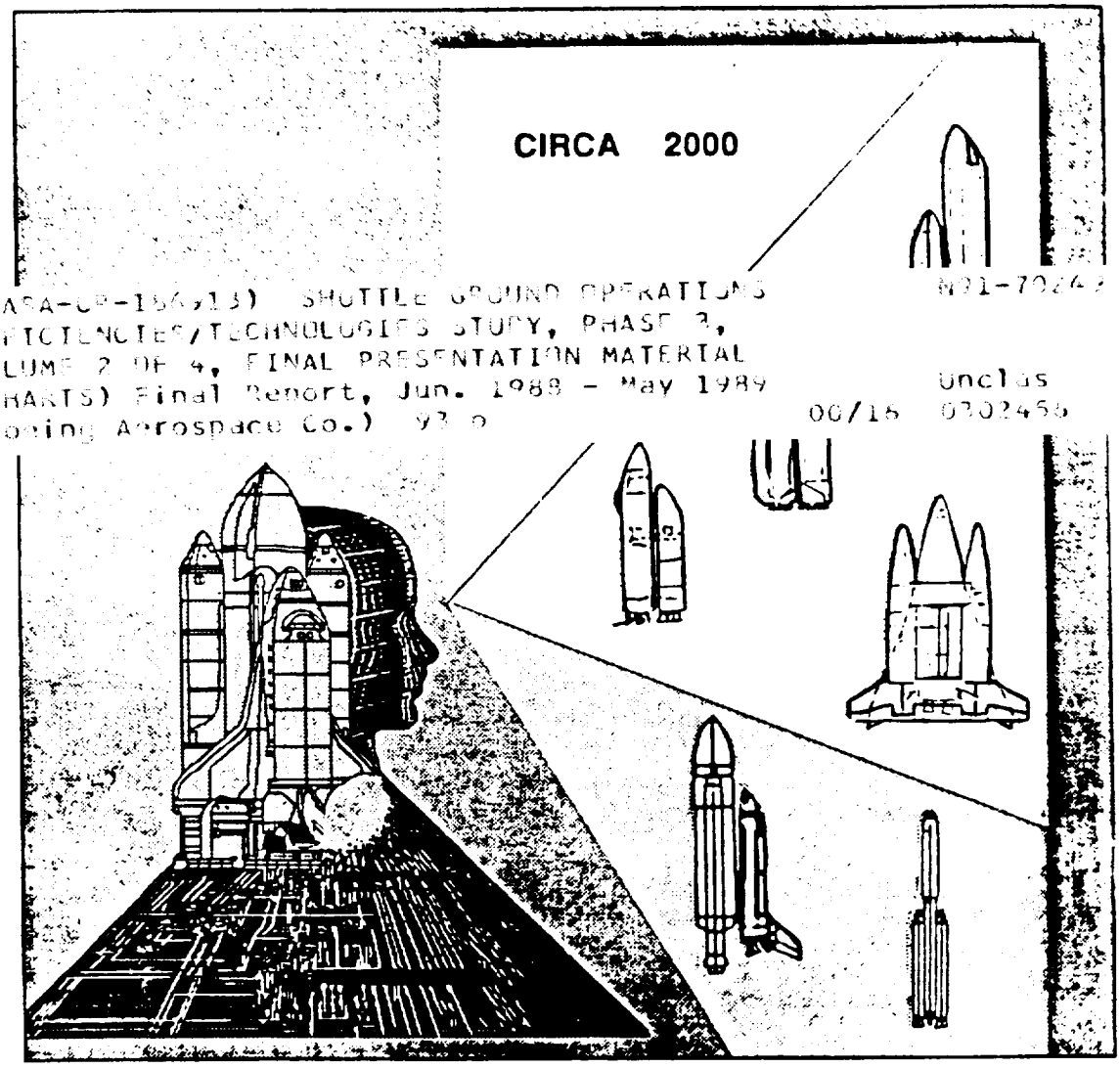
Shuttle Ground Operations Efficiencies/Technologies Study

BOEING

AEROSPACE OPERATIONS



(NASA-CR-156713) SHUTTLE GROUND OPERATIONS EFFICIENCIES/TECHNOLOGIES STUDY, PHASE 3, VOLUME 2 OF 4, FINAL PRESENTATION MATERIAL (CHARTS) Final Report, Jun. 1988 - May 1989 (Boeing Aerospace Co.) 93 p
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FINAL REPORT PHASE 3
Volume 2 of 4

FINAL PRESENTATION

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NAS10-11344
May 4, 1989

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ROUNDTABLE WORKSHOP AGENDA

FIRST DAY

DISCUSSION OF S G O E / T ELEMENTS

- MANAGEMENT / SYSTEM ENGINEERING
- AVIONICS & SOFTWARE
- POWER / STRUCTURES & MATERIALS
- PROPULSION
- FACILITIES & SUPPORT EQUIPMENT

A. L. SCHOLZ
D. J. LOWRY
R. J. BYRD

SECOND DAY -- Call to order -- 0800

DISCUSSION / SPLINTER SESSIONS	ALL
SUMMARY AND WRAPUP	DICKINSON / SCHOLZ

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ROUNDTABLE WORKSHOP AGENDA

DISCUSSION OF S G O E / T ELEMENTS	A. L. SCHOLZ
MANAGEMENT / SYSTEM ENGINEERING	A. L. SCHOLZ
AVIONICS & SOFTWARE	D. J. LOWRY
POWER / STRUCTURES & MATERIALS	R. J. BYRD
PROPULSION	R. J. BYRD
FACILITIES & SUPPORT EQUIPMENT	LOWRY / BYRD

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STUDY OBJECTIVES

PHASE 1
(Completed 5/4/87)

USING THE STS SYSTEM AS A WORKING MODEL AND CERTIFIED DATA SOURCE, IDENTIFIED EXISTING OR NEW TECHNOLOGIES AND CHANGES TO FLIGHT HARDWARE OR PROCESSING METHODOLOGIES TO REDUCE VEHICLE PROCESSING TIME, PROGRAM MANPOWER (AND COSTS).

PHASE 2
(Complete 5/4/88)

ANALYZE AND APPLY COST DRIVERS, DEFINED IN PHASE 1, TO THE ALS PROGRAM REQUIREMENTS. DEVELOP AND DOCUMENT SIMPLIFIED LAUNCH SYSTEM OPERATIONS CRITERIA (SLSOC) BASED ON THESE COST DRIVERS.

STUDY OBJECTIVES
(Cont'd)

PHASE 3
(Scheduled Completion May 89)

INITIATE A SERIES OF WORKSHOPS INVOLVING BOTH GOVERNMENT AND CONTRACTOR SYSTEM DESIGNERS TO COLLECTIVELY ADDRESS THE OPERATIONAL COST DRIVERS IDENTIFIED IN THE SGOE / T (SHUTTLE GROUND OPERATIONS EFFICIENCIES / TECHNOLOGIES) STUDY. STIMULATE THE SYSTEM DESIGNERS TO UTILIZE THIS DATA IN THEIR APPROACH TO DRASTICALLY REDUCING LIFE CYCLE COSTS FOR THE ALS PROGRAM.

ROUNDTABLE WORKSHOP OBJECTIVE

OBJECTIVE:

PRESENT STUDY DATA AND STIMULATE DESIGNERS TO DEVELOP POTENTIAL SOLUTIONS THAT SIMPLIFY BOTH VEHICLE AND LAUNCH OPERATIONS (TO CONTRIBUTE TO REDUCING LIFE CYCLE COSTS FOR THE ALS PROGRAM).

- ENSURE LAUNCH SITE (USERS) ISSUES ARE CLEARLY UNDERSTOOD BY DESIGNERS (YOU MUST KNOW WHAT THE PROBLEM IS BEFORE YOU CAN TAKE CORRECTIVE ACTION.)
- REVIEW THE SLSOC CONCEPTS DERIVED FROM STS OPERATIONAL COST DRIVERS
- UTILIZE LAUNCH SITE EXPERTISE TO PROVIDE SYSTEM DESIGNERS AND PROGRAM MANAGEMENT THE OPPORTUNITY TO BRAINSTORM THEIR SYSTEM CONCEPTS THAT WOULD PROVIDE FOR ALS OPERATIONAL SIMPLICITY.
- STIMULATE PLANNING FOR OPERATIONAL SIMPLIFICATION OF HARDWARE, SOFTWARE, AND OPERATIONS BEFORE THE SYSTEM DESIGN CONCEPTS ARE FIRMLY ESTABLISHED. (DESIGN FOR OPERATIONS -- R & M 2000)
- INCREASE USEABILITY (AT THE EXPENSE OF PERFORMANCE IF NECESSARY)

ROUNDTABLE WORKSHOP
GENERAL

- HISTORICAL OPERATIONAL DATA FROM SHUTTLE LAUNCH OPS.
- 1st TIME THAT LAUNCH SITE DATA HAS BEEN COLLECTED, PUBLISHED, AND MADE AVAILABLE TO DESIGNERS TO THIS LEVEL OF DETAIL.
- REVIEWS OF ALL STAS CONTRACTOR TRADE STUDIES INDICATE THAT, IN OUR OPINION, THEY DID NOT UNDERSTAND THE LAUNCH SITE IMPACT(S) OF THEIR DESIGN PROPOSALS -- NOR THE ASSOCIATED COSTS FOR OPERATIONS.
- REALISTIC LAUNCH SITE DATA IN DATABASE SHOULD PROVIDE AN IMPROVED "CREDIBILITY FACTOR" TO CONTRACTOR "TRADE STUDY RESULTS".
- OUR DESIGN SUGGESTIONS ARE THOUGHT STIMULATORS – NOT REQUIREMENTS AND SHOULD BE CONSIDERED OPERATIONAL CRITERIA!
  (CRITERION - A STANDARD ON WHICH A JUDGEMENT OR DECISION MAY BE BASED)
- USE OF THIS DATA (BY ALL) SHOULD SIMPLIFY FUTURE DESIGNS (FROM AN OPERATIONAL STANDPOINT) BY EARLY USE OF LAUNCH SITE OPERATIONAL COST DRIVER INFORMATION IN SYSTEM CONCEPT DEVELOPMENT ACTIVITIES.

ROUNDTABLE WORKSHOP BACKGROUND

- DATA COLLECTION (51-L)
  - FLOWS, TIMELINES, AND PROBLEM AREAS; e.g., HEAD COUNT AND MAN - HOURS
  - COST DATA
  - OPERATIONAL DOCUMENTATION
- DATA ANALYSES (STUDY TASKS)
  - COST DATA FOR OPERATIONAL FLOW ELEMENTS (WORKLOAD INDICATORS FOR 51-L)
  - IDENTIFICATION OF OPERATIONAL COST DRIVERS
  - IDENTIFICATION OF TECHNOLOGY THAT COULD REDUCE EITHER SERIAL TIME OR MAN - HOURS TO COMPLETE TASKS TO REDUCE THE COST OF RECURRING OPERATIONS
- RECOMMENDATIONS (STUDY RESULTS)
  - RECOMMENDED INCORPORATION OF "AVAILABLE" TECHNOLOGY ITEMS IN BOTH CURRENT AND FUTURE SYSTEMS / SUB - SYSTEMS
  - IDENTIFICATION OF NEW TECHNOLOGY ITEMS FOR DEVELOPMENT – BENEFITS FROM DEVELOPMENT (AVAILABILITY) INCLUDE:
    - AUTONOMOUS SYSTEMS TO REDUCE PEOPLE REQUIRED FOR GROUND PROCESSING.
    - SHORTER TURNAROUND TIME AT THE LAUNCH SITE TO REDUCE RECURRING COSTS FOR THE GROUND OPERATIONS ACTIVITIES FOR THE REST OF THE PROGRAM.

ROUNDTABLE WORKSHOP IMPLEMENTATION TEAM

- THE TEAM IS MADE UP OF THE FOLLOWING MEMBERS / ORGANIZATIONS:
  - Lt. J. PAYNE — ALS PROGRAM OFFICE REPRESENTATIVE
  - W. J. DICKINSON — KSC SGOE / T STUDY MANAGER
  - A. L. SCHOLZ — BOEING SGOE / T STUDY MANAGER
- MEETINGS WILL BE OPEN AND ACCESSIBLE TO OTHERS (WITH ALS PROGRAM OFFICE APPROVAL).
- LETTER DISTRIBUTED SOLICITING ATTENDEE REQUESTS FOR ACCESS SO THAT OUTSIDE ACCESS REQUIREMENTS CAN BE EVALUATED.

ROUNDTABLE WORKSHOP APPROACH

APPROACH:

EACH OF THE SIX SLSOC ELEMENTS WILL BE USED AS THE "THEME" (OR PRIMARY TOPIC) IN THE DISCUSSIONS TO OPTIMIZE THE SYSTEM:

- VEHICLE PERFORMANCE HAS BEEN THE ONLY DRIVER IN THE PAST (OPS HISTORY)
- OPERATIONAL FLEXIBILITY AND LOWER COST OF RECURRING OPERATIONS MUST ALSO BE CONSIDERED BY THE DESIGNERS (ALONG WITH PERFORMANCE REQUIREMENTS).
- FLIGHT HARDWARE DESIGN DRIVES LAUNCH SITE FACILITIES AND OPERATIONS COSTS
- IDENTIFY OPERATIONS IMPACTS
  - SIMPLIFY TEST AND CHECKOUT / TESTABILITY / QUALITY / OPERABILITY / LOGISTICS (ALL ASPECTS OF PROGRAM)
  - PROVIDE MAINTAINABILITY THRU ACCESSIBILITY AND SUPPORTABILITY
  - IDENTIFY TECHNOLOGIES NEEDED
  - REDUCE COST
  - ESTABLISH RELIABILITY OF SCHEDULES FOR SCHEDULED OPERATIONS
  - USE LAUNCH SITE COST DATA IN OPERATIONAL TRADE STUDIES

S G O E/T STUDY
ROUNDTABLE WORKSHOP
by **BOEING**

SGOE / T___ ALS Phase II Contractor WORKSHOP
SLSOC
(Simplified Launch Systems Operational Concepts)

PRESENTED TO
ALS PHASE 2 PRIME CONTRACTORS

MANAGEMENT & SYSTEM ENGINEERING

- M 1) ● PROCUREMENT
- M 2) ● DESIGN / BUILD TEAMS
- M 3) ● DEMING STYLE MANAGEMENT
- M 4) ● LIFE CYCLE COSTS
- M 5) ● DESIGN TO COST
- M 6) ● UNIFIED LIFE CYCLE ENGINEERING
- M 7) ● RISK MANAGEMENT
- M 8) ● RELIABILITY / OPERABILITY
- M 9) ● MAINTAINABILITY / SUPPORTABILITY
- M 10) ● LOGISTICS SUPPORT
- M 11) ● OPERATIONAL TEST REQUIREMENTS
- M 12) ● QUALITY ASSURANCE
- M 13) ● SAFETY
- M 14) ● SECURITY
- M 15) ● CONNECTIVITY ARCHITECTURE

ELIMINATE

- M 1) O MULTIPLE PRIME CONTRACTORS ON SAME PROGRAM
- M 6) O TIGER TEAMS FOR STATUS (SEE L 1) (Requires 100% Computer Connectivity)
- M 1) O SEPARATE DESIGN CONTRACTORS / VOLUMINOUS INTERFACE CONTROL
- M 12) O LARGE QUALITY INSPECTION TEAMS
- M 10) O CANNIBALIZATION
- M 4) O COST OVERRUNS & UNLIMITED LCC
- M 7) O EXORBITANT COST TO ATTEMPT ZERO RISK REQUIREMENTS

AVIONICS & SOFTWARE

- ● AUTONOMOUS VEHICLE
  - A 1) ● BIT / BITE (ON - BOARD CHECKOUT)
  - A 2) ● FAULT TOLERANT AVIONICS SUITE
  - A 1) ● VEHICLE HEALTH & STATUS MONITORING SYSTEM
  - A 4) ● MINIMAL LAUNCH CONTROL INTERFACE
  - A 1) ● RETURNED VEHICLE SELF - TEST FOR REFLIGHT
  - A 3) ● AUTONOMOUS G N&C
  - A 4) ● OPTICAL / IR / RF LINK ONLY TO GSE
- ● SOFTWARE
  - A 5) ● COMMON "CORE" SOFTWARE FOR C / O, LAUNCH, FLIGHT
  - A 5) ● OPERATIONS DATA OVERLAYS (C / O, LAUNCH, MISSION)

ELIMINATE

- A 6) O RELATED GSE
- A 4) O HARDWIRE CONNECTS TO GSE
- E 1) O GROUND POWER REQUIREMENTS

POWER

- E) ● LOW MAINTENANCE ENERGY STORAGE
- E) ● PROPELLANT GRADE FUEL CELLS
- E) ● STATE - OF - ART ENERGY SOURCES
- E) ● SYSTEM SIZED TO PROVIDE ON - BD PWR FOR GROUND OPERATIONS

ELIMINATE

- A 6) O RELATED GSE
- E) O GROUND POWER REQMTS

STRUCTURES & MATERIALS

- ● IMPROVED STRUCTURE
  - S 1) ● MINIMIZE LEAK PATHS
  - S 2) ● STRUCTURAL INTEGRITY VERIFICATION
  - S 3) ● INTEGRAL TPS
- S 4) ● ORDNANCE
  - S 4.1) ● WEAPON DESTRUCT
  - S 4.2) ● LASER IGNITION
  - S 4.3) ● ACCELERATION / CLEVIS SEPARATION
  - S 4) ● NITINOL / E - M DEVICES

ELIMINATE

- S 3) ● SEPARABLE TPS
- S 4) ● ALL ORDNANCE
- S 4) ● PROCESSING SAFETY RESTRICTIONS

PROPULSION

- ● INTEGRATED PROPULSION SYSTEM
  - P 1) ● SIMPLIFIED ROBUST PROPULSION SYSTEM
  - P 1.1) ● FULLY THROTTLEABLE ENGINES (MULTI-PHASE)
  - P 1.2) ● SOFT ENGINE START
  - P 1.3) ● TVC BY DELTA THRUST AND / OR RCS / OR AERO
  - P 1.4) ● ONE OXIDIZER / ONE FUEL

ELIMINATE

- P 2) ● SEPARATE OMS AND RCS
- P 3) ● HIGH MAINTENANCE TURBOPUMPS
- P 4) ● HYDRAULICS
- P 5) ● HYPERGOLS
- P 6) ● GN_2 / He ON-BOARD PURGES
- P 7) ● GN_2 / He PRESSURE SYSTEM
- P 8) ● GIMBALLED ENGINES
- P 8) ● EXTENSIVE RECOVERY & REFURBISHMENT

FACILITIES & SUPPORT EQUIPMENT

- L 1) ● 100% COMPUTER CONNECTIVITY
  - ● AUTOMATION
    - L 2) ● ELECTRONIC OMFs
    - L 3) ● TEXT AND GRAPHICAL DATA ACQUISITION
    - L 4) ● TEST REQUIREMENT VERIFICATION
  - ● STAGE ASSEMBLY
    - L 5) ● INITIAL NEAR LAUNCH CENTER
    - L 5) ● FINAL AT LAUNCH CENTER
- L 6) ● HORIZONTAL PROCESSING
  - L 7) ● HORIZONTAL TRANSPORT
  - ● PAYLOADS
    - L 10) ● ONE AUTONOMOUS CONTAINER
  - ● PAD
    - L 8) ● BARREN PAD
    - L 9) ● ERECT / MATE STAGES AT PAD
    - L 8.1) ● DEEP WATER EXHAUST BUFFER
    - L 8) ● LIGHTNING / LIGHTING TOWER
    - L 8.2) ● FLY-AWAY CONNECTS ONLY
    - L 8) ● PROPELLANT FARM
    - L 8) ● PAVED TOW - WAY
  - ● MOBILE EQUIPMENT
    - L 6 ● STANDARD AIRCRAFT TUG
    - L 6 ● STRAP-ON WHEELED DOLLIES
    - L 6 ● MOBILE CRANE
  - ● BUILDINGS
    - L 6 ● HORIZONTAL PROCESSING FACILITY

ELIMINATE

- O AUTOMATION
  - L 1) O ISOLATED DATABASES
  - L 2) O PAPERWORK RELATED TO TEST
  - L 4) O REQUIREMENTS VERIFICATION
  - L 3) O PRINTED TRANSFER OF TEXT / DATA
- L 10) O PAYLOAD / VEHICLE INTEGRATION VERIFICATION TESTING
- L 9) O LIFTING VEHICLES CLEAR OF GROUND
- O PAD EQUIPMENT
  - L 4) O HARDWIRE CONNECTS
  - L 8.4) O ACCESS STRUCTURES
  - L 8.3) O SWINGARMS
  - L 8) O RETRACTING UMBILICALS
  - L 8.5) O T-O HOLD-DOWN
  - L 8.6) O DELUGE WATER
  - L 8.6) O SOUND SUPPRESSION WATER
  - L 8.1) O FLAME TRENCH / DEFLECTOR
  - L 8.7) O ECS
  - P 8) O He / GN_2 STORAGE
  - E) O GROUND POWER
  - L 7) O CRAWLER WAY
- O MOBILE EQUIPMENT
  - L 7) O CRAWLER / TRANSPORTER
  - L 7) O MOBILE LAUNCH PLATFORM
- O BUILDINGS
  - L 6) O VAB
  - L 6) O VPF
  - L 6) O RPSF

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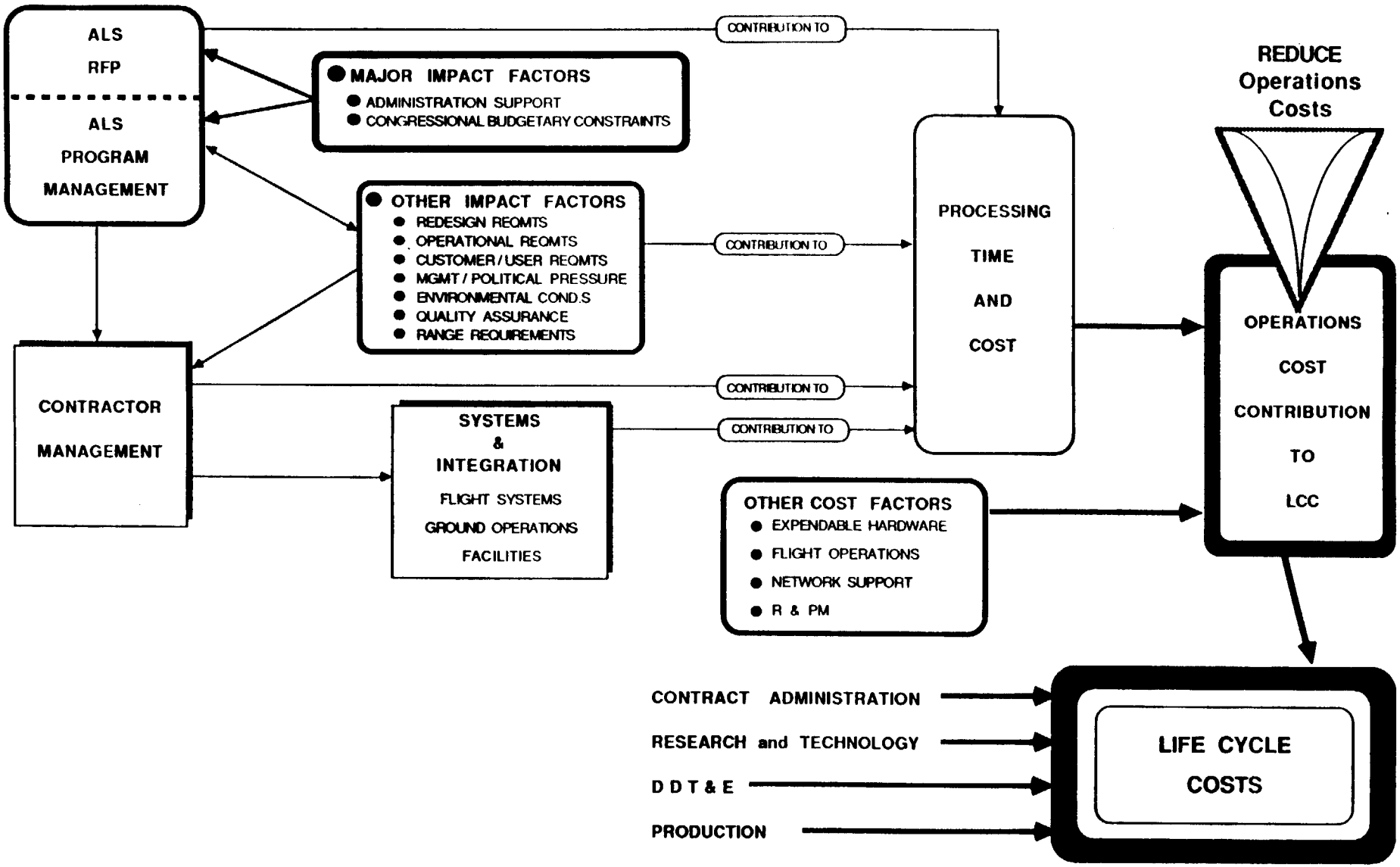
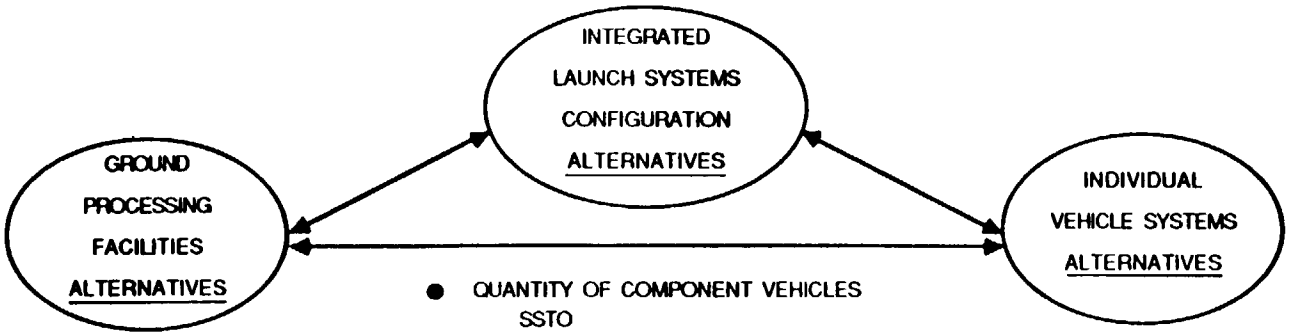

ALS
RFP
ALS
PROGRAM
MANAGEMENT
CONTRIBUTION TO
MAJOR IMPACT FACTORS
ADMINISTRATION SUPPORT
CONGRESSIONAL BUDGETARY CONSTRAINTS
OTHER IMPACT FACTORS
REDESIGN REQMTS
OPERATIONAL REQMTS
CUSTOMER/USER REQMTS
MGMT/POLITICAL PRESSURE
ENVIRONMENTAL COND.S
QUALITY ASSURANCE
RANGE REQUIREMENTS
CONTRIBUTION TO
PROCESSING
TIME
AND
COST
REDUCE
Operations
Costs
CONTRACTOR
MANAGEMENT
CONTRIBUTION TO
SYSTEMS
&
INTEGRATION
FLIGHT SYSTEMS
GROUND OPERATIONS
FACILITIES
CONTRIBUTION TO
OTHER COST FACTORS
EXPENDABLE HARDWARE
FLIGHT OPERATIONS
NETWORK SUPPORT
R & PM
OPERATIONS
COST
CONTRIBUTION
TO
LCC
CONTRACT ADMINISTRATION
RESEARCH and TECHNOLOGY
D D T & E
PRODUCTION
LIFE CYCLE
COSTS

SLSOC ALTERNATIVES
(VERTICAL LAUNCH ASSUMED)



- VEHICLE PROCESSING MODE
  - VERTICAL
  - HORIZONTAL
  - COMBINATION
- PAYLOAD PROCESSING MODE
  - VERTICAL
  - HORIZONTAL
  - COMBINATION
- PAYLOAD INTEGRATION
  - OPF ONLY
  - VAB ONLY
  - PAD ONLY
  - COMBINATION
- VEHICLE MATE
  - HORIZONTAL
  - VERTICAL
- ERECTION
  - VAB
  - PAD
- VEHICLE ACCESS
  - ALL LOCATIONS
  - OPF ONLY
  - COMBINATION
- TRANSFER TO PAD
  - ML / CT vs DOLLIES
  - BARGE
  - LANDING GEAR
  - ERECTOR / TRANSPORTER
  - RAIL
- PAD SYSTEMS

- QUANTITY OF COMPONENT VEHICLES
  - SSTO
  - 2 - STAGE
  - 3 - STAGE
- COMPONENT VEHICLE MATING
  - STACK
  - PARALLEL
  - COMBINATION
- FUEL
  - SINGLE
  - MULTIPLE
- RECOVERABLE
  - ALL
  - PART
  - NONE
- LANDING
  - HORIZONTAL
  - VERTICAL
  - LAND
  - WATER
- MANNED
  - FLIGHT CREW
  - PASSENGER MODULE ONLY

THE UNAVOIDABLE INTERRELATIONSHIPS OF GROSS VEHICLE CONFIGURATION, VEHICLE SYSTEMS, AND GROUND SUPPORT PROCESSING ARE INDICATED. PRELIMINARY DESIGN MUST ACCOMMODATE EXPERIENCED PERSONNEL FROM ALL THREE TO MINIMIZE LCC

- PROPELLANTS
  - RP-1
  - LH2
  - CH4
  - C3H8
  - SOLIDS
  - HYPERGOLS
- ON - BOARD POWER
  - FUEL CELLS
  - BATTERIES
  - COMBINATIONS
  - HYDRAULIC SUPPLY
    - APU
    - MPS
- PNEUMATICS
  - VALVE CONTROL
- TEST - MANUAL
  - AUTOMATIC
  - AUTONOMOUS
  - INTEGRATED
- PRESSURIZATION
  - AUTOGENOUS
  - MPS

SIMPLIFIED LAUNCH SYSTEM OPERATIONAL CRITERIA SAMPLE DATA SHEET

NO: xx Corresponds to the Operations Requirement number on the SLSOC chart:

- M - Management & System Engineering
- A - Avionics & Software
- E - Power
- S - Structures & Materials
- P - Propulsion
- L - Facilities & Support Equipment

Title: A cryptic description of the SLSOC Operations Requirement for which:

- Management / Engineering Systems:
  Needing implementation to drastically reduce related Cost Drivers
- Hardware related:
  Indicates the system or device, which must be changed or eliminated to drastically reduce related Cost Drivers.

Operations Requirement: A short statement of the SLSOC.

Rationale: A description, derived from past experience which made this item a Cost Driver.

Sample Concept: Represents an example concept which might result from "brainstorming" a potential solution for the Cost Driver.

Technology Requirement: Indicates related "technology" (existing or near-term) which might be used in the solution.

Technology References: List of NASA/RECON or DIALOG numbers referring to the Phase 2 Final Report, Volume 5, Technology References, which includes the abstract of each.

SIMPLIFIED LAUNCH SYSTEM OPERATIONAL CRITERIA
On-Board Checkout

No: A 1

Operations Requirement:

Current configurations require extensive use of GSE to support vehicle checkout. Future systems should incorporate onboard checkout and minimize (preferably eliminate) GSE.

Vehicles should have sufficient self-test capability to verify flight readiness or isolate problem to LRU.

Rationale:

Current configurations require complex GSE hookups to support system test and operational verification. The configuration verification, required for test hookup and calibration, defeats efficient operations.

To accomplish order-of-magnitude cost reduction, we must achieve 160-Hr or better turnaround time for recoverable stages. (160-Hrs was the original STS Turnaround goal whose actuals have grown an order-of-magnitude). In addition to turnaround times exceeding 1500 hours, aging recoverable vehicles will impose requirements for structural inspections which will require extensive time periods offline.

ELV's must have comparable processing times.

Vehicles should be capable of launch by meeting "Minimum Equipment List" similar to commercial airline approach.

SIMPLIFIED LAUNCH SYSTEM OPERATIONAL CRITERIA
On-Board Checkout - (Cont'd)

Sample Concept:

After a firm set of test requirements has been defined early in the design phase, the associated hardware/software required to support on-board testing must be incorporated in each subsystem. It is important to maintain subsystem self-test autonomy.

BIT identifies and records anomalies during flight. After landing, BIT/BITE isolates problem to LRU level. After replacement, BIT/BITE retests and verifies flight readiness. Ideally, recoverable vehicles would include sensors for complete structural integrity to avoid extensive downtimes.

Technology Requirement:

Further development of Vehicle Health Monitoring System (VHMS) with BIT/BITE to meet specific requirements. Development of structural sensors including corrosion.

Technology References: (FROM NASA RECON)

87N10079, 87A33872, 87A32118, 86N20489, 86A32796, 86A31260, 86A30591, 86A23765, 85X77042, 85X70467, 85N20697, 85N16753, 85N16897, 85N16898, 85N16900, 85N11594, 85N13194, 85A45082, 85A28633, 85N34596, 85A45975, 85A45398, 85A26804, 85A24795, 85N22528, 84X76865, 84X74856, 84X71619, 84N14754, 84N26573, 84N34500, 84A46661, 83A49578, 83A45473

EXAMPLE RECON ABSTRACT NO. 1

87N10079# ISSUE 1 PAGE 13 CATEGORY 6 86/02/00 17 PAGES UNCLASSIFIED DOCUMENT DCAFE070125

UTTL: Experience with the Onboard Checkout And Monitoring System (OCAMS) of a military aircraft resulting improvements and the consequence for future design.

AUTH: A/NUMBERGER, K.; B/PROBST, K.

CORP: Messerschmitt-Boelkow-Blohm G.m.b.H., Ottobrunn (West Germany).

SAP: Avail: NTIS HC A25/MF A01; DFVLR, Cologne, West Germany, DM 150; In DFVLR Proceedings of the 13th Symposium on Aircraft Integrated Data Systems p 75-92 (SEE N87-10075 01-06)

CIO: GERMANY,FEDERAL REPUBLIC OF

MAJS: /*AIR DATA SYSTEMS/ *AVIONICS/ *CHECKOUT/ *ENGINE MONITORING INSTRUMENTS/ *MILTARY AIRCRAFT

MINS: / AIRCRAFT DESIGN/ COMPUTER SYSTEMS DESIGN/ ONBOARD DATA PROCESSING

ABA: ESA

ABS: The Onboard Checkout and Monitoring System was designed to provide for test and diagoosis of defects to avionic and certain nonavionic equipments. Experience showed what could be improved. Engine and structure monitoring must be improved, still more information would be useful to store, and it was realized that the high sensitivity of the BIT detected also very transientfaults. In order to cover these problems, the data acquisition unit of the crash recorder system will be extended with an engine and structural life monitoring system. Using the opportunity of introducing a data communication bus into the avionic system, facilities for data collection, correlation, and event monitoring will be initiated. Based on this the principal structure of the monitoring and test systems of future aircraft can be designed.

EXAMPLE RECON ABSTRACT NO. 2

85N16753# ISSUE 8 PAGE 1066 CATEGORY 60 84/10/00 6 PAGES UNCLASSIFIED DOCUMENT

UTTL: Hardware/software codesign for maintainable systems

AUTH: A/FRANK, G. A.

CORP: Research Triangle Inst., Research Triangle Park, N.C.; AVAIL. NTIS

SAP: HC A13/MF A01; In AGARD Design for Tactical Avionics Maintainability 6 p (SEE N85-16731 08-01)

CIO: UNITED STATES

MAJS: /*ARCHITECTURE (COMPUTERS)/ *COMPUTER AIDED DESIGN/ *COMPUTER SYSTEMS PROGRAMS/ *COMPUTERS/ *HARDWARE/ *INFORMATION THEORY/ *INTERFACES

MINS: / COMPUTER PROGRAMS/ DATA PROCESSING EQUIPMENT/ GRAPHS (CHARTS)/ LOGIC DESIGN/ MACHINE TRANSLATION/ MAINTENANCE/ MILITARY TECHNOLOGY/ PETRI NETS/ PRODUCT DEVELOPMENT

ABA: E.A.K.

ABS: The codesign of software/hardware which can improve the maintainability of military systems is discussed. The following methods are outlined: (1) support of the design verification process to make it more complete and less costly; (2) reduction of the cost of a system modification by providing accurate, machine readable documentation of the system design; and (3) support of the detection, isolation, and correction of faults on both software and hardware. Development of techniques for software/hardware codesign of high performance signal processors is examined. The methodology is based on the representation of both software and hardware as directed graphs. The system of computer aided design (CAD) tool that support this methodology is the architecture design and assessment system (ADA). The system has two types of components: graph processing modules, which can be applied to any graph, and interfaces to specialized tools, which operate on specific kinds of graphs. The graph processing tools include an interactive graphics editor, a library manager, a Petri net analysis tool, and a Petri net simulator. The interfaces include an HDL interface, and Ada interface, and a reliability tool interface.

EXAMPLE RECON ABSTRACT NO. 3

85A24795*# ISSUE 10 PAGE 1347 CATEGORY 18 85/02/00 4 PAGES UNCLASSIFIED DOCUMENT

UTTL: Expanding role for autonomy in military space

AUTH: A/EVANS, D. D.; B/GAJEWSKI, R. R. PAA: A/(California Institute of Technology, Jet Propulsion Laboratory, Pasadena, CA); B/(USAF, Space Technology Center, Kirtland AFB, NM)

CORP: Jet Propulsion Lab., California Inst. of Tech., Pasadena; Air Force Space Technology Center, Kirtland AFB, N. Mex.

CIO: UNITED STATES; Aerospace America (ISSN 0740-722X), vol. 23, Feb. 1985, p. 74-77.

MAJS: /*AUTONOMY/ *MILITARY SPACECRAFT

MINS: /AIRBORNE/ SPACEBORNE COMPUTERS/ ARTIFICIAL INTELLIGENCE/ EXPERT SYSTEMS/ FAULT TOLERANCE/ ONBOARD DATA PROCESSING

ABA: M.S.K.

ABS: The Jet Propulsion Laboratory is currently transferring satellite on-board autonomy technology to the USAF for use in military spacecraft as a means of lowering the ground support requirements. The techniques were proven on the Viking and Voyager spacecraft and permitted on-board fault detection and correction. New military satellites will incorporate an autonomous redundancy and maintenance management subsystem in an on-board computer, while the system will still be subject to ground-based safing commands for situations demanding deeper analyses. A level 5 autonomy will need 256 kb memory, 10 Mb non-volatile data storage and 50 W power and will weigh 20 kg. Systems will be periodically checked and compared with an ideal in the data base. Deviations detected will result in a rollback and redundant examination by two microprocessors, which can initiate correction commands until operational criteria are met. The development of the expert systems to the point that they satisfy military specifications is expected to take 10 yrs.

ROUNDTABLE WORKSHOP AGENDA

DISCUSSION OF S G O E / T ELEMENTS	A. L. SCHOLZ
MANAGEMENT / SYSTEM ENGINEERING	A. L. SCHOLZ
AVIONICS & SOFTWARE	D. J. LOWRY
POWER / STRUCTURES & MATERIALS	R. J. BYRD
PROPULSION	R. J. BYRD
FACILITIES & SUPPORT EQUIPMENT	LOWRY / BYRD

SGOE / T — ALS Phase II Contractor WORKSHOP
MANAGEMENT & SYSTEM ENGINEERING

- M 1) ● PROCUREMENT
- M 2) ● DESIGN / BUILD TEAMS
- M 3) ● DEMING STYLE MANAGEMENT
- M 4) ● LIFE CYCLE COSTS
- M 5) ● DESIGN TO COST
- M 6) ● UNIFIED LIFE CYCLE ENGINEERING
- M 7) ● RISK MANAGEMENT
- M 8) ● RELIABILITY / OPERABILITY
- M 9) ● MAINTAINABILITY / SUPPORTABILITY
- M 10) ● LOGISTICS SUPPORT
- M 11) ● OPERATIONAL TEST REQUIREMENTS
- M 12) ● QUALITY ASSURANCE
- M 13) ● SAFETY
- M 14) ● SECURITY
- M 15) ● CONNECTIVITY ARCHITECTURE

ELIMINATE

- M 1) ○ MULTIPLE PRIME CONTRACTORS ON SAME PROGRAM
- M 6) ○ TIGER TEAMS FOR STATUS (SEE L 1) (Requires 100% Computer Connectivity)
- M 1) ○ SEPARATE DESIGN CONTRACTORS / VOLUMINOUS INTERFACE CONTROL
- M 12) ○ LARGE QUALITY INSPECTION TEAMS
- M 10) ○ CANNIBALIZATION
- M 4) ○ COST OVERRUNS & UNLIMITED LCC
- M 7) ○ EXORBITANT COST TO ATTEMPT ZERO RISK REQUIREMENTS

SLSOC
Procurement

No: M 1

Operations Requirement:

Government procurement must utilize a contracting mode that establishes prime contractors with sufficient system integration authority to define system (hardware and software) configuration requirements. This will enable cost-effective management for the total system architecture (including hardware acceptance and sub-contractor control).

Rationale:

Contracts that specify GFE, such as engines, and dictate detailed specifications rather than end product performance severely limit a prime contractor's ability to achieve the optimum design or manage the job in a cost effective manner. Most detail hardware specifications limit the contractor's capability to be innovative and cost effective.

FOR:

Sample Concept:
Technology Requirement:
Technology References:
} See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC
Design/Build Teams

No: M 2

Operations Requirement:

Beginning with the conceptual definition through the design phase, integrate the experience and knowledge of specialists in all areas, including manufacturing, procurement, ground operations, etc.

Rationale:

As a result of compartmentalized organization responsibilities, past vehicle designs have not fully utilized and integrated the knowledge and experience of specialists in all functional organizations.

The past sequence of hardware development, whereby the hardware designer completes his design (without input from manufacturing, purchasing, operations, etc.) and "throws it over the fence", for the other organizations to do the best they can in producing and operating the hardware in a cost-effective way, has led to life cycle cost an order-of-magnitude higher than necessary.

FOR:

Sample Concept:
Technology Requirement:
Technology References:
} See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC
Deming Style Management

No: M 3

Operations Requirement:

Traditional compartmented management style must be replaced with Deming-type, team-style management with integrated quality.

Rationale:

In maturing over the past twenty-five years, aerospace management, both in and out of government, have succumbed to bureaucratic disease whereby the first consideration of any management or technical problem is how it will affect the "status quo". If the effect is negative in any way, the answers are often skewed preventing top management from making cost effective decisions. Top management also suffers from biased decisions made to accommodate their "status quo".

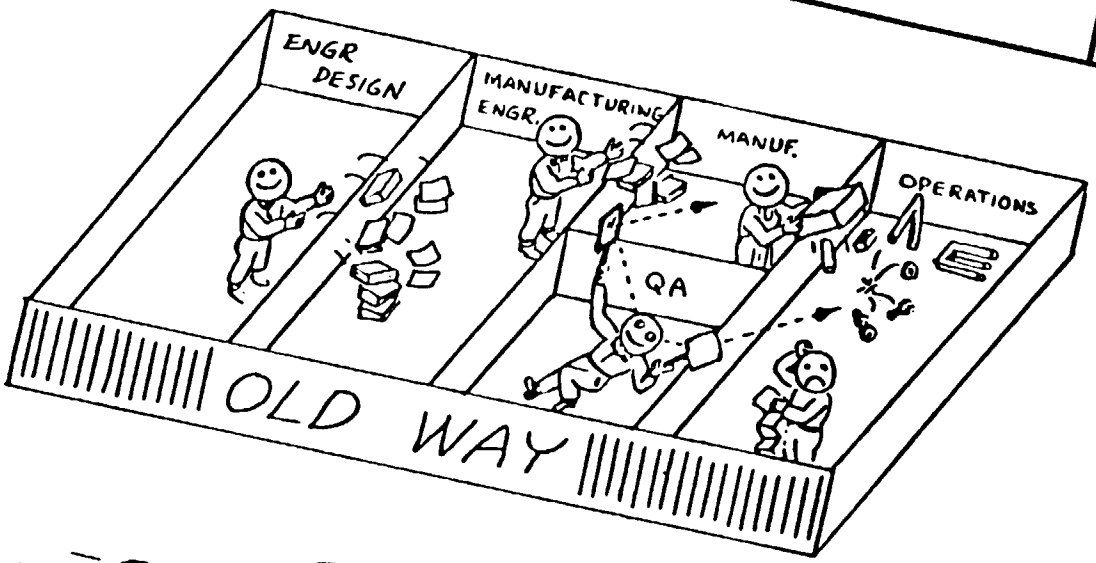
FOR:

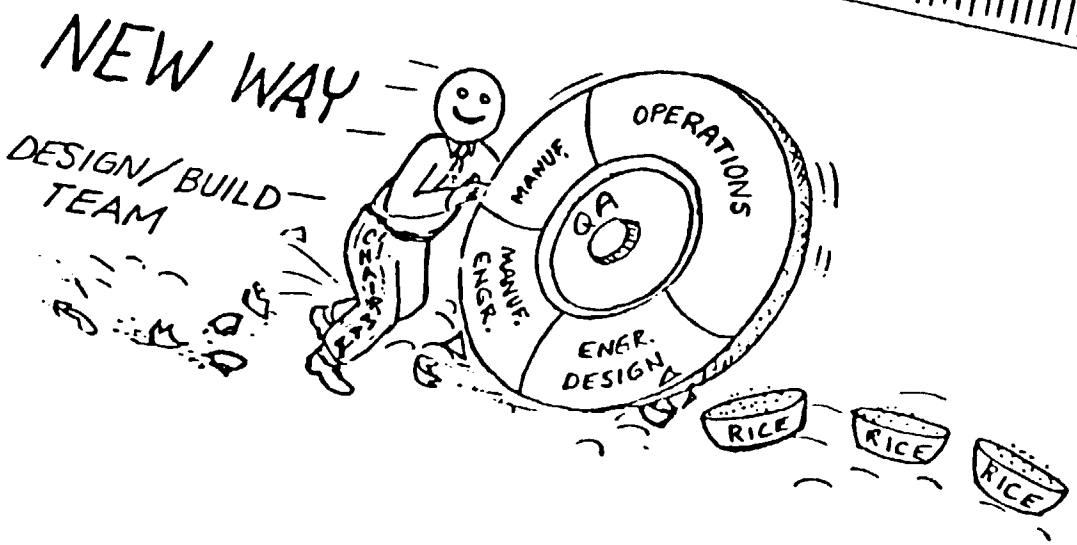
Sample Concept:
Technology Requirement:
Technology References:

See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

ALS Phase II Contractor WORKSHOP
MANAGEMENT TECHNOLOGY

PRESENTED TO
ALS PHASE 2
PRIME
CONTRACTORS





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SLSOC
Life Cycle Costs (LCC)

No: M 4

Operations Requirement:

Operations efficiency must be considered during concept development and design.

Rationale:

Operations requirements have been disregarded in the past because they are brought up too late in the design cycle to be implemented in a cost-effective manner.

For Example (FY-85 Operations Costs For 8 Flights):

SRB	$464.2m	Flight Ops	$345.3m
ET	415.8m	Orbiter Hdwre	162.6m
Launch Ops	347.5m	Crew Equip.	36.3m
Propellants	30.3m	SSME	51.6m
GSE	24.1m	Contract Admin.	17.1m

Subtotal	$1894.8m
Plus Network Support	$ 20.4m
R & PM	274.2m
FY-85 Total Cost	$2189.4M (or $ 273.5M per flight)

Minimizing upfront program costs multiplies Life Cycle Cost.

FOR:

Sample Concept:
Technology Requirement:
Technology References:

See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC
Design to Cost

No: M 5

Operational Requirement:

Assure that adequate Design-to-Cost budget is allocated to operational considerations such as maintainability / supportability.

Rationale:

The history of previous programs is fraught with Life Cycle Cost extravagances caused by inadequate front-end budget considerations for operations related design.

FOR:

Sample Concept:
Technology Requirement:
Technology References:

See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC
ULCE (Unified Life Cycle Engineering)

No: M 6

Operations Requirement:

Use Unified Life Cycle Engineering (ULCE). This is a design engineering environment in which computer-aided design technology is used to continually assess and improve the quality of a product during the active design phases as well as throughout its entire life cycle. This is accomplished by integrating and optimizing design attributes for producibility and supportability with design attributes for performance, operability, cost, and schedule.

Rationale

No integrated methodology or discipline has been used to provide advantageous computerized integration of the procedures dealing with designing for producibility and design for supportability -- with those dealing with designing for performance, cost, and schedule.

FOR:

Sample Concept:
Technology Requirement:
Technology References:

See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC
Risk Management

No: M 7

Operational Requirement:

The unmanned ALS program requires compliance with a non-emotional, well-engineered risk management program.

Rationale:

Trying to provide a "zero-risk" launch program is like dividing cost by zero.

The emotionalism and overreaction to the loss of Challenger, has impacted the STS program far more than a logical risk management program. In addition to the two plus years of manifests that were lost, future vehicle processing times have tripled from the pre-Challenger goal.

Launch readiness decisions must be made by technically qualified managers based on a disciplined test and qualification requirements compliance database.

FOR:

Sample Concept:
Technology Requirement:
Technology References:
} See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC
Reliability / Operability

No: M 8

Operational Requirement:

To provide a vehicle with adequate system availability, resiliency, and schedule dependability in order not to impact schedule and resulting processing cost (i.e. manpower and overtime).

Rationale:

The processing history at ETR and KSC of both expendable and recoverable vehicles support this requirement.

FOR:

Sample Concept:
Technology Requirement:
Technology References:

See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC
Maintainability/Supportability

No: M 9

Operational Requirement:

Maintainability / supportability must get high priority in Design / Build Team representation.

Rationale:

Analysis of STS cost drivers in Phase 1 of this study includes, for example, documentation of some 226 maintainability issues and 104 accessibility issues. Most of these would not have occurred if adequate consideration / priority had been assigned before the design was cast in concrete.

FOR:

Sample Concept:
Technology Requirement:
Technology References:

See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC
Logistics Support

No: M 10

Operational Requirement:
Provide adequate spares provisioning from the beginning.

Rationale:

Spare parts provisioning is yet another illustration that the Shuttle Program was not prepared for an operational schedule. The conscious decision was made to postpone spare parts procurements in favor of budget items of perceived higher priority. The policy proved to be shortsighted and has led to the inefficiencies of cannibalization to support the flight rate.

From the Challenger Presidential Commission Report, "The logistics support for 51-L ground processing was inadequate, since it created a need to remove parts from other orbiters to continue 51-L operations. For 51-L, 45 out of approximately 300 required parts were cannibalized. These parts ranged from bolts to an OMS TVC actuator and a fuel cell. The significance to operations of cannibalization is that it creates (1) significantly increased efforts to accomplish the same work due to multiple installation and retest requirements, (2) schedule disruption due to added work and normally later part availability, and (3) orbiter damage potential due to increased physical activity in the vehicles. These efforts make cannibalization operationally unacceptable."

FOR:

Sample Concept:
Technology Requirement:
Technology References:
} See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC
Operational Test Requirements

No: M 11

Operational Requirement:

Valid operational test requirements should be defined by the Design/Build Team (see M2) and integrated into VHMS (Vehicle Health Monitoring System) where possible.

Rationale:

Current and past LV programs, at both ETR and KSC, test and retest at the instigation of individual design, test, and technical management organizations (Contractor, NASA, and Aerospace). All of these practice CYA to extreme levels. Further, "once a test, always a test", with little or no effort made to remove requirements for tests that are no long necessary. Many of these tests are the result of inadequate incorporation of operations experience in the design and many qualification test requirements are carried into operations as basic test requirements unnecessarily.

Even where the design includes self-test capability, old habits die hard. For example, on IUS, pre-deployment checkout utilizes a VHMS and verifies IUS readiness for deployment in approximately two minutes. Equivalent ground testing requires extensive manpower and GSE which manually sequences each test step, with serial, manpower-intensive data analysis. Each time the IUS is moved, it is retested in this manner. The result is many additional weeks of test time.

FOR:

Sample Concept:
Technology Requirement:
Technology References:

See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC
Quality Assurance

No: M 12

Operational Requirement:

A modern QA program that virtually eliminates the requirement for a large force of Quality inspectors with its inherent inefficiencies impacting processing times and costs.

Rationale:

Quality Assurance places emphasis on inspection. As a result of the Challenger loss and the Presidential Commission Report, program management has amplified this problem by increased manpower and efforts to inspect quality into the product. American industry, led by Japan's implementation of Deming's methods, is beginning to understand that inspection is not only costly, but also ineffective.

FOR:

Sample Concept:
Technology Requirement:
Technology References:
} See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC
Safety

No: M 13

Operations Requirement:

Special safety requirements, particularly for ordnance and propellant related items, must be reduced to a bare minimum and preferably eliminated where possible.

Rationale:

Hazardous operations and conditions in the vehicle preparation area greatly affect operations times and increase costs. During such times, technicians are prevented from doing useful work on the vehicle, and only one task can proceed at any one time. To minimize these delays, ordnance operations must be absolutely minimized and preferably eliminated from the processing flow.

FOR: S

Sample Concept:
Technology Requirement:
Technology References:
} See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC
Security

No: M 14

Operational Requirement:

Security requirements which impact costs (most do) should be minimal and realistic.

Rationale:

Operational costs for past and current programs have been significantly impacted by security requirements; cost impact data was not available or considered. This cost impact includes security control and accountability of paperwork; controlled access areas; screenrooms; equipment that meets Tempest requirements; separate software; etc.

FOR:

Sample Concept:
Technology Requirement:
Technology References:
} See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC
Connectivity Architectures

No: M 15

Operational Requirement:

Conform to computer interface standards to allow complete connectivity, both text and graphics, between organizations (Design, Manufacturing, Logistics, Operations, etc.).

Rationale:

Current methods of information flow are inadequate and error prone.

Connectivity architecture is rapidly becoming available that allows ready interchange of data among different computer operating systems and databases.

Significant cost reduction in LCC can be made by contractual requirement to utilize industry/government standards shown on the next two charts.

FOR:

Sample Concept:
Technology Requirement:
Technology References:
} See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

STRUCTURE OF MIL-STD-1840A

IDSS IMPLEMENTED BY THIS NEW MIL-STD

MIL-STD-1840A

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

MIL-SPEC-SGML

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

(TEXT)

MIL-SPEC-IGES

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

(GRAPHICS)

Architectures

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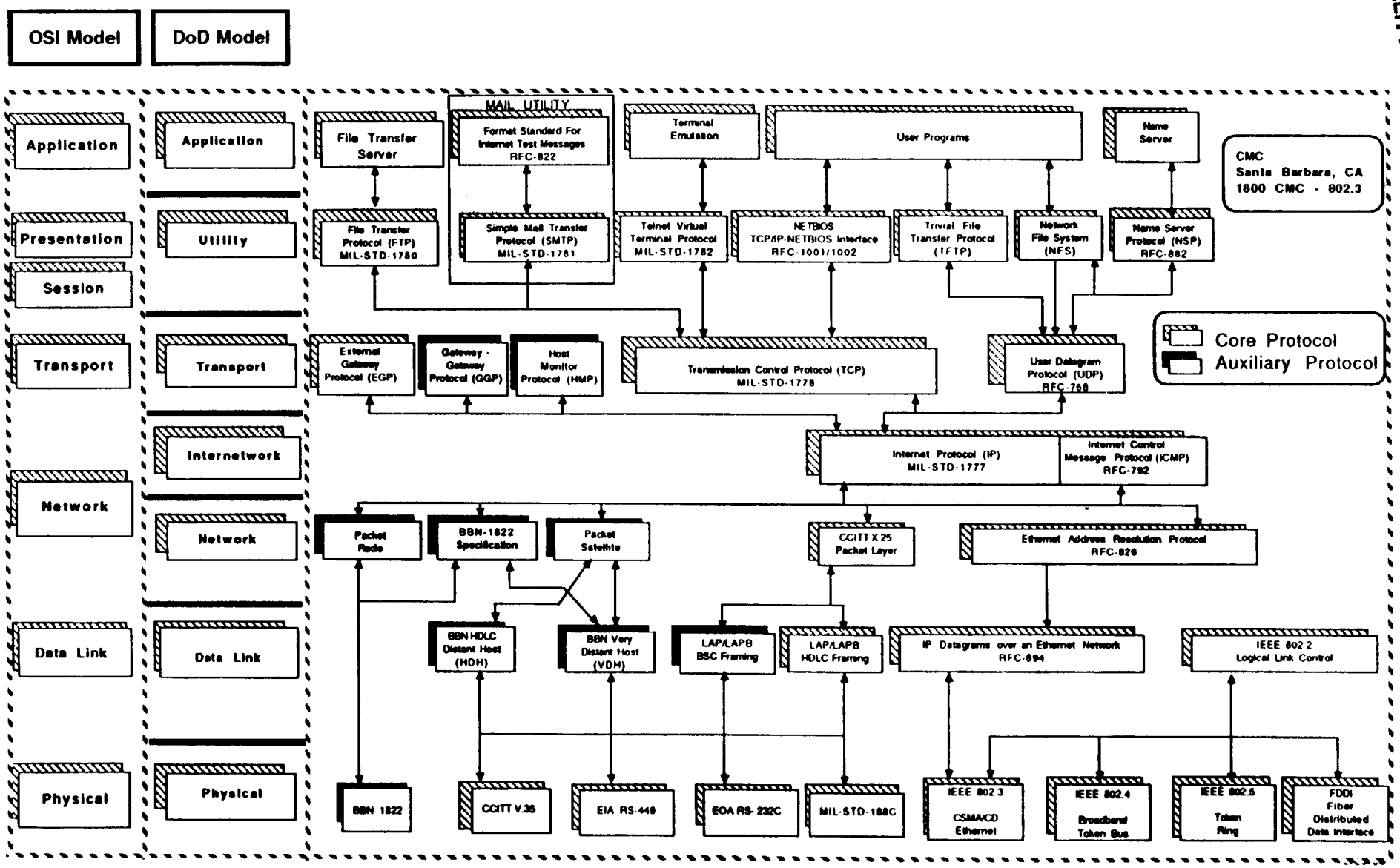

ROUNDTABLE WORKSHOP AGENDA

DISCUSSION OF S G O E / T ELEMENTS	A. L. SCHOLZ
MANAGEMENT / SYSTEM ENGINEERING	A. L. SCHOLZ
AVIONICS & SOFTWARE	D. J. LOWRY
POWER / STRUCTURES & MATERIALS	R. J. BYRD
PROPULSION	R. J. BYRD
FACILITIES & SUPPORT EQUIPMENT	LOWRY / BYRD

SGOE / T — ALS Phase II Contractor WORKSHOP AVIONICS & SOFTWARE

- AUTONOMOUS VEHICLE
  - A 1) ● BIT / BITE (ON - BOARD CHECKOUT)
  - A 2) ● FAULT TOLERANT AVIONICS SUITE
  - A 1) ● VEHICLE HEALTH & STATUS MONITORING SYSTEM
  - A 4) ● MINIMAL LAUNCH CONTROL INTERFACE
  - A 1) ● RETURNED VEHICLE SELF - TEST FOR REFLIGHT
  - A 3) ● AUTONOMOUS G N & C
  - A 4) ● OPTICAL / IR / RF LINK ONLY TO GSE
- SOFTWARE
  - A 5) ● COMMON "CORE" SOFTWARE FOR C / O, LAUNCH, FLIGHT
  - A 5) ● OPERATIONS DATA OVERLAYS (C / O, LAUNCH, MISSION)

ELIMINATE

- A 6) ○ RELATED GSE
- A 4) ○ HARDWIRE CONNECTS TO GSE
- E 1) ○ GROUND POWER REQUIREMENTS

SLSOC
On-Board Checkout

No: A 1

Operations Requirement:

Current configurations require extensive use of GSE to support vehicle checkout. Future systems should incorporate onboard checkout and minimize (preferably eliminate) GSE.

Vehicles should have sufficient self-test capability to verify flight readiness or isolate problem to LRU.

Rationale:

Current configurations require complex GSE hookups to support system test and operational verification. The configuration verification, required for test hookup and calibration, defeats efficient operations.

To accomplish order-of-magnitude cost reduction, we must achieve160-Hr or better turnaround time for recoverable stages. (160-Hrs was the original STS Turnaround goal whose actuals have grown an order-of-magnitude). In addition to turnaround times exceeding 1500 hours, aging recoverable vehicles will impose requirements for structural inspections which will require extensive time periods offline.

ELV's processing times would also be enhanced by use of on-board checkout capabilities.

FOR:

Sample Concept:
Technology Requirement:
Technology References:

See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC
Fault Tolerant Avionics Suite

No: A 2

Operations Requirement:

Avionics systems must provide for higher reliability by providing levels of fault tolerance in support of mandated system availability.

Rationale

To support onboard checkout and mission success the entire avionics suite must be designed to provide that level of fault tolerance required to assure that the system is available when required. This is best accomplished by assuring the robustness of all mission critical systems, and providing fault tolerance where it is required.

FOR:

Sample Concept:
Technology Requirement:
Technology References:

See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC
Title: Autonomous GN&C

No: A 3

Operations Requirement:

Eliminate vehicle dependence on GN&C GSE for test and checkout.

Rationale:

On-board Vehicle Health Monitoring System (VHMS) for GN&C can eliminate / simplify / speed-up ground operations.

FOR:

Sample Concept:
Technology Requirement:
Technology References:

See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC
No Hardwire to Vehicle; Minimal Launch Control Interface; No Ground Power

No: A 4

Operations Requirement:

Minimize hardwire connections to vehicle to simplify vehicle erection and pad connection sequence. Also, drastically reduce quantity of control and data functions from Launch Control Center to pad. Eliminate requirement for ground power.

Rationale:

All systems must be dramatically reduced or simplified to achieve required cost reduction. O&M of vehicle hard connects is costly and labor intensive.

FOR:

Sample Concept:
Technology Requirement:
Technology References:
} See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC
Software Commonality

No: A 5

Operational Requirement:

The vehicle should utilize the same software for ground operations test and integration as for flight.

Rationale:

Current STS ground operations are accomplished with several different programs depending on the stage of testing. This results in many hours of time for reloading the main computer memory. For example the final prelaunch load requires 14 clock-hours to accomplish.

FOR:

Sample Concept:
Technology Requirement:
Technology References:

See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC
Related GSE

No: A 6

Operational Requirement:

Minimize (preferably eliminate) GSE that is in direct support of vehicle systems.

Rationale:

Every item of GSE requires a small army in support (engineers, technicians, mechanics, inspectors, clerks, etc.). All of these contribute to processing time and cost.

FOR:

Sample Concept:
Technology Requirement:
Technology References:
} See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

ROUNDTABLE WORKSHOP AGENDA

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SGOE / T— ALS Phase II Contractor WORKSHOP
POWER

- E) ● LOW MAINTENANCE ENERGY STORAGE
- E) ● PROPELLANT GRADE FUEL CELLS
- E) ● STATE - OF - ART ENERGY SOURCES
- E) ● SYSTEM SIZED TO PROVIDE ON - BOARD POWER FOR GROUND OPERATIONS

ELIMINATE

A 6)	O	RELATED GSE
E)	O	GROUND POWER REQMTS

SLSOC
Eliminate Requirement for Ground Power

No: E

Operational Requirement:

Vehicle systems that operate off vehicle power without requirement for ground power connection at any time during checkout or launch operations.

Onboard power source capable of providing sufficient power for ground O&M, T&C/O, and launch operations without connection to facilities or GSE.

Provide a low maintenance, state-of-the-art energy storage source. If energy source is H2-O2 fuel cell, then it should use propellant-grade cryos.

Rationale:

The requirement for ground power not only requires complex GSE, but also requires umbilical connections and, in some cases, towers and swingarms. Each of these require extensive checkout time and personnel (engineers, technicians, mechanics, inspectors, and clerks) in support.

Requirement for special high-grade H2 and O2 for fuel cells creates additional logistics, GSE, personnel, and timeline needs.

FOR:

Sample Concept:
Technology Requirement:
Technology References:
} See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SGOE / T— ALS Phase II Contractor WORKSHOP
STRUCTURES & MATERIALS

- IMPROVED STRUCTURE
  - S 1) MINIMIZE LEAK PATHS STRUCTURAL
  - S 2) INTEGRITY VERIFICATION
  - S 3) INTEGRAL TPS
- S 4) ORDNANCE
  - S 4.1) WEAPON DESTRUCT
  - S 4.2) LASER IGNITION
  - S 4.3) ACCELERATION / CLEVIS SEPARATION
  - S 4) NITINOL / E - M DEVICES

ELIMINATE

- S 3) SEPARABLE TPS
- S 4) ALL ORDNANCE
- S 4) PROCESSING SAFETY RESTRICTIONS

SLSOC
Minimize Leak Paths

No: S 1

Operations Requirement:

Develop systems with fewer separable connections and leakpaths in integrated systems.

Rationale:

Contemporary tankage and plumbing are leak sensitive and require constant ground operations vigilance. Any configuration simplification has positive consequences on ground support operations. Possible weight savings.

FOR:

Sample Concept:
Technology Requirement:
Technology References:

See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC
Structural Integrity Verification

No: S 2

Operational Requirement:

Provide on-board structural verification for recoverable vehicles. .

An alternate approach is robust design for the number of launches required; then throw away.

Rationale:

To avoid extensive recoverable vehicle downtimes which severely impact manifest capability. This downtime causes drastic increase in life cycle costs because of reduced flight rate.

FOR:

Sample Concept:
Technology Requirement:
Technology References:
} See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC
No Ordnance

No: S 4

Operations Requirement:

Eliminate all ordnance devices or provide ordnance which is inherently safe for handling purposes. Ordnance elements, if required, must be introduced into the processing flow with the minimum possible impact. The objective would be to eliminate or drastically reduce "area clear" requirements levied by ordnance activities.

Rationale:

There are five types of ordnance devices currently used on STS: propulsion (SRM's), ignition, release, separation, and range safety. The special handling, safety, area clear, and training requirements make this a major cost area in ground processing.

FOR:

Sample Concept:
Technology Requirement:
Technology References:

See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC
Independent Weapon Destruct

No: S 4.1

Operations Requirement:

Provide ground-based anti-missile-type battery of circa 1995 weapon systems to provide near-range vehicle destruct. Eliminate extensive non-productive manhours for "area clear" during range safety ordnance installation. Minimize "safety army" and procedures that accommodate contemporary systems and methods.

Rationale:

Elimination of vehicle range safety ordnance and associated non-productive manhours and operational cost is highly desirable. Consider current range safety regulations negotiable.

FOR:

Sample Concept:
Technology Requirement:
Technology References:
} See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC
Laser Ignition

No: S 4.2

Operational Requirement:

Eliminate pyrotechnic type ordnance where possible; at least, provide system with less stringent safety requirements.

Rationale:

There are four types of ordnance devices currently used on STS: ignition, release, separation, and range safety. The special handling safety, area clear, and training requirements make this a major cost area in ground processing.

FOR:

Sample Concept:
Technology Requirement:
Technology References:

See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

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SGOE / T — ALS Phase II Contractor WORKSHOP
PROPULSION

- INTEGRATED PROPULSION SYSTEM

P1) ● SIMPLIFIED ROBUST PROPULSION SYSTEM

P1.1) ● FULLY THROTTLEABLE ENGINES (MULTI-PHASE)

P1.2) ● SOFT ENGINE START

P1.3) ● TVC BY DELTA THRUST AND/ OR RCS / OR AERO

P1.4) ● ONE OXIDIZER / ONE FUEL

ELIMINATE

P 2) ○ SEPARATE OMS AND RCS

P 3) ○ HIGH MAINTENANCE TURBOPUMPS

P 4) ○ HYDRAULICS

P 5) ○ HYPERGOLS

P 6) ○ GN_2 / He ON-BOARD PURGES

P 7) ○ GN_2 / He PRESSURE SYSTEM

P 8) ○ GIMBALLED ENGINES

P 9) ○ EXTENSIVE RECOVERY & REFURBISHMENT

SLSOC

Simplified Robust Propulsion System

No: P 1

Operations Requirement:

Simplified, integrated, robust propulsion system that, using the same oxidizer and fuel, provides the essential elements of:

main propulsion

orbit insertion

attitude/rendezvous control

Rationale:

Current propulsion systems started with an engine design and then the MPS built around it.

There is a necessity to simplify and integrate all propulsion systems in order to radically minimize the supporting operations and maintenance.

FOR:

Sample Concept:
Technology Requirement:
Technology References:

See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC

Fully Throttleable Engines (multi-phase)

No: P 1.1

Operations Requirement:

Design and develop main propulsion system rocket engines that are fully throttleable from near 0 to 100%. For upper stages, this is an alternate to a straight pressure-fed engine but has higher related operations cost, since it doesn't eliminate turbopumps.

Rationale:

The SSMEs can be throttled from 65% to over 100% only. With multiple restart and lower thrust capability, the MPS could be used for orbital maneuvering (OMS); thereby saving cost, weight, and T&C/O of separate OMS systems.

FOR:

Sample Concept:
Technology Requirement:
Technology References:

See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC

Soft Engine Start

No: P 1.2

Operations Requirement:

Revise rocket engine start transient time specifications to allow significantly slower start time.

Rationale:

Existing SSME rapid start can reduce life expectancy and increase refurbishment frequency of turbopump bearings, seals, and propellant valves.

FOR:

Sample Concept:
Technology Requirement:
Technology References:

See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC

TVC by Delta Thrust and/or RCS/or Aero

No: P 1.3

Operations Requirement:

Provide TVC or some form of vehicle attitude control during MPS operation if gimballed engines are eliminated.

Rationale:

Simplifying the vehicle systems and ground operations by deleting gimballed engines and associated systems requires alternate method of TVC or vehicle attitude control during MPS operation as proposed in Item P1.

FOR:

Sample Concept:
Technology Requirement:
Technology References:

See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC
One Oxidizer / One Fuel

No: P 1.4

Operations Requirement:

Simplify propellant procurement, transport, storage, pumping, safety equipment and procedures by designing vehicles using only one oxidizer and one fuel.

Rationale:

Each individual propellant ground system requires its own little army of engineers, technicians, safety, and expensive, hazardous facilities / GSE.

STS has five propellant components, each of which require separate procurement, transport, storage, pumping , GSE, safety, operational procedures, engineers, technicians, etc.

FOR:

Sample Concept:
Technology Requirement:
Technology References:
} See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC
Eliminate Separate OMS and RCS

No: P 2

Operations Requirement:

Delete OMS and RCS as separate systems from MPS.

Rationale:

If MPS can be utilized for OMS and RCS, it may significantly lighten vehicle and will simplify ground support operations.

FOR:

Sample Concept:
Technology Requirement:
Technology References:

See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC
Eliminate High-Maintenance Turbopumps

No: P 3

Operations Requirement:

The ideal requirement is to eliminate high maintenance turbopumps. The turbopumps must be made more robust to reduce refurbishment/ maintenance requirements for recoverable stages.

Rationale:

Turbopumps are costly to develop and manufacture, heavy, run at very high RPM, and are cavitation-sensitive devices.

Rocket engine cost, refurbishment frequency, refurbishment cost, and T&C/O time consumption are largely driven by turbopump sensitivity.

Pressure-fed engines with plug nozzles are a viable prospect as specific impulse is relatively insensitive to chamber pressure per se.

FOR:

Sample Concept:
Technology Requirement:
Technology References:

See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC
No Hydraulics

No: P 4

Operations Requirement:

Provide high thrust actuators for vehicle systems using a system other than hydraulic.

Rationale:

Hydraulic systems are heavy, complex, and plagued with O&M and GSE activities. Vehicle and ground support operations would be greatly simplified if a simpler, more reliable alternative is developed.

FOR:

Sample Concept:
Technology Requirement:
Technology References:

See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC
No Hypergols

No: P 5

Operations Requirement:

No use of hypergols for launch, orbital propulsion, or APU systems.

Rationale:

A very significant quantity of non-productive manhours occurs during each flow for "area clear" required during hazardous "opening", entry, or operation of OMS and RCS orbiter systems. There is also a snowballing effect in facilities and O&M requirements for special ventilation, scrubbers and a multitude of safety equipment, including a small army specially trained to do their job in SCAPE (self-contained atmospheric protective ensemble) suits. Further, a pound of hypergol costs about $8.00, whereas, a LOX/H2/H2 mix costs less than $0.22/lb; a LOX/CH4 mix costs less than $0.15/lb; and a LOX/C3H8 costs less than $0.08/lb.

Further, the use of hypergols (and solid propellants also) at the launch rates and large quantities envisioned presents a very severe environmental hazard.

FOR:

Sample Concept:
Technology Requirement:
Technology References:
} See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC

No GN2/He On-board Purges

No: P 6

Operations Requirement:

Delete launch vehicle on-board GN2 and He purge systems.

Rationale:

Subject systems add weight to vehicle and electro / mechanical / pneumatics require special small O&M army and much time for ground processing and launch.

FOR:

Sample Concept:
Technology Requirement:
Technology References:

See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC
No GN2/He Pressure Systems

No: P 7

Operations Requirement:

Delete GN2 and He valves control plumbing and propellant tankage pressure systems.

Rationale:

Elimination of GN2 and He storage bottles, supply valves, manifolds, plumbing, and multiple test and checkout, will significantly lighten the vehicle, and simplify and speed-up ground support operations.

FOR:

Sample Concept:
Technology Requirement:
Technology References:
} See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC

No Gimballed Engines

No: P 8

Operations Requirement:

Devise thrust vector or vehicle attitude control system which eliminates need for gimballed engines and associated hydraulics, seals, pivots, bellows, etc.

Rationale:

Gimbal systems are expensive and heavy, and add a severe burden of O&M, and test and checkout to ground support operations.

FOR:

Sample Concept:
Technology Requirement:
Technology References:

See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

ROUNDTABLE WORKSHOP AGENDA

DISCUSSION OF S G O E / T ELEMENTS	A. L. SCHOLZ
MANAGEMENT / SYSTEM ENGINEERING	A. L. SCHOLZ
AVIONICS & SOFTWARE	D. J. LOWRY
POWER / STRUCTURES & MATERIALS	R. J. BYRD
PROPULSION	R. J. BYRD
FACILITIES & SUPPORT EQUIPMENT	LOWRY / BYRD

SGOE / T — ALS Phase II Contractor WORKSHOP
FACILITIES & SUPPORT EQUIPMENT

L 1) ● 100% COMPUTER CONNECTIVITY

● AUTOMATION
- L 2) ● ELECTRONIC OMI's
- L 3) ● TEXT AND GRAPHICAL DATA ACQUISITION
- L 4) ● TEST REQUIREMENT VERIFICATION

● STAGE ASSEMBLY
- L 5) ● INITIAL NEAR LAUNCH CENTER
- L 5) ● FINAL AT LAUNCH CENTER

L 6) ● HORIZONTAL PROCESSING
- L 7) ● HORIZONTAL TRANSPORT

● PAYLOADS
- L 10) ● ONE AUTONOMOUS CONTAINER

● PAD
- L 8) ● BARREN PAD
- L 9) ● ERECT / MATE STAGES AT PAD
- L 8.1) ● DEEP WATER EXHAUST BUFFER
- L 8) ● LIGHTNING / LIGHTING TOWER
- L 8.2) ● FLY-AWAY CONNECTS ONLY
- L 8) ● PROPELLANT FARM
- L 6) ● PAVED TOW - WAY

● MOBILE EQUIPMENT
- L 6 ● STANDARD AIRCRAFT TUG
- L 6 ● STRAP-ON WHEELED DOLLIES
- L 6 ● MOBILE CRANE

● BUILDINGS
- L 6 ● HORIZONTAL PROCESSING FACILITY

ELIMINATE

O AUTOMATION
- L 1) O ISOLATED DATABASES
- L 2) O PAPERWORK RELATED TO TEST
- L 4) O REQUIREMENTS VERIFICATION
- L 3) O PRINTED TRANSFER OF TEXT / DATA

L 10) O PAYLOAD / VEHICLE INTEGRATION VERIFICATION TESTING

L 9) O LIFTING VEHICLES CLEAR OF GROUND

O PAD EQUIPMENT
- L 4) O HARDWIRE CONNECTS
- L 8.4) O ACCESS STRUCTURES
- L 8.3) O SWINGARMS
- L 8) O RETRACTING UMBILICALS
- L 8.5) O T-O HOLD-DOWN
- L 8.6) O DELUGE WATER
- L 8.6) O SOUND SUPPRESSION WATER
- L 8.1) O FLAME TRENCH / DEFLECTOR
- L 8.7) O ECS
- P 6) O He / GN_2 STORAGE
- E) O GROUND POWER
- L 7) O CRAWLER WAY

O MOBILE EQUIPMENT
- L 7) O CRAWLER / TRANSPORTER
- L 7) O MOBILE LAUNCH PLATFORM

O BUILDINGS
- L 6) O VAB
- L 6) O VPF
- L 6) O RPSF

SLSOC
100% Computer Connectivity

No: L 1

Operations Requirement:

All computers associated in any manner with operations, flight, or ground must provide and maintain complete connecting (bridging).

Rationale

The vast amount of data required to support and maintain any operational system requires that the maximum efficiency in operations be always maintained. Paperwork currently requires a large portion of the allocated operations budget. A potential reduction of 5% of the total LCC can be achieved by automation of paperwork. Isolated databases must be eliminated to accomplish this.

FOR:

Sample Concept:
Technology Requirement:
Technology References:

See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC
Automated Electronic OMI's

No: L 2

Operations Requirement

Operational and support procedures should be computer-based and maintained.

Rationale:

Conventional hard copy procedures are difficult and expensive to maintain. The manual update, copy and distribution of procedures does not provide for cost effective operations. The lack of procedural discipline results in many errors. Automated procedures would control approvals, procedural sequence, data recording and associated support data presentation.

FOR:

Sample Concept:
Technology Requirement:
Technology References:

See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC
Text and Graphical Data Acquisition

No: L 3

Operations Requirement:

Import and export of text and graphics requires that data formats be standardized. Eliminate hard copy transfer of text and data for information and for approvals.

Rationale:

The large volume of operations and support data is currently generated, maintained, and distributed in hard copy form and is highly labor intensive.

FOR:

Sample Concept:
Technology Requirement:
Technology References:

See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC
Automatic Test Requirements Verification

No: L 4

Operations Requirement:

Test requirements verification must be automatically correlated with the completion of the associated procedures.

Rationale:

Current manual method is inefficient, inadequate, and error prone.

FOR:

Sample Concept:
Technology Requirement:
Technology References:

See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC
Final Stage Assembly at Launch Site

No: L 5

Operations Requirement:

Perform initial stage assembly at manufacturing facility near Launch Center. Perform all stage assembly, refurbishment and T&C/O in one building at the launch center; including installation of autonomous payload.

Rationale:

Simplifies transportation from manufacturing facilities to Launch Center. Vertical clearance inside a C-5A cargo plane is 13.5 ft. . Any larger loads must use the SCM (Space Cargo Modified) C-5A or be transported by barge: a lengthy, harzardous, and expensive alternative. The average C-5A delivery flight costs $150K.

Simplifies and minimizes assembly and T&C/O facilities.

More efficient use of personnel who can be cross-utilized for assembly and for checkout. Proximity of manufacturing facility to Launch Center further enables cross-utilization.

FOR:

Sample Concept:
Technology Requirement:
Technology References:
} See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC
Horizontal Processing

NO.: L 6

Operations Requirement:

Provide combination of vehicle and facilities design resulting in simplest, least costly launch cycle.

Rationale:

Ground processing mode comparison of positives and negatives indicates horizontal processing meets the operations requirement better than vertical processing. Vertical processing requires more facilities, GSE, people, hazardous operations, and time.

FOR:

Sample Concept:
Technology Requirement:
Technology References:

See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC
Horizontal Transport

No.: L 7

Operations Requirement

Simplify vehicle rotation, eliminate high - lift VAB scenarios, and related extensive GSE and GSO army.

Rationale

Conventional rotation, lift, and mate in the VAB requires large mobilization for complex, interrelated GSO, equipment, and personnel.

FOR:

Sample Concept:
Technology Requirement:
Technology References:

See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC

Barren Pad

No: L 8

Operational Requirement:

Barren pad with essentially no GSE or supporting structures.

Rationale:

A major contributor to ground operations cost is the complexity of GSE and structures at the pad which require constant maintenance and/or refurbishment and modifications. Each of which require small armies of supporting personnel (engineers, technicians, mechanics, clerks, etc.)

A "barren pad" would have:

* Simple raised concrete structure
* Deep water exhaust buffer
* Lightning/lighting tower
* Propellant farm
* Mobile crane (as required)
* Flyaway propellant connections
* Wireless (infrared/optical/RF) control & data connections

A "barren pad" would not have:

* Access structures
* Swingarms
* Retracting umbilicals
* T-0 holddown
* Firebrick flame trench and deflectors
* Deluge water system
* Sound suppression water system
* Large pad terminal connection room
* Ground power system and related GSE
* ECS GSE
* Vehicle system GSE
* Hardwire connections to vehicle
* Office and shop facilities

SLSOC

Deep Water Exhaust Buffer

No: L 8.1

Operations Requirement:

Simplify flame trench and deflector to eliminate frequent costly maintenance.

Rationale:

Replacement of firebrick, major refurbishment at repetitive intervals, and consistently high structural erosion of flame deflectors is costly. These should be greatly reduced or eliminated. This aspect is aggravated by high launch rate, e.g., weekly.

FOR:

Sample Concept:
Technology Requirement:
Technology References:

See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC
Flyaway Connects Only
(No Retracting Umbilical Carrier Plates)

No: L 8.2

Operations Requirement:

Provide simplified vehicle umbilical disconnect systems.

Rationale:

Contemporary quick-disconnect umbilical carriers are very complex, launch-damage susceptible, and manpower-intensive for test and checkout. Post-launch refurbishment is repetitive, costly, and time consuming.

FOR:

Sample Concept:
Technology Requirement:
Technology References:
} See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC
No Swingarms

No: L 8.3

Operations Requirement:

Simplify or eliminate all swingarms with the related ground support operations, equipment, and structures to dramatically reduce repetitive costs.

Eliminate repetitive tests and checkout at pad and post launch refurbishment.

Rationale:

Contemporary swingarms are expensive, complex, O&M intensive, and launch critical systems.

FOR:

Sample Concept:
Technology Requirement:
Technology References:

See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC
No Vehicle or Payload Access Structure

No: L 8.4

Operations Requirement:

No vehicle or payload access structure.

Minimize vehicle resident time at pad. Rollout, erect, fuel, verify satisfactory self-test, launch.

Limited LRU changeout capability at pad (boattail).

Rationale:

Current STS requires two weeks or more at the pad for extensive interface systems test and checkout, payload access for O&M, vertical P/L insertion, closeout and all-systems verifications. This time period and tedious process is not acceptable for reduced cost and high launch rate.

FOR:

Sample Concept:
Technology Requirement:
Technology References:
} See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC
Simplified Holddown/release

No: L 8.5

Operations Requirement:

Greatly simplify vehicle holddown systems at pad.

Rationale:

Holddown system of some kind is mandatory to restrain vehicle in high winds and to stabilize motion during engine start. Existing method is costly, dangerous, time-consuming, and not required for continuously variable thrust.

FOR:

Sample Concept:
Technology Requirement:
Technology References:
} See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC
No Deluge or Sound Suppression Water

No: L 8.6

Operations Requirement:

Eliminate very extensive facilities, personnel, test and checkout procedures, and costly O&M of pad water systems.

Rationale:

If the vehicle does not possess the STS-style MLP/SRB interface physics, sound suppression water is not mandatory. If there are no tower hydraulics, swingarms or heat sensitive GSE/cabling at the pad, deluge water is not mandatory.

Gross simplification of launch pad facilities and operations is essential to reduce cost-to-orbit by factor of 10.

FOR:

Sample Concept:
Technology Requirement:
Technology References:

See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC
No Pad ECS

No: L 8.7

Operations Requirement:

The barren pad has no complex internal rooms and GSE requiring STS-style pre-launch inert atmosphere and positive pressurization. Delete similar systems providing vehicle ECS.

Rationale:

These are costly in O&M personnel and test / checkout / pre-launch validation time, and are not necessary in the proposed "barren pad".

FOR:

Sample Concept:
Technology Requirement:
Technology References:

See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC
Erect / Mate Stages at Pad

No. : L 9

Operations Requirement

Eliminate complex rotation, mate, and associated GSE and bridge cranes in VAB. Also, eliminate need to transport very large, delicate, awkward assembly to launch pad.

Rationale:

Mating remotely from launch site requires army of men and GSE for complex lifting / rotation harness, bridge cranes, MLP, C / T, platform retraction, and very expensive, labor intensive O & M " tree " to support all this equipment.

FOR:

Sample Concept:
Technology Requirement:
Technology References:

See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC
Payloads: Standard Autonomous Cargo Container

No: L 10

Operations Requirement:

Provide only simple mechanical interface between launch vehicle and payload.

Rationale:

Orbiter payload bay modifications and payload flight support equipment software modifications are among the most time consuming ground support operations.

For existing ELV's; each interface requires extensive GSE and T&C/O.

FOR:

Sample Concept:
Technology Requirement:
Technology References:
} See WORKSHOP DATA REFERENCE DOCUMENT, March 1989

SLSOC
Facilities Summary

These simple, limited - scope exercises indicate a realistic (even conservative) potential reduction in Shuttle - equivalent headcount of 693 people by application of these few SLSOCs having quantified data. In Summary:

● Provide robust TPS	162
● Eliminate pyrotechnics	60
● Eliminate hydraulics	37
● Eliminate hypergols	106
● Eliminate CTs & MLPs	104
● Provide barren pad	224
	693

ROUNDTABLE WORKSHOP AGENDA

BREAK FOR THE DAY -- 1630

CALL TO ORDER -- 0800	W. J. DICKINSON
DISCUSSION / SPLINTER SESSIONS	ALL
SUMMARY AND WRAPUP	DICKINSON / SCHOLZ

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National Aeronautics and Space Administration

Report Documentation Page

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15. Supplementary Notes

This document is phase 3 of a 3-phase study. Phase 1 has been published as NASA CR-180581 thru 180585.

16. Abstract

This volume contains charts supporting the Final Oral Presentations conducted during the ALS contractor Workshops, namely: 1) General Dynamics 3/22&23,1989, 2) Martin Marietta 3/29 &30, and 3) Boeing Seattle 4/5&6. This data was used in conjunction with the expanded level of details contained in Volume 3, ALS Contractor Workshop Data Reference Document - SLSOC.

Bulk of the presentation is Simplified Launch System Operational Criteria (SLSOC) operational analyses in the areas of: 1) Management and System Engineering, 2) Avionics and Software, 3) Power, 4) Structures, 5) Propulsion, and 6) Facilities and Systems Equipment.

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