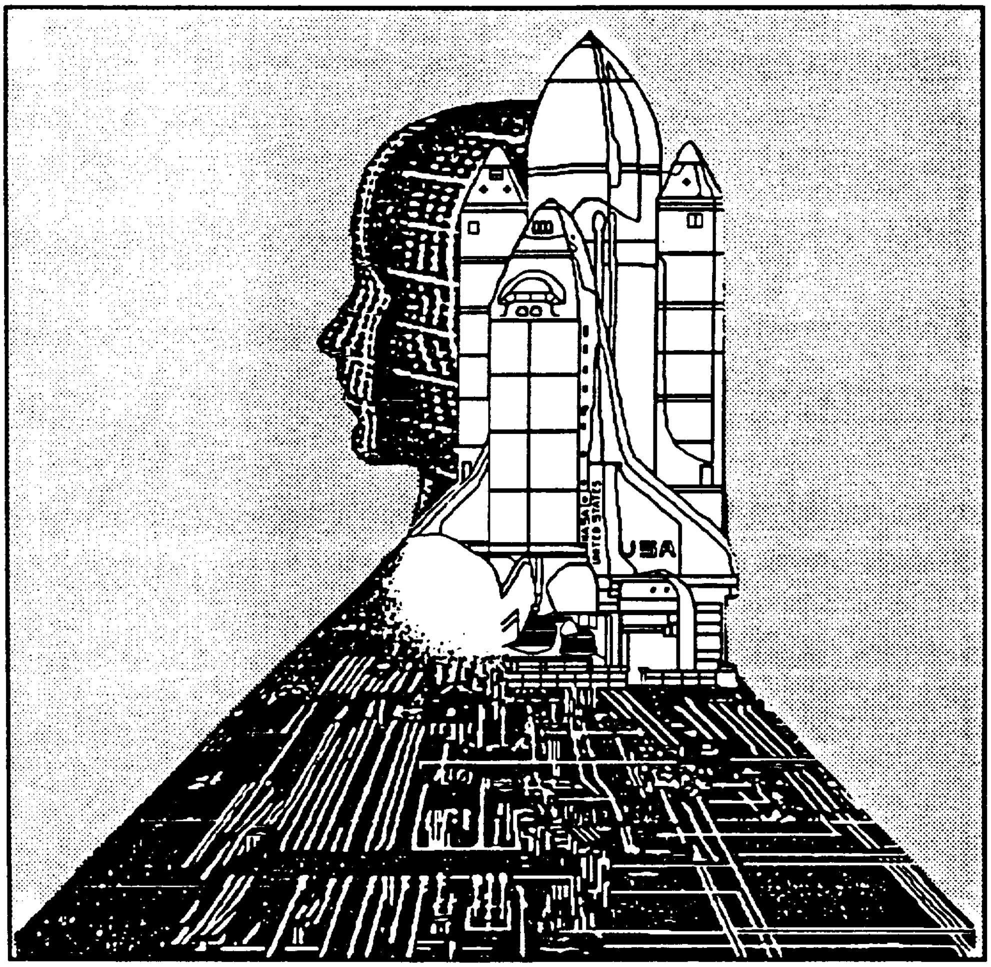
BOEING

Shuttle Ground Operations Efficiencies/Technologies Study

AEROSPACE OPERATIONS



FINAL PRESENTATION MATERIAL

VOLUME 3 of 5

FINAL REPORT - Phase 1

KENNEDY SPACE CENTER

NAS10-11344

May 4, 1987

(NASA-CR-180583) SHUTTLE GROUND OPERATIONS EFFICIENCIES/TECHNOLOGIES (SGOE/T) STUDY. VOLUME 3: FINAL PRESENTATION MATERIAL Final Report, Jun. 1986 - May 1987 (Boeing Aerospace Co.) 190 p Avail: NTIS HC

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SHUTTLE GROUND OPERATIONS EFFICIENCIES/TECHNOLOGIES STUDY

FINAL PRESENTATION MATERIAL

FINAL REPORT - VOL 3
- PHASE 1 -
MAY 4, 1987

KENNEDY SPACE CENTER
NAS10-11344

BOEING

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SPACE SHUTTLE GROUND OPERATIONS EFFICIENCIES/TECHNOLOGIES STUDY PHASE 1 FINAL REPORT

The final report for the Shuttle Ground Operations Efficiencies/Technologies Study is made up of five volumes.

Volume 1	Executive Summary
Volume 2	Ground Operations Evaluation
Volume 3	Final Presentation Material
Volume 4	Preliminary Issues Database (PIDB)
Volume 5	Technology Information Sheets (TIS)

Volume 1

The Executive Summary volume provides a brief overview of the major elements of the Study, reviews the findings, and reflects the development of the recommendations resulting from the Study.

Volume 2

The Ground Operations Evaluation volume describes the breath and depth of the various Study elements selected as a result of an operational analysis conducted during the early part of the Study. Analysis techniques used for the evaluation are described in detail. Elements selected for further evaluation are identified; the results of the analysis documented; and a follow-on course of action recommended. The background and rationale for developing recommendations for the current Shuttle or for future programs is presented.

Volume 3

The Final Presentation Material volume contains the most recent version of the charts used in the Final Phase 1 Oral Briefing at KSC on April 6, 1987, and to the STAS (Space Transportation Architecture Study) IPR-5 (Interim Program Review) held at MSFC on April 8, 1987. The KSC, April 6 notation in the title block was used for both packages because the reviews were held so closely together. This volume contains all charts in their final form and any differences from charts presented are minor.

Volume 4

The Preliminary Issues Database (PIDB) was assembled very early in the Study as one of the fundamental tools to be used throughout the Study. Data was acquired from a variety of sources and compiled in such a way that the data could be easily sorted in accordance with a number of different analytical objectives. The system was computerized to significantly expedite sorting and make it more usable. This volume summarizes the information contained in the PIDB and provides the reader with the capability to manually find items of interest. How that information was used in this Study is explained in greater detail in Volumes 2 and 3.

Volume 5

The Technology Information Sheet volume was assembled in database format during Phase 1 of the Study. This document was designed to provide a repository for information pertaining to 144 OMI (Operations and Maintenance Instructions) controlled operations in the OPF, VAB and PAD. It provides a way to accumulate information about required crew sizes, operations task time duration (serial and/or parallel), special GSE required, and identification of a potential application of existing technology -- or the need for the development of a new technology item.

PHASE 1
FINAL PRESENTATION

OPENING STATEMENTS . . . . Bill Dickinson

SHUTTLE GROUND OPERATIONS EFFICIENCIES/TECHNOLOGIES STUDY

OVERVIEW .... Art Scholz

PRODUCTS .... Mitch Hart/David Lowry

SUMMARY .... Art Scholz

ACRONYM LIST

ACRBC	Acceptance/Checkout Requirements & Backout Criteria
APU	Auxiliary Power Unit
ATKB	Automated Technology Knowledge Base
CAD	Computer Aided Design
CAE	Computer Aided Engineering
CAL	Calibration
CAM	Computer Aided Manufacturing
CG	Center of Gravity
COMM	Communications
DOP	Detailed Operating Procedure
DPS	Data Processing System
DRCR	Drawing Release Change Record
ECLSS	Environmental Control & Life Spport System
EPD&C	Electrical Power Distribution & Control
ETR	Eastern Test Range
GN&C	Guidance, Navigation, and Control
GSE	Ground Support Equipment
HDP	Hardware Data Package
HYD	Hydraulic System
IDSS	Integrated Design Support System
IMIS	Integrated Maintenance Information System
IUS	Inertial Upper Stage
KSC	Kennedy Space Center
LCC	Life Cycle Cost
MPS	Main Propulsion System
OMI	Operations and Maintenance Instruction
OMRSD	Operational Maintenance Requirements & Specifications Document
OPF	Orbiter Processing Facility
PDS	Procedure Deviation Sheet
PI	Primary Investigator
PIDB	Preliminary Issues Data Base
PM	Preventive Maintenance
POCC	Payload Operations Control Center
PR	Purchase Requisition
PRACA	Problem Reporting and Corrective Action
PRSD	Power Reactant Storage and Distribution
QA	Quality Assurance
RAMCAD	Reliability & Maintainability thru Computer-Aided Design
SPP	Shuttle Payload Procedure
SPDMS	Shuttle Processing Data Management System
SSME	Space Shuttle Mission Engineering
STAS	Space Transportation Architecture Study
STE	Special Test Equipment
STS	Space Transportation System
TARS	Turnaround and Reconfiguration Simulation
TIS	Technology Identification Sheet
WCCS	Window Cavity Conditioning System
XTKB	Extended Technology Knowledge Base

SHUTTLE GROUND OPERATIONS EFFICIENCIES/TECHNOLOGIES STUDY

STUDY OBJECTIVES

The Primary Objective of the Study continues to be to reduce the overall operational cost of the Shuttle Program either through improving the efficiency of the Ground Operations or with the addition of selected technology elements to cut costs.

Increased use of automation to 1) evaluate systems and 2) conduct operations will have several ways of reducing cost and providing benefits:

- Increase the speed of the total checkout (reduce time-in-flow requirements)
- Reduce manpower requirements
- Reduce the possibility of human error
- Minimize documentation changes (increase test-to-test consistency and provide the potential for "learning curve" reductions for manual tasks).

Lack of emphasis of maintenance requirements during the early design portion of the program has had a very significant impact on recurring, operational costs. By-passing these considerations in favor of other high priority items to save front end costs in the design phase of the Shuttle has increased operational costs at KSC.

While it may be too late to "significantly" change the existing Shuttle system, per se, development of launch site requirements for use by the various vehicle design agencies should be very beneficial for future programs, both manned and unmanned.

STUDY OBJECTIVES

USING THE CURRENT STS SYSTEM AS A WORKING MODEL, IDENTIFY EXISTING OR NEW TECHNOLOGIES AND CHANGES TO FLIGHT HARDWARE OR PROCESSING METHODOLOGIES TO REDUCE VEHICLE PROCESSING TIME, PROGRAM MANPOWER (AND COSTS). DEMONSTRATE THESE CAPABILITIES ON THE CURRENT SHUTTLE PROGRAM, WHERE POSSIBLE, AND DOCUMENT THEM FOR USE AS GUIDELINES FOR USE ON STAS (SPACE TRANSPORTATION AND ARCHITECTURE STUDY) AND OTHER FUTURE PROGRAMS. A DECISION WAS MADE TO CONCENTRATE ON ORBITER, VEHICLE INTEGRATION, AND LAUNCH PROCESSING ACTIVITES FOR THIS PHASE OF THE STUDY.

APPROACH --

- OVERALL ANALYSIS OF CURRENT SHUTTLE GROUND OPERATIONS:
  - ASSEMBLY
  - TEST & CHECKOUT
  - MAINTAINABILITY
  - LOGISTICS SUPPORT
  - LAUNCH OPERATIONS
  - SERVICING
  - GROUND SUPPORT EQUIPMENT
  - OPERATIONS MANAGEMENT

- STUDY FOCUS -- KSC

- STUDY OUTPUTS --
  - -- RECOMMENDATIONS ON "HOW TO ACHIEVE" MORE EFFICIENT OPERATIONS
  - -- IDENTIFICATION OF EXISTING/NEW TECHNOLOGY TO FACILITATE PROCESSING

STUDY SCHEDULE

All scheduled activities have been completed except for the Final Report.

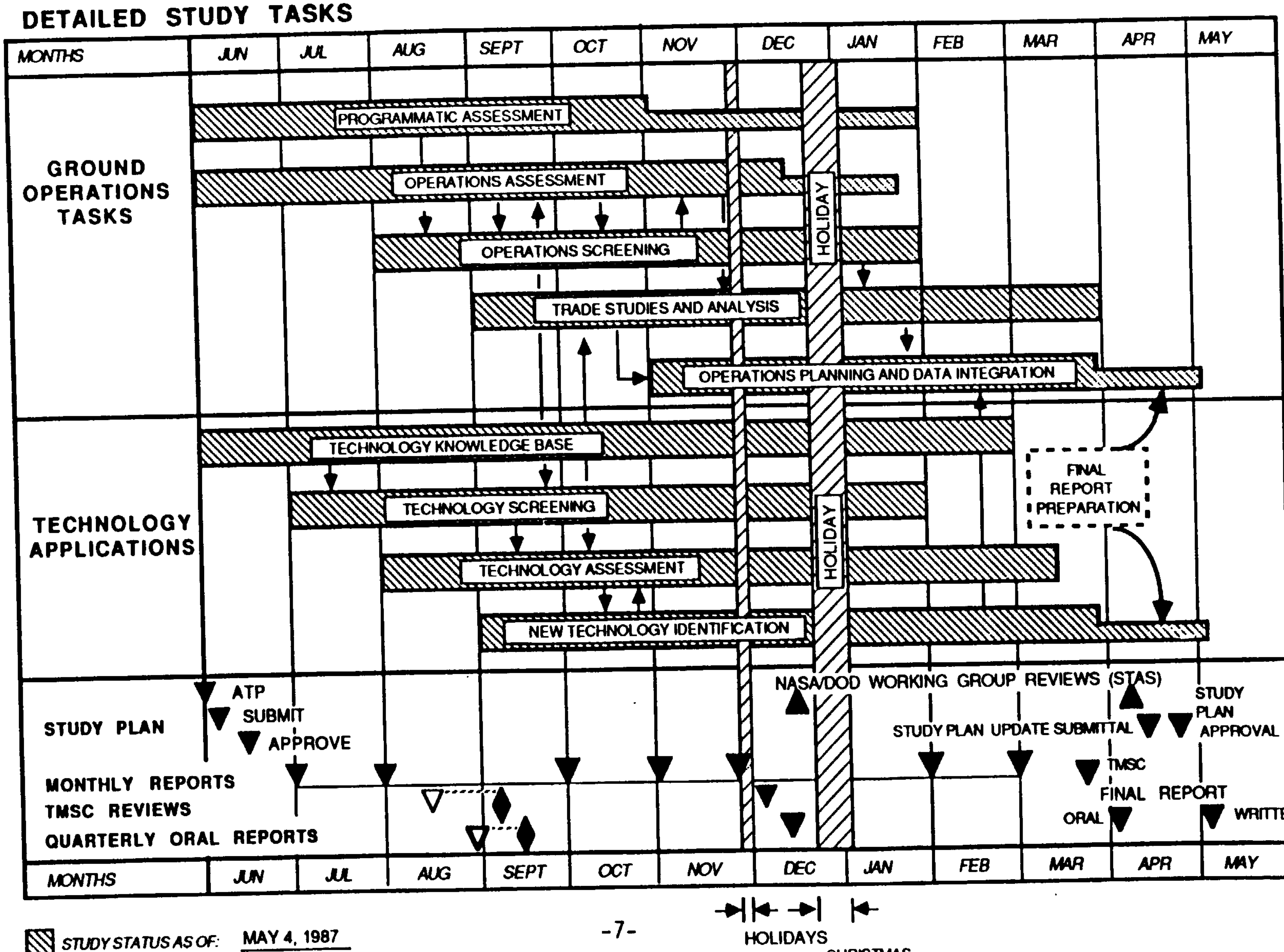
All activities have been completed on schedule and within allocated budgets.

S G O E/T STUDY
PHASE 1 FINAL
PRESENTATION
by BOEING

STUDY SCHEDULE

PRESENTED AT
KSC
APR. 6, 1987

DETAILED STUDY TASKS



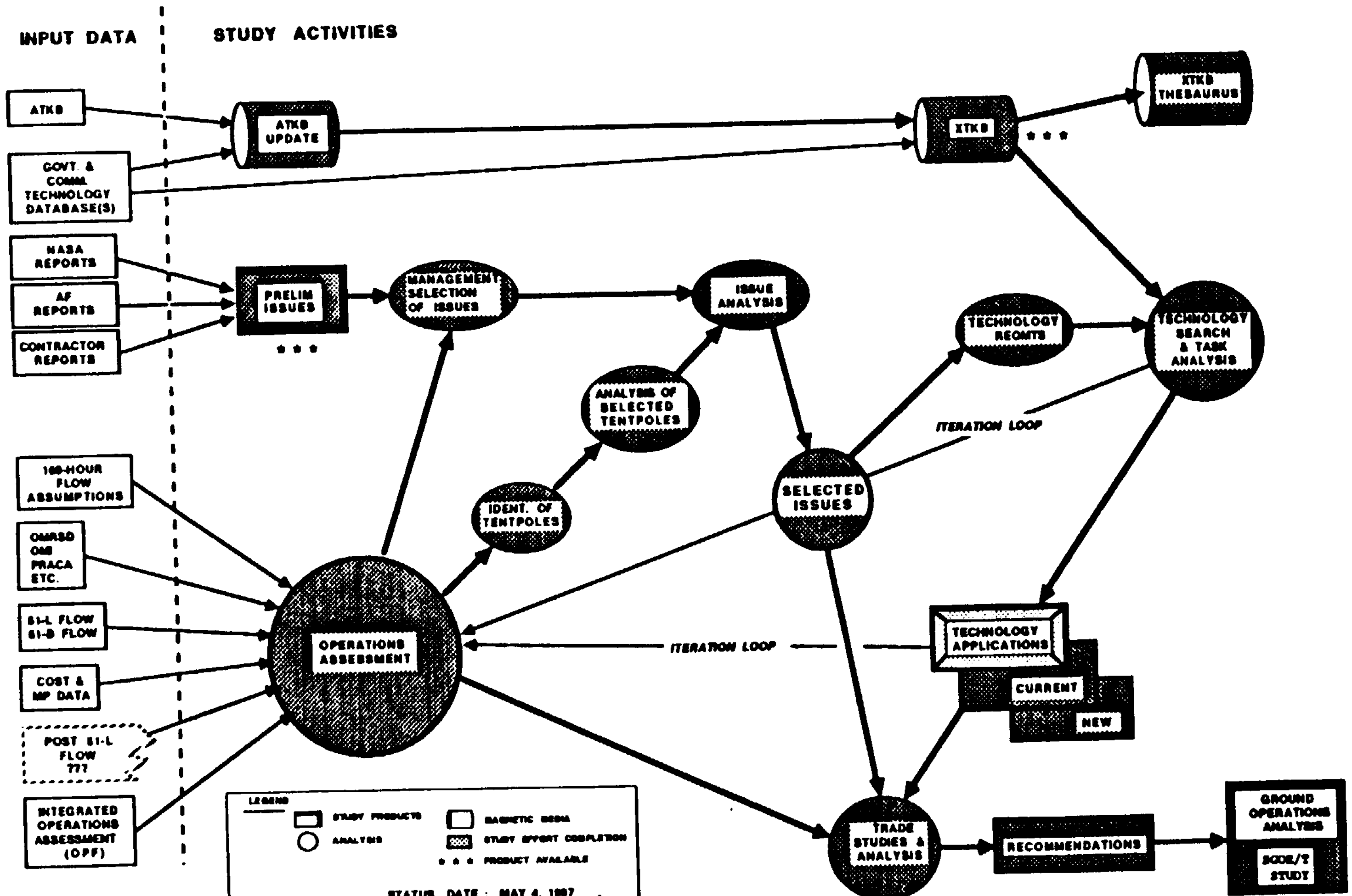
STUDY FLOW

The Study Flow diagram has been a useful device to track progress of the various tasks associated with the main thrust of the Study. The Final Report and clean-up of parts of the Ground Operations Analysis will be completed this next month before the end of the contract. The actual makeup of the Final Report has not yet been finalized. That activity will take place this next month and the report will be released about the first of May, 1987.

SGOE/T STUDY
PHASE 1 FINAL
PRESENTATION
by BOEING

STUDY FLOW

PRESENTED AT
KSC
APR. 6,1987



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ENGINEERING TOOLS

The PIDB (Preliminary Issues Data Base) has been printed and will be provided as a part of the Final Report -- around May 1, 1987.

The ATKB was brought to this Study from an earlier study (OTV Launch Operations Study) and expanded with additional data from various databases. This expanded system was named the XTKB. The XTKB (Expanded Technology Knowledge Base) is complete and available for use at this time. It is available only on magnetic media in our office. Currently this system only contains information relevant to automation because that has been the primary subject of interest to us in this Study. It could be extended to other subjects. In Phase 2 it will be put on-line for use by NASA and the Air Force.

A rather extensive file of reference material used or reviewed during this Study has been set up so that it could be made available to others.

As we mentioned in our Midterm Report, we have set up a Technology Identification Sheets (TIS) database to hold "specific test peculiar" information. It is being provided as an element of the Final Report so that if one should desire to investigate one of the tasks further, the basic information and system would be available for use.

PRACA access was acquired and made available for Study purposes. OMRSD access was also provided to us. Neither of these databases were utilized to any major extent because the information was not directly useful to us in this Study. Neither database is a serial, integrated function that contributes to the accomplishment of the on-going work.

ENGINEERING TOOLS

1. PRELIMINARY ISSUES DATABASE
2. XTKB (EXTENDED AUTOMATION TECHNOLOGY KNOWLEDGE BASE)
3. REFERENCE FILE SYSTEM
4. TECHNOLOGY IDENTIFICATION SHEETS (TIS)
5. PRACA EXCERPTS
6. OMRSD

ANALYSIS SUPPORT

This chart shows the relationship of the various Study data elements:

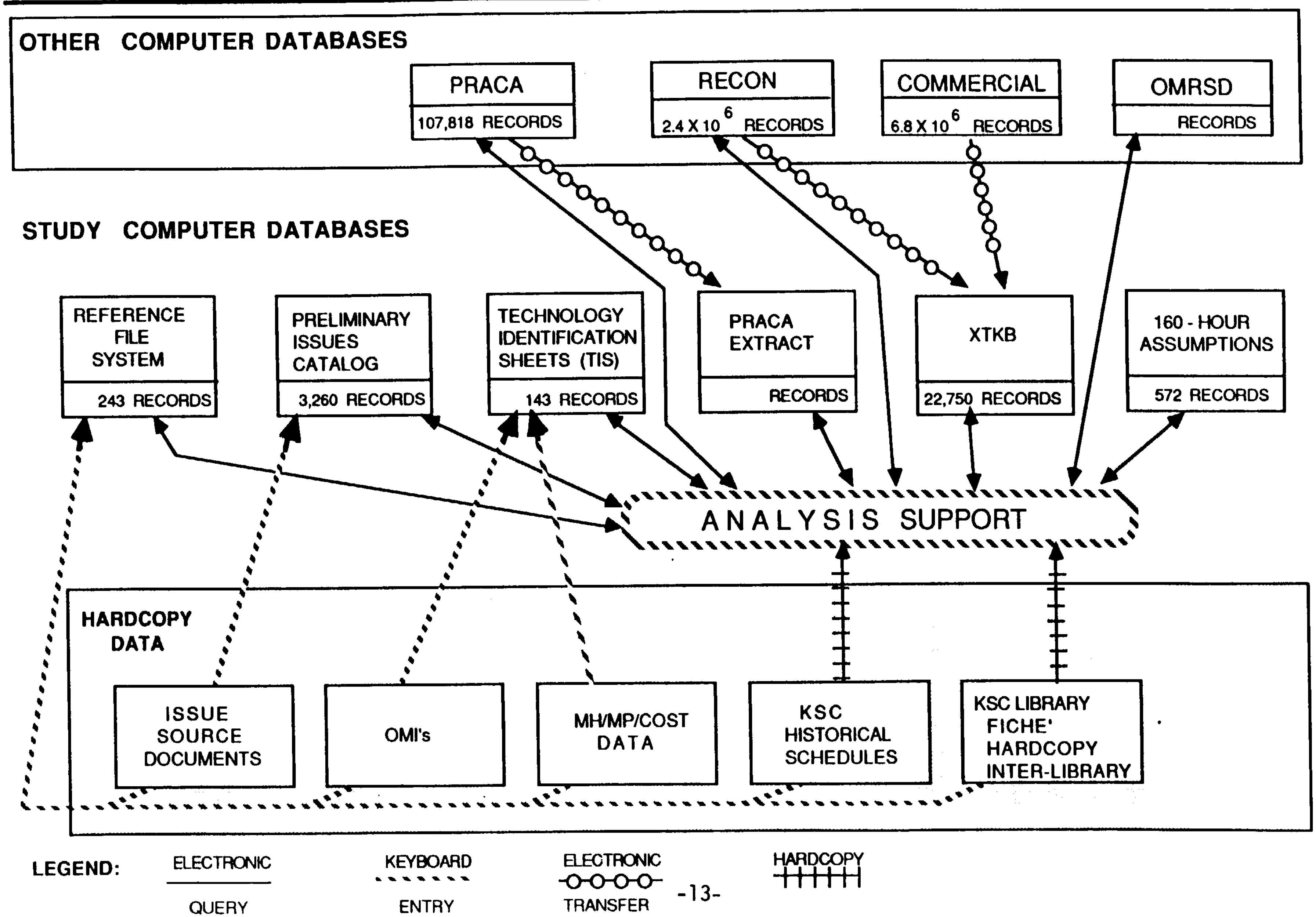
1) external databases
2) hardcopy data we have been able to acquire
3) database information that we have established

We have indicated how the data is available to the analyst; 1) by electronic transfer of selected data elements from external databases to our internal system, 2) via electronic query of those database systems by the analyst, or 3) through the use of hardcopy data, previously identified during one of the electronic query sessions, and obtained from a library, the author, or through some other means.

S G O E/T STUDY
PHASE 1 FINAL
PRESENTATION
by BOEING

ANALYSIS SUPPORT

PRESENTED AT
KSC
APR. 6,1987



TECHNICAL SURVEYS

The four trips were directly applicable to technology identification/utilization. Significant information was obtained that could be directly applied to various Study activities.

The trip to Seattle provided us with insight in new management techniques being implemented in the development of airplanes. There were also several hardware elements applicable to the Shuttle processing activities at KSC.

The trip to Wright-Patterson Air Force Base not only reinforced our concern about the need, but verified that significant benefits can be gained from establishing maintenance requirements and providing capabilities to meet those requirements early in the conceptual design phase of a program.

The trip to Rome Air Development Center provided us with updated information on anomaly resolution.

The trip to the Naval Surface Weapons Center confirmed our analysis and reinforced our contention that some form of the Nitinol technology could be used as a replacement of ordnance devices.

TECHNICAL SURVEYS

FOUR TECHNICAL SURVEY TRIPS WERE MADE DURING THIS STUDY:

1. BOEING - SEATTLE

2. WRIGHT-PATTERSON AIR FORCE BASE (WPAFB)

3. ROME AIR DEVELOPMENT CENTER (RADC)

4. NAVAL SURFACE WEAPON CENTER (NSWC)

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SURVEY TRIPS (Cont'd)
(BOEING - SEATTLE)

1. THE TRIP TO BOEING-SEATTLE PROVIDED INSIGHT INTO SEVERAL TOPICS
   WITH DIRECT APPLICATION TO THE STUDY:

   * 7J7 PROGRAM DEVELOPMENT MANAGEMENT CONCEPTS
   * NDE TECHNOLOGY (INCLUDING BACK-SCATTER X-RAY)
   * INTEGRATED FAULT TOLERANT AVIONICS SUITE (IFTAS)
   * 767 (AND 747) BUILT-IN TEST AND INTEGRATED TESTING
   * MANIPULATIVE ROBOTIC SYSTEMS
   * OPTICAL SENSORS AND PROCESSORS

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SURVEY TRIPS (Cont'd)
(WPAFB)

2. SIGNIFICANT INFORMATION WAS OBTAINED FROM THE AIR FORCE HUMAN RESOURCES LAB (AFHRL) AT WPAFB.

   THEY ARE INVOLVED IN THE DEVELOPMENT OF FUTURE AEROSPACE SYSTEMS DESIGN TECHNIQUES TO REDUCE LIFE CYCLE COSTS (LCC) WITH A PROJECT KNOWN AS ULCE (UNIFIED LIFE CYCLE ENGINEERING)

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SURVEY TRIPS (Cont'd)
(RADC)

3. THE ROME AIR DEVELOPMENT CENTER (RADC) TRIP IN MARCH, 1987 PROVIDED AN UPDATE ON AIR FORCE RESEARCH OF BUILT-IN-TEST (BIT) TECHNIQUES AND THE STATUS OF RECOMMENDATIONS TO DOD ON VARIOUS ASPECTS OF ANOMALY RESOLUTION (FAULT DETECTION, FAULT ISOLATION, AND FAULT RESOLUTION).

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SURVEY TRIPS (Cont'd)
(NSWC)

4. THE TRIP TO THE NAVAL SURFACE WEAPONS CENTER (PREVIOUSLY KNOWN AS THE NAVAL ORDNANCE LAB -- NOL), WHERE NITINOL WAS DEVELOPED, PROVIDED DETAIL ON STATUS OF NITINOL APPLICATION, DEVELOPMENT, AND INSIGHT INTO ONE OF ITS POTENTIAL USES; e.g., AS A SUBSTITUTION FOR ORDNANCE DEVICES.

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STUDY EMPHASIS

* THE TYPE OF TECHNOLOGY AND MANAGEMENT REQUIRED TO SUPPORT OPERATIONALLY EFFICIENT GROUND OPERATIONS WILL BE ADDRESSED IN THE REMAINDER OF THE PRESENTATION.

* BUDGETARY CONCERNS CAUSED A CONSCIOUS DECISION TO NOT REQUIRE LIFE CYCLE COST CONSIDERATIONS EARLY IN THE DESIGN PHASE OF THE SHUTTLE PROGRAM. THE FOCUS WAS ON ECONOMY, RELIABILITY, FAIL SAFE/FAIL OPERATIONAL RATHER THAN ON LCC. THIS ALLOWED THE INCORPORATION OF OPERATIONAL INEFFICIENCIES INTO THE DESIGN OF THE VEHICLE.

* CONTROL OF LIFE CYCLE COSTS (LCC) MANDATES OPERATIONAL EFFICIENCIES.

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SHUTTLE GROUND OPERATIONS EFFICIENCIES/TECHNOLOGIES STUDY

OVERVIEW . . . . Art Scholz

PRODUCTS . . . . Mitch Hart/David Lowry

- ISSUES
- OPS ANALYSIS
- TENTPOLES (12)
  - ANOMALY RESOLUTION
  - UNIFIED LIFE CYCLE ENGINEERING
- TRADE STUDIES
- VEHICLE BLOCK CHANGES
- SPACE STATION TECHNOLOGY

SUMMARY . . . . Art Scholz

GROUND OPERATIONS TASK MANAGEMENT

The funnel chart shows pictorially how the ground operations task has been managed. The scope of the Study was so broad, and the information available so vast, it was necessary to quickly funnel the information, using computerized methods, into pertinent specific buckets (issues). Simultaneously, an operations analysis was made using the KSC data elements shown. The resultant high-payoff operations issues were then researched for potential technology to increase efficiency. The technology candidates were then used in trade studies to produce a Ground Operations Analysis and the other Study Outputs.

GROUND OPERATIONS TASK MANAGEMENT

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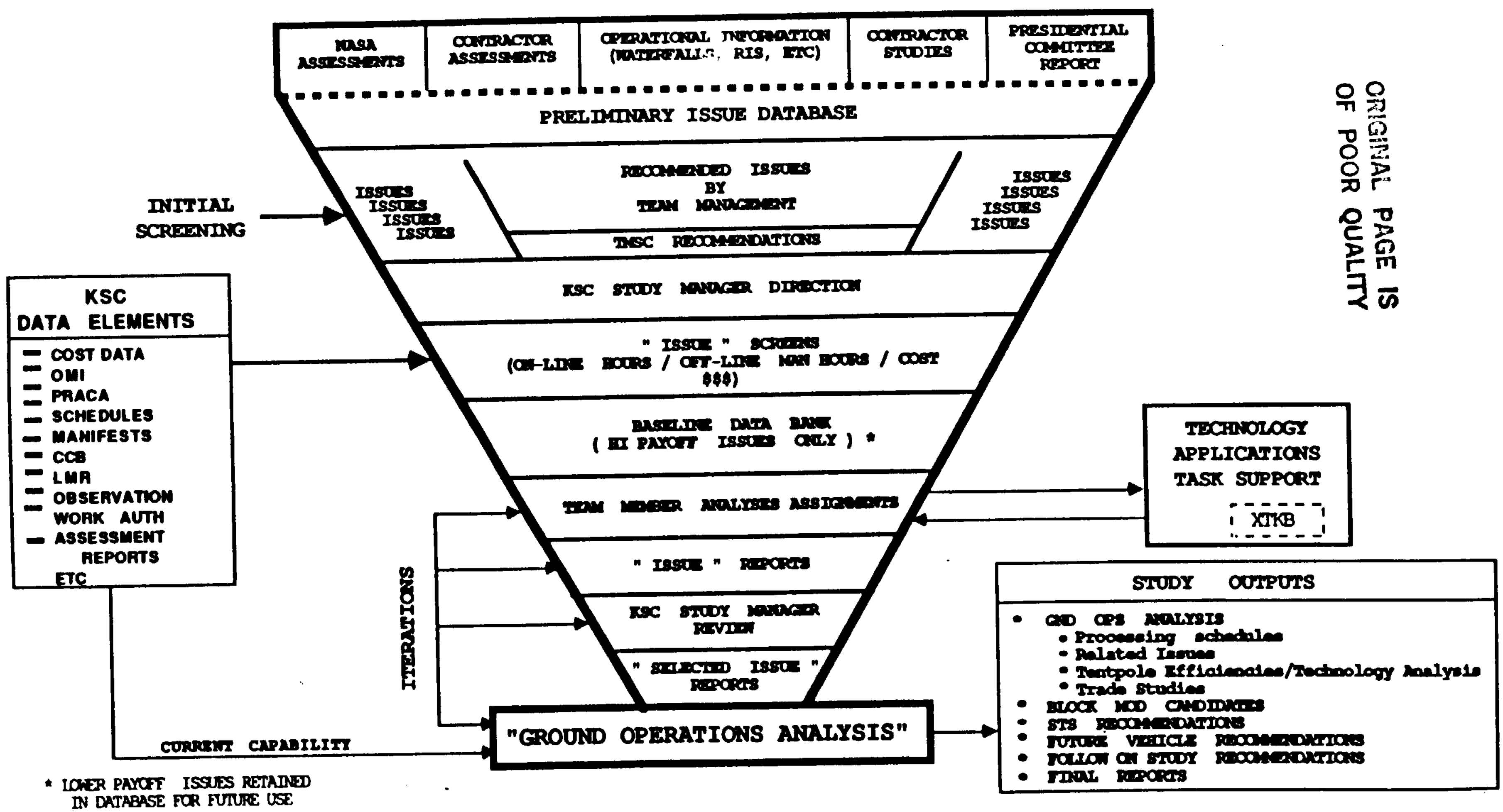

GROUND OPERATIONS TASK MANAGEMENT

TASK SCHEDULES

This chart shows how the Ground Operations and Technology Analyses Tasks were scheduled to assure completion of topics in a timely manner that would support the overall Study.

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TASK SCHEDULES

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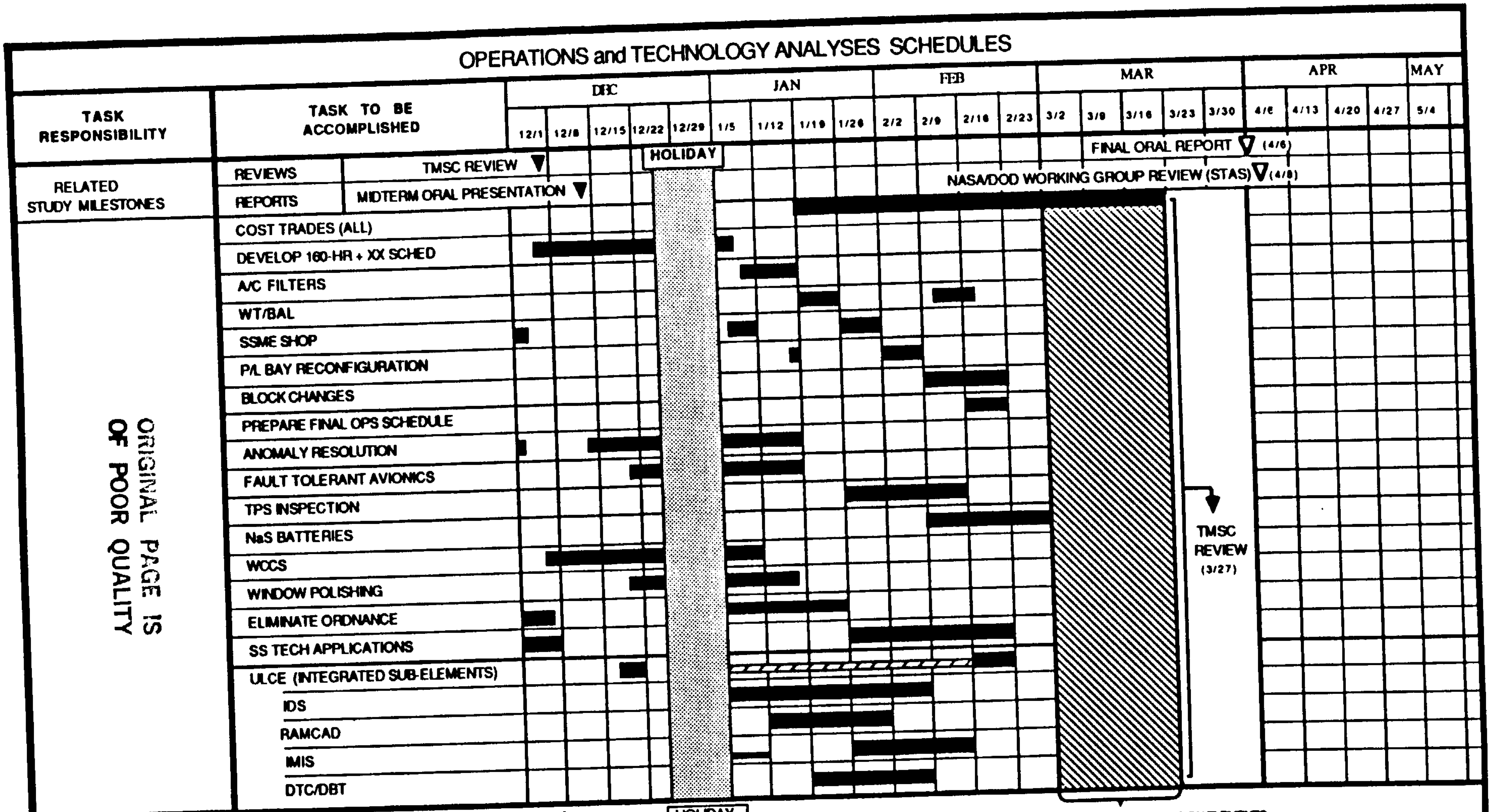
APR. 6,1987



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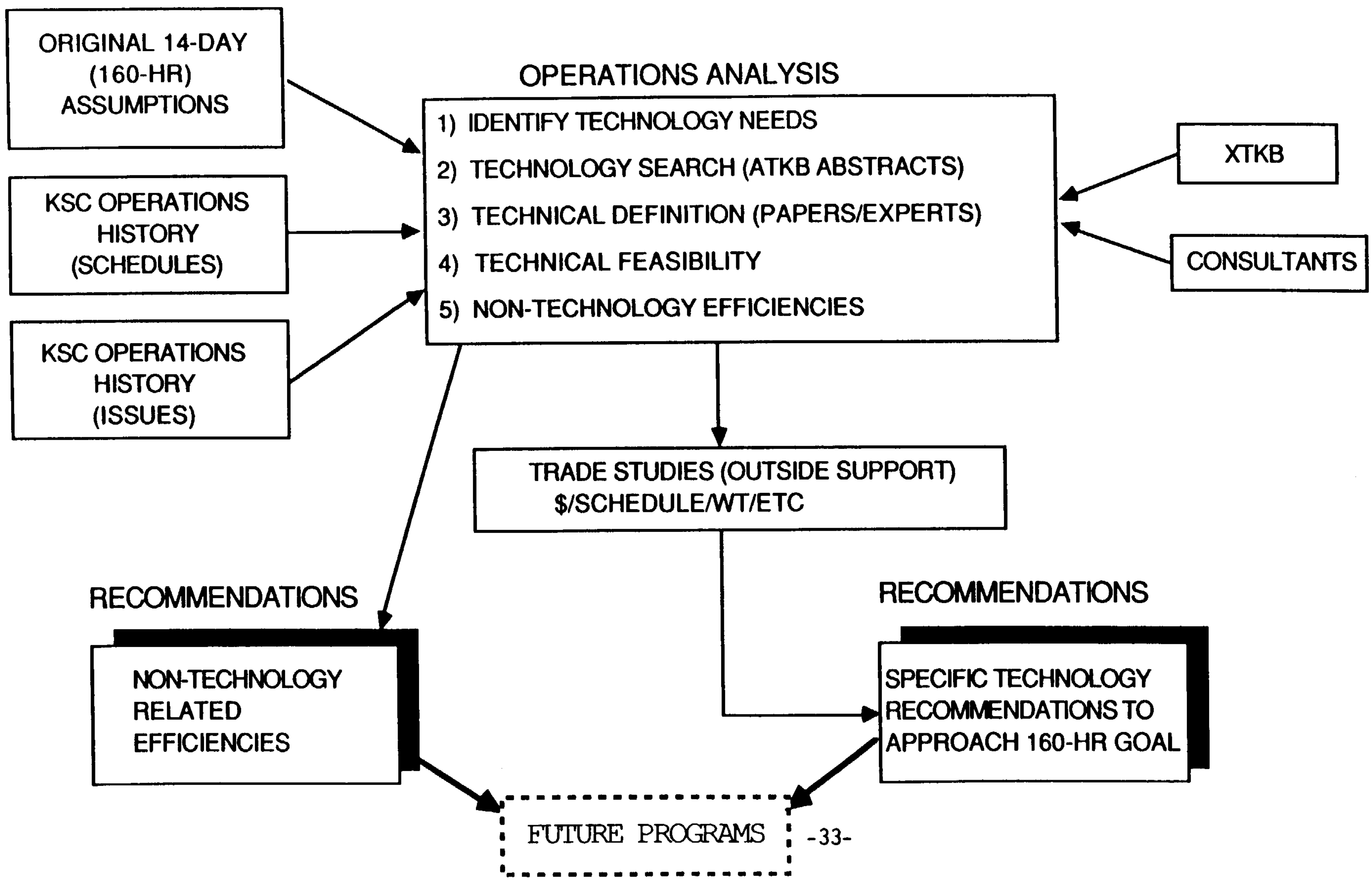
NOTES: TASK BARS INCLUDE:
NEW TECHNOLOGY DATA COLLECTION
APPLICATION OF NEW TECHNOLOGY
TIME SAVINGS BENEFITS

OPERATIONS ANALYSIS FLOW

This chart summarizes the resources utilized to arrive at specific recommendations for both non-technology (timeline) and technology improvements. It relates the three basic inputs to the operations analysis, the technology search database (XTKB), and the consultant support, all of which provide the basis for the trade studies and recommendations. These recommendations will be for Future Programs (STAS and others) and/or Block Change Candidates for the existing Shuttle.

OPERATIONS ANALYSIS FLOW



ISSUES

Issues are items impacting operational areas such as assessability, cannibalization, or safety which have surfaced from our source documentation or our operational analysis.

We identified 40 different issue topics in our Issues Database for sort purposes. The number of description entries currently range from a low of 3 to a high of 750. The number of entries is indicative of the degree of documented attention.

ISSUES

	NO. ENTRIES		NO. ENTRIES
ASSESSABILITY	104	METHODS	17
AUTOMATION	27	MISSION	38
CANNIBALIZATION	14	MODULARIZATION	8
CHANGE CONTROL	30	PAPERWORK	104
COMMONALITY	45	PLANNING	39
CONSTRAINTS	18	PROCEDURE	94
COST/MANHOURS	101	QA	107
DESIGN	750	REDUNDANCY	33
DESIGN CRITERIA	298	RELIABILITY	51
DISCIPLINE	125	REQUIREMENTS	167
DRAWING SYSTEM	30	SAFETY	250
EFFICIENCY	30	SECURITY	20
EXPERT SYSTEM	16	STANDARDS	33
FAULT DETECTION	54	SURFACE TRANSP.	15
INTEGRATION	11	TECHNOLOGY	91
INTERFACE	42	TIME/CYCLE	3
ISOLATION	24	TIME/OFF-LINE	8
LOGISTICS/SPARES	81	TIME/ON-LINE	22
MAINTAINABILITY	226	TRAINING/CERTIF	31
MANAGEMENT	82	WAIVERS	10

PRELIMINARY ISSUES DATABASE

The left-hand column lists the source of "issues" descriptions entered into the database. The number in the box is the number of different issue descriptions entered from each source.

Since each description may relate to more than one "issue", i.e., Maintainability and Design Criteria, there may be multiple issues for the same description.

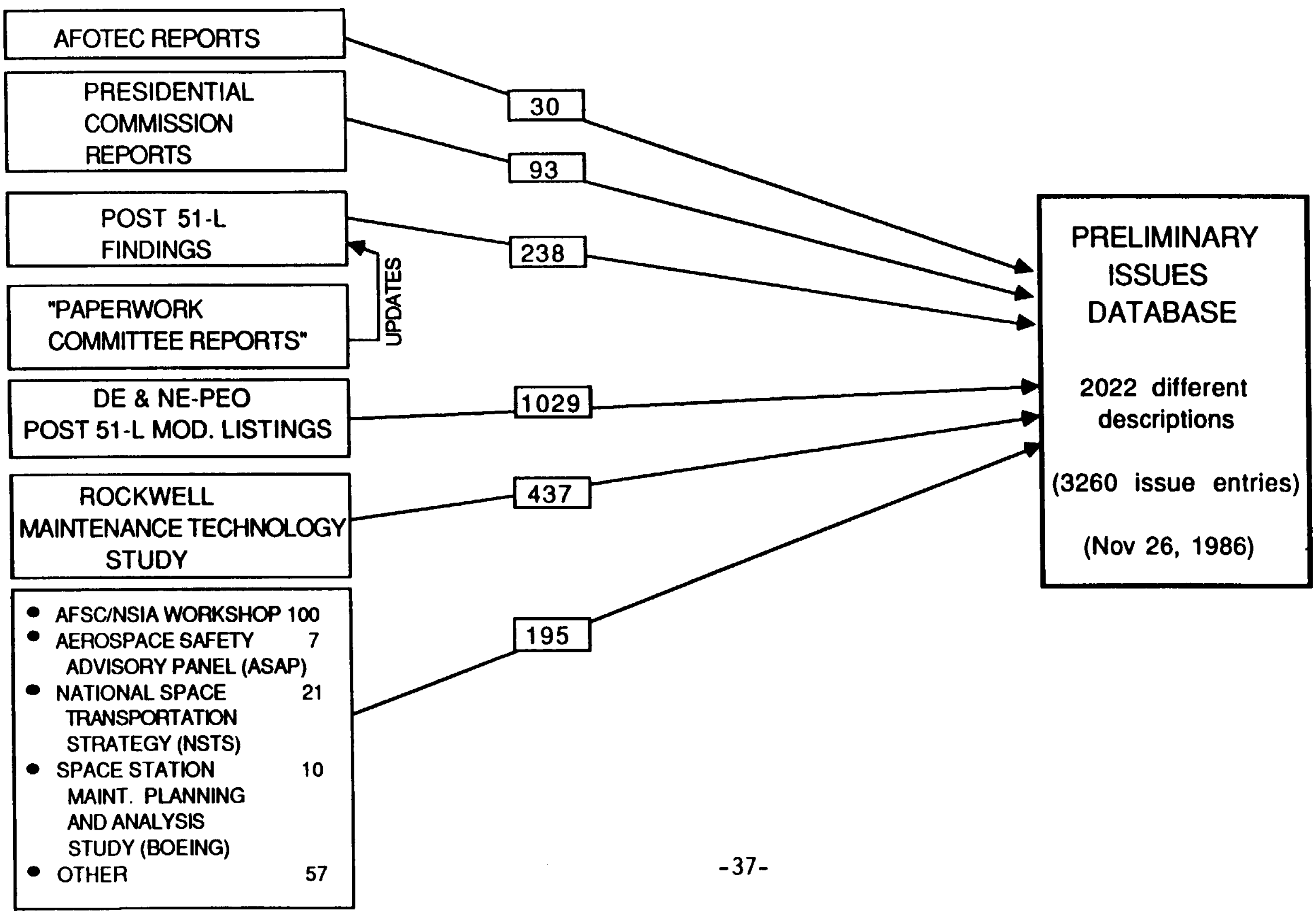
Currently, there are 2022 different descriptions with 3260 issue entries.

We have incorporated the results of the KSC Paperwork Committee Reports as an update to the Post 51-L Findings.

Permission to use Contractor STAS Reports in our database was never received.

PRELIMINARY ISSUES DATABASE

INFORMATION DATA SOURCES



PRELIMINARY ISSUES DATABASE CONTENT

On this chart, the database content is identified with the ID number series assigned for input. This makes it easy to enter or retrieve by source.

At the Quarterly Review in September, we reviewed the database structure and retrieval system in detail. We have the capability to rapidly retrieve information from this database by searching for issue, operation, location, hardware, source, or key words.

For those interested, there is a 700 page printout of the total database content in ID number sequence (or source) available. This printout includes a comprehensive description of the database and a numerical sort that identifies the ID numbers by "issue". This enables a manual sort using the printout for any of the "issues". Anyone with a use for this printout may request a copy through Bill Dickinson, KSC PT-FPO.

PRELIMINARY ISSUES DATABASE (PIDB) CONTENT

INDEX NO. SERIES	TOPIC
100	EXCERPTS FROM PRESIDENTIAL COMMISSION REPORT (VOLS. I & II)
200-400	COMPLETE 51-L FINDINGS
500	EXCERPTS FROM AEROSPACE SAFETY ADVISORY PANEL
600	EXCERPTS FROM AIR FORCE OPERATIONS & TEST EVALUATION CENTER REPORTS (AFOTEC)
700	EXCERPTS FROM NATIONAL SPACE TRANSPORTATION STRATEGY
900	COMPLETE DR. LUCAS LETTER TO NASA HQ ON "OPERATIONAL EFFECTIVENESS (MAY '82)
1000-1600	COMPLETE ROCKWELL MAINTENANCE TECHNOLOGY STUDY
1700	EXCERPTS FROM AFSC/NSIA SPACE TRANSPORTATION PANEL WHITE PAPERS ON "COST REDUCTION & COST CREDIBILITY"
1800-2800	COMPLETE DE AND NE-PEO "RETURN TO FLIGHT STATUS MOD LIST"
3000	EXCERPTS FROM "SPACE STATION MAINT. PLNG. & ANALYSIS STUDY" (BOEING)

OPERATIONAL ISSUES / PROBLEMS / FIXES

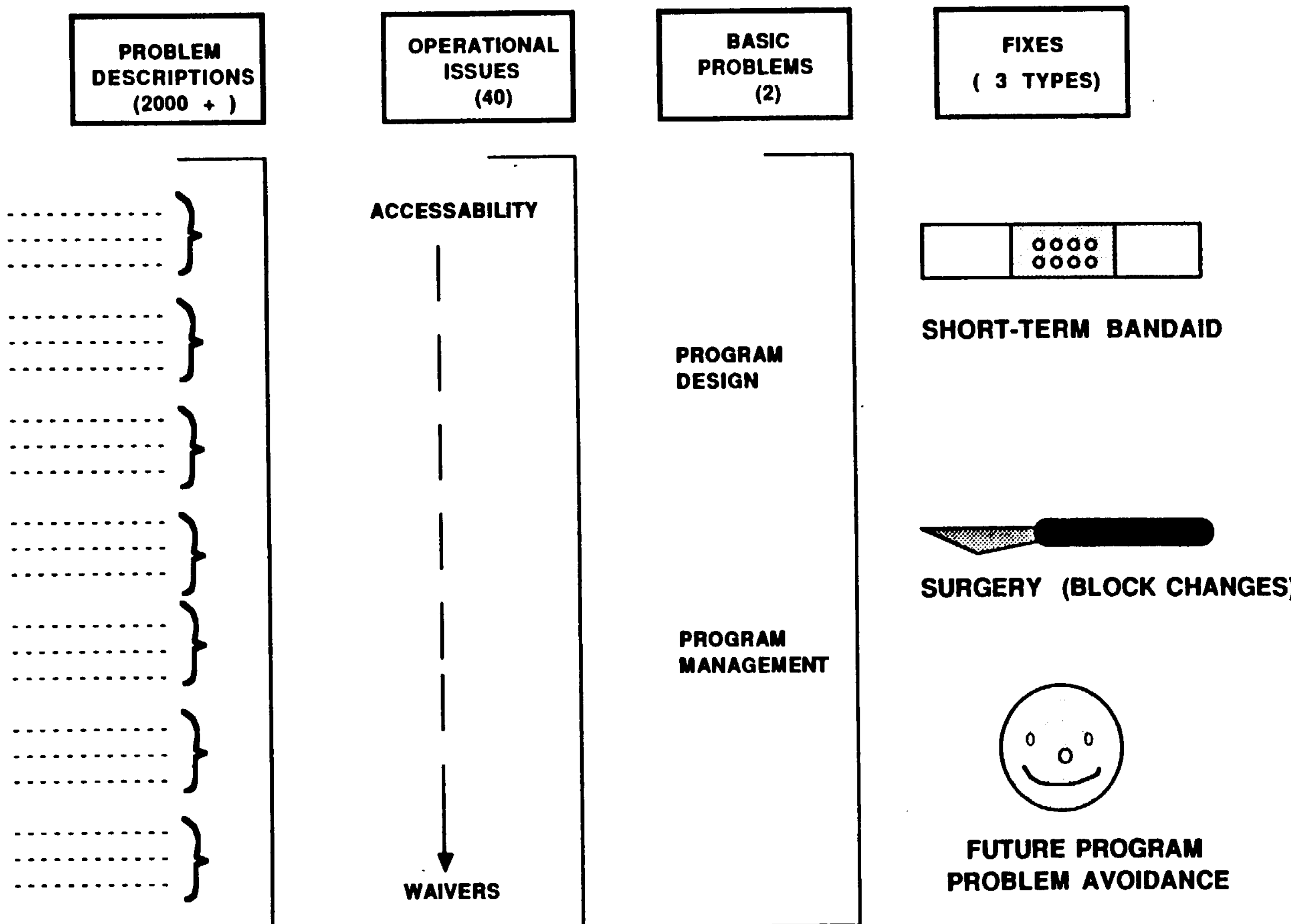
In our Preliminary Issues Database, there are 2000 issues which, when analyzed, were put into 40 buckets such as Safety, QA, Interface, etc.

When analyzed further, these issues were then divided into only two basic problem areas -- Program Design and Program Management. These two basic problems are, in large part, a result of early STS budget limitations and "then-current state-of-the-art" technology.

In searching for potential solutions to "tentpole issues", the possible technology or timeline solutions fall into three categories:

- Short term bandaids
- Surgery (Block Changes for STS)
- Future program problem avoidance (STAS)

OPERATIONAL ISSUES / PROBLEMS / FIXES



HIGH PAYOFF TECHNOLOGY POTENTIAL

The chart depicts the growth of processing time from the original 160 hour design goal to the current goal of 680 hours and the current capability of 1040 hours which combines the best as-run vehicle times for OPF, VAB, and PAD. It should be noted that the current capability may be significantly impacted by additional safety related test and inspection requirements resulting from 51-L.

Four selected examples from the OPF and PAD processing provide a total of 840 hours of potential serial or parallel time improvement (through the use of technology) to meet the initial design goals.

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HIGH PAYOFF TECHNOLOGY POTENTIAL

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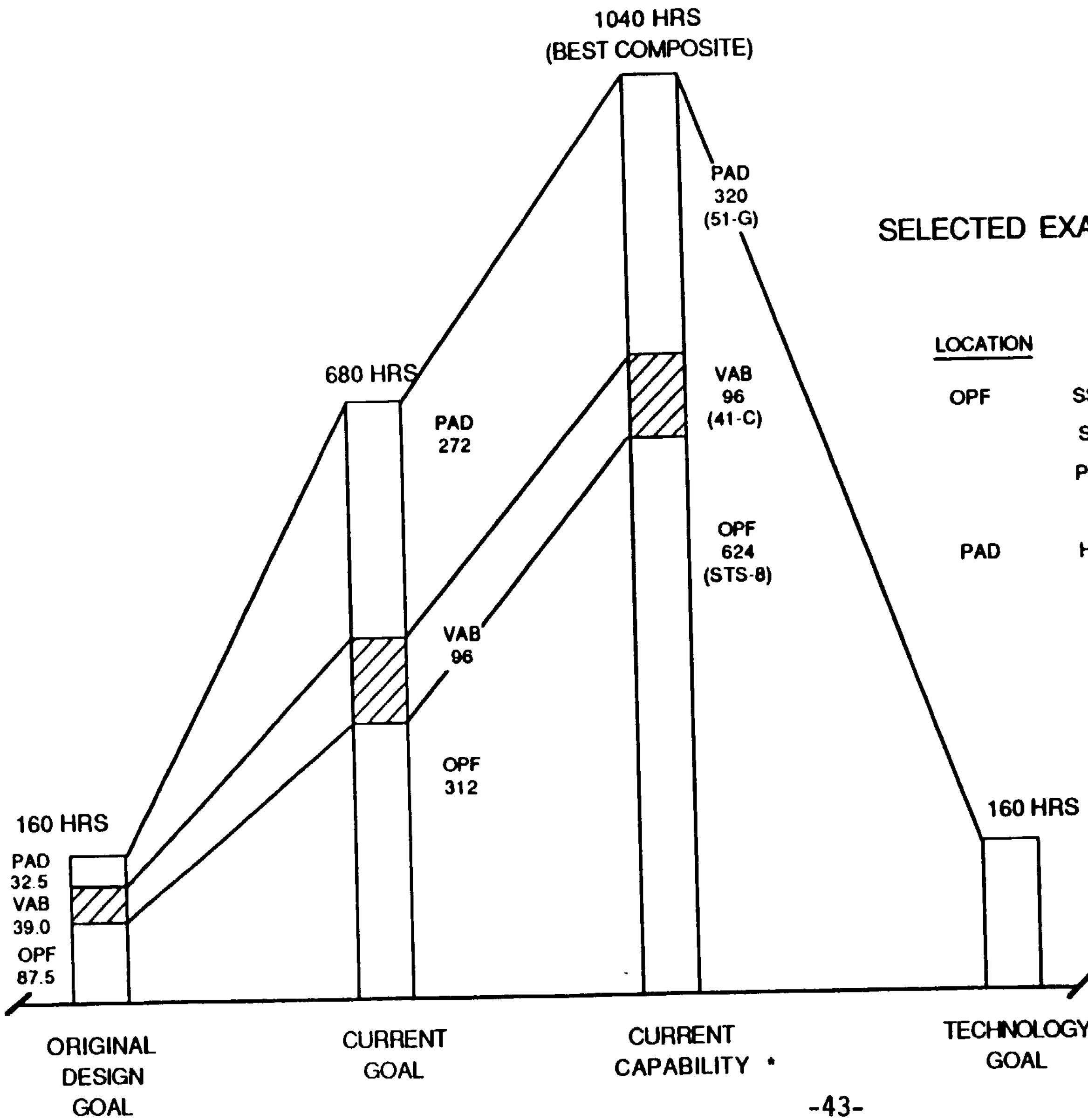


SELECTED EXAMPLES:

LOCATION	POTENTIAL PAYOFF SOURCE	POTENTIAL PAYOFF * * (CURRENT CAPABILITY HOURS) MINUS (160-HR GOAL)
OPF	SSME SCHEDULED MAINT. * * *	260 - 24 = 236 HRS
	SYSTEM REVERIFICATION	360 - 50 = 310 HRS
	PAYLOAD BAY RECONFIGURATION	368 - 32 = 336 HRS
PAD	HAZARDOUS SERVICING & CD PREPS	212 - 8.5 = 203 HRS
	POTENTIAL PAYOFF	840 HRS

NOTES:

* EXCLUDING POST 51-L **OMRSD** REVISIONS

* * INCLUDES BOTH SERIAL AND PARALLEL TIME

* * * MPS/SSME LEAK & FUNCTIONAL TEST 216 HRS
SSME PUMP R & R / INSPECTION 112 HRS
(PORTIONS IN PARALLEL)

OPERATIONS ANALYSIS

	160-HR*	VS 51-L*
A. LANDING AREA	1.0	10.5
B. SAFING & DESERVICING	8.0	416.5
C. PAYLOAD REMOVAL PREPS.	8.0	25.0
D. MISSION UNIQUE P/L ACCOM.	24.0	429.5
EQUIPMENT REM/INST.	-	-
E. ORBITER SCHEDULED MAINT.	24.0	1132.5
F. PROPULSION SYSTEM SCHED. MAINT.	24.0	893.0
G. UNSCHED. MAINT.& SYSTEM REFURB.	50.0	753.5
H. TPS REFURBISHMENT	40.0	191.0
I. ORBITER INTEGRATED TEST	10.0	359.5
J. PREPS FOR MATING	10.0	0.5
K. TOW ORBITER TO VAB	0.0	0.5
L. TRANSFER AISLE ORBITER	5.0	18.5
PREMATE OPERATIONS	-	-
M. ORBITER MATE & I/F VERIF.	15.0	144.0
N. SHUTTLE I/F TEST	19.0	0.0
O. MOVE TO PAD	7.0	13.5
P. MLP MATE TO PAD & PAD VALID.	3.0	39.5
Q. PAYLOAD INST. IN PCR	13.0	174.0
R. FUEL CELL DEWAR LOADING	10.0	6.5
S. SHUTTLE LAUNCH READINESS VERIF.	6.5	57.5
T. P/L INST. & LAUNCH READINESS	9.0	273.5
VERIFICATION	-	-
U. CABIN CLOSEOUT	1.0	0.0
V. HAZARDOUS SERVICE/SERVICE	8.0	543.5
DISCONNECT	-	-
W. LAUNCH FROM STANDBY (CD)	2.0	121.5

OPERATIONS ANALYSIS

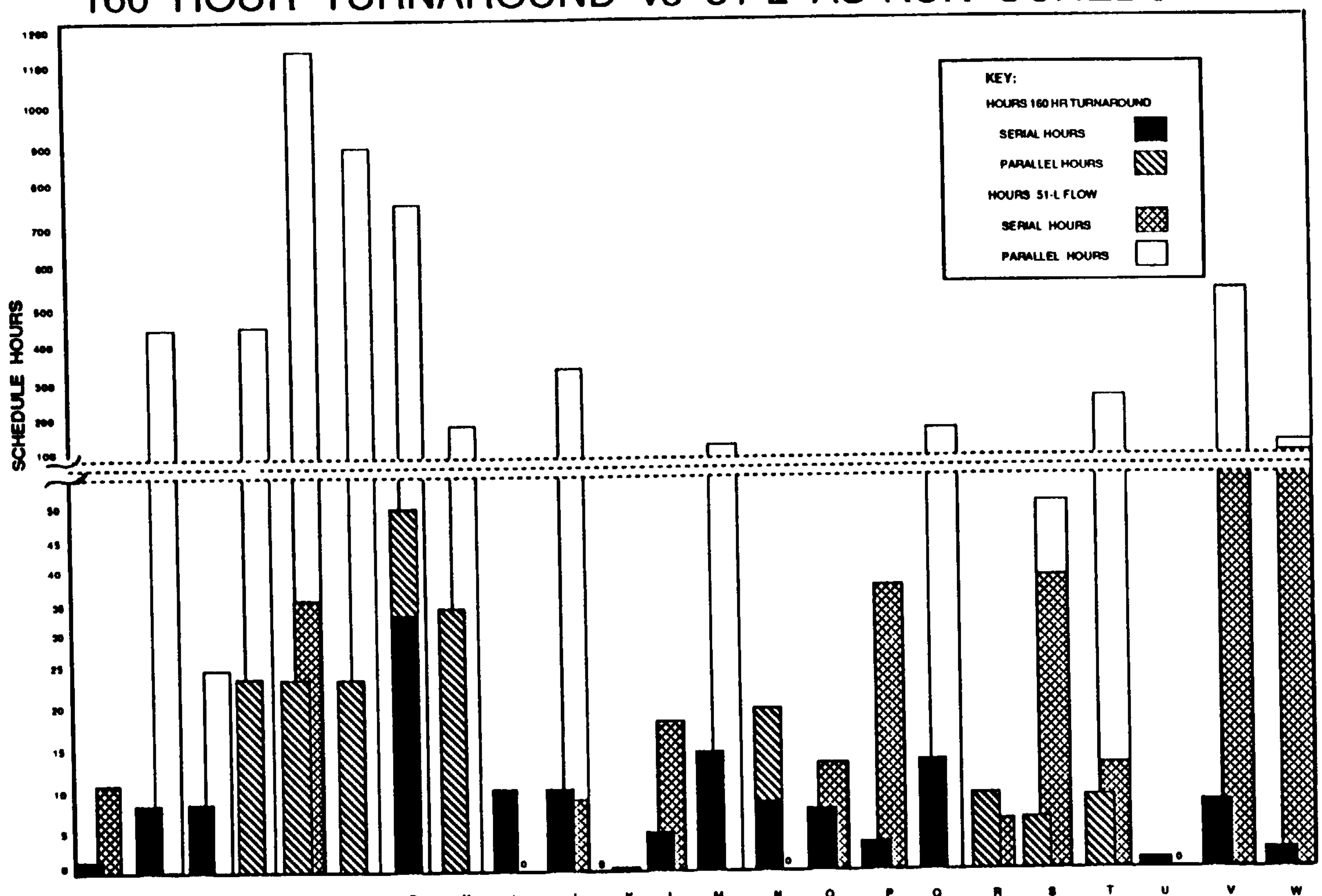
The Shuttle design criteria for launch operations (ref. JSC 07700) turnaround remains 160-hrs, although it is understood this is under revision. Obviously, because of various compromises in the basic design, actual turnaround time can not approach this goal. Nevertheless, this was a valuable tool in our Operations Analysis to help determine where the individual growth areas developed.

Our final report details the individual OMI's which are now used to process the vehicle and how they relate to the original concept. This is particularly valuable in establishing design goals for future vehicles.

* SERIAL AND PARALLEL TIME

OPERATIONS ANALYSIS

160 HOUR TURNAROUND vs 51-L AS-RUN SCHEDULE



MAJOR OPERATIONS ACTIVITY

(Column letters identified on facing page)

TECHNOLOGY & EFFICIENCIES CANDIDATES

Each of the bars on this chart represents the time required (during the OPF processing of 51-L) to support operations for most of the tentpoles

The Operations Analysis surfaced tentpoles(1-5) in the area of "timeline improvements"; that is, efficiency items that did not require new technology to implement. Because this type of item is being vigorously pursued by NASA and the SPC since 51-L with literally hundreds of people, we directed our prime study effort to new technology. Nevertheless, we have included several serendipitous items as timeline improvements not related to new technology but which go beyond the "bandaid" stage and need an extra push.

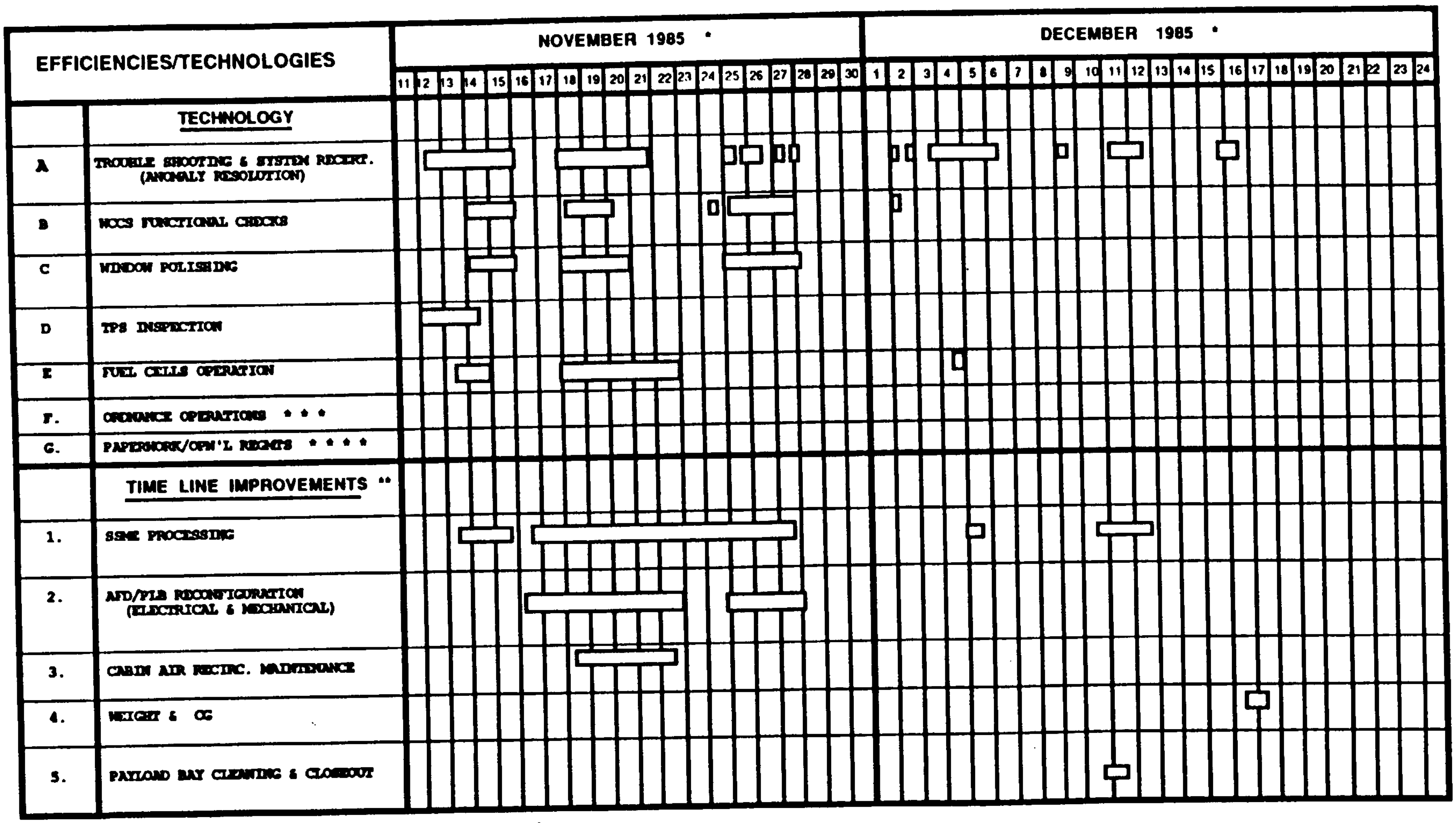
The main thrust of our effort centered around tentpole activities that could be made more efficient through the use of new technology. Our Operations Analysis identified tentpoles (A-G), which, when matched with related issues, provided promising candidates for efficiency improvements. Tentpoles A through E occur in the OPF. Tentpole "F", Ordnance Operations, occur in the VAB and at the Pad. Tentpole "G", Paperwork & Operational Requirements occurs throughout the total vehicle processing.

S G O E/T STUDY
PHASE 1 FINAL
PRESENTATION
by BOEING

TECHNOLOGY & EFFICIENCIES CANDIDATES

PRESENTED AT
KSC
APR. 6,1987

51-L OPF PROCESSING
- - TIMELINES TO SUPPORT IDENTIFIED TENTPOLES - -



* All timebars indicate 3 shift/day operations
** Does not require new technology - but goes beyond the bandaid fix
*** Tentpole "F", Ordnance operations in the VAB and at the Pad
**** Tentpole "G", Paperwork and Operational Requirements, occurs throughout STS

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SGOE/T STUDY
PHASE 1 FINAL
PRESENTATION
by BOEING

TENTPOLE ISSUE SUMMARY

PRESENTED AT
KSC
APR. 6,1987

	TENTPOLE	ISSUES				SHIFTS (1)	TECH MHRS (2) (3)	ENGR/ QA/ETC MHRS
		Design	Access.	Maintain.	Cost			
TIMELINE IMPROVEMENTS	1. SSME Processing	X	X	X	X	47	3792	N/A
	2. AFD/PLB Reconfiguration	X	X		X	30	1680	
	3. Cabin Air Recirc.	X	X	X	X	12	384	
	4. Weight & CG	X			X	1	128	
	5. PayLoad Bay Cleaning	X			X	3.5	112	
TECHNOLOGY APPLICATIONS	A. Anomaly Resolution	X	X	X	X	48	964	
	B. WCCS Functional Checks	X	X	X	X	23	920	
	C. Window Polishing			X	X	24	384	
	D. (4) TPS Inspection			X	X	7	632	
	E. Fuel Cell Operation	X		X	X	21.5	N/A	
	F. Ordnance Operations	X	X	X	X	N/A	N/A	
	G. Paperwork	X		X	X	N/A	N/A	N/A

(1) OTHER OPERATIONS MAY BE BEING WORKED IN PARALLEL
(2) DOES NOT INCLUDE TROUBLESHOOTING OR RETEST NOT ASSOCIATED WITH AN OMI
(3) MANHOUR DATA NOT COMPLETE
(4) NOT VEHICLE DEPENDENT DEPENDS ON GSE AVAILABILITY

SHORT-TERM BANDAID
BLOCK CHANGES
FUTURE PROGRAM PROBLEM AVOIDANCE

TENTPOLE "1"
SSME PROCESSING

Inadequate SSME off-line maintenance facilities at KSC are the basic cause of this tentpole. To perform major SSME maintenance in the OPF requires major on-line system support (ECS, GN&C, EPD, Hydraulics, MPS, PV&D, Crew Systems, Instrumentation, & Communications).

To overcome this operational shortcoming and provide on-line schedule relief, it will be necessary to provide off-line facilities. There are 14 pending ESR's and 2 SR's submitted by Rocketdyne which would significantly improve the immediate SSME processing problem. Cell 5 Mods have been approved. BOD is expected in Oct '87. The remainder of the Mods are planned for FY '88 and FY '89.

Increased engine subsystem reliability and spare engines should further resolve this tentpole, but at a much later time.

TENTPOLE "1"
SSME PROCESSING

OMI: V1001, V1009, V1011, V1201, V5005, V5043, V5057, V5058, V5E02, V5E06, V5EXX (20-30 LRU's)

OMI DESCRIPTION: PROCEDURES TO PROCESS THE SPACE SHUTTLE MAIN ENGINE INCLUDING -- HEAT SHIELD REMOVAL AND INSTALLATION, LEAK AND FUNCTIONAL TEST (MPS & SSME), MAIN ENGINE R&R, AND MAIN ENGINE FRT. VARIOUS LRU R&R (MAJOR MAINTENANCE -- HIGH PRESSURE FUEL & OXIDIZER TURBO PUMP).

ASSOCIATED ISSUES: DESIGN / TIME ON-LINE / COST-MANHOURS / ACCESSABILITY / REQUIREMENTS / RELIABILITY / MAINTAINABILITY / EFFICIENCY

TYPICAL ISSUE SOURCE: SGOE/T STUDY (OPERATIONS ANALYSIS), ROCKETDYNE

TYPICAL ISSUE DESCRIPTION: TO PERFORM SSME MAINTENANCE ON-LINE REQUIRES <u>ALL</u> ORBITER MAJOR SYSTEMS SUPPORT. WORKSPACE IN THE AFT SECTION IS SO LIMITED THAT TIMELINES ARE LENGTHENED PRODUCING SCHEDULE CONFLICTS WITH OTHER SYSTEMS AND AFFECTING COMPLETION OF TASKS. FREQUENT ACCESS THROUGH THE HEAT SHIELD TO SUPPORT ENGINE SERVICING WAS NOT AN ORIGINAL DESIGN REQUIREMENT.

EFFICIENCY REQUIREMENTS: MAKE PROVISIONS TO ACCOMPLISH SSME REPAIRS, MODIFICATIONS, MAINTENANCE, AND TESTING <u>OFF-LINE</u>

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TENTPOLE "1"
SSME PROCESSING (Cont'd)

<u>CONCLUSIONS & RECOMMENDATIONS</u> SHOP MODIFICATIONS SHOULD BE COMPLETED IN TIME TO SUPPORT RESTART OF OPERATION IN ORDER TO OBTAIN MAXIMUM BENEFIT SINCE MANY MAINTENANCE AND INSPECTION OPERATIONS ARE ANTICIPATED AND COULD BE ACCOMPLISHED OFF-LINE.

THERE WERE 14 PENDING ESR'S AND 2 SR'S SUBMITTED BY ROCKETDYNE TO ENLARGE THE PRESENT ENGINE SHOP TO IMPROVE ACCESSABILITY AND TO MAJOR ENGINE MAINTENANCE, CHECKOUT AND MODIFICATION OFF-LINE. STATUS OF THESE IS ENCOURAGING: CELL 5 MODS (~$400K) HAVE BEEN APPROVED WITH EXPECTED BOD OF OCTOBER '87. TENTATIVE APPROVAL OF $400K FOR FY88 AND $400K FOR FY'89 HAS BEEN GIVEN FOR A TOTAL OF $1.2M.

PROVIDE ACCESS DOORS IN AFT HEAT SHIELD FOR SSME AREAS REQUIRING PERIODIC ACCESS.

TENTPOLE "2"
AFD/PLB RECONFIGURATION

Almost all issue source documentation points out that NASA has attempted to be "all things to all payloads" in providing flexibility for payload customers -- with the result of bogging down all aspects of mission planning and ground operations. The impact of individual differences in the payload requirements ricochets throughout the STS Program with the attendant problems of getting the changes into all the documentation in a timely manner. Specifically, in the area of ground operations, it impacts the flow time significantly.

Issue sources such as the AFSC/NSIA Space Transportation Panel (Cost Reduction & Cost Credibility Workshop White Papers), point out the need for drastic changes in cargo interfaces.

TENTPOLE "2"
AFD/PLB RECONFIGURATION

OMI'S: N52XX, V3512, LSOC TPS'S

OMI DESCRIPTION: PROCEDURES REQUIRED TO DECONFIGURE AND RECONFIGURE BOTH THE AFT FLIGHT DECK (AFD) AND THE PAYLOAD BAY TO CHANGE SUPPORT FROM THE DOWN-CARGO TO THE UP-CARGO.

ASSOCIATED ISSUES: DESIGN / DESIGN CRITERIA / TIME/ON-LINE / COST/MANHOURS

TYPICAL ISSUE SOURCE: ROCKWELL PROJECT OFFICE-LSS, E/T STUDY OPS ANALYSIS, AFSC/NSIA SPACE TRANSPORTATION PANEL

TYPICAL ISSUE DESCRIPTION: IN ORDER TO ACCOMMODATE A WIDE VARIETY OF CARGO CONFIGURATIONS, FLEXIBILITY DESIGNED INTO THE PAYLOAD BAY HAS CAUSED THE DECONFIGURATION / RECONFIGURATION TIMELINE TO GREATLY EXCEED THE ORIGINAL LIMITS.

EXAMPLES OF THIS FLEXIBILITY ARE:

1. ATTACH POINTS CAN BE LOCATED AT 3.933 IN. INCREMENTS.
2. SMCH CABLES MUST BE REPOSITIONED TO MATCH LOCATION OF CARGO.
3. PRSD TANK SET 4 CAN BE ADDED TO PROVIDE ADDITIONAL POWER.
4. FLUID SERVICES CAN ALSO BE ADDED.

EFFICIENCY REQUIREMENTS: REDUCE PAYLOAD RECONFIGURATION ON-LINE TIME AND COST/MANHOURS REQUIRED TO SUPPORT THE NEXT MISSION.

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TENTPOLE "2"
AFD/PLB RECONFIGURATION
(Cont'd)

CONCLUSIONS AND RECOMMENDATIONS:

CURRENT ORBITERS:

MODIFICATION OF PRESENT ORBITER WOULD BE TOO COSTLY BUT NEW GSE COULD REDUCE TIME AND MANHOURS.

1. PROVIDE A STRONGBACK THAT COULD BE USED TO INSTALL THE PAYLOAD

2. PROVIDE ADDITIONAL SPARE PAYLOAD FITTINGS AND BRIDGE SO THE OPERATIONS CARGO CONFIGURATIONS CAN BE ESTABLISHED OFF-LINE.

FUTURE VEHICLES:

ESTABLISH DESIGN CRITERIA EARLY FOR FUTURE VEHICLES

1. DEVELOP A PAYLOAD BAY THAT SUPPORTS CLEANLINESS REQUIREMENTS.

2. PERMANENTLY INSTALL A FIXED NUMBER OF PAYLOAD FITTINGS AND RESTRICT THE CONFIGURATION AND LOCATION OF PAYLOADS TO MATCH THESE FITTINGS.

3. MAKE USE OF FIBER OPTIC BUS ARCHITECTURE TO REDUCE WEIGHT AND PROVIDE A LIMITED NUMBER OF ACCESS PORTS FOR THE PAYLOAD INTERFACES.

4. STANDARDIZE ALL PAYLOAD-TO-ORBITER INTERFACES.

5. PROVIDE ONLY POWER AND A LIMITED CONTROL CAPABILITY FROM THE ORBITER.

6. BEST SOLUTION FROM GROUND OPS STANDPOINT -- COMPLETELY CONTAINERIZED CARGO (WITH MINIMAL POWER/CONTROL/DATA INTERFACES PROCESSED COMPLETELY OFF-LINE).

TENTPOLE "3"
CABIN AIR RECIRCULATION

Maintainability was insufficiently considered in the design of the air recirculation filters and debris screens. After each flight these screens and filters must be removed and cleaned. To gain access to these, several electronic modules must be removed. This is not only a time consuming operation but also requires that the power be removed from the orbiter and access is restricted to the crew module. In addition, retest and validation is required for the electronics removed and replaced.

This system should be redesigned to provide for easy access and maintainability.

Note: Major source of lint comes from the blue cotton flight suits of the astronauts who are not required to wear clean-room smocks during ground operations. Obtain lint-free suits or enforce cleanroom rules for all personnel.

TENTPOLE "3"
CABIN AIR RECIRCULATION MAINTENANCE

OMI: V6018

OMI DESCRIPTION: TO PERFORM ROUTINE MAINTENANCE ON THE CABIN FAN, IMU, AND AVIONICS BAY 1, 2, 3 DEBRIS SCREENS. THE CONDENSING HEAT EXCHANGER WILL BE INSPECTED FOR CORROSION AND BIOLOGICAL GROWTH; WATER SAMPLES WILL BE OBTAINED FROM THE CONDENSING HEAT EXCHANGER AND ANALYZED FOR BIOLOGICAL GROWTH. TOTAL SYSTEM WILL BE INSPECTED AND VACUUMED.

ASSOCIATED ISSUES: ACCESSABILITY / DESIGN / MAINTAINABILITY / EFFICIENCY

TYPICAL ISSUE SOURCE: E/T STUDY OPERATIONS ANALYSIS

TYPICAL ISSUE DESCRIPTION: THE PERFORMANCE OF THIS PROCEDURE REQUIRES POWER TO BE OFF THE VEHICLE AND ACCESS RESTRICTED TO THE CREW MODULE.

80% OF LINT COMES FROM ASTRONAUTS SUITS.

EFFICIENCY REQUIREMENT: REDUCE TIME REQUIRED AND MANHOURS TO MAINTAIN THE CABIN AIR RECIRCULATION SYSTEM.

CONCLUSIONS:
1. PRESENT SYSTEM WAS NOT DESIGNED FOR MAINTAINABILITY
2. ASTRONAUT'S SUITS ARE THE MAIN SOURCE OF CONTAMINATION.

RECOMMENDATION:
1. REDESIGN THE SYSTEM TO IMPROVE THE ACCESSABILITY OF THE EQUIPMENT WITH PARTICULAR ATTENTION TO THE FILTERS AND DEBRIS SCREENS.
2. USE NON-LINT PRODUCING MATERIAL FOR ASTRONAUT'S SUITS.

TENTPOLE "4"
WEIGHT AND CG

OPF operations personnel requested a load cell system in the jacking system modification at the OPF. The request was rejected because there were scales available for this purpose at KSC. Scales must be sent to California for calibration annually. To calibrate locally, a $20,000 tool is required.

Considering the manpower and time required to accomplish the weight and cg determination, and the OMRSD requirement to do this every flight, this capability should be reconsidered. Ultimately a reliable weight log should eliminate the requirement.

TENTPOLE "4"
WEIGHT AND CG

OMI: V5101

OMI DESCRIPTION: TO CONFIGURE FOR AND PERFORM A THREE-POINT ORBITER WEIGHING.

ASSOCIATED ISSUES: DESIGN(GSE) / REQUIREMENT / TIME/ON-LINE / COST/MANHOURS

TYPICAL ISSUE SOURCE: NASA KSC NE-PEO, E/T STUDY OPS ANALYSIS

TYPICAL ISSUE DESCRIPTION: OPERATION EXCEEDS THE EXPECTED TIMELINE AND REQUIRES SIXTEEN TECHNICIANS TO SUPPORT

WEIGHT LOG DOES NOT COMPARE WITH ACTUAL WEIGHTS

EFFICIENCY REQUIREMENT: DETERMINE WEIGHT OF THE ORBITER AT THREE POINTS WITHOUT REQUIRING SIXTEEN TECHNICIANS 12 HOURS TO ACCOMPLISH THE TASK

CONCLUSIONS & RECOMMENDATION:

1. THIS OPERATION SHOULD BE ELIMINATED WITH THE DEVELOPMENT OF AN ACCURATE WEIGHT LOG. USE COMPUTER AIDED INFORMATION SYSTEM TO MAINTAIN AND PRODUCE WEIGHT LOG.

OR 2. ADD A LOAD CELL SYSTEM TO THE OPF JACKING SYSTEM SO THAT THE WEIGHT DATA CAN BE OBTAINED WHENEVER THE VEHICLE IS JACKED AND LEVEL AND PROVIDE WEIGHT SET TO CALIBRATE SCALES.

TENTPOLE "5"
PAYLOAD BAY CLEANING & CLOSEOUT

The original requirements for contamination control were the same as commercial airplanes. All of the facilities and GSE were designed to meet these requirements; however, the cargo community has since imposed much tighter controls to inspect and clean the payload bay which has added significantly to the OPF and PAD processing time.

There are two possible solutions that should be pursued to eliminate this activity. The first would be to modify the existing facilities to provide a clean environment anytime the payload bay doors are opened (probably not realistic). The second would be to require all cargo to be qualified to operate in the existing environment (containerize the cargo to control the contamination where necessary). This last method would have the extra benefit of security for DOD cargo.

TENTPOLE "5"
PAYLOAD BAY CLEANING & CLOSEOUT

OMI: V1176

OMI DESCRIPTION: TO CLEAN ACCESSIBLE PAYLOAD BAY SURFACES TO ONE OF THREE CLEANLINESS LEVEL OPTIONS AND TO QUALITATIVELY ASSESS THE TYPES AND LEVELS OF VARIOUS CONTAMINANTS WITH THE INTENT OF IMPROVING CONTAMINATION CONTROLS.

ASSOCIATED ISSUES: COST/MANHOURS / REQUIREMENTS / DESIGN / TIME/ON-LINE

TYPICAL ISSUE SOURCE: SGOE/T STUDY (OPERATIONS ANALYSIS)

TYPICAL ISSUE DESCRIPTION: NO TIME WAS ORIGINALLY ALLOTTED FOR PAYLOAD BAY CLEANING BECAUSE CLEANLINESS REQUIREMENTS DID NOT DEMAND SPECIAL ATTENTION. CARGO REQUIREMENTS NOW REQUIRE TIGHT CONTAMINATION CONTROLS

EFFICIENCY REQUIREMENT:

* REDUCE TIME REQUIRED FOR SPECIAL CLEANING OF PAYLOAD BAY OR --
* PAYLOAD DESIGNS MUST ACCOMMODATE RELAXED CLEANLINESS REQUIREMENT OR PROVIDE THEIR OWN PROTECTION. CARGO REQUIREMENTS NOW IMPOSE TIGHT CONTAMINATION CONTROLS

CONCLUSIONS & RECOMMENDATIONS:

CURRENT STS: CARGO REQUIREMENTS ARE DICTATING THE CLEANLINESS LEVEL OF THE PAYLOAD BAY. PROVIDE A FACILITY/CARGO BAY THAT WILL SUPPORT THE CLEANLINESS REQUIREMENTS OF THE CARGO COMMUNITY OR REQUIRE THE CARGO COMMUNITY TO ACCEPT REDUCED CLEANLINESS REQUIREMENTS.

FUTURE VEHICLES: CONTAINERIZE THE PAYLOAD TO PROVIDE THEIR OWN CONTAMINATION CONTROL.

TENTPOLE "A"
ANOMALY RESOLUTION

To accomplish a high degree of maintainability, system faults must be easily detected, isolated, accessed and repaired.

For the Orbiter, there are 24 OMI's currently used for troubleshooting and retest. There are 11 associated issues including accessability, interface, and isolation. Fault tolerant circuitry is also related.

There is an obvious requirement to reduce the time and effort involved in all aspects of anomaly resolution through incorporating this requirement in the design specification of future vehicles and including it in block changes for Shuttle.

There is technology available today, commercially and in the AF, which can accomplish anomaly resolution an order-of-magnitude better than the fifteen year old technology in the Orbiter. Imbedded circuitry and fault tolerant designs currently under development will support easy maintainability in this area.

TENTPOLE "A"
ANOMALY RESOLUTION

RELATED OMI's: V1003, V1005, V1008, V1022, V1028, V1034, V1048, V1053, V1060, V1062, V1065, V1080, V1084, V1086, V1098, V1103, V1123, V1161, V1173, V1177, V1178, V1200, S3500

OMI DESCRIPTION: APPROXIMATELY 24 OMI'S CURRENTLY REQUIRED TO TROUBLESHOOT PROBLEMS AND RETEST SYSTEMS DURING EACH TURNAROUND PROCESSING.

ASSOCIATED ISSUES: FAULT DETECTION / EFFICIENCY / DESIGN CRITERIA / DESIGN / ACCESSABILITY / INTERFACE / ISOLATION / MODULARIZATION / TECHNOLOGY

TYPICAL ISSUE SOURCE: STS MAINTENANCE TECHNOLOGY STUDY, PHASE III SUMMARY RPT, 5/30/86, ROCKWELL

TYPICAL ISSUE DESCRIPTION: "SYSTEM DOWNTIME COULD BE DECREASED BY INCORPORATING BOTH ANOMALY DETECTION AND FAULT ISOLATION."

"IMPROVE SYSTEM ACCESSABILITY AND PROVIDE INCREASED BUILT-IN-TESTING, FOR AUTOMATIC FAULT DETECTION/ISOLATION."

"PROVIDE THE CAPABILITY FOR GROUND SYSTEMS TO PERFORM DIAGNOSTIC MONITORING AND CHECKOUT OF ON-BOARD SYSTEMS."

TENTPOLE "A" ANOMALY RESOLUTION (Cont'd)

Thru the XTKB we have obtained 42 different papers and documents pertinent to this issue. Typical titles include: "Integrated Testing & Maintenance Technologies", "Design for Tactical Avionics Maintainability", "Artificial Intelligence in Maintenance, Proceedings of the Joint Services Workshop". These documents provide overwhelming evidence as to what can be done in this area.

In the Seattle Technology Review trip, we reviewed the applicability of the Automated Overall Test for the 767 airplane conducted just prior to rollout. The information on the chart shows what can be accomplished with today's technology--without considering technology that is in development.

With the Rome Air Development Center (RADC) technology review trip, we updated our information on the status of RADC supported BIT development and their future plans.

TENTPOLE "A"
ANOMALY RESOLUTION
(Cont'd)

TECHNOLOGY REQUIREMENT: AN AUTOMATED SELF-CHECK SYSTEM (SIMILAR TO SYSTEM USED FOR FINAL ACCEPTANCE OF 767 AIRPLANE) FOR ALL ORBITER SYSTEMS. ULTIMATE GOALS: SELF-TEST, FAULT TOLERANT, VEHICLE SYSTEMS WITH LITTLE OR NO GSE FOR FUTURE VEHICLES.

TECHNOLOGY SEARCH RESULTS:

* 42 VERY PERTINENT PAPERS AND DOCUMENTS LOCATED THROUGH XTKB AND RECON
* SEATTLE TECHNOLOGY REVIEW TRIP
  * REVIEWED APPLICABILITY OF 767 AIRPLANE AUTOMATED OVERALL TEST CONDUCTED JUST PRIOR TO ROLLOUT
    * CONDUCTED BY 6 TECHNICIANS OVER THREE REGULAR SHIFTS
    * AUTOMATED TEST EQUIP CART CONNECTED TO A/C DATABUS & TOUCHSCREENS
    * CORRECTIVE ACTION AND RETEST ON COMMAND
    * ALL TEST DATA STORED BY TEST SET PROVIDES DATA TRAIL FOR QA AND CLOSEOUT
    * NO QA REQUIRED ON-SITE
  * RELATED TECHNOLOGY -- INTEGRATED FAULT-TOLERANT AVIONICS SUITE
    * LAYERED ARCHITECTURE
    * INTERNAL REDUNDANCY
    * TRANSPARENT TO HARDWARE CHANGES
    * COULD REPLACE HARDWARE WITHOUT SYSTEM "POWERDOWN"
* ROME AIR DEVELOPMENT CENTER (RADC) TECHNOLOGY REVIEW TRIP
  * REVIEWED STATUS OF ARTIFICIAL INTELLIGENCE APPLICATION COMMITTEE RECOMMENDATIONS TO DOD
  * REVIEWED STATUS OF RADC FUNDED BUILT-IN-TEST (BIT) DEVELOPMENT

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ANOMALY RESOLUTION
(Cont'd)

TECHNOLOGY BREAKTHROUGHS

* META-RULES FOR EXPERT SYSTEMS
  (INFERENCE RULES FOR A.I.)

* PROLIFERATION OF ENGINEERING WORK STATIONS

TECHNOLOGY DEVELOPMENTS (TESTABILITY AREAS)

1. SELF-IMPROVING DIAGNOSTICS

2. MORE EFFECTIVE FAULT DETECTION AND ISOLATION

3. DISCRIMINATION BETWEEN FALSE ALARMS AND INTERMITTENT FAULTS

4. REDUCTION OF SKILLS REQUIRED FOR MAINTENANCE

5. INTEGRATED DIAGNOSTICS

6. DESIGN FOR TESTABILITY

ANAMOLY RESOLUTION
(A.I. APPLICATIONS TO TESTABILITY PROBLEMS)
(Cont'd)

Potential AI solutions for these six areas can be adapted to eight basic applications:

1. Computer-Aided Preliminary Design for Testability(CAPDT) provides a testability assistant directly available during design phases.

2. Smart Built-In Test (Smart BIT) used in boxes or cards can identify intermittent faults and reduce false alarms.

3. Smart System Integration Test (Smart SIT) is a system level Smart BIT which performs testing while the system is operating.

4. Maintenance Expert - Box (ME Box) provides offline test management with self-improvement of functional tests.

5. Maintenance Expert - System (ME SYS) describes the kind of capability that can be expected in the immediate future.

6. Maintenance Expert - Smart (ME Smart) incorporates the benefits/risks of including learning capability in the maintenance expert system and its ability to access to Smart BIT information.

7. Automatic Test Program Generation (ATPG) would be able to understand circuit functional operation; however, this application has the lowest payoff.

8. Smart Bench is a maintenance expert system developed for use with bench test equipment controlled by an engineering work station.

The facing page is a matrix of Anomaly/Testability Problems vs. AI Applications.

ANAMOLY RESOLUTION
(A.I. APPLICATIONS TO TESTABILITY PROBLEMS)
(Cont'd)

TESTABILITY PROBLEMS / ARTIFICIAL INTELLIGENCE

PROBLEMS / A.I.	1 CAPDT TEST	2 SMART BIT	3 SMART SIT	4 ME BOX	5 ME SYS	6 ME SMART	7 ATPG	8 SMART BENCH
BIT/ATE FAILURE COVERAGE	X	X	X	X	-	-	-	-
SELF-IMPROVING DIAGNOSTICS	-	-	X	X	-	X	-	X
MORE EFFECTIVE FAULT DET. & ISOLATION	X	X	X	-	-	X	-	X
DISCRIMINATING INTER/FALSE	-	X	X	-	-	X	-	-
REDUCING FALSE ALARMS	X	X	X	-	-	X	-	-
ISOLATING INTERM. FAILURES	X	X	X	-	-	X	-	X
REDUCING SKILL LEVEL FOR M	X	X	X	-	-	X	-	X
TESTABILITY FOM	X	-	-	-	-	-	-	-
DESIGN/TEST PROCESS INTEG.	X	-	-	-	-	-	-	-
CAT. COMPLEXITY AND COST	X	X	X	X	X	X	X	X
DATA COMPRESSION AND MANAGEMENT	-	X	X	-	-	X	-	-
INTERFACING & UPWARD COMPAT.	X	-	-	-	-	-	-	-
MAN/MACHINE INTERFACE	X	-	X	X	X	X	-	X

(X) REFERS TO PARAGRAPH NUMBERS ON PAGE 70

CONCLUSIONS AND RECOMMENDATIONS

In June 1984, an Artificial Intelligence Applications Committee with ten DoD and Industry members and chaired by Anthony Coppola, Chief of the Reliability & Maintainability Engineering Techniques section of the Rome Air Development Center developed four major recommendations in this area for DoD. Allowing for very minor changes in the past two years, these recommendations are still valid and apply to NASA equally well.

ANOMALY RESOLUTION
CONCLUSIONS AND RECOMMENDATIONS (Cont'd)

ARTIFICIAL INTELLIGENCE APPLICATIONS COMMITTEE RECOMMENDATIONS TO DOD:

* SPECIFIC APPLICATIONS OF MAINTENANCE EXPERT SYSTEMS SHOULD BE STARTED IMMEDIATELY, AND MULTI-APPLICATION MAINTENANCE EXPERTS DEVELOPED AND STANDARDIZED.

* DEVELOP SMART BIT FOR DIGITAL ELECTRONIC SYSTEMS TO MINIMIZE FALSE ALARMS, IDENTIFY INTERMITTENT FAILURES, IMPROVE COVERAGE OF BIT. (NOTE: RADC CONTRACTOR TO PROVIDE SEVERAL PROTOTYPES IN 1989. W-P AVIONICS LAB AND RADC DOING F-16 MAINTENANCE PROTOTYPE TESTING AT HILL AFB AND WARNER ROBBINS AFB, RESPECTIVELY)

* FUND APPLIED R&D FOR AI FOR MAINTENANCE, INCLUDING
  1. AUTOMATING THE CREATION AND PRESENTATION OF TECHNICAL MANUALS.
  2. APPLYING AI TO MAINTENANCE INFORMATION SYSTEMS AND DATABASES.
  3. DEVELOPING REQUIREMENTS FOR EXPERT SYSTEM LANGUAGES AND COMPUTER SYSTEMS.

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ANOMALY RESOLUTION CONCLUSIONS AND RECOMMENDATIONS (Cont'd)

4. DEVELOPING CRISIS ALERTING SYSTEMS.

5. DEVELOPING AI SYSTEMS FOR AUTOMATIC TEST PROGRAM GENERATION (ATPG).

6. APPLYING AI TECHNIQUES TO VLSI, VHSIC DESIGN FOR FAULT TOLERANCE AND TESTABILITY.

7. DEVELOPING KNOWLEDGE-BASED COMPUTER AIDED INSTRUCTION (CAI) SYSTEMS FOR MAINTENANCE TRAINING.

8. DEVELOPING SELF-IMPROVING DIAGNOSTICS AND TEST PROGRAM SETS.

* FOSTER AN INTEGRATED DOD-INDUSTRY APPROACH FOR AI/ES (ARTIFICIAL INTELLIGENCE/EXPERT SYSTEMS)
    * JOINT GROUP ACTIVITIES
    * SUPPORT INDUSTRY IR&D

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ANOMALY RESOLUTION CONCLUSIONS AND RECOMMENDATIONS (Cont'd)

SHUTTLE

* INCLUDE IMPROVED ANOMALY RESOLUTION IN BLOCK CHANGES IN THE EARLY 1990'S TIME FRAME.

  SYSTEMS WHICH SHOULD BE CONSIDERED INCLUDE:

  * ELECTRICAL POWER DISTRIBUTION & CONTROL (EPD&C)
  * POWER REACTANT STORAGE & DISTRIBUTION (PRSD)
  * ENVIRONMENTAL CONTROL & LIFE SUPPORT SYSTEM (ECLSS)
  * DATA PROCESSING SYSTEM (DPS)
  * COMMUNICATIONS (COMM)
  * GUIDANCE, NAVIGATION, & CONTROL (GN&C)
  * MAIN PROPULSION SYSTEM (MPS)
  * AUXILIARY POWER UNIT (APU)
  * HYDRAULIC SYSTEM (HYD)

ANOMALY RESOLUTION CONCLUSIONS AND RECOMMENDATIONS (Cont'd)

CONCLUSIONS AND RECOMMENDATIONS

SHUTTLE

With STS activity planned for another 15 years, serious consideration should be given to incorporating some degree of improved anomaly resolution via block changes in the early 1990's when the improvements now under intensive development begin to reach fruition.

FUTURE VEHICLES

Because of the significant investment required to develop the hardware, software and techniques in the areas of EXPERT SYSTEMS and ARTIFICIAL INTELLIGENCE for testability, NASA should join the DoD/Industry team. DoD has been funding and developing the early progress in this area.

Specifically, the STS and STAS design agencies should develop/expand direct contact with key AFSC personnel at the Rome Air Development Center and the Wright-Patterson Avionics Laboratory.

ANOMALY RESOLUTION CONCLUSIONS AND RECOMMENDATIONS (Cont'd)

SHUTTLE

* WHILE THE SHUTTLE COST TRADES MAY NOT JUSTIFY INCORPORATION, IT WILL BE IMPORTANT FOR FUTURE VEHICLE PROOF OF CONCEPT.

FUTURE VEHICLES

* NASA DESIGN AGENCIES DEVELOP/EXPAND DIRECT CONTACTS (IN AREAS OF EXPERT SYSTEMS AND ARTIFICIAL INTELLIGENCE FOR TESTABILITY) WITH:
    * ROME AIR DEVELOPMENT CENTER
    * WRIGHT-PATTERSON AVIONICS LAB

TENTPOLE "B"
WINDOW CAVITY CONDITIONING SYSTEM
(WCCS)

This tentpole surfaced from the Study Operational Analysis as a time-consuming item that was not anticipated in the original 160-hr schedule.

During 51-L processing a total of 152 hrs were used on the as-run schedule involving __??__ (unknown manhours).

To-date we have no progress on possible technology improvements.

The current situation could be somewhat improved by having tested asssemblies available in spares.

Further improvement could be made by vehicle mods to relocate the units to an easily accessible location.

TENTPOLE "B"
WINDOW CAVITY CONDITIONING SYSTEM (WCCS)

OMI: V1076

OMI DESCRIPTION: TO PROVIDE PROCEDURES TO VERIFY THE FUNCTIONAL CORRECTNESS OF THE ORBITER WINDOW CAVITY CONDITIONING SYSTEM.

ASSOCIATED ISSUES: TECHNOLOGY / COST/MANHOURS / TIME/CYCLE / EFFICIENCY

TYPICAL SOURCE: KSC HISTORICAL SCHEDULES -- SGOE/T STUDY (OPS ANALYSIS)

TYPICAL ISSUE DESCRIPTION: NO TIME WAS ALLOTTED IN THE ORIGINAL 160-HR TURNAROUND. THE STSXX SCHEDULE ALLOTTED 92-HRS AND THE 51-L FLOW REQUIRED 152 HRS TO COMPLETE

TECHNOLOGY REQUIREMENTS: POSSIBLE ALTERNATIVES INCLUDE:

1. A NEW DESICCANT WITH RELIABLE INDICATORS FOR VISUAL INSPECTION.

2. IMPROVE THE ACCESSABILITY OF THE DESICCANT ASSEMBLIES.

3. A NEW METHOD TO CONTROL THE MOISTURE INGESTED OR TRAPPED IN THE CAVITIES BETWEEN THE WINDOW PANES

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TENTPOLE "B"
WINDOW CAVITY CONDITIONING SYSTEM
(Cont'd)

TECHNOLOGY SEARCH RESULTS:

1. NO DESICCANT HAS BEEN IDENTIFIED WITH THE DESIRED PROPERTIES.
2. DESICCANT ASSEMBLIES COULD BE RELOCATED TO THE PAYLOAD BAY.
3. BUILT-IN DRY PURGE FOR USE DURING THE ASCENT AND DESCENT PORTION OF THE FLIGHT.

CONCLUSIONS AND RECOMMENDATIONS:

1. THE DESICCANT ASSEMBLIES SHOULD BE RELOCATED TO BE READILY ACCESSIBLE.
2. THE DESICCANT ASSEMBLIES SHOULD BE REDESIGNED TO BE "QUICK CHANGE".
3. TESTED SPARES AT THE ASSEMBLY LEVEL SHOULD BE PROVIDED.

TENTPOLE "C"
WINDOW POLISHING

This is another tentpole which surfaces from the Study Operational Analysis. It took 144 hrs to accomplish this task during 51-L processing.

The technology requirement lists several possibilities on the chart. Best potential technology solution to date is diamond-type carbon coating for outer panes of windshields.

A Nitinol-jettisonable lexan-type overlay which doesn't require orbiter penetrations is another possibility.

TENTPOLE "C"
WINDOW POLISHING

OMI: V7253

OMI DESCRIPTION: TO POLISH THE ORBITER EXTERNAL WINDOW SURFACE FOR CONTAMINATION REMOVAL.

ASSOCIATED ISSUES: TECHNOLOGY / MAINTAINABILITY / COST/MANHOURS

TYPICAL SOURCE: KSC HISTORICAL SCHEDULES; SGOE/T STUDY (OPERATIONS ANALYSIS)

TYPICAL ISSUE DESCRIPTION: NO TIME WAS ALLOCATED FOR THIS TASK IN THE ORIGINAL 160-HRS
-- 60 HRS IS ALLOCATED ON THE STS-XX INTEGRATED OPERATIONS ASSESSMENT
-- IT TOOK 144 HRS TO ACCOMPLISH THE TASK DURING 51-L PROCESSING.

WINDOW CONTAMINATION IS APPARENTLY DUE PRIMARILY TO SEPARATION MOTORS

TECHNOLOGY REQUIREMENT: POSSIBLE DESIGN SOLUTIONS INCLUDE:

- DEVELOP A NEW MATERIAL FOR THE WINDSHIELD WITH SURFACE THAT CONTAMINATION WILL NOT ADHERE TO.
- PROVIDE AN OVERLAY OR TREATMENT THAT COULD EITHER BE JETTISONED AFTER ASCENT OR REMOVED AFTER FLIGHT.
- REDESIGN THE SRB SEPARATION MOTOR EXHAUST TO PREVENT IT FROM IMPINGING ON THE WINDOWS

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TENTPOLE "C"
WINDOW POLISHING
(Cont'd)

<u>TECHNOLOGY SEARCH RESULTS:</u>

POSSIBLE CANDIDATES:

- o CARBON COATING WITH HARDNESS PROPERTY OF DIAMONDS
    - o ION BEAM OR SPUTTERING
    - o CHEMICAL VAPOR DEPOSITION
    - o APPLICATION R&D
        - o SDIO (CRYSTALLINE CARBON.TECHNOLOGY INITIATIVE)
        - o PENN STATE (CONSORTIUM ON DIAMOND FILM)
        - o BATTELLE/TRACKING DEVELOPMENTS
        - o NASA/LeRC
        - o COMMERCIAL COMPANIES (CRYSTALLUME, OVONIC SYNTHETIC MATERIALS)
- o POLYCRYSTALLINE MgAL204 SPLINEL (FOR HIGH PERFORMANCE WINDOWS)
- o USE NITINOL TO JETTISON AN OVERLAY

<u>CONCLUSIONS AND RECOMMENDATIONS</u>

BEST BET - CARBON COATING (DIAMOND-LIKE) FOR ORBITER WINDSHIELDS.

RECOMMEND CONTACTING BRUCE BANKS, ELECTROPHYSICS OFFICE CHIEF, LeRC FOR FURTHER FOLLOW-UP

TENTPOLE "D"
TPS INSPECTION

NASA is already exploring the technology for a new TPS system. This tentpole is for the post-flight/pre-flight inspection of the existing tile system.

NASA is currently funding two separate studies:

NDT-TPS Moisture Measurement / Microwave Method

NDT Acoustic excitation/laser sensing

The potential of a Backscatter X-Ray, currently being used successfully by Boeing, Seattle for solid rocket engine inspection,is considered a viable candidate and will be pursued in Phase 2 of the Study.
To date we have been unable to obtain bonded tile samples for testing.

The NDT Acoustic Excitation/Laser Sensing Study by EG&G has completed Phase I. Results of that study indicates that this method has potential.

TENTPOLE "D"
TPS INSPECTION

?

OMI: V6028

OMI DESCRIPTION: TO PERFORM POST-LANDING AND PRE-FERRY VISUAL SURVEY INSPECTION OF ORBITER THERMAL PROTECTION SUBSYSTEM (TPS)

ASSOCIATED ISSUES: TECHNOLOGY / COST/MANHOURS

TYPICAL ISSUE SOURCE: ROCKWELL LSS, E/T STUDY OPS ANALYSIS, JSC RESIDENT OFFICE

TYPICAL ISSUE DESCRIPTION: VISUAL INSPECTION IS NOW BEING USED TO DETERMINE THE CONDITION OF THE TILES AND FILLER BARS AFTER FLIGHT. A VACUUM OPERATED PULL TEST IS USED TO VERIFY THE BOND LINE. BOTH OF THESE TESTS REQUIRE TOO MUCH TIME AND MANPOWER AND ARE NOT RELIABLE.

TECHNOLOGY REQUIREMENT: A RELIABLE TEST METHOD TO INSPECT THE TILE SYSTEM TO INCLUDE: CRACKS OR WATER IN THE TILE, ADEQUATE BOND LINE AND CONDITION OF FILLER BAR. INSPECTION METHOD SHOULD BE NON-INVASIVE, AUTOMATED, AND CAPABLE OF COMPUTER ANALYSIS.

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TENTPOLE "D"
TPS INSPECTION
(Cont,d

TECHNOLOGY SEARCH RESULTS

- o ACOUSTIC EXCITATION/LASER SENSING
  - o NASA/KSC FUNDED STUDY
  - o EG&G/IDAHO NATIONAL ENGINEERING LABORATORY (INEL)
  - o PHASE I COMPLETED -- RESULTS:
    - o NON-CONTACTING ACOUSTO-OPTIC SENSING SHOWN TO BE FEASIBLE
    - o RESONANCE VIBRATIONS OF THE TILES STUDIED ARE AFFECTED BY DISBONDS
    - o SIMILAR TILES HAVE SIGNIFICANTLY DIFFERENT SPECTRA BUT ALL OF THE TILES STUDIED SHOW COMMON SPECTRAL FEATURES
    - o INSIGHT GAINED IN UNDERSTANDING PHENOMENA AND REQUIREMENTS TO MAKE IT AN OPERATIONAL TOOL
  - o PHASE II OBJECTIVES
    - o REFINE AND QUALIFY SENSOR DESIGN
    - o MODEL AND ANALYSE THE DYNAMIC TILE BEHAVIOR
    - o PROTOTYPE SYSTEM DESIGN
    - o FABRICATION, CHECKOUT, INTEGRATION INTO ORBITER PROCESSING

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TPS INSPECTION
(Cont'd)

- o BACKSCATTER X-RAY IMAGERY
  - o POTENTIAL TECHNOLOGY FOR AUTOMATED NON-INVASIVE INSPECTION
  - o ESTABLISHED TECHNIQUE FOR IUS ENGINE INSPECTION
  - o REQUESTS FOR TILE SAMPLES (FROM KSC, JSC, AND ROCKWELL), TO MAKE CURSORY TRIAL TESTS AT SEATTLE, HAVE BEEN NON-PRODUCTIVE
- o CONCLUSIONS AND RECOMMENDATIONS
  - o ACCELERATE EG&G ACOUSTIC EXCITATION/LASER SENSING STUDY
  - o MAKE BONDED TILES AVAILABLE FOR LIMITED BACKSCATTER X-RAY TESTS

TENTPOLE "E"
POWER REACTANT STORAGE & DISTRIBUTION
(PRSD)

The launch processing time required for the fuel cells is not consistent with the requirement for an operational capability. A new technology requirement exists for fuel cells with minimal maintenance -- or replacement of fuel cells with new technology batteries.

Development of advanced fuel cells and batteries is proceeding slowly.

TENTPOLE "E"
POWER REACTANT STORAGE & DISTRIBUTION (PRSD)

OMI: V1091, V1022, V1077, V1093, V5R01, V5R03

OMI DESCRIPTION: POWER REACTANT STORAGE AND DISTRIBUTION (PRSD) SYSTEM DESERVICING, VENTING, TESTING, AND REMOVAL/INSTALLATION (INCLUDING TANK SET 4).

ASSOCIATED ISSUES: DESIGN CRITERIA / COST/MANHOURS / FAULT DETECTION / TIME/ON-LINE

TYPICAL SOURCE: ROCKWELL LSS, KSC HISTORICAL SCHEDULES, SGOE/T STUDY (OPS ANALYSIS)

TYPICAL ISSUE DESCRIPTION: OUR OPS ANALYSIS HIGHLIGHTED THIS TASK AS A TENTPOLE BECAUSE THE TASK TIME IS UNREASONABLE FOR AN OPERATIONAL VEHICLE. THE FOLLOWING TIME WAS USED DURING THE 51-L PROCESSING FLOW:

TANK SET 4 R&R	120 HRS	
OPF OPS & T/S	139 HRS	
PAD OPS (PURGE/LOAD)	36 HRS	(7 HRS WERE PAD CLEAR & 17 LOCAL CLEAR FOR THIS OPERATION)

TECHNOLOGY REQUIREMENT: DEVELOP NEW, HIGH POWER-DENSITY FUEL CELLS OR BATTERIES THAT REQUIRE SIGNIFICANTLY LESS ON-LINE MAINTENANCE THAN THE CURRENT FUEL CELL SYSTEM. REPLACE THE CURRENT FUEL CELLS.

TECHNOLOGY SEARCH RESULTS TO-DATE: EARLY CANDIDATES APPEAR TO BE:

1. ALKALINE/ALKALINE REGENERATIVE FUEL CELL SYSTEM (RFCS)
2. INDIVIDUAL PRESSURE VESSEL (IPU) $Ni\text{-}H_2$ BATTERY
3. NaS BATTERIES (LONG TERM)
4. $Li/SOCL_2$ BATTERIES (LONG TERM)

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POWER REACTANT STORAGE AND DISTRIBUTION (PRSD) (Cont'd)

CONCLUSIONS AND RECOMMENDATIONS

WITH THE EXISTING MISSION REQUIREMENTS FOR STS, THE FUEL CELL STILL APPEARS THE BEST OPTION FOR THE ORBITER ENERGY STORAGE SYSTEM. IF THE MISSION DURATION SHOULD CHANGE DRASTICALLY IN EITHER DIRECTION, HOWEVER, BATTERIES OR SOLAR SYSTEMS COULD BECOME VIABLE OPTIONS SUBJECT TO DETAILED TRADE STUDIES.

THE ORBITER FUEL CELLS ARE SEVERAL TIMES THE EFFICIENCY OF THOSE FOR APOLLO. DEVELOPMENT OF RELIABLE, EASILY MAINTAINABLE, HIGH DENSITY FUEL CELLS SHOULD BE PURSUED. SDIO HAS RECENTLY RELEASED AN RFP FOR A FUEL CELL TO HAVE 30 TIMES THE POWER DENSITY OF SHUTTLE FUEL CELLS.

FOR FUTURE VEHICLES, THERE ARE A NUMBER OF PROMISING ENERGY STORAGE DEVICES IN VARIOUS STAGES OF DEVELOPMENT IN THE AREAS OF: REGENERATIVE FUEL CELL SYSTEMS, Ni/H BATTERIES, Na/S BATTERIES, AND Li/SOCL BATTERIES. THE NaS BATTERY, AT THIS TIME, APPEARS TO BE THE BEST FOR MEETING LONG TERM FUTURE REQUIREMENTS. ITS CURRENT SHORTCOMINGS ARE WELL KNOWN AND REQUIRE FURTHER DEVELOPMENT (ACCELERATED RESEARCH FOR THE CERAMIC ELECTROLYTE AND CATHODE CONTAINER).ANY SPECIFIC RECOMMENDATIONS WOULD, OF COURSE, INVOLVE DETAILED TRADE STUDIES OF PERFORMANCE, ENERGY DENSITY, MAINTAINABILITY, LIFE CYCLE COSTS, DEVELOPMENT RISK, ETC.

TENTPOLE "F"
ORDNANCE OPERATIONS

From our Operations Analysis, it was evident that ordnance operations must be significantly reduced for efficient launch operations. In addition, the logistics cost of handling ordnance could be significantly reduced.

While there appears to be no evident replacement for solid rocket ignitors, there are a significant number of small ordnance devices (see list on chart) which could possibly be replaced with non-ordnance type devices.

TENTPOLE "F"
ORDNANCE OPERATIONS

OMI: V5012, B5304, S5009, T5142

OMI DESCRIPTION: PROCEDURES FOR INSTALLING, HOOKUP AND CHECKOUT OF ALL ORDNANCE DEVICES USED IN THE SHUTTLE SYSTEMS.

ASSOCIATED ISSUES: COST/MANHOURS / TIME/ON-LINE / SAFETY

TYPICAL SOURCE: KSC HISTORICAL SCHEDULES

TYPICAL ISSUE DESCRIPTION: A TOTAL OF 106 HRS OF PROCESSING TIME IS SPENT IN ORDNANCE OPERATIONS IN THE FOLLOWING AREAS:

OPF ---------------- 8 HRS
E/T CHECKOUT CELL - 24 HRS
VAB --------------- 44 HRS
PAD --------------- 36 HRS (20 HRS IS PAD CLEAR)

TECHNOLOGY REQUIREMENTS: REPLACE ORDNANCE RELEASE DEVICES WITH NON-EXPLOSIVE DEVICES. CANDIDATES FOR REPLACEMENT ARE:

- ORBITER MAIN & NOSE GEAR STRUT RELEASE
- ORBITER/ET SEPARATION BOLTS
- SRB HOLDDOWN BOLTS
- SRB/ET AFT SEPARATION SYSTEM
- SRB/ET FWD SEPARATION SYSTEM
- SRB FRUSTUM SEPARATION
- SRB PARACHUTE LINE CUTTER
- SRB MAIN PARACHUTE RELEASE
- TSM DROP WEIGHT RELEASE BOLTS
- ET H2 VENT ARM RELEASE
- (NOTE: IGNITION DEVICES ARE EXCLUDED)

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TENTPOLE "F"
ORDNANCE OPERATIONS
(Cont'd)

TECHNOLOGY SEARCH RESULTS TO DATE

* NITINOL APPLICATION (NITINOL - A NICKEL-TITANIUM "MEMORY" ALLOY, CAN BE MECHANICALLY DEFORMED AND THEN RETURNED TO ORIGINAL SHAPE BY HEAT WHILE EXERTING UP TO 300K PSI).

  - o DEVELOPED IN 1962 BY NAVAL ORDNANCE LAB, NOW NAVAL SURFACE WEAPONS CENTER (NSWC). "ON-THE-SHELF' ALL THESE YEARS, IT IS NOW STIMULATING NEW DESIGN CONCEPTS BECAUSE OF ITS UNIQUE PROPERTIES. EXAMPLES ARE:

    - o A NITINOL TORSION TUBE HAS BEEN USED TO TRIGGER THE RAPID AND RELIABLE RELEASE OF SATELLITE INSTRUMENT BOOMS, REPLACING AN EXPLOSIVE BOLT

    - o OTHER TYPICAL SATELLITE USES INCLUDE SUN SEEKER/TRACKER, TORSION DRIVES AND TRIGGER MECHANISMS

    - o DURING SEATTLE TECHNICAL SURVEY TRIP, ROBOTIC APPLICATIONS WERE DEMONSTRATED WHICH INDICATED FURTHER APPLICATIONS DEVELOPMENT OF NITINOL OR SIMILAR ALLOYS HAVING POTENTIAL FOR THIS TECHNOLOGY.

TENTPOLE "F"
ORDNANCE OPERATIONS
(Cont'd)

An early candidate appears to be Nitinol which is a Nickel-Titanium alloy with a memory triggered by temperature change. While this alloy has been known for many years, its availability has been limited and its potential use to replace existing devices not cost-effective. Now, however, potential space applications have brought it into the spotlight and development funding could greatly expand its uses. It is a definite candidate for replacing numerous ordnance devices.

TENTPOLE "F"
ORDNANCE OPERATIONS
(Cont'd)

TECHNOLOGY SEARCH RESULTS TO DATE (Cont'd)

- TECHNOLOGY REVIEW TRIP WAS MADE TO NSWC. DISCUSSION OF THE TEN (NON-IGNITION) ORDNANCE DEVICES ON SHUTTLE LED TO CONCLUSION THAT THE POTENTIAL IS THERE TO SUBSTITUTE NITINOL-TYPE DEVICES. FOLLOWUP ACTION SHOULD BE PLANNED.

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ORDNANCE OPERATIONS
(Cont'd)

CONCLUSIONS AND RECOMMENDATIONS

- o A SIGNIFICANT REDUCTION CAN BE MADE IN SHUTTLE AND FUTURE VEHICLE TURNAROUND TIME WITH ELIMINATION OF ORDNANCE DEVICES
- o NITINOL TECHNOLOGY HAS POTENTIAL TO ACCOMPLISH AT LEAST PART OF THIS FOR NON-IGNITION ORDNANCE
- o RECOMMEND DEVELOPMENT OF STATEMENT-OF-WORK FOR NSWC TO PROVIDE NITINOL DESIGN PARAMETERS APPROPRIATE TO DESIGN OF SUCH DEVICES.

  USING NSWC NITINOL PARAMETERS AND BASIC SHUTTLE DESIGN REQUIREMENTS, PREPARE RFP FOR SUBSTITUTE ORDNANCE DEVICES - BUT NOT LIMITED TO NITINOL TECHNOLOGY

TENTPOLE "G"
PAPERWORK AND OPERATIONAL REQUIREMENTS
(ULCE/CALS)

The evidence, in all the issue source documentation, is that (because of the overwhelming amount of paperwork) it has become impossible for everyone involved to work to the same information base. Throughout the system, different versions of the same information are being used at any one point in time. The issue description on the chart, taken from the Presidential Commission Report, is typical of well over 100 Issue Source documentation comments.

TENTPOLE "G"
PAPERWORK AND OPERATIONAL REQUIREMENTS
(ULCE/CALS)

OMI: ALL

OMI DESCRIPTION: ALL OMI'S, OMRSD'S, PROCEDURES, PRACA, AND OTHER PAPERWORK CONTRIBUTE TO OVERALL PROGRAM TENTPOLE.

ASSOCIATED ISSUES: PAPERWORK / AUTOMATION / CHANGE CONTROL / COST/MANHOURS / DESIGN / DISCIPLINE / INTEGRATION / INTERFACE / METHODS / LOGISTICS/SPARES / MAINTAINABILITY / MANAGEMENT / PLANNING PROCEDURE / QA / REQUIREMENTS / SAFETY / STANDARDS / TECHNOLOGY / WAIVERS

TYPICAL ISSUE SOURCES: PRESIDENTIAL COMMISSION REPORT; 51-L FINDINGS; PROPOSED MODS; VARIOUS COMMITTEE AND STUDY FINDINGS.

TYPICAL ISSUE DESCRIPTIONS: DURING THE DOCUMENT REVIEW, MANY AREAS OF UNCLEAR OR INCONCISE DOCUMENTATION WERE NOTED. INSTRUCTIONS IN WAD'S ARE FREQUENTLY NOT CLEAR OR PRECISE. THE OMRSD SYSTEM IS A VERY DIFFICULT ONE TO PAPER TRACK WITH RESPECT TO AUDITING REQUIREMENTS. THE OMP AND PSP, WHICH ARE THE KSC SUPPORTING DOCUMENTS TO THE OMRSD SYSTEM, ARE USUALLY INCORRECT IN THAT THE DEVIATIONS AND REVISIONS ARE INVARIABLY INCORPORATED BETWEEN THE PUBLICATION OF ONE DOCUMENT AND THE OTHER. FINALLY, THE OMP IS NOT A CLOSED LOOP SYSTEM AND IS SUFFICIENTLY COMPLEX THAT THE COGNIZANT SYSTEMS ENGINEER IS THE ONLY PERSON WHO KNOWS THE FULL STATUS OF OMRSD REQUIREMENTS.

BASICALLY, THE SYSTEM IS NOT SIMPLIFIED FOR THE ORIGINATOR, PERFORMER,OR VERIFIER; AND THEREFORE, IS NOT A TOOL, BUT AN IMPEDIMENT TO GOOD WORK AND GOOD RECORDS - THE ONLY REASONS FOR IT'S EXISTENCE.

TENTPOLE "G"
PAPERWORK AND OPERATIONAL REQUIREMENTS (ULCE/CALS) (Cont'd)

The magnitude of the requirements for a completely integrated, all-encompassing computerized system frightens everyone who understands the complexity of implementing it. However tough that is; there is no alternative since the piecemeal system(s) being implemented from the bottom up will never hack it.

TENTPOLE "G"
PAPERWORK AND OPERATIONAL REQUIREMENTS (ULCE/CALS) (Cont'd)

TECHNOLOGY REQUIREMENT: AUTOMATION OF PAPERWORK IS BEING IMPLEMENTED AT THE "GRASS ROOTS" LEVEL TO SOLVE INDIVIDUAL, LOCALIZED PROBLEMS -- EVERYONE HAS A DIFFERENT SYSTEM. THE COMPLEXITY OF THE TOTAL INFORMATION FLOW IS SO VAST THAT IT IS CURRENTLY IMPOSSIBLE FOR EVERYONE TO WORK WITH THE SAME INFORMATION IN REAL-TIME. THE REQUIREMENT EXISTS TO DEVELOP AN INTEGRATED "BIRTH-TO-DEATH", COMPUTERIZED, ALL-ENCOMPASSING SYSTEM -- DESIGN CRITERIA, DESIGN, MANUFACTURING, QA, OPERATIONS, LOGISTICS, AND ALL OTHER INVOLVED DISCIPLINES, NASA CENTERS, AND CONTRACTORS.

TECHNOLOGY SEARCH RESULTS TO-DATE: A SEARCH OF AVAILABLE TECHNOLOGY, USING THE XTKB, IDENTIFIED A DEVELOPMENTAL PROGRAM AT WPAFB DEALING WITH THE METHODOLOGY OF "UNIFIED LIFE CYCLE ENGINEERING".

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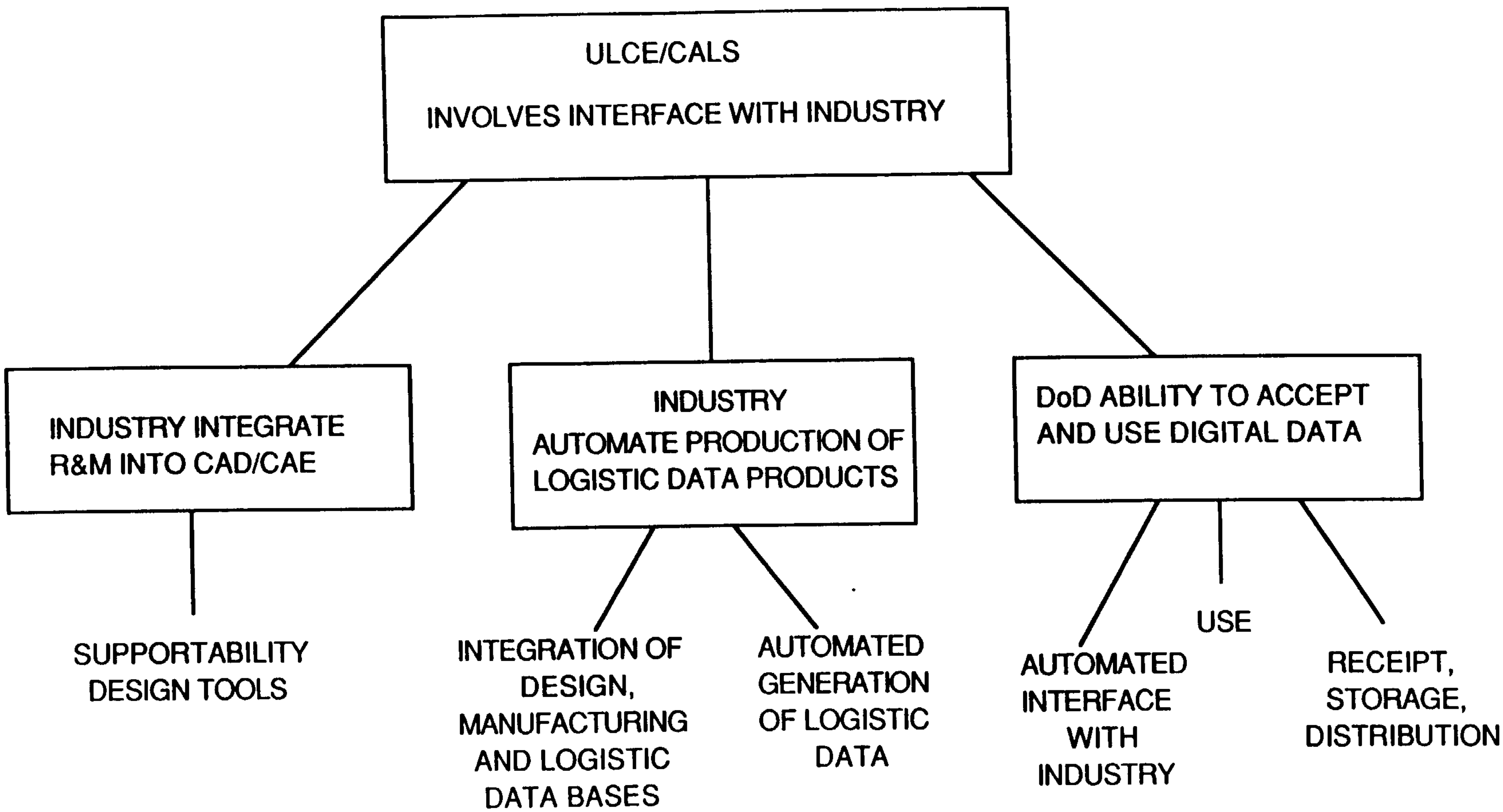
S G O E/T STUDY
PHASE 1 FINAL
PRESENTATION
by BOEING

ULCE/CALS SCOPE

PRESENTED AT
KSC
APR. 6,1987



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UNIFIED LIFE CYCLE ENGINEERING (ULCE)

"ULCE is a WPAFB term, Within the DoD the same activity is "CALS" (Computer Aided Logistics System).

ULCE contains the basic computer aided tools required to support the new design methods.

To achieve maximum effect from ULCE/CALS requires that NEW management techniques be placed in effect and compliance must be from the TOP down.

UNIFIED LIFE CYCLE ENGINEERING (ULCE)

- INTEGRATED DESIGN TOOLS
  - INTEGRATED DESIGN SUPPORT SYSTEM (THE BACKBONE OF ULCE)
  - R & D COMPUTER AIDED DESIGN TOOLS
    - CREW CHIEF AND CAD MODELING
    - RELIABILITY AND MAINTAINABILITY THROUGH COMPUTER-AIDED DESIGN
    - TURNAROUND AND RECONFIGURATION SIMULATION
  - OPERATIONS COMPUTER AIDED TOOL
    - INTEGRATED MAINTENANCE INFORMATION SYSTEM
- IMPROVED DESIGN MANAGEMENT

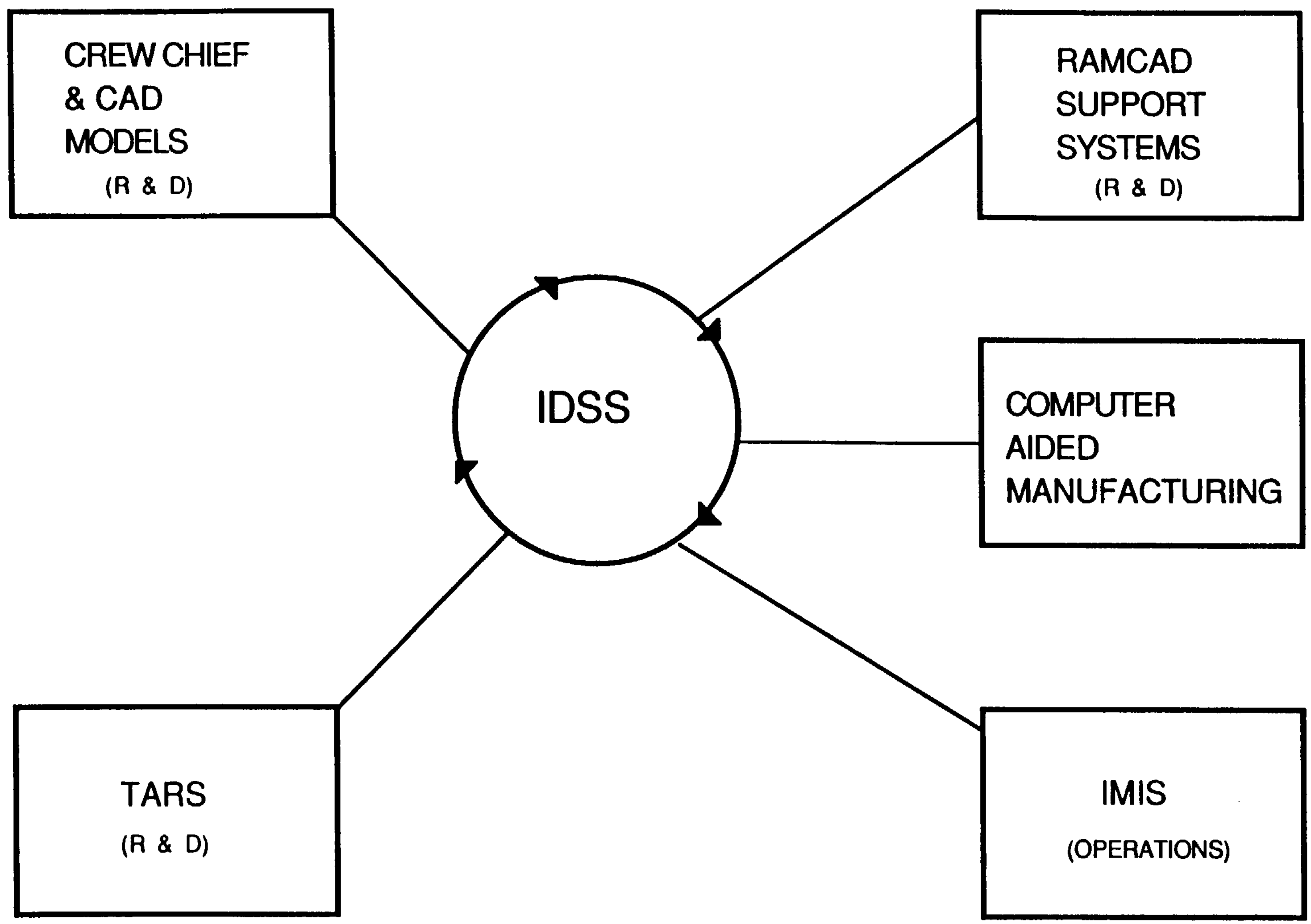
BACKBONE OF ULCE

IDSS provides the basis for electronic interchange of information between all phases of the project, a 'Birth to Death' information system.

Allows for the technology to expand and grow within each of the major components i.e. R&D, Manufacturing, operations by standardizing the interchange of information between them, a layered architecture.

Utilization of IDSS must be mandated from the start of a new project.

INTEGRATED DESIGN SUPPORT STRUCTURE



IDSS IS THE BACKBONE OF ULCE/CALS

INTEGRATED DESIGN SUPPORT SYSTEM

IDSS will make a significant improvement over the process of paper based information interchange, and allow the user to concentrate on the quality of the data, rather then its quanity.

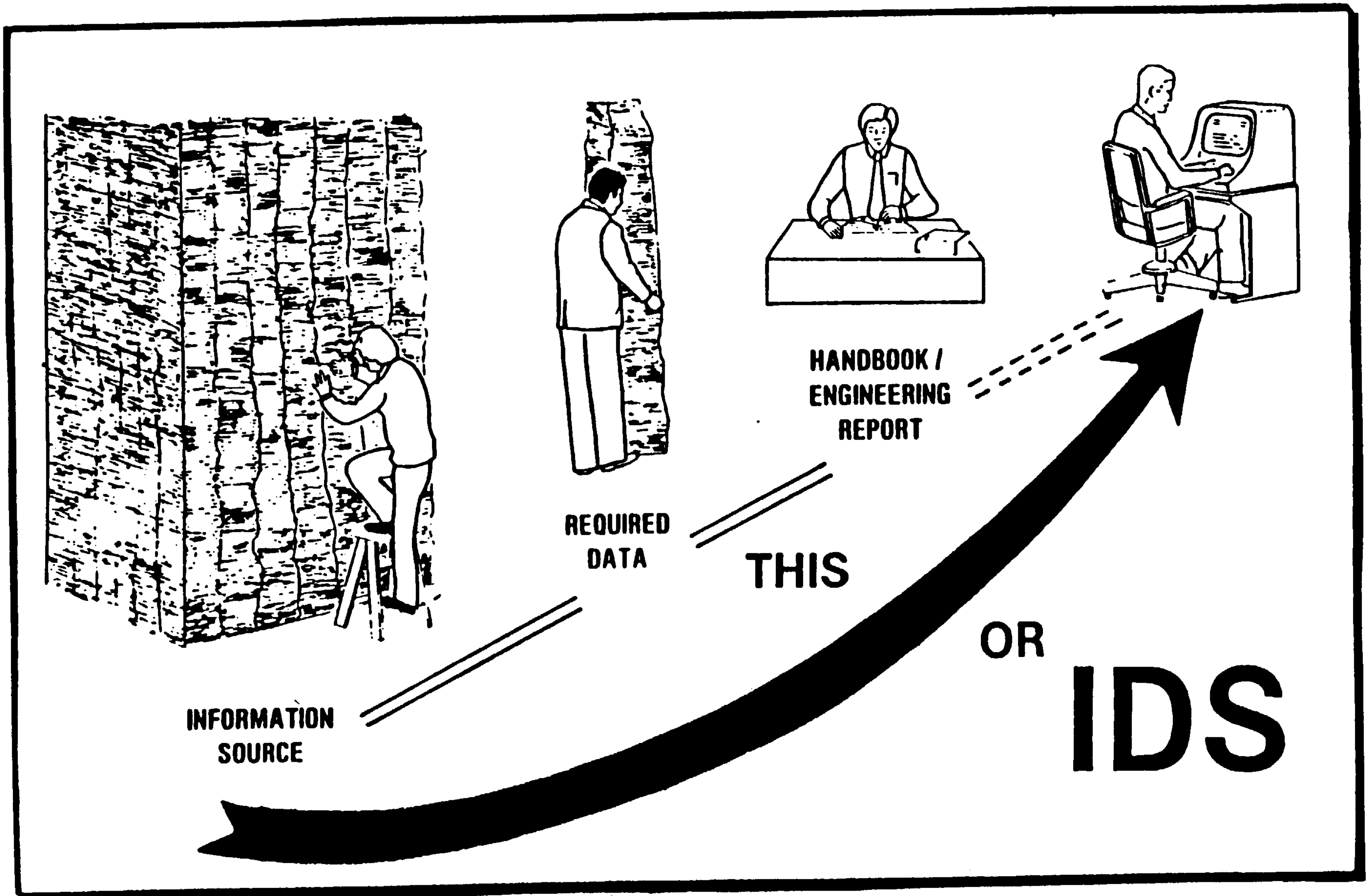
DoD has placed a cost of MAINTAINING their current paper based information systems at $400M annually, mainly in labor.

S G O E/T STUDY
PHASE 1 FINAL
PRESENTATION
by BOEING

INTEGRATED DESIGN SUPPORT SYSTEM

INFORMATION MANAGEMENT SYSTEM

PRESENTED AT
KSC
APR. 6,1987

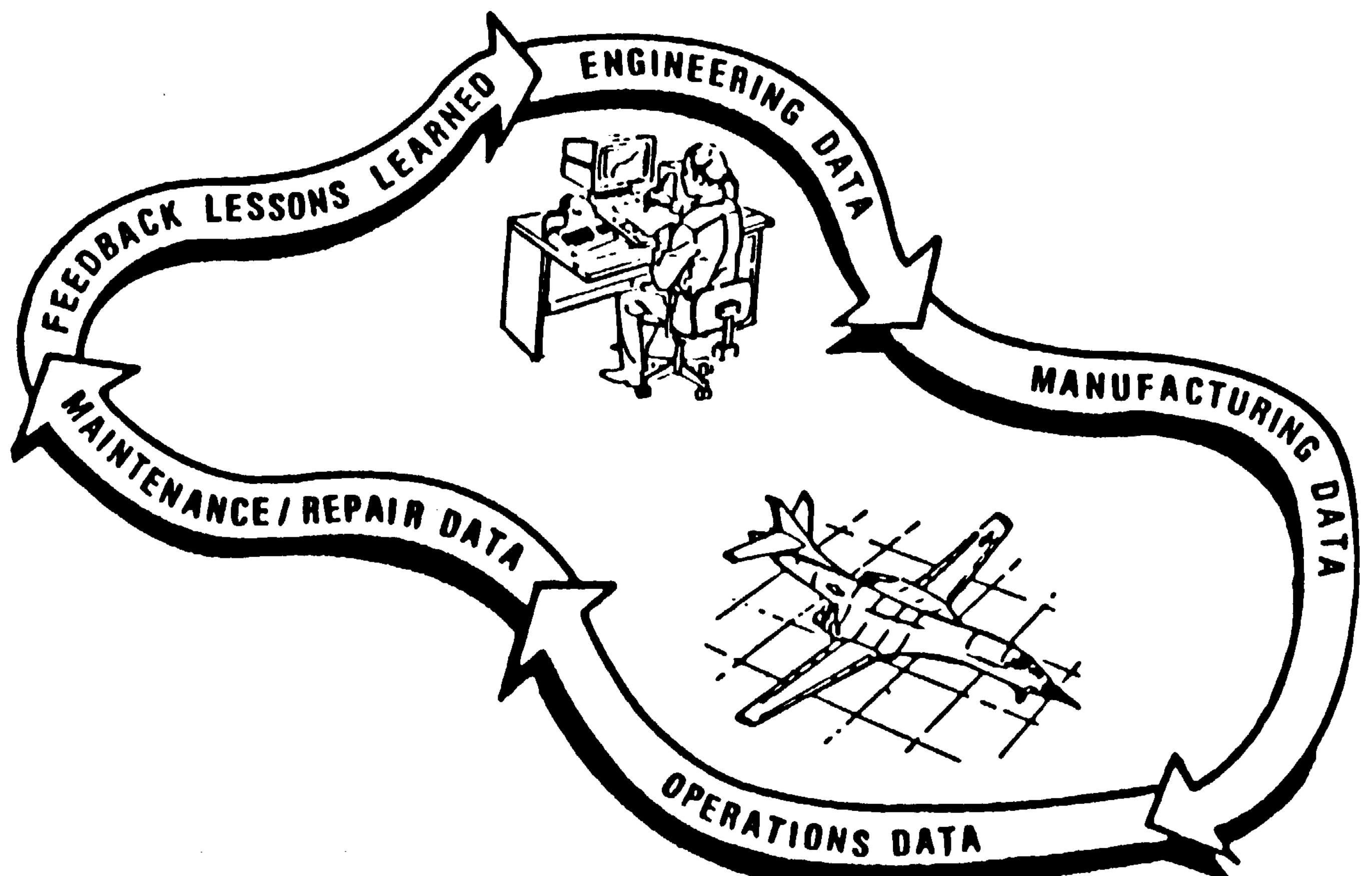


INTEGRATED DESIGN SUPPORT SYSTEM (CONCEPT)

IDSS will provide for an almost effortless flow of information throughout all phases of a project, i.e, R&D, Manufacturing, Operations.

This will allow each area to be cognizant of the effect of their products(output) on the rest of the system, providing a path for lessons learned.

INTEGRATED DESIGN/SUPPORT SYSTEM
CONCEPT



STRUCTURE OF MIL STANDARD 1840A

MIL-STD-1840A will provide the basis for DATA FORMATS for all of the systems discussed, and all future systems to be developed.

Provides standards for both text and graphical data.

Has been mandated to programs such as:

ATF

LHX

JVX

SSN-21

STRUCTURE OF MIL-STD-1840A

IDSS IMPLEMENTED BY THIS NEW MIL-STD

<u>MIL-STD-1840A</u>

BASIC
APPENDICES
A. TECHNICAL PUBLICATIONS
B. PRODUCT DATA
   1. ENGINEERING DRAWINGS
   2. PRINTED WIRING BOARDS
   3. 3-D PRODUCT MODELS

<u>MIL-SPEC-SGML</u>

BASIC
APPENDICES
A. DDTD FOR MIL-M-38784 (OTHERS TO BE ADDED)
B. TAGGING SET

(TEXT)

<u>MIL-SPEC-IGES</u>

BASIC
APPENDICES
A. TECH ILLUSTRATIONS
B. ENGINEERING DRAWINGS
C. PRINTED WIRING BOARDS
D. 3-D PRODUCT MODELS

(GRAPHICS)

CREW CHIEF

Crew Chief is a working system , available today.

Is used to evaluate the performance of the technician within a specific working environment i.e Payload bay, flight deck, equipment racks etc.

Very useful in evaluating proposed design for maintainability, support analysis.

CREW CHIEF

- 3-D SKELETAL LINK SYSTEM
- MATH MODELS OF ANTHROPOMETRY
- BODY SEGMENT MOBILITY LIMITS
- STRENGTH CAPABILITY ANALYSIS
- VISIBILITY AND ACCESSABILITY ANALYSIS

RELIABILITY and MAINTAINABILITY through COMPUTER AIDED DESIGN

There are several R & M computer models available today in support of both electrical and mechanical systems design analysis.

Very few will allow interchange of information because of the lack of integrated information format standards (IDSS will provide this standard).

Will provide near real time R&M maintainability modeling for early on design analysis.

RELIABILITY AND MAINTAINABILTY through COMPUTER AIDED DESIGN (RAMCAD)

- INTEGRATED COMPUTER AIDED ENGINEERING (CAE) / COMPUTER AIDED DESIGN (CAD) WITH R & M MODELS AND DATABASES
  - 70 MODELS
  - 35 DATABASES
  - VERY FEW INTERFACE WITH CAD/CAE
- PROVIDES NEAR REAL-TIME RELIABILITY & MAINTAINABILITY DESIGN ANALYSIS
- 82% OF ALL MODELS AND DATABASES ARE GOVERNMENT OWNED

TARS
(TURNAROUND AND RECONFIGURATION SIMULATION)

Similar to Crew Chief, but emphasis is more towards the vehicle and how is interacts within the processing facility.

Interface of the man with the vehicle and facility is also provided.

Used to eliminate the need for mock-ups and pathfinders.

TARS
(TURNAROUND AND RECONFIGURATION SIMULATION)

- INTERFACE OF MAN AND MACHINE SIMULATION
- SIMULATION FOR ACCURACY, EFFICIENCY AND SUPPORTABILITY
  - VALIDATE VEHICLE MECHANICAL SUBSYSTEM INTEGRATION
  - VERIFY PHYSICAL ACCESS
  - REDUCE REQUIREMENTS FOR MOCK-UPS AND PATHFINDERS

INTEGRATED MAINTAINENCE INFORMATION SYSTEM (IMIS)

IMIS has the largest payback potential for current Shuttle efficiency improvement.

Is similar in process to, but provides a larger degree of integration than, the current SPDMS.

Potential savings in current Shuttle fleet operations... $2.6B.

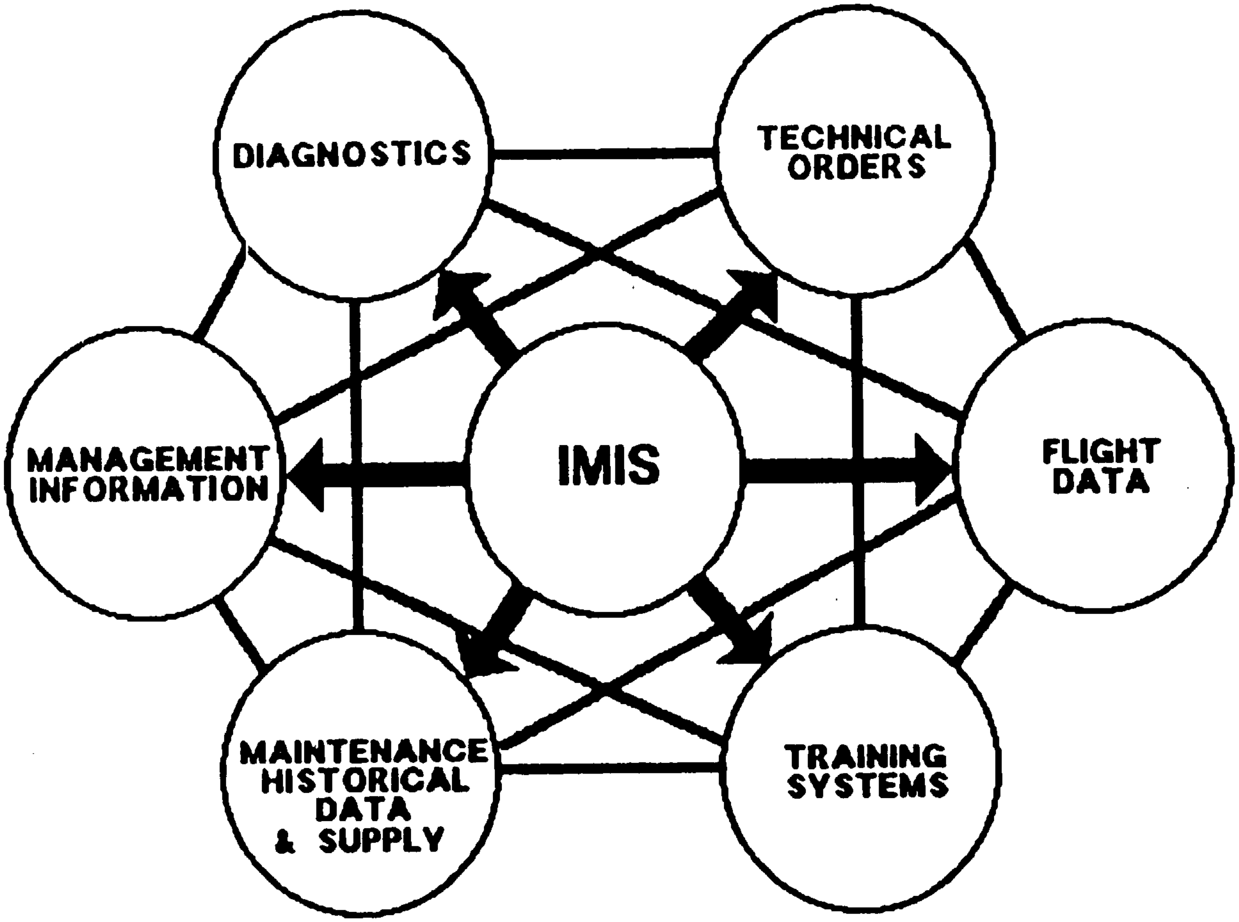
Potential increase in flight rate over 8/year(best so far FY 1985)...30%.

This technology is in development, proof of concept is complete, draft RFP is on the street.

SGOE/T STUDY
PHASE 1 FINAL
PRESENTATION
by BOEING

INTEGRATED MAINTENANCE INFORMATION SYSTEM (IMIS)

PRESENTED AT
KSC
APR. 6,1987



SAVINGS RESULTING FROM USE OF IMIS (EXAMPLE)

OFF-LINE ACTIVITIES

PARTS, TOOLS, TEST EQUIPMENT & SE (MERL)	24 hrs
RESOLUTION OF OPEN PAPER	72 hrs
CAL-CERT VERIFICATION	2 HRS
PROCEDURE VERIFICATION DEVIATION/WAIVERS (TCR)	48 HRS
TAIR-BOOK STATUS CONTROL	12 HRS
PAPER CLOSE-OUT	72 HRS
SUMMARY REPORT	8 HRS
MALFUNCTION RESOLUTION/APPROVAL TO PROCEED	6 HRS
TOTAL OFF LINE ACTIVITIES	244 HRS

SAVINGS DUE TO INCORPORATION OF IMIS CONCEPTS

OFF LINE SAVINGS OF 80% OR 50 HRS VS 244 HRS

RUN TIME SAVINGS OF 30% OR 112 HRS VS 168 HRS

SAVINGS RESULTING FROM USE OF IMIS (EXAMPLE)

Seq. Task No: 79.000 Facility: OPF OMI Page Count: 591
OMI No: V1007 OMI Title: PVD STRUCTURAL LEAKAGE/POSITIVE PRESSURE TESTING AND FILTER MAINTENANCE (LPS)
Subtask OMI(s): V1111 , V3511 , V3512 , V3555 ,
V5067 , , , , ,
, , , ,
Prerequisite Task OMI:
Hazard: N Level: Vehicle Power Required: Y LCC Support Required: Y
GSE: A70-0769 , C70-1187-2 , F70-0033-1 , S70-0534 ,
S70-0858 , S70-1310 , ,

Activity Description:TO DETERMINE THE LEAKAGE ACROSS THE ORBITER'S FUSELAGE AND STRUCTURAL BULKHEADS AND FOR COMPARTMENTS TO MAINTAIN A POSITIVE PRESSURE UNDER NORMAL PURGE FLOWRATES AND INSTRUCTIONS TO REMOVE AND REPLACE PVD VENT FILTERS.

Personnel:	Head Count	Man Hours	Remarks		
Mech. Tech:	2	48.0			
Elec. Tech:	2	48.0			
Quality:	1	24.0	N/A		
LCC Ops:	0	0.0	N/A		
Support:	0	0.0	N/A		
Engineering:	2	48.0	N/A		
Total:	7	168.0		Time:	24.0

Issues: MAINTAINABILITY :DESIGN CRITERIA :TIME/ON-LINE :

DoD FUNDING for ULCE/CALS

DoD commitment for the next 36 months is $686M.

This represents a combined Army, Navy, Air Force (Joint Pentagon) activity.

Where is NASA??

Can they afford not to participate??

DOD FUNDING
for
ULCE/CALS

FY 1987 DOLLARS (MILLIONS)

	FY 87	FY 88	FY 89
OSD	13.6	13.0	13.0
ARMY	23.6	41.2	149.5
NAVY	84.0	89.0	44.0
AIR FORCE	52.5	58.2	65.2
DIA	---	22.4	16.5
DOD TOTAL	173.7	223.8	288.2

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A DRIVE BEGINS TO CREATE A CAD/CAM MILITARY MARKET

Some 50 companies and standards-setting agencies involved in computer-aided design and engineering are working with the Pentagon to produce a report on how the military can shift from its reliance on paper designs and documentation to CAD/CAM and related electronic systems. The group's interest is being spurred by the Defense Department's Computer-Aided Logistics Support program. CALS requires that all U. S. military services use digital data to support logistics by 1990, a requirement that is expected to spark a major military market in hardware and software for storing and processing technical data. The Yankee Group, a Boston market research and consulting group, estimates that the five Naval Systems Commands alone will spend almost $2 billion on CALS for hardware, software, training, documentation, and maintenance. Stand-alone work stations for 10% of the Navy's engineering personnel could ring up $100 million, says the Yankee Group. Another reason the companies and agencies are eager to get involved in the Pentagon's planning is self-defense. The military, and particularly the Navy, which does far more of its own design and engineering than the other services, will almost certainly use its buying power to enforce a set of standards. The group contributing to the report wants to have a say in what standards are adopted. The report is scheduled to be published by the National Computer Graphics Association by the end of April. □

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RECOMMENDATION

"GRASS ROOTS" IMPROVEMENTS CAN BE REALIZED IN CURRENT SYSTEMS BY IMPLEMENTING CONCEPTS SUCH AS IMIS (INTEGRATED MAINTENANCE INFORMATION SYSTEM).

ALL FUTURE PROGRAMS SHOULD MANDATE, FROM THE TOP, THE UTILIZATION OF THESE METHODOLOGIES.

DESIGN/BUILD TEAMS (STRUCTURE)

New management technology is required to achieve maximum effect from computer aided design tools.

New design management is the hardest part to establish but without it the new design methods will not work.

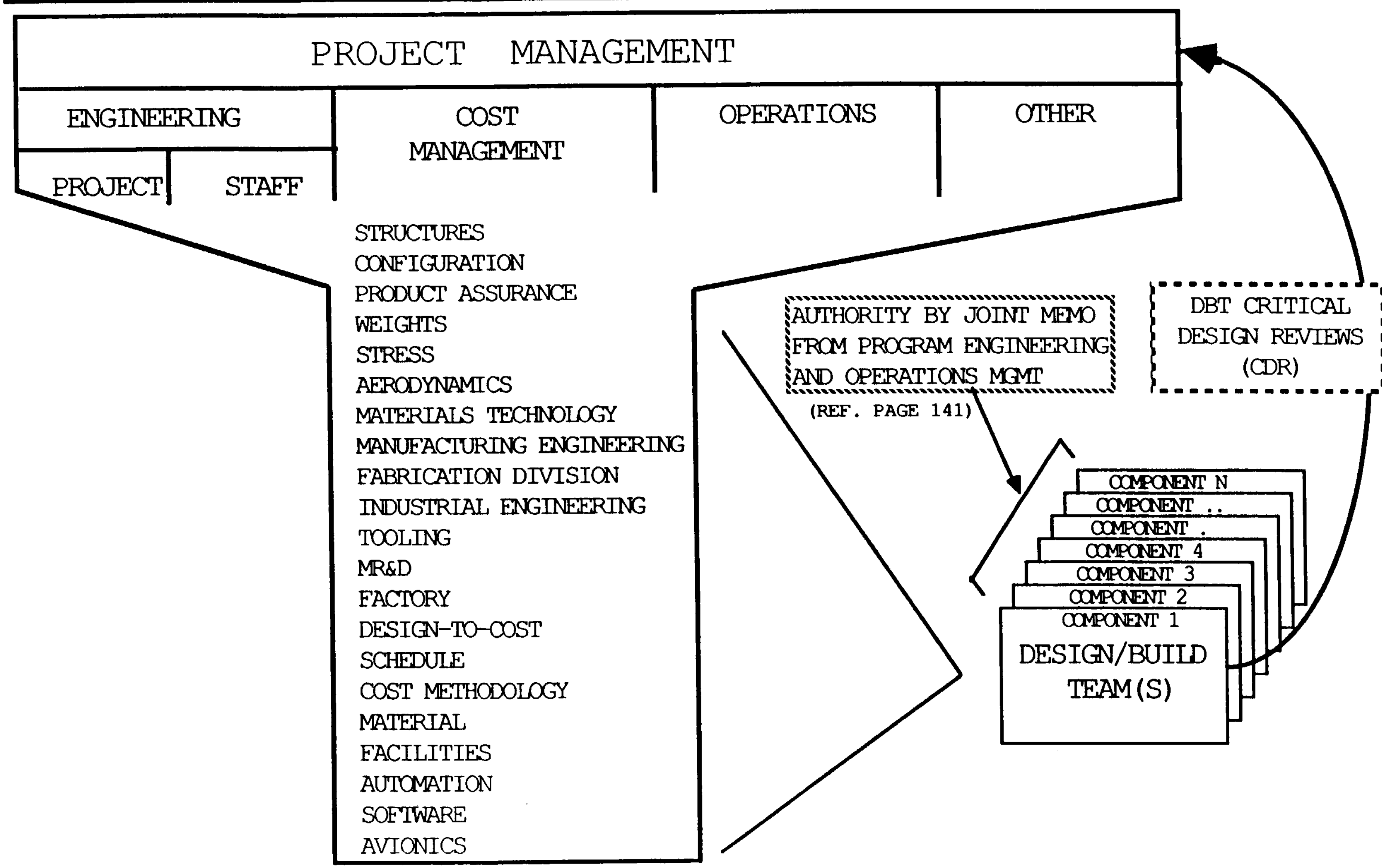
Design Build Teams DO NOT report back to functional fathers. They have complete design responsibility, within the team, for their specific assignment per Joint Authority Memo.

Design/Build Team(s) reports directly to Project Management.

Requires larger effort on the part of System Engineering to establish firm operational, performance and cost requirements to the sub-system level.

These new management methods are in place within Boeing. Pilot projects have proven their value.

DESIGN / BUILD TEAMS (STRUCTURE)



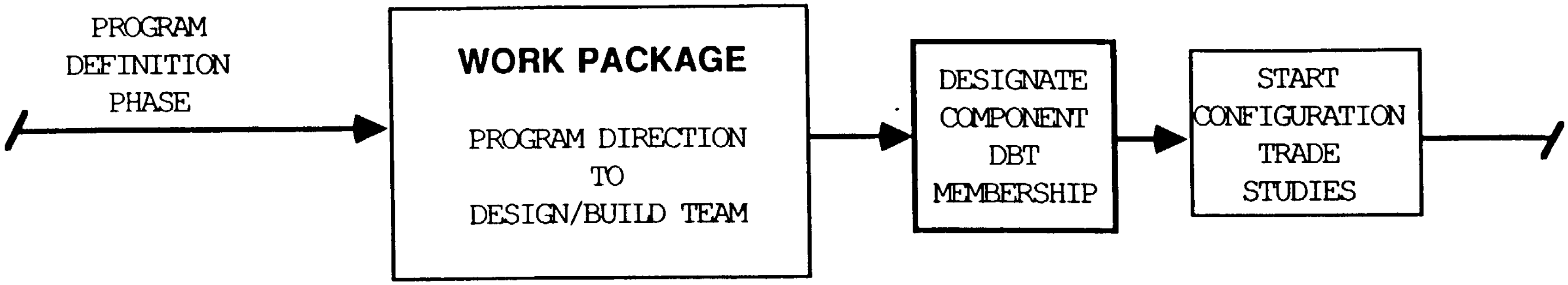
DESIGN/BUILD TEAM (DBT) AUTHORITY

All Design/Build Teams (DBT) will be initiated by joint memo from Program Engineering and Operations Management.

The memo will establish each design package and the schedule for its implementation by the assigned team.

It will be the responsibility of the Engineering and Manufacturing management to identify the DBT co-chairmen. The co-chairmen will consist of one person from Engineering Project Design and one from Manufacturing Engineering.

DESIGN/BUILD TEAM (DBT) AUTHORITY



- o COMPONENT CONFIGURATION
- o WEIGHT
- o FUNCTIONAL REQUIREMENT
- o BASELINE SOW
  (STATEMENT-OF-WORK)
- o BASELINE COMPONENT COST
- o BASELINE MARKET VALUE
- o TRADE STUDY FACTORS
- o SELECT DBT CO-CHAIRMEN
  (ENGR. & MFG.)
- o SCHEDULE
- o AUTHORITY OF DBT

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DESIGN / BUILD TEAMS
(INDEPENDENT)

- DBT SUPPORTED BY DESIGN-TO-COST DEVELOPMENT OF BASELINE COST
  (AS TARGET COST INPUTS TO TRADE STUDIES)

- DBT TO ASSESS PROGRAM RISK FOR EACH TRADE STUDY CANDIDATE
  (HIGH RISK CANDIDATES REFERRED "UPSTAIRS" FOR DECISION GO AHEAD)

- DBT CONTINUES OPERATION THRU DETAILED DESIGN RELEASE PHASE
  (TO ASSURE REALIZATION OF PROJECTED COST REDUCTIONS)

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DESIGN / BUILD TEAMS
(RESPONSIBILITY)

- DBT IS RESPONSIBILE TO ACHIEVE TECHNICAL AND COST GOALS
  (MONITORED REGULARLY BY PROGRAM MANAGER FOR COMPLIANCE WITH TOTAL
  REQUIREMENTS)
- DBT MEMBERS MUST FEEL THAT THEY HAVE THE RIGHT AND OBLIGATION TO INFLUENCE OTHER TEAM MEMBERS. MEMBERS ARE REQUIRED TO COORDINATE WITH AFFECTED TEAMS IN THE INTERFACE AREAS.
- DBT CORE MEMBERS MUST BE CO-LOCATED TO PROVIDE PERSON-TO-PERSON CONTACT AND SPEED THE INFORMATION FLOW.

MANAGEMENT TECHNOLOGY

This New Management method will shatter existing "Rice Bowls".

Will instill a real feeling of team participation in ALL project Members.

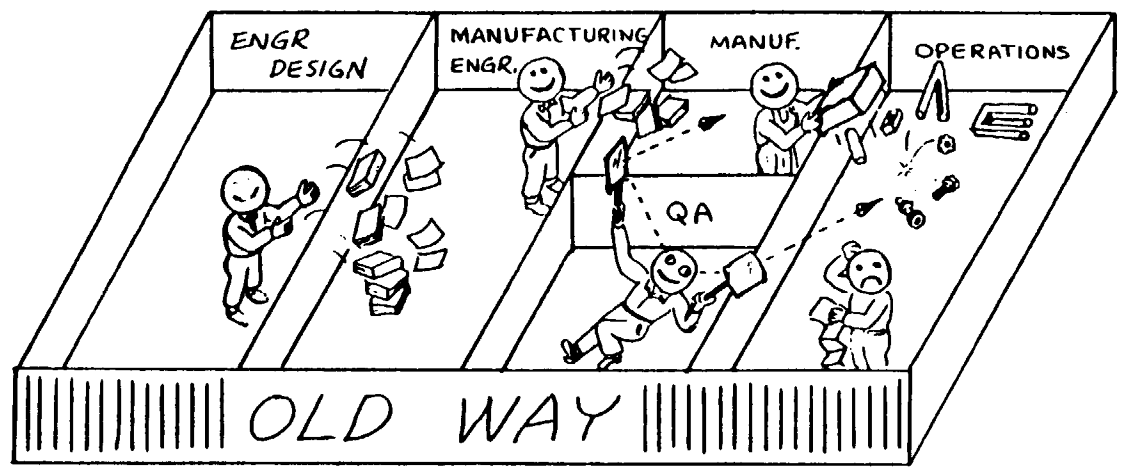
Is also the most difficult to achieve because it requires EACH project member to:

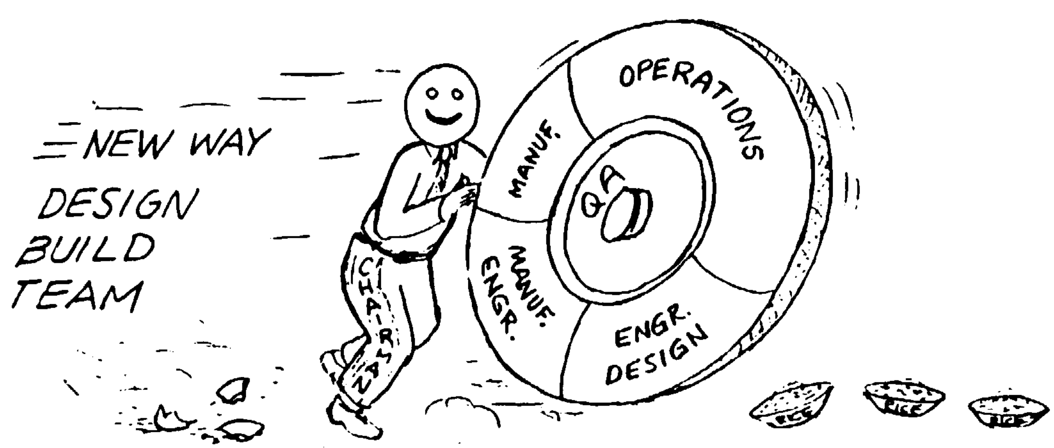
Desire -- the change in the way of doing business

Belief -- that change can be accomplished within the system

This requires firm leadership from the TOP.

MANAGEMENT "TECHNOLOGY"





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TRADE STUDIES

TENTPOLE	TRADE DESCRIPTION	POTENTIAL MAGNITUDE
SSME PROCESSING	SHOP DESIGN/CONSTRUCTION COST VERSUS LONG RUN VARIABLE LABOR AND TIME SAVINGS	SIGNIFICANT ON-LINE PROCESSING TIME AND MANPOWER SAVINGS
PLB/AFD RECONFIGURATIONS	DESIGN AND FABRICATION OF STRONG-BACK TRADED AGAINST PER FLIGHT SAVINGS	SIGNIFICANT ON-LINE PROCESSING TIME REDUCTION
CABIN AIR	REDESIGN OF CABIN AIR SYSTEM TO PRECLUDE FUTURE DIRECT LABOR EXPENDITURES	RELATIVELY SMALL IN THAT NO ON-LINE SAVINGS ARE PROJECTED
WEIGHT & C.G. OPS.	INSTALLATION COST OF LOAD CELLS VERSUS SIGNIFICANT PROCESSING SPEEDUP	SIGNIFICANT OPF REDUCTION OF ON-LINE TIME
PAYLOAD BAY CLEANING	SIGNIFICANT UP-FRONT COSTS OF REDESIGN AND MODIFICATION TO OPF TO ACHIEVE LONG RUN LABOR REDUCTIONS	PROBABLY NOT COST EFFECTIVE. PAYLOAD REQUIREMENTS BETTER SOLUTION FROM OPS VIEWPOINT
ANOMALY RESOLUTION	HIGH UP-FRONT DEVELOPMENT COSTS VS SIGNIFICANT REDUCTION IN LCC AND TURNAROUND TIME	WELL DOCUMENTED, MAJOR LIFE CYCLE COST SAVINGS IN THE $B FOR FUTURE VEHICLE. LIMITED POSSIBILITIES FOR SHUTTLE.

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TRADE STUDIES (Cont'd)

TENTPOLE	TRADE DESCRIPTION	POTENTIAL MAGNITUDE
WCCS FUNCTION CHECKS	REDESIGN FOR ACCESSABILITY	MODERATE SAVINGS, MAINLY MANHOURS. PROBABLY NOT COST EFFECTIVE FOR SHUTTLE.
WINDOW POLISHING	SMALL COST OF COATING	NO ON-LINE SAVINGS, SIGNIFICANT DIRECT LABOR SAVINGS
TPS INSPECTION	SIGNIFICANT IMPLEMENTATION COST FOR R & D OF AUTOMATED SYSTEM.	MAJOR REDUCTION IN ON-LINE TIME AND OFF-LINE MANHOURS
FUEL CELL OPERATIONS	REQUIRES DEVELOPMENT OF NEW LOW MAINTENANCE FUEL CELLS	SIGNIFICANT IMPROVEMENT POTENTIAL IN ON-LINE AND OFF-LINE MANHOURS
ORDNANCE OPERATIONS	MODERATE REDESIGN AND MATERIAL COSTS COMPARED WITH SIGNIFICANT LABOR SAVINGS AND REDUCED TURNAROUND TIME	VERY SIGNIFICANT ON-LINE REDUCTION; WOULD SPEED UP ENTIRE SHUTTLE PROCESSING FLOW; SIGNIFICANT SAVINGS.
PAPERWORK REQUIREMENTS	INCORPORATE ULCE CONCEPTS	LIFE CYCLE COST REDUCTIONS IN $B FOR FUTURE VEHICLES. LIMITED FOR SHUTTLE EXCEPT FOR IDSS/IMIS

OPERATIONAL LIFE CYCLE COST FACTORS

OPERATIONS COST (FY 85 Actuals per NASA)

$2189.4M for 8 Flights

For Example:

$$SRB = \frac{464.2M}{2189.4M} = 21.2\% \text{ of Ops Cost}$$

$$(FY\ 85)\ Cost/Flt = \frac{2189.4M}{8} = 273M \text{ or } 246M \text{ (From Congressional Record)}$$

LCC

Ops	246 M/Flt x 100 Flt/Veh =	24.6 B/Veh	=	86%
R & D		1.65 B/Veh	=	6%
Manufacturing		2.4 B/Veh	=	8%
Total		28.6 B/Veh		100%

OPERATIONAL LIFE CYCLE COST FACTORS

LCC COSTS AS A PERCENT OF ACTUAL 1985 OPERATIONS
-DATA SUPPLIED BY NASA TO OMB & CBO-

Item	Operations % x .86	= LCC %
SRB	21.2	18.23
ET	18.9	16.25
GRD OPERATIONS	15.9	13.68
PROPELLANTS	1.4	1.2
GSE	1.1	0.95
FLIGHT OPERATIONS	15.6	13.42
ORBITER EQUIPMENT	7.4	6.36
CREW EQUIP	1.7	1.46
SSME	2.4	2.06
CONTRACT ADMIN.	.9	0.77
NETWORK SUPPORT	1.0	0.86
R & PM	12.5	10.75
Total	100.0%	86.0%

Estimated LCC for a single Orbiter = $28.7B
Assumed number of flights per Orbiter = 100
Remaining portion of LCC is Design & Manufacturing = 14%

COST TRADE - FUTURE VEHICLES
ANOMALY RESOLUTION

ANOMALY RESOLUTION - FUTURE VEHICLES

There are two very significant cost trades in the Study:

1) Anomaly Resolution

2) Unified Life Cycle Engineering/Computer Aided Logistics System (ULCE/CALS).

The Anomaly Resolution chart shown here (based on DoD program statistics) shows the impact on Life Cycle Costs when the Anomaly Resolution Components are instituted at the concept phase of a program and carried all the way through.

The Estimate of Anomaly Resolution Cost Impact figures were extracted from the "Integrated Testing and Maintenance Technologies" WPAFB, 1983 report.

S G O E/T STUDY
PHASE 1 FINAL
PRESENTATION
by **BOEING**

COST TRADE - FUTURE VEHICLES
ANOMALY RESOLUTION

PRESENTED AT
KSC
APR. 6,1987

ANOMALY RESOLUTION - POTENTIAL COST IMPACT

LIFE CYCLE PHASE	% OF SYSTEM LIFE-CYCLE COST	X	ESTIMATE OF ANOMALY RESOLUTION COST IMPACT	=	IMPACT OF ANOMALY RESOLUTION ON LIFE-CYCLE COST
o **R&D Design**	10%		Up 10%		Up 1.0%
o **Production**	30%		Up 5%		Up 1.5%
o **Operation & Maintenance**	(60%)				
Repair Labor Costs	32%		Down 13.1%		Down 4.2%
Spares & Repair Material	14%		Down 15%		Down 2.1%
Operation	10%		Down 15%		Down 1.5%
Initial Logistics Support	4%		--------		--------
	100%		----		$\boxed{\text{Down 5.3\%}}$

FOR 100 FLIGHT VEHICLE, THIS REPRESENTS (.053 X 28.6B) = $1.5B

SHUTTLE LIFE CYCLE COST SAVINGS UTILIZING ONLY IMIS CONCEPTS

This approach involves a re-design of SPDMS and associated systems, provides a realistic approach to improved Shuttle operations efficiencies.

A savings of 28% of the ground operations costs (16% of the LCC) yields 4.5% gross savings, less 1.1% (source OMB) cost of ground processing systems provides a net cost impact of 3.4%.

3% net LCC savings at currrent Shuttle LCC of $28.65B (source OMB) is $859M per vehicle.

SHUTTLE LIFE CYCLE COST SAVINGS UTILIZING ONLY IMIS CONCEPTS

LIFE CYCLE PHASE	% OF SYSTEM LCC	ULCE COST IMPACT	IMPACT OF ULCE ON LCC
R & D DESIGN	6%	0%	N/A
PRODUCTION	8%	0%	N/A
O & M	86%	DOWN 3.4%	DOWN 3%

NET: DOWN 3%

SHUTTLE LIFE CYCLE COSTS UTILIZING ALL ULCE CONCEPTS

These figures are based on achieving a DOD/commerical LCC distribution.

The conclusion from this chart is Shuttle vehicle modifications will have to be evaluted on an <u>individual block modification basis</u> and will not make any significant improvements directly in Vehicle LCC because of the significant cost associated with re-manufacturing.

Proof of concept may be a more important factor.

SHUTTLE LIFE CYCLE COSTS UTILIZING ALL ULCE CONCEPTS

LIFE CYCLE PHASE	% OF SYSTEM LCC		ULCE COST IMPACT	IMPACT OF ULCE ON LCC
	current	goal		
R & D DESIGN	6%	10%	up 66%	up 6.6%
PRODUCTION	8%	30%	up 375%	up 112.5%
O & M	86%	60%	down 30.2%	down 18.1%

net: up 101%

FUTURE VEHICLE -- LIFE CYCLE COST SAVINGS UTILIZES ALL ULCE CONCEPTS

Based on data from 'INTEGRATED TESTING AND MAINTENANCE TECHNOLOGIES' WPAFB, 1983

Includes all of the design concepts from ULCE

FUTURE VEHICLE -- LIFE CYCLE COST SAVINGS UTILIZES ALL ULCE CONCEPTS

LIFE CYCLE PHASE	% OF SYSTEM LCC	ULCE COST IMPACT	IMPACT OF ULCE ON LCC
R & D DESIGN	10%	UP 20%	UP 2%
PRODUCTION	30%	UP 10%	UP 3%
O & M	60%	DOWN 19%	DOWN 11.4%

NET: DOWN 6.4%

TRADE STUDY SUMMARY (SHUTTLE)

Extensive data gathering and research is required before complete cost trades can be accomplished. If one of the previous recommendations is given a go-ahead, a separate study needs to be initiated to provide the relevant cost data.

To be most effective, this effort would require joint NASA and SPC cooperation.

TRADE STUDY SUMMARY

SHUTTLE

- SHUTTLE WILL ALWAYS BE AN R&D VEHICLE BECAUSE IT WAS NOT DESIGNED FOR EFFICIENT OPERATIONS.
- THE COST FOR MAJOR BLOCK MODS NECESSARY TO MAKE IT A TOTALLY OPERATIONAL VEHICLE IS PROBABLY NOT COST EFFECTIVE (NOT TO MENTION OUT-OF-SERVICE FLIGHT LOSSES).
- THE POTENTIAL FOR INCREASING LAUNCH OPERATIONS EFFICIENCY WITHOUT MAJOR BLOCK MODS IS MINIMAL (IN THE ORDER OF 10%) -- AND THIS POTENTIAL WILL BE OVERWHELMED FOR THE NEXT SEVERAL FLIGHTS BY ADDITIONAL SAFETY REQUIREMENTS.
- IF ORBITERS ARE TAKEN OUT-OF-SERVICE FOR MAJOR MANDATORY SAFETY MODS, THEN THERE ARE EFFICIENCY AND TECHNOLOGY CANDIDATES WHICH MAY BE COST-EFFECTIVE IF PACKAGED WITH THE SAFETY MODS.
- REMAINING OPERATIONAL LIFE OF ORBITER WILL BE CRITICAL IN DETERMINING LCC EFFECTIVENESS OF PROPOSED MODS.

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TRADE STUDY SUMMARY

SHUTTLE (Cont'd)

- WITHOUT MAJOR BLOCK MODIFICATIONS TO THE SHUTTLE, ONLY MINIMAL OPERATIONAL EFFICIENCIES CAN BE ACHIEVED.

- THERE IS A CLEAR LACK OF DATA FOR USE IN DETAILED COST TRADES IN SELECTING MODIFICATIONS.

- ANALYSIS INDICATES THAT GREATEST IMPROVEMENTS IN CURRENT OPERATIONS CAN BE GAINED VIA RE-DESIGN OF SPDMS (SHUTTLE PROGRAM DATA MANAGEMENT SYSTEM) TO CONFORM TO IMIS, AND ASSOCIATED SYSTEMS. POTENTIAL SAVINGS -- $2.6B PLUS INCREASE OF UP TO 30% IN LAUNCH RATE (BASED ON FY 1985 RATE OF 8/YEAR).

- SHUTTLE VEHICLE MODIFICATIONS MAY BE BEST USED AS PROOF OF CONCEPT FOR FUTURE VEHICLES EVEN THOUGH INDIVIDUAL MODS MAY NOT BE COST EFFECTIVE BY THEMSELVES.

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TRADE STUDY SUMMARY

FUTURE VEHICLES

- o MAJOR CHANGES IN DESIGN AND MANAGEMENT METHODOLOGY ARE REQUIRED.
- o NEW TECHNOLOGY INVOLVES MANAGEMENT AND COMPUTER AIDED TOOLS.
  - o ULCE/CALS (UNIFIED LIFE CYCLE ENGINEERING/COMPUTER AIDED LOGISTICS SYSTEM)
  - o DBT/DTC (DESIGN BUILD TEAM/DESIGN TO COST)
- o WITHOUT CONSISTENT LONG-TERM TOP MANAGEMENT COMMITMENT, THIS WILL NOT WORK.
- o POTENTIAL LCC SAVINGS, AS COMPARED TO CURRENT SHUTTLE OPERATIONS, IS A REDUCTION OF 29.5% ($8B).

SHUTTLE O&M DOWN	18.1%	(TO GET TO DOD 60/40 LCC)
FUTURE VEHICLE LCC -- DUE TO ULCE	6.4%	
FUTURE VEHICLE LCC -- DUE TO ANOMALY RESOLUTION	5.3%	

- o FUTURE VEHICLES, BEGINNING WITH THE DESIGN CONCEPT PHASE, MUST PUT LIFE CYCLE COSTS AHEAD OF PERFORMANCE. WE ARE HAULING CARGO VIA FREIGHTER -- NOT PARTICIPATING IN A YACHT RACE.

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VEHICLE BLOCK CHANGE CANDIDATES
(Reduction of Ground Operations Time & Manhours)

- DE AND NE-PEO HAVE OVER 500 SPECIFIC CANDIDATES FOR VEHICLE AND GSE MODIFICATIONS DEVELOPED AT THE SYSTEM ENGINEER LEVEL. (THESE ARE INCLUDED IN OUR PRELIMINARY ISSUES DATABASE ID: 1800 TO 2900)
- APPROACHED FROM THE VIEWPOINT OF OMI PROCESSING, WE HAVE IDENTIFIED 32 OPERATIONS WHICH APPEAR TO HAVE LIKELY SYSTEM CANDIDATES FOR DESIGN CHANGES THAT COULD SIGNIFICANTLY REDUCE BOTH PROCESSING TIME AND MANHOURS
- SOME OF THE DE AND NE-PEO CANDIDATES ARE PERTINENT TO THE OPERATIONS IDENTIFIED BY OMI
- THE NEXT TWO CHARTS LIST THE CANDIDATES AND DE/NE-PEO OVERLAP

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VEHICLE BLOCK CHANGE CANDIDATES (TECHNOLOGY IMPROVEMENTS)

TIS	OMI	HOURS	TECH M/H	SYSTEM	DE/NE-PEO MODIFICATONS
3	V1158	56	336	FRCS and OMS pod	Y
5	V1091	48	192	PRSD LO2 and LH2	Y
10	V9001VL1-V14	?	?	power up and power down	N
15	V5043VL1-VL3	96	1632	SSME heat shield removal/inst.	N
17	V1011.01-.07	252	2064	SSME eng leak and functional	Y
19	V5006.01-.03	12	96	PLB doors	N
21	V1009.01-.05	264	2112	MPS leak and functional	N
22	V6018	92	368	cabin air debris screens	N
23	V5E02	36	360	SSME hp turbopump	N
24	V5E06	36	324	SSME hp turbopump	N
34	V9002.01-.10	68	212	ground power	N
35	V1131	24	120	hydraulic system GN2	N
38	V1134	8	48	water drain	N
39	V1078	48	288	APU lube oil	Y
41	V1153	8	56	APU water servicing	Y
47	V1018.02-.04	8	48	APU/water spray boiler	Y

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VEHICLE BLOCK CHANGE CANDIDATES (TECHNOLOGY IMPROVEMENTS Cont'd)

TIS	OMI	HOURS	TECH M/H	SYSTEM	DE/NE-PEO MODIFICATIONS
48	V1055	24	168	potable water	Y
54	V1196	24	168	APU fuel tank servicing	Y
56	V1165	72	288	nose landing gear	Y
57	V1003	12	72	electrical power	N
68	V1041	12	72	ECLSS	N
69	V5050	24	96	crew equipment	N
74	V1037	24	240	ammonia boiler	N
79	V1007	24	96	PVD structural leakage test	N
81	V1034	?	?	flight control	N
82	V5101	12	192	weight and balance (GSE only)	N
83	N52XX	48	240	cargo/equipment removal	N
85	N/A	168	336	cargo/equipment reconfiguration	N
86	N/A	192	1344	payload bay reconfiguration	N
87	N/A	120	840	PLB radiator	N
88	N/A	72	288	Orbiter/PLB interface	N
204	S0024	100	?	hydrazine	N

SPACE STATION TECHNOLOGIES
(APPLICABLE TO SHUTTLE AND STAS)

Significant technology developments are being funded by the Space Station Program which will be directly applicable to ground operations for both Shuttle block changes and STAS.

Typical technologies and their eventual application to vehicle and ground operations are matrixed on the opposite chart.

SPACE STATION TECHNOLOGIES APPLICABLE TO SHUTTLE AND STAS

ADAPT TECHNOLOGY BEING DEVELOPED FOR SPACE STATION TO SHUTTLE/STAS -- TO SAVE TIME AND $$$ -- FOR GROUND OPERATIONS

SPACE STATION DEVELOPMENT $$$	VEHICLE & GROUND OPERATIONS (SHUTTLE/STAS)			
	Elect Pwr	GN&C	Data Mgmt	Assembly & Checkout
EXPERT SYSTEM				
Fault Diagnosis	X	X	X	
Trend Analysis	X	X	X	
Power Management	X	X		
Fault Tolerance	X	X		
Attitude Control		X		
ROBOTICS				
Teleoperation				X
Proximity Touch & Force Sensing				X
Range & Image Understanding				X
End Effectors				X
POWER				
Batteries	X			
Fuel Cells	X			
OTHER				
Video Probe				X
Electron Beam Welding				X

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SHUTTLE GROUND OPERATIONS EFFICIENCIES/TECHNOLOGIES STUDY

OVERVIEW . . . . Art Scholz

PRODUCTS . . . . Mitch Hart/David Lowry

SUMMARY . . . . Art Scholz

- SHUTTLE
- FUTURE VEHICLES

FOLLOW-ON STUDY

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SUMMARY

<u>SHUTTLE</u>

* WHILE SELECTED BLOCK MODIFICATIONS MAY PROVIDE SOME OPERATIONAL EFFICIENCIES, THEY DO NOT APPEAR TO SUPPORT MAJOR LIFE CYCLE COST REDUCTION.

    * COST OF MODIFICATION AND EXTENDED LOSS OF FLIGHTS. OUTWEIGH GAINS IN LIFE CYCLE COSTS.

    * EXCEPTIONS TO THIS MAY DEVELOP:

        1) WHEN MODS CAN BE PACKAGED WITH MANDATORY SAFETY MODS.
        2) WHEN EARLY PROOF OF HARDWARE FOR FUTURE VEHICLES IS A PERCEIVED ADVANTAGE.

SUMMARY
(Cont'd)

SHUTTLE

* SHUTTLE LAUNCH OPERATIONS EFFICIENCY IMPROVEMENTS VERY LIMITED
    * BASIC SHUTTLE DESIGN DICTATES THE BASIC OMRSD AND RESULTING OPERATIONAL FLOWS.
    * TREND IN OPPOSITE DIRECTION FOR NEXT SEVERAL LAUNCHES BECAUSE OF CHALLENGER AND NEWLY IMPOSED SAFETY REQUIREMENTS.
    * IMMEDIATE PRIORITY TO SSME ENGINE SHOP ENLARGEMENT AND MODIFICATION. IMPROVE ACCESSABILITY AND ENABLE MAJOR ENGINE MAINTENANCE, CHECKOUT AND MODIFICATION TO BE ACCOMPLISHED OFF-LINE AT KSC. THIS WILL REDUCE TURNAROUND TIME BY SEVERAL DAYS (COST APPROX. $1.2M).
* GROUND SUPPORT OPERATIONS EFFICIENCY IMPROVEMENTS:
    * POTENTIAL FOR 3% REDUCTION IN LCC AND UPWARDS OF 30% INCREASE IN LAUNCH RATE AS COMPARED TO THE LAUNCH RATE IN FY '85.

SUMMARY
(Cont'd)

FUTURE VEHICLES

GOAL: ACHIEVE A SIGNIFICANT REDUCTION IN OPERATIONAL LCC COSTS

* UTILIZE ULCE/CALS TO PROVIDE ON-LINE ACCESS TO COMMON OR INTEGRATED DATABASES FOR ALL ELEMENTS (DESIGN, MANUFACTURING, QA, RELIABILITY, LOGISTICS, & OPERATIONS).

* OPERATIONAL REQUIREMENTS MUST BE A PART OF THE EARLY DESIGN PHASE IF RECURRING LAUNCH OPERATIONS COSTS ARE TO BE REDUCED SIGNIFICANTLY. OVER-ALL VEHICLE INTEGRATION MUST BE EMPHASIZED EARLY IF LIFE CYCLE COSTS ARE TO BE CONTROLLED.

* BOTH MANNED AND UNMANNED VEHICLES MUST USE VEHICLE BIT/BITE FOR GROUND CHECKOUT & COUNTDOWN (ELIMINATE MOST CHECKOUT GSE) AT THE LAUNCH SITE.

* LARGE COMPLEX LAUNCH CONTROL CENTERS MUST BE ELIMINATED. MASSIVE GROUND/VEHICLE DATA & CONTROL LINKS MUST GO AWAY.

SUMMARY
(Cont'd)

FUTURE VEHICLES (Cont'd)

* MUST DEVELOP HIGH POWER-DENSITY, LOW MAINTENANCE ENERGY SOURCES TO ACCOMMODATE SIGNIFICANT INCREASES IN ENERGY REQUIREMENTS DURING FLIGHT OPERATIONS.

* MUST ELIMINATE HYDRAULICS, SRB'S, HYDRAZINE, AND ASSOCIATED HAZARDOUS OPERATIONS TO REDUCE VEHICLE TURNAROUND TIME AND DECREASE LIFE CYCLE COST.

* MUST ELIMINATE ORDNANCE TO REDUCE SPECIAL VEHICLE HANDLING REQUIREMENTS, HAZARDOUS OPERATIONS IMPACT ON LCC AND VEHICLE TURNAROUND TIME AS WELL.

* MUST OPERATE WELL WITHIN VEHICLE SYSTEMS PERFORMANCE SPECS TO REDUCE MAINTENANCE, LCC, AND TURNAROUND TIME.

* TO PROVIDE OPERATIONAL CONTINUITY AFTER THE FACTORIES MOVE ON TO OTHER PROJECTS, PLAN TO UTILIZE LAUNCH SITE SUB-ASSEMBLY AND ASSEMBLY AS A FACTORY ANNEX AND RETAIN ASSEMBLY TYPE SKILLS AT THE LAUNCH SITE.

SUMMARY
(Cont'd)

PAYLOADS:

* PAYLOADS MUST BE PROCESSED OFF-LINE TO SPEED VEHICLE TURNAROUND

* PAYLOADS MUST BE PREPACKAGED AND HAVE MINIMAL INTERFACES (MECHANICAL, POWER, CONTROL, DATA)

  -- ELIMINATE ENVIRONMENTAL AND SPECIAL HANDLING REQUIREMENTS; e.g., HORIZONTAL vs VERTICAL LOADING.

SUMMARY
(Cont'd)

TECHNOLOGY APPLICATIONS AND DEVELOPMENT OF OPERATIONAL REQUIREMENTS TO REDUCE GROUND OPERATIONS LCC MUST BE AGGRESSIVELY PURSUED.

* ULCE/CALS UTILIZATION: NASA SHOULD TAKE ADVANTAGE OF THIS TECHNOLOGY DEVELOPMENT EFFORT AND JOIN THE DOD/INDUSTRY TEAM & COMMITTEES; AND TRANSFER TECHNOLOGY TO NASA PROJECTS.
* ANOMALY RESOLUTION: NASA SHOULD TAKE ADVANTAGE OF THIS RAPIDLY DEVELOPING TECHNOLOGY IN BIT/BITE, FAULT RESOLUTION, FAULT-TOLERANT SYSTEM HARDWARE (COMPUTERS AND SOFTWARE), ETC.; AND TRANSFER AVAILABLE TECHNOLOGY ELEMENTS TO NASA PROJECTS. THIS COULD BE EXPEDITED BY JOINING DOD/INDUSTRY TEAM & COMMITTEES.
* INCREASED FUNDING FOR ACCELERATED TECHNOLOGY DEVELOPMENT.
  * ELIMINATE (OR REDUCE) HAZARDOUS SYSTEMS
    - ELIMINATION OF ORDNANCE (CONSIDER NITINOL)
    - TOXIC AND HYPERGOLIC FLUIDS
  * HIGH DENSITY POWER SOURCES
    - NaS BATTERIES
    - FUEL CELLS
  * ELIMINATE HYDRAULICS
  * PROPELLANT GRADE RCS SYSTEMS
  * AUTOMATED STRUCTURAL INSPECTION

SUMMARY
(Cont'd)

TECHNOLOGY APPLICATIONS AND DEVELOPMENT OF OPERATIONAL REQUIREMENTS TO REDUCE GROUND OPERATIONS LCC MUST BE AGGRESSIVELY PURSUED.

* EVOLVING SPACE STATION TECHNOLOGY SHOULD BE MONITORED CLOSELY WITH GOAL OF INCORPORATING TECHNOLOGY DEVELOPED THERE IN FUTURE VEHICLES; i.e., EXPERT SYSTEMS IN THE AREAS OF FAULT DIAGNOSIS, TREND ANALYSIS, POWER MANAGEMENT, FAULT TOLERANT SYSTEMS; AS WELL AS OTHER APPLICABLE DEVELOPMENTS IN PROPULSION, POWER (BATTERIES, FUEL CELLS), ETC.

STUDY PHASE 2

BASED ON PHASE 1 STUDY RESULTS AND USING STAS ARCHITECTURES, SPECIFIC CONFIGURATIONS WILL BE RECOMMEMDED TO THE KSC STUDY MANAGER FOR HIS APPROVAL PRIOR TO USE.

PREPARE A CONCEPTUAL GROUND OPERATIONS PLAN FOR THE VEHICLE(S) TO BE IDENTIFIED FROM ONE OR TWO SELECTED ARCHITECTURES; e.g., 1) AN EXPENDABLE, UNMANNED CARGO VEHICLE, 2) A MANNED CARGO VEHICLE.

DESIGN CONCEPTS/REQUIREMENTS FOR ULCE/CALS SHALL BE EXPANDED:

COORDINATION BETWEEN DOD AND NASA/KSC WILL BE ESTABLISHED, WITH PARTICIPATION ON ASSOCIATED TECHNICAL ADVISORY GROUPS ENCOURAGED AND DEVELOPED.

DEVELOP OPERATIONAL SUPPORTABILTY REQUIREMENTS AND DESIGN CONCEPTS (TO INCLUDE A CHECKLIST HANDBOOK FOR DESIGNERS AND PROGRAM MANAGERS).

STUDY PHASE 2
(Cont'd)

LAUNCH SITE FACILITY CONCEPTS FOR THE VEHICLES UNDER STUDY WILL BE DEVELOPED. THESE CONCEPTS WILL BE DEVELOPED FOR THE MOST EFFICIENT PROCESSING (BOTH TIME AND MANHOURS) AND WILL BE OPTIMIZED JOINTLY WITH THE OPERATIONS CONCEPTS.

HIGHLIGHT NEW AND DEVELOPING TECHNOLOGIES THAT APPLY TO SUBJECTS OF STUDY.

THE XTKB WILL BE PLACED ON-LINE FOR USE FOR NASA AND AIR FORCE PERSONNEL.

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15. Supplementary Notes * 16. (Continued)
These additional benefits include items such as: a smaller chance for "human error" through automation, reduced number of people required for operations, smaller number of documentation changes, and an increase in test-to-test consistency. Document these findings and capabilities for use as guidelines for use on STAS and other future programs for both manned and unmanned vehicles.

16. Abstract Using the current STS as a working model: identify existing, or new technologies, changes to flight hardware, or changes to processing methodologies that would reduce the processing time and program manpower costs of space vehicle processing. Document methods of improving efficiency of ground operations and identify tehcnology elements that could reduce cost. Study emphasis is on:
1) Identification of specific technology items.
2) Management approaches required to develop, operate, support and control operationally efficient ground processing activities.
Prime study results are:
1) Identification of existing, or new technology that would make vehicle processing less costly. 2) Recommendations for the use of selected technology items in the current STS program. 3) Recommendations for the research and/or development of specific technology items for use on future programs to make their processing (and operation more efficient. 4) Identification of new management techniques necessary to achieve and control these more efficient operations.
Increased use of automation to provide current and more comprehensive managements reports, operational analysis support, evaluation of systems, conduct of operations and other ways to cut costs and provide additional benefits. *see 15

17. Key Words (Suggested by Author(s))
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