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BRIEFING ON MANUFACTURING TECHNOLOGY (MT) COST DRIVER ANALYSIS --ETC(U)
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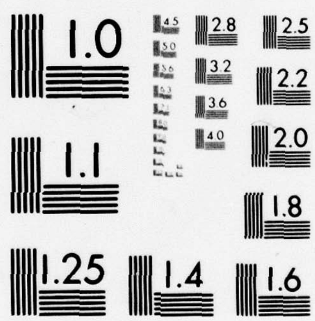

MICROCOPY RESOLUTION TEST CHART
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BRIEFING

on

MANUFACTURING TECHNOLOGY (MT) COST DRIVER ANALYSIS PROGRAM

to

NAVAL AIR SYSTEMS COMMAND
DEPARTMENT OF THE NAVY
WASHINGTON, D.C.

by

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June 27, 1979

NAVAL AIR SYSTEMS COMMAND

MANUFACTURING TECHNOLOGY (MT) COST-DRIVER ANALYSIS PROGRAM

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ACKNOWLEDGMENT

MR. T. J. GILBRIDE, HEAD
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NAVAL AIR SYSTEMS COMMAND

MR. GILBRIDE PROVIDED VALUABLE INSIGHT AND GUIDANCE ON COST ANALYSIS AND COST AND WEIGHT DISTRIBUTION.

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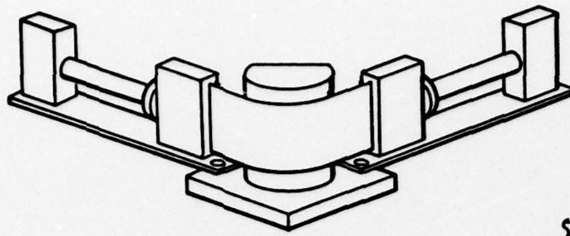
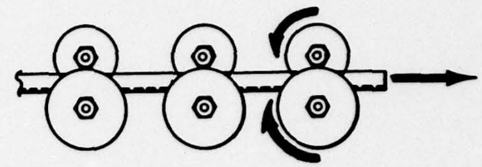
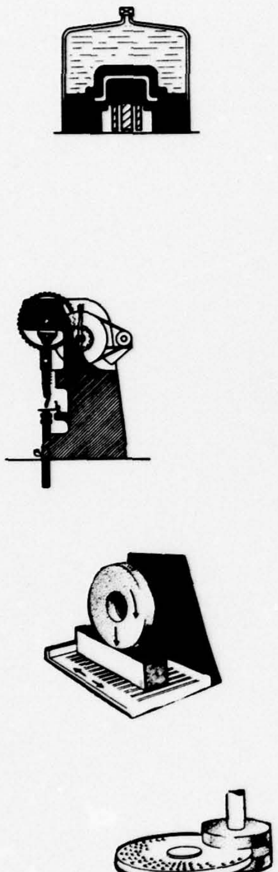
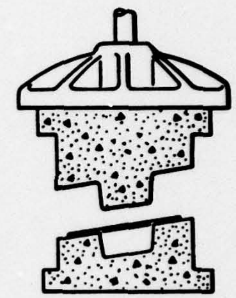
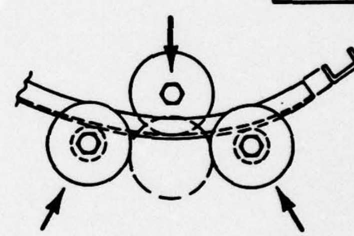


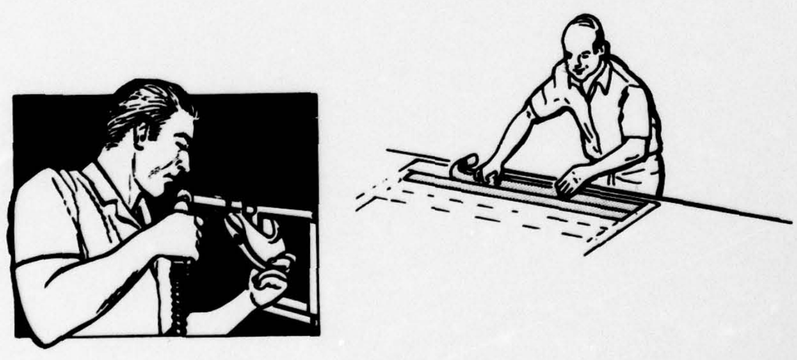


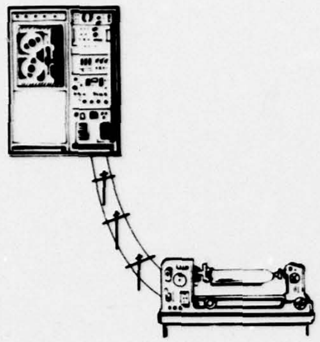
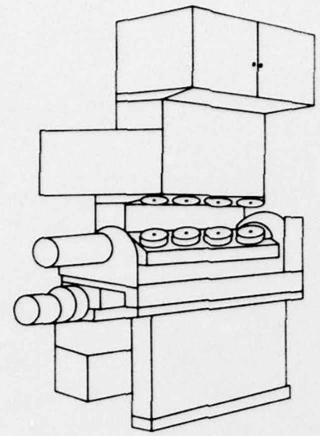
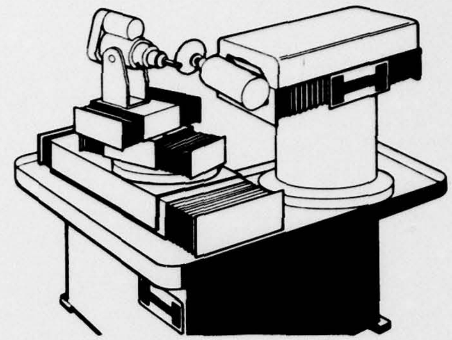
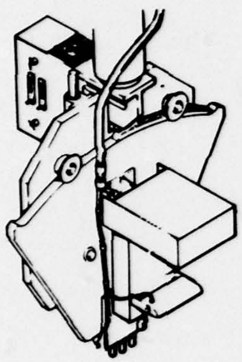


MANUFACTURING TECHNOLOGY (MT)







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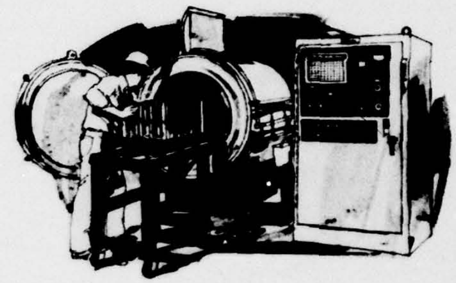
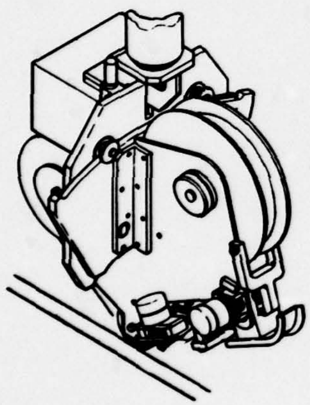
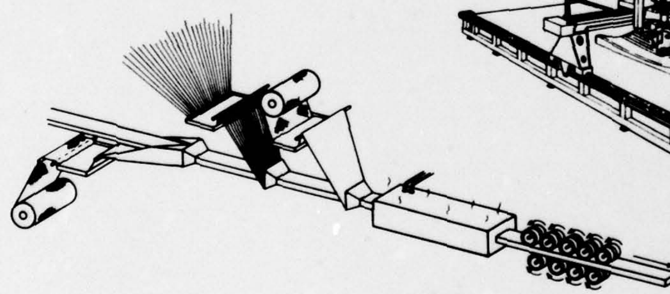
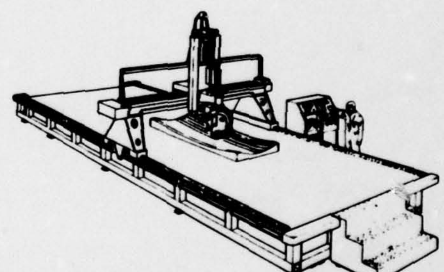
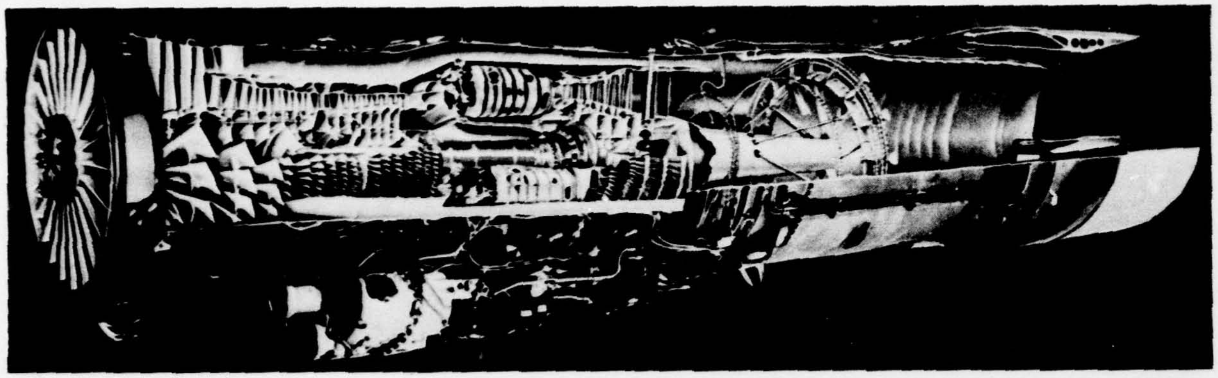
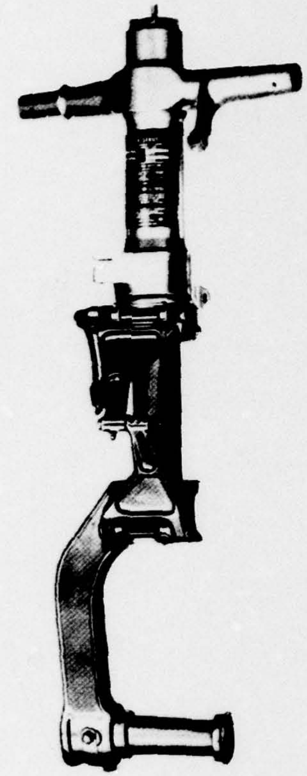
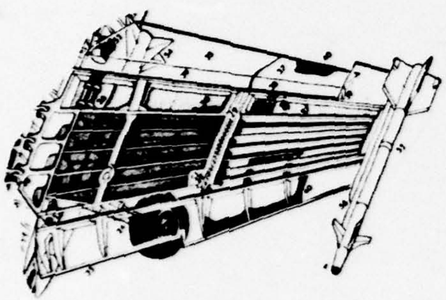
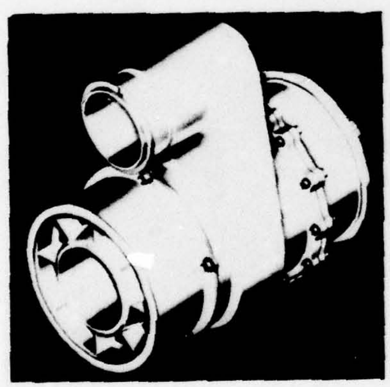





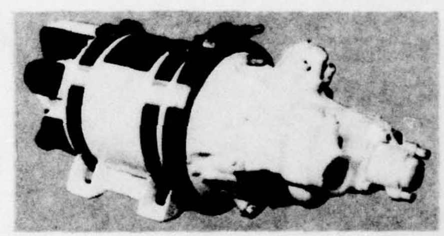






REPRESENTATIVE MAJOR SUBSYSTEMS IN NAVY AIRCRAFT





NAVAL AIR SYSTEM COMMAND

MANUFACTURING TECHNOLOGY (MT) BEST DRIVES ANALYSIS PROGRAM

CONTENTS

EXECUTIVE SUMMARY

NAVAL AIR SYSTEMS COMMAND

MANUFACTURING TECHNOLOGY (MT)
COST DRIVER ANALYSIS PROGRAM

EXECUTIVE SUMMARY

The need for the U. S. Navy to arrest and reduce costs throughout the aircraft system life cycle is becoming increasingly important. Qualitative and quantitative data and other information on cost drivers useful during the design, manufacture, operation and maintenance of aircraft systems are essential. The challenge of designing and manufacturing to lowest cost by necessity will become increasingly severe due to the growing problems of inflation, systems sophistication, changing international pressures, labor and energy costs. It will continue to sharply erode the ability of the Department of Defense to purchase the necessary weapon systems. The number of new aircraft types being developed for the Defense inventory is decreasing, while there is a need for increased performance and reduced operations and maintenance costs. The U.S. Navy therefore requires aircraft weapon performance which is affordable. The U.S. aerospace industry, through Government and industry R&D programs, which identify and resolve cost-driver problems, is a world leader, in fact, it is probably the only high-technology industry in which the U.S. has retained the competitive edge.

This study is in response to the urgent need to reduce manufacturing costs of aircraft systems. The subsystems studied were:

- Airframes,
- Engines,
- Mechanical and hydraulic systems, and
- Crew systems.

This study was only concerned with cost drivers in the manufacture of components in aerospace companies, i.e., acquisition costs. The cost drivers in aircraft rework, overhaul, and remanufacture are covered in a separate study conducted for the Naval Air Rework Facilities by Systems Consultants, Inc.

The objectives of this manufacturing technology (MT) cost-driver analysis program were to:

- Identify cost drivers in Navy aircraft manufacture,
- Identify cost driver commonality, and
- Provide a basic framework for evaluating manufacturing technology (MT) projects.

To accomplish this program, a series of visits were made. Three aircraft manufacturers, two engine manufacturers, and four mechanical systems/accessory manufacturers were visited. Discussions took place with management, manufacturing engineers, design engineers, and production supervision. Most important was that the manufacture of each product was studied on the shop floor. In most visits, detailed discussions took place on the cost drivers for specific discrete parts. Many letter and phone contacts were made. Significant reports, such as the proceedings of the AFML Sagamore and French Lick meetings and the NMAB aerospace cost-savings report (NMAB-326) were studied and found very useful.

Navy aircraft performance requirements are unique. They offer challenges and opportunities for innovation to the aircraft design and manufacturing engineers. Examples of the important performance requirements peculiar to Navy aircraft, posing cost problems, are:

- Heavier landing gear due to high sink rates
- Arresting gear
- Corrosion avoidance (salt-air environment)
- Catapult take-off
- Carrier landings
- Folding wings and tails.

In general, stronger, more durable construction is required than for land-based aircraft.

Manufacturing cost drivers are the result of the customer's need for increased performance at an affordable cost. Performance includes higher speeds, higher altitudes, greater maneuverability, reduced weight, less fuel consumption, and better quality improving reliability and maintainability. This results in today's requirement of providing more at lower costs. Cost drivers are the result of the thrust by engineering to achieve and exceed performance goals, including the introduction of advanced materials, the natural desire for progress, the need to find a better way and to remain competitive.

Increased aircraft performance depends upon the excellence of engineering design. Affordable aircraft performance depends upon MT recognizing cost drivers, in both design and manufacture – avoiding cost drivers in new designs and by improving manufacturing methods for existing products. Cost drivers can be avoided in aircraft design by design-to-cost (DTC). Early identification of cost drivers and early corrective action in existing and new products depends upon proficiency in manufacturing-to-cost (MTC). There is a need for proven innovative MT ahead of advanced aerospace system design.

The cost drivers identified have been related to various categories of aircraft system development and manufacture. These are:

- Performance
- Design
- Material
- Manufacturing.

As an example of a segment of the study, the cost drivers for auxiliary components are listed below using the above categories.

- Performance related
  - Reduced weight
  - Higher operating speeds
  - Increased reliability and maintainability
- Design related
  - High part count
  - Nonstandardization
  - Tight tolerances

- Material related
  - Cost
  - Availability
  - Utilization
  - Energy
  - Inventory
- Manufacturing related
  - Inspection
  - Equipment
  - Cyclic production
  - Small lot sizes
  - Job shop environment
  - Highly skilled labor
  - Metal removal
  - High scrap rate
  - Deburring/hand finishing
  - Heat treatment
  - Hand fit-up
  - Energy (autoclave curing)

From each analysis of cost drivers, conclusions have been drawn and recommendations made for the different subsystems.

The airframes subsystem, which frequently represents more than 50 percent of the total cost of aircraft, was analyzed in the following two categories:

- Primary structures (fuselage, bulkheads, wing box, ribs, spars)
- Secondary structures (fairings, doors, control surfaces).

The cost drivers in the primary structure were identified as:

- Use of titanium
- Metal-removal equipment becoming obsolete
- Tight tolerances
- Assembly/installation costs
- Requirements for interchangeability
- Heat treatment
- Hand finishing and blending
- Fit-up for electron beam (EB) welding.

With secondary structures representing approximately 1/3 of the airframe structure cost, the following cost drivers were identified:

- Sheet metal fabrication
- Assembly tooling cost
- Numerous small, hand-fitted, parts
- Excessive numbers, sizes, and types of fasteners
- Corrosion protection
- Excessive damage in service (logistic spares problem).

10

Aircraft engine cost drivers were analyzed in two categories:

- Rotating components
- Nonrotating components or static structures.

Examples of the cost drivers in rotating components are:

- Metal removal
- Low material utilization
- Assembly
- Casting quality
- Hard-facing processes
- Hole drilling
- Heat-treatment distortion
- Test, inspection and evaluation (TI&E).

For the nonrotating or static structures of engines, the following cost drivers were identified:

- Part count
- Joining (welding and brazing)
- Tooling
- Deburring.

A series of matrix charts have been prepared as a result of the industry visits and studying important references. These charts indicate the cost drivers for major subsystems – airframe, engine, mechanical systems, auxiliary systems – in four impact categories:

- High
- Average
- Low
- None.

Cost drivers have been categorized for the major subsystems in broad terms:

- Those common to most industries
- Those aerospace related
- Those technology related.

The cost drivers are indicated in terms of important manufacturing operations, e.g., material removal, and these have been further divided into categories such as:

- Material availability
- Equipment replacement
- Chip-removal
- Inspection
- In-plant handling
- Heat treatment/processing.

Similarly, the cost drivers for assembly/installation have also been analyzed and presented in the following categories:

- Multitype fasteners
- Fastener quantity
- Fastener installation
- Accessibility
- Hole tolerances.

The indications of the impacts of the various cost drivers should be analyzed further, as, in the majority of cases, the only possible way to accurately determine these impacts is to conduct detailed cost estimates of the various operational sequences in the manufacture of any component and to normalize these for a series of different aircraft subsystems, e.g., fuselage nose, midfuselage, rear fuselage, where cost varies depending on accessibility, complexity, and many other factors.

From the overview matrix charts presented, the following conclusions have been made:

- Major cost drivers common to all industry are inflation, energy, material, and equipment.
- A commonality of cost drivers exists throughout all subsystems.
- Major cost drivers common to the aerospace industry are metal removal, material utilization, high part count, and fastener installation.
- Airframe manufacture represents the highest impact cost drivers and provides the greatest opportunity for cost reduction.
- Engines, mechanical systems, and crew systems have most commonality among the cost drivers, e.g., material removal, heat treatment, TI&E, and many specifications.

General conclusions from this study are that we must accelerate our efforts to change the emphasis from only performance to affordable performance. Spiraling aircraft costs must be better controlled. It was also concluded that many cost drivers are designed into aircraft. This emphasizes the importance of the "window of opportunity" in the aircraft design process, i.e., the conceptual and preliminary design phases, where only a few percent of the program expenditure has been committed, yet decisions have been made which sometimes determine 90 to 95 percent of the total program costs. This leverage at the conceptual and preliminary design phases is extremely important. It increases with the increasing sophistication of the aircraft being designed. As soon as detail design and manufacturing planning commences, the cost savings possible rapidly diminish to just a few percent and the cost to achieve those savings becomes significant. Furthermore, each component being redesigned using different materials or more sophisticated manufacturing processes will have to meet Form, Fit, and Function requirements, hence, providing little opportunity for innovation in the cost saving process at this late stage.

Further conclusions related to MT are:

- Minimum new MT has been introduced into production in the past 10 years.
- Most MT cost drivers are common to all subsystems.
- MT projects should be selected that provide a high return-on-investment (ROI).
- Emerging MT still displays significant cost drivers.

- MT should be developed and proven acceptable before introduction into production; and
- Developing MT on a production program is seldom cost effective.

From the analysis of the cost drivers and the conclusions derived, the following general recommendations are made with regard to the selection of MT projects. These should provide:

- Maximum cost savings at design conception
- Potential high cost savings for future aircraft systems
- Compatibility with Navy aircraft objectives
- Maximum synergistic effects throughout all subsystems
- Greatest commonality between subsystems
- Minimum design change and retesting
- Transition of emerging MT to production acceptance.

An MT project should not be selected simply to improve a manufacturing process that is already obsolete.

Certain constraints exist on the introduction of new manufacturing technologies. Some of these constraints apply to almost all new technologies in the aerospace industry. New technologies must be tried and proven satisfactory in service before their acceptance. It is difficult to introduce new technologies into an ongoing program because of redesign, retesting, and retooling requirements. New technologies are sometimes difficult to introduce because of the investments required for new equipment and the tendency to "let's make it with what we've got". No single company can afford the total investment for new equipment or manufacturing development for introducing major new technologies. There is also the problem of fear of failure and the tendency to let the other company try it first.

Other problems which also constrain the utilization of new technologies are:

- Reduced budgets
- Inflation
- Limited MT funds
- Logistic problems (customer inventory)
- Retraining of personnel (industry and field support).

It is difficult to determine what advanced technology is most effective and – even more important – what is the ROI.

Navy aircraft manufacture depends heavily on manpower. It is a cyclic industry with excessive capacity. It is a highly skilled industry. While it is driven by product excellence and is, therefore, high-technology oriented, there is little automation.

Although, in some cases, design-to-cost (DTC) and manufacturing-to-cost (MTC) principles are discussed, they are not widely or uniformly practiced and program overruns can sometimes be traced directly to a failure to fully understand and apply these DTC and MTC principles.

The aerospace industry and the customer have necessarily placed heavy emphasis on increased performance over the years. In fact, the United States has led the world in designing and building some of the finest military aircraft in the world and certainly is a world leader in commercial aircraft design and manufacture. We have accomplished this, however, at ever-increasing costs and are now faced with the situation that we might be pricing ourselves out of the business. Similar to the automotive industry, the aircraft industry is now forced to increase the number of trade-offs at all levels of aerospace vehicle development. These trade-offs are between performance at any cost and affordable performance, e.g., minimized weight and minimized manufacturing cost.

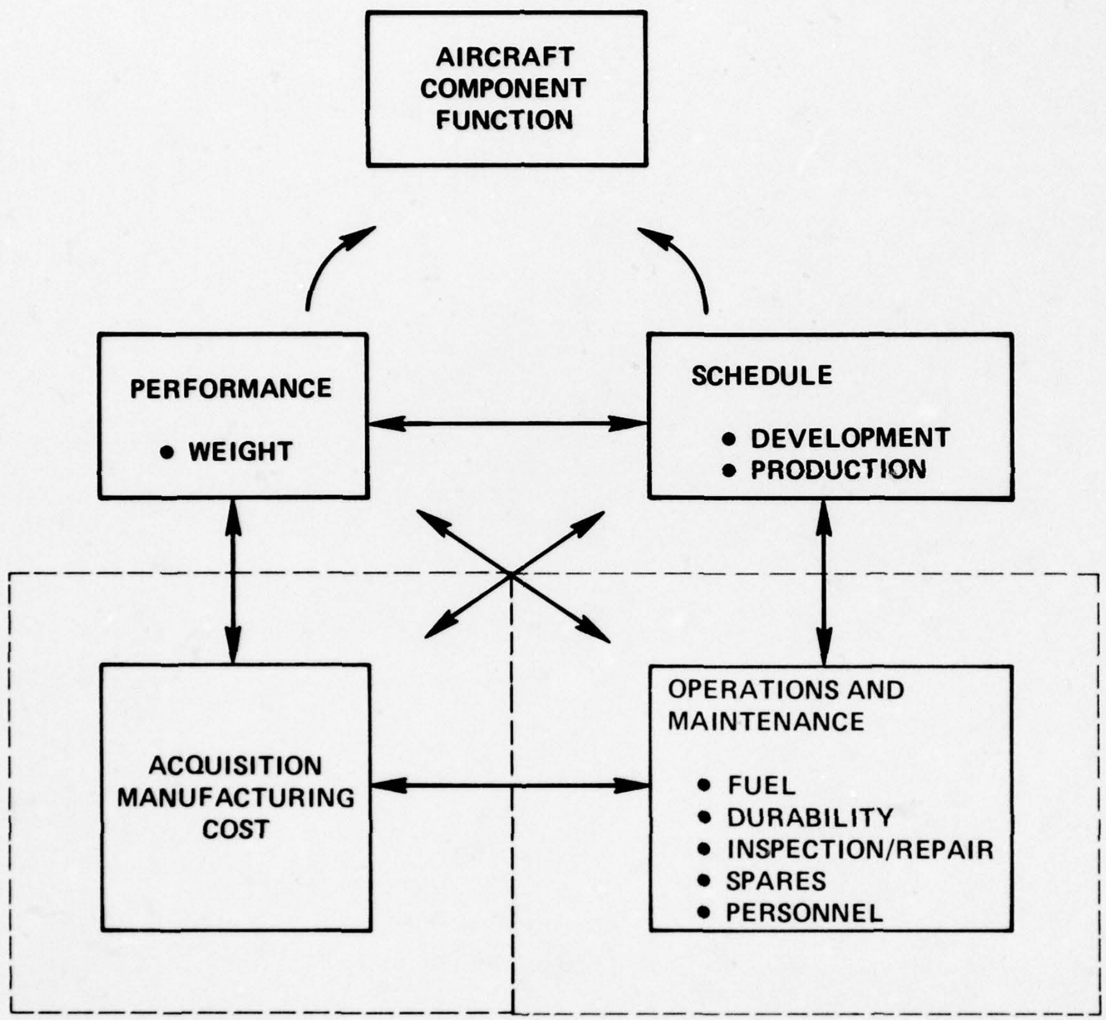
Manufacturing technology must receive increased support and emphasis must now be placed on "cost" – both acquisition and operations and maintenance. The need is urgent because, although we have made great progress in advancing the performance of our aircraft since World War II, we still use a number of the same machines and processes; for example, equipment for sheet metal manufacture today shows little change from the types used during 1940-1945. The major exception is, of course, computer-aided manufacture (CAM) and heavier performance equipment.

The recommendations for emerging processes emphasize CAM and computer-aided inspection (CAI). Computer-related MT projects are major cost cutters. However, it is important that MT projects related to the use of the computer be carefully coordinated to avoid redundant efforts.

A major portion of MT funding should be directed toward new technology to reduce the potential of creating new cost drivers in tomorrow's product.

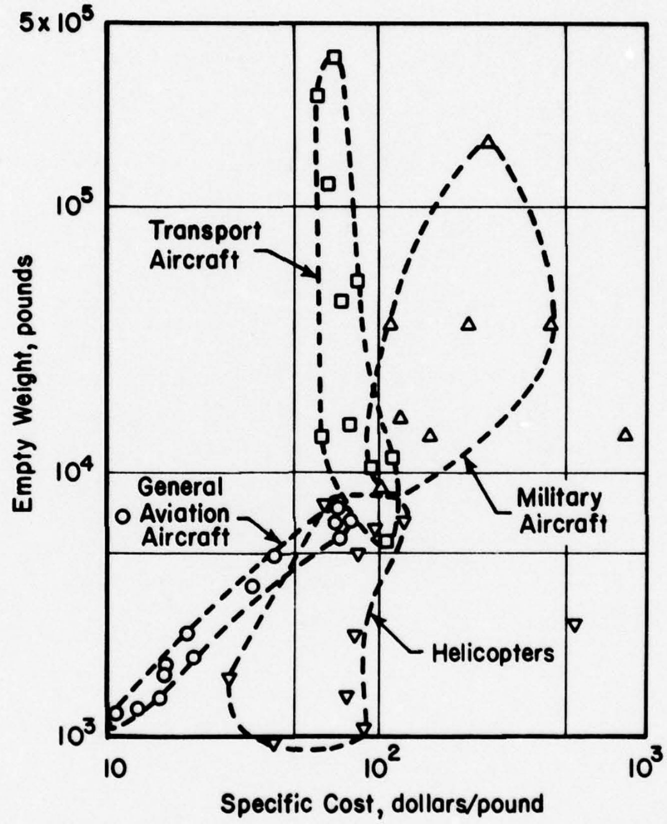
Cost avoidance is better than cost cutting.

We must balance the scale between performance and manufacturing costs.

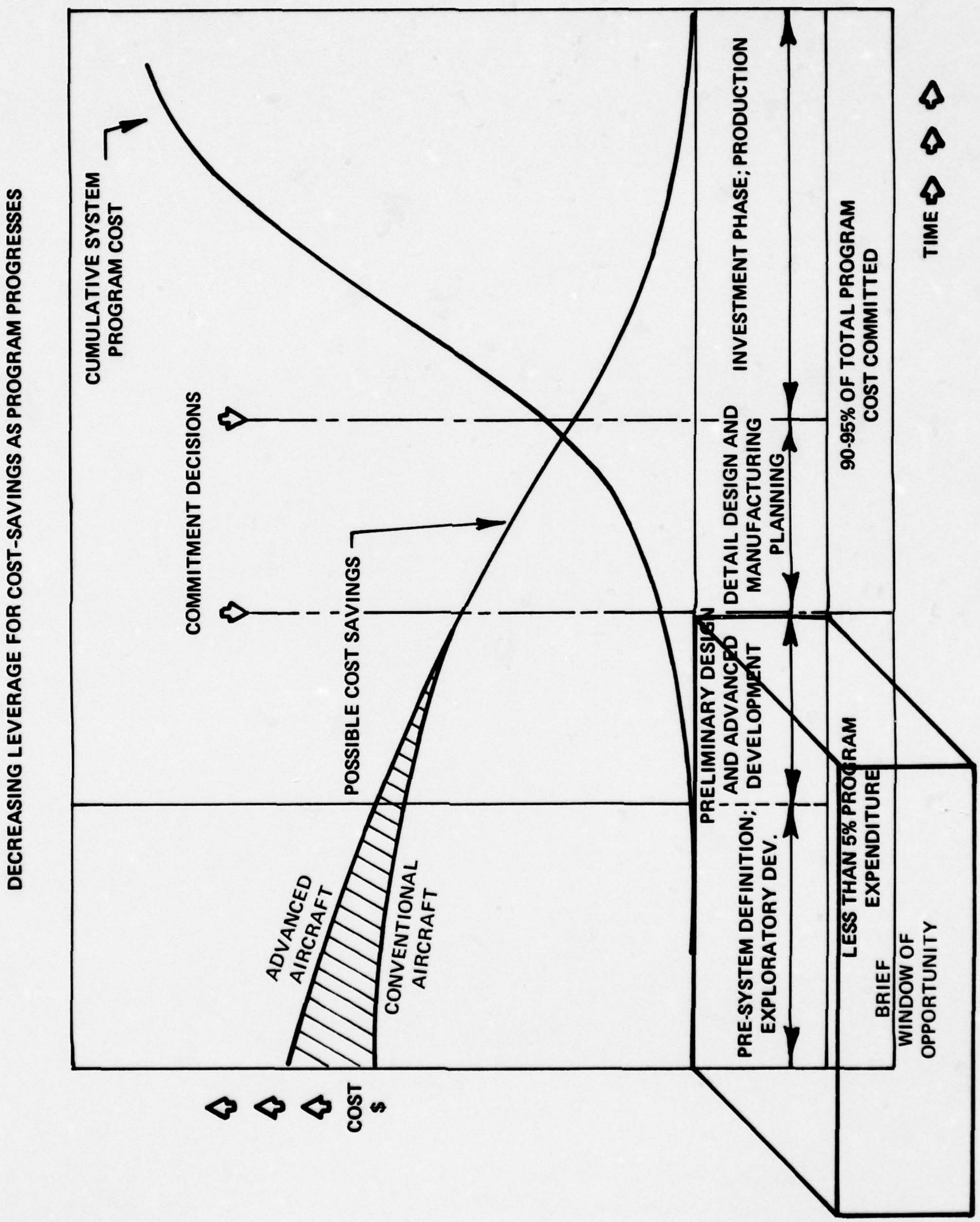


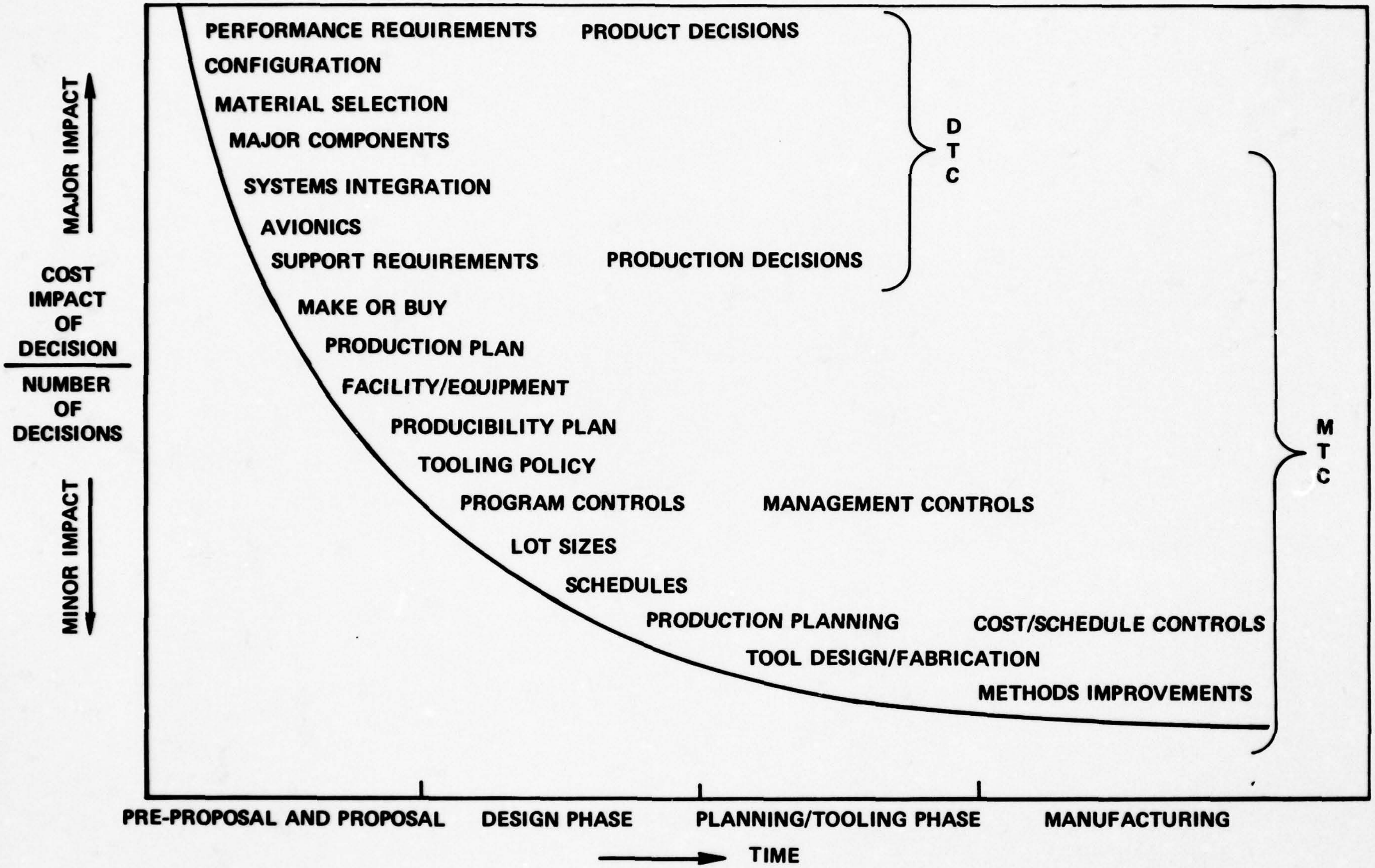
INTERACTIONS BETWEEN DESIGN AND OTHER DISCIPLINES

VIEWGRAPHS FROM DETAILED PRESENTATION SUPPORTING EXECUTIVE SUMMARY



EMPTY WEIGHT VERSUS SPECIFIC COST FOR VARIOUS CLASSES OF AIRCRAFT


DECREASING LEVERAGE FOR COST-SAVINGS AS PROGRAM PROGRESSES
COST $
ADVANCED AIRCRAFT
CONVENTIONAL AIRCRAFT
POSSIBLE COST SAVINGS
COMMITMENT DECISIONS
CUMULATIVE SYSTEM PROGRAM COST
PRE-SYSTEM DEFINITION; EXPLORATORY DEV.
PRELIMINARY DESIGN AND ADVANCED DEVELOPMENT
DETAIL DESIGN AND MANUFACTURING PLANNING
INVESTMENT PHASE; PRODUCTION
LESS THAN 5% PROGRAM EXPENDITURE
90-95% OF TOTAL PROGRAM COST COMMITTED
BRIEF WINDOW OF OPPORTUNITY
TIME



IMPACT OF COST VS DECISION

MANUFACTURING TECHNOLOGY (MT) COST DRIVER ANALYSIS PROGRAM

OBJECTIVES

WHAT IS A COST DRIVER?

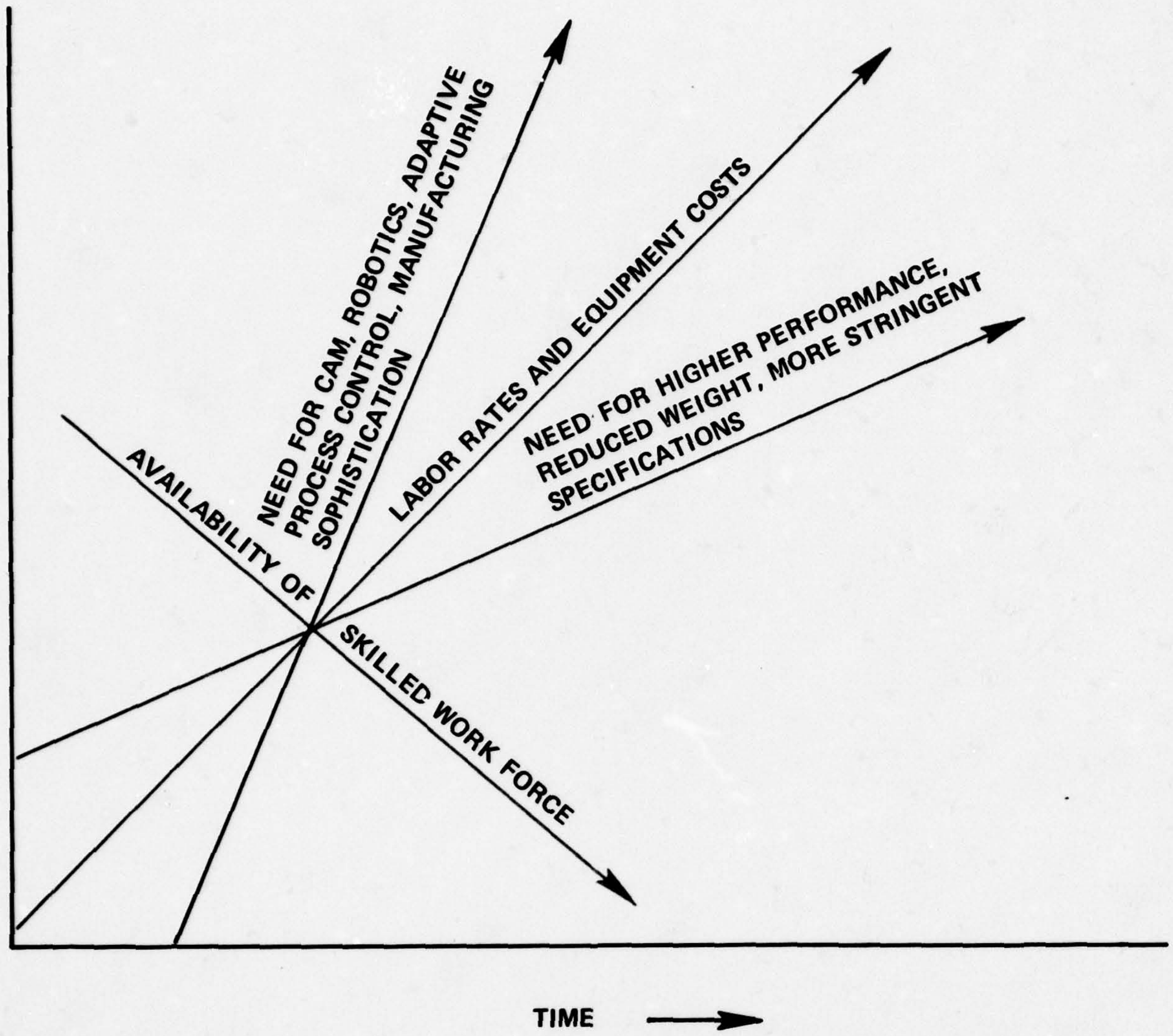
- THE MAJOR ELEMENT (S) HAVING THE GREATEST IMPACT ON THE TOTAL COST

WHY IDENTIFY COST DRIVERS?

- TO PROVIDE FOCAL POINT FOR COST–EFFECTIVE APPLICATION OF MT INVESTMENT

MANUFACTURING TECHNOLOGY (MT) COST DRIVER ANALYSIS PROGRAM

- OBJECTIVES
  - – IDENTIFY COST DRIVERS IN NAVY AIRCRAFT MANUFACTURE
  - – IDENTIFY COST DRIVER COMMONALITY
  - – PROVIDE BASIC FRAMEWORK FOR EVALUATING MT PROJECTS



THE DILEMMA OF MANUFACTURING

IDENTIFICATION OF COST DRIVERS

BY

AIRCRAFT SUBSYSTEM

- AIRFRAME
- ENGINE
- MECHANICAL SYSTEMS
  - LANDING GEAR, ETC.
- AUXILIARY SYSTEMS
  - AIR CONDITIONING SYSTEMS
  - FUEL SYSTEMS
  - PUMP EQUIPMENT
  - CONTROLLED-SPEED DRIVES, ETC.

MANUFACTURING TECHNOLOGY (MT) COST DRIVER ANALYSIS PROGRAM

SCOPE OF PROGRAM

- VISITED
  - 3 AIRCRAFT MANUFACTURERS
  - 2 ENGINE MANUFACTURERS
  - 4 MECHANICAL SYSTEMS/ACCESSORY MANUFACTURERS
- INTERVIEWED
  - MANAGEMENT
  - DESIGN ENGINEERS
  - MANUFACTURING ENGINEERS
  - PRODUCTION SUPERVISION
- TOURED PRODUCTION AREAS

PERFORMANCE REQUIREMENTS FOR NAVY AIRCRAFT POSING COST PROBLEMS

- HEAVIER LANDING GEAR (HIGH SINK RATE REQUIREMENTS)
- ARRESTING GEAR REQUIREMENTS
- SUPERIOR CORROSION PROTECTION (SALT-AIR ENVIRONMENT)
- CATAPULT REQUIREMENTS
- CARRIER LANDINGS
- FOLDING WINGS AND TAILS
- IN GENERAL, STRONGER CONSTRUCTION THAN LAND-BASED AIRCRAFT

MAJOR MANUFACTURING COST DRIVERS

ARE THE RESULT OF

- CUSTOMER'S NEED FOR AN AFFORDABLE PRODUCT WITH INCREASED PERFORMANCE
  - REDUCED WEIGHT
  - FLY FASTER, HIGHER, ETC.
  - BETTER QUALITY MEANS RELIABILITY & MAINTAINABILITY
  - LOWER OWNERSHIP COSTS
  - LESS ENERGY CONSUMPTION

RESULTS IN THE REQUIREMENT

- MUST PROVIDE MORE-FOR-LESS COST

PLUS

- DRIVE BY ENGINEERING TO ACHIEVE AND EXCEED PERFORMANCE GOALS
- INTRODUCTION OF NEW MATERIALS
- NATURAL DESIRE FOR PROGRESS AND NEED TO FIND A BETTER WAY

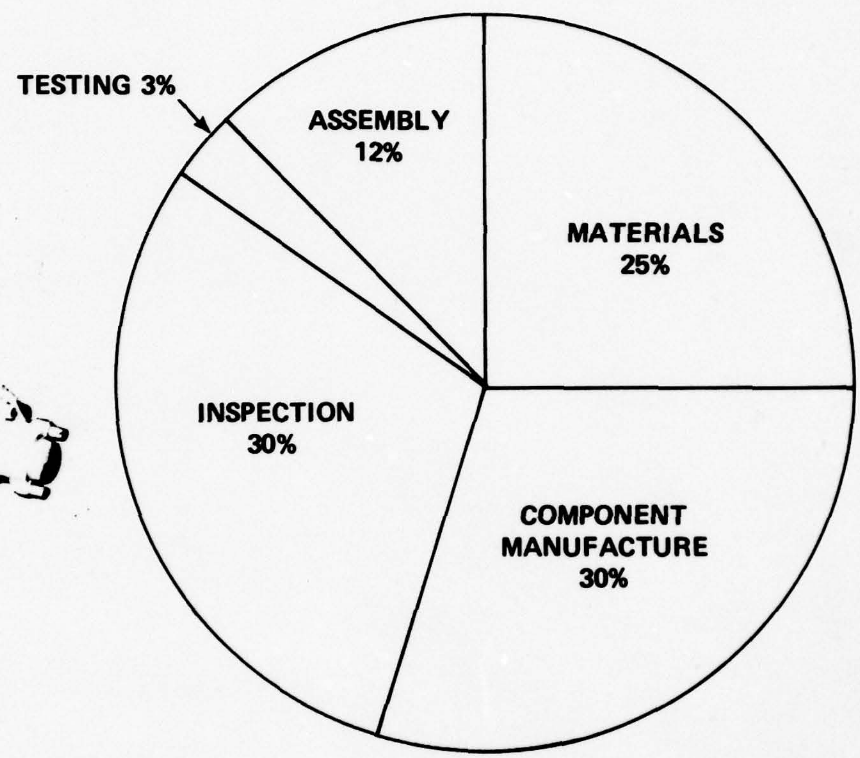
AFFORDABLE PERFORMANCE DEPENDS UPON:

- MINIMIZE COST DRIVERS IN NEW AIRCRAFT (DESIGN-TO-COST)
- EARLY IDENTIFICATION OF COST DRIVERS IN EXISTING PRODUCTS (MANUFACTURING-TO-COST)
- INNOVATIVE MANUFACTURING TECHNOLOGY IN ADVANCE OF NEED
- IMPROVED MANUFACTURING TECHNOLOGIES FOR EXISTING PRODUCTS
- STRONG DESIRE TO REMAIN COMPETITIVE

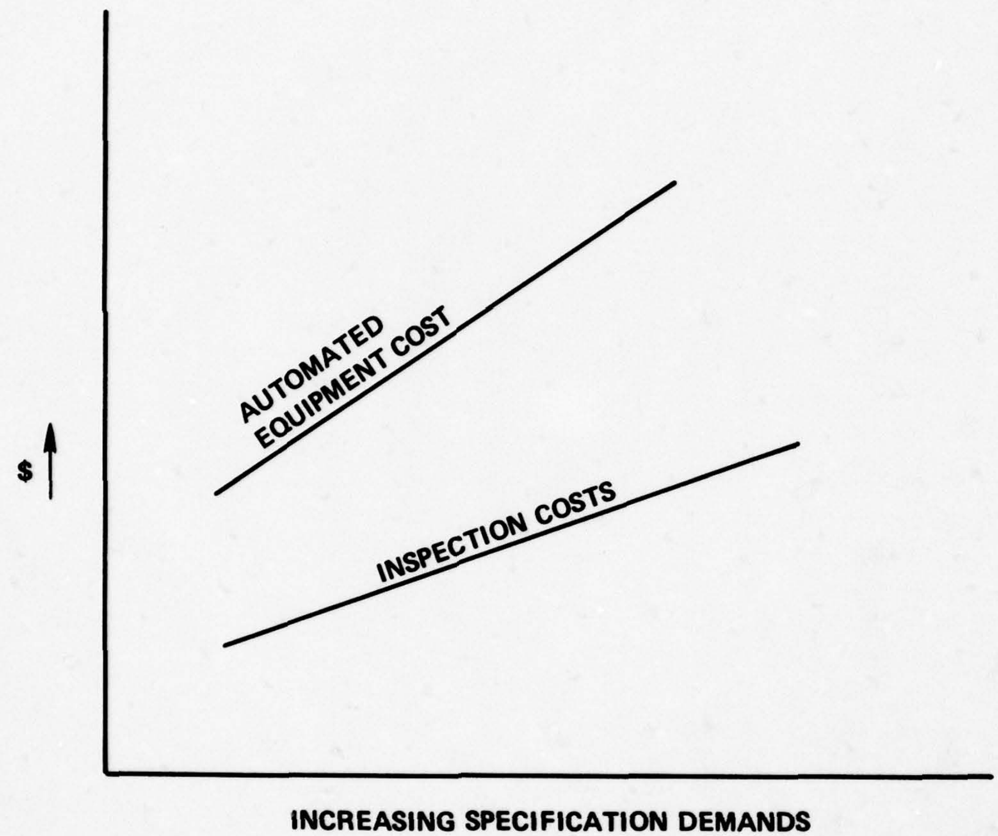
COST DRIVERS

AUXILIARY SYSTEMS

COST BREAKDOWN FOR TYPICAL AIRCRAFT SUBSYSTEM COMPONENT CONSTANT SPEED DRIVE



TIGHTER SPECIFICATIONS IN MECHANICAL SYSTEMS INDUSTRY CAUSE COST PROBLEMS



MAJOR COST DRIVERS

AUXILIARY SYSTEMS

- PERFORMANCE RELATED
  - REDUCED WEIGHT
  - HIGHER OPERATING SPEEDS
  - INCREASED RELIABILITY
- DESIGN RELATED
  - HIGH PART COUNT
  - NON-STANDARDIZATION
  - TOLERANCES

MAJOR COST DRIVERS

AUXILIARY SYSTEMS (CONTINUED)

- MATERIAL RELATED
  - COST
  - AVAILABILITY
  - UTILIZATION
  - ENERGY
- MANUFACTURING RELATED
  - INSPECTION
  - EQUIPMENT
  - CYCLIC PRODUCTION
  - SMALL LOT SIZES
  - HIGHLY SKILLED LABOR

MAJOR COST DRIVERS

AUXILIARY SYSTEMS (CONTINUED)

- MANUFACTURING RELATED (Continued)
  - DEBURRING/HAND FINISHING
  - METAL REMOVAL
  - HIGH SCRAP RATE
  - HEAT TREATMENT
  - HAND FIT-UP
  - ENERGY IN AUTOCLAVE CURING
  - HIGH TOOL COUNT

RECOMMENDED COST CUTTERS

AUXILIARY SYSTEMS (CONTINUED)

- AUTOMATED EQUIPMENT FOR:
  - BURR REMOVAL
  - POLISHING
- AUTOMATED INSPECTION EQUIPMENT
- ALTERNATIVES TO AUTOCLAVE CURING
- POSSIBILITY OF GROUP TECHNOLOGY
- IMPROVED METAL REMOVAL TECHNOLOGY
- NET SHAPE PARTS
- JOB SHOP CONTROL

CONCLUSIONS

AUXILIARY SYSTEMS (CONTINUED)

- HIGHLY SPECIALIZED INDUSTRY
- SPECIFICATIONS ARE CONTROLLED BY THE CUSTOMER AND THE PRIME CONTRACTOR
- CAUGHT IN COST SQUEEZE
  - LABOR VERSUS AUTOMATED EQUIPMENT
- SAME COST DRIVERS AS IN OTHER SUBSYSTEMS
- DEPENDS ON SUBCOMPONENT SUPPORT FROM A LIMITED NUMBER OF SPECIALIZED SUPPLIERS (LACK OF COMPETITION)

RECOMMENDATIONS

AUXILIARY SYSTEMS

- SPECIFICATION STANDARDIZATION
  - "IN-HOUSE" DESIGNS (DTC)
  - NAVY, AIR FORCE, ARMY
  - PRIME CONTRACTOR
- GROUP TECHNOLOGY IN MANUFACTURING (MTC)
  - INSTEAD OF FUNCTIONAL FLOW
- "PIGGY BACK" OFF OTHER MT PROJECTS, E.G., AIRFRAMES, ENGINES
  - LASER WELDING/HEAT TREATMENT
  - NET SHAPE PARTS
  - NEW NDI/NDT METHODS

RECOMMENDATIONS

AUXILIARY SYSTEMS
(CONTINUED)

- IN GENERAL, MT PROJECTS SELECTED SHOULD BE APPLICABLE TO THE INDUSTRY IN GENERAL – NOT A SPECIFIC MANUFACTURER'S COMPONENT
- OTHER SUBSYSTEM MT PROJECTS SHOULD BE EVALUATED FOR COMMONALITY WITH SYSTEMS COMPONENT COST DRIVERS

RECOMMENDATIONS

AUXILIARY SYSTEMS (CONTINUED)

- AUTOMATED INSPECTION
- METAL REMOVAL TECHNOLOGY
- ALTERNATIVES TO AUTOCLAVE
- CAM APPLICATIONS
- TOLERANCE RELAXATION

CONCLUSIONS

AIRFRAMES

- STRONG INDICATION THAT WE ARE MANUFACTURING TODAY'S AIRFRAMES WITH YESTERDAY'S TECHNOLOGY
- AIRFRAME COST DRIVERS ESCALATE AND ARE DIFFICULT TO REMOVE
- AIRFRAME STRUCTURES (PRIMARY AND SECONDARY) PROVIDE THE MOST POTENTIAL OF SYSTEMS STUDIED FOR ROI WITH MT PROJECTS

RECOMMENDATIONS

AIRFRAMES

SELECT MT PROJECTS THAT PROVIDE:

- IMMEDIATE INCORPORATION INTO CURRENT PROGRAMS WITHOUT ENGINEERING REDESIGN AND ARE APPLICABLE TO FUTURE PROCUREMENTS
- COMMON TO OTHER AIRCRAFT SUBSYSTEMS
- SUBSTANTIAL ROI – WITH MINOR ENGINEERING REDESIGN ON CURRENT PROGRAMS AND PROVIDE PROVEN TECHNOLOGY FOR FUTURE PROCUREMENT
- "SEED MONEY" FOR PROVING EMERGING NEW MATERIALS, MANUFACTURING PROCESSES, AND EQUIPMENT REQUIREMENTS TO MAKE NEW PROCUREMENT POSSIBLE AT AFFORDABLE COST

CONCLUSIONS

ENGINES

- MAJOR COST FACTOR IS PERFORMANCE REQUIREMENTS
- GREAT DEAL OF COMMONALITY IN COST DRIVERS FOR ALL ENGINE COMPONENTS
  - – METAL REMOVAL
  - – WELDING
  - – CHECKING AND CORRECTING DISTORTIONS
- NEW TECHNOLOGY – METHODS/PROCESSES AND MATERIAL ADVANCES WILL PROVIDE MAJOR COST SAVINGS IN ENGINE MANUFACTURE

RECOMMENDATIONS

ENGINES

FOR MANUFACTURING TECHNOLOGY PROJECTS

- NEAR TERM
  - IMPROVED METAL REMOVAL METHODS
  - IMPROVED NDI/NDT TECHNOLOGY
- LONG TERM
  - NET SHAPE PART TECHNOLOGY
  - REDUCTION OF MACHINED PARTS
  - LAMINATED STRUCTURE, SUPERPLASTIC FORMING/ DIFFUSION BONDING, ETC.
- STANDARDIZATION OF MATERIALS

COST DRIVERS

BY

MAJOR SUBSYSTEM

- COMMON TO MOST INDUSTRY
- AEROSPACE RELATED
- TECHNOLOGY RELATED

MAJOR COST DRIVERS BY SUBSYSTEM

SUBSYSTEM \ COST DRIVER	COST DRIVERS COMMON TO MOST INDUSTRY								
	LACK OF R&D FUNDING	SPECIFICATION COMPLEXITY OF OSHA, ETC.	MATERIAL SHORTAGE	NEW EQUIPMENT	MATERIAL COSTS	LACK OF SKILLED MANPOWER	ENERGY COSTS	EQUIPMENT OBSOLESCENCE	INFLATION
AIRFRAME	◍	◍	◍	●	●	◍	●	●	●
ENGINE	◍	◍	●	●	●	◍	●	●	●
MECHANICAL SYSTEMS	●	◍	◍	◍	●	◍	●	◍	●
CREW SYSTEMS	●	◍	◍	◍	●	◍	●	◍	●

● HIGH IMPACT
◍ AVERAGE IMPACT
● LOW IMPACT
● NO IMPACT

MAJOR COST DRIVERS BY SUBSYSTEM

SUBSYSTEM \ COST DRIVER	AEROSPACE TECHNOLOGY RELATED COST DRIVERS													
	MATERIAL UTILI-ZATION	METAL REMOVAL COSTS	NUMBER OF PARTS	PROCESSING AND HEAT TREATMENT	FASTENER INSTAL-LATION	SHEET METAL FABRICATION	LACK OF NEAR NET FORGINGS	CORROSION PROTECTION	HAND FIT-UP	DESIGN CHANGES	TESTING REQUIREMENTS	ASSEMBLY/INSTALLATION	HYDRAULIC SYSTEMS INSTALLATION	WIRING INSTALLATIONS
AIRFRAME	High	Average	High	Average	High	High	Average	High	High	High	Average	Average	Average	Average
ENGINE	High	High	Average	High	Low	Low	High	Average	Average	Average	Average	Average	Low	High
MECHANICAL SYSTEMS	High	High	Average	High	High	High	Low	Average	Average	Average	Average	Low	High	High
CREW SYSTEMS	High	High	High	Average	Low	Average	High	Average	Average	Average	Average	Average	Low	Low

● HIGH IMPACT
● AVERAGE IMPACT
● LOW IMPACT
● NO IMPACT

MAJOR COST DRIVERS BY SUBSYSTEM

SUBSYSTEM \ COST DRIVER	AEROSPACE INDUSTRY-RELATED COST DRIVERS									
	WEIGHT REDUCTION OPERATIONS	PERFORMANCE VERSUS COST SYNDROME	LACK OF DTC	CYCLIC PRODUCTION	LACK OF SPECIFICATION/ STANDARDIZATION	LACK OF AUTOMATION AND LOW PRODUCTION RATES	HIGH SKILL REQUIREMENTS	HIGHER QUALITY REQUIREMENTS	USE OF COBALT	CONTROLLED MANU-FACTURING CONDITIONS
AIRFRAME	●	●	●	●	◦	◦	◦	◦	●	●
ENGINE	●	●	●	●	◦	●	◦	◦	●	●
MECHANICAL SYSTEMS	●	●	◦	◦	●	◦	◦	◦	●	●
CREW SYSTEMS	●	●	●	●	●	◦	●	●	◦	◦

● HIGH IMPACT
◦ AVERAGE IMPACT
● LOW IMPACT
● NO IMPACT

CONCLUSIONS FROM MATRIX CHARTS

- COMMONALITY OF COST DRIVERS EXIST THROUGHOUT ALL SUBSYSTEMS
- MAJOR COST DRIVERS COMMON TO ALL INDUSTRY INFLATION – ENERGY – MATERIAL – EQUIPMENT
- MAJOR COST DRIVERS COMMON TO AEROSPACE – METAL REMOVAL – HIGH PART COUNT – MATERIAL UTILIZATION
- AIRFRAME MANUFACTURE HAS HIGHEST IMPACT COST DRIVERS
- ENGINES – MECHANICAL SYSTEMS – CREW SYSTEMS HAVE MOST COMMONALITY BETWEEN COST DRIVERS – METAL REMOVAL – HEAT TREATMENT – INSPECTION COST – SPECIFICATIONS

RECOMMENDATIONS

EMERGING PROCESSES

COMPUTER TECHNOLOGY

- CAM
- CAD
- CAI
- COMPUTER RELATED MT PROJECTS ARE MAJOR COST CUTTERS AT ALL LEVELS OF AEROSPACE DESIGN AND MANUFACTURING
- HOWEVER, A GREAT DEAL OF FUNDING IS NOW ALLOCATED TO COMPUTER-AIDED TECHNOLOGY AND MT PROJECTS RELATED TO USE OF THE COMPUTER SHOULD BE VERY CAREFULLY REVIEWED TO AVOID REDUNDANT EFFORTS

MANUFACTURING TECHNOLOGY (MT) COST DRIVERS

OVERVIEW OF MAJOR MANUFACTURING TECHNOLOGY (MT) COST DRIVERS

COMMON TO ALL SUBSYSTEMS

METAL REMOVAL – MATERIAL COST/AVAILABILITY
ENERGY COST – HIGH MAN-HOURS

AIRFRAME

FASTENERS – PART COUNT – ASSEMBLY/INSTALLATION

ENGINE

EXOTIC ALLOYS – MATERIAL UTILIZATION

LANDING GEAR

SPECIAL STEELS – HEAT TREATMENT

CREW SYSTEM COMPONENTS

INSPECTION COSTS – TIGHT SPECIFICATIONS

CONCLUSIONS AND RECOMMENDATIONS

GENERAL CONCLUSIONS

AIRCRAFT MANUFACTURE

- DEPENDS HEAVILY ON MANPOWER
- IS A CYCLIC INDUSTRY
- HAS LITTLE AUTOMATION
- HAS FEW CUSTOMERS, EXCESSIVE CAPACITY
- HIGHLY SKILLED INDUSTRY
- HIGH TECHNOLOGY ORIENTED
- DRIVEN BY PRODUCT EXCELLENCE

GENERAL CONCLUSIONS
(Continued)

- MOST COST DRIVERS ARE DESIGNED INTO AIRCRAFT
- MOST COST DRIVERS ARE COMMON TO ALL SUBSYSTEMS
- EMPHASIS MUST CHANGE FROM PERFORMANCE TO AFFORDABLE PERFORMANCE
- SPIRALLING AIRCRAFT COSTS MUST BE BETTER CONTROLLED
- MINIMUM NEW MANUFACTURING TECHNOLOGY HAS BEEN PRODUCTIONIZED IN THE LAST 10 YEARS

GENERAL CONCLUSIONS
(Continued)

- MANUFACTURING TECHNOLOGY (MT) PROJECTS CAN BE SELECTED THAT PROVIDE A HIGH RETURN ON INVESTMENT (ROI)
- EMERGING MANUFACTURING TECHNOLOGIES STILL DISPLAY SIGNIFICANT COST DRIVERS
- DEVELOPING MANUFACTURING TECHNOLOGY ON A PRODUCTION PROGRAM IS SELDOM COST COMPETITIVE
- IS THE U.S. AEROSPACE MANUFACTURING INDUSTRY LOSING ITS COMPETITIVE EDGE?

RECOMMENDATIONS

SELECTION OF MT PROJECTS

- ENERGY SAVERS
  - ALTERNATES TO AUTOCLAVE
  - LOCALIZED HEAT TREATMENT VS FURNACE
  - THERMALLY EFFICIENT EQUIPMENT
- MATERIAL CONSERVATION
  - NET SHAPE PARTS
  - SHEET METAL VS MACHINED PARTS
  - MACHINING TECHNOLOGIES
  - CONVENTIONAL VS EXOTIC MATERIALS
  - RECYCLING
- IMPROVED QUALITY CONTROL
  - IMPROVED NDT/NDI
  - AUTOMATION
  - FRACTURE MECHANICS ANALYSIS DATA
- D.T.C. – M.T.C.
  - COMPARATIVE AND QUANTITATIVE COST DATA BANKS
  - GROUP TECHNOLOGY

RECOMMENDATIONS
(Continued)

SELECTION OF MT PROJECTS
(CONTINUED)

- NEW TECHNOLOGIES – EXAMPLES
  - COMPOSITES – SDF/DB – LASER APPLICATIONS
  - METAL LAMINATED STRUCTURE – ADHESIVE BONDING – HIGH PRESSURE FORMING
- CAM-CAI
  - CRITICALLY IMPORTANT AREA BUT AVOID REDUNDANT EFFORTS
  - CONFIGURATION CONTROL
  - PROCESS SIMULATION
  - INSPECTION AND QUALITY APPLICATION
- CORROSION PROTECTION
  - COATINGS
  - DISSIMILAR MATERIALS
- MISCELLANEOUS
  - FIBRE OPTICS – LASER HARDENING
  - LOW COST TOOLING – PART PROTECTION

GENERAL RECOMMENDATIONS

SELECT MANUFACTURING TECHNOLOGY (MT) PROJECTS THAT PROVIDE:

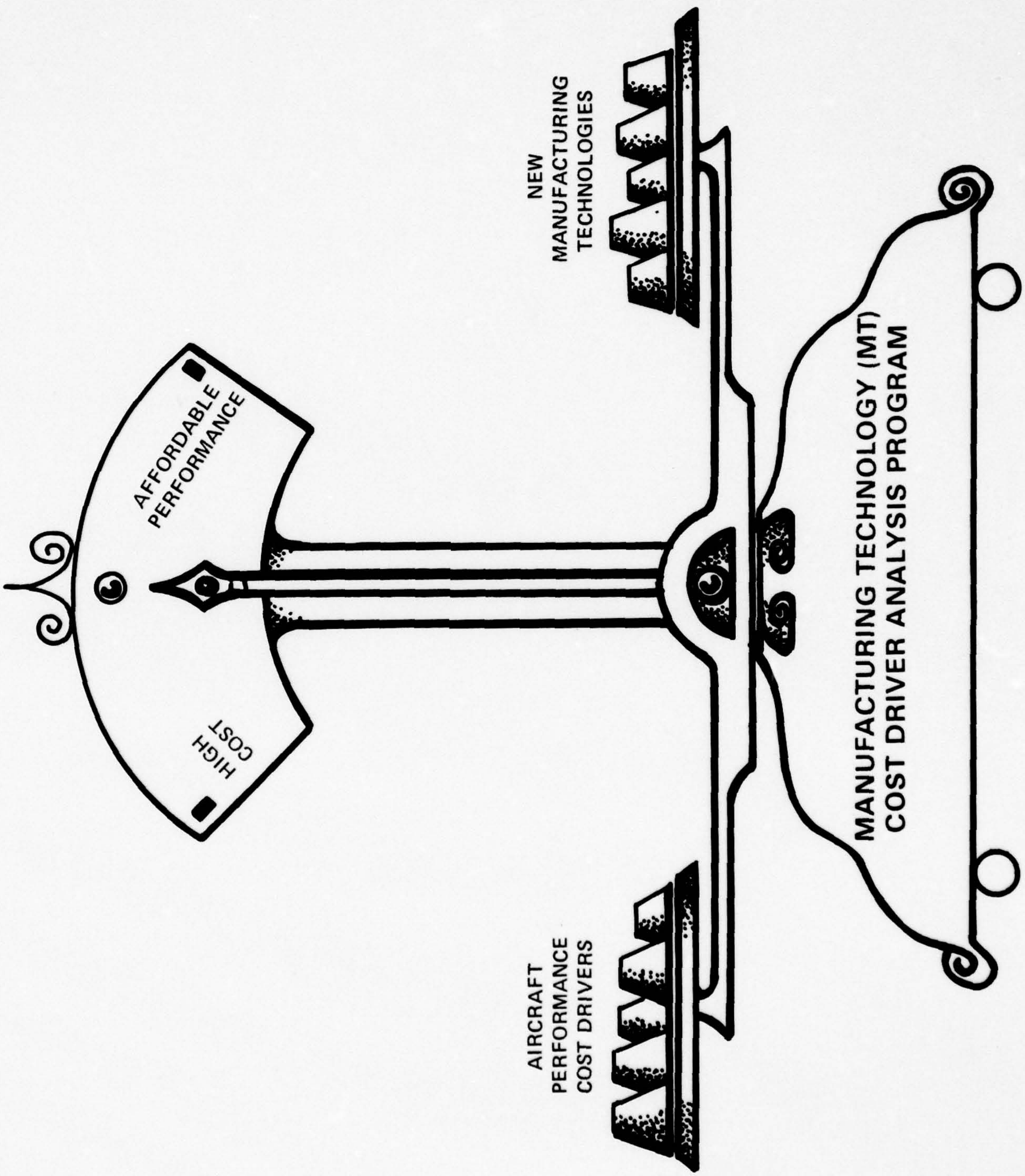
- COMPATIBILITY WITH NAVY AIRCRAFT OBJECTIVES
- POTENTIAL HIGH COST SAVINGS FOR FUTURE AIRCRAFT SYSTEMS
- MAXIMUM COST SAVINGS AT DESIGN CONCEPTION
- MAXIMUM SYNERGISTIC EFFECTS
- GREATEST COMMONALITY BETWEEN SUBSYSTEMS
- MINIMUM DESIGN CHANGE AND RE-TESTING
- ACCEPTANCE OF EMERGING MANUFACTURING TECHNOLOGY

DO NOT SELECT MANUFACTURING TECHNOLOGY (MT) PROJECTS THAT:

- IMPROVE A MANUFACTURING TECHNOLOGY THAT IS OBSOLETE

GENERAL RECOMMENDATIONS
(Continued)

- AVOID COST DRIVERS BY FULLY UTILIZING DESIGN-TO-COST (DTC) AND MANUFACTURING-TO-COST (MTC)
- BALANCE THE SCALE BETWEEN PERFORMANCE AND MANUFACTURING COST
  - BE SURE THE PERFORMANCE CAN BE AFFORDED
- STOP THE TREND TOWARD EQUIPMENT OBSOLENCE
- PURSUE ADVANCED MANUFACTURING TECHNOLOGY WITH THE SAME VIGOR AS WE HAVE PERFORMANCE


HIGH COST
AFFORDABLE PERFORMANCE
AIRCRAFT PERFORMANCE COST DRIVERS
NEW MANUFACTURING TECHNOLOGIES
MANUFACTURING TECHNOLOGY (MT)
COST DRIVER ANALYSIS PROGRAM

MANUFACTURING TECHNOLOGY (MT) COST-DRIVER ANALYSIS PROGRAM

OBJECTIVES

WHAT IS A COST DRIVER?

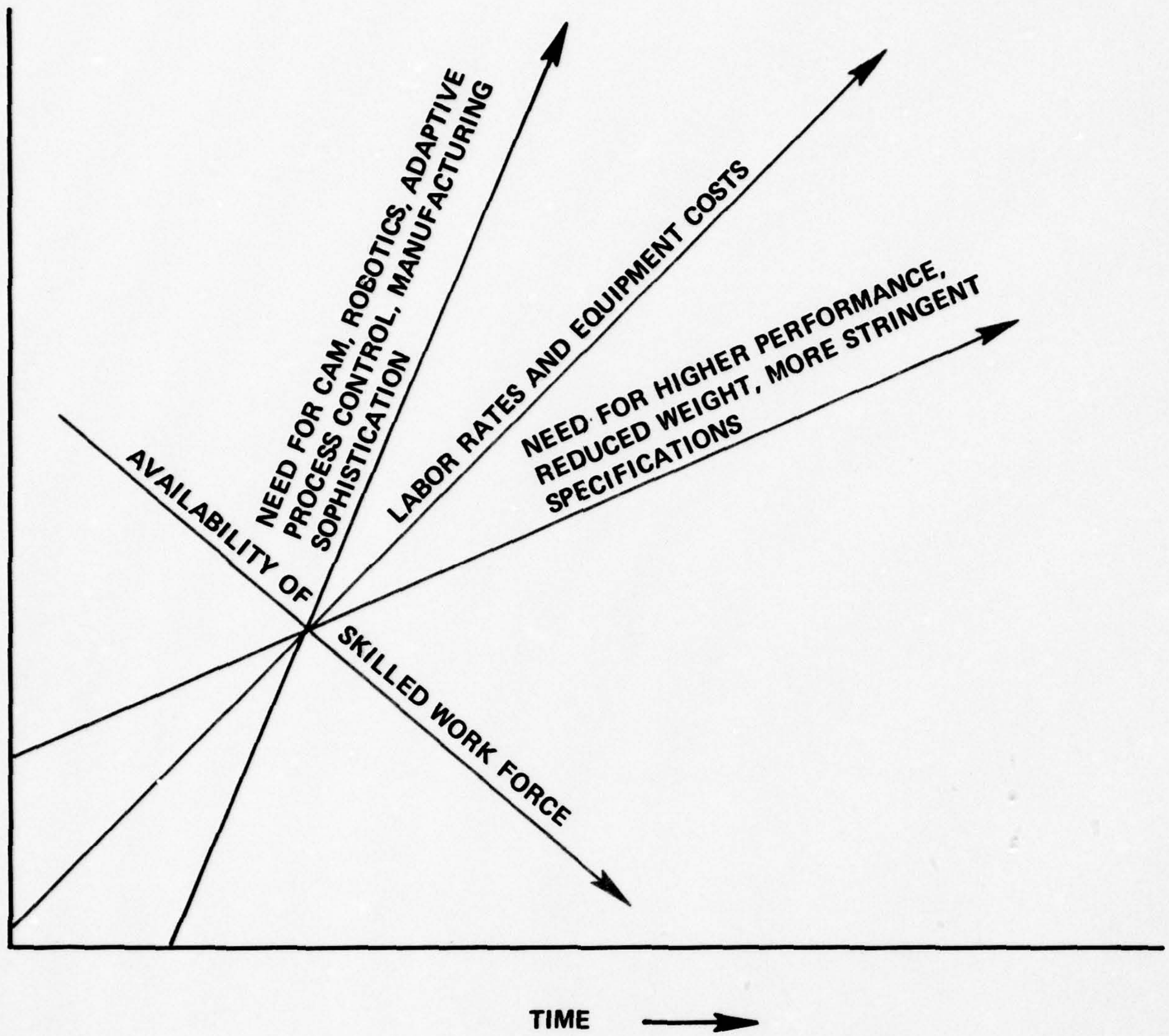
- THE MAJOR ELEMENT (S) HAVING THE GREATEST IMPACT ON THE TOTAL COST

WHY IDENTIFY COST DRIVERS?

- TO PROVIDE FOCAL POINT FOR COST–EFFECTIVE APPLICATION OF MT INVESTMENT

MANUFACTURING TECHNOLOGY (MT) COST DRIVER ANALYSIS PROGRAM

- OBJECTIVES
  - IDENTIFY COST DRIVERS IN NAVY AIRCRAFT MANUFACTURE
  - IDENTIFY COST DRIVER COMMONALITY
  - PROVIDE BASIC FRAMEWORK FOR EVALUATING MT PROJECTS



THE DILEMMA OF MANUFACTURING

IDENTIFICATION OF COST DRIVERS

BY

AIRCRAFT SUBSYSTEM

- AIRFRAME
- ENGINE
- MECHANICAL SYSTEMS
  - – LANDING GEAR, ETC.
- AUXILIARY SYSTEMS
  - – AIR CONDITIONING SYSTEMS
  - – FUEL SYSTEMS
  - – PUMP EQUIPMENT
  - – CONTROLLED-SPEED DRIVES, ETC.

MANUFACTURING TECHNOLOGY (MT) COST DRIVER ANALYSIS PROGRAM

SCOPE OF PROGRAM

- VISITED
  - 3 AIRCRAFT MANUFACTURERS
  - 2 ENGINE MANUFACTURERS
  - 4 MECHANICAL SYSTEMS/ACCESSORY MANUFACTURERS
- INTERVIEWED
  - MANAGEMENT
  - DESIGN ENGINEERS
  - MANUFACTURING ENGINEERS
  - PRODUCTION SUPERVISION
- TOURED PRODUCTION AREAS

IDENTIFICATION OF COST DRIVERS

- EXAMINED AIRCRAFT SUBSYSTEMS TO IDENTIFY:
  - HIGH MAN-HOUR CONTENT
  - EXCESSIVE MATERIAL COSTS
  - IMPACT OF EQUIPMENT COSTS
- IDENTIFIED COMMON COST DRIVERS
- PRODUCED FRAMEWORK TO MATCH COST DRIVERS AND MT PROJECTS

PERFORMANCE REQUIREMENTS FOR NAVY AIRCRAFT POSING COST PROBLEMS

PERFORMANCE REQUIREMENTS FOR NAVY AIRCRAFT POSING COST PROBLEMS

- HEAVIER LANDING GEAR (HIGH SINK RATE REQUIREMENTS)
- ARRESTING GEAR REQUIREMENTS
- SUPERIOR CORROSION PROTECTION (SALT-AIR ENVIRONMENT)
- CATAPULT REQUIREMENTS
- CARRIER LANDINGS
- FOLDING WINGS AND TAILS
- IN GENERAL, STRONGER CONSTRUCTION THAN LAND-BASED AIRCRAFT

CONCLUSIONS

PECULIAR TO NAVY AIRCRAFT

- **NAVY AIRCRAFT ARE:**
  - **AFFECTED BY THE SAME COST DRIVERS AS ALL AIRCRAFT**

PLUS

- **ADDED STRUCTURAL AND ANTI-CORROSION REQUIREMENTS**

INTERACTION OF DESIGN FEATURES WITH MANUFACTURING TECHNOLOGY (MT)

HIGH-SPEED VERSUS LOW-SPEED AIRCRAFT

LOW SPEED AIRCRAFT DESIGN FEATURES VERSUS MANUFACTURING TECHNOLOGY REQUIREMENTS

	DESIGN FEATURES	MT REQUIREMENTS
SUBSYSTEMS COMPONENTS	• USE EXISTING ENGINE – AVIONICS – ACCESSORIES, ETC.	• MINIMUM – METHODS IMPROVEMENTS ONLY
STRUCTURE	• PRIMARILY S/M – MINIMUM MACHINED PARTS • CONSTANT SECTION FUSELAGE • CONSTANT SECTION CONTROL SURFACES • USE LH/RH INTERCHANGEABLE COMPONENTS (LANDING GEAR, CONTROL SURFACES)	• MINIMUM – LOW COST S/M TOOLING • COMMON USE TOOLING • MINIMUM EQUIPMENT REQUIREMENTS
ASSEMBLY AND INSTALLATION	• CONVENTIONAL ALUMINUM FASTENERS • LAP SKIN – JOINTS • LOW PRESSURE HYDRAULIC SYSTEMS • DESIGNED FOR BREAK-BACK SUBASSEMBLIES	• PERMITS MAXIMUM USE OF AUTOMATIC RIVETING: • M.T. IS AVAILABLE, PROVEN, AND ONLY REQUIRES CONTINUED MANUFACTURING-TO-COST IMPROVEMENTS

HIGH SPEED AIRCRAFT DESIGN FEATURES VERSUS MANUFACTURING TECHNOLOGY REQUIREMENTS

	DESIGN FEATURES	MT REQUIREMENTS
SUBSYSTEMS	• ENGINE IN DEVELOPMENT PARALLEL WITH AIRFRAME – ADVANCED AVIONICS-HIGH PERFORMANCE ACCESSORIES	• NEW MT REQUIREMENTS – NEW TOOLING – EQUIPMENT INVESTMENTS • CONTINUED MT – MTC
STRUCTURE	• EXTENSIVE USE OF EXOTIC METALS • DOUBLE CURVATURE FUSELAGE • EXTENSIVE S/M AND MACHINE PROFILING • TAPERED WINGS, CONTROL SURFACES • COMPOSITES	• NEW MT FOR MACHINING EXOTIC METALS • EXPENSIVE MACHINE TOOLS • CAM REQUIREMENTS • NEW MT FOR COMPOSITE MANUFACTURE • CONTINUED MT – MTC
ASSEMBLY AND INSTALLATION	• EB WELDING • SPECIAL PURPOSE FASTENERS • BUTT JOINTS – FAYING SURFACES • PRESSURE SEALING • HIGH PRESSURE HYDRAULIC SYSTEMS • HIGH DENSITY WIRING/TUBING • WIRE SHIELDING	• LIMITED USE OF AUTOMATIC RIVETING • MT FOR EB WELDING • HIGH MAN-HOURS FOR CLOSE TOLERANCE ASSEMBLY • MT FOR DEVELOPMENT OF HIGH PRESSURE HYDRAULIC FITTINGS AND TUBING • AVOID RF PROBLEMS

CONCLUSIONS

DESIGN FEATURES

- LOW VERSUS HIGH COST DESIGN FEATURES ARE APPARENT
- EARLY IDENTIFICATION OF COST DRIVERS IS POSSIBLE
- DEVELOPMENT OF NEW MANUFACTURING TECHNOLOGY IN CONJUNCTION WITH NEED IS A DIASTER
- "DE-BUGGING" WHEN INTRODUCED IN SERVICE

MANUFACTURING COST DRIVERS
VS
AFFORDABLE PERFORMANCE

MAJOR MANUFACTURING COST DRIVERS

ARE THE RESULT OF

- CUSTOMER'S NEED FOR AN AFFORDABLE PRODUCT WITH INCREASED PERFORMANCE
  - REDUCED WEIGHT
  - FLY FASTER, HIGHER, ETC.
  - BETTER QUALITY MEANS RELIABILITY & MAINTAINABILITY
  - LOWER OWNERSHIP COSTS
  - LESS ENERGY CONSUMPTION

RESULTS IN THE REQUIREMENT

- MUST PROVIDE MORE-FOR-LESS COST

PLUS

- DRIVE BY ENGINEERING TO ACHIEVE AND EXCEED PERFORMANCE GOALS
- INTRODUCTION OF NEW MATERIALS
- NATURAL DESIRE FOR PROGRESS AND NEED TO FIND A BETTER WAY

AFFORDABLE PERFORMANCE DEPENDS UPON:

- MINIMIZE COST DRIVERS IN NEW AIRCRAFT (DESIGN-TO-COST)
- EARLY IDENTIFICATION OF COST DRIVERS IN EXISTING PRODUCTS (MANUFACTURING-TO-COST)
- INNOVATIVE MANUFACTURING TECHNOLOGY IN ADVANCE OF NEED
- IMPROVED MANUFACTURING TECHNOLOGIES FOR EXISTING PRODUCTS
- STRONG DESIRE TO REMAIN COMPETITIVE

AFFORDABLE PERFORMANCE DEPENDS UPON:
(Continued)

- INCREASED AIRCRAFT PERFORMANCE DEPENDS UPON:
  - EXCELLENCE OF ENGINEERING DESIGN
- AFFORDABLE AIRCRAFT DEPENDS ON:
  - EXCELLENCE OF MANUFACTURING TECHNOLOGY (MT)

APPROACHES TO DESIGN TO COST

APPROACHES TO DESIGN TO COST

COMPANY A

ENGINEERING

PROVIDED {
- TARGET COST BY MAJOR SUBSYSTEM
- TRADE STUDY DATA
- DO'S AND DON'T'S GUIDE

- PERFORM OWN COST ESTIMATING (MINI-ESTIMATORS)
- COST/WEIGHT TRADE-OFFS – A CONTINUOUS EFFORT

DESIGN TO COST COORDINATOR

- GENERATES DTC DATA

APPROACHES TO DESIGN TO COST
(Continued)

COMPANY A

OUTSIDE PROCUREMENT

- MONITORS VENDORS' DTC PERFORMANCE

HIGHLIGHTS

- HEAVY RELIANCE ON ENGINEERING
- NO DIRECT INTERACTION WITH MANUFACTURING
- DTC PRIMARILY AN ENGINEERING RESPONSIBILITY

APPROACHES TO DESIGN TO COST

COMPANY B

PRIOR TO DESIGN START

- TARGET COST PROVIDED TO ALL MAJOR ORGANIZATIONS

PRODUCIBILITY ENGINEERS

- TEAM WORKS "ON BOARD" WITH ENGINEERING
- PROGRESSIVE ESTIMATES
  - PARAMETRIC THROUGH FINAL RELEASE
- CHAIR WEEKLY COORDINATION MEETINGS
  - ENGINEERING – MATERIALS – MANUFACTURING –
  - PRODUCTION – QC

FOLLOW-UP

- MONTHLY COMPUTER REPORTS WEIGHT/COST SCHEDULES

APPROACHES TO DESIGN TO COST
(Continued)

COMPANY B

HIGHLIGHTS

- ENTIRE ORGANIZATION PROVIDED TARGETS
- CONSTANT MONITORING
- ESTIMATING IS DONE BY PROFESSIONALS
- TEAM APPROACH – GOOD RELATIONS
- MANUFACTURING HAS VOICE IN DESIGN
- MANAGEMENT ALERTED EARLY TO PROBLEM AREAS

RECOMMENDED
APPROACHES TO DESIGN-TO-COST
&
MANUFACTURING-TO-COST

START WITH DESIGN-TO-COST

- ESTABLISH D.T.C. TEAM
- ENGINEERING – MANUFACTURING ENGINEERING – MATERIAL QUALITY CONTROL – ESTIMATORS
- ENGINEERS NEED MANUFACTURING INPUT ON COST DRIVERS
- COST AVOIDED ARE COSTS SAVED
- DO IT RIGHT THE FIRST TIME
- SET A PRICE CEILING ON PERFORMANCE

CONTINUE WITH MANUFACTURING-TO-COST

- PROVIDE NEW COST EFFECTIVE EQUIPMENT
- MINIMUM BUT ADEQUATE TOOLING
- SET TIGHT BUDGETS AND GOALS
- MONITOR PERFORMANCE (COST/SCHEDULE)
- DEVELOP INNOVATIVE MANUFACTURING METHODS/PROCESSES

AND

- TAKE CORRECTIVE ACTION WHEN INDICATED

RECOMMENDATIONS

DESIGN-TO-COST

ENGINEERING, MANUFACTURING ENGINEERING, AND QC PROVIDE:

- REALISTIC SCHEDULES (ENGINEERING/MANUFACTURING)
- TIGHT, BUT OBTAINABLE
- "TIME TO DO IT RIGHT THE FIRST TIME"
- ADEQUATE "TRADE-OFF STUDIES"
- COST VERSUS PERFORMANCE

FOLLOW THROUGH:

- MANUFACTURING TO COST
- TOOLING CONSISTENT WITH RATE/QUANTITY

RECOMMENDATIONS
DESIGN-TO-COST (DTC) APPROACH

DURING PROPOSAL PHASE

- SET PRELIMINARY TARGET COSTS
  - ALL ORGANIZATIONS
- ASSESSMENT OF COSTS FOR THE INTRODUCTION OF:
  - NEW MATERIALS
  - NEW PROCESSES/METHODS
  - NEW EQUIPMENT REQUIREMENTS
- ACTIVE PARTICIPATION OF DTC TEAM
- SET A TRADE-OFF PRICE CEILING ON PERFORMANCE
  - WEIGHT – TOLERANCES

RECOMMENDATIONS
DESIGN-TO-COST (DTC) APPROACH
(Continued)

THROUGH ALL ENGINEERING PHASES

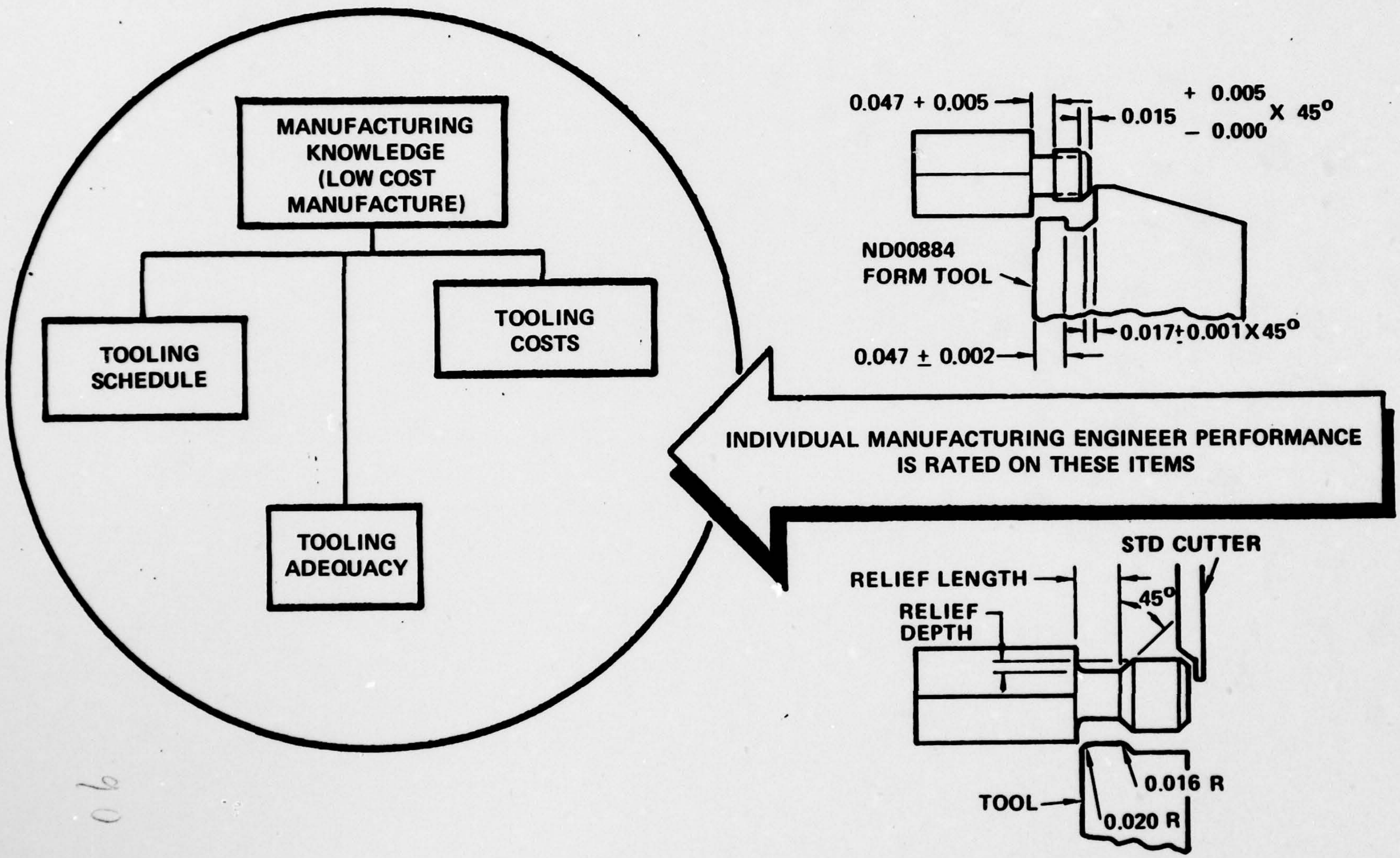
- SET FIRM COST TARGETS
- ACTIVE PARTICIPATION OF DTC TEAM
- MONITORING OF COST/SCHEDULE TO TARGETS
- COST VERSUS PERFORMANCE TRADE-OFFS
- MONITOR AND EVALUATE COST IMPACT OF CHANGES

RECOMENDATIONS
MANUFACTURING-TO-COST (MTC) PROGRAM

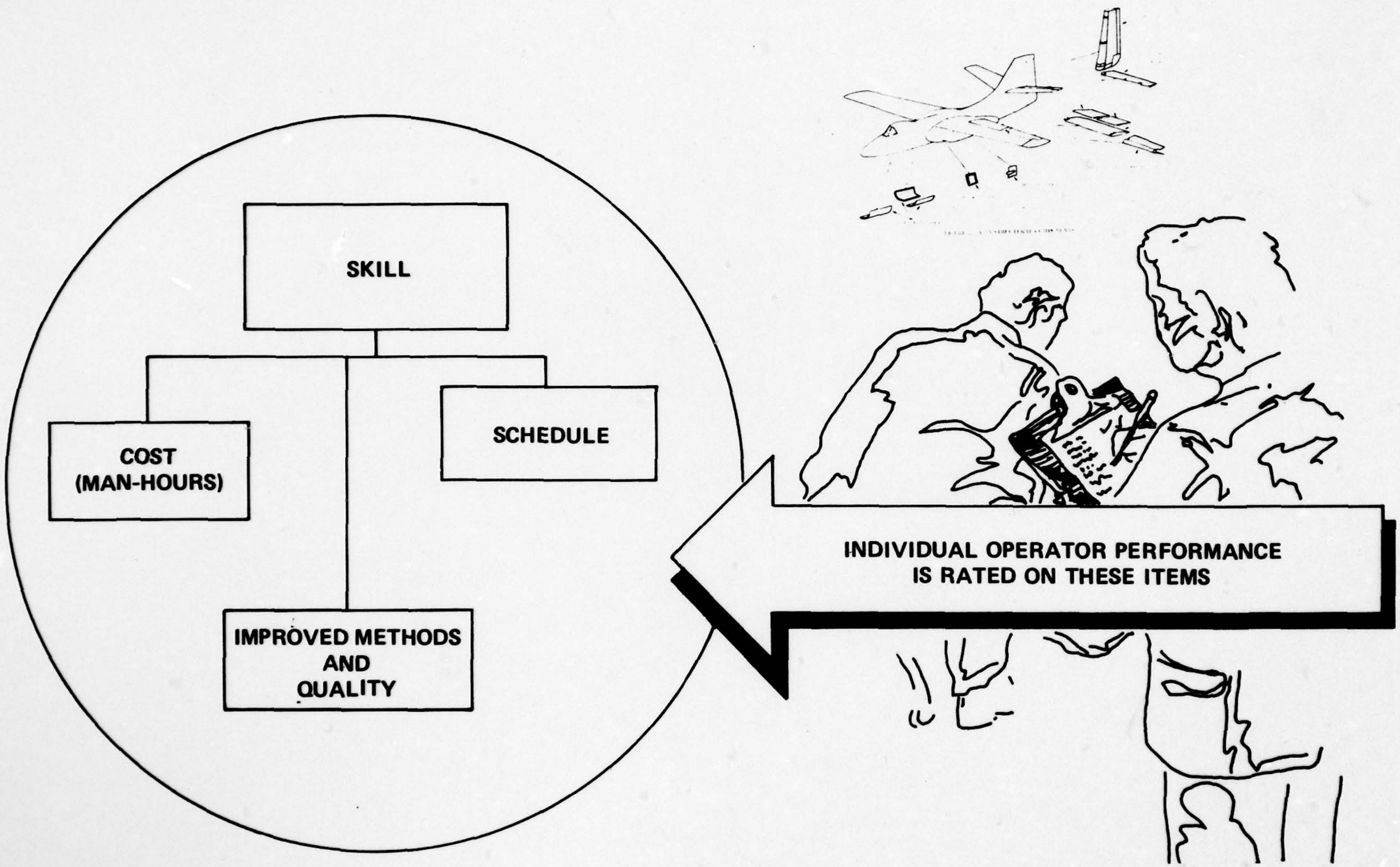
PROPOSAL PHASE THROUGH ENTIRE PROGRAM

- PROVIDE COST TRACKING
  - MATERIAL/SUBCONTRACTING
  - IN-HOUSE LABOR
  - TOOLING
- PROVIDE COST TRADE-OFFS
  - EQUIPMENT VS MANHOURS
  - TOOLING VS PRODUCTION MANHOURS
  - SCHEDULE VS OVERTIME
- CONTINUED METHOD/PROCESSES IMPROVEMENT
- AVOID QUESTIONABLE CHANGE

PRESENT AIRCRAFT MANUFACTURING ENGINEERING PRIORITIES



PRESENT AIRCRAFT MANUFACTURING TEAM PRIORITIES

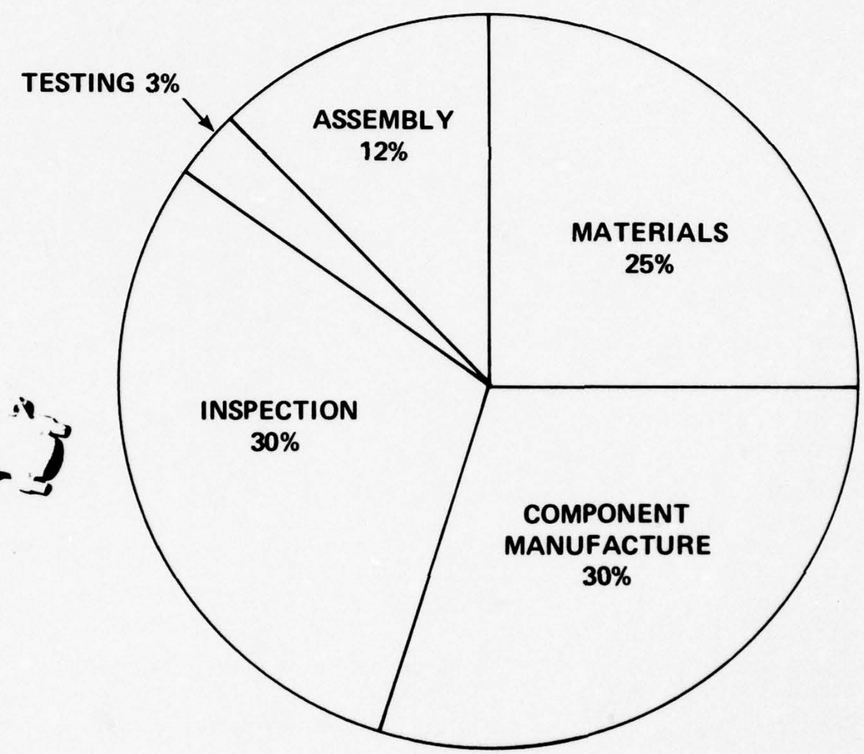


SUBSYSTEMS ANALYSIS

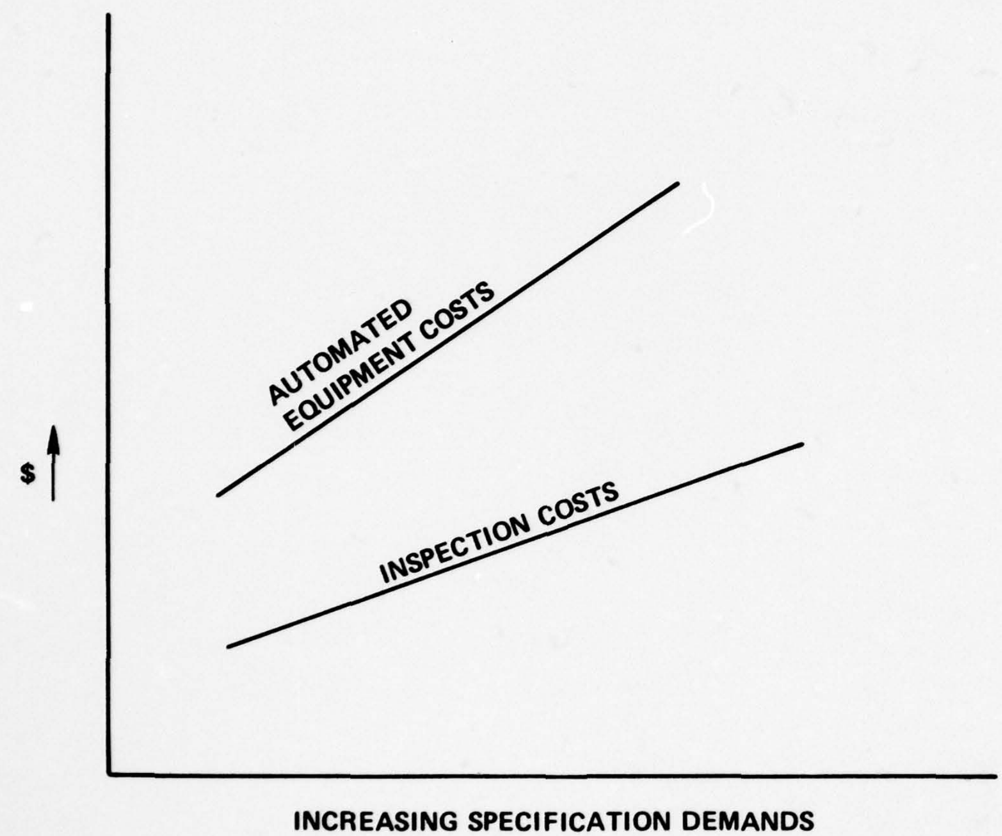
COST DRIVERS

AUXILIARY SYSTEMS

COST BREAKDOWN FOR TYPICAL AIRCRAFT SUBSYSTEM COMPONENT CONSTANT SPEED DRIVE



TIGHTER SPECIFICATIONS IN MECHANICAL SYSTEMS INDUSTRY CAUSE COST PROBLEMS



COST DRIVERS

AUXILIARY SYSTEMS

- INCREASED PERFORMANCE
  - REDUCED WEIGHT – HIGHER OPERATING SPEEDS
- TIGHTER SPECIFICATIONS
  - NEW EQUIPMENT
- MATERIAL AVAILABILITY/COST
  - COBALT, VANADIUM PERMADOR, MAGNESIUM CASTINGS, INCONEL
- INSPECTION COST
  - COST OF AUTOMATED EQUIPMENT

AD-A080 962 BATTELLE COLUMBUS LABS OH F/G 1/3

BRIEFING ON MANUFACTURING TECHNOLOGY (MT) COST DRIVER ANALYSIS --ETC(U)

JUN 79 B R NOTON DLA900-78-C-1715

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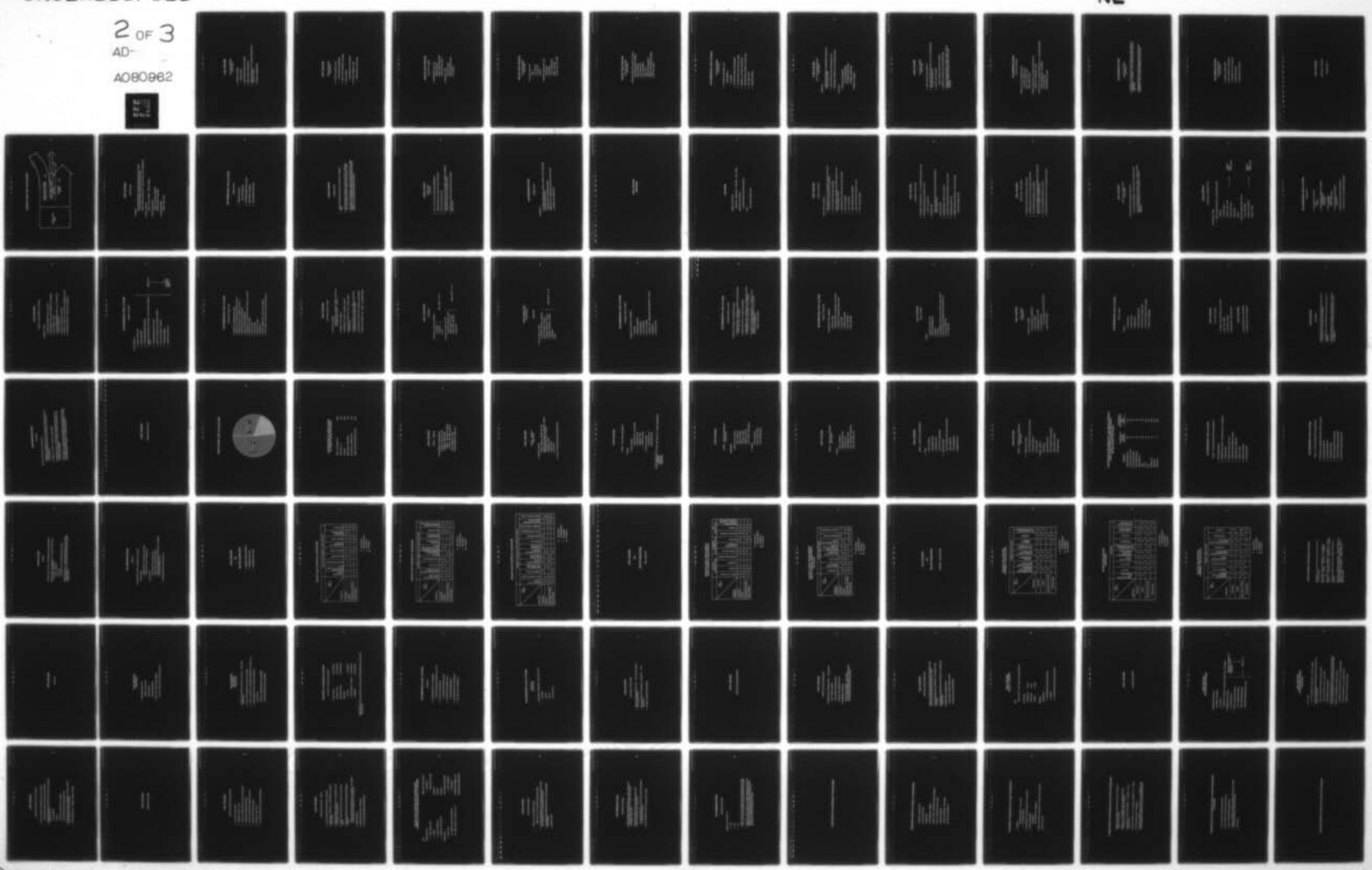
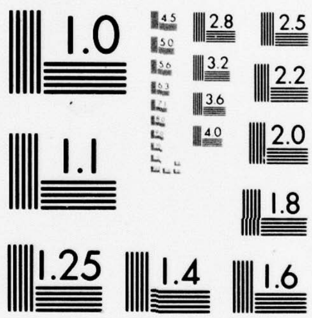




MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

COST DRIVERS

AUXILIARY SYSTEMS (CONTINUED)

- AUTOCLAVE CURING
  - ENERGY COSTS
- HAND STRAIGHTENING, POLISHING
- SMALL OROFICE MACHINING
- HIGH PART COUNT (UP TO 2,500) IN COMPLEX FUEL CONTROL VALVES
- TESTING OF COMPONENTS

COST DRIVERS

AUXILIARY SYSTEMS (CONTINUED)

- ELECTRICAL ENERGY COST
  - FOR BRAZING AND BONDING
- HAND FIT-UP FOR MANUAL WELDING
- SPECIAL GEARS
  - MACHINING/HEAT TREATMENT
- MATERIAL REMOVAL COST
  - LOW MATERIAL UTILIZATION

MAJOR COST DRIVERS

AUXILIARY SYSTEMS

- PERFORMANCE RELATED
  - REDUCED WEIGHT
  - HIGHER OPERATING SPEEDS
  - INCREASED RELIABILITY
- DESIGN RELATED
  - HIGH PART COUNT
  - NON-STANDARDIZATION
  - TOLERANCES

MAJOR COST DRIVERS

AUXILIARY SYSTEMS (CONTINUED)

- MATERIAL RELATED
  - COST
  - AVAILABILITY
  - UTILIZATION
  - ENERGY
- MANUFACTURING RELATED
  - INSPECTION
  - EQUIPMENT
  - CYCLIC PRODUCTION
  - SMALL LOT SIZES
  - HIGHLY SKILLED LABOR

100

MAJOR COST DRIVERS

AUXILIARY SYSTEMS (CONTINUED)

- MANUFACTURING RELATED (Continued)
  - DEBURRING/HAND FINISHING
  - METAL REMOVAL
  - HIGH SCRAP RATE
  - HEAT TREATMENT
  - HAND FIT-UP
  - JOB SHOP ENVIRONMENT
  - ENERGY IN AUTOCLAVE CURING
  - HIGH TOOL COUNT

RECOMMENDED COST CUTTERS

AUXILIARY SYSTEMS
(CONTINUED)

- AUTOMATED EQUIPMENT FOR:
  - BURR REMOVAL
  - POLISHING
- AUTOMATED INSPECTION EQUIPMENT
- ALTERNATIVES TO AUTOCLAVE CURING
- POSSIBILITY OF GROUP TECHNOLOGY
- IMPROVED METAL REMOVAL TECHNOLOGY
- NET SHAPE PARTS
- JOB SHOP CONTROL

CONCLUSIONS

AUXILIARY SYSTEM INDUSTRY (CONTINUED)

DRIVEN BY

- HIGHER PERFORMANCE REQUIREMENTS IMPOSED BY PRIME CONTRACTORS
- LACK OF SPECIFICATION STANDARDIZATION
- INCREASED EQUIPMENT AND AUTOMATION COSTS

RELIES ON

- JOB SHOP ENVIRONMENT
  - EXCESSIVE MANPOWER
  - REDUNDANT OPERATIONS
  - EXCESSIVE INSPECTION
- PRESENT EQUIPMENT

CONCLUSIONS

AUXILIARY SYSTEMS
(CONTINUED)

- HIGHLY SPECIALIZED INDUSTRY
- SPECIFICATIONS ARE CONTROLLED BY THE CUSTOMER AND THE PRIME CONTRACTOR
- CAUGHT IN COST SQUEEZE
  - LABOR VERSUS AUTOMATED EQUIPMENT
- SAME COST DRIVERS AS IN OTHER SUBSYSTEMS
- DEPENDS ON SUBCOMPONENT SUPPORT FROM A LIMITED NUMBER OF SPECIALIZED SUPPLIERS (LACK OF COMPETITION)

RECOMMENDATIONS

AUXILIARY SYSTEMS

- SPECIFICATION STANDARDIZATION
  - "IN-HOUSE" DESIGNS (DTC)
  - NAVY, AIR FORCE, ARMY
  - PRIME CONTRACTOR
- GROUP TECHNOLOGY IN MANUFACTURING (MTC)
  - INSTEAD OF FUNCTIONAL FLOW
- "PIGGY BACK" OFF OTHER MT PROJECTS, E.G., AIRFRAMES, ENGINES
  - LASER WELDING/HEAT TREATMENT
  - NET SHAPE PARTS
  - NEW NDI/NDT METHODS

RECOMMENDATIONS

AUXILIARY SYSTEMS (CONTINUED)

- IN GENERAL, MT PROJECTS SELECTED SHOULD BE APPLICABLE TO THE INDUSTRY IN GENERAL – NOT A SPECIFIC MANUFACTURER'S COMPONENT
- OTHER SUBSYSTEM MT PROJECTS SHOULD BE EVALUATED FOR COMMONALITY WITH SYSTEMS COMPONENT COST DRIVERS

RECOMMENDATIONS

AUXILIARY SYSTEMS (CONTINUED)

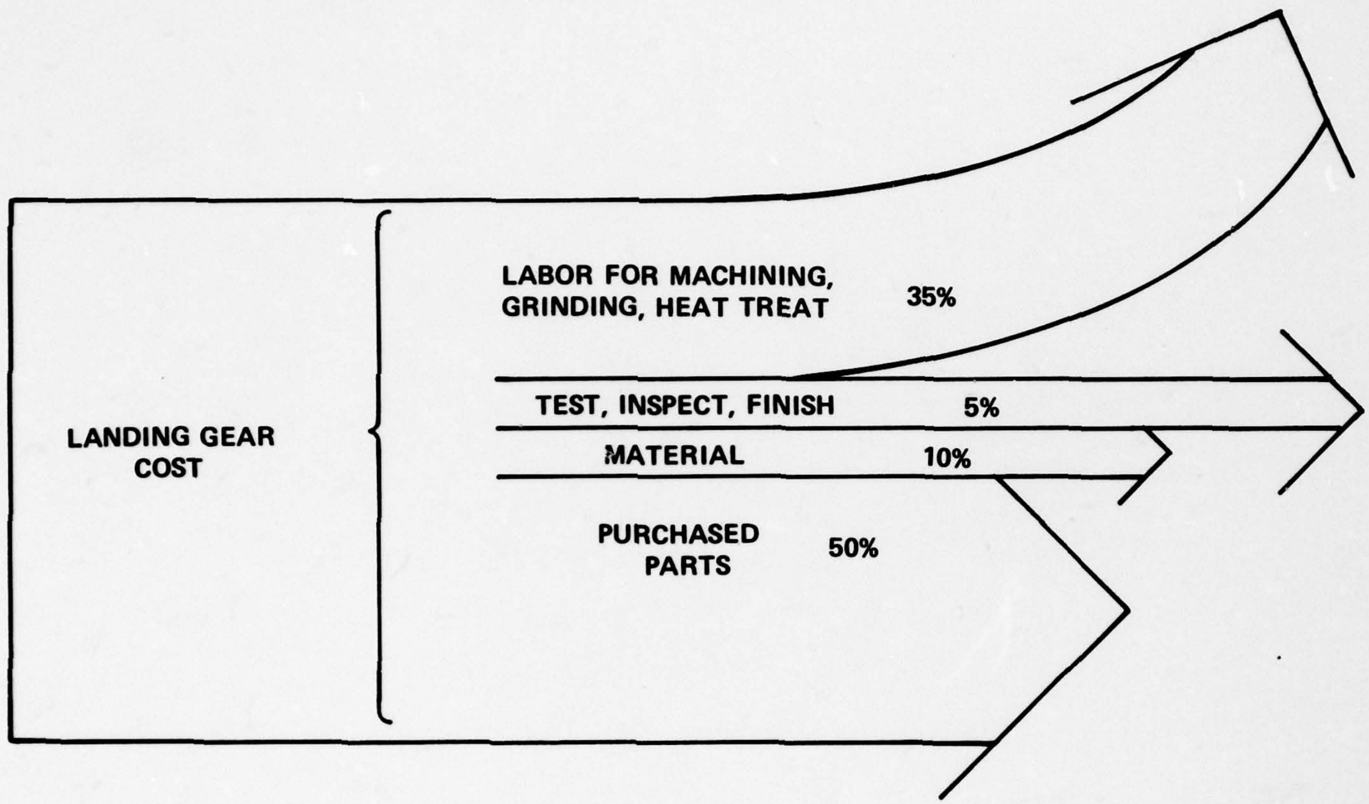
- AUTOMATED INSPECTION
- METAL REMOVAL TECHNOLOGY
- ALTERNATIVES TO AUTOCLAVE
- CAM APPLICATIONS
- TOLERANCE RELAXATION

COST DRIVERS

MECHANICAL SYSTEMS

LANDING GEAR

LANDING GEAR COST ALLOCATIONS



COST DRIVERS

LANDING GEAR

- GENERAL
  - – NAVY REQUIREMENTS FOR HIGHER-SINK RATES (22 VERSUS 12 FPS FOR AIR FORCE) RESULTS IN HEAVIER GEAR
  - – MOST LANDING GEARS HAVE A PART COUNT OF 250 COMPONENTS
- METAL REMOVAL
  - – METAL "SCULPTURING", HAND-FINISHING
- USE OF 300 M STEEL
  - – PRIMARY BLOCKER FORGINGS
  - – SOME CRACKING PROBLEMS
- DESIGN PROBLEMS
  - – SPACE LIMITATIONS

RECOMMENDED COST CUTTERS

LANDING GEAR

- PRESSURE WELDING
  - HOLLOW FORGINGS
- PRECISION POWDER METALLURGY
- ISOTHERMAL FORGINGS
- HIGH-STRENGTH CASTINGS

CONCLUSIONS

LANDING GEAR

- LANDING GEAR MANUFACTURE IS A SPECIALTY PRODUCT LINE
- COST DRIVERS ARE PRIMARILY RELATED TO METAL REMOVAL, HEAT TREATMENT AND TEST, INSPECT AND EVALUATE (TI&E)
- INCREASED PERFORMANCE LANDING GEARS AND SPECIFICATIONS IMPOSED BY THE AIRFRAME MANUFACTURER ARE NOT CONTROLLABLE BY THE LANDING GEAR MANUFACTURER

CONCLUSIONS

LANDING GEAR
(Continued)

- HALF OF COST IS IN PURCHASED COMPONENTS
- NONSTANDARD-EACH AIRCRAFT GEAR DIFFERENT
- HAVE NOT ADAPTED TO NC
- LONG DEPRECIATION ON GOVERNMENT-OWNED EQUIPMENT—LIMITS NEW TECHNOLOGY IMPLEMENTATION
- PRIMARILY BLOCKER FORING-NO CAST OR POWDER METAL PARTS

RECOMMENDATIONS

LANDING GEAR

- PRIMARILY
  - MT PROJECTS RELATED TO METAL REMOVAL AND ADVANCED WELDING TECHNOLOGIES
  - IMPROVED HEAT TREATING METHODS
  - IMPROVED TEST, INSPECTION AND EVALUATION (TI&E)
  - ALTERNATE FOR 300 M STEEL

COST DRIVERS
AIRFRAME

AIRFRAME

PRIMARY STRUCTURE:

FUSELAGE – BULKHEADS – WING BOX – RIBS – SPARS

SECONDARY STRUCTURE:

FAIRINGS, DOORS, CONTROL SURFACES

NOTE

EXCLUDES LANDING GEAR

COST DRIVERS

PRIMARY AIRFRAME

COST OF METAL REMOVAL

- INCREASED USE OF TITANIUM (COST OF EQUIVALENT PART IN TITANIUM, 5-7 GREATER THAN ALUMINUM)
- LACK OF CLOSE TOLERANCE FORGINGS
- METAL REMOVAL EQUIPMENT BECOMING OBSOLETE (DUE TO REPLACEMENT COSTS)
- EMPHASIS ON METAL PROFILING (WEIGHT SAVINGS)
- TIGHT TOLERANCES
- HEAT TREATMENT
- HAND FINISHING AND BLENDING
- USE OF EXOTIC METALS (SUPER ALLOYS)
- FIT-UP FOR EB WELDING

COST DRIVERS

SECONDARY STRUCTURE

- REPRESENT APPROXIMATELY 1/3 OF AIRFRAME STRUCTURAL COST
- PERFORMANCE (WEIGHT/STRENGTH RATIO)
  - LACK OF TRADE-OFFS
- CHEM-MILLING
  - LONG LEAD TIME ITEM FOR SUBCONTRACTORS; MASKING OPERATIONS COSTLY
- MACHINED PARTS
- NUMEROUS SMALL HAND-FITTED PARTS
- EXCESSIVE FASTENERS (BOTH NUMBER, SIZE AND TYPE)
- CORROSION PROTECTION
- EXCESSIVE DAMAGE IN SERVICE (LOGISTIC PROBLEM)
  - HIGH REPLACEMENT COSTS

COST DRIVERS

SHEET-METAL FABRICATION

- EXCESSIVE PROFILING FOR WEIGHT REDUCTION
- HAND-WORKING DUE TO HEAT TREATMENT DISTORTION
- HOT FORMING REQUIREMENTS (TITANIUM)
- LACK OF HIGH-PRESSURE FORMING EQUIPMENT (FOR LAMINATED STRUCTURE, SINEWAVE FORMINGS, ETC.)
- LACK OF STANDARDIZATION OF CLIPS, ETC.
- DESIGNS REQUIRING "CLOSE FIT-UP" OR NESTING OF PARTS

COST DRIVERS

SHEET-METAL FABRICATION
(CONTINUED)

- NEW EQUIPMENT APPROACHES REQUIRED
  - LACK OF NEW EQUIPMENT FOR SHEET-METAL MANUFACTURE
  - LITTLE ACCOMPLISHED SINCE 1940 TO 1950 – EXCEPT BLADDER PRESS AND ADVANCED STRETCH PRESSES WITH HIGHER TONNAGE

COST DRIVERS

SHEET-METAL DISCRETE PARTS

TWO DISTINCT TYPES

- ADDED STANDARD MANUFACTURING OPERATIONS
  - JOGGLES
  - FLANGED HOLES
  - SPECIAL LINEAL TRIM
  - SPECIAL END TRIM
  - BEND RADII
  - BEADS

  → NORMAL SHOP OPERATIONS

- MANUFACTURING COMPLEXITIES
  - HEAT TREATMENT
  - SPECIAL TOLERANCES
  - SPECIAL FINISH

  → SPECIAL SHOP OPERATIONS

RECOMMENDED COST CUTTERS

SHEET METAL

- MULTI-SPINDLE ROUTERS
  - N/C
  - TRACER
- HIGH PRESSURE FORMING EQUIPMENT
  - OVER 30,000 PSI
  - LARGE BED
- HEAT TREATMENT
  - CRYOGENIC
  - SPRAY QUENCHING
- TITANIUM ROUTING EQUIPMENT
  - LASER OR ?
- IMPROVED HOT FORMING TECHNOLOGY
- AUTOMATED HEAT TREATMENT/PROCESSING

COST DRIVERS

PRIMARY AND SECONDARY AIRFRAME

ASSEMBLY COSTS

- EXCESSIVE NUMBER OF DETAIL PARTS
- REQUIREMENT FOR LARGE NUMBER OF FASTENERS
- HIGH ASSEMBLY COSTS
- "FIT-UP" REQUIREMENTS ESPECIALLY TO MAINTAIN INTERCHANGEABILITY
- PROFILING FOR WEIGHT SAVINGS
- EXCESSIVE TOOLING TO LOCATE AND ASSEMBLE PARTS
- INTERCHANGEABILITY VERSUS REPLACEABILITY

RECOMMENDED COST CUTTERS

PRIMARY AIRFRAME

METAL REMOVAL

- GROUP TECHNOLOGY
- DNC/NC MACHINES
- ELECTRON BEAM/LASER WELDING
- IMPROVED MACHINING TECHNOLOGY (REF. METCUT RESEARCH DATA)
- TITANIUM POWDER METALLURGY
- USE BETA TITANIUM ALLOYS WHERE POSSIBLE
- MORE "NET FORMED" FORGINGS

} IMPROVE OR

- DIFFUSION BONDING
- LAMINATED STRUCTURE

} ELIMINATE MACHINED PARTS

RECOMMENDED COST CUTTERS

SECONDARY STRUCTURE

- LAMINATED BONDED STRUCTURES
- REDUCTION OF COMPOUND CURVATURE PARTS
- INCREASED USE OF AUTOMATIC RIVETING
- IMPROVED NDT/NDI TECHNOLOGY
- USE OF ADHESIVE BONDING
- SUPERPLASTIC FORMED/DIFFUSION BONDED TITANIUM
- PRECISION CASTINGS
- SPOT WELDING
- LIQUID SHIMS
- WELD/RIVET BOND
- COMPOSITES
- REDUCE NUMBER AND TYPES OF FASTENERS
- REPLACEABILITY INSTEAD OF INTERCHANGEABILITY

COST DRIVERS

FASTENER INSTALLATIONS

- TYPE OF FASTENER
  - CONVENTIONAL ALUMINUM VERSUS TAPER LOK TITANIUM (COST RATIO: 1 TO 15)
- NUMBER OF FASTENERS
- ACCESSIBILITY (BLIND, CONFINED AREAS)
- HOLE SIZING (TAPER LOK, BALL SIZING, INTERFERENCE FITS)
- VARIOUS SIZES AND TYPES IN COMMON STRUCTURE (EXCESSIVE HEAD CONFIGURATIONS)
- DESIGN NOT SUITABLE FOR AUTOMATIC EQUIPMENT
- SEALING (INTEGRAL FUEL TANKS – PRESSURIZATION)

COST VARIATION

FASTENERS

- MATERIAL (TYPE OF FASTENER)
  - ALUMINUM
  - TITANIUM
  - STEEL

  } COST RANGE 1 TO 55

- METHOD OF INSTALLATION
  - AUTOMATIC INSTALLATION
  - POWER ASSIST TOOLING
  - HAND TOOLS (WRENCHS)
  - HAND BUCK

  } LABOR COSTS 1 TO 10

COST VARIATION
(Continued)

FASTENERS

- **TYPE OF INSTALLATION**
  - ALUMINUM THROUGH ALUMINUM
  - STEEL THROUGH TITANIUM
  - TITANIUM THROUGH TITANIUM
  - TITANIUM THROUGH ALUMINUM
  - ACCESSIBLE
  - BLIND

} LABOR COSTS 1 TO 10

RECOMMENDED COST CUTTERS

FASTENER INSTALLATIONS

ELIMINATE OR REDUCE FASTENERS

- WELDING
- ADHESIVE BONDING
- WELD-BONDING
- RIVET-BONDING
- USE OF CASTINGS
- SUPERPLASTIC FORMED/DIFFUSION BONDED TITANIUM
- COMPOSITES
- UNITIZED PARTS

RECOMMENDED COST CUTTERS

FASTENER INSTALLATIONS

ELIMINATE OR REDUCE FASTENERS (Continued)

- EXPANDED USE OF AUTOMATIC EQUIPMENT (CONVENTIONAL, HI-LOK, TWO PIECE, FASTENERS)
- DESIGN FOR USE OF AUTOMATIC EQUIPMENT
- STANDARDIZE USE OF FASTENERS BY ENGINEERING (DO NOT LET ENGINEER HAVE FREE USE OF ANY FASTENER)
- ALLOW FOR TOOLING ACCESSIBILITY (CHANNELS MAY BE CHEAPER TO MANUFACTURE BUT ARE THEY COST EFFECTIVE ON ASSEMBLY?)
  - TRADE-OFFS REQUIRED

130

RECOMMENDED COST CUTTERS

PRIMARY STRUCTURE

ALTERNATIVES FOR ASSEMBLY

- SPOT WELDING
- FORMED BEADS TO ELIMINATE STIFFENERS
- AUTOMATIC FASTENER INSTALLATION
- LIQUID SHIMS
- ADHESIVE BONDING
- RIVET BONDING
- WELD BONDING

COST DRIVERS

INSTALLATIONS

WIRING

- HARNESS FABRICATION
- MULTI-PIN CONNECTORS
- TESTING
- POTTING
- ENVIRONMENT PROTECTION OF WIRES, PLUGS, TUBING
- FEED THROUGH IN PRESSURIZED BULKHEADS, ETC.
- FIELD MAINTENANCE
- R.F. SHIELDING

COST DRIVERS

INSTALLATIONS (CONTINUED)

HYDRAULIC SYSTEMS

- HIGH PRESSURE COMPONENTS
- TITANIUM TUBING
- HIGH PRESSURE FITTINGS
- LEAK PREVENTION
  - BOTH IN MANUFACTURE AND SERVICE
- FIELD MAINTENANCE

RECOMMENDED COST CUTTERS

INSTALLATIONS

WIRING

- FIBER OPTICS
- MULTIPLEXING
- RIBBON WIRE
- IMPROVED CONNECTORS
- REDUCTION OF CONNECTORS
- FLEXIBLE PRINTED CIRCUIT BOARDS
- MODULAR HARNESSES

COST DRIVERS

FUEL TANK SEALING

- INTEGRAL (SEALING GROOVES, SEALANT)
- FUEL CELL (BAGS)
- OPERATOR TRAINING
- MAINTENANCE COSTS (SERVICE)

COST CUTTERS

- STANDARD SEALING TECHNIQUES
- STANDARD REPAIR TECHNIQUES

CONCLUSIONS

AIRFRAMES

- STRONG INDICATION THAT WE ARE MANUFACTURING TODAY'S AIRFRAMES WITH YESTERDAY'S TECHNOLOGY
- AIRFRAME COST DRIVERS ESCALATE AND ARE DIFFICULT TO REMOVE
- AIRFRAME STRUCTURES (PRIMARY AND SECONDARY) PROVIDE THE MOST POTENTIAL OF SYSTEMS STUDIED FOR ROI WITH MT PROJECTS

RECOMMENDATIONS

AIRFRAME

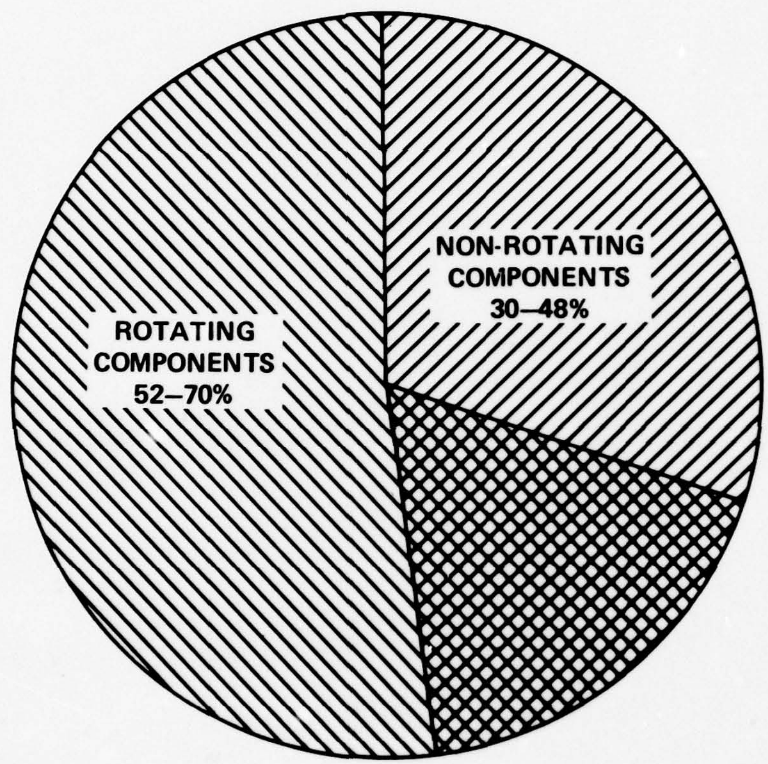
SELECT MT PROJECTS THAT PROVIDE:

- IMMEDIATE INCORPORATION INTO CURRENT PROGRAMS WITHOUT ENGINEERING REDESIGN AND ARE APPLICABLE TO FUTURE PROCUREMENTS
- COMMON TO OTHER AIRCRAFT SUBSYSTEMS
- SUBSTANTIAL ROI – WITH MINOR ENGINEERING REDESIGN ON CURRENT PROGRAMS AND PROVIDE PROVEN TECHNOLOGY FOR FUTURE PROCUREMENT
- "SEED MONEY" FOR PROVING EMERGING NEW MATERIALS, MANUFACTURING PROCESSES, AND EQUIPMENT REQUIREMENTS TO MAKE NEW PROCUREMENT POSSIBLE AT AFFORDABLE COST

COST DRIVERS

ENGINE MANUFACTURE

BASIC ENGINE COST ALLOCATIONS



DISTRIBUTION OF LABOR COSTS IN ENGINE MANUFACTURING

METAL CHIP REMOVAL:	62.0%
EDM, ECM, ETC.:	7.5%
WELDING:	12.0%
BRAZE/HEAT TREATMENT:	4.5%
SHEET METAL FABRICATION:	2.0%
MISCELLANEOUS MANUFACTURING:	12.0%

140

COST DRIVERS

ENGINE – GENERAL

- PERFORMANCE REQUIREMENTS
  - – ENGINE LIFE (20 YR PLUS)
  - – TURBINE TEMPERATURE
    - PRESENT: 2800–2950° RANKINE
    - FUTURE: 3200–3600° RANKINE
  - – MACH NUMBER ON DECK
  - – MACH NUMBER AT 35,000 FEET

COST DRIVERS

ENGINE — GENERAL
(CONTINUED)

- MANUFACTURING
  - METAL REMOVAL COSTS/CHIP LOSS
  - MATERIAL AVAILABILITY AND COST (COBALT, RENÉ, SUPERALLOYS, TITANIUM)
  - EQUIPMENT COSTS
  - LABOR COSTS
  - INFLATION
- LACK OF SPECIFICATION STANDARDIZATION

COST DRIVERS

ENGINE – ROTATING COMPONENTS*

TURBINE

- DISC (ROTORS)
  - – LOW MATERIAL UTILIZATION
  - – MACHINING COST
  - – ASSEMBLY COST
  - – INSPECTION COST
- AIRFOILS (BLADES)
  - – CASTING QUALITY
  - – MACHINING COST

*NOTE COMMONALITY OF COST DRIVERS IN ALL ENGINE COMPONENTS:
- – MACHINING
- – MATERIAL
- – INSPECTION.

COST DRIVERS

ENGINE – ROTATING COMPONENTS
(CONTINUED)

COMPRESSOR

- IMPELLER AND ROTOR
  - METAL REMOVAL
  - HAND FINISHING
  - MATERIAL COSTS
  - INSPECTION COSTS
  - LACK OF NDE PROCEDURES
- BLADES
  - METAL REMOVAL
  - HARD FACING COSTS
  - HIGH COST MATERIAL

COST DRIVERS

ENGINE – ROTATING COMPONENTS
(CONTINUED)

- GEARS
  - METAL REMOVAL
  - HOBBING OR SHAVING
  - HOLE DRILLING
  - EB EQUIPMENT COSTS
  - HEAT TREATMENT DISTORTION
  - HIGH REJECTION RATE

COST DRIVERS

ENGINE – NONROTATING COMPONENTS

- CASES
  - METAL REMOVAL
  - WELDING/BRAZING
  - NUMEROUS PARTS
  - LACK OF NDE PROCEDURES
- DUCTS AND RINGS
  - HEAT TREATMENT AND WELD DISTORTION
  - METAL REMOVAL
  - WELDING/BRAZING
  - NUMEROUS PARTS

COST DRIVERS

ENGINE – NONROTATING COMPONENTS
(CONTINUED)

- FLANGES AND FRAMES
  - HEAT TREATMENT AND WELD DISTORTION
  - MATERIAL REMOVAL
  - TOOLING COSTS
- MISCELLANEOUS
  - DEBURRING
  - HOLE PREPARATION
  - HAND FINISHING AND BLENDING
  - TOOLING COST (CUTTING)
  - EQUIPMENT COST

COMPARATIVE MACHINABILITY AND METAL REMOVAL COSTS FOR TYPICAL ENGINE MATERIALS
(All With Carbide Tool Inserts)

MATERIAL	MACHINABILITY RATING (PERCENT)	APPROXIMATE MACHINING COST, $\$/IN.^3$ (1973 $)
LOW-CARBON STEEL	100	0.25
LOW ALLOY STEEL 9310	45	.50
321 STAINLESS STEEL	45	.60
410 STAINLESS STEEL	40	.65
GREEK ASCOLOY	35	.70
A286	30	.85
A110Ti	25	1.00
6-4Ti	20	1.25
INCONEL 718	14	2.90
IN100 (P.M.)	8	3.30
WASPALLOY	14	2.90

RECOMMENDED COST CUTTERS

ENGINE – ROTATING/NONROTATING COMPONENTS

- DIFFUSION BONDING
- POWDER METALLURGY (HIP AND SUPERALLOY POWDERS)
- LASER WELDING
- INERTIA WELDING (FRICTION)
- AUTOMATED PRECISION BALANCING
- LASER SURFACE HARDENING
- LASER DRILLING
- IMPROVED ECM/EDM
- PLASMA WELDING

RECOMMENDED COST CUTTERS

ENGINE – ROTATING/NONROTATING COMPONENTS

- SUPERPLASTIC FORMED/DIFFUSION BONDED TITANIUM
- NC-CNC-DNC EQUIPMENT
- ADVANCED COMPOSITES
- PRECISION CASTINGS
- IMPROVED DEBURRING TECHNIQUES
- AUTOMATED INSPECTION PROCESSES
- SPECIFICATION STANDARDIZATION

CONCLUSIONS

ENGINES

- MAJOR COST FACTOR IS PERFORMANCE REQUIREMENTS
- GREAT DEAL OF COMMONALITY IN COST DRIVERS FOR ALL ENGINE COMPONENTS
  - – METAL REMOVAL
  - – WELDING
  - – CHECKING AND CORRECTING DISTORTIONS
- NEW TECHNOLOGY – METHODS/PROCESSES AND MATERIAL ADVANCES WILL PROVIDE MAJOR COST SAVINGS IN ENGINE MANUFACTURE

RECOMMENDATIONS

ENGINES

FOR MANUFACTURING TECHNOLOGY PROJECTS

- NEAR TERM
  - IMPROVED METAL REMOVAL METHODS
  - IMPROVED NDI/NDT TECHNOLOGY
- LONG TERM
  - NET SHAPE PART TECHNOLOGY
  - REDUCTION OF MACHINED PARTS
  - LAMINATED STRUCTURE, SUPERPLASTIC FORMING/ DIFFUSION BONDING, ETC.
- STANDARDIZATION OF MATERIALS

COST DRIVERS

BY

MAJOR SUBSYSTEM

- COMMON TO MOST INDUSTRY
- AEROSPACE RELATED
- TECHNOLOGY RELATED

MAJOR COST DRIVERS BY SUBSYSTEM

COST DRIVER / SUBSYSTEM	COST DRIVERS COMMON TO MOST INDUSTRY								
	LACK OF R&D FUNDING	SPECIFICATION COMPLEXITY OF OSHA, ETC.	MATERIAL SHORTAGE	NEW EQUIPMENT	MATERIAL COSTS	LACK OF SKILLED MANPOWER	ENERGY COSTS	EQUIPMENT OBSOLESCENCE	INFLATION
AIRFRAME	AVERAGE IMPACT	AVERAGE IMPACT	AVERAGE IMPACT	HIGH IMPACT	HIGH IMPACT	AVERAGE IMPACT	HIGH IMPACT	HIGH IMPACT	HIGH IMPACT
ENGINE	AVERAGE IMPACT	AVERAGE IMPACT	HIGH IMPACT	HIGH IMPACT	HIGH IMPACT	AVERAGE IMPACT	HIGH IMPACT	HIGH IMPACT	HIGH IMPACT
MECHANICAL SYSTEMS	LOW IMPACT	AVERAGE IMPACT	AVERAGE IMPACT	AVERAGE IMPACT	HIGH IMPACT	AVERAGE IMPACT	HIGH IMPACT	AVERAGE IMPACT	HIGH IMPACT
CREW SYSTEMS	LOW IMPACT	AVERAGE IMPACT	AVERAGE IMPACT	AVERAGE IMPACT	HIGH IMPACT	AVERAGE IMPACT	HIGH IMPACT	AVERAGE IMPACT	HIGH IMPACT

● HIGH IMPACT
● AVERAGE IMPACT
● LOW IMPACT
● NO IMPACT

MAJOR COST DRIVERS BY SUBSYSTEM

SUBSYSTEM \ COST DRIVER	AEROSPACE INDUSTRY-RELATED COST DRIVERS									
	WEIGHT REDUCTION OPERATIONS	PERFORMANCE VERSUS COST SYNDROME	LACK OF DTC	CYCLIC PRODUCTION	LACK OF SPECIFICATION/ STANDARDIZATION	LACK OF AUTOMATION AND LOW PRODUCTION RATES	HIGH SKILL REQUIREMENTS	HIGHER QUALITY REQUIREMENTS	USE OF COBALT	CONTROLLED MANU-FACTURING CONDITIONS
AIRFRAME	●	●	●	●	○	○	○	○	◉	◉
ENGINE	●	●	●	●	○	●	○	○	●	◉
MECHANICAL SYSTEMS	●	●	○	○	●	○	○	○	◉	◉
CREW SYSTEMS	●	●	●	●	●	○	●	●	○	○

● HIGH IMPACT
○ AVERAGE IMPACT
◉ LOW IMPACT
● NO IMPACT

MAJOR COST DRIVERS BY SUBSYSTEM

SUBSYSTEM \ COST DRIVER	AEROSPACE TECHNOLOGY RELATED COST DRIVERS: MATERIAL UTILI-ZATION	METAL REMOVAL COSTS	NUMBER OF PARTS	PROCESSING AND HEAT TREATMENT	FASTENER INSTAL-LATION	SHEET METAL FABRICATION	LACK OF NEAR NET FORGINGS	CORROSION PROTECTION	HAND FIT-UP	DESIGN CHANGES	TESTING REQUIREMENTS	ASSEMBLY/INSTALLATION	HYDRAULIC SYSTEMS INSTALLATION	WIRING INSTALLATIONS
AIRFRAME	High	Average	High	Average	High	High	Average	High	High	High	Average	Average	Average	Average
ENGINE	High	High	Average	High	Low	Low	High	Average	Average	Average	Average	Average	Low	High
MECHANICAL SYSTEMS	High	High	Average	High	High	High	Low	Average	Average	Average	Average	Low	High	High
CREW SYSTEMS	High	High	High	Average	Low	Average	High	Average	Average	Average	Average	Average	Low	Low

● HIGH IMPACT
● AVERAGE IMPACT
● LOW IMPACT
● NO IMPACT

COST DRIVERS

BY

MAJOR SUBSYSTEM

METAL REMOVAL

RELATIVE COST DRIVER IMPACT
METAL REMOVAL (MACHINING)

AIRCRAFT SUBSYSTEM / COST DRIVER	MATERIAL AVAILABILITY/COST				EQUIPMENT REPLACEMENT COST			CHIP REMOVAL COST		
	SUPER ALLOY STEELS	TITANIUM	ALUMINUM	CONVENTIONAL STEELS	N/C, DNC, CNC, ETC.	CONVENTIONAL EQUIPMENT	ECM, EDM	SUPER ALLOY STEELS	TITANIUM	CONVENTIONAL MATERIAL, ALUMINUM CONVENTIONAL STEEL
AIRFRAME	●	●	○	○	●	○	●	●	●	○
ENGINE	●	●	○	○	●	○	○	●	●	○
MECHANICAL SYSTEMS	●	●	○	○	●	○	●	●	●	○
CREW SYSTEMS	●	●	○	○	○	○	●	○	●	○

● HIGH IMPACT
○ AVERAGE IMPACT
● LOW IMPACT
● NO IMPACT

RELATIVE COST DRIVER IMPACT
METAL REMOVAL (MACHINING)
(Continued)

COST DRIVER / AIRCRAFT SUBSYSTEM	MISCELLANEOUS COSTS							
	TOLERANCES	SPECIFICATION COMPLEXITY	PROFILING	HEAT TREATING/ PROCESSING	CONVENTIONAL MILLING, DRILLING, TURNING	HAND FINISHING AND FIT-UP	INSPECTION COSTS	IN-PLANT HANDLING
AIRFRAME	○	○	●	○	○	○	●	○
ENGINE	●	●	●	●	●	●	○	○
MECHANICAL SYSTEMS	●	●	●	●	●	○	○	●
CREW SYSTEMS	●	●	○	○	○	●	●	●

● HIGH IMPACT
○ AVERAGE IMPACT
● LOW IMPACT
● NO IMPACT

COST DRIVERS

BY

MAJOR SUBSYSTEM

ASSEMBLY/INSTALLATION

MAJOR COST DRIVERS
ASSEMBLY/INSTALLATION

COST DRIVER / SUBSYSTEM	ASSEMBLY/INSTALLATION							
	NOT DESIGNED FOR BREAK-BACK SUB-ASSEMBLIES	EXCESSIVE NUMBER SMALL PARTS	SEQUENCE REQUIREMENTS	EXCESSIVE TOOLING REQUIREMENTS	PART AVAILABILITY TO LINE ASSEMBLY	HAND-FIT AT ASSEMBLY	SHIMMING	PART HANDLING/PRO-TECTION REQUIREMENTS
AIRFRAME	●	●	●	●	○	●	●	●
ENGINE	●	○	●	●	○	○	●	●
MECHANICAL SYSTEMS	●	○	●	●	○	○	●	○
CREW SYSTEMS	○	●	○	○	○	●	●	○

- ● HIGH IMPACT
- ○ AVERAGE IMPACT
- ● LOW IMPACT
- ● NO IMPACT

MAJOR COST DRIVERS
FASTENERS

COST DRIVER / SUBSYSTEM	CLOSE TOLERANCE HOLE PREPARATION	QUANTITY	MULTI-TYPE	INSTALLATION COSTS	UNSUITABLE FOR AUTOMATIC INSTALLATION	FUEL AND PRESSURE-SEALING REQUIREMENTS	ACCESSIBILITY	TWO-PIECE	CLOSED AREAS – BLIND-RIVETING	COUNTER-SINK AND RIVET SHAVING
	FASTENERS									
AIRFRAME	●	●	●	●	●	●	●	●	●	○
ENGINE	●	●	●	●	●	○	●	○	●	●
MECHANICAL SYSTEMS	○	●	●	●	●	●	●	●	●	●
CREW SYSTEMS	○	○	●	●	○	○	●	○	●	●

● HIGH IMPACT
○ AVERAGE IMPACT
● LOW IMPACT
● NO IMPACT

MAJOR COST DRIVERS
ASSEMBLY/INSTALLATION

COST DRIVER / SUBSYSTEM	ASSEMBLY/INSTALLATION								
	SUPERPLASTIC FORMING/DIFFUSION BONDING	COMPOSITE LAY-UP	AUTOCLAVE CURING	ADHESIVE BONDING METAL	HONEYCOMB SANDWICH CONSTRUCTION	EB WELDING	CONVENTIONAL WELDING GAS/ARC/ETC.	SPOT WELDING	BRAZING
AIRFRAME	●	●	●	● (grey)	●	●	●	●	●
ENGINE	●	● (grey)	●	● (grey)	●	●	●	●	● (grey)
MECHANICAL SYSTEMS	●	●	●	●	●	● (grey)	● (grey)	●	●
CREW SYSTEMS	●	● (grey)	● (grey)	● (grey)	●	●	●	● (grey)	●

● HIGH IMPACT
● (grey) AVERAGE IMPACT
● LOW IMPACT
● NO IMPACT

CONCLUSIONS FROM MATRIX CHARTS

– COMMONALITY OF COST DRIVERS EXIST THROUGHOUT ALL SUBSYSTEMS

– MAJOR COST DRIVERS COMMON TO ALL INDUSTRY INFLATION – ENERGY – MATERIAL – EQUIPMENT

– MAJOR COST DRIVERS COMMON TO AEROSPACE – METAL REMOVAL – HIGH PART COUNT – MATERIAL UTILIZATION

– AIRFRAME MANUFACTURE HAS HIGHEST IMPACT COST DRIVERS

– ENGINES – MECHANICAL SYSTEMS – CREW SYSTEMS HAVE MOST COMMONALITY BETWEEN COST DRIVERS – METAL REMOVAL – HEAT TREATMENT – INSPECTION COST – SPECIFICATIONS

COST DRIVERS

MATERIAL

COST DRIVERS
MATERIAL

- INCREASING COST FOR:
  - ENERGY TO PRODUCE
  - RAW MATERIAL
  - SOURCE DEPENDENT
- LONG "LEAD TIME" PROCUREMENT
  - COST OF INVENTORY (TO PROTECT SUPPLY)

COST DRIVERS
MATERIAL
(Continued)

- POOR UTILIZATION OF MATERIAL (OVERALL, LESS THAN 30 PERCENT)
- LACK OF RECLAMATION OF SCRAP (TITANIUM)
- LACK OF "NEAR NET" FORGINGS, POWDER METALLURGY, ETC.
- HIGH EQUIPMENT COSTS FOR METAL REMOVAL
  - DNC, CNC, NC
  - GRADUAL OBSOLESCENCE OF EQUIPMENT
  - A MAJOR PROBLEM FOR MANAGEMENT

MATERIAL UTILIZATION FACTORS*

MATERIAL UTILIZATION FACTORS*

• SHEET METAL:	45-50 PERCENT
MACHINE PLATE:	14-25 PERCENT
MACHINE BAR/ROD:	20-25 PERCENT
FORGINGS	
– BLOCKER	8-12 PERCENT
– CONVENTIONAL FORGING:	12-22 PERCENT
– PRESSINGS:	56-83 PERCENT

*REFERENCE AIR FORCE MATERIALS LABORATORIES SAGAMORE MANUFACTURING COST MEETING.

RECOMMENDED COST CUTTERS

MATERIALS

- STANDARDIZATION OF HARDWARE
  - LIMITATIONS ON ENGINEERING CALL-OUTS
- MATERIAL RECLAMATION
  - IN-HOUSE SCRAP SEGREGATION
- ADVANCED PROCUREMENT BUYS
  - CUSTOMER COMMITMENTS
- EXTENDED SHELF-LIFE MATERIALS
- NET SHAPE PART TECHNOLOGY

RECOMMENDED COST CUTTERS

MATERIALS (CONTINUED)

- REFURBISH, PERISHABLE, AND HAND TOOLS
  - CUTTERS
  - GAGES
  - DRILLS
  - AIR TOOLS, ETC.

170

CONCLUSIONS

MATERIALS COST DRIVERS

- RAPIDLY BECOMING ONE OF THE MAJOR *COST DRIVERS*, IF NOT THE MAJOR ONE
- WE ARE LIVING IN A NEW WORLD OF SCARCITY – RAW MATERIALS
- ENERGY TO REFINE AND PROCESS

COST DRIVERS

MANUFACTURING ENGINEERING

COST DRIVERS

MANUFACTURING ENGINEERING

- ENGINEERING CHANGES CAUSE: (CONTINUED)
  - TOOL DESIGN CHANGES
  - TOOL REWORK AND SCRAPPAGE
  - REWORK AND SCRAPPED PARTS
- COMPRESSED SCHEDULES
  - EXCESSIVE MANPOWER – OVERTIME – IN ALL AREAS, ENGINEERING TO MANAGEMENT AND PROBLEMS IN OBTAINING MATERIAL

COST DRIVERS

MANUFACTURING ENGINEERING

- LACK OF INTERACTION BETWEEN DESIGN ENGINEER AND *MANUFACTURING ENGINEER (DESIGN-TO-COST)*
- LATE ENGINEERING RELEASES DUE TO SCHEDULE CON-STRAINTS
- PROGRESSIVE ENGINEERING RELEASES DUE TO SCHEDULE CONSTRAINTS
- ENGINEERING CHANGES CAUSE:
  - RE-RELEASE OF WORK INSTRUCTIONS
  - REVISED N/C RE-PROGRAMMING

COST DRIVERS
QUALITY CONTROL

COST

4-5% OF SALES – BUT 10-30% OF MANUFACTURING

ALLOCATION

PREVENTIVE – 15-20%

DETECTION – 57-65

OTHERS – 28-15%

PROBLEM

INADEQUATE

- ACCEPTANCE/REJECTION CRITERIA
- NDI/NDT
- FRACTURE MECHANICS ANALYSIS DATA

COST DRIVERS

ENGINEERING DESIGN

COST DRIVERS
ENGINEERING DESIGN

- COMPRESSED SCHEDULE
  - – EXCESSIVE MANPOWER
  - – OVER-TIME
  - – ALTERNATE MATERIAL (BLOCKER VERSUS CONV. FORGINGS)
- PROGRESSIVE RELEASES
  - – REVISED DESIGNS

  } RELEASE OF INCOMPLETE DESIGNS TO MEET SCHEDULE → RESULTS IN

- EFFECT ON MANUFACTURING
  - – TOOL REWORK/SCRAPPAGE
  - – PART REWORK/SCRAPPAGE
  - – EXCESSIVE MANPOWER/OVER-TIME

COST DRIVERS
ENGINEERING DESIGN
(Continued)

- NET EFFECT
  - – UP TO 100 PERCENT INCREASE IN "START-UP COSTS"
- LACK OF MANUFACTURING/ENGINEERING INTERACTION AT DESIGN CONCEPTION
  - – BUILT-IN EXCESSIVE MANUFACTURING COSTS
  - – LACK OF DESIGN-TO-COST "TRADE-OFFS"
  - – PERFORMANCE VERSUS COST
- LACK OF CONTINUING MANUFACTURING COST REDUCTION BY METHODS IMPROVEMENT (THIS IS MANUFACTURING-TO-COST)
- IMPACT OF ENGINEERING CHANGE TRAFFIC
  - – ACCOUNTS FOR 36 PERCENT OF NO. 1 AIRPLANE COST
  - – AND 20 PERCENT OF NO. 20 AIRPLANE COST
  - – THEREFORE, A MAJOR COST-DRIVER

CONCLUSIONS

ENGINEERING IMPACT ON COST DRIVERS

- COST DRIVERS ARE DESIGNED INTO THE PRODUCT
  - ENGINEERING DESIGN IS A MAJOR COST DRIVER
- DESIGN ENGINEERING SOMETIMES PLACES COST IN SECOND CONSIDERATION TO:
  - PERFORMANCE
  - WEIGHT
  - ADVANCED TECHNOLOGY THRUSTS
  - MEETING DESIGN RELEASE SCHEDULES
- ONCE COST DRIVERS ARE DESIGNED IN, MAJOR EFFORTS ARE REQUIRED TO DRIVE THEM OUT
- COST DRIVERS ARE A "WOMB-TO-TOMB" PROBLEM

COST DRIVERS

EMERGING PROCESSES

COST DRIVERS

ADVANCED COMPOSITE STRUCTURES

- HIGH COST OF MATERIAL
- EXCESSIVE HAND "LAY-UP"
- LACK OF AUTOMATED NDT AND NDI TECHNIQUES
- FASTENER CORROSION PROBLEMS
- LACK OF AUTOMATION IN MANUFACTURING
- CURING COSTS (ENERGY COSTS)
- MATERIAL "SHELF-LIFE"
- FIELD MAINTENANCE AND REPAIR PROBLEMS

COST DRIVERS

LAMINATED STRUCTURE – METAL

- LACK OF ENGINEERING DESIGN ALLOWABLES
- INSUFFICIENT "IN-SERVICE" EXPERIENCE (CUSTOMER RELUCTANCE)
- MANUFACTURING TECHNOLOGY FOR FORMING CLOSE TOLERANCE "NESTED PARTS"
- PRESENT LIMITATIONS ON PLY BUILD-UP (OVER FOUR PLIES)
- IMPROVED BONDING METHODS/PROCESSES (PRESSURE, TOOLING)
  - NEW TOOLING APPROACHES SUCH AS THERMALLY-EFFICIENT CLOSED DIES AS ALTERNATIVE TO AUTOCLAVE
- DAMAGE REPAIR
- INADEQUATE NDI/NDT TECHNIQUES
- PLUS ADHESIVE BONDING CONSTRAINTS

MAJOR COST DRIVERS FOR SUPERPLASTIC FORMED/DIFFUSION BONDED 6AL-4V TITANIUM

SIZE

CONFIGURATION

- SINGLE SHEET (SPF)
- 2 SHEET
- 3 SHEET (SANDWICH)
- GREATER THAN 3 SHEETS

COMPLEXITY

- CORE TYPE
  - (A) CONSTANT DEPTH OR TAPERED
  - (B) SINGLE, DOUBLE, OR MULTI-LAYER

COMPLEXITY (CONTINUED)

- DOUBLERS
- MACHINED FITTINGS

CHEM-MILL

TOOLING

MATERIAL

POST SPF/DB OPERATIONS

- FINAL TRIMMING
- MACHINING

EQUIPMENT (PRESSES, ETC.)

ENGINEERING DESIGN COSTS

CONCLUSIONS

EMERGING PROCESSES

- ARE STILL IN THE EMBRYO STAGE
  - SOME MT, BUT LITTLE PRODUCTION APPLICATION
- MT PROJECTS DIRECTED AT THE IDENTIFIED COST DRIVERS ARE MANDATORY FOR TOMORROW'S AIRCRAFT
- FEW EMERGING PROCESSES CAN BE UTILIZED ON PRESENT PROCUREMENT
- CONSERVATISM

RECOMMENDATIONS

EMERGING PROCESSES

- CLOSE COORDINATION BETWEEN NAVY, ARMY, AIR FORCE TO ESTABLISH MT PROJECTS FOR BRINGING THE NEW PROCESSES "ON STREAM"
- A MAJOR PORTION OF THE MT FUNDING SHOULD BE DIRECTED TOWARDS NEW TECHNOLOGY
  - TO REDUCE POTENTIAL OF CREATING NEW COST DRIVERS IN TOMORROW'S PRODUCT
- COST AVOIDANCE IS BETTER THAN COST CUTTING

RECOMMENDATIONS

EMERGING PROCESSES

COMPUTER TECHNOLOGY

- CAM
- CAD
- CAI
- COMPUTER RELATED MT PROJECTS ARE MAJOR COST CUTTERS AT ALL LEVELS OF AEROSPACE DESIGN AND MANUFACTURING
- HOWEVER, A GREAT DEAL OF FUNDING IS NOW ALLOCATED TO COMPUTER-AIDED TECHNOLOGY AND MT PROJECTS RELATED TO USE OF THE COMPUTER SHOULD BE VERY CAREFULLY REVIEWED TO AVOID REDUNDANT EFFORTS

CONSTRAINTS ON EMERGING TECHNOLOGIES

EMERGING MANUFACTURING TECHNOLOGIES

- COMPUTER TECHNOLOGY
- NET SHAPE METHODS
- COMPOSITES
- HIGH PRESSURE FORMING
- SUPER PLASTIC FORMING/DIFFUSION BONDING
- METAL LAMINATION STRUCTURES
- ADHESIVE BONDING
- LASER CUTTING/HEAT TREATMENT
- NEUTRON RADIOGRAPHY

CUSTOMER CONSTRAINTS ON NEW TECHNOLOGY

- FUNDING
  - – REDUCED BUDGETS – INFLATION
  - – MT FUNDS LIMITED
- ACCEPTANCE OF NEW TECHNOLOGY BY INDUSTRY
- LOGISTIC PROBLEMS
  - – INVENTORY
  - – RE-TRAINING OF PERSONNEL
- WHAT ADVANCED TECHNOLOGY IS MOST COST EFFECTIVE?
- WHAT'S THE ROI?

CONSTRAINTS ON INTRODUCTION OF NEW TECHNOLOGY

- MUST BE TRIED AND PROVEN SATISFACTORY IN SERVICE BEFORE ACCEPTANCE
- DIFFICULT TO INTRODUCE INTO ON-GOING PROGRAM (RE-DESIGN, RE-TESTING, AND RE-TOOLING)
- INVESTMENT FOR NEW EQUIPMENT, "LET'S MAKE IT WITH WHAT WE GOT"
- FEAR OF FAILURE, "LET THE OTHER COMPANY TRY IT FIRST"
- "NOT INVENTED HERE" SYNDROME
- NO SINGLE COMPANY CAN AFFORD TOTAL INVESTMENT FOR NEW EQUIPMENT OR MANUFACTURING DEVELOPMENT COSTS

CONSTRAINTS ON INTRODUCTION OF NEW TECHNOLOGY
(Continued)

- LACK OF NEW SYSTEMS PROCUREMENT
- RE-TRAINING OF EMPLOYEES (NEW SKILLS)
- LACK OF ENGINEERING DESIGN DATA
- LACK OF FUNDING TO PRODUCTIONIZE NEW MANUFACTURING METHODS/PROCESSES FOR NEW MATERIALS
- INFLATION

MANUFACTURING TECHNOLOGY (MT) COST DRIVERS

AD-A080 962   BATTELLE COLUMBUS LABS OH   F/G 1/3
BRIEFING ON MANUFACTURING TECHNOLOGY (MT) COST DRIVER ANALYSIS --ETC(U)
JUN 79 B R NOTON   DLA900-78-C-1715
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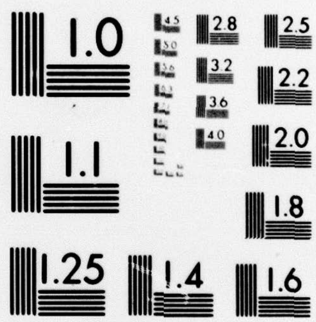

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

OVERVIEW OF MAJOR MANUFACTURING TECHNOLOGY (MT) COST DRIVERS

COMMON TO ALL SUBSYSTEMS

METAL REMOVAL – MATERIAL COST/AVAILABILITY
ENERGY COST – HIGH MAN-HOURS

AIRFRAME

FASTENERS – PART COUNT – ASSEMBLY/INSTALLATION

ENGINE

EXOTIC ALLOYS – MATERIAL UTILIZATION

LANDING GEAR

SPECIAL STEELS – HEAT TREATMENT

CREW SYSTEM COMPONENTS

INSPECTION COSTS – TIGHT SPECIFICATIONS

MANUFACTURING TECHNOLOGY (MT) COST DRIVERS

AIRFRAMES

MACHINING

TITANIUM – PROFILING – TOLERANCES

SHEET METAL

PROFILING – HAND WORKING – HOT FORMING

ASSEMBLY

EXCESSIVE PART COUNT & FASTENERS – AERODYNAMIC SMOOTHNESS – TOLERANCE REQUIREMENTS

INSTALLATION

SEALING – HIGH PRESSURE HYDRAULICS – WIRING

CONCLUSIONS AND RECOMMENDATIONS

GENERAL CONCLUSIONS

AIRCRAFT MANUFACTURE

- DEPENDS HEAVILY ON MANPOWER
- IS A CYCLIC INDUSTRY
- HAS LITTLE AUTOMATION
- HAS FEW CUSTOMERS, EXCESSIVE CAPACITY
- HIGHLY SKILLED INDUSTRY
- HIGH TECHNOLOGY ORIENTED
- DRIVEN BY PRODUCT EXCELLENCE

GENERAL CONCLUSIONS
(Continued)

- MOST COST DRIVERS ARE DESIGNED INTO AIRCRAFT
- MOST COST DRIVERS ARE COMMON TO ALL SUBSYSTEMS
- EMPHASIS MUST CHANGE FROM PERFORMANCE TO AFFORDABLE PERFORMANCE
- SPIRALLING AIRCRAFT COSTS MUST BE BETTER CONTROLLED
- MINIMUM NEW MANUFACTURING TECHNOLOGY HAS BEEN PRODUCTIONIZED IN THE LAST 10 YEARS

GENERAL CONCLUSIONS
(Continued)

- MANUFACTURING TECHNOLOGY (MT) PROJECTS CAN BE SELECTED THAT PROVIDE A HIGH RETURN ON INVESTMENT (ROI)
- EMERGING MANUFACTURING TECHNOLOGIES STILL DISPLAY SIGNIFICANT COST DRIVERS
- DEVELOPING MANUFACTURING TECHNOLOGY ON A PRODUCTION PROGRAM IS SELDOM COST COMPETITIVE
- IS THE U.S. AEROSPACE MANUFACTURING INDUSTRY LOSING ITS COMPETITIVE EDGE?

GENERAL CONCLUSIONS
(Continued)

- MANUFACTURING TECHNOLOGY THRUSTS ARE JUST AS IMPORTANT AS PERFORMANCE THRUSTS
- LAGGING MANUFACTURING TECHNOLOGY HAS RESULTED IN SPIRALLING AIRCRAFT COSTS
- STRONG EVIDENCE WE ARE BUILDING TODAY'S AIRCRAFT WITH YESTERDAY'S TECHNOLOGY
- EMPHASIS IS CHANGING FROM PERFORMANCE TO AFFORDABLE PERFORMANCE
- MANUFACTURING TECHNOLOGY CAN MAKE PERFORMANCE AFFORDABLE
- OVER THE YEARS, THE AEROSPACE INDUSTRY AND THE CUSTOMER HAVE PLACED HEAVY EMPHASIS ON INCREASED PERFORMANCE. THE U.S. HAS LEAD THE WORLD IN DESIGNING AND BUILDING SOME OF THE BEST MILITARY AIRCRAFT IN THE WORLD AND LEADS THE WORLD IN COMMERCIAL AIRCRAFT.

RECOMMENDATIONS

SELECTION OF MT PROJECTS

- ENERGY SAVERS
  - ALTERNATES TO AUTOCLAVE
  - LOCALIZED HEAT TREATMENT VS FURNACE
  - THERMALLY EFFICIENT EQUIPMENT
- MATERIAL CONSERVATION
  - NET SHAPE PARTS
  - SHEET METAL VS MACHINED PARTS
  - MACHINING TECHNOLOGIES
  - CONVENTIONAL VS EXOTIC MATERIALS
  - RECYCLING
- IMPROVED QUALITY CONTROL
  - IMPROVED NDT/NDI
  - AUTOMATION
  - FRACTURE MECHANICS ANALYSIS DATA
- D.T.C. – M.T.C.
  - COMPARATIVE AND QUANTITATIVE COST DATA BANKS
  - GROUP TECHNOLOGY

RECOMMENDATIONS
(Continued)

SELECTION OF MT PROJECTS
(CONTINUED)

- NEW TECHNOLOGIES – EXAMPLES
  - COMPOSITES – SDF/DB – LASER APPLICATIONS
  - METAL LAMINATED STRUCTURE – ADHESIVE BONDING – HIGH PRESSURE FORMING
- CAM-CAI
  - CRITICALLY IMPORTANT AREA BUT AVOID REDUNDANT EFFORTS
  - CONFIGURATION CONTROL
  - PROCESS SIMULATION
  - INSPECTION AND QUALITY APPLICATION
- CORROSION PROTECTION
  - COATINGS
  - DISSIMILAR MATERIALS
- MISCELLANEOUS
  - FIBRE OPTICS – LASER HARDENING
  - LOW COST TOOLING – PART PROTECTION

GENERAL RECOMMENDATIONS

SELECT MANUFACTURING TECHNOLOGY (MT) PROJECTS THAT PROVIDE:

- COMPATIBILITY WITH NAVY AIRCRAFT OBJECTIVES
- POTENTIAL HIGH COST SAVINGS FOR FUTURE AIRCRAFT SYSTEMS
- MAXIMUM COST SAVINGS AT DESIGN CONCEPTION
- MAXIMUM SYNERGISTIC EFFECTS
- GREATEST COMMONALITY BETWEEN SUBSYSTEMS
- MINIMUM DESIGN CHANGE AND RE-TESTING
- ACCEPTANCE OF EMERGING MANUFACTURING TECHNOLOGY

DO NOT SELECT MANUFACTURING TECHNOLOGY (MT) PROJECTS THAT:

- IMPROVE A MANUFACTURING TECHNOLOGY THAT IS OBSOLETE

GENERAL RECOMMENDATIONS

- AVOID COST DRIVERS BY FULLY UTILIZING DESIGN-TO-COST (DTC) AND MANUFACTURING-TO-COST (MTC)
- BALANCE THE SCALE BETWEEN PERFORMANCE AND MANUFACTURING COST
  - BE SURE THE PERFORMANCE CAN BE AFFORDED
- STOP THE TREND TOWARD EQUIPMENT OBSOLENCE
- PURSUE ADVANCED MANUFACTURING TECHNOLOGY WITH THE SAME VIGOR AS WE HAVE PERFORMANCE

IMPORTANT REFERENCES ON COST REDUCTION USED IN STUDY

- SUMMARY OF AIR FORCE/INDUSTRY MANUFACTURING COST REDUCTION STUDY, AIR FORCE MATERIALS LABORATORY, AFML-TM-LT-73-1, JANUARY, 1973
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- AEROSPACE COST SAVINGS – IMPLICATIONS FOR NASA AND THE INDUSTRY, NATIONAL MATERIALS ADVISORY BOARD, NATIONAL ACADEMY OF SCIENCES, REPORT NO. NMAB-328, 1975