Space Division
North American Rockwell

ISPLS
CONTRACT NAS8-27692
FIRST PERFORMANCE REVIEW
CHART NO. 1 DATE 10-6-71

IN-SPACE PROPELLANT LOGISTICS
AND
SAFETY
FIRST PERFORMANCE REVIEW

FOR THE PERIOD 26 JUNE THRU 15 SEPT 1971

6 OCTOBER 1971

DPD NO. 262
DR NO. MA-03

IN-SPACE PROPELLANT LOGISTICS

AND

SAFETY

FIRST PERFORMANCE REVIEW

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6 OCTOBER 1971

DPD NO. 262
DR NO. MA-03

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Space Division North American Rockwell	OUTLINE	ISPLS CONTRACT NAS8-27692 FIRST PERFORMANCE REVIEW CHART NO. 2 DATE 10-6-71

ISPLS
INTRODUCTION
R.E. SEXTON

PROJECT I
REQUIREMENTS
G.A. OLSON

PROJECT I
PROPELLANT LOGISTICS SYSTEMS ANALYSIS
R.L. MOORE

PROJECT II
SYSTEMS SAFETY ANALYSIS
W. PLAISTED

ISPLS
SUMMARY ACTIONS FUTURE ACTIVITIES
R.E. SEXTON

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PUROPOSE OF FIRST QUARTER REVIEW

- NR PRESENTATION OF FIRST QUARTER STATUS AND ANALYSIS RESULTS
- REQUEST FOR NASA APPROVAL OF PERFORMANCE, STATUS, AND DIRECTION OF STUDY

STUDY OBJECTIVES

THE IN-SPACE PROPELLANT LOGISTICS AND SAFETY PROGRAM IS BEING CONDUCTED AS TWO RELATED BUT DISTINCT PROJECT EFFORTS.

PROJECT I, "AN OVERALL SYSTEMS/OPERATIONS ANALYSIS," DEVELOPS USER PROPELLANT REQUIREMENTS ALTERNATIVES, ANALYZES LOGISTICS SYSTEM CONCEPTS FOR PROVIDING IN-SPACE PROPELLANTS, PERFORMS SENSITIVITY AND COST EFFECTIVENESS EVALUATIONS, AND DEVELOPS PROGRAM PLANNING DATA FOR A SELECTED PROPELLANT LOGISTICS SYSTEM FOR FUTURE NASA SPACE PROGRAM.

PROJECT II, "SYSTEM/SAFETY ANALYSIS," ANALYZES IN-SPACE PROPELLANT LOGISTICS OPERATIONS AND IDENTIFIES HAZARDS UNIQUE TO THE FUNCTIONS OF TRANSPORT, TRANSFER, AND STORAGE OF LARGE AMOUNTS OF CRYOGENIC PROPELLANTS, AND OTHER FLUIDS OF SIGNIFICANT AMOUNTS, IN SPACE. FROM THIS ANALYSIS, CORRECTIVE MEASURES, GUIDELINES AND REQUIREMENTS ARE DEVELOPED.

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STUDY OBJECTIVES

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CONTRACT NAS8-27692
FIRST PERFORMANCE REVIEW
CHART NO. 4 DATE 10-6-71

PROJECT I - LOGISTICS

ANALYSIS OF ACTIVITIES/OPTIONS IN PROPOSED NASA SPACE PROGRAMS FROM STANDPOINT OF PROPELLANT LOGISTICS

- DEFINE FLUID RESUPPLY REQUIREMENTS OF MAJOR IN SPACE ELEMENTS
- ANALYZE CONCEPTS OF ORBITAL PROPELLANT LOGISTICS AND DETERMINE MOST COST EFFECTIVE APPROACH

PROJECT II - SAFETY

ANALYSIS OF SPACE PROPELLANT LOGISTIC OPERATIONS FROM A SYSTEM SAFETY VIEWPOINT

- DEFINE POTENTIAL HAZARDS ASSOCIATED WITH PROPELLANT LOGISTICS
- RECOMMEND MEANS TO REDUCE OR ELIMINATE POTENTIAL HAZARDS

STUDY TEAM

THE KEY PERSONNEL AND THEIR RESPONSIBILITIES
ARE SHOWN IN THE PROGRAM ORGANIZATION CHART.

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STUDY TEAM

ISPLS
CONTRACT NAS8-27692
FIRST PERFORMANCE REVIEW
CHART NO. 5 DATE 10-6-71

R. E. SEXTON
PROGRAM MANAGER

- PROJECT I
  SYSTEMS/OPNS ANALYSIS
  R.L. MOORE
  LEAD ENGR
- PROJECT II
  SAFETY STUDY
  W. E. PLAISTED
  LEAD ENGR

	PROJECT I			PROJECT II	
TASK GROUP LEADERS	OPNS ANALYSIS T.J. DOLAN	SYSTEMS ANALYSIS & INTERFACES R.J. MILLIKEN	SUPPORT REQUIREMENTS TECHNOLOGY & PROGRAMS R.L. MOORE	GUIDELINES & REQUIREMENTS J.R. COOK	SYSTEM SAFETY ANALYSIS G. RUFF
ASSIGNED TASKS:	1-1 NASA SPACE PROGRAM LEVELS 1-2 LOGISTIC TRAFFIC MODELS 1-3 TIME-PHASED FLUID RESUPPLY 1-8 IN-SPACE MAINTENANCE 1-9 ROLE OF MAN	1-4 MOST ECONOMICAL METHOD OF OPERATION 1-5 SYSTEM INTERFACES 1-6 ORBITAL STORAGE/SPACE SHUTTLE DEPENDING RELATIONSHIPS 1-7 ORBITAL STORAGE/ OTHER PROGRAM DEPENDING RELATIONSHIPS	1-10 AREAS OF TECH UNCERTAINTY 1-11 NEEDED TECH DEVELOPMENT 1-12 RECOMMENDED TECH EMPHASIS & FUNDING 1-13 FACILITIES & GSE 1-14 IMPLEMENTATION PLAN	2-1 LITERATURE REVIEW 2-5 CORRECTIVE MEASURES 2-6 SAFETY GUIDELINES AND REQUIREMENTS	2-2 LOGISTICS OPERATION 2-3 SYSTEM SAFETY ANALYSIS 2-4 TRADEOFF STUDIES

SCHEDULE POSITION , PROJECT I: SYSTEMS/OPERATIONS ANALYSIS

THE SCOPE OF THE WORK REQUIRED IN TASKS 2 AND 3 HAS BEEN EXPANDED TO ACCOMMODATE THE CLUSTERING ANALYSIS, AND THE COMPLETION OF TASK 2 HAS BEEN RESCHEDULED FROM AUGUST 31, 1971, TO SEPTEMBER 30, 1971. FURTHER IT IS NOW PLANNED THAT LOGISTICS CONCEPTING AND TRAFFIC MODELING WILL CONTINUE IN PARALLEL WITH MUCH OF TASK 4 AS AN ITERATIVE PROCESS, THEREFORE, IN THE FUTURE, ACTIVITIES OF THE NATURE OF THOSE DEFINED IN TASKS 2 AND 3 WILL BE MANAGED AS AN INTEGRAL PART OF TASK 4.

AS A FURTHER POINT OF INTEREST, TASK 4 WAS INITIATED AHEAD OF SCHEDULE TO GAIN AN EARLY UNDERSTANDING OF THE COST ELEMENTS AND TO DEVELOP THE COSTING METHODOLOGY. PROGRAM MILESTONES ARE SHOWN IN THE LOWER PART OF THE CHART: ALL THOSE SCHEDULED TO DATE HAVE BEEN MET. SIGNIFICANT UNSCHEDULED EVENTS WHICH HAVE OCCURRED ARE ALSO INDICATED AS MILESTONES.

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North American Rockwell

PROJECT I SYSTEMS OPERATIONS ANALYSIS

ISPLS
CONTRACT NAS8-27692
FIRST PERFORMANCE REVIEW

CHART NO. 6 DATE 10-6-71

PROGRAM MANAGER R.E.SEXTON

STATUS AS OF 9/15/71

PROJECT I SYSTEMS/OPERATIONS ANALYSIS

PHASE I (REQUIREMENTS AND CONCEPT DEVELOPMENT) TASKS:

- I-1 DENTIFY NASA SPACE PROGRAM REQUIREMENTS
- I-2 DEVELOP LOGISTICS TRAFFIC MODELS
- I-3 TIME PHASE RESUPPLY AND TRANSPORTATION

PHASE II (PROPELLANT LOGISTICS SYSTEM ANALYSIS) TASKS:

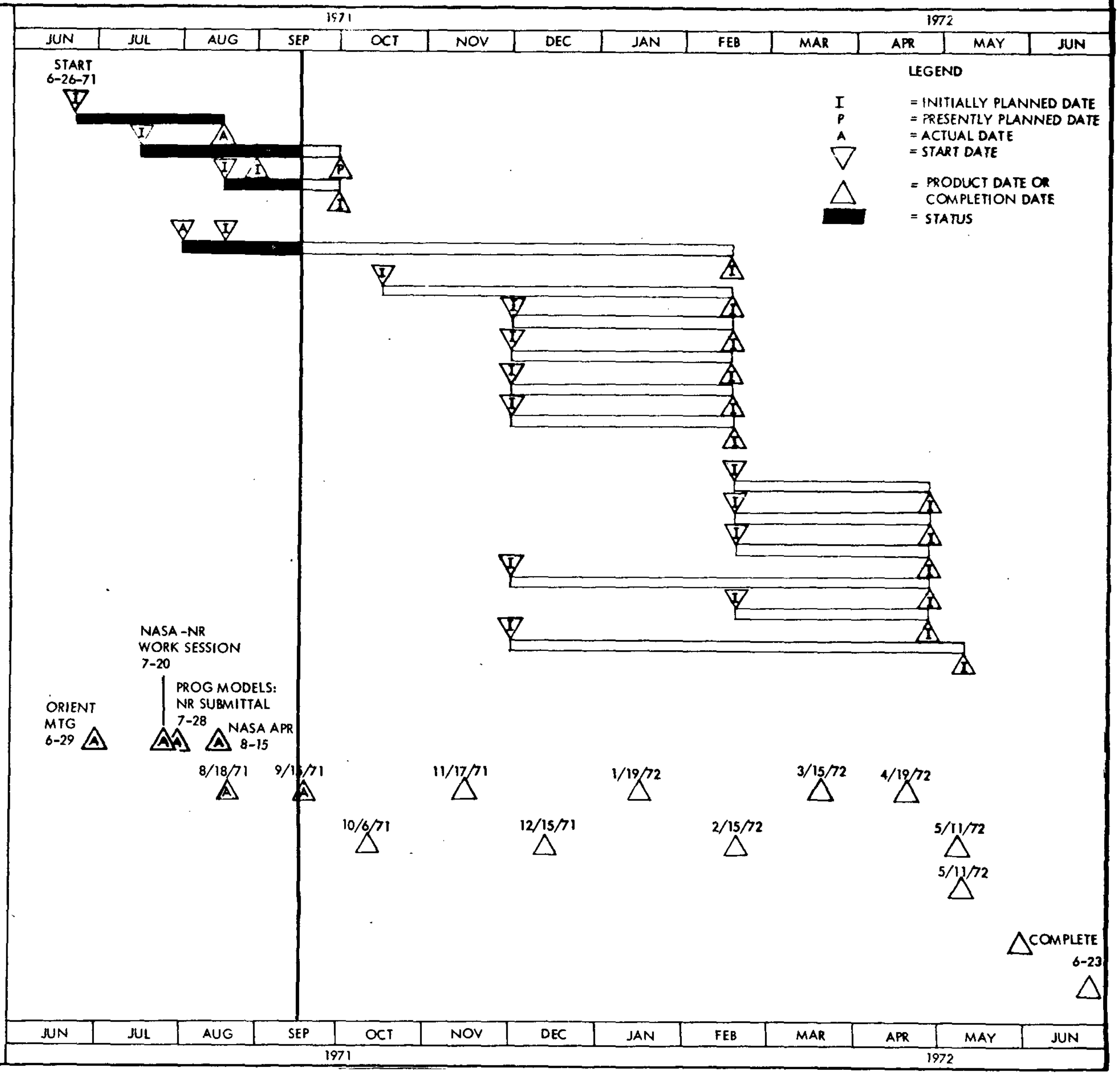
- I-4 SPACE MOST RECOMMENDED METHOD OF OPERATION
- I-5 DEFINE INTERFACE REQUIREMENTS
- I-6 DETERMINE EFFECT OF ORBITAL STORAGE ON SHUTTLE
- I-7 DETERMINE EFFECT OF ORBITAL STORAGE ON PROGRAM ELEMENTS
- I-8 DETERMINE MAINTENANCE REQUIREMENTS
- I-9 DETERMINE ROLE OF MAN

PHASE III (PROGRAM PLANNING AND DOCUMENTATION) TASKS:

- I-10 IDENTIFY AREA OF TECHNICAL UNCERTAINTY
- I-11 DEFINE NEEDED TECHNICAL DEVELOPMENT
- I-12 RECOMMEND TECHNICAL EMPHASIS AND FUNDING
- I-13 DEFINE FACILITY/GSE REQUIREMENTS
- I-14 DEVELOP PROJECT IMPLEMENTATION PLAN
- I-15 DOCUMENTATION

MILESTONES - PROJECT I

- CONTRACT
- ACTIVITY LETTERS
- PERFORMANCE REVIEWS
- FINAL REPORTS - INITIAL SUBMITTAL
- CUSTOMER COMMENTS
- FINAL SUBMITTAL



SCHEDULE POSITION, PROJECT II: SYSTEM SAFETY ANALYSIS

PROJECT II WAS INITIATED TWO MONTHS SUBSEQUENT TO PROJECT I. ALL TASKS ARE ON SCHEDULE. MUCH APPLICABLE DATA HAS BEEN DEVELOPED ON RECENT RELATED IN-HOUSE STUDIES WHICH PROVIDE A STRONG BASE FOR THE ISPLS EFFORT.

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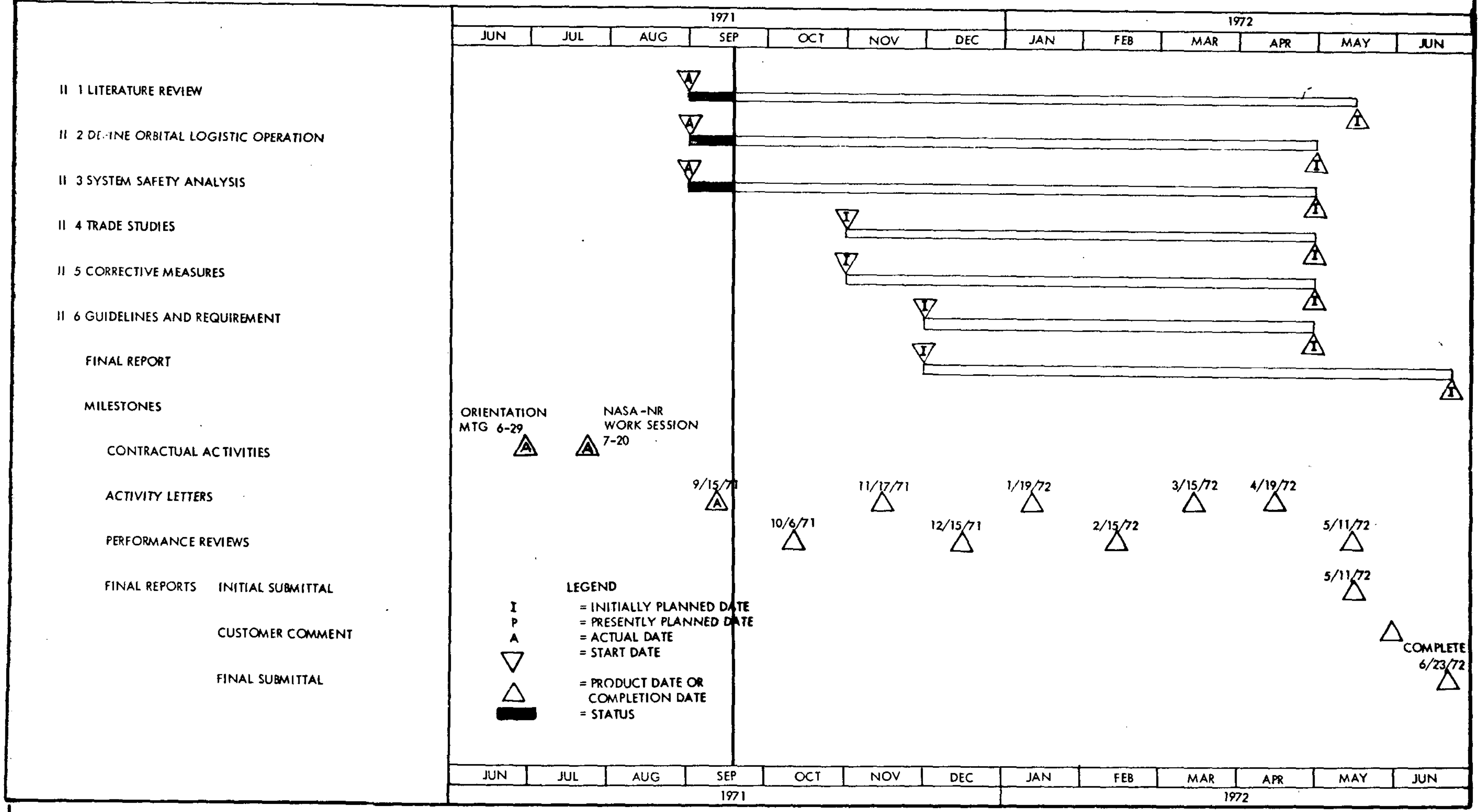
PROJECT II SYSTEM SAFETY ANALYSIS

ISPLS
CONTRACT NAS8-27692
FIRST PERFORMANCE REVIEW
CHART NO. 7 DATE 10-6-71

PROGRAM MANAGER R.E.SEXTON

STATUS AS OF 9/15/71



13

STUDY GROUND RULES

THE STUDY GROUND RULES WERE ESTABLISHED AT THE ORIENTATION MEETING. THE REQUIREMENT FOR INTERNATIONAL UNITS AS THE PRIMARY SYSTEM OF UNITS HAS BEEN DELETED PER NASA DIRECTION.

FOR THE ISPLS PROGRAM, BASELINE PHYSICAL AND PERFORMANCE CHARACTERISTICS FOR SPACE ELEMENTS, I.E., SPACE SHUTTLE, SPACE TUG, RNS AND CIS, REFLECT FINAL DATA FROM PHASES OF THOSE PROGRAMS WHICH HAD BEEN COMPLETED BY NAR AT THE TIME OF INITIATION OF THE ISPLS STUDY. THIS WAS DONE TO PRECLUDE THE ISPLS SCHEDULE FROM BEING DEPENDENT ON THE SCHEDULE, AND YET-TO-BE-DETERMINED RESULTS, OF OTHER IN-PROCESS STUDIES. THE SENSITIVITY ANALYSES SCHEDULED FOR LATER IN THE ISPLS PROGRAM WILL PROVIDE SOME INSIGHT INTO IMPLICATIONS OF CHANGING BASELINES.

STUDY GROUND RULES

- NASA SPACE PROGRAM PLAN IS BASIS OF STUDY
- SPACE SHUTTLE TO BE BASIC DELIVERY SYSTEM (161C DESIGNATED CONFIGURATION)
- HYDROGEN AND OXYGEN ARE ONLY PROPELLANTS TO BE CONSIDERED FOR PROJECT I
- ORBITAL PROPELLANT STORAGE / TRANSFER CONCEPTS WILL BE UNMANNED MODE
- IN-SPACE MAINTENANCE SHALL BE CONDUCTED FROM A MANNED SUPPORT VEHICLE
- DOCKING TERMINALS SHALL BE COMPATIBLE WITH SPACE SHUTTLE & TUG
- EVA'S SHALL BE MINIMIZED
- MAJOR SYSTEM SAFETY EMPHASIS - EARTH ORBITAL REGIME
- PROJECT II SAFETY CONSIDERATIONS - TRANSPORT, HANDLING, STORAGE, TRANSFER OF O_2, H_2, N_2 AND N_2H_4
- ONLY UNIQUE GROUND OPERATIONS WILL BE CONSIDERED FOR SAFETY ANALYSIS
- NO DOD MISSIONS CONSIDERED
- MAXIMUM UTILIZATION OF OPSS PROGRAM DATA
- THERMAL CHARACTERISTICS OF INSULATION SAME AS FOR OPSS

SPACE SHUTTLE ORBITER

161C CONFIGURATION

THE BASIC CONFIGURATION AND PERFORMANCE OF THE SHUTTLE ORBITER USED IN THIS STUDY IS SHOWN HERE AND ON THE NEXT FEW CHARTS. IT IS THAT DEFINED IN THE NR PHASE B FINAL REPORT, SD71-114, DATED 25 JUNE 1971. ISPLS INTEREST IN THE CONFIGURATION FOCUSES ON THE CARGO BAY AND THE OMS PROPELLANT TANKS.

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SPACE SHUTTLE ORBITER
161C CONFIGURATION

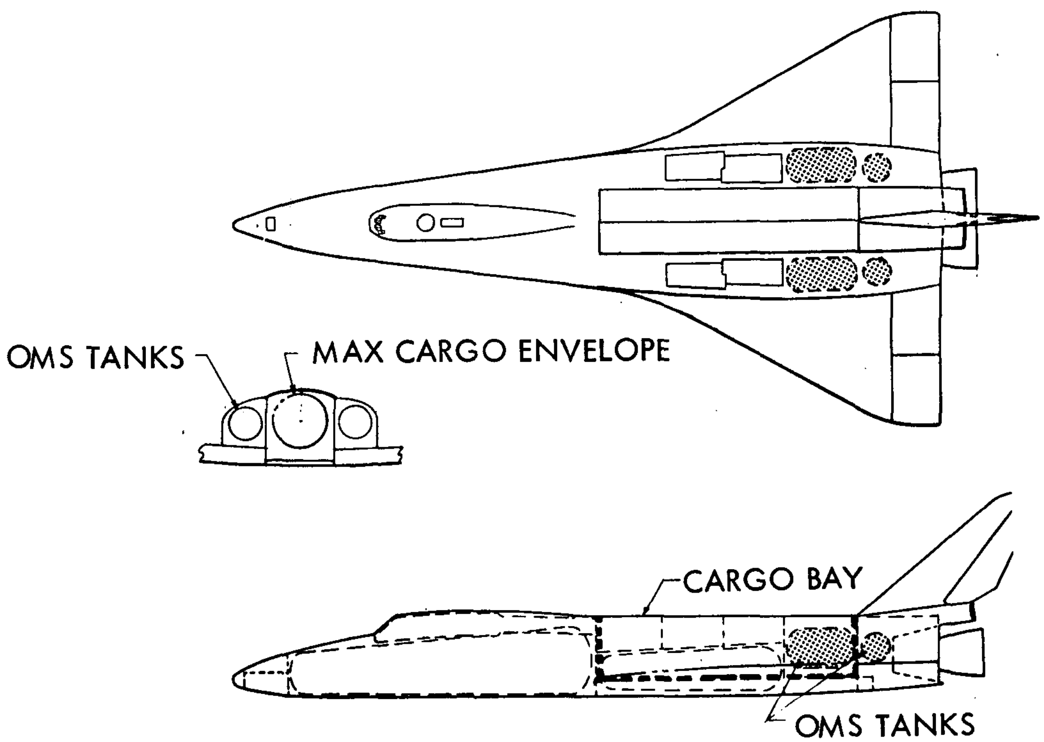
ISPLS
CONTRACT NAS8-27692
FIRST PERFORMANCE REVIEW
CHART NO. 9 DATE 10-6-71

ORBITER WEIGHTS

INERT WEIGHT	237,700 LB (107,800 KG)
PROPELLANT (MAX CAPACITY)	
ASCENT	562,000 LB (255,000 KG)
OMS	39,000 LB (17,700 KG)

PAYLOAD CAPABILITY

BAY SIZE	15' DIA x 60' (4.57 x 18.3 M)
TO 100 nmi AT 28.5°	65,000 LB (29,500 KG)
TO 100 nmi AT 90°	40,000 LB (18,100 KG)



SHUTTLE ORBITER CARGO BAY DEFINITION

THE DIMENSIONS OF THE CARGO BAY AND ITS RELATIONSHIP TO THE SURROUNDING STRUCTURE AND CARGO ATTACH POINTS ARE SHOWN.

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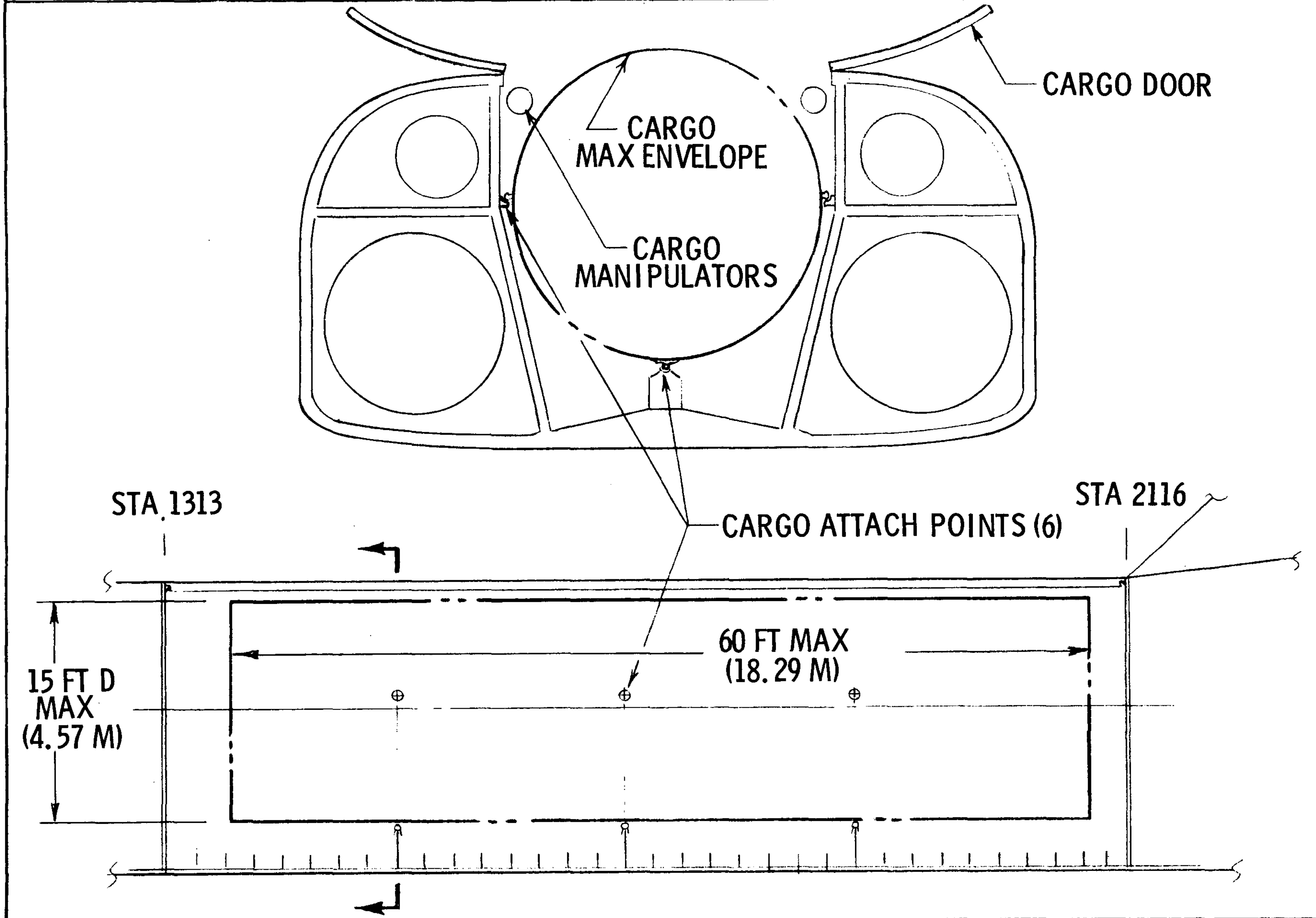
SHUTTLE ORBITER CARGO BAY DEFINITION

ISPLS
CONTRACT NAS8-27692
FIRST PERFORMANCE REVIEW
CHART NO. 10 DATE 10-6-71



ORBITAL MANEUVERING SYSTEM (OMS)

PROPELLANT DATA

THE AVAILABILITY OF OMS PROPELLANT IN RELATION TO MAXIMUM PAYLOAD WEIGHT IS SHOWN HERE FOR SELECTED ORBITAL INCLINATIONS OF THE EARTH ORBITAL SHUTTLE.

THE OMS CAPACITY IS 39000 LBS AND THE TANKS ARE SEPARATE FROM THE MAIN ENGINE TANKS USED DURING ASCENT. THE MAXIMUM OMS ALLOWABLE ON-BOARD IS THE MAXIMUM WHEN THE MAXIMUM PAYLOAD INDICATED AT THE BOTTOM OF THE CHART IS PLACED IN THE PAYLOAD BAY. IF THE PAYLOAD BAY IS OFF-LOADED, A CORRESPONDING ADDITIONAL WEIGHT OF PROPELLANT CAN BE ADDED IN THE OMS TANKS UNTIL THEY ARE FULL. ABOUT 20,000 LBS OF OMS PROPELLANT ARE REQUIRED ON-BOARD FOR THE ABORT CONTINGENCY DURING ASCENT. IF THE ABORT DOES NOT OCCUR, THIS PROPELLANT IS AVAILABLE FOR OTHER USE WHEN THE ASCENT IS COMPLETED AND THE SHUTTLE REACHES A 50 x 100 nmi ORBIT PORTIONS OF THE OMS MUST BE HELD FOR CIRCULARIZATION, CONTINGENCIES, AND FOR DEORBIT; THE AMOUNT OF PROPELLANT INDICATED IN THE CHART IS AVAILABLE FOR OTHER MANEUVERS OR IS AVAILABLE FOR TRANSFER TO OTHER USERS WHEN THE SHUTTLE REACHES A 100 x 100 nmi ORBIT

ORBITAL MANEUVERING SYSTEM (OMS) PROPELLANT DATA (PAYLOAD BAY LIMITED TO 65,000 LBS)

	ORBITAL INCLINATION OF SHUTTLE LAUNCH			
	28.5°	31.5°	55.0°	90.0°
OMS TANK CAPACITY	39.0K#	39.0K#	39.0K#	39.0K#
MAX OMS ALLOWABLE ON-BOARD	37.1	35.4	21.0	19.5
REQUIRED FOR ONCE AROUND ABORT	(20.4)	(20.4)	(20.0)	(19.5)
USED FOR CIRCULARIZATION AT 100 nmi	2.3	2.3	2.2	2.0
HOLD FOR ON-ORBIT CONTINGENCY MANEUVERS (1)	4.6	4.5	4.3	4.0
REQUIRED FOR DEORBIT FROM 100 nmi	4.4	4.4	4.4	4.4
OMS AVAILABLE FOR OTHER USE AT 100 nmi ORBIT	25.8	24.2	10.1	9.1
MAX LAUNCH WEIGHT IN PAYLOAD BAY	65.0	65.0	65.0	40.0

(1) BASED ON ΔV = 200 fps, FULLY LOADED

SHUTTLE PAYLOAD CAPABILITY

THE CURRENT STUDY IS BASED ON THE EARTH ORBITAL SHUTTLE DEFINED IN THE NORTH AMERICAN ROCKWELL, GENERAL DYNAMICS JOINT PHASE B DESIGN CONTRACT NAS9-10960 COMPLETED IN JUNE OF 1971.

THE SHUTTLE HAS THE CAPABILITY OF PLACING IN ORBIT THE PAYLOAD WEIGHT SHOWN IN THE UPPER RIGHT PORTION OF THE CHART PLUS THE ORBITAL MANEUVERING SYSTEM PROPELLANT (OMS) SHOWN IN THE BOTTOM PORTION OF THE CHART AS A FUNCTION ORBITAL INCLINATION OF THE SHUTTLE LAUNCH. THE PAYLOAD IS LIMITED TO 65,000 LB SO THAT AT THE LOWER INCLINATIONS IT IS PERMISSIBLE TO CARRY LARGER QUANTITIES OF OMS PROPELLANT. THE OMS TANK CAPACITY IS 39,000 LB AND THEY ARE SEPARATE FROM THE MAIN ENGINE PROPELLANT TANK.

THE PAYLOAD PERFORMANCE OF THE SHUTTLE TO HIGHER ALTITUCES IS SHOWN IN THE UPPER LEFT PORTION OF THE CHART. THE SHUTTLE HAS A UNIFORM PAYLOAD PERFORMANCE CAPABILITY FROM 100 TO OVER 300 N MI FOR THE EASTERLY LAUNCHES.

THE UNIFORM CAPABILITY RESULTS FROM THE FACT THAT A MINIMUM OF ABOUT 20,000 LB OF OMS IS REQUIRED ON BOARD FOR ALL LAUNCHES TO PROVIDE FOR A "ONCE AROUND THE WORLD" ABORT AND RECOVERY AT KSC IN THE EVENT OF A MAIN ENGINE FAILURE DURING ASCENT. IF THE ABORT DOES NOT OCCUR PART OF THIS OMS PROPELLANT MARKED "AVAILABLE FOR OTHER USE AT 100 N MI CAN THEN BE USED TO TAKE THE MAXIMUM PAYLOAD ON UP TO THE HIGHER ALTITUDES. THE DIFFERENCE BETWEEN THE TOTAL OMS ON BOARD AND THAT "AVAILABLE FOR OTHER USE" IS OMS PROPELLANT HELD FOR CONTINGENCY MANEUVERS AND FOR DEORBIT.

THE ALTITUDE CAPABILITY OF THE SHUTTLE CAN BE FURTHER INCREASED BY OFF LOADING PAYLOAD AND ON LOADING A CORRESPONDING WEIGHT OF ADDITIONAL OMS PROPELLANT UNTIL THE OMS TANKS ARE FULL (39,000 LB). THEREAFTER ALTITUDE CAPABILITY INCREASES AS PAYLOAD IS STILL FURTHER OFFLOADED. WITH FULL OMS TANKS AND NO PAYLOAD, THE SHUTTLE CAN ACHIEVE BETTER THAN 600 N MI DEPENDING ON CONTINGENCY ALLOWANCES, ADDITIONAL ALTITUDE DERIVED FROM BOOSTER PERFORMANCE, AND OTHER FACTORS.

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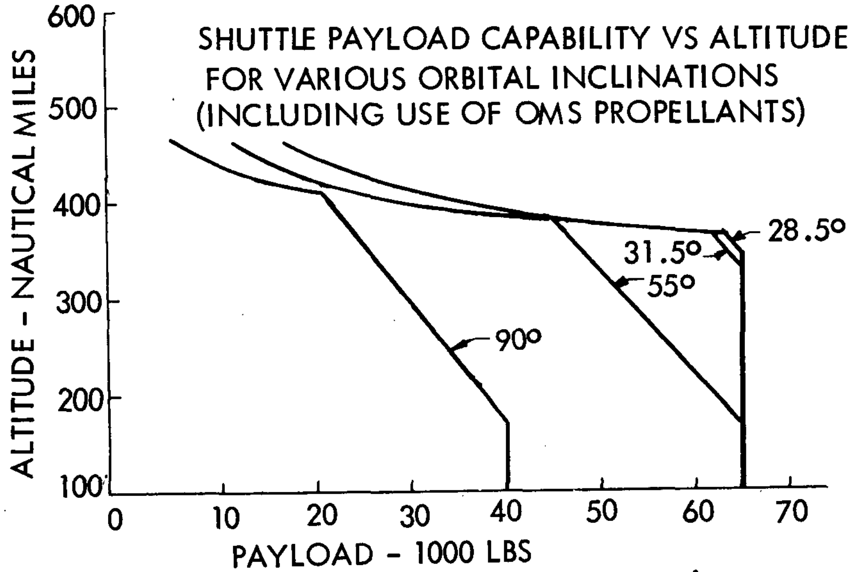
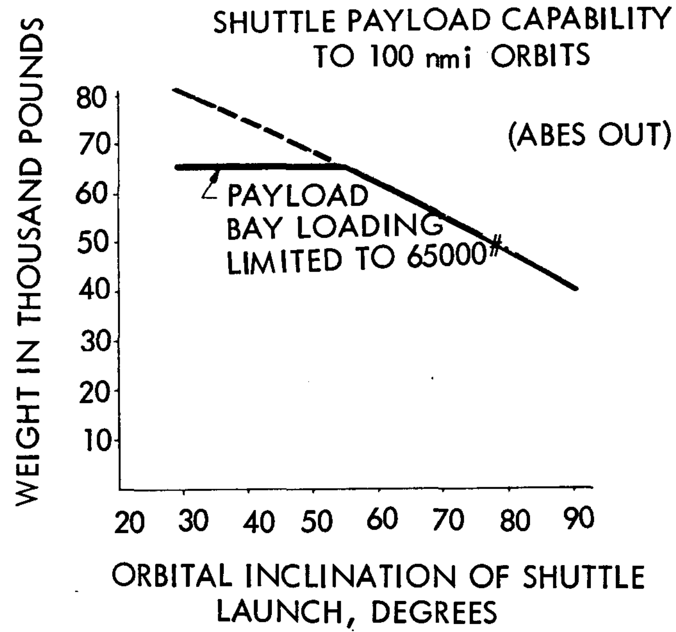
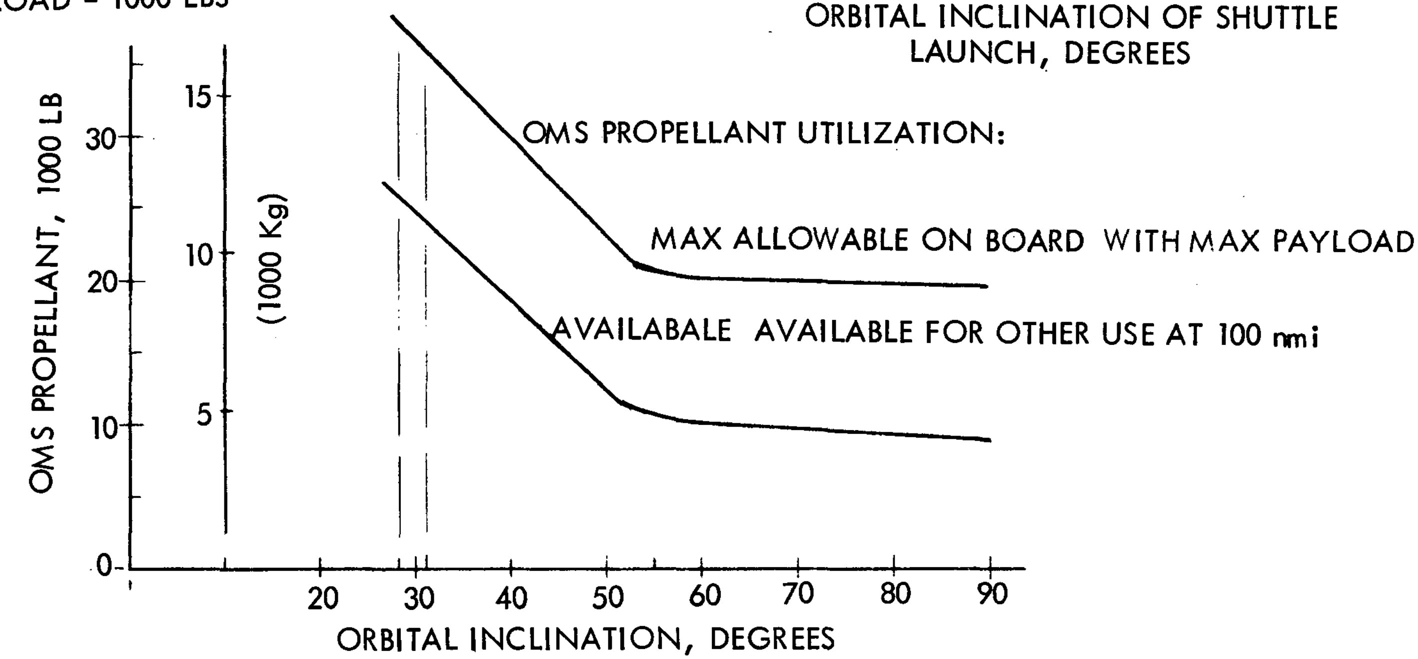
North American Rockwell

SHUTTLE PAYLOAD CAPABILITY

ISPLS
CONTRACT NAS8-27692
FIRST PERFORMANCE REVIEW
CHART NO. 12 DATE 10-6-71







MARK II SYSTEM AND ORBITER

BECAUSE OF THE DYNAMICS OF THE SPACE SHUTTLE CONFIGURATION AND PERFORMANCE DESIGN REQUIREMENTS THESE RECENT SPECIFICATIONS ARE SHOWN FOR COMPARISION WITH THE ISPLS BASELINE SHUTTLE. IT APPEARS THAT THE ISPLS RESULTS TO DATE WOULD BE APPLICABLE HERE EXCEPT FOR THE OMS ANALYSIS. IT IS RECOMMENDED HOWEVER, THAT THE ISPLS STUDY CONTINUE TO USE THE 161 C SHUTTLE FOR ANALYSIS.

MARK II SYSTEM AND ORBITER

- EXTERNAL HYDROGEN AND OXYGEN TANKS (SINGLE OR DUAL)
- 15' x 60' PAYLOAD BAY
- 40,000 POUND POLAR ORBIT PAYLOAD
- 65,000 POUND DUE EAST PAYLOAD
- 1,100 nmi CROSSRANGE
- STAGING VELOCITY 6,000 FPS ± 1,000 FPS (REAL)
- ABES WHEN DESIRED FOR ORBITAL FLIGHT MAY BE LOCATED IN THE PAYLOAD BAY AND
- SHALL BE CONSIDERED PART OF THE PAYLOAD WEIGHT CAPABILITY
- ABORT TO ORBIT IS NOT REQUIRED
- CREW SIZE OF 4 FOR 7 DAYS AT 14.7 PSI CABIN PRESSURE
- MAXIMUM USE OF ALUMINUM
- OMS RCS AND APU USE STORABLE HYPERGOLIC PROPELLANTS

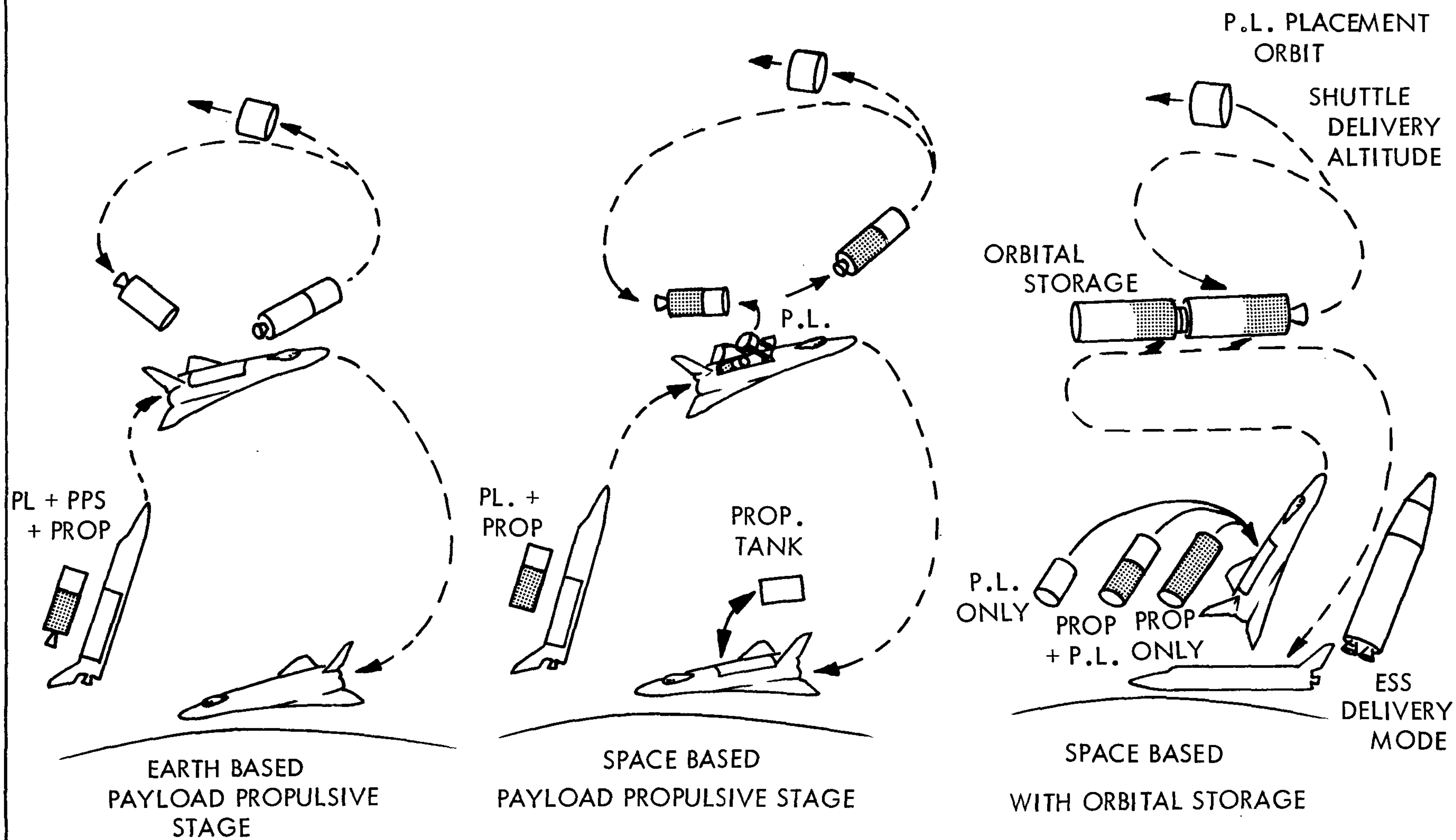
SCOPE OF ANALYSIS FOR IN-SPACE PROPELLANT LOGISTICS AND SAFETY

BASED ON THE INSIGHT GAINED FROM THE CONTRACT WORK THUS FAR, IT APPEARS THERE ARE THREE DISTINCT CLASSES OF SPACE PROGRAMS WHICH MUST BE ADDRESSED:

1. AN EARTH BASED PROGRAM INCORPORATES A PAYLOAD PROPULSIVE STAGE (PPS) WHICH IS LAUNCHED FROM EARTH IN THE SHUTTLE CARGO BAY ALONG WITH ITS PAYLOAD AND SUFFICIENT PROPELLANTS TO CARRY THE PAYLOAD TO ITS PLACEMENT ALTITUDE FROM LOW EARTH ALTITUDE AND RETURN TO RENDEZVOUS WITH THE SHUTTLE IN LOW EARTH ORBIT.
2. A SPACE BASED PAYLOAD PROPULSIVE STAGE CREATES A MUCH DIFFERENT OPERATIONAL CONCEPT WITH A NUMBER OF OPTIONS NOT AVAILABLE IN A GROUND BASED PROGRAM. IN THIS PROGRAM THE PAYLOAD PLUS THE NECESSARY PROPELLANTS ARE BROUGHT FROM THE EARTH SURFACE TO LOW EARTH ORBIT IN A SHUTTLE CARGO BAY. THE PROPELLANTS AND PAYLOAD ARE TRANSFERRED TO THE PPS, THE PPS PLACES THE PAYLOAD INTO ITS PROPER ORBIT AND RETURNS TO LOW ORBIT TO AWAIT THE NEXT SHUTTLE RENDEZVOUS. THE SHUTTLE IN THE MEANTIME RETURNS TO EARTH WITH THE EMPTY PROPELLANT TANK.
3. THE ADDITION OF IN-ORBIT STORAGE CAPABILITY TO THE SPACE BASED PROGRAM PROVIDES THE OPPORTUNITY TO MAXIMIZE UTILIZATION OF SHUTTLE CAPABILITY BY BRINGING PROPELLANTS INTO LOW EARTH ORBIT AS SHARED CARGO WITH OTHERWISE NON-PROPELLANT OR PPS RELATED SHUTTLE CARGO AND STORING IT FOR LATER USE BY THE SPACE BASED PPS. THIS LEADS TO A YET DIFFERENT AND MORE COMPLEX ANALYSIS.

THE EXPENDABLE SECOND STAGE (ESS) FOR USE WITH SHUTTLE BOOSTER IS AN ALTERNATE EARTH TO ORBIT DELIVERY SYSTEM WHICH WILL BE EVALUATED LATER IN THE STUDY IN CONJUNCTION WITH SPACE BASED PROGRAMS.

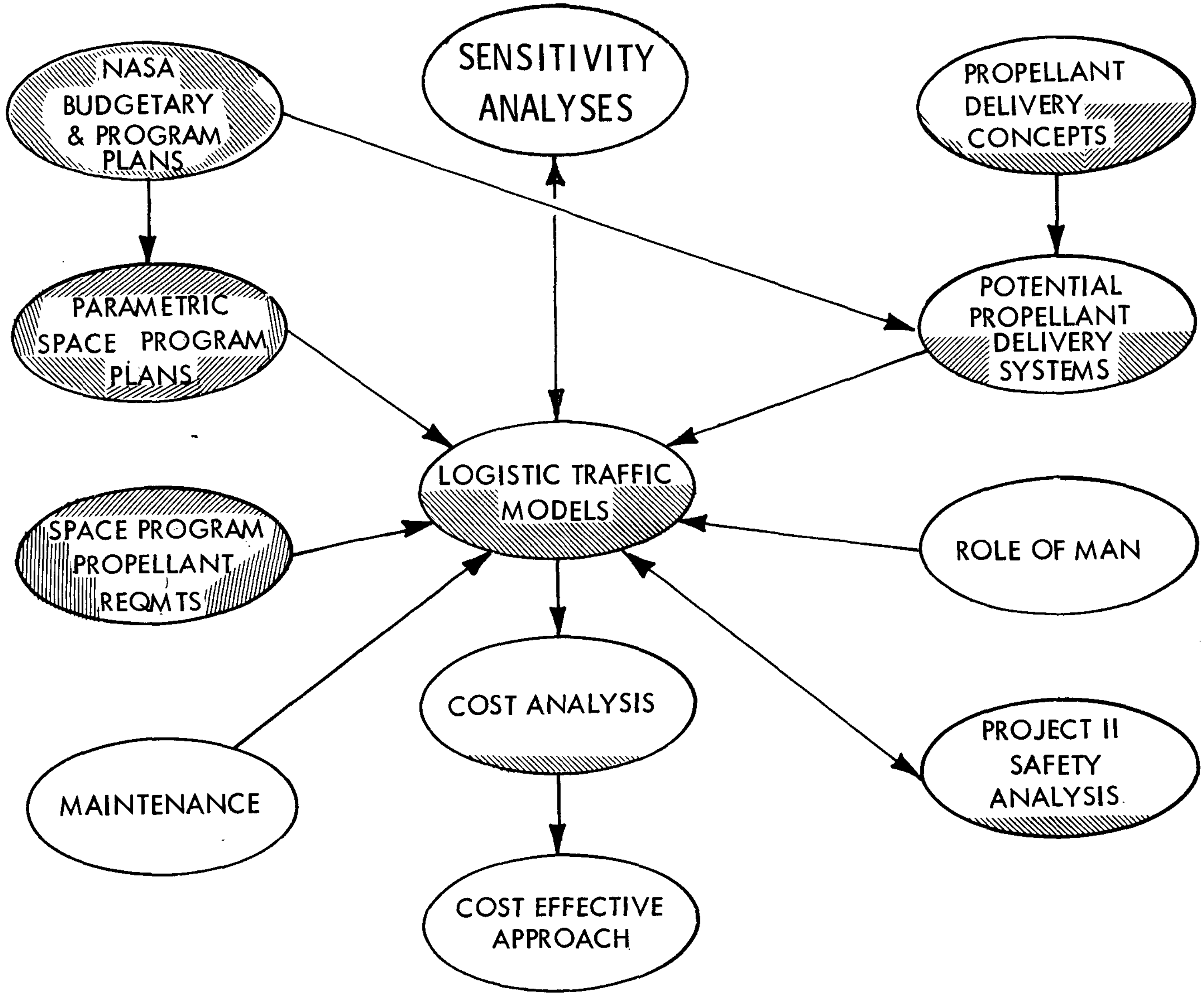
Space Division North American Rockwell	SCOPE OF ANALYSIS FOR IN-SPACE PROPELLANT LOGISTICS AND SAFETY	ISPLS CONTRACT NAS8-27692 FIRST PERFORMANCE REVIEW CHART NO. 14 DATE 10-6-71



PROJECT I AND PROJECT II PROGRAM ELEMENTS

THE SIMPLIFIED LOGIC DIAGRAM FOR PROJECTS I AND II IS PRESENTED IN THE NEXT TWO CHARTS. THE MAJOR PROGRAM ELEMENTS, HOW THEY RELATE TO EACH OTHER, AND HOW THE TWO PROJECTS INTERRELATE IS SHOWN. THE PROGRAM ELEMENTS ARE SHADED TO INDICATE DEGREE OF COMPLETION.

PROJECT 1
PROPELLANT LOGISTICS SYSTEMS ANALYSIS
PROGRAM ELEMENTS



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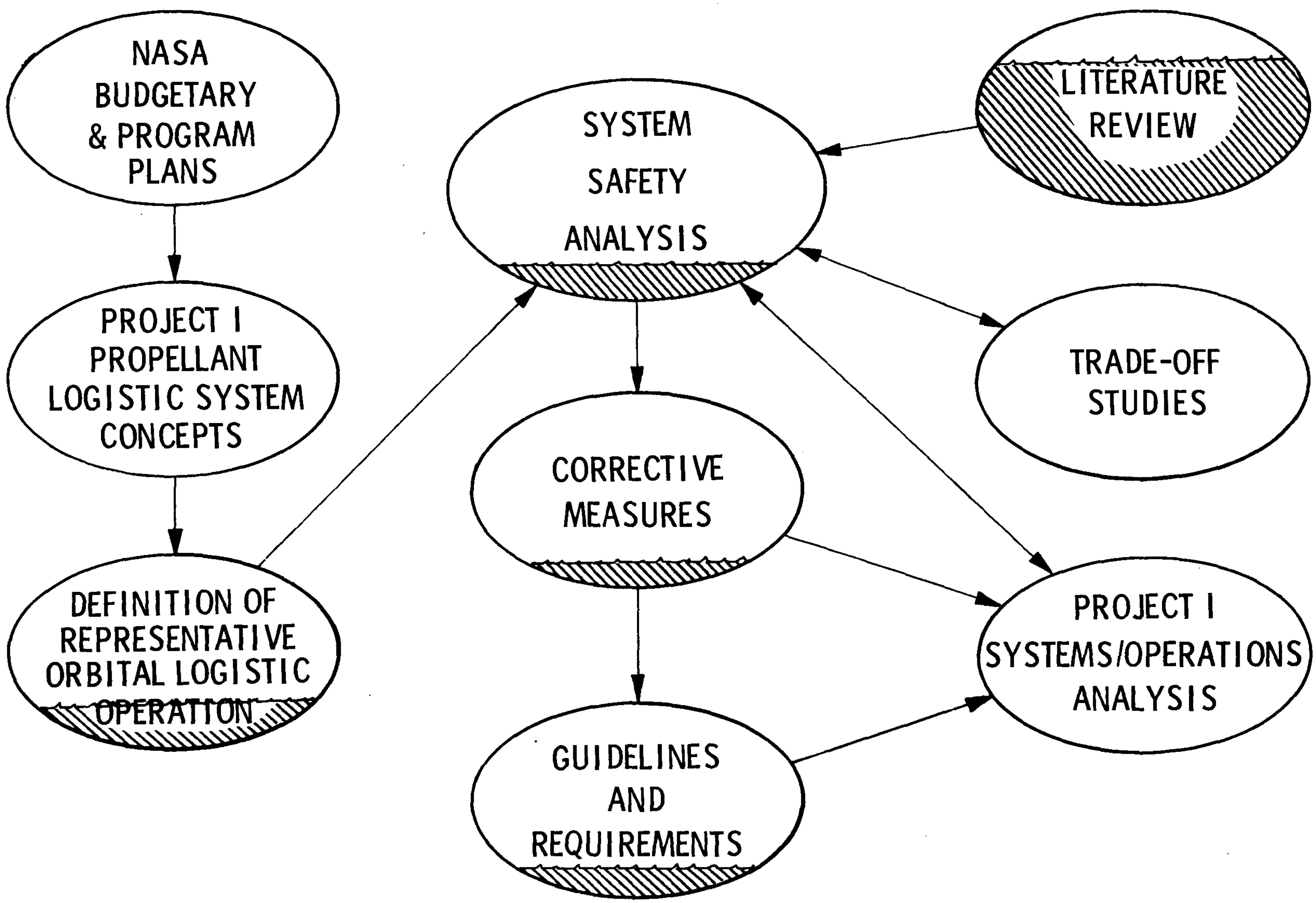
PROJECT II - SYSTEM SAFETY PROGRAM ELEMENTS

ISPLS
CONTRACT NAS8-27692
FIRST PERFORMANCE REVIEW
CHART NO. 16 DATE 10-6-71



PROGRAM PROGRESS

THE IN-SPACE PROPELLANT LOGISTICS AND SAFETY PROGRAM HAS ALREADY DEVELOPED DATA OF SIGNIFICANCE. THE WORK OF GREATEST INTEREST IS LISTED HERE AND IS FURTHER DISCUSSED IN THE BRIEFING.

PROGRAM PROGRESS

- 12 YEAR PARAMETRIC SPACE PROGRAM DEVELOPED FOR USE IN STUDY
  - PROPULSIVE STAGES FOR PAYLOAD PLACEMENTS DEFINED (USER OF PROPELLANTS IN SPACE)
  - USER TRAFFIC MODELS DEVELOPED FOR FIVE SPACE PROGRAM PLANS
  - USER PROPELLANT REQUIREMENTS DEVELOPED
- GENERIC PROPELLANT LOGISTICS CONCEPTS IDENTIFIED
- OMS PROPELLANTS USAGE ANALYZED
- POTENTIAL FOR DELIVERY OF PROPELLANTS AS SUPPLEMENTAL CARGO DETERMINED
- PROPELLANT LOGISTICS TRAFFIC MODELS COMPLETED FOR FIVE GROUND BASED SPACE PROGRAM PLANS
- PROPELLANT LOGISTICS TRAFFIC ANALYSIS IN PROGRESS FOR SPACE BASED PROGRAMS
- COSTING ACTIVITIES IN PROGRESS
- PROPELLANT TRANSFER AND PROPELLANT LOSS ANALYSIS INITIATED (NOT INCLUDED IN BRIEFING)
- IN-HOUSE SYSTEMS SAFETY ACTIVITIES HAVE PROVIDED FIRM BASE FOR CONTRACTUAL EFFORT INITIATED 9/1/71
  - MAJOR PORTION OF PROPELLANTS SAFETY LITERATURE SEARCH COMPLETED
  - APPLICABLE OPSS SAFETY CRITICAL ELEMENTS IDENTIFIED
  - PRELIMINARY SYSTEMS SAFETY CRITERIA FOR ISPLS ISSUED
  - FUNCTIONAL FLOWS, FMEA'S AND HAZARD ANALYSIS INITIATED

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NASA SPACE PROGRAM REQUIREMENTS

ACCOMPLISHMENT OF THE GENERAL OBJECTIVE OF THE REQUIREMENTS TASK FOR PROJECT I INVOLVED THREE BASIC STEPS.

THE FIRST STEP WAS A REVIEW OF NASA SPACE PROGRAM PROJECTIONS AND CLASSIFICATION OF MAJOR ALTERNATIVES.

IN THE SECOND STEP, THE PAYLOAD PLACEMENT MODEL SUPPLIED BY THE NASA WAS INCORPORATED AS A STUDY BASELINE. THEN THE BACKGROUND DATA CONCERNING NASA SPACE PROGRAM PROJECTIONS AND ALTERNATIVES WAS UTILIZED TO CONSTRUCT A SET OF FIVE ALTERNATE SPACE MISSION PROGRAM MODELS AROUND THE BASELINE PROGRAM TO PROVIDE REASONABLE COVERAGE OF NASA PLANNING OPTIONS.

IN-SPACE PROPELLANT REQUIREMENTS DATA FOR THE ALTERNATE PROGRAM LEVELS, GENERATED IN THE THIRD STEP, INCLUDE VEHICLES AND ORBITAL CONDITIONS AS WELL AS TIME-PHASED PROPELLANT NEEDS.

OUTLINE

ISPLS
INTRODUCTION
R.E. SEXTON

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G.A. OLSON

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R.L. MOORE

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W. PLAISTED

ISPLS
SUMMARY
ACTIONS
FUTURE ACTIVITIES
R.E. SEXTON

Space Division
North American Rockwell

NASA SPACE PROGRAM REQUIREMENTS

ISPLS
CONTRACT NAS8-27692
FIRST PERFORMANCE REVIEW
CHART NO. 19 DATE 10-6-71

OBJECTIVE: DETERMINE PROPELLANTS REQUIRED IN EARTH ORBIT FOR SUPPORT OF THE TOTAL NASA CONTEMPLATED SPACE PROGRAM

BASELINE: NASA PAYLOAD PLACEMENT MODEL, 1979-1990, BY W. A. FLEMING, DATED MARCH 15, 1971

NASA SPACE PROGRAM PROJECTIONS

- MAJOR ELEMENTS CONTEMPLATED
- MAJOR SUBSTITUTIONS
- POTENTIAL SHIFTS IN TIMING

PARAMETRIC SPACE MISSION PROGRAM MODELS

- FIVE LEVELS TO COVER RANGE OF NASA PLANNING OPTIONS

DATA DEVELOPMENT

- PAYLOAD PLACEMENT REQUIREMENTS
- TIME-PHASED PLACEMENT PROGRAMS
- USER PROPELLANTS
- ALTERNATE LEVELS OF PROPELLANT REQUIREMENTS BY TIME & LOCATION

PAYLOAD PLACEMENTS PARAMETRIC SPACE PROGRAM (1979-1990)

THE BASELINE PAYLOAD PLACEMENT PROGRAM, IDENTIFIED AS THE "FLEMING MODEL", IS INCORPORATED AS LEVEL "C" IN THE PARAMETRIC SPACE PROGRAM. THE FLEMING MODEL CONTAINS A TOTAL OF 598 PAYLOAD PLACEMENTS IN THE 12-YEAR MISSION PERIOD. THESE INVOLVE MULTIPLE PLACEMENTS FOR 78 SPECIFIC TYPES OF MISSIONS.

PROGRAM LEVELS "B" AND "A" REPRESENT REDUCTIONS IN NUMBERS OF PLACEMENTS WHILE RETAINING ALL OF THE BASIC 78 MISSION TYPES. WITH THE EXCEPTION OF PLANETARY AND SPACE STATION MISSIONS, THESE LEVELS CONTAIN 3/4 AND 1/2 OF THE FLEMING MODEL PLACEMENTS, RESPECTIVELY. THE PLANETARY PROGRAMS ARE UNCHANGED AT THESE LEVELS. THERE IS NO SPACE STATION AT THE "A" LEVEL.

A NEW LUNAR PROGRAM IS INCLUDED IN BOTH THE "D" AND "E" LEVELS. THE LUNAR MISSIONS INVOLVE A 10-FLIGHT AUTOMATED LUNAR PROGRAM IN THE EARLY '80'S AND A MANNED PROGRAM IN THE LATE '80'S. LEVEL "E" DIFFERS FROM "D" ONLY IN THE INCLUSION OF AUGMENTED PLANETARY MISSIONS REQUIRING EITHER AN RNS OR CIS.

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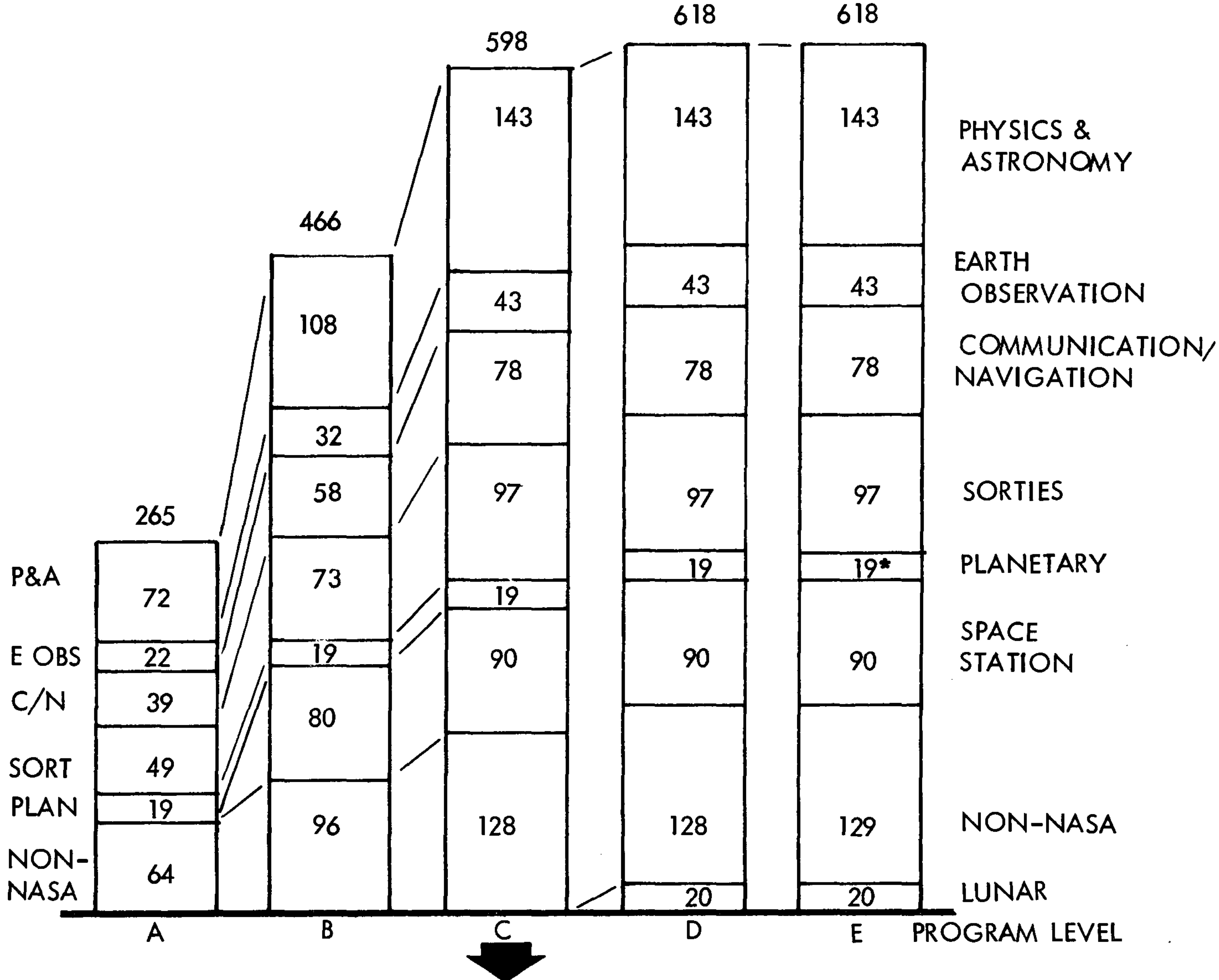
PAYLOAD PLACEMENTS
PARAMETRIC SPACE PROGRAM
(1979-1990)

ISPLS
CONTRACT NAS8-27692
FIRST PERFORMANCE REVIEW
CHART NO. 20 DATE 10-6-71



NASA MAR '71 (FLEMING) MODEL

*INCLUDES 5 RNS/CIS HIGH-ENERGY MISSIONS

LUNAR AND AUGMENTED PLANETARY MISSIONS

THESE LUNAR AND AUGMENTED PLANETARY MISSIONS ARE DESCRIBED SEPARATELY BECAUSE THEY ARE NOT A PART OF THE NASA-SUPPLIED PLAN FOR THE 1979-1990 TIME PERIOD.

THE RENEWED LUNAR MISSION PROGRAM BEGINS IN 1980 WITH A 10-FLIGHT AUTOMATED LUNAR PROGRAM INVOLVING BOTH ORBITERS AND LANDERS WITH ROVERS AND SAMPLE RETURN. THIS IS THE "OPTION 1" PROGRAM SUGGESTED BY THE SPACE SCIENCE BOARD IN ITS 1970 SUMMER STUDY--BUT DEFERRED HERE BY TWO YEARS. A REUSABLE TUG WOULD PROVIDE TRANS-LUNAR INJECTION OF THE AUTOMATED SPACECRAFT.

THE MANNED LUNAR PROGRAM CONTAINS TWO PHASES: (1) A THREE-YEAR EXPLORATION/ TRANSITION PHASE INVOLVING SORTIE-TYPE MISSIONS, AND (2) AN APPLICATIONS PHASE. THE LATTER WOULD UTILIZE SUPPORT SYSTEMS LIKE THOSE DESCRIBED IN THE LUNAR SURFACE BASE STUDY. THE MANNED LUNAR PROGRAM REQUIRES EITHER AN RNS OR CIS AT TWO FLIGHTS PER YEAR BEGINNING IN 1986.

THE AUGMENTED PLANETARY PROGRAM CONTAINS THREE INNER PLANET MISSIONS WHICH PERFORM SURFACE SAMPLE AND RETURN OPERATIONS. TWO HEAVY JUPITER MISSIONS ALSO ARE PROJECTED TO YIELD VERY HIGH SCIENTIFIC RETURN. ALL FIVE MISSIONS UTILIZE EITHER AN RNS OR CIS FOR TRANS-PLANETARY INJECTION, STARTING IN 1984.

LUNAR & AUGMENTED PLANETARY MISSIONS
PROGRAM LEVELS D & E

AUTOMATED LUNAR MISSIONS, SPACE SCIENCE BOARD, OPTION 1

5 ADVANCED ORBITERS

- 100 KG SCIENCE PAYLOADS WITH RELAY TRACKING SATS

5 LANDERS (1500 KG SCIENCE)

- ALSEP-TYPE STATION
- 300 KG ROVER
- SAMPLE RETURN SYSTEM

MANNED LUNAR PROGRAM

PERFORMANCE: RNS MIN. ENERGY
REPEATABLE LUNAR MISSION
BASELINE (PHASE III STUDY)
PAYLOAD: 175,000 LB/15,000 LB

EXPLORATION & TRANSITION PHASE--

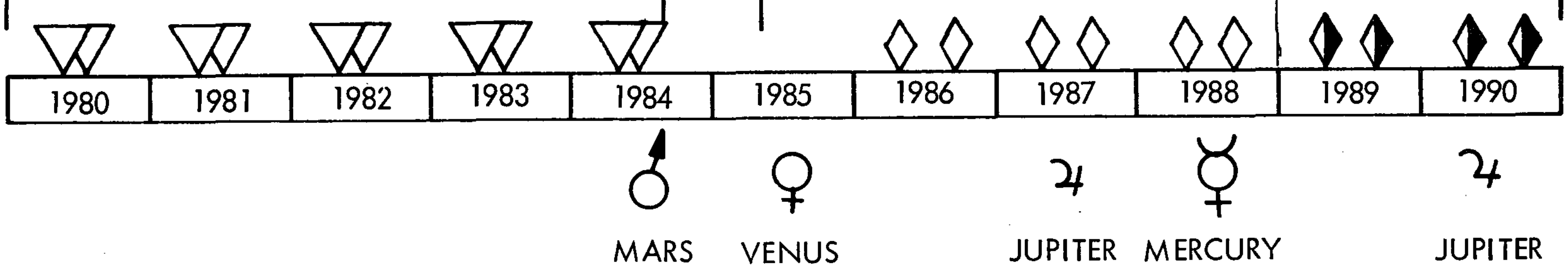
- ORBIT & SURFACE SORTIES

(6 FLIGHTS/3 YEARS)

APPLICATIONS PHASE--

- SURFACE OPERATIONS

(2 FLIGHTS/YR)



AUGMENTED PLANETARY MISSIONS (LEVEL E ONLY)

- MARS ORBITER, SURFACE SAMPLE & RETURN
- VENUS ORBITER, SURFACE SAMPLE & RETURN
- JUPITER ORBITERS, PROBES & IO LANDER/ROVER
- MERCURY ORBITER, SURFACE SAMPLE & RETURN
- TOUR OF GALLILEAN SATELLITES, GANYMEDE LANDER/ROVER

PARAMETRIC SPACE PROGRAM (1979-1990)

DISTRIBUTION OF PLACEMENTS

THIS TABLE, WHICH IS IN TWO PARTS, LISTS ALL OF THE MISSIONS IN THE PARAMETRIC SPACE PROGRAM. THE MISSIONS SUPPLIED BY NASA IN THE FLEMING MODEL ARE DESIGNATED BY THE NUMERALS 1 THROUGH 78. TO DIFFERENTIATE THOSE ADDED BY THE CONTRACTOR, ALPHA-NUMERIC SYMBOLS ARE USED. L-1 THROUGH L-4 DESIGNATE THE LUNAR MISSIONS ADDED AT THE "D" PROGRAM LEVEL, AND P-1 THROUGH P-4 DESIGNATE THE AUGMENTED PLANETARY MISSIONS.

THE TOTAL NUMBERS OF PLACEMENTS (INCLUDING REVISITS) FOR EACH MISSION AT EACH OF THE ALTERNATE PROGRAM LEVELS ARE SHOWN IN FIVE COLUMNS DESIGNATED "A" THROUGH "E". NOTE THAT THE BASIC FLEMING MODEL PLACEMENTS ARE RETAINED AT THE "D" AND "E" PROGRAM LEVELS.

ALL OF THESE MISSIONS WILL BE A PART OF THE LOGISTICS MODEL TO BE DISCUSSED LATER. HOWEVER, MANY OF THESE MISSIONS WILL BE PERFORMED BY THE EARTH-TO-ORBIT SHUTTLE USING ON-BOARD OMS PROPELLANTS AND WITHOUT THE USE OF A SEPARATE PAYLOAD PROPULSIVE STAGE. THESE MISSIONS, THEREFORE, DO NOT POSE SEPARATE IN-ORBIT PROPELLANT REQUIREMENTS AND ARE NOT A PART OF THE PROPELLANT REQUIREMENTS MODEL. SHADED NUMERALS ARE USED IN THE ACCOMPANYING TABLE TO IDENTIFY THE NON-PROPELLANT USERS (PLUS TWO TITAN PLANETARY MISSIONS). THE RESULTANT NUMBER OF PLACEMENTS WHICH POSE POTENTIALPPROPELLANT REQUIREMENTS AT THE "A" THROUGH "E" PROGRAM LEVELS ARE 168, 243, 318, 338 AND 338, RESPECTIVELY, FOR THE 12-YEAR PERIOD.

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PARAMETRIC SPACE PROGRAM (1979-1990) DISTRIBUTION OF PLACEMENTS (TABLE 1 OF 2)

CATEGORY	NO	TITLE			SPACE PROGRAM LEVEL A	B	C	D	E
					NUMBER OF FLIGHTS				
PHYSICS & ASTRONOMY	1	ASTRONOMY EXPLORER		A	7	11	15	15	15
	2	RADIO EXPLORER		B	4	6	9	9	9
	3	MAGNETOSPHERE EXPLORER.		LOW	6	9	12	12	12
	4	MAGNETOSPHERE EXPLORER		MEDIUM	6	9	12	12	12
	5	MAGNETOSPHERE EXPLORER		HIGH	6	9	12	12	12
	6	ORBITING SOLAR OBSERVATORY			1	1	1	1	1
	7	GRAVITY/RELATIVITY EXPERIMENT		C,E	1	2	2	2	2
	8	GRAVITY/RELATIVITY EXPERIMENT		B,D	1	2	2	2	2
	9	RADIO INTERFEROMETER		SYNC	1	1	1	1	1
	10	SOLAR ORBIT PAIR		SYNC	1	2	2	2	2
	11	SOLAR ORBIT PAIR		1.0 AU	1	2	2	2	2
	12	OPTICAL INTERFEROMETER		PAIR	2	2	2	2	2
	13	HEAO & HIGH ENERGY SOLAR ASTRONOMY			4	4	4	4	4
	14	REVISITS			12	16	22	22	22
	15	LST (STAR) & (RAM)			2	2	2	2	2
	16	LST REVISITS			8	12	17	17	17
	17	LARGE SOLAR OBSERVATORY			1	2	2	2	2
	18	LARGE SOLAR OBSERVATORY REVISITS			5	9	13	13	13
	19	LARGE RADIO OBSERVATORY			1	1	1	1	1
	20	LARGE RADIO OBSERVATORY REVISITS			2	6	10	10	10
EARTH OBSERVATIONS	21	POLAR EARTH OBSERVATIONS SATELLITE		R&D	6	9	12	12	12
	22	SYNCHRONOUS EARTH OBSERVATIONS SATELLITE		R&D	3	4	6	6	6
	23	EARTH PHYSICS SATELLITE		R&D	3	5	7	7	7
	24	SYNCHRONOUS METEOROLOGICAL SATELLITE		SYS DEMO	1	2	2	2	2
	25	TIROS		SYS DEMO	2	2	3	3	3
	26	POLAR EARTH RESOURCES SATELLITE		SYS DEMO	3	5	6	6	6
	27	SYNCHRONOUS EARTH RESOURCES SATELLITE		SYS DEMO	4	5	7	7	7
COMMUN-ICATION/ NAVIGATION	28	APPLICATIONS TECHNOLOGY SATELLITE	SYNC	R&D	4	5	7	7	7
	29	SMALL APPLICATIONS SATELLITE	SYNC	R&D	6	9	12	12	12
	30	SMALL APPLICATIONS SATELLITE	POLAR	R&D	6	9	12	12	12
	31	COOPERATIVE APPLICATIONS	SYNC	R&D	2	2	2	2	2
	32	COOPERATIVE APPLICATIONS	POLAR	R&D	2	2	2	2	2
	33	MEDICAL NETWORK SATELLITE	SYNC	SYS DEMO	2	2	2	2	2
	34	EDUCATION BROADCAST SATELLITE	SYNC	SYS DEMO	2	2	2	2	2
	35	FOLLOW-ON SYSTEM DEMONSTRATION	SYNC	SYS DEMO	6	13	20	20	20
	36	TRACKING AND DATA RELAY	SYNC	OPER	5	7	10	10	10
	37	PLANETARY RELAY SATELLITE	SYNC	OPER	4	7	9	9	9
SORTIES	38	GENERAL SCIENCE RESEARCH MODULE			7	12	16	16	16
	39	GENERAL APPLICATIONS MODULE			9	14	19	19	19
	40	DEDICATED SCIENCE AND RESEARCH MODULAR ASTRONOMY			13	20	27	27	27
	41	DEDICATED APPLICATIONS MODULE - EARTH OBSERVATION			8	12	17	17	17
	42	EARTH OBSERVATION			2	3	4	4	4
	43	BIOLOGICAL RESEARCH			1	1	1	1	1
	44	ASTRONOMY			4	5	7	7	7
	45	FLUID MANAGEMENT			1	2	2	2	2
	46	TELEOPERATOR			1	1	1	1	1
	47	MANNED WORK PLATFORM			1	1	1	1	1
	48	LARGE TELESCOPE MIRROR TEST			1	1	1	1	1
	49	ASTRONAUT MANEUVERING UNIT (AMU)			1	1	1	1	1

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Space Division North American Rockwell	PARAMETRIC SPACE PROGRAM (1979-1990) DISTRIBUTION OF PLACEMENTS (TABLE 2 OF2)	ISPLS CONTRACT NAS8-27692 FIRST PERFORMANCE REVIEW CHART NO. 23 DATE 10-6-71

CATEGORY	NO	TITLE		SPACE PROGRAM LEVEL A	B	C	D	E
PLANETARY	50	VIKING		2	2	2	2	2
	51	MARS SAMPLE RETURN		2	2	2	2	
	52	VENUS EXPLORER		1	1	1	1	1
	53	VENUS RADAR MAPPING		1	1	1	1	1
	54	VENUS EXPLORER LANDER		2	2	2	2	
	55	JUPITER PIONEER ORBITER		2	2	2	2	2
	56	GRAND TOUR (JUN)		2	2	2	2	2
	57	JUPITER TOPS ORBITER/PROBE		2	2	2	2	1
	58	URANUS TOPS ORBITER/PROBE		2	2	2	2	2
	59	ASTEROID SURVEY		1	1	1	1	1
	60	COMET RENDEZVOUS		2	2	2	2	2
	P-1	MERCURY SURFACE SAMPLE & RETURN	RNS/CIS					1
	P-2	VENUS SURFACE SAMPLE & RETURN	RNS/CIS					1
	P-3	MARS SURFACE SAMPLE & RETURN	RNS/CIS					1
	P-4	JUPITER ORBITERS/PROBES & SATELITTE LANDERS	RNS/CIS					2
SPACE STATION	61	STATION MODULES CORE			8	8	8	8
	62	STATION MODULES - OTHERS			8	8	8	8
	63	CREW CARGO			57	65	65	65
	64	PHYSICS LAB			1	1	1	1
	65	COSMIC RAY LAB			1	1	1	1
	66	LIFE SCIENCE LAB			2	2	2	2
	67	EARTH OBSERVATIONS LAB			2	2	2	2
	68	COMMUNICATIONS/NAVIGATION LAB			1	2	2	2
	69	SPACE MANUFACTURING LAB				1	1	1
NON-NASA	70	COMSAT SATELLITES	SYNC	6	8	11	11	11
	71	U.S. DOMESTIC COMMUNICATIONS	SYNC	10	16	21	21	21
	72	FOREIGN DOMESTIC COMMUNICATIONS	SYNC	13	19	26	26	26
	73	NAVIGATION & TRAFFIC CONTROL		5	8	10	10	10
	74	NAVIGATION & TRAFFIC CONTROL	SYNC	3	5	6	6	6
	75	TOS METEOROTOGICAL		6	9	12	12	12
	76	SYNCHRONOUS METEOROLOGICAL	SYNC	6	9	12	12	12
	77	POLAR EARTH RESOURCES		11	16	22	22	22
	78	SYNCHRONOUS EARTH RESOURCES	SYNC	4	6	8	8	8
LUNAR	L-1	AUTOMATED LUNAR PROGRAM ORBITERS					5	5
	L-2	AUTOMATED LUNAR PROGRAM LANDERS					5	5
	L-3	MANNED SORTIE-CLASS MISSIONS	RNS/CIS				6	6
	L-4	POST-SORTIE SURFACE OPERATIONS	RNS/CIS				4	4
TOTAL		1979-1990 TWELVE YEAR TOTAL		265	466	598	618	618

USER VEHICLE SUMMARY

THE SPECTRUM OF PAYLOAD PROPULSIVE STAGES WHICH ARE POTENTIAL USERS OF CRYOGENIC PROPELLANTS, SPECIFICALLY LH_2 AND LO_2, INCLUDE BOTH GROUND-BASED AND SPACE-BASED VEHICLES.

THE FIRST FOUR VEHICLES SHOWN ARE UTILIZED AT DIFFERENT PROGRAM LEVELS TO PERFORM PAYLOAD PLACEMENTS FOR THE PROPELLANT USER MISSIONS IN THE FLEMING MODEL AS IDENTIFIED IN THE PRECEDING TABLE. CENTAUR IS USED ONLY AS A GROUND-BASED VEHICLE. THE CENTAUR CHARACTERISTICS LISTED ARE FROM A GENERAL DYNAMICS REPORT. THE INTERIM TRANSFER STAGE SHOWN IS REPRESENTATIVE OF A CENTAUR GT-DERIVATIVE DESIGN. ITS PROJECTED CHARACTERISTICS ARE FROM AN MSC ADVANCED STUDIES PLANNING DATA BOOK DATED APRIL 19, 1971. TWO TUG DESIGNS ARE INCLUDED TO REPRESENT GROUND-BASED AND SPACE-BASED REQUIREMENTS. THE GROUND-BASED TUG IS REPRESENTED BY THE SINGLE-STAGE ORBIT-TO-ORBIT SHUTTLE (OOS) CURRENTLY BEING STUDIED BY THIS CONTRACTOR FOR THE USAF. THE SPACE-BASED TUG IS REPRESENTED BY THE SINGLE STAGE DESIGN DEVELOPED DURING THE "PRE-PHASE A STUDY FOR ANALYSIS OF A REUSABLE SPACE TUG", CONTRACT NAS9-10925.

THE RNS AND CIS ARE MAJOR ALTERNATIVES. PER THE ISPLS STUDY GROUND RULES, THE CHARACTERISTICS REPRESENT LARGE TANK DESIGNS FROM THE "NUCLEAR FLIGHT SYSTEM DEFINITION STUDY," NAS8-24975, AND "S-II STAGE INTERORBITAL SHUTTLE CAPABILITY ANALYSIS," NAS7-200 (CO 2021). THE CIS PROPELLANT LOADING PERMITS PERFORMANCE OF THE SAME LUNAR MISSIONS AS THE RNS.

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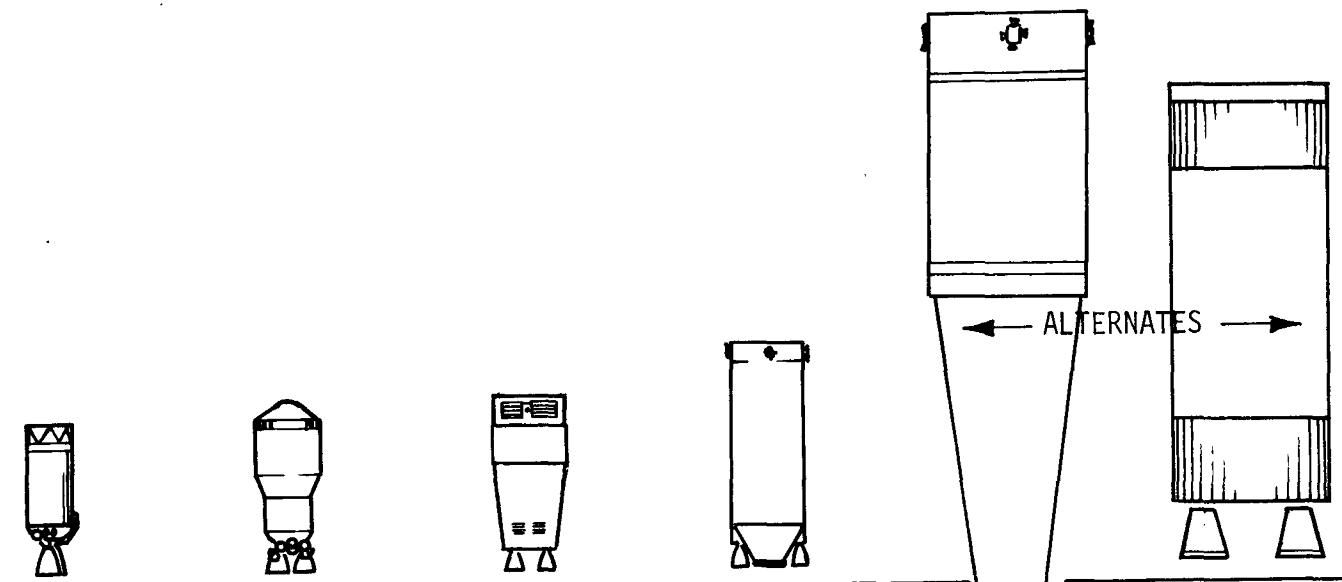
USER VEHICLE SUMMARY

ISPLS
CONTRACT NAS8-27692
FIRST PERFORMANCE REVIEW
CHART NO. 24 DATE 10-6-71



	GROUND-BASED			SPACE-BASED		
	CENTAUR	INTERIM TRANSFER STAGE	TUG (OOS)	SPACE TUG	RNS	CIS
LENGTH - FT	31.5	32.8	36	47	194	100
DIAMETER - FT	10	12.5	15	15	33	33
WEIGHTS - LB						
GROSS	35,300	50,300	67,500	83,400	373,000	1,095,000
PROPELLANT	30,200	45,000	60,200	73,200	295,800	990,000
I_{sp} - SEC	444	444	470	463	775	459
PROG. LEVEL YR OPERATIONAL	A EXISTING	A B C '79*	B C '85 / D E '79	B C '85 / D E '79	D '86 / E '84	D '86 / E '84

*LEVEL A '79 EXPENDABLE/'85 REUSABLE

PROGRAM LEVEL COMPOSITION GUIDE

THE ALTERNATE PAYLOAD PLACEMENT MODELS, WHICH REPRESENT ALTERNATE LEVELS OF SPACE PROGRAM ACTIVITIES, ARE DESCRIBED IN PART BY THE VARIOUS LEVELS OF TRAFFIC AND MAKE-UP OF MISSIONS. THEY ARE ALSO DESCRIBED IN PART BY THE PAYLOAD PROPULSIVE STAGES WHICH ARE EMPLOYED AT EACH SPECIFIC LEVEL.

THE MISSION PORTION OF THE ACCOMPANYING CHART IS ESSENTIALLY A RECAP WHICH OUTLINES THE MAKE-UP OF THE ALTERNATE PROGRAM LEVELS IN TERMS OF THE EARTH ORBITAL, PLANETARY AND LUNAR MISSION AREAS.

PAYLOAD PROPULSIVE STAGES FOR USE AT THE ALTERNATE PROGRAM LEVELS REPRESENT ASCENDING LEVELS OF VEHICLE AVAILABILITY AND ASCENDING LEVELS OF REQUIRED PROGRAM FUNDING. THUS CONSISTENCY IS MAINTAINED WITH THE ASCENDING LEVELS OF SPACE MISSION ACTIVITY THROUGH THE "A" TO "E" LEVELS.

THE 12-YEAR PROGRAM PERIOD IS SPLIT INTO TWO 6-YEAR PERIODS IN ORDER TO ACCOMMODATE TIME-PHASED IOC DATES, PARTICULARLY FOR THE TUG. THE SELECTIONS LEAN HEAVILY TO THE EARLY INTRODUCTION OF REUSABLE PAYLOAD PROPULSIVE STAGES BECAUSE OF ANTICIPATED COST SAVINGS RELATIVE TO THE EXPENDABLE VEHICLES.

THE RNS AND CIS ALTERNATIVES REPRESENT LATER OPERATIONAL CAPABILITIES PARTICULARLY SINCE THE MANNED LUNAR PROGRAM IS NOT INTRODUCED UNTIL 1986.

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PROGRAM LEVEL COMPOSITION GUIDE

ISPLS
CONTRACT NAS8-27692
FIRST PERFORMANCE REVIEW
CHART NO. 25 DATE 10-6-71

	SPACE PROGRAM LEVEL				
	A	B	C	D	E
MISSION AREA ● EARTH ORBITAL	HALF OF FLEMING (NO STATION)	3/4 OF FLEMING (STATION '82)	FLEMING	FLEMING	FLEMING
			(SPACE STATION IN '81)		
● PLANETARY	FLEMING	FLEMING	FLEMING	FLEMING	INCORPORATE 5 RNS/CIS FLIGHTS
● LUNAR	NONE	NONE	NONE	AUTOMATED LUNAR PROGRAM (10 FLIGHTS) MANNED INITIATED IN '86 (2 RNS/ CIS PER YEAR)	(10 FLIGHTS)
PAYLOAD PROPULSIVE STAGES ● EXPENDABLE '79-84	FW-4S AGENA CENTAUR ITS*				
● REUSABLE '79-'84 '85-'90	ITS	ITS TUG	ITS TUG	TUG TUG RNS/CIS '86	TUG TUG RNS/CIS '84

*INTERIM TRANSFER STAGE (PRE-TUG)

SPACE TRAFFIC MODEL - PROGRAM LEVEL C

EACH OF THE FIVE PROGRAM LEVELS IS DESCRIBED BY A SET OF TABULAR DATA AS SHOWN HERE IN TWO PARTS FOR THE BASELINE PROGRAM LEVEL "C". AS IN THE EARLIER SUMMARY TABLE, ALL MISSIONS INCLUDED IN THE 12-YEAR PARAMETRIC PROGRAM ARE LISTED. IN THIS TABLE, OF COURSE, ONLY THE PLACEMENTS FOR EACH MISSION CONTAINED IN PROGRAM LEVEL "C" ARE INCLUDED. THE 12-YEAR TOTALS FOR EACH MISSION LISTED IN THE FAR RIGHT COLUMN REPRESENT THE LEVEL "C" COLUMN IN THE PREVIOUS SUMMARY TABLE, "PARAMETRIC SPACE PROGRAM (1979-1990), DISTRIBUTION OF PLACEMENTS."

THE DISTRIBUTION OF PLACEMENTS BY YEAR, THE THEORETICAL ΔV REQUIREMENTS AND THE PAYLOADS FOR EACH MISSION OF THE "C" LEVEL WERE ALL SUPPLIED BY THE NASA AS PART OF THE FLEMING MODEL. SELECTION OF PAYLOAD PROPULSIVE STAGES WAS PERFORMED BY THE CONTRACTOR AND APPROVED BY THE NASA FOR USE IN THE STUDY.

THOSE MISSIONS WHICH ARE PERFORMED BY THE EARTH-TO-ORBIT SHUTTLE WITHOUT A PAYLOAD PROPULSIVE STAGE ARE IDENTIFIED BY THE TERM "NONE" IN THE PROPULSIVE STAGE COLUMN.

TWO OTHER MISSIONS, PLANETARY MISSIONS NUMBERS 50 and 56, ARE CONSIDERED TO POSE NO SEPARATE IN-SPACE PROPELLANT REQUIREMENTS ALTHOUGH BOTH USE CENTAUR AS UPPER STAGES. THESE VIKING AND GRAND TOUR MISSIONS ARE ASSUMED TO BE ON-GOING PROGRAMS WHICH WILL BE LAUNCHED WITH THE TITAN III.

Space Division
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SPACE TRAFFIC MODEL
PROGRAM LEVEL C
(TABLE 1 OF 2)

CHART NO. 26 DATE 10-6-71

CATEGORY	NO.	TITLE		ΔV ABOVE 100 X 100 FT/SEC*	MISSION PAYLOAD LB	PROPULSIVE STAGE(S) ABOVE SHUTTLE 79-84	85-90	79	80	81	82	83	84	85	86	87	88	89	90	12-YEAR TOTAL
PHYSICS & ASTRONOMY (143)	1.	ASTRONOMY EXPLORER	A	592	720	NONE		2		1	2	2	1		2	1	2	2		15
	2.	RADIO EXPLORER	B	13,000	720	ITS	TUG		2	1			1	2		1			2	9
	3.	MAGNETOSPHERE EXPLORER	LOW	2,510	1,200		TUG	1	1	1	1	1	1	1	1	1	1	1	1	12
	4.	MAGNETOSPHERE EXPLORER	MEDIUM	10,720	1,000		TUG	1	1	1	1	1	1	1	1	1	1	1	1	12
	5.	MAGNETOSPHERE EXPLORER	HIGH	11,000	600	ITS	TUG	1	1	1	1	1	1	1	1	1	1	1	1	12
	6.	ORBITING SOLAR OBSERVATORY		856	1,900	NONE			1											1
	7.	GRAVITY/RELATIVITY EXPERIMENT		692	1,500	NONE							1						1	2
	8.	GRAVITY/RELATIVITY EXPERIMENT	B, D	11,000	500	ITS	TUG			1						1				2
	9.	RADIO INTERFEROMETER	SYNC	13,660	6,000					1										1
	10.	SOLAR ORBIT PAIR	SYNC	12,917	1,900		TUG						1					1		2
	11.	SOLAR ORBIT PAIR	1.0 AU	11,000	1,900		TUG						1					1		2
	12.	OPTICAL INTERFEROMETER	PAIR	12,917	3,500	ITS	TUG										2			2
	13.	HEAO		468	19,700	NONE		1						1						4
		HIGH ENERGY STELLAR ASTRONOMY		468	21,000	NONE					1							1		
	14.		REVISITS	468	3,500	NONE			2	2	2	2	2	2	2	2	2	2	2	22
	15.	LST (STAR)		856	21,300	NONE				1										2
		LST (RAM)		856	30,000	NONE								1						
	16.	LST	REVISITS	856	3,500	NONE					2	2	2	1	2	2	2	2	2	17
	17.	LARGE SOLAR OBSERVATORY		856	27,000	NONE						1					1			2
	18.	LARGE SOLAR OBSERVATORY	REVISITS	856	3,500	NONE							2	2	2	2	1	2	2	13
	19.	LARGE RADIO OBSERVATORY		856	19,300	NONE								1						1
	20.	LARGE RADIO OBSERVATORY	REVISITS	856	3,500	NONE									2	2	2	2	2	10
EARTH OBSERVATION (43)	21.	POLAR EARTH OBSERVATIONS SAT.	R&D	1,330	2,500	ITS	TUG	1	1	1	1	1	1	1	1	1	1	1	1	12
	22.	SYNCHRONOUS EARTH OBSERVATIONS SAT.	R&D	14,100	1,000		TUG		1		1		1		1		1		1	6
	23.	EARTH PHYSICS SAT.	R&D	1,020	600		TUG		1	1	1	1		1		1		1		7
	24.	SYNCHRONOUS METEOROLOGICAL SAT.	SYS. DEMO	14,100	1,000						1	1								2
	25.	TIROS	SYS. DEMO	1,940	1,000	ITS	TUG			1				1					1	3
	26.	POLAR EARTH RESOURCES SAT.	SYS. DEMO.	1,330	2,500		TUG								2	4				6
	27.	SYNCHRONOUS EARTH RESOURCES SAT.	SYS. DEMO.	14,100	1,000	ITS	TUG			1	2	1				1	2			7
COMMUNI-CATION/ NAVIGATION (78)	28.	APPLICATIONS TECHNOLOGY SAT.	SYNC. R&D	14,100	7,950	ITS	TUG	1		1		1	1		1		1	1		7
	29.	SMALL APPLICATIONS SAT.	SYNC. R&D	14,100	600		TUG	1	1	1	1	1	1	1	1	1	1	1	1	12
	30.	SMALL APPLICATIONS SAT.	POLAR R&D	3,800	600		TUG	1	1	1	1	1	1	1	1	1	1	1	1	12
	31.	COOPERATIVE APPLICATIONS	SYNC. R&D	14,100	820			1					1							2
	32.	COOPERATIVE APPLICATIONS	POLAR R&D	3,800	820		TUG				1							1		2
	33.	MEDICAL NETWORK SAT.	SYNC. SYS. DEMO.	14,100	2,000			2												2
	34.	EDUCATION BROADCAST SAT.	SYNC. SYS. DEMO.	14,100	2,145				2											2
	35.	FOLLOW-ON SYSTEM DEMONSTRATION	SYNC. SYS. DEMO.	14,100	2,000		TUG			2	2	2	2	2	2	2	2	2	2	20
	36.	TRACKING & DATA RELAY	SYNC. OPER.	14,100	2,300		TUG	1	2	1		2	1			2	1			10
	37.	PLANETARY RELAY SAT.	SYNC. OPER.	14,100	1,000	ITS	TUG	2	1				1	2				1	2	9
SORTIES (97)	38.	GENERAL SCIENCE RESEARCH MODULE		360	27,500	NONE				2	3	4	4	3						16
	39.	GENERAL APPLICATIONS MODULE		0	30,000	NONE				2	3	2	3	2	3		3	1		19
	40.	DEDICATED SCIENCE & RESEARCH MODULAR	ASTRONOMY	360	29,500	NONE							1	3	4	5	4	5	5	27
	41.	DEDICATED APPLICATIONS MODULE - EARTH	OBSERVATION	0	22,500	NONE							2	2	2	2	2	3	4	17
		PALLET TYPE MODULE																		
	42.	EARTH OBSERVATION		171	6,000	NONE			1	1	2									4
	43.	BIOLOGICAL RESEARCH		360	4,300	NONE		1												1
	44.	ASTRONOMY		360	5,700	NONE			2	2	2	1								7
	45.	FLUID MANAGEMENT		360	7,100	NONE			1			1								2
	46.	TELEOPERATOR		360	5,000	NONE			1											1
	47.	MANNED WORK PLATFORM		360	6,700	NONE				1										1
	48.	LARGE TELESCOPE MIRROR TEST		360	13,000	NONE		1												1
	49.	ASTRONAUT MANEUVERING UNIT (AMU)		360	3,800	NONE			1											1

*THEORETICAL MINIMUM, ONE-WAY, POINT-TO-POINT ΔV

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SPACE TRAFFIC MODEL
PROGRAM LEVEL C
(TABLE 2 OF 2)

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CHART NO 27 DATE 10-6-71

CATEGORY	NO	TITLE		ΔV ABOVE 100 X 100 FT/SEC*	MISSION PAYLOAD LB	PROPULSIVE STAGE(S) ABOVE SHUTTLE 79 - 84	PROPULSIVE STAGE(S) ABOVE SHUTTLE 85 - 90	79	80	81	82	83	84	85	86	87	88	89	90	12-YEAR TOTAL
PLANETARY (18)	50	VIKING		15,400	7,700	— NONE (TIIIF/C) —		1		1										2
	51	MARS SAMPLE RETURN		15,400	22,000	—	TUG												2	2
	52	VENUS EXPLORER		13,400	1,000	ITS	—		1											1
	53	VENUS RADAR MAPPING		13,400	7,900	ITS	—				1									1
	54	VENUS EXPLORER LANDER		13,400	7,300	—	TUG							1			1			2
	55	JUPITER PIONEER ORBITER		22,700	900	ITS	—				2									2
	56	GRAND TOUR (JUN)		25,900	1,500	—NONE (TIIID/C/BII)—		2												2
	57	JUPITER TOPS ORBITER/PROBE		22,700	3,300	—	TUG							1		1				2
	58	URANUS TOPS ORBITER/PROBE		24,000	3,700	—	TUG								1			1		2
	59	ASTEROID SURVEY		13,400	27,000		—						1							1
	60	COMET RENDEZVOUS		13,400	24,000		TUG				1			1						2
	P-1	MERCURY SURFACE SAMPLE & RETURN	RNS/CIS																	0
	P-2	VENUS SURFACE SAMPLE & RETURN	RNS/CIS																	0
	P-3	MARS SURFACE SAMPLE & RETURN	RNS/CIS																	0
	P-4	JUPITER ORBITER/PROBES & SATELLITE LANDERS	RNS/CIS																	0
SPACE STATION (90)	61	STATION MODULES-CORE		592	20,000	— NONE —				1			1	1	3	2				8
	62	STATION MODULES - OTHERS		592	20,000	— NONE —				5				3						8
	63	CREW CARGO		592	20,000	— NONE —				1	6	6	6	6	8	8	8	8	8	65
	64	PHYSICS LAB		592	22,000	— NONE —						1								1
	65	COSMIC RAY LAB		592	30,000	— NONE —											1			1
	66	LIFE SCIENCE LAB		592	33,000	— NONE —				1				1						2
	67	EARTH OBSERVATIONS LAB		592	25,000	— NONE —				1				1						2
	68	COMMUNICATIONS/NAVIGATION LAB		592	19,000	— NONE —						1							1	2
	69	SPACE MANUFACTURING LAB		592	25,000	— NONE —													1	1
NON-NASA (128)	70	COMSAT SATELLITES	SYNC	14,100	1,420	ITS	TUG	2	1	1		2	1	1			2	1		11
	71	U.S. DOMESTIC COMMUNICATIONS	SYNC	14,100	2,145	↕	TUG	1	2	1	1	2	2	2	2	2	2	2	2	21
	72	FOREIGN DOMESTIC COMMUNICATIONS	SYNC	13,000	1,000	↕	TUG		2	6	2	2			4	5	2	1	2	26
	73	NAVIGATION & TRAFFIC CONTROL		13,948	700	↕	TUG	3	1	2		1		1		1		1		10
	74	NAVIGATION & TRAFFIC CONTROL	SYNC	13,400	700	↕	TUG		1	1		1		1		1		1		6
	75	TOS METEOROLOGICAL		1,940	1,000	↕	TUG	1	1	1	1	1	1	1	1	1	1	1	1	12
	76	SYNC METEOROLOGICAL	SYNC	14,100	1,000	↕	TUG	1	1	1	1	1	1	1	1	1	1	1	1	12
	77	POLAR EARTH RESOURCES		1,330	2,500	ITS	TUG	4		4		4		4				6		22
	78	SYNCHRONOUS EARTH RESOURCES	SYNC	14,100	1,000	—	TUG							4			4			8
LUNAR (0)	L-1	AUTOMATED LUNAR PROGRAM ORBITERS																		0
	L-2	AUTOMATED LUNAR PROGRAM LANDERS																		0
	L-3	MANNED SORTIE-CLASS MISSIONS	RNS/CIS																	0
	L-4	POST-SORTIE SURFACE OPERATIONS	RNS/CIS																	0
TOTAL								33	34	55	46	51	47	62	51	56	56	57	50	598

* THEORETICAL MINIMUM, ONE-WAY, POINT-TO-POINT ΔV

PROPELLANT REQUIREMENTS SUMMARY

QUANTITIES OF PROPELLANTS REQUIRED ANNUALLY IN ORBIT ARE PLOTTED VERSUS CALENDAR YEAR FOR THE 12-YEAR PROGRAM AND FOR EACH OF THE FIVE PROGRAM LEVELS. THE VALUES SHOWN APPLY TO THE CASE OF A GROUND-BASED TUG AS APPROPRIATE. VALUES FOR A SPACE-BASED TUG ARE SOMEWHAT HIGHER. QUANTITIES OF PROPELLANTS REQUIRED BY THE TWO MAJOR ALTERNATES, THE RNS AND CIS, ARE SHOWN AT THE "D" AND "E" LEVELS. THE "D" LEVEL VALUES ARE BASED ON ABOUT 300,000 AND 990,000 POUNDS OF PROPELLANTS FOR THE RNS AND CIS, RESPECTIVELY,FOR BOTH THE L-3 AND L-4 MISSIONS; THE "E" LEVEL INCREMENTS ARE 195,000 AND 500,000 POUNDS OF PROPELLANTS FOR THE RNS AND CIS, RESPECTIVELY, FOR THE P-1, 2 AND 3 MISSIONS; AND 244,000 AND 755,000 POUNDS FOR THE RNS AND CIS, RESPECTIVELY, TO PERFORM THE P-4 MISSIONS. (PROPELLANT QUANTITIES, OF COURSE, ARE ONLY INPUT DATA TO A SYSTEMS ANALYSIS AND DO NOT CONSTITUTE A CRITERION FOR COMPARING THESE ALTERNATIVES.)

IT IS IMPORTANT TO NOTE THAT THE DATA PLOTTED IN THE ACCOMPANYING FIGURE ARE BASED ON THE SIMPLIFYING ASSUMPTION OF A SEPARATE FLIGHT OF THE PAYLOAD PROPULSIVE STAGE FOR EACH PAYLOAD PLACEMENT. SINCE THE SUBSEQUENT LOGISTICS ANALYSIS RECONSTRUCTS THE PROPELLANT REQUIREMENTS BASED ON AN ANALYSIS OF PAYLOAD CLUSTERING TO PERFORM MULTIPLE PLACEMENTS WITH MANY PROPULSIVE STAGE FLIGHTS, THE CURVES SHOWN HERE CONSTITUTE A REFERENCE ONLY RATHER THAN A STUDY OUTPUT.

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PROPELLANT REQUIREMENTS SUMMARY
GROUND BASED TUG

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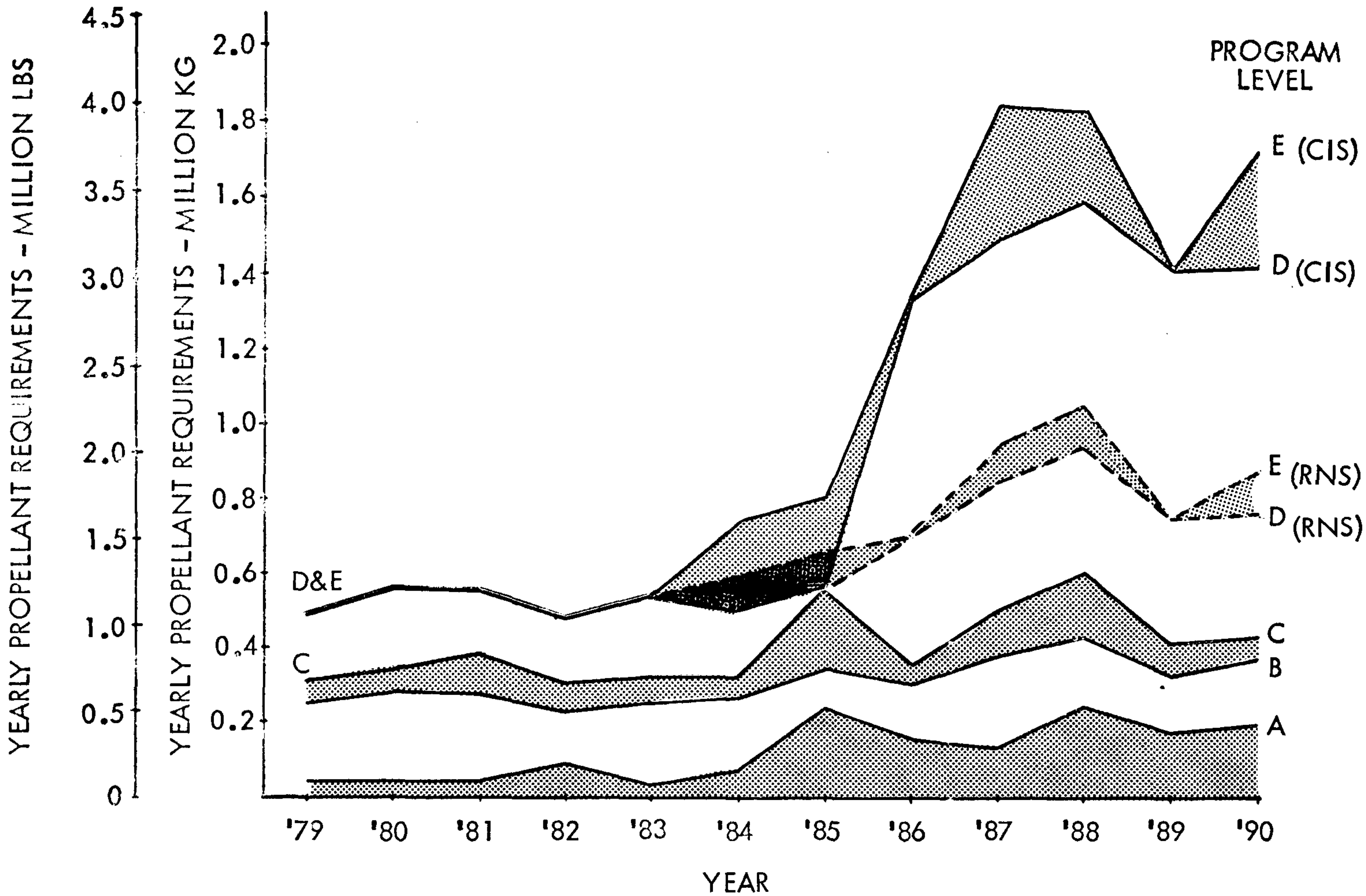
CONTRACT NAS8-27692
FIRST PERFORMANCE REVIEW
CHART NO. 28 DATE 10-6-71



ORBITAL ALTITUDE AND INCLINATION REQUIREMENTS

ORBIT PLACEMENT AND PAYLOAD INJECTION DESTINATIONS ARE PLOTTED ON AN ALTITUDE-INCLINATION MAP FOR ALL MISSIONS IN THE PARAMETRIC SPACE PROGRAM. THE MAP IS HELPFUL IN IDENTIFYING GROUPINGS OF MISSIONS BY SIMILAR DESTINATIONS AND STARTING ORBITS FOR PAYLOAD PROPULSIVE STAGES. THESE, IN TURN, PROVIDE BASIC CONDITIONS FOR LATER ANALYSIS OF PAYLOAD CLUSTERING AND IN-ORBIT PROPELLANT LOGISTICS CONCEPTS AND OPERATIONS.

THE MASKED REGION BETWEEN 100 AND ABOUT 425 N MI ALTITUDE AND EXTENDING SLIGHTLY BELOW 28.5 DEGREES DESCRIBES THE NOMINAL IN-SPACE OPERATING REGIME OF THE SPACE SHUTTLE. MAJOR GROUPS OF MISSIONS PERFORMED BY THE SHUTTLE ALL-THE-WAY INCLUDE THE SPACE STATION, SHUTTLE SORTIES, AND A GROUP OF ASTRONOMY MISSIONS (LARGE SPACE TELESCOPE AND OBSERVATORIES), THE LATTER AT 28.5 AND 30 DEGREES INCLINATION. THE LOW MAGNETOSPHERIC EXPLORER MISSIONS (3B, C AND D) AND THE APPLICATIONS SATELLITES (30 AND 32 AT 90^{o} INCLINATION) DO REQUIRE PROPULSIVE STAGES SINCE THEIR ORBITS ARE HIGHLY ELLIPTICAL. ONLY THEIR PERIGEES ARE SHOWN ON THE PLOT.

MAJOR GROUPINGS OF MISSIONS OCCUR AT SYNCHRONOUS EQUATORIAL, AT 28.5 AND 30 DEGREES INCLINATION, AND AT THE POLAR (90 TO 100 DEGREES) REGION.

DESTINATION CONDITIONS ARE GOVERNING IN PAYLOAD CLUSTERING: AND PAYLOAD PROPULSIVE STAGE BEGIN-BURN ORBITAL CONDITIONS ARE DOMINANT IN CONSIDERATION OF IN-ORBIT PROPELLANT LOGISTICS. SINCE BOTH THE EQUATORIAL AND 28.5 DEGREE MISSIONS INVOLVE PROPULSIVE STAGE STARTS FROM 100 X 100 N MI ORBITS AT 28.5 DEGREE INCLINATIONS, A MEANINGFUL GROUPING OF LOCATION REQUIREMENTS IS EVIDENT.

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ORBITAL ALTITUDE & INCLINATION REQUIREMENTS

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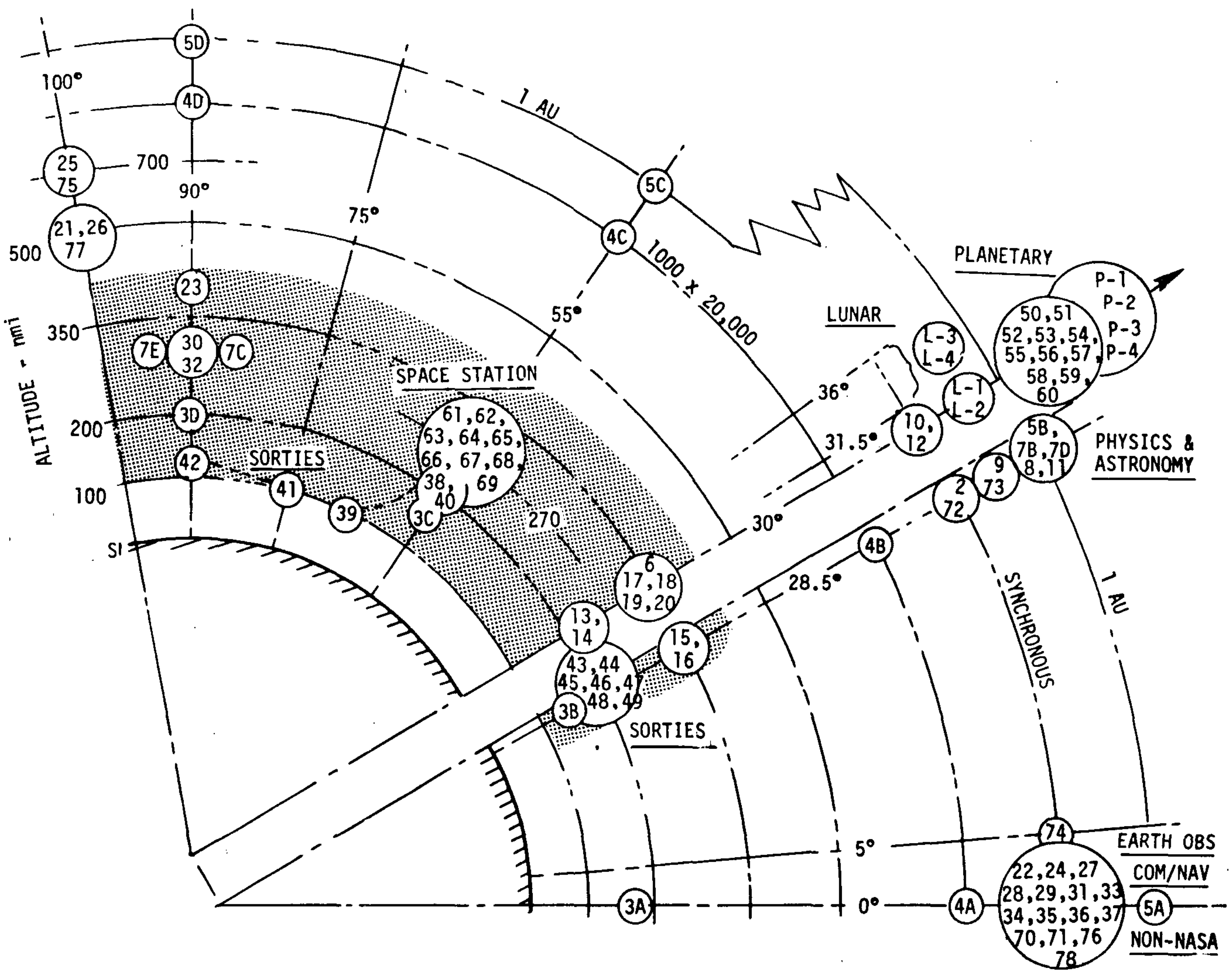
FIRST PERFORMANCE REVIEW
CHART NO. 29 DATE 10-6-71



USER PROPELLANT REQUIREMENTS DISTRIBUTION BY ORBITAL INCLINATION AT 100 N MI

IN CONTRAST TO THE PRECEDING CHART WHICH SHOWED MISSION PAYLOAD DESTINATION PARAMETERS, THIS FIGURE INDICATES THOSE INCLINATIONS AT WHICH THE SHUTTLE NOMINALLY DEPLOYS ITS PAYLOADS AND PAYLOAD PROPULSIVE STAGES. ALSO WHEREAS THE PRECEDING CHART IDENTIFIED ALL MISSIONS, THE ACCOMPANYING FIGURE LISTS THE NUMBER OF PAYLOAD PLACEMENTS IN THE 12-YEAR PROGRAM WHICH UTILIZE PAYLOAD PROPULSIVE STAGES. THEIR DISTRIBUTION OVER FIVE ORBITAL INCLINATIONS AT DEPLOYMENT AND BEGIN-BURN IS SHOWN. THE TOTAL NUMBER OF PLACEMENTS REQUIRING PAYLOAD PROPULSIVE STAGES AT THE "C" LEVEL IS 318. ALMOST TWO-THIRDS OF THESE ARE DEPLOYED IN 28.5 DEGREE ORBITS.

TOTAL PROPELLANTS REQUIRED BY PAYLOAD PROPULSIVE STAGES FOR THESE PLACEMENTS IN A 12-YEAR PERIOD IS 10,077,000 POUNDS. ALMOST 9,000,000 POUNDS ARE REQUIRED AT 28.5 DEGREE ORBITS FOR USE IN DUE-EAST AND EQUATORIAL PLACEMENTS. THIS REPRESENTS MORE THAN 88 PERCENT OF ALL IN-ORBIT PAYLOAD PROPULSIVE STAGE PROPELLANT NEEDS AT THE "C" PROGRAM LEVEL. THE PREPONDERANCE OF PROPELLANT USAGE HERE REFLECTS BOTH THE LARGE NUMBER OF PLACEMENTS AND THE HIGH ENERGY REQUIREMENTS FOR THE SYNCHRONOUS PLACEMENTS. NOTE THAT THE SUM OF THE PROPELLANTS REQUIRED AT 30 AND 28.5 DEGREE INCLINATION REPRESENTS 94 PERCENT OF THE TOTAL. IN CONTRAST THE POLAR AND NEAR-POLAR PLACEMENTS INVOLVE LOW EARTH ORBIT OR ELLIPTICAL ORBITS OF RELATIVELY MODEST ENERGY. CONSEQUENTLY, PROPELLANT REQUIREMENTS ARE RELATIVELY SMALL.

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USER PROPELLANT REQUIREMENTS DISTRIBUTION BY ORBITAL INCLINATION AT 100 nmi

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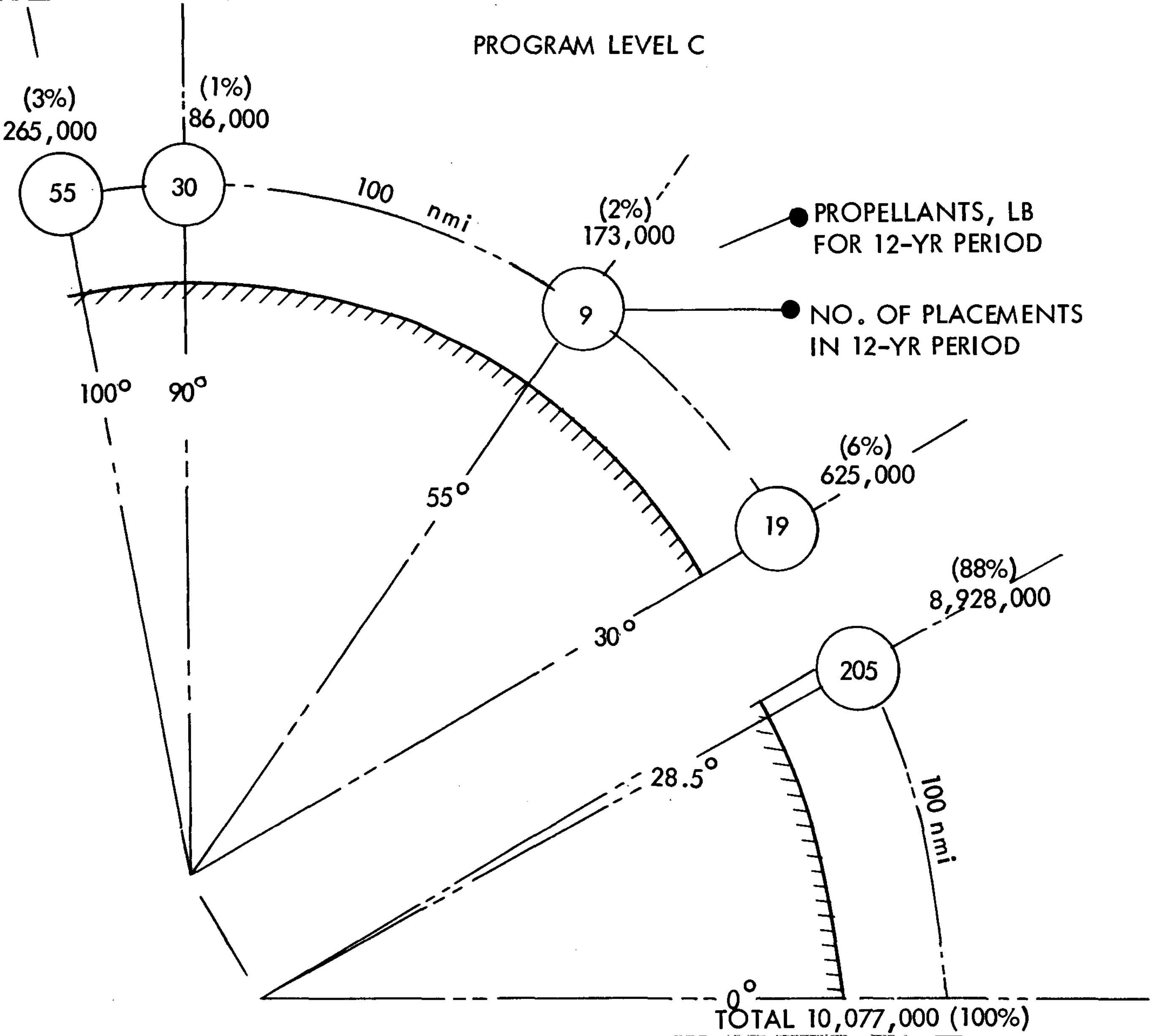
PROGRAM LEVEL C



PARAMETRIC SPACE PROGRAM REQUIREMENTS DATA UTILIZATION

THE NASA SPACE PROGRAM REQUIREMENTS TASK FOR PROJECT 1 HAS BEEN COMPLETED. THE FULL TASK OUTPUT, WHICH WILL BE A PART OF THE STUDY FINAL REPORT, WILL DOCUMENT THE ITEMS LISTED IN THE CHART UNDER "TASK I-1 OUTPUT."

PROGRAM LEVEL ACTIVITY SELECTIONS AND PAYLOAD PROPULSIVE STAGE SELECTIONS AND DEFINITIONS FROM THIS REQUIREMENTS ACTIVITY WILL CONTINUE TO INFLUENCE BOTH THE CONTENT AND THE FINDINGS OF THE STUDY. THE STRUCTURED DATA BASE IS APPLIED FIRST IN THE DEVELOPMENT OF LOGISTICS MODELS. MATCHING AND TIME-PHASING OF REQUIREMENTS AND LOGISTICS RESUPPLY WILL THEN SUPPORT DEVELOPMENT AND ANALYSIS OF ORBITAL STORAGE AND TRANSFER NEEDS AND THE ANALYSIS OF CONCEPTS EFFECTIVENESS FOR EACH OF THE PROGRAM LEVEL ALTERNATIVES.

THE SPECIFIC STRUCTURING OF DATA WAS PLANNED TO FACILITATE LATER PERFORMANCE OF TASKS SUCH AS TASK I-7, "DETERMINE FEASIBILITY DEPENDENCE OF ORBITAL STORAGE ON MAJOR ELEMENTS." THIS INVOLVES FEASIBILITY DEPENDENCE ON WHETHER THERE IS A LUNAR PROGRAM, ON THE RNS/CIS MAJOR SUBSTITUTION, ON THE AVAILABILITY OF A TUG AND ON SPACE-BASING VERSUS GROUND-BASING ALTERNATIVES.

LASTLY, THE FINDINGS OF THE STUDY SHOULD BE QUALIFIABLE OVER A REASONABLY BROAD RANGE OF CONDITIONS.

TASK I-1 OUTPUT:

- MAKE-UP & MAJOR SUBSTITUTIONS IN CONTEMPLATED SPACE PROGRAM
- ALTERNATE SPACE PROGRAM LEVELS
- USER TRAFFIC MODEL FOR EACH PROGRAM LEVEL & MAJOR SUBSTITUTION
- USER CHARACTERISTICS & OPERATIONAL MODES
- USER PROPELLANTS FOR EACH MISSION
- USER PROPELLANT REQUIREMENTS AT EACH PROGRAM LEVEL & MAJOR SUBSTITUTION

HOW MUCH?	QUANTITIES OF LH_2 & LO_2
WHEN?	TIME-PHASING
WHERE?	ORBIT ALTITUDE & INCLINATION

UTILIZATION IN STUDY:

PROPELLANT RESUPPLY MODELS, ORBITAL STORAGE NEEDS, CONCEPT ALTERNATIVES

SENSITIVITIES-- COST/EFFECTIVENESS FEASIBILITY DEPENDENCE → QUALIFIED INTERFACE RECOMMENDATIONS

MOST ECONOMICAL, FEASIBLE METHODS OF OPERATION AT PROGRAM LEVELS → QUALIFIED PROGRAM REQUIREMENTS & PLAN

PROPELLANT LOGISTICS SYSTEMS ANALYSIS OUTLINE

IN THIS SECTION OF THE BRIEFING LOGISTICS CONCEPTS ARE ESTABLISHED AND THEIR PERFORMANCE EFFECTIVENESS IS QUANTITATIVELY DEFINED. THESE CONCEPTS ARE DESIGNED TO TRANSPORT PROPELLANTS TO THE USING VEHICLES DEFINED IN THE PREVIOUS SECTION. THE LOGISTICS CONCEPTS ARE DERIVED FROM THE CHARACTERISTICS OF THE USING VEHICLES; NAMELY, GROUND BASED, SPACE BASED, REUSABLE OR NON-REUSABLE. THE CONCEPTS ARE EVALUATED BY DEVELOPING FLIGHT-BY-FLIGHT TRAFFIC MODELS TO DETERMINE THE AMOUNT OF PROPELLANT REQUIRED, THE NUMBER OF LOGISTICS FLIGHTS REQUIRED TO SUPPLY THE PROPELLANT TO ORBIT, THE NUMBER OF USER VEHICLE FLIGHTS, AND THE NUMBER OF USER VEHICLES EXPENDED IN DELIVERING THE PAYLOADS TO THE DESIRED ORBIT FOR EACH PROGRAM LEVEL. EFFECTIVE CONCEPTS WILL MINIMIZE EACH OF THESE PARAMETERS. SUBSEQUENTLY THE COST OF EACH CONCEPT WILL BE DETERMINED AND A MEASURE OF COST EFFECTIVENESS WILL BE DEFINED FOR COMPARISON. THE MOST COST EFFECTIVE CONCEPT WILL BE IDENTIFIED FOR EACH PROGRAM LEVEL. THIS DEFINITION IS THE PRIMARY PRODUCT OF THE STUDY.

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PROPELLANT LOGISTICS SYSTEMS ANALYSIS
OUTLINE

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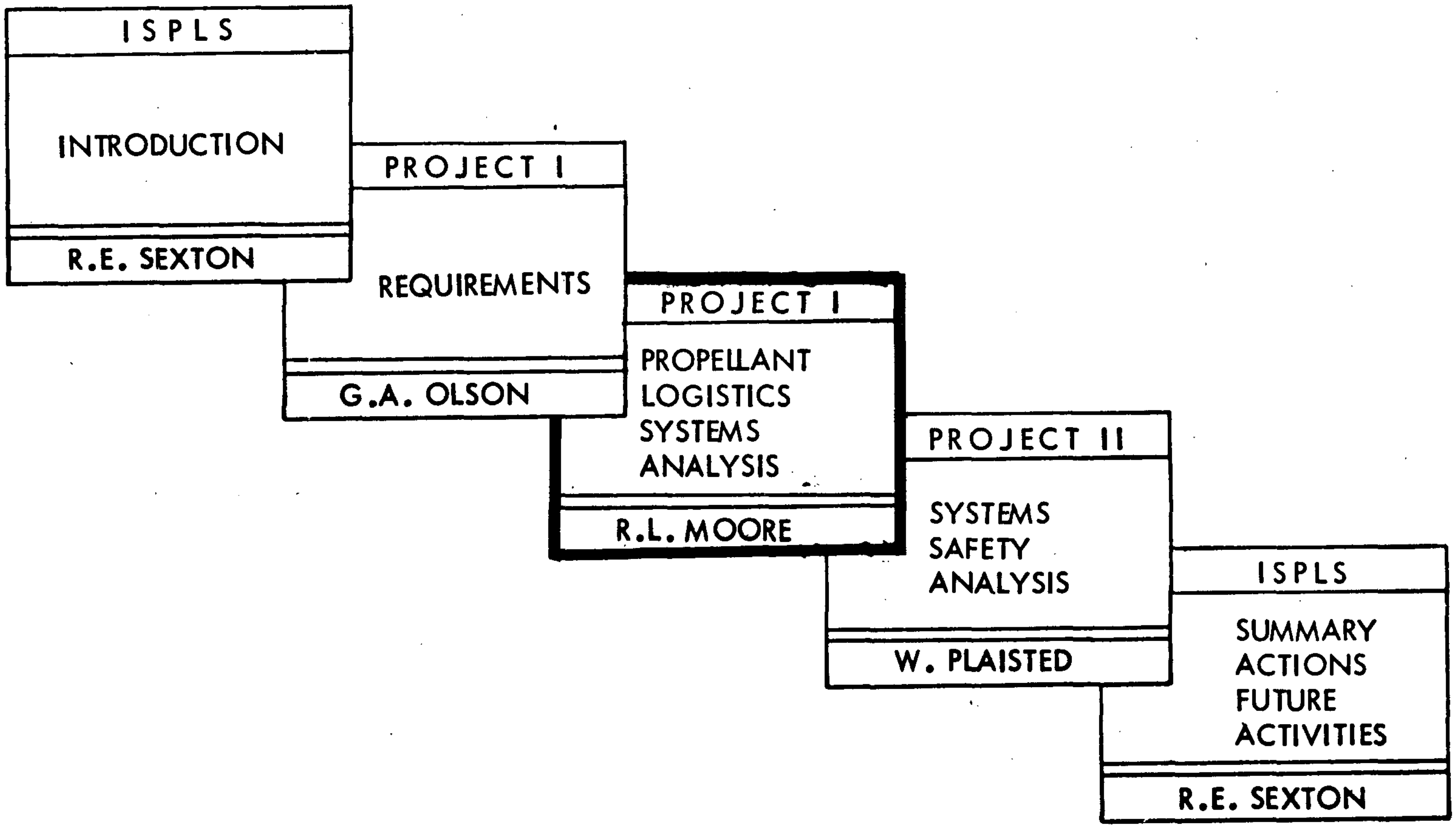
CHART NO. 32 DATE 10-6-71



2

REQUIREMENTS/LOGISTICS ALTERNATIVES INTEGRATION

THE MAJOR VARIABLES IN THE LOGISTICS SYSTEM DEFINITION PROBLEM ARE THE FIVE LEVELS OF SPACE PROGRAM ACTIVITIES, THE SHUTTLE TRANSPORT MODE, THE PAYLOAD-PROPELLANT OPTIONS, AND THE BASING MODE FOR THE PPS -- EITHER GROUND OR SPACE -- AND WITH THE SPACE-BASED PPS THE USE OR NON-USE OF ORBITAL PROPELLANT STORAGE. EACH OF THE FEASIBLE CONCEPTS POSSIBLE WITH THESE PARAMETERS WILL BE INVESTIGATED IN THIS STUDY.

THE GROUND-BASED PPS PERFORMANCE IS BASED ON THE NR ORBIT-TO-ORBIT SHUTTLE (CHEMICAL) FEASIBILITY STUDY (OOS) AND THE SPACE-BASED PPS IS BASED ON THE REUSABLE SPACE TUG STUDY BY NR FOR NASA. THE GROUND BASED PPS IS SMALLER AND LIGHTER THAN THE CORRESPONDING SPACE-BASED PPS BECAUSE IT IS A MUCH SIMPLER VEHICLE WHICH CANNOT PERFORM MANY OF THE FUNCTIONS OF THE LATTER. THE GROUND-BASED VEHICLE IS REUSABLE BUT CANNOT BE CHECKED OUT, MAINTAINED, OR FUELED IN SPACE, NO DOCKING OR UNDOCKING CAPABILITY IS PRESENT, IT HAS LESS SOPHISTICATED GUIDANCE, NAVIGATION, AND COMMUNICATIONS, AND CANNOT BE MANNED. ITS LIGHTER WEIGHT AND HIGHER PERFORMANCE ENGINE (ISP = 470 SEC), RESULT IN A MORE EFFICIENT STAGE.

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REQUIREMENTS/LOGISTICS ALTERNATIVES INTEGRATION

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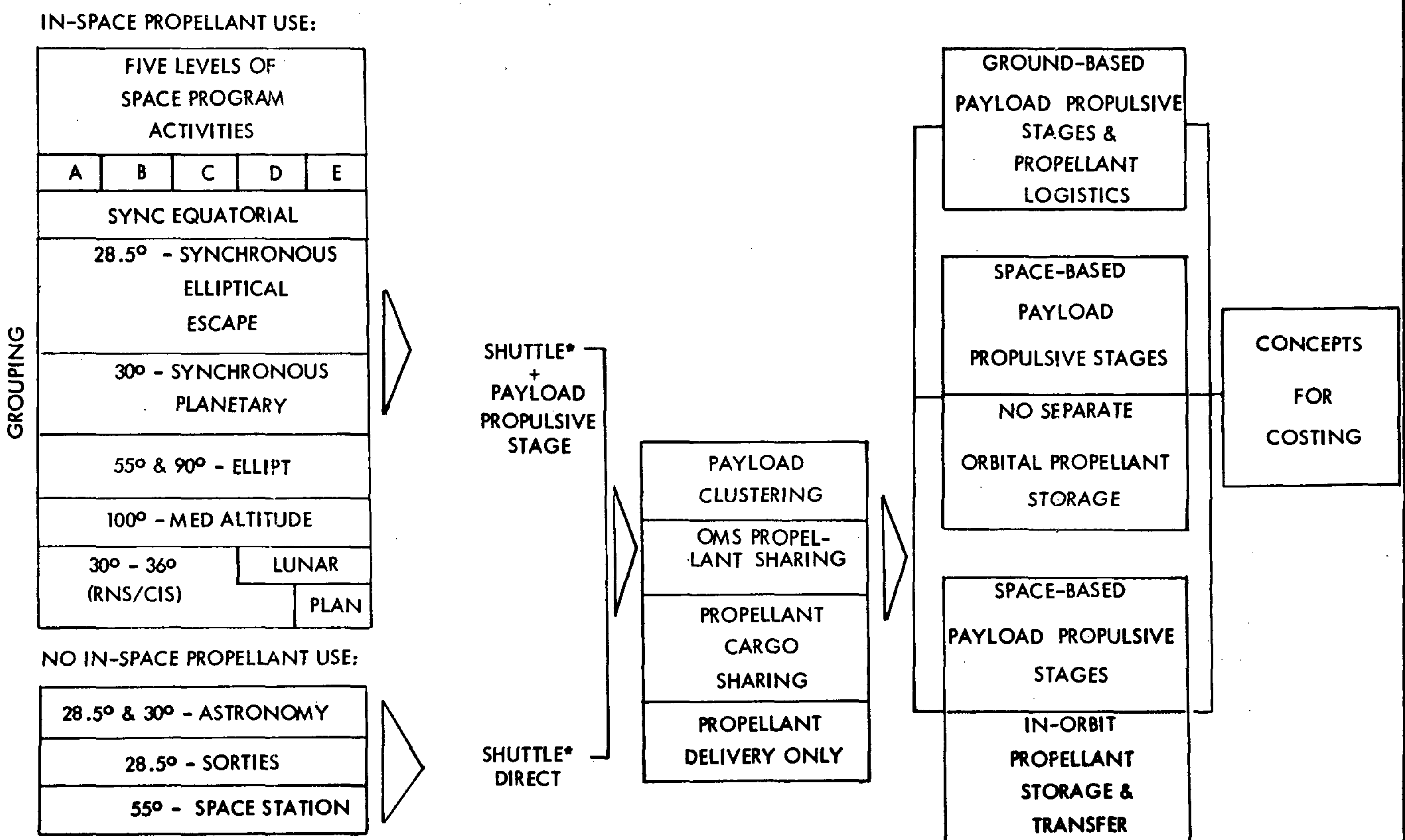

*ESS & INT-21 ALTERNATES FOR SELECT CONDITIONS

PROCEDURE FOR ANALYSIS

A BASELINE CONCEPT WAS DEFINED BASED ON THE SIMPLEST LOGISTICS SYSTEM WHICH COULD SATISFY THE NEEDS OF THE FIVE PROGRAM LEVELS. THIS CONCEPT UTILIZED ONE PAYLOAD AND ONE PAYLOAD PROPULSIVE STAGE (PPS) - SUCH AS FW-4S, AGENA, CENTAUR, OR TUG - PER SHUTTLE FLIGHT (1:1). THE SHUTTLE WAS SELECTED AS THE TRANSPORT VEHICLE FOR THE BASELINE CONCEPT BECAUSE IT MOST CLOSELY MATCHES THE NEEDS OF THE LOGISTICS SYSTEM IN TERMS OF FLIGHT RATES AND WEIGHT AND VOLUME CAPACITY PER FLIGHT. ALTERNATE TRANSPORT VEHICLES ARE THE INT-21 AND THE EXPENDABLE SECOND STAGE (ESS). VEHICLES UTILIZED FOR ANALYSIS IN THE STUDY ARE CONSTRAINED TO THOSE DEFINED IN EXISTING STUDIES.

PROCEDURE FOR ANALYSIS

- REFERENCE CONCEPT (1:1)
  - ONE SHUTTLE ORBITER LAUNCH FOR EACH SCIENTIFIC PAYLOAD PLACEMENT. CARGO BAY CONTAINS:

    SINGLE SCIENTIFIC PAYLOAD
    PAYLOAD PROPULSIVE STAGE (PPS)
    PROPELLANT REQUIRED FOR PLACEMENT IN PPS

  - SHUTTLE TO 100 nmi CIRCULAR ORBIT AT P.L. PLACEMENT INCLINATION
  - PPS TRANSPORTS PAYLOAD TO PLACEMENT ALTITUDE
  - PPS RECOVERED AT 100 nmi IF REUSABLE
- PAYLOADS GROUPED BY SIMILAR INCLINATIONS FOR EXAMINATION
- PAYLOAD CLUSTERING/PROPELLANT SHARING EVALUATED BASED ON FOLLOWING GROUND RULES:
  - PAYLOADS LAUNCHED IN SAME YEAR
  - PAYLOADS LAUNCHED TO SAME INCLINATION BAND
  - PAYLOADS FIT SHUTTLE ORBITER CARGO CONSTRAINTS
  - 25% VOLUME PENALTY FOR REPACKAGING
  - SHUTTLE MISSION DURATION = 7 DAYS
- COST TO BE DEVELOPED FOR SYSTEMS SELECTED

PRIMARY GROUND-BASED PAYLOAD DELIVERY OPTIONS

THE PRIMARY GROUND-BASED LOGISTICS CONCEPT IS ILLUSTRATED HERE SHOWING BOTH THE BASELINE ONE-TO-ONE CONCEPT AND A PAYLOAD CLUSTERING OPTION WHICH RESULTS IN THE DELIVERY OF MULTIPLE PAYLOADS TO ORBIT ON A SINGLE SHUTTLE FLIGHT. THE PPS IS USED AS A SHUTTLE UPPER STAGE--THE SHUTTLE BEING LIMITED IN ALTITUDE TO 200-400 MILES AND INCLINATIONS ABOVE 28.5°.

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PRIMARY*
GROUND BASED PAYLOAD OPTIONS
FOR PROPELLANT ANALYSIS

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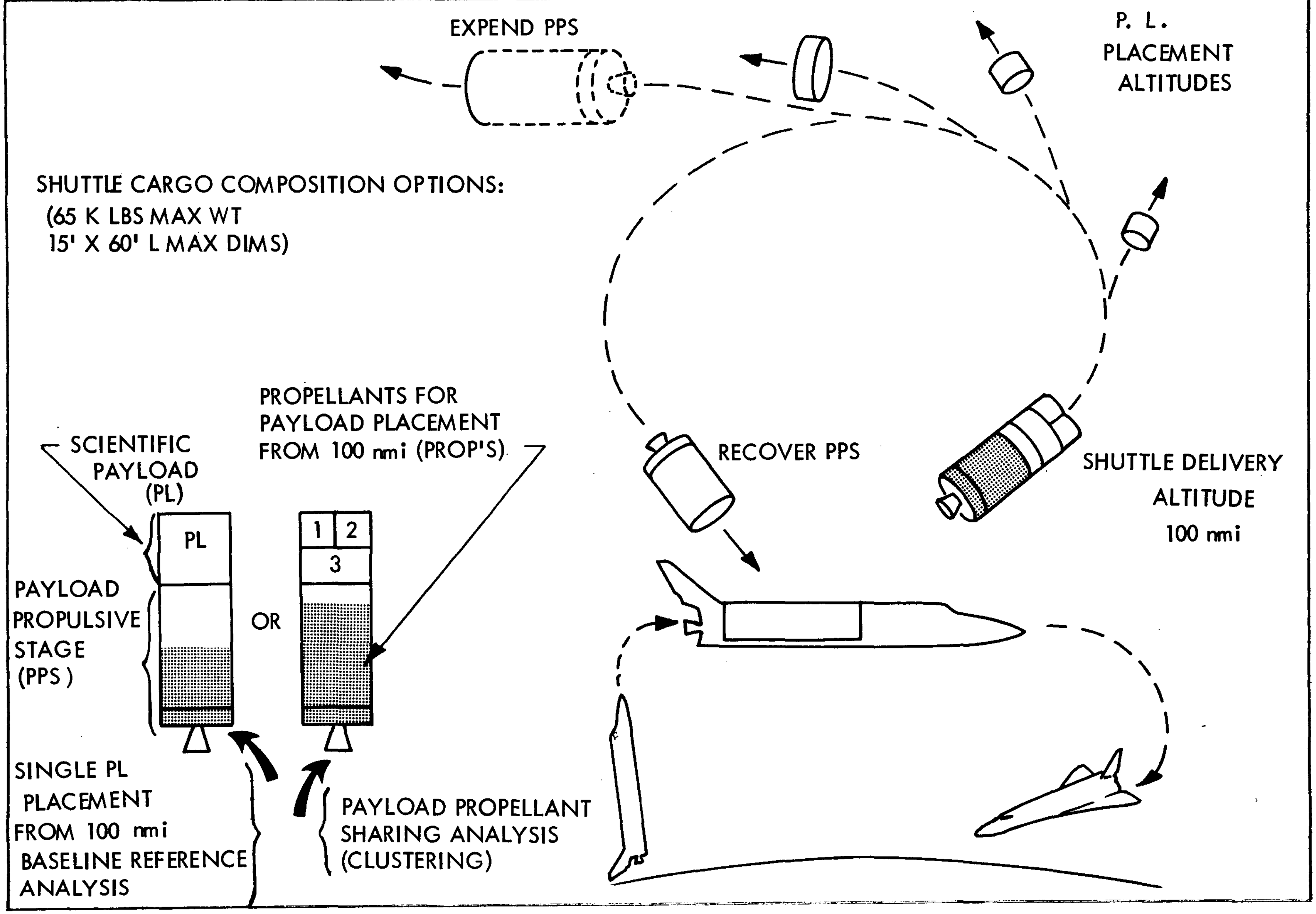
CHART NO. 35 DATE 10-6-71



ALTERNATE GROUND-BASED CONCEPTS

DUAL LAUNCHES WITH ASSEMBLY IN ORBIT ARE REQUIRED FOR PLANETARY MISSIONS 59 & 60, ASTEROID SURVEY AND COMET RENDEZVOUS, RESPECTIVELY, IN PROGRAM LEVELS A, B, AND C BECAUSE THE VEHICLES POSTULATED TO BE IN THE INVENTORY AT THOSE TIMES DO NOT HAVE SINGLE-VEHICLE CAPABILITY. THE LOGISTICS MODE FOR THIS CASE IS ILLUSTRATED ON THE LEFT SIDE OF THE CHART. ON THE RIGHT SIDE, THE SHUTTLE ORBIT MANEUVERING SYSTEM (OMS) OPTION IS SHOWN WHEREIN THE SHUTTLE DELIVERY CAPABILITY IS EXTENDED ABOVE THE NOMINAL 100 NM BY BURNING ITS OMS PROPELLANT. THE ACTUAL IMPROVED ALTITUDE PERFORMANCE CAPABILITY WAS GIVEN ON AN EARLIER CHART.

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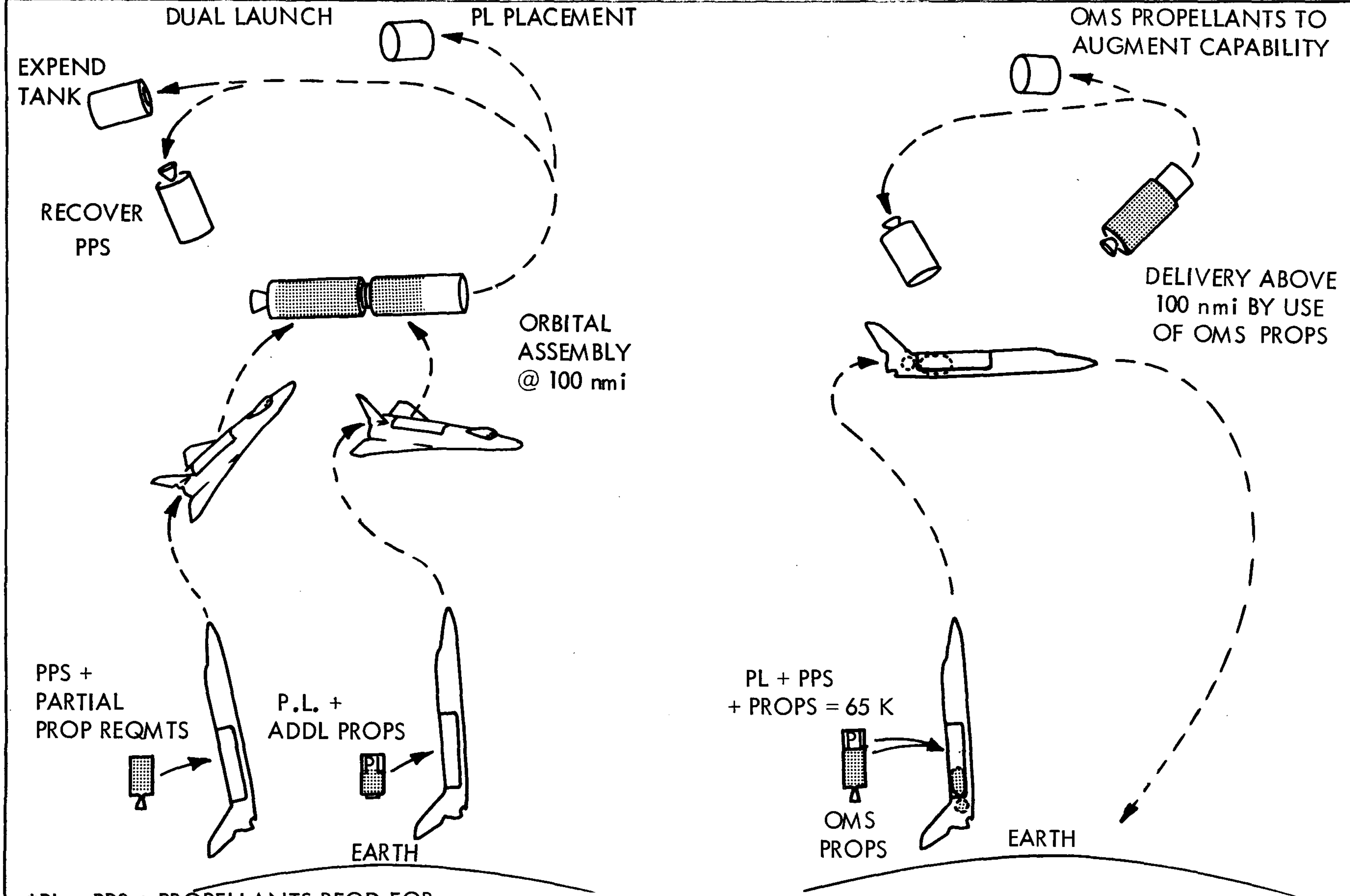
ALTERNATE* GROUND BASED SCIENTIFIC PAYLOAD DELIVERY CONCEPTS FOR PROPELLANT ANALYSIS

ISPLS
CONTRACT NAS8-27692
FIRST PERFORMANCE REVIEW
CHART NO. 36 DATE 10-6-71



*PL + PPS + PROPELLANTS REQD FOR PLACEMENT FROM 100 nmi 65000 LBS

BASELINE REFERENCE ANALYSIS

THE WEIGHT OF PROPELLANTS REQUIRED BY THE VARIOUS PAYLOAD PROPULSIVE STAGES TO PLACE EACH OF THE PAYLOADS IDENTIFIED IN THE PROGRAM LEVELS OF THE PREVIOUS SECTION IN THE DESIRED ORBIT USING THE BASELINE CONCEPT WERE DETERMINED AND ARE SUMMARIZED ON THIS AND THE NEXT CHART FOR A PORTION OF THE LEVEL C PROGRAM. THE PROPELLANT LEVEL IS A FUNCTION OF THE PAYLOAD WEIGHT, THE INITIAL AND FINAL ORBIT PARAMETERS, THE SPECIFIC IMPULSE OF THE ENGINE-STAGE SYSTEM, AND THE BURNOUT WEIGHT OF THE STAGE. PROPELLANT REQUIREMENTS WERE CALCULATED FOR EACH OF THREE MISSION CHARACTERISTIC VELOCITIES - THE IDEAL MINIMUM GIVEN IN THE FLEMING PROGRAM MODEL - THE IDEAL PLUS A 5% PAD - AND A 10% PAD. THE TEN PERCENT CORRECTION IS BASED ON A TYPICAL EARTH ORBIT MISSION REQUIRING MULTIPLE DOCKINGS. A FIVE PERCENT CORRECTION IS MORE REPRESENTATIVE OF SINGLE-BURN MISSIONS SUCH AS PLANETARY INJECTIONS. THE PAD INCLUDES 2% FOR FLIGHT PERFORMANCE RESERVES, 2% FOR PROPELLANT LOSSES AFTER CLOSING OUT THE TANK, AND 1% FOR CONTINGENCIES. THE MISSIONS ARE GROUPED BY FINAL ORBITAL INCLINATION OF THE PAYLOAD. THE PLANETARY MISSIONS ARE THE LARGEST PROPELLANT CONSUMERS AND PPS MUST BE EXPENDED ON SOME MISSIONS AS THERE IS NOT SUFFICIENT PROPELLANT CAPACITY IN THE SELECTED VEHICLE TO PERMIT RECOVERY WHICH REQUIRES ABOUT TWICE AS MUCH PROPELLANT AS THE EXPENDED MODE.

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1:1 BASELINE REFERENCE ANALYSIS
GROUND BASED PPS

PROGRAM LEVEL "C" 1985-1990

15' DIAM X 36' LONG, 7,270 LBS

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FIRST PERFORMANCE REVIEW

CHART NO. 37 DATE 10-6-71

	PAYLOAD NO.	PAYLOAD DIAM	PAYLOAD LENGTH	PAYLOAD WEIGHT	VEHICLE	PROPELLANT	SHUTTLE PAYLOAD DIAM	SHUTTLE PAYLOAD LENGTH	SHUTTLE PAYLOAD WEIGHT	
0^o SYNC	22	4	6	1000	GBT	50972	15	42	59242	
	24	5	8	1000		50972		44	59242	
	27	4	6	1000		50972		42	59242	
	28	15	20	7950		27193 ①		56	42413	TUG EXPENDED
	29	6.5	12	600		50257		48	58127	
	31	6.5	12	820		50650		48	58730	
	33	12	15	2000		52758		51	62028	
	34	10	19	2145		53017		55	62432	
	35	12	15	2000		52758		51	62028	
	36	12	15	2300		53294		51	62864	
	37	10	20	1000		50972		56	59242	
	70	6.5	12	1420		51722		48	60412	
	71	10	19	2145		53017		55	62432	
	76	5	8	1000		50972		44	59242	
	78	6	6	1000		50972		42	59242	
5^o	74	5	8	700		44877		44	52847	
28.5^o	2	4.5	3.3	720		41975		39.3	49965	
	72	4	12	1000		42415		48	50685	
	3	4	8	1200		3441		44	11911	
	4	5	8	1000		28449		44	36719	
	9	12	15	6000		55881		51	69151	OFFLOAD PROP. INTO OMS TANK
	5	4	6	600		29439		42	37309	
	8	4	5	500		29317		41	37087	
	11	10	12	1900		31031		48	40201	
29^o	73	5	8	700	GBT	49181		44	57151	

① REDUCED ΔV PAD FROM 10% TO 5 % TO ACCOMMODATE PAYLOAD

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1:1 BASELINE REFERENCE ANALYSIS
GROUND BASED PPS
PROGRAM LEVEL "C" 1985-1990

15' DIAM X 36' LONG, 7,270 LBS

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FIRST PERFORMANCE REVIEW

CHART NO. 38 DATE 10-6-71

	PAYLOAD NO.	PAYLOAD DIAM	PAYLOAD LENGTH	PAYLOAD WEIGHT	VEHICLE	PROPELLANT	SHUTTLE PAYLOAD DIAM	SHUTTLE PAYLOAD LENGTH	SHUTTLE PAYLOAD WEIGHT	
30° PLANETARY	10	10	12	1900	GBT	43224	15	48	52394	
	12	7	10	3500		45715	15	46	56485	
	51	14	22.5	22000		55931 (1)	14	22.6	22000	EXP. TUG,
							15	36	63201	2 LAUNCHES
	52	5	12	1000		45371	15	48	53641	
	53	10	12	7900		56746		48	71916	OFFLOAD PROP. INTO OMS TANK
	54	10	15	7300		55757		51	70327	OFFLOAD PROP. INTO OMS TANK
	55	10	15	900		34368 (1)		51	42538	EXPEND TUG
	57	10	12	3300		44464 (1)		48	55034	EXPEND TUG
	58	10	15	3700		51807 (1)	15	51	62777	EXPEND TUG
	59	10	35	27000		56492 (1)	10	35	27000	EXP. TUG,
							15	36	63762	2 LAUNCHES
	60	10	35	24000		51546 (1)	16	35	24000	EXP. TUG,
							15	36	58816	2 LAUNCHES
	3	4	8	1200		3441	15	44	11911	
	4	5		1000		28449		44	36719	
	5	4	6	600		29439		42	37309	
55°	23	3.5	6.5	600		1376		42.5	8646	
	30	6.5	12	600		5552		48	13422	
	32	6.5	12	820		5622		42	13712	
	3	4	8	1200		3441		44	11911	
	4	5	8	1000		28449		44	36719	
	5	4	6	600		29439		42	37309	
99.15°	21	6	12	2500		1804		48	11574	
	26	6	12	2500		1804		48	11574	
	27	4	6	1000		50972		42	59242	
100.7°	25	5	10	1000		2520		46	10790	
	75	5	6	1000	GBT	2520		42	10790	

SHUTTLE PAYLOAD UTILIZATION

UTILIZATION OF SHUTTLE PAYLOAD CAPACITY THROUGHOUT THE 12 YEARS OF THE FLEMING MODEL USING THE BASELINE (1:1) CONCEPT AND THE PROPELLANT WEIGHTS FROM THE PREVIOUS CHART ARE SHOWN TO BE ABOUT 65%. THEREFORE, ON AVERAGE, ABOUT 35% OF THE SHUTTLE CAPABILITY MAY BE EXPLOITED FOR PROPELLANT UTILIZATION.

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SHUTTLE PAYLOAD UTILIZATION PROGRAM LEVEL C

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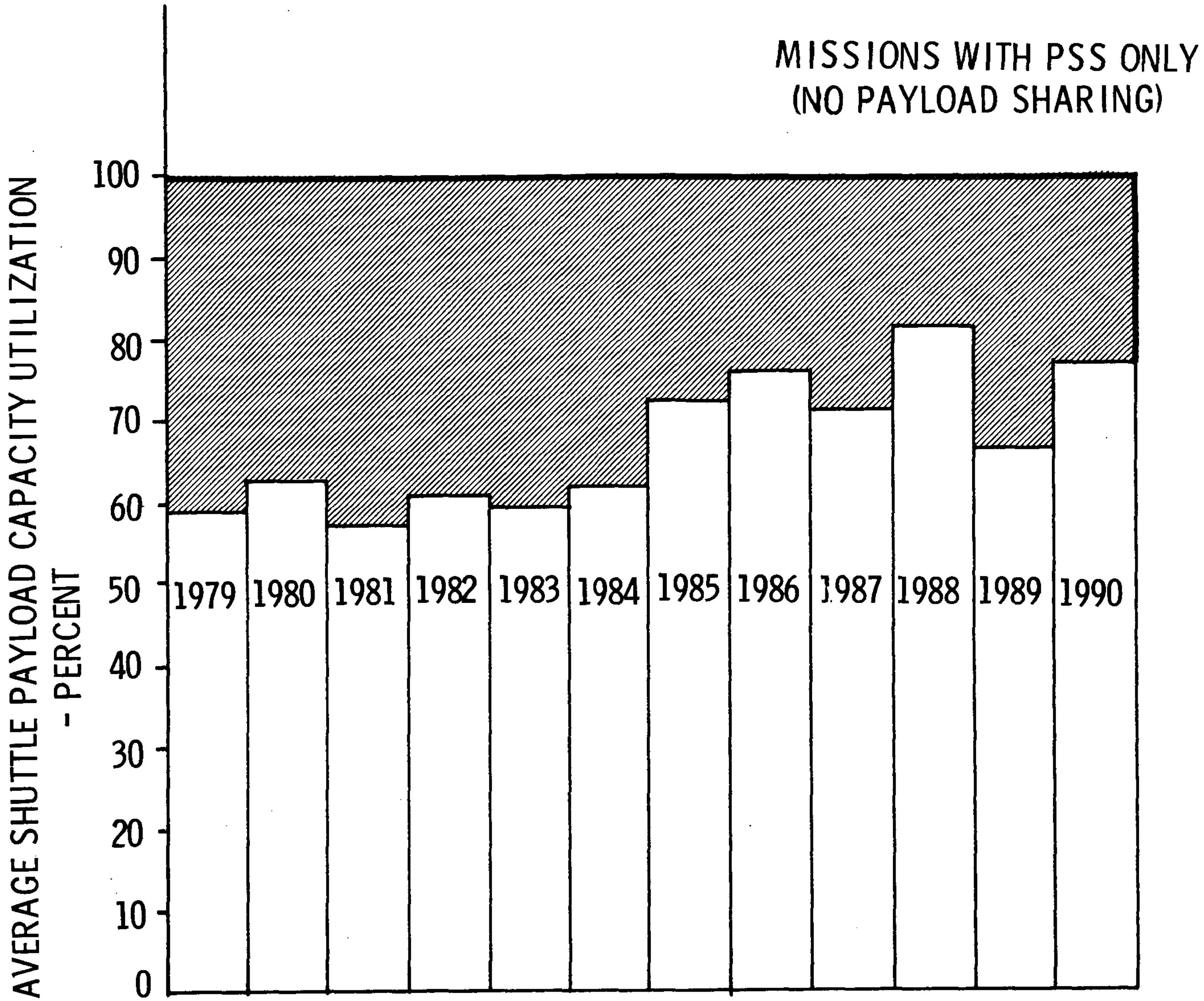
CHART NO. 39 DATE 10-6-71



PLACEMENT DISTRIBUTION FOR PAYLOAD GROUPING ANALYSIS

THE SPATIAL DISTRIBUTION OF FLEMING PROGRAM LEVEL PAYLOADS WAS DETERMINED AS A FUNCTION OF ORBITAL INCLINATION AND ALTITUDE. THE RESULTS ARE SUMMARIZED HERE FOR MISSIONS REQUIRING PAYLOAD PROPULSIVE STAGES. A MAJORITY OF 207 OUT OF THE 320 FLIGHTS PASS THROUGH A KEY AT 28.5° X 100 NM; AND 131 OF THESE TERMINATE IN THE IDENTICAL SYNCHRONOUS, EQUATORIAL ORBIT. THIS COMMON LOCATION, THE 35 PERCENT UNUSED CAPABILITY OF THE SHUTTLE, AND THE RELATIVELY SMALL SIZE AND WEIGHTS OF MANY OF THE FLEMING PAYLOADS WITH RESPECT TO THE SHUTTLE CARGO BAY PERMITTED A GROUPING OR CLUSTERING OF MULTIPLE PAYLOADS ON A SINGLE SHUTTLE FLIGHT ALONG WITH A COMMON PPS. THE UTILIZATION OF THIS CONCEPT--CALLED CLUSTERING OR PAYLOAD-PROPELLANT SHARING--LED TO THE ANALYSIS OF THE FIRST ALTERNATE TO THE BASELINE (1:1) CONCEPT.

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PLACEMENT DISTRIBUTION FOR PAYLOAD GROUPING ANALYSIS

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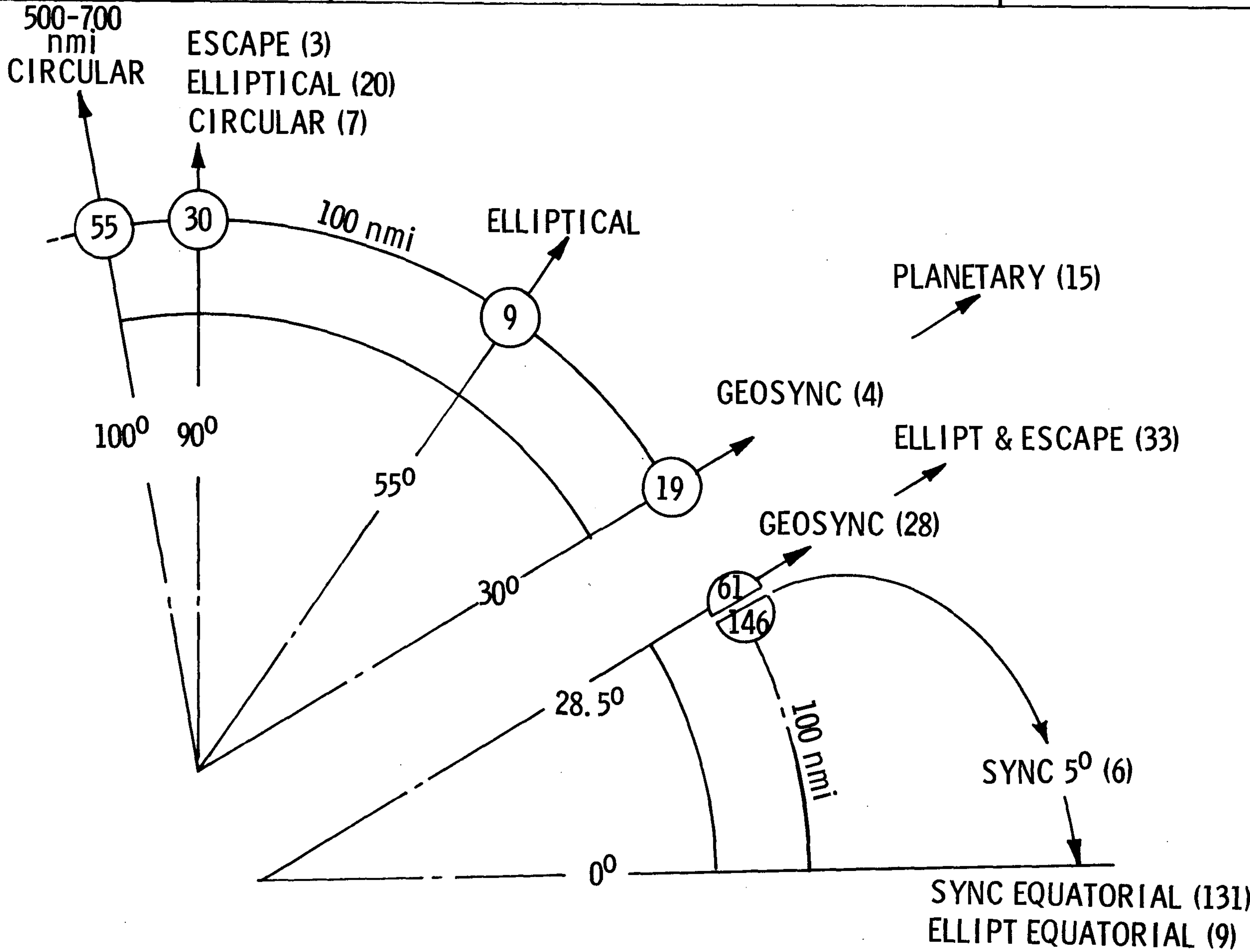
CHART NO. 40 DATE 10-6-71



PAYLOAD-PROPELLANT SHARING DESIGN IMPLICATIONS

EFFICIENT UTILIZATION OF THE SHUTTLE FOR CLUSTERING OF PAYLOADS REQUIRES REPACKAGING OF ABOUT 30 PERCENT OF THE DEFINED PAYLOADS. FOR EACH SUCH REPACKAGING, A 25 PERCENT VOLUMETRIC PENALTY WAS ABSORBED. THIS REPACKAGING WOULD NOT HAVE BEEN REQUIRED HAD THE PAYLOADS INITIALLY BEEN SIZED FOR THE DELIVERY IN THE SHUTTLE CARGO BAY. OPTIMIZED SHAPES HAVE BEEN DEFINED WHICH WILL MAXIMIZE THE SHUTTLE'S VOLUMETRIC CAPACITY. OTHERS MAY ALSO EXIST. THESE REPRESENT ONE ASPECT OF A MUCH LARGER CONSIDERATION WITH MULTIPLE PAYLOADS--TOTAL PAYLOAD INTEGRATION OF EACH SHUTTLE FLIGHT--FROM MISSION PLANNING THROUGH PAYLOAD DESIGN, AND ORBITAL CHECKOUT AND RELEASE FROM THE PPS.

PAYLOAD-PROPELLANT SHARING DESIGN IMPLICATIONS

OPTIMIZE SHAPE

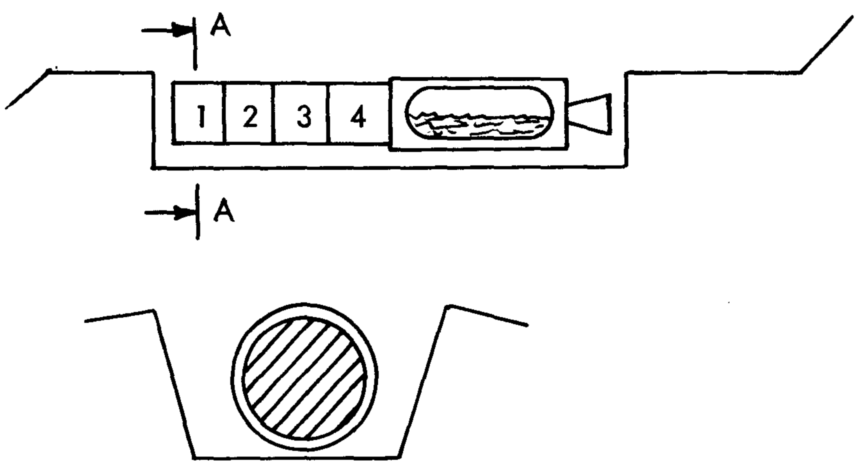
DISK

CYLINDER

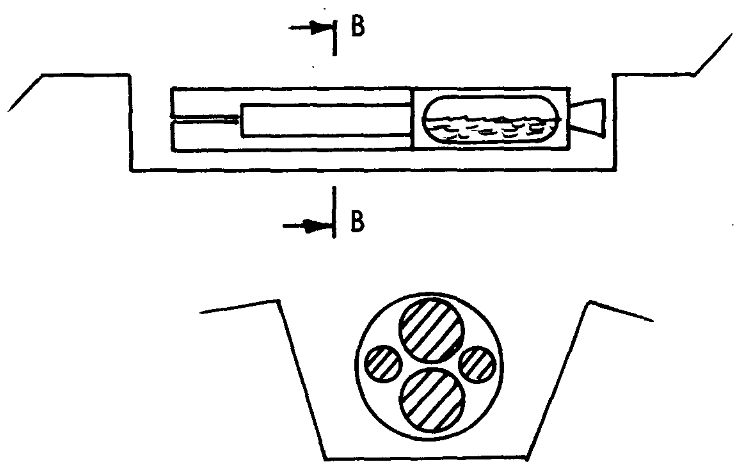
OPTIMIZE SIZE

DISK - CARGO BAY DIAMETER

CYLINDER D $\leq$ 1/2 CARGO BAY DIAMETER



A-A



B-B

PAYLOAD-PROPELLANT SHARING ANALYSIS

A DETAILED ANALYSIS WAS PERFORMED FOR ALL THE MISSIONS IN THE FLEMING MODEL TO EVALUATE THE PAYLOAD-PROPELLANT SHARING CONCEPT. THE PAYLOAD SELECTION CRITERIA FOR CLUSTERING WERE PRESENTED EARLIER ON THE "PROCEDURE FOR ANALYSIS" CHART. FOR EACH YEAR THE PAYLOADS WERE GROUPED BY ORBIT INCLINATION AND SELECTED PAYLOADS WERE "FLOWN" ON A PAPER SIMULATION OF THE MISSION. THE FIVE PAYLOADS LISTED ARE AN EXAMPLE CHOSEN FROM THE 1981 POLAR MISSIONS. THE PROPELLANTS REQUIRED FOR EACH OF THE PAYLOAD PLACEMENTS ARE ALREADY KNOWN FROM THE BASELINE CONCEPT CALCULATIONS. THE PROBLEM IS TO DETERMINE HOW MANY OF THE PAYLOADS CAN BE CARRIED ON A SINGLE SHUTTLE FLIGHT ALONG WITH THE GROUND-BASED PPS AND CAN THE PPS AVAILABLE IN THAT YEAR CARRY THE PROPELLANT NECESSARY FOR THE COMBINED MISSION.

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PAYLOAD-PROPELLANT SHARING ANALYSIS

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FIRST PERFORMANCE REVIEW
CHART NO. 42 DATE 10-6-71

- WITHOUT SHARING

MISSION	PAYLOAD	D	L	INCL	ALT	PROPELLANT*	SHUTTLE FLTS
21	POLAR EARTH OBS	6	12	99.15	500	1462	1
23	EARTH PHYSICS	3.5	6.5	90	400	941	1
25	TROS	5	10	100.7	700	1937	1
30	SMALL APPLICATIONS	6.5	12	90	300×3000	4375	1
75	NS METEOROLOGICAL	5	6	100.7	700	1987	1
						10752 LBS	5

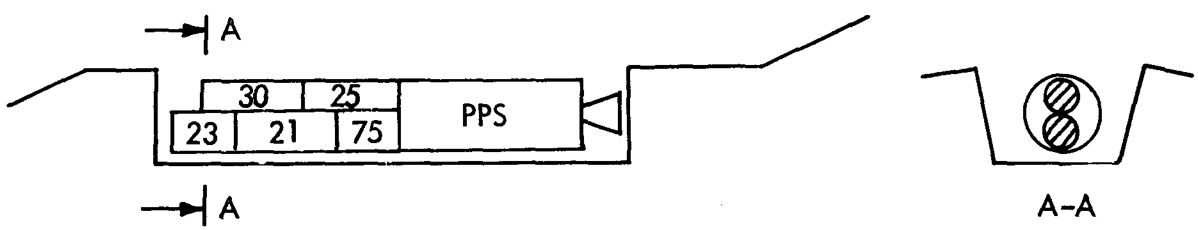
- WITH SHARING

		D	L	INCL	ALT	PROPELLANT*	SHUTTLE FLTS
	23 + 30 + 21 + 25 + 75	12.5	18.5	90-100.7	300-3000	26318 LBS	1

- CHANGE

PROPELLANT	SHUTTLE FLTS
+146%	-80%

- CARGO BAY CONFIGURATION



* BASED ON INTERIM TRANSFER STAGE & + 10%ΔV PAD

PAYLOAD CLUSTERING - PROPELLANT SHARING MISSION PLANNING (C-8-81)

GROUND-BASED CONCEPT

TO DETERMINE THE PROPELLANT REQUIREMENTS FOR THIS MISSION, ALL THE FLIGHT MANEUVERS OF THE PPS MUST BE DEFINED, THE CHARACTERISTIC VELOCITIES DETERMINED FOR EACH MANEUVER, THE POINT FOR PAYLOAD RELEASE ESTABLISHED, AND THE PROPELLANT CALCULATED FOR EACH MANEUVER. THE TOTAL PROPELLANT IS THE SUM OF THE INDIVIDUAL MANEUVER PROPELLANTS. FOR THE MISSION PRESENTED, TWELVE SEPARATE BURNS ARE REQUIRED. (THE SIMPLIFIED APPROACH DID NOT PERMIT COMBINED PLANE CHANGES AND ALTITUDE CHANGES) AND THE TOTAL PROPELLANTS ARE GIVEN FOR THREE PPS CONFIGURATIONS. MAXIMUM SHUTTLE CAPABILITY OF 40,000 POUNDS TO POLAR ORBIT LIMITS THE AVAILABLE PROPELLANT AS SHOWN. FOR THIS MISSION THE SPACE-BASED PPS IS SHUTTLE LIMITED AND CANNOT BE USED.

THE RESULTS ARE SUMMARIZED ON THE PREVIOUS CHART COMPARING THE BASELINE (WITHOUT SHARING) CONCEPT WITH THE PAYLOAD-PROPELLANT SHARING CONCEPT. APPRECIABLE REDUCTION IN SHUTTLE FLIGHTS IS ACHIEVED AT SOME INCREASE IN PPS PROPELLANTS. MANY OTHER MISSION COMBINATIONS WERE EXAMINED AND THE PREDOMINANT CLUSTERING MISSION ACTUALLY RESULTS IN A DECREASE OF PROPELLANTS OVER THE BASELINE CONCEPT. THIS MISSION TRANSPORTS MULTIPLE PAYLOADS TO A COMMON ORBIT.

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PAYLOAD CLUSTERING - PROPELLANT SHARING MISSION PLANNING (C-8-81) GROUND BASED CONCEPT

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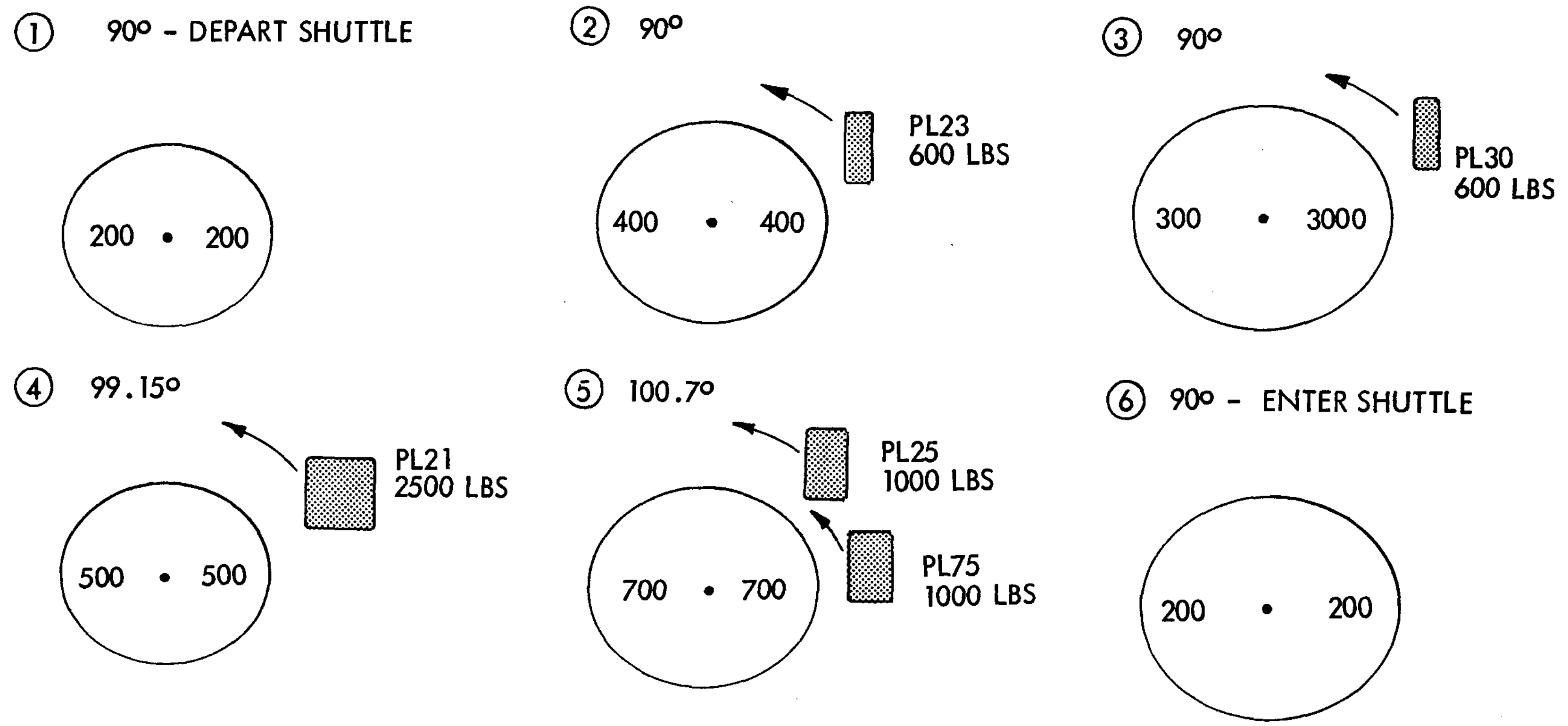
CHART NO. 43 DATE 10-6-71



VEHICLE	ΔV + (PAD)	W_{PL}	W_{BO}	W_G*	W_P	$W_{P\,MAX}$
ITS	18359 (1.1)	5700	5250	40000	26318	29050
GB TUG	18359 (1.1)	5700	7270	40000	25605	27030
SB TUG	17500 (1.05)	5700	10201	40000	25173**	24099**

* MAX SHUTTLE CAPABILITY TO 90° X 200 X 200
** MISSION PROPELLANT EXCEEDS CAPACITY

TRAFFIC MODEL

TRAFFIC MODELS WERE PREPARED FOR ALL FIVE PROGRAM LEVELS BASED ON THE PAYLOAD-PROPELLANT SHARING CONCEPT. A PORTION OF ONE TRAFFIC MODEL FROM ONE YEAR IN PROGRAM C, THE FLEMING PROGRAM, IS PRESENTED TO INDICATE THE CLUSTERING VARIATIONS. THIS PORTION WAS SELECTED TO INCLUDE THE MISSION PREVIOUSLY DESCRIBED, C-8-81.

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TRAFFIC MODEL PROGRAM LEVEL C 1981 (SAMPLE)

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FIRST PERFORMANCE REVIEW
CHART NO. 44 DATE 10-6-71

FLIGHT NO.	PAYLOAD DESCRIPTION	L	W_g	W_p	ORBIT i X ALT	NOTES
C-1-81	1 + 15	47.5	22020	0	28.5° X 270-350	
C-2-81	2	35	720		28.5° X 193000	
	ITS	32.8	40043	34798		
		36.3	40768			
C-3-81	3+4+5	22	2800		55° X 180-1AU	
	ITS	32.8	47500	42243		
		54.8	50300			
C-4-81	8	5	500		28.5° X 1 AU	
	ITS	32.8	29194	23944		
		37.8	29694			
C-5-81	9	15	6000		28.5° X 38646	1.05 ΔV
	ITS	32.8	49407	44157		
		47.8	55407			
C-6-81	14	13	3500	0	30° X 230	REVISIT
C-7-81	14	13	3500	0	30° X 230	REVISIT
C-8-81	21+23+25+30+75		5700		90-100.7° X 400-3000	
	ITS	37.9	31563	26318		
		51.3	37268			
C-9-81	27+28+76	26R + SS	9950		0° X 19300	ITS EXPENDED
	ITS	37.8	35050	29800		
		58.8	45000			

SS = SIDE BY SIDE
R = REPACKAGED

TRAFFIC MODEL SUMMARY
GROUND-BASED CONCEPT

THE SHARED CONCEPT TRAFFIC MODEL ANALYSIS RESULTS FOR THE 2,500 MISSIONS IN THE FIVE PROGRAM LEVELS IS PRESENTED AND COMPARED WITH SIMILAR RESULTS FROM THE BASELINE CONCEPT ANALYSIS. A SIGNIFICANT REDUCTION IN BOTH SHUTTLE FLIGHTS AND TOTAL SPACE PROPELLANT REQUIRED IS OBTAINED. THE NUMBER OF EXPENDED VEHICLES DOES NOT VARY SIGNIFICANTLY BETWEEN THE TWO CONCEPTS. THESE TRAFFIC MODEL OUTPUTS WILL SERVE AS THE PRIMARY INPUTS TO THE COSTING DETERMINATION AND THE FINAL MEASURE OF COST EFFECTIVENESS.

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TRAFFIC MODEL SUMMARY
GROUND-BASED CONCEPT

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FIRST PERFORMANCE REVIEW
CHART NO. 45 DATE 10-6-71

PROGRAM LEVEL

	A	B	C	D	E
MISSIONS	268	474	608	628	628
BASELINE SHUTTLE FLIGHTS	266	471	611	770/860*	809/920*
BASELINE - PPS FLIGHTS	180	237	327	484/574	523/634
SHARED - PPS FLIGHTS	102	123	186	381/471	420/531
SHARED SHUTTLE FLIGHT REDUCTION	78	114	141	103/103	103/103
BASELINE PROPELLANT WEIGHT K LBS)	3198	7605	10077	15464/22364	16279/25110
SHARED PROPELLANT WEIGHT (K LBS)	2298	4257	6860	13064/19964	13879/22710
SHARED PROPELLANT WEIGHT REDUCTION (K LBS)	900	3448	3217	2400/2400	2400/2400
BASELINE PPS EXPENDED	21	9	19	18	22
SHARED PPS EXPENDED	21	7	22	18	22

* RNS/CIS

PAYLOAD CLUSTERING PROPELLANT SHARING RESULTS

THE YEAR-TO-YEAR REDUCTION IN SHUTTLE FLIGHTS AND SPACE PROPELLANT IS GIVEN FOR PROGRAM LEVEL C FOR THE BASELINE (WITHOUT) AND THE (WITH) PAYLOAD-PROPELLANT SHARING. AN AVERAGE OF 270,000 POUNDS OF PROPELLANT AND TWELVE SHUTTLE FLIGHTS ARE ELIMINATED EACH YEAR AT NO SACRIFICE OF SCIENTIFIC OBJECTIVES.

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PAYLOAD CLUSTERING - PROPELLANT SHARING
COMPARATIVE RESULTS
GROUND BASED CONCEPT
PROGRAM LEVEL C

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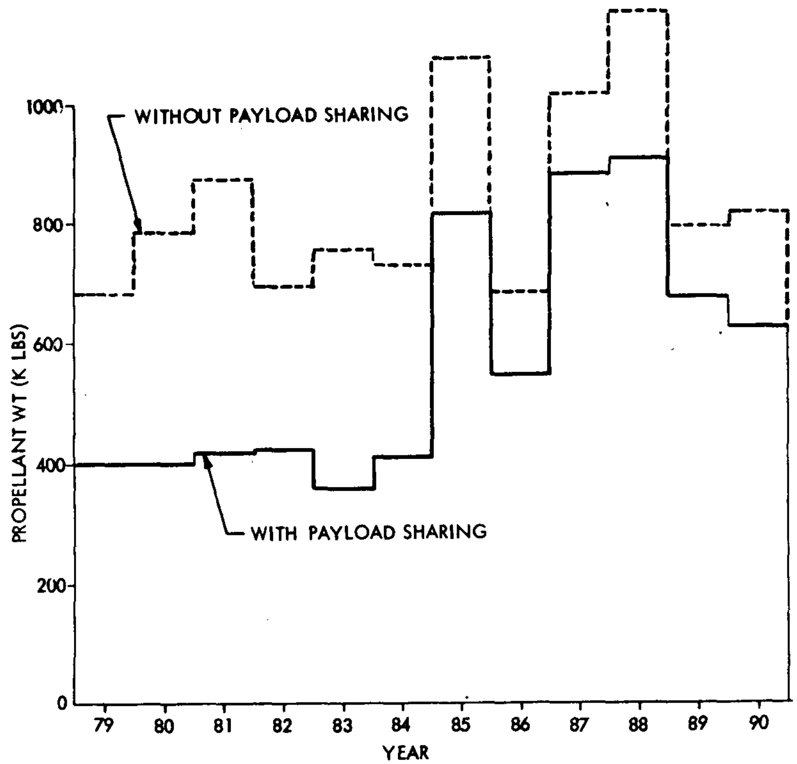
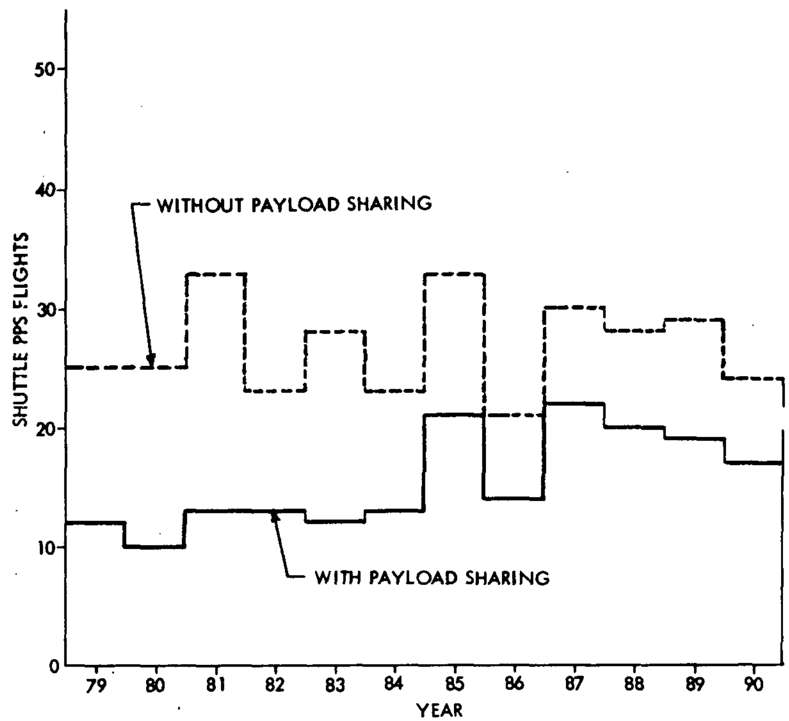
CHART NO. 46 DATE 10-6-71





SCOPE OF ANALYSIS

THIS TRANSITION CHART INTRODUCES THE THIRD BASIC LOGISTICS CONCEPT, SPACE-BASING. IN THIS MODE OF OPERATION, THE PPS REMAINS IN ORBIT BETWEEN MISSIONS AND IS ONLY OCCASIONALLY RETURNED TO EARTH FOR MAJOR OVERHAUL. THE PRINCIPAL ADVANTAGES OF THIS CONCEPT ARE THE POTENTIAL PAYLOAD GAIN RESULTING FROM THE ELIMINATION OF THE PPS AS A FIXED ELEMENT OF THE SHUTTLE PAYLOAD AND THE CAPACITY TO UTILIZE THE AVAILABLE OMS PROPELLANT. SPACE-BASING THE PPS WILL, HOWEVER, REQUIRE IMPROVED INSULATION TO REDUCE HYDROGEN BOILOFF, DOCKING MECHANISMS TO MATE WITH PAYLOADS, SOME FORM OF ON-ORBIT MAINTENANCE BETWEEN MISSIONS, AND ADDITIONAL PROPELLANTS TO COMPENSATE FOR TRANSFER LOSSES, TO PREVENT ORBIT DECAY AND FOR RENDEZVOUS AND DOCKING WITH SHUTTLE PAYLOADS. TWO MODES OF SPACE-BASING ARE DISCUSSED LATER IN THE BRIEFING, ORBITAL STORAGE OF PROPELLANTS BETWEEN MISSIONS AND NO STORAGE.

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SCOPE OF ANALYSIS FOR IN-SPACE PROPELLANT LOGISTICS AND SAFETY

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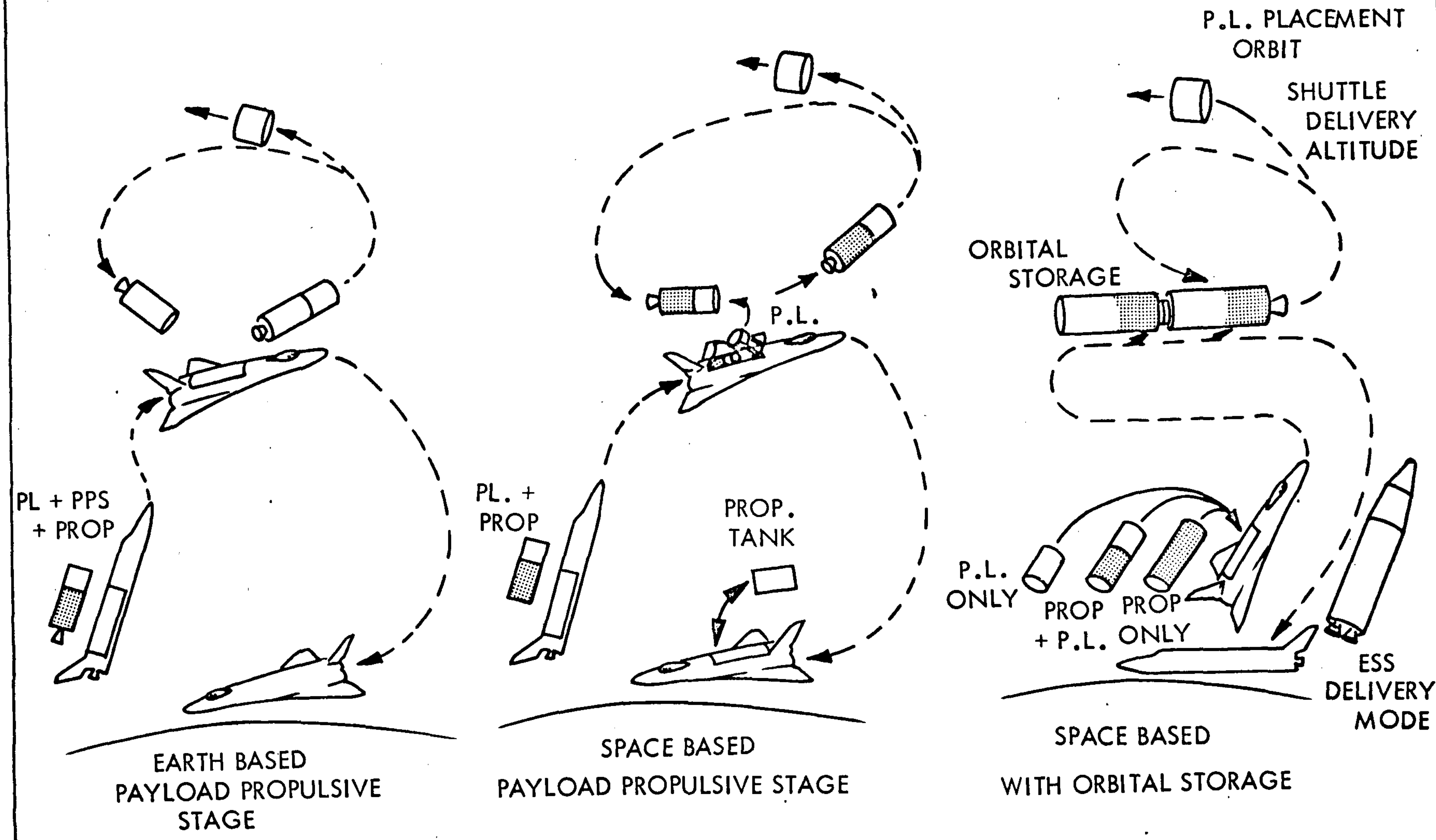
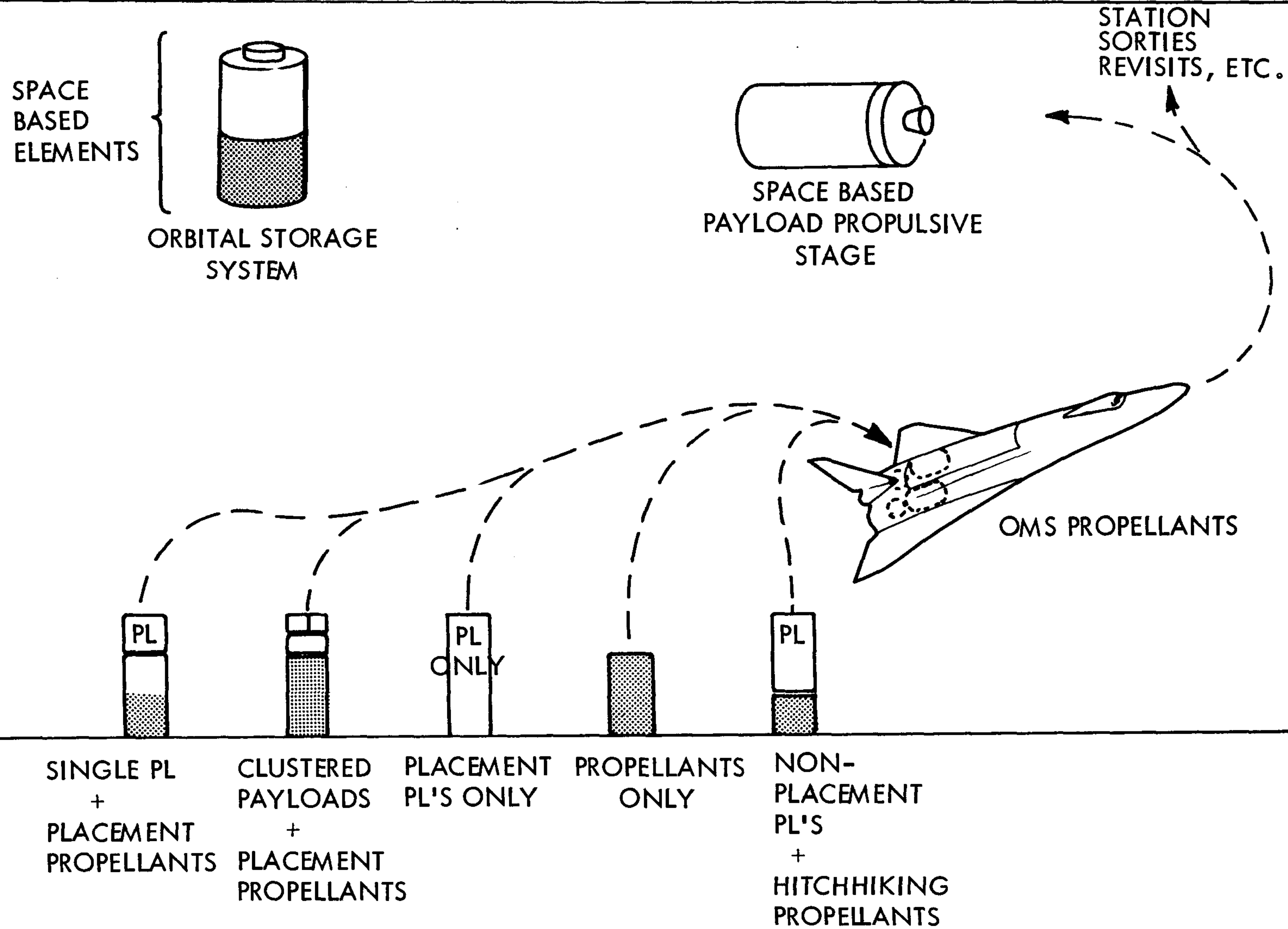
CHART NO. 47 DATE 10-6-71



OPERATIONAL PROPELLANT LOGISTICS CONCEPTS

THE SPACE-BASED CONCEPT IS CAPABLE OF TRANSPORTING THE SAME TYPES OF LOGISTICS PAYLOADS AS THE GROUND-BASED CONCEPT WITH ONE NOTABLE EXCEPTION. WITH SPACE-BASING, THE REGULAR NEED FOR PROPELLANT TO BE SUPPLIED TO THE ORBITING PPS NECESSITATES A NEW PAYLOAD CONSISTING OF PROPELLANT AND ITS TANK ESPECIALLY DESIGNED TO FULLY UTILIZE THE CARGO BAY. THIS TANK CAN ALSO BE USED TO RESUPPLY A STORAGE SYSTEM AND CAN POSSIBLY BE THE STORAGE SYSTEM, ITSELF, IF CERTAIN INSULATION PROBLEMS CAN BE SOLVED.

OPERATIONAL PROPELLANT LOGISTICS CONCEPTS



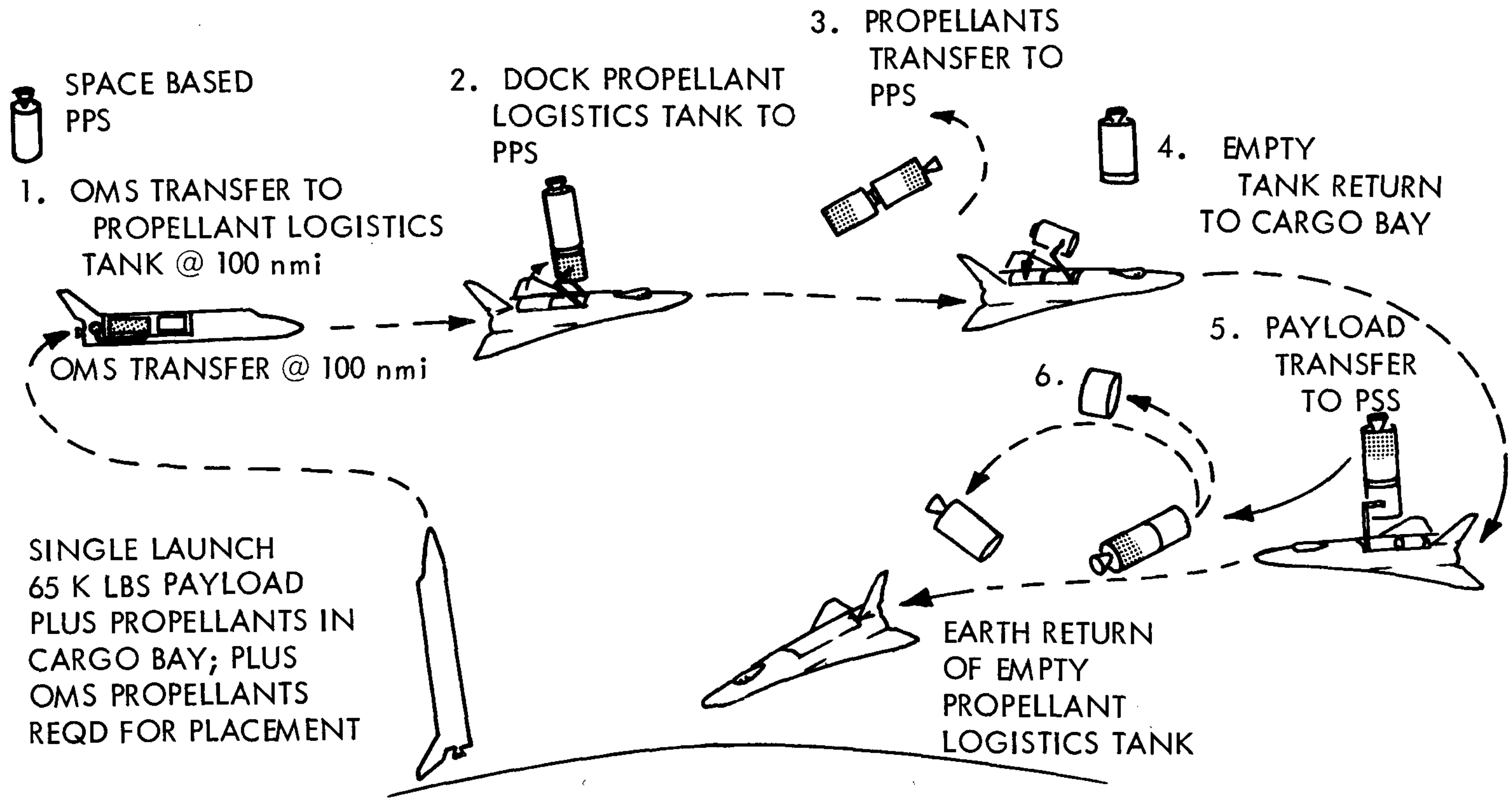
SHUTTLE CARGO BAY* COMPOSITION OPTIONS

* ALTERNATE EARTH TO ORBIT LOGISTICS, ie. ESS OR INT-21 REQUIRE SEPARATE ANALYSIS

SPACE-BASED PROPELLANT LOGISTICS WITH NO ORBITAL STORAGE

THE OPERATIONAL APPROACH TOWARDS SPACE-BASING WITHOUT ORBITAL PROPELLANT STORAGE IS PRESENTED TO ILLUSTRATE A TYPICAL MISSION SCENARIO. HOMOGENEOUS OR MIXED PAYLOADS ARE POSSIBLE AND RENDEZVOUS AND DOCKING ARE REQUIRED. PROPELLANT TRANSFER TO THE PPS REQUIRES ROTATION OR TRANSLATION OF THE TANK-PPS SYSTEM TO SETTLE THE PROPELLANTS PRIOR TO AND DURING PUMPING. FOLLOWING TRANSFER, THE PAYLOAD CAN THEN BE DOCKED TO THE PPS AND THE EMPTY TANK IS RETURNED TO THE CARGO BAY FOR TRANSPORT TO EARTH.

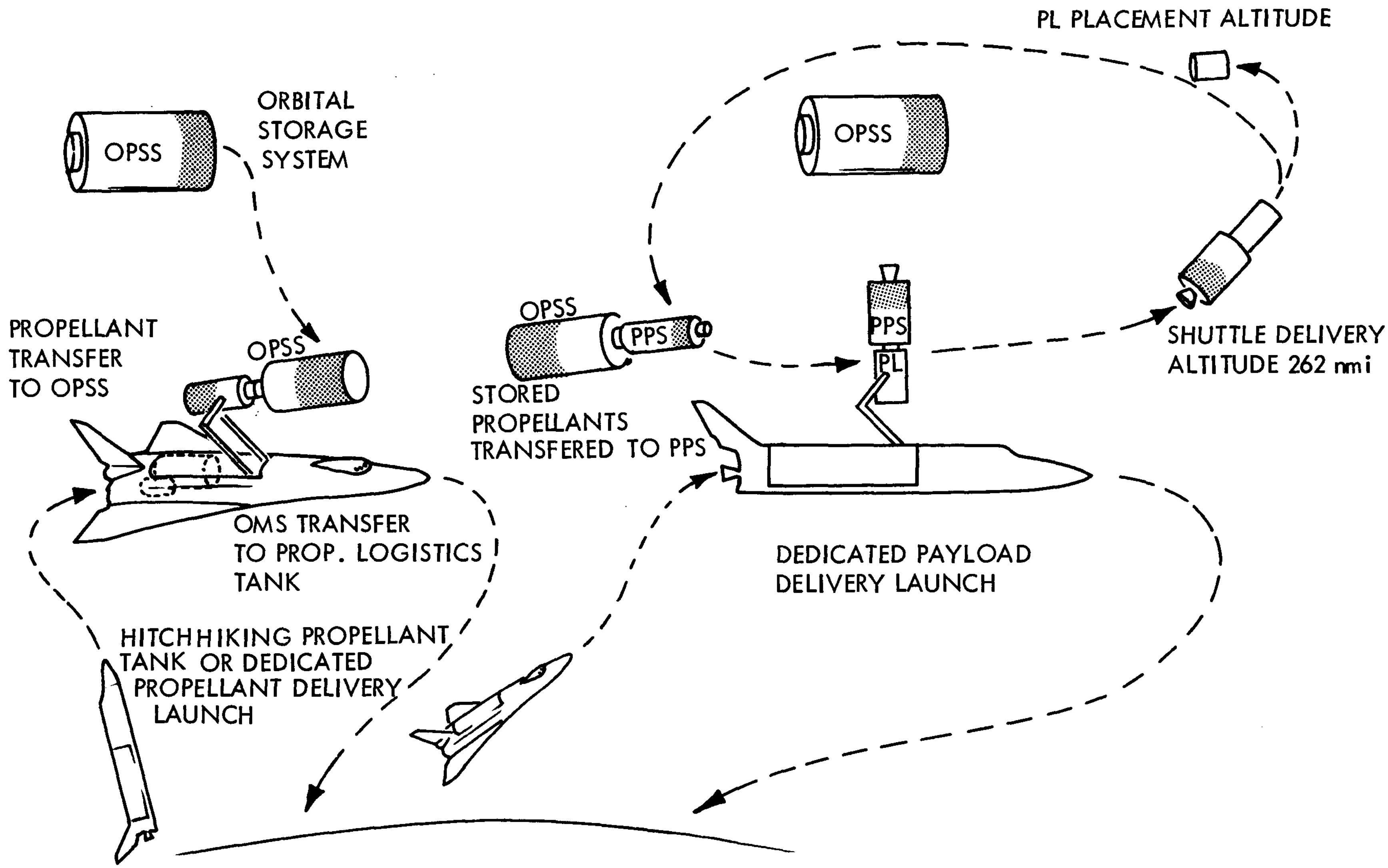
SPACE BASED PROPELLANT LOGISTICS WITH NO ORBITAL STORAGE



PROPELLANT LOGISTICS WITH ORBITAL STORAGE

THE SPACE-BASING WITH ORBITAL STORAGE CONCEPT IS PRESENTED WITH TWO SEPARATE SHUTTLE MISSIONS: REFUELING THE ORBITAL PROPELLANT STORAGE SYSTEM (OPSS), AND A SATELLITE PLACEMENT SCENARIO. THE REFUELING IS SIMILAR TO REFUELING AN ORBITING PPS. OMS PROPELLANT IS ALSO UTILIZED. THE PLACEMENT SEQUENCE REQUIRES THE ORBITING PPS TO DOCK WITH OPSS FOR PROPELLANT LOADING THEN DOCK WITH THE MISSION PAYLOAD FIXED TO THE EXTENDED ORBITER MANIPULATORS (FOLLOWING ITS OUTGASSING, THERMAL EQUILIBRIUM, SUBSYSTEMS ACTIVATION, AND CHECKOUT). PPS THEN DELIVERS THE SCIENCE PAYLOADS(S) TO THE DESIRED ORBIT(S) AND RETURNS TO AN OPTIMUM STORAGE ORBIT AND INITIATES A QUIESCENT MODE TO AWAIT THE NEXT SHUTTLE MISSION. THIS DECOUPLING OF PAYLOADS AND PROPELLANTS IS NECESSARY FOR SOME OF THE PLANETARY MISSIONS WHICH UTILIZE LARGE PAYLOADS AND HIGH PROPELLANT CONSUMPTION.

PROPELLANT LOGISTICS WITH ORBITAL STORAGE



ALTERNATE PROPELLANT DELIVERY MODE WITH ORBITAL STORAGE

AN ALTERNATE SCHEME OF DELIVERING PROPELLANT TO THE OPSS IS ILLUSTRATED WHICH UTILIZES THE PPS AS A THIRD STAGE BETWEEN THE SHUTTLE WHICH REMAINS AT 100 NM ALTITUDE (TO MAXIMIZE ITS PAYLOAD CAPABILITY) AND THE OPSS WHICH IS ORBITING AT SOME HIGHER ALTITUDE TO MINIMIZE ORBIT DELAY. A TRADEOFF IS REQUIRED BETWEEN SHUTTLE PROPELLANTS AND OPSS ORBIT MAINTENANCE PROPELLANTS TO ESTABLISH THE OPTIMUM TRANSFER AND STORAGE ORBIT. IN THIS SCENARIO THE PPS DELIVERS THE NEW FULL TANK PLUS ANY OMS TO THE OPSS AND THE OLD EMPTY TO THE ORBITER.

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ALTERNATE PROPELLANT DELIVERY MODE WITH ORBITAL STORAGE SPACE BASED

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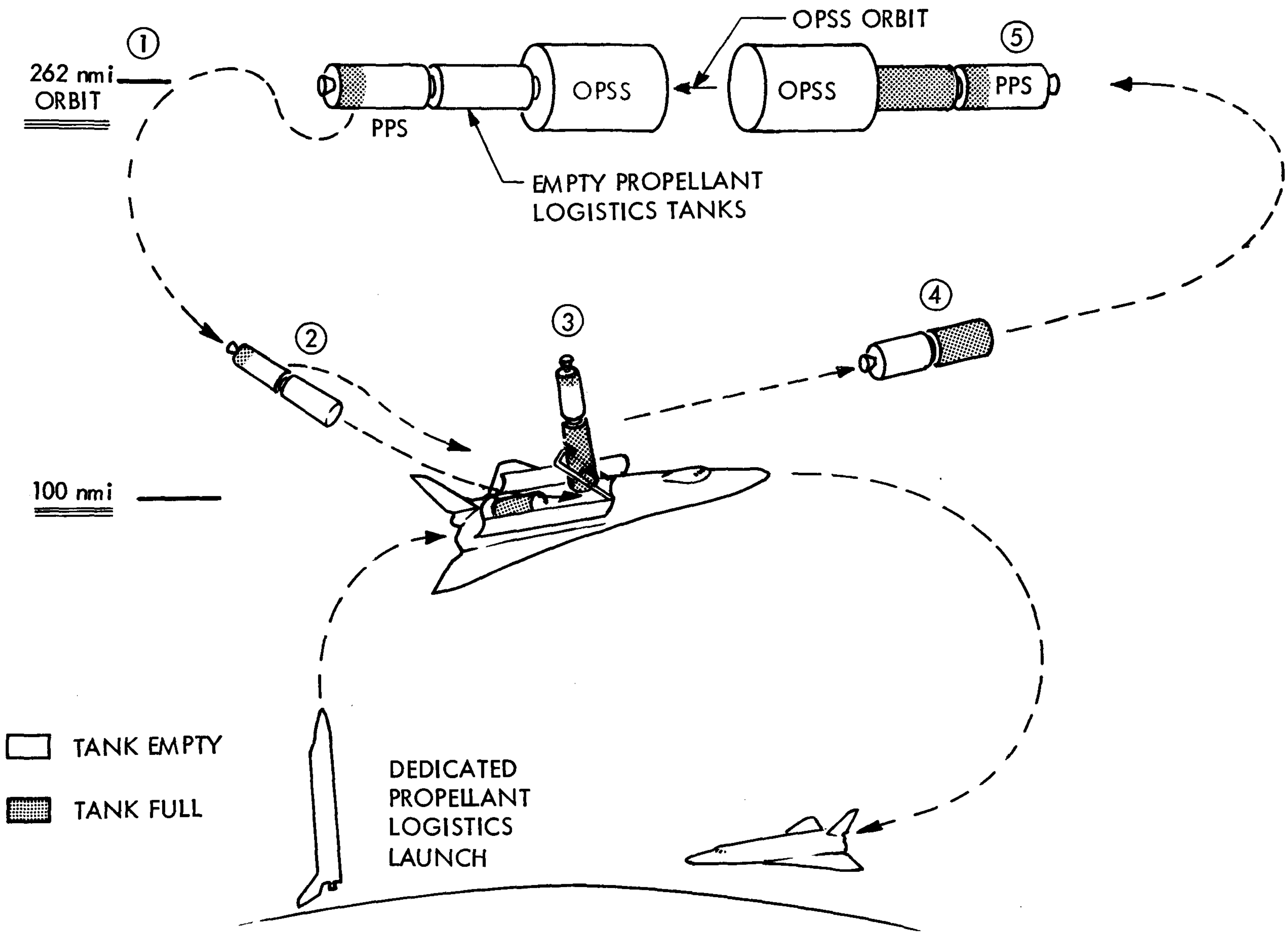
FIRST PERFORMANCE REVIEW
CHART NO. 51 DATE 10-6-71



1:1 BASELINE REFERENCE ANALYSIS, SPACE BASED PPS

PPS MISSION PROPELLANTS HAVE BEEN DETERMINED FOR THE SPACE-BASED CONCEPT SIMILAR TO THOSE FOR THE GROUND-BASING. THE RESULTS ARE AGAIN SUMMARIZED ON THIS AND THE NEXT CHART. IN ADDITION, THE PROPELLANT TANK DESIGNATION (T-3, ETC.), LENGTH, WEIGHT, AND PROPELLANT LOADING BY MISSION IS LISTED. BECAUSE OF THE PARTICULAR PPS SELECTED, PERFORMANCE IS SOMEWHAT REDUCED OVER THE GROUND-BASED PPS AND INCREASED PROPELLANTS ARE REQUIRED. THIS HAS NECESSITATED INCREASED DEPENDENCE ON OMS AVAILABILITY FOR THE HIGHER ENERGY MISSIONS.

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1:1 BASELINE REFERENCE ANALYSIS
SPACE BASED PPS

PROGRAM LEVEL "C" 1985-1990

15' DIAM X 47' LONG, 10,200 LBS

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CONTRACT NAS8-27692
FIRST PERFORMANCE REVIEW
CHART NO. 52 DATE 10-6-7

	PAYLOAD NO.	PAYLOAD DIAM	PAYLOAD LENGTH	PAYLOAD WEIGHT	PROPELLANT WT. (S.B. TUG)	Note	PROPELLANT TANK LENGTH	PROPELLANT TANK WEIGHT	PROPELLANT TANK PROPELLANT	SHUTTLE PAYLOAD LENGTH	SHUTTLE PAYLOAD WEIGHT	SHUTTLE PAYLOAD OMS PROP	
0° SYNC	22	4	6	1000	65834	1	T-2 42	6000	58000	48	65000	7834	
0° SYNC	24	5	8	1000	65834	1	T-2 42	6000	58000	50	65000	7834	
0° SYNC	27	4	6	1000	65834	1	T-2 42	6000	58000	48	65000	7834	
0° SYNC	28	15	20	7950	33220		T-3 38	5100	33220	58	46270	0	EXP TUG
0° SYNC	29	6.5	12	600	72606		T-2 42	6000	58400	54	65000	14202	
0° SYNC	31	6.5	12	820	73009		T-2 42	6000	58180	54	65000	14829	
0° SYNC	33	12	15	2000	67533	1	T-2 42	6000	57000	57	65000	10533	
0° SYNC	34	10	19	2145	67780	1	T-3 32	5100	57755	51	65000	10025	
0° SYNC	35	12	15	2000	67533	1	T-2 42	6000	57000	57	65000	10533	
0° SYNC	36	12	15	2300	68043	1	T-2 42	6000	56700	57	65000	11343	
0° SYNC	37	10	20	1000	65834	1	T-3 38	5100	58900	58	65000	6934	
0° SYNC	70	6.5	12	1420	66548	1	T-2 42	6000	57580	54	65000	8968	
0° SYNC	71	10	19	2145	67780	1	T-3 32	5100	57755	51	65000	10025	
0° SYNC	76	5	8	1000	65834	1	T-2 42	6000	58000	50	65000	7834	
0° SYNC	78	6	6	1000	65834	1	T-2 42	6000	58000	48	65000	7834	
5°	74	5	8	700	64670		T-2 42	6000	58300	50	65000	6370	
28.5°	2	4.5	3.3	720	60424		T-2 42	6000	58280	45.3	65000	2144	
28.5°	72	4	12	1000	60875		T-2 42	6000	58000	54	65000	2875	
28.5°	3	4	8	1200	4817					8	1200	4817	
28.5°	4	5	8	1000	40624		T-3 38	5100	40624	46	46724	0	
28.5°	9	12	15	6000	69390	1	T-2 42	6000	53000	57	65000	16390	
28.5°	5	4	6	600	42263		T-3 38	5100	42263	44	47963	0	
28.5°	8	4	5	500	42138		T-3 38	5100	42138	43	47738	0	
28.5°	11	10	12	1900	43890		T-3 38	5100	43890	50	50890	0	
29°	73	5	8	700	70955		T-2 42	6000	58300	50	65000	12655	

1 ΔV PAD REDUCES FROM 10% TO 5%

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1:1 BASELINE REFERENCE ANALYSIS
SPACE BASED PPS
PROGRAM LEVEL "C" 1985-1990

15' DIAM X 47' LONG, 10,200 LBS

ISPLS
CONTRACT NAS8-27692
FIRST PERFORMANCE REVIEW
CHART NO.53 DATE 10-6-71

	PAYLOAD NO.	PAYLOAD DIAM	PAYLOAD LENGTH	PAYLOAD WEIGHT	PROPELLANT WT. (S.B. TUG)	PROPELLANT TANK LENGTH	PROPELLANT TANK WEIGHT	PROPELLANT TANK PROPELLANT	SHUTTLE PAYLOAD LENGTH	SHUTTLE PAYLOAD WEIGHT	SHUTTLE PAYLOAD OMS PROP	
30° PLANETARY	10	10	12	1900	61488	T-3 38	5100	58000	50	65000	3448	
	12	7	10	3500	64997	T-3 38	5100	56400	48	65000	7597	
	51	14	22.5	22000	68108	T-3 38	5100	68108	22.5	22000	0	
									38	65000	9208	EXP TUG
	52	5	12	1000	65177	T-3 38	5100	58900	50	65000	6277	
	53	10	12	7900	69555 (1)	T-3 38	5100	52000	50	65000	17555	
	54	10	15	7300	68613 (1)	T-3 38	5100	52600	53	65000	16013	
	55	10	15	900	48157	T-3 38	5100	48157	53	54157	0	EXP TUG
	57	10	12	3300	58569	T-3 38	5100	56600	50	65000	1969	EXP TUG
	58	10	15	3700	67774	T-3 38	5100	56200	53	65000	11574	EXP TUG
	59	10	35	27000	62785	T-3 38	5100					EXP TUG
	60	10	35	24000	57722	T-3 38	5100					EXP TUG
55°	3	4	8	1200	4817				8	1200	4817	
	4	5	8	1000	40624	T-3 38	5100	40624	46	46724	0	
	5	4	6	600	42263	T-3 38	5100	42263	44	47963	0	
90°	23	3.5	6.5	600	1704				6.5	600	1704	
	30	6.5	12	600	7865				12	600	7865	
	32	6.5	12	820	7936				12	820	7936	
	3	4	8	1200	4817				8	1200	4817	
	4	5	8	1000	40624	T-3 38	5100	40624	46	46724	0	
	5	4	6	600	42263	T-3 38	5100	42263	44	47963	0	
99.15	21	6	12	2500	2470				12	2500	2470	
	26	6	12	2500	2470				12	2500	2470	
	77	12	15	2500	2470				15	2500	2470	
100.7	25	5	10	1000	3535				10	1000	3535	
	75	5	6	1000	3535				6	1000	3535	

EXCESS PROPELLANT AVAILABLE

ON SHUTTLE MISSIONS

THIS CHART INDICATES THE MAGNITUDE OF EXCESS PROPELLANT WHICH MAY BE CARRIED ON ROUTINE SHUTTLE MISSIONS FOR SPACE BASED PROPELLANT USE PROVIDED A MEANS IS PROVIDED FOR ACCUMULATING, STORING AND TRANSFERING PROPELLANT IN SPACE. AMONG 0-30° MISSIONS IN PROGRAM LEVEL C (WITHOUT CLUSTERING OF PAYLOADS) THERE ARE 233 MISSIONS IDENTIFIED IN WHICH EXCESS OMS PROPELLANT CAN BE CARRIED TO SPACE IN THE SHUTTLE BEYOND THAT REQUIRED FOR USE OF A SPACE BASED TUG TO MAKE THE PAYLOAD PLACEMENT MISSIONS. THE AVERAGE EXCESS PROPELLANT ON EACH SHUTTLE FLIGHT IS 18100 LBS AND A TOTAL OF 4,220,000 LBS OVER THE 12 YEAR PROGRAM. THIS IS ABOUT 30% OF THE TOTAL PROPELLANT REQUIREMENT FOR MAKING ALL PROGRAM LEVEL C PAYLOAD PLACEMENT MISSIONS WITH A SPACE BASED TUG.

THE LOWER HALF OF THE CHART SHOWS THE EXCESS PROPELLANT WHICH COULD BE CARRIED IN A CARGO BAY TANK BY PAYLOAD SHARING ON DIRECT SHUTTLE PAYLOAD PLACEMENT MISSIONS WHICH DO NOT INVOLVE THE USE OF A "PROPELLANT PROPULSIVE STAGE". HERE THERE ARE 17 MISSIONS IN WHICH A 20' LONG PROPELLANT TANK AND 78 MISSIONS IN WHICH A 38' LONG PROPELLANT TANK COULD BE PLACED IN THE SHUTTLE BAY WITH THE PAYLOAD. THE TOTAL PROPELLANT WHICH COULD BE DELIVERED TO SPACE IN THIS WAY AND MADE AVAILABLE FOR OTHER SPACE BASED MISSION IS 4,869,000 LBS OR ABOUT 38% OF TOTAL PROGRAM REQUIREMENTS. EXCESS OMS MAY ALSO BE AVAILABLE HERE BUT IS NOT SHOWN BECAUSE OMS WOULD BE USED BY THE SHUTTLE IN THESE MISSIONS.

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EXCESS PROPELLANT AVAILABLE ON SHUTTLE MISSIONS

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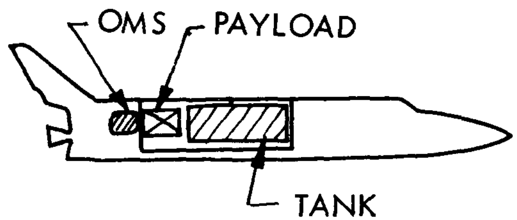
FIRST PERFORMANCE REVIEW
CHART NO. 54 DATE 10-6-71

PROGRAM LEVEL C
0-30° MISSIONS 1979 - 1990



- EXCESS OMS PROPELLANT AVAILABLE ON 233 PAYLOAD PROPULSIVE STAGE MISSIONS* ———— 4,220,000#

AVERAGE PAYLOAD:	LENGTH	12.2'
	WEIGHT	1980#
AVERAGE EXCESS OMS:		18100#

- NET PROPELLANT AVAILABLE FROM PAYLOAD SHARING ON 95 SHUTTLE DIRECT MISSIONS (NO PPS) ———— 4,869,000#

P.L. BAY TANK	NO. OF MISSIONS	AVERAGE PAYLOAD LENGTH	AVERAGE PAYLOAD WT (K/#)	PROPELLANT (K/#) AVERAGE	PROPELLANT (K/#) TOTAL
20'	17	8.6	36.3'	25.0	425
38'	78	11.0'	2.9	56.9	4,444
					4,869

TOTAL 9,089,000#

(TOTAL PROPELLANT USED ON ALL PPS* MISSIONS≈14,000,000#)

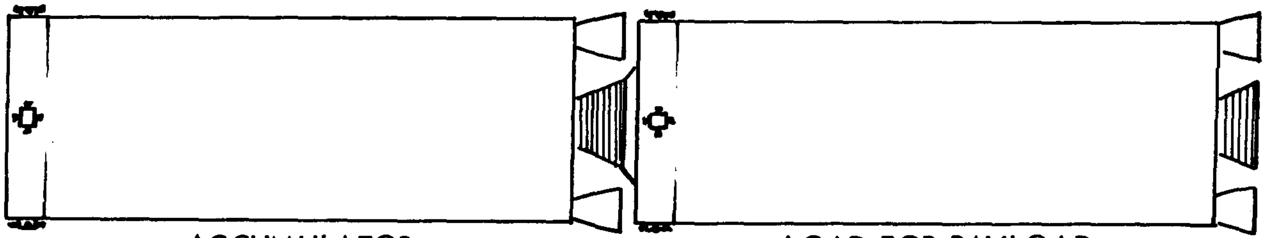
* ASSUME ALL FLOWN BY SPACE BASED TUG

CONCEPT FOR SUPPLEMENTAL PROPELLANT DELIVERY CAPABILITY

A PRELIMINARY OPSS CONCEPT HAS BEEN DEFINED BASED ON THE IDEA OF UTILIZING "EXISTING" HARDWARE AS THE ORBITAL STORAGE SYSTEM. THESE ITEMS COULD RANGE FROM SHUTTLE CARGO BAY PROPELLANT TANKS, TO ACTIVE AND/OR EXPENDED PPS'S, AND INCLUDES ACTIVE/EXPENDED RNS'S OR CIS'S, DEPENDING ON THE STORAGE CAPACITY REQUIREMENTS. FOR A SPACE-BASED TUG USED AS AN OPSS, THE ORBIT MAKEUP PROPELLANTS ARE LISTED ALONG WITH THE NOMINAL SHUTTLE FLIGHT RATES TO INDICATE THAT THE PROPELLANT RESUPPLY INTERVAL IS NOT UNREASONABLE WITH RESPECT TO THE MONTHLY LOSS QUANTITIES. THE PRIMARY ADVANTAGE IN USING ACTIVE PPS FOR STORAGE IS THAT IT PROVIDES A BACKUP PROPULSIVE CAPABILITY AND AT THE SAME TIME ACTS AS AN EFFICIENT STORAGE TANK BECAUSE OF ITS LONG TERM INSULATION DESIGN AND HIGH MASS FRACTION.

Space Division North American Rockwell	CONCEPT FOR SUPPLEMENTAL PROPELLANT DELIVERY CAPABILITY	ISPLS CONTRACT NAS8-27692 FIRST PERFORMANCE REVIEW CHART NO. 55 DATE 10-6-71

TWO TUGS MAINTAINED IN SPACE



ACCUMULATOR

LOAD FOR PAYLOAD PLACEMENT MISSIONS

- SPACE BASED TUG
  - TANK CAPACITY 73,000 LBS EACH
  - BOIL-OFF LOSS RATE ≈ 144 LBS/MONTH
  - ORBITAL MAINTENANCE
    - @ 260 nmi ≈ 1 LB/MONTH
    - @ 100 nmi ≈ 1000 LBS/MONTH

- AVERAGE TIME BETWEEN MISSIONS, (LEVEL C, 0-30°):
  - TUG MISSIONS (W/O CLUSTERING) ≈ 18.6 DAYS
  - SHUTTLE PAYLOAD DELIVERIES (W/O CLUSTERING) ≈ 18.6 DAYS
  - "SHUTTLE DIRECT" FLIGHTS ≈ 43.3 DAYS

PROVIDES FOR:

- ACCUMULATING EXCESS PROPELLANT DERIVED FROM ALL SHUTTLE FLIGHTS
  - OMS
  - PAYLOAD SHARING SATELLITE DELIVERIES
  - PAYLOAD SHARING, SHUTTLE DIRECT MISSIONS

REQUIREMENTS/LOGISTICS ALTERNATIVES INTEGRATION

THE CONCEPTS WHICH HAVE BEEN DESCRIBED IN THIS SECTION ARE DEFINED AND ANALYZED IN TERMS OF TECHNICAL PERFORMANCE CAPABILITY ONLY. IN THE NEXT SECTION, THE FUNDAMENTAL COST FACTORS ARE ESTABLISHED WHICH PROCEDE THE ACTUAL EVALUATION OF THE CONCEPTS TO DETERMINE THE PRIMARY PRODUCT OF THIS STUDY, THE MOST COST-EFFECTIVE PROPELLANT LOGISTICS SYSTEM FOR EACH OF THE FIVE PROGRAM LEVELS.

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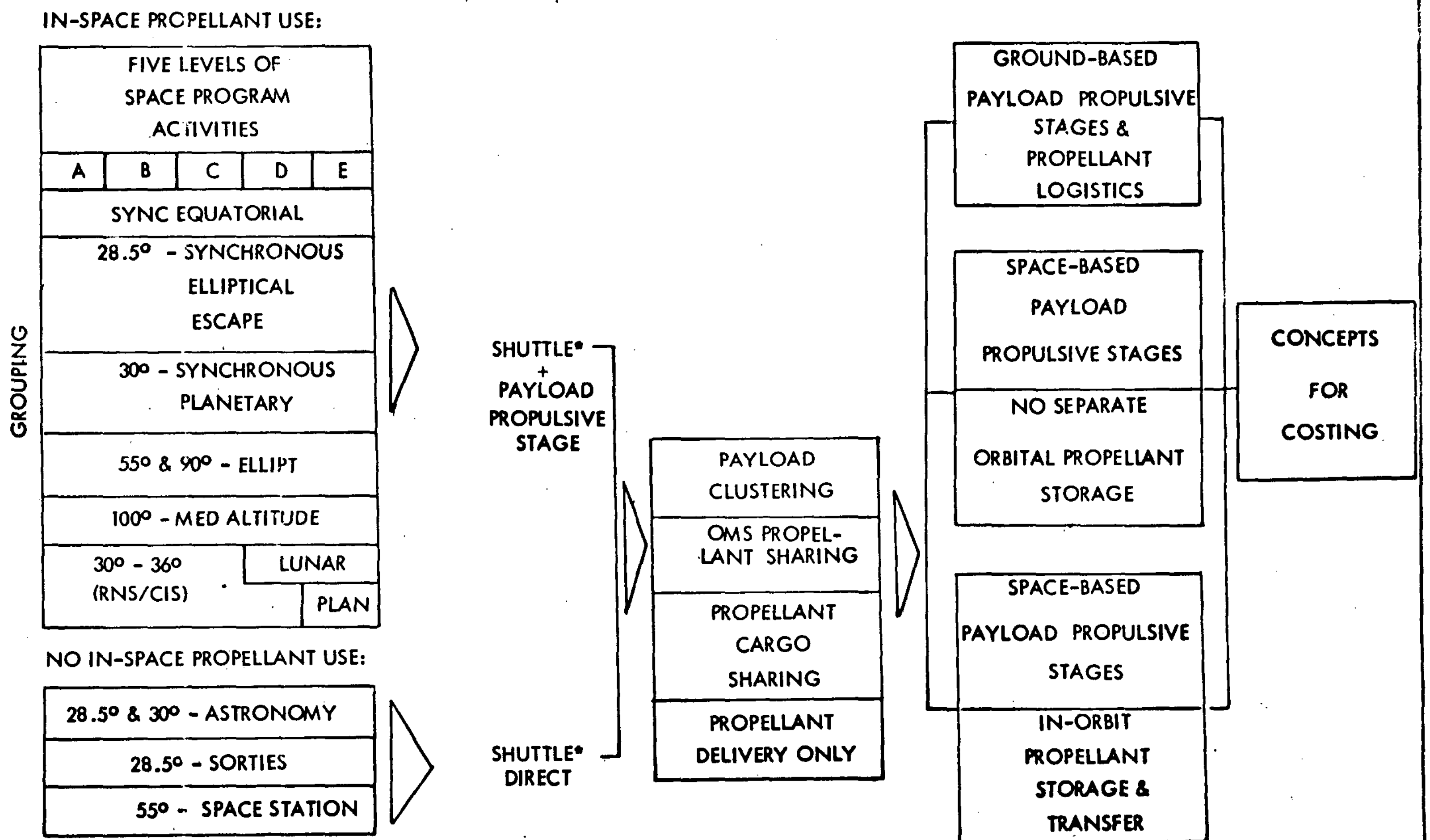
REQUIREMENTS/LOGISTICS ALTERNATIVES INTEGRATION

ISPLS
CONTRACT NAS8-27692
FIRST PERFORMANCE REVIEW
CHART NO. 56 DATE 10-6-71



*ESS & INT-21 ALTERNATES FOR SELECT CONDITIONS

COSTING

THE OBJECTIVES OF THE COSTING EFFORT ARE TO PRICE THE PROGRAM ELEMENTS, CONDUCT TRADEOFF STUDIES OF SYSTEM ALTERNATIVES, AND DEVELOP PROGRAM COSTS WHICH WILL LEAD TO THE MOST ECONOMICAL SYSTEM SELECTION FOR EACH PROGRAM LEVEL A THROUGH E. IN ACCORDANCE WITH THE STUDY PLAN THE COSTING EFFORT HAS JUST BEEN INITIATED AND WILL CONTINUE INTO 1972. THE OVERALL APPROACH AND METHODOLOGY HAVE BEEN DEVELOPED. VEHICLES AND CERTAIN OTHER MAJOR PROGRAM ELEMENTS HAVE BEEN PRICED FOR USE IN THE STUDY. THE COST OF DELIVERY OF PROPELLANT TO SPACE IN DOLLARS PER POUND DELIVERED HAS BEEN CALCULATED FOR SEVERAL DELIVERY MODES. THE PRICING OF PAYLOAD DELIVERY MISSIONS AND THE PRICING OF THE PROGRAM LEVELS A THROUGH E IS SCHEDULED LATER IN THE CONTRACT.

COSTING

APPROACH - METHODOLOGY

PROGRAM COST ELEMENTS

PROPELLANT DELIVERY MISSIONS

PAYLOAD PLACEMENT MISSIONS

COSTING GROUND RULES

GROUND RULES FOR COSTING ARE SHOWN IN THE ACCOMPANYING CHART. VEHICLE COSTS SUCH AS SHUTTLE, TUG (GROUND BASED AND SPACE BASED) AND BOOSTER-EXPENDABLE SECOND STAGE (ESS) HAVE BEEN TAKEN FROM OTHER NR CONTRACTUAL STUDIES OF THESE SYSTEMS. STORAGE AND DEPOT COSTS ARE AVAILABLE FROM THE NR ORBITAL PROPELLANT STORAGE SYSTEM STUDY. EXTRAPOLATIONS WILL BE MADE FROM THAT STUDY FOR NEW STORAGE CONCEPTS. ALTHOUGH A GROUND RULE OF THE CURRENT STUDY PROVIDES FOR ROM COSTING, THE STUDY IS BASED ON THE GREATER LEVEL OF DETAIL EXISTING IN THE RELATED STUDIES FROM WHICH COSTS ARE DERIVED. THE ANALYSIS IN THE PRESENT STUDY WILL ALSO BE CARRIED TO A COMPARABLE LEVEL OF DETAIL.

THE EMPLOYMENT OF UNIT COSTS PER MISSION AND PER POUNDS OF PROPELLANT DELIVERED WILL FACILITATE TRADEOFF AND SENSITIVITY STUDIES AND WILL PROVIDE FOR QUICK PRICING OF PROGRAM LEVELS A THROUGH E UNDER ALTERNATE MODES OF OPERATIONS.

Space Division North American Rockwell	COSTING GROUND RULES	ISPLS CONTRACT NAS8-27692 FIRST PERFORMANCE REVIEW CHART NO. 58 DATE 10-6-71

- 1971 DOLLARS
- ROUGH ORDER, MAGNITUDE COSTS (ROM)
- COSTS DERIVED FROM EXISTING STUDIES & PROGRAMS

  COSTS ESTIMATED FOR NEW EQUIPMENT AND MODIFICATIONS
- DEVELOPMENT, PRODUCTION AND OPERATION COSTS FOR ALL VEHICLES & HARDWARE DEDICATED TO PROPELLANT LOGISTIC USE (DEPOT, TANKS, ETC.)
- PRODUCTION AND OPERATION COSTS ONLY FOR THE VEHICLES (SHUTTLE, TUG, ETC.)
- COSTS DEVELOPED ON A UNIT BASIS WHEREEVER POSSIBLE
  - COST PER MISSION
  - DOLLARS PER POUND OF PROPELLANT DELIVERED
- DEVELOP PROGRAM COSTS FOR PROGRAM LEVELS A THROUGH E
  - DELIVERY SYSTEM COSTS ONLY
  - INCLUDE DELIVERY VEHICLE COSTS AS WELL ON PROPELLANT USED
  - EXCLUDE PAYLOAD COSTS (i.e., SATELLITES, EXPERIMENTS PLACED IN ORBIT

PROGRAM COSTING PROCEDURE

GROUND BASED MISSIONS WILL BE PRICED IN ACCORDANCE WITH THE PROCEDURE INDICATED IN THE TOP PORTION OF THE CHART. VEHICLE AND HARDWARE PRODUCTION (PURCHASE) COSTS WILL BE PRORATED TO MISSIONS ON THE BASIS OF MISSION LIFE. THESE COSTS ARE COMBINED WITH OPERATION COSTS, WHICH INCLUDE LAUNCH, RECYCLE, AND MAINTENANCE COSTS FOR EACH MISSION AND ARE APPLIED TO THE NUMBER OF FLIGHTS OF EACH VEHICLE TYPE DEFINED IN THE MISSION ANALYSIS TASKS TO YIELD PROGRAM COSTS.

FOR SPACE BASED MISSIONS WHERE PROPELLANT IS TAKEN FROM A STORAGE AND TRANSFER FACILITY, IT IS NECESSARY TO CALCULATE THE PROPELLANT COSTS SEPARATELY AND APPLY THESE COSTS TO THE PROPELLANT EMPLOYED IN EACH MISSION AS INDICATED IN THE BOTTOM PORTION OF THE CHART. IN GENERAL PROPELLANT DELIVERY COSTS WILL BE CALCULATED SEPARATELY FROM STORAGE COSTS IN ORDER TO EVALUATE CANDIDATE DELIVERY AND STORAGE MODES SEPARATELY. STORAGE FACILITY COSTS INCLUDING DEVELOPMENT COSTS WILL BE PRORATED OVER THE TOTAL QUANTITY OR PROPELLANT EMPLOYED IN THE PRGORAM BEING EVALUATED.

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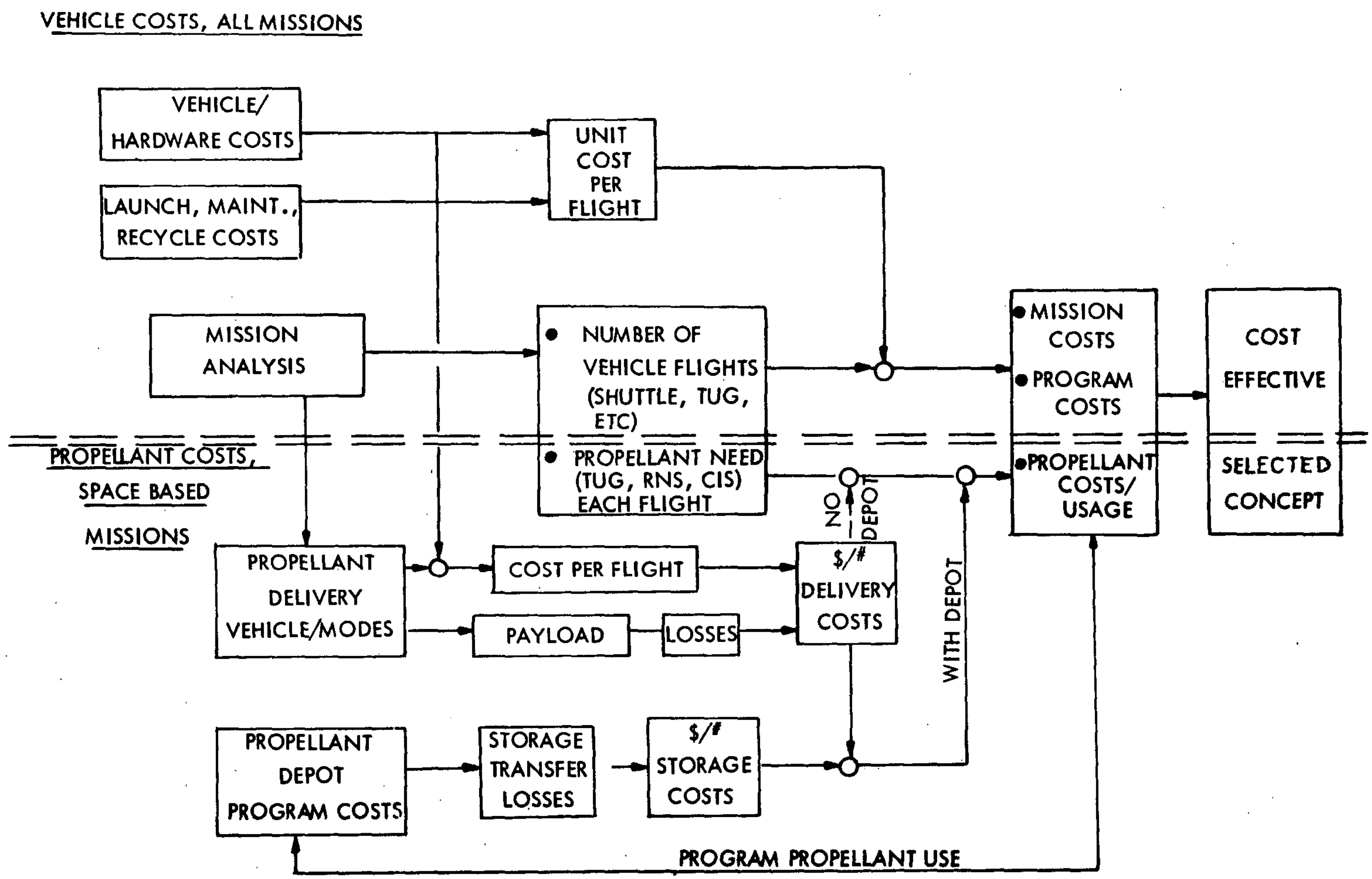
PROGRAM COSTING PROCEDURE

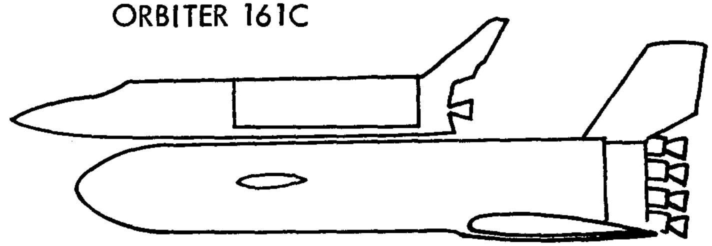
ISPLS
CONTRACT NAS8-27692
FIRST PERFORMANCE REVIEW
CHART NO. 59 DATE 10-6-71



ORBITAL SPACE SHUTTLE COST SUMMARY

FOR USE IN THE ISPLS STUDY, EARTH ORBITAL SHUTTLE COSTS HAVE BEEN DERIVED DIRECTLY FROM THE PHASE B PROGRAM DEFINITION STUDY OF THE ORBITER AND BOOSTER CONDUCTED JOINTLY BY NORTH AMERICAN ROCKWELL AND GENERAL DYNAMICS CORPORATIONS. TOTAL PROGRAM PRODUCTION AND OPERATION COSTS ARE AMORTIZED OVER THE TOTAL NUMBER OF LAUNCHES FOR WHICH THE PROGRAM WAS PRICED YIELDING AN AVERAGE OF $5.7 MILLION DOLLARS PER SHUTTLE FLIGHT. THIS VALUE IS USED THROUGHOUT THE ISPLS STUDY AS THE COST OF DELIVERY OF SHUTTLE PAYLOADS INTO SPACE.

ORBITAL SPACE SHUTTLE COST SUMMARY



SHUTTLE PROGRAM

10 YEAR
444 LAUNCHES
5 ORBITERS
4 BOOSTERS

PROGRAM COSTS

DEVELOPMENT	$7.10 B
PRODUCTION	1.35 B
OPERATIONS*	1.20 B
TOTAL PROGRAM	$9.65 B

DERIVED FROM NR/GD PHASE B SHUTTLE PROGRAM DEFINITION CONTRACT NO. NAS9-10960

AMORTIZED PROGRAM COSTS FOR ISPLS

PRODUCTION ($1.35 B/444)	$3.0 M
OPERATIONS ($1.19 B/444)	2.7 M
AVERAGE COST PER SHUTTLE LAUNCH	$5.7 M

*OPERATIONS INCLUDES:
- LAUNCH COSTS
- MAINTENANCE/RECYCLE COSTS
- PROGRAM SPARES
- KSC COSTS

PROGRAM ELEMENT COST SUMMARY

THE AVERAGE HARDWARE PRODUCTION OR PURCHASE COSTS FOR PAYLOAD PROPULSIVE STAGES EMPLOYED IN THE STUDY ARE IDENTIFIED IN THIS CHART. TOTAL MISSION COSTS WILL ALSO INCLUDE THE COST OF SHUTTLE DELIVERIES FOR GROUND BASED MISSIONS AND THE COST OF PROPELLANT IN SPACE FOR SPACE BASED MISSIONS. THE PRODUCTION COSTS HAVE BEEN PRORATED TO AVERAGE COSTS PER MISSION ON THE BASIS OF THE INDICATED MISSION LIFE FOR EACH VEHICLE. THE AVERAGE COSTS PER MISSION ALSO INCLUDE AN ALLOWANCE FOR ESTIMATED LAUNCH RECYCLE AND MAINTENANCE COSTS. THE MISSION LIVES HAVE BEEN BASED PRINCIPALLY ON DATA ON ENGINE LIFE FOR THE RECOVERABLE VEHICLES AND ON THE AVERAGE NUMBER OF STARTS AND BURN TIME CALCULATED FOR THE FLEMING MODEL MISSIONS IN PROGRAM LEVEL C. ENGINE SPECIFICATIONS HAVE BEEN DERIVED FROM THE REUSABLE SPACE BASED TUG STUDY AND THE GROUND BASED ORBIT TO ORBIT SHUTTLE STUDY CONDUCTED BY NR FOR NASA AND THE AIR FORCE, RESPECTIVELY.

IN THE CASE OF THE SPACE BASED TUG, WITH A LIFE OF 50 MISSIONS, IT HAS BEEN ASSUMED THAT THE VEHICLE IS RECYCLED TO THE GROUND EVERY 10 MISSIONS FOR MAINTENANCE. THE COST PER MISSION IN THIS CASE ALSO INCLUDES AN ALLOWANCE FOR PLACING THE VEHICLE IN SPACE AND RETRIEVING IT EVERY 10TH MISSION EMPLOYING THE EARTH ORBITAL SHUTTLE.

THE TANKS LISTED IN THE CHART ARE EMPLOYED FOR CARRYING PROPELLANT IN THE SHUTTLE PAYLOAD BAY. THE AVERAGE COST PER MISSION FOR THESE TANKS INCLUDES DEVELOPMENT COSTS PRORATED OVER 500 MISSIONS.

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PROGRAM ELEMENT COST SUMMARY

ISPLS
CONTRACT NAS8-27692
FIRST PERFORMANCE REVIEW
CHART NO. 61 DATE 10-6-71

PROGRAM ELEMENT		AVERAGE UNIT PRODUCTION COST \$ MILLION	MISSION LIFE (NO. OF FLIGHTS)	AVERAGE UNIT COST PER MISSION \$ MILLION (1)
• GROUND BASED EXPENDABLE				
• FW4S DERIVATIVE		0.1	1	.1
• AGENA		3.0	1	3.2
• CENTAUR		9.0	1	9.5
• GROUND BASED RECOVERABLE				
• INTERIM TRANSFER STAGE		11.5	10	1.8
• GROUND BASED TUG		17.2	36	1.4
• SSV PROPELLANT LOGISTICS TANKS				(2)
CIS LO_2-H_2 WEIGHT LIMITED	T3	1.6	100	.050
RNS < H_2 + (O_2) VOLUME LIMITED	T4	2.7	100	.078
RNS < H_2 VOLUME LIMITED	T5	2.2	100	.063
• SPACE BASED RECOVERABLE				
• TUG		38.1	50	1.3

(1) INCLUDING LAUNCH COSTS, EXCLUDING SHUTTLE COSTS

(2) PRORATED DEVELOPMENT COSTS INCLUDED FOR DEDICATED PROPELLANT LOGISTIC HARDWARE

PROPELLANT DELIVERY COSTS
(DOLLARS PER POUND)

THE DOLLARS PER POUND OF PROPELLANT DELIVERED ARE BASED ON THE VEHICLE COSTS PER MISSION AND THEIR PAYLOAD DELIVERY CAPABILITIES.

THE INCREASE OF THE PAYLOAD CAPABILITY OF THE SHUTTLE TO 65,000 LBS OVER EARLIER SPECIFICATIONS HAS REDUCED PROPELLANT DELIVERY COSTS TO VALUES LOWER THAN THAT INDICATED IN EARLIER STUDIES.

THE ANOMALOUS SITUATION OF IDENTICAL COSTS FOR PAYLOAD DELIVERY TO 100 NM AND 262 NM EMPLOYING THE SHUTTLE ALONE WITHOUT OMS PROPELLANT TRANSFER RESULTS FROM THE FACT THAT THE SHUTTLE HAS A UNIFORM PAYLOAD PERFORMANCE CAPABILITY FROM 100 TO ABOUT 300 NM. WHEN THE SHUTTLE IS LAUNCHED, SUFFICIENT ORBITAL MANEUVERING SYSTEM (OMS) PROPELLANT IS ABOARD TO PROVIDE FOR A "ONCE AROUND THE WORLD" ABORT MANEUVER IN CASE OF A MAIN ENGINE FAILURE DURING ASCENT. IF THE ABORT DOES NOT OCCUR APPROXIMATELY 24,200 LB. OF PROPELLANT IS AVAILABLE FOR OTHER USES AND CAN THEN BE EMPLOYED TO TAKE THE SHUTTLE WITH FULL PAYLOAD TO HIGHER ALTITUDE. IF THE EXCESS OMS IS TRANSFERRED TO THE PROPELLANT RECEIVER THEN A LARGER PROPELLANT PAYLOAD DELIVERY RESULTS IN A REDUCED COST PER POUND DELIVERED.

PROPELLANT DELIVERY COSTS (DOLLARS PER POUND)

(EXCLUDES DEPOT COSTS)
31.5° ORBIT

	NO OMS TRANSFER			WITH OMS TRANSFER		
	SHUTTLE		SHUTTLE + TUG	SHUTTLE		SHUTTLE + TUG
	100 nmi	262 nmi	262 nmi	100 nmi	262 nmi	262 nmi
$/POUND DELIVERED	$101	$101	$139	$72	$94	$97
PROPELLANT (K LB)						
PROPELLANT PAYLOAD IN SHUTTLE BAY	59.9	59.9	59.9	59.9	59.9	59.9
EXCESS OMS AVAILABLE AT 100 nmi	24.2	24.2	24.2	24.2	24.2	24.2
OMS USED BY SHUTTLE/TUG	--	20.0	6.5	--	20.0	7.6
REMAINING OMS	24.2	4.2	24.2	24.2	4.2	16.6
PROPELLANT DELIVERED	59.9	59.9	53.4	84.1	64.1	76.5
COSTS PER FLIGHT						
SHUTTLE + PL TANK	$ 5.75M	$ 5.75M	$5.75M	$ 5.75M	$ 5.75M	$ 5.75M
TUG	--	--	1.3	--	--	1.3
	5.75	$ 5.75	$ 7.05	$ 5.75	$ 5.75	$ 7.05

SPACE BASED TUG
$/LB INCLUDES 5% FOR PROPELLANT LOSSES

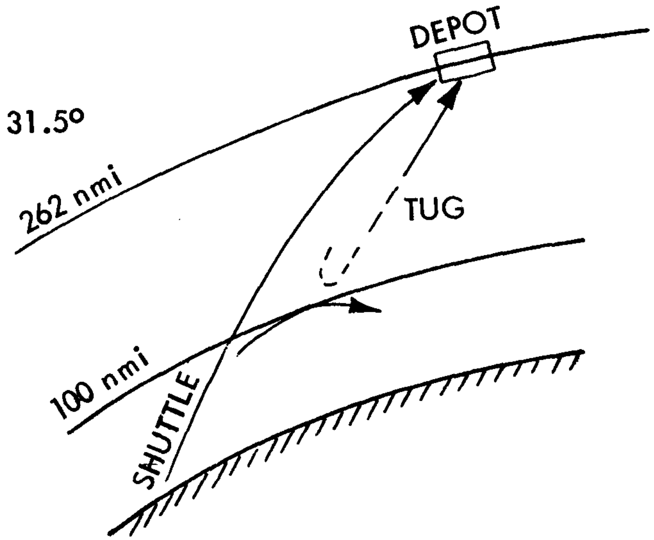
W

PROPELLANT DELIVERY AND STORAGE MODES FOR COSTING ANALYSIS

THE PROPELLANT DELIVERY MODES UNDER STUDY WOULD PROVIDE FOR DELIVERY OF PROPELLANT EITHER TO A STORAGE FACILITY OR DIRECTLY TO SPACE BASED USERS WHICH INCLUDE TUG, REUSABLE NUCLEAR SHUTTLE (RNS) OR CHEMICAL INTERORBITAL SHUTTLE (CIS). COSTS ARE CALCULATED ON THE BASIS OF DOLLARS PER POUND DELIVERED FOR THESE MODES. THE ALTITUDE OF 262 NM IS SELECTED BECAUSE 31.5^{o} AT 262 NM IS A PRIME CANDIDATE FOR LOCATION OF A PROPELLANT STORAGE DEPOT. IT HAS THE ADVANTAGE OF BEING RENDEZVOUS COMPATIBLE WITH KSC LAUNCHES ONCE A DAY AND IS SYNCHRONOUS WITH REPEATING LUNAR GEOMETRY SO THAT IT IS SUITABLE FOR RNS/CIS RENDEZVOUS. OTHER ALTITUDES WILL ALSO BE CONSIDERED AS REQUIRED.

THE STORAGE ALTERNATIVES UNDER STUDY INCLUDE THE LARGE BASELINE DEPOTS TAKEN FROM THE OPSS STUDY WHICH ARE RNS/CIS SUPPORTIVE, SMALLER DEPOTS, AND THE USE OF CERTAIN VEHICLES THEMSELVES FOR ACCUMULATING AND STORING PROPELLANT. THE EMPLOYMENT OF TWO TUGS IN SPACE WITH ONE UTILIZED AS A PROPELLANT ACCUMULATOR AND THE OTHER EMPLOYED FOR MISSION PAYLOAD DELIVERIES WHEN REQUIRED APPEARS TO HAVE SOME SIGNIFICANT ADVANTAGES WHICH ARE UNDER STUDY.

Space Division North American Rockwell	PROPELLANT DELIVERY MISSIONS FOR COSTING ANALYSIS	ISPLS CONTRACT NAS8-27692 FIRST PERFORMANCE REVIEW CHART NO. 63 DATE 10-6-71



STORAGE MODES

OPSS DEPOTS

	CIS SUPPORT	RNS SUPPORT
FIXED TANK S-II DERIVATIVE	X	X
MODULAR	X	X

PROPELLANT DELIVERY MODES

		OMS TRANSFER:
● SHUTTLE DIRECT	- 100 nmi - 262 nmi	
● SHUTTLE + TUG	- 262 nmi	WITH
● BOOSTER ESS	- 100 nmi - 262 nmi	WITHOUT

- BOOSTER ESS TO 100, TUG PICKS UP PAYLOAD DELIVERS TO 262

- CHEMICAL INTERORBITAL STAGE CIS EMPLOYED AS DEPOT
- TWO OR MORE SPACE BASED TUGS
- SMALLER DEPOTS (TANK + ATTITUDE CONTROL)

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OUTLINE

ISPLS
INTRODUCTION
R.E. SEXTON

PROJECT I
REQUIREMENTS
G.A. OLSON

PROJECT I
PROPELLANT
LOGISTICS
SYSTEMS
ANALYSIS
R.L. MOORE

PROJECT II
SYSTEMS
SAFETY
ANALYSIS
W. PLAISTED

ISPLS
SUMMARY
ACTIONS
FUTURE
ACTIVITIES
R.E. SEXTON

SAFETY LOGIC

THE CONTRACT EFFORT FOR THE SYSTEM SAFETY ANALYSIS WAS INITIATED SEPTEMBER 1. LOGISTICS CONCEPTS FROM PROJECT I WERE EVALUATED FOR DEFINITION OF THE REPRESENTATIVE LOGISTIC ORBITAL OPERATIONS REQUIRED FOR THE SYSTEM SAFETY ANALYSIS. INFORMATION FROM THE LITERATURE SEARCH AND RELATED STUDIES HAS BEEN INTEGRATED WITH THE SYSTEM SAFETY ANALYSIS AS AN AID IN ESTABLISHING CRITERIA AND IDENTIFYING HAZARDS WHICH MUST BE ELIMINATED, REDUCED, OR CONTROLLED. TRADEOFF STUDIES FOR DEVELOPING THE MOST COST EFFECTIVE PROPELLANT LOGISTIC SYSTEM WILL BE IMPACTED BY THE RESULTS OF THE SYSTEM SAFETY ANALYSIS. RESULTANT CORRECTIVE MEASURES FOR HAZARD REDUCTION AND CONTROL WILL BE FOLLOWED BY GUIDELINES AND REQUIREMENTS.

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PROJECT II - SYSTEM SAFETY PROGRAM ELEMENTS

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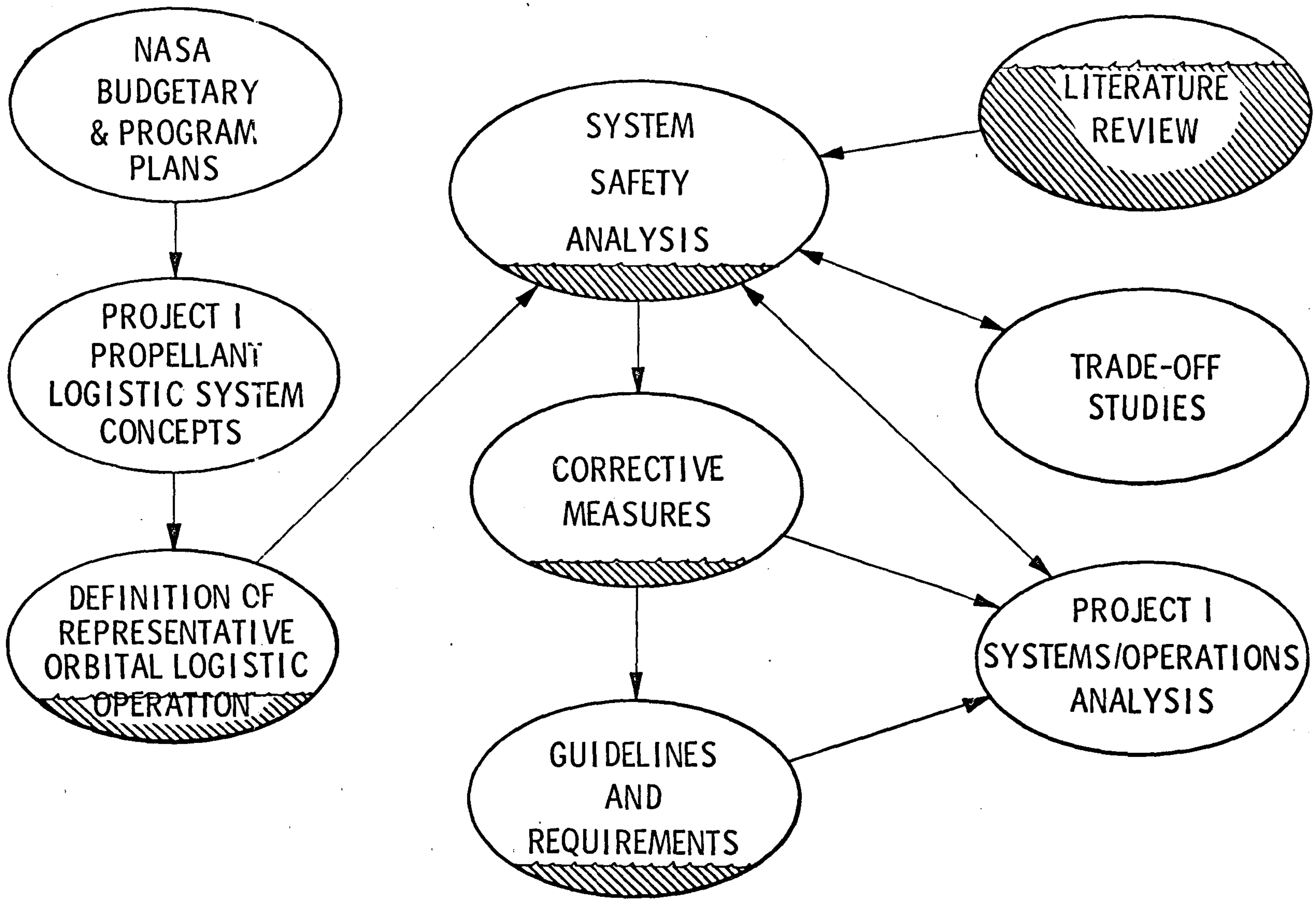
CONTRACT NAS8-27692
FIRST PERFORMANCE REVIEW
CHART NO. 65 DATE 10-6-71



129

ORBITAL PROPELLANT STORAGE SYSTEM (OPSS)
IN-HOUSE SAFETY STUDY

DURING THE TWO MONTHS PRIOR TO CONTRACT START OF PROJECT II, SYSTEM SAFETY ANALYSIS, AN IN-HOUSE SAFETY STUDY OF THE ORBITAL PROPELLANT STORAGE SYSTEM (OPSS) CO 1980 - S-II NAS7-200, WAS PERFORMED. INFORMATION FROM THIS SAFETY STUDY AND THE LITERATURE SEARCH TASK II-1 WAS USED TO DEVELOP SYSTEM SAFETY CRITERIA AND GUIDELINES WHICH WOULD BE APPLICABLE TO THE IN SPACE PROPELLANT LOGISTICS AND SAFETY (ISPLS) STUDY. PRELIMINARY RESULTS OF THE AEROSPACE CORPORATION "ORBITING PROPELLANT DEPOT SAFETY STUDY" PROVIDED BY H. SCHAEFER, NASA HQ, WERE ALSO FACTORED INTO THIS STUDY.

- UTILIZED OPSS AND SPACE SHUTTLE STUDIES
- SUPPORTED BY LITERATURE SEARCH DOCUMENTATION
- PRELIMINARY FFBD, FMEA, HAZARD ANALYSES DEVELOPED
- PRELIMINARY CRITERIA FOR ISPL SYSTEM SAFETY DEVELOPED
    - UTILIZED PRELIMINARY CONCEPT DATA IN COORDINATION WITH PROJECT I
    - APPLICABLE SAFETY CRITERIA FROM OPSS, SPACE SHUTTLE AND CIS
    - OTHER CRITERIA DEVELOPED FROM OPSS HAZARD ANALYSES
- PROVIDED DATA TO PROJECT I FOR USE IN CONCEPT DEVELOPMENT

LITERATURE SEARCH

THE INITIAL REVIEW CATEGORIES WERE ESTABLISHED FOR THE LITERATURE SEARCH AND LITERATURE SCREENING BY KEY WORDS (AUTOMATIC) AND BY SUBJECT (MANUAL) WERE PERFORMED. THE AUTOMATIC SCREENING INCLUDED RUNS OF NASA STAR, AND CSTAR, NR TECHNICAL INFORMATION PROCESSING SYSTEM (TIPS), DEFENSE DOCUMENTATION CENTER (DDC) AND BUREAU OF STANDARDS (BOULDER). MANUAL SCREENING INCLUDED CHEMICAL PROPULSION INFORMATION AGENCY SUMMARIES AND ENGINEERING ABSTRACTS. 1030 TITLES WERE EVALUATED AND 100 DOCUMENTS WERE CHOSEN FOR REVIEW. 50 OF THESE DOCUMENTS HAVE BEEN SUMMARIZED ON INDEX CARDS. ISPLS PROJECT II HAS BEEN TIED INTO THE SELECTIVE DISSEMINATION OF INFORMATION (SDI) SYSTEM AT THE NR TECHNICAL LIBRARY TO RECEIVE AUTOMATIC NOTIFICATIONS AS NEW PERTINENT DOCUMENTS ARE RECEIVED BY THE LIBRARY.

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LITERATURE SEARCH

ISPLS
CONTRACT NAS8-27692
FIRST PERFORMANCE REVIEW
CHART NO. 67 DATE 10-6-71

- INITIAL COMPUTER SEARCH COMPLETE
- SECOND SCREENING OF LIKELY TITLES COMPLETE
- 100 TITLES REQUESTED FOR DETAILED REVIEW
- 50 DOCUMENTS RECEIVED AND SUMMARIZED
- CONTINUATION SEARCH BY SDI IN PROCESS--TO CONTINUE THROUGHOUT STUDY

LITERATURE REVIEW

(EXAMPLE)

EACH DOCUMENT CHOSEN FOR DETAILED REVIEW WAS SUMMARIZED AS SHOWN IN THE EXAMPLE.

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LITERATURE REVIEW
(INDEX CARD)

ISPLS
CONTRACT NAS8-27692
FIRST PERFORMANCE REVIEW
CHART NO. 68 DATE 10-6-71

TITLE: HIGH ALTITUDE EXPLOSION PROPERTIES OF THE H_2 - O_2 SYSTEM IN VENTED TANKS

AUTHOR: S. KAYE, R.T. MURRAY (GDA)

AGENCY/PUBLISHER: ADVANCES IN CRYOGENIC ENGINEERING

DOC NO: VOL 13 DATE: 1968 PAGES: 545-554

SUMMARY:

AN IGNITION SOURCE CAUSED FIRES OR EXPLOSIONS WHEN H_2 & O_2 WERE LEAKED INTO A TEST CHAMBER AT 65 & 35 mm Hg - NONE AT 0.5 mm Hg

NICKEL RIBBON, AT AMBIENT TEMP., AND LOW PRESSURES IS CATALYTIC TO H_2 - O_2 REACTION

SMALL VENTS RESTRICT DISCHARGE & CAUSE LARGE OVER-PRESSURES
LARGE VENTS ALLOW BACK-DIFFUSION OF AMBIENT AIR & PERMIT REACTIONS

CONTAMINATION OF PURGE GAS WITH OVER 2% O_2 IS HAZARDOUS

LITERATURE REVIEW
(EXAMPLES)

CERTAIN CRITICAL AREAS/CONDITIONS WERE IDENTIFIED DURING THE LITERATURE REVIEW AND GUIDELINES WERE GENERATED.

"HYDROGEN-OXYGEN REACTION STUDIES" GDC 1967 PROVIDED INFORMATION ON HYDROGEN DISCHARGED INTO A PURGE GAS NITROGEN CONTAMINATED WITH 2, 4, 7 AND 10% OXYGEN AND AT 3 AMBIENT PRESSURES OF (65, 35 AND .5 MM HG). FIRES AND EXPLOSIONS OCCURRED WITH PURGE GAS CONTAINING AS LITTLE AS 2 % OXYGEN FOR PRESSURES OF 65 AND 35 MM HG. SOME REACTION DID OCCUR AT PRESSURES OF .5 MM HG. HYDROGEN LEAKING INTO THE CARGO BAY OF THE SHUTTLE COULD PROVIDE A POTENTIAL HAZARD. THIS HAZARD BECOMES CRITICAL DURING REENTRY WHEN THE OXYGEN CONCENTRATION AND PRESSURES REACH A POINT THAT FIRES AND EXPLOSIONS RESULT. GUIDELINE 6.1.5 WAS GENERATED BECAUSE OF THIS HAZARD.

"EFFECTS OF VACUUM ON CRYOGENS" ATLANTIC RESEARCH 1964, SHOWED THAT CRYOGENS FORM SOLID PARTICLES WHEN SUBJECTED TO A VACUUM ENVIRONMENT. GUIDELINE 6.2.4 IS REQUIRED TO INSURE THAT OPERATIONS WHICH FOLLOW VENTING PROPELLANTS TO A VACUUM WILL NOT BE IMPEDED BY THE SOLID CRYOGENS.

CRITICAL AREAS/CONDITIONS IDENTIFIED

- PROPELLANT LEAKAGE INTO CARGO BAY OF SHUTTLE
  - "HYDROGEN - OXYGEN REACTION STUDIES", GDC 1967
  - GUIDELINE 6.1.5 - NO SHUTTLE CARGO SHALL BE PERMITTED TO LEAK, VENT OR DISCHARGE PROPELLANT INTO THE CARGO BAY
- EVAPORATIVE FREEZING OF BULK LIQUIDS
  - "EFFECTS OF VACUUM ON CRYOGENS", ATL. RESEARCH 1964
  - GUIDELINE 6.2.4 - BULK QUANTITIES OF LIQUIDS SHOULD NOT BE VENTED TO SPACE VACUUM IF SUBSEQUENT OPERATIONS WOULD BE IMPEDED BY THE SOLID PARTICLES AND CHUNKS THAT WOULD BE FORMED

EXAMPLE OF FFBD DEVELOPED

(OPSS IN-HOUSE SAFETY STUDY)

FUNCTIONAL FLOW BLOCK DIAGRAMS WERE DEVELOPED FOR THE OPSS IN-HOUSE SAFETY STUDY. A FIRST LEVEL FLOW FOR THE SHUTTLE DELIVERY OF A PROPELLANT TANK TO AN OPSS IS SHOWN IN FFBD 4.0, PERFORM PROPELLANT TRANSFER OPERATION. THE OPERATIONAL STEP 4.5 TRANSFER/UNLOAD PROPELLANT WAS CHOSEN AS AN EXAMPLE FOR THE SYSTEM SAFETY ANALYSIS.

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EXAMPLE OF FFBD DEVELOPED (OPSS INHOUSE SAFETY STUDY)

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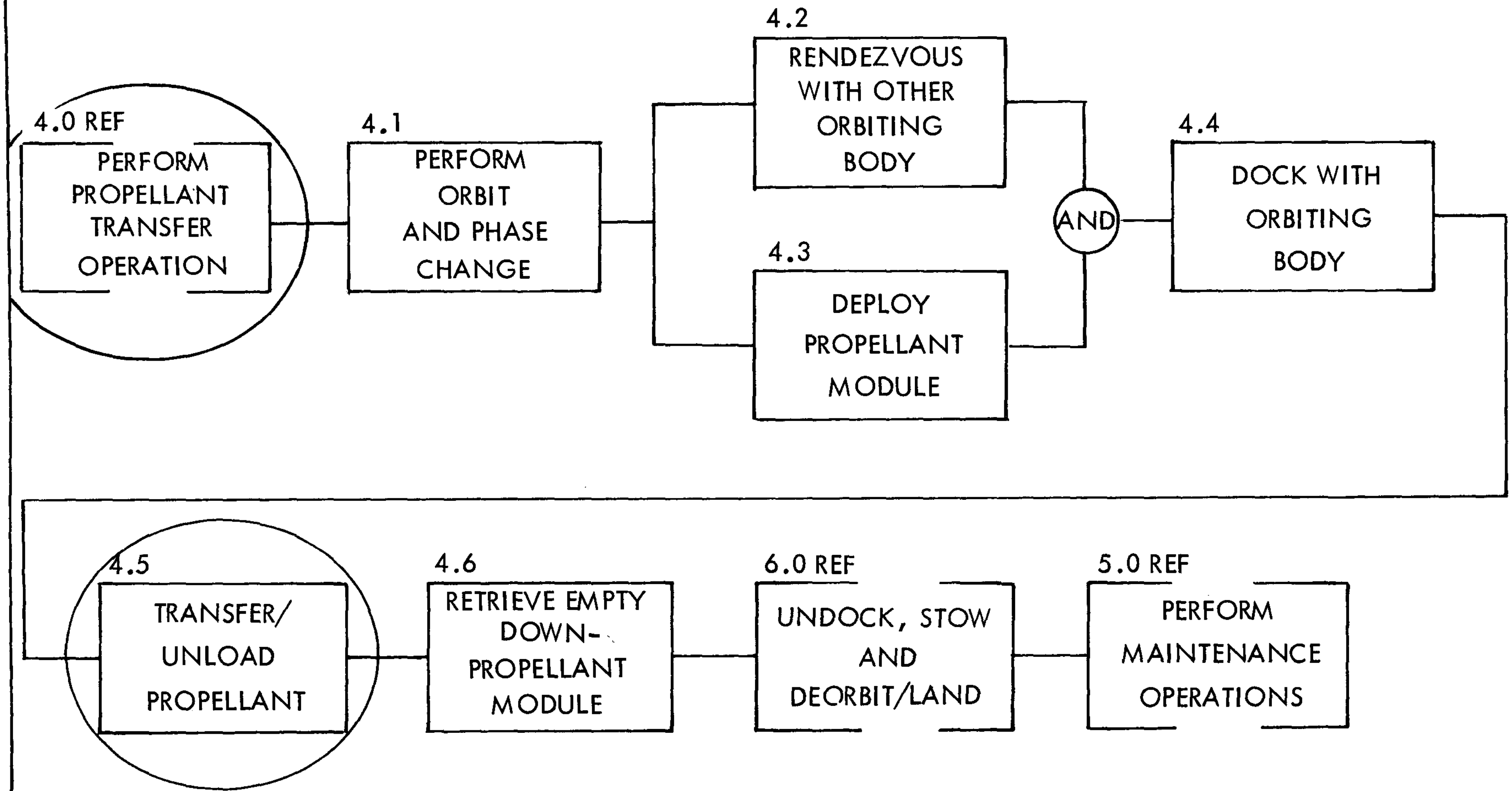
FIRST PERFORMANCE REVIEW
CHART NO. 70 DATE 10-6-71



FFBD 4.0 PERFORM PROPELLANT TRANSFER OPERATION (1ST LEVEL)

EXAMPLE OF FMEA DEVELOPED

FAILURE MODE EFFECTS ANALYSIS (FMEA) 4.5 WERE PERFORMED FOR THE SHUTTLE DELIVERY OF A PROPELLANT TANK FFBD 4.0 AND OPERATIONAL STEP 4.5 TRANSFER/UNLOAD PROPELLANT. FAILURE MODE 4.5.1 FAILURE OF LINE INTERCONNECT FIXTURE INDEXING PROBES TO RIGIDIZE FIXTURE WAS SELECTED TO ILLUSTRATE THE ANALYSIS.

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EXAMPLE OF FMEA

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CONTRACT NAS8-27692
FIRST PERFORMANCE REVIEW
CHART NO. 71 DATE 10-6-71

MISSION PHASE
FIRST LEVEL FUNCTION

PROGRAM

REF. FFBD	OPERATIONAL STEP	FAILURE MODE	FAILURE EFFECT A - SYSTEM C - MISSION B - SUBSYSTEM D - PERSONNEL	HAZARD IDENTIFIED YES/NO	PRIMARY CAUSE
4.0	4.5 TRANSFER/UNLOAD PROPELLANTS (OPS)	FAILURE OF LINE INTERCONNECT FIXTURE INDEXING PROBES TO RIGIDIZE FIXTURE	A RENDERS SYSTEM INOPERATIVE B DAMAGE TO PROBES C MISSION DELAY	YES YES NO	METEOROID SHIELD NOT RETRACTED/FAILURE OF DRIVE MECHANISM
		FAILURE OF LINE EXTENSION BELLOWS	A_1 FIRE/EXPLOSION (IF CONFINED) A_2 ICE CRYSTAL CLOUD FORMATION B RENDERS SUBSYSTEM INOPERATIVE C MISSION DELAY D THERMAL/FRAGMENTATION	YES	MECHANICAL FAILURE
		FAILURE OF QD TO SEAL	B LEAKAGE AT QD	YES	CONTAMINATION/ DEFECTIVE SEAL
		FAILURE OF AUTOMATICALLY OPERATED ELECTRICAL CONNECTORS TO EXTEND	A RENDERS SYSTEM INOPERATIVE C MISSION DELAY	NO NO	LOSS OF POWER/ INDEXING PROBES MISALIGNED
		GAS GENERATOR FAILS TO OPERATE	A SYSTEM BECOMES INOPERATIVE B_1 LOSS OF PRESSURANT B_2 PUMP CAVITATION	NO NO YES	ELECTROMECHANICAL FAILURE
		HEAT EXCHANGER FAILS	A SYSTEM CONTAMINATION B FUNCTIONAL DEGRADATION C DELAY OF MISSION D LOSS OF HABITABLE ENVIRONMENT	YES YES NO YES	BURN THROUGH OR LEAK

EXAMPLE OF A HAZARD ANALYSIS

THE HAZARD ANALYSIS APPROACH IS SIMILAR IN FORMAT TO THAT USED FOR NR'S SHUTTLE OPERATION. THE CODE FOR THE ISPLS STUDY INVOLVING OPERATION/PHASE, HAZARD GROUP AND SUBSYSTEM IS AS FOLLOWS

OPERATION/PHASE		HAZARD GROUP	CODE	SUBSYSTEM	CODE
PRELAUNCH	A	FIRE/EXPLOSION/IMPLOSION	1	AVIONICS	1
		REDUCED INTEGRITY OF		PROPULSION	2
LAUNCH/ASCENT	B	STRUCTURE OR EQUIPMENT	2	VEHICLE SUPPORT	3
ORBITAL	C	CONTAMINATION	3	MECHANICAL	4
		CORROSION	4	STRUCTURAL	5
DEORBIT	D	TOXICITY	5	MATERIALS	6
		HEAT/TEMPERATURE	6	GSE	7
LANDING	E	LOSS OF THRUST	7	FACILITIES	8
		LOSS OF CREW	8	PAYLOAD	9
SAFING	F	IMPACT	9	SAFING	10
		LOSS OF ATTITUDE CONTROL	10	PROPELLANT	11
		LOSS OF MISSION	11	HUMAN	12
		LOSS OF HABITABLE ENVIRONMENT	12	PRESSURIZATION	13
		LOSS OF COMMUNICATION	13		
		DISTURBANCES	14		

FROM FMEA 4.5.1 THE SUBSYSTEM - PROPELLANT - 11 IS EVALUATED FOR THE OPERATION/PHASE - ORBITAL - C UNDER HAZARD GROUP - REDUCED INTEGRITY OF STRUCTURE OR EQUIPMENT - 2.

THE HAZARD DESCRIPTION/EFFECTS AND ACTION RECOMMENDED ARE COMPLETED AND THE HAZARD ANALYSIS IS FORWARDED TO PROJECT I FOR ADDITIONS AND CONCURRENCE.

Space Division North American Rockwell	EXAMPLE OF HAZARD ANALYSIS	ISPLS CONTRACT NAS8-27692 FIRST PERFORMANCE REVIEW CHART NO. 72 DATE 10-6-71

Contract NAS8-27692

Location/Site Involved ______

HAZARD ANALYSIS

Page ___ of ___
Date ______
Rev ______

End Item	Subsystem	Subsystem Ident. No.
OPS	PROPELLANT TRANSFER	11

Operation/Phase	Op. Ident. No.
ORBITAL	C
Hazard Group	**Hazard Grp. Code**
REDUCED INTEGRITY OF STRUCTURE OR EQUIPMENT	2
References	**Authority**
FMEA 4.5.1	PROJECT II TASK II-3

Hazard Description/Effects A hazard exists during preparation for transfer hookup when the line interconnect fixture meteoroid shield has not been retracted prior to docking. The hazard results in damage to the indexing probes as they are forced into the shield instead of the mating interconnect half. The effect of this damage would result in loss of capability to rigidize the interface for transfer line connection. This damage may also cause the index probe chain drive to break, rendering the system inoperative.

Originator	Group	Ext.	Hazard Class
			CRITICAL

Copies to: ___Structural _X_Mechanical ___Materials ___GSE ___Other

___Avionics ___Propulsion ___Vehicle Support ___Facilities _X_ Payload _X_ Sys Safety

Action Recommended:

Provide a meteoroid shield design for the line interconnect fixture which is capable of being retracted after docking and incorporating the capability for automatic withhold of probe and line extension activation when the shield is not retracted.

OPSS SAFETY ANALYSIS

CRITICAL AREAS/CONDITIONS IDENTIFIED

CRITICAL AREAS/CONDITIONS WERE IDENTIFIED DURING THE OPSS SAFETY ANALYSIS.

A HAZARD COULD BE CREATED WHEN A DOWN PROPELLANT MODULE WHICH HAS LOST PRESSURE EITHER BY SYSTEM LEAK OR METEOROID PENETRATION IS TRANSFERRED TO THE ORBITER CARGO BAY. DURING RE-ENTRY THE DIFFERENTIAL IN PRESSURE ON THE TANK COULD CAUSE AN IMPLOSION AND A FIRE OR EXPLOSION COULD FOLLOW.

THE PRIMARY REASON FOR CONSIDERING THE USE OF SLUSH CRYOGENS IN AN OPSS IS THE DENSITY ADVANTAGE. A HAZARD COULD RESULT FROM ABNORMALLY HIGH HEAT LEAKS INTO THE PROPELLANT MODULE WHICH WOULD MELT THE SOLID FRACTION. THE MELTING SOLID WOULD EXPAND AND OVERFLOW THE TANK. THIS HIGH VOLUME FLOW IN LONG VENT LINES COULD REFLECT HIGH BACK PRESSURES INTO THE PROPELLANT TANK AND COULD RESULT IN OVER-STRESSING THE TANK.

OPSS SAFETY ANALYSIS (EXAMPLES)

- CRITICAL AREAS/CONDITIONS IDENTIFIED

  - PROPELLANT MODULES WHICH HAVE LOST PRESSURIZATION BY LEAKS OR VENTING TO VACUUM COULD CAUSE FIRE/EXPLOSION IN CARGO BAY UPON RE-ENTRY IN EARTH'S ATMOSPHERE

  - ENVIRONMENTAL/THERMAL AND EMERGENCY CONTROL OF LH_2 SLUSH DURING GROUND OPERATIONS

SYSTEM SAFETY CRITERIA

PRELIMINARY SYSTEM SAFETY CRITERIA WAS DEVELOPED FOR THE IN-SPACE PROPELLANT LOGISTICS AND SAFETY STUDY. SEVERAL EXAMPLES HAVE BEEN SELECTED FROM THE LIST.

SYSTEM SAFETY CRITERIA
ISPLS STUDY

- ANY OPERATIONAL MODE OF LOGISTIC PROPELLANT ELEMENTS IN WHICH PROPELLANT TANKAGE IS OPENED TO SPACE VACUUM ENVIRONMENT SHALL INCORPORATE A PROVISION FOR TANK PRESSURIZATION WHEN THE TANK IS TO BE RETURNED TO EARTH IN THE SHUTTLE ORBITER

- PROVISIONS SHALL BE INCORPORATED IN ALL ORBITAL PROPELLANT LOGISTIC ELEMENTS TO MEASURE THE QUANTITY OF PROPELLANTS TRANSFERRED INTO OR REMOVED FROM STORAGE ELEMENTS AND THE NUMBER OF PRESSURE CYCLES IMPOSED ON THE PRESSURIZED TANK

- ANY PROPELLANT MODULE DAMAGED TO THE EXTENT THAT LEAKAGE OF PROPELLANTS COULD BE EXPECTED TO OCCUR IN THE SHUTTLE ORBITER BAY UPON RE-ENTRY, SHALL NOT BE RETURNED TO EARTH BY THE ORBITER

ISPLS GUIDELINE SAMPLE

PRELIMINARY GUIDELINES WERE DEVELOPED FROM THE LITERATURE SEARCH AND THE OPSS STUDY. A SAMPLE GUIDELINE IS SHOWN TO ILLUSTRATE THE FORMAT AND CONTENT AND INTERRELATIONSHIP WITH THE HAZARD ANALYSIS, THE LITERATURE SEARCH, AND CROSS REFERENCES WITH OTHER GUIDELINES.

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ISPLS GUIDELINE SAMPLE

ISPLS
CONTRACT NAS8-27692
FIRST PERFORMANCE REVIEW
CHART NO. 75 DATE 10-6-71

ISPLS GUIDELINE

NO. 6.2.1

HAZARD GROUP: 2

MISSION PHASE/EVENT: 4.0 PROPELLANT TRANSFER

APPLICABLE SUBSYSTEM/FUNCTIONS: 11. OPD PROPELLANT TANKS AND LINES

GUIDELINE TITLE: SOLID/LIQUID SEPARATION IN SLUSH

STATEMENT: A MEANS MUST BE PROVIDED TO ENSURE A UNIFORM MIXTURE OF SLUSH CRYOGENS DURING PROPELLANT TRANSFER.

REMARKS:

WHEN PROPELLANT TRANSFER IS INITIATED THE SOLID FRACTION AVAILABLE TO THE TRANSFER LINES WILL BE GREATER THAN WHEN TRANSFER IS TERMINATED UNLESS MEANS ARE PROVIDED TO KEEP THE SLUSH UNIFORMLY MIXED. COMPACTION OR BRIDGING OF THE SOLID FRACTION COULD LEAD TO RESTRICTION OR BLOCKAGE OF THE PROPELLANT FLOW.

REFERENCES: 19A, 22, 28

CROSS REFERENCES: 6.1.1, 6.3.1

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OUTLINE

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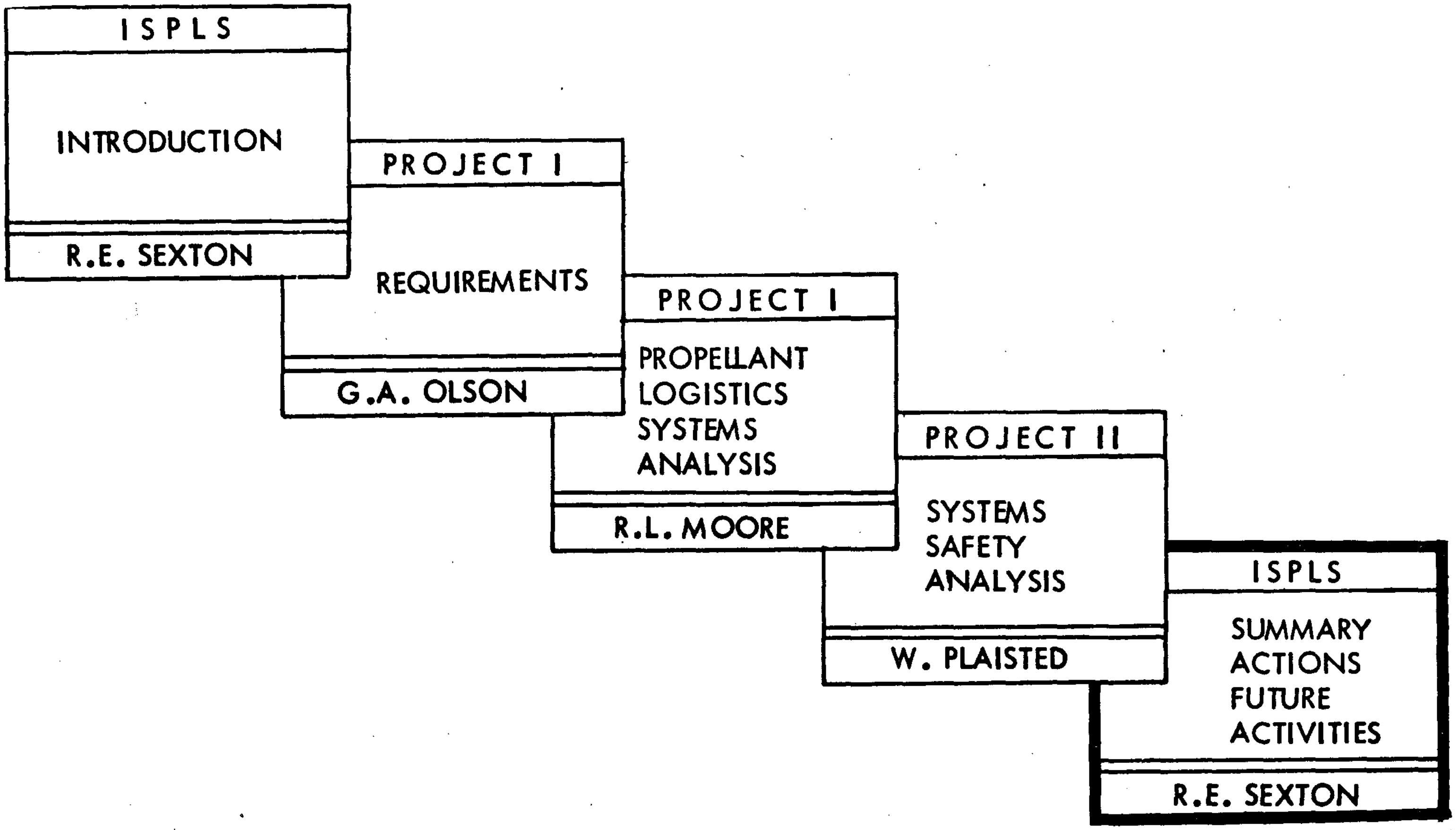
FIRST PERFORMANCE REVIEW
CHART NO. 76 DATE 10-6-71



ISPLS
FIRST QUARTER SUMMARY

THE OBSERVATIONS GIVEN ON THE CHART SUPPORT FOUR MAJOR CONCLUSIONS FROM THE WORK ACCOMPLISHED THUS FAR:

1. ORBITAL PROPELLANT LOGISTICS WILL BE A BIG BUSINESS
2. SOME LOGISTICS CONCEPTS ARE READILY PREFERABLE TO OTHERS
3. PROPELLANTS AND PAYLOADS ARE INEXTRICABLY TIED TOGETHER IN A PREFERABLE CONCEPT
4. A SINGLE LOGISTICS CONCEPT WILL NOT BE OPTIMUM FOR ALL FIVE SPACE PROGRAMS.

THESE CONCLUSIONS SUGGEST THAT THERE IS CONSIDERABLY MORE WORK YET TO BE DONE IN PROPELLANT LOGISTICS SYSTEMS AND PAYLOAD INTEGRATION.

PUROPOSE OF FIRST QUARTER REVIEW

- NR PRESENTATION OF FIRST QUARTER STATUS AND ANALYSIS RESULTS
- REQUEST FOR NASA APPROVAL OF PERFORMANCE, STATUS, AND DIRECTION OF STUDY

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FUTURE ACTIVITIES

- SYSTEMS FOR COSTING
- SPACE BASED PROPELLANT LOGISTICS SYSTEMS ANALYSIS
- TRANSPORT AND TRANSFER LOSSES INTEGRATION:
  - PROPELLANT REQUIREMENTS
  - SYSTEMS COSTS
- COST ANALYSIS OF QUANTITATIVELY DEFINED PROPELLANT LOGISTICS CONCEPTS
- IDENTIFICATION OF MAJOR SENSITIVITY FACTORS
- H_2 SLUSH ANALYSIS
- ULTIMATE GOAL IS TO DETERMINE COST EFFECTIVENESS OF
  - GROUND BASED PROGRAMS
  - SPACE BASED PROGRAMS WITH NO ORBITAL STORAGE
  - SPACE BASED PROGRAMS WITH ORBITAL STORAGE
- CONTINUE DETAILED REVIEW OF SELECTED SAFETY DOCUMENTS
- DEVELOP FUNCTIONAL FLOWS, INTERFACES, TIME LINES
- CONTINUE DEVELOPMENT OF MISSION LEVEL FMEA'S FOR PROJECT I IDENTIFIED MISSION CONCEPTS
- CONDUCT HAZARD ANALYSES (SYSTEM, OPERATIONAL, INTERFACES)
- INITIATE TRADEOFF SAFETY DATA (NOVEMBER)
- INITIATE CORRECTIVE MEASURES DEVELOPMENT (NOVEMBER)
- INITIATE GUIDELINES AND REQUIREMENTS DEVELOPMENT (DECEMBER)

FUTURE ACTIVITIES

FUTURE ACTIVITIES FOR THE NEXT PERFORMANCE PERIOD WILL INCLUDE THE FOLLOWING TASKS.

- PROPELLANTS ARE THE MAJOR SPACE PAYLOAD AND WILL SIGNIFICANTLY INFLUENCE SHUTTLE TRAFFIC MODELING
- RNS/CIS ESTABLISH A MAJOR INCREASE IN PROPELLANT REQUIREMENTS
- PAYLOAD PROPELLANT SHARING HAS BEEN SHOWN TO BE FEASIBLE FOR A GROUND BASED PROGRAM WITH PROPULSIVE STAGES
  - 43% REDUCTION IN SHUTTLE FLIGHTS
  - 32% REDUCTIONS IN PROPELLANT REQUIREMENTS
  - ADDITIONAL IMPROVEMENT POSSIBLE WITH MORE DETAILED ANALYSIS
  - MAJOR DRIVER FOR COST EFFECTIVENESS
- PAYLOAD INTEGRATION, DIRECTION AND CONTROL SHOULD BE ESTABLISHED EARLY
  - SHAPE & STRUCTURAL SUPPORT
  - PHYSICAL AND FUNCTIONAL INTERFACE
- INTEGRATED MISSION PLANNING SHOULD BE INITIATED EARLY
- OMS PROPELLANTS REPRESENT A 4.2 $\bar{M}$ LBS SHUTTLE PENALTY IF NOT USED IN SPACE
- UNUSED CARGO SPACE IN NON-PPS RELATED SHUTTLE LAUNCHES PROVIDES OPPORTUNITY FOR IN-SPACE SUPPLY OF 4.8 $\bar{M}$ LBS OF PROPELLANTS
- EFFICIENT UTILIZATION OF SHUTTLE CAPABILITY BY PROPELLANT SHARING OF CARGO SPACE REQUIRES IN-SPACE TRANSFER AND STORAGE
- UTILIZATION OF SUPPLEMENTARY PROPELLANTS MAY BE A STRONG DRIVER IN DETERMINING COST EFFECTIVENESS OF ORBITAL STORAGE
- RESULTS TO DATE APPEAR TO BE SENSITIVE TO SHUTTLE CAPABILITY, PAYLOADS AND PAYLOAD PROPULSIVE STAGE SIZES