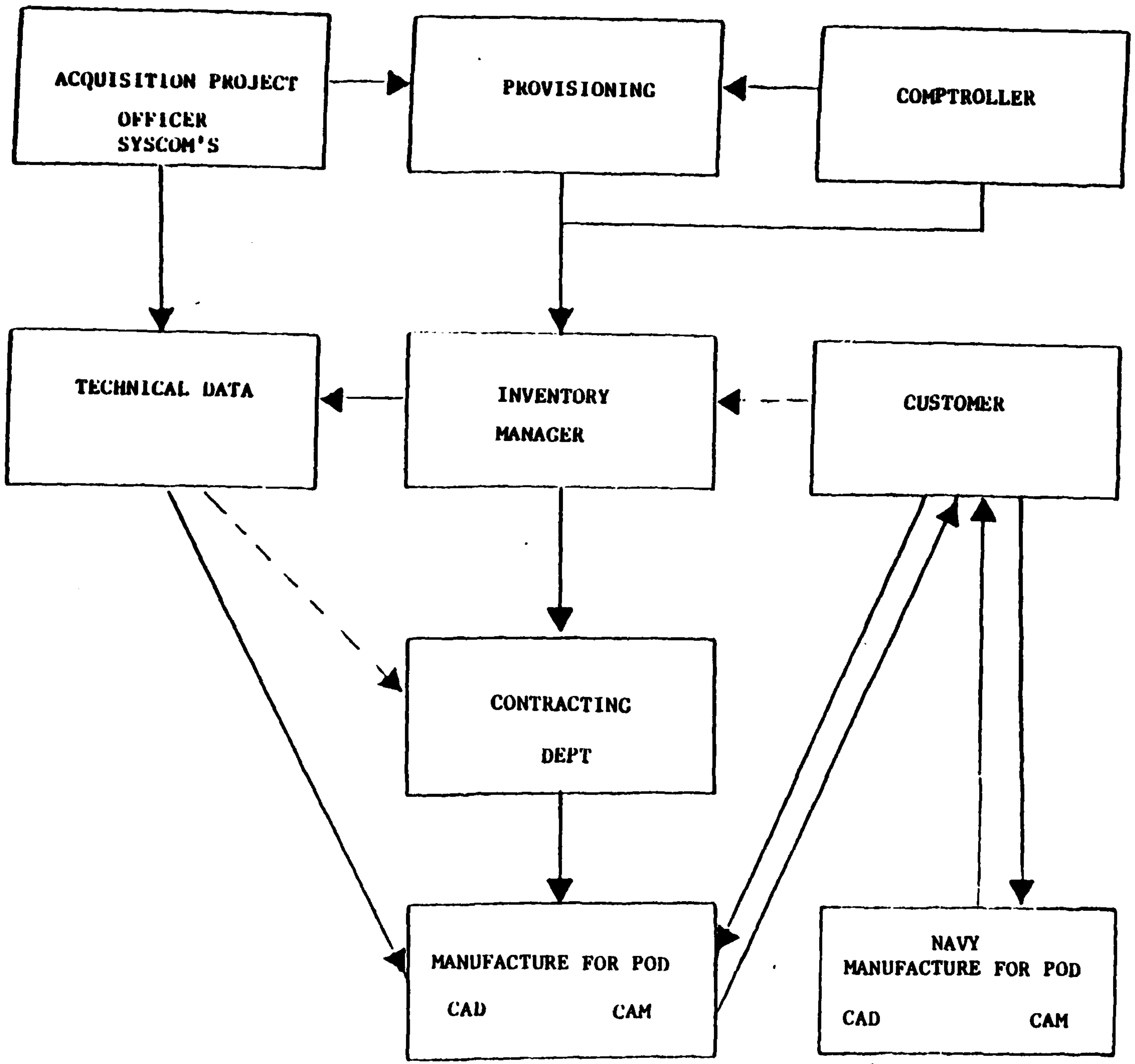
Eventual POD deployment, pilot plant installations and location decisions would have to be based on results of earlier demonstrations and R&D project successes. Major suppliers would then compete for joint industry/Navy cost-sharing demonstrations. POD facilities that could be fielded in forward areas (US base, foreign base, tenders) and transportable POD units to upgrade platform and escort ships tool shop capabilities were among the options recommended for evaluation. The integration of the POD system with the Inventory Control Points at SPCC and ASO and the existing procurement system for spares and parts is another factor that needs to be evaluated prior to deployment decisions. For example, the POD technical information data requirements could be controlled at the ICP, and bidder's lists for POD suppliers generated through ASO/SPCC. Figure 20 illustrates one of several POD system options that was developed under this task. The intent was to analyze deployment options that mesh with the current procurement system and which lay the ground work for future implementation of POD manufacturing systems to provide replacement parts as needed directly to the customers.

The overall conceptual POD program network which was developed under this task is contained in Appendix E. This and the POD system planning schedule were based on preliminary recommendations and are included to provide a framework and format for PMP development.

- **Investment Requirements Assessed and Funding Strategy Developed for POD**

During the development of the Investment Strategy, SAI collected data relevant to the funding needed to support the POD Program, current, proposed, and projected. Related efforts and shortfalls were identified that would require reprogramming of funds. Acceleration benefits were calculated for FY 84 and FY 85. The goals and payoffs to the supply system were also calculated, and potential benefits of manufacturing modernization efforts and technology transfer to the industrial base were highlighted in a briefing developed to summarize this strategy.

Figure 20 Potential POD System Concept



Key initiatives that were recommended included not only the manufacturing technologies and information handling systems identified earlier, but also projects to determine manufacturing database and baseline design requirements and materials and standards analysis. Fifty-six projects identified for research, development and demonstrations, and estimated costs requirements are detailed in Appendix E. The investment requirements for FY84 were estimated at $8.5 million and for FY85 at $17.6 million. Of this amount only $2.5 and $2.6 was identified in POM funding plans. Associated and related funding for current and proposed POD research programs were identified and proposed through 1990 for about $250 million investment. A 5 to 1 payback over a 10-year period was calculated and cumulative cost saving potential illustrated in Figure 21 is based on the funding profile summarized in Figure 22.

- **Electronic Supply Problems Identified and Technical Options/Investment Strategy Developed**

The investment strategy required for integrated circuits diminishing source of supply and technical options for electronics spares and replacement parts received increased attention during this period. A recent study showed that over one half of all unavailability for Naval aircraft is due to electronics. A chief problem in terms of inventory is the obsolete integrated circuit. The SAI study of this problem area identified patterns and solution options across the spectrum of Navy and DoD electronics parts. Lengthened operational life of Navy weapons systems have caused electronics and avionics systems to age to the point where these components are no longer manufactured commercially.

Potential solutions to the general problem include:

- Buyout prior to manufacturing shut down
- Cannibalize good parts from other system/sources
- Redesign/refit electronics with more modern componentry
- Remanufacture/reverse/engineer
- Emulate
- Tailor parts from standard set.

Figure 21 Estimated POD Cost Benefits - Navy

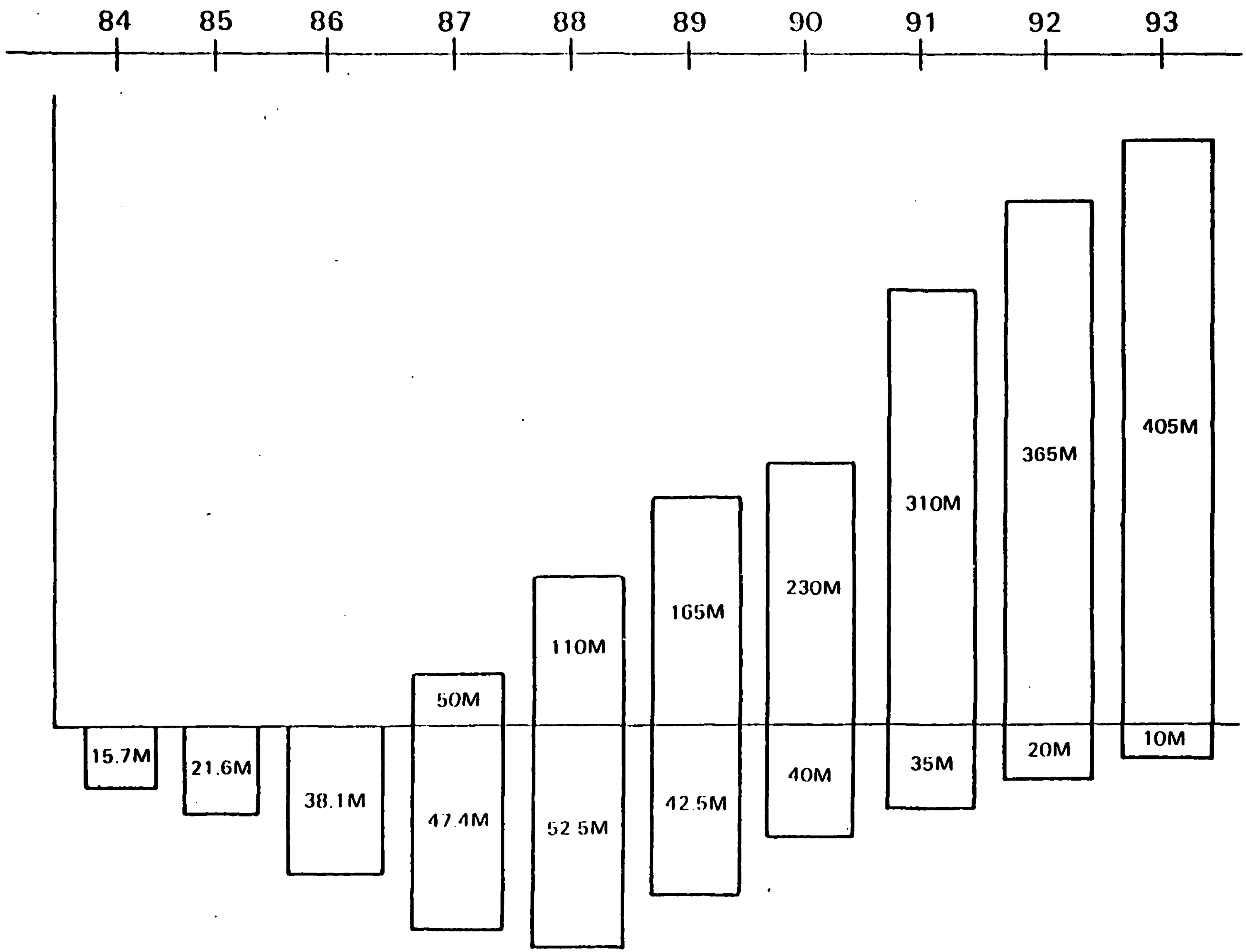


**Figure 22 Associated and Related Funding ($M)**

| | 84 | 85 | 86 | 87 | 88 | 89 | 90 |
|---|---|---|---|---|---|---|---|
| CURRENT POD | 2.5 | 2.6 | 8.7 | 8.9 | 9.2 | 9.65 | |
| PROPOSED POD | 4.5 | 10.0 | 27.0 | 29.0 | 27.0 | 23.0 | 16.0 |
| NAVCIM | 4.65 | 5.0 | 10.0 | 10.0 | 10.0 | | |
| UNIVERSITY RESEARCH | 4.0 | 4.0 | 4.5 | 5.0 | 5.0 | 5.0 | 5.0 |

The problem is broad and each solution has ranges of applicability. The fact that normal repair procedures waste large numbers of good components is a target for early exploitation, for example. The more costly solutions, buyout, remanufacture, emulation and tailored circuits required detailed business analyses as to the investment and benefit anticipated. See Appendix E for a copy of this plan.

**Task 5 - Implementation Plan**

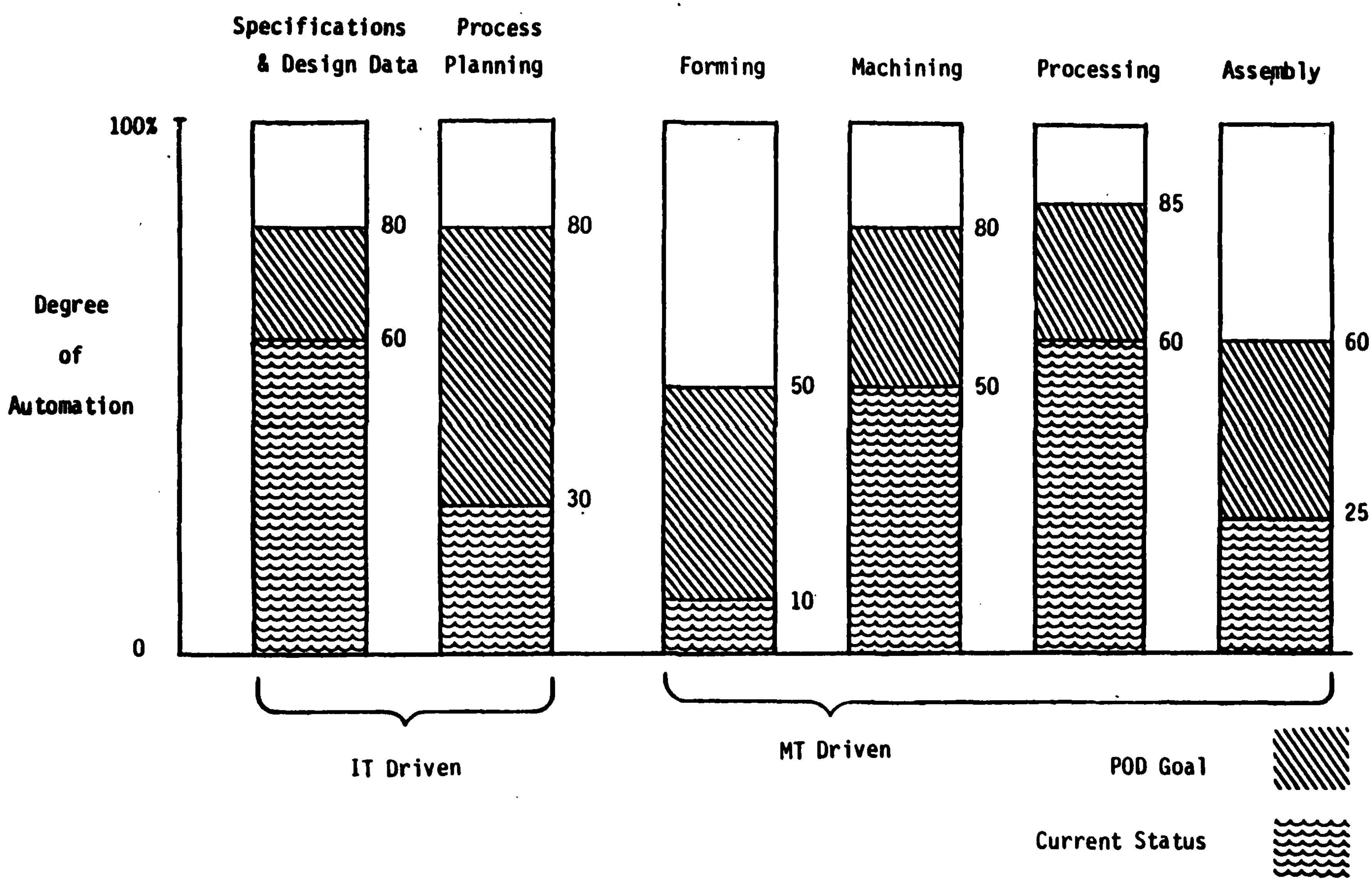
Under this task SAI developed near-term plans for both mechanical and electronic program implementation. The objective of this task was to determine priorities for action and funding in high payoff areas and identify research needed to move a POD system into a production operation as quickly as possible. Empirical data requirements were highlighted as a prerequisite for quantifying and validating cost impacts and benefits of POD systems for any major manufacturing operation.

- **Near Term Project Recommendations Utilize State-of-the-Art Technology**

*Figure 23 summarizes the relative* state of the art in manufacturing technology. The bars on the chart indicate the relative degree of automation, indicate the general areas needed for POD R&D and identify the area needing the most attention. For example in process planning most of the work is done manually. The development of generative process planning and the establishment of effective hierarchical computer information base systems is therefore a key to economic payoff for POD facilities. Maximum flexibility for low volume, automated manufacturing will be based on increasing capability and integrating systems capable of coordinated and balanced operations.

The basic technology push will come from increased computer power and advanced information handling control capabilities. The declining cost of computer power (about 50% every 30 months) is adding to the increased productivity of design engineers, draftsmen and manufacturing engineers doing work that involves repetitive operations or many changes. The basic tools are available, but R&D is needed to integrate CAD/CAM/CAPP/CAT techniques into the manufacturing process and

Figure 23 Status of Automation Technology for POD



determine life cycle cost impacts for POD parts as discussed under Task 3 Economic Analysis. Long term improvements will then focus on more efficient designing and processing using families of parts and utilize advances in manufacturability, assembly/disassembly, and replacement capabilities for remanufacturing.

Figure 23 also illustrates the near term goal objectives for POD development with cross-hatched segments representing improvements possible through R&D. For example, the current state of the art for forming technologies is relatively low and the potential for automating techniques in that area may have high payoff for POD systems. Nearnet shape technologies can eliminate machining, reduce scrap and minimize labor input and handling by forming single components using powder metallurgy instead of multipiece complex assembly. It can also replace wrought and machined parts, diecast parts, and those made by forging or conventional sandcasting. If promising results are shown in early demonstrations, it is a candidate with high potential.

- **The Use of Advanced Technology to Improve Low Volume Production Economics Was Assessed**

The relationship of unit cost and production volume as shown on Figure 24 indicates the general economies of scale for mass produced items. As production volume increases, unit cost decreases. The hatched area represents the penalties paid by the military for low volume spares and replacement parts, particularly for out-of-production items. The shaded area represents potential cost savings of POD systems using advanced technology for small batch production. Figure 25 compares the relationship of production flexibility with production capacity and shows the cost tradeoff for different methods of production ranging from highly automated dedicated equipment to very flexible standard machines that are manually controlled. At present the area of small batch production does not achieve economies of scale possible for mass produced items. Highly flexible POD systems will have to capitalize upon advanced technology to improve low volume production capability.

Figure 24 Effect of Applying Advanced Technology to Low Volume Production

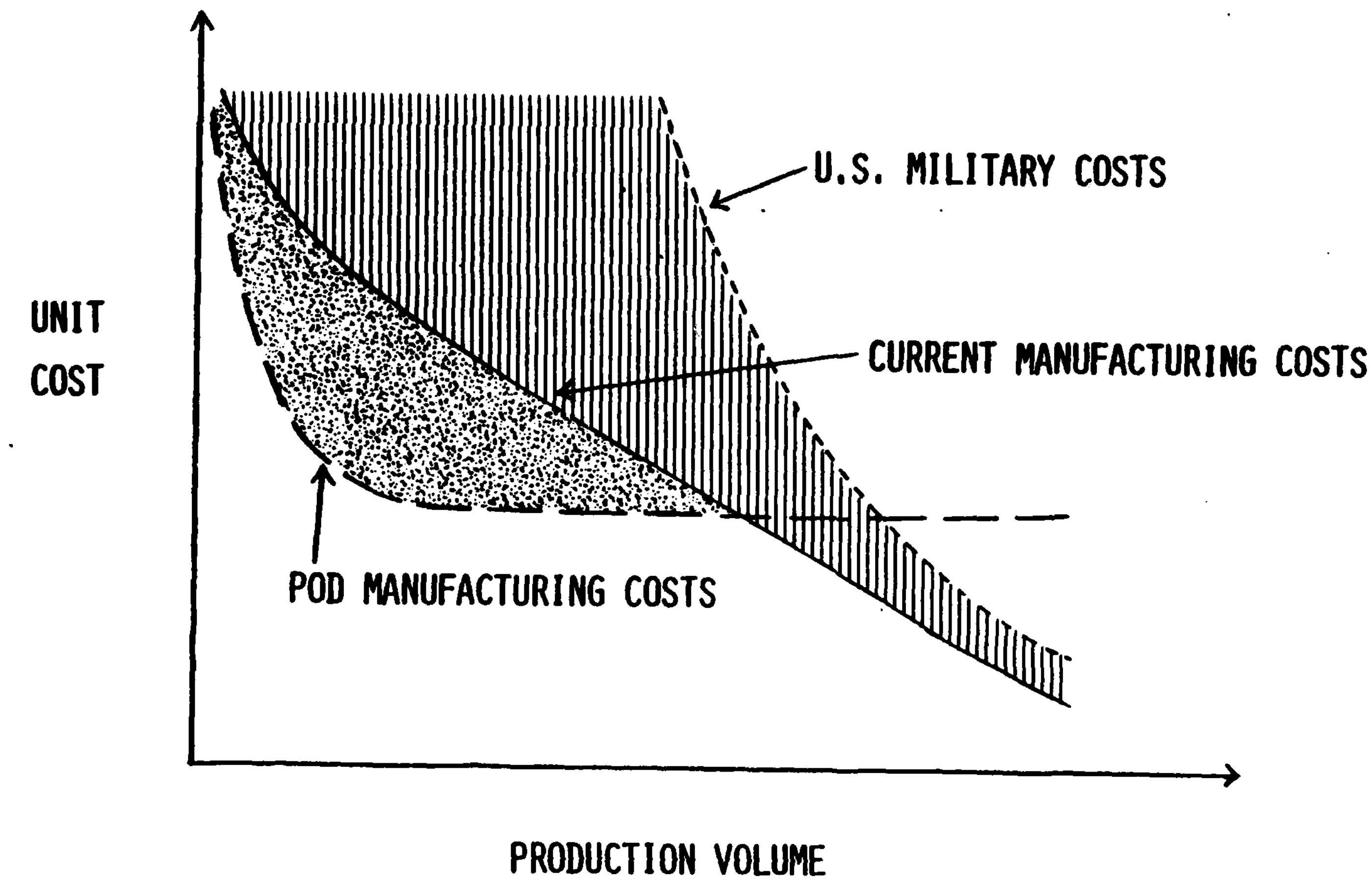
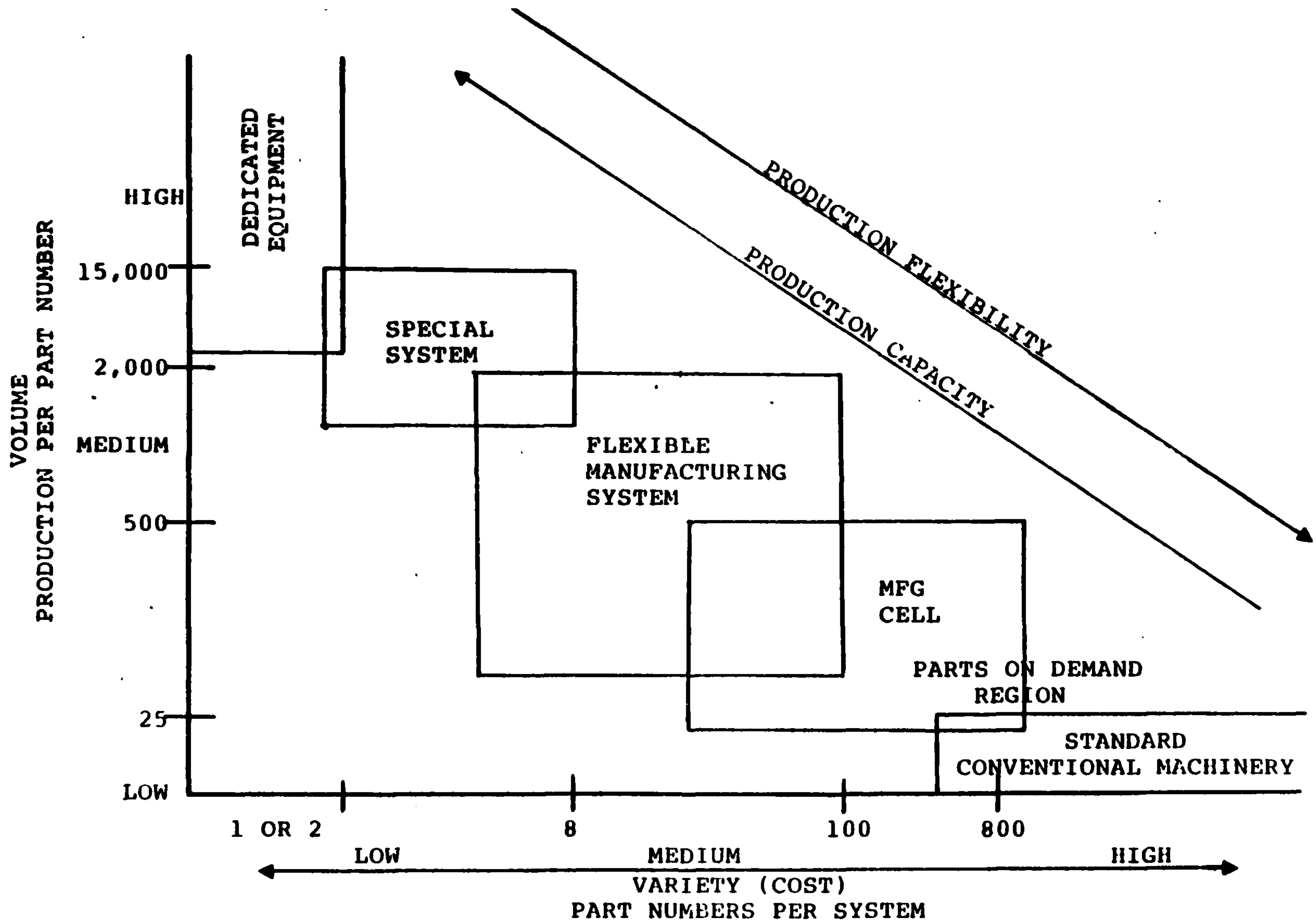


Figure 25 Manufacturing Flexibility and Production Capacity



- **Commercial and Prototype Systems Shown to Lower Processing Costs and Production Time**

Looking at state of the art in commercial practice, an analysis was made of current flexible manufacturing capabilities. Plant surveys, interviews with experts and consultants, and technical literature reviews were used to evaluate time and cost elements and other quantifiable impacts. Total processing time, average number of operations, floor space, manpower, and machine tool requirements were included in the analysis. Figure 26 illustrates one element, production time savings, from six case studies of prototype systems in the United States, Japan, and Germany. These case studies represent production of a range of products from small cutting tools (Case Study A-Kawasaki, Japan) to complex wing boxes (Case Study E-MBB, West Germany) and locomotive frames (Case Study F-General Electric, Pennsylvania). Some other quantifiable benefits are shown in Figure 27. After the introduction of FMS operations to a plant, companies experience numerous benefits. For example, John Deere, manufacturer of transmission cases and clutch housings, finds that setup time is virtually nil; they can respond quickly to changes in production levels, mix and even changes in design as well as being able to process components in fairly random order. NGL, an aircraft weapon systems manufacturers in the UK, found that stock and work-in-process turned over 24 times a year compared to a previous average of 3.3 times.

- **POD Systems Reduce Order Size, Inventory Level, and Lead Time Requirements**

The results of these studies were used to estimate impacts of using advanced flexible systems to reduce order size, inventory level, and lead time requirements for the military, objectives established earlier in the project. These estimates are based on using advanced POD systems for low volume spare parts production. For example, Figure 28 compares the current inventory procedure (large saw-tooths) with a POD system (smaller saw-tooths). The inventory level required for each procedure is represented by the dashed lines and indicates significant inventory level reduction. It should also be noted that a fully functioning POD system would not have to be maintained at a steady level but could fluctuate according to actual demand.

Figure 26 Reduced Manufacturing Production Time for FMS Prototype Systems

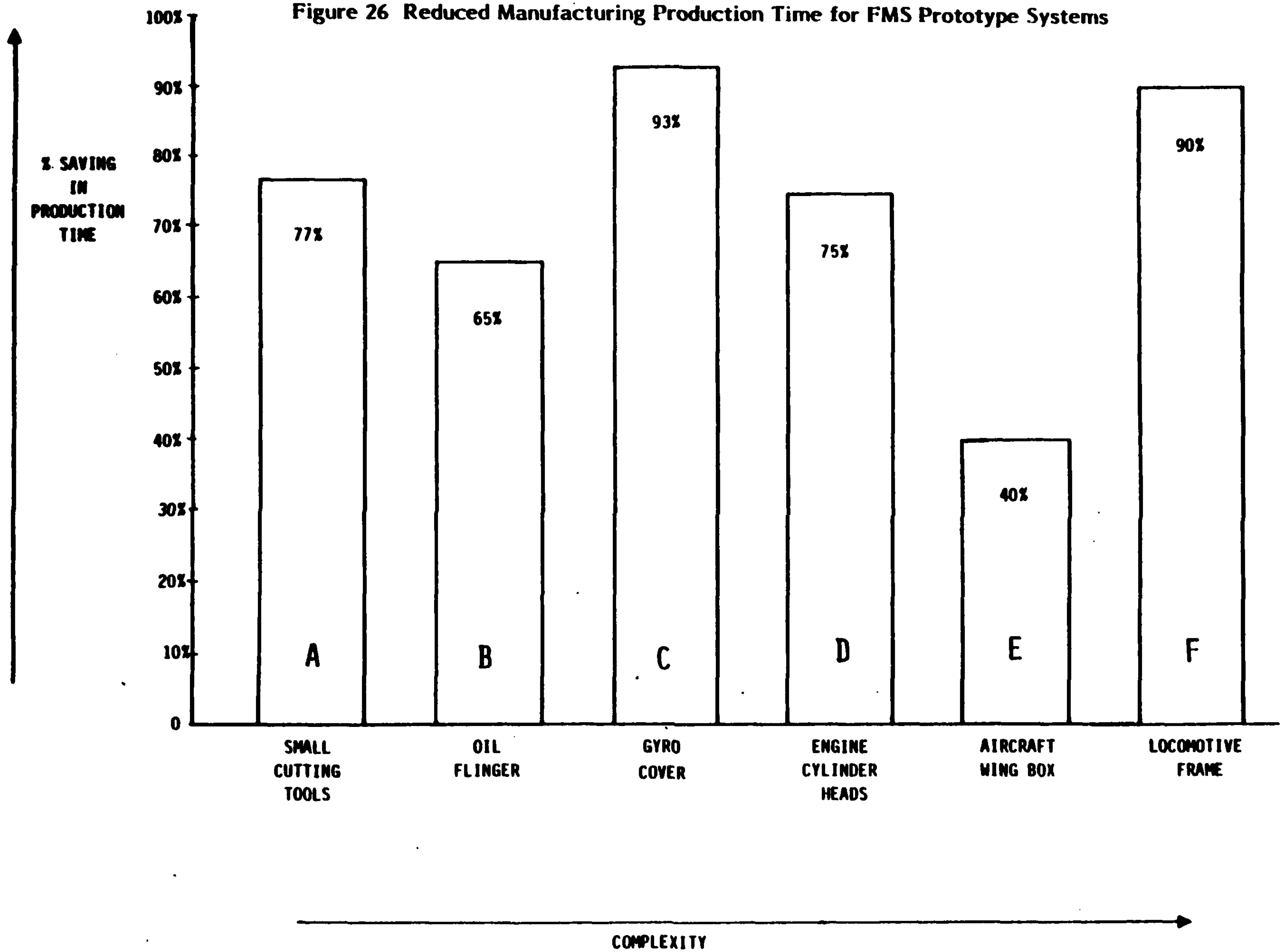


Figure 27 Quantified Impacts of Commercial Flexible Manufacturing Systems

| INDUSTRY | REDUCED NO. OF MACHINES TOOLS | REDUCED PERSONNEL | INCREASED AVERAGE USE OF MACHINES | REDUCED FLOOR SPACE | REDUCED AVERAGE NUMBER OF OPERATIONS | REDUCED TOTAL PROCESSING TIME |
|---|---|---|---|---|---|---|
| KAWASAKI, JAPAN (1) | 50 → 6 88% | 79 → 16 77% | 20 → 73% | 1500 → 360 $M^2$ 76% | 15 → 8 47% | 18.6 → 4.2 DAYS 77% |
| NIIGATA ENG CO, JAPAN (2) | 31 → 5 81% | 31 → 4 87% | | | | 16 → 4 DAYS, 75% |
| MBB GERMANY (3) | 44% | 44% | | 30% | | 30 → 18 MONTHS, 40% |
| GE LOCOMOTIVE ERIE, PA (4) | 29 → 9 69% | | 10 → 50% | 25% | | 16 DAYS → 16 HRS, 90% |

(1) MANUFACTURE OF 4000 DIFFERENT CUTTING TOOLS, CASE STUDY A.
(2) MANUFACTURE OF CYLINDER HEADS IN BATCHES OF 6 TO 30, CASE STUDY D.
(3) MANUFACTURE OF AIRCRAFT WING BOX. FMS REDUCED CAPTIAL INVESTMENT BY 9%, CASE STUDY E.
(4) MANUFACTURE OF DIESEL LOCOMOTIVES. ACHIEVED A PRODUCTIVITY INCREASE OF 240%, CASE STUDY F.

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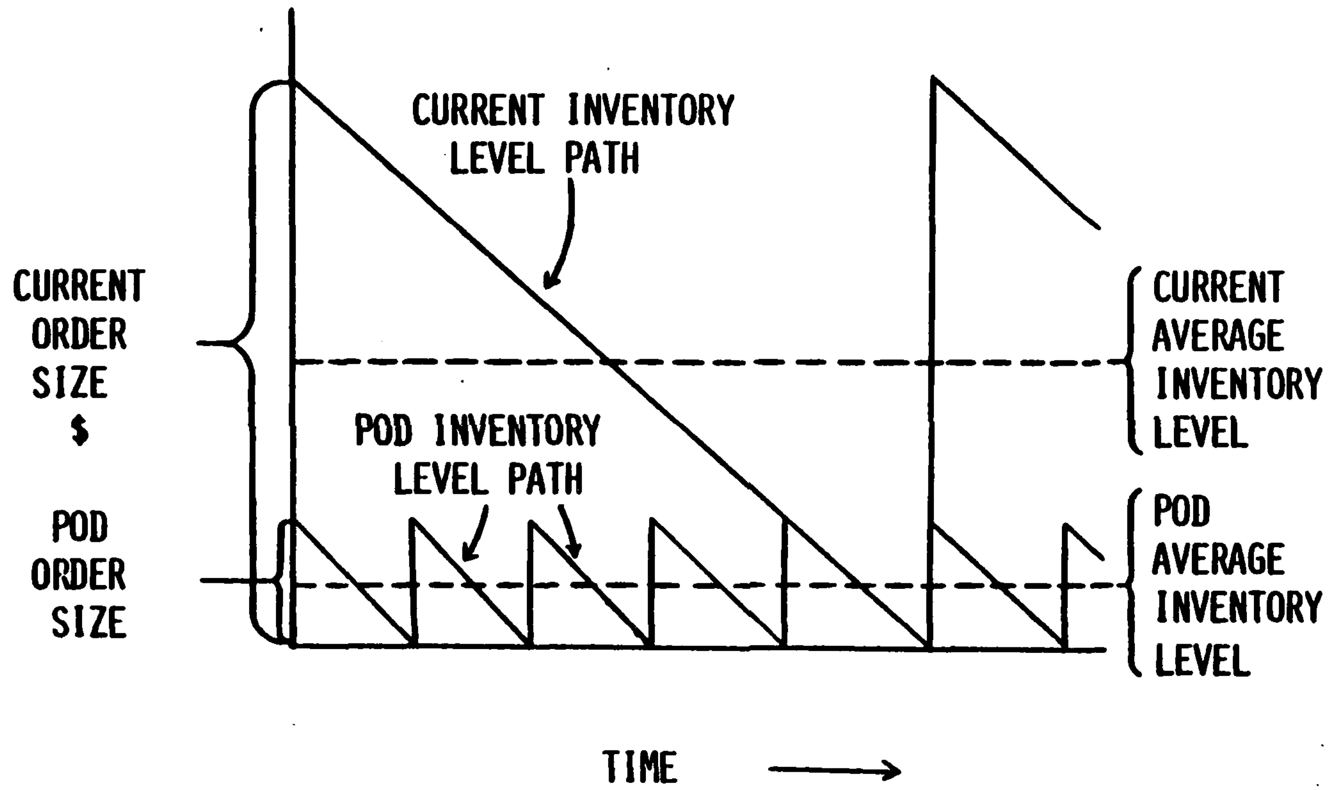
Figure 28 Reduced Order Size and Inventory Level



Other estimated benefits to the supply system include increased readiness capability, increased supply source availability through the alternative POD system, 10-20% reduction in holding and procurement costs, 30-70% reduction in lead time for critical parts, as well as a significant reduction in minimum stock inventory requirements.

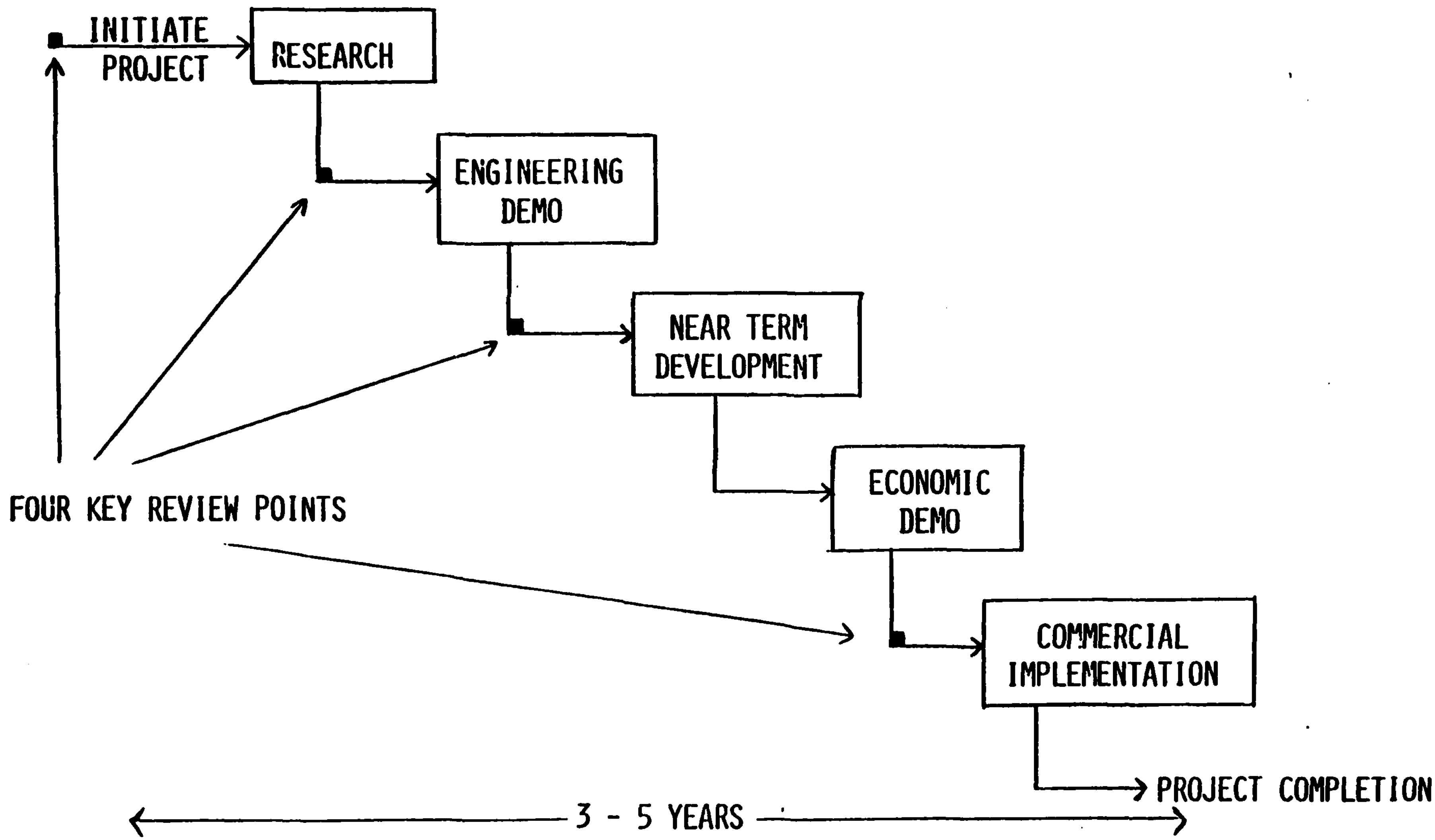
These overall benefits accrue from both direct and indirect cost saving projections. The direct savings come from reduced life cycle design (data) costs by using "stored data" and reduced production costs for small batches by reducing set up and production time. The indirect cost saving areas include increased competition and second sourcing, decreased Inventory Control Point (ICP) management costs, simplified POD procurement practices, direct customer-vendor contact, and lower inventory holding costs.

The POD investment outcome can only be estimated at this time since insufficient experience has been obtained with the technology needed for very low volume production. Also, the government must change its procurement practices to take full advantage of POD. We believe, however, that the 5 to 1 savings to cost ratio illustrated earlier in Figure 21 can readily be obtained. It may be even greater if all elements of the program are successful.

- **Development Cycle Highlights High Payoff Areas**

The development cycle for technology projects is illustrated in Figure 29 indicating the four key review points over a 3-5 year period where management can make corrections and alter the program as needed. Research projects are needed to focus on specific high-payoff areas where advanced technology can significantly contribute to improved supply system procedures. The development cycle recommended is based on fully exploring the available commercial capabilities and developments and then initiating technology advances as necessary to complement commercial developments. Ongoing reviews and monitoring activities are needed to assure that advantage is also taken of other government programs as appropriate.

Figure 29 POD Development Cycle for Technology Projects



The earliest engineering demonstrations are needed to focus research development on the highest payoff areas and adaptations of commercial capability. During the near-term development cycle, non-technology changes and requirements will be identified to assure the results maximize the achievements of POD program initiatives.

Throughout the cycle an incremental approach to implementation will be used. Based upon successful technology demonstations, POD systems will be designed and integrated into testbeds to demonstrate economics. Reviews at this point will include activities designed to transfer technology to the industrial base and DOD spare parts suppliers as appropriate.

- **Criteria for POD Implementation Developed**

The criteria recommended for selecting the manufacturing sites for a test program are based on the available options which derive from the development strategy selected. The decision for that strategy was based on development efforts which examine the two paths illustrated earlier in Figure 19: Navy obligation and Navy incentives. Since the specific capability for repairing/replacing worn parts is not being addressed elsewhere in the community, at least one test site should be installed at a Naval installation to determine feasibility and cost impacts resulting from the Navy obligation path. The other path requires stimulating and speeding up the incorporation of new technology into those portions of the civilian market that supply DoD through Naval incentives for development efforts. Figure 30 identifies some candidate organizations capable of providing early demonstrations and covers in-place facilities and R&D groups developing relevant technology.

- **Two-Stage Implementaton Process to First Test Feasibility and Then Assess It Under Operational Conditions**

Full-scale implementation of the POD systems will depend upon analysis of the efficiency and economics demonstrated in the testbeds. It will also require the incorporation of new acquisition policies to facilitate integration of POD operations

Figure 30 Leading Organizations with POD Technology Capability

| | IN-PLACE FACILITIES | R&D CAPABILITY | DOD ACTIVITIES* |
|---|---|---|---|
| MACHINING OF MECHANICAL PARTS | NBS, GE, RCA | CARNEGIE MELLON, NBS, GARRETT, CAM-I, PURDUE IITRI, U. WISCONSIN | • ARSENAL<br>• NARF<br>• SHIPYARDS<br>• SHIPS |
| ASSEMBLY OF MECH/ELECTRICAL/ ELECTRONICS PARTS | WESTINGHOUSE, IBM, GENERAL ELECTRIC | DRAPER, WESTINGHOUSE, IBM, GENERAL ELECTRIC, NRL, UMASS, SRI | • REWORK FACILITY (CHINA LAKE) |
| PRODUCTION OF INTEGRATED CIRCUITS | TI, FOUNDRIES, RCA, BELL LABS, IBM | BOEING, RCA, WESTINGHOUSE, TI, NAC, ERADCOM, MICOM, RPI | • NAC<br>• ERADCOM |
| PRODUCTION OF MECHANICAL PARTS TO NEAR NET SHAPE | HOEGANAES-PM AMERICAN GFM-ROTARY FORGE | CARNEGIE MELLON, NARF/SHIPYARD, MIT, SUTHERLAND | • NARF<br>• SHIPYARD<br>• ARSENAL (WATERVLIET) |

*EXAMPLES OF SPECIFIC DoD ACTIVITIES WHERE DEMONSTRATIONS COULD BE LOCATED

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into the supply system. At this point the review decisions will be based on determining the appropriateness of introducing new manufacturing technology in government or in industry and the requirements for investment incentives to help underwrite defense investments for commercial implementation and prototype lines. Contractor incentives can include some kind of business guarantee, tax breaks, IMIP and MT funds for improvements, and in special cases GFE may be needed.

Existing facilities, both military and commercial, will be used in the initial stages. Incremental application of measures will be used to determine success and applicability and to provide hard data for analysis. The results will then be used to make the decision to incentivize the transfer of technology to industry or commit to full scale field deployment in GOCO and GOGO plants.

Deployment options for POD systems which were examined include industrial prime contractors and subcontractors, as well as the in-house organic complex including Navy shipyards, air repair facilities (NARF), and weapon stations involved in overhaul, repair, and remanufacturing operations. The Parts-on-Demand systems will be developed to improve technical capabilities and tested at all levels to evaluate system capability to provide spare parts over the lifetime of weapon systems. There is excellent potential to move POD systems to forward areas since they will take less space and information handling is not dependent upon specific individuals knowledge of part fabrication since data are stored in a computer.

- **POD Program Management and Major Tasks for Mechanical and Electronic Systems Developed to Provide Proof of Principle and Operational Data**

The overall POD program management was divided into two key areas that have high impact: mechanical and electronic parts. These programs will be coordinated and involve parallel efforts addressing the technology base, demonstrations, and technology transfer functions appropriate for these types of parts. For the short run we recommend that efforts focus on unavailable machined parts and integrated circuits which currently have no source of supply. The following series of charts illustrate the program management plan which was developed and identify the key elements for developing new procedures and pilot programs. Figure 31 provides an overview of the management functions and Figures 32 and 33 list some of the specific areas to be addressed in the mechanical and electronic program development.

Both mechanical and electronic components include complex manufacturing operations. Of course, the manufacture of mechanical components is very different from ICs and therefore the production costs will have an entirely different base. A significant portion of the IC problem may be solved by non-manufacturing approaches using a programmable chip approach or prefabricated gate arrays needing only metalization. No such analog exists for the mechanical components which will have to be fabricated from the raw materials using a full complement of manufacturing hardware/tools.

The new procedures for the POD Mechanical Program include things in the area of competition and spare part prices. Key recommendations include the development of guidelines and engineering review procedures to allow the buyers of spare parts to understand supply sources, pricing structure, and practices that inhibit the ready procurement of spares such as data rights clauses. The pilot manufacturing program, which is highly condensed in Figure 32, highlights the three elements needed as a wedge for efficient program development: developing alternative manufacturing capabilities for low volume machined parts without a source of supply, advanced methods of recapturing design data for critical spares, and information handling tools such as process planning, monitoring and control systems.

The POD Electronic Program, summarized in Figure 33, is a similarly structured program addressing both new procedures and a pilot program focusing on solving existing source problems for integrated circuits (IC). Focus is on procurement practices and computerized aids to assist personnel in optimum selection and control of various ICs, guidelines for an engineering design review board to determine technical data requirements, and procedures to make spare parts a factor in source selection for new systems so that designs don't inherently become troublesome later on. The basis for the pilot program is 278 unavailable ICs identified by the Defense Electronics Supply Command. The first step in developing a system to replace these

Figure 31 POD Program Management Overview

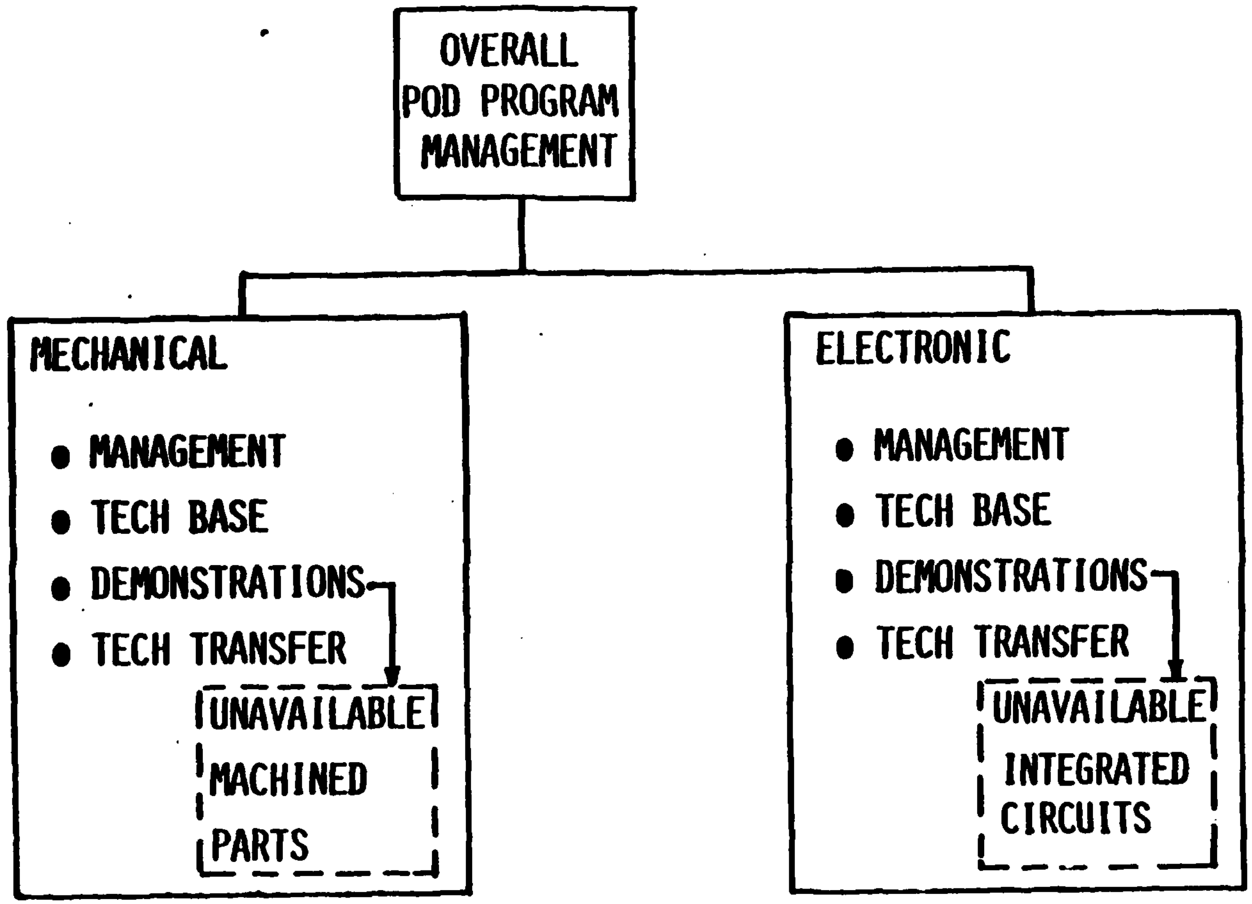


Figure 32 POD Mechanical Program Overview

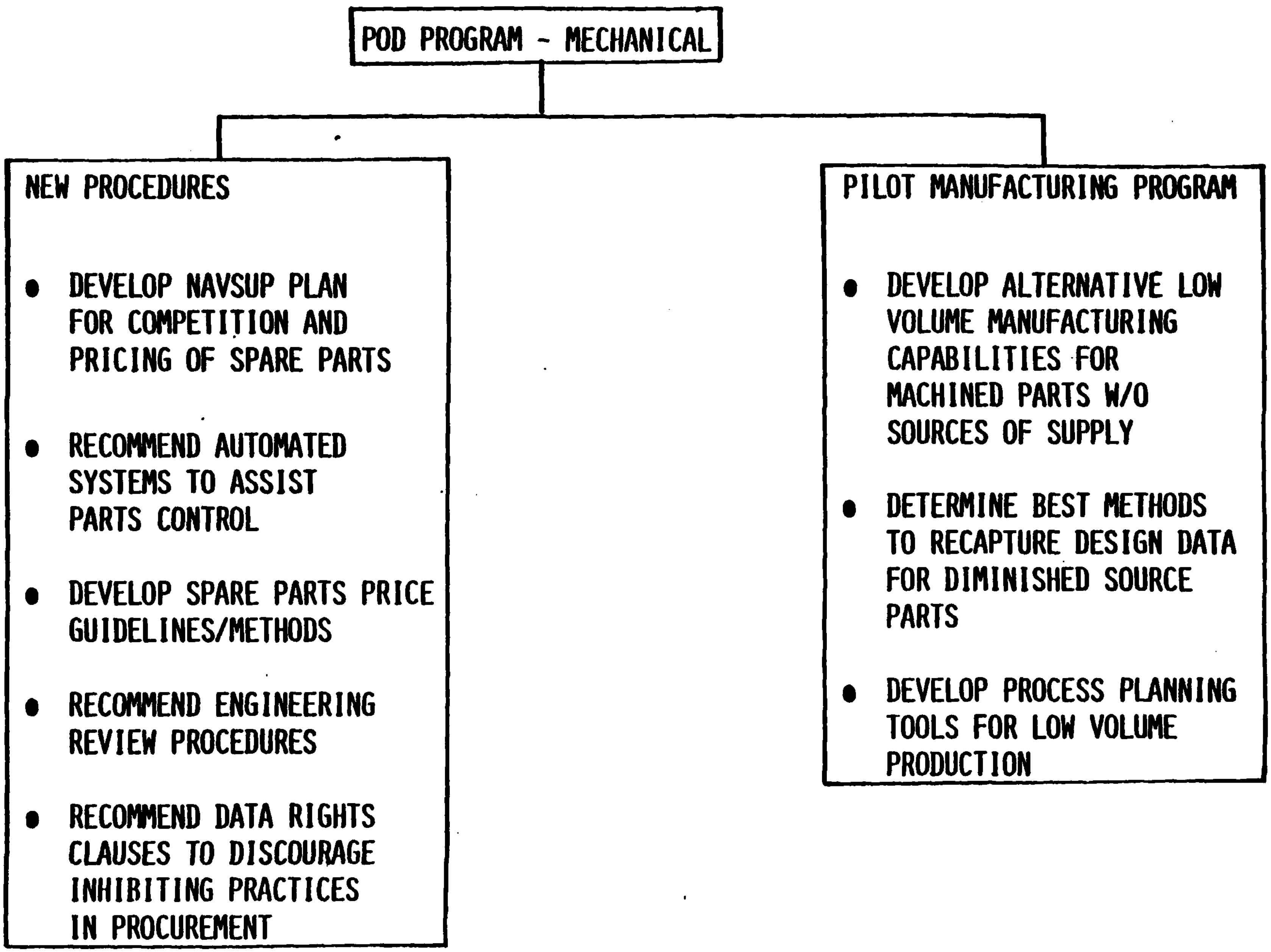
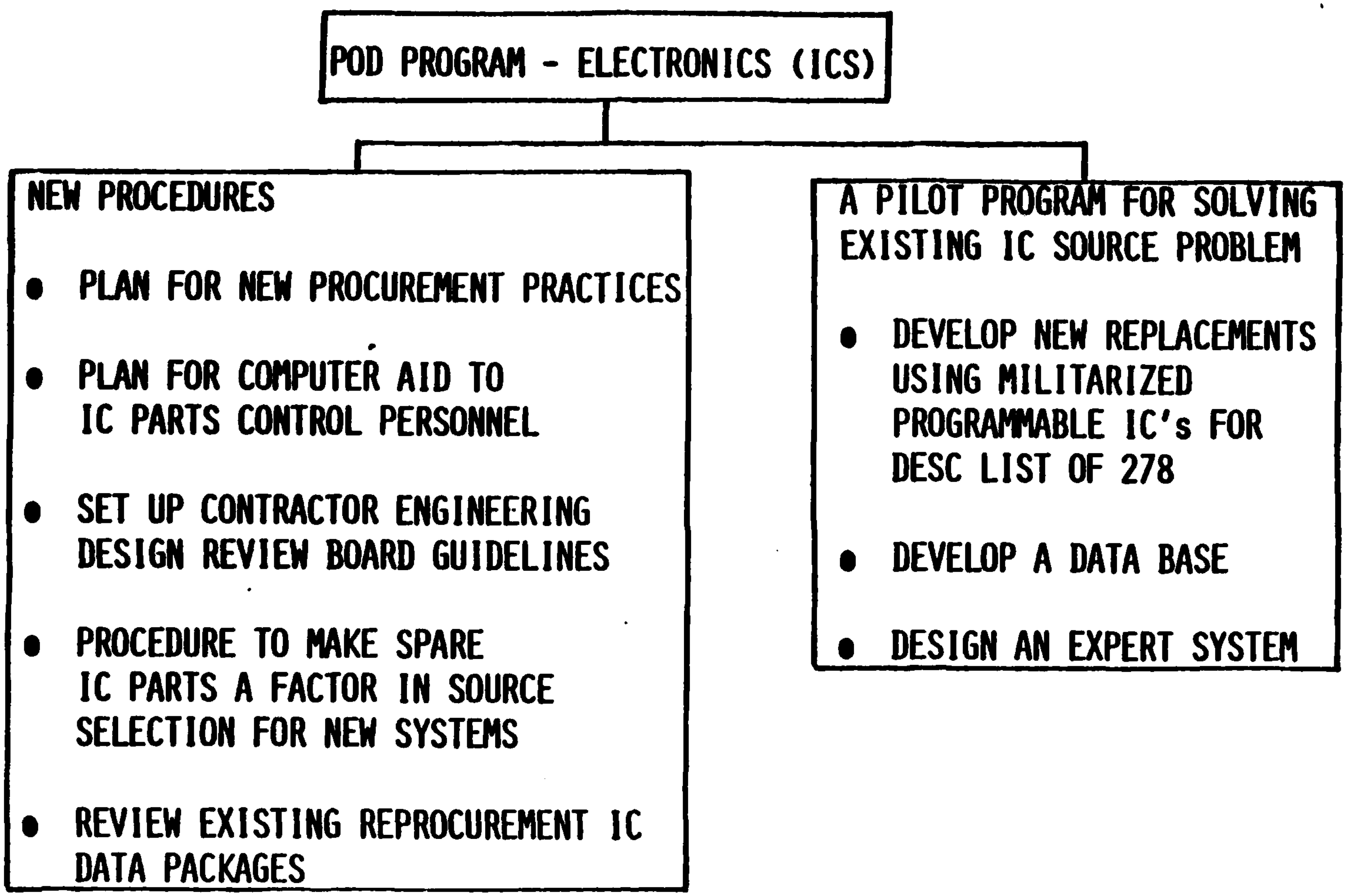


Figure 33 POD Electronic Program Overview



ICs is the development of a database and expert systems to determine the best solution for the IC problem at hand. Assuming that the full range of possible solutions is contained in the program as well as the full range of IC problems and requirements, a set of rules will be established for solution selection. It may be necessary to go into the design area but since much of the technology is highly specialized, a software program condensing the knowledge of experts would have long range benefit. Eventually, the part could then be designed based on the electrical parameters of the circuit without knowing the internal specifications.

The near-term (FY84, 85) plan and long-range (FY84-90) overview were developed to allow a rapid startup in critical areas and proof of principle to demonstrate high payoff potential. Figure 34 summarizes the major tasks for executing the mechanical program in FY84 and FY85. The current pilot system at NBS is being used to demonstrate adaptive machining capability for small mechanical parts. The major drive is to develop that capability for a mix of parts and demonstrate an integrated programmable system with multipurpose centers able to eventually work with worn or broken parts. The parts specification and database development require an expert system to reconstruct data and manufacture new parts based on form, fit and function requirements.

In addition to machining, both forming and assembly operations have been identified as key project areas for early funding. Technology demonstations in the forming area are focused on developing the capability to produce parts to near net shape and highlight promising technologies such as the use of powder metallurgy and programmable dies. Automated assembly for POD systems will require focused R&D in areas such as soft fixturing and programmable robotic systems. The payoff in the long term will depend upon the development of generative process planning and models to enable automated reconfiguring for changing processing requirements of a POD system. In addition, on-line in-process inspection systems are needed to assure quality control, integrated CAD/CAM/CAT systems to provide direct design capabilities and reconstruction of worn/broken parts, and advanced material handling systems for interface and integration of plant floor activity to improve scheduling and control of production operations.

Figure 34 POD Program Major Tasks Mechanical

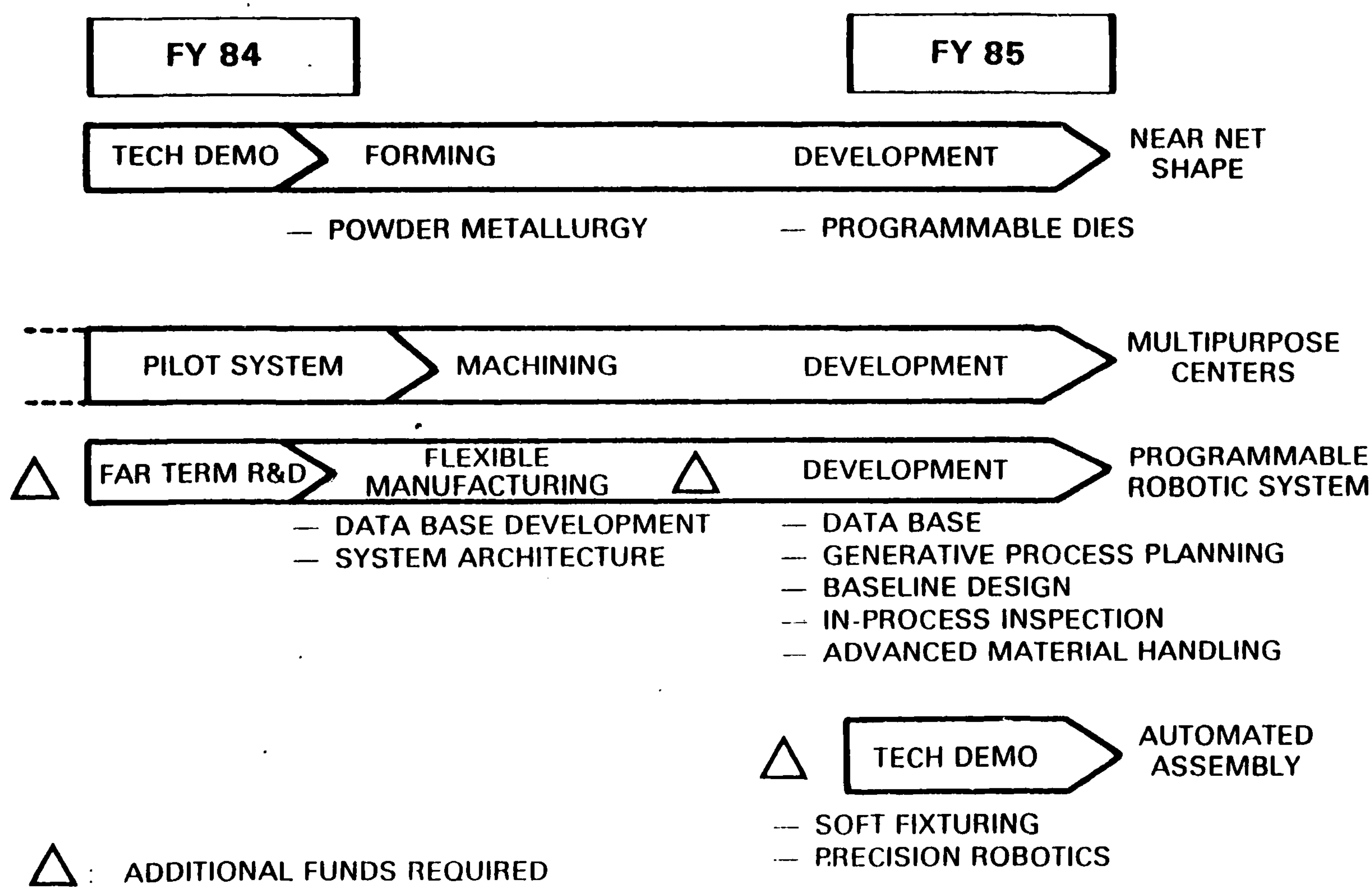


Figure 35 summarizes the major tasks identified for the electronics program. The first demonstration needed is a pilot system to provide proof of programmable chip replacement theory. It will be based on the development of a knowledge base for an IC expert replacement system and will lead to automated replacement ICs and automatic programming of replacement chips. Other aspects of the electronics problem in addition to unavailable integrated circuits will require both procurement analysis and investigation of other hard manufacturing solutions.

- **POD Demonstration and Deployment Plan**

Figure 36 summarizes the demonstration and deployment plan for POD implementation. On the left hand side of the chart the four major manufacturing process areas and the spare part replacement objectives are indicated. A seven-year plan is shown which is keyed to sequential demonstrations cycles to determine data base requirements and baseline designs for POD plants. A comprehensive and fast moving program is needed to increase the competition among ideas and approaches and create further opportunities to interface with the ultimate users. The six sequential elements indicated by numbers in Figure 36 are:

1 = Demonstrate process capability (testing and calibration)
2 = Breadboard/pilot lines, laboratory scale testing
3 = Production scale, system integration
4 = Economic validation demonstration in industrial environment
5 = Pilot plant design and development
6 = POD facility installation and deployment

Concurrent with achieving demonstration and deployment milestones will be an aggressive R&D program to fill in the technology gaps and standards development for integrated POD systems. Continual refinement and evaluation of efforts is needed to keep the focus on Navy/DoD logistics problems, quantitify the benefits, allow for new initiatives, and eleminate non-productive projects. As specific projects are implemented, technology transfer and incentives to the industrial base are important to integrate POD successes.

Figure 35 POD Program Major Task Electronics

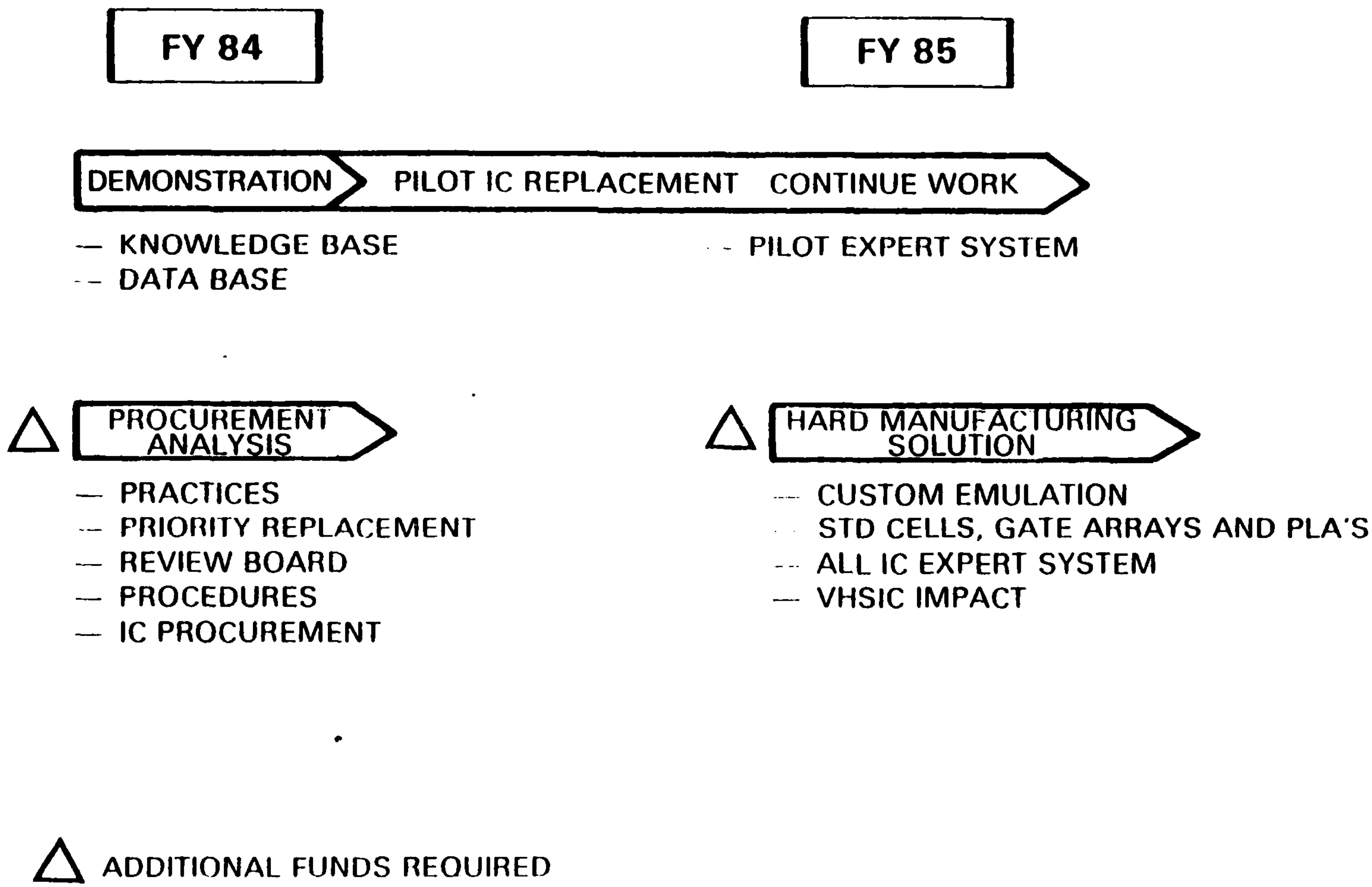


Figure 36 Demonstration and Deployment Plan

| AREA | OBJECTIVES | PARTS | START/FINISH 83 | 84 | 85 | 86 | 87 | 88 | 89 | 90 |
|---|---|---|---|---|---|---|---|---|---|---|
| MACHINING | SMALL-LARGE PARTS, SHAFTS, PRISMATIC, COMPLEX | MECHANICAL | 1 | 2 | 3 | 4 | | 5 | 6 | |
| ASSEMBLY | PARTS/KITS, SUBASSEMBLY, PUMPS, MOTORS | MECHANICAL ELECTRICAL ELECTRONIC | | 1 | 2 | 3 | 4 | 5 | 6 | |
| PROCESSING | EMULATION, STANDARD CELLS, GATE ARRAY, COMPILERS | INTEGRATED CIRCUITS | | 1 | 2 | 3 | 4 | 5 | 6 | |
| FORMING | PM TO NEAR NET SHAPE INV. CASTING HOT FORGING | MECHANICAL | | | 1 | 2 | 3 | 4 | 5 | 6 |

## SUMMARY

In conclusion, the following summary has been prepared to provide the reader with a thumbnail sketch of the POD Program as it evolved during this study.

**Overall Goals**

- Improve logistics support within military spare parts supply system
- Improve readiness, sustainability, surge/mobilization

**Program Objectives**

- Reduce production, procurement and holding costs of spare parts
- Reduce procurement lead-time

**Program Scope**

- Weapon system spare parts, inventory resupply, and critical parts procurement
- Electronic, mechanical, and electrical parts
- Specifications, information handling, control, and manufacturing systems for low volume production

**Technical Approach**

- Early demonstrations to prove technology capability
- Aggressive R&D program
- Continual evaluation and assessment
- Integrate technology into operational facilities
- Transfer technology to industrial base

**Schedule**

- Time-phased program started in 1983
- Accelerate and continue through 1990 and beyond

**Cost**

- Projected overall cost to DoD $250 million

**Products**

- Facilities/technology capable of fast, economical production of DoD spare parts in small batches as needed
- Procurement system capable of effectively utilizing facility/technology capability

**Risks**

- Little risk with the technology, but ongoing evaluation needed of applicability
- Failure to integrate results into most effective configurations
- Failure to create procurement/supply system which takes advantage of facilities/technology

**Risk Avoidance**

- Structure program plan with necessary decision points
- Provide funding for critical initiatives

# REFERENCES

## References

1. Logistics Cost Estimation.

The logistics cost estimates and analysis discussed in the Report are based on the following sources of data.

Inventory Value: Based on FY83 OSD Budget for the Navy, Annual Report to Congress.

Holding Cost Estimates: Based on NAVSUP Pub508, Basic Inventory Manager's Manual, Cyclical levels and forecasting per DoD Inst. 4140.39, Stockage Policy Analysis.

Annual Procurement Costs: Based on Federal Budget Trends itemized in FY84 Annual Report to Congress, including:
1) Peacetime Operating Spares Procurement
2) Stock Fund Peacetime Inventory Billed Requirements
3) War Reserve Secondary End Items/Spare Parts Funding

Insurance Items as % of Inventory:

Based on ASO and SPCC Inventory Records of Mark 0 items. Mark 0 items represent low demand insurance parts and include about 3/4 of the Navy managed inventory.

Dormant Inventory Items:

Based on SPCC Records, Computer Printout showing items not requested for 5-9 years.

DLA: 1,353,935
GSA: 29,766

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Spare Parts Determined as Potential POD Candidates:

Based on NAVSUP data as of 3 March 1983 all Navy managed and interest items consisted of 2,174,725 line items. Those managed by DLA, GSA, Navy Syscoms, and other DoD managed items were deleted from the sample based on the selection criteria developed for the study (e.g., limit survey to only Navy managed items and parts in inventory).

The following figure summarizes the cost problem areas examined during this study and Tables 2 and 3 illustrate defense spending projections

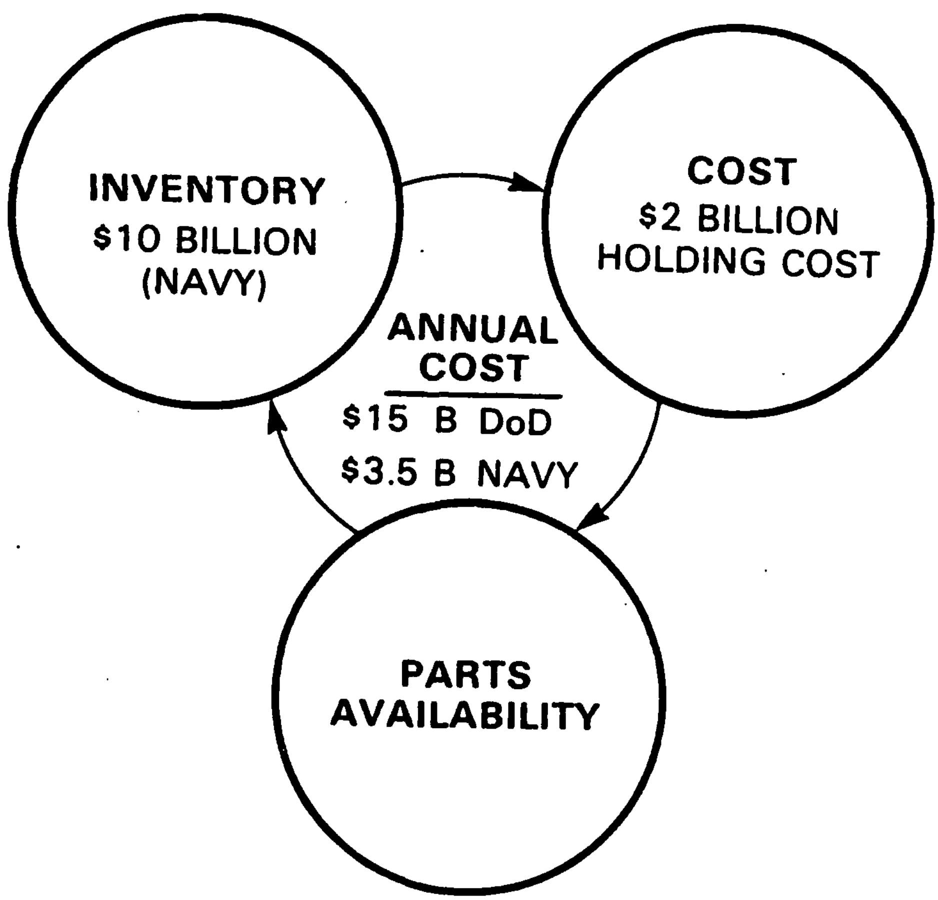


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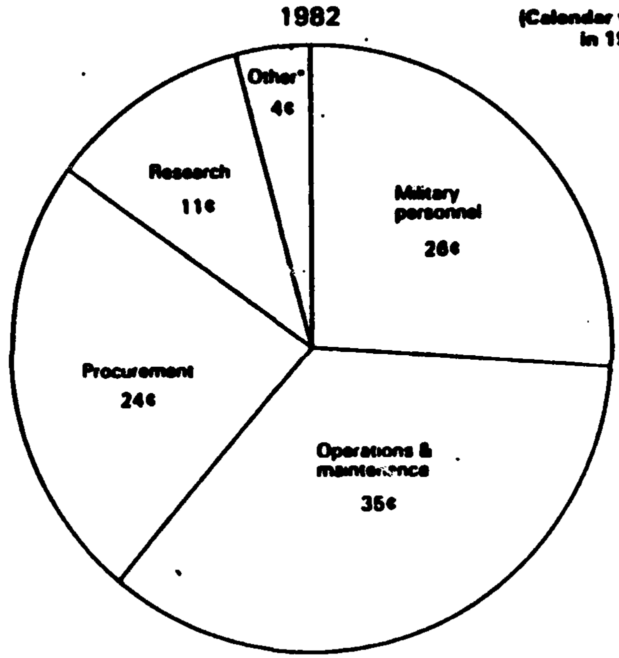
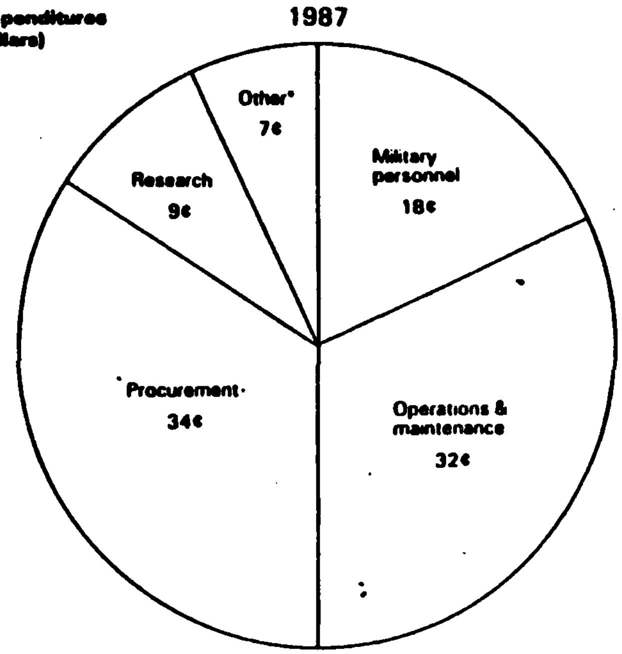
**Table 2**
**Growth in National Defense Expenditures by Program by Service**

| Program/Service | National Defense Expenditures (billions of 1972 $) 1982 | 1987 | Change 1982/87 (%) |
|---|---|---|---|
| **Total** | 80.1 | 118.5 | 48 |
| **Military Personnel, Total** | 20.9 | 21.8 | 4 |
| **Operations and Maintenance, Total** | 27.9 | 37.8 | 35 |
| Army | 6.8 | 9.0 | 32 |
| Navy | 8.4 | 10.8 | 29 |
| Marines | .6 | .8 | 14 |
| Air Force | 7.3 | 10.6 | 45 |
| Other | 4.8 | 6.5 | 35 |
| **Procurement, Total** | 19.1 | 40.7 | 113 |
| Army | 4.4 | 9.0 | 105 |
| Navy | 7.4 | 12.9 | 74 |
| Marines | .2 | .7 | 250 |
| Air Force | 6.9 | 17.1 | 148 |
| Other | .2 | .9 | 350 |
| **Research and Development, Total** | 8.6 | 10.6 | 23 |
| Army | 1.6 | 2.1 | 31 |
| Navy | 2.5 | 3.6 | 44 |
| Air Force | 3.8 | 3.4 | −11 |
| Other | .7 | 1.5 | 114 |
| **Military Construction, Total** | 1.0 | 3.3 | 230 |
| Army | .2 | 1.0 | 400 |
| Navy | .3 | .8 | 166 |
| Air Force | .3 | 1.2 | 300 |
| Other | .2 | .3 | 50 |
| **Family housing, total** | .7 | 1.3 | 86 |
| **Other than Dept. of Defense** | 1.7 | 3.0 | 77 |

Source: Derived from current dollar values provided from defense budget documents and deflated to 1972 prices by BIE.

**National Defense,**
**Purchases by Program, 1982 & 1987**
**Dollar Breakdown**
**(Calendar year expenditures in 1972 dollars)**




*Includes military construction, family housing, and non-DoD defense programs

2. Logistic Problem Areas.

The following list summarizes areas of concern highlighted by the Department of Defense and represent logistic problem areas which must be addressed and various approaches to the solution.

- Defense Inspector General Joseph H. Sherick, Deputy Undersecretary for Acquisition and Management, Mary Ann Gilleecs, Defense Department Inspector Generals Office: Report on overpricing of spare parts.

- GAO Study, "Material Shortages Reportedly Impair Navy Readiness," Dec. 10, 1983.

- Defense Secretary Caspar Weinberger: Project Directives to revamp Pentagon procedures for purchasing spare parts and to prevent overcharges.

- Air Force "Zero Overpricing" Suggestion Program.

- Air Force Management Analysis Group on Spare Part Acquisition; includes Major General Dewey Lowe, Major General Russ Mohney, Brig Gen. Jim Denver.

- Navy Secretary John F. Lehman, Jr. letter to Sperry Corporation to repay $80,000 in alleged overcharges for spare parts.

- Undersecretary of Army, James Ambrose testimony to Congress on spare engines for M1 tanks from AVCO.

- Deputy Defense Secretary Paul Thayer directive to "alert" defense contractors of DoD's firm intention to clamp down on overpricing of parts and keep prices under control.

- Assistant Inspector General John Melchner: testimony to Congress on supply system problems.

- Lawrence J. Korb, Asst. Defense Secretary for Manpower, Reserve Affairs and Logistics: remarks at Industrial College of the Armed Forces.

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