BELLCOMM, INC.
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SUBJECT: MT Presentation to OMSF Management Council

DATE: May 27, 1970

FROM: B. T. Howard

Mr. P. E. Culbertson - NASA/MT:

This letter summarizes our participation in the development of your recent presentation to the OMSF Management Council and forwards observations which may be helpful in further enhancing the OMSF planning process and in identifying the areas requiring additional study. Draft copies of the presentation material submitted to you and your staff are compiled in Attachment II, arranged generally in the order of your presentation. Our observations based on participation in this activity are summarized in Attachment I.

B. T. Howard

Attachments

Copy to
W. O. Armstrong - NASA/MTX
E. W. Hall - NASA/MTG
A. D. Schnyer - NASA/MTE COPY TO
M. G. Waugh - NASA/MT-1
J. W. Wild - NASA/MTE

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ATTACHMENT 1

COMMENTS ON PRESENTATION MATERIAL

The following comments are based on Bellcomm participation in the development of the NASA/MT presentation to the OMSF Management Council.

Payloads

1. A preliminary analysis indicates that the shuttle aided by auxiliary propulsion is an adequate delivery mechanism for all anticipated automated spacecraft. Results indicate that the 25,000 lb. (270 n.mi. x 55°) and 15' diameter by 60' long payload model is adequate. However, it is most important to modify the missions to reflect the shuttle concept and constraints, since that may significantly alter the quantitative description of the payload requirements and the delivery mode to orbit.

2. Further preliminary studies show that if the large cargo bay is adopted, the shuttle may be capable of competing most effectively with the space station and may also be capable of mission modes that are potentially superior in economic and performance characteristics to those of the station. At this time these concepts are intriguing, but are not sufficiently developed to make a definitive comparison with the space station alternatives. Without further study of these alternatives it is not possible to pass judgement on a sound basis.

3. A contribution of value to both items 1 and 2 above would be the development of a flight experiment program for the shuttle similar to the blue or green books associated with the station.

4. There was approximate agreement among the Center staff papers that 100,000 pounds to low earth orbit is a desirable but not necessary capability; perhaps the ability to orbit 75,000 pounds is adequate. This situation requires clarification since this large lift capability is a pivotal feature of the long term flexibility of MSF to meet changing requirements.

Shuttle

1. There are three interrelated issues; size and weight of internal payload (dealt with above), alternative configurations and alternative development approaches. The last issue is principally a function of program needs. That is, if the shuttle delays the resumption of MSF (due to funding requirements) too long, then an alternative approach leading to earlier flight at less investment will be mandatory.

   Numerous alternative shuttle concepts have been identified. A basic assumption has to be made concerning the market for the shuttle. Assuming a high traffic model forces the attempt to achieve full reusability. If we restrict ourselves very stringently to those concepts that involve the development of two reusable stages (the primary distinguishing properties of the baseline shuttle), we find only three general configurations.

   a) Lifting orbiter on a ballistic booster

      This includes SERV/MURP but is not limited to them since the orbiter could participate in the orbit insertion propulsion.

   b) Ballistic orbiter on a ballistic booster

      Our studies indicate that this is a reasonable configuration, quite competitive with the baseline. Again, the velocity split between the stages should be varied to examine the various attractive choices.

   c) Ballistic orbiter on a lifting booster

      This is just the reverse of a).

   If the stringent criteria are relaxed, the field opens up to include a wide range of contestants. They are however, principally what one would consider to be interim configurations, a step in the evolution to a shuttle. There is one configuration of serious merit from this group, that is,

d) Either a lifting or ballistic orbiter on an all expendable new "minimum cost design" launch vehicle.

2. The Center staff papers presented the following consensus of ideas;

a) The relative costs of new developments are probably correct in revealing the cost ordering of alternatives, but the absolute costs are not meaningful estimates.

b) The current shuttle concept (phase B) is not suited to phased development for reasons of performance and economy.

Large Lift

1. The payload studies (first section) do not clearly identify any major advantage to payload capability in excess of the Titan growth family (TIII-L-4).

2. The cost analysis does not clearly indicate any distinction in non-recurring costs between Titan growth and Saturn carry-on options, although differences in recurring costs are indicated that favor Titan. This depends on continuing Titan production for other needs.

3. For several hundred million additional dollars, various versions of the 156" or 260" SRM using either SIVB or SII can be developed. Recurring costs lie between those of Titan derivatives and Saturn follow-on.

4. The 12" SRM plus SIVB appears competitive with Titan growth versions.

5. The O.I.S. concept for use with the shuttle appears technically valid but requires substantially better cost analysis.

Space Tug

1. No definitive design concepts enjoying wide support have yet emerged.

2. There is a basic problem with space based tug operations (as opposed to ground based operations) due to orbit plane precession.

3. There is serious doubt that the USAF performance requirements can be met even with a vehicle specifically designed to that mission only.

Cislunar Shuttle

1. The requirements, both programmatic and performance, for a cislunar shuttle (chemical or nuclear) have not been clearly established.

2. Chemical shuttles have not been given sufficient attention.

Lunar Exploration

1. At this time there is very little concern about, and certainly almost no study of, possible alternatives for filling the impending gap in lunar exploration. With the passing of the Saturn/Apollo system man will not be able to return to the moon again unless we initiate a new program. This issue is twofold;

   a) What are the practical alternative programs?

   b) Is it permissible to leave ourselves without the capacity to return to the moon rapidly, even if we do not expect to exercise such an option?

   The lunar exploration program is in need of comprehensive examination for the purpose of lending structure and priorities to the set of possible future choices.

2. The lunar surface base has always been tacitly accepted as the ultimate capability of the lunar exploration program. It is not clear that this is an appropriate long range goal.

Near Term Gap Fillers

1. If this class of mission is to be seriously considered, then a careful review of the early Apollo Extension System studies, completed in 1965, is warranted.

Space Station

1. The space station configuration is more sensitive to the interface with the transportation vehicle than it is to the flight experiments.

2. It seems feasible to achieve a space station capability using the shuttle as the launch vehicle.

3. The relationship of the current Skylab program to the space station needs clarification.

Program Alternatives

1. It is understood that one of the principal purposes of the presentation was the illumination of possible FY 1972 program decisions through examination of their long range implications. For this purpose program alternatives were structured based on the a priori resolution of two major issues generated by recognition of a near-future constrained resources environment:

   a. The question of Saturn V production, resolved so as to continue the suspension, and

   b. The question of the order of serial development of the space station and space shuttle, resolved in favor of initiating the latter in FY 1972.

   The major issues to be illuminated by the alternatives became the following:

   a. The space shuttle development approach, clearly an FY 1972 consideration, and

   b. The approach to and time-phasing of the development of long-duration MSF capability, an FY 1972 consideration because of the potential of Skylab.

An issue raised by electing to suspend Saturn V production is the question of resumption of manned luanr exploration, but here development of the alternatives revealed general insensitivity to FY 1972 decisions. (There is a possible interface with the Apollo program, but there was no variation in alternatives for the period covering the runout of Apollo.)

2. The approach taken in structuring program alternatives was based on developing alternative paths from FY 1972 toward accomplishment of program objectives derived from STG Option II. Formal evaluation of the relative merits of the

alternatives, however, is complicated by the fact that they were not constrained similarly in resources or in timing of achievement. This tends to restrict the evaluation criteria to those associated with management appeal.

3. An alternative approach warranting consideration for future use is a more evolutionary, less deterministic one. Preliminary assessment revealed that the program objectives of STG Option II could not be achieved because of resources considerations. At the same time, there is available as near-term direction the President's space policy statement of March 7, 1970, which was made after consideration of the STG Report. In effect, considering this statement in the light of the expected national environment should define the FY 1972 "truths." It would appear appropriate to develop programs which evolve from those "truths" via alternative paths to the future. Maintaining near-term fiscal constraints on those alternatives would further illuminate FY 1972 decisions.

4. Direct pursuit of STG Option II as a target for the MSF program was discarded for budgetary reasons. However, the program alternatives eventually synthesized were priced out at values not too different from Option II for the near future. In particular, the FY 1972 figures are almost identical, and for FY 1973 Option II funding is lower than two of the alternatives. The suspicion is that failure to consider more severe resources constraints for the near future may have obscured some of the real FY 1972 issues.

5. The level of detail in the characterization of program alternatives during the later periods is not entirely compatible with our understanding of the integrated program reflected in STG Option II. As a concept involving lower cost, flexible operations in cislunar space, the integrated program affords sufficient guidance to point the way to the future. The detailed implementation will depend in good part on the market for its use, but that market appears to be slipping farther into the future. For this reason estimating the future use of the capability will probably remain difficult for some time, and it may turn out

that the market will not unfold until at least preliminary capability is available. Hence, it would appear appropriate to avoid tying significant FY 1972 decisions to any current view of the ultimate application to be made of the integrated program systems.

ATTACHMENT 2

(NASA-CR-126026) MT PRESENTATION OF OMSF MANAGEMENT COUNCIL (Bellcomm, Inc.) 125 p

N79-73250

Unclas
00/81 12190

PAYLOADS

MAJOR PROGRAM ELEMENTS

	Wt. (lbs)	Dia (ft)	Launch Frequency
. DOD			
- SYNCHRONOUS ORBIT	10 K	?	4/yr
. MAJOR PROGRAM ELEMENTS			
- SPACE STATION MODULE			
PHASE B STATION	∿ 120 K	33	∿ 1/10 yr's
LARGE INDEPENDENT STATION	∿ 120 K	22 or 33	∿ 1/10 yr's
LARGE MODULAR STATION	∿ 40 K (module)	15 (module)	∿ 3 modules/10 yr'
SMALL INDEPENDENT STATION	∿ 50 K	15	∿ 6/10 yr's
- TUGS			
TUG (λ=.8	∿ 49 K	15	∿ 9/yr
TUG (λ=.9)	∿ 44 K	15	∿ 3/yr
ADV. CENT	∿ 44 K	10	∿ 8/yr
CENT	∿ 35 K	10	∿22/yr
TRANSTAGE	∿ 27 K	10	∿11/yr
AGENA	∿ 15 K	5	∿ 7/yr
TANDEM BURNER II	∿ 5 K	5	∿ 5/yr
- NUCLEAR SHUTTLE			
INTEGRAL	∿ 300 K	33	∿ 1/yr
MODULAR	∿ 50 K module	22 module	∿ 8 modules/yr
. SPACE STATION LOGISTICS			
CREW ROTATION (12 MEN)	∿ 10 K	15	4/yr
LOGISTICS	∿ 68 K	$\leq$ 15	depends on shuttle payload

TYPICAL UNMANNED PAYLOADS

I LABORATORY CLASS	WEIGHT	MAX LENGTH/ DIA. (FEET)	ALTITUDE	INCLINATION	FREQ.
A. MAN ASSOCIATED					
SOLAR	25,000	15/39	270	55	
STELLAR U.V.	32,000	15/57	↓	↓	
X-RAY	21,000	15/41			
HI-ENERGY SURVEY	25,000	15/24			
EARTH SURVEYS	30,000	15/30			
MAT'L SCIENCE	26,000	15/15			
BIOLOGY	18,700 & 4100*	15/15 & 15/20			
COSMIC RAY LAB.	39,000 & 19000*	15/36			
FLUID PHYSICS	13000 & 25000*	15/15 & 15/35			
ATMOSPHERIC PHYSICS	26,000	15/36			
B. UNMANNED					
OAO	6,000	12.5/9.58	400 X 400	35	
HEAO	23,000	42/8.92	200 X 200	23.5	
ATS	2,200	12.5/9.58	19,300 X 19,300	0	1/4YRS
NIMBUS	1,500	11.5/4.83	600 X 600	100	1/4YRS
ERTS	2,000	4.775/4.75	500 X 500	100	

* TWO MODULES

TYPICAL UNMANNED PAYLOADS CONT

II HIGH ENERGY CLASS (UNMANNED)	WEIGHT	MAX. LENGTH/ DIA. (FEET)	ALTITUDE	INCLINATION	FREQ./YRS
MARS VIKING 77	9700	12.5/9.58			1/4
HIGH DATA RATE MARS ORBITER	7000	12.5/9.58			"
VENUS EXPLORER PROBES	635	—			"
VENUS EXPLORER ORBITER	660	—			2/4
JUPITER PROBE	2200	5.58/2.65			1/4
JUPITER-SAT.-PLUTO SWINGBY	1,500	5.58/2.65			2/4
JUP-URAN-NEPTUNE SWINGBY	1,500	5.58/2.65			"
ASTEROID BELT SOLAR ELECTRIC	1,500				1/4
COMET D'ARREST FLYBY	1000	12.5/9.58			"
III MAJOR PROGRAM ELEMENTS					
PHASE B STATION	~120,000	45/33	270	55	1/10
LARGE INDEPENDENT STATION	~120,000	~60/22 or 33	270	55	1/10
LARGE MODULAR STATION	~40,000 (MOD)	60/15 (MOD)	270	55	3 MOD/10 YR.
SMALL INDEPENDENT STA.	~50,000	60/15	SEVERAL	SEVERAL	6/10
CENTAUR	~35,000	30/10	270/100	55/28.5	~22
TUG	~50,000	TBD/15 or 22	270/100	55/28.5	~9
NUCLEAR SHUTTLE (INTEGRAL)	~300,000	~140/53	100	28.5	1
NUCLEAR SHUTTLE (MODULAR)	~50,000 (MODULE)	60/15 or 22	270	55	8 MODULES

TYPICAL UNMANNED PAYLOADS CONT'

	WEIGHT	MAX. LENGTH/ DIA. (FEET)	ALTITUDE	INCLINATION	FREQ./YR
IV SPACE STATION					
CREW ROTATION (12 MEN)	~10,000	SHUTTLE DEPENDENT	270	55	4
LOGISTICS	~70,000	SHUTTLE DEPENDENT	270	55	DEPENDS ON SHUTTLE PAYLOAD
V LUNAR PROGRAM					
LUNAR ORBIT SPACE STA.	~100,000	46/33	~60	HIGH	1/3
LUNAR SURFACE BASE	~60,000	26/33	SURFACE	SURFACE	1/3
L E M B.	~50,000	~25/22	N/A	N/A	2
LUNAR SHUTTLE	~600,000	~80/33	N/A	N/A	1
VI REPRESENTATIVE SMALL UNMANNED SATELLITES					
ATMOS. EXPLORER	600	4.775/4.75	2,100 X 30	100.	3/4
CLUSTER	800	5.583/2.65	110,000 X 110,000	28.5	1/4
NAV T/C	750	4.775/4.75	19,300 X 33,600	0	
COMMUNICATIONS					
WORLD WEATHER WATCH	1800	11.5/4.83	600 X 600	100	1/2
E S S A LOW ALT.	1200		900 X 900	101	1
IMP	675		10,000 X 200	28.5	3/4
I S I S	490	4.775/4.75	1,900 X 270	90.	
INTELSAT V	5000		19000 X 19000	0.	

PROGRAM ELEMENT CAPABILITIES

SHEET NO. ____ OF ____
JOB NO. ____
SUBJECT ____
BY ____ DATE ____
CHKD. BY ____ DATE ____

ESTIMATED SPACE SHUTTLE EARTH ORBIT CAPABILITY

SHUTTLE ALONE

270 N.M. / 55°	100 NM. / 28°	NOMINAL P/L BAY
50K	75K	15 X 60
25K	50K	15 X 60
10K	26K	10 X 35

SHUTTLE WITH TUG TO SYNCHRONOUS ORBIT

49K TUG ($\lambda' = .8$)

EOS NOM. P/L	DELIVERY, EXPENDABLE	DELIVERY, RECOVERABLE	RETRIEVAL	ROUND TRIP
50K	15K	0	0	0
25K	9K	0	0	0
10K	—	—	—	—

44K TUG ($\lambda' = .9$)

50K	20K	9K	3.5K	2.5K
25K	14K	6.5K	3.5K	2.5K
10K	—	—	—	—

PROGRAM ELEMENT CAPABILITIES

- Shuttle (IOC - "77")

Inert P/L to 270 nm/55°	P/L Bay Dia. (ft)	Duration (days)
50K	15 x 60	7
25K	15 x 60	7
10K	10 x 35	7

- Tugs*

	P/L to 270 nm/55° (lbs)	P/L to Geosynchronous (lbs)
Tug (λ = .9)	17,500 (R) 26,800 (E)	7,700 (R) 18,700 (E)
Tug (λ = .8)	3,000 (R) 21,800 (E)	13,710 (E)
Adv. Centaur	10,000 (R) 17,000 (E)	500 (R) 13,000 (E)
Centaur	16,000 (E)	13,600 (E)
Transtage	5,000 (E)	2,500 (E)
Agena	4,000 (E)	2,500 (E)
Tandem Burner II	1,200 (E)	800 (E)

*INITIAL TUG ORBIT = 100 NM/28.5°

COMPARISON OF SPACE SHUTTLE CAPABILITY

COMPARISON OF SHUTTLE CAPABILITY FOR UNMANNED PAYLOADS

NASA EARTH ORBIT	50 K	25 K	10 K
Astronomy			
OAO	✓	✓	✓
OSO	✓	✓	✓
HEAO	✓	✓	X, Payload size limited
Space Physics			
Atmos. Explorer	+A	+A	+BII
IMP	+A	+A	+BII
ISIS	+A	+A	+BII
Cluster	+A	+A	+A
Earth Obs.			
Nimbus	✓	+A	+BII
Garp Equat.	+A	+A	+A
Garp Geosta.	+A	+A	+A
Garp Polar.	✓	+A	+BII
ERTS E & F	✓	+A	+BII
Communications			
ATS H & J	+A	+A	+A
Broadcast	+A	+A	+A
NAV T/C	+A	+A	+A

NOTE: A, Agena Stage
BII, Burner II, Plus Apogee kick stage (e.g., FW4) if necessary
C, Centaur Stage
✓, Direct delivery, no injection stage required

COMPARISON OF SHUTTLE CAPABILITY FOR UNMANNED PAYLOADS, CONTINUED

NON-NASA EARTH ORBIT	50 K	25 K	10 K
Communications			
U. S. Domestic	+A	+A	+A
Intelsat V	+C	+C	X
Canadian Domestic	+A	+A	+A
S. A. Reginal	+A	+A	+A
India Domestic	+A	+A	+A
FAA (ATC)	+A	+A	+A
Aero. Maritime	+A	+A	+A
Earth Observations			
World Weather Watch	✓	+A	+BII
ESSA Low Altitude	+A	+A	+BII
Earth Resources	✓	✓	+BII
ESSA Synchronous	+A	+A	+A

COMPARISON OF SHUTTLE CAPABILITY FOR UNMANNED PAYLOADS, CONTINUED

PLANETARY & INTERPLANETARY	50 K	25 K	10 K
Mars Viking 77	+C	+C	X
High Data Rate Mars Orbiter	+C	+C	X
Venus Explorer Probes	+A	+A	+A
Venus Explorer Orbiters	+A	+A	+A
Jupiter	+C	+C	X
Jupiter-Sat-Pluto Swingby	+C	+C	X
Jupiter-Uran-Neptune Swingby	+C	+C	X
Asteroid Belt Solar Electric	+A	+A	+A
Comet D'Arrest Flyby	+A	+A	+A

COMPARISON OF SHUTTLE CAPABILITY TO DELIVER

MAJOR PROGRAM ELEMENT PAYLOADS

	Space Shuttle Altitude	50 K EOS		25 K EOS		10 K EOS	
		55°Inc.	28.5°Inc.	55°Inc.	28.5°Inc.	55°Inc.	28.5°Inc
• DOD							
- SYNCHRONOUS ORBIT	100 nm	-	✓	-	✓	-	X
• MAJOR PROGRAM ELEMENTS							
- SPACE STATION MODULE							
PHASE B STATION	270	X	X	X	X	X	X
LARGE INDEPENDENT STATION	270	X	X	X	X	X	X
LARGE MODULAR STATION	270	✓	✓	X	(Marginal)	X	X
SMALL INDEPENDENT STATION	270	✓	✓	X	X	X	X
- NUCLEAR SHUTTLE							
INTEGRAL	100	X	X	X	X	X	X
MODULAR	270	(DIA. LIMIT)		X	X	X	X
• SPACE STATION LOGISTICS							
CREW ROTATION (12 MEN)	270	✓	✓	✓	✓	(DIA. LIMIT)	
LOGISTICS	270	DEPENDS ON FREQUENCY					

✓, CAN BE DELIVERED

X, CANNOT BE DELIVERED

COMPARISON OF SHUTTLE CAPABILITY TO DELIVER

FULLY LOADED ON-ORBIT TUGS

	Space Shuttle Altitude	50 K EOS		25 K EOS		10 K EOS	
		55°Inc.	28.5°Inc.	55°Inc.	28.5°Inc.	55°Inc.	28.5°Inc.
- TUGS							
TUG (λ=.8)	270	√	√	X	√	X	X
	100	√	√	X	√	X	X
TUG (λ=.9)	270	√	√	X	√	X	X
	100	√	√	X	√	X	X
ADV. CENT	270	√	√	X	√	X	X
	100	√	√	X	√	X	X
CENT	270	√	√	X	√	X	X
	100	√	√	√	√	X	X
TRANSTAGE	270	√	√	√	√	X	X
	100	√	√	√	√	X	(MARGINAL)
AGENA	270	√	√	√	√	X	√
	100	√	√	√	√	√	√
TANDEM BURNER II	270	√	√	√	√	√	√
	100	√	√	√	√	√	√

√, CAN BE DELIVERED WITH FULL PROPELLANT LOAD
X, CANNOT BE DELIVERED WITH FULL PROPELLANT LOAD

SUMMARY

- 50 K SHUTTLE ALONE OR IN COMBINATION WITH A TUG ACCOMMODATES ALL PAYLOADS EXCEPT:
  - PHASE B SPACE STATION OR,
  - LARGE INDEPENDENT SPACE STATION
  - INTEGRAL NUCLEAR SHUTTLE OR,
  - NUCLEAR SHUTTLE MODULES
- 25 K SHUTTLE ALONE OR IN COMBINATION WITH A TUG ACCOMMODATES ALL PAYLOADS EXCEPT:
  - ALL SPACE STATION MODULES
  - INTEGRAL AND MODULAR NUCLEAR SHUTTLES
- 10 K SHUTTLE ALONE OR IN COMBINATION WITH AN AGENA OR BURNER II (PLUS AN APOGEE KICK STAGE IN SOME CASES) CAN ACCOMMODATE ALL THE EARTH ORBIT MISSIONS WITH THE EXCEPTION OF INTELSAT V AND HEAO. THE PLANETARY MISSIONS WOULD BE RESTRICTED TO THE VENUS PROBES, ASTEROID BELT SOLAR ELECTRIC AND THE COMET D'ARREST FLYBY.
  - THE LARGER TUGS, SPACE STATION MODULES AND NUCLEAR SHUTTLES CANNOT BE ACCOMMODATED.

SHUTTLE

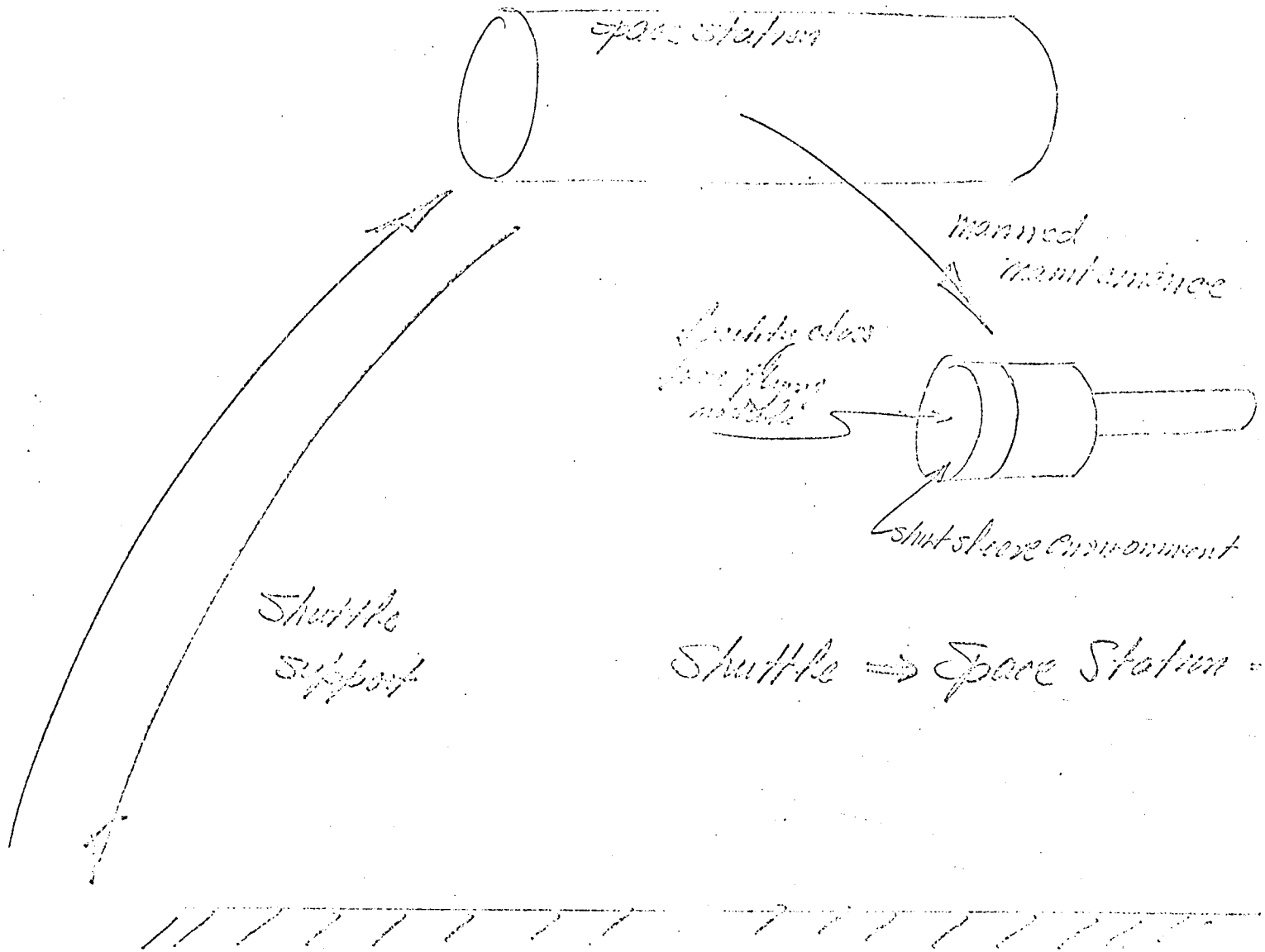
SHUTTLE IMPACT ON THE PAYLOAD MODEL

- THE PRESENT PAYLOAD MODEL DOES NOT INCLUDE THE SHUTTLE AS AN INTEGRAL ELEMENT
- SHUTTLE AVAILABILITY MEANS THAT NEW INTERFACES APPEAR IN ITS INTEGRATION INTO THE SYSTEM. FOR EXAMPLE
  - A) THE SUPPORT OF FACILITY CLASS INSTRUMENTS
  - B) THE IMPACT ON SATELLITE DESIGN AND LAUNCH
  - C) INSTRUMENT EVOLUTION
  - D) THE SHUTTLE AS AN EXPERIMENT PLATFORM

TYPICAL FACILITY CLASS INSTRUMENTS

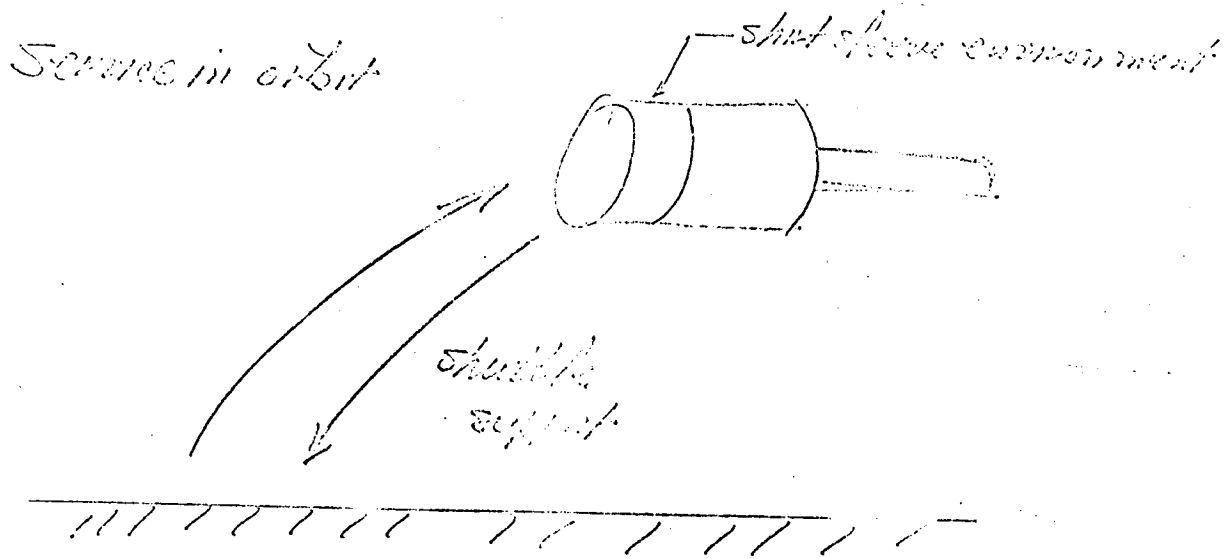
THESE ARE LARGE INSTRUMENTS WITH LONG USEFUL LIFETIMES WHICH CAN BE FLOWN ATTACHED TO A SPACE STATION OR FREE.

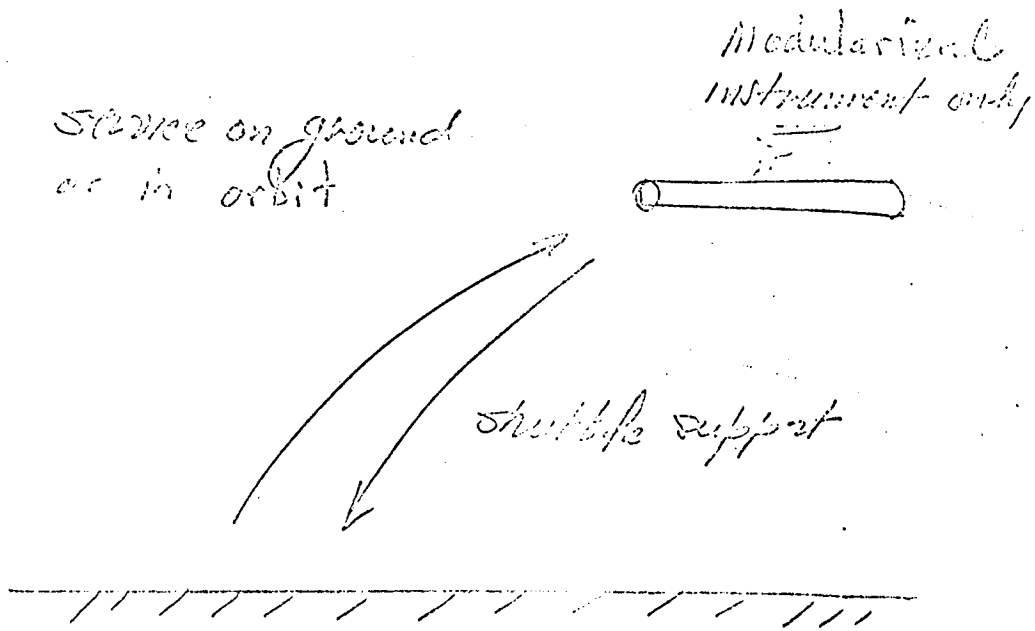
OAO 120" TELESCOPE	6600 POUNDS
HEAO	40,000
SOLAR ASTRONOMY I	3500
II	2685
EARTH SURVEY	7950
COSMIC RAY I	2000
II	185,00



Shuttle ⇒ Space Station ∴ Instrument

Shuttle → Instrument





UNMANNED SATELLITES

NIMBUS	1300 POUNDS
ATS	1500-2000
DATA RELAY SATELLITE SYSTEM	1600
BROADCAST SATELLITE	6000

SHUTTLE IMPACT ON UNMANNED SATELLITES

- A 25 K SHUTTLE PLUS A CENTAUR CAN DELIVER EVERY SATELLITE IN THE 1970 - 1980 LONG RANGE NASA PLAN.

- IMPORTANT COST REDUCTIONS MAY BE REALIZED BECAUSE

  A) INSTRUMENTS CAN BE ALIGNED, CALIBRATED AND OPTIMIZED IN SPACE THUS REDUCING THE PRE-LAUNCH REQUIREMENTS.

  B) FAILED COMPONENTS, MAJOR SUB ASSEMBLES, OR EVEN ENTIRE INSTRUMENTS CAN BE RETURNED TO EARTH FOR LARGE REPAIRS.

  C) SPACE RELIABILITY CAN BE OBTAINED BY ACCESS AND REPAIR CAPABILITIES INSTEAD OF REDUNDANCY AND SEVERE COMPONENT RELIABILITY REQUIREMENTS.

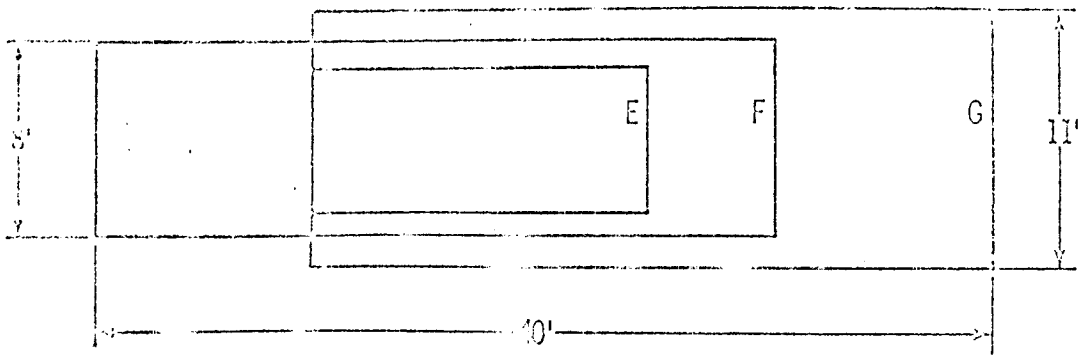
- CLUSTERING OF SATELLITES INTO A SMALL NUMBER OF ALTITUDE/INCLINATIONS REGIMES (e.g., 250 NM, 28°; 600 NM, 100°; 20,000 NM, 0°) MAKES MORE SATELLITES ACCESSIBLE ON A SINGLE SHUTTLE MISSION.

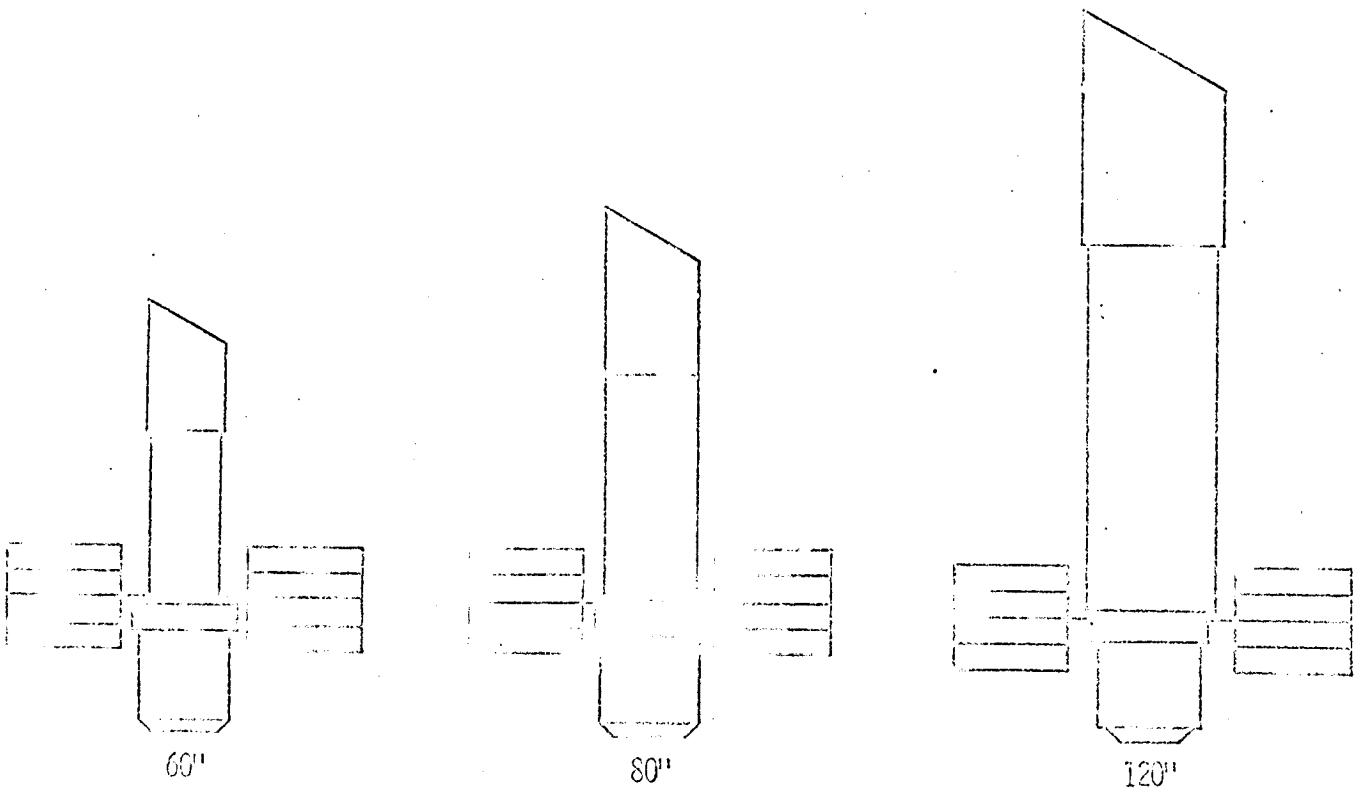
ORBITAL OBSERVATORY PROGRAM CHARACTERISTICS

OAO PROJECT PROPOSAL

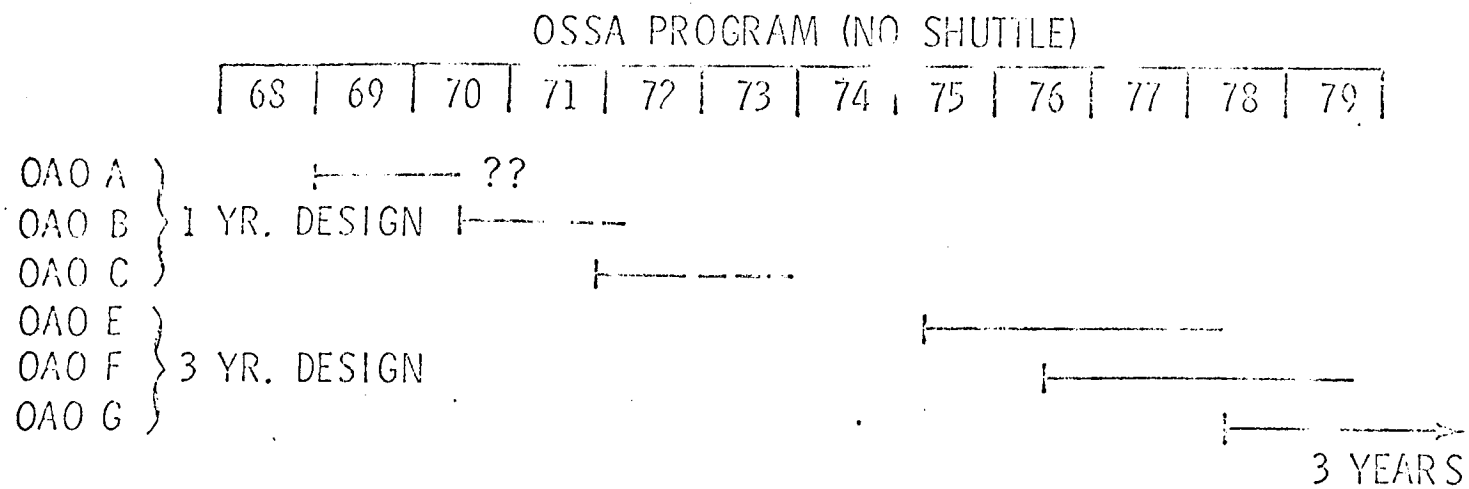
1. SERIES OF OPERATIONAL TELESCOPES (60", 80", 120") AT ~$100 M EACH, ORBITAL MAINTENANCE, NO RECOVERY
2. NO PLANNED IN ORBIT TEST OF MIRROR FIGURE OR OPTICAL SYSTEM PERFORMANCE
3. DESIGN GOAL IS DIFFRACTION LIMITED PERFORMANCE OF EQUIVALENT 80" SYSTEM
4. SCIENCE IMPROVED BY SMALL INCREASES IN TELESCOPE SIZE USING SAME BASIC DESIGN
5. STEADY SCIENCE OUTPUT FROM 2-3 TELESCOPES OPERATING SIMUTANEOUSLY
6. PAYLOAD DIVERSITY THROUGH MUTIPLE LAUNCHES AND IN ORBIT MODULE REPLACEMENT

OAO EVOLUTIONARY DEVELOPMENT





OAO LAUNCH SCHEDULE



——— DESIGN LIFE (ACTUAL LIFE FOR OAO A)

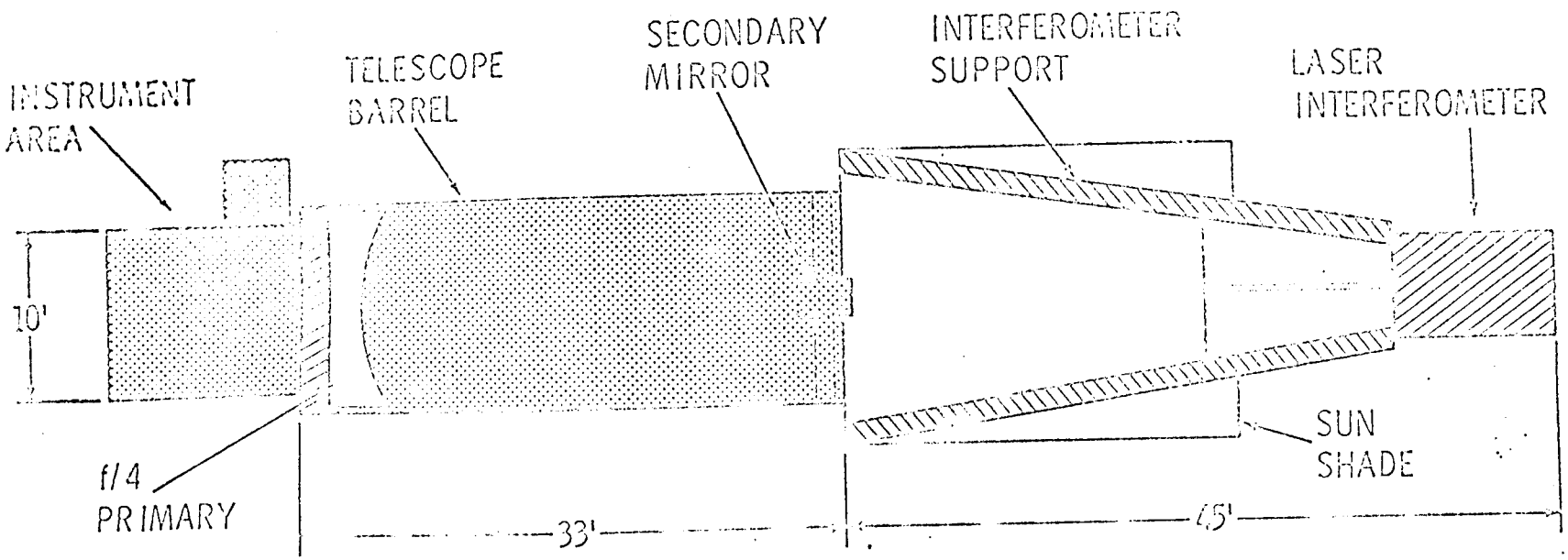
- - - - - PROBABLE LIFE BASED ON PRESENT OAO EXPERIENCE

ORBITAL OBSERVATORY PROGRAM CHARACTERISTICS

PROPOSAL TO TAKE ADVANTAGE OF SHUTTLE

1. ONE DEVELOPMENTAL 120" TELESCOPE, UPGRADE DURING EARTH RETURN PHASE, THEN REORBIT
2. IN ORBIT TESTING OF TELESCOPE QUALITY
3. DESIGN GOAL IS 120" DIFFRACTION LIMITED PERFORMANCE IN UV
4. SCIENCE IMPROVED BY REFIGURING EXISTING SYSTEM
5. INTERRUPTED SCIENCE OUTPUT DURING ORBITAL TESTS AND GROUND UPGRADING
6. PAYLOAD DIVERSITY THROUGH GROUND RETURN CYCLE AND IN ORBIT MODULE REPLACEMENT

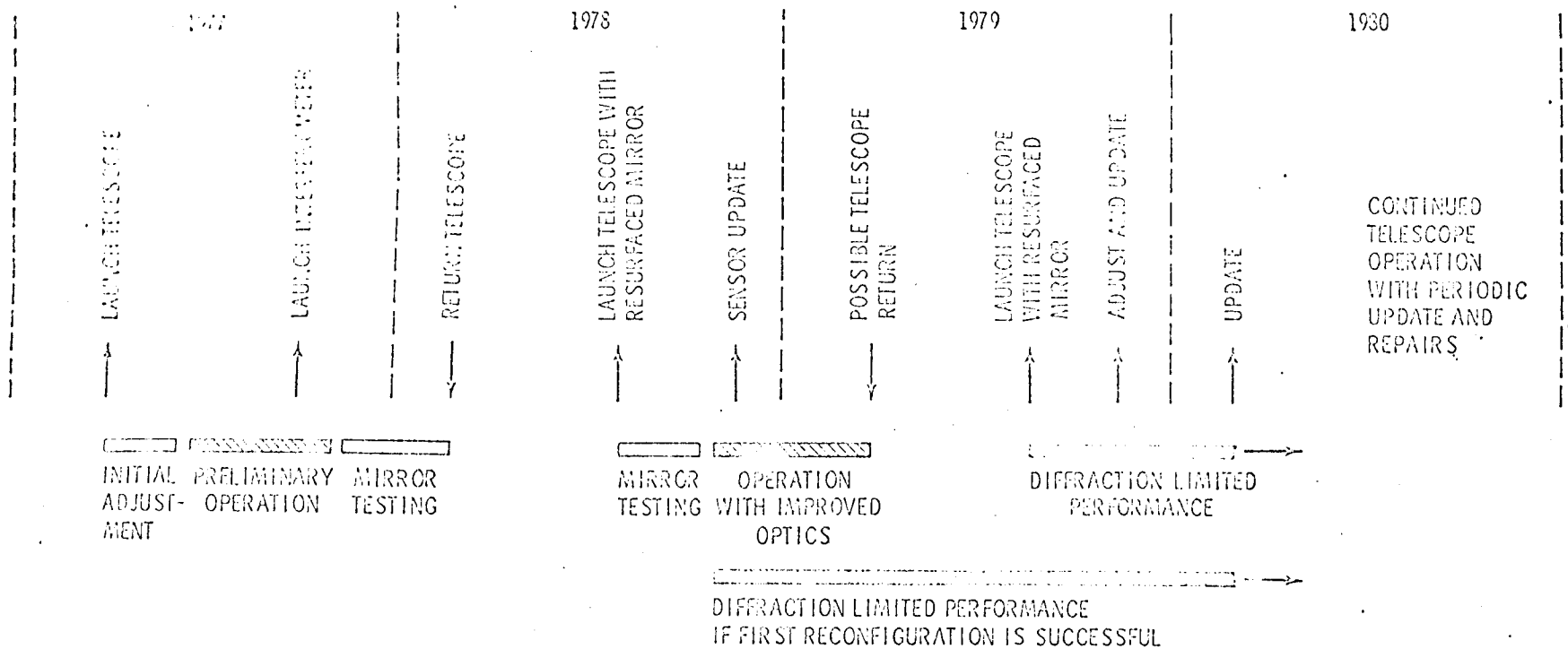
TELESCOPE IN TESTING CONFIGURATION WITH INTERFEROMETER ATTACHED



TESTING PROCEDURE FOR DIFFRACTION LIMITED PERFORMANCE

a) PRIMARY MIRROR TESTED WITH INTERFEROMETER
b) SYSTEM OPTICS TEST BY HARTMANN METHOD
c) ALL MIRROR FINISHING AND COATING DONE ON GROUND
d) MAJOR SUBASSEMBLIES (INTERFEROMETER, SYSTEM TESTING EQUIPMENT, DETECTORS, SPECTROMETERS) ATTACHED IN ORBIT

TIMELINE FOR SHUTTLE/TELESCOPE OPERATIONS



LEGEND

- TELESCOPE IN ORBIT BUT NOT OPERATIVE
- PARTIAL TELESCOPE OPERATION
- DIFFRACTION LIMITED OPERATION

THE SHUTTLE AS AN EXPERIMENT PLATFORM

- IF NASA'S CONVAIR 990 EXPERIENCE CAN BE APPLIED TO THE SHUTTLE, ONE COULD EXPECT

  A) GREATLY REDUCED LEAD TIMES FOR EXPERIMENTS

  B) INCREASED PARTICIPATION BY SCIENTISTS BECAUSE OF RAPID EXPERIMENT CYCLING

  C) RAPID EVOLUTION OF INSTRUMENTS THROUGH SEVERAL FLIGHTS.

  D) SIGNIFICANT COST REDUCTIONS BECAUSE STANDARD LABORATORY INSTRUMENTS ARE FREQUENTLY ADEQUATE.

- THE SHUTTLE COULD PERFORM POLAR ORBIT MISSIONS AND HAVE ACCESS TO HIGH ENERGY ORBITS.

- THE INVESTIGATOR AND TECHNICIAN CAN BE AVAILABLE FOR MONITORING, REPAIR, AND RECONFIGURING.

PROGRAMATIC ISSUES

- DOD INTERESTS AND MISSIONS ARE POORLY DEFINED FOR NASA PLANNING PURPOSES.

- THE SPACE STATION PAYLOAD MODEL AND THE OSSA PROSPECTUS ARE ONLY THE FIRST STEPS IN AN ITERATIVE SOLUTION FOR THE PAYLOAD MODEL. A MODEL IN WHICH THE SHUTTLE IS AVAILABLE IS NECESSARY.

- A RATIONAL SET OF CRITERIA FOR ASSIGNING EXPERIMENTS TO POTENTIAL SPACECRAFT ELEMENTS (INCLUDING SH, SSM, SATELLITES, AND SS MODULES) MUST BE ESTABLISHED BEFORE THE NEED FOR EACH ELEMENT CAN BE ASSESSED. FOR EXAMPLE

  A) SHOULD FREE FLYING MODULES AND LARGE FACILITY CLASS INSTRUMENTS BE SUPPORTED BY A SPACE STATION OR BY THE SHUTTLE?

  B) IF A SHUTTLE IS AVAILABLE AS AN EXPERIMENT PLATFORM IT IS COMPETITIVE WITH THE SPACE STATION FOR SHORT MISSIONS. ARE THERE IMPORTANT, LONG DURATION, MISSIONS WHICH ONLY A STATION CAN PERFORM?

- HARD ENGINEERING AND ECONOMIC STUDIES OF SATELLITE DESIGN AND OPERATIONS IN THE SHUTTLE-ASSISTED MODE AND THE CV-990 SHUTTLE ON-BOARD EXPERIMENT MODE NEED TO BE CARRIED OUT AS A BASIS FOR MAJOR DECISIONS ON ALTERNATIVES PAYLOAD OPERATIONS IN THE SHUTTLE ERA.

TRANSPORTATION ISSUES

CREW

SMALL PAYLOAD

ROUND TRIP

$/FLT

- INTEGRATED PROGRAM
- CONFIGURATIONS
- ECONOMICS

BULK CARGO

LARGE PAYLOAD

ASCENT ONLY

$/LB

SHUTTLE ECONOMIC ISSUES

- ECONOMIC CRITERIA
  - DEVELOPMENT — $/YEAR; TOTAL $
  - OPERATIONS — $/FLIGHT; $/LB PAYLOAD
- ECONOMIC ANALYSIS - INSUFFICIENT FOR COMMITMENT TO A CONCEPT.
- SHUTTLE MUST BE PART OF TRANSPORTATION SYSTEM TO ENABLE MEANINFGUL COST ANALYSES.

SPACE SHUTTLE/INTEGRATED PROGRAM ISSUES

- TRAFFIC MODEL UNCERTAINTY/DYNAMICS
- CONTINGENCY FOR HIATUS IN MSF DUE TO SHUTTLE IOC SLIPPAGE
- ROLE OF SPACE SHUTTLE
  - PAYLOAD DELIVERY AND RETURN
  - LAUNCH VEHICLE STABLE REPLACEMENT
  - HIGH ENERGY MISSIONS
  - SEPARATE MISSION VEHICLE

TRAFFIC

	SHUTTLE PAYLOAD		NUMBER OF FLIGHTS*	
	WEIGHT	SIZE	SAT-V	SHUTTLE
	25K	15X60	> 40	1500
**	50	15X60	> 40	750
**	50	22X60	> 20	800
	100	33X60	0	600

*INTEGRATED PLAN MISSION MODEL - 1976 THROUGH 1984

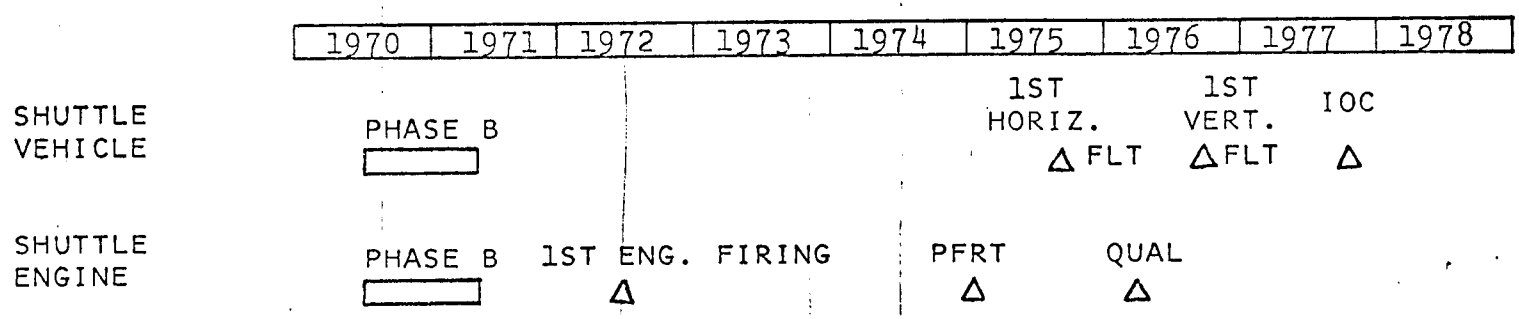
ISSUES

- TRAFFIC INFLUENCED BY MISSION CAPABILITY
- TRAFFIC INFLUENCED BY AVAILABILITY AND ECONOMICS OF LARGE LIFTING SYSTEM
- ** CENTERS INDICATE THAT TOTAL TRANSPORTATION JOB COULD BE ACCOMPLISHED WITH A SHUTTLE PAYLOAD OF FROM 50-100K.

SPACE SHUTTLE ISSUES

- TRAFFIC MODEL

- DEVELOPMENT SCHEDULE



- PAYLOAD SIZE

  - < 50K - NEED LARGE LIFT LAUNCH VEHICLE

  - > 50K - PERHAPS NO OTHER LAUNCH VEHICLE

SHUTTLE TECHNOLOGY

CONFIGURATION ORIENTED SUBSYSTEMS

- THERMAL PROTECTION SYSTEMS
- PROPULSION (ROCKETS AND JET ENGINES)
- STRUCTURE
- LANDING FIELD
- WING DESIGN

OPERATIONS

- PERFORMANCE (PAYLOAD UP-DOWN)
- INTACT ABORT
- LANDING MODE
- LANDING SITE

OPERATIONAL CHARACTERISTICS

- GROSS WEIGHT $\leq$ 3.5 MILLION POUNDS, PAYLOAD SIZE (15' X 60'), PAYLOAD WEIGHT 20,000 POUNDS MINIMUM TO SPACE STATION

- FULLY REUSABLE SYSTEM/0-OF-M REDUCTION IN OPERATING COST

  CURRENT $\sim$ 1000 \$/# P/L ONE WAY
  FUTURE $\sim$ 100 \$/# P/L ROUND TRIP

- PASSENGER/CARGO MIX FLEXIBILITY (3G ASCENT)

- 60 SEC. LAUNCH/24 HR. UP/24 HR. RETURN/2 WK. TURN AROUND

- INTACT ABORT WITH FULL PAYLOAD/DITCHING CAPABILITY

- 100 MISSION LIFE OF BOOSTER AND ORBITER

- FAIL-OPERATIONAL/FAIL-SAFE IN ALL SUBSYSTEMS (0^2S IN ELECTRICAL)

- EXTENSIVE ON-BOARD COMMAND/CONTROL AND CHECKOUT

SYSTEM REQUIREMENTS

- LIFTING CONFIGURATIONS (SUBSONIC AND HYPERSONIC)
- REUSABLE RADIATION COOLED AERO-THERMAL PROTECTION SYSTEM
- ADVANCED HIGH PRESSURE/TWO POSITION NOZZLE LOX-LH_2 ROCKET ENGINE
- ADVANCED STRUCTURAL MATERIALS AND BUILDING TECHNIQUES
- ADVANCED AVIONICS APPLICATIONS
- BOOSTER FLYBACK (300 N.M. OR MORE)
- RUNWAY LANDING FOR ORBITER & BOOSTER
- ADVANCED AIRBREATHING PROPULSION (LOW SFC, HIGH T/W)

INCREMENTAL DEVELOPMENT APPROACHES

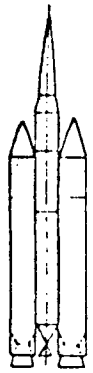
- ADVANTAGES
  - REDUCES EARLY ANNUAL FUNDING
  - REDUCES PEAK ANNUAL FUNDING
  - REDUCES TECHNOLOGICAL RISKS
- CONFIGURATIONS
  - REUSABLE BOOSTER/EXPENDABLE ORBITER/CREW SPACECRAFT (CSM)
    - REUSABLE VEHICLE TECHNOLOGY EVOLVED
    - OPERATING COSTS ESTABLISHED
    - DELAYS DEVELOPMENT OF COMPLEX ORBITER
    - EXPENDABLE STAGE USED FOR LARGE LIFTING CAPABILITY
  - EXPENDABLE BOOSTER/REUSABLE ORBITER
    - REUSABLE VEHICLE TECHNOLOGY EVOLVED
    - OPERATING COSTS ESTABLISHED
    - DELAYS DEVELOPMENT OF REUSABLE BOOSTER - ALLOWS FOR ADJUSTMENT TO ORBITER GROWTH

ALTERNATIVE CONCEPTS

- SEPARATE CREW VEHICLES
- REUSABLE BALLISTIC SYSTEMS
- SINGLE-STAGE-TO-ORBIT
- EXPENDABLE HARDWARE

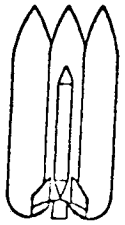
- ISSUES
  - -SOME CONCEPTS NOT PROPERLY EVALUATED
  - -CONCEPTS ARE MISSION DEPENDENT
  - -ECONOMICS

ALTERNATIVE SHUTTLE CONCEPTS



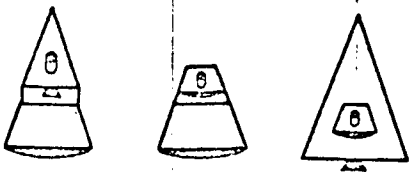
LDC TITAN/REUSABLE S/C

MCD BOOSTER/REUSABLE S/C



REUSABLE CORE/EXPENDABLE TANKS

LCB/REUSABLE UPPER STAGE



REUSABLE FIRST AND SECOND STAGES

SINGLE STAGE TO ORBIT

CONCLUSIONS

- EVOLUTIONARY GAP FILLER IS NOT FEASIBLE WITH CURRENT SHUTTLE CONCEPT
- EVOLUTIONARY DEVELOPMENT OF CURRENT SHUTTLE CONCEPT WILL REDUCE YEARLY EXPENDITURE, DELAY ULTIMATE IOC, AND INCREASE TOTAL COST.
- A 100,000 POUND PAYLOAD CAPACITY TO 28.5° LEO IS DESIRED BUT NOT MANDATORY FOR THE FINAL TRANSPORTATION SYSTEM
- RELATIVE SHUTTLE COSTS ARE FAIRLY CREDIBLE, BUT ABSOLUTE COSTS MUST BE USED WITH CAUTION.
- IF THE SHUTTLE IS TO BE THE ONLY LAUNCH VEHICLE FOR SA&T PAYLOADS, A LIFTING CAPACITY OF 50,000 POUNDS IS DESIRED

LARGE LIFT CAPABILITY

LARGE LIFT CAPABILITY ISSUES

(LOW USE RATE)

- Restart S II or SIVB production
- Exploit Titan production base
- New vehicle development
- Production/Inventory management
- Suitability for interim logistic missions
- Shuttle booster upper stage vs all expendable
- Existing vs new second stage
- Compatibility with interim first stage
- Compatibility with interim lunar program

SUMMARY OF EXPENDABLE VEHICLES

CONFIGURATION	PAYLOADS		COSTS	
	100 X 28	270 X 55	N. R.	REC.
INT-20	140	120	133	56
INT-21	270	180 (DIRECT)	190	85
T III L-2	64	55	175	23.3
T III L-4	91	80	175	27.6
260/SIVB	95	86	385	46
156/SIVB	150	135	380	44.5
120/SIVB	105	95	185	38
260/SII	>150	>150	490	62
260/NEW	>150	>150	715	48
SUMMARY OF EXPENDABLE SECOND STAGES FOR REUSABLE BOOSTER				
SIVB	80-105	70-90	50*	18
S II (DERIV)	≥150	≥125	200*	45
NEW (LO_2/LH_2) (400-700 K)	>150	>125	300*	30

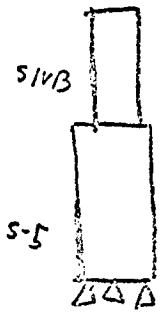
*Preliminary-stage mods only

CONCLUSIONS

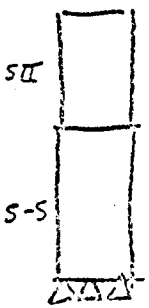
- SATURN CONTRACTOR START UP COSTS NOT DECISIVE FACTOR
- STAGE STORABILITY NOT A PROBLEM
- INT 21 OR 20 COST COMPETITIVE WITH OTHER EXPENDABLE OPTIONS FOR LOW USE
- TITAN GROWTH DERIVATIVE COST EFFECTIVE
  - DEPENDS ON CONTINUING TITAN III PRODUCTION
  - PAYLOAD < 100,000 LBS
- 156" & 260" SRM'S NOT COST EFFECTIVE WITH LOW USE RATE
- SEVEN SEGMENT 120" SRM'S/SIVB COST EFFECTIVE SATURN DERIVATIVE
  - COMPETITIVE WITH INT21/20 OR TITAN
- SHUTTLE BOOSTER/EXPENDABLE SECOND STAGE PAYLOAD CAPABILITY COMPARABLE TO INT 20/21
  - COST COMPARISON UNCERTAIN
  - SII OR SIVB VS NEW STAGE?
- POSSIBLE INTERIM LOGISTICS AND/OR INTERIM LUNAR PROGRAM REQUIREMENTS COULD BE DECISIVE

LAUNCH VEHICLES FOR LARGE LIFT CAPABILITY

SATURN

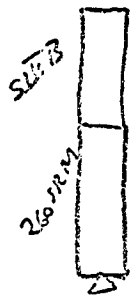


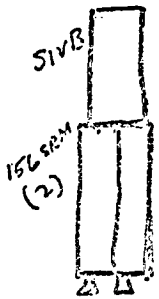
INT-20

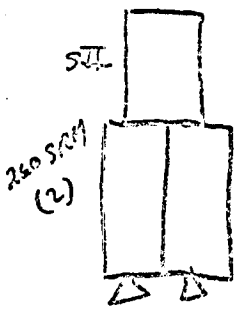


INT-21

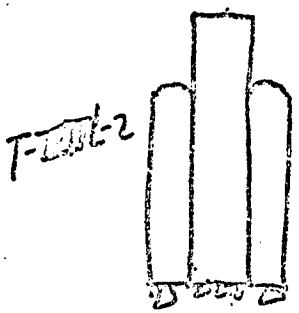
OTHER

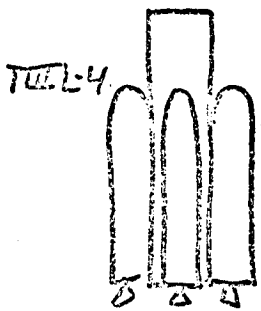




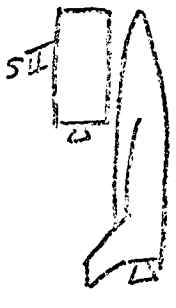


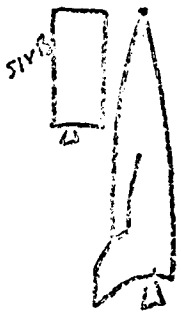
TITAN

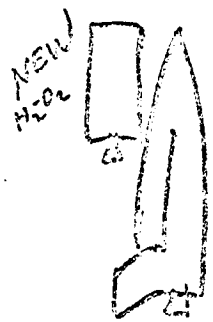




ORBITAL INSERTION







SATURN V DERIVATIVES

CONFIGURATION	INT-20	INT-21
PAYLOADS:		
100 x 28 1/2	140	270
270 x 55	120	180 (DIRECT)
COSTS:		
NON REC. (TOTAL)	133[1]	190
DDRE	(130)	75
START UP		115
LAUNCH	3	0
RECURRING (TOTAL)	66	85
PRODUCTION	56	75
TRANSPORTATION	5	5
LAUNCH	5	5

NOTES:

1. INT-20 BEST GUESS (TELECON WITH R. DAVIS/MSFC)
2. NO SAT V PRODUCTION, MODEL 2A
3. NO STORAGE PROBLEMS (ENGINES STORED IN CONTAINERS)
4. RESTART ON SIVB REQUIRED
5. IOC FY77, INCLUDES STATIC STAGE FIRINGS

LARGE DIAMETER CORE TITAN

CONFIGURATION	TIII L-2	TIII L-4
PAYLOADS		
100 x 28 1/2	64	91
270 x 55	55	80
COSTS		
NON REC. (TOTAL)	175.3 (BOTH OR L-4)	
DDR&E	145.3	
FAC		
FLIGHT TEST	30	
RECURRING (TOTAL)		
(MAN-RATED)	23.3	27.7

NOTES:

1. NO STORAGE PROBLEMS.
2. LAUNCH AT LC37B
3. FACILITY MAINTENANCE COSTS AT 37B OR $2-to5 $\bar{M}$/YR.
4. COSTS DEPENDENT ON 12/YR PROD. OF TITAN POST 1977
5. NO LEARNING CURVE ON (4). IF (4) NOT TRUE CAN ACCELERATE BUY AND STORE TO MAINTAIN PRICE.
6. IOC CY77 (EARLIEST AVAILABLE CY74)

OTHER EXPENDABLE LAUNCH VEHICLES

(ALL SRM BOOSTED)

	SIVB			SII	NEW[4]
CONFIGURATION					
UPPER STAGE	260	3-156(4)/	4-120(7)/	2-260	260
BOOSTER		1-156(4)/	1-120(7)/		
PAYLOADS					
100 x 28-1/2	95	150	105	>150	>150
270 x 55	86	135	95	>150	>150
COSTS					
NON. REC. (TOTAL)[1]	385	380	185	490	715
DDRE	340	340	100	400	640
FAC.	35	30	35	50	35
FLIGHT TEST	10	10	50	40	40
RECURRING (TOTAL)[2]	46	44.5	38	62	48
PROD	38	36	30	50	40
TRANS.	2	2	2	3	2
LAUNCH	6	6.5	6	9	6

NOTES:

1. DDR&E includes 156 & 260 SRM hardware for two flight tests (¢ SIVB hardware where used)
2. 156 costs assumed same as 260"
3. 260 & 156 SRM costs very rate sensitive
4. Based on Lewis Research in-house studies - costs B/C ROM. (400-500 K Stage)

ORBIT INJECTION STAGES
(USE SHUTTLE BOOSTER)

TYPE	SIVB	SII DERIV.	NEW
GROSS WEIGHT (K)	240	1000	400-700
COSTS			
N.R[3]	50	250[1]	300[2]
RECURRING	18	45	30

NOTES:

1. INCLUDES ASTRIONICS (TELECON R. DAVIS, MSFC)
2. B/C ROM
3. EXCLUDES ENGINES
4. DOES NOT INCLUDE START UP COSTS AT MCDAC OR NAR S/D

SPACE TUG

SPACE TUG ISSUES

- SYSTEM COMMONALITY-EARTH ORBIT, LUNAR AND PLANETARY MISSIONS REQUIREMENTS
- FUNCTIONAL SIMILARITIES BETWEEN NASA AND AIR FORCE VEHICLES
  - FEASIBILITY OF SINGLE TUG TO SYNCHRONOUS ORBIT QUESTIONABLE
  - GROUND BASED AND/OR SPACE BASED
- SPACE TUG SIZE AND DESIGN APPROACH
  - MISSION FREQUENCY DISTRIBUTION
  - OPERATIONAL MODES (GROUND BASED, SPACE BASED, & INTERFACES WITH ORBITAL SYSTEMS)
  - PAYLOAD WEIGHT AND VOLUME OF EOS
- SPACE TUG SCHEDULE PHASING WITH RESPECT TO EOS
- SPACE TUG MODULES AND KITS COSTS
- TECHNOLOGY
  - INTERFACES WITH INTEGRATED PROGRAM HARDWARE
  - LONG LIFE, REUSABILITY, AND FLEXIBLE OPERATIONS
  - MAIN H_2/O_2 PROPULSION SYSTEM

POTENTIAL SPACE TUG OPERATIONAL REQUIREMENTS

MISSION AREA	OPERATIONS

EARTH ORBIT	• SPACE BASE AND SPACE STATION SUPPORT ACTIVITIES
	  • TRANSFER PAYLOADS FROM EOS AND NUCLEAR SHUTTLE
	  • ORBIT KEEPING
	  • INSPECTION
	  • SPACE BASE ASSEMBLY
	• SATELLITE PLACEMENT AND RETRIEVAL (INTERMEDIATE AND HIGH ENERGY ORBITS)*
	• IN SITU SATELLITE SERVICING AND INSPECTION*
	• ON ORBIT RESCUE
	• SATELLITE AND UNMANNED INTERPLANETARY SPACECRAFT LAUNCH
	• CREW SHUTTLE TO SYNCHRONOUS ORBIT

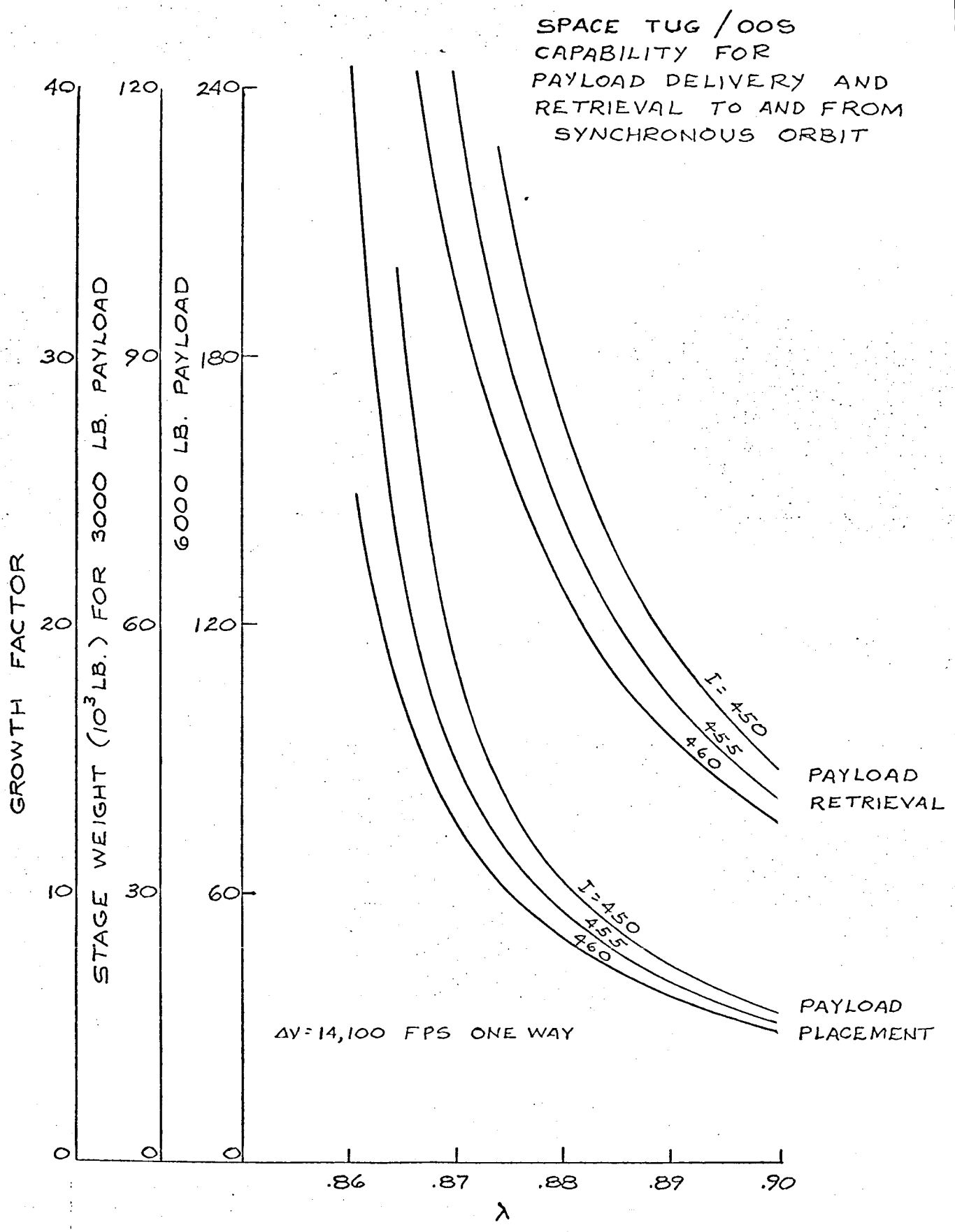
LUNAR	• LUNAR SURFACE TO ORBIT CREW TRANSFER • DELIVERY OF LUNAR SURFACE BASE AND OTHER SURFACE PAYLOADS • SATURN V 4TH STAGE • RESCUE • TUG CAPSULE AS SHORT TERM BASE ON SURFACE • SURFACE MOBILITY SYSTEM
PLANETARY	• MIDCOURSE CORRECTION MANEUVERS • RESCUE (DUAL SPACECRAFT MODE, EARTH RETURN) • PLANETARY ESCAPE AND EARTH CAPTURE MANEUVERS (LOW ENERGY MISSIONS) • MARS PROPULSIVE LANDER

*COMMON WITH DOD REQUIREMENTS

SPACE TUG/OOS

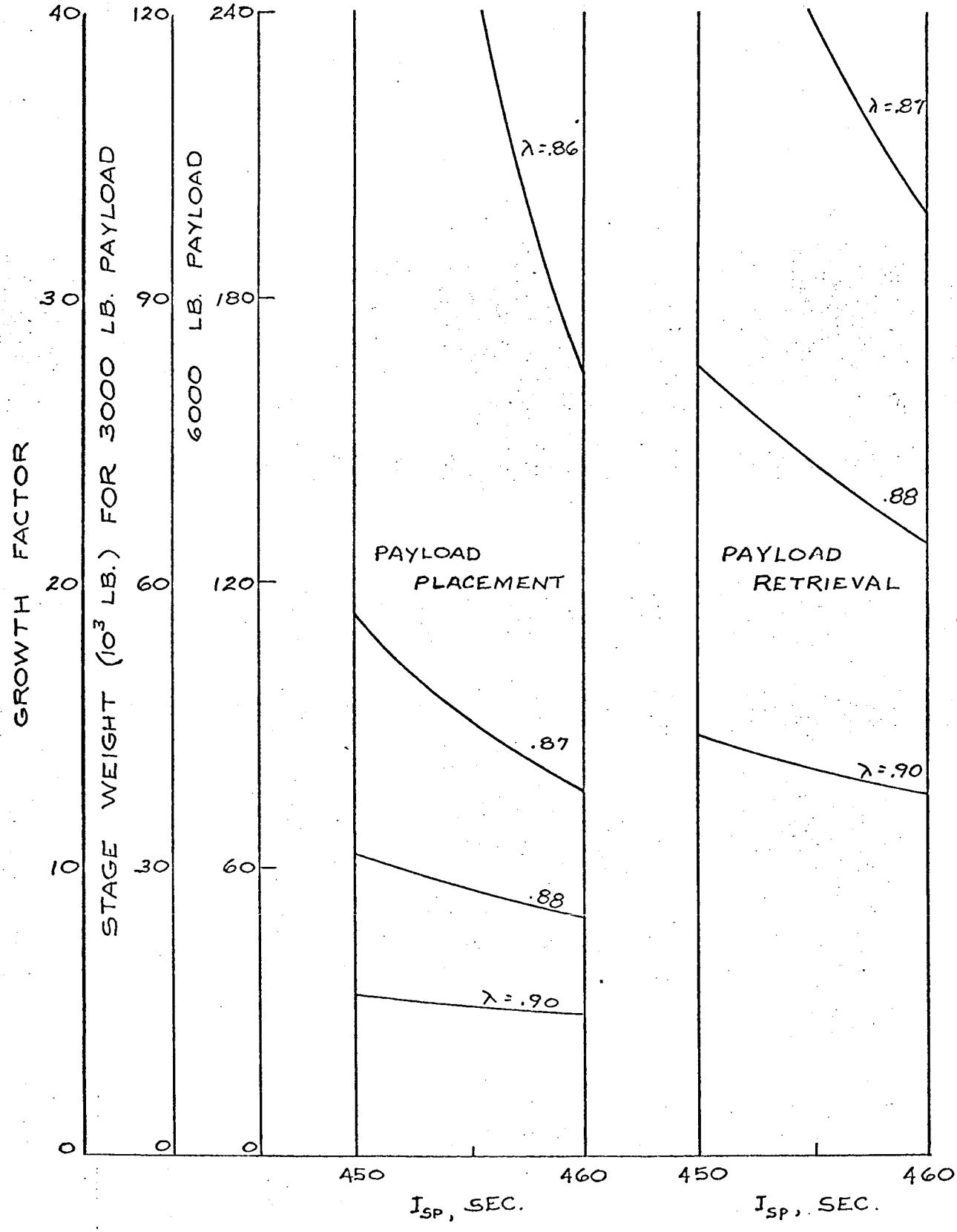
FUNCTIONAL SIMILARITIES AND DIFFERENCES

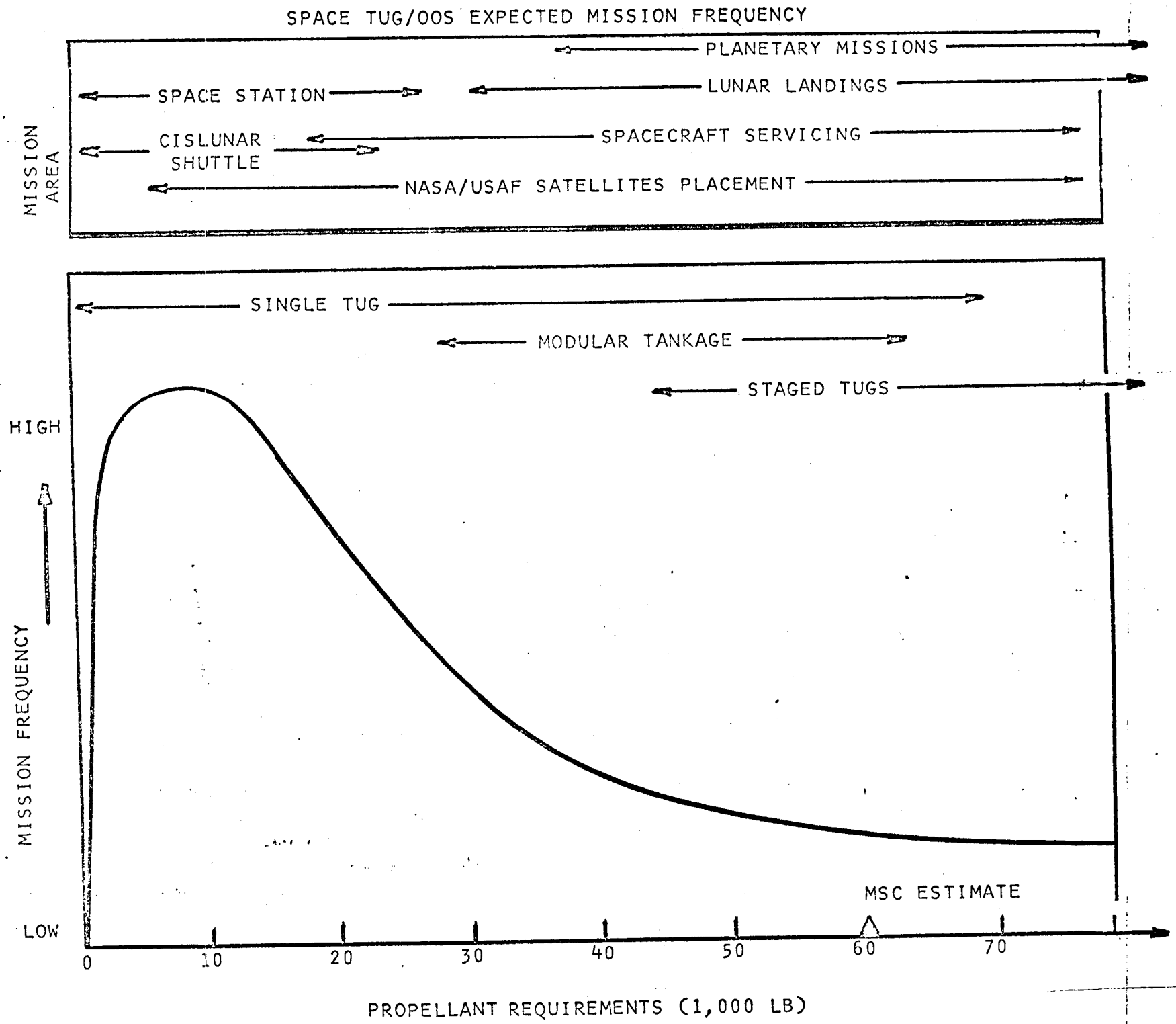
NASA SPACE TUG CONCEPT	USAF OOS CONCEPT
EOS TRANSPORTABLE TO ORBIT AND RETURN	SAME
H_2/O_2 PROPULSION	SAME
REUSABLE, MANNED AND UNMANNED	REUSABLE UNMANNED
SPACE BASED	GROUND BASED (ELIMINATES PHASING PROBLEM, ACCESSIBLE TO ALL INCLINATIONS)
HIGHLY VERSATILE MULTI-APPLICATION WITH DIVERSE RANGE OF ΔV'S AND PAYLOADS	LIMITED SPECIFIC APPLICATIONS WITH LIMITED RANGE OF ΔV'S AND PAYLOADS
EARTH ORBITAL, LUNAR AND PLANETARY MISSIONS	EARTH ORBITAL MISSIONS ONLY
PROPULSION MODULE/ASTRIONICS/CARGO, PLUS CREW COMPARTMENT AND VARIETY OF MISSION KITS	PROPULSION MODULE/ASTRIONICS/CARGO, PLUS FEW MISSION KITS
INTERFACES WITH EOS, SPACE STATION/BASE, NUCLEAR SHUTTLE, LOW AND HIGH ENERGY MISSION PAYLOADS	INTERFACES WITH EOS, VARIOUS PAYLOAD MODULES


SPACE TUG / OOS
CAPABILITY FOR
PAYLOAD DELIVERY AND
RETRIEVAL TO AND FROM
SYNCHRONOUS ORBIT
GROWTH FACTOR
STAGE WEIGHT (10^3 LB.) FOR 3000 LB. PAYLOAD
6000 LB. PAYLOAD
40
30
20
10
0
120
90
60
30
0
240
180
120
60
0
I = 450
455
460
PAYLOAD
RETRIEVAL
I = 450
455
460
PAYLOAD
PLACEMENT
ΔV = 14,100 FPS ONE WAY
.86
.87
.88
.89
.90
λ

SPACE TUG/OOS CAPABILITY FOR PAYLOAD DELIVERY AND RETRIEVAL TO AND FROM SYNCHRONOUS ORBIT

$\Delta V = 14{,}100$ FPS ONE WAY




SPACE TUG/OOS EXPECTED MISSION FREQUENCY
MISSION AREA
PLANETARY MISSIONS
SPACE STATION
LUNAR LANDINGS
CISLUNAR SHUTTLE
SPACECRAFT SERVICING
NASA/USAF SATELLITES PLACEMENT
SINGLE TUG
MODULAR TANKAGE
STAGED TUGS
HIGH
MISSION FREQUENCY
LOW
MSC ESTIMATE
0
10
20
30
40
50
60
70
PROPELLANT REQUIREMENTS (1,000 LB)

SPACE TUG SIZE AND DESIGN APPROACH

- NASA MAY NEED 2 OR MORE SIZES, BASED ON MISSION ANALYSIS
- PROPULSION MODULE COULD BE INTEGRAL, CORE PLUS MODULAR TANKS OR FULLY MODULAR
- HIGH ΔV REQUIREMENTS COULD BE ACHIEVED BY LARGE TANKS, STAGING TANKS, STAGING VEHICLES OR EXPENDING VEHICLES
- COMPATIBILITY WITH SV OR TITAN LAUNCH VEHICLES TO DELIVER TO LEO

OPERATIONS AND OPERATIONAL MODES

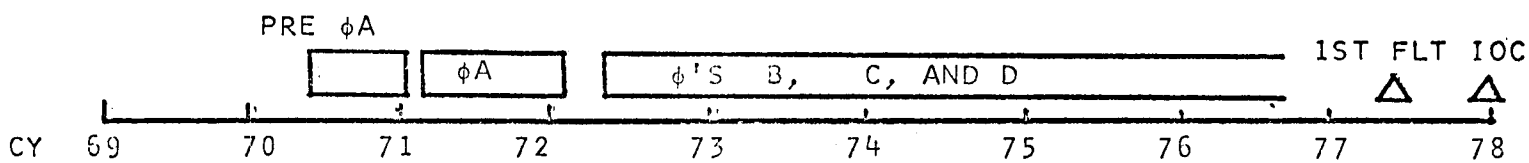
- SPACE BASED VS GROUND BASED
- REFUELING BY EOS OR ORBITAL PROPELLANT STATION
- MAINTENANCE AT MAINTENANCE DEPOT OR BY ANOTHER TUG
- RETURN TO GROUND VIA EOS FOR MAJOR REFURBISHMENT OR USE AS EXPENDABLE VEHICLE
- OPERATIONS IN ASSOCIATION WITH NUCLEAR SHUTTLE
- IMPACT OF NODAL REGRESSION

SPACE TUG

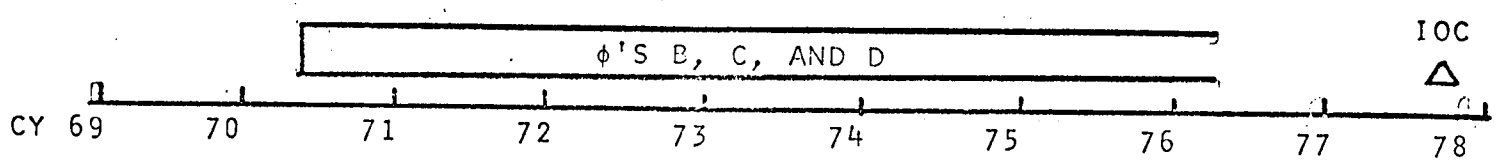
SCHEDULING AND FUNDING ISSUE

- SPACE TUG/OOS SHOULD BE DEVELOPED TO EOS TIME SCALE FOR NASA AND AF EARTH ORBITAL MISSIONS
- NASA KITS AND SYSTEM REQUIREMENTS FOR LUNAR AND PLANETARY MISSIONS INTRODUCED AT APPROPRIATE DATES TO REDUCE PEAK FUNDING REQUIREMENTS
- IOC FOR EOS AND SPACE TUG/OOS - LATE 1977

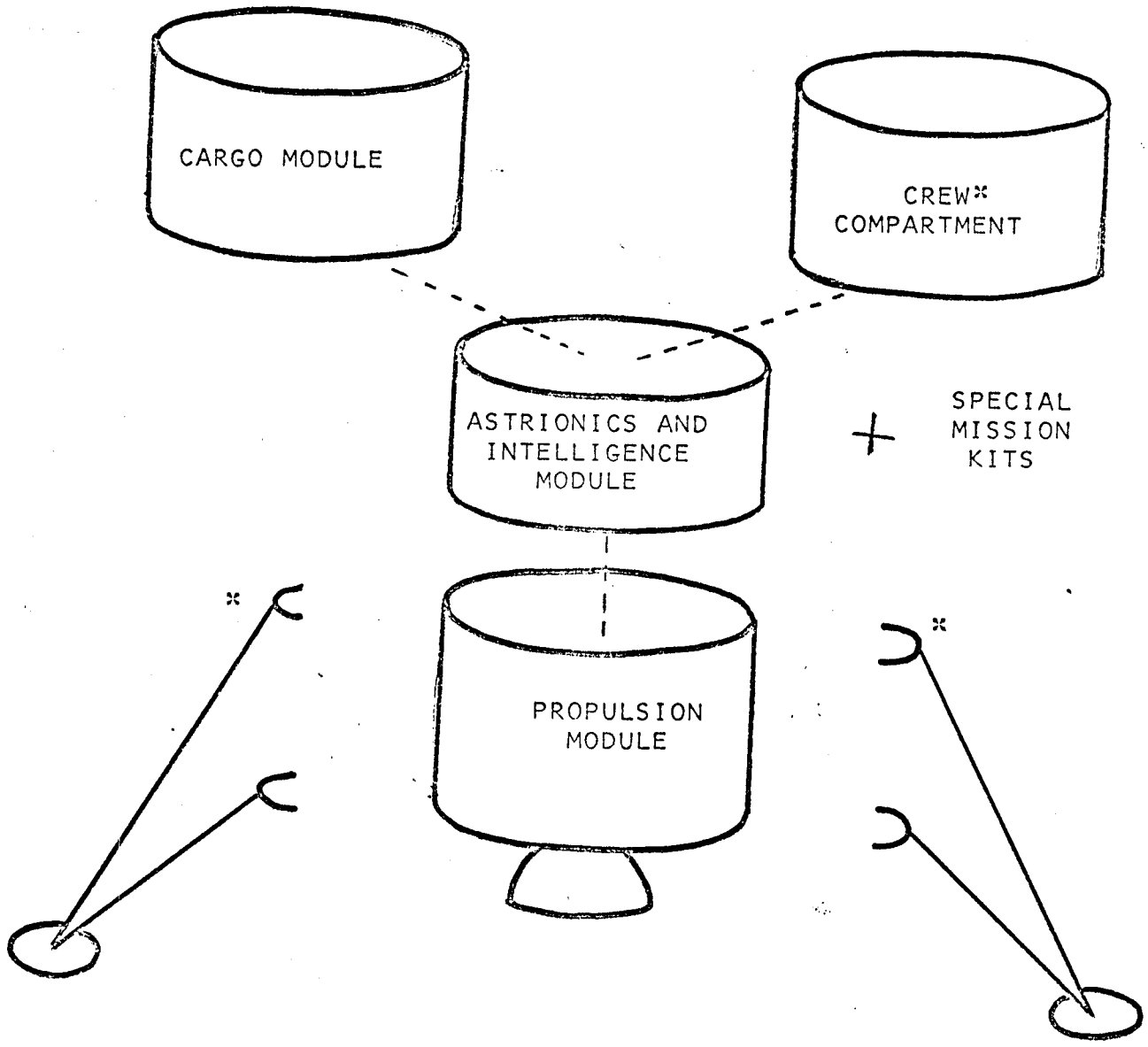
SPACE TUG/OOS SCHEDULE



EOS SCHEDULE



SPACE TUG/OOS COMPONENT MODULES



*FOR NASA APPLICATIONS ONLY

SPACE TUG COSTS

	NON RECURRING ($M)		RECURRING ($M)
BASIC PROPULSION UNIT	450-1000		
PROPULSION MODULE		400-800	15-25
INTELLIGENCE MODULE*		50-200	8-10
MAJOR MODULES	400-1400		
CREW MODULE		300-1000	15-30
CARGO MODULE*		100- 400	7-15
KIT OPTIONS	65-130		
LANDING GEAR		50-100	.5-1
MANIPULATOR		15- 30	3-7
TOTAL NON RECURRING COST	915-2530		
TOTAL RECURRING COST			
• BASIC UNIT			23-35
• WITH CARGO MODULE + MANIPULATOR			33-57
• WITH CARGO MODULE + CREW MODULE			45-80

*COMMON WITH CISLUNAR SHUTTLE

TECHNOLOGY

- LONG LIFE, REUSABILITY, FLEXIBLE OPERATIONS
- INTERFACES WITH INTEGRATED PROGRAM HARDWARE
- MAIN H_2/O_2 PROPULSION - MODIFICATION OF EXISTING ENGINE SUCH AS RL-10 OR NEW ENGINE
- GROUND BASED VERSUS SPACE BASED SUBSYSTEMS REQUIREMENTS (I.E., REVACUATED INSULATION)

CISLUNAR SHUTTLE

LUNAR TRANSPORTATION REQUIREMENTS

Lunar surface base or extended exploration requires

- Transportation system to lunar orbit with about 100 KLB capability
- 3 - 10 flights to establish surface base
- 3 - 5 flights per year to conduct operations

This traffic justifies development of lunar shuttle

COMPARISON OF LUNAR SHUTTLE OPTIONS

Either nuclear (NERVA) or chemical (H-O) propulsion could be used

- Technology is available
- Compatible with all proposed launch systems

Choice between nuclear and chemical

- Nuclear offers single-stage mode,
  fewer space shuttle tanker flights,
  growth potential for Manned Mars Missions
- Chemical performance is competitive only with complex mission mode

Nerva is most advanced engine available in appropriate time period

OPERATIONAL CONSIDERATIONS

Chemical

- Single stage - large, uneconomical
- Two stage - performance may be competitive, operations more complex
- Aerobraker - possibly attractive performance but not yet evaluated
- Cluster of space tugs - lower development cost but reduced performance

Nuclear

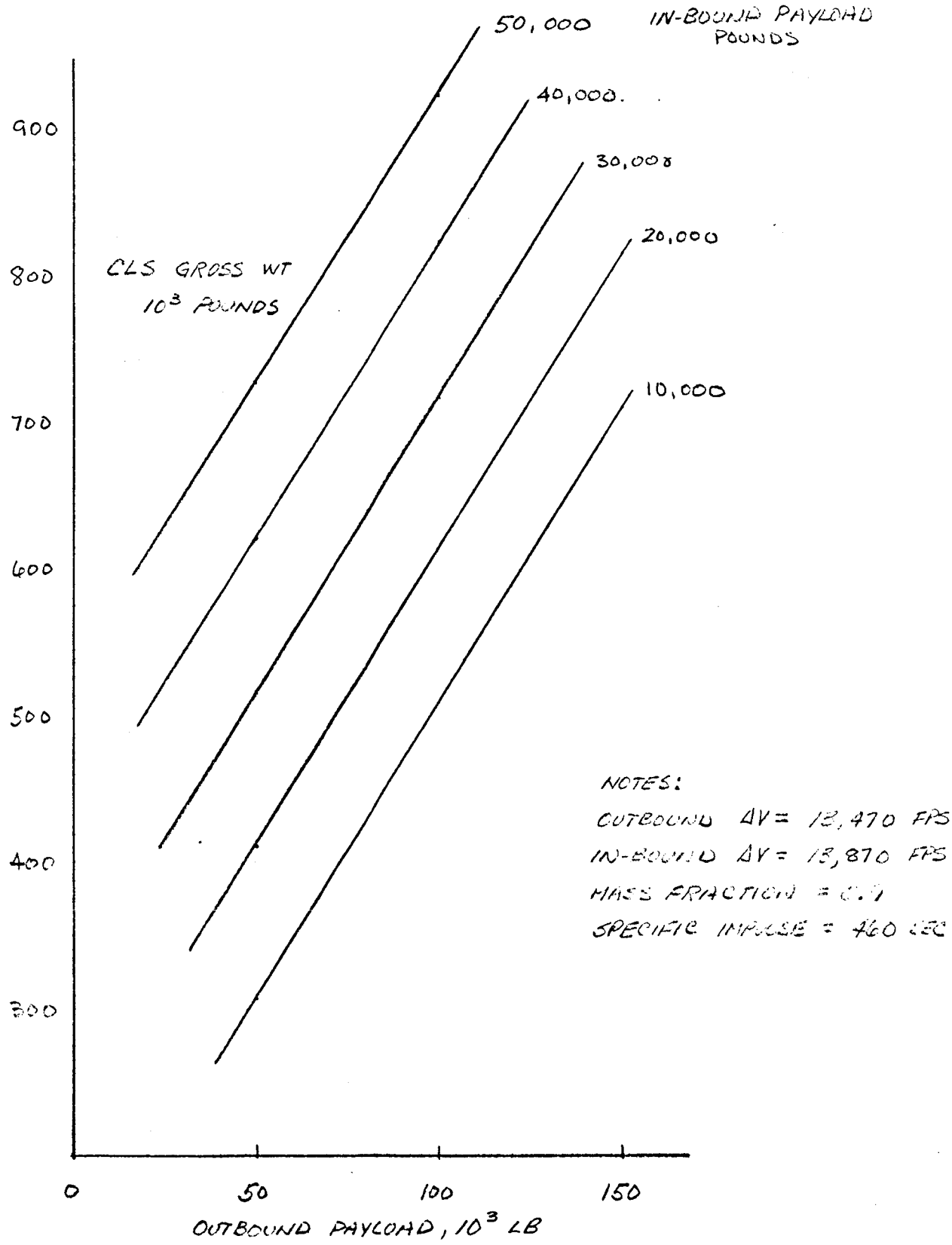
- Radiation protection: Must be provided by vehicle configuration, separation distance, shields
- Aftercooling: Must be accommodated by guidance system; some delay in rendezvous; small performance penalty
- Single stage

SUMMARY

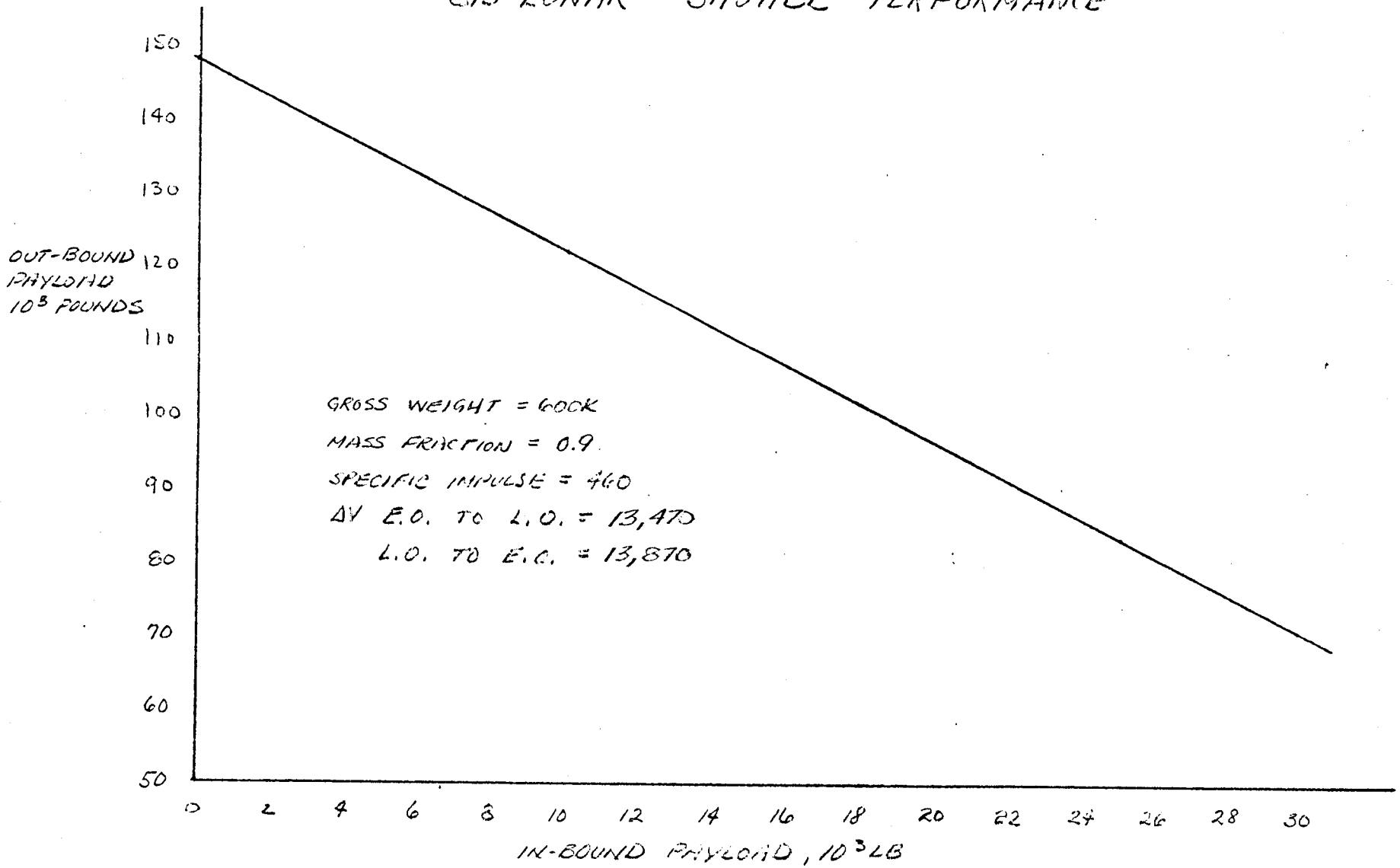
- Lunar exploration justifies reusable transportation system
- Reusable nuclear stage offers combination of

  High performance, economy, simple mission mode, and applicability to Manned Planetary Missions. Radiation can be accommodated with moderate penalty.
- Chemical propulsion may be competive with more complex mission mode, although probably not useful for more ambitious missions.
- Significant recurring cost savings with nuclear (for same mission modes)

CIS-LUNAR SHUTTLE SIZING

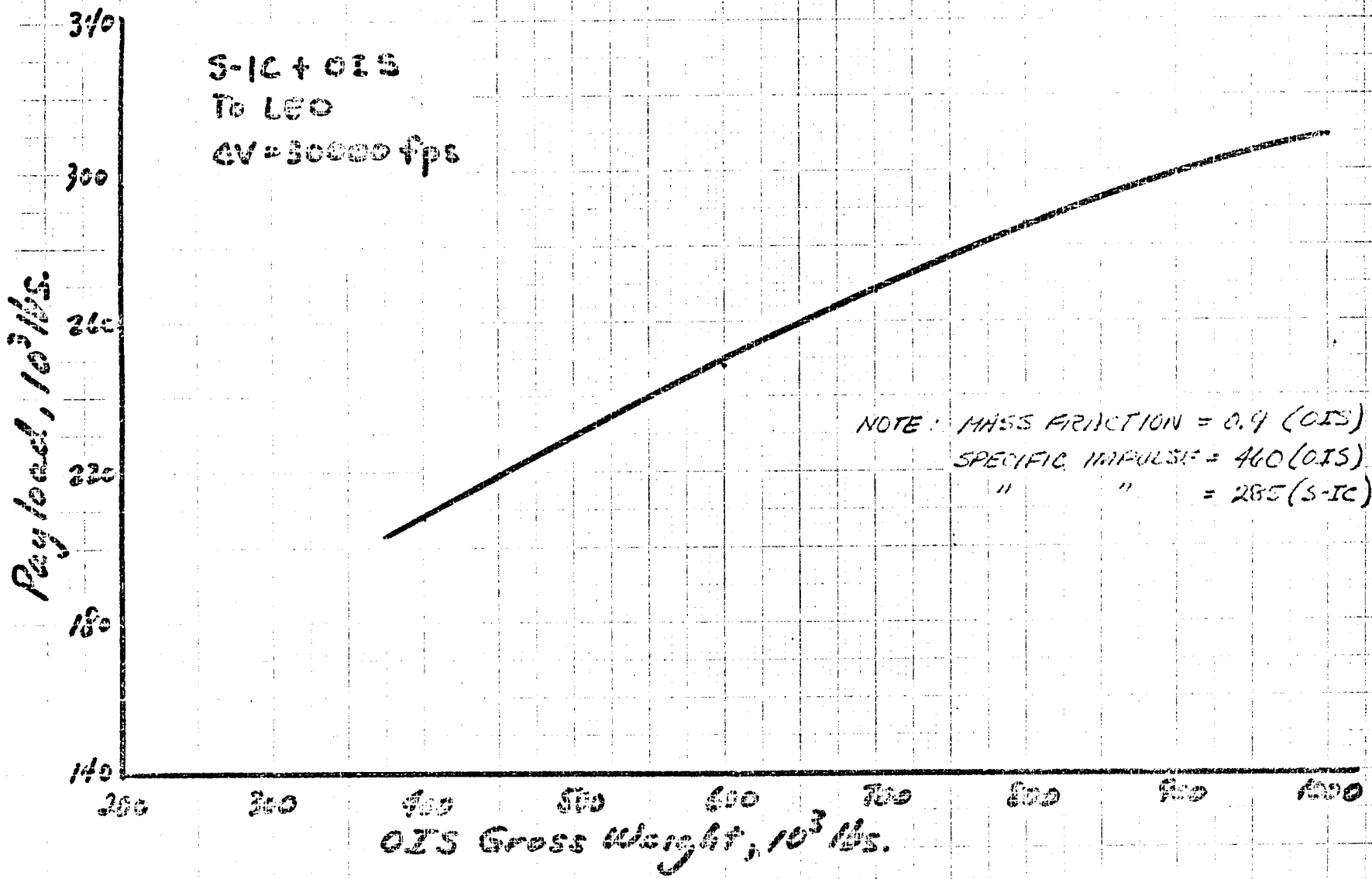


CIS-LUNAR SHUTTLE PERFORMANCE

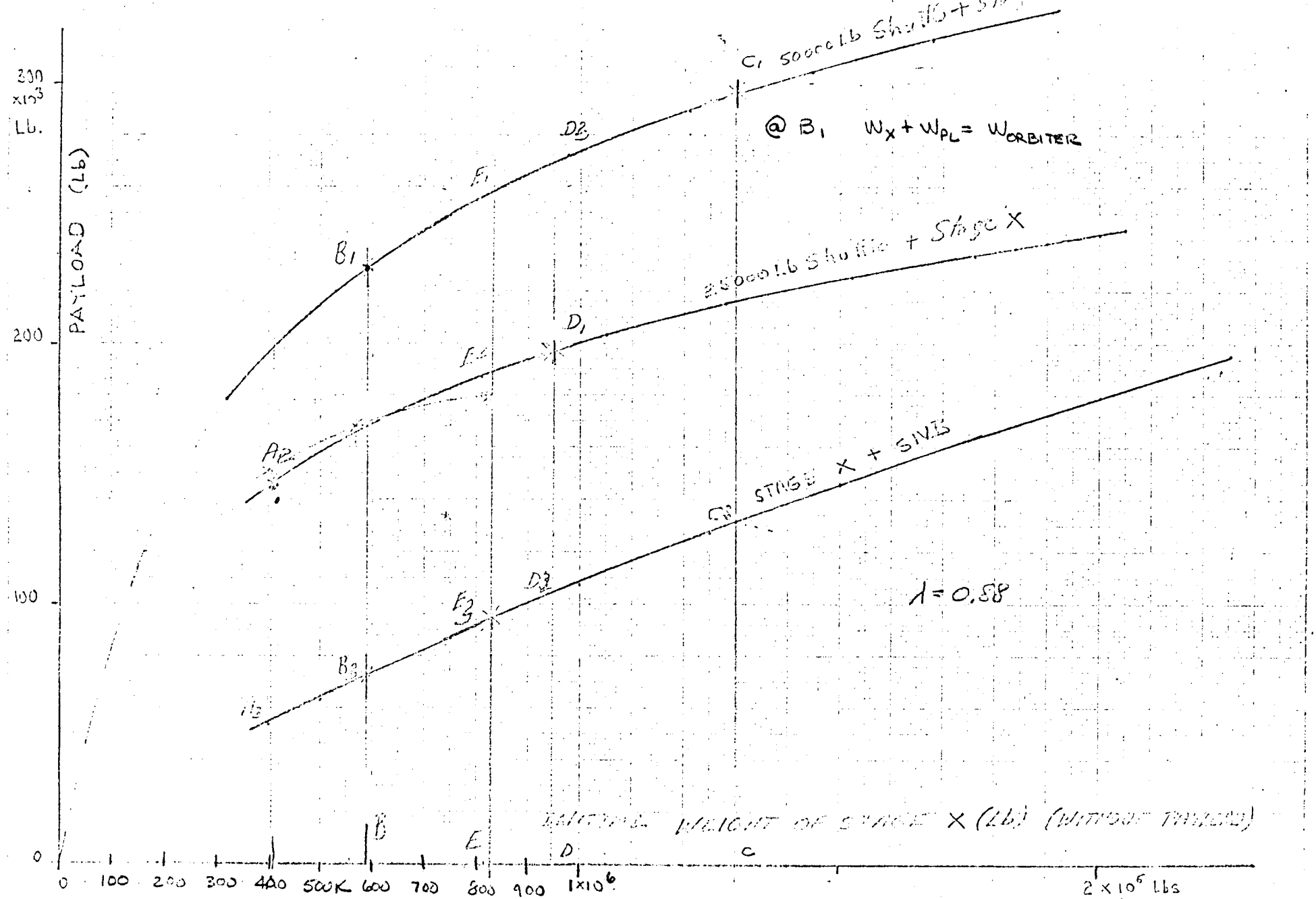


10 X 10 TO ½ INCH 46 1323
7 X 10 INCHES MADE IN U.S.A.
KEUFFEL & ESSER CO.

OIS/S-IC PERFORANCE



OIS PERFORMANCE OIV SHUTTLE



Use of Space Tugs For Lunar Sorties

LM/B

50,000 lb. gross weight

$\lambda = .8$ (lander)

$.83$ (other stages)

$I_s = 460$ sec

7 stages required for 1 landing + return of 20,000 lb ballistic spacecraft.

7 stages required for 1 landing + return to LEO of 5,000 lb crew capsule.

Stretched OOS

75,000 lb. gross weight

$\lambda = .8$ (lander)

$.85$ (other stages)

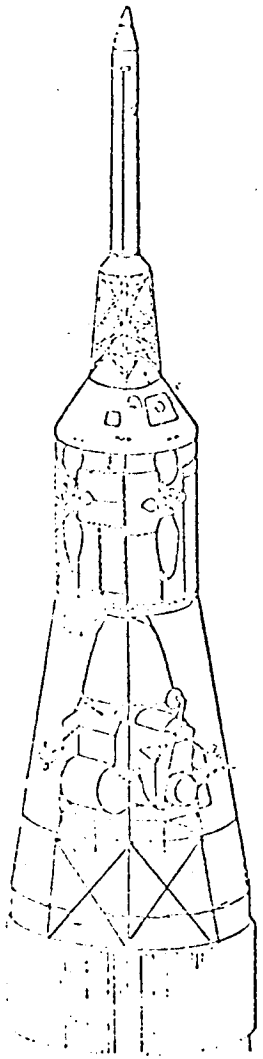
$I_s = 444$ sec

4 stages required for 1 landing + return of 20,000 lb. ballistic spacecraft.

4 stages required for 1 landing + return to LEO of 5000 lb crew capsule.

NEAR TERM GAP FILLERS

APOLLO EARTH ORBITAL CAPABILITY



SPACECRAFT

LM/LAB

STRIPPED ASCENT STAGE

- WEIGHT 1250 LBS (+ 400 LB MOUNTING)
- PRESSURIZED VOLUME 240 CU. FT.

21 DAY CSM

BLOCK II CSM PLUS:

- 1000 LB "PLUG-IN" MODULE IN SM
- 2000 LB RCS FOR MAPPING MISSION

45 DAY CSM

BLOCK II CSM PLUS:

- 1000 LB IN CM
- 3000 LB IN SM

MISSIONS

SAT IB LAUNCH:

- 100 NM, 50° INCLINATION ORBIT
- 21 DAY CSM WITH LM/LAB

SAT V LAUNCH

- LOW POLAR ORBIT
  - 21 DAY CSM WITH LM/LAB
  - 45 DAY CSM WITH LM/LAB
- GEO SYNCHRONOUS ORBIT
  - 45 DAY CSM WITH LM/LAB

EARTH ORBITAL MISSION WEIGHT SUMMARY

LM/LAB (240 CU.FT. PRESSURIZED VOLUME)

BASIC ASCENT STAGE STRUCTURE	1101 LBS
REMOVE SUPPORTS, COVERS, ETC	-307
ADD CREW RESTRAINTS, MINIMUM LIGHTING, METEOROID SHIELDING, AIRLOCK, DISPLAYS, AND COMMUNICATIONS	+455
TOTAL	1250
STRUCTURE FOR MOUNTING LM ADAPTER	400

21 DAY CSM

CM	3,000
SM	11,800
SM "PLUG-IN" MODULE	1,000
SPS REENTRY PROPELLANT	1,000
RCS (FOR MAPPING MISSION)	2,000
TOTAL	28,800

45 DAY CSM

EXTENDED CM	14,000
EXTENDED SM	14,800
TOTAL	28,800

USING SAT IB L/V TO 100 NM EARTH ORBIT —

21 DAY CSM	28,800
LM/LAB	1,250
LM/LAB MOUNTING	400
LM ADAPTER	4,000
TOTAL	34,450

SAT IB CAPABILITY 35,500

USING SAT V L/V FOR —

	GEOSYNCHRONOUS ORBIT	POLAR ORBIT
45 DAY CSM	28,800	28,800
LM/LAB	1,250	1,250
LM/LAB MOUNTING	400	400
LM ADAPTER	4,000	4,000
SPS RETRO PROPELLANT	16,000	1,000
TOTAL	50,450	35,510
SAT V CAPABILITY —	55,000	40,000

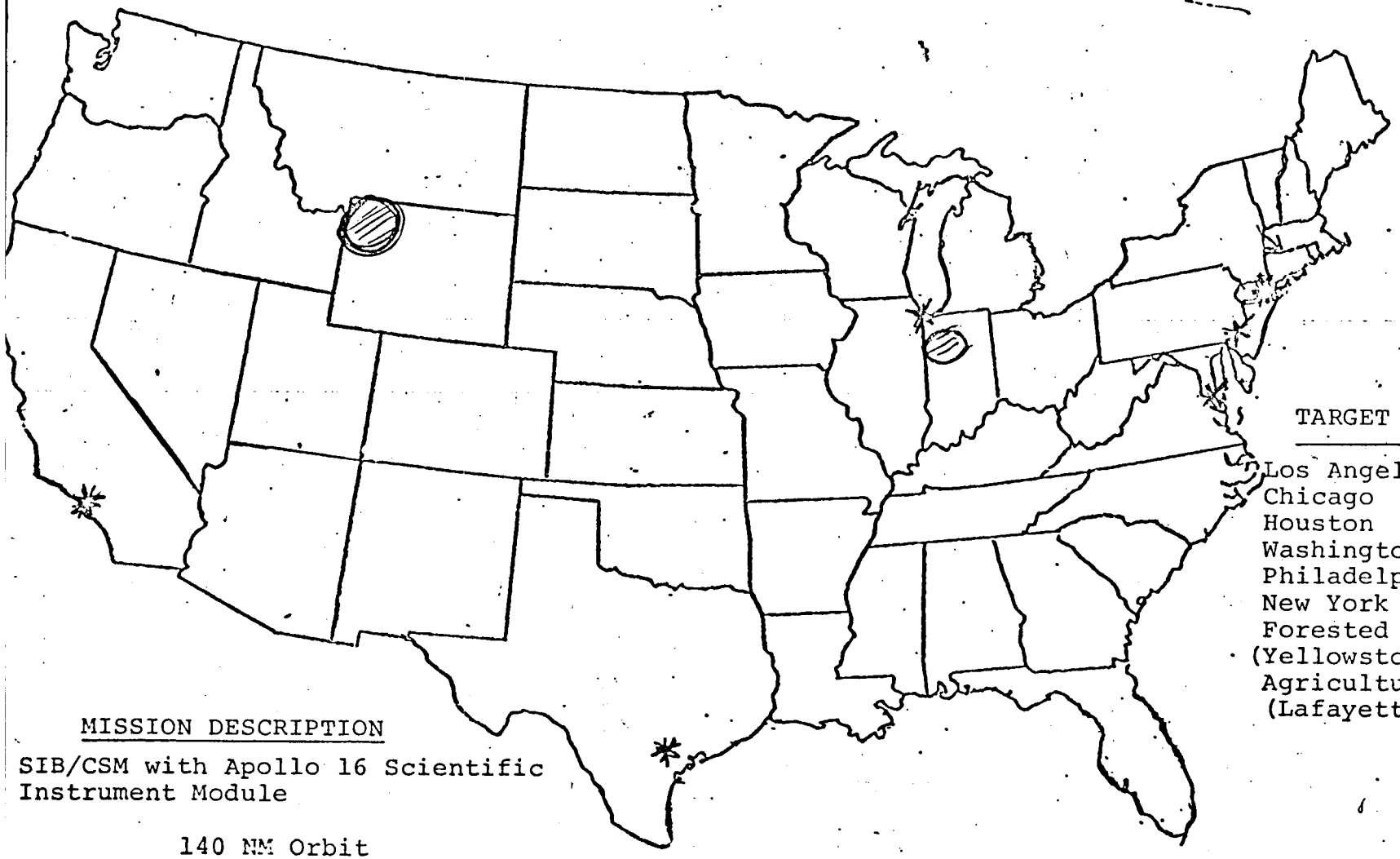
[illegible]

- IMPROVED ASSESSMENT OF MAN'S ABILITY TO PERFORM SCIENTIFICALLY USEFUL TASKS IN SPACE
- DEVELOPMENT OF SPACECRAFT SYSTEMS TO IMPROVE MAN'S ABILITY TO FUNCTION EFFECTIVELY IN SPACE
- SCIENTIFIC OBSERVATION OF THE EARTH AND EXTRA-TERRESTRIAL PHENOMENA (CONCENTRATING ON EARTH RESOURCES SURVEY AND ASTRONOMY)
- PERFORMANCE OF PHYSICAL, CHEMICAL, AND BIOLOGICAL EXPERIMENTS UNDER ZERO GRAVITY CONDITIONS

[illegible]

EARTH OBSERVATION COVERAGE

- 14 DAY MISSION -



TARGET	PHOTOGRAPHIC OPPORTUNITIES
Los Angeles	6
Chicago	6
Houston	5
Washington D.C.	6
Philadelphia	7
New York	10
Forested Area (Yellowstone Park)	11
Agricultural Area (Lafayette, Ind.)	6

MISSION DESCRIPTION

SIB/CSM with Apollo 16 Scientific Instrument Module

140 NM Orbit
50° Inclination
Instrumentation:

3" Mapping Camera
24" Panoramic Camera
X-Ray Spectrometer
γ-Ray Spectrometer

SPACE STATION

SPACE STATION MISSION MODES

Mission of the "70's":

- ✓. Low altitude earth orbit

Advanced Missions

- ✓. Space Base
- . Geosynchronous earth orbit
- . Lunar Orbit
- . Lunar Surface Station
- ✓. Planetary Mission Module
- . Planetary Surface Station

ALTERNATE SPACE STATION CONFIGURATIONS
TRANSPORTATION INTERFACE

Space Station Characteristics	MISSION OF THE "70's"								ADVANCED MISSIONS			
	Shuttle			Launch Vehicles					Nuclear Shuttle			LM/B
	P/L Bay	OIS [1]	OIS S-IVB	Int-21	Int-20	SRM/SII [2]	SRM/S-IVB [3]	TIIIG	Geosynch. & Lunar	Planet Mission Module	Planet Surf.	Lunar Landing
Diameter (ft)	≤ 15 or ≤ 22	≤33	≤ 22	= 33 *	≤ 22	≤ 33	≤ 22	≤ 15'	≤ 33	≤ 33	≤ 33	TBD
Weight (lbs) [4]	≤ 33K (50K)	≤107K (160K)	≤ 53K (80K)	≤ 120K (180K) [4]	≤80 K (120K)	≤73K (110K)	≤90 K (135K)	≤ 60K (90K)	≤ 67 K (100K)	≤ 133K (200K)	≤80 K (120K)	≤ 33 K (50K)
Crew Size	≤ 6	≤ 12	≤ 6	= 12	≤ 8	≤ 12	≤ 10	≤ 6	≤ 12	≤ 6	≤ 6	≤ 6

1. New orbital insertion stage
2. SRM = 4 - 156" (3)
3. SRM = 3-156" (4)/1 - 156" (4) sequentially burned
4. 50 percent weight growth allowance

* Phase B Space Station

SPACE STATION/SPACE SHUTTLE COMPATIBILITY

INTERNAL (P/L BAY):

SMALL AUTONOMOUS STATION

- STATION CHARACTERISTICS - DIA. $\leq$ 15' (22'), WT. $\leq$ 50 K, CREW SIZE $\leq$ 6.
- EQUIVALENT PHASE B STATION - 2 OR 3 DOCKED STATIONS.
- SEVERAL STATIONS - ORBITAL PARAMETERS OPTIMIZED FOR ON-BOARD SA&T.
- POSSIBLE DOD MISSION IMPLICATIONS - STATION IMMEDIATELY MANNED.
- SMALL STATION USE FOR ADVANCED MISSIONS PREFERRED OVER PHASE B STATION

LARGE MODULAR STATION

- STATION CHARACTERISTICS - DIA. $\leq$ 15' (22'), MODULE WT. 50K, CREW SIZE $\leq$?
- EQUIVALENT PHASE B STATION - 2 OR 3 DOCKED MODULES
- MODULAR STATION USE FOR ADVANCED MISSIONS PREFERRED OVER PHASE B STATION

EXTERNAL (OIS):

AUTONOMOUS STATIONS

- STATION CHARACTERISTICS - DIA. $\leq$ 33' (22') WT. $\leq$ 160 K (80 K), CREW SIZE $\leq$ 12(6)
- PHASE B OR OTHER LARGE STATION ACCOMMODATED ON S-II OIS
- SMALL STATION ACCOMMODATED ON S-IVB OIS
- EQUIVALENT PHASE B STATION - 2 OR 3 DOCKED SMALL STATIONS
- SMALL STATION USE FOR ADVANCED MISSIONS PREFERRED OVER PHASE B STATION

ISSUES

- DESIRABLE SPACE STATION CONFIGURATION WOULD NOT PRECLUDE ITS USE FOR ADVANCED MISSIONS

- SPACE STATION OPERATIONAL AND SA&T FUNCTIONS DO NOT CONSTRAIN CONFIGURATION ALTERNATIVES SERIOUSLY

- SPACE STATION/TRANSPORTATION SYSTEMS INTERFACES IS PRIMARY DETERMINING FACTOR OF STATION CONFIGURATION, E.G., PHASE B STATION/INT-21.
  - STATION/SHUTTLE INTERNAL COMPATIBILITY
    - SMALL AUTONOMOUS STATION
    - LARGE MODULAR STATION - HOW LARGE?

- SPACE STATION/SPACE SHUTTLE IOC TIMING
  - STATION OPERATIONAL PRIOR TO SHUTTLE
  - SHUTTLE OPERATIONAL PRIOR TO STATION

ATTACHMENT NO. 2
GREENING

SPACE STATION OPTIONS

POSSIBLE SPACE STATION MISSION MODES

Mission of the "70's":

✓. Low altitude earth orbit

Advanced Missions

✓. Space Base

✓. Geosynchronous earth orbit

✓. Lunar Orbit

. Lunar Surface Station

✓. Planetary Mission Module

. Planetary Surface Station

✓ INCLUDED IN ØB STUDIES

EARTH ORBITAL SPACE STATION

STUDIES CONCLUDE A DESIREABLE SPACE STATION SHOULD PROVIDE:

- GENERAL PURPOSE RESEARCH FACILITY
  - ADEQUATE ELECTRICAL POWER (25 KW)
  - MULTI-ORIENTATION STABILIZATION
  - DATA MANAGEMENT + COMMUNICATIONS
  - COMMON LABORATORY FACILITIES
  - SEPARATE EXPERIMENT MODULES
- CREW OF APPROXIMATELY 12
  - ~ 4 OPERATIONAL
  - ~ 8 RESEARCH
- ACCOMODATIONS FOR LONG DURATION HABITABILITY
- PRESSURIZED VOLUME OF ABOUT 30,000 FT^3 (120,000 LB)

OPTION – Φ 'B' SPACE STATION / SAT V LAUNCHED

DISCRIPTION: SAT V LAUNCHES A COMPLETE, INTEGRAL STATION CONTAINING SUB SYSTEMS, LIVING, WORKING AND LABORATORY VOLUMES.

PRO:

- NO ORBITAL ASSEMBLY REQUIRED
- COMPLETE SYSTEMS TEST ON GROUND
- Φ B STUDY RESULTS

CON:

- SIZE + WEIGHT OF STATION MODULE REQUIRES AN ADDITIONAL STAGE FOR SYNCHRONOUS MISSIONS

QUESTION:

- SATURN V AVAILABILITY

OPTION - SPACE STATION LAUNCHED BY SHUTTLE/ORBIT INSERTION STAGE

DESCRIPTION: SHUTTLE BOOSTER STAGE AND OIS LAUNCHES A COMPLETE, INTEGRAL STATION CONTAINING SUBSYSTEMS, LIVING, WORKING AND LABORATORY VOLUMES. MODULE MAY BE 22 TO 33 FT IN DIAMETER.

PRO:

- NO ORBITAL ASSEMBLY REQUIRED
- COMPLETE SYSTEMS TEST ON GROUND
- ØB STUDY RESULTS SUBSTANTIALLY APPLICABLE

CON:

- SIZE + WEIGHT OF STATION MODULE REQUIRES AN ADDITIONAL STAGE FOR SYNCHRONOUS MISSIONS

QUESTION:

- ORBITAL INSERTION STAGE DEVELOPMENT AND AVAILABILITY

OPTION – SHUTTLE LAUNCHED / DEDICATED MODULES

DESCRIPTION: CLUSTER OF MODULES (15 FT DIAM) TO PROVIDE A ▭ Φ B STATION CAPABILITY – POSSIBLE CONFIGURATION – LIVING MODULE, SUBSYSTEM MODULE, LABORATORY MODULE

PRO:

- SATURN V NOT REQUIRED

CON:

- MULTIPLE LAUNCHES AND ORBITAL ASSEMBLY, NO SINGLE MODULE CAPABILITY

QUESTION:

- SHUTTLE PAYLOAD SIZE AND WEIGHT

OPTION – SHUTTLE LAUNCHED / INDEPENDENT MODULES

DESCRIPTION: 15 FT DIAM MODULE CONTAINING FACILITIES FOR A SMALL CREW (~3) WITH A LIMITED LABORATORY [redacted]

PRO:
- SMALL MODULE MAY HAVE BROAD MISSION APPLICATION IE SYNCHRONOUS, LUNAR, PLANETARY
- BROAD UTILIZATION IE SMALL SPACE STATION, INDEPENDENT MODULE CLUSTER, HYBRID CLUSTER
- SINGLE PRODUCTION ITEM
- SATURN V NOT REQUIRED

CON:
- SMALL STATION CREW SIZE NOT LARGE ENOUGH FOR SPECIALIZATION
- MULTIPLE LAUNCHES AND ORBITAL ASSEMBLY REQUIRED FOR CLUSTER OPERATION
- INDEPENDENT [redacted] MODULE CLUSTER PROVIDES LIMITED STATION CAPABILITY

QUESTION:
- SHUTTLE PAYLOAD SIZE AND WEIGHT

CURRENT ACTIVITY

- AEROSPACE CONFIGURATION STUDY
- LOEWY - SNAITH MAINTAINABILITY STUDIES

PLANNED ACTIVITY

- PHASE B OPTIONS PERIOD

POST APOLLO PROGRAM

POST APOLLO LUNAR PROGRAM OPTIONS

NO SATURN V RESTART

1. STAY WITH BASELINE PROGRAM. LET APOLLO RUN OUT. ACCEPT LARGE (7-9 YEAR) GAP IN LUNAR EXPLORATION.

2. USE SHUTTLE/TUG FOR LUNAR PROGRAM IN '77 TO '80'S. ACCEPT GAP FROM '74-'77.

3. U/M PROGRAM. ORBITER/LANDER/ROVER PROGRAM IN EARLY TO LATE '70'S. NO GAP

SATURN V RESTART

4. STRETCH OUT APOLLO WITH A FEW FOLLOW-ONS TO RUN PROGRAM INTO LATE '70'S. FOLLOW-ON APOLLOS ARE MODESTLY UPRATED. NO GAP.

5. APOLLO DERIVATIVES IN MID AND LATE '70'S. LITTLE OR NO GAP.

LEVELS OF LUNAR ACTIVITY

LEVEL	CHARACTERISTICS AND CAPABILITIES
I. EXPLORATORY	USE APOLLO AND SURVEYOR-ORBITER FOR GLOBAL STUDY. SELECTED SAMPLING OF MAJOR FEATURES.
II. TEMPORARY BASE	2-8 WEEK STAY TIME. TEST BED FOR MANNED PLANETARY OPERATIONS. REGIONAL MOBILITY. ASTRONOMY AND GEOPHYSICS OBSERVATORY.
III. LUNAR BASE	VERY LONG STAY TIME. GLOBAL MOBILITY VIA LOSS OR LONG RANGE MOBILITY VIA ROVER OR FLYER. IN DEPTH LOCAL, GLOBAL, AND COMPARATIVE LUNAR SCIENCE. SCIENTIFIC STATION. RESOURCE EXPLORATION.

LEVELS & OPTIONS

OPTIONS	LEVELS BY 80 I	II	III	ADVANTAGES	DISADVANTAGES
1	YES	NO	NO	BASIC PROGRAM	7-9 YR GAP
2	YES	YES	NO	DERIVATIVE OF PRESENT PROGRAM	3 YR GAP
3	YES	SOME	NO	EARLY COMPLETION OF LEVEL I. NO GAP	RESTRICTED CAPABILITY. U/M
4	YES	SOME	NO	NOT A COMPLETELY NEW SYSTEM. NO GAP	SAT-V RESTART
5	YES	YES	SOME	AMBITIOUS. NO GAP	SAT-V RESTART

ISSUES

- IS A GAP IN LUNAR EXPLORATION ACCEPTABLE?
  IF NOT, HOW CAN GAP BE FILLED?
  1. SATURN/APOLLO
  2. SATURN/ECSM/ELM OR LM-B
  3. INTEGRATED PROGRAM: SHUTTLE/NUC. SHUTTLE/LOSS/LM-B
  4. SHUTTLE/TUG
- SHOULD THE LSB BE A GOAL?
- CAN LUNAR EXPLORATION SERVE AS A TEST BED FOR THE MANNED PLANETARY PROGRAM?

PROGRAM ALTERNATIVES

PROGRAM RATIONALE

GENERAL

- CONDUCT ALL APOLLO MISSIONS PRIOR TO SKYLAB-I
- LAUNCH SKYLAB-II 2 YEARS AFTER SKYLAB-I
- INITIATE SPACE SHUTTLE DEVELOPMENT IN FY 72

PROGRAM ALTERNATIVES

	I- ALL-UP SHUTTLE	II- PHASED SHUTTLE	III- EVOLUTIONARY SHUTTLE
MARKET ASSESSMENT	. VIRTUALLY ALL SHUTTLE/TUG IN EARTH ORBIT WITH EARLY NEED FOR RESUMPTION OF LUNAR	. PRINCIPALLY LONG-DURATION EARTH ORBIT. LUNAR DEFERRED	. UNCERTAIN - SHUTTLE/TUG OR LONG-DURATION EARTH ORBIT. LUNAR DEFERRED.
PROGRAM EMPHASIS	. FLEXIBLE, ECONOMIC CISLUNAR TRANSPORTATION	. LONG-DURATION EARTH ORBIT CAPABILITY WITH FLEXIBLE LOGISTICS	. EQUAL (BUT REDUCED) ON FLEXIBLE, ECONOMIC TRANSPORTATION AND LONG-DURATION MSF CAPABILITY
SYSTEM PRIORITIES	. SPACE SHUTTLE SPACE TUG LUNAR ELEMENTS SPACE STATION	. SPACE STATION SPACE SHUTTLE SPACE TUG LUNAR ELEMENTS	. SPACE STATION/SPACE SHUTTLE SPACE TUG LUNAR ELEMENTS

PROGRAM ALTERNATIVES

- I - ALL-UP SHUTTLE
- II - PHASED SHUTTLE
- III - EVOLUTIONARY SHUTTLE
  AND LONG DURATION MSF

I - ALL-UP SHUTTLE

ACTIVITIES	1975	1980	1985
Earth Orbit	Skylab II	Space Shuttle; Space Shuttle + Space Tug	Space Shuttle + Space Tug; Space Shuttle + SSM
Lunar		Lunar Site Surveys Shuttle + CLS + Tug	Lunar Operations Shuttle + CLS + Tug + SSM; Lunar Surface Base

MISSIONS	1975	1980						1985	
Space Shuttle (∿ 50K P/L)		4	10	20	20	20	20	30	30
Space Tug (LM-B ∿ 60K)			5	7	7	7	7	7	9
Cislunar Shuttle (OIS) (Chemical∿600K)				1	1	1	1	2	2
SSM (∿ 50K modular)					1				1

42.381 50 SHEETS 5 SQUARE
42.382 100 SHEETS 5 SQUARE
42.389 200 SHEETS 5 SQUARE
NATIONAL

II - PHASED SHUTTLE

ACTIVITIES	1975	1980	1985
Earth Orbit	Skylab II	Shuttle Orbiter (S-IC)	Shuttle Orbiter (S-IC) SSM (LLV) / Space Shuttle + Tug / Space Shuttle + SSM (LLV)
Lunar			Lunar Orbit Base / Shuttle + CLS + Tug + SSM / Lunar Surface Base

MISSIONS	1975	1980				1985			
Shuttle Orbiter		4	6	10	10				
SSM (ø B type ∿100K)			1			1			
Space Shuttle (∿50K P/L)						30	30	30	30
Space Tug (LM-B ∿60K)						7	9	9	9
Cislunar Shuttle (chemical ∿600K)						2	2	2	2
LLV (S-IC)		4	6	10	10				
LLV (S-IC + S-II')			1			1			

42 381 50 SHEETS 5 SQUARE
42-382 100 SHEETS 5 SQUARE
42-389 200 SHEETS 5 SQUARE

III - EVOLUTIONARY SHUTTLE AND LONG DURATION MSF

ACTIVITIES	1975	1980	1985
Earth Orbit	Skylab II; L/B Shuttle (LLV); Skylab III (LLV); L/B shuttle (LLV); SSM (LLV); L/B Shut.		Space Shuttle + Tug; Space Shuttle + SSM (LLV)
Lunar			Lunar Orbit Base Shuttle + CLS + Tug + SSM; Lunar Surface Base

MISSIONS	1975			1980			1985			
Skylab III (6 men, 2 yrs.)		1								
Shuttle (Reusable Lifting Body)		4	6	10	10					
SSM (ØB type ∿100K)					1		1			
Space Shuttle (∿50K P/L)						10	30	30	30	30
Space Tug (LM-B ∿60K)						5	9	9	9	9
Cislunar Shuttle (Chemical ∿600K)							2	2	2	2
LLV (T-III')		5	6	10	11					

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MISSIONS

I - ALL-UP SHUTTLE

Earth Orbit

Shuttle	- Shuttle + 50K P/L
Shuttle + Tug	- Shuttle delivery of LM-B PM (50K). Crew capsule (5-7K) and P/L delivered separately by shuttle.
Shuttle + SSM	- Shuttle delivery of 50K modular SSM. P/L and crew delivered separately by shuttle.

Lunar

Shuttle + CLS + Tug

a. Shuttle booster launches CLS (fueled with 540K of propellant). CLS propellant used for insertion into E. O.

b. 9 shuttle flights to refuel CLS in E. O.

c. CLS injects into TLI and inserts into lunar orbit: 1 Tug (with propellant) + 1 Tug (without propellant) + P/L

d. Tug conducts lunar landing mission. Empty tug provides for safety, obtaining fuel from CLS if necessary.

e. CLS returns 1 Tug with crew to E. O. Return of other PM is marginal.

Shuttle + CLS + Tug + SSM

- Shuttles insert SSM and Tug into E. O. CLS is inserted into E.O. and refueled as above. CLS transports SSM + Tug to lunar orbit.
  Tug conducts lunar landing mission. Resupply from E.O. in same manner. CLS used for return to E.O. SSM remains in lunar orbit.

II - PHASED SHUTTLE

Earth Orbit

Shuttle Orbiter + S-IC	- Launch by S-IC. Insertion into E.O. by shuttle orbiter.
SSM + LLV (S-IC + S-II')	- INT-21' inserts 100K SSM into E.O.
Shuttle + Tug	- Same as for Option I
Shuttle + SSM	- Insertion of SSM into E.O. as above. SSM resupply and crew return by shuttle.

Lunar

Shuttle + CLS + Tug + SSM	- Essentially same as for Option I, but SSM (∿100K) is inserted into E.O. by LLV. One CLS required to transport SSM to lunar orbit.

III - EVOLUTIONARY SHUTTLE

Earth Orbit

Skylab III + LLV	- Skylab II (∿ 90K) inserted into E. O. by T-III' (90K capability)
Shuttle + LLV	- Resuable lifting body spacecraft inserted into E.O. by T-III'. Provides manning and logistics for Skylab.
SSM + LLV	- SSM (∿ 90K) inserted into E.O. by T-III'.
Space Shuttle + Tug	- Same as for Option I.
Space Shuttle + SSM	- Same as for Option II.

Lunar

Shuttle + CLS + Tug + SSM	- Same as for Option II.

MISSION DESCRIPTIONS

- I - ALL-UP SHUTTLE
- II - PHASED SHUTTLE
- III - EVOLUTIONARY SHUTTLE AND LONG DURATION MSF

I - ALL-UP SHUTTLE MISSIONS

MISSION	MISSION PROFILE/MODE	OBJECTIVES	PAYLOADS
Earth Orbit			
. Space Shuttle	. Low altitude E.O. 0-90° inclination. 7-30 days	. SA&T Defense	. U/M satellites for E.O. insertion . Automated and manned on board expts . Manned lab . SSM
	. 270 NMI/55° E.O. 7-30 days	. Logistics	. Crew, expts and consumables for space station
. Space Tug	. Altitude from leo to synchronous	. SA&T Defense	. U/M satellites for E.O. insertion . U/M planetary probes
. Space Station	. 270 NMI/55° E.O. Long Duration	. SA&T	. Automated and manned on board expts . Manned lab
		. Logistics	. Facilities for repair and maintenance of retrieved satellites
Lunar			
. Lunar Site Surveys	. Single mission to lunar orbit. Tug descent to surface for 28-day sortie. Ascent to orbit and return to E.O.	. Lunar site survey and science	. Lunar surface expts
. Lunar Operations	. Dual mission to lunar orbit. Station in lunar orbit. Tug descent to surface for 28-day sortie and ascent to orbit. Resupply from E.O.	. Lunar exploration and base site selection	. Lunar surface and orbital expts
		. Logistics	. Crew, expts and consumables for station

II - PHASED SHUTTLE MISSIONS

MISSION	MISSION PROFILE/MODE	OBJECTIVES	PAYLOADS
Earth Orbit			
. Shuttle Orbiter	. Low altitude. 28-50° inclination. 7-30 days	. SA&T	. Manned on board expts . Manned lab . Piggyback automated on board expts and U/M satellites for E.O. insertion
		. Logistics	. Crew, expts and consumables for space station
. Space Shuttle	. Same as I	. Same as I	. Same as I except for SSM
. Space Tug	. Same as I	. Same as I	. Same as I
. Space Station	. Same as I	. Same as I	. Same as I
Lunar			
. Lunar Orbit Base	. Same as I (Lunar operations)	. Same as I	. Same as I

III - EVOLUTIONARY SHUTTLE AND LONG DURATION MSF MISSIONS

MISSION	MISSION PROFILE/MODE	OBJECTIVES	PAYLOADS
Earth Orbit			
. Skylab III	. 270 NMI/55° E.O. 2 years	. SA&T Long duration MSF	. Manned expts and manned lab
. Shuttle (Reusable L/B)	. Low altitude E.O. 28-90° inclination 7-30 days	. SA&T	. Manned on board expts . Manned lab . Piggyback automated on board expts and U/M satellites for E.O. insertion
. Space Shuttle	. Same as I	. Same as I	. Same as I except for SSM
. Space Tug	. Same as I	. Same as I	. Same as I
. Space Station	. Same as I	. Same as I	. Same as I
Lunar			
. Lunar orbit base	. Same as II	. Same as II	. Same as II

PLANNING FACTORS

The following planning factors were developed to assist in pricing Options I, II, and III.

Option I

Space Station Module

1. One flightworthy SSM will come out of the development program.

2. One additional SSM will be procured as a spare.

All-Up Shuttle

1. The maximum number of flights per year, assuming a two-week turn around time and the better part of a week on orbit, is 14. Allowing for outage use 10 flights/year/vehicle.

2. Three flightworthy vehicles will come out of the development program.

3. Each vehicle has a 100-flight useful lifetime.

4. The earth orbital shuttle activity requires 74 flights between 1978 and 1986 at a rate of 10 per year. This necessitates one vehicle.

5. There are 100 shuttle flights in support of the lunar program in the period 1980-86 at a rate of 20 per year. Two vehicles were assumed adequate to meet this requirement. However, more may be required depending on how long a period is permitted for orbital refueling of the cislunar shuttle. For example, 5 shuttle vehicles are required to fuel the CLS in three weeks.

6. In addition to the three shuttle vehicles from the development program, procure one more vehicle in 1984 and procure the equivalent of one vehicle in spare parts.

Tug

1. A tug will have a useful lifetime of 100 reuses or three years (if left in orbit).

2. One tug per year will be expended to inject a planetary spacecraft.

3. Three tugs will be procured in 1979 (may come from development program); one additional tug will be procured each year; every three years one more tug will be procured.

4. If the lunar missions are conducted with rescue capability, an additional tug may be required depending on the assumption made regarding storability in lunar orbit for about one year.

Cis-Lunar Shuttle

1. The CLS returns to earth orbit from each lunar mission. If it is fully reusable, then only one back up is required. If it is considered expended after reaching earth orbit, then one per year is required.

Summary Option I

SSM: One from the development program plus one spare, 1981

Shuttle: Three from the development program, 1978; one spare, 1984; and one equivalent vehicle in spare parts, 1984.

Tug: Three from the development program, 1979; one per year plus one additional every third year.

CLS: One from the development program and one per year, 1985.

Option II

Space Station Module

1. One flightworthy SSM from the development program, 1979.

2. One spare SSM as backup, 1979.

3. One SSM for lunar orbiting base, 1982.

Shuttle Orbiter Stage

1. Two flightworthy vehicles from the development program, 1978.

2. An additional vehicle in 1982.

3. One equivalent vehicle in spare parts, 1982.

Shuttle Booster Stage

1. Three flightworthy vehicles from the development program, 1982.

2. One equivalent vehicle in spare parts, 1982.

S-IC Interim Booster Stage

1978	1979	1980	1981
4	7	10	10

S-IC/S-II Interim Launch Vehicle

1979, 1; 1982, 1; plus $50 M/yr for MOC

Space Tug

Same rationale as Option I with 1982 IOC

CLS

Same rationale as Option I with 1982 IOC

Option III

Skylab III

Two for 1977

SSM

Same as Option II with 1980 as the earth orbital program IOC and 1982 as the lunar program IOC

Shuttle (Reusable lifting body spacecraft)

Two flightworthy vehicles from the development program, 1977.

All-Up Space Shuttle

1. Four flightworthy vehicles from the development program, 1981.

2. One equivalent vehicle in spare parts, 1981-83.

CLS

Same rationale as Option I with 1981 IOC.

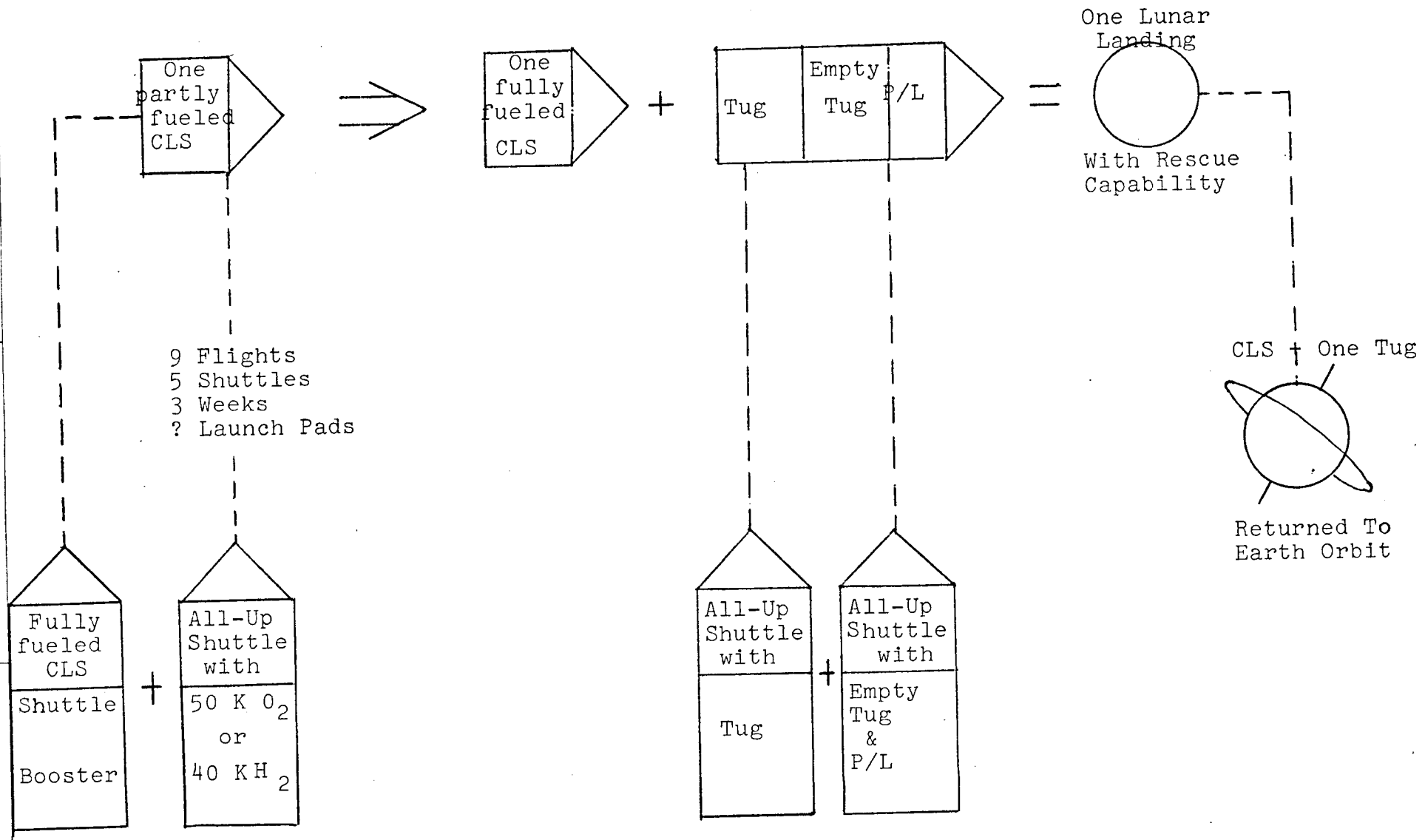
T-III

1977	1978	1979	1980	1982
5	6	10	11	1

LUNAR MISSION FLIGHT SCHEMATICS

- OPTION I
- OPTION II, III

OPTION I FLIGHT SCHEMATIC



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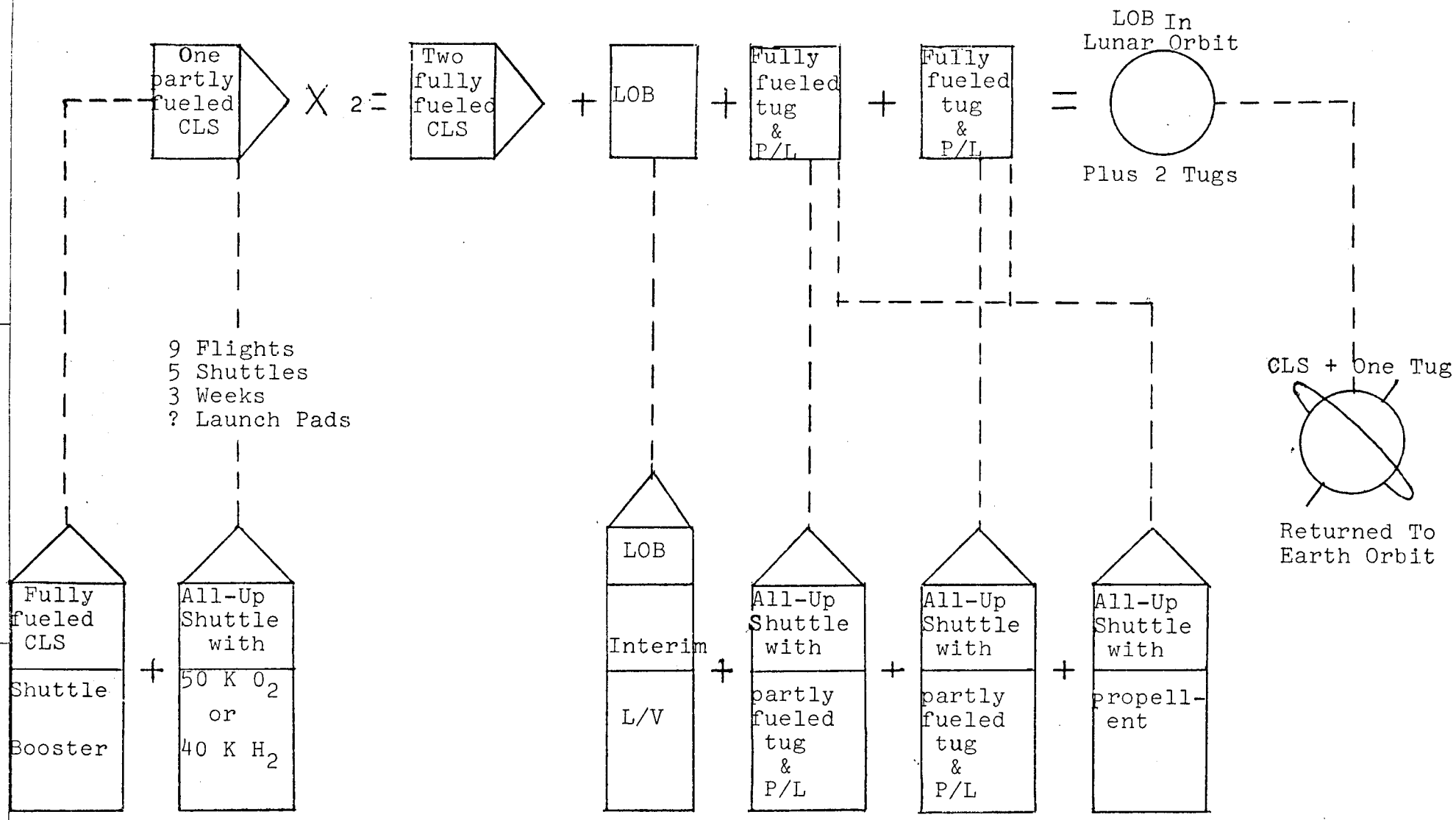
OPTION II, III, FLIGHT SCHEMATIC



MAJOR ISSUES

- RISK OF ALL-UP SHUTTLE VS. HIATUS IN MSF FLIGHT ACTIVITY
- SHUTTLE- COMPATIBLE SSM VS LARGE ϕB - TYPE SSM
- ACCEPTABILITY OF CONCURRENT INTRODUCTION OF SPACE TUG PM AND CHEMICAL CISLUNAR SHUTTLE REPRESENTING SAME STATE-OF-ART?
- DESIRABILITY OF RESUMING LUNAR EXPLORATION ON BASIS OF APOLLO ONLY?