(NASA-CR-179088) STORABLE SPACE TUG SYSTEMS STUDY REQUIREMENTS ASSESSMENT M16 (Grumman Aerospace Corp.) 174 p Avail: NTIS

N87-70384

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REPORT No. B80-RP-95-73-002

STORABLE SPACE TUG SYSTEMS STUDY

REQUIREMENTS ASSESSMENT MTG

12 APRIL 1973

CONTRACT NAS8-29674

PREPARED FOR

GEORGE C. MARSHALL SPACE FLIGHT CENTER

BY

GRUMMAN AEROSPACE CORPORATION

BETHPAGE, NEW YORK 11714

STORABLE SPACE TUG SYSTEMS STUDY

REQUIREMENTS ASSESSMENT MEETING

12 APRIL 1973

CONTRACT NAS 8-29674

RPT. NO. B80-RP-95-73-002

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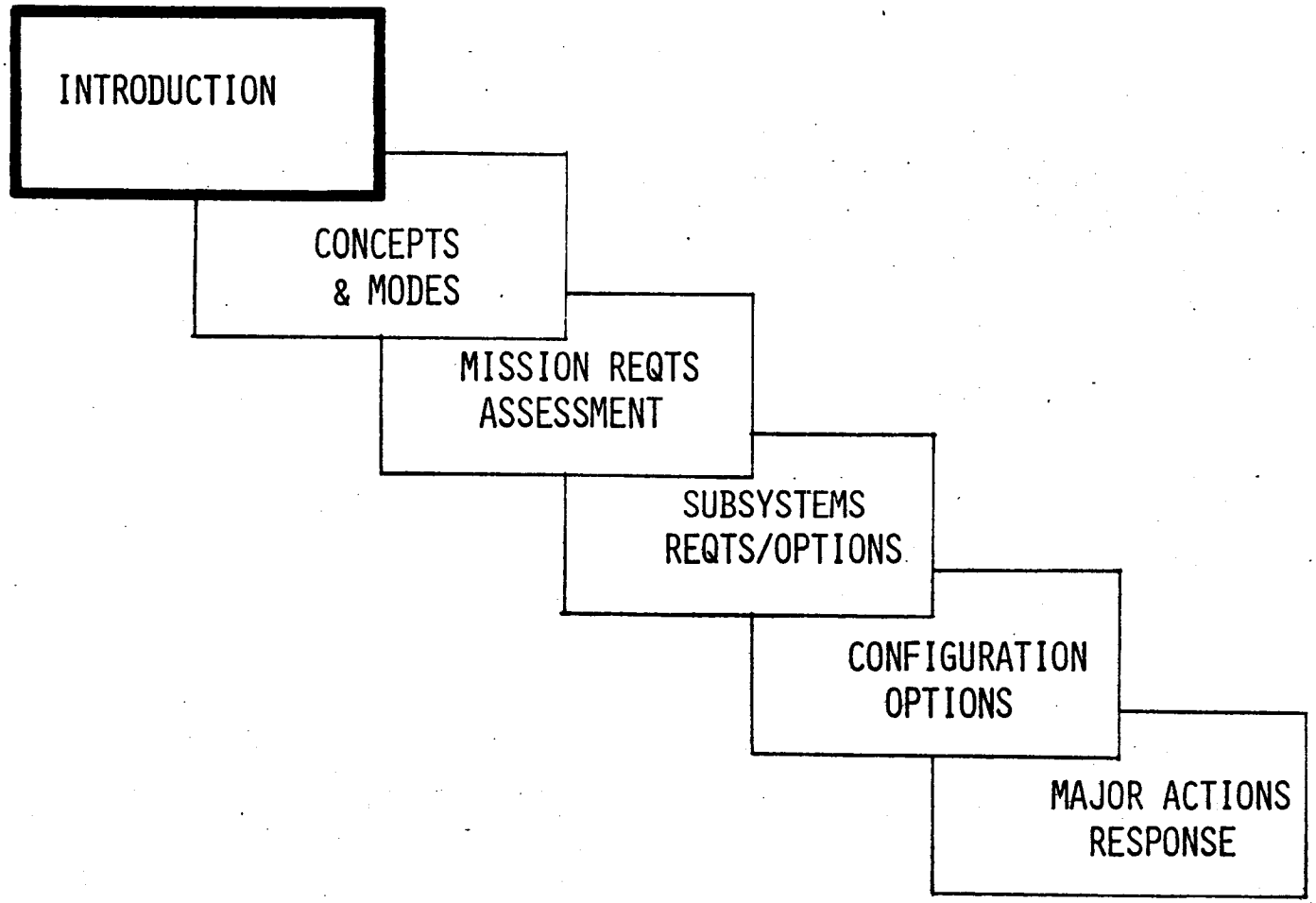
OUTLINE



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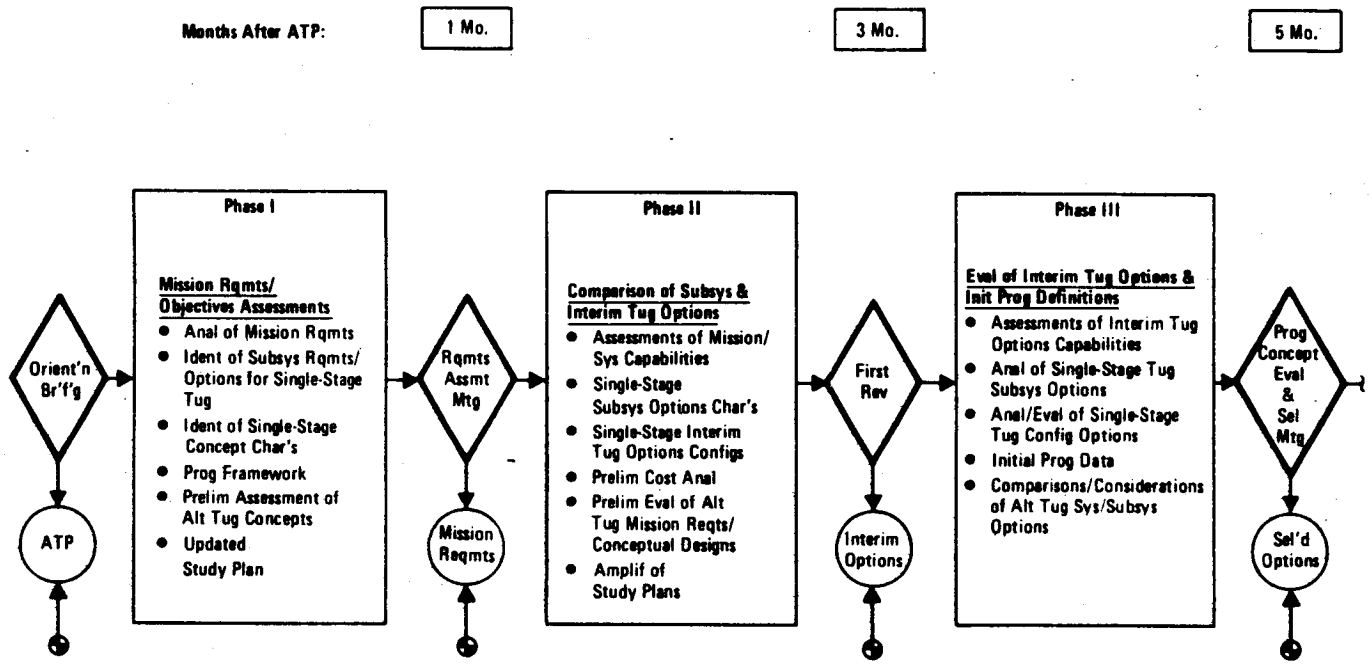
STUDY PLAN – PHASING SEQUENCE



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SPACE TUG STUDY ORGANIZATION

SPACE PROGRAMS
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VICE PRESIDENT
F. RAYMES, DEPUTY

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SPACE TUG
R. M. WATSON
STUDY MANAGER
G. SMITH, DEPUTY

MISSION ANALYSIS	SUBSYSTEMS ANALYSES	CONFIGURATIONS & SUPPORT SYSTEMS	PROGRAMMATIC & COST ANALYSES	PROGRAM DEFINITIONS
TASK 5.1	TASK 5.2	TASK 5.3	TASK 5.4	TASK 5.5
A. NATHAN	M. DANDRIDGE	C. GOODWIN	R. McCAFFREY	G. SMITH
• CHARACTERISTICS & REQUIREMENTS/ OBJECTIVES • MISSION ACCOMPLISHMENT	• FUNCTIONAL REQUIREMENTS • CAPABILITY & EVOLUTION • TECHNOLOGY REQUIREMENTS • SUBSYSTEM & COMPONENT COMPATIBILITY • REFURBISHMENT & REUSE TECHNIQUES • CHECKOUT & OPERATIONS	• CAPABILITY & COMPONENT MATCHING • OPERATIONS, EQUIPMENT & INTERFACE DEFINITION • CONFIGURATION DESIGN ANALYSES & DEFINITION	• PROJECT SCHEDULES • FACILITIES • LOGISTIC SUPPORT • COST • PROJECT ASSESSMENT	• DETAILED PROGRAM DEFINITIONS • SENSITIVITY ANALYSIS • PROGRAM DATA COMPILATION

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GRUMMAN PERSONNEL - DISCIPLINE PANELS

SYSTEMS ENGINEERING

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B.FRUMKIN-REL./MAINT.
H.WOLF - SAFETY
R. EBERL - WEIGHTS

SHUTTLE INTERFACE

R. PRATT*

PROPULSION

L. DEUTSCH*
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MISSION/PL/USER RQMTS & INT.

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A. ALBERI*
A. MENDELSOHN

ASTRIONICS

R. TELLALIAN* - G&N
L. OTTENBERG - COMM.
T. NEWMAN - DATA MGMT
H. DUBOVY - POWER

* GRUMMAN CHAIRMEN/
CO-CHAIRMEN

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SUMMARY STATUS

MAJOR ACTIVITIES - ATP THROUGH REQUIREMENTS ASSESSMENT

- MISSION ANALYSIS - TRAFFIC MODEL/REF. MISSION ASSESSMENT
- SUBSYSTEM ANALYSIS - REQUIREMENTS/OPTIONS
- CONFIGURATION CONCEPTS/MODES - DEFINITION
- STUDY PLAN - UP DATED
- REQUIREMENTS DOCUMENTATION - ASSESSMENT AND COMMENT
- PROGRAMMATICS AND COST - WBS AND WBS DICTIONARY

MAJOR ACTIVITIES PLANNED - THROUGH FIRST REVIEW

- MISSION ANALYSIS - COMPLETE REQTS, ALLOC, CONCEPT PERF COMPAR, SYST. TRADES
- SUBSYSTEM ANALYSIS - SUBSYST. OPTIONS: SCHEMATICS, COST/WT/REL.,DRIVER TRADES
- CONFIG/SUPPT SYST ANAL - DEF. & PRELIM ANAL OF CONCEPT DESIGNS, SUPPT SYST ANAL
- PROGRAMMATICS & COST - SUBST OPT. COSTS/SCHEDS,PRELIM CONCEPT COSTS/TRADES
- PROGRAM DEFINITIONS - PROG. DEF. METHODOLOGY AND FORMATS, FINAL REPORT OUTLINE

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REQUIREMENTS ASSESSMENT OVERVIEW

- o REQUIREMENTS SOURCE INDEX
- o REQUIREMENTS COMPILATION METHODOLOGY
- o PROGRAM & MISSION REQUIREMENTS OVERVIEW
- o TIME-PHASING OF REQUIREMENTS

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REQUIREMENTS SOURCE INDEX

CONTRACTUAL

- DATA PACKAGE - TUG SYSTEMS STUDY, APRIL 1973
- ANNEX A, DOD MISSION DESCRIPTIONS, FEBRUARY 1973
- DOD MISSION MODEL FOR STS, REVISED AUGUST 1971
- NETWORK INTEGRATION STUDY, JUNE 1972
- AFSCF SYSTEM PLANNING INFORMATION, OCTOBER 1970
- SHUTTLE PAYLOAD ACCOMMODATIONS, MARCH 1973
- SHUTTLE FLIGHT AND GROUND SYSTEMS SPEC, MARCH 1973
- TMX-64713, NATURAL ENVIRONMENT DESIGN REQUIREMENTS, JANUARY 1973
- TMX-64627, SPACE AND PLANETARY ENVIRONMENT CRITERIA, 1971 REV.
- MSFC HDBK-505, STRUCTURAL DESIGN AND VERIFICATION RQMTS., JUNE 1971
- STORABLE TUG SYSTEMS STUDY SOW, NOVEMBER 1972
- AIR FORCE AFSCP 800-3, A GUIDE FOR PROGRAM MANAGEMENT, MAY 1971
- NASA NHB 7121.4, GUIDELINES FOR PROJECT PLANNING, JULY 1972

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REQUIREMENTS SOURCE INDEX (CONT.)

REFERENCES

- o TOPSS
- o SOAR II
- o TUG LAUNCH SITE SERVICE INTERFACE STUDY
- o MSFC BASELINE TUG DEFINITION DOCUMENT, JUNE 1972
- o OOS DEFINITION DOCUMENT PLUS ADDENDUM, FEBRUARY 1973
- o MSC IN-HOUSE STUDY REPORT, JANUARY 1973
- o AFSCF SPACE/GROUND INTERFACE
- o SAFETY IN EARTH ORBIT (CONTRACT NAS 9-12004)
- o IN-SPACE PROPELLANT SYSTEM SAFETY (CONTRACT NAS 8-27692)
- o R. M. PARSONS REPORT, MARCH 1972
- o KSC OPS AND CHECKOUT PLAN FOR PAYLOAD CARRIERS, DECEMBER 1972
- o TECH REPORTS ON SHUTTLE FROM DE/KSC

- * STDN SPEC AND USERS GUIDE
- * SGLS SPEC AND USERS GUIDE

* DATA REQUIRED

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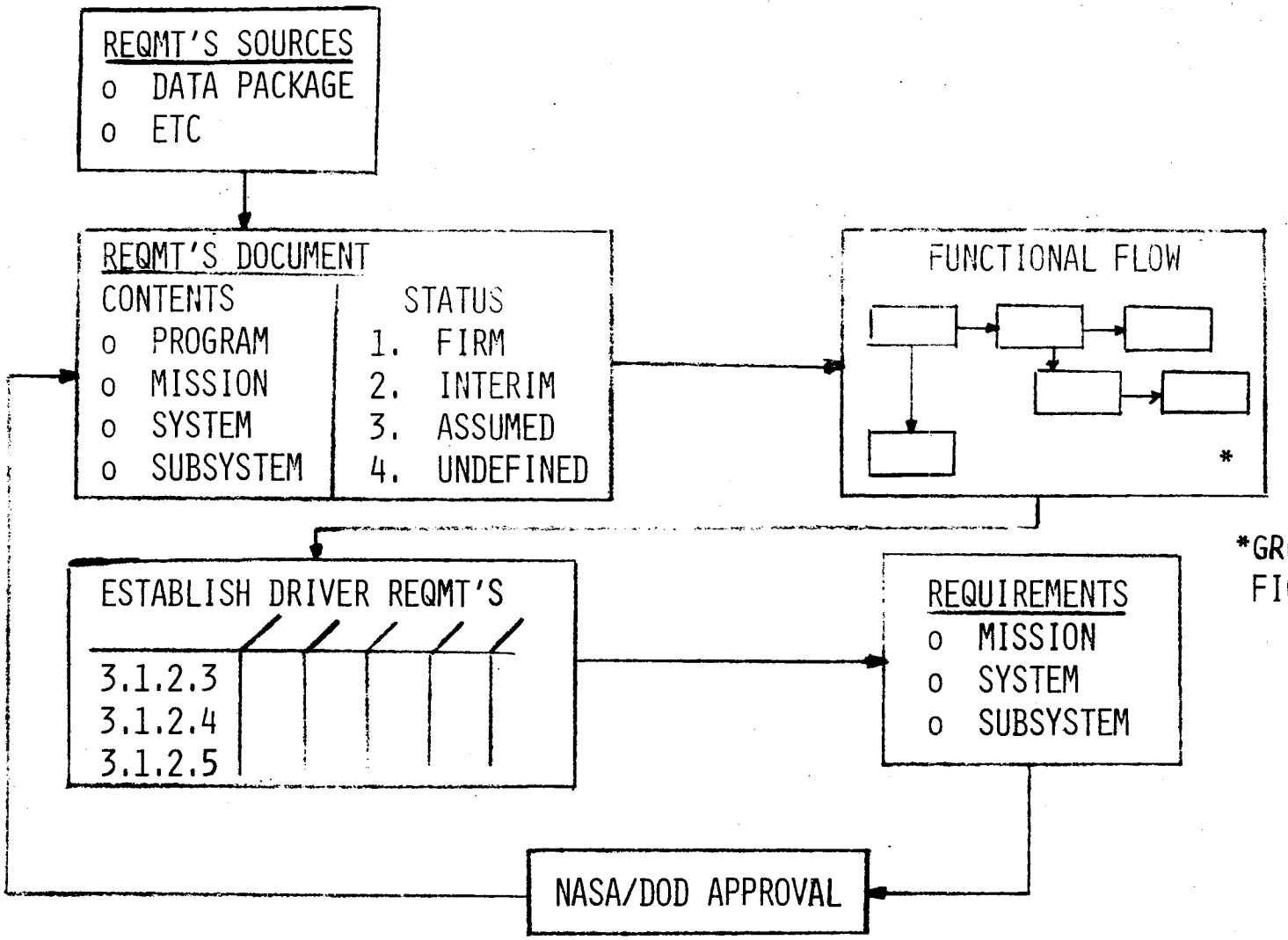
REQUIREMENTS SOURCE INDEX

The two viewgraphs identify the documents being utilized as a source of programmatic and technical requirements.

The contractual documents consist of the updated Data Package, the storable Space Tug Statement of Work, and their referenced documents. The other references consist of government and contractor documents which are related to the Space Tug Systems Study.

The purpose of presenting this requirements source index is two-fold: First, to provide the government with visibility as to our sources of Tug-related requirements; and, Second, to solicit suggestions on any additional data that should be brought to our attention or comments on the validity of the data in some of the references listed.

REQUIREMENTS COMPILATION METHODOLOGY



*GRUMMAN PROPOSAL
FIG. NO. 1.5.1-6

REQUIREMENTS COMPILATION METHODOLOGY

We have generated a Requirements Document which will be the source reference for all program, mission, system and subsystem requirements during the conduct of this study. Each requirement is assigned a status (1 through 4) and its source is documented. Government approved requirements are assigned a status of either 1 or 2, depending on the progress of related trade studies. All requirements specified in the Data Package were assigned a status of 1 or 2. Other specified requirements are assigned a status of 3, subject to government approval, and undefined requirements (i.e., TBD's) are assigned a status of 4.

A functional analysis is being performed to systematically establish the Tug "driver" requirements and form the basis for requirements allocation at the subsystem level. This also provides traceability of requirements to the mission functional flow. Requirements, as they are generated, are incorporated in the Requirements Document with their status subject to government approval.

It is our objective to provide a Tug Requirements Document at the conclusion of this study with most requirements having a status of 1.

A preliminary draft of the Requirements Document is available for government review.

PROGRAM REQUIREMENTS

- SPACE TUG WILL BE REUSABLE
- REUSABLE TUG UTILIZES EARTH STORABLE MAIN PROP
- TUG DESIGNED AS UNMANNED VEHICLE; CONSISTENT WITH SAFETY IMPLICATIONS OF OPERATING IN VICINITY OF MANNED ORBITER
- TOTAL WT OF TUG, PAYLOAD & INSTALLATION HDWRE $\leq$ 65K LBS
- TUG (PLUS PAYLOAD) SHALL BE DIMENSIONALLY COMPATIBLE WITH 15′ x 60′ ORBITER CARGO BAY CLEAR VOLUME INCLUDING STRUCTURAL DEFLECTIONS AND THERMAL DISTORTION
- NO PROPELLANT SHARING BETWEEN TUG/SHUTTLE OR TUG/PAYLOAD
- MINIMUM MISSION COMPLETION RELIABILITY IS 0.97
- TUG PORTION OF SAFE RETURN PROBABILITY $>$ 0.999
- 0.995 PROBABILITY/MISSION OF NO FAILURE DUE TO METEOROID PENETRATION

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MISSION REQUIREMENTS

- o REUSABLE SPACE TUG MAY BE MULTISTAGED; CAN INCLUDE EXPENDABLE ELEMENTS (TANKS, KICK STAGES)
- o REUSABLE TUG MAY BE USED IN EXPENDABLE MODE
- o TUG MISSION MODES ARE:
  - PAYLOAD DEPLOYMENT, INCLUDING PLANETARY (MINIMUM REQUIREMENT FOR INTERIM TUG)
  - MULTIPLE PAYLOAD DEPLOYMENT
  - PAYLOAD RETRIEVAL
  - PAYLOAD DELIVERY AND RETRIEVAL
  - SORTIE OPERATIONS
  - PAYLOAD SERVICING
- o TUG SIZED TO MAXIMIZE RETRIEVAL CAPABILITY (ASSUMED TUG SEPARATION WEIGHT IS 64,020 LB).

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MISSION REQUIREMENTS (CONT.)

- NOMINAL TUG DEPLOYMENT ORBIT IS 150 N. MI.
- ORBITER IS ACTIVE VEHICLE DURING ORBITER TUG TERMINAL RENDEZVOUS AND DOCKING
- TUG IS DESIGNED TO BE IN UNPOWERED CONDITION DURING SHUTTLE ASCENT AND DESCENT EXCEPT FOR SAFETY MONITOR AND THERMAL REQUIREMENTS
- TUG WILL ASSURE SAFE OPERATION WHILE PASSIVELY CONTAINED IN ORBITER CARGO BAY
- TUG WILL BE COMPATIBLE WITH ALL SHUTTLE ABORT MODES AND PROCEDURES
- TUG WILL BE CAPABLE OF SECURE COMMUNICATIONS
- TUG DESIGN GOAL IS TO ATTAIN A HIGH LEVEL OF AUTONOMOUS OPERATION.

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MISSION REQUIREMENTS (CONT.)

- TUG WILL BE CAPABLE OF LAUNCH FROM READY STANDBY WITHIN TWO HOURS
- TUG WILL BE CAPABLE OF ACCEPTING CHANGES IN MISSION ASSIGNMENT, TARGET OR PAYLOAD EPHEMERIS UP TO WITHIN TWO HOURS OF LAUNCH
- TUG, WITH OR WITHOUT PAYLOAD ATTACHED, WILL BE CAPABLE OF BEING REMOVED AND INSERTED WHEN THE ORBITER IS IN A VERTICAL OR HORIZONTAL POSITION
- TUG (AND PAYLOAD) WILL BE CAPABLE OF BEING REMOVED, REPLACED AND RETURNED TO A STANDBY STATUS WITHIN TEN HOURS.

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PROGRAM AND MISSION REQUIREMENTS

A summary of the storable Space Tug program and mission requirements is shown on the previous charts.

In general, program requirements are those which will be inviolate during this study in that no analyses are anticipated that would result in their changing. The mission requirements are presently all firm or interim (Status 1 or 2) requirements, but analyses/tradeoffs will be performed during this study which may result in either further clarification and/or modifications to some of these requirements.

TIME-PHASED REQUIREMENTS

INTERIM TUG

1. INTERIM TUG 10C - DEC. 1979 TO DEC. 1981

2. ORBITAL LIFE TIME (ASSUMED): 1 DAY IN ORBITER CARGO BAY
   3 DAYS FREE-FLIGHT

3. NOT APPLICABLE

4. PHYSICAL ENVELOPE AND MECHANICAL INTERFACES BETWEEN INTERIM AND EVOLVED TUGS ARE INTENDED TO BE THE SAME

5. CAPABLE OF DEPLOYING CURRENT DESIGN PAYLOADS (APPENDIX A) AND RETURNING TO SHUTTLE WITHOUT PAYLOAD: DELIVERY TO GEOSYNCHRONOUS ORBIT CAN BE AT ANY LONGITUDE

6. NOT SPECIFIED - (CAPABILITY: TBD)

7. NOT APPLICABLE

8. NOT APPLICABLE

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TIME-PHASED REQUIREMENTS

COMMENTS

1. IOC'S OF GROWTH TUGS DETERMINED BY ANALYSES/TRADEOFFS
2. DRIVEN FIRST BY MULTIPLE DEPLOYMENT MISSIONS AND FINALLY BY DEPLOY & RETRIEVE AND/OR MULTIPLE SERVICING MISSIONS
3. ASSUMED GOAL FOR GROWTH VERSION
4. USE OF INTERIM MAIN ENGINES AFFECTS OVERALL TUG LENGTH
5. AVAILABILITY OF LOW COST PAYLOADS OPEN
6. DEPENDENT ON TUG PERFORMANCE CAPABILITY AND ORBITAL LIFETIME
7. AVAILABILITY OF LOW COST PAYLOADS OPEN
8. SAME AS ABOVE

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TIME-PHASED REQUIREMENTS

GROWTH AND DIRECT DEVELOPED TUG

1. DIRECT DEVELOPED TUG IOC - DEC. 1983

2. ORBITAL LIFETIME: 1 DAY IN ORBITER CARGO BAY
   6 DAYS FREE-FLIGHT

3. TUG DESIGN SHALL NOT PRECLUDE EXTENDING MISSION DURATION TO 30 DAYS (DIRECT DEVELOPED TUG ONLY)

4. NOT APPLICABLE

5. SAME DEPLOYMENT REQUIREMENTS FOR LOW COST DESIGN PAYLOADS (APPENDIX A)

6. CAPABLE OF DEPLOYING MULTIPLE PAYLOADS ($\leq$ 3)

7. CAPABLE OF RETRIEVING LOW COST DESIGN PAYLOADS; TUG IS ACTIVE ELEMENT DURING RENDEZVOUS AND DOCKING WITH PAYLOAD THAT IS 3-AXIS OR SPIN STABILIZED

8. CAPABLE OF DEPLOYING ONE PAYLOAD AND RETRIEVING ANOTHER ON A SINGLE MISSION

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TIME-PHASED REQUIREMENTS (CONT.)

INTERIM TUG

9. NOT APPLICABLE

10. DESIGN TO BE REUSED

11. MINIMUM MAINTENANCE/GROUND TURNAROUND IS A DESIGN OBJECTIVE

12. NOT REQUIRED

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TIME-PHASED REQUIREMENTS (CONT.)

COMMENTS

9. ASSUMED GOAL FOR GROWTH VERSION. AVAILABILITY OF LOW COST PAYLOADS OPEN

10. GOAL OF 20 MISSIONS FOR GROWTH VERSION ASSUMED.

11. GOAL OF TWO WEEK TURNAROUND FOR GROWTH VERSION ASSUMED.

12. ASSUMED GOAL FOR GROWTH VERSION. KICK STAGE CONFIGURATIONS REQUIRE DISCUSSION.

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TIME-PHASED REQUIREMENTS (CONT.)

GROWTH AND DIRECT DEVELOPED TUG

9. PROVIDE CAPABILITY OF SERVICING PAYLOADS ON STATION (DIRECT DEVELOPED TUG ONLY)

10. DESIGN TO MINIMUM LIFE OF 20 MISSIONS WITH A DESIGN GOAL OF 100 MISSIONS (DIRECT DEVELOPED TUG ONLY.)

11. MINIMIZE MAINTENANCE AND INSPECTION OF SYSTEMS NOMINAL MAINTENANCE/REFURBISHMENT TIME OF TWO WEEKS (DIRECT DEVELOPED TUG ONLY).

12. CAPABLE OF MONITORING AND COMMANDING THE PAYLOAD WHEN THE PAYLOAD IS ATTACHED OR IN VICINITY OF TUG (DIRECT DEVELOPED TUG ONLY).

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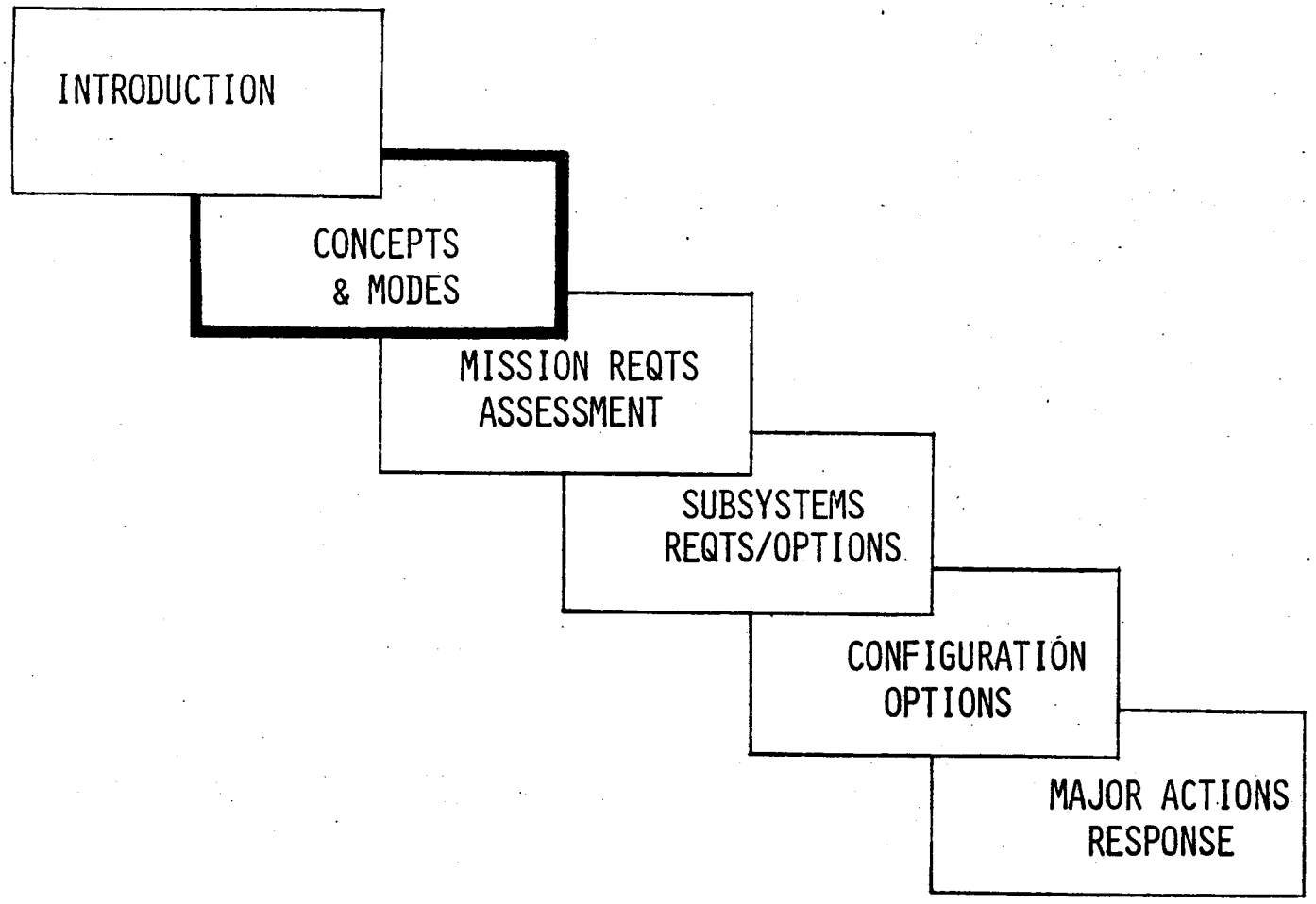
TIME-PHASED REQUIREMENTS

The previous charts list some of the mission/system level requirements/goals for the direct developed Tug and the growth version of the interim Tug, and the comparable minimum requirements for the interim Tug.

The "Comment" charts provide a judgement value, based on preliminary analyses, as to the "drivers" which are important in establishing the time-phasing of introducing the growth requirements/goals into the evolutionary Tug program.

One factor which strongly influences time-phasing of requirements is the timing of the introduction of the low-cost payloads which are capable of retrieval and/or servicing.

OUTLINE



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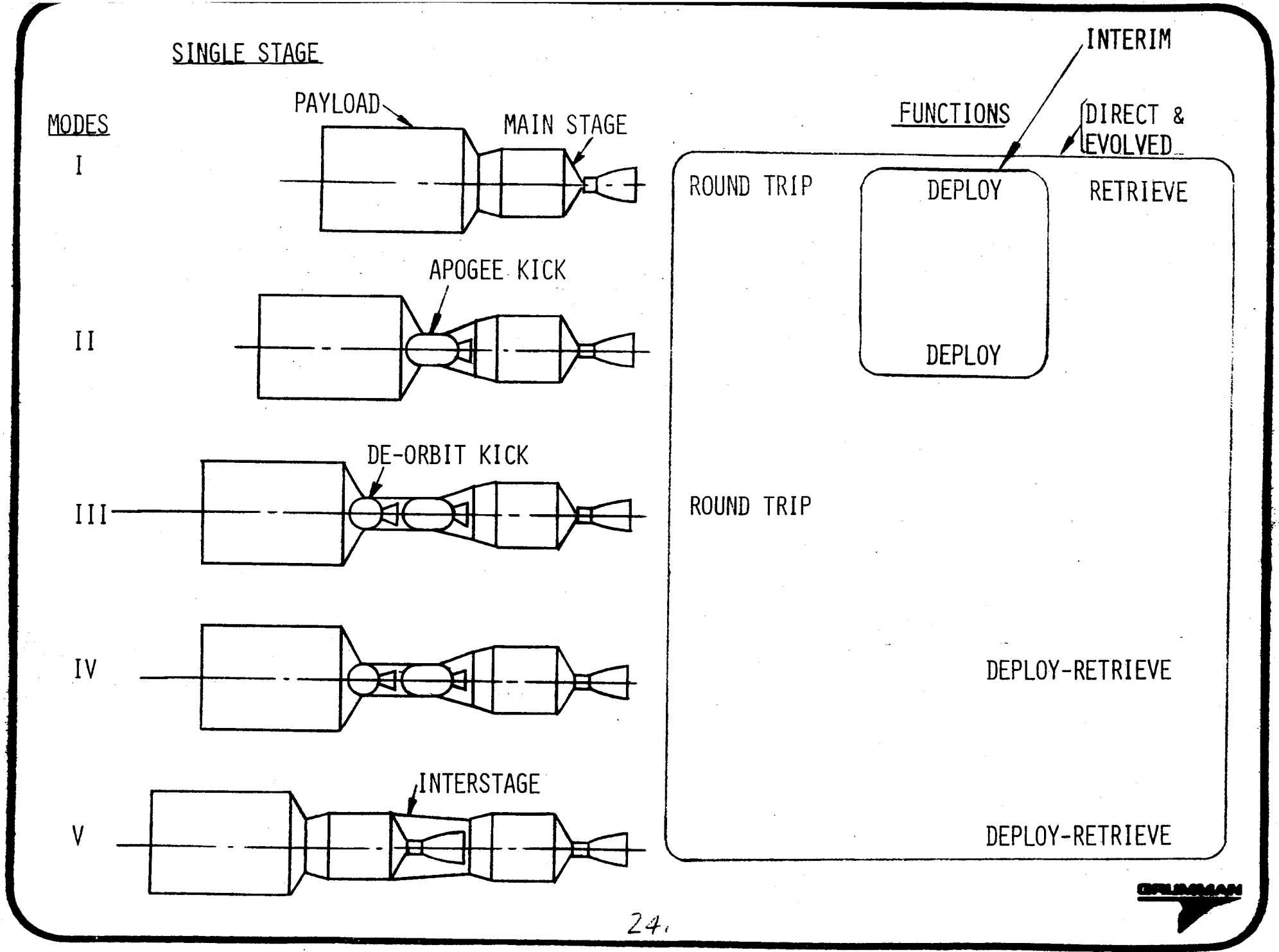
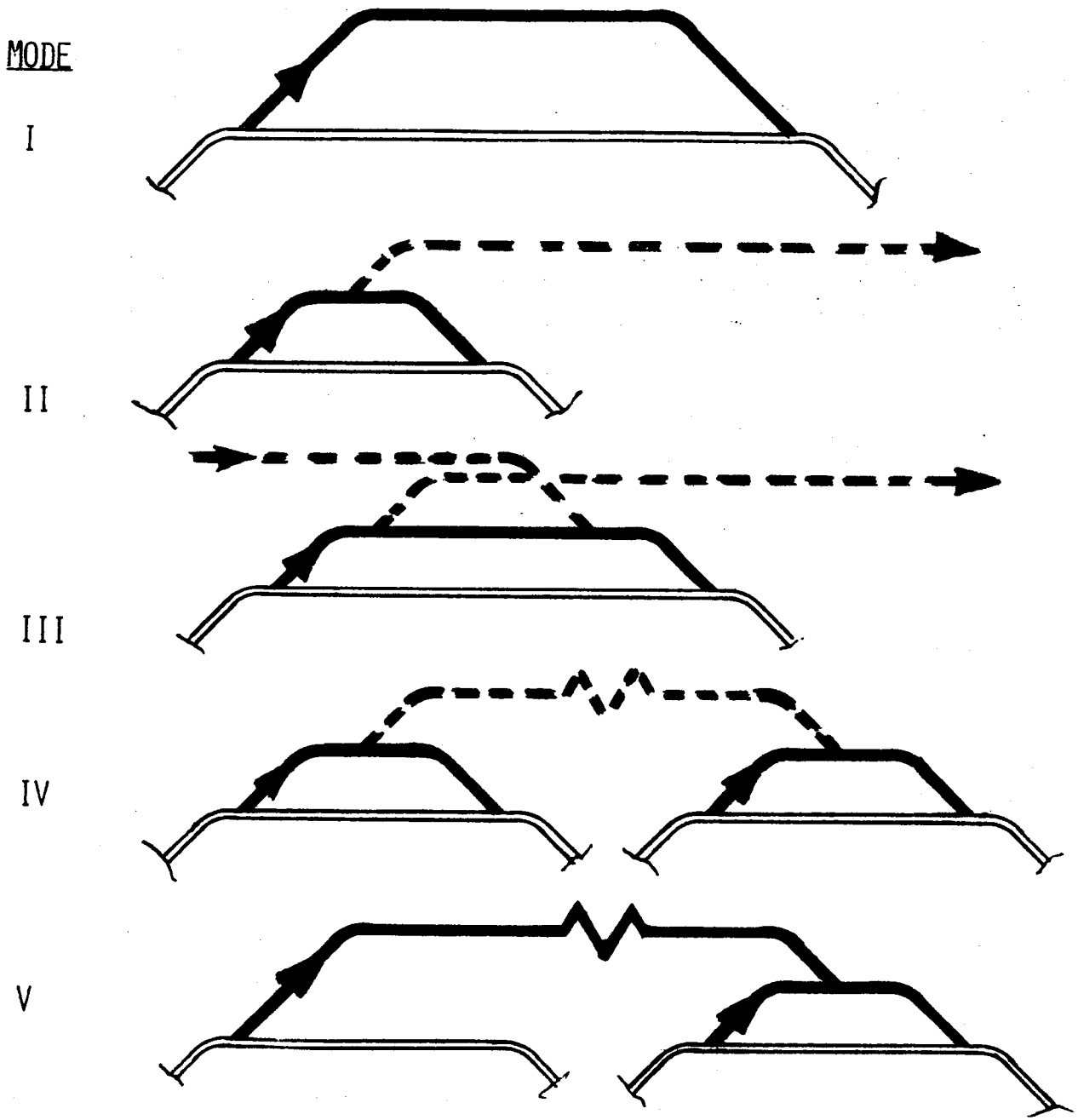

SINGLE STAGE
MODES
I
II
III
IV
V
PAYLOAD
MAIN STAGE
APOGEE KICK
DE-ORBIT KICK
INTERSTAGE
FUNCTIONS
INTERIM
DIRECT & EVOLVED
ROUND TRIP
DEPLOY
RETRIEVE
DEPLOY
ROUND TRIP
DEPLOY-RETRIEVE
DEPLOY-RETRIEVE

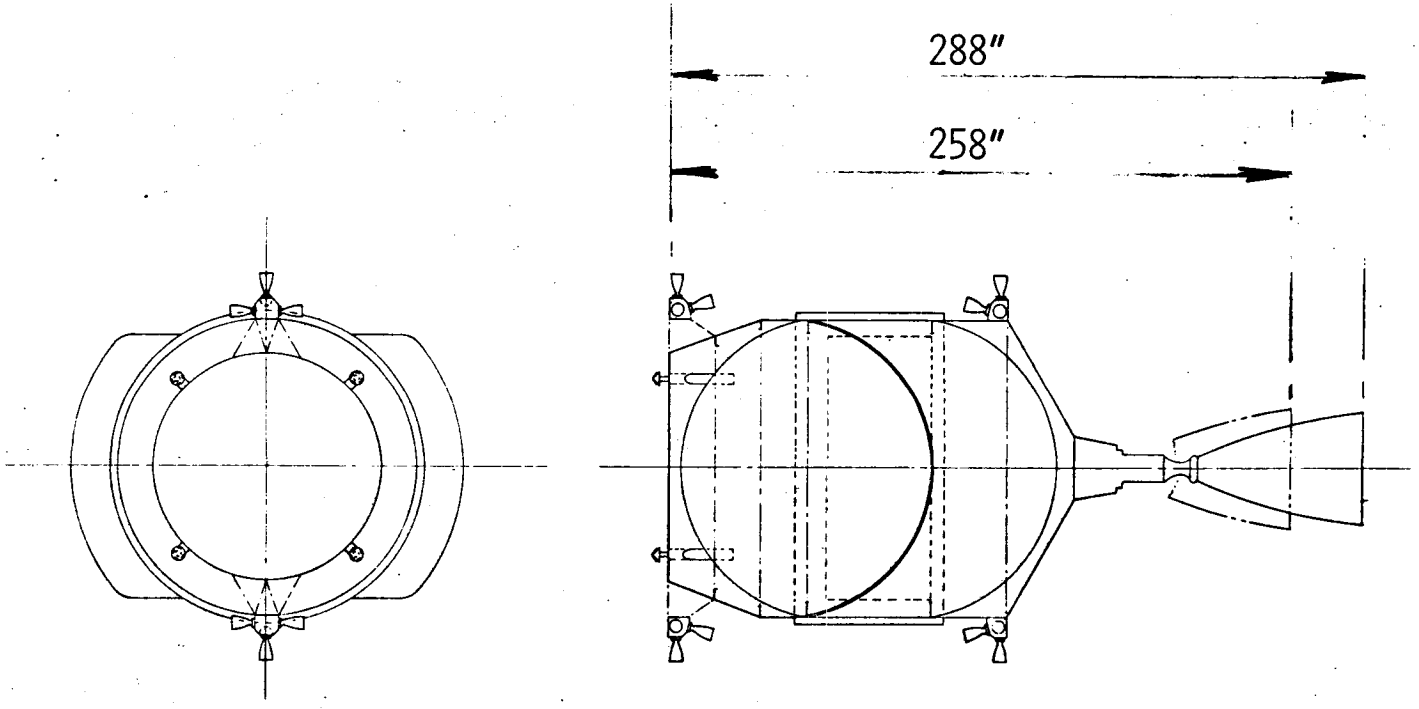
SINGLE STAGE MODES



LEGEND

- TUG
- P.L.+KICK STAGE
- ORBITER

SINGLE STAGE BASE



MAIN ENGINE - INTERIM = UPRATED AGENA 8096

- EVOLVED = NEW, F = 10,000 LB.

PROPELLANT CAPACITY - FUEL = 19,857 LB.

- OX = 39,714 LB.

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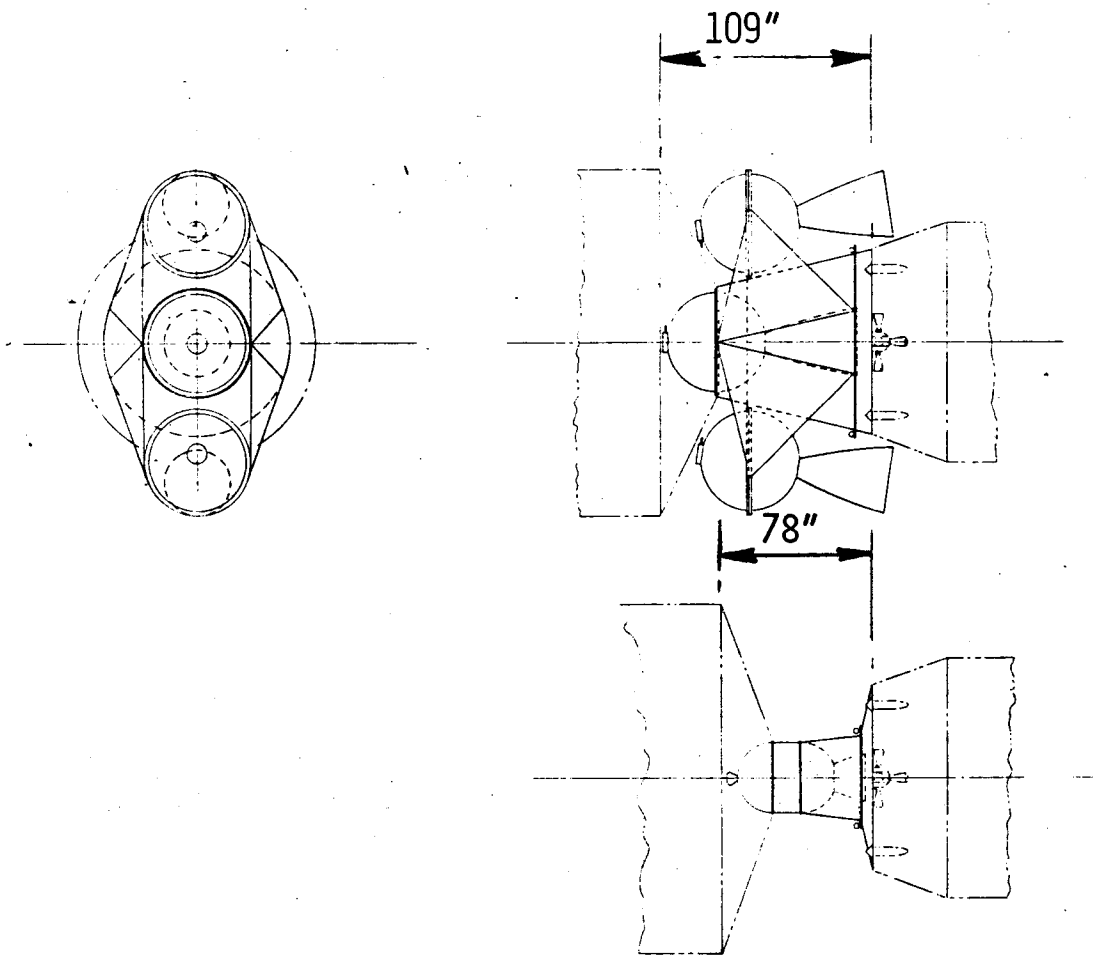
KICK STAGES - SINGLE STAGE BASE



NEW DESIGN

2 APOGEE MOTORS
WT. = 4325 LB. EACH
1 DE-ORBIT MOTOR
WT. = 4620 LB.

EXISTING DESIGN

ONE APOGEE MOTOR
TE 364-4
WT = 2478 LB.

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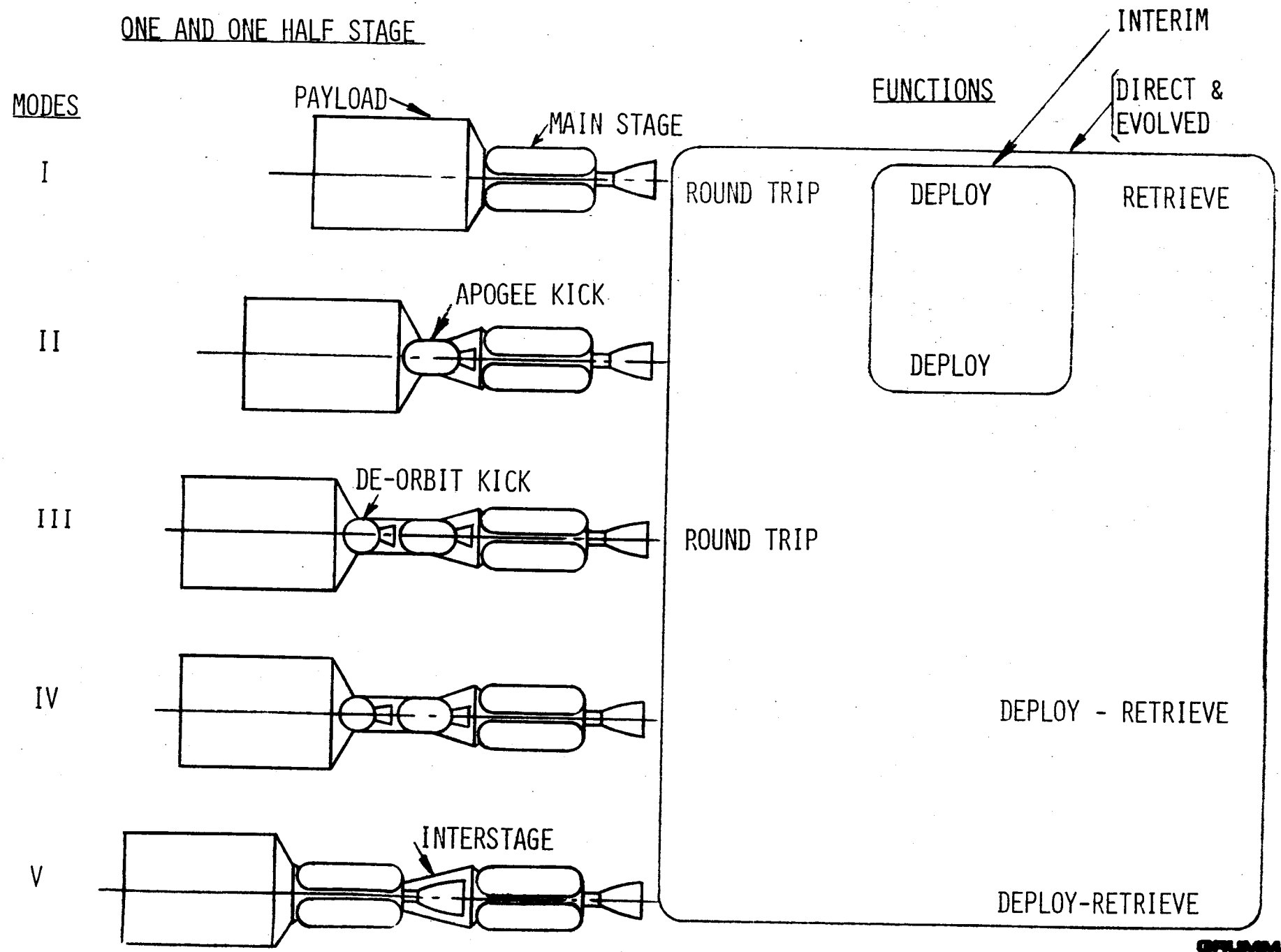
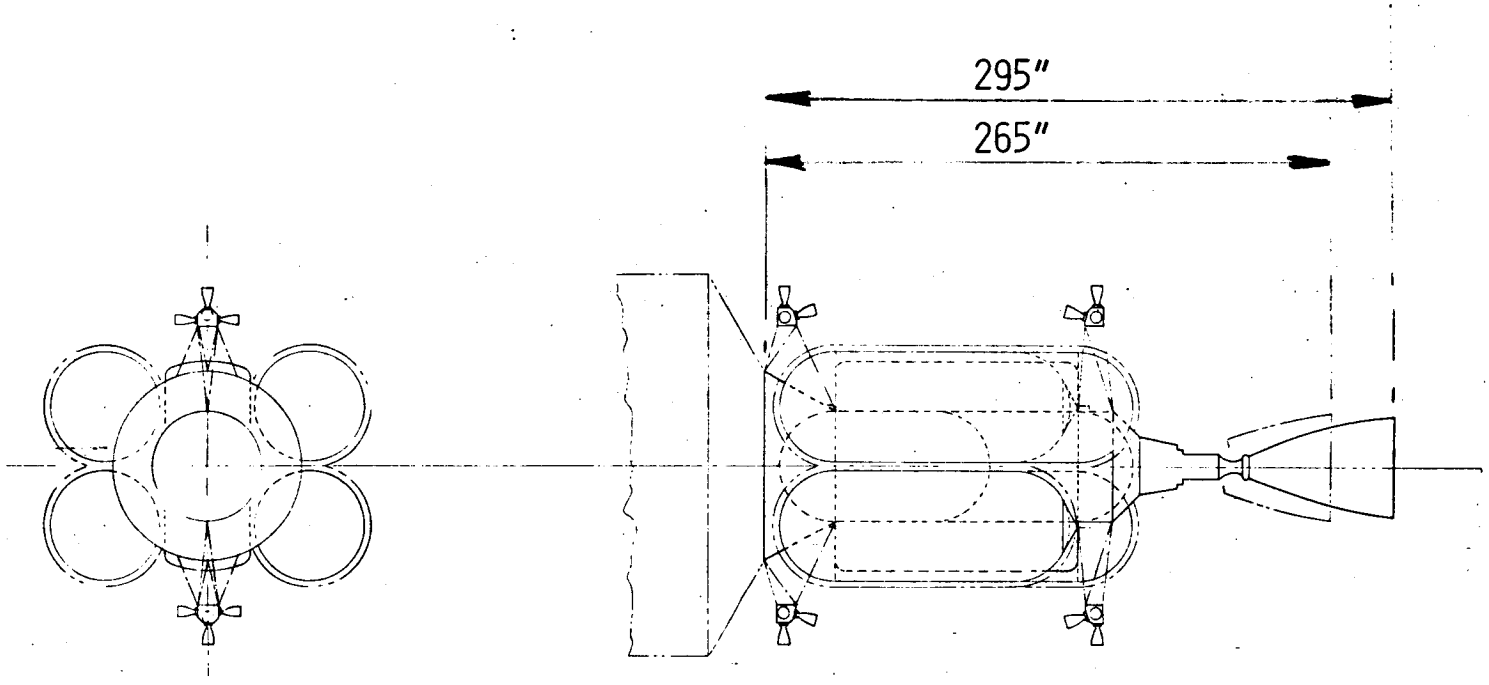

ONE AND ONE HALF STAGE
MODES
FUNCTIONS
INTERIM
DIRECT & EVOLVED
I
PAYLOAD
MAIN STAGE
ROUND TRIP
DEPLOY
RETRIEVE
II
APOGEE KICK
DEPLOY
III
DE-ORBIT KICK
ROUND TRIP
IV
DEPLOY - RETRIEVE
V
INTERSTAGE
DEPLOY-RETRIEVE

ONE AND ONE HALF STAGE BASE



MAIN ENGINE - INTERIM = UPRATED AGENA 8096

- EVOLVED = NEW F = 10,000 LB.

PROPELLANT CAPACITIES - MAIN STAGE - FUEL = 4,400 LB.

OX = 8,800 LB.

DROP TANKS - FUEL = 15,600 LB.

OX = 31,200 LB.

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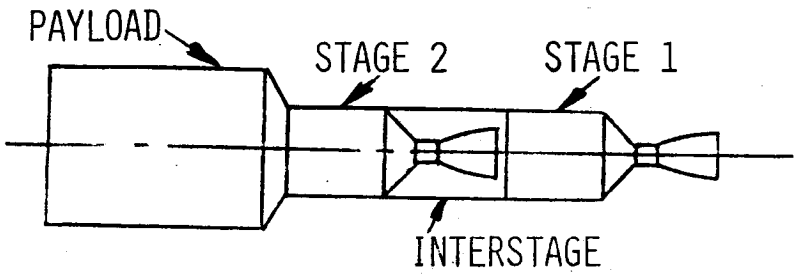
TWO STAGE

MODES

SLING SHOT

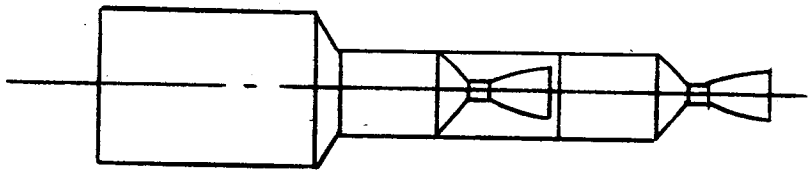


FUNCTIONS

ROUND TRIP DEPLOY RETRIEVE

INTERIM

LADDER

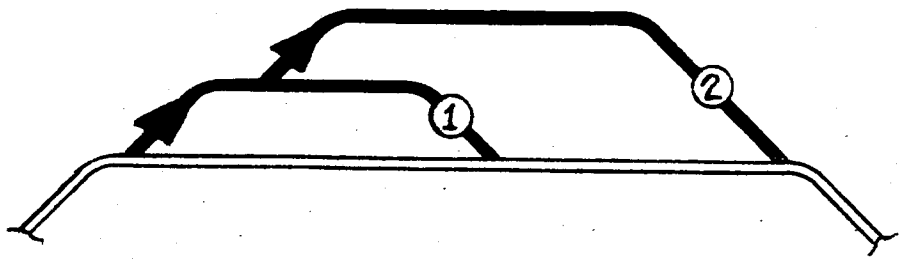


DIRECT & EVOLVED

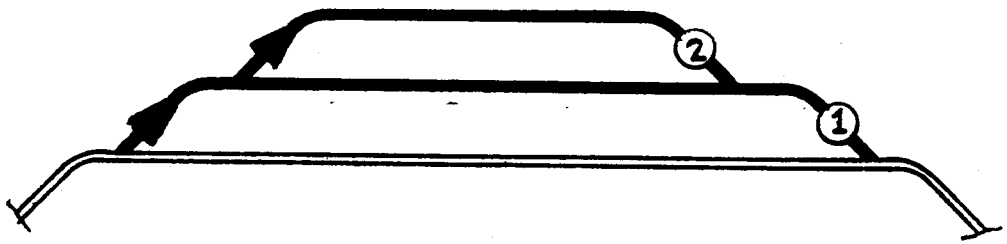
ROUND TRIP DEPLOY RETRIEVE

TWO STAGE MODES

MODE
SLING
SHOT



LADDER



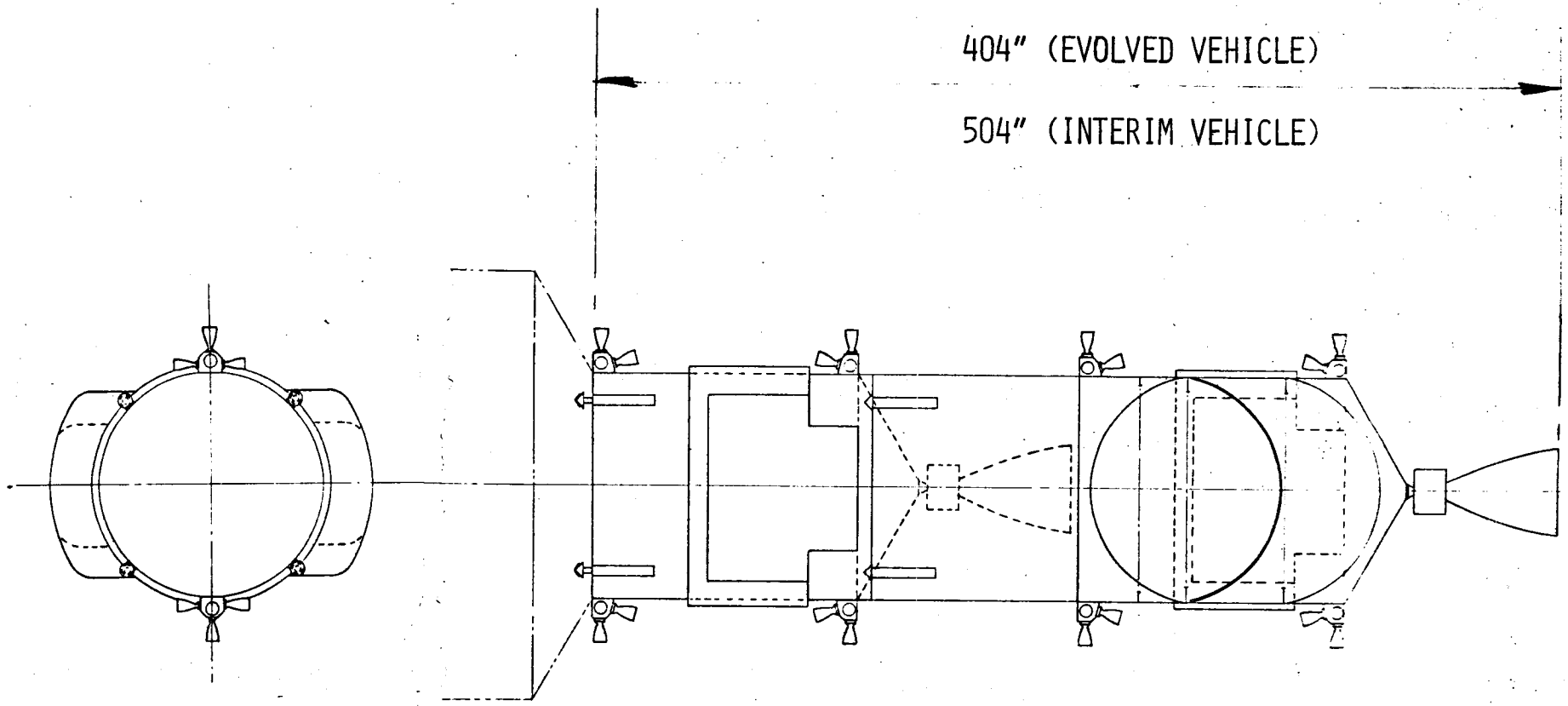
LEGEND

TUG

P.L.+KICK STAGE

ORBITER

TWO STAGE BASE



MAIN ENGINES - INTERIM = UPRATED AGENA 8096

EVOLVED = NEW, F = 8,000 LB.

PROPELLANT CAPACITY - FUEL = 9,300 LB. PER STAGE

OX = 18,600 LB PER STAGE

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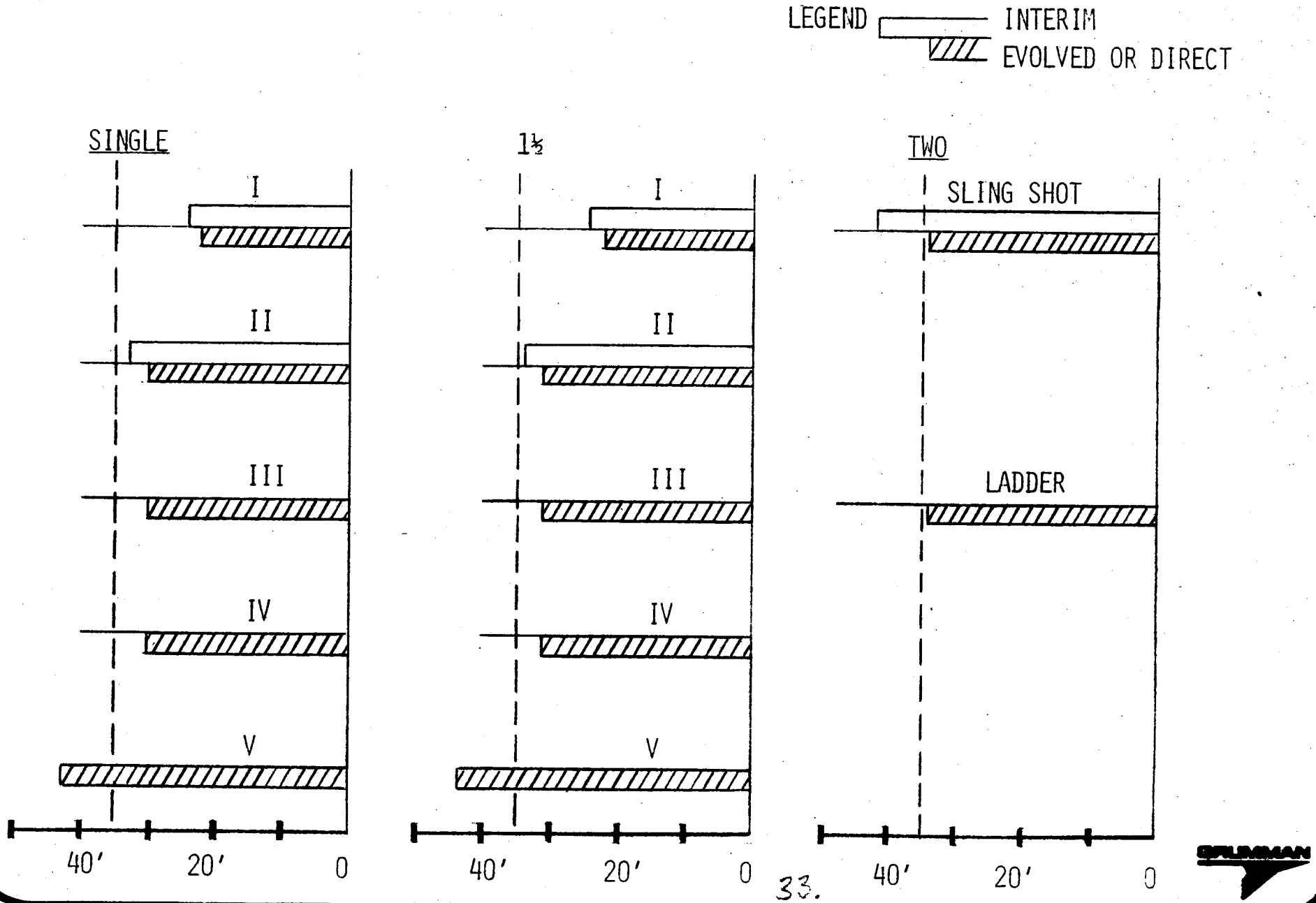
NOMINAL TUG LENGTH SUMMARY

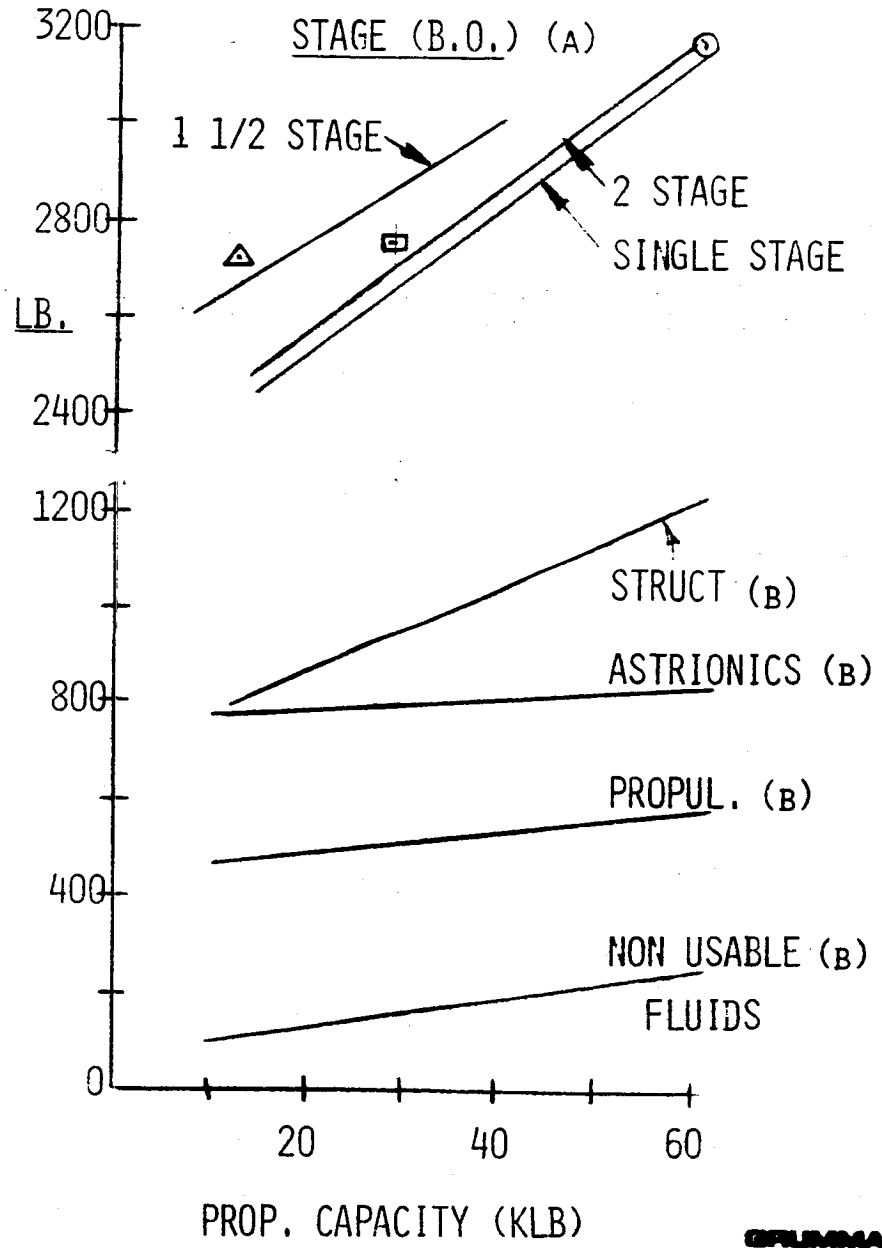


NOMINAL CONFIGURATIONS-WEIGHT

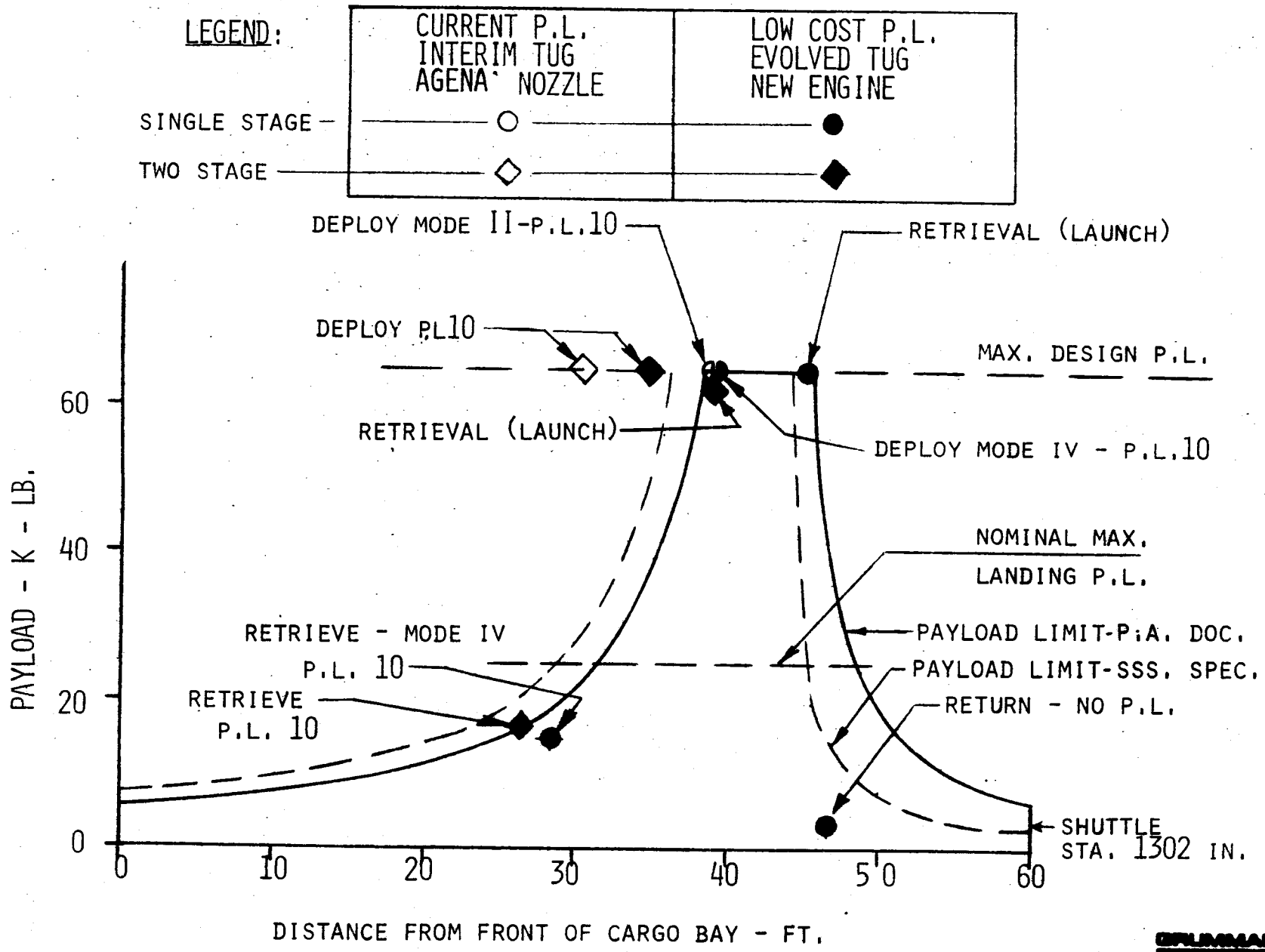
	SINGLE	1 1/2	TWO
MAIN STAGE	2905	2530	2540 x 2
INTERSTAGE	-	-	350
NON USABLE FLUIDS	250	130	160x2
MODE I BURN OUT (A)	3155	2660	5750
DROP TANKS INCLUDING NON USABLE FLUIDS		1040	

(A) EXCLUDING MAIN ENGINE RESERVES

(B) SINGLE STAGE SUBSYSTEM WTS.



NOMINAL TUGS AND ORBITER PAYLOAD C.G. LIMITS



CONCEPTS/MODES

The previous pages show the range of gross configuration options we have identified as having some promise of meeting the evolutionary and direct development mission requirements. We have started by classifying as generically "single stage" all those stage arrangements which use the full size tug as the central element with either apogee or de-orbit SRM's, or both, added for higher performance. Similarly with the one-and-a-half stage base. Within each of the three general categories illustrated, single, one-and-a-half, and two stage, there are many possible subsystem and programmatic options.

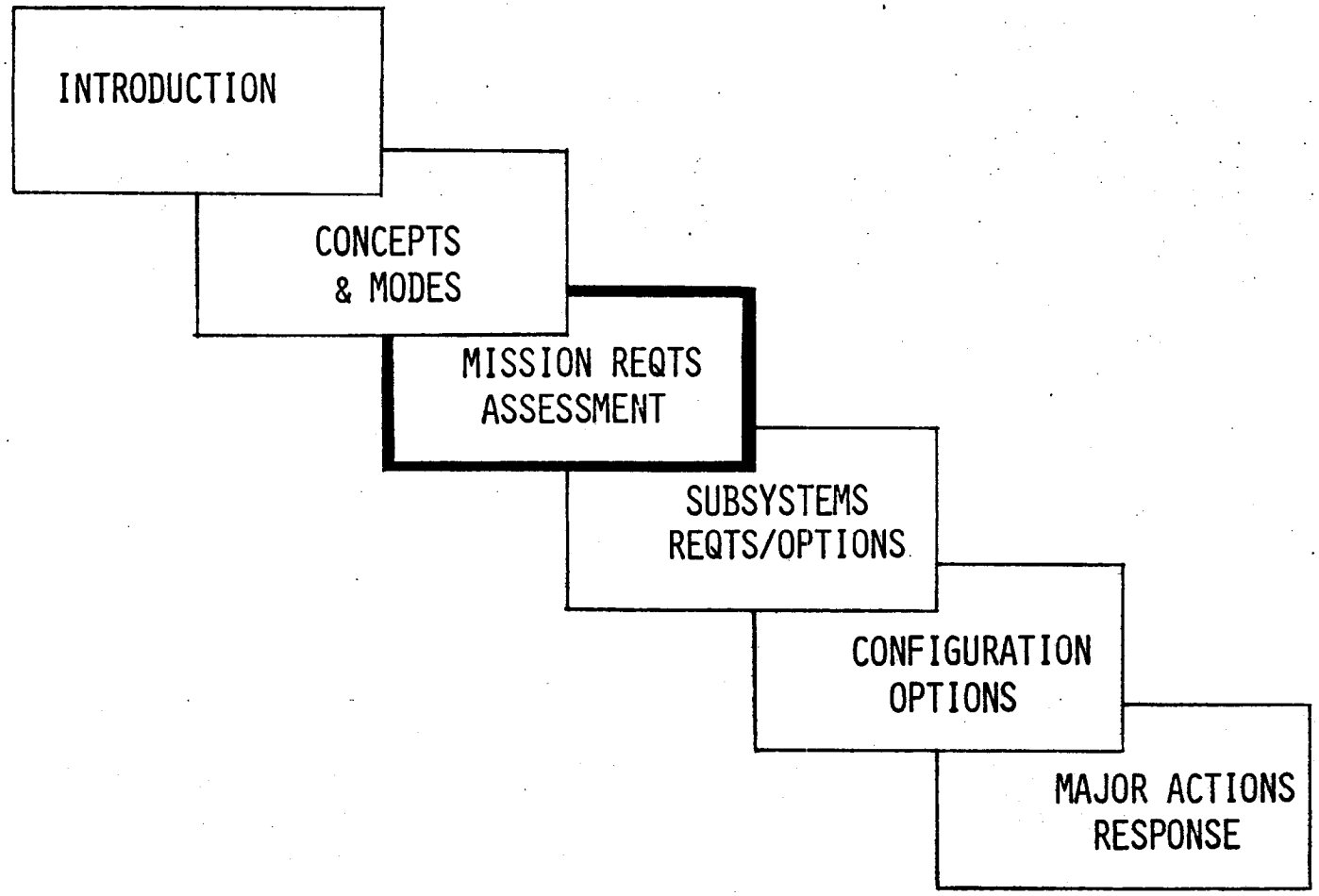
The normal configurations shown stand as points of departure for more continuous study. The changes evident since our proposed configurations were published are part of the maturing process. Prominent amongst these are:

- All integral main propellant tanks now show a slight "V" form at the main girth frames, reducing manufacturing problems and slightly shortening the tanks.
- The Avionics have been moved into side mounted panniers, - reducing structural cutouts and reducing Tug overall length.
- The ACS clusters are now repositioned, - straddling the operational C.G. range and reducing forward directed plume infringement on the payload.
- The one-and-a-half stage core vehicle has reduced propellant capacity and bigger drop tanks to maximize performance.

The kick stages illustrate two examples. One, a new design with twin apogee SRM's and one de-orbit SRM; the three SRM's we sized for maximum payload capability and are nearly the same weight; they are arranged side by side for minimum length. The other, the TE364-4, is an existing apogee SRM kick stage and spin table.

The final three viewgraphs of this section summarize for these nominal configurations the stack length, the base vehicle dry weight, and the payload C.G. with respect to the Orbiter limits. As might be expected, our first shot at a two-stage arrangement would be improved by a reduction in length.

OUTLINE



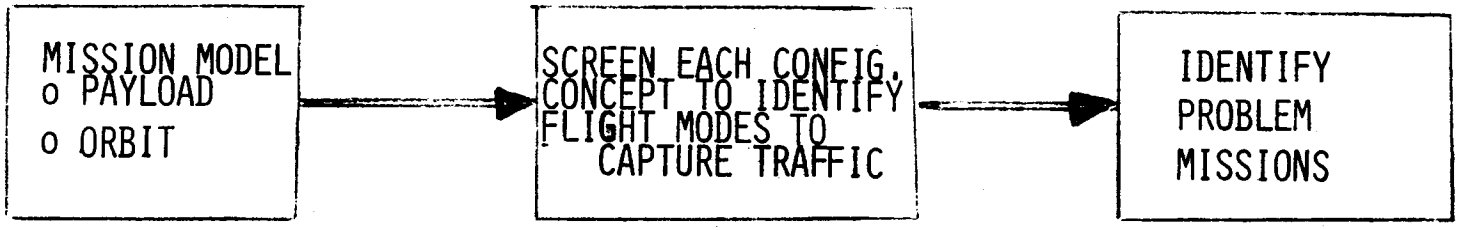
GRUMMAN

MISSION REQUIREMENTS EVALUATION

- o IDENTIFICATION OF REQUIRED FLIGHT MODES
- o ASSESSMENT OF MISSION MODEL
- o ASSESSMENT OF REFERENCE MISSIONS
  - PERFORMANCE
  - S/S DRIVERS, PAYLOAD IMPACTS, CRITICAL EVENTS & UNIQUE TRAJ. ISSUES
  - SELECTION OF MISSIONS FOR FLT. OPS. ANALYSIS
- o RECOMMENDED TRADE STUDIES
  - MPS
  - APS
  - NAVIGATION
  - TRAJECTORY

GRUMMAN

FLIGHT MODE IDENTIFICATION



GROUNDRULES & ASSUMPTIONS

- o ALL "CURRENT DESIGN" PAYLOADS MUST BE DEPLOYED
  - ASSUME INTERIM TUG PERFORMANCE
- o ALL "LOW COST" PAYLOADS MUST BE RETRIEVED EXCEPT:
  - PLANETARY MISSION
  - MISSION MODEL #9
- o INCREASE COMPLEXITY OF TUG CONFIG FLIGHT MODE UNTIL MISSION MODEL IS CAPTURED
- o CONSIDER SINGLE STG, 1½ STAGE & 2 STAGE CONFIGURATIONS

FLIGHT MODE IDENTIFICATION

The objectives of this first reporting period is to assess the mission requirements. This function has been performed by reversing the process used to assess candidate concepts. That is, we have assumed baseline vehicles for the storable single, $1\frac{1}{2}$, and 2 stage concepts and assessed their capability to capture the entire traffic. This process identifies the problem payloads and requirements, and provides a preliminary comparison of TUG family concepts.

The procedure for this assessment is as follows:

(1) evaluate each configuration capture capability in its primary mode

(2) increase the complexity of the flight mode by adding kick stages or other operating modes until the maximum percentage of traffic is captured

(3) identify the problem payloads.

ASSUMED CONFIGURATION CHARACTERISTICS

		SINGLE STAGE	1-1/2 STAGE	2 STAGE
MAIN STAGE				
BURN OUT WEIGHT LESS FPR	LB =	3180	2720	2770
40% CONSUMABLES	LB =	280	280	280
F. P. R.	LB =	200	200	150
EQUIV. INERT WEIGHT		3660	3200	3200
ISP INTERIM	SECS =	324	324	324
EVOLVED	SECS =	339	339	339

KICK STAGE

λ' = .90
Wo LB = 3000
ISP SECS = 290

DROP TANK

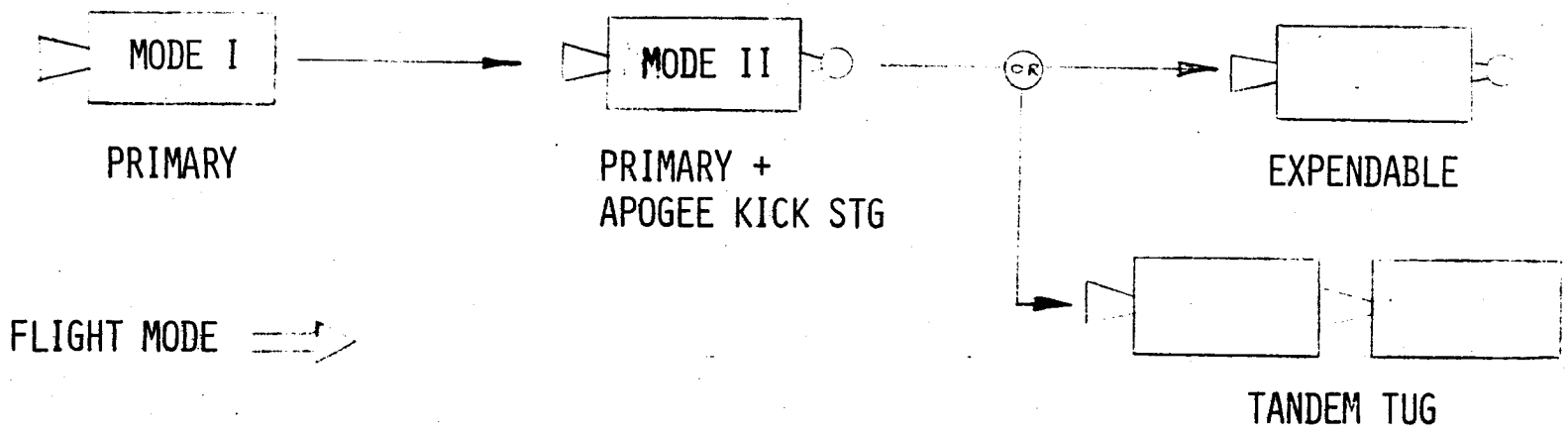
λ' = .975
B/O WT LB = 1040

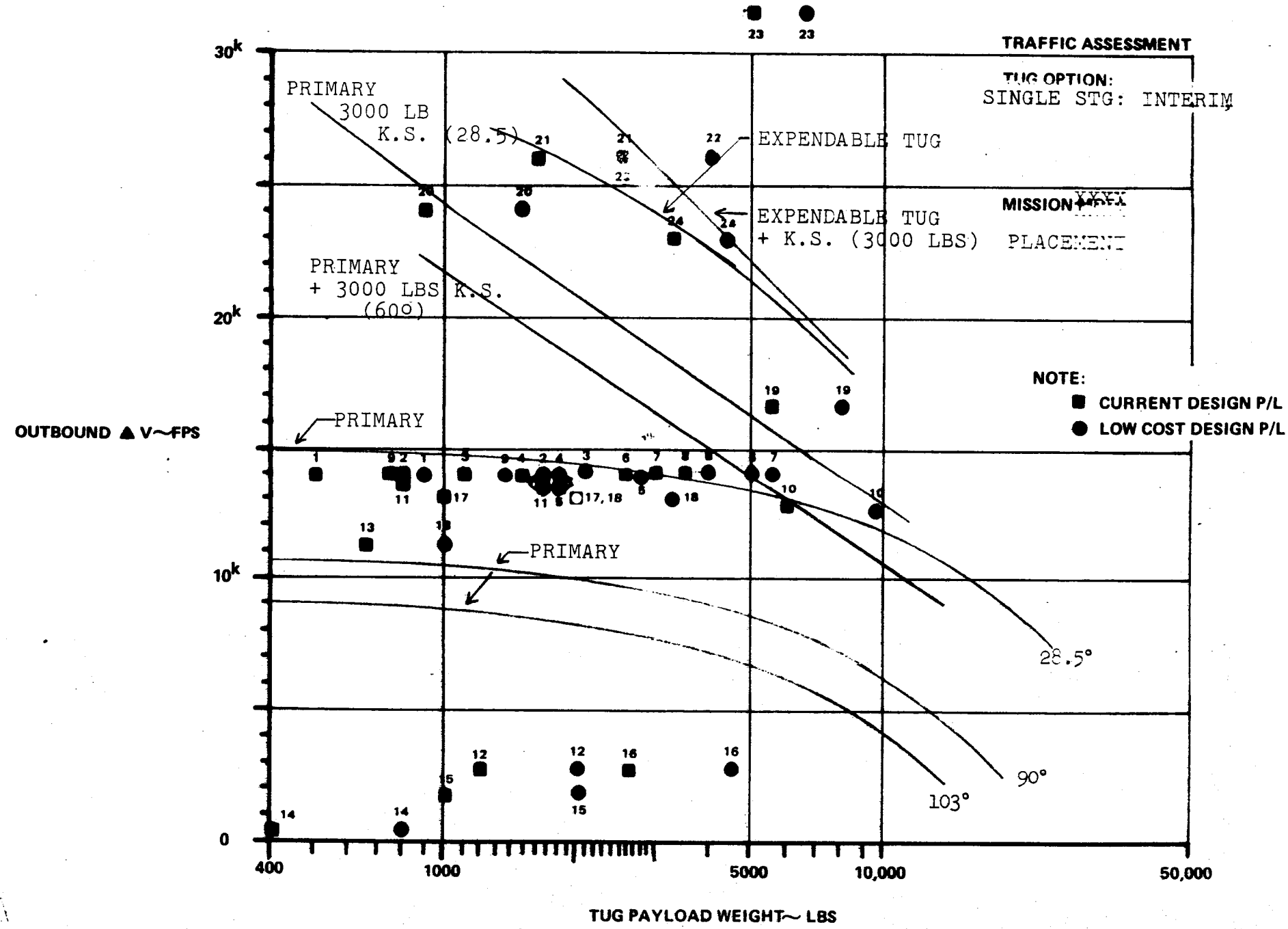
AGENA

λ' = .9083
W_P LB = 13550
ISP SEC = 295

GRUMMAN

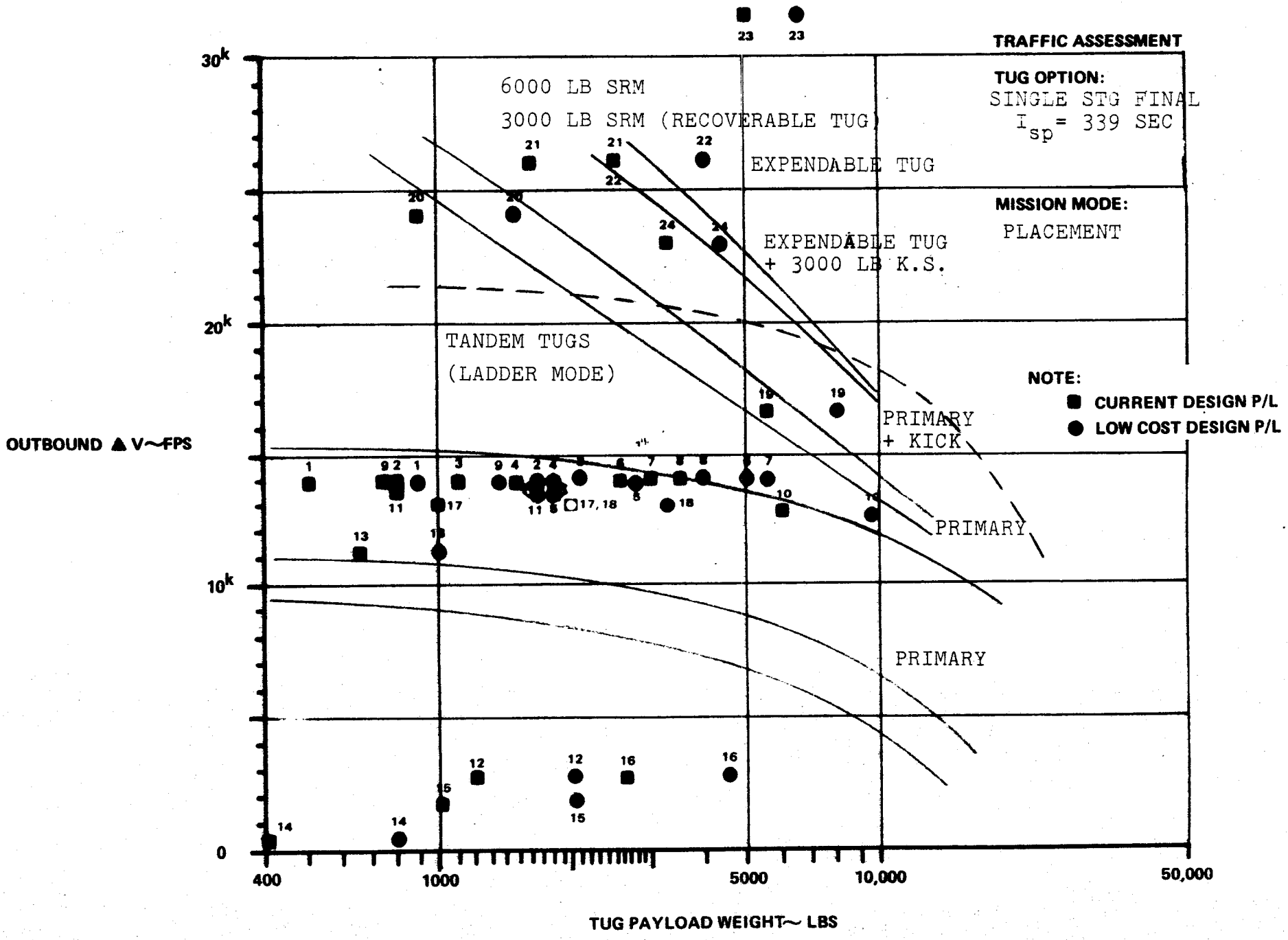
TUG CONFIGURATION: SINGLE STG INTERIM/FINAL
MISSION APPLICATION: PLACEMENT
PAYLOAD: CURRENT DESIGN/LOW COST




TRAFFIC ASSESSMENT
TUG OPTION:
SINGLE STG: INTERIM
MISSION
PLACEMENT
PRIMARY
3000 LB
K.S. (28.5)
EXPENDABLE TUG
EXPENDABLE TUG
+ K.S. (3000 LBS)
PRIMARY
+ 3000 LBS K.S.
(60°)
PRIMARY
PRIMARY
28.5°
90°
103°
NOTE:
CURRENT DESIGN P/L
LOW COST DESIGN P/L
OUTBOUND ▲V~FPS
30k
20k
10k
0
400
1000
5000
10,000
50,000
TUG PAYLOAD WEIGHT~ LBS

44.

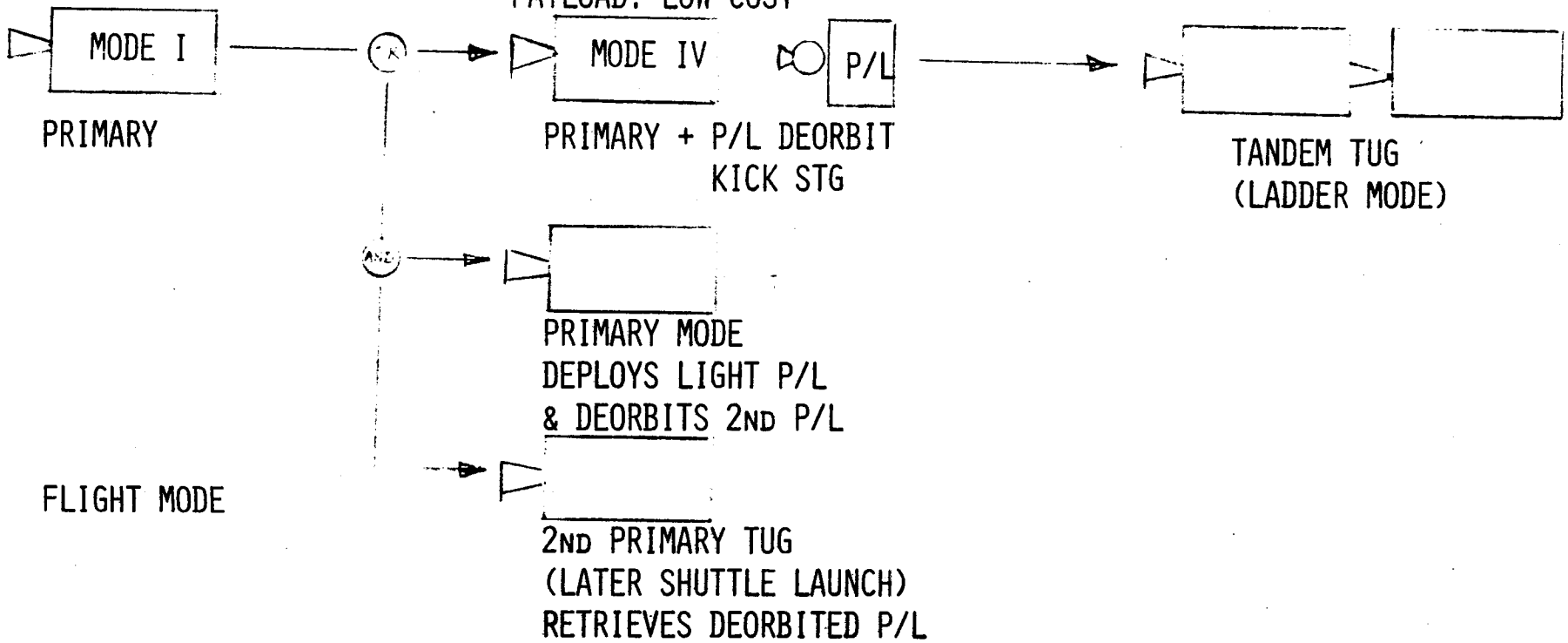
Figure 1


TRAFFIC ASSESSMENT
TUG OPTION:
SINGLE STG FINAL
I_{sp} = 339 SEC
MISSION MODE:
PLACEMENT
6000 LB SRM
3000 LB SRM (RECOVERABLE TUG)
EXPENDABLE TUG
EXPENDABLE TUG
+ 3000 LB K.S.
TANDEM TUGS
(LADDER MODE)
PRIMARY
+ KICK
PRIMARY
PRIMARY
NOTE:
CURRENT DESIGN P/L
LOW COST DESIGN P/L
OUTBOUND ▲V~FPS
30k
20k
10k
0
400
1000
5000
10,000
50,000
TUG PAYLOAD WEIGHT~ LBS

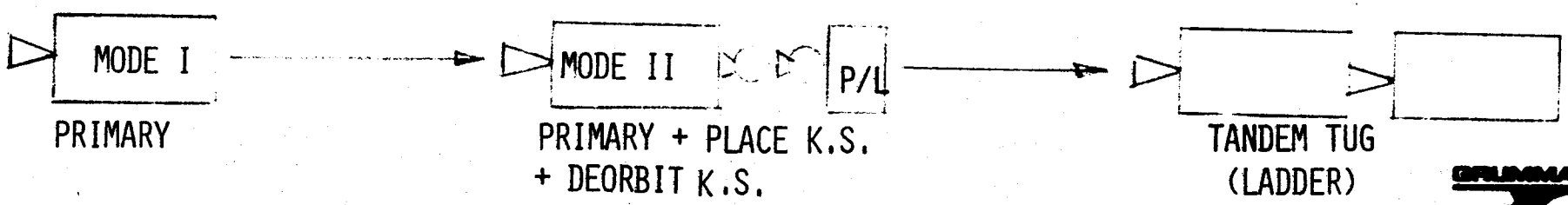
45.

Figure 1

TUG CONFIGURATION: SINGLE STG FINAL
MISSION APPLICATION: RETRIEVAL
PAYLOAD: LOW COST



TUG CONFIGURATION: SINGLE STG FINAL
MISSION APPLICATION: PLACEMENT & RETRIEVAL
PAYLOAD: LOW COST



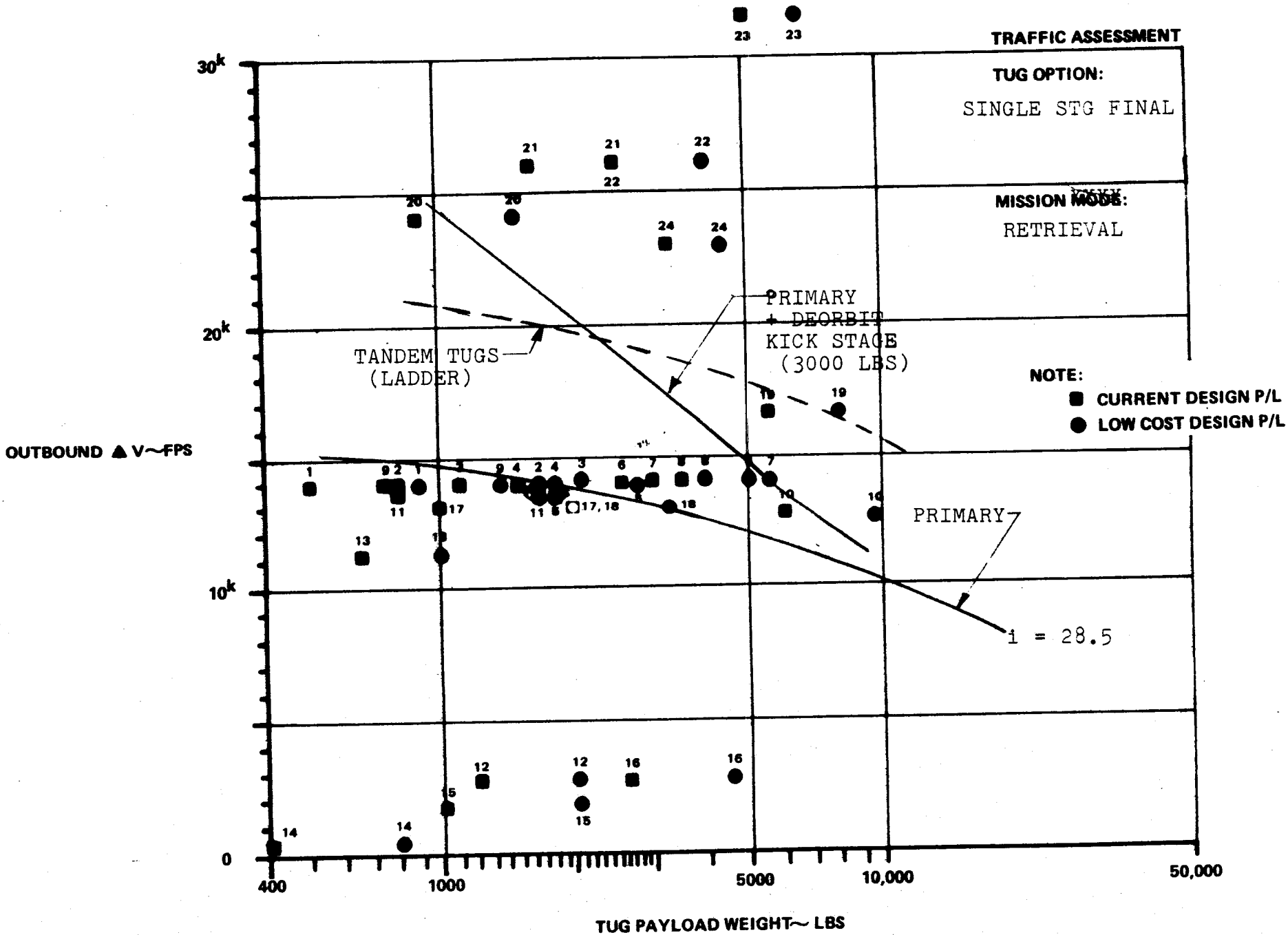
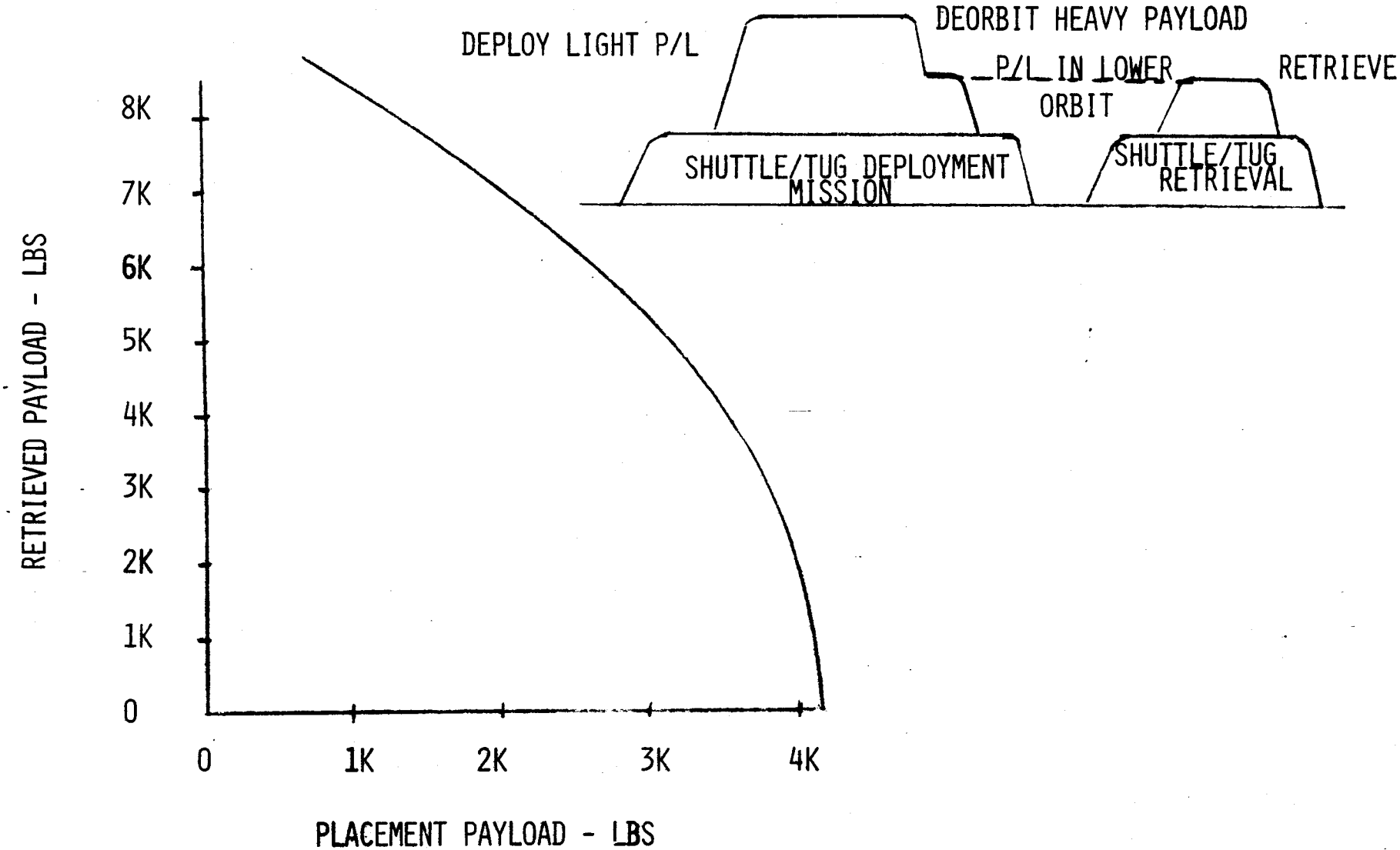

TRAFFIC ASSESSMENT
TUG OPTION:
SINGLE STG FINAL
MISSION MODE:
RETRIEVAL
PRIMARY
+ DEORBIT
KICK STAGE
(3000 LBS)
TANDEM TUGS
(LADDER)
PRIMARY
i = 28.5
NOTE:
CURRENT DESIGN P/L
LOW COST DESIGN P/L
OUTBOUND ▲V~FPS
30k
20k
10k
0
400
1000
5000
10,000
50,000
TUG PAYLOAD WEIGHT~ LBS

Figure 1

DEPLOY & DEORBIT PERFORMANCE
SYNCHRONOUS EQUATORIAL ORBIT



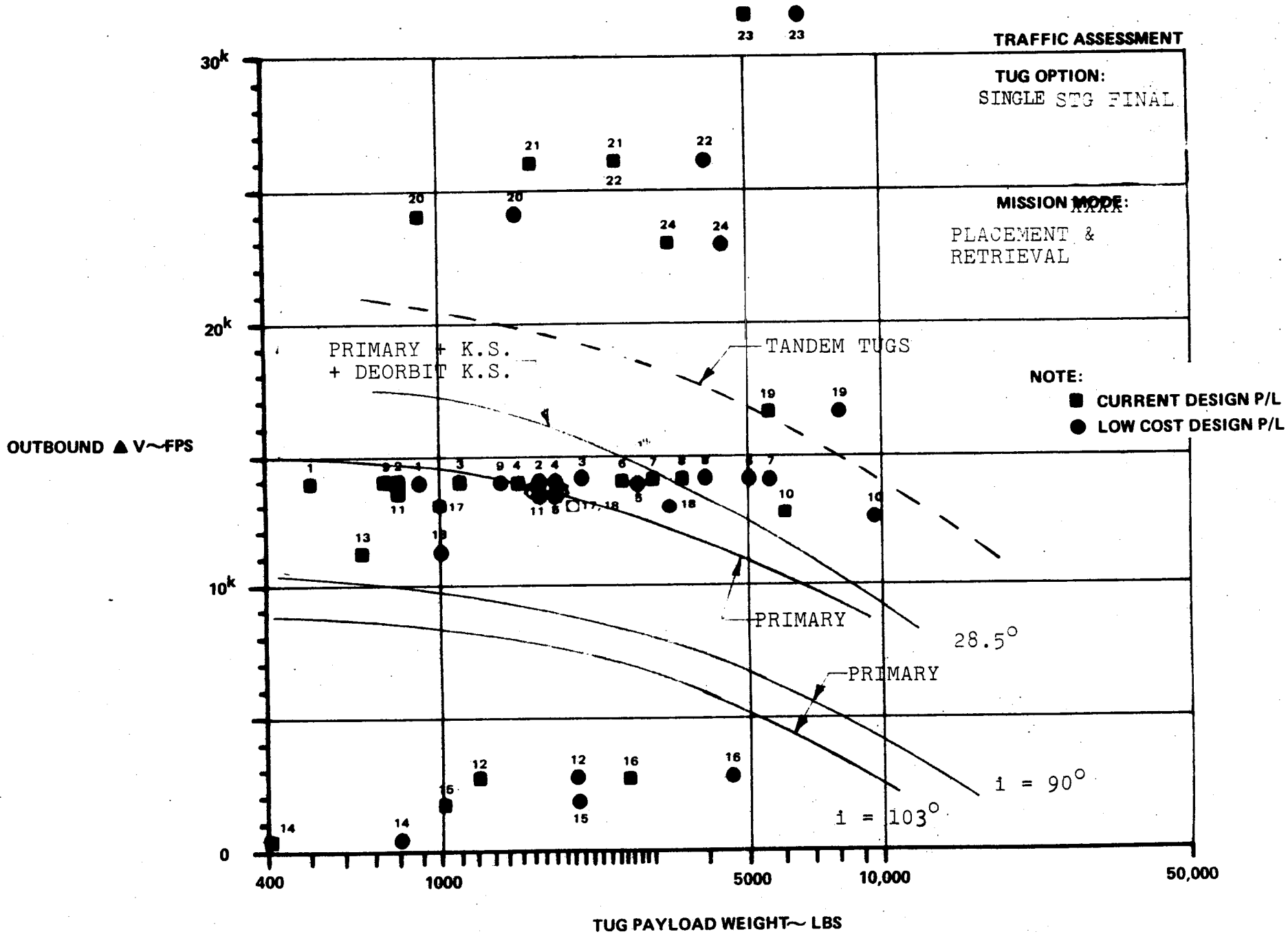

TRAFFIC ASSESSMENT
TUG OPTION:
SINGLE STG FINAL
MISSION MODE:
PLACEMENT & RETRIEVAL
PRIMARY + K.S. + DEORBIT K.S.
TANDEM TUGS
NOTE:
CURRENT DESIGN P/L
LOW COST DESIGN P/L
PRIMARY
PRIMARY
28.5°
i = 90°
i = 103°
OUTBOUND ▲V~FPS
30k
20k
10k
0
400
1000
5000
10,000
50,000
TUG PAYLOAD WEIGHT~ LBS

Figure 1

CAPTURE SUMMARY - SINGLE STAGE

MISSION APPLICATION	PLACEMENT					
FLIGHT MODE	PRIMARY	PRIMARY + K.S.	EXPEND	EXPEND + K.S.	TANDEM TUGS	NOT CAPTURED
SINGLE STAGE INTERIM CURRENT P/L's CAPTURED	1, 2,3,4 5,6,7*,9 11,12,14 15,16,17, 18	7,8,10*, 13	10,19,21, 23**, 24	22		
SINGLE STAGE FINAL LOW COST P/Ls CAPTURED	1,2,3,4 5,8*,9,11 12,14,15, 16,17,18	6,7,8, 10*,13	10,19,20, 23**	21,24	---	22

MISSION APPLICATION	RETRIEVAL				PLACEMENT & RETRIEVAL			
FLIGHT MODE	PRIM	PRIM + DEORB K.S.	TANDEM ***	NOT CAPT.	PRIM	PRIM + MULTI-K.S.	TANDEM	NOT CAPT.
SINGLE STAGE FINAL LOW COST P/Ls CAPTURED	1,2*,4* 12,13*, 14,15, 16	2,3,4 5,6,7* 8,11, 13	7,10		1,11,12 14,15, 16	2,3,4 5	6,7,8 13	10

* MARGINAL CAPABILITY IN THIS MODE

** ONLY 18,400 FPS REQ'D FROM TUG

*** DEPLOY AND DEORBIT CAN CAPTURE #7

GRUMMAN

CAPTURE SUMMARY - SINGLE STAGE FAMILY

PLACEMENT: The interim Tug family has the performance capability to deploy all "current design" payloads. Of the total 24 missions, 15 can be deployed in the primary mode, 4 in a Tug retrieval mode with kick stage and 6 in an expendable mode.

Mission #10 is marginal for the primary + kick stage mode. It is assumed that Mission #10 is performed with a due-East launch out of ETR with execution of the plane change by the Tug. Similar marginal performance is present for DOD Missions 10, 4b and 3b.

In evaluating Mission #23, it is assumed that the Tug incremental velocity requirement is 18,400 fps. The remainder of the velocity requirement is supplied by the payloads low thrust engines.

The final Tug family can capture all "low cost" payloads with the exception of the planetary mission, Mission #22. Emphasis will be placed on determining the optimum kick stage size to capture the planetary missions while satisfying the deployment/retrieval requirements of the geosynchronous and 60° inclination missions.

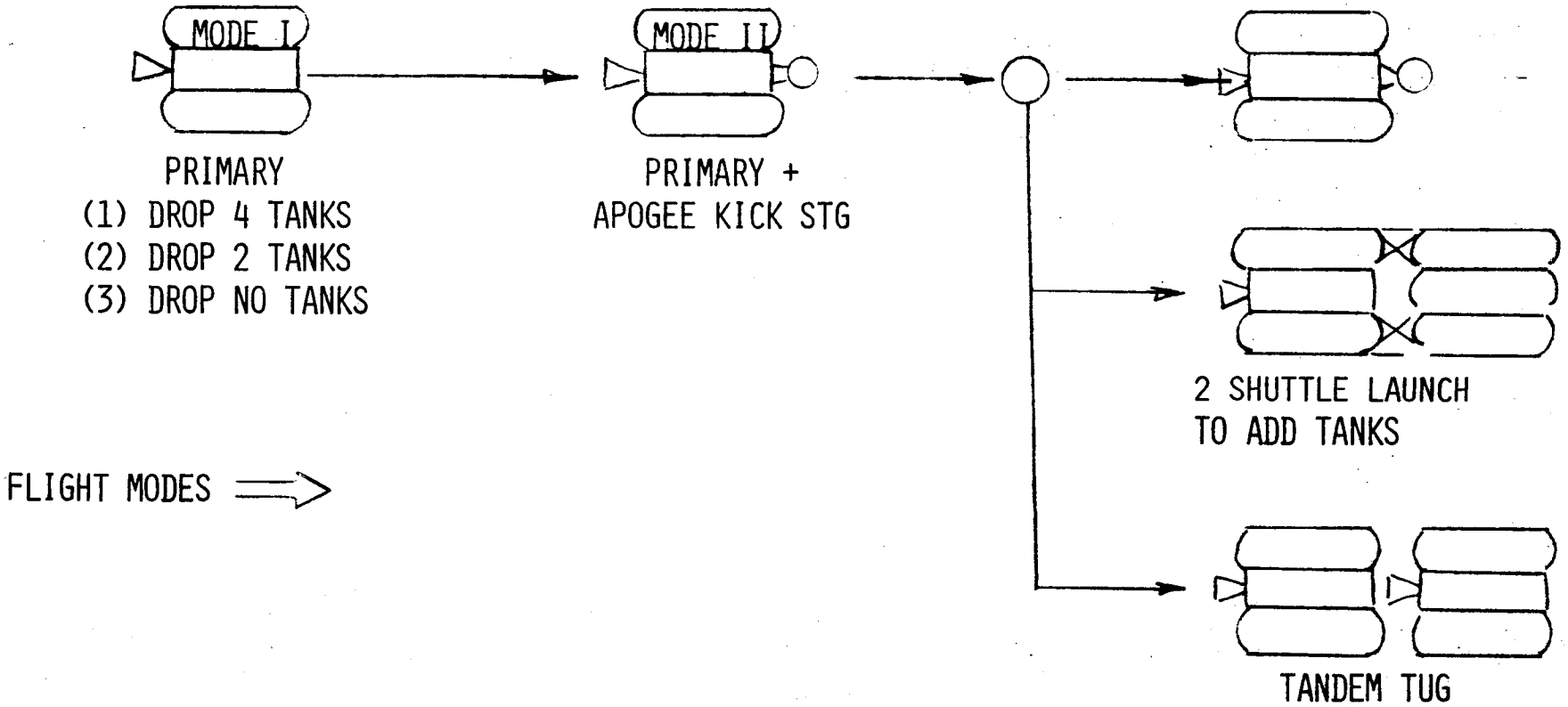
If recovery of the Tug in planetary missions is found to be cost effective, more study emphasis should be placed on assembly of two Tugs while in orbit and the utilization of a ladder (trapeze) mode requiring a Tug-to-Tug rendezvous and dock.

RETRIEVAL: The final storable Tug can retrieve all "low cost" payloads using the mode in which a Tug deploys a light payload and de-orbits a heavy payload for subsequent retrieval on a second flight. Of the total 16 retrieval missions, 8 can be retrieved in the primary mode, 9 require a de-orbit kick stage on the payload, and 2 require a Tandem Tug arrangement or the "Deploy and Nudge" flight schedule. Mission #10 and DOD Mission 10, 4b and 3b require more in-depth analysis to determine their impact on the Tug design.

PLACEMENT/RETRIEVAL: The "final" single stage Tug has sufficient performance to capture 6 missions in a primary configuration. Four missions require a multi-kick stage arrangement and four require a Tandem Tug flight mode. Mission #10 cannot be captured in the placement/retrieval mission application.

It is assumed that the Placement/Retrieval Mission requirement does not apply to the DOD missions.

TUG CONFIGURATION: 1 1/2 STG INTERIM
MISSION APPLICATION: PLACEMENT
PAYLOAD: CURRENT DESIGN



TUG CONFIGURATION: 1 1/2 STG FINAL
MISSION APPLICATION: PLACEMENT
PAYLOAD: LOW COST

(FLIGHT MODES SAME AS INTERIM)

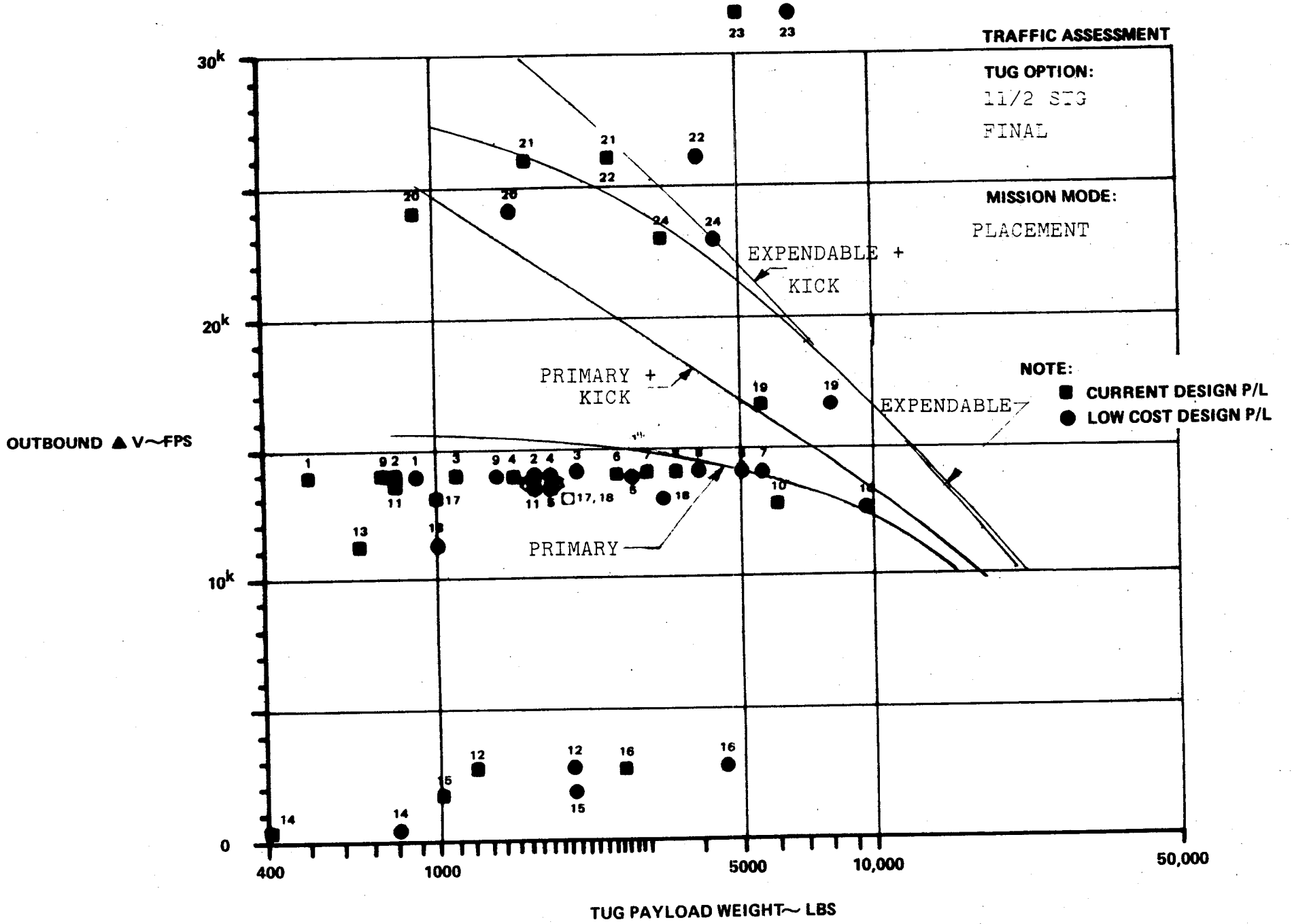
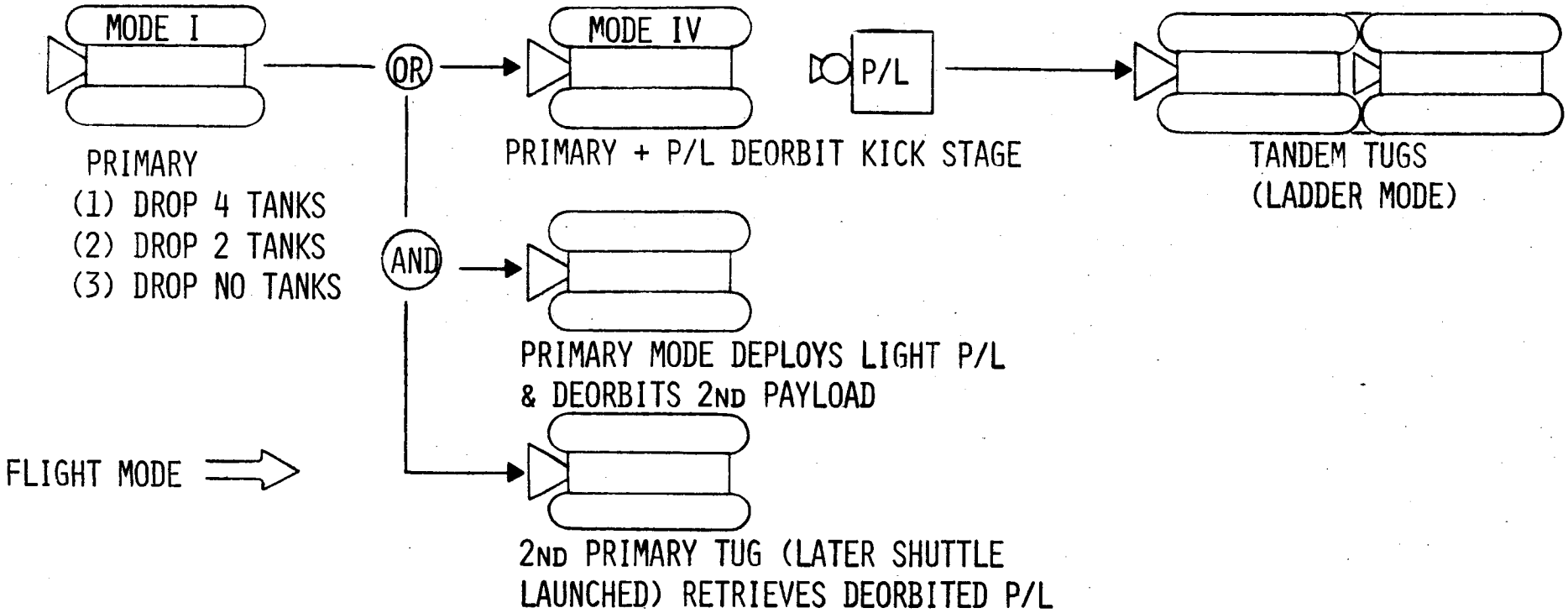
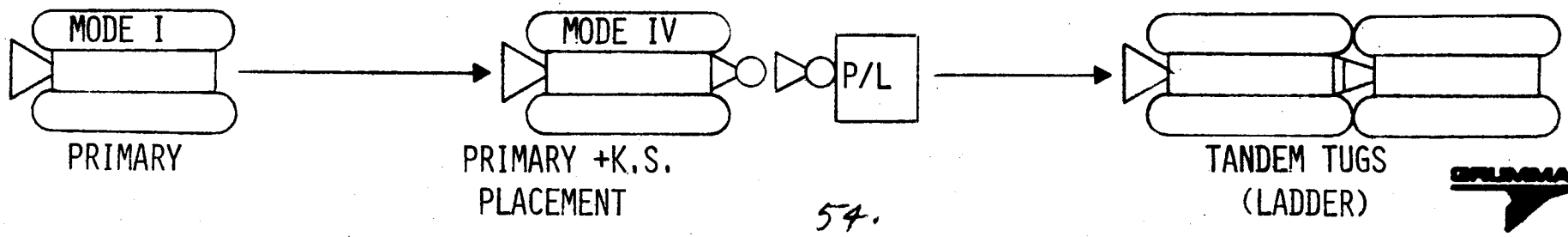

TRAFFIC ASSESSMENT
TUG OPTION:
11/2 STG
FINAL
MISSION MODE:
PLACEMENT
EXPENDABLE + KICK
PRIMARY + KICK
EXPENDABLE
PRIMARY
NOTE:
CURRENT DESIGN P/L
LOW COST DESIGN P/L
OUTBOUND ▲V~FPS
30k
20k
10k
0
400
1000
5000
10,000
50,000
TUG PAYLOAD WEIGHT~ LBS

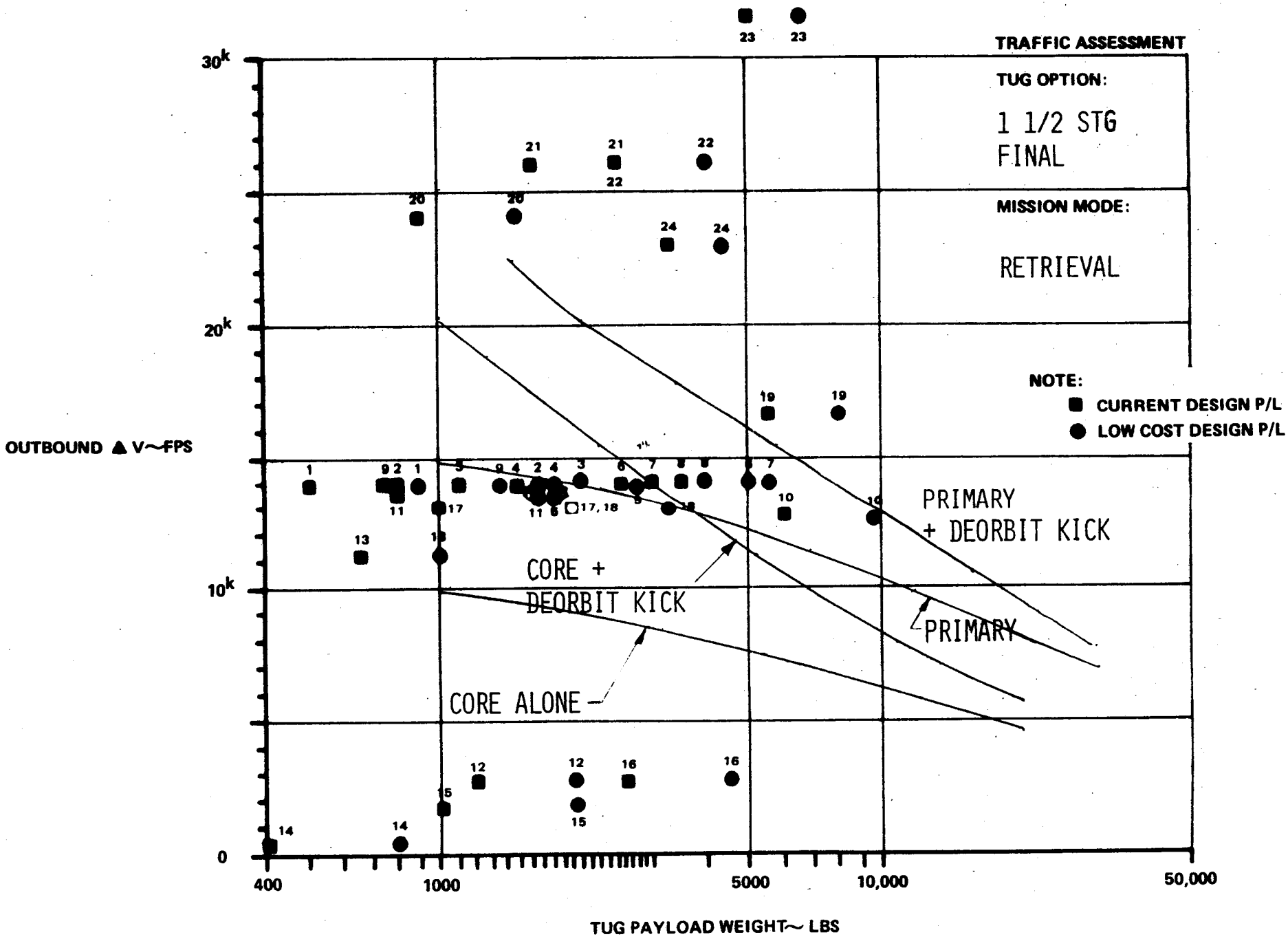
Figure 1

TUG CONFIGURATION: 1½ STG FINAL
MISSION APPLICATION: RETRIEVAL
PAYLOAD: LOW COST



TUG CONFIGURATION: 1½ STG FINAL
MISSION APPLICATION: PLACEMENT & RETRIEVAL
PAYLOAD: LOW COST




TRAFFIC ASSESSMENT
TUG OPTION:
1 1/2 STG
FINAL
MISSION MODE:
RETRIEVAL
NOTE:
CURRENT DESIGN P/L
LOW COST DESIGN P/L
PRIMARY
+ DEORBIT KICK
CORE +
DEORBIT KICK
PRIMARY
CORE ALONE
OUTBOUND ▲ V~FPS
30k
20k
10k
0
400
1000
5000
10,000
50,000
TUG PAYLOAD WEIGHT~ LBS

55.

Figure 1

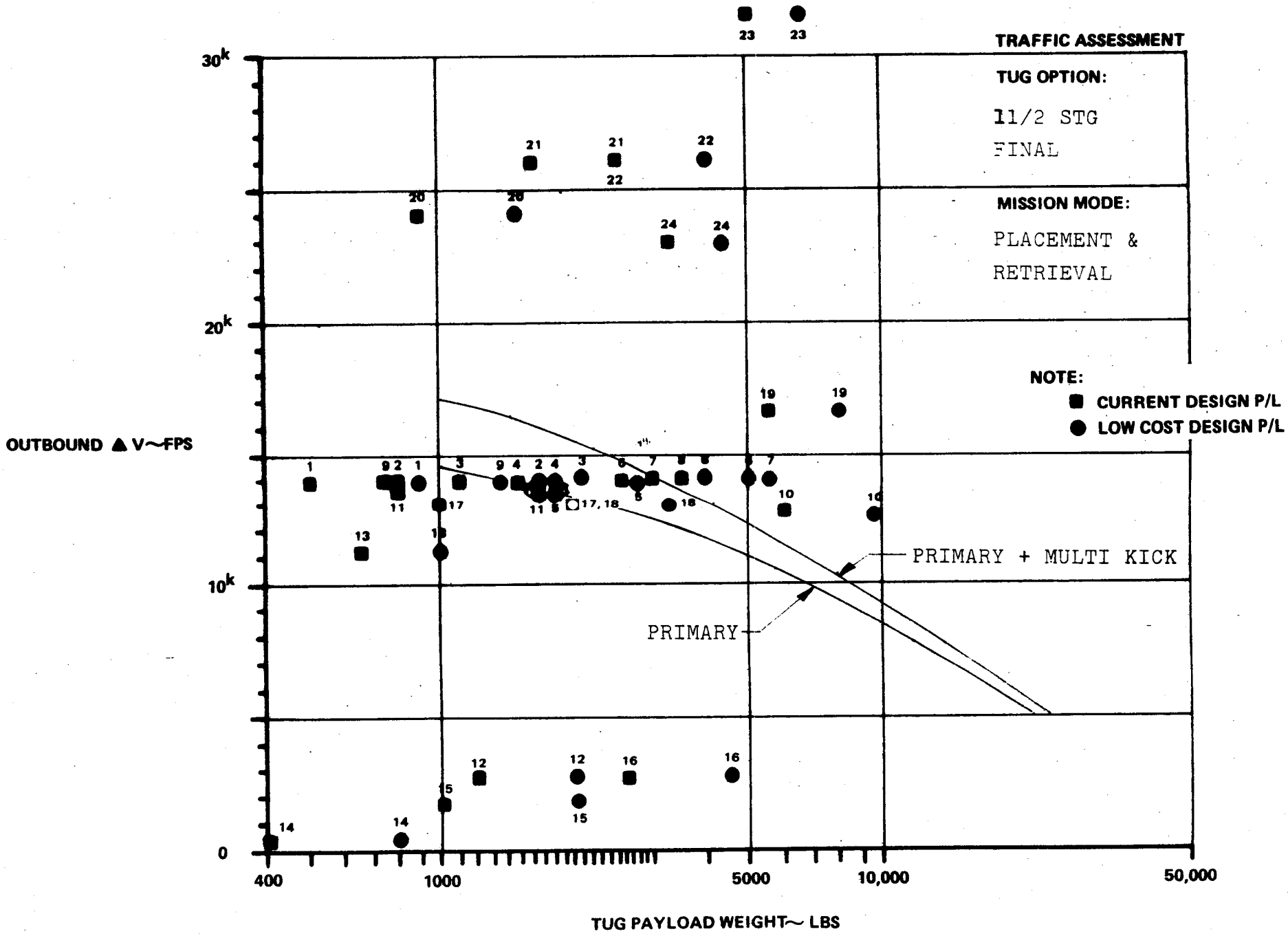

TRAFFIC ASSESSMENT
TUG OPTION:
11/2 STG
FINAL
MISSION MODE:
PLACEMENT &
RETRIEVAL
NOTE:
CURRENT DESIGN P/L
LOW COST DESIGN P/L
PRIMARY + MULTI KICK
PRIMARY
OUTBOUND ▲V~FPS
30k
20k
10k
0
400
1000
5000
10,000
50,000
TUG PAYLOAD WEIGHT~ LBS

Figure 1

CAPTURE SUMMARY - 1½ STAGE FAMILY

MISSION APPLICATION	PLACEMENT				
FLIGHT MODE	PRIMARY	PRIMARY + K.S.	EXPEND	EXPEND + K.S.	NOT CAPTURED
1½ STAGE FINAL	1, 2, 3, 4 5,6*, 7,* 8 9, 11, 12, 13	6, 7, 10, 20	19, 23**	21, 24*	22, 24
LOW COST P/L'S CAPTURED	14, 15, 16 17, 18				

MISSION APPLICATION	RETRIEVAL					PLACE & RETRIEVE		
FLIGHT MODE	CORE	PRIM	CORE + DEORB K.S.	PRIM + DEORB K.S.	NOT CAPT	PRIM	PRIM + MULTI-K.S.	NOT CAPT
1½ STAGE FINAL	12 14 15 16*	1, 2, 3* 4, 11, 13* 16	3, 5, 13	6, 7, 8	10	1, 11, 12 14, 15, 16	2, 3, 4 5, 13	6, 7, 8 10
LOW COST P/L'S CAPTURED								

* MARGINAL CAPABILITY IN THIS MODE

** ONLY 18,400 FPS REQ'D FROM TUG

TANDEM TUG DATA NOT AVAILABLE

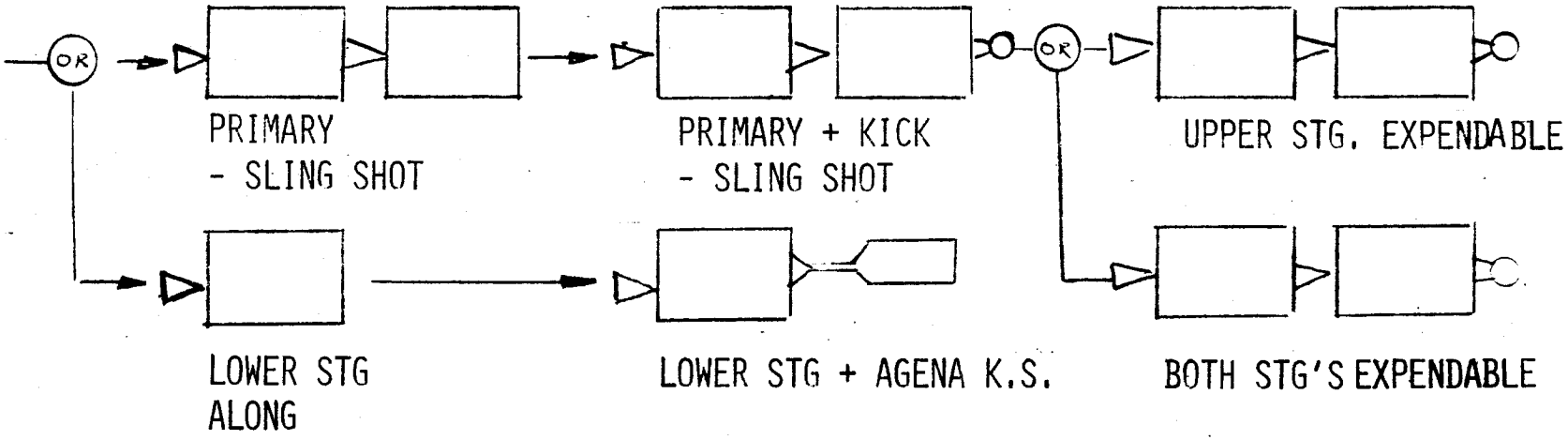
CAPTURE SUMMARY - $1\frac{1}{2}$ STAGE FAMILY

Placement: The $1\frac{1}{2}$ stage can capture 17 of the 24 missions in the primary mode. A kick stage is required for missions 6, 7, 10, and 20 while missions 19, 23, 21, and 24 require expendable flight mode. Investigation of larger kick stages is required for mission 22.

Retrieval: Missions 12, 14, 15, and 16 can be captured with the core vehicle alone while missions 1, 2, 3, 4, 11, and 13 require the primary flight mode. A deorbit kick stage is required to capture 3 and 5 with a core vehicle while missions 6, 7, and 8 require the primary mode with a deorbit kick stage. More detailed analysis of mission 10 is required (note that mission 10 performance requirements are similar to DOD missions 8, 10, and 46).

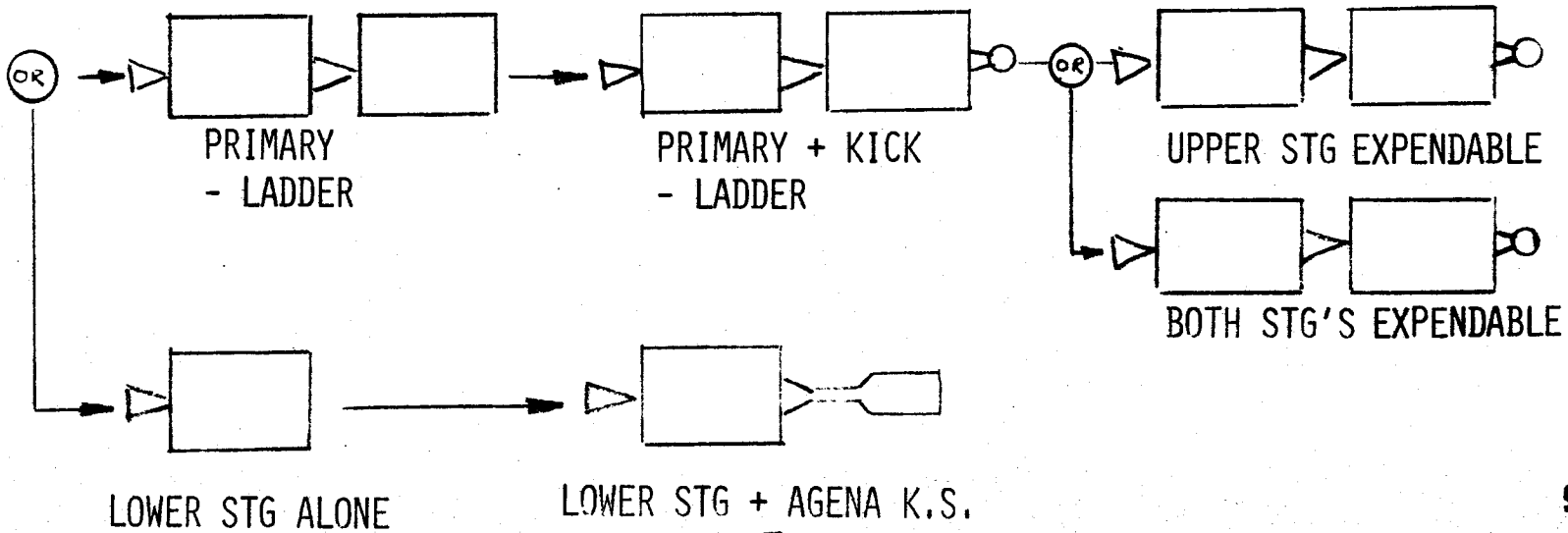
Placement/Retrieval: Six missions can be retrieved with the primary mode or core vehicle while missions 2, 3, 4, 5, and 13 require multiple kick stages. Missions 6, 7, 8, and 10 cannot be captured with this mission application

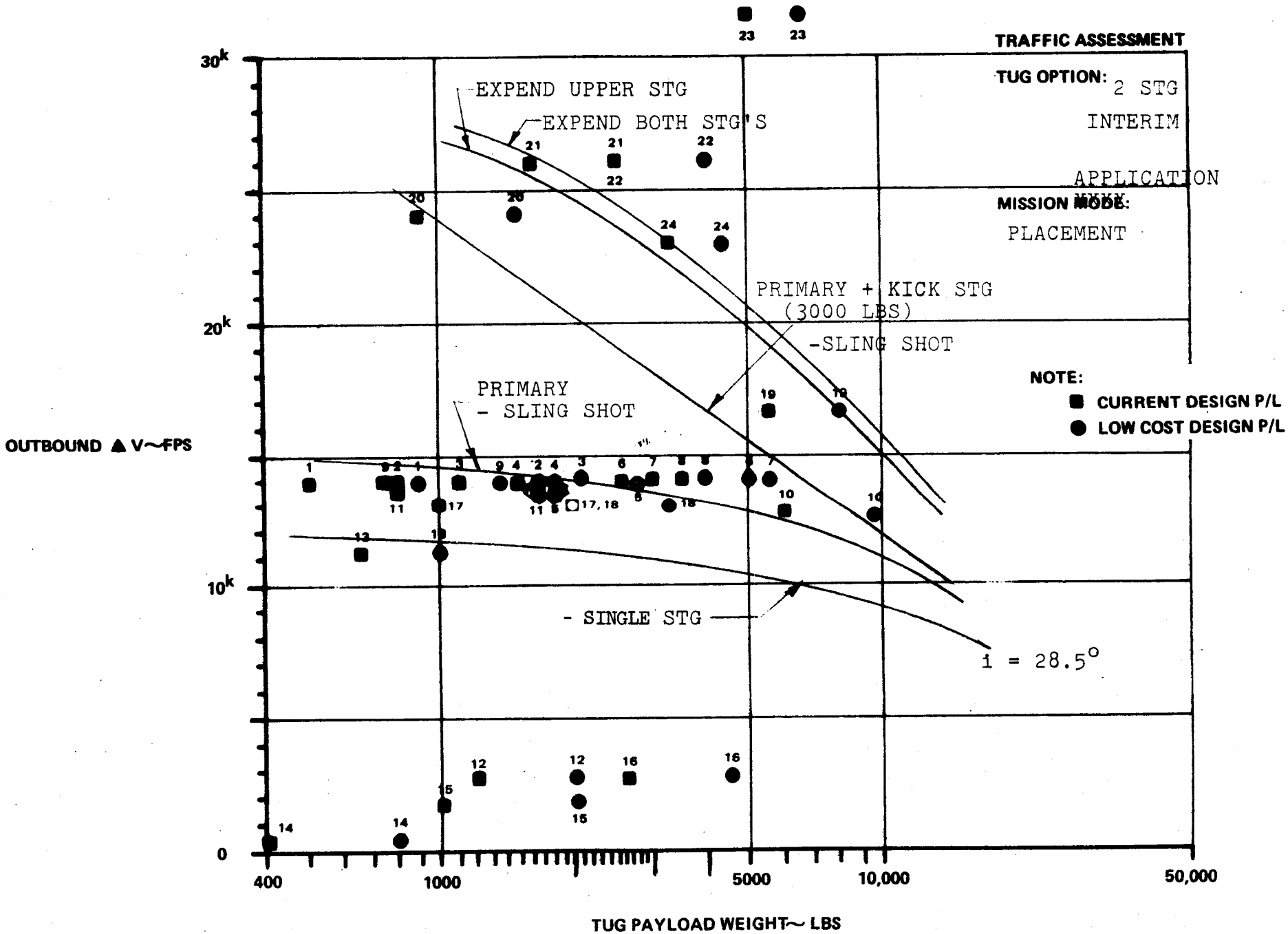
TUG CONFIGURATION: 2 STG INTERIM
MISSION APPLICATION: PLACEMENT
PAYLOAD: CURRENT DESIGN



TUG CONFIGURATION: 2 STG FINAL
MISSION APPLICATION: PLACEMENT
PAYLOAD: LOW COST

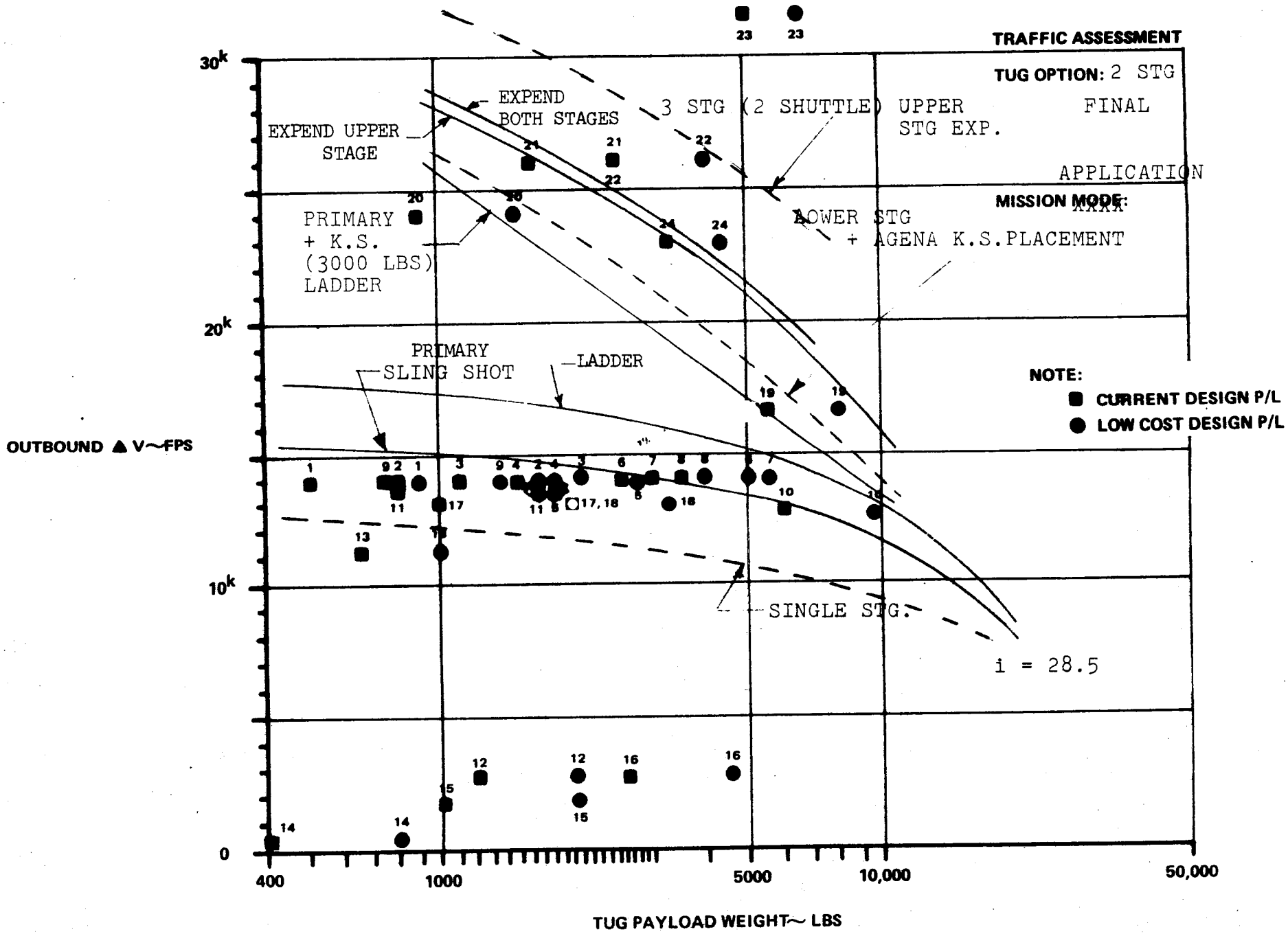
FLIGHT MODES ⇨




TRAFFIC ASSESSMENT
TUG OPTION: 2 STG INTERIM
MISSION MODE: APPLICATION PLACEMENT
NOTE:
CURRENT DESIGN P/L
LOW COST DESIGN P/L
EXPEND UPPER STG
EXPEND BOTH STG'S
PRIMARY + KICK STG (3000 LBS)
-SLING SHOT
PRIMARY - SLING SHOT
- SINGLE STG
i = 28.5°
OUTBOUND ▲V~FPS
30k
20k
10k
0
400
1000
5000
10,000
50,000
TUG PAYLOAD WEIGHT~ LBS

60.

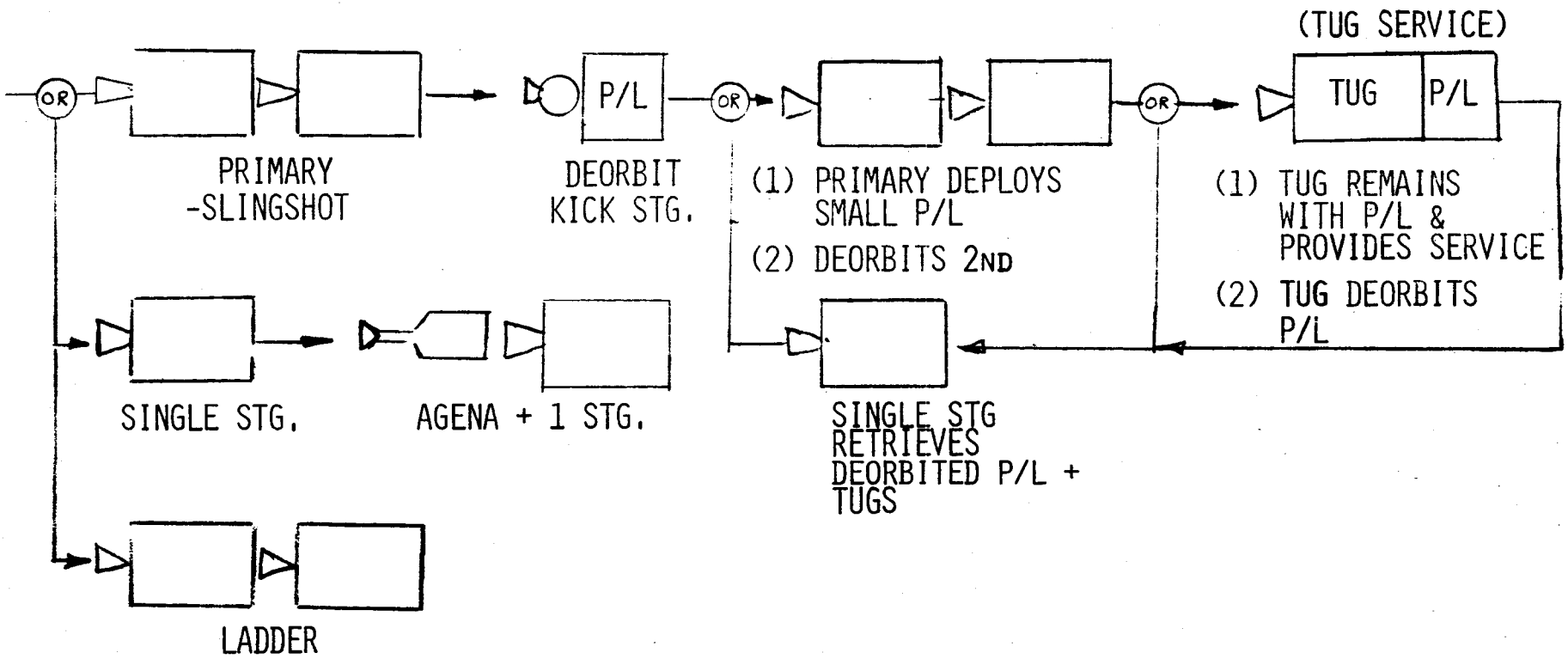
Figure 1


TRAFFIC ASSESSMENT
TUG OPTION: 2 STG
FINAL
APPLICATION
MISSION MODE:
EXPEND BOTH STAGES
3 STG (2 SHUTTLE) UPPER STG EXP.
EXPEND UPPER STAGE
PRIMARY + K.S. (3000 LBS) LADDER
LOWER STG + AGENA K.S.PLACEMENT
PRIMARY SLING SHOT
LADDER
SINGLE STG.
i = 28.5
NOTE:
CURRENT DESIGN P/L
LOW COST DESIGN P/L
OUTBOUND ▲V~FPS
30k
20k
10k
0
400
1000
5000
10,000
50,000
TUG PAYLOAD WEIGHT~ LBS

61.

Figure 1

TUG CONFIGURATION: 2 STG. FINAL
MISSION APPLICATION: RETRIEVAL
PAYLOAD: LOW COST



FLIGHT MODES ⟹

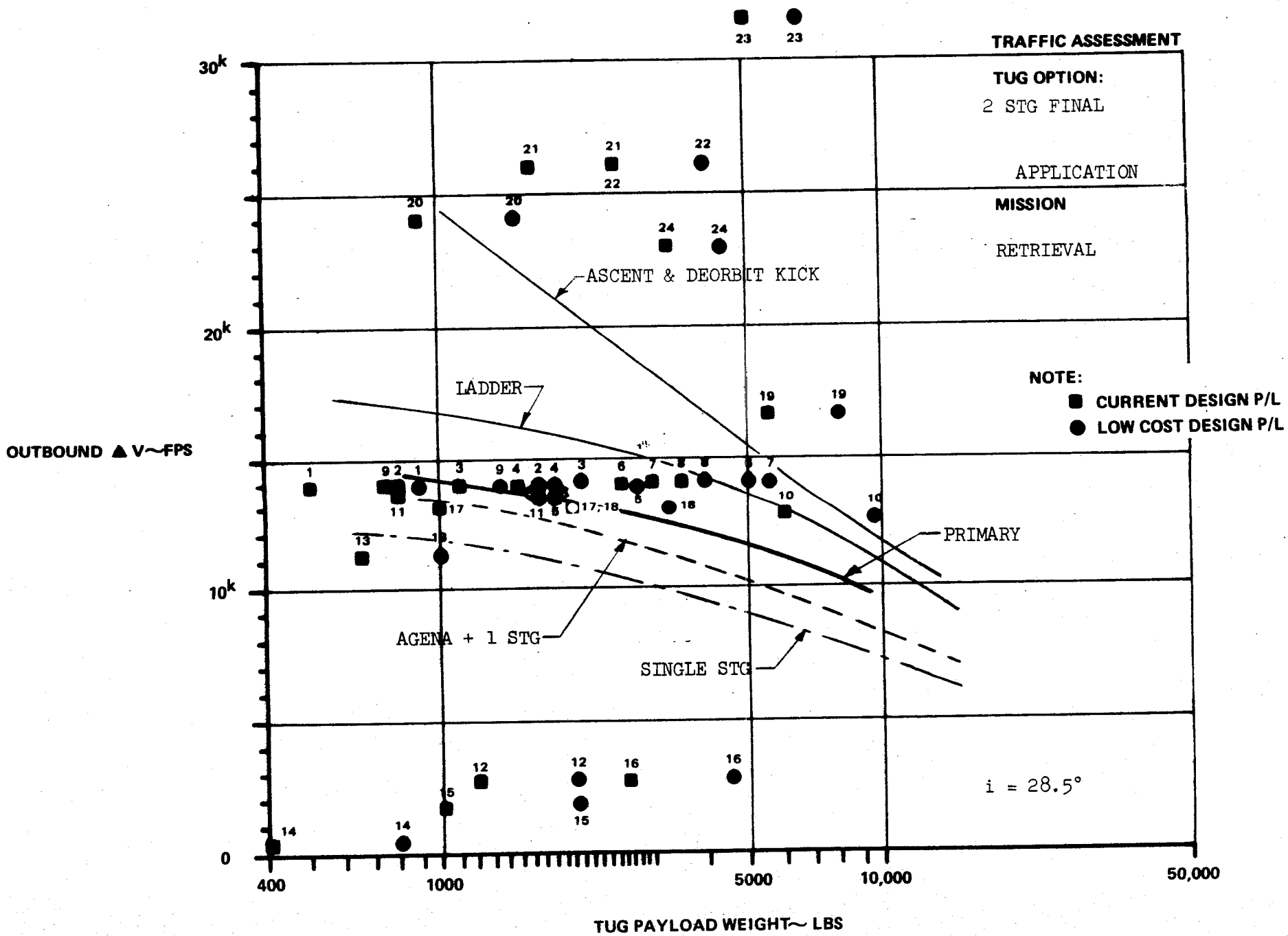
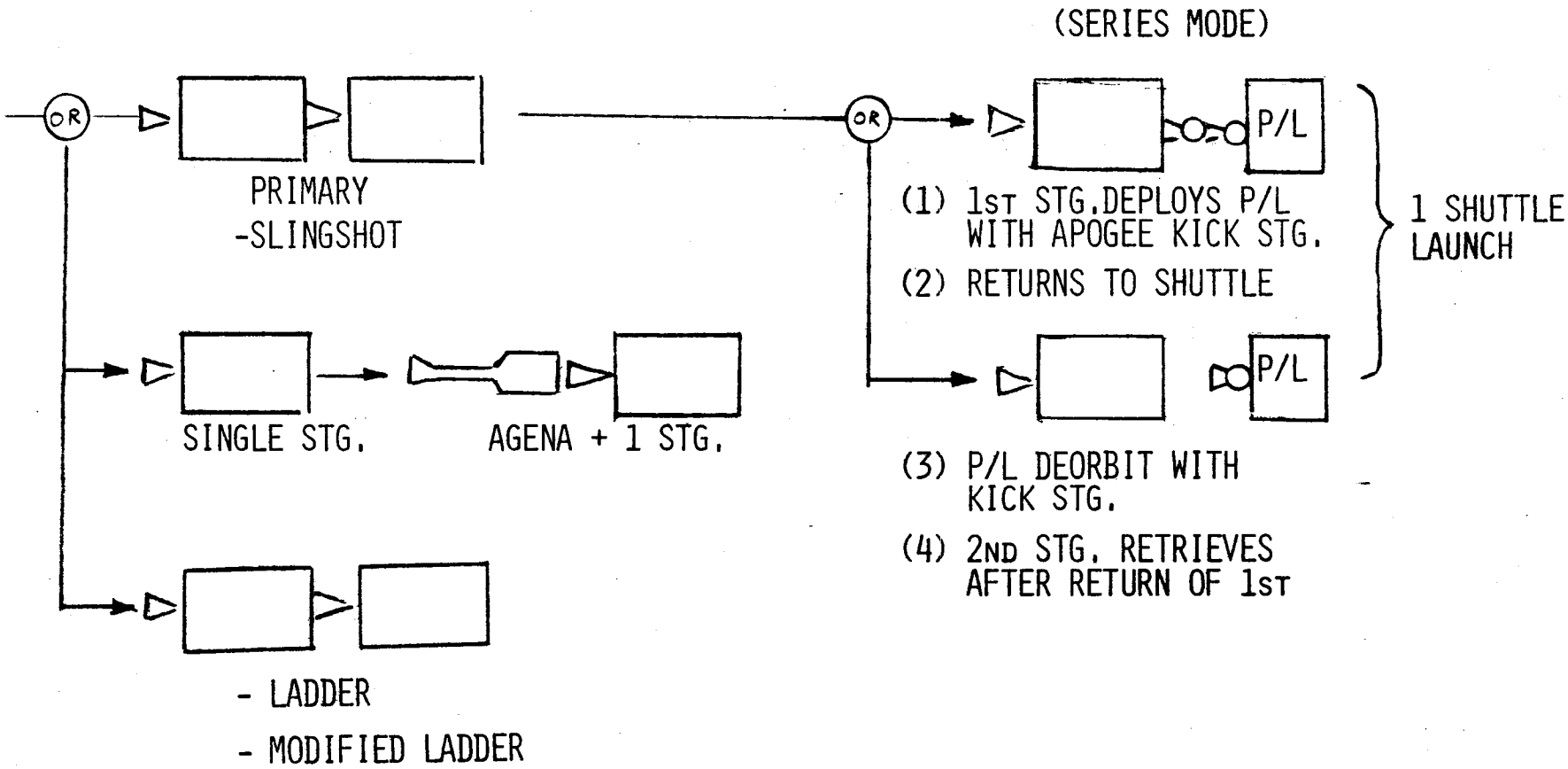

TRAFFIC ASSESSMENT
TUG OPTION:
2 STG FINAL
APPLICATION
MISSION
RETRIEVAL
NOTE:
CURRENT DESIGN P/L
LOW COST DESIGN P/L
ASCENT & DEORBIT KICK
LADDER
PRIMARY
AGENA + 1 STG
SINGLE STG
i = 28.5°
OUTBOUND ▲V~FPS
30k
20k
10k
0
400
1000
5000
10,000
50,000
TUG PAYLOAD WEIGHT~ LBS

Figure 1

TUG CONFIGURATION: 2 STG. FINAL
MISSION APPLICATION: PLACEMENT/RETRIEVAL
PAYLOAD: LOW COST



FLIGHT MODES ⇨

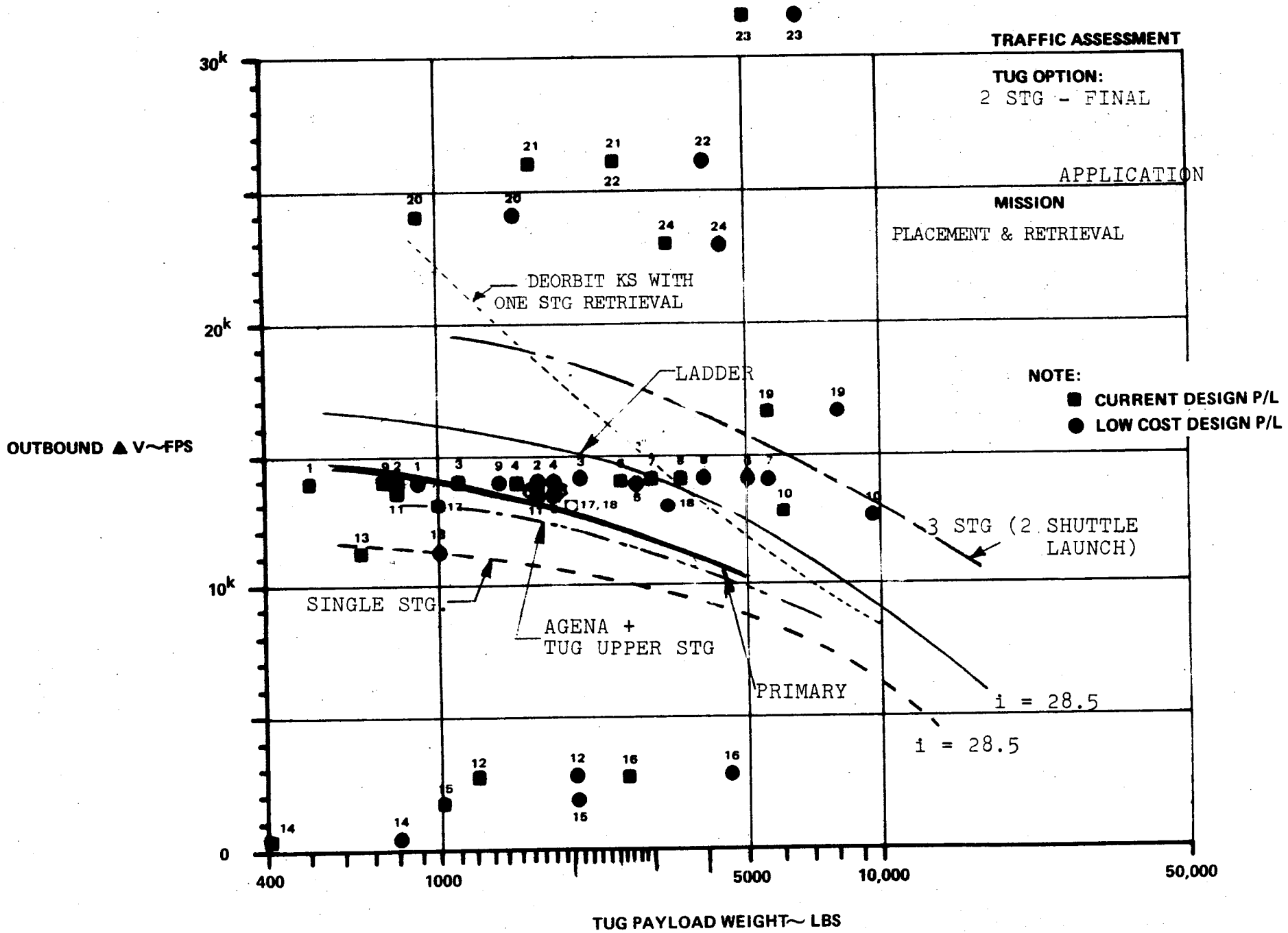

TRAFFIC ASSESSMENT
TUG OPTION:
2 STG - FINAL
APPLICATION
MISSION
PLACEMENT & RETRIEVAL
NOTE:
CURRENT DESIGN P/L
LOW COST DESIGN P/L
DEORBIT KS WITH
ONE STG RETRIEVAL
LADDER
3 STG (2 SHUTTLE
LAUNCH)
SINGLE STG
AGENA +
TUG UPPER STG
PRIMARY
i = 28.5
i = 28.5
OUTBOUND ▲V~FPS
30k
20k
10k
0
400
1000
5000
10,000
50,000
TUG PAYLOAD WEIGHT~ LBS

Figure 1

2 STG. TRAFFIC ASSESSMENT

MISSION APPLICATION / FLT. MODE	PLACEMENT: 1 STG	PRIME	PRIME + KICK	LADDER MODE	EXPEND	NOT CAPT'D.
o INTERIM	12,14	1,2,3 4,5,9	6,7,8		10,19	22
o CURRENT P/L	15,16	11,17 18	13,20		23**, 24	
o FINAL o LOW COST P/L	12,14 15,16	1,2,3, 4,5,9, 11,17, 18	3,5,6, 7, 8 13		10,19 20, 23**	21,22 24

(1) EVALUATE LARGE KICK STG'S FOR PLANETARY MISSIONS

(2) REDUCE MISSION MODEL 10 WEIGHT TO CURRENT DESIGN FOR AT LEAST RETRIEVAL

* MARGINAL CAPABILITY IN THIS MODE.

** ONLY 18,400 FPS REQ'D FROM TUG.

MISSION APPLICATION / FLT. MODE	RETRIEVAL: 1 STG	PRIME	LADDER	P/L DEORB	NOT CAPT'D	PLACEMENT & RETRIEVAL: 1 STG	PRIME	SERIES MODE	LADDER	NOT CAPT'D.
o FINAL o LOW COST P/L	12, 14 15, 16	1, 11	2,3,4, 5,8*, 13	6,7,8	10	12,14, 15,16	1		2,3,4, 5,11, 13	6,7,8, 10

CAPTURE SUMMARY - 2-STAGE FAMILY

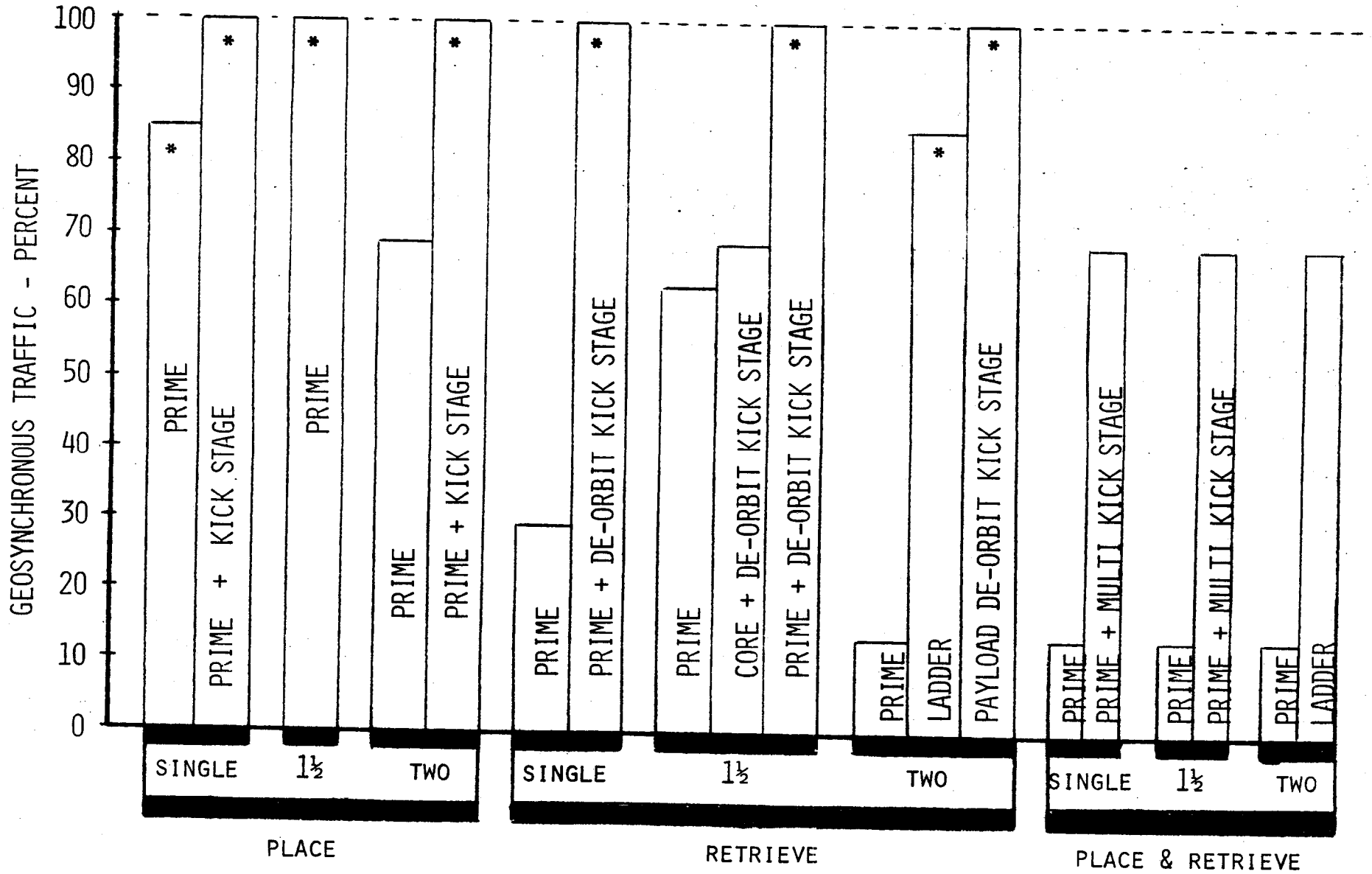
PLACEMENT: Four missions can be performed with one of the two stages (also DOD Missions 5 and 16). Nine require the primary slingshot mode and six require a kick stage. The planetary missions #19, 21, 23, 24, require an expendable Tug flight mode. Further analysis of the kick stage requirements for Mission #22 is required to determine if the mission can be captured.

The final Tug captures the same number of "low cost" payloads in the same flight mode. The exception is Mission #21, which requires additional analysis of the kick stage sizing to determine capture feasibility.

RETRIEVAL: Missions #14, 12, 15 and 16 (DOD 5 and 16) can be retrieved with one of the two stages. The primary mode (slingshot) is required for the synchronous equatorial Mission #1 only. Mission No's. 2, 3, 4, 5, 11, and 13 (also DOD No's 11, 9, 3a, b, 15, 17, 12b) require the ladder mode or de-orbit kick stage, with one of the two stages for used retrieval (#13 requires further analysis). Missions #10, 6, and 7 require use of the "Deploy and Nudge" mode or a de-orbit kick stage and two stages for retrieval. (DOD Mission 8, 10 and 4b are marginal for a one-stage retrieval with de-orbit kick stage.)

PLACEMENT/RETRIEVAL: Missions #12, 14 and 15 can be performed with one of the two stages while #1 and 16 require the primary mode. The ladder mode captures No's. 2, 3, 4, 5, 8, 11 and 13, while Missions 6, 7 and 10 require multi-kick stage modes. Analysis of the Series Mode has not been completed at this time and may alter the distributions in this assessment.

CONCEPT COMPARISON - GEOSYNCH



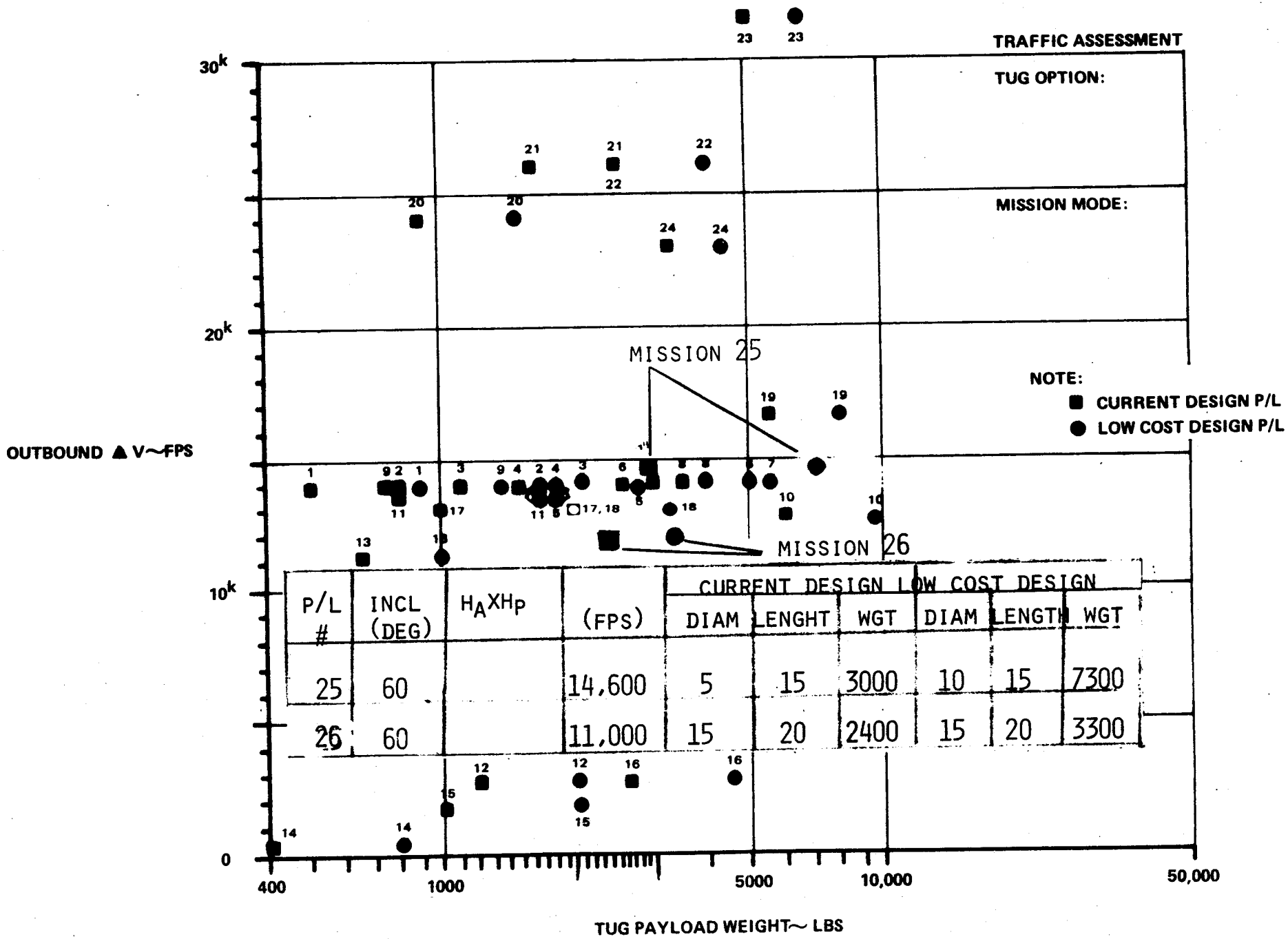
CONCEPT COMPARISON-GEOSYNCH

Placement: The $1\frac{1}{2}$ stage can capture 100% of the geosynchronous traffic in the primary mode while the single stage captures 85%, and the 2 stage, 70%. The single stage and 2 stage concepts require kick stage flight modes to place the entire geosynchronous traffic model. The 2 stage, however, used in a ladder mode can capture the entire geosynchronous placement tasks without kick stage assistance or can utilize one of the stages with a large kick stage, sized for the planetary missions, for 100% capture.

Retrieval: Each concept family can retrieve all geosynchronous traffic in the mode in which a light payload is placed and the excess performance utilized to deorbit a heavy payload for subsequent retrieval on a second Shuttle launch. The $1\frac{1}{2}$ stage concept can retrieve 64% in the primary mode while the single stage retrieves 30% and the 2 stage, 14%. The 2 stage ladder mode, however, can retrieve 85% of the traffic. All concepts can retrieve 100% of the traffic if deorbit kick stages are used.

Placement/Retrieval: All concepts capture 14% of the traffic in their primary mode. The single stage and $1\frac{1}{2}$ stage family captures approximately 70% of the traffic in the multi-kick stage mode, while the 2 stage captures 70% in the ladder mode.

RECOMMENDED MISSION MODEL ADDITIONS



P/L #	INCL (DEG)	$H_A X H_P$	(FPS)	CURRENT DESIGN DIAM	CURRENT DESIGN LENGHT	CURRENT DESIGN WGT	LOW COST DESIGN DIAM	LOW COST DESIGN LENGTH	LOW COST DESIGN WGT
25	60		14,600	5	15	3000	10	15	7300
26	60		11,000	15	20	2400	15	20	3300

Figure 1

RECOMMENDED MISSION MODEL ADDITIONS

It is recommended that the DOD and the NASA mission models be combined in one unclassified model by adding two more missions to the NASA mission model with the characteristics shown on the chart. This will provide a common bench mark for concept comparison and avoid double bookkeeping.

PERFORMANCE ASSESSMENT AND RECOMMENDATIONS

	NO	MISSION	MISSION APPLICATION							SINGLE STG FLT MODE									PAYLOAD K LBS		COMMENTS
										PLACE				RETRV			P & R				
			PLACE	RETRIEVE	PLACE/RETRV	MULTI-PLACE	MULTI-RETRV	SERVICE	SORTIE	PRIMARY	PRIM + KS	EXPEND	TANDEM	PRIMARY	DEORB KS	TANDEM	PRIMARY	MULTI KS	TANDEM	1ST ALT ①	2ND ALT ②	
SYNC EQ	1	SYNC EQ			●												2	1		3.2	1.3	
	2	MISSION 3A	●							1	2									4.0	8.5	1 FINAL 2 INTERIM
	3	MISSION 3B		●											1					5.6		
	4	MISSION 9					●	●									1			1.4		1 REDUCE TO 1 VISIT
HI ENERGY	5	HIGH ENERGY			●												1	2		2.1	4.0	2 COMPLEX OP'N
	6	MISSION 8	●			●				1										4.0		
	7	MISSION 4				●				1	2									3.1	8.5	1 REDUCE TO 2 SAT
HI-INCL	8	HI-INCL CIRC			●												1			18.0		
	9	HI-INCL ELLIP			●												1			10.1		
	10	MISSION 7	●	●						1				2						10.2	6.0	1 PLACE 2 RETRV
PLAN	11	PLANETARY	●							2	1									8.2	3.5	1 LARGE K.S.

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PERFORMANCE ASSESSMENT & RECOMMENDATIONS

	NO.	MISSION	MISSION APPLICATION							11/2 STAGE FLT MODE										PAYLOAD K LBS		COMMENTS
										PLACE				RETRIEVE				P & R				
			PLACE	RETRIEVE	PLACE/RETRV	MULTI-PLACE	MULTI-RETRV	SERVICE	SORTIE	PRIMARY	PRIM + K.S.	EXPENDABLE	TANDEM	CORE	CORE + D/O KS	PRIMARY	PRIM +D/O KS	TANDEM	PRIMARY	PRI+MULT KS	TANDEM	1ST ALT 1	2ND ALT 2	
SYNCH-EQ	1	SYNCH EQ			●														2	1		3.0	1.3	
	2	MISSION 3A	●							1	2											5.5	8.9	
	3	MISSION 3B		●											1	2						3.0	2.1	2 MARGINAL CAP
	4	MISSION 9						●											1			1.3		1 REDUCE TO 1 VISIT
ENERGY	5	HIGH ENERGY			●														1	2		1.7	3.5	2 COMPLEX OP'N
	6	MISSION 8	●			●				1	2											5.5	8.9	
HI-	7	MISSION 4				●					1	2										4.8	9.0	1 REDUCE TO 3 SAT.
HI-INCL	8	HI-INCL CIRC			●														1			25.0		
	9	HI-INCL ELLIP			●														1			10.4		
	10	MISSION 7	●	●						1						2						10.2	9.0	1 PLACE 2 RETRV
PLAN	11	PLANETARY	●																			8.0	13.0	

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PERFORMANCE ASSESSMENT & RECOMMENDATIONS

	NO.	MISSION	MISSION APPLICATION							TWO STAGE FLT MODE											PAYLOAD K LBS		COMMENTS
										PLACE					RETRIEVE				P & R				
			PLACE	RETRIEVE	PLACE/RETRV	MULTI-PLACE	MULTI-RETRV	SERVICE	SORTIE	ONE STAGE	PRIMARY	PRIM + KS	LADDER	EXPEND	ONE STAGE	PRIMARY	LADDER	P/L DEORBIT	ONE STAGE	PRIMARY	SERIES	LADDER	1ST ALT 1	2ND ALT 2	
SYNC EQ	1	SYNC EQ																				1	3.0		2 COMPEX OP'N
	2	MISSION 3A									1	2											7.5	6.5	1 FIN. 2 INTERIM
	3	MISSION 3B															1						4.2		
	4	MISSION 9																				1	3.1		1 RED. 2 VISITS
HI ENERGY	5	HIGH ENERGY																		2		1	4.0	1.5	
	6	MISSION 8											1										7.0		1 SLINGSHOT
HI	7	MISSION 4										1											5.1		1 RED. - 3 SAT'S
HI-INCL	8	HI-INCL CIRC																	1				7.8		
	9	HI-INCL ELLIP																	1				4.6		
	10	MISSION 7								1						2							10.1	6.1	1 PLACE 2 RETRV
PLAN	11	PLANETARY										1	2										8.5	7.0	2 MARGINAL CAP

SELECTION OF REPRESENTATIVE DESIGN MISSIONS

GROUND RULES

- o INCLUDE MISSIONS TO COVER ALL MISSION ORBIT CATEGORIES
  - SYNC EQ.
  - HIGH ENERGY
  - HIGH INCLINATION
  - PLANETARY
- o INCLUDE MISSIONS TO COVER ALL MISSION APPLICATIONS
  - PLACEMENT
  - RETRIEVAL
  - MULTIPLE PLACE
  - SERVICE
  - SORTIE

PLACE/RETRIEVE

- o INCLUDE MISSIONS TO COVER ALL CRITICAL EVENTS IDENTIFIED IN TOPSS
- o INCLUDE MISSIONS TO COVER CRITICAL SIZING CRITERIA FOR S/S

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REFERENCE MISSION INTEGRATION MATRIX

A review of the NASA and DOD missions indicate that a reduced number of reference missions for detailed analysis would adequately cover the range of requirements imposed by all eleven. The facing page chart is a matrix of requirements which include mission application, unique trajectory factors, critical events identified in TOPSS and critical subsystem mission drivers. The eleven missions have been grouped in categories of mission orbit characteristics (i.e., geosynchronous, high energy, highly inclined and planetary). The objective of the mission selection process is to include all elements in each category, with the minimum number of representative missions.

Missions 1, 4, 5, 7, 8, 9 and 10 include the greatest number of requirements. Missions 1 and 4 are both in the geosynchronous class. Mission 4, however, is the only mission which includes the servicing function and is representative of an entire class of multiple satellite operations at geosynchronous orbit. It is recommended that both missions be retained with #4 (DOD Mission #9) used as the reliability mission due to the number of rendezvous, number of MPS burns, large EPS requirement and long flight time.

Missions 5 and 7 provide the largest number of representative requirements in the high energy class. It is recommended that Mission 6 (DOD Mission 8) be dropped and the mission requirements imposed on the communications and thermal systems be included in the ground rule sections of the data package. Because Missions 6 and 7 represent the only multipayload deployment mission application, it is recommended the Mission 7 (DOD Mission 4) be used as the representative profile in the high energy class. (Note, however, the number of satellites that can be deployed in this mission may be required to be reduced to two). Of the high inclination missions, Number 9 provides the greatest number of critical requirements, and is recommended as the representative mission in this class. The tracking access limitation imposed by Number 8 should be included in the ground rule sections of the data package. The unique trajectory problems associated with #10 (DOD Mission 7) is picked up by DOD Mission 4.

Mission 7 is the only Planetary mission and should be retained as one of the representative missions. It is also recommended that DOD Mission 3a be used, including a kick stage configuration, as the representative mission for the interim Tug.

	NO	MISSION	MISSION APPLICATION							CRITICAL EVENTS (TOPSS)													
			PLACEMENT	RETRIEVAL	PLACE/RETRIEVE	MULTI-PLACE	MULTI-RETRIEVE	SERVICE	SORTIE	SHUTTLE DEPLOY TUG/PL	SHUTTLE DEPLOY TUG	TUG DEPLOY P/L	RENDEZVOUS WITH P/L	TUG DOCK WITH P/L	TUG DOCK FOR SERVICE	ORB REND WITH TUG	ORB/TUG RETRIEVAL	ORB/TUG/PL RETRIEVE	CLOSE & DOCK TUG/TUG	STAGE SEP	REND WITH 2ND TUG	SEP PROPELLANT MODULE	DEPLOY MULTI-SAT'S
SYNCH EQ	1	SYNCH EQUAT			●					●		●	●	●		●		●					
	2	MISSION 3A	●							●		●				●	●			●			
	3	MISSION 3B		●							●		●	●		●		●		●			
	4	MISSION 9					●	●			●		●		●		●		●	●	●		
HI-ENERGY	5	HIGH ENERGY			●					●		●	●	●		●		●		●			
	6	MISSION 8	●			●				●						●	●						●
	7	MISSION 4				●				●						●	●		●	●	●		●
HI-INCL	8	HIGH INCL - CIRC			●					●		●	●	●		●		●					
	9	HIGH INCL - ELLIP			●					●		●	●	●		●		●					
	10	MISSION 7	●	●						●		●	●	●		●		●					
PLAN	11	PLANETARY	●							●						●	●			●			

NO.	UNIQUE TRAJ FACTORS							CRITICAL SUBSYSTEM DRIVERS																
								MPS			APS			GN & C			COMM		DMS	THERM		EPS
	REND AT SYNCH ORBIT	REND IN ELLIPT ORBIT	NODAL REGRESSION	APSIDE CONTROL	CATCH-UP PHASING	NON-HOHMANN X'FER	COMM ACCESS	NO. OF BURNS	ΔV LOSSES	MIN TIME BETWEEN BURN	MAX THRUST	MIN THRUST	TANK SIZING	RENDEZVOUS SENSOR	ORBIT NAV	IMU PERF	ACCESS TIME	MAX RANGE	AUTONOMY	HOT DESIGN MISSION	COLD DESIGN MISSION	PWR DURATION
1	●				●				●		●	●		●								●
2																						●
3		●									●	●		●								
4	●				●			●			●	●	●	●								●
5		●	●	●	●	●					●			●								
6																		●			●	
7			●	●	●	●	●									●	●					
8					●		●				●			●			●		●	●		
9		●	●	●	●	●	●				●			●			●		●			
10		●	●	●	●	●	●										●		●			
11									●	●												

MISSION DRIVERS

MISSION TYPE	MISSION	TRAJECTORY ISSUES	S/S DRIVERS	PAYLOAD REQM'TS
SYNC EQ.	NASA SYNCH EQ. DOD MISSION 3A DOD MISSION 3B	GENERAL: o TIME OF FLT TO RETRIEVE; ΔV VS FLT TIME o INCLINATION DRIFT OF TARGET (.8°/YR) SINGLE STG: o RETRIEVAL REND'Z FOR MULTI-KICK STG MISSION 2 STG: o NODAL REGRESSION o TUG TO TUG RENDEZVOUS o SPLIT-UP OF FPR 1½ o STAGING GROUND RULES	MPS o ΔV-LOSS FOR 1ST PERIGEE BURN G&N o TIME FOR NAV STATE VECTOR CONVERGENCE o 200-300NM REND'Z ACQ. RNG. APS o REND'Z BRAKING SIZES MIN THRUST o DOCKING & FINE POINTING FOR P/L SUPPORT SIZES MAX THRUST, MIN. MIN. IMPULSE EPS o LONG DURATION FOR P/L SUPPORT (25 KW - HRS)	o POINTING REQMT FOR P/L CHECKOUT .2° FOR 6-24 HRS) o CHECKOUT REQMT CONFLICTS WITH TIME FOR RETRIEVAL - 26 HRS TO TUG DEPLOY - 7 HRS TO MOI - 24 HRS TO P/L STATION - 6-24 HRS P/L C/O - 12 HRS NAV 3½ DAYS FOR DEPLOY OF P/L

MISSION TYPE	MISSION	TRAJECTORY ISSUES	S/S DRIVERS	PAYLOAD REQMTS
	DOD MISSION 9	GENERAL o FLT TIME FOR RENDEZVOUS	MPS o MAX NO. OF BURNS 12 APS o MAX NO. OF RENDZ WILL SIZE APS TANKS EPS o POTENTIALLY LARGEST DRAWER OF POWER - LASER RDR - MPS BURNS - HI APS ACTIVITY RELIABILITY o PROPOSE MISSION 9 AS REL. MISSION	o DOES 2000 LBS OF SERVICE EQUIPMENT REQ. 300 WATTS? o APS JET LOGIC & PLUME DEFLECTORS FOR CLOSE-IN OPERATIONS

MISSION DRIVERS

MISSION TYPE	MISSION	TRAJECTORY ISSUES:	S/S DRIVERS	PAYLOAD REQ'MTS
HI INCL.	NASA HI-INC CIRC.	o SHUTTLE DE-ORBIT OPPORTUNITY IMPACTS MISSION TIMING	o DEPLOYMENT: WITH OFF-LOADED TANKS. G&N o DOCKING WITH MIN COMMUNICATIONS DATA MANAGEMENT o MAX AUTONOMY COMM o ACCESS TIME 57% IN VOID 1 HR LONGEST VOID THERMAL o LONGEST TIME WITH LIGHT PRO-PELLANT LOAD AT LOW ALTITUDE.(6HRS)	

MISSION DRIVERS(CONTINUED)

MISSION TYPE	MISSION	TRAJECTORY ISSUES:	S/S DRIVERS	PAYLOAD REQ'MTS
	HI INC. NON CIRC.	o SAME AS ABOVE		
	DOD: MISSION 7	o SAME CONSIDERATIONS AS DOD MISSION 4 AND NASA HI-ENERGY MISSION		

MISSION DRIVERS

MISSION TYPE	MISSION	TRAJECTORY ISSUES.	S/S DRIVERS	PAYLOAD REQUIREMENTS
HI ENERGY	o NASA 29° HI ENERGY	GENERAL: o ROUND TRIP MISSION TIME CRITICAL DUE TO NODAL REGR. o PHASING & REND'Z IN ELLIPTICAL ORBIT.	G&N o RENDEZVOUS SENSOR REQUIREMENTS	o TIME FACTOR MAY PRE-CLUDE P/L CHECKOUT.
	o MISSION 8		COMM o MAX RANGE o MULTIPLE DEPLOY THERMAL o DEEPEST SPACE ENVIRONMENT o LONG RETURN FLIGHT TIME WITH LOW PROP. LOADING.	o MULTIPLE DEPLOYMENT COMMUNICATION INTER-LOCK

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MISSION DRIVERS(CONTINUED)

MISSION TYPE	MISSION	TRAJECTORY ISSUES.	S/S DRIVERS	PAYLOAD REQM'TS.
	o DOD MISSION 4	GENERAL: o PHASING REQM'TS WITH OTHER CONSTELLATIONS o NON-APSIDE INSERTION INTO MISSION ORBIT. o CONTROL OF MISSION ORBIT LINE-OF-NODE COMBINED WITH ASCENT PHASING REQM'T. o NODAL REGRESSION IMPACTS RETURN MISSION o WTR VS ETR LAUNCH-SHUTTLE LUANCH AZ. TRADE	G&N o SHORT TIME PERIOD BETWEEN ASCENT TRANSFER & INSERTION INTO MISSION ORBIT MAY PRECLUDE AUTON. NAV. UPDATE - DESIGN MISSION FOR IMU.	

MISSION DRIVERS

MISSION TYPE	MISSION	TRAJECTORY ISSUES	S/S DRIVERS	PAYLOAD REQ'MTS.
PLANETARY		o ΔV LOSSES DUE TO LOW T/W & LONG BURN ARC.	MPS o MIN TIME BETWEEN MAJOR BURNS (10 MIN) DRIVES ENGINE THERMAL REQM'TS. o KICK STG SIZING	o RESTRICTION TO .3Q'S MAY REQ. THROTTEABLE ENGINE

RECOMMENDED REFERENCE MISSIONS

1 - NASA SYNC. EQ.

2 - DOD MISSION 9

3 - DOD MISSION 4 OR NASA HIGH ENERGY

4 - NASA HIGH INCLINATION NON-CIRC.

5 - NASA PLANETARY

6 - DOD MISSION 3A

IN ADDITION

- o INCLUDE DOD MISSION 8 DRIVER REQUIREMENTS FOR COMM AND THERMAL IN DATA PACKAGE GUIDELINES
- o STUDY IMPACT OF DOD MISSION 3B ON RENDEZVOUS APPROACH
- o INCLUDE THE NASA HIGH INCLINATION CIRC. COMM ACCESS TIME REQUIREMENTS IN DATA PACKAGE GUIDELINES
- o REDUCE DOD MISSION 9 PAYLOAD SERVICES TO 3 SATELLITES
- o REDUCE DOD MISSION 4 PAYLOADS TO 2, BUT STUDY ALTERNATE SHUTTLE/TUG FLIGHT MODES TO ACHIEVE REQUIRED 4 P/L'S.

TRADE STUDIES

As a result of our review of the requirements and preliminary assessment of the candidate configurations and flight modes, several trade studies will be performed and scheduled for completion by the first review.

Selected Trajectory Studies:

An evaluation will be made to determine the mission profile feasibility of the round trip (single stage) using kick stages to place the satellite and a payload de-orbit kick stage for return.

The ΔV losses for the planetary and geosynchronous missions will be defined using single burn and multiburn approaches to support selection of MPS thrust levels. In addition, a preliminary assessment of Flight Performance reserves will be made.

A preliminary assessment of the terminal rendezvous geometry will be made to provide the requirements for APS thrust size and jet location.

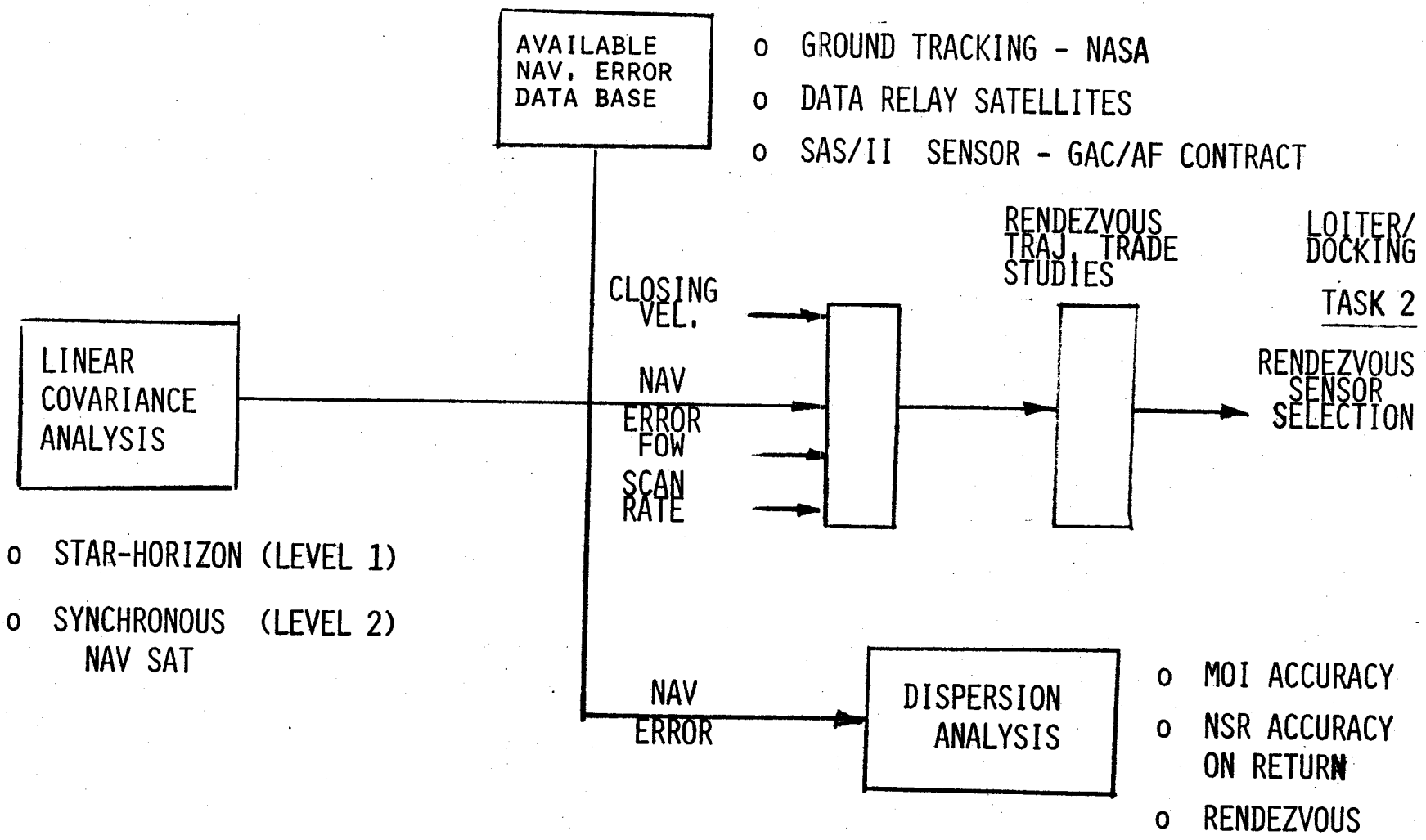
Assessment of the ΔV vs. flight time for the geosynchronous multiple deployment missions will be made to support definition of the Mission profile.

An assessment of the impact of nodal regression on the Ladder Mode of operation will be made. Emphasis will be placed on performing DOD Mission 4 in this flight mode because it shows the potential to be able to deploy the full set of satellites in one mission.

Navigation Studies

A linear covariance analysis will be performed on a Level I autonomous navigation septem using a horizon/star tracker system and a Level II system represented by 621B. Each system has mission related compatibility problems. The Level I system is restricted due to the slow convergence of the state vector while the Level II septem is impacted by geometry. The results of the linear covariance analysis will be used to evaluate ΔV uncertainties for inclusion in the ΔV-Budgets of each mission. In addition, this data will be used to determine and establish the acquisition range requirement for the rendezvous sensor.

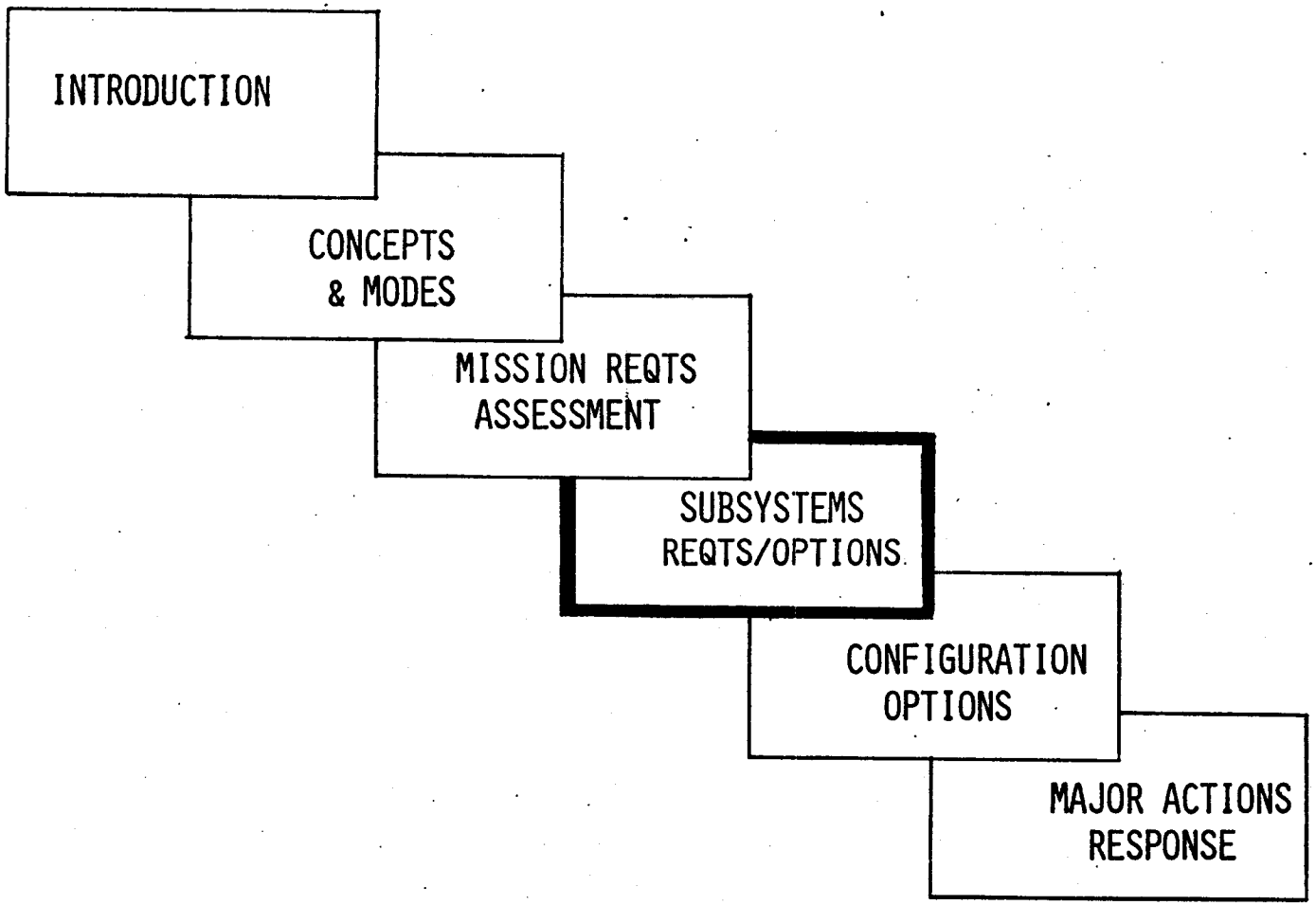
NAVIGATION ANALYSIS



KEY TRAJECTORY ISSUES

- o RENDEZVOUS PLAN FOR MULTI KICK STG PLACEMENT/RETRIEVAL FLIGHT MODE
- o ΔV-LOSS FOR FIRST PERIGEE BURN - MPS SIZING
  - PLANETARY
  - GEOSYNCH
- o RENDEZVOUS APPROACH GEOMETRY AND LATERAL ΔV REQUIREMENTS - APS JET SIZE, LOCATION AND APS TANK SIZING.
- o MULTI DEPLOYMENT ΔV vs FLIGHT TIME
- o 2 STAGE LADDER MODE (TRAPEZE) vs MODIFIED LADDER vs SERIES MODE FOR PLACEMENT/RETRIEVAL IN ELLIPTICAL INCLINED ORBIT.
- o FPR EVALUATION

OUTLINE



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TASK 2 SUBSYSTEMS ANALYSES - DRIVER REQUIREMENTS SUMMARY

- o MAIN PROPULSION: MAXIMIZE ISP, MINIMIZE RESIDUALS & INERTS
- o AUXILIARY PROPULSION: REDUNDANCY, DEADBAND OPERATION, RATES, CLEANLINESS OF EXHAUST
- o GUIDANCE, NAVIG. & CONTROL: RETRIEVAL & AUTONOMY
- o COMMUNICATIONS: FREQUENCY MANAGEMENT, DATA RATES, RANGE
- o DATA MANAGEMENT: DATA PROCESSING, AUTONOMY
- o ELECTRICAL POWER: MISSION DURATION, POWER, TOTAL ENERGY
- o THERMAL CONTROL: END-OF-MISSION ENVIRONMENT/DURATION
- o S/S SAFETY: PRE-ENTRY SAFING, NO VENTING IN P/L BAY
- o GROUND OPERATIONS: GROUND HOLD, SERVICING, CHECKOUT, DRAIN ON PAD

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MAIN PROPULSION SUBSYSTEM "DRIVER" REQUIREMENTS

o TOTAL IMPULSE PER MISSION	20×10^6, LB - SEC
o MISSION DUTY CYCLES	
- NUMBER AND DURATION OF BURNS	12 BURNS/TBD
- TIME BETWEEN LAUNCH AND FIRST BURN	30 HOURS
- DURATION OF FINAL BURN	70 - TBD, SEC.
- MAXIMUM SINGLE BURN	TBD
- MINIMUM TIME BETWEEN BURNS	12 MIN
- MAXIMUM TIME BETWEEN BURNS	72 HOURS
- MAXIMUM TIME ON-ORBIT	163 HOURS
- ΔV LOSSES AS A FUNCTION OF THRUST-TO-WEIGHT	TBD
- VEHICLE CENTER-OF-GRAVITY EXCURSIONS	TBD
o ABORT/SAFETY CRITERIA	
- MINIMUM TIME BETWEEN FAILURE AND ENTRY/LANDING	5 MINUTES
- REDUCE PROPELLANTS AND PRESSURANTS TO SAFE LEVELS	TBD
- NO VENTING IN PAYLOAD BAY	
o MISSION ENVIRONMENT	
- THERMAL, STATIC AND DYNAMIC LOADS, ACOUSTIC	
o GROUND OPERATIONS	
- MAXIMUM GROUND HOLD TIME LOADING TO LAUNCH	30 HOURS
- SERVICING AND CHECKOUT	OFF-LINE

MAIN PROPULSION SUBSYSTEM REQUIREMENTS

o THRUST, LBS	6000	-	16,900
o ISP, LBF-SEC/LBM	311	-	340
o MIXTURE RATIO	1.6	-	2.7
o ENGINE			
- WEIGHT, LBS,	210	-	420
- LENGTH, IN	55	-	120
- EXPANSION RATIO (ϵ)	100	-	400
- NUMBER OF STARTS	140	-	200
- LIFE, HOURS	6	-	19
o GIMBAL ANGLE, DEGREES	0	-	10
o NPSP			
- FUEL, PSI	3.4	-	14
- OXIDIZER, PSI	5.0	-	15
o PROPELLANT TEMPERATURE			
- OPERATING , ^{o}F	40	-	80
- NON-OPERATING, ^{o}F	40	-	120

TASK 2 - SUBSYSTEM ANALYSES - MAIN PROPULSION SUBSYSTEM (MPS)

IDENTIFICATION OF MPS OPTIONS

		INTERIM	GROWTH	DIRECT DEVEL.
o FEED SYSTEMS (CONT.)				
- GAUGING SYSTEM	PROBE- - - - - -	X	X	X
	POINT SENSORS- -	X	X	X
	R.F. - - - - - - -		X	X
	OTHER- - - - - -	X	X	X
- COMPONENTS	EXISTING - - - -	X	X	X
	MODIFIED - - - -	X	X	X
	NEW- - - - - - -	X	X	X
- PROP. ACQUISITION	SCREEN - - - - -	X	X	X
	APS SETTLING - -	X	X	X
- LINE ROUTING	THRU PROP. TANK-	X	X	X
	OUTSIDE- - - - -	X	X	X
- INTERCONNECTED WITH APS - - - - - - - - - - - - - -		X	X	X
- PROPELLANT UTILIZATION	PASSIVE- - - - -	X	X	X
	ACTIVE - - - - -	X	X	X
- HELIUM STORAGE	SUPERCRITICAL- -	X	X	X
	EXISTING AMBIENT	X	X	X
	NEW AMBIENT- - -	X	X	X

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TASK 2 - SUBSYSTEM ANALYSES - MAIN PROPULSION SUBSYSTEM (MPS)

IDENTIFICATION OF MPS OPTIONS

		INTERIM	GROWTH	DIRECT DEVEL.
o PROPELLANTS				
- OXIDIZERS	N_2O_4	X	X	X
	HDA	X		
- FUELS	MMH	X	X	X
	A-50	X	X	X
	UDMH	X		
o ENGINES				
- AGENA	8096A	X		
	8096B	X	X	
- OME WITH PUMP PACKAGE		X	X	X
- NEW HIGH PRESSURE ENGINE			X	X
- SRM FOR KICK STAGES		X	X	X
o FEED SYSTEMS				
- TANK PRESSURIZATION	HELIUM	X	X	X
	AUTOGENOUS	X	X	X
	BOOST PUMPS		X	X

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TASK 2 - SUBSYSTEMS ANALYSES - MAIN PROPULSION SUBSYSTEM (MPS)

MPS CAPABILITIES ANALYSES

- ✓ o PROPELLANT SELECTION
- o ENGINE SELECTION, INTERIM & FINAL
- o ACTIVE VS. PASSIVE P.U. CONTROL INC. GAUGING SYSTEM TRADES
- ✓ o TANK PRESSURIZATION, AUTOGENOUS VS. AMB. He VS. SUPERCRIT He VS. BOOST PUMPS
- ✓ o DUMP AND INERTING TRADES
- o PROPELLANT ACQUISITION, APS SETTLING VS. PROP. RETENTION
- o DROP TANK DISPOSAL TRADES
- o ENGINE THERMAL CONDITIONING TRADES
- o EVOLUTION/PERFORMANCE GROWTH ANALYSES

MAIN PROPULSION SUBSYSTEM (MPS)

The primary MPS functional requirement is to provide the thrust to satisfy the basic mission delta-V requirements. As such the MPS driver requirement is to provide the highest specific inpulse at the lowest inert weight. Since residual propellants impact inert weight a corollary driver requirement is to minimize trapped/residual propellants.

The gravity losses dictate that the MPS provide at least 6000 lb. thrust. For a new development engine or the modified OME, tradeoffs between gravity induced Δv losses and engine weight will set the optimum thrust requirement. All engines considered must be reusable, with up to 200 cycles and 19 hours life required. The detailed burn timeline sets the requirements for critical engine restart times, pressurization section (particularly supercritical helium) requirements, and subsystem thermal requirements.

Of particular concern to the MPS design is the requirement to dump propellants. This will drive the design of the fill and vent sections and set any requirements for Shuttle/Tug fluid interfaces.

The Tug must be capable of multi-burn operation in a zero g environment. This produces a requirement for propellant acquisition prior to each start, which will be satisfied either by surface tension acquisition devices or APS settling.

The MPS will be designed to operate only in a non-manned mode (i.e. at sufficient distance from the Shuttle that MPS failures would not produce a hazardous situation). This infers a different safety requirement for Shuttle operation (in the P/L Bay or close to the Shuttle) than for Tug MPS operation, thus allowing a relief on operational redundancy. Sufficient redundancy is still required to preclude a hazardous failure during Shuttle operations.

AUXILIARY PROPULSION SUBSYSTEM "DRIVER" REQUIREMENTS

- TOTAL IMPULSE PER MISSION
- ACCELERATION RATES, LINEAR & ANGULAR
- TIME IN LIMIT CYCLE OPERATION
  - DEADBAND LIMITS
- VEHICLE WEIGHTS, INERTIAS, & CENTER-OF-GRAVITY EXCURSIONS
- REDUNDANCY CRITERIA
- ABORT/SAFETY CRITERIA
  - REDUCE PROPELLANTS AND PRESSURANTS TO SAFE LEVELS
  - ISOLATE FAILED THRUSTERS
  - VERIFY PROPELLANT QUANTITY PRE-DOCKING
  - NO VENTING IN PAYLOAD BAY
- CLEANLINESS OF EXHAUST PLUMES
- GROUND OPERATIONS
  - SERVICING
  - CHECKOUT

AUXILIARY PROPULSION SUBSYSTEM REQUIREMENTS

o THRUST	25 - 150 LB
o ISP (STEADY STATE)	230 - 300 SEC
o TOTAL IMPULSE	100,000 - 200,000 LB-SEC
o MIN. IMPULSE BIT	0.25 - 1.50 LB-SEC
o DEADBAND OPERATION	NARROW (0.5^{o}) 26 HOURS WIDE (5°) 95 HOURS
o ANGULAR ACCELERATION	$1^{o}/SEC^{2}$
o LINEAR ACCELERATION	0.2-0.3 FT/SEC^{2}
o FAILURE CRITERIA	FO/FS
o THREE AXIS TRANSLATION	
o THREE AXIS ROTATION	

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TASK 2 - SUBSYSTEM ANALYSES - AUX. PROPULSION SUBSYSTEM (APS)

IDENTIFICATION OF APS OPTIONS

		INTERIM	GROWTH	DIRECT DEVEL.
o PROPELLANTS				
- MONOPROPELLANT	N_2H_4	X	X	X
- BIPROPELLANT	N_2O_4/MMH	X	X	X
	SAME AS MPS PROPELLANTS	X	X	X
o ENGINES				
- EXISTING MONOPROPELLANT ENGINES*		X	X	X
- EXISTING BIPROPELLANT ENGINES*		X	X	X
- NEW ADVANCED ENGINES			X	X
o TANKAGE				
- LM/APOLLO		X	X	X
- OTHER EXISTING TANKS		X	X	X
- NEW DEVELOPMENT			X	X
- INTERCONNECTED (REFILLABLE)		X	X	X
- COMMON WITH MPS		X	X	X
o SUPPLEMENTAL COLD GAS JETS		X	X	X

* SEE SEPARATE LIST

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CANDIDATE APS BIPROPELLANT ENGINE OPTIONS

MFGR	DESIGNATION	THRUST, LBS
BELL	ARE	100
	LFV	100
MARQUARDT	R-4D-5	100
	R-15A	100
	R-1E	22
	R-4DV	100
	R-4D-7	100
	R-4B	100
ROCKETDYNE	SE-8	93
	SE7-1	73
	SE-9	45
TRW	URSA 25	25
	S-4B ACE	150
	URSA 100R	100

CANDIDATE APS MONOPROPELLANT ENGINE OPTIONS

MFGR	DESIGNATION	THRUST, LBS
MARQUARDT	R-14C	75
	R-30	155/65
	R-24B	25
ROCKET RESEARCH	MR-3A	27
	MR-36A	170
	MR-39A	50
	MR-27A	75
	MR-7A	23
TRW	M-50M	50
HAMILTON STANDARD	REA-19	25
	REA-20	100
	REA-9	75
	REA-12-2	25
	REA-13	23

TASK 2 - SUBSYSTEM ANALYSES - AUX. PROPULSION SUBSYSTEM (APS)

APS CAPABILITIES ANALYSES

- ✓ o THRUST LEVEL, NUMBER, AND LOCATION TRADES
- o BI-LEVEL VS. SINGLE LEVEL THRUST
- o RELIABILITY/REDUNDANCY STUDY
- ✓ o MONOPROPELLANT VS. BIPROPELLANT
- o PROPELLANT STORAGE (COMMON WITH MPS, MODULARIZED, CENTRALIZED)
- o PROPELLANT RETENTION (BLADDERS, BELLOWS, SCREENS)
- o PRESSURANT STORAGE (COMMON WITH MPS, DEDICATED)
- o ENGINE THERMAL CONTROL TRADES
- o EVOLUTION/PERFORMANCE GROWTH ANALYSES

AUXILIARY PROPULSION SUBSYSTEM (APS)

The APS must provide full three axis rotational and three axis translational control and in addition must be designed to be fail-operational-fail safe. The subsystem is driven by its requirements to satisfy translational and rotational accelerations and yet minimize propellant consumption during limit cycle operation. These ranges of requirements may drive the thruster locations or dictate bimodal or mixed thrust engines. A particularly severe APS requirement is to provide efficient vehicle control with the large x-axis c.g. travel which will be experienced (3200 lb. vehicle weight with payloads from 0-9000 lb.). This factor may dictate particular thruster locations or impact redundancy decisions.

While the MPS need not be man rated, the APS must operate in close proximity to the Shuttle and must be designed with the FO-FS redundancy. The APS must maintain attitude hold during Shuttle/Tug rendezvous and thus must operate within one "manipulator length" of the Shuttle and its crew.

Exhaust plume cleanliness is a critical requirement due to the contamination sensitivity of some of the many different types of payloads to be carried. This factor will be an important discriminator in the APS propellant selection.

GUIDANCE, NAVIGATION AND CONTROL SUB-SYSTEM "DRIVER" REQUIREMENTS

- o PAYLOAD RETRIEVAL
  - GEOSYNCHRONOUS AND HIGHLY ELLIPTICAL ORBIT MISSIONS DRIVE RENDEZVOUS RADAR SENSOR PERFORMANCE (RANGE/ANGLE DATA ACQUISITION/ACCURACIES)
- o AUTONOMY
  - AUTONOMOUS NAVIGATION
    - o LONG DURATION OF 1ST PERIGEE BURN DRIVES IMU PERFORMANCE (GYRO/ACCELEROMETER PERFORMANCE)
    - o REQUIRED ASCENT AND DESCENT TRANSFER PERFORMANCE DRIVES ON-ORBIT NAVIGATION SYSTEM UPDATE (POSITION/VELOCITY ACCURACIES)
  - AUTONOMOUS DOCKING
    - o POLAR MISSION DRIVES REMOTE TV (NON-AUTONOMOUS) DOCKING OPTION DUE TO LIMITED GROUND COVERAGE

GUIDANCE, NAVIGATION & CONTROL SUBSYSTEM REQUIREMENTS

o NAVIGATION SYSTEM PERFORMANCE (SYNCHRONOUS ALTITUDE, DEPLOYMENT) - ACCURACIES

	- POSITION (-3σ), NM	- VELOCITY (-3σ), NM	
TANGENTIAL	60	20	DATA PACKAGE
NORMAL	20	50	
RADIAL	70	70	

o DOCKING SENSOR - GUIDANCE AND CONTROL DOCKING ACCURACIES CONSISTENT WITH THE FOLLOWING DOCKING MECHANISM CONDITIONS:

RADIAL MISALIGNMENT	±6 INCHES	DATA PACKAGE
LONGITUDINAL VELOCITY	0.1 TO 1.0 FPS	
LATERAL VELOCITY	0.3 FPS	
ANGULAR MISALIGNMENT	±3 DEGREES	
ANGULAR RATE	±2.4 DEG/SECOND	

GUIDANCE, NAVIGATION & CONTROL SUBSYSTEM REQUIREMENTS (CONT.)
(NOMINAL ASSUMPTIONS)

- o RENDEZVOUS RADAR SENSOR
  - ANGLE & RANGE ACQUISITION RANGE:
    30 NM/300 NM (SKIN TRACK/PASSIVE COOPERATIVE)
  - MEASUREMENT ACCURACIES (3σ) - PASSIVE COOPERATIVE MODE
    RANGE: $\pm$ 120 FT (BIAS)/80 FT (RANDOM)
    RANGE RATE: $\pm$ 1 FT/SEC
    LINE OF SIGHT AZIMUTH/ELEVATION ANGLE: 8 MR (BIAS)/2 MR (RANDOM)
    LINE OF SIGHT AZIMUTH/ELEVATION ANGLE RATE: $\pm$ 0.2 MR/SEC
- o IMU

- ANGULAR RATE CAPABILITY	50°/SEC
- HEADING ALIGNMENT	30 $\widehat{\text{SEC}}$
- GYRO BIAS	0.03°/HR (7 DAY STABILITY ALL AXES)
- GYRO UNBALANCE	0.1°/HR/G
- GYRO SCALE FACTOR	50 PPM
- ACCELEROMETER RANGE	6G
- ACCELEROMETER BIAS	50 μG (7 DAY STABILITY ALL AXES)
- ACCELEROMETER SCALE FACTOR	50 PPM

TASK 2 - SUBSYSTEM ANALYSES - GUIDANCE, NAVIGATION AND CONTROL (GNC) OPTIONS

		INTERIM	GROWTH	DIRECT DEVEL.
- INERTIAL MEASUREMENT UNIT	o DELCO CAROUSEL V	X	X	X
	o LITTON LN-15	X	X	
	o LITTON LN-30	X	X	X
	o KEARFOTT KT-70	X	X	
	o MIT DODECAHEDRON			X
- NAVIGATION STATE VECTOR UPDATE	o HORIZON SCANNER/ STAR TRACKER (LEVEL I AUTONOMY)		X	X
	o SYNC. NAVIG. SATELLITE SYSTEM (LEVEL II AUTONOMY)		X	X
	o STDN/AFSCF TRACKING/ UPLINK (LEVEL III AUTONOMY)	X		
- RENDEZVOUS SENSOR	o APOLLO LM RENDEZVOUS RADAR (MODIFIED)		X	
	o ITT SCANNING LASER RADAR			X
- PAYLOAD DOCKING SYSTEM	o REMOVE TV		X	
	o ON-BOARD ACTIVE LASER			X
	o PASSIVE COOPERATIVE DOCKING SYSTEM		X	

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TASK 2 - SUBSYSTEM ANALYSES - GUIDANCE, NAVIGATION AND CONTROL (GN&C)

GN & C CAPABILITY ANALYSES

- ✓ o GIMBALLED PLATFORM VS. STRAPDOWN IMU
- ✓ o RENDEZVOUS/DOCKING SENSOR SELECTION
- ✓ o AUTONOMOUS NAVIGATION TECHNIQUES
  - VARIOUS LEVELS OF AUTONOMY
- o GN&C REDUNDANCY
- o VEHICLE ATTITUDE/TRANSLATION/ΔV CONTROL STUDIES
- o MANEUVER GUIDANCE/TARGETING

GUIDANCE NAVIGATION AND CONTROL (GN AND C) SUBSYSTEM

The Space Tug GN and C subsystem design is driven by two major requirements:

- o Payload Retrieval (Rendezvous/Docking)
- o Autonomy

The Geosynchronous and Highly Elliptical Orbit payload retrieval missions will place the most demanding acquisition range and data accuracy requirements on the Space Tug Rendezvous Radar Sensor. Requirements for both a Skin Track Mode and a Passive Cooperative Mode have been identified. Prime candidates being considered include a modified RCA Apollo LM RF Radar and an ITT developed scanning laser radar. Two options are available for the laser: Ga As and Yag.

The major GN and C Subsystem design issue with respect to Autonomy is "Autonomous Navigation. Inertial Measurement Unit (IMU) gyro and accelerometer required performance is driven by the time criticality/long duration of the 1st perigee burn since apogee cannot be missed by more than an equivalent ΔV of 30 ft/sec. Preliminary indications are that the nominal IMU performance values specified herein can satisfy the above mission navigation requirements.

The on-orbit ascent and descent transfer performance requirements directly drives the navigation system update position/velocity accuracies. For example, one of the more stringent mission constraints is the 15 n.mi ΔH requirement following descent transfer from geosynchronous orbit. Primary navigation update system candidates being investigated to meet data package accuracies for position and velocity tangential, normal, and radial components are:

- o Horizon Scanner/Star Tracker configuration (Level I Autonomous configuration)
- o Synchronous Navigation Satellite System (Level II Autonomous configuration)

Performance capabilities of these systems, as well as, other candidates are discussed and evaluated in the Grumman Astrionics- Group 4 - splinter session handout, as well as preliminary IMU (Gimballed vs. Strapdown) and Rendezvous Radar Sensor Selection trade study data.

Tug to payload docking will require a sensor to provide the Tug GNC/DMS computer with relative range/range rate/angle data in order to meet the Tug data package defined guidance and control docking accuracies. Remote TV, on-board active laser, and passive cooperative docking system are the candidates being investigated. The polar mission will place severe constraints on the Remote TV application due to the limited ground station coverage associated with this mission.

COMMUNICATIONS SUBSYSTEM "DRIVER" REQUIREMENTS

- o FREQUENCY MANAGEMENT
  - SGLS/STDN COMPATIBILITY
  - DEDICATED VS TIME-SHARED
- o ALL ATTITUDE COMMUNICATION
- o - N. MI. RANGE FOR 16 KBS TLM
- o TBD RANGE FOR 256 KBS DATA
- o - N.MI. RANGE FOR B&W TV: SNR/BW TBD
- o SPREADING THE R.F. SPECTRUM
  - INTERFERENCE REQUIREMENTS (CCIR)
  - CODING (VITERBI CODING)

COMMUNICATIONS SUBSYSTEM REQUIREMENTS

DOD	REQUIREMENT	NASA
16KBS/TBD/TBD/10^{-5}	TLM/SNR/BW/BER	16. KBS/TBD DB/TBD KHz/10^{-6}
256KBS/TBD/TBD/10^{-5}	DATA/SNR/BW/BER	———
2KBS/TBD	CM/SUCCESS CRITERIA	1 KBS/LESS THAN ONE 22 BIT MSG REJECTED PER 1000 RECEIVED
PRN/TBD DB IN 1 Hz NBW	RANGING/SNR FOR 60 SEC CODE ACQUISITION	PRN/32 DB IN 1 Hz NBW
CARRIER/TBD	RANGE RATE/SUCCESS CRITERIA	CARRIER/TBD
TBD	DATA VIA SATELLITE	TBD
B& W/TBD	TV/SUCCESS CRITERIA	B & W/TBD

TASK 2 - SUBSYSTEM ANALYSIS - COMMUNICATIONS (COMM) SUBSYSTEM

IDENTIFICATION OF OPTIONS

	INTERIM	GROWTH	DIRECT DEVELOP
o TUG COMMUNICATIONS UP TO DEPLOYMENT STATION			
- CONTROL OF TUG BY ORBITER	X	X	X
- CONTROL OF TUG BY GROUND STATION	X	X	X
- AUTONOMOUS TUG			X
o BASEBAND PROCESSOR			
- COMPATIBLE WITH FREQUENCY DIVISION MULTIPLEX (STDN/SGLS)	X	X	X
- COMPATIBLE WITH SPREAD SPECTRUM			X
o POWER AMPLIFIER			
- SOLID STATE			X
- TUBE (IF POWER REQUIREMENTS EXCEED 20-30 WATTS)			X

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TASK 2 - SUBSYSTEMS ANALYSES

COMMUNICATIONS SUBSYSTEM CAPABILITY ANALYSES

- ✓ o FREQUENCY MANAGEMENT
  - STDN/SGLS COMPATIBILITY
  - DEDICATED vs TIME-SHARED
- o RENDEZVOUS STUDY
- o AUTONOMY STUDY
- o REDUNDANCY/RELIABILITY STUDY
- o ANTENNA COVERAGE
- o OBC VS. GND CHECKOUT
- ✓ o OFF-THE-SHELF VS MODIFIED VS. NEW EQUIPMENT
- o PERFORMANCE GROWTH
- o PAYLOAD SERVICE TECHNIQUES

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COMMUNICATIONS SUBSYSTEM "DRIVER" REQUIREMENTS

Simultaneous communications between STS elements, STS payloads, and mission control could result in excessive Tug communication equipment and expansion of ground station/TDRS system facilities. However, a preliminary analyses that recognizes the communications requirements and systems limitations results in control of the Tug by the orbiter. This limits the frequency management problem. Additionally, it is highly desirable (relative to operations and cost) to have a communication system that is compatible with the STDN/SGLS frequency formats. Preliminary GAC analysis and discussions with Motorola indicate that this is feasible. These same discussions indicate that this design could include a transceiver/transponder that is compatible with all STDN/SGLS channel assignments. Use of this assembly drives the Tug to use of time sharing for multiple payloads.

Relaying 256 KBS data via the Tug could have a serious impact on Tug communications. It appears that the sensor data from the payload must be transmitted to the ground in order to have a successful payload mission. It is probable that the Tug will be available for data relay only a small percentage of the payloads mission timeline. As a result, the impact on Tug communications may not be worthwhile. For example, the difference in power required between 256 KBS data and 16 KBS data (for the same range/ success criteria) is about 16 times, while doubling (or halfing) the range results in a four times power increase (decrease).

The CCIR (Comité Consultatif International des Radio) is a member of the International Telecommunication Union, an agency of the UN. The U.S. military largely follows the recommendations of these agencies. GAC understands that the orbiter communication and the TDRS system will meet CCIR radiated flux density requirements. These requirements are specified to preclude interference with existing ground station channel assignments used by other services e.g. common carriers. The implication of this is some form of spread spectrum.

DATA MANAGEMENT SUBSYSTEM "DRIVER" REQUIREMENTS

- o TUG SUBSYSTEMS DATA PROCESSING REQUIREMENTS
  - GN&C (DATA ACQUISITION, SENSOR PROCESSING, COMPUTATIONS, COMMANDS)
  - GN&C, COMM, EPS, MPS, APS (SUBSYSTEMS MONITORING)
  - REDUNDANCY MANAGEMENT (FAILURE DETECTION, FAULT ISOLATION & RECONFIGURATION)
  - ON BOARD CHECKOUT
- o ACCURACY OF GN&C ORBIT PREDICTION CALCULATIONS
- o MISSION PHASES WHICH REQUIRE THE MAXIMUM NUMBER OF SIMULTANEOUS COMPUTER OPERATIONS
  - RENDEZVOUS & DOCKING MANEUVERS
  - MAIN ENGINE BURNS
- o DOWN LINK DATA DUMP RATE
- o TIME BETWEEN DATA DUMPS TO GROUND
- o AUTONOMY & RETRIEVAL
- o SHUTTLE SOFTWARE COMPATIBILITY

DATA MANAGEMENT SUBSYSTEM REQUIREMENTS

o COMPUTER			
- MAIN MEMORY, K WORDS	32	-	60
- WORD LENGTH, BITS/WORDS	16	-	32
- THRUPUT, KOPS	240	-	400
- LANGUAGE		HAL	
o SENSORS	230		400
o TAPE RECORDER			
- CAPACITY, M BITS	15	-	80
- RECORD RATE, KBPS	5	-	16
- PLAYBACK RATE, KBPS	50	-	16
- RECORD TIME, MINUTES	50	-	82

IDENTIFICATION OF OPTIONS

	INTERIM	GROWTH	DIRECT DEVELOP.
COMPUTERS			
- CDC 469 (DERIVATIVE)	X		X
- BENDIX 910	X		X
- GARRETT ADAPT RF 20	X		X
- HUGHES HDP-4	X		X
- HONEYWELL 402 (MODIFIED VIKING)	X		X
- NEXT GENERATION		X	
TAPE RECORDERS			
- LEACH	X		X
- ODETICS	X		X
- RCA	X		X
- LOCKHEED	X		X
DATA ACQUISITION & DATA BUS CONTROLLER/TLM FORMATTER			
- RADIATION	X		X
- SCI	X		X
- TELEDYNE	X		X
ADVANCED MASS MEMORY			
- FERRO ACOUSTIC		X	X
- CHARGED COUPLE DEVICES		X	X
- MNOS		X	X

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TASK 2 - SUBSYSTEM ANALYSIS - DATA MANAGEMENT SUBSYSTEM (DMS)

DMS CAPABILITY ANALYSES

- o DMS EVOLUTION TRADES
- o IMPACT OF AUTONOMY
- o PARTITIONING OF FIXED SOFTWARE FROM MISSION DEPENDENT SOFTWARE
- o CANDIDATE COMPUTER TRADES
- o DMS REDUNDANCY SELECTION
- o INTEGRATED VS. FEDERATED COMPUTER I/O
- o AUXILIARY VS. RESIDENT MEMORY
- o DATA BUS VS. HARDWIRE
- ✓ o OBC (ON BOARD CHECKOUT) VS. GROUND CHECKOUT
  - SENSOR/SIGNAL ESTIMATE

DMS DRIVERS, REQUIREMENTS, OPTIONS AND STUDIES

The order of the drivers listed in the Driver Requirements chart corresponds to the order of requirements in the requirements chart. Tug data processing requirements drive DMS storage requirements which drives the computer memory size; accuracy drives computer word size while the number of simultaneous operations drives computer throughput size.

The NASA Data Package requirement for commonality of Tug software (S/W) with shuttle S/W drives selection of the computer higher order language HAL. HAL will also permit use of shuttle S/W development facilities etc. thereby greatly reducing the cost of the primary cost driver in DMS.

The preliminary TUG sensor/signal estimate (to be supplied at the ASTRIONICS Group 4 Descipline Monitor panel.) indicates that 230 to 400 sensors will be required.

Tape recorder requirements vary depending upon their source. The numbers in the left hand column reflects TOPSS desirements. Those in the right hand column have been driven by the Tug data dump rate (asumed to be the real time rate defined in the Data Package) of 16 KBS and the maximum time which tug is out of ground contact, 82 minutes (GAC estimate based on GAC mission trajectory analysis results of Tug polar orbit mission).

These ranges of DMS requirements drive equipment selection as shown in the DMS Options Chart. Computer options are identified in three separate categories. The existing category defines suppliers of off the shelf equipment, the modified category lists existing equipment which may be modified to meet Tug requirements and next generation equipment is also noted. Probable vendor sources are listed for other key equipments and new technology options for mass memory devices are cited.

Studies to be performed during the first phase will drive the overall subsystem configuration. Results well define level of DMS equipment redundancy, feasibility of utilizing a data bus as compared to hardwire and feasibility of incorporating the Data Bus Controller and Telemetry Formatter into the computers Input/Output Unit.

ELECTRICAL POWER SUBSYSTEM DRIVER REQUIREMENTS

- o MISSION DUTY CYCLES
  - TIME TUG IS IN ORBITER
  - TIME TO TUG DEPLOYMENT
  - TIME TUG IS MATED TO PAYLOAD(S)
  - TOTAL MISSION DURATION
- o POWER REQUIREMENTS
  - TUG SUBSYSTEMS
  - PAYLOADS
- o TOTAL ENERGY STORED
- o GROUND OPERATIONS
  - GROUND HOLD TIME, LOADING TO LAUNCH
  - SERVICING (REACTANT LOADING) AND CHECKOUT
- o SAFETY CRITERIA
  - PRE-ENTRY SAFING
  - NO VENTING IN PAYLOAD BAY
- o EQUIPMENT LOCATIONS
  - WIRE RUNS
- o REDUNDANCY CRITERIA

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ELECTRICAL POWER SUBSYSTEM REQUIREMENTS

POWER SOURCE			
o NOMINAL/ESSENTIAL POWER LEVELS	500	2500	WATTS
o PAYLOAD POWER LEVELS	300	700	WATTS
ENERGY STORAGE			
o MISSION DURATION	29	163	HOURS
o ELECTRICAL ENERGY REQ'TS	30	150	KWH
o TUG/PAYLOAD MATED TIME	0	58	HOURS
o PAYLOAD ENERGY REQTS	0	40	KWH
o GROUND HOLD TIME	0.5	12	HOURS
o TUG/SHUTTLE MATED TIME (VENT REQTS)	2	12	HOURS

IDENTIFICATION OF SUBSYSTEM OPTIONS

	INTERIM	GROWTH	DIRECT DEVELOP.
- EXISTING			
o LM EXPENDABLE BATTERIES	X		
o CSM REUSEABLE BATTERIES	X		
- MODIFIED			
o MODIFIED SHUTTLE FUEL CELL	X	X	X
o PEAKING PRIMARY OR SECONDARY BATTERY	X	X	X
o ELECTRO-MECH. CONTROLS	X	X	X
o WIRE-ROUND OR FLAT			X
- NEW			
o AMBIENT GASEOUS STORAGE	X		
o SUPERCRITICAL CRYO STORAGE	X	X	X
o SOLID STATE CONTROLS		X	X
- ADVANCED			
o LOW WEIGHT TUG FUEL CELL			X
o SUBCRITICAL CRYO STORAGE			X
o INTEGRATED TENSION MEMBRANE STORAGE			X

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EPS REQUIREMENTS AND OPTIONS

Major EPS requirements are dictated by mission duration and power levels which determines the total quantity of energy to be provided to the Tug. A continuous task is the goal of reducing power requirements through detailed analysis of avionics and propulsion subsystems. Additional driver requirements that affect EPS design are ground operations, safety criteria and utilization equipment locations.

Significant options affecting EPS are the power source and energy storage. Power sources such as RTG's, solar cells, primary batteries (expendable) and secondary batteries (reuseable) can be rejected due to availability, weight and operational complexities. Fuel cells offer the optimum choice of minimum weight and maximum growth potential. Fuel cell options include modified shuttle fuel cells or advanced ultra light weight fuel cells. Energy storage options include cryogenic storage, existing technology ambient gaseous storage and advanced technology integrated and filament wound storage. Additional EPS options include the requirement for emergency and/or peaking batteries, electromechanical or solid state power controls and round or flat distribution control wiring.

Candidate EPS options to be evaluated include existing qualified hardware, modified hardware requiring delta qualification, new desgns, and advanced concepts requiring additional development. Maximum utilization is made of existing or modified hardware for cost reduction, unless the weight savings and/or reduced operational complexity of new or advanced technology hardware, can be shown to be cost effective.

The major factors to be addressed in the trades are cost, weight, redundancy, maintenance and operational complexity. The objective is to arrive at an optimum power subsystem offering the lowest development cost at a reasonable weight, for each compatible set of subsystems.

The latest update of the electrical power requirements indicates an increase in total energy to over 100KWH compared with a nominal proposal requirement of 65 KWH. The significant increases are due to payload requirements, electrical heater estimates and redundant IMU's The major impact of increased energy requirements is directed toward optimum methods of energy storage. As electrical energy requirements increase cryogenic storage becomes more favorable.

SUBSYSTEM CAPABILITY ANALYSES

- ✓ ELECTRICAL POWER LOAD PROFILE
- ✓ BATTERY VS. FUEL CELL
- ✓ NEW VS. MODIFIED FUEL CELL
- AMBIENT GAS VS. SUPERCRIT CRYO STORAGE
- POWER SOURCE REDUNDANCY/COST ANALYSIS
- ELECTRO-MECH. VS. SOLID STATE POWER CONTROL
- EMERG/PEAK BATT REQMTS. STUDY
- FUEL CELL WATER STORAGE VS. EVAPORATION
- ROUND VS. FLAT WIRE
- INTEGRATED POWER/PROPULSION STORAGE

THERMAL CONTROL SUBSYSTEM "DRIVER" REQUIREMENTS

- o NATURAL ENVIRONMENTS/NASA TMX-64713
- o MISSION TIMELINES
  - TOTAL MISSION DURATION
  - CONSUMABLES TIMELINES
  - POWER DISSIPATION
  - ENGINE DUTY CYCLES
  - DURATION & ENVIRONMENT NEAR END OF MISSION
- o ORBITER PAYLOAD ENVIRONMENT
  - ON THE GROUND/GROUND SERVICING
  - ON ORBIT
  - DURING ENTRY, LANDING & SAFING
- o TUG SUBSYSTEMS
  - EQUIPMENT POWER REQUIREMENTS
  - PROPELLANTS AND EQUIPMENT THERMAL LIMITATIONS
  - EQUIPMENT LOCATIONS
  - APS THRUSTER PLUMES

TASK 2 - SUBSYSTEMS ANALYSES - THERMAL CONTROL (T/C)

IDENTIFICATION OF THERMAL CONTROL OPTIONS

PROPELLANT T/C	- INSULATION
	- COATINGS
	- TRANSIENT EFFECTS
AVIONICS T/C	- LOCATION SELECTION
	- PASSIVE
	- HEATERS
	- LOUVERS
	- HEAT PIPES
FUEL CELL T/C	- PUMPED LOOPS
	- HEAT PIPES
	- SUPPLEMENTARY BOILERS
ENGINES & PLUMES	- LOCATION SELECTION
	- HEATERS
	- INSULATION
	- COATINGS

TASK 2 - SUBSYSTEMS ANALYSES - THERMAL CONTROL (T/C)

THERMAL CONTROL SUBSYSTEM CAPABILITY ANALYSES

✓ REQUIREMENTS	- THERMAL DESIGN REFERENCE MISSION DEFINITION
	- SUBSYSTEM THERMAL REQUIREMENTS CHARACTERISTICS & CONSTRAINTS
PROPELLANT T/C	- PROPELLANT REQUIREMENTS VS. T/C COMPLEXITY
	- COATING SENSITIVITY VS. INSULATION WT.
✓ AVIONICS T/C	- POWER PROFILE/ENVIRONMENT VS. TEMP LEVELS
	- DETAIL ATTACHMENT & HEAT REJECTION DESIGNS
	- REQUIREMENTS VS. EXTENT OF T/C COMPLEXITY
FUEL CELL T/C	- HEAT PIPE VS. PUMPED LOOP, DETAIL DESIGN
	- RADIATOR CONTROL COMPLEXITY VS. SUPPLEMENTARY BOILER
	- RADIATOR/BOILER SIZING DESIGN
ENGINES & PLUMES T/C	- ENGINE LOCATION & CANT EFFECT ON PERFORMANCE, HEATING & CONTAMINATION
	- HEATER & INSULATION SIZING
	- ENGINE RADIATION PROTECTION
OVERALL T/C	- INTEGRATED SYSTEM THERMAL PERFORMANCE PREDICTION

THERMAL CONTROL SUBSYSTEM

The key drivers to the Thermal Control Subsystem are the basic equipment and propellant requirements (thermal limitations) together with the mission parameters which affect the natural and induced environment. The fact that a storable Tug is a massive thermal heat sink with a limited mission duration offers possibilities for thermal control not available to lighter weight spacecraft or spacecraft missions of long duration.

Mission timelines which track the use of consumables and events (such as power dissipation, reactant and propellant expenditures, engine burns, etc.) are prerequisite to the transient analysis. The most dynamic thermal changes will take place near the end of the mission when the main propulsion tanks are near empty. This places added emphasis on the definition of end-of-mission events and environments such as the payload bay entry and soakback duration end environment.

TASK 2 - SUBSYSTEMS ANALYSES - OUTPUTS FOR 1ST REVIEW

- o SUBSYSTEMS DEFINITION FOR
  - INTERIM TUG
  - GROWTH VERSION OF INTERIM TUG
  - DIRECT DEVELOPMENT TUG
- o SUBSYSTEMS DEFINITION INCLUDES
  - SCHEMATICS
  - WEIGHTS
  - ESTIMATED DEVELOPMENT TIMES
  - POTENTIAL TECHNOLOGY ISSUES
  - POTENTIAL EVOLUTION
  - SAFETY ASSESSMENT
  - PRELIMINARY SUBSYSTEM COMPATIBILITY, RELIABILITY & LIFE
  - PRELIMINARY CHECKOUT APPROACH
- o COMPLETION OF "DRIVER" TRADES & STUDIES
  - SEE SEPARATE LISTING, BY SUBSYSTEM

TASK 2 - SUBSYSTEMS ANALYSES - OUTPUTS FOR 1ST REVIEW (CONT)

MAIN PROPULSION

- PROPELLANT SELECTION & PRELIM ENGINE SELECTION
- PRELIM P.U. TRADE RESULTS

AUXILIARY PROPULSION

- THRUST LEVEL & NUMBER/LOCATION OF THRUSTERS
- BILEVEL VS. SINGLE LEVEL THRUST

GUIDANCE, NAVIGATION & CONTROL

- PLATFORM VS. STRAPDOWN IMU
- RENDEZVOUS/DOCKING SENSOR SELECTION
- AUTONOMOUS NAVIGATION TECHNIQUES
- REDUNDANCY/RELIABILITY

COMMUNICATIONS

- FREQUENCY MANAGEMENT STUDY
- RENDEZVOUS STUDY
- AUTONOMY STUDY
- REDUNDANCY/RELIABILITY
- ANTENNA STUDY

TASK 2 - SUBSYSTEMS ANALYSES - OUTPUTS FOR 1ST REVIEW (CONT)

DATA MANAGEMENT

- REDUNDANCY SELECTION
- INTEGRATED VS. FEDERATED COMPUTER I/O
- OBC VS. GROUND CHECKOUT
- DATA BUS VS. HARDWIRE

ELECTRICAL POWER

- BATTERY VS. FUEL CELL
- ADVANCED TUG VS. MODIFIED SHUTTLE FUEL CELL
- AMBIENT GAS VS. SUPERCRITICAL CRYO STORAGE
- POWER SOURCE REDUNDANCY

THERMAL CONTROL

- PRELIMINARY RESULTS OF FUEL CELL T/C STUDY
- PRELIMINARY RESULTS OF AVIONICS T/C STUDY
- PRELIMINARY RESULTS OF PROPELLANT TANKS T/C STUDY
- PRELIMINARY RESULTS OF ENGINES/EXHAUST PLUMES T/C STUDY

STRUCTURAL DESIGN CONDITIONS

TANKAGE

- o SYSTEM PRESSURE
- o HYDROSTATIC PRESSURE
- o TEMPERATURES
- o INERTIAL FORCES
- o LOADING SPECTRUM

MICROMETEOROID SHIELDING

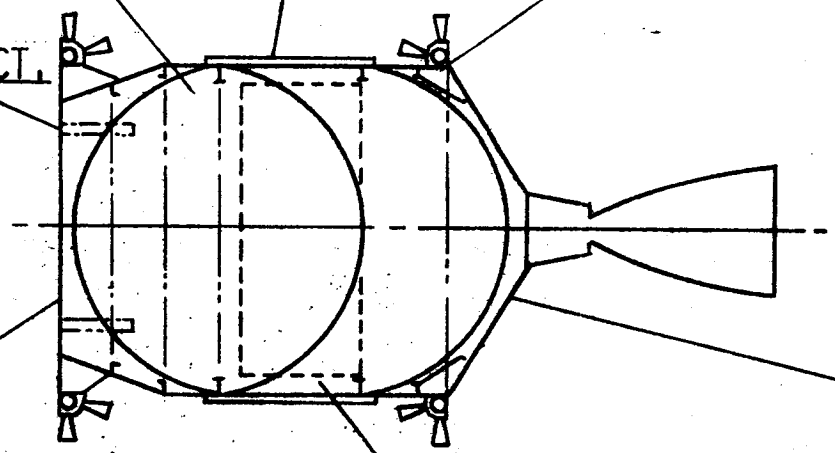
- o NATURAL ENVIRONMENT

EXTERNAL SHELL

- o LAUNCH
- o ASCENT
- o ORBITAL MANEUVERS
- o ENTRY
- o LANDING
- o CRASH
- o TUG/ORBITER DOCKING
- o GROUND HANDLING

TUG TO PL DOCKING STRUCT.

- o DOCKING MANEUVERS



THRUST STRUCTURE

- o ENGINE FIRING:
  - START & SHUTDOWN
  - THRUST OVERSHOOT
  - NUMBER & DURATION OF FIRINGS
  - ENGINE GIMBAL

PAYLOAD SUPPORT STRUCTURE

- o LAUNCH
- o ASCENT
- o ORBITAL MANEUVERS
- o ENTRY
- o LANDING
- o CRASH

SECONDARY STRUCTURE

- o STEADY-STATE ACCELERATIONS
- o VIBRATION INDUCED FORCES

DESIGN DRIVERS

STRUCTURAL/MECHANICAL

TANKAGE:

- o SUSTAINED/CYCLIC PRESSURES AND TEMPERATURES FOR SERVICE LIFE (20/100 MISSIONS)
- o FRACTURE MECHANICS ANALYSIS:
  - ESTABLISH PROOF PRESSURE FACTORS
  - VERIFY SERVICE LIFE

PRIMARY STRUCTURE:

- o LIFT-OFF/ASCENT FOR 65K GROSS WT. ESTABLISH DESIGN LOADS (3G)
- o CRASH - - WE HAVE RECCOMMENDED
  - NO IN FLIGHT TUG PROPELLANT DUMP
  - CRASH LANDING COMBINED WITH FULL TUG TANKS (PAD ABORT) BE GROUNDRULED OUT FOR THIS STUDY.

MECHANICAL:

- o TUG/PAYLOAD AND TUG/ORBITER DOCKING MECHANISMS DESIGNED BY RESPECTIVE MANEUVER RATES/MISSALIGNMENTS (TBD)

DETAIL STRUCTURAL TRADES/OPTIONS

TANK

- o α°
- o COMMON DOME - HONEYCOMB VS. TWIN MEMBRANE
- o MATERIAL - ALUM VS. STEEL VS. TITANIUM
- o CYLINDRICAL ELEMENT STRINGER - INTEGRAL VS. ATTACHED

EXTERNAL SHELL

- o HONEYCOMB VS. SHEET STRINGER VS. TRUSSWORK
- o MATERIAL - ALUM VS. TITANIUM VS. COMPOSITES

THRUST STRUCTURE

- o HONEYCOMB VS. SHEET STRINGER VS. TRUSS
- o MATERIAL - ALUM VS. TITANIUM VS. COMPOSITES

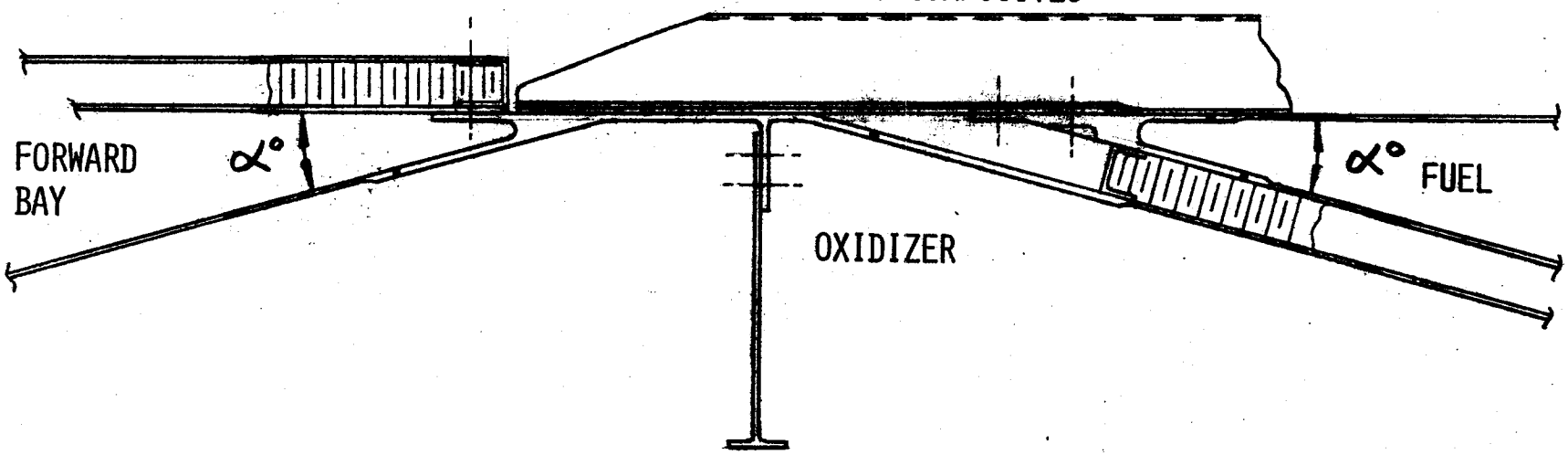
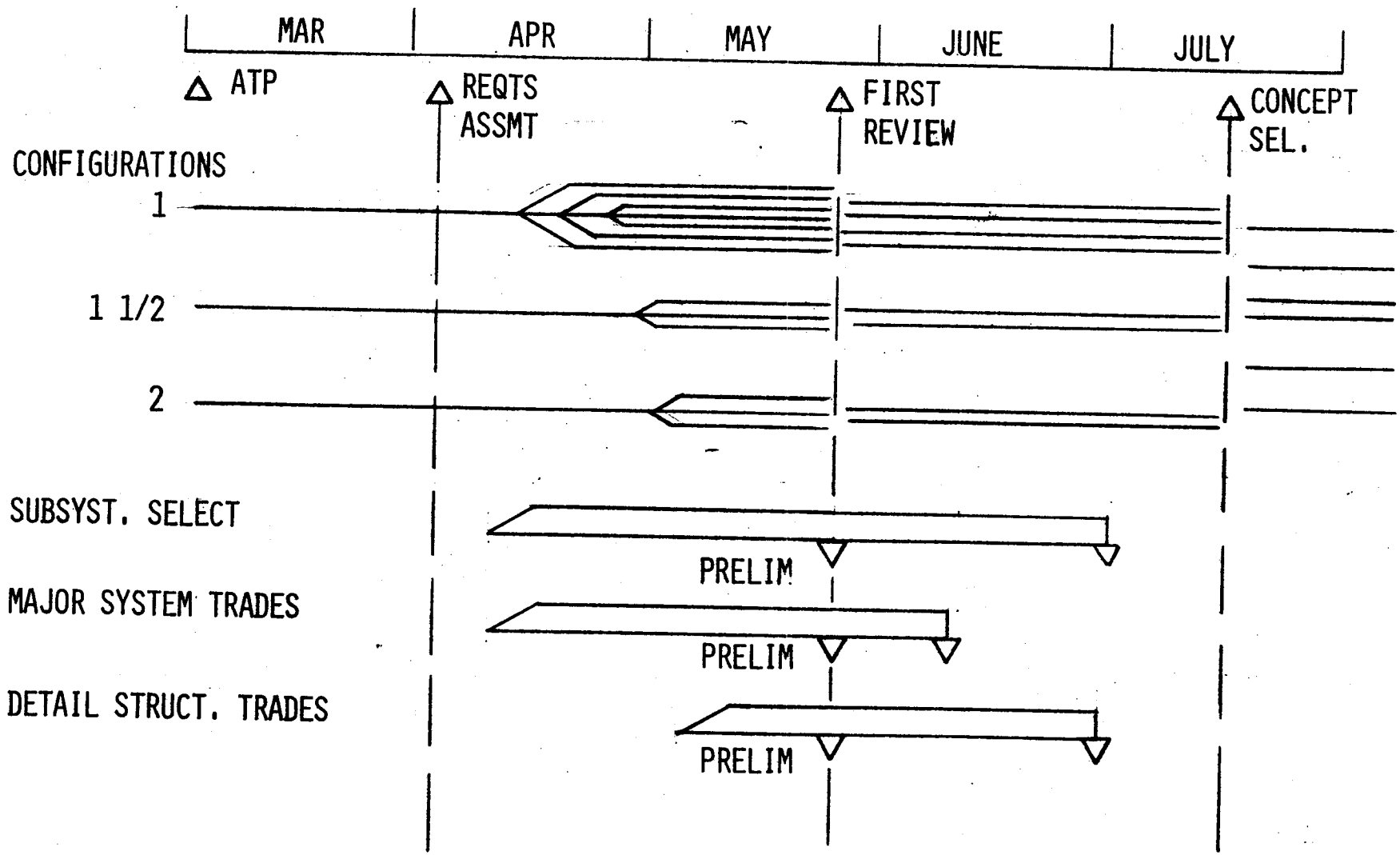


ILLUSTRATION OF TYPICAL DETAIL STRUCTURAL TRADES

CONCEPT & STRUCTURES/MECHANICAL SCHEDULE



STRUCTURE

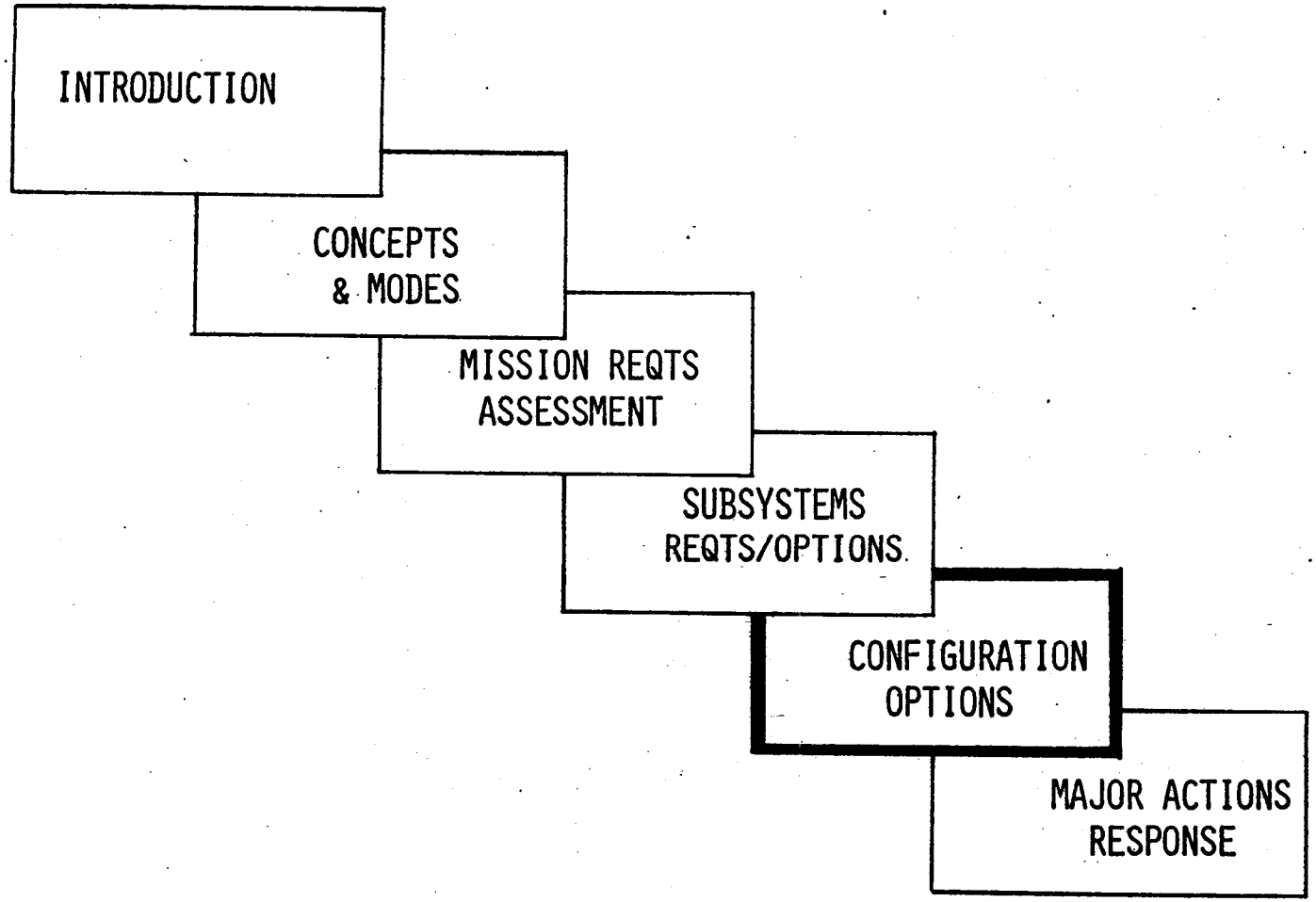
The Tug/Payload structural design conditions shown represent the spectrum of natural and induced environments to be used in the study. The external shell structure will be primarily designed by the launch and ascent conditions when the Tug is in the payload bay for a gross weight of 65,000 lbs; the critical accelerations occur during lift-off and max boost. If the crash condition tug gross weight is 65,000 lbs. (i.e., no fuel dump) the resulting loads will be a major driver in sizing the shell and tank components. It is recommended that the Tug/Payload should not be designed for the crash condition in the fully loaded configuration. Design for the ground handling, transportation and storage should be such as to have minimum effect on primary structure; local attachments and fittings may be sized for these loads. The engine thrust structure is critical for the interim engine (16,000 lbs. thrust) start and shut down conditions. Loads spectra induced by these firings may affect the fatigue life of the thrust structure.

The tankage is to be evaluated for fractures which may occur because of existing flaws. Fracture mechanics analyses will be carried out for the sustained/cyclic loads, temperatures and corrosive environments to establish proof test factors. In addition, service life will be evaluated for loadings and environmental exposure subsequent to proof test. The payload support structure will be evaluated for launch/ascent as well as the induced forces caused by the tug engine gimbal during orbital maneuvers.

Structural trade studies and options will be carried out for various structural configurations and for selected materials.

Structural trade studies and options will be carried out for various structural configurations and for selected materials.

OUTLINE



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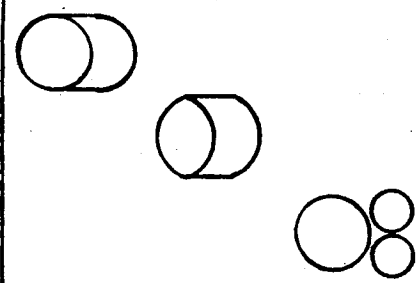
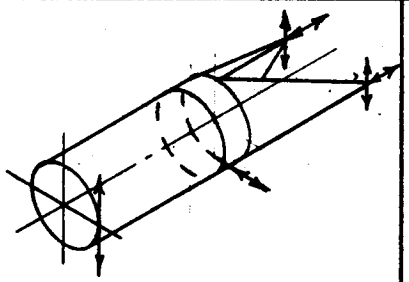
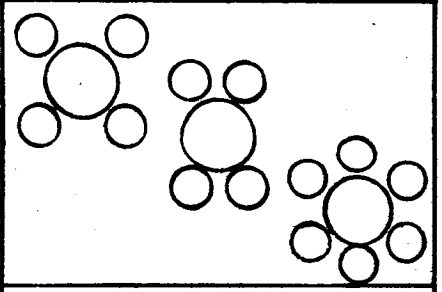
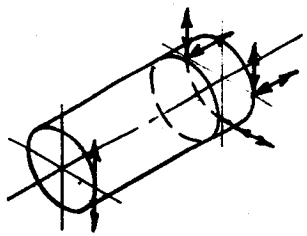
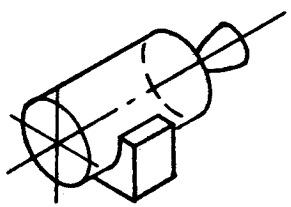
CONFIGURATION TRADES & OPTIONS

? WEIGHT, STIFFNESS, PAYLOAD, OPN'L FLEX., COST, C.G. ?

	TANKS	SUPPT - LOAD PATHS	PROPULSION	EQUIP.	APS
	NO — SHAPE—ARGNT			LOCATION	
SINGLE STAGE			M.R. - 1.6 → 2.7 CHAMBER PRESSURE	FWD	NUMBER
STAGE AND ONE HALF			EXPANSION RATIO	SIDES	REDUNDANCY
TWO STAGE			FIXED NOZZLE EXTENDABLE NOZZLES THRUST LEVEL	AFT	LOCATION IMPINGE-MENT

o PROPELLANT TEMPERATURE RANGE/TANK PRESSURE

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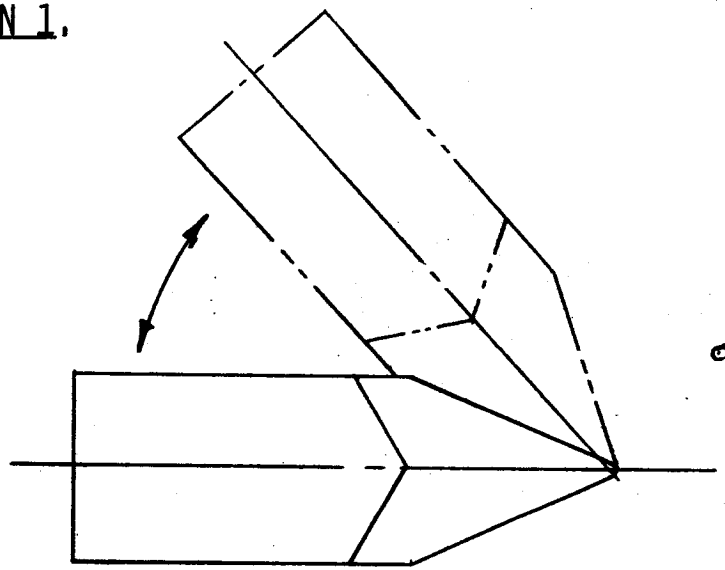
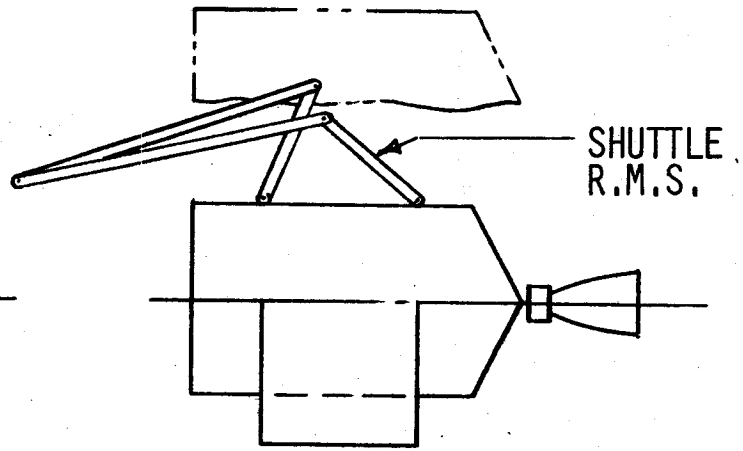
ORB/TUG ADAPTER AND DEPLOYMENT RETRIEVAL MECHANISM

OPTION 1.



OPTION 2.



PRIME ISSUES:

- o CAN SHUTTLE RMS HANDLE DEPLOYMENT/RETRIEVAL UNAIDED?
- o RELATIVE PAYLOAD SENSITIVITY TO ADAPTER WEIGHT AND TUG INERT WEIGHT.

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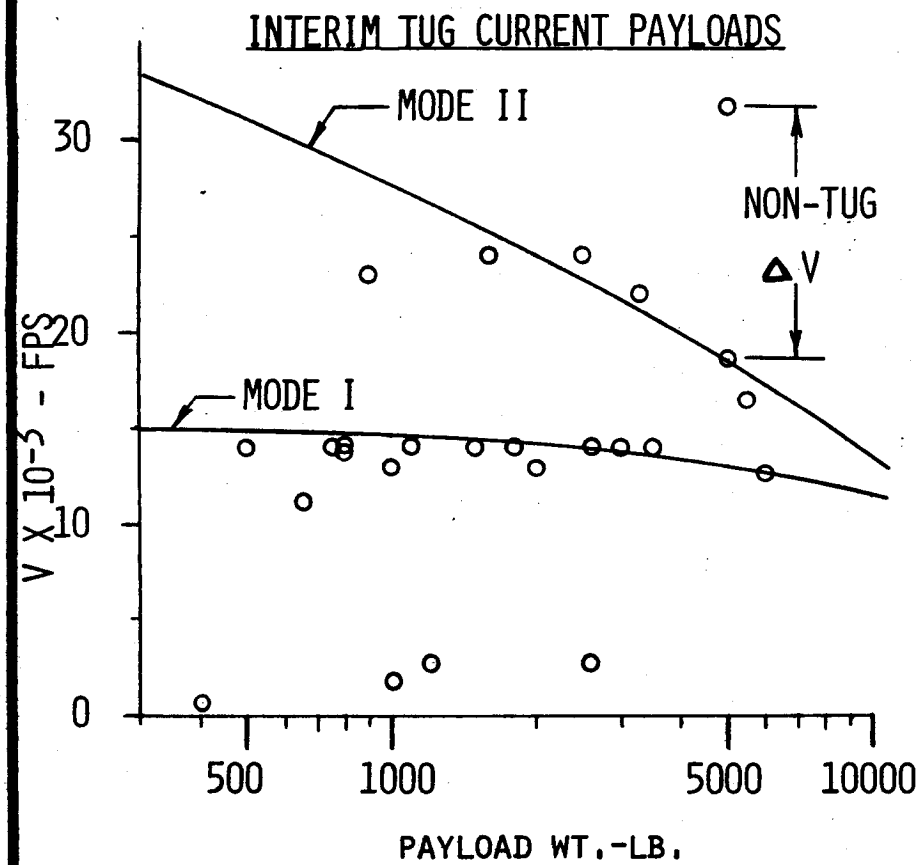
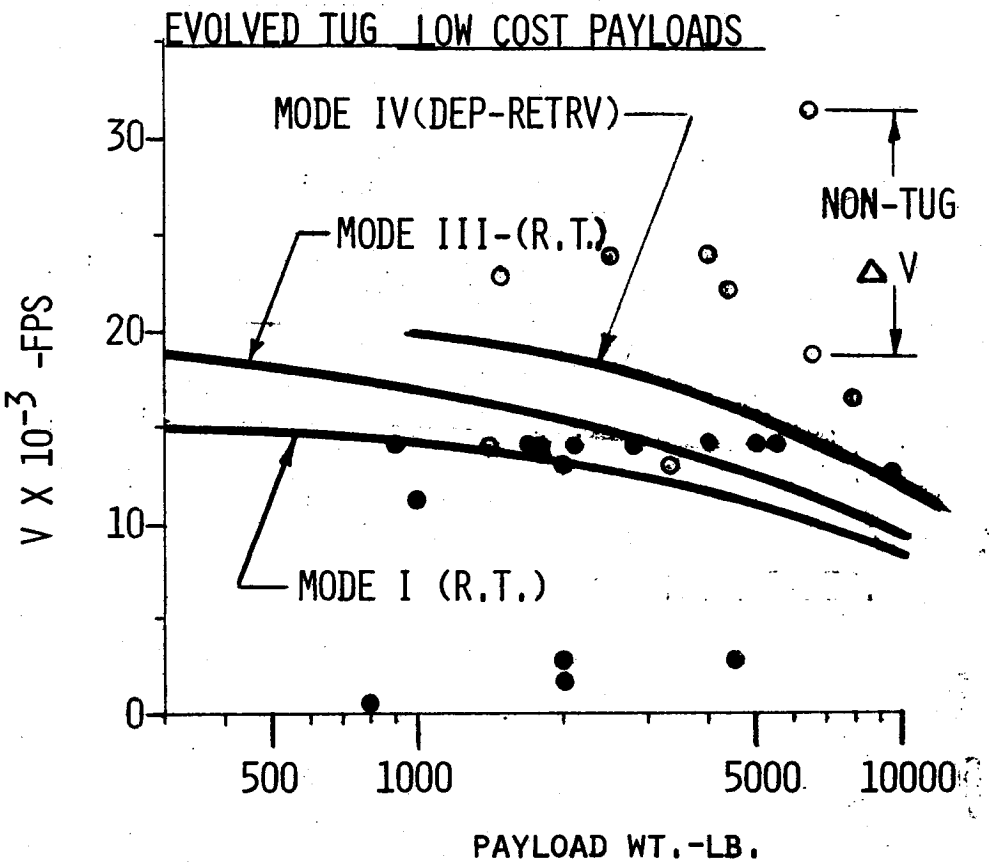
SINGLE STAGE PAYLOAD CAPTURE CAPABILITY





o - DEPLOY

● - ROUND TRIP

o FOR SINGLE STAGE STORABLE TUG KICK STAGES ARE NEEDED.

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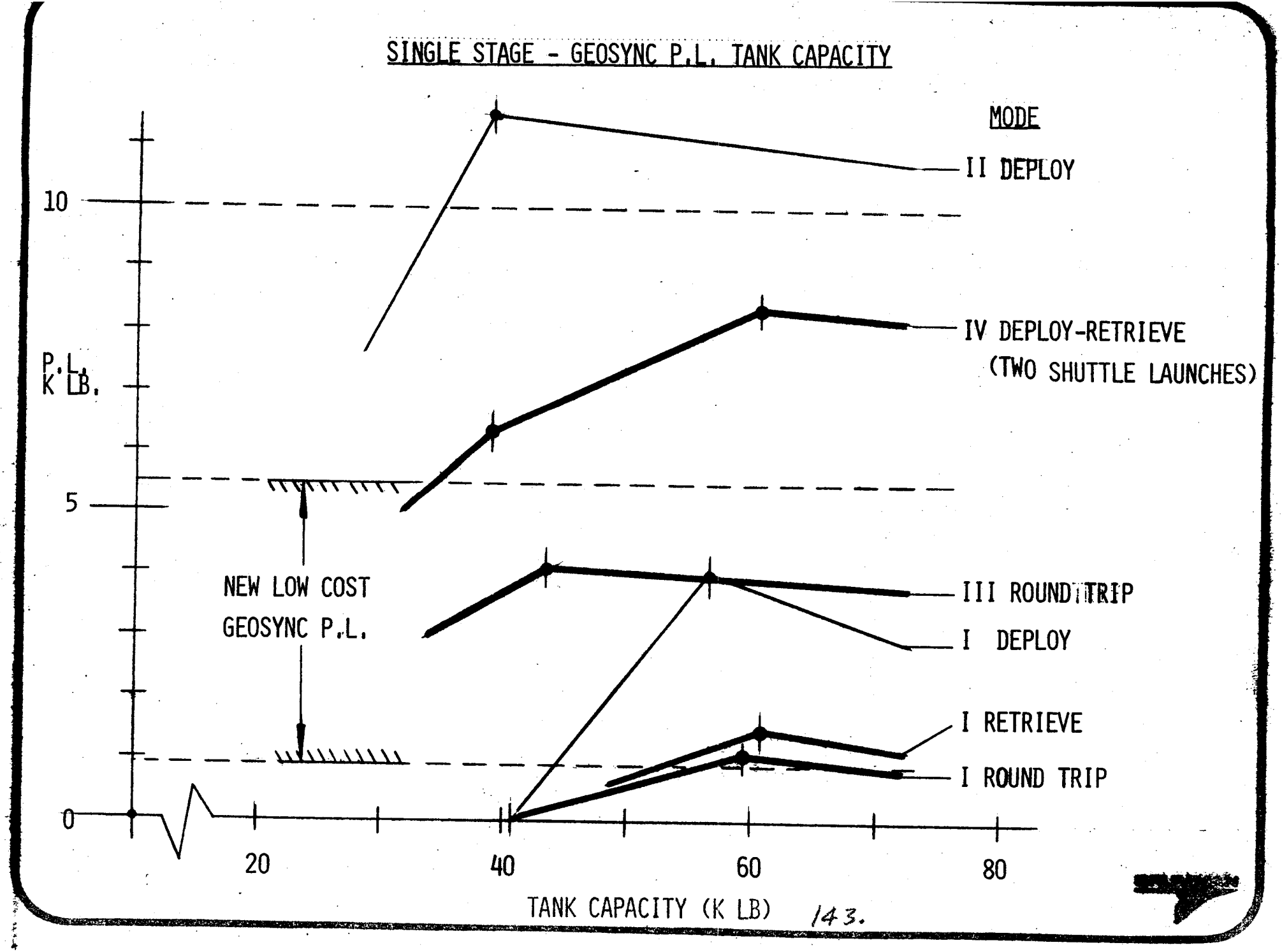
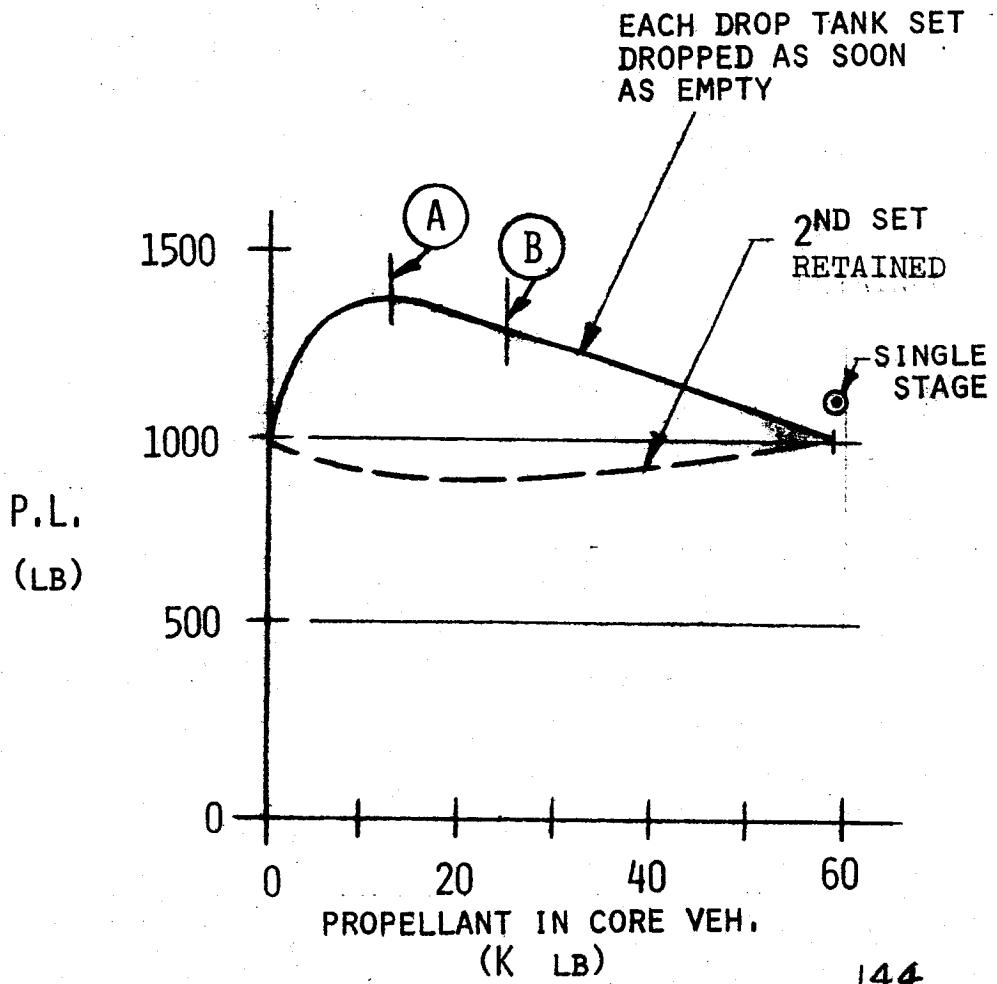
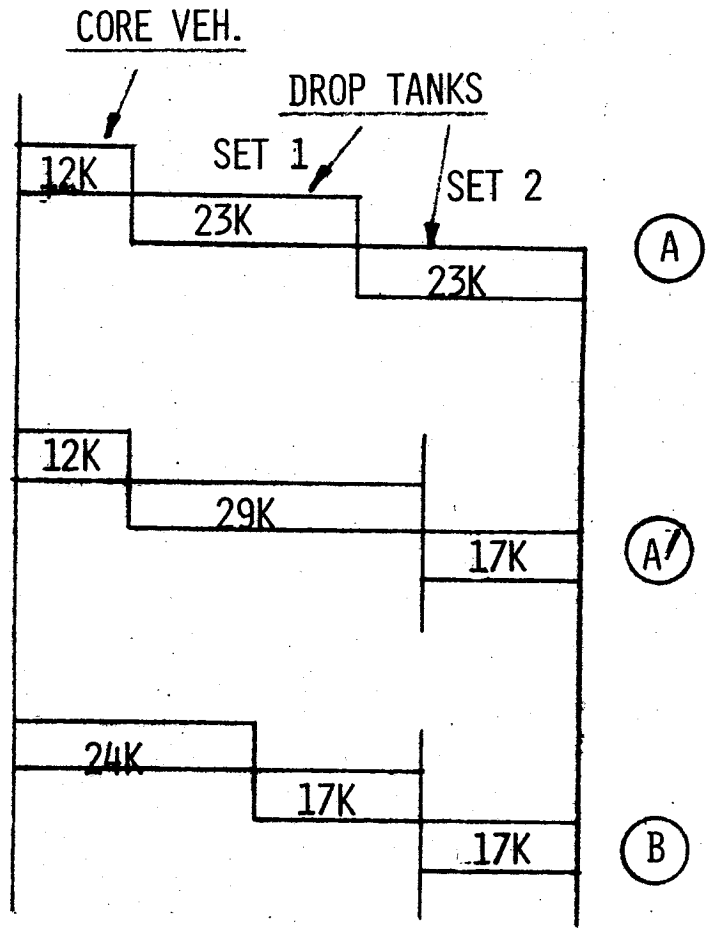

SINGLE STAGE - GEOSYNC P.L. TANK CAPACITY
MODE
II DEPLOY
IV DEPLOY-RETRIEVE
(TWO SHUTTLE LAUNCHES)
III ROUND TRIP
I DEPLOY
I RETRIEVE
I ROUND TRIP
NEW LOW COST
GEOSYNC P.L.
P.L.
K LB.
10
5
0
20
40
60
80
TANK CAPACITY (K LB)

1½ STAGE SIZING OPTIONS

GEOSYNC ROUNDTRIP PAYLOAD MODE I



PROPELLANT CAPACITY ALLOCATION OPTIONS TO OPTIMIZE MODES I AND II



SIZING - SUMMARY OF TRADE ISSUES

SINGLE STAGE - - - - - - - - - - REDUCE CAPACITY TO MAXIMIZE KICK STAGE PAYLOADS?

1-1/2 STAGE - - - - - - - - - - OPTIMUM CAPACITY WITH AND WITHOUT KICK STAGES?

2 STAGE- - - - - - - - - - - - - INCREASED CAPACITY REDUCES TRAJECTORY COMPLEXITY?

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CONFIGURATION ANALYSIS

In summary, our efforts during the next phase will be directed toward the generation and comparison of Space Tug flight modes and their related configuration requirements. Parametric evaluation and conceptual design synthesis of potentially viable Tug configurations will be conducted. Sufficient concept and configuration iterations will be executed to provide satisfactory evidence that reasonable payload/mission objectives can be achieved. Definition of interim-to-evolved evolutionary approaches and direct development approaches are an integral part of this process.

Due to the inherent interrelationship between the Tug general configuration and its structural arrangement, special attention will be given to the effects of configuration arrangement on structural weight and complexity during the configuration synthesis process.

Primary attention will be given to identifying propellant tank shape, quantity, and arrangement options and combining them with viable support and deployment/retrieval schemes as well as engine and subsystem location/installation requirements. Of particular importance during this process will be the choice of propellant tank capacities, which as already shown, dramatically affects payload capability as a function of flight mode and evolutionary status.

MISSION/TRAFFIC MODEL DRIVER REQUIREMENTS

- o DEPLOYMENT - PLANETARY (NASA MISSION NOS. 21, 22 AND 24)
- o RETRIEVAL - NASA MISSION NO. 10
- o TRAJECTORY COMPLEXITY - DOD MISSION NO. 4 AND NASA HIGH ENERGY MISSIONS
- o RELIABILITY DRIVER - DOD MISSION NO. 9 OR GEOSYNCHRONOUS DEPLOY AND RETRIEVE
- o AUTONOMY - HIGH INCLINATION MISSIONS
- o THERMAL DESIGN - HIGH INCLINATION MISSIONS
- o OPERATIONAL COSTS - MULTIPLE DEPLOYMENT
  PAYLOAD SERVICING
  DEPLOY AND RETRIEVE

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SHUTTLE INTERFACE DRIVER REQUIREMENTS

- o GROSS PAYLOAD WEIGHT OF 65K LBS
- o PAYLOAD CG ENVELOPE
- o SAFETY AND ABORT CONSIDERATIONS E.G., PROPELLANT DUMP
  - ON LAUNCH PAD
  - IN PAYLOAD BAY DURING FLIGHT
  - PRIOR TO RETRIEVAL
- o LOAD FACTORS - ASCENT

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PAYLOAD INTERFACE DRIVER REQUIREMENTS

- OVERALL TUG CONCEPT LENGTH (35 FT. LIMIT)
- CONTAMINATION
- PAYLOAD SERVICES
- SUPPORT OF PAYLOAD CHECKOUT
- PAYLOAD SPIN/DESPIN
- PAYLOAD CAPTURE AND DOCKING
- PAYLOAD INTERFACES WITH DEORBIT KICK STAGE
- FREQUENCY MANAGEMENT

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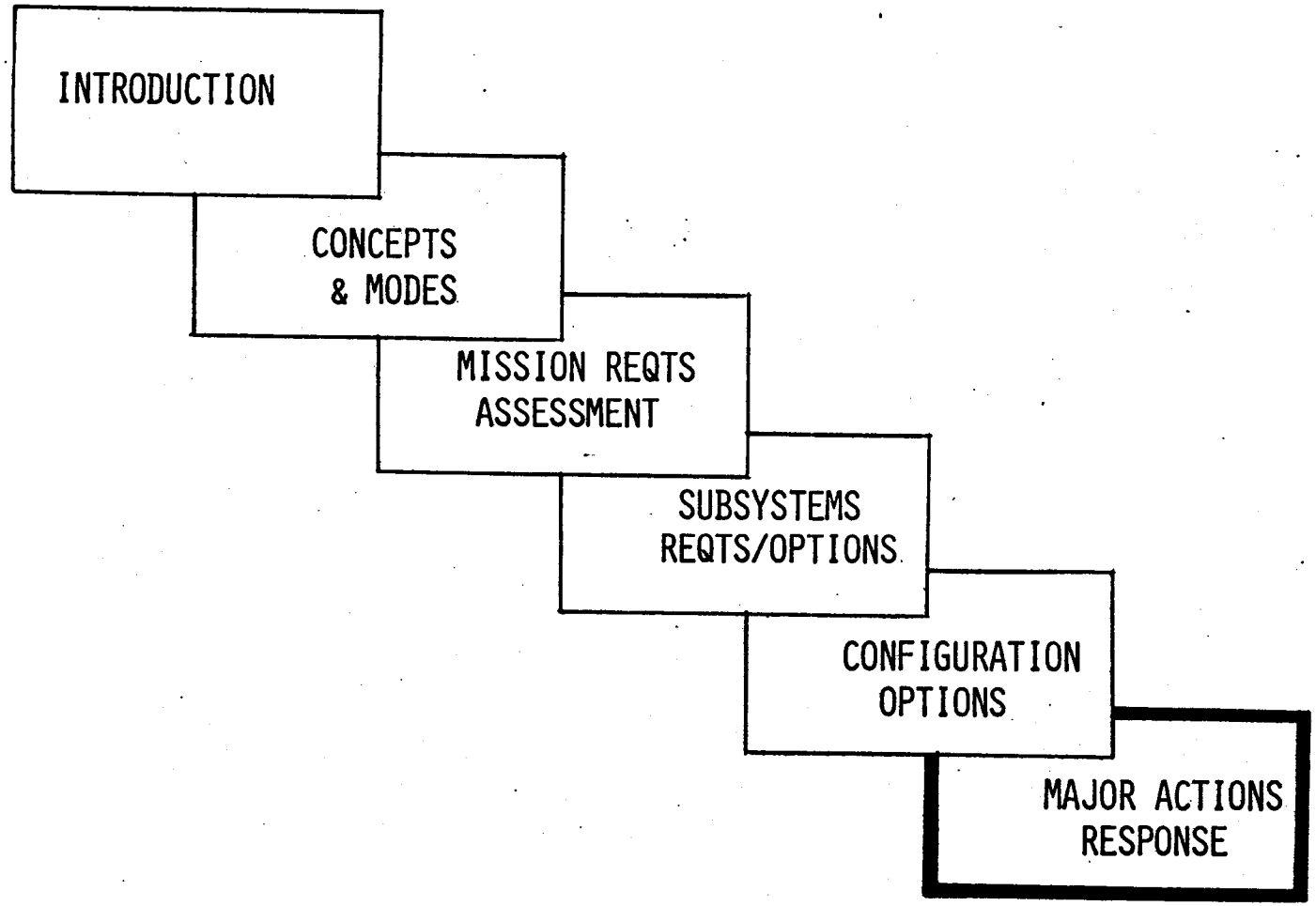
OUTLINE



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STORABLE SPACE TUG SYSTEMS STUDY

GRUMMAN COMMENTS - DATA PACKAGE

- o DOCUMENT REVIEWED FROM STANDPOINT OF
  - RESOLUTION OF QUESTIONS SUBMITTED 16 MAR
  - NEED FOR CLARIFICATION OF ADDED DATA/INFORMATION
- o NUMBER OF COMMENTS BY SECTION SUMMARIZED BELOW
- o SIGNIFICANT COMMENTS SUMMARIZED ON SUBSEQUENT PAGES

SECTION	TITLE	NO. OF COMMENTS/QUESTIONS
I	INTRODUCTION	2
II	GUIDELINES AND REQUIREMENTS	5
III	GROUND COMM NETWORK	1
IV	GROUND OPERATIONS PLANS	1
V	SYSTEM SAFETY CRITERIA	2
VI	PROGRAMMATICS/COST DATA	1
VII	SPACE SHUTTLE DEFINITION	0
VIII	RELATED STUDIES	0
APP A	MISSION MODEL	0
APP B	MISSION CHARACTERISTICS	0
		12

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STORABLE SPACE TUG SYSTEMS STUDY

GRUMMAN COMMENTS - DATA PACKAGE

SUMMARY OF SIGNIFICANT ITEMS

SECTION I INTRODUCTION

(1) o DATA PACKAGE DIFFERS FROM CONTRACT

- DP: DIRECT DEVELOP TUG OPNL SHUTTLE IOC + (2 OR 4) YRS.
- CONTRACT: ...SATISFY SPECIFIC MISSIONS SHUTTLE IOC + 4 YRS.

o WILL DATA PACKAGE BE CHANGED TO REFLECT CONTRACT

(2) o MINIMUM ORBIT LIFETIME FOR INTERIM TUG OPEN

- DATA PACKAGE FEB '73: "MINIMUM ORBITAL LIFETIME OF TWO DAYS."
- DATA PACKAGE APR '73: UNSPECIFIED

o WILL NASA/DOD PROVIDE UNIFORM GUIDELINE OR SHOULD CONTRACTOR DEVELOP HIS OWN ORBITAL LIFETIME CRITERIA

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STORABLE SPACE TUG SYSTEMS STUDY

GRUMMAN COMMENTS - DATA PACKAGE

SUMMARY OF SIGNIFICANT ITEMS - CONTINUED

SECTION II GUIDELINES AND REQUIREMENTS

1. o ABORT REQUIREMENTS
   - o DATA PACKAGE: TUG SHALL BE COMPATIBLE WITH ALL SHUTTLE ABORT MODES AND PROCEDURES
   - o SPECIFICATION MJ072-001 SHUTTLE SAFE MISSION TERMINATION
     - FAIL SAFE DEORBIT/DIRECT REENTRY WITH 25000 LBS RETURN PAYLOAD
   - o MUST TUG FUEL BE DUMPED TO ACCOMMODATE THE 25000 LB LIMITATION
   - o TUG PAYLOAD FAILURE PRIOR TO DEPLOY IS EXAMPLE OF RATIONALE FOR QUESTION
2. o INDUCED ENVIRONMENTAL EFFECTS ON TUG PAYLOADS
   - o DATA PACKAGE: TUG NOT INDUCE ENVIRONMENTAL EFFECTS SIGNIFICANTLY GREATER (10% - 20%) THAN THOSE INDUCED BY SHUTTLE
   - o DOES THIS REQUIREMENT APPLY TO ALL ENGINES PRODUCING 15000 LBS THRUST
   - o IF APPLICABLE E.G. THRUST LEVELS ALLOWABLE FOR AGENA (8096) EXCEED LIMITATION

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STORABLE SPACE TUG SYSTEM STUDY

GRUMMAN COMMENTS - DATA PACKAGE

SUMMARY OF SIGNIFICANT ITEMS

SECTION II - CONTINUED

(3) PROPELLANT QUANTITIES

- o DATA PACKAGE: STORABLE TUG PROPELLANT TANKS MUST BE DESIGNED FOR EMERGENCY OFFLOADING AT THE PAD
- o IS OFFLOADING ACCOMMODATED WITH TUG IN P/L BAY AFTER DRAIN IS MANUALLY CONNECTED

(4) ON ORBIT MISSION DURATION

- o DATA PACKAGE: TUG DESIGN SHALL NOT PRECLUDE... ON ORBIT MISSION DURATION OF 30 DAYS WITH REDUCED PERFORMANCE CAPABILITY
- o WHAT IS THE THIRTY DAY MISSION TIMELINE OF SIGNIFICANT EVENTS.

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STORABLE SPACE TUG SYSTEM STUDY

GRUMMAN COMMENTS - DATA PACKAGE

SUMMARY OF SIGNIFICANT ITEMS

SECTION III GROUND COMMUNICATION NETWORK

(1) SGLS AND STDN DATA NEEDS

- o DATA PACKAGE: GENERAL INFORMATION IS PROVIDED IN REFERENCED DOCUMENTATION
- o WILL NASA/DOD PROVIDE:
  - DETAILED PERFORMANCE SPECIFICATIONS FOR SGLS AND STDN
  - USERS GUIDE FOR STDN
  - USERS GUIDE FOR SGLS (IF AVAILABLE)

SECTION IV GROUND OPERATIONS PLAN

(1) SAFE AND PURGE

- o DATA PACKAGE: SAFING WILL BE ACCOMPLISHED BY DISCONNECTING AND CAPPING OVERBOARD STORABLE PROPELLANT DUMP LINES...
- o IS IT NASA/DOD INTENT THAT DUMP LINES BE RECONNECTED AFTER RETRIEVAL BY ORBITER PRIOR TO ENTRY.

GRUMMAN

STORABLE SPACE TUG, SYSTEM STUDY

GRUMMAN COMMENTS - DATA PACKAGE

SUMMARY OF SIGNIFICANT ITEMS

SECTION V SYSTEM SAFETY CRITERIA

(1) ON ORBIT RETRIEVAL

- o DATA PACKAGE: TUG PROPELLANTS AND PRESSURANTS SHALL BE REDUCED TO A PRE-DETERMINED SAFE LEVEL PRIOR TO TUG RETRIEVAL
- o DOES THIS REQUIREMENT APPLY TO APS PRIOR TO TUG ACQUISITION BY THE RMS

(2) POTENTIAL TANK FAILURE DETECTION

- o DATA PACKAGE: PROVISION TO DETECT POTENTIAL TANK FAILURES
- o IS THE USE OF FRACTURE MECHANICS ANALYSIS OR PROOF TESTING ADEQUATE

GRUMMAN

STORABLE SPACE TUG SYSTEM STUDY

GRUMMAN COMMENTS - DATA PACKAGE

SUMMARY OF SIGNIFICANT ITEMS

SECTION VI PROGRAMMATICS/COST DATA

(1) TUG MILESTONES

- o DATA PACKAGE: "APPROPRIATE SCHEDULES SHOULD BE INCLUDED FOR EACH CONCEPT"
- o WHAT MILESTONES SHOULD BE ASSUMED FOR 2980 INTERIM TUG FOR PHASE C/D ATP AND TUG FIRST ORBITAL FLIGHT
- o SHOULD SAME ATP - TFOF RELATIONSHIP BE MAINTAINED FOR INTERIM AND DIRECT DEVELOPED TUGS

GRUMMAN

STORABLE SPACE TUG SYSTEMS STUDY

GRUMMAN COMMENTS - PAYLOAD ACCOMMODATION DOCUMENT

- o DOCUMENT REVIEWED FROM STANDPOINT OF
  - NEED FOR CLARIFICATION OF EXISTING DATA
  - IDENTIFICATION OF ADDITIONAL DATA REQUIRED
- o NO. OF COMMENTS BY SECTION SUMMARIZED BELOW
- o SIGNIFICANT COMMENTS SUMMARIZED ON SUBSEQUENT PAGES

SECTION		NO. OF. COMMENTS/QUESTIONS
1.	INTRODUCTION	0
2.	SPACE SHUTTLE SYSTEM DESCRIPTION	2
3.	PERFORMANCE	0
4.	STRUCTURAL/MECHANICAL	9
5.	AVIONICS	2
6.	ELECTRICAL POWER	0
7.	ORBITAL MANEUVERING AND REACTION CONTROL	1
8.	ENVIRONMENTAL CONTROL/LIFE SUPPORT	1
9.	CREW PROVISIONS	1
10.	INDUCED ENVIRONMENT	5
		21

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STORABLE SPACE TUG SYSTEMS STUDY

GRUMMAN COMMENTS - PAYLOAD ACCOMMODATION DOC.

SUMMARY OF SIGNIFICANT ITEMS

1. SECTION 2

   o "INTERFACE PROVISIONS FOR PAYLOAD PROPULSIVE STAGE FILL, VENT, & DRAIN ARE ALSO PROVIDED."

   o "THE ACCESS, REMOVAL, AND LOADING OF PAYLOAD ITEMS ON PAD MUST BE ACCOMPLISHED TBD HOURS BEFORE LAUNCH?

     - DO THESE 2 ITEMS, TAKEN TOGETHER, IMPLY THE NEED FOR REMOTE EMERGENCY ON-PAD PROPELLANT DRAIN CAPABILITY?

       (I.E. - NO ACCESS FOR MANUAL HOOK-UP OF DRAIN LINES?)

1. SECTION 4

   o PAYLOAD RETENTION SYSTEM

     - WHAT ARE Y DIMENSIONS OF ATTACHMENT LOCATIONS
     - MAY OTHER DETERMINANT LOAD PATHS BE CONSIDERED?
     - WILL ORBITER SUPPORT POINT DESIGN LOS BE BASED ON TUG REQ'TS?

   o CENTER-OF-GRAVITY ENVELOPE

     - C.G. ENVELOPE IN PAYLOAD ACCOM. DOC. DIFFERS FROM THAT IN MJ072-0001, SPACE SHUTTLE FLT/GND. SYSTEM SPEC DATED 2 MAR 73

   o DEPLOYMENT/RETRIEVAL SYSTEM

     - MANIPULATOR DIMENSIONAL DETAILS?
     - ARE TIP-OFF RATES LINEAR?

GRUMMAN

STORABLE SPACE TUG SYSTEMS STUDY

GRUMMAN COMMENTS - PAYLOAD ACCOMMODATION DOCUMENT

SUMMARY OF SIGNIFICANT ITEMS

2. SECTION 4 (CONT)
   - o TIMELINE INFORMATION
     - TIMELINE FROM SHUTTLE LAUNCH TO TUG DEPLOY?
     - TIMELINE FROM TUG RETRIEVAL/DOCKING TO ORBITER LANDING
     - TIME TO DEPLOY 65K PAYLOAD? RETRIEVE 25K PAYLOAD?
3. SECTION 5
   - o ENCRYPTION - DESCRIPTION EQUIPMENT (---"DATA EXCHANGE BY RF")
     - ARE THERE SAFETY RESTRICTIONS GOVERNING AN OPERATING RF ANTENNA WITHIN THE PAYLOAD BAY?
4. SECTION 7
   - o RCS CHARACTERISTICS
     - APPROPRIATE THRUSTERS INHABITED DURING DEPLOYMENT?
     - PLUME TEMPS IN TUG DEPLOY/RETRIEVE ENVELOPE?
5. SECTION 10
   - o AVAILABILITY OF PRELIMINARY INDUCED ENVIRONMENT DATA
     - SHOCK & VIBRATION, SOUND PRESSURE LEVELS
     - EMC DATA
     - CONTAMINATION

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STORABLE SPACE TUG SYSTEMS STUDY

GRUMMAN STATUS - ORIENTATION BRIEFING ACTION ITEMS

SUMMARY "BOX SCORE"

A. NO. OF ITEMS - BY DISCIPLINE PANEL:

PANEL	DUE PRIOR TO R.A. MTG	DUE AT R.A. MTG.	TOTAL
o SYSTEM INTEGRATION	2	3	5
o SPACE OPS/FLT TECHNIQUES			
- FLT OPS	2	1	3
- GND OPS	0	0	0
o MISS'N/PL/USER REQT'S AND INTERFACES	0	4	4
o PROGRAMMATIC & COST	2	1	3
	6	9	15

B. GRUMMAN STATUS:

- o ITEMS DUE PRIOR TO REQUIREMENTS ASSESSMENT MEETING - COMPLETE
- o ITEMS DUE AT REQUIREMENTS MEETING - PREPARED TO DISCUSS AT PANEL MEETINGS

GRUMMAN

GRUMMAN STATUS - ORIENTATION BRIEFING ACTION ITEMS

NO.	PANEL	ITEM	STATUS	REMARKS
1.	SYST. ENGINEERING	o PL ACCOM. DATA REQ'D & NEED DATES	DUE AT RA MEETING	o DISCUSS AT PRES. & PANEL MEETINGS
2.	" "	o DRY WT. CONTINGENCY RECOMMENDATION	COMPLETE	o SUBMIT 16 MARCH
3.	" "	o REVIEW REQUIREMENT DELTA'S: INTERIM VS. DIRECT TUG - SENSITIVITY ANAL ADDN'S? - IMPACT ON STUDY?	DUE AT RA MEETING	o DISCUSS AT PANEL MEETINGS - 30 DAY IMPACT - PAYLOAD SERVICING
4.	" "	o CLARIFY APPL./DEF. OF KICK STAGES (PROVIDE TO COR)	DUE AT RA MEETING	o DISCUSSED 21 MAR o DISCUSS AT PANEL MTGS.
5.	" "	o PROVIDE LIST OF REQ'D PROP. DATA/FORMATS/NEED DATES	COMPLETE	o SUBMIT 8 MARCH
6.	SPACE OPS/FLT TECH.	o MISSION ANAL DATA OUTPUT FORMATS (RECOMMENDATIONS)	COMPLETE	o SUBMIT 16 MARCH

GRUMMAN

STORABLE TUG SYSTEMS STUDY

GRUMMAN STATUS - ORIENTATION BRIEFING ACTION ACTION ITEMS

(CONTINUED)

NO.	PANEL	ITEM	STATUS	REMARKS
7.	SPACE OPS/FLT TECH	o SUBMIT DATA PKG. QUESTION ON AUTONOMY (INCLUDE CANDIDATE LEVELS)	COMPLETE	o SUBMIT 16 MARCH
8.	" " " "	o RECOMMEND "WORST CASE" MISSION FOR RELIABILITY ANALYSIS	DUE AT RA MEETING	o RECOMMEND AT PANEL MEETING
9.	MISSION/PL/USER REQT'S & INTERFACES	o INVESTIGATE HIGHLY ELLIPT. LOW EARTH ORBIT MISSIONS - EXPOSE DESIGN DRIVERS	DUE AT RA MEETING	o REPORT RESULTS AT PRES.& PANEL MTGS.
10.	" "	o IDENTIFY IMPACT ON SUBSYST. REQT'S OF PROVIDING PL SERVICES	DUE AT RA MEETING	o REPORT AT PRES. & PANEL MTGS.
11.	" "	o DEFINE APPR. TO SCREENING TUG OPTIONS (CRITERIA/APPL.)	DUE AT RA MEETING	o DISCUSS AT COR MEETING
12.	" "	o IDENTIFY MISSIONS REQ'G UNREALISTIC OP'L MODES	DUE AT RA MEETING	o REPORT AT PRES. & PANEL MTGS.

GRUMMAN

STORABLE TUG SYSTEMS STUDY

GRUMMAN STATUS - ORIENTATION BRIEFING ACTION ITEMS

NO.	PANEL	ITEM	STATUS	REMARKS
13.	PROGRAMMATICS & COST	o SUBMIT RECOMMENDED WBS	COMPLETE	o SUBMIT 20 MARCH
14.	PROGRAMMATICS AND COST	o PREPARE/SUBMIT PRELIM WBS DICTIONARY	COMPLETE	o SUBMIT 2 APRIL
15.	PROGRAMMATICS AND COST	o DESCRIBE PROPOSED COST ESTIMATING METHODOLOGY	DUE AT RA MEETING	o REPORT AT PANEL MEETING

GRUMMAN

STORABLE SPACE TUG SYSTEMS STUDY

STUDY PLAN UPDATE - SUMMARY OF RESULTS

- NASA/DOD COMMENTS ON ORIENT, BRIEF'G/STUDY PLAN REC. 28 MAR.
  - 3 GENERAL COMMENTS
  - 12 SPECIFIC COMMENTS
- GRUMMAN REVIEW OF COMMENTS
  - GENERAL COMMENTS: 3 ITEMS - CONCUR/INCORP IN STUDY PLAN
  - SPECIFIC COMMENTS: 10 ITEMS - CONCUR/INCORPORATE
    2 ITEMS - DISCUSSED/RESOLVED WITH COR
- STUDY PLAN UPDATED AND EXPANDED
  - INCORPORATES MODS FROM NEGOTIATION AND ORIENTATION BRIEFING
  - INCORPORATES NASA/DOD COMMENTS OF 28 MAR 73
- 90 COPIES DELIVERED TO NASA/DOD 11 APR 73

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STORABLE SPACE TUG SYSTEMS STUDY

NASA/DOD STUDY PLAN COMMENTS - GRUMMAN EXCEPTION ITEMS

A. NASA/DOD COMMENTS

- o SPECIFIC ITEM #2: MAN LOADING LOW-TASK 3.2 (OPS, EQUIP. AND INTERFACE DEF.)
- o SPECIFIC ITEM #3: MAN LOADING LOW-TASK 4.2 & 4.3 (FAC. ANAL & LOGISTICS SUPP'T ANAL)

B. GRUMMAN RESPONSE

- o MANPOWER ADEQUATE CONSIDERING DATA BASE, EXPERIENCE, & PLANNED APPR.

C. RATIONALE

- o EXTENSIVE USE OF PAST EXPERIENCE & STUDY DATA
  - APOLLO/LM
  - SHUTTLE STUDIES
  - OMS STUDIES/PROPOSAL
  - TUG IN-HOUSE STUDIES/PROPOSAL
- o UTILIZE RESULTS OF TOPSS, SOAR, LAUNCH SITE SERVICES STUDIES

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STORABLE SPACE TUG SYSTEMS STUDY

NASA/DOD STUDY PLAN COMMENTS/GRUMMAN RESPONSES

NASA/DOD COMMENT	GRUMMAN RESPONSE
GENERAL	
1. o REFLECT DOD PARTICIPATION AS APPROPRIATE	o CONCUR - INCORPORATED
2. o UPDATE STUDY PLAN SCHEDULE PER NASA LTR PD-TUG-C-73-16	o CONCUR - INCORPORATED
3. o AMPLIFY DEFINITION OF SAFETY ANALYSIS	o CONCUR - INCORPORATED
SPECIFIC	
1. o CLARIFY DOD "SPECIAL REQT'S OUTPUT SHOWN UNDER "RELATED EFFORTS"	o DELETED - HOLDOVER FROM ORIG. PROPOSAL - CLOSE NASA/DOD CONTR. COORD. MAKES OBSOLETE
2. MAN-LOADING INADEQUATE: TASKS 2.5 (REPAIR/REUSE) AND 2.6 (C/O & OPS ANAL.)	o CONCUR - REALLOCATE TO INCREASE THESE AREAS

GRUMMAN

NASA/DOD STUDY PLAN COMMENTS/GRUMMAN RESPONSES (CONT.)

NASA/DOD COMMENT	GRUMMAN RESPONSE
SPECIFIC (CONT'D)	
2. (CONT) o MAN-LOADING LOW-TASK 3.2 (OPS, EQUIP. & INTERFACE DEF.)	o EXCEPTION - BELIEVE ADEQUATE BASED ON DATA BASE, EXPERIENCE & PLANNED APPROACH (WILL TRACK PROGRESS CLOSELY)
3. o MAN-LOADING LOW-TASK 4.2 (FAC. ANAL) & 4.3 (LOG SUPP'T ANAL)	o EXCEPTION - RATIONALE SAME AS ABOVE
4. o CLARIFICATION OF MISSION ANALYSIS TASK FLOW DIAGRAM	o CONCUR - INCORPORATED CORRECTION
5. o MAN-LOADING LOW-TASK 2.3 (TECHNOLOGY REQTS) WITH ADVENT OF DIRECT DEVELOPED TUG	o CONCUR - REALLOCATE TO INCREASE THIS AREA
6. o INADEQUATE RECOGNITION OF OPERATIONS CONSIDERATIONS IN CONCEPT IDENTIFICATION PROCESS (REF TO ORIENT. BRIEF'G HANDOUT)	o CONCUR - ORIENT. BRIEF'G LIGHT IN THIS AREA - DETAILED DESCRIP. PROVIDED IN STUDY PLAN

GRUMMAN

STORABLE SPACE TUG SYSTEMS STUDY

NASA/DOD STUDY PLAN COMMENTS/GRUMMAN RESPONSES (CONT.)

NASA/DOD COMMENT	GRUMMAN RESPONSE
SPECIFIC (CONT'D)	
7. o TASK 3 OBJECTIVE -"RECOMMEND OPTIONS ON BASIS OF GREATEST CAPABILITY FOR LEAST DEV./LOW OPERATING COST"	o CONCUR-WORDING INCORPORATED
8. o SUBSYSTEM SYNTHESIS (SELECTION) PROCESS MUST CONSIDER OPERATING COST, TRAFFIC MODEL & FLEET SIZE AS WELL AS DDT&E	o CONCUR -STUDY PLAN SO STATES
9. o PROPOSED STUDY OF INTERCHANGEABLE FRONT END OPTIONS SHOULD ADDRESS AVIONICS/OP'L ASPECTS, NOT DESIGN OF MECHANISM	o CONCUR - ASSUME ADAPTOR WT INCL. IN PL WT - USE TOPSS INFO FOR SERVICING & SPIN/DE-SPIN KITS.
10. o VALIDATE WT. OF SHUTTLE/TUG STRUCTURAL/ FLUID INTERFACES EARLY IN STUDY	o CONCUR - STUDY PLAN IDENTIFIES AS EARLY EFFORT

GRUMMAN

STORABLE SPACE TUG SYSTEMS STUDY

NASA/DOD STUDY PLAN COMMENTS/GRUMMAN RESPONSES (CONT'D)

NASA/DOD COMMENT	GRUMMAN RESPONSE
SPECIFIC (CONT'D)	
11. o SPECIAL ITEMS WHICH ARE SUBJECT OF SENSITIVITY STUDIES SHOULD BE INTEGRAL PART OF BASELINE OPTIONS; THEY SHOULD NOT BE CONSIDERED AS "ADD ONS"	o CONCUR - REQUIREMENTS AND IMPLEMENTATION OPTIONS FOR SPECIAL ITEMS ARE CONSIDERED FROM OUTSET OF STUDY.
12. o SENSITIVITY ANALYSES SHOULD CONSIDER IMPACT ON MISSIONS AS WELL AS IMPACT ON DESIGN, PROGRAMMATIC ISSUES AND COST	o CONCUR - INCORPORATED IN STUDY PLAN.

GRUMMAN