STORABLE SPACE TUG SYSTEMS STUDY

DATA DUMP

VOLUME 8, PROGRAMMATICS & COST: BOOK 1

19 SEPTEMBER 1973

REPORT NO. 300RP-73-0011

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PREPARED FOR

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TABLE 5.2.3-2 EQUIPMENT LIST

WBS NO. 320-03-03-05 & -06

27 AUG., 1973 REV. (1)

CONFIGURATION APOGEE KICK STAGE SUBSYSTEM/COMPONENT ELECTRICAL POWER SUBSYSTEM DATE: 13 AUG., 1973

MAJOR COMPONENT	DEVELOPMENT STATUS			PHYSICAL CHARACTERISTICS						TECHNICAL CHARACTERISTICS	RELIABILITY		PROGRAMATIC			NOTES
	STATE-OF-THE-ART RATING	MONTHS TO QUAL	OTHER PROGRAM USAGE	MATERIALS	WEIGHT (LBS)	SIZE: LENGTH (INCHES)	SIZE: WIDTH (INCHES)	SIZE: HEIGHT (INCHES)	VOLUME (CUBIC INCHES)	POWER (INPUT/OUTPUT) DATA TRANSFER RATE COMPUTER STORAGE CAP. NUMBER OF CIRCUITS THRUST SPECIFIC IMPULSE	EQUIVALENT OPERATING HOURS	MTBF (HOURS)	UNITS PER VEHICLE	EQUIVALENT UNITS FOR S/S TEST	EQUIVALENT UNITS FOR MAJOR GND TST	
PRIMARY BATTERY	5	6	-	AG-ZN, Mg.	3	7	4	4	112	2 AMP-HR RATED CAPACITY @ 30V; 3 AMP AVG. DISCH. OVER 0.5 HR.	0.5	30,000	1	-	1	MANUALLY ACTIVATED AG-ZN BATTERY SELLER: EAGLE PICHER.
POWER DIST & CONTROL	5	-	LM		25	-	-	-	-	ASSORTED WIRE, CONNECTORS & SOLID STATE POWER CONTROLLERS	0.5		SHIP SET	-	SHIP SET	

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REPORT
DATE
CODE 26512

CONFIGURATION 110A-1 WBS NO. 320-04-[illegible]-04

SUBSYSTEM/~~COMPONENT~~ MPS (AUX. STAGE) DATE:

COMPONENT NAME	DEVELOPMENT STATUS			PHYSICAL CHARACTERISTICS						TECHNICAL CHARACTERISTICS		RELIABILITY		PROGRAMATIC			NOTES
	STATE-OF-THE-ART RATING	MONTHS TO QUAL	OTHER PROGRAM USAGE	MATERIALS	WEIGHT (LBS)	SIZE: LENGTH (INCHES)	SIZE: WIDTH (INCHES)	SIZE: HEIGHT (INCHES)	VOLUME (CUBIC INCHES)	POWER (WATTS)		EQUIVALENT OPERATING HOURS	MTBF (HOURS)	UNITS PER VEHICLE	EQUIVALENT UNITS FOR S/S TEST	EQUIVALENT UNITS FOR MAJOR GND TST	
SRM	3	24	DELTA, BURNER II, ETC.		1667	74	37	—	[illegible] 80 K	180	$I_{sp}=295$, $\lambda'=.92$ $\epsilon=50$			2/9	0	0	ME. -TEM364 OR SVM-4A

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REPORT
DATE
CODE 28512

CONFIGURATION Apogee Kick Stage (AKS) WBS NO. [illegible] SUBSYSTEM/COMPONENT Auxiliary Propulsion System (APS) DATE: 5/3/[illegible]

COMPONENT NAME	DEVELOPMENT STATUS: STATE-OF-THE-ART RATING	DEVELOPMENT STATUS: MONTHS TO QUAL	DEVELOPMENT STATUS: OTHER PROGRAM USAGE	PHYSICAL CHARACTERISTICS: MATERIALS	PHYSICAL CHARACTERISTICS: WEIGHT (LBS)	PHYSICAL CHARACTERISTICS: SIZE: LENGTH (INCHES)	PHYSICAL CHARACTERISTICS: SIZE: WIDTH (INCHES)	PHYSICAL CHARACTERISTICS: SIZE: HEIGHT (INCHES)	PHYSICAL CHARACTERISTICS: VOLUME (CUBIC INCHES)	TECHNICAL CHARACTERISTICS: POWER (WATTS)	TECHNICAL CHARACTERISTICS	RELIABILITY: EQUIVALENT OPERATING HOURS	RELIABILITY: MTBF (HOURS)	PROGRAMATIC: UNITS PER VEHICLE	PROGRAMATIC: EQUIVALENT UNITS FOR S/S TEST	PROGRAMATIC: EQUIVALENT UNITS FOR MAJOR S/S TEST	NOTES
Nitrogen Tank	5	≤12	–	6Al 4V	1.02	4.750	–	–	50	–	Burst Press. = 6660 PSI Operating = 3000 PSI		10^7	1			Airite P/N 6359
Solenoid Valve	5	≤12	–		2.3					64			67,000	1			LSC 270-713
Regulator (single stage)	4	≤12	–		1.5					–		2	67000	1			LSC 310-305-3 (Mod to one stage)
Thruster Valve	4	≤12	–		0.75					10	0.25" ID. required		333,000	12	One Shipset	None	
Thrusters	5	–	–		0.2					–			–	12			Nozzle machinings
Quick Disconnect	5	≤12			0.5					–			10^6	1			Nitrogen fill & vent

General Note: Tank sized to provide 12 hr. wide deadband and 1 hr. narrow deadband control.

8.7 FLIGHT SCHEDULE

Included in support of our flight schedule definition for concept 110A-1 are the following tables:

- Fleet Size and Vehicle Usage
- Flight Element Requirements
- Kick Stage Definition
- Payload ID of Payloads Flown
- Flight Operations Buildup
- Programmatic Data Summary Storable Tug Concept 110A-1

110A-1 FLEET SIZE & VEHICLE USAGE

	1979	80	81	82	83	84	85	86	87	88	89	90	Total
CAPTURE MODEL													
Total Flts		16	13	17	27	24	21	21	26	19	26	20	230
Prog.Build Up Model													
ETR Reuse		3	12	17	20	20	16	17	21	17	16	17	176
Expand						2		1	1		3	1	8
WTR Reuse					7	2	5	3	4	2	7	2	32
Total Flts		3	12	17	27	24	21	21	26	19	26	20	216
										Lost Missions			+ 2
NATIONAL FLEET													
VEH 1		2	6	8	7	1E							
2		1	6	9	12	1E							
3					8	17	5	1E					
4						5	16	3	1E				
5								17	9	2	1E		
6									17	2	3E		
7										15	8E		
8											15	5E	
9												15	
10 Lost Tug													
11 Lost Tug													
DOD Traffic													
Reuse Flts		1	6	9	14	11	10	10	12	11	10	11	105
DOD Fleet													
VEH 1		1	6	9	14	11	10	10	12	11	10	11	
2 Lost Tug													

FLIGHT ELEMENT REQUIREMENTS OPTION: 1 110A-1

ITEM			CALENDAR YEAR 80	81	82	83	84	85	86	87	88	89	90	TOTAL
SHUTTLE FLIGHTS		TOTAL	8	6	9	14	11	10	10	12	11	10	11	112
BASIC TUG FLIGHTS	ETR	RECOVERED	8	6	9	10	10	8	8	10	10	7	10	96
		EXPENDED												0
	WTR	RECOVERED				4	1	2	2	2	1	3	1	16
	(TOTAL)		(8)	(6)	(9)	(14)	(11)	(10)	(10)	(12)	(11)	(10)	(11)	(112)
KICK STAGES	KS 101													
	KS 102					1	1							2
	(TOTAL)					(1)	(1)							(2)

TABLE 4.3.1.2-6
DOD TRAFFIC

PRELIMINARY

FLIGHT ELEMENT REQUIREMENTS OPTION: 1 110A-1

ITEM			CALENDAR YEAR 80	81	82	83	84	85	86	87	88	89	90	TOTAL
SHUTTLE FLIGHTS		TOTAL	8	7	8	13	13	11	11	14	8	16	9	118
BASIC TUG FLIGHTS	ETR	RECOVERED	8	7	8	10	10	8	9	11	7	9	7	94
		EXPENDED					2		1	1		3	1	8
	WTR	RECOVERED				3	1	3	1	2	1	4	1	16
	(TOTAL)		(8)	(7)	(8)	(13)	(13)	(11)	(11)	(14)	(8)	(16)	(9)	(118)
KICK STAGES	KS 101				2		2		3	2				9
	KS 102			1	2					1			1	3
	(TOTAL)			(1)	(4)		(2)		(3)	(3)			(1)	(12)

TABLE 4.3.1.2-5

NASA TRAFFIC

FLIGHT ELEMENT REQUIREMENTS OPTION: 1 110A-1

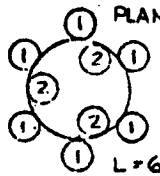
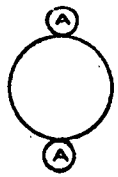
ITEM			CALENDAR YEAR 80	81	82	83	84	85	86	87	88	89	90	TOTAL
SHUTTLE FLIGHTS		TOTAL	16	13	17	27	24	21	21	26	19	26	20	230
BASIC TUG FLIGHTS	ETR	RECOVERED	16	13	17	20	20	16	17	21	17	16	17	190
		EXPENDED					2		1	1		3	1	8
	WTR	RECOVERED				7	2	5	3	4	2	7	2	32
	(TOTAL)		(16)	(13)	(17)	(27)	(24)	(21)	(21)	(26)	(19)	(26)	(20)	(230)
KICK STAGES	KS 101				2		2		3	2				9
	KS 102			1		1	1			1			1	5
	(TOTAL)			(1)	(2)	(1)	(3)		(3)	(3)			(1)	(14)

RELIABILITY = +2 FLTS

TABLE 4.3.1.2-7
COMBINED NASA/DOD TRAFFIC

CONCEPT 110A-1

KICK STAGE DEFINITION

KICK STAGE DESIGNATION	GEOMETRY (all stages >10 ft diam. & are 5.5 ft long unless otherwise noted)		PERFORMANCE (Geosynch Payload) (lbs)	SRM CHARACTERISTICS INDIVIDUAL WEIGHT (lbs)	NUMBER	TOTAL SRM WEIGHT (lbs)	STAGE INERT WEIGHT (lbs)	TOTAL STAGE WEIGHT (lbs)
KS 101	 PLANETARY L = 6 ft 8 in	STAGE 1	5000 lbs TO ΔV = 18,400 fps	1667	6	10002	–	10002
		STAGE 2		1667	3	5001	545	5546
		(TOTAL)						(15548)
KS 102	 DEPLOY AKS		8207	1667	2	3334	529	(3863)

BAS 9-6-71

TABLE 4.3.1.2-8

FLIGHT	PAYLOAD ID OF PAYLOADS FLOWN		
	1980	1981	1982
1	9	8*	ALL
2	17	10	
3	26	11	
4		1 + 8	
5		1 + 3 + 4	
6		3 + 3 + 3	
7		25 + 25	
8		31	
9		31	
10		34	
11		35	
12		35	
TOTAL P/L'S FLOWN	3	18	24

TOTAL P/L'S SCHEDULED	25	23	24
TOTAL FLTS SCHEDULED	16	13	17

* Flown with AKS for test purposes only. AKS not req'd for mission.

CONCEPT 110A-1

COSTED FLIGHT BUILDUP

TABLE 4.3.1.2-9

I-8.7-7

FLIGHT OPERATIONS BUILDUP - 110A-1

The methodology used to establish the 110A-1 flight buildup is keyed to achieving all flights defined by the 100% payload capture analysis after the second year of operations. The primary factors considered include: NASA defined Shuttle/Tug launch constraints. initial ETR ground crew launch capabilities, and flight mode buildup.

Shuttle/Tug launch constraints affect the first year of operations and allow only 3 flights. During the second year of operations the allowable Shuttle/Tug launches exceed the payload capture traffic model.

Initial ground crew launch capability is based on a 90% learning factor applied to the minimum ground crew for Tug launch to launch processing during mature turnaround at the 100th flight. The 15 flight ground crew launch capability shown in the second year can only be achieved if the ground crew had been able to achieve the experience associated with 12 flights in the first year. However, since Shuttle/Tug launches are limited to only 3 flights in 1980, the full benefits of potential ground crew learning cannot be realized. Therefore, 1981 is limited to 12 launches since it is equivalent to the first year of full ground crew activity. We recommend that the minimum ground crew be retained for the first two years to limit the initial cost of operations. Additional personnel would be added at the end of 1981 in order to accommodate the higher launch rates required in 1982 and 1983.

During the flight buildup period we recommend that flight crew experience be developed by starting with the simplest flight mode and then progressively introducing the more complex flight modes required for 1982. For example, in 1980 the Tug is limited to single payload deploy missions. During the second year some multi payload deploy and single payload deploy with apogee kick stage flights are introduced.

Our recommended flight buildup for 110A-1, including 3 flights in 1980 and 12 flights in 1981, encompasses 218 total flights through 1990 or 12 less than 100% payload capture traffic.

110A-1 FLIGHT OPERATIONS BUILDUP

INPUTS	CY 80	81	82	83	TOTAL FLTS.
	▽ IOC				
o 100% PAYLOAD CAPTURE ETR+WTR FLTS	16	13	17	27	230
ETR FLTS	16	13	17	20	
o SHUTTLE/TUG LAUNCH CONSTRAINT - ETR	3	21			
o INITIAL GROUND CREW LAUNCH CAPABILITY - ETR	12	15	16		
o TUG FLIGHT MODE BUILDUP					
SINGLE DEPLOY	3	ALL	ALL	ALL	
SINGLE DEPLOY WITH KICK STAGE	NONE	SOME	ALL	ALL	
MULTI DEPLOY	NONE	SOME	ALL	ALL	
MULTI DEPLOY WITH KICK STAGE	NONE	NONE	ALL	ALL	
SORTIE	NONE	NONE	NONE	ALL	
RECOMMENDED FLIGHT BUILDUP ETR+WTR FLIGHTS	3	12	17	27	218
ETR FLIGHTS	3	12	17	20	

BUILDUP RATIONALE

- o GROUND CREW LEARNING NOT MAXIMIZED IN 1980 I.E. 1981 1ST YR. OF MAX. ACTIVITY
- o LIMIT INITIAL OPERATIONS COST WITH MINIMUM GROUND CREW THROUGH 1981, THEN ADD PERSONNEL FOR 100% CAPTURE
- o EASE INTO COMPLEX FLIGHT MODES TO MAXIMIZE FLIGHT OPERATIONS CREW LEARNING

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PROGRAMMAITC DATA SUMMARY
STORABLE TUG CONCEPT 110A-1

PROJECT HARDWARE UTILIZATION (AUTONOMY IIIA)

	MAIN STAGE INIT	MAIN STAGE EVOL	ORBITER INTERFACE	AKS 101	AKS 102			
VEHICLE TEST								
PTV	1*		-	-	-			
STA	1		1	1	-			
1 AT	1		-	1	-			
FLT TEST VEH	1*		1*	1	-			
VEHICLE OPS								
TEST HDWR CONV	*		*					
NATIONAL FLEET	11		4	5	9			
NASA	9		2	3	9			
DOD	2		2	2	-			
TOTAL FLEET	11			14A				

SHUTTLE FLIGHTS

	TEST	OPERATIONS		
	INIT	INIT	EVOL	TOTAL
ETR	1	186		186
WTR	-	32		32
COMBINED	1	218		218
NASA	1	112		112
DOD	-	106		106

OPNL YEARS

	INIT	EVOL	TOTAL
ETR	11		11
WTR	8		8

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I-61-10

PROGRAM SENSITIVITY TO IOC SHIFT - 110A-1

Two programmatic options are available for implementing program concept 110A-1 under a 2 year delay. First the baseline schedule could be shifted 2 years and start at October 77 ATP. The second option uses a schedule stretch out from the original 75 ATP to the delayed 81 IOC milestone. Both schedule options assume that the original flight build-up is delayed. We examined the implications of IOC shift with respect to operations, production and development.

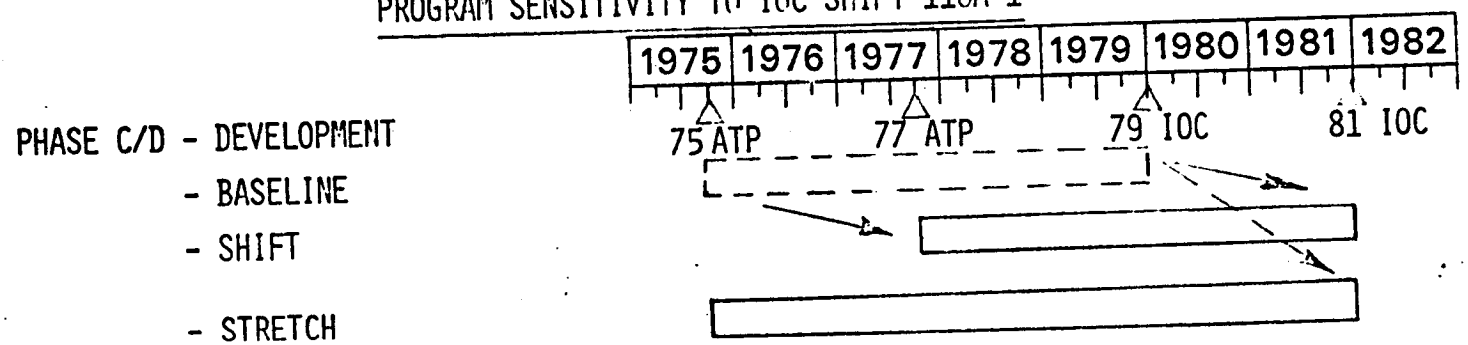
IOC delay results in 79 undeployed payloads for either the shift or stretch development schedule options.

Considering vehicle production two different factors should be addressed. They include schedule implications on manufacturing learning and the availability of existing hardware. For the schedule shift option, manufacturing learning can be more efficiently transferred from test article fabrication to vehicle production, than in a stretchout situation. Basic draw back of schedule shift is that the delay in ATP may make the availability of planned existing hardware questionable. On the other hand the stretch option allows early contractual arrangements for vendor support.

The impact of IOC delay on development was reviewed with respect to the following: schedule, type of contractor support available to NASA/DOD for defining Tug/Shuttle systems and interfaces, vehicle test, facilities SR&T and cost. For the first two years of the stretched schedule, Tug/Shuttle systems and interfaces would be defined by the government with support of a prime contractor. This is a vital period for assuring that the two vehicles are compatible as illustrated by the Apollo LM/CSM relationship. The impact on vehicle test, facilities and SR&T are similar for both schedule options. Assuming that the initial period of schedule stretch is devoted to systems engineering studies, we estimate that cost of stretch-out will be $7M. Peak funding occurs in 1981 and is $63M for the schedule stretch option.

1-8-8-T

PROGRAM SENSITIVITY TO IOC SHIFT 110A-1



	SHIFT	VS STRETCH
OPERATIONS IMPACT		
UNDEPLOYED PAYLOADS	79	79
PRODUCTION IMPACT		
EXIST HARDWARE AVAIL	FAIR	BEST
MFG. TEST ART/PROD LEARN	BEST	FAIR
DEVELOPMENT IMPACT		
SCHEDULE	51 MO	75 MO
SYS & INTERFACE DEFINED BY	GOVT + STUDY CONTR	GOVT + PRIME CONTR
VEHICLE TEST	2 YR DELAY	1 1/2 YR DELAY
FACILITIES	2 YR DELAY	AS REQUIRED
SR&T	2 YR DELAY	AS REQUIRED
DDT&E	220	227
PAF (YR)	81(81)	63(81)

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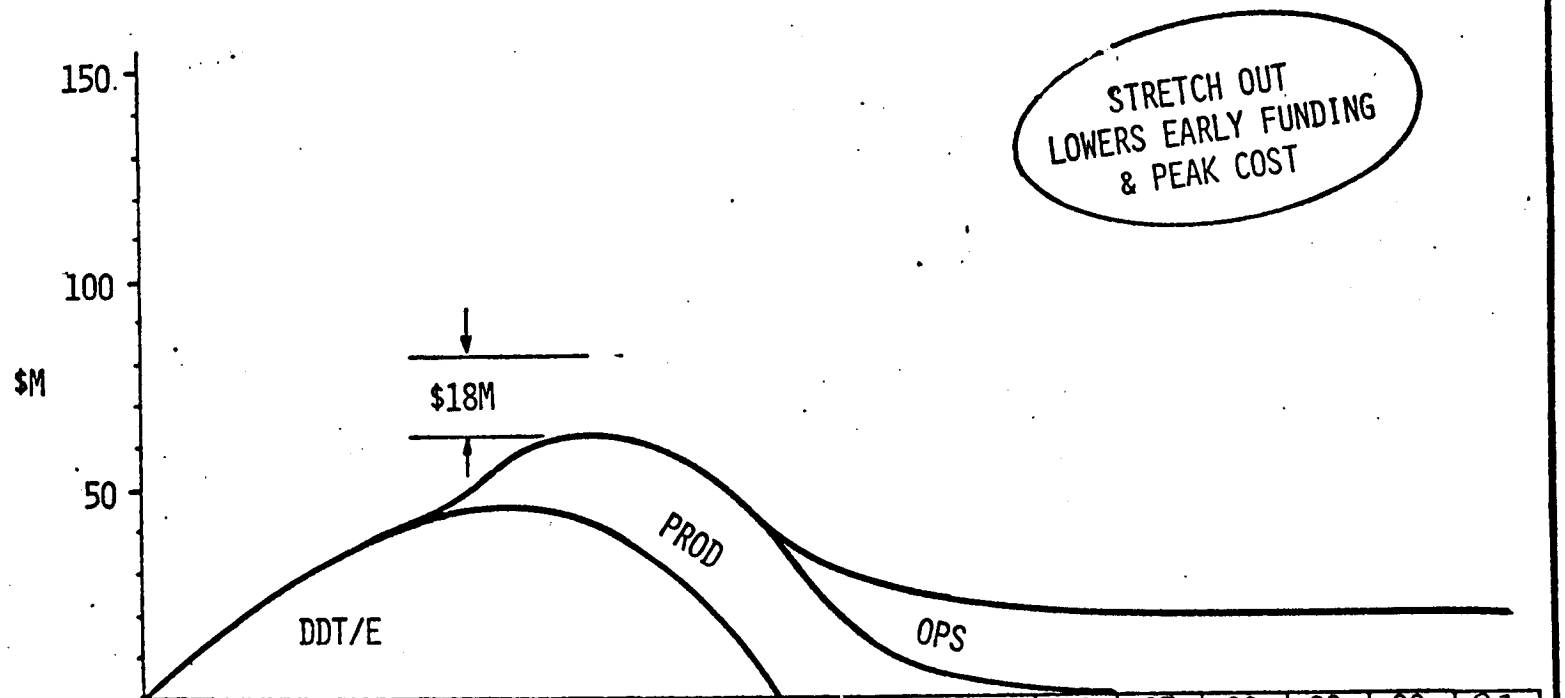
T-8.8-2

PHASE C/D STRETCH FOR DELAYED IOC - 110A-1



CY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	
FY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	
DDT&E	11	21	36	46	47	36	26	4									
PROD					13	27	28	22	13	6	4	2					
OPS							4	9	14	18	21	21	22	22	22	20.16	
TOTAL	11	21	36	46	60	63	58	35	27	24	25	23	22	22	22	20.16	6

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I-ff-3

8.9 Risk Assessment

In making an assessment of the risk associated with each configuration in each capability option we have considered the type of technology items associated with each vehicle and the impact that it would have on the program if, for one reason or another, the item would be unavailable and an alternative solution would be required. The impact is defined, usually, in terms of added weight, lost performance and total program cost increase; in some cases the impact can be decreased weight or reduced cost.

It is assumed that all of the weight increases and all of the cost increases will occur simultaneously without benefit of any offsetting decreases in either weight or cost. For example in configuration 110A-1 we have assumed that the +4 lb. weight impact of abandoning spun aluminum tanks in favor of welded aluminum tanks is combined with a $10.0 million cost increase as a result of abandoning aluminum tanks in favor of titanium tanks due to materials compatibility or fracture mechanics issues.

Taking the summation of all the weight increases, these are converted to costs by using the $75K/lb. figure derived when we were first selecting subsystem options for incorporation with 110A-1. The $75K/lb. number represents the last step (actually the slope of the line) in our subsystems synthesis process which provides a curve of Δ weight versus Δ total program costs as we added lighter and more costly subsystems options to achieve a behicle with 3500 lb. deploy capability. In this manner we arrived at a estimate of the costs expected if we had to recover the weight growth.

In similar fashion we then summed all of the potential cost increases, ignoring any offsetting cost decreases, and added these to the dollars representing the weight increases. The 110A-1 has no projected performance loss since it uses the OME 7.5K engine; the assumption is that the basic OME will have been developed to meet its weight, performance and reusability goals for the Shuttle Orbiter. In the case of configurations which use the Class I engine, for example 410AD-2, we have assumed that a 3 second Isp performance loss is possible. To convert this performance loss to costs we use the payload sensitivity factor to loss in Isp (97 lbs/sec), divide this by the payload sensitivity to inert weight and then multiply by $111/lb. to convert it to costs.

Taking all of the costs and adding them together we get a total low cost risk value of $15.3M for 110A-1 which ranges to a high value of 94.3M for 320A-3A/320AE-3A.

8.10 RISK ASSESSMENT (continued)

Where no suitable alternative exists (for example the Class I engine, or the laser radar, or the Space Storable SRM) we have identified that item as both a cost and a schedule risk without attempting to quantify the risk. In general, we are relying on the successful completion of the proposed SR&T programs to reduce or eliminate the risk of schedule slippage.

Taking configuration 110A as an example:

110A-1: This is an extremely low risk program with only two items representing a technical risk, the spun-form aluminum tanks and the prestressed filament reinforced (PFR) helium tanks. Both of these items are low risk and both have suitable, low risk alternatives available.

The incorporation of separate tanks (rather than the nested tanks used in the other configurations) further reduces the risk associated with this configuration. Level III (rather than Level IIB) autonomy also reduces the risk since there is no reliance on the 621B Navigation Satellite program. The OME 7.5K engine is the lowest risk engine program available, so its use on 110A-1 further reduces risk. The use of scaled-up LM batteries rather than fuel cells with their associated cryogenic storage tanks and valves is again the lowest risk approach available for providing electrical power. The all-aluminum structure is the lowest cost/lowest risk approach available. The short mission duration (34 hours) eliminates the need for multi-layer insulation (MLI) on most of the external surfaces there minimizing the risk of damage to the MLI during vehicle ground operations.

Since the 110A-1 does not have to communicate with payloads it has the the lowest risk communications equipment, a dedicated frequency station, to develop. Although our current approach includes making the communications equipment compatible with the NASA Tracking and Data Relay Satellite System (TDRSS) an option which can further reduce risk, is to eliminate the requirement for this equipment to meet the spread spectrum and CCIR interference requirements associated with TDRSS. The modifications of an existing IMU (the Carousel VB) and an existing computer (the CDC 469) are again the lowest risk approach identified in the GN&C and DMS areas.

Although the use of an apogee kick stage (AKS) to deploy heavier payloads reduces the sensitivity of the configuration to inert weight growth or I_{sp} loss, it does add complication to flight operations, increasing risk. Elimination of the AKS can further reduce the risk of this configuration.

R

110A-1 RISK ASSESSMENT

TECHNOLOGY ITEM	
TECHNOLOGY ITEM IMPACT	
• SPUN-FORM AL TANKS	+4 LB
• PFR TANK	+48 LB
• MATERIALS COMPATIBILITY	-32 LB
• FRACTURE MECHANICS	
• HEAT PIPES	+5 LB

VEHICLE SENSITIVITY (DEPLOY)	PLAIN	WITH AKS
$\frac{\partial P/L}{\partial W \text{ FIXED}}$ (LB/LB)	-3.83	-2.32
$\frac{\partial P/L}{\partial ISP}$ (LB/SEC)	117	90.2

EXTREMELY LOW RISK PROGRAM

I-19-2

- TECHNICAL RISK
  - POTENTIAL WT IMPACT: +57 LB ≈ 132 LB OF PAYLOAD (W/AKS)
  - POTENTIAL ISP LOSS: MIN WITH OME 7.5K ENG
  - USE OF AKS MINIMIZES VEHICLE SENSITIVITIES & RISK
  - OPEN WEIGHT REDUCTION OPTIONS: FUEL CELLS, GRAPHITE COMPOSITE
- SCHEDULE RISK
  - PROPOSED SR&T PROGRAMS (COMPLETED PRIOR TO ATP) PROTECT AGAINST SCHEDULE SLIP
- COST RISK
  - POTENTIAL Δ COST $15.3 M

110A-1 RISK ASSESSMENT

The technology items and their potential impact are shown on the opposite chart. If the spun-form aluminum tank does not meet its goals, a welded gore aluminum tank adds 4 lbs to the vehicle. Similarly if the prestressed filament reinforced (PFR) tank is replaced by a 6Al4V titanium tank, 48 lbs are added. If materials compatibility or fracture mechanics data indicate the need to change propellant tank material from aluminum to titanium a 32 lb weight reduction would be offset by a $10M cost increase. If heat pipes were replaced by adding louvers and electrical heaters a 5 lb weight increase would result. To recover the minor impact on payload capability due to these possible weight increases, fuel cells and graphite composites are open options.

The use of the OME 7.5K engine provides high confidence that the weight, performance and reusability goals will be met because the basic engine will have been developed for use in the Shuttle Orbiter. As a result there is no projected potential weight or Isp loss with this engine.

Schedule risk is minimized by the proposed SR&T programs which provide the feasibility of the approach 4 months prior to ATP.

Converting all of the potential weight increases to a total program cost at a $75K/lb value and adding the potential cost increase items, yields a total cost risk of $15.3M for 110A-1.

RISK ASSESSMENT 110A-1

BASELINE	ALTERNATIVE	WEIGHT LBS	TOTAL PROGRAM COST $M
SPUN ALUM TANKS	WELDED ALUM TANKS TITANIUM TANKS	+4 -32	+10.0
PFR TANKS (HELIUM)	6Al-4V TITANIUM	+48	+0.97
ALUM. TANK MATERIAL (COMPATIBILITY DATA & FRACTURE MECHANICS DATA	TITANIUM	(SEE ABOVE)	-
HEAT PIPES	LOUVERS & HEATERS	+5	NONE

SUMMING HIGHER WEIGHTS & COSTS ONLY ----- 57 LBS ----------$10.97M

CONVERT WEIGHT TO $ at $75K/LB --------(57 X 75 K)--------- 4.28

TOTAL COST RISK ---------- $15.25M

Section 8.10 Supporting Research and Technology

This section includes a summary matrix chart which identifies all of the SR & T items and where they are applied to each configuration in each capability option.

Following the summary matrix there are individual tables for each configuration which summarize the technology items for that particular configuration and give a very brief synopsis of the type of SR & T program proposed and the estimated funding and schedule requirements. The text following each table is the facing page text prepared for the main presentation.

Following the tables for each configuration, an additional form is filled out for each technology item providing status information, justification for the proposed SR & T program, objectives, technical approach, and a more detailed schedule showing when the proposed program must be completed in order to support the particular configuration.

In dealing with the subject of SR & T we have identified two distinct groups - one where technology is needed and the other where there is no doubt that the technology is available and it is a straightforward engineering task to accumulate data that will preclude making a "false start" where several alternates are under study; we have called the latter group "desired data".

The storable Tug will benefit from the fact that the APOLLO IM program has used similar materials, propellants, equipments and procedures; the Shuttle Orbiter will expand on this data base for the Tug. The low number of identified SR & T items and the modest sums projected are based on the assumption that several existing or planned efforts related to the Shuttle will continue to provide data. These include the planned propellant and materials compatibility testing in support of the Shuttle Orbital Maneuvering Subsystem, its engines, tanks and components both at NASA/WSTF and at the Shuttle contractor's facilities. In addition, we have identified the Air Force funded efforts to develop the advanced Micron IMU for aircraft programs, as an effort which we would build-on rather than to start from scratch.

We have not attempted to detail the SR & T programs required on the Class I engine (with or without the two position nozzle) except to point out the uncertainty associated with the anticipated engine life and the predicted performance of very high expansion ratios within the mixture ratio of interest. The engine contractor will provide the proposed SR & T efforts required on the engine and we will provide comments on same at NASA's request.

The overall "message" which we hope will become obvious to the reader is that there are no real "show-stoppers" among the SR & T items identified.

TECHNOLOGY REQUIREMENTS AND "DESIRED DATA"

		110-A1	410AD-2	310-3A 310RE-3A	320-3A 320AE-3A	310-3B 310ARE-3B	510A-3B 510ADE-3B
S R & T	CLASS I ENGINE, HIGH E PERF		X	X	X	X	
	TWO-POSITION NOZZLE				X		
	LASER RADAR		X	(X)	(X)	(X)	(X)
	PFR HELIUM TANK	X	X	X	X	X	X
	ADVANCED FUEL CELL				X		
	ADVANCED IMU		X	(X)	(X)	(X)	(X)
	GRAPHITE COMPOSITE		X	X	X	X	
	SPUN-FORM ALUM. TANKS	X					X
	LONG TERM SPACE STORABLE SRM		X				(X)
DESIRED DATA	MATERIALS COMPATIBILITY DATA	X	X	X	X	X	X
	FRACTURE MECHANICS DATA	X	X	X	X	X	X
	HEAT PIPE DATA	X	X	X	X	X	X

(X) REQUIRED PRIOR TO GO AHEAD ON EVOLVED TUG CONFIGURATIONS

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I-8.10-2

110A-1 TECHNOLOGY REQUIREMENTS & DESIRABLE DATA

	ITEM	SR&T FUNDS $K	SR&T SCHEDULE MOS.	PROPOSED PROGRAM
SR&T	SPUN-FORM ALUM TANKS	50	6	SPIN-FORM 5 FT. DIA, HEAT TREAT, SECTION & TEST SAMPLES
SR&T	PFR HELIUM TANKS	125	12	FAB & TEST 3 TANKS UNDER DYNAMIC & STATIC LOADING; AND ENVIRONMENTAL & COMPATIBILITY TESTS
DESIRABLE DATA	MATERIALS COMPATIBILITY DATA	25	6	6A14VT1; 2219-T87 & 2219T81; WITH N_2O_4 AND MMH UP TO 130°F
DESIRABLE DATA	FRACTURE MECHANICS DATA	25	6	6A14VT1; 2219-T87; Kic, Kth & FLAW GROWTH WITH N_2O_4 & MMH UP TO 130°F
DESIRABLE DATA	HEAT PIPES	100	12	FAB & TEST VARIABLE CONDUCTANCE HP RADIATOR PANEL & HEADER FOR TURN DOWN RATIO & SHUT OFF HEAT FLUX DATA

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TECHNOLOGY REQUIREMENTS AND DESIRED DATA - 110A-1

The upper part of the facing chart contains the supporting research and technology (SR&T) items required for 110A-1; the lower part of the chart contains what we have termed as "desired data". The distinction between the two is that the "desired data" items do not require technology but are considered straightforward engineering development tasks to produce design data prior to Tug program go-ahead (ATP); this will preclude impacting Tug schedules should the data indicate the desireability of an alternative approach, (vis., titanium propellant tanks rather than aluminum).

The total SR&T funds requested for 110A-1 is $325K to be expended over a 12 month period culminating 4 months prior to Tug ATP. The low funding request is consistent with the high percantage of existing state-of-the-art materials, equipment designs, and lubrication and testing procedures incorporated in 110A-1.

[illegible] 3A, 320A-3A/320AE-3A, 310-3B/310 ARE-3B, 510A-3B/510ADE-

STORABLE SPACE TUG SUPPORTING RESEARCH AND TECHNOLOGY - Main Propulsion (Discipline)

TITLE Prestressed Filament Reinforced (PFR) Tanks WBS No. 320-03-04-02

STATUS Structural Composites Industries, Inc. (SCI) and Arde-Portland, Inc. are under contract to LeRC to demonstrate the feasibility of the PFR tanks. This program will result in the construction of a 24 in. diam. Ardeform PFR tank of the type assumed by our study. If successful the basic technology will be proven.

JUSTIFICATION
A PFR ambient helium storage tank is comparable with the weight of a SHe tank and its associated heat exchanger. It provides a simple and less operationally complex system compared to the SHe tank. The PFR tank also provides a leak-before-burst design which results in increased Tug safety.

OBJECTIVES
Design, fabricate, and test 3 to 6 PFR tanks to demonstrate that current manufacturing and quality control techniques are adequate to produce a reliable, low weight tank suitable for containing gaseous helium (or hydrogen and oxygen in the case of fuel cell reactant tanks). The program will resemble a pre-qualification test program which will demonstrate the ability of the PFR tank to undergo the dynamic loading, compatibility, environmental exposure and etc. tests required for acceptance as a flight item.

TECHNICAL APPROACH

Fabricate 3 to 6 tanks and subject them to a pre-qualification test program to demonstrate the maturity of the design.

MANPOWER 2 man years FUNDING $125,000

SPECIALIZED FACILITIES
Available at tank manufacturers

TARGET SCHEDULE TASKS	MONTHS AFTER GO-AHEAD 1 2 3 4 5 6 7 8 9 10 11 12	13 14 15 16 17 18 19 20 21 22 23 24 25
Fabricate Tanks		
Test Program		
Analysis and Report		

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BRUNSMAN

ALL EXCEPT 410AD-2

STORABLE SPACE TUG SUPPORTING RESEARCH & TECHNOLOGY

DISCIPLINE MAIN PROPULSION (MPS) TITLE PRESTRESSED FILAMENT REINFORCED (PFR) TANKS WBS 320-03-04-02

TARGET SCHEDULE CY	1973	1974	1975	1976	1977	1978	1979
TUG ∅ C/D ATP MILESTONES			1980 TUG△		1982 TUG△		1984 TUG△
TASKS							
Fabricate Tanks							
Test Program							
Analysis and Report							

RESOURCE REQUIREMENTS FY	1974	1975	1976	1977	1978	1979	TOTAL
MANPOWER (MAN YEARS)	1	1					
FUNDING							
a) DIRECT LABOR	$ 38,000	$ 37,000					$ 75,000
b) EQUIPMENT & MAT'L	$ 30,000	$ 20,000					$ 50,000
c) FACILITIES							
d) OTHER (SPECIFY)							
TOTAL	$ 68,000	$ 57,000					$125,000

SPECIALIZED FACILITIES	
TYPE/LOCATION/AVAILABILITY	ARDE, SCI, or Similar
FACILITIES DEV. TIME & COST	None

110 A-1, 610 A-5B/610 ADE-3B

STORABLE SPACE TUG SUPPORTING RESEARCH AND TECHNOLOGY - STRUCTURES
(Discipline)

TITLE SPIN FORMING OF 2219-T 81 DOMES FOR TANKS

WBS No. 320-05-01-01-02

STATUS Hot technique of spin forming 2219 is feasible. However, the technique has not been demonstrated nor have design allowables been established.

JUSTIFICATION A weight savings can be achieved if 2219 aluminum alloy can be spun to achieve a temper of at least T81

OBJECTIVES To demonstrate a combination of hot and cold spin forming to achieve a minimum of T81 temper in 2219 spun domes

TECHNICAL APPROACH Small scale, approximately 5 foot domes will not be hot spun approximately to size. Domes will then be heat treated to the unstable "W" condition and spun cold to size to achieve a T-31 temper. After heat treatment to T81 scale domes will be sectioned for mechanical property evaluation and thickness control.

MANPOWER 3000 MHRS

FUNDING

SPECIALIZED FACILITIES NONE

TARGET SCHEDULE

MONTHS AFTER GO-AHEAD

TASKS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Spin Form Dome																									
Evaluate Mech. Properties and Thickness Control																									
Report																									

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I-8.10-7

110 A-1, 510 A-3B/510 ADE-3B

STORABLE SPACE TUG SUPPORTING RESEARCH & TECHNOLOGY

DISCIPLINE STRUCTURES TITLE SPIN FORMED 2219-T8 TANK DOMES WBS 520-03-01 = 01/02

TARGET SCHEDULE CY	1973	1974	1975	1976	1977	1978	1979
TUG ∅ C/D ATP MILESTONES			1980 TUG △		1982 TUG △		1984 TUG △
TASKS							
○ HOT SPIN FORM 8 FT DIA. DOMES TO APPROX SIZE							
○ HEAT TREAT TO "W" COND							
○ SPIN FORM COLD TO SIZE TO T-31 TEMPER							
○ HEAT TREAT TO T-81							
○ SECTION TANK TO OBTAIN MATERIAL PROP. & THICKNESSES							

RESOURCE REQUIREMENTS FY	1974	1975	1976	1977	1978	1979	TOTAL
MANPOWER (MAN YEARS) 1 ½ MAN YEARS							
FUNDING							
a) DIRECT LABOR							
b) EQUIPMENT & MAT'L							
c) FACILITIES							
d) OTHER (SPECIFY)							
TOTAL							

SPECIALIZED FACILITIES
TYPE/LOCATION/AVAILABILITY
FACILITIES DEV. TIME & COST

NONE

ALL TUG VEHICLES

STORABLE SPACE TUG SUPPORTING RESEARCH AND TECHNOLOGY - Structures
(Discipline)

TITLE Material Compatibility

WBS No. 320-03-01-01

STATUS Material compatibility of Ti-6AL-4V STA and 2219-T87 Aluminum alloy in the presence of MMH at temperatures up to 150°F is required. Compatibility of N_2O_4 with 2219-T87 is also required.

JUSTIFICATION Compatibility of propellants with tankage material must be assessed to obtain the reuse life of the tanks under cyclic loads.

OBJECTIVES The objective of the program is to obtain the static and fatigue properties of the tankage parent and weldment materials under cyclic exposure to propellants and load.

I-8.10-4

TECHNICAL APPROACH Static and fatigue properties of candidate materials specimens will be obtained prior to and after exposure to the propellants. Tests will be performed at R.T. and 150°F.

MANPOWER One man-year

FUNDING $ 25 K

SPECIALIZED FACILITIES

TARGET SCHEDULE TASKS	MONTHS AFTER GO-AHEAD 1 2 3 4 5 6 7 8 9 10 11 12	13 14 15 16 17 18 19 20 21 22 23 24 25
Test Plan		
Spec. Fab.		
Test		
Report		

ALL TUG VEHICLES

STORABLE SPACE TUG SUPPORTING RESEARCH & TECHNOLOGY

DISCIPLINE STRUCTURES TITLE MATERIALS COMPATIBILITY DATA WBS 320-03-01

TARGET SCHEDULE CY	1973	1974	1975	1976	1977	1978	1979
TUG Ø C/D ATP MILESTONES			1980 TUG △		1982 TUG △		1984 TUG △
TASKS							
• FABRICATE & TEST MATERIAL SPECIMENS OF PARENT MAT'L & WELDMENTS TO OBTAIN COMPATIBILITY DATA FOR N_2O_4 & MMH UP TO 200°F. MATERIALS 6AL-4V, 2219-T87 & T-81							

RESOURCE REQUIREMENTS FY	1974	1975	1976	1977	1978	1979	TOTAL
MANPOWER (MAN YEARS) ONE MANYEAR							
FUNDING							
a) DIRECT LABOR							
b) EQUIPMENT & MAT'L							
c) FACILITIES							
d) OTHER (SPECIFY)							
TOTAL							

SPECIALIZED FACILITIES

TYPE/LOCATION/AVAILABILITY

FACILITIES DEV. TIME & COST

ALL TUG VEHICLES

STORABLE SPACE TUG SUBSYSTEM TECHNOLOGY - Structure
(Discipline)

TITLE Fracture Mechanics Test Data

WBS No. 326-03-01-01-02

STATUS Fracture mechanics test data for thin gage (.020 to .040) for Titanium 6AL-4V STA and 2219-T87 aluminum alloy exposed to N_2O_4 and MMH at temperatures up to 200°F is not available.

JUSTIFICATION Fracture mechanics data for thin gage tank material are required to assess the fracture mode and life cycle of the tug propellant tanks.

OBJECTIVES The objectives of the program are to obtain K_{ic}, K_{th} and flaw growth data for parent and weldment materials in the induced thermal environment up to 200°F. Data to be obtained prior to and after exposure to the candidate propellants. In addition to fracture mechanics data, NDE techniques are to be employed on the test specimens to assess flaw detection capability.

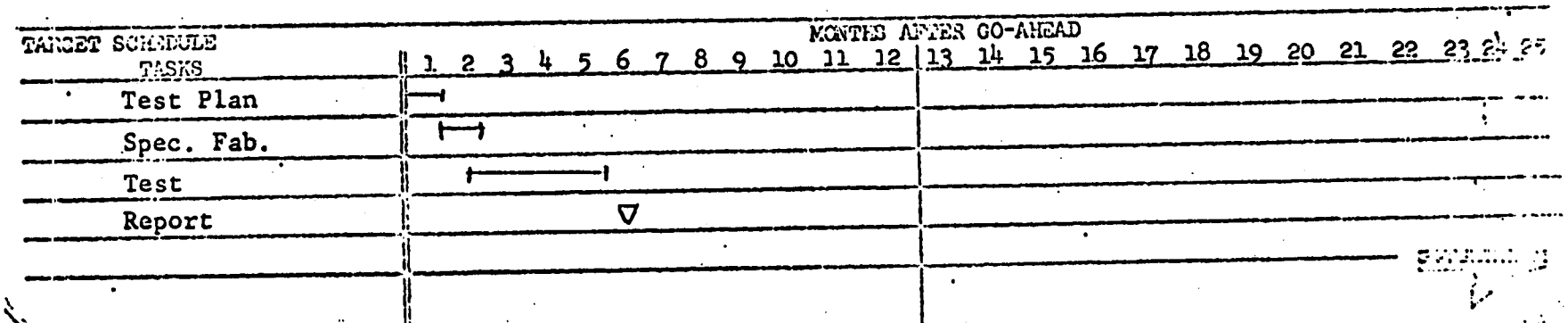
I-8-10-11

TECHNICAL APPROACH Standard fracture elemental specimens are to be employed. Tests are to be employed. Tests are to be conducted at room temperature and at 150 and 200°F. Surface flaws of various sizes are to be used and NDE techniques are to be employed to document size where practical.

MANPOWER One man-year

FUNDING $25K

SPECIALIZED FACILITIES



ALL TUG VEHICLES

STORABLE SPACE TUG SUPPORTING RESEARCH & TECHNOLOGY

DISCIPLINE STRUCTURES TITLE FRACTURE MECHANICS DATA WBS 320-03-01 = 01 02

TARGET SCHEDULE CY	1973	1974	1975	1976	1977	1978	1979
TUG Ø C/D ATP MILESTONES			1980 TUG △		1982 TUG △		1981 TUG △
TASKS							
o FABRICATE & TEST MAT'L SPECIMENS (Parent metal & weldments) to obtain K_{IC} K_{TH} & FLAW GROWTH DATA FOR INDUCED ENVIRONMENTS INCL. 200°F. ALSO STATIC & FATIGUE DATA. MAT'LS 6AL-4V & 2219-T87 & T81							

RESOURCE REQUIREMENTS FY	1974	1975	1976	1977	1978	1979	TOTAL
MANPOWER (MAN YEARS)							
ONE MAN YEAR							
FUNDING							
a) DIRECT LABOR							
b) EQUIPMENT & MAT'L							
c) FACILITIES							
d) OTHER (SPECIFY)							
TOTAL							

SPECIALIZED FACILITIES

TYPE/LOCATION/AVAILABILITY

FACILITIES DEV. TIME & COST

I-8.10-12

110A-1, 410AD-2, 310-3A/310RE-3A, 320A-3A/320AE-3A, 310-3B/310ARE-3B, 610A-3B/610ADE-3B

STORABLE SPACE TUG SUPPORTING RESEARCH AND TECHNOLOGY - Thermal Control
(Discipline)

TITLE: SPACE TUG HEAT PIPES

WBS No. 320-04-02

STATUS: Heat pipes (HP) are currently being used in both ground and space application. The variable conductance heat pipe (VCHP) principle is particularly attractive for Tug application but requires further development.

JUSTIFICATION: The fuel cell and certain high power density avionics units carried on the Space Tug require active cooling. Trade studies which have examined pumped loop radiators, sublimators and various heat pipes have indicated the obvious merits of the variable conductance heat pipe. A VCHP radiator could interface with the pumped loop heat transport system of the fuel cell, eliminating the cost and complexity of a selective stagnation radiator with its associated unreliable automatic bypass valves. A VCHP header, a heat transport device, could provide for high power density avionics heat transport without recourse to the active loop.

I-8.10-13

OBJECTIVES: Emphasis will be placed on experimentally obtaining the large turn down ratios which appear theoretically achievable and in developing predictive techniques.

TECHNICAL APPROACH: Design, fabricate and test a VCHP radiator and VCHP header and experimentally determine performance with emphasis on turn down ratio and shut off heat flux levels.

MANPOWER: 5580 manhours

FUNDING: $100K

SPECIALIZED FACILITIES: Grumman Thermal Laboratory

TARGET SCHEDULE

TASKS	MONTHS AFTER GO-AHEAD 1 2 3 4 5 6 7 8 9 10 11 12	13 14 15 16 17 18 19 20 21 22 23 24 25
Establish Test Plan	-	
Material Procurement	-	
Design & Fab Test Specimens	———	
Conduct Engineering Tests	———	
Analyse Test Results	———	
Final Report		

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STORABLE SPACE TUG SUPPORTING RESEARCH & TECHNOLOGY

DISCIPLINE _____ TITLE _____ WBS _____

TARGET SCHEDULE CY	1973	1974	1975	1976	1977	1978	1979
TUG Ø C/D ATP MILESTONES			1980 TUG △		1982 TUG △		1984 TUG △
TASKS							
TEST PLAN							
DESIGN & FAB TEST SPECIMEN							
CONDUCT TEST							
ANALYSIS & FINAL RPT							

RESOURCE REQUIREMENTS FY	1974	1975	1976	1977	1978	1979	TOTAL
MANPOWER (MAN YEARS)	1.5	1.5					
FUNDING							
a) DIRECT LABOR							
b) EQUIPMENT & MAT'L	100K						
c) FACILITIES							
d) OTHER (SPECIFY)							
TOTAL							

SPECIALIZED FACILITIES TYPE/LOCATION/AVAILABILITY FACILITIES DEV. TIME & COST: GRUMMAN THERMAL LAB, BETHPAGE N.Y., AVAILABLE & FULLY DEVELOPED

I-8.10-14

8.11 SPECIAL COST SENSITIVITIES

8.11.1 AUTONOMY

8.11.2 0.97 RELIABILITY/REDUNDANCY ANALYSIS

8.11.3 30-DAY MISSION

8.11.4 DOD COMMUNICATION REQUIREMENTS

8.11.5 PAYLOAD COMMAND CONTROL AND CHECKOUT

8.11.6 ELECTRICAL POWER TO PAYLOADS

8.11.7 DESIGN LIFE

8.11.8 SPIN STABILIZED PAYLOAD RETRIEVAL

8.11.9 RENDEZVOUS AND DOCKING

8.11.10 NESTED DOME VS. SEPARATE TANK

8.11.11 IN-FLIGHT PROPELLANT DUMP

8.11.12 MAIN ENGINE SENSITIVITY

8.11.13 USE OF RDM IN OPTION TWO

8.11.14 SENSITIVITY TASK RESULTS SUMMARY

8.11.1- Ground/Onboard Autonomy Trade Study

The results of our autonomy trade study is presented in Figure 1 and concludes the following:

- Autonomy level IV is best suited to Option 1 concept 110A-1
- Autonomy level II is best suited for Options 2 and 3 where Option 3 starts with level III and evolves to level II.

The level I systems degraded performance resulting from the slow convergence characteristics of the Horizon Scanner/Star Tracker system makes this system unattractive. Our performance studies to date on this level I system have been preliminary in nature and we recommend that NASA and DOD initiate SR&T studies which combine a detail navigation analysis with a complete vehicle performance evaluation.

The level II system selected in our baselines requires the use of the 621B NAV SAT. This introduces significant schedule risk and technology issues. This NAV SAT system has sufficient coverage for spacecraft below 2000 N.M., introducing as a result the need for dedicated ground beacons (1-way doppler) for high altitude TUG operations. It is recommended that the interferometer approach which utilizes undedicated RF sources as landmarks be considered as an option.

The level III system is a compromise approach. It introduces high development and operating cost for software for both the ground and on-board computer systems.

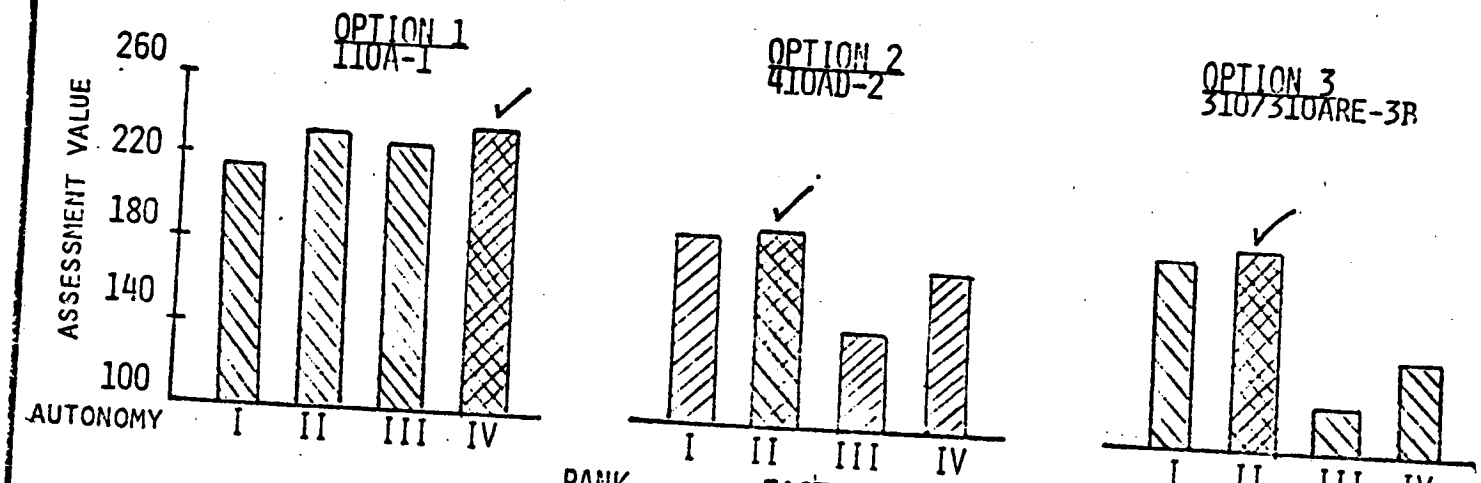
The level IV system is attractive for Option I due to low development costs. The high ground involvement and costs precludes the use of this approach for the more complex Option 2 and 3 programs.

Figure 2 summarizes the cost sensitivities for the three concepts evaluated. Figure 3 outlines the weights and performance. Figures 4 thru 5 lists the weights, DDT&E costs and production costs of the avionics systems used in the sensitivity evaluation.

FIG 1

AUTONOMY SENSITIVITY STUDY

- 0 LEVEL I — PERFORMANCE PENALTIES HIGHEST
- 0 LEVEL II — MOST ATTRACTIVE FOR OPTIONS 2 AND 3
  - RECOMMEND EVAL. OF INTERFEROMETER SYSTEM
- 0 LEVEL III — A COMPROMISE SYSTEM WITH HIGH COST GROUND & ONBOARD SOFTWARE
- 0 LEVEL IV — MOST ATTRACTIVE FOR LOW DDT & E OPTION 1



RANK	FACTORS	WT.
1	DDT & E	10
2	COST/FLT	8
3	COMPLEXITY	6
4	PERFORMANCE	5
5	TOTAL $	4
6	TECH. RISK	4
7	SCHED. RISK	3
8	SHUTTLE COMPT	1

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Fig. -2

AUTONOMY SENSITIVITY STUDY

DELTA COSTS - $M

OPTION	1				2				3			
CONCEPT	110A-1				410AD-2				310/310ARE-3B			
AUTONOMY LEVEL	I	II	III*	IV	I	II*	III	IV	I	II*	III	IV
DDT & E												
o Avionics	3.0	1.5	-	-1.3	1.5	-	-1.5	-11.0	1.5	-	-1.5	-11.0
o Flt OPS	-3.1	-3.1	-	-3.1	-	-	+6.9	1.7	-	-	6.9	+ 1.7
SUB TOTAL	- .1	-2.6	-	-4.4	1.5	-	5.4	-9.3	1.5	-	5.4	-9.3
PRODUCTION												
o Avionics	5.0	1.6	-	-0.8	3.1	-	-3.5	-11.0	4.5		-5.1	-16.0
OPERATIONS												
o Flt OPS	-34.0	-34.0	-	9.5	-	-	45.0	58.0	-	-	65.2	87.6
TOTAL Δ PROGRAM	-29.1	-35.0	-	4.3	4.6	-	46.9	37.7	6.0	-	65.5	62.3

* BASELINE

Fig. 3 AUTONOMY SENSITIVITY STUDY-WEIGHT & PERFORMANCE

OPTION	1				2				3			
CONCEPT	110A-1				410AD-2				310/310ARE-3B			
AUTONOMY LEVEL	I	II	III*	IV	I	II*	III	IV	I	II*	III	IV
WEIGHTS (LBS)												
o Structure	1294	1294	1294	1294	1269	1269	1269	1269	1267	1267	1267	1267
o Thermal	77	77	77	77	69	69	69	69	69	69	69	69
o Astrionics	693	657	596	573	839	801	743	685	839	801	743	685
o Propulsion	734	734	734	734	737	737	737	737	738	738	738	738
DRY WT.	2798	2762	2701	2678	2914	2876	2818	2760	2913	2881	2817	2759
o Contingency	280	276	270	268	291	288	282	276	291	288	282	276
DRY WT. + CONT.	3078	3038	2971	2946	3205	3164	3100	3036	3204	3169	3099	3035
o Non-Usable	234	234	234	234	247	247	247	247	247	247	247	247
FIXED WEIGHT	3312	3272	3205	3180	3452	3411	3347	3283	3451	3416	3346	3282
δ DELTA-V(fps)												
o Outbound	360	-30	0	0	390	0	30	30	390	0	30	30
o Inbound	105	0	0	0	105	0	0	0	105	0	0	0
PERFORMANCE												
o Deploy	2905	3805	4014	4111	4013	4914	5100	5466	3962	4841	5049	5292
o Retr'v.	-	-	-	-	1210	1574	1641	1780	1187	1543	1621	1709
o Rnd. Trip	-	-	-	-	821	1080	1132	1256	801	1054	1111	1175
o Deploy with AKS	7312	8099	8207	8265	5203	6021	6143	6409	-	-	-	-

* BASELINE

Fig. 4 - AUTONOMY SENSITIVITY STUDY - ASTRIONICS LIST

OPTION 1 ; CONCEPT 110A-1 DATE 8/31/73

SUBSYSTEM o Component	AUTONOMY LEVEL I # UNITS	TOT'L WT(LBS)	DDT&E ($M)	PROD. ($M)	AUTONOMY LEVEL II # UNITS	TOT'L WT.(LBS)	DDT&E ($M)	PROD. ($M)	AUTONOMY LEVEL III # UNITS	TOT'L WT.(LBS)	DDT&E ($M)	PROD ($M)	AUTONOMY LEVEL IV # UNITS	TOT'L WT.(LBS)	DDT&E ($M)	PROD. ($M)
GN&C																
o IMU	1	45	2.00	.532	1	45	2.00	.532	1	45	2.00	.532	1	45	2.00	.532
o Star Tracker	1	17	1.16	.245	1	17	1.16	.245	1	17	1.16	.245	1	17	1.16	.245
o APS Cont'l Elect.	2	36	3.40	.450	2	36	3.40	.450	2	36	3.40	.450	2	36	3.40	.450
o ME/TVC Cont'l Elect.	1	10	3.40	.450	1	10	3.40	.450	1	10	3.40	.450	1	10	3.40	.450
o Rate Gyro Assembly	1	5	0.40	.061	1	5	0.40	.061	1	5	0.40	.061	1	5	0.40	.061
o Horizon Tracker	1	425	1.72	.217												
o Satellite Rec'vr					1	37	1.00	.05								
o Doppler Rec'vr					1	8	)									
o L-Band Antenna					4	0.3	)0.5	.03								
o Combiner/Doppler Detect.					1	6	)									
		(156)	(12.08)	(1.955)		(164)	(11.86)	(1.818)		(113)	(10.36)	(1.738)		(113)	(10.36)	(1.738)
DMS																
o Computer	2	30	0.60	.500	2	30	0.60	.500	2	26	0.60	.500	2	22	0.60	.500
o Mass Memory	1	19	1.30	.070												
o Tape Recorder	1	14.5	1.30	.080	1	14.5	1.30	.080	1	14.5	1.30	.080				

Fig. 4 AUTONOMY SENSITIVITY STUDY - ASTRIONICS LIST (CONT.)

OPTION 1 ; CONCEPT 110A-1 DATE 8/31/73

SUBSYSTEM o Component	AUTONOMY LEVEL I # UNITS	AUTONOMY LEVEL I TOT'L WT(LBS)	AUTONOMY LEVEL I DDT&E ($M)	AUTONOMY LEVEL I PROD. ($M)	AUTONOMY LEVEL II # UNITS	AUTONOMY LEVEL II TOT'L WT.(LBS)	AUTONOMY LEVEL II DDT&E ($M)	AUTONOMY LEVEL II PROD. ($M)	AUTONOMY LEVEL III # UNITS	AUTONOMY LEVEL III TOT'L WT.(LBS)	AUTONOMY LEVEL III DDT&E ($M)	AUTONOMY LEVEL III PROD ($M)	AUTONOMY LEVEL IV # UNITS	AUTONOMY LEVEL IV TOT'L WT.(LBS)	AUTONOMY LEVEL IV DDT&E ($M)	AUTONOMY LEVEL IV PROD. ($M)
DMS (CONT)																
o FSI Controller/TLM Formater	1	18	2.8	.080	1	18	2.8	.080	1	18	2.8	.080	1	18	2.8	.080
o DACU's	4	28	1.2	.880	3	21	1.2	.660	3	21	1.2	.660	3	21	1.2	.660
o Sensors	200	40	0.6	.100	190	38	0.6	.100	180	36	0.6	.100	18	36	0.6	.100
		(149.5)	(7.8)	(1.71)		(121.5)	(6.5)	(1.42)		(115.5)	(6.5)	(1.42)		(97)	(5.2)	(1.34)
COMM																
o R'CUR (4)		5	0.8	.120	1	5	0.8	.120	1	5	0.8	.120	1	5	0.8	.120
X'MTR (1)	1	16				16				16				16		
o Aux X'MTR	1	5	0	.002	1	5	0	.002	1	5	0	.002	1	5	0	.002
o Power Ampl	2	2	0.15	.012	2	2	0.15	.012	2	2	0.15	.012	2	2	0.15	.012
o Diplexer	2	2	0.02	.002	2	2	0.02	.002	2	2	0.02	.002	2	2	0.02	.002
o Antenna Switch	1	1	0.03	.005	1	1	0.03	.005	1	1	0.03	.005	1	1	0.03	.005
o Base Band Processor	1	3	4.50	.190	1	3	4.50	.190	1	3	4.50	.190	1	3	4.50	.190
o OMNI Ant.	2	1	0.120	.006	2	1	0.120	.006	2	1	0.120	.006	2	1	0.120	.006
		(35)	(5.62)	(.34)		(35)	(5.62)	(.34)		(35)	(5.62)	(.34)		(35)	(5.62)	(.34)

Fig. 4. AUTONOMY SENSITIVITY STUDY - ASTRIONICS LIST (CONT.)

OPTION 1 ; CONCEPT 110A-1 DATE 8/31/73

SUBSYSTEM o Component	AUTONOMY LEVEL I				AUTONOMY LEVEL II				AUTONOMY LEVEL III				AUTONOMY LEVEL IV			
	# UNITS	TOT'L WT(LBS)	DDT&E ($M)	PROD. ($M)	# UNITS	TOT'L WT.(LBS)	DDT&E ($M)	PROD. ($M)	# UNITS	TOT'L WT.(LBS)	DDT&E ($M)	PROD ($M)	# UNITS	TOT'L WT.(LBS)	DDT&E ($M)	PROD. ($M)
EPS																
o Primary Battery	1	201	1.36	.015	1	184	1.36	.015	1	180	1.36	.015	1	176	1.36	.015
o Emerg. Battery	1	10	0.35	.003	1	10	0.35	.003	1	10	0.35	.003	1	10	0.35	.003
o Vehicle Wiring		50				50				50				50		
o Connectors		30	1.06	.190		30	1.06	.190		30	1.06	.190		30	1.06	.190
o Saundries		16				16				16				16		
o Solid State Power Cont'r		18	0.05	.009		18	0.05	.009		18	0.05	.009		18	0.05	.009
o Electro-Mech RCCB		6				6				6				6		
		(331)	(2.82)	(.217)		(314)	(2.82)	(.217)		(310)	(2.82)	(.217)		(306)	(2.82)	(.217)
TOTAL WT.		(653)				(616.8)				(556)				(533)		
TOTAL DDT&E			(28.3)				(26.8)				(25.3)				(24.0)	
Fleet Size = 11 Total Production				(42.2)				(38.8)				(37.2)				(36.4)

I-B.11.1-7

Fig. 5 AUTONOMY SENSITIVITY STUDY - ASTRIONICS LIST

OPTION 2 ; CONCEPT 410 AD-1 DATE 8/31/73

SUBSYSTEM / o Component	AUTONOMY LEVEL I				AUTONOMY LEVEL II				AUTONOMY LEVEL III				AUTONOMY LEVEL IV			
	# UNITS	TOT'L WT(LBS)	DDT&E ($M)	PROD. ($M)	# UNITS	TOT'L WT.(LBS)	DDT&E ($M)	PROD. ($M)	# UNITS	TOT'L WT.(LBS)	DDT&E ($M)	PROD ($M)	# UNITS	TOT'L WT.(LBS)	DDT&E ($M)	PROD. ($M)
GN&C																
o IMU (Micron)	2	20	6.60	.600	2	20	6.60	.600	2	20	6.60	.600	2	20	6.60	.600
o Star Tracker	2	34	1.16	.480	2	34	1.16	.480	1	17	1.16	.240	1	17	1.16	.240
o APS Cont'l Elect.	2	36	3.40	.880	2	36	3.40	.880	2	36	3.40	.880	2	36	3.40	.880
o ME/TVC Cont'l Elect.	1	10	3.40	.440	1	10	3.40	.440	1	10	3.40	.440	1	10	3.40	.440
o Horizon Tracker	1	42.5	1.72	.217												
o Satellite Receiver					1	37	1.00	.05								
o Doppler Receiver					1	8	0.50	.03								
o L-Band Antenna					4	1.2										
o Combiner/Doppler Detect.					1	6										
o Laser Radar	1	40	8.20	.600	1	40	8.20	.600	1	40	8.20	.600				
		(182.5)	(24.48)	(3.22)		(192.2)	(24.26)	(3.08)		(123)	(22.76)	(2.76)		(83.0)	(14.56)	(2.16)
DMS																
o Computer	2	30	0.6	.600	2	30	0.6	.600	2	26	0.6	.600	2	22	0.6	.600
o Mass Memory	2	38	1.3	.140												
o Tape Recorder	1	14.5	1.3	.08	1	14.5	1.3	.08								
o FSI Controller/ TLM Formater	1	18	2.8	.08	1	18	2.8	.08	1	14.5	1.3	.08				
o Dacus	4	28	1.2	.88	3	21	1.2	.88	3	21	1.2	.88	3	21	1.2	.88
o Sensors		40	0.6	.105		38	0.6	.105		36	0.6	.105		36	0.6	.105
		(168.5)	(7.8)	(1.89)		(121.5)	(6.5)	(1.75)		(115.5)	(6.5)	(1.75)		(97)	(52)	(1.67)

Fig. 5 AUTONOMY SENSITIVITY STUDY - ASTRIONICS LIST (CONT.)

OPTION 2 ; CONCEPT 410ADE-2 DATE 8/31/73

SUBSYSTEM / o Component	AUTONOMY LEVEL I				AUTONOMY LEVEL II				AUTONOMY LEVEL III				AUTONOMY LEVEL IV			
	# UNITS	TOT'L WT(LBS)	DDT&E ($M)	PROD. ($M)	# UNITS	TOT'L WT.(LBS)	DDT&E ($M)	PROD. ($M)	# UNITS	TOT'L WT.(LBS)	DDT&E ($M)	PROD ($M)	# UNITS	TOT'L WT.(LBS)	DDT&E ($M)	PROD. ($M)
COMM																
o R'cvr	1	8	1.29	.11	1	8	1.29	.11	1	8	1.29	.11	1	8	1.29	.11
o X'mtr	1	5			1	5			1	5			1	5		
o R'cvr	1	16	.81	.12	1	16	.81	.12	1	16	.81	.12	1	16	.81	.12
o X'mtr	1	5			1	5			1	5			1	5		
o Aux' X'mtr	1	5	-	.001	1	5	-	.001	1	5	-	.001	1	5	-	.001
o Power Amp 1	1	1	.150	.005	1	1	.150	.005	1	1	.150	.005	1	1	.150	.005
o Power Amp 2	1	3	-	.005	1	3	-	.005	1	3	-	.005	1	3	-	.005
o Baseband Processor	1	6	4.5	.182	1	6	4.5	.182	1	6	4.5	.182	1	6	4.5	.182
o Diplexer 1	2	2	.02	.002	2	2	.02	.002	2	2	.02	.002	2	2	.02	.002
o Diplexer 2	2	2	.02	.002	2	2	.02	.002	2	2	.02	.002	2	2	.02	.002
o Antenna Switch 1	2	2	.03	.010	2	2	.03	.010	2	2	.03	.010	2	2	.03	.010
o Antenna Switch 2	2	2	-	.010	2	2	-	.010	2	2	-	.010	2	2	-	.010
o Antenna	2	1	.12	.004	2	1	.12	.004	2	1	.12	.004	2	1	.12	.004
o Antenna	2	1	-	.004	2	1	-	.004	2	1	-	.004	2	1	-	.004
o Power Splitter	1	1	.02	.002	1	1	.02	.002	1	1	.02	.002	1	1	.02	.002
o TV Assembly	1	12	1.05	.150	1	12	1.05	.150	1	12	1.05	.150	1	12	1.05	.150
		(72)	(8.01)	(.607)		(72)	(8.01)	(.607)		(72)	(8.01)	(.607)		(72)	(8.01)	(.607)

Fig. 5 AUTONOMY SENSITIVITY STUDY - ASTRIONICS LIST (CONT.)

OPTION 2 ; CONCEPT 410 AD-1 DATE 8/31/73

SUBSYSTEM / o Component	AUTONOMY LEVEL I # UNITS	AUTONOMY LEVEL I TOT'L WT(LBS)	AUTONOMY LEVEL I DDT&E ($M)	AUTONOMY LEVEL I PROD. ($M)	AUTONOMY LEVEL II # UNITS	AUTONOMY LEVEL II TOT'L WT.(LBS)	AUTONOMY LEVEL II DDT&E ($M)	AUTONOMY LEVEL II PROD. ($M)	AUTONOMY LEVEL III # UNITS	AUTONOMY LEVEL III TOT'L WT.(LBS)	AUTONOMY LEVEL III DDT&E ($M)	AUTONOMY LEVEL III PROD ($M)	AUTONOMY LEVEL IV # UNITS	AUTONOMY LEVEL IV TOT'L WT.(LBS)	AUTONOMY LEVEL IV DDT&E ($M)	AUTONOMY LEVEL IV PROD. ($M)
EPS																
o Modified Fuel Cell	1	90	3.50	.147	1	90	3.50	.147	1	90	3.50	.147	1	90	3.50	.147
o Emergency Battery	1	15	0.35	.003	1	15	0.35	.003	1	15	0.35	.003		15	0.35	.003
o Re'Actant Storage									1	66			1	66		
o Cryo Hydrogen Tank Assy.	1	66	11.5	.314	1	66	11.5	.314			11.5	.314			11.5	.314
o Cryo Ox Tank Assy	1	68			1	68			1	68			1	68		
o Vehicle Wiring		55	1.140	.202		55	1.140	.202		55	1.140	.202		55	1.140	.202
o Connectors		30				30				30				30		
o Sundries		20				20				20				20		
o Solid State Pwr. Control		21	.50	.01		21	.50	.01		21	.50	.01		21	.50	.01
o Electro-Mech RccB		9				9				9				9		
		(374)	(16.99)	(.676)		(374)	(16.99)	(.676)		(374)	(16.99)	(.676)		(374)	(16.99)	(.676)
TOTAL		(797)				(759)				(684)				(626)		
TOTAL DDT&E			(57.28)				(55.76)				(54.26)				(44.76)	
FLEET SIZE = 11 PRODUCTION $				(70.29)				(67.21)				(63.69)				(56.21)

I-8.11.1-10

Fig. 6 AUTONOMY SENSITIVITY STUDY - ASTRIONICS LIST

OPTION 3 ; CONCEPT 310 ARE-1 DATE 8/31/73

SUBSYSTEM o Component	AUTONOMY LEVEL I # UNITS	AUTONOMY LEVEL I TOT'L WT(LBS)	AUTONOMY LEVEL I DDT&E ($M)	AUTONOMY LEVEL I PROD. ($M)	AUTONOMY LEVEL II # UNITS	AUTONOMY LEVEL II TOT'L WT.(LBS)	AUTONOMY LEVEL II DDT&E ($M)	AUTONOMY LEVEL II PROD. ($M)	AUTONOMY LEVEL III # UNITS	AUTONOMY LEVEL III TOT'L WT.(LBS)	AUTONOMY LEVEL III DDT&E ($M)	AUTONOMY LEVEL III PROD ($M)	AUTONOMY LEVEL IV # UNITS	AUTONOMY LEVEL IV TOT'L WT.(LBS)	AUTONOMY LEVEL IV DDT&E ($M)	AUTONOMY LEVEL IV PROD. ($M)
GN&C																
o IMU	2	20	6.60	.600	2	20	6.60	.600	2	20	6.60	.600	2	20	6.60	.600
o Star Tracker	2	34	1.16	.480	2	34	1.16	.480	2	34	1.16	.480	2	34	1.16	.480
o APS Cont'l Elect.	2	36	3.40	.880	2	36	3.40	.880	2	36	3.40	.880	2	36	3.40	.880
o ME/TVC Cont'l Elect.	1	10	3.40	.440	1	10	3.40	.440	1	10	3.40	.440	1	10	3.40	.440
o Horizon Tracker	1	42.5	1.72	.217												
o Satellite Rec'vr					1	37	1.00	.05								
o Doppler Rec'vr					1	8	.50	.03								
o L-Band Antenna					4	1.2										
o Combiner/Doppler Detect.					1	6										
o Laser Radar	1	40	8.20	.600	1	40	8.20	.600	1	40	8.20	.600				
		(182.5)	(24.48)	(3.22)		(192.2)	(24.26)	(3.08)		(123)	(22.76)	(3.00)		(83.0)	(14.56)	(2.40)
DMS																
o Computer	2	30	.6	.600	2	30	.6	.600	2	26	.6	.600	2	22	.6	.600
o Mass Memory	2	38	1.3	.140												
o Tape Recorder	1	14.5	1.3	.080	1	14.5	1.3	.080	1	14.5	1.3	.080				
o FSI Controller/ TLM Formater	1	18	2.8	.080	1	18	2.8	.080	1	18	2.8	.080	1	18	2.8	.080
o Dacus	4	28	1.2	.880	3	21	1.2	.880	3	21	1.2	.880	3	21	1.2	.880
o Sensors		40	.6	.105		38	.6	.105		36	.6	.105		36	.6	.105
		(168.5)	(7.8)	(1.89)		(121.5)	(6.5)	(1.75)		(115.5)	(6.5)	(1.75)		(97)	(5.2)	(1.67)

Fig. 6 AUTONOMY SENSITIVITY STUDY - ASTRIONICS LIST (CONT.)

OPTION 3 ; CONCEPT 310 ARE-1 DATE 8/31/73

SUBSYSTEM o Component	AUTONOMY LEVEL I # UNITS	TOT'L WT(LBS)	DDT&E ($M)	PROD. ($M)	AUTONOMY LEVEL II # UNITS	TOT'L WT.(LBS)	DDT&E ($M)	PROD. ($M)	AUTONOMY LEVEL III # UNITS	TOT'L WT.(LBS)	DDT&E ($M)	PROD ($M)	AUTONOMY LEVEL IV # UNITS	TOT'L WT.(LBS)	DDT&E ($M)	PROD. ($M)
COMM																
o R'cvr	1	8	1.29	.11	1	8	1.29	.11	1	8	1.29	.11	1	8	1.29	.11
o X'mtr	1	5			1	5			1	5			1	5		
o R'cvr	1	16	.81	.12	1	16	.81	.12	1	16	.81	.12	1	16	.81	.12
o X'mtr	1	5			1	5			1	5			1	5		
o Aux' X'mtr	1	5	-	.001	1	5	-	.001	1	5	-	.001	1	5	-	.001
o Power Amp 1	1	1	.150	.005	1	1	.150	.005	1	1	.150	.005	1	1	.150	.005
o Power Amp 2	1	3	-	.005	1	3	-	.005	1	3	-	.005	1	3	-	.005
o Baseband Processor	1	6	4.5	.182	1	6	4.5	.182	1	6	4.5	.182	1	6	4.5	.182
o Diplexer 1	2	2	.02	.002	2	2	.02	.002	2	2	.02	.002	2	2	.02	.002
o Diplexer 2	2	2	.02	.002	2	2	.02	.002	2	2	.02	.002	2	2	.02	.002
o Antenna Switch 1	2	2	.03	.010	2	2	.03	.010	2	2	.03	.010	2	2	.03	.010
o Antenna Switch 2	2	2	-	.010	2	2	-	.010	2	2	-	.010	2	2	-	.010
o Antenna	2	1	.12	.004	2	1	.12	.004	2	1	.12	.004	2	1	.12	.004
o Antenna	2	1	-	.004	2	1	-	.004	2	1	-	.004	2	1	-	.004
o Power Splitter	1	1	.02	.002	1	1	.02	.002	1	1	.02	.002	1	1	.02	.002
o TV Assembly	1	12	1.05	.150	1	12	1.05	.150	1	12	1.05	.150	1	12	1.05	.150
		(72)	(8.01)	(.607)		(72)	(8.01)	(.607)		(72)	(8.01)	(.607)		(72)	(8.01)	(.607)

I-8.11.1-12

Fig. 6 AUTONOMY SENSITIVITY STUDY - ASTRIONICS LIST (CONT.)

OPTION 3 ; CONCEPT 310 ARE-1 DATE 8/31/73

SUBSYSTEM / o Component	AUTONOMY LEVEL I				AUTONOMY LEVEL II				AUTONOMY LEVEL III				AUTONOMY LEVEL IV			
	# UNITS	TOT'L WT(LBS)	DDT&E ($M)	PROD. ($M)	# UNITS	TOT'L WT.(LBS)	DDT&E ($M)	PROD. ($M)	# UNITS	TOT'L WT.(LBS)	DDT&E ($M)	PROD ($M)	# UNITS	TOT'L WT.(LBS)	DDT&E ($M)	PROD. ($M)
EPS																
o Modified Fuel Cell	1	90	3.50	.147	1	90	3.50	.147	1	90	3.50	.147	1	90	3.50	.147
o Emergency Battery	1	15	.35	.003	1	15	.35	.003	1	15	.35	.003	1	15	.35	.003
o Re'Actant Storage																
- Cryo Hydrogen Tank Assy	1	69	11.5	.314	1	69	11.5	.314	1	69	11.5	.314	1	69	11.5	.314
- Cryo Ox Tank Assy.	1	71			1	71			1	71			1	71		
o Vehicle Wiring		55				55				55				55		
o Connectors		30	1.14	.202		30	1.14	.202		30	1.14	.202		30	1.14	.202
o Sundries		20				20				20				20		
o Solid State Pwr. Contr.		21	.50	.01		21	.50	.01		21	.50	.01		21	.50	.01
o Electro-Mech. RccB		9				9				9				9		
		(380)	(16.99)	(.676)		(380)	(16.99)	(.676)		(380)	(16.99)	(.676)		(380)	(16.99)	(.676)
TOTAL		(803.)				(765)				(690)				(632)		
TOTAL DDT&E			(57.28)				(55.76)				(54.26)				(44.76)	
FLEET SIZE = 16																
PRODUCTION $				(102.24)				(97.76)				(92.64)				(81.76)

I-8.1.1-13

8.11.2 - RELIABILITY/REDUNDANCY SENSITIVITY ANALYSIS

OBJECTIVE

I. DETERMINE THE IMPACT ON REDUNDANCY REQUIREMENTS OF A .97 RELIABILITY LEVEL FOR RETRIEVE AND DEPLOY MISSIONS OF 72 AND 36 HOURS.

II. DETERMINE IF PROGRAMMATIC COST SAVINGS CAN BE REALIZED BY ALTERING THE .97 RELIABILITY/REDUNDANCY LEVEL.

GRUMMAN

I. REDUNDANCY SENSITIVITY TO MISSION

ASSUMPTIONS

- o RELIABILITY REFERENCE MISSION OF 168 HOURS (144 TUG + 24 ORBITER) IS THE BASELINE FOR ESTABLISHING REDUNDANCY REQUIREMENTS.

- o TO ACHIEVE .97 FOR THE 410AD-2 CONFIGURATION, 67 LBS OF REDUNDANCY IS INCLUDED

  - IMU
  - OX VENT VALVE
  - APS VENT VALVE
  - FUEL VENT VALVE
  - COMPUTER
  - APS ELECTRONICS
  - 2 RECEIVERS
  - 4 THRUSTER ISOLATION VALVES

- o ALL ABOVE REDUNDANCY IS SAFETY ESSENTIAL EXCEPT THE IMU

GRUMMAN

APPROACH

- REMOVE REDUNDANCY IN A WEIGHT-EFFECTIVE MANNER TO MEET SAFETY OR .97 RELIABILITY GOAL.

- MEASURE COST AND WEIGHT SAVINGS IF SAFETY CONSTRAINT WERE LIFTED.

GRUMMAN

RESULTS

- IF SAFETY CONSTRAINT RETAINED, A REDUNDANT 10 LB IMU CAN BE REMOVED FOR BOTH MISSIONS WITH A TEN TUG COST SAVINGS OF $2.2 MILLION. RELIABILITY IS .9902 AND .9825 FOR RETRIEVE AND DEPLOY MISSIONS - WELL ABOVE .97 RELIABILITY TARGET.

- IF SAFETY CONSTRAINT WERE LIFTED:

  DEPLOY MISSION (36 HRS)

  - ALL REDUNDANCY CAN BE REMOVED
  - WEIGHT SAVINGS OF 67 LBS PER VEHICLE
  - TEN TUG COST SAVINGS OF $12.3 MILLION
  - RELIABILITY OF .9803

  RETRIEVE MISSION (72 HRS)

  - ALL REDUNDANCY EXCEPT 4 THRUSTER ISOLATION VALVES CAN BE REMOVED
  - WEIGHT SAVINGS OF 61 LBS PER VEHICLE
  - TEN TUG COST SAVINGS OF $11.8 MILLION
  - RELIABILITY OF .9707

GRUMMAN

II. PROGRAMMATIC COST SENSTIVITY TO REDUNDANCY/RELIABILITY

ASSUMPTIONS

- BASELINE CONFIGURATION IS 410AD-2 WITH REDUNDANCY REQUIRED TO PROVIDE .97 RELIABILITY FOR 168 HR (144 TUG + 24 ORBITER) MISSION.

- TUG CARRYING COSTS FOR ADDITIONAL WEIGHT
  - $100,000 $/LB FOR MINIMUM DDT&E LOWER PERFORMANCE VEHICLES
  - $400,000 $/LB FOR HIGH PERFORMANCE VEHICLES

GRUMMAN

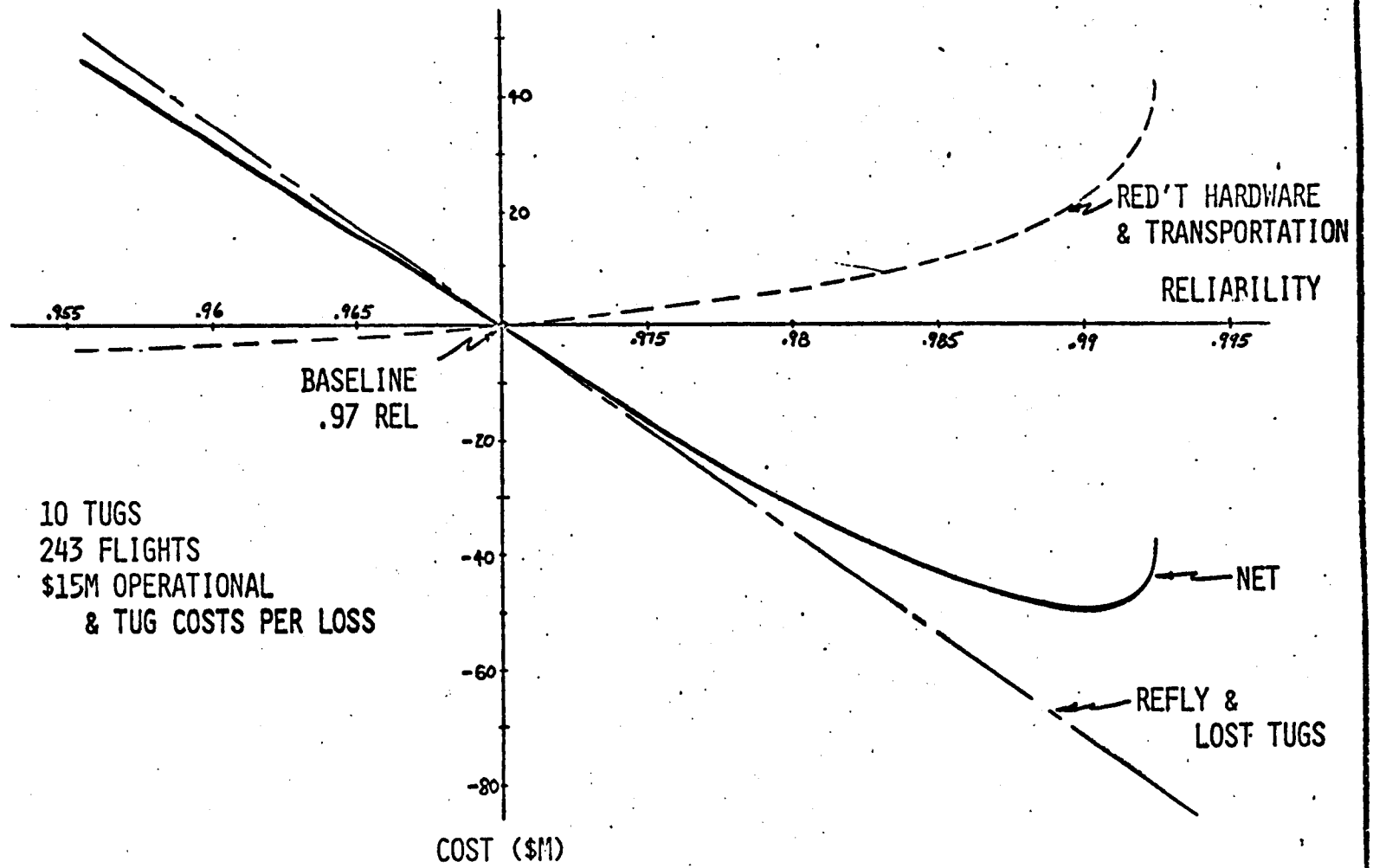
APPROACH

- o COMPARE THE PROGRAMMATIC COST DELTA's DUE TO INCREASING OR DECREASING THE REDUNDANCY/RELIABILITY LEVEL.
  - MISSION OPERATIONAL AND LOST TUG COSTS
    = Δ UNRELIABILITY X NUMBER MISSION X (TUG + OPERATIONAL COSTS/FLT)
    (243) ($15M)
  - REDUNDANT HARDWARE COSTS
    = HARDWARE COST X NUMBER OF VEHICLES IN FLEET
    (10)
  - TRANSPORTATION COSTS
    = WEIGHT OF REDUNDANT HARDWARE X CARRYING COST PER LB.
    ($100,000 TO $400,000)

GRUMMAN

PROGRAMMATIC COST VARIATION WITH RELIABILITY LEVEL

o $100,000/LB CARRYING COSTS



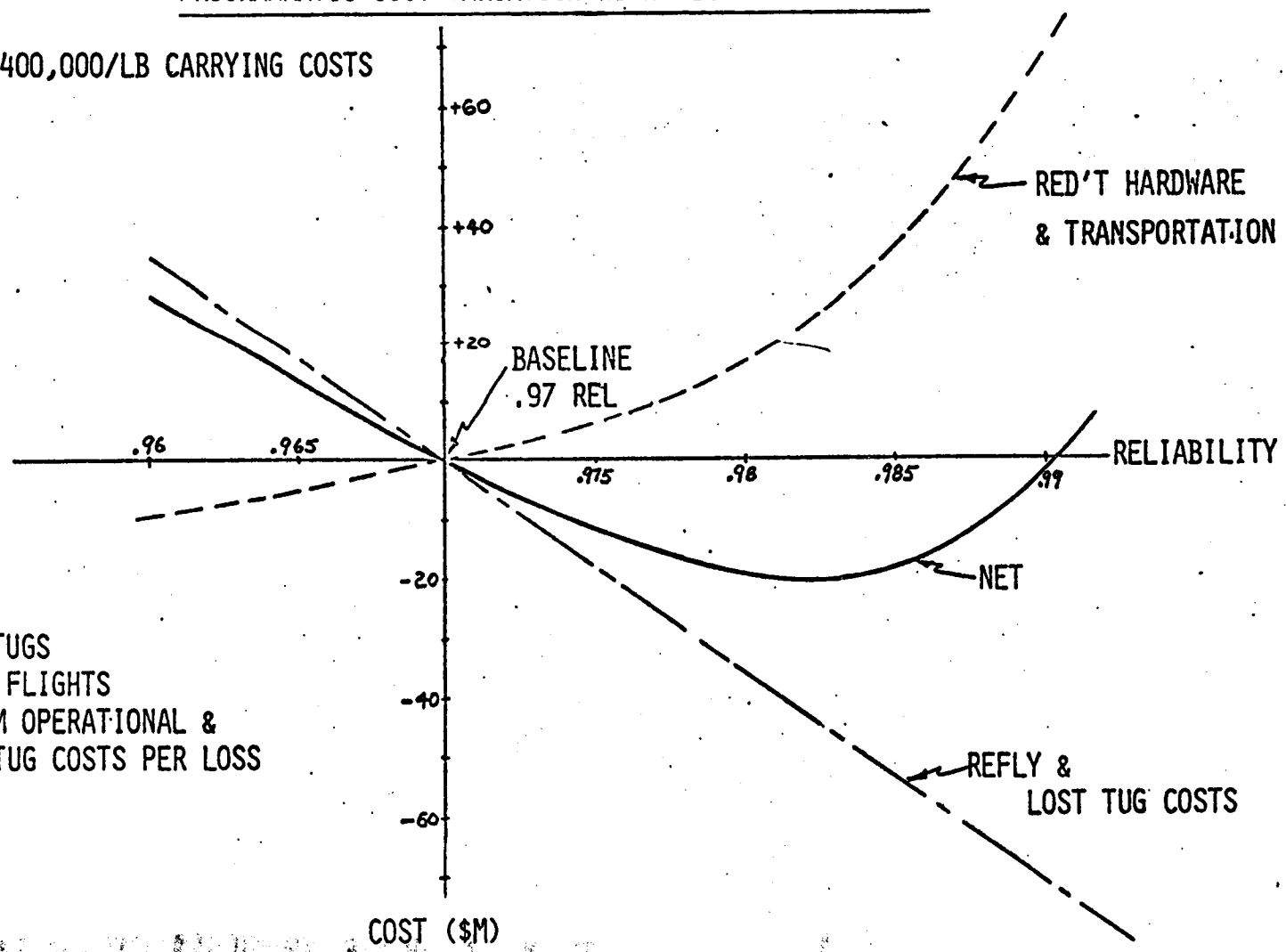
10 TUGS
243 FLIGHTS
$15M OPERATIONAL
& TUG COSTS PER LOSS

SAVINGS OF $55M WITH ADDITIONAL REDUNDANCY AT .991 RELIABILITY

GRUMMAN

PROGRAMMATIC COST VARIATION WITH RELIABILITY LEVEL

o $400,000/LB CARRYING COSTS



10 TUGS
243 FLIGHTS
$15M OPERATIONAL &
TUG COSTS PER LOSS

SAVINGS OF $20M WITH ADDITIONAL REDUNDANCY AT .982 RELIABILITY

GRUMMAN

RELIABILITY GOAL BASED ON PROGRAMMATIC COST

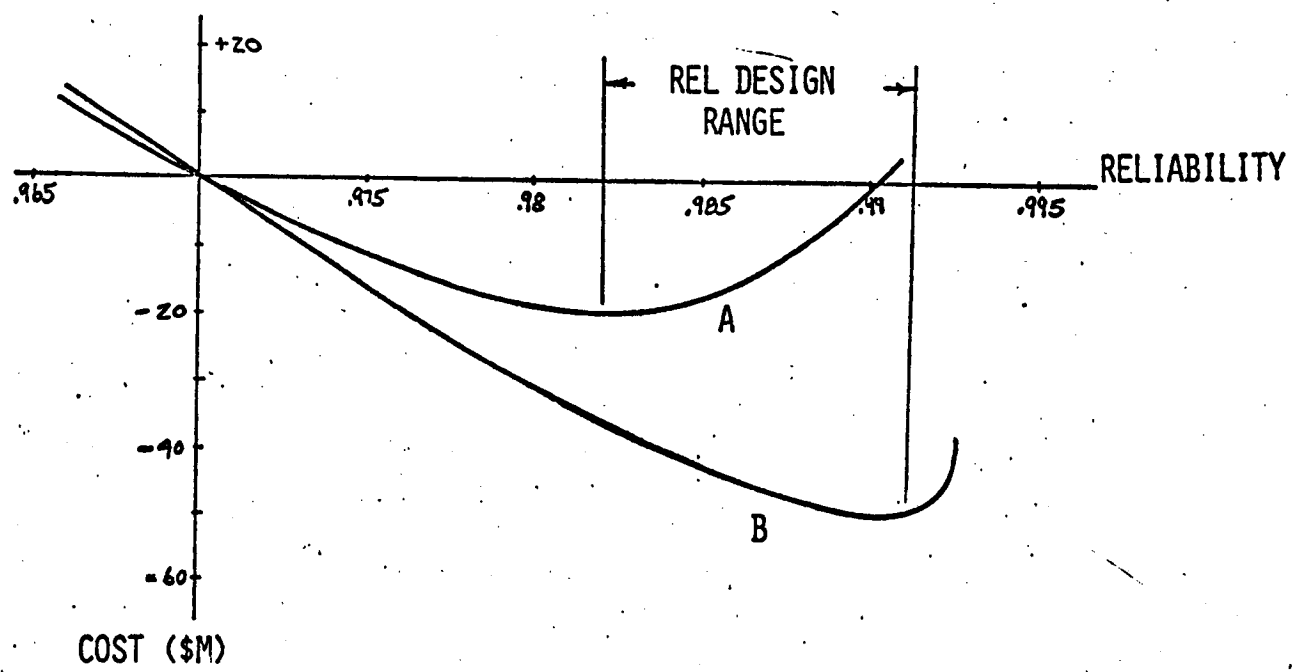
BASELINE - 410A-2 CONFIGURATION

.97 RELIABILITY

TRANSPORTATION COSTS

A- $400,000/LB

B- $100,000/LB



COST-EFFECTIVE RELIABILITY RANGE .982 - .991

GRUMMAN

EQUIPMENT REDUNDANCY ANALYSIS

- THE SYSTEM LEVEL ANALYSIS CAN BE PERFORMED ON AN INDIVIDUAL EQUIPMENT BASIS WITH COMPARABLE RESULTS.

- INDIVIDUAL COST-EFFECTIVE EQUIPMENT REDUNDANCY LEVELS CAN THUS BE DEFINED AS EACH INDIVIDUAL DESIGN IS HARDENED WHILE OTHER DESIGNS ARE STILL SOFT.

- ECONOMIC REDUNDANCY SELECTION CRITERION
  - ADD REDUNDANCY IF

$$\Delta \text{ UNRELIABILITY} > \frac{\$ \text{ REDUNDANT HARDWARE} + \$ \text{ TRANSPORTATION}}{\$ \text{ MISSION AND } \$ \text{ LOST TUG}}$$

GRUMMAN

ILLUSTRATION OF EQUIPMENT LEVEL ANALYSIS ON STAR TRACKER

HARDWARE COST =	81K
WEIGHT =	17 LBS
NUMBER OF VEHICLES =	10
NUMBER OF FLIGHTS =	243
COST OF MISSION & TUG LOST =	$15M
COST PER LB =	$100K TO $400K

FOR $100K PER LB

$$\Delta \text{ UNREL.} > \frac{\$81K \times 10 + 17 \times \$100K}{243 \times \$15\ M}$$

$$> .0007$$

FOR $400K PER LB.

$$\Delta \text{ UNREL.} > \frac{\$81K \times 10 + 17 \times \$400K}{243 \times \$15M}$$

$$> .0021$$

ADD ONE ORDER OF REDUNDANCY TO STAR TRACKER SINCE

$$\Delta \text{ UNREL.} = .0047$$

GRUMMAN

EQUIPMENT REDUNDANCY NOMOGRAPH

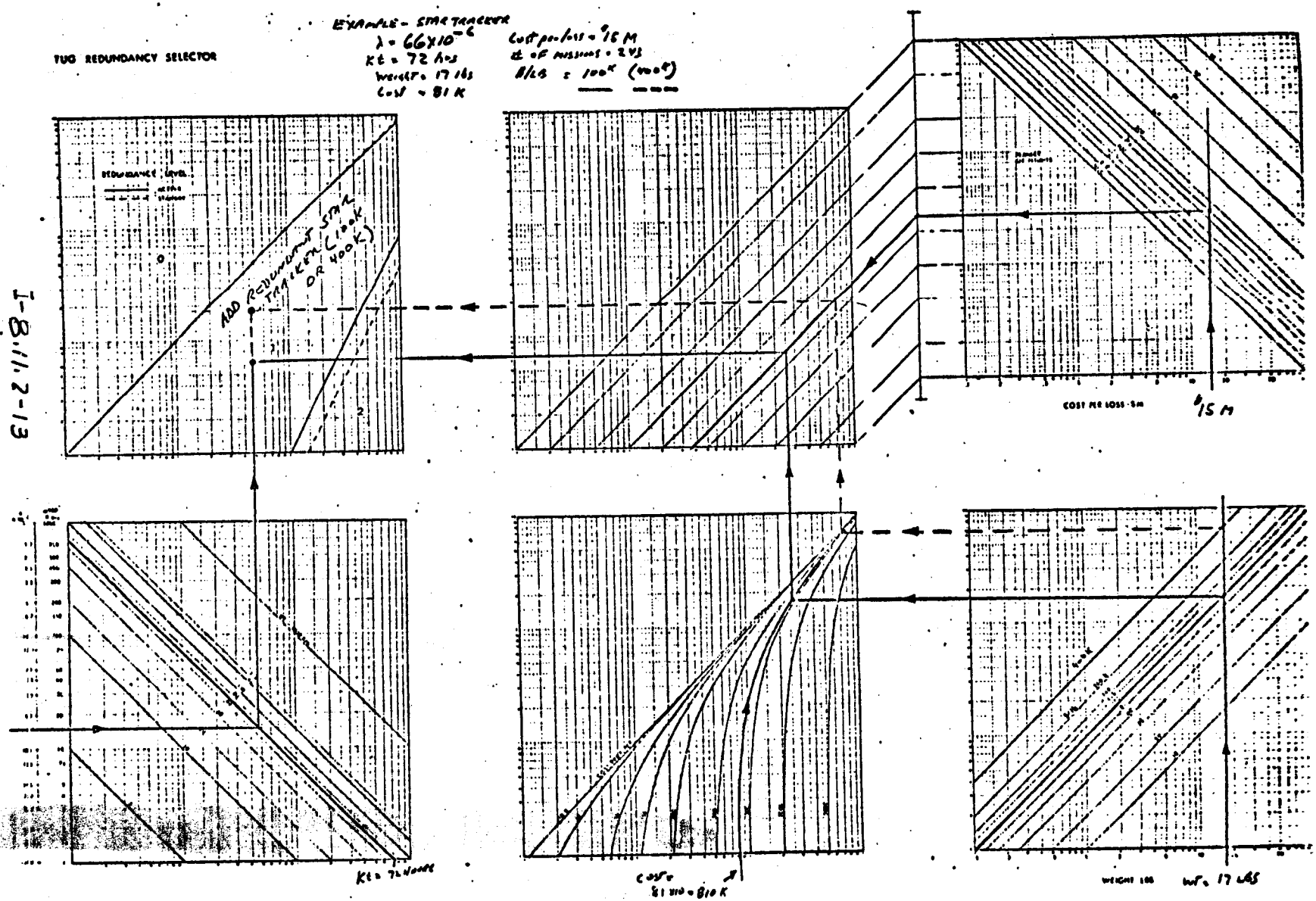
- A NOMOGRAPH HAS BEEN DEVELOPED TO PERFORM "TABLE TOP" ANALYSES, AND IS CONTAINED IN THE NEXT CHART.
- THE STAR TRACKER IS ILLUSTRATED FOR THE TWO TRANSPORTATION COST EXTREMES OF $100K AND $400K.
- DECISION CONFIDENCE CAN BE EASILY ASSESSED BY DETERMINING THE EQUIPMENT PARAMETER (FAILURE RATE, COST, OPERATING TIME, ETC.) RANGES OVER WHICH THE REDUNDANCY LEVEL DOES NOT VARY.

GRUMMAN

TUG REDUNDANCY SELECTOR

EXAMPLE - STAR TRACKER
$\lambda = 66 \times 10^{-6}$
Kt = 72 hrs
WEIGHT = 17 lbs
COST = 81 K

COST PER LOSS = $15 M
OF MISSIONS = 2 YR
B/LS = 100K (400K)



CONCLUSIONS

- o PROGRAMMATIC COST SAVINGS OF $20M TO $55M RELIAZABLE IF ADDITIONAL. REDUNDANCY INCORPORATED.

- o COST EFFECTIVE RELIABILITY DESIGNS RANGE BETWEEN .982 AND .991 FOR 168 HR. REFERENCE MISSION
  - MINIMUM DDT&E TUGS - 0.991
  - HIGH PERFORMANCE TUGS - 0.981

RECOMMENDATIONS:

- o FURTHER STUDY TO DEFINE OPTIMUM RELIABILITY/REDUNDANCY FOR EACH CONFIGURATION USING APPROPRIATE MIX OF DEPLOY, RETRIEVE AND ROUND TRIP MISSIONS.

GRUMMAN

8.11.3 - 30 DAY SERVICING MISSION SENSITIVITY STUDY

OBJECTIVE

- ESTABLISH STORABLE SPACE TUG PERFORMANCE CAPABILITY FOR SERVICING 4 SATELLITES IN GEOSYNCHRONOUS ORBIT ON A SINGLE MISSION

ISSUES

- GUIDELINES AND ASSUMPTIONS
- DELTA-V BUDGET AND CONSUMABLES USAGE
- AUXILIARY PROPULSION SUBSYSTEM (APS) REQUIREMENTS
- ELECTRICAL POWER SUBSYSTEM (EPS) REQUIREMENTS
- CONFIGURATION ARRANGEMENT
- WEIGHT SUMMARY AND PERFORMANCE EVALUATION
- MISSION SUCCESS RELIABILITY EVALUATION
- COST IMPACT
- DEVELOPMENT RISK AND TECHNOLOGY ISSUES

30 DAY SERVICING MISSION

GUIDELINES AND ASSUMPTIONS

- STORABLE TUG PERFORMS 30 DAY MISSION DURING WHICH TIME 4 SATELLITES ARE SERVICED
- MISSION TIMELINE AND MAIN PROPULSION DELTA-V BUDGETS USED FROM MSFC LETTER PD-TUG-E (74-30) DATED 10 AUGUST 1973 WITH THE FOLLOWING EXCEPTION
- RENDEZVOUS AND DOCKING DELTA V WAS MODIFIED TO REFLECT TPI, TPF AND DOCKING MANEUVERS CONSISTENT WITH BASELINE TUG MANEUVER TABLES
- THE OPTION 2 BASELINE CONCEPT, 410AD-2, WAS USED AS THE POINT OF DEPARTURE FOR THIS ANALYSIS
- A 500 LB SERVICE UNIT WAS BASELINED. WEIGHT OF SPACE REPLACEABLE UNITS (SRU) IS ESTABLISHED BY PERFORMANCE ANALYSIS
- TWO SERVICING MODES TO BE CONSIDERED
  - SERVICE MODE I EXPENDS ALL REPLACED SRU'S AT EACH SPACECRAFT SERVICED. TUG RETURNS ONLY WITH 500 LB SERVICE UNIT
  - SERVICE MODE II CARRIES A CONSTANT PAYLOAD (SERVICE UNIT PLUS SRU'S) THROUGHOUT THE MISSION
- NO SPECIFIED MISSION SUCCESS RELIABILITY GOAL FOR SERVICING MISSION. CAPABILITY DETERMINED BY ANALYSIS

PERFORMANCE ANALYSIS FOR SERVICING MISSION: MODE I

TUG DELTA-V BUDGET

CONFIG. CONCEPT 410AD-2

1-STG SERVICES 4 PL--REPL PARTS & DISC

		DV MAIN	DV APS
		********	********
1	THRUST ST	0.0	0.0
6	TDI	7424.0	0.0
11	MCC	0.0	22.0
15	MDI	5874.0	0.0
20	TPI	30.0	0.0
23	MCC	0.0	0.1
26	TPF	0.0	35.0
29	DOCK PL 1	0.0	8.0
35	THRUST FR PL 1	0.0	10.0
39	PDI	47.0	0.0
43	MCC	0.0	0.2
47	MDI	47.0	0.0
51	TPI	30.0	0.0
54	MCC	0.0	0.1
57	TPF	0.0	35.0
60	DOCK PL 2	0.0	8.0
66	THRUST FR PL 2	0.0	10.0
70	PDI	110.0	0.0
74	MCC	0.0	0.3
78	MDI	110.0	0.0
82	TPI	30.0	0.0
85	MCC	0.0	0.1
88	TPF	0.0	35.0
91	DOCK PL 3	0.0	8.0
97	THRUST FR PL 3	0.0	10.0
**	PDI	54.0	0.0
**	MCC	0.0	0.2
**	MDI	54.0	0.0
**	TPI	30.0	0.0
**	MCC	0.0	0.1
**	TPF	0.0	35.0
**	DOCK PL 4	0.0	8.0
**	THRUST FR PL 4	0.0	10.0
**	TDI	5874.0	0.0
**	MCC	0.0	17.0
**	PDI	3750.0	0.0
**	MCC	0.0	11.0
**	CIRC	4376.0	0.0
**	ADJ	0.0	13.0
**	CONTINGENCY 1.7(	473.6	0.0
		********	********
TOTALS		28313.6	276.1

TUG WEIGHT HISTORY

CONFIG. CONCEPT 410AD-2

1-STG SERVICES 4 PL--REPL PARTS & DISC

		WT BEF	DLT PAY	WT AFT	PRO-MAIN	PRO-APS
		********	********	********	********	********
1	THRUST ST	63721.0	0.0	63721.0	0.0	0.0
2	NB RELEASE ST	63721.0	0.0	63721.0	0.0	0.0
3	WB	63721.0	0.0	63720.9	0.0	0.0
4	S_EW IMU TOI	63720.9	0.0	63701.7	0.0	19.3
5	NB IMU TOI	63701.7	0.0	63701.6	0.0	0.1
6	TOI	63701.6	0.0	32186.0	31515.6	0.0
7	FC REACT & MPS VENT	32186.0	0.0	32087.0	0.0	0.0
8	WB	32087.0	0.0	32086.8	0.0	0.2
9	S_EW MCC	32086.8	0.0	32081.9	0.0	4.8
10	NB MCC	32081.9	0.0	32081.9	0.0	0.0
11	MCC	32081.9	0.0	31987.5	0.0	94.4
12	WB	31987.5	0.0	31987.2	0.0	0.2
13	S_EW IMU MOI	31987.2	0.0	31977.6	0.0	9.7
14	NB IMU MOI	31977.6	0.0	31977.4	0.0	0.2
15	MOI	31977.4	0.0	18632.0	13345.4	0.0
16	FC REACT & MPS VENT	18632.0	0.0	18533.0	0.0	0.0
17	WB	18533.0	0.0	18531.4	0.0	1.6
18	S_EW TRACK	18531.4	0.0	18517.4	0.0	14.0
19	NB TRACK	18517.4	0.0	18516.0	0.0	1.5
20	TPI	18516.0	0.0	18465.0	51.0	0.0
21	S_EW TRACK	18465.0	0.0	18451.0	0.0	13.9
22	NB TRACK	18451.0	0.0	18450.2	0.0	0.8
23	MCC	18450.2	0.0	18449.9	0.0	0.2
24	SLEW TRACK	18449.9	0.0	18436.0	0.0	13.9
25	NB TRACK	18436.0	0.0	18435.1	0.0	0.8
26	TPF	18435.1	0.0	18348.9	0.0	86.2
27	S_EW DOCK	18348.9	0.0	18321.1	0.0	27.7
28	NB DOCK	18321.1	0.0	18320.9	0.0	0.2
29	DOCK PL 1	18320.9	0.0	18301.3	0.0	19.6
30	ADD PL 1	18301.3	5000.0	23301.3	0.0	0.0
31	WB	23301.3	0.0	23301.0	0.0	0.3
32	S_EW DEPLOY	23301.0	0.0	23297.5	0.0	3.5
33	NB DEPLOY	23297.5	0.0	23297.5	0.0	0.0
34	DROP PL 1	23297.5	-5171.6	18125.9	0.0	0.0
35	THRUST FR PL 1	18125.9	0.0	18101.6	0.0	24.3
36	WB	18101.6	0.0	18101.5	0.0	0.1
37	S_EW IMU POI	18101.5	0.0	18100.2	0.0	1.3
38	NB IMU POI	18100.2	0.0	18100.1	0.0	0.1
39	POI	18100.1	0.0	18022.1	78.1	0.0
40	WB	18022.1	0.0	18003.7	0.0	18.4
41	S_EW MCC	18003.7	0.0	18003.1	0.0	0.7
42	NB MCC	18003.1	0.0	18003.0	0.0	0.0
43	MCC	18003.0	0.0	18002.5	0.0	0.5
44	WB	18002.5	0.0	17984.1	0.0	18.4
45	S_EW IMU MOI	17984.1	0.0	17982.8	0.0	1.3
46	NB IMU MOI	17982.8	0.0	17982.8	0.0	0.1
47	MOI	17982.8	0.0	17905.2	77.6	0.0
48	WB	17905.2	0.0	17903.1	0.0	2.1
49	S_EW TRACK	17903.1	0.0	17899.8	0.0	3.3
50	NB TRACK	17899.8	0.0	17898.3	0.0	1.5
51	TPI	17898.3	0.0	17849.0	49.3	0.0
52	S_EW TRACK	17849.0	0.0	17845.7	0.0	3.2
53	NB TRACK	17845.7	0.0	17844.2	0.0	1.5
54	MCC	17844.2	0.0	17844.0	0.0	0.2

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55	SLEW TRACK	17444.0	0.0	17840.7	0.0	3.2
56	NB TRACK	17840.7	0.0	17839.2	0.0	1.5
57	TPF	17839.2	0.0	17755.8	0.0	83.5
58	SLEW DOCK	17755.8	0.0	17749.3	0.0	6.5
59	NB DOCK	17749.3	0.0	17749.0	0.0	0.3
60	DOCK PL 2	17749.0	0.0	17730.0	0.0	19.0
61	ADD PL 2	17730.0	5000.0	22730.0	0.0	0.0
62	#9	22730.0	0.0	22729.7	0.0	0.3
63	SLEW DEPLOY	22729.7	0.0	22726.3	0.0	3.4
64	NB DEPLOY	22726.3	0.0	22726.3	0.0	0.0
65	DEP PL 2	22726.3	-5171.6	17554.7	0.0	0.0
66	THRUST FR PL 2	17554.7	0.0	17531.2	0.0	23.5
67	#9	17531.2	0.0	17531.1	0.0	0.1
68	SLEW INU POI	17531.1	0.0	17529.8	0.0	1.3
69	NB INU POI	17529.8	0.0	17529.7	0.0	0.1
70	POI	17529.7	0.0	17353.3	176.4	0.0
71	#9	17353.3	0.0	17318.5	0.0	34.8
72	SLEW MCC	17318.5	0.0	17317.8	0.0	0.6
73	NB MCC	17317.8	0.0	17317.8	0.0	0.0
74	MCC	17317.8	0.0	17317.1	0.0	0.7
75	#9	17317.1	0.0	17282.2	0.0	34.9
76	SLEW INU MOI	17282.2	0.0	17280.9	0.0	1.3
77	NB INU MOI	17280.9	0.0	17280.9	0.0	0.1
78	MOI	17280.9	0.0	17106.9	173.9	0.0
79	#9	17106.9	0.0	17104.7	0.0	2.2
80	SLEW TRACK	17104.7	0.0	17101.6	0.0	3.1
81	NB TRACK	17101.6	0.0	17100.0	0.0	1.6
82	TPI	17100.0	0.0	17052.9	47.1	0.0
83	SLEW TRACK	17052.9	0.0	17049.8	0.0	3.1
84	NB TRACK	17049.8	0.0	17048.2	0.0	1.6
85	MCC	17048.2	0.0	17048.0	0.0	0.2
86	SLEW TRACK	17048.0	0.0	17044.9	0.0	3.1
87	NB TRACK	17044.9	0.0	17043.3	0.0	1.6
88	TPF	17043.3	0.0	16963.6	0.0	79.7
89	SLEW DOCK	16963.6	0.0	16957.4	0.0	6.2
90	NB DOCK	16957.4	0.0	16957.1	0.0	0.3
91	DOCK PL 3	16957.1	0.0	16938.9	0.0	18.2
92	ADD PL 3	16938.9	5000.0	21938.9	0.0	0.0
93	#9	21938.9	0.0	21938.6	0.0	0.3
94	SLEW DEPLOY	21938.6	0.0	21935.3	0.0	3.3
95	NB DEPLOY	21935.3	0.0	21935.3	0.0	0.0
96	DEP PL 3	21935.3	-5171.6	16763.7	0.0	0.0
97	THRUST FR PL 3	16763.7	0.0	16741.2	0.0	22.4
98	#9	16741.2	0.0	16741.1	0.0	0.1
99	SLEW INU POI	16741.1	0.0	16739.9	0.0	1.2
**	NB INU POI	16739.9	0.0	16739.8	0.0	0.1
**	POI	16739.8	0.0	16656.9	82.9	0.0
**	#9	16656.9	0.0	16637.1	0.0	19.8
**	SLEW MCC	16637.1	0.0	16636.5	0.0	0.6
**	NB MCC	16636.5	0.0	16636.4	0.0	0.0
**	MCC	16636.4	0.0	16636.0	0.0	0.4
**	#9	16636.0	0.0	16616.2	0.0	19.8
**	SLEW INU MOI	16616.2	0.0	16614.9	0.0	1.2
**	NB INU MOI	16614.9	0.0	16614.9	0.0	0.1
**	MOI	16614.9	0.0	16532.6	82.3	0.0
**	#9	16532.6	0.0	16530.2	0.0	2.3
**	SLEW TRACK	16530.2	0.0	16527.2	0.0	3.0
**	NB TRACK	16527.2	0.0	16525.6	0.0	1.6
**	TPI	16525.6	0.0	16480.1	45.5	0.0
**	SLEW TRACK	16480.1	0.0	16477.1	0.0	3.0
**	NB TRACK	16477.1	0.0	16475.4	0.0	1.6
**	MCC	16475.4	0.0	16475.2	0.0	0.2
**	SLEW TRACK	16475.2	0.0	16472.2	0.0	3.0
**	NB TRACK	16472.2	0.0	16470.6	0.0	1.6
**	TPF	16470.6	0.0	16393.0	0.0	77.0
**	SLEW DOCK	16393.0	0.0	16387.6	0.0	6.0
**	NB DOCK	16387.6	0.0	16387.2	0.0	0.3
**	DOCK PL 4	16387.2	0.0	16369.7	0.0	17.6
**	ADD PL 4	16369.7	5000.0	21369.7	0.0	0.0
**	#8	21369.7	0.0	21369.4	0.0	0.3
**	SLEW DEPLOY	21369.4	0.0	21366.2	0.0	3.2
**	NB DEPLOY	21366.2	0.0	21366.1	0.0	0.0
**	DEP PL 4	21366.1	-5171.6	16194.5	0.0	0.0
**	THRUST FR PL 4	16194.5	0.0	16172.8	0.0	21.7
**	#8	16172.8	0.0	16169.9	0.0	2.9
**	SLEW INU TOI	16169.9	0.0	16168.7	0.0	1.2
**	NB INU TOI	16168.7	0.0	16168.3	0.0	0.5
**	TOI	16168.3	0.0	9420.6	6747.6	0.0
**	FC REACT & MPS VENT	9420.6	0.0	9321.6	0.0	0.0
**	#8	9321.6	0.0	9320.6	0.0	1.0
**	SLEW MCC	9320.6	0.0	9320.3	0.0	0.3
**	NB MCC	9320.3	0.0	9320.2	0.0	0.1
**	MCC	9320.2	0.0	9299.0	0.0	21.2
**	#9	9299.0	0.0	9298.0	0.0	1.0
**	SLEW INU POI	9298.0	0.0	9297.3	0.0	0.7
**	NB INU POI	9297.3	0.0	9296.8	0.0	0.5
**	POI	9296.8	0.0	6585.3	2711.5	0.0
**	FC REACT & MPS VENT	6585.3	0.0	6486.3	0.0	0.0
**	#8	6486.3	0.0	6485.4	0.0	0.8
**	SLEW MCC	6485.4	0.0	6485.2	0.0	0.2
**	NB MCC	6485.2	0.0	6485.1	0.0	0.1
**	MCC	6485.1	0.0	6475.5	0.0	9.5
**	#8	6475.5	0.0	6474.7	0.0	0.8
**	SLEW INU CIRC	6474.7	0.0	6474.2	0.0	0.5
**	NB INU CIRC	6474.2	0.0	6473.4	0.0	0.8
**	CIRC	6473.4	0.0	4328.9	2144.5	0.0
**	#8	4328.9	0.0	4328.7	0.0	0.1
**	SLEW ADJ	4328.7	0.0	4328.6	0.0	0.2
**	NB ADJ	4328.6	0.0	4328.4	0.0	0.2
**	ADJ	4328.4	0.0	4320.9	0.0	7.5
**	#8	4320.9	0.0	4320.7	0.0	0.1
**	SLEW EOS CAPTURE ST	4320.7	0.0	4320.6	0.0	0.2
**	NB EOS CAPTURE ST	4320.6	0.0	4319.0	0.0	1.6
**	CONTINGENCY 1.7%	4319.0	0.0	4135.0	184.1	0.0
					********	********
TOTALS					8812.7	990.6

I-8 11/3+5

PERFORMANCE ANALYSIS FOR SERVICING MISSION: MODE II

TUG DELTA-V BUDGET

CONFIG. CONCEPT 410AD-2

1-STG SRVCS 4 PL IN GEOS--BRG PRTS BK

		DV MAIN	DV APS
		********	********
1	THRUST ST	0.0	0.0
6	TDI	7424.0	0.0
11	MCC	0.0	22.0
15	MDI	5874.0	0.0
20	TPI	30.0	0.0
23	MCC	0.0	0.1
26	TPF	0.0	35.0
29	DOCK PL 1	0.0	8.0
35	THRUST FR PL 1	0.0	10.0
39	PDI	47.0	0.0
43	MCC	0.0	0.2
47	MDI	47.0	0.0
51	TPI	30.0	0.0
54	MCC	0.0	0.1
57	TPF	0.0	35.0
60	DOCK PL 2	0.0	8.0
66	THRUST FR PL 2	0.0	10.0
70	PDI	110.0	0.0
74	MCC	0.0	0.3
78	MDI	110.0	0.0
82	TPI	30.0	0.0
85	MCC	0.0	0.1
88	TPF	0.0	35.0
91	DOCK PL 3	0.0	8.0
97	THRUST FR PL 3	0.0	10.0
**	PDI	54.0	0.0
**	MCC	0.0	0.2
**	MDI	54.0	0.0
**	TPI	30.0	0.0
**	MCC	0.0	0.1
**	TPF	0.0	35.0
**	DOCK PL 4	0.0	8.0
**	THRUST FR PL 4	0.0	10.0
**	TDI	5874.0	0.0
**	MCC	0.0	17.0
**	PDI	3750.0	0.0
**	MCC	0.0	11.0
**	CIRC	4376.0	0.0
**	ADJ	0.0	13.0
**	CONTINGENCY 1.7(	473.6	0.0
		********	********
TOTALS		28313.6	276.1

TLG WEIGHT HISTORY

CONFIG. CONCEPT 410AD-2

1-STG SRVCS 4 PL IN GEOS--BRG PRTS BK

		WT BEF	DLT PAY	WT AFT	PRO-MAIN	PRO-APS
		********	********	********	********	********
1	THRUST ST	63721.0	0.0	63721.0	0.0	0.0
2	NB RELEASE ST	63721.0	0.0	63721.0	0.0	0.0
3	WB	63721.0	0.0	63720.9	0.0	0.0
4	S_EW IMU TOI	63720.9	0.0	63698.7	0.0	22.2
5	NB IMU TOI	63698.7	0.0	63698.6	0.0	0.1
6	TOI	63698.6	0.0	32184.5	31514.1	0.0
7	FC REACT & MPS VENT	32184.5	0.0	32060.8	0.0	0.0
8	WB	32060.8	0.0	32060.5	0.0	0.2
9	SLEW MCC	32060.5	0.0	32054.9	0.0	5.6
10	NB MCC	32054.9	0.0	32054.9	0.0	0.0
11	MCC	32054.9	0.0	31960.6	0.0	94.3
12	WB	31960.6	0.0	31960.3	0.0	0.2
13	S_EW IMU MOI	31960.3	0.0	31949.2	0.0	11.1
14	NB IMU MOI	31949.2	0.0	31949.0	0.0	0.2
15	MOI	31949.0	0.0	18615.5	13333.5	0.0
16	FC REACT & MPS VENT	18615.5	0.0	18491.8	0.0	0.0
17	WB	18491.8	0.0	18490.2	0.0	1.6
18	S_EW TRACK	18490.2	0.0	18474.1	0.0	16.1
19	NB TRACK	18474.1	0.0	18472.6	0.0	1.5
20	TPI	18472.6	0.0	18421.7	50.9	0.0
21	S_EW TRACK	18421.7	0.0	18405.7	0.0	16.0
22	NB TRACK	18405.7	0.0	18404.8	0.0	0.8
23	MCC	18404.8	0.0	18404.6	0.0	0.2
24	S_EW TRACK	18404.6	0.0	18388.6	0.0	16.0
25	NB TRACK	18388.6	0.0	18387.7	0.0	0.8
26	TPF	18387.7	0.0	18301.7	0.0	86.0
27	S_EW DOCK	18301.7	0.0	18269.8	0.0	31.9
28	NB DOCK	18269.8	0.0	18269.6	0.0	0.2
29	DOCK PL 1	18269.6	0.0	18250.0	0.0	19.6
30	ADD PL 1	18250.0	5000.0	23250.0	0.0	0.0
31	WB	23250.0	0.0	23249.8	0.0	0.3
32	SLEW DEPLOY	23249.8	0.0	23245.7	0.0	4.0
33	NB DEPLOY	23245.7	0.0	23245.7	0.0	0.0
34	DROP PL 1	23245.7	-5000.0	18245.7	0.0	0.0
35	THRUST FR PL 1	18245.7	0.0	18221.2	0.0	24.4
36	WB	18221.2	0.0	18221.2	0.0	0.1
37	S_EW IMU POI	18221.2	0.0	18219.4	0.0	1.7
38	NB IMU POI	18219.4	0.0	18219.4	0.0	0.1
39	POI	18219.4	0.0	18140.8	78.6	0.0
40	WB	18140.8	0.0	18123.9	0.0	16.9
41	S_EW MCC	18123.9	0.0	18123.0	0.0	0.9
42	NB MCC	18123.0	0.0	18123.0	0.0	0.0
43	MCC	18123.0	0.0	18122.5	0.0	0.5
44	WB	18122.5	0.0	18105.5	0.0	17.0
45	S_EW IMU MOI	18105.5	0.0	18103.8	0.0	1.7
46	NB IMU MOI	18103.8	0.0	18103.7	0.0	0.1
47	MOI	18103.7	0.0	18025.7	78.1	0.0
48	WB	18025.7	0.0	18023.7	0.0	2.0
49	S_EW TRACK	18023.7	0.0	18019.4	0.0	4.3
50	NB TRACK	18019.4	0.0	18018.0	0.0	1.4
51	TPI 8.11.3-7	18018.0	0.0	17968.4	49.6	0.0
52	S_EW TRACK	17968.4	0.0	17964.1	0.0	4.3
53	NB TRACK	17964.1	0.0	17962.8	0.0	1.4
54	MCC	17962.8	0.0	17962.5	0.0	0.2

55	SLEW TRACK	17962.5	0.0	17958.3	0.0	4.3
56	NB TRACK	17959.3	0.0	17956.9	0.0	1.4
57	TPF	17956.9	0.0	17872.9	0.0	84.0
58	SLEW DOCK	17872.9	0.0	17864.4	0.0	8.5
59	NB DOCK	17864.4	0.0	17864.1	0.0	0.3
60	DOCK PL 2	17864.1	0.0	17845.0	0.0	19.1
61	ADD PL 2	17845.0	5000.0	22845.0	0.0	0.0
62	NB	22845.0	0.0	22844.7	0.0	0.3
63	SLEW DEPLOY	22844.7	0.0	22840.7	0.0	4.0
64	NB DEPLOY	22840.7	0.0	22840.7	0.0	0.0
65	DROP PL 2	22840.7	-5000.0	17840.7	0.0	0.0
66	THRUST FR PL 2	17840.7	0.0	17816.8	0.0	23.9
67	NB	17816.8	0.0	17816.7	0.0	0.1
68	SLEW INU POI	17816.7	0.0	17815.1	0.0	1.7
69	NB INU POI	17815.1	0.0	17815.0	0.0	0.1
70	POI	17815.0	0.0	17635.7	179.3	0.0
71	NB	17635.7	[illegible]	17603.9	0.0	31.8
72	SLEW MCC	17603.9	0.0	17603.0	0.0	0.8
73	NB MCC	17603.0	0.0	17603.0	0.0	0.0
74	MCC	17603.0	0.0	17602.3	0.0	0.7
75	NB	17602.3	0.0	17570.4	0.0	31.9
76	SLEW INU MOI	17570.4	0.0	17568.7	0.0	1.7
77	NB INU MOI	17568.7	0.0	17568.6	0.0	0.1
78	MOI	17568.6	0.0	17391.8	176.8	0.0
79	NB	17391.8	0.0	17389.8	0.0	2.0
80	SLEW TRACK	17389.8	0.0	17385.7	0.0	4.1
81	NB TRACK	17385.7	0.0	17384.2	0.0	1.4
82	TPI	17384.2	0.0	17336.3	47.9	0.0
83	SLEW TRACK	17336.3	0.0	17332.2	0.0	4.1
84	NB TRACK	17332.2	0.0	17330.8	0.0	1.4
85	MCC	17330.8	0.0	17330.6	0.0	0.2
86	SLEW TRACK	17330.6	0.0	17326.5	0.0	4.1
87	NB TRACK	17326.5	0.0	17325.0	0.0	1.4
88	TPF	17325.0	0.0	17244.0	0.0	81.0
89	SLEW DOCK	17244.0	0.0	17235.8	0.0	8.2
90	NB DOCK	17235.8	0.0	17235.5	0.0	0.3
91	DOCK PL 3	17235.5	0.0	17217.0	0.0	18.5
92	ADD PL 3	17217.0	5000.0	22217.0	0.0	0.0
93	NB	22217.0	0.0	22216.8	0.0	0.3
94	SLEW DEPLOY	22216.5	0.0	22212.9	0.0	3.9
95	NB DEPLOY	22212.9	0.0	22212.9	0.0	0.0
96	DROP PL 3	22212.9	-5000.0	17212.9	0.0	0.0
97	THRUST FR PL 3	17212.9	0.0	17189.8	0.0	23.0
98	NB	17189.8	0.0	17189.7	0.0	0.1
99	SLEW INU POI	17189.7	0.0	17188.1	0.0	1.6
**	NB INU POI	17188.1	0.0	17188.0	0.0	0.1
**	POI	17188.0	0.0	17102.9	85.1	0.0
**	NB	17102.9	0.0	17085.0	0.0	17.9
**	SLEW MCC	17085.0	0.0	17084.2	0.0	0.8
**	NB MCC	17084.2	0.0	17084.1	0.0	0.0
**	MCC	17084.1	0.0	17083.7	0.0	0.5
**	NB	17083.7	0.0	17065.7	0.0	17.9
**	SLEW INU MOI	17065.7	0.0	17064.1	0.0	1.6
**	NB INU MOI	17064.1	0.0	17064.0	0.0	0.1
**	MOI	17064.0	0.0	16979.5	84.5	0.0
**	NB	16979.5	0.0	16977.4	0.0	2.1
**	SLEW TRACK	16977.4	0.0	16973.4	0.0	4.0
**	NB TRACK	16973.4	0.0	16971.9	0.0	1.5
**	TPI	16971.9	0.0	16925.2	46.8	0.0
**	SLEW TRACK	16925.2	0.0	16921.1	0.0	4.0
**	NB TRACK	16921.1	0.0	16919.7	0.0	1.5
**	MCC	16919.7	0.0	16919.4	0.0	0.2
**	SLEW TRACK	16919.4	0.0	16915.4	0.0	4.0
**	NB TRACK	16915.4	0.0	16914.0	0.0	1.5
**	TPF	16914.0	0.0	16834.8	0.0	79.1
**	SLEW DOCK	16834.8	0.0	16826.9	0.0	8.0
**	NB DOCK	16826.9	0.0	16826.6	0.0	0.3
**	DOCK PL 4	16826.6	0.0	16805.5	0.0	18.0
**	ADD PL 4	16808.5	5000.0	21808.5	0.0	0.0
**	NB	21808.5	0.0	21808.3	0.0	0.3
**	SLEW DEPLOY	21808.3	0.0	21804.5	0.0	3.8
**	NB DEPLOY	21804.5	0.0	21804.4	0.0	0.0
**	DROP PL 4	21804.4	-5000.0	16804.4	0.0	0.0
**	THRUST FR PL 4	16804.4	0.0	16781.9	0.0	22.5
**	NB	16781.9	0.0	16779.3	0.0	2.6
**	SLEW INU TOI	16779.3	0.0	16777.7	0.0	1.6
**	NB INU TOI	16777.7	0.0	16777.3	0.0	0.4
**	TOI	16777.3	0.0	9775.5	7001.8	0.0
**	PC REACT & NPS VENT	9775.5	0.0	9651.8	0.0	0.0
**	NB	9651.8	0.0	9650.8	0.0	0.9
**	SLEW MCC	9650.8	0.0	9650.4	0.0	0.5
**	NB MCC	9650.4	0.0	9650.3	0.0	0.1
**	MCC	9650.3	0.0	9628.3	0.0	22.0
**	NB	9628.3	0.0	9627.4	0.0	0.9
**	SLEW INU POI	9627.4	0.0	9626.5	0.0	0.9
**	NB INU POI	9626.5	0.0	9626.0	0.0	0.5
**	POI	9626.0	0.0	6818.5	2807.5	0.0
**	PC REACT & NPS VENT	6818.5	0.0	6694.7	0.0	0.6
**	NB	6694.7	0.0	6694.0	0.0	0.7
**	SLEW MCC	6694.0	0.0	6693.7	0.0	0.3
**	NB MCC	6693.7	0.0	6693.6	0.0	0.1
**	MCC	6693.6	0.0	6681.7	0.0	9.9
**	NB	6683.7	0.0	6683.0	0.0	0.7
**	SLEW INU CIRC	6683.0	0.0	6682.4	0.0	0.6
**	NB INU CIRC	6682.4	0.0	6681.6	0.0	0.7
**	CIRC	6681.6	0.0	4468.1	2213.5	0.0
**	NB	4468.1	0.0	4468.0	0.0	0.1
**	SLEW ADJ	4468.0	0.0	4467.8	0.0	0.2
**	NB ADJ	4467.8	0.0	4467.6	0.0	0.1
**	ADJ	4467.6	0.0	4459.8	0.0	7.8
**	NB	4459.8	0.0	4459.7	0.0	0.1
**	SLEW EOS CAPTURE ST	4459.7	0.0	4459.5	0.0	0.2
**	NB EOS CAPTURE ST	4459.5	0.0	4458.1	0.0	1.4
**	CONTINGENCY 1.7%	4458.1	0.0	4268.1	190.0	0.0
TOTALS					********	********
					57938.0	1019.6

30 DAY SERVICING MISSION

AUXILIARY PROPULSION SYSTEM (APS)

- APS SENSITIVITY ISSUES
  - WEIGHT PENALTY OF ADD-ON MONOPROPELLANT SERVICING MISSION KIT
  - EFFECT ON BASELINE APS SELECTION OF DESIGNING TO SERVICING MISSION REQUIREMENTS
- REQUIREMENTS
  - USABLE APS PROPELLANT = 991 LB SERVICE 1, 1020 LB SERVICE 2
  - BASELINE APS USABLE PROPELLANT = 450 LB.
  - TANKS SIZED FOR 110% OF USABLE PROPELLANT DELTA
  - SERVICING MISSION TANKS SIZED FOR 1.1 (991-450) = 595 LBS. PROPELLANT
- WEIGHT PENALTY OF APS SERVICING MISSION KIT
  - ADDITIONAL HARDWARE WEIGHT = 94.7 LB.

    2 HELIUM TANKS @ 16.1 LB EACH = 32.2LB
    5 PROPELLANT TANKS @ 10.5 LB EACH = 52.5 LB
    LINES AND SUPPORTS = 10.0 LB

  - EFFECTIVE PROPELLANT WEIGHT INCREASE = 161 LB
    EFFECTIVE PROP. WT = 27% ACTUAL PROP. WT.

30 DAY SERVICING MISSION

AUXILIARY PROPULSION SYSTEM (APS) (CONT'D)

- SENSITIVITY ISSUE
  - EFFECT ON BASELINE APS SELECTION (MONOPROPELLANT VS BIPROPELLANT) OF DESIGNING TO SERVICING MISSION REQUIREMENTS (1020 LB USABLE APS PROPELLANT)
- RESULTS
  - DESIGNED FOR SERVICING MISSION, OFF LOADED FOR BASELINE PROPELLANT REQUIREMENTS

	EFFECTIVE WEIGHT (LB)	DDT&E COST ($M)	TOTAL PROGRAM COST ($M)
MONOPROPELLANT SYSTEM 24 THRUSTERS, 25 LB THRUST	417	3.1	40.6
BIPROPELLANT SYSTEM 24 THRUSTERS, 25 LB THRUST	391	4.6	46.5

- CONCLUSION: RETAIN MONOPROPELLANT APS DESIGN FOR SERVICING MISSION
  - EQUIVALENT COST PER LB SAVED ON THE BIPROP SYSTEM = $5.9M/26 LB = $227K/LB
  - OTHER SUBSYSTEM IMPROVEMENTS WITH $100-200K COST/LB ARE AVAILABLE AND ARE MORE COST EFFECTIVE.

30 DAY SERVICING MISSION

EPS ASSUMPTIONS AND GUIDELINES

- MISSION TIMELINE DEVELOPED FROM REFERENCE MISSION IN MSFC LETTER PD-TUG-E(74-30) DATED 10 AUGUST 1973.

- PAYLOAD POWER SUPPORT REQUIREMENTS FOR SERVICE MODES I AND II PER AIR FORCE LETTER XRZ DATED 13 AUGUST 1973.

- MODIFIED SHUTTLE FUEL CELL (BASELINED FOR TUG CONFIGURATION 410AD-2) IS A 2.5 KW STACK AT 28VDC AND CAN SUPPORT THE SERVICING MISSION PEAK POWER REQUIREMENTS WITHIN VOLTAGE REGULATION.

- THEREFORE ONLY ADDITIONAL FUEL CELL REACTANTS (AND STORAGE CAPACITY) ARE REQUIRED TO SUPPORT THE 30 DAY SERVICING MISSION.

- THE BASELINE TUG EQUIPMENT DUTY CYCLES CAN BE SELECTIVELY REDUCED CONSISTENT WITH THE LONGER MISSION DURATION. MAJOR REDUCTIONS WERE (SEE TABLE):
  - MINIMAL DMS COMPUTER AND DACU DUTY CYCLES
  - 25% DUTY CYCLE FOR CATALYST HEATERS
  - MAIN ENGINE BROUGHT UP TO TEMPERATURE PRIOR TO BURNS

410AD-2 BASELINE & ON-ORBIT SERVICING
MISSION POWER REQUIREMENTS

• SUBSYSTEM - Equip.	No.	Power (Watts)	BASELINE Duty Cycle % or (Time)	BASELINE Avg. Power (Watts)	SERVICING Duty Cycle	SERVICING Avg. Power (Watts)
• GN&C						
* - IMU (Micron)	2	15	100	30	100	30
- Star Tracker	1	28	50	14	20	6
- Laser Radar	1	35	(2HR)	1	(8HR)	1
- Satellite Rcvr	1	85	5	5	5	5
- Doppler Rcvr	1	10	15	2	15	2
- Combiner Doppler Det	1	4	15	1	15	1
* - APS Cont Elect	1	13	100	13	35	3
- ME/TVC Cont	1	15	(1HR)	1	(8HR)	1
				67		49
• COMM						
- S-Band Ded-Rcvrs	2	8	100	16	100	16
-Xmitter	1	34	25	8.5	10	4
* - S-Band Sel-Revrs	2	8	25	4	10	2
* -Xmitter	1	34	25	8.5	10	4
- Aux. Xmitter	1	34	10	3.5	5	2
* - Power Amp	1	20	25	5	10	2
- Power Amp	1	100	10	10	5	5
- BB Processor	1	4	100	4	100	4
- Ant. Switch	1	1	Neg.	1	Neg.	1
- TV Assy.	1	10	10	1	10	1
- Secure Comm	5	8	1 @ 100	16	1 @100	12
			3 @ 25	-	3 @ 10	-
			1 @ 10	-	1 @ 5	-
				78		53
• DMS						
* - Computer	2	39	100	78	1 @100	
					1 @ 10	43
- Tape Recorder	1	8	75	6	50	4
* - FSI Controller	1	23	100	23	100	23
* - DACU	3	21	100	63	2 @ 70	36
					1 @ 30	
* - Sensors	190	0.1	100	19	100	19
				189		125
		ASTRIONICS SUB-TOTAL		334		227
• APS					625HR@ 25%	
* - Catalyst Heaters	24	83	100	83	93HR@100%	28
* - Thruster Assy	12	24	-	4		4
- Thruster Isolat. Valves	2	70	-	-		-
				87		32
• MPS						
- Lo Level Sensor	1	2	100	2	100	2
- Engine Heater	1	40	100	40	79HRS + Eng.Warmup	8
- Engine Valves,Pre Valve	4	32	-			
- Gimbal Drive Actuators	2	90	-	5		1
- Pre-Valves	2	32	-			
				47		11
		UTILIZATION EQUIP. SUB-TOTAL		468		270
• EPS						
* - Dist. & Control	-	-	100%	47		27
		TOTAL EQUIP POWER REQMT		515		297

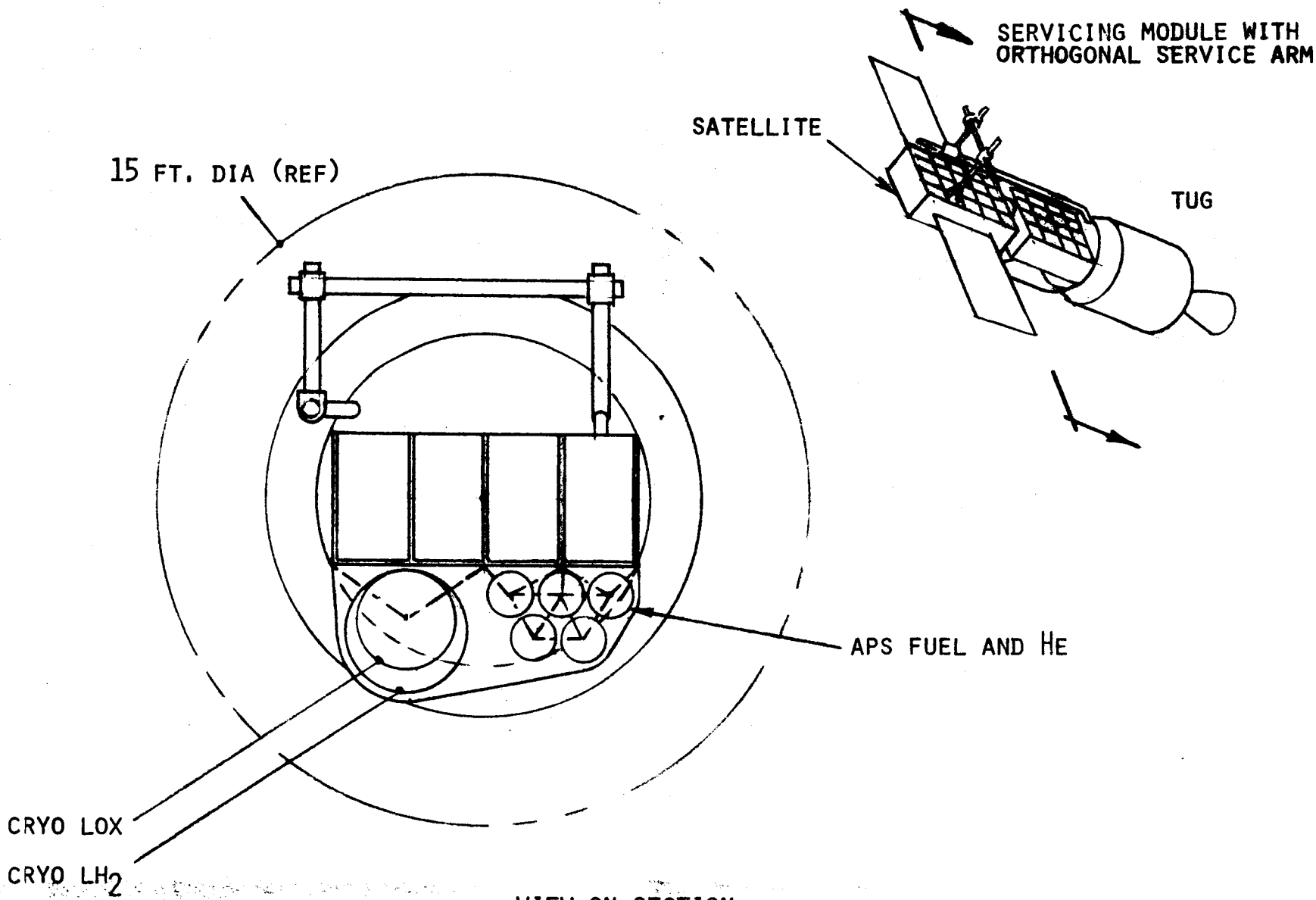
* ESSENTIAL EQUIPMENT

F-8.11.3-12

EPS REQUIREMENTS FOR 30 DAY SERVICING MISSION

MISSION	VEHICLE				TOTAL ENERGY (KWH)	CRYO STORAGE REQUIREMENTS			
						HYDROGEN		OXYGEN	
	AVERAGE POWER (WATTS)	ENERGY (KWH)	AVERAGE POWER (WATTS)	ENERGY (KWH)		H_2 (LBS)	INERT TANK WT. (LBS)	O_2 (LBS)	INERT TANK WT. (LBS)
BASELINE 410AD-2 TUG	580	68	300	32	100	10	66	80	68
SERVICE MODE I	297	214	160	116	340	34	94	272	102
SERVICE MODE II	297	214	300	237	451	45	106	360	117

SERVICING MODULE



VIEW ON SECTION

30 DAY SERVICING MISSION
WEIGHT SUMMARY

	VEHICLE WEIGHT (LBS)	
	SERVICE I	SERVICE II
410AD-2 TUG	3411	3411
DELTA APS INERT. WT.	95	95
DELTA EPS INERT. WT.	62	89
DELTA STRUCTURAL WT.	47	53
DELTA 10% CONTINGENCY	20	24
EQUIVALENT TUG FIXED WT.	3635	3672
SERVICING UNIT	500	500
EQUIVALENT BURNOUT WT.	4135	4172

GRUMMAN

30 DAY SERVICING MISSION

PERFORMANCE SUMMARY

- BASELINE PERFORMANCE (FROM PERFORMANCE ANALYSES)

	TOTAL WT (LBS.)	WT EACH OF 4 PARTS
- SERVICE I	686	171.5
- SERVICE II	96 *	24

* FIN WT - BO WT = 4268 - 4172

- POTENTIAL PERFORMANCE IMPROVEMENTS

  - SERVICE I - IF SERVICE UNIT RETURN WEIGHT IS LESS THAN 500 LBS

S.U. WT RETURNED	TOTAL SRU WT DEPLOYED
500 (BASELINE)	686
300	1418
0	2516

  - SERVICE II - IF HIGHER PERFORMANCE CLASS II MAIN PROPULSION ENGINE IS SUBSTITUTED FOR CLASS I ENGINE IN BASELINE.

$$\text{SRU WT} = \frac{6 \text{ SEC } I_{sp} (97)}{366} + 7\,(1.1) = 159 + 8 = 167 \text{ LB}$$

TOTAL SRU WT = 96 + 167 = 263 LB

GRUMMAN

RELIABILITY SENSITIVITY - 30 DAY MISSION

(410AD-2)

	168 HRS	720 HRS
STRUCTURE	.99900	.99569
PROPULSION		
- MPS	.99133	.96445
- APS	.99882	.99071
AVIONICS		
- GN&C	.99405	.97108
- COMM	.99912	.99596
- DMS	.99936	.99576
- THERMO	.99871	.99376
- POWER	.99238	.96838
TOTAL	.9730	.8817

GRUMMAN

30 DAY SERVICING MISSION

COST IMPACT

COST INCREASE FOR SERVICING KIT

SUBSYSTEM	SERVICE I DDT&E	SERVICE I UNIT COST	SERVICE I TOTAL PROGRAM	SERVICE II DDT&E	SERVICE II UNIT COST	SERVICE II TOTAL PROGRAM
APS	0	$423K	$4.2M	0	$423K	$4.2M
EPS	$8.1M	$620K	$14.3M	$8.1M	$690K	$15.0M
STRUCTURE	$240K	$18K	$420K	$264K	$21K	$474K
TOTAL	$8.3M	$1.1M	$18.9M	$8.4M	$1.1M	$19.7M

GRUMMAN

30 DAY SERVICING MISSION

DEVELOPMENT RISK AND TECHNICAL ISSUES

- THERE ARE NO DEVELOPMENT OR TECHNICAL ISSUES ASSOCIATED WITH PROVIDING THE TUG SERVICE KIT HARDWARE TO SUPPORT THE 30 DAY SERVICING MISSION.

- THERE MOST CERTAINLY WILL BE DEVELOPMENT ISSUES ASSOCIATED WITH DESIGN AND OPERATIONAL DEVELOPMENT OF THE SERVICING MODULE AND ASSOCIATED PAYLOAD INTERFACES. THESE WERE NOT CONSIDERED AS PART OF TUG PROGRAM DEFINITION.

GRUMMAN

30 DAY SERVICING MISSION

SUMMARY

- PERFORMANCE CAPABILITY
  - TOTAL SRU DELIVERY CAPABILITY IN SERVICE MODE I IS 686 LB. CAN BE INCREASED TO 2516 LB IF SERVICE UNIT IS NOT RETURNED TO SHUTTLE
  - TOTAL SRU ROUND TRIP CAPABILITY IN SERVICE MODE II IS 96 LB. CAN BE INCREASED TO 263 LB IF HIGHER PERFORMANCE ENGINE IS INCORPORATED IN TUG.
- COST IMPACT TO TUG PROGRAM FOR SERVICE MODES I AND II RESPECTIVELY ARE $8.3 - $8.4M DDT&E AND $18.9 - $19.7M TOTAL PROGRAM COST.
- TUG ADD-ON EQUIPMENT WAS PROVIDED IN KIT FORM AND INTEGRATED WITH SERVICE UNIT INTO A SERVICING MODULE.
- THERE ARE NO TUG PROGRAM DEVELOPMENT OR TECHNICAL ISSUES ASSOCIATED WITH PROVIDING THE SERVICING KIT.

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8.11.4 - DOD COMMUNICATION REQUIREMENTS SENSITIVITY STUDY

OBJECTIVE

STARTING WITH A COMMUNICATIONS SYSTEM THAT MEETS BASIC NASA REQUIREMENTS, DETERMINE THE IMPACT OF EXPANDING TO THE FULL NASA/DOD CAPABILITY COMMUNICATIONS SYSTEM OF CONCEPT 310RE-3A.

GUIDELINES AND ASSUMPTIONS

DEFINE THE IMPACT IN TWO INCREMENTS, STARTING WITH THE BASIC NASA REQUIREMENTS (STDN COMPATIBLE):

1. ADD TDRS COMPATIBILITY (SPREAD SPECTRUM)
2. ADD DOD COMMUNICATIONS REQUIREMENTS (SGLS COMPATIBILITY PLUS SECURE COMM)

STUDY AREAS

- WEIGHT IMPACT
- PERFORMANCE IMPACT
- COST IMPACT
- DEVELOPMENT RISK AND TECHNOLOGY ISSUES

COMPONENT	BASIC NASA (STDN)			BASIC NASA + TDRS (SPREAD SPECTRUM)			FULL CAPABILITY (SGLS +) (SECURE COMM.)		
	COMP WT (LBS)	QTY	TOTAL WT (LBS)	COMP WT (LBS)	QTY	TOTAL WT (LBS)	COMP WT (LBS)	QTY	TOTAL WT (LBS)
1. CCS X'ceiver	9	1	9	13	1	13	13	1	13
2. DFS X'ceiver	14	1	14	21	1	21	21	1	21
3. Aux X'Mtr	5	1	5	5	1	5	5	1	5
4. 5W Power Amp	1	1	1	1	1	1	1	1	1
5. 20W Power Amp	3	1	3	3	1	3	3	1	3
6. DFS/CSS B.B. Proc	3	1	3	4	1	4	6	1	6
7. DFS Diplexer	1	2	2	1	2	2	1	2	2
8. CSS Diplexer	1	2	2	1	2	2	1	2	2
9. Antenna Switch	1	2	2	1	2	2	1	2	2
10. DFS Antenna	0.5	2	1	0.5	2	1	0.5	2	1
11. CSS Antenna	0.5	2	1	0.5	2	1	0.5	2	1
12. Power Splitter	1	1	1	1	1	1	1	1	1
13. TV Assembly	12	1	12	12	1	12	12	1	12
14. DFS B.B. Proc	-	-	-	-	-	-	-	-	-
15. Secure Comm	-	-	-	-	-	-	6	5	30
TOTAL SYSTEM WEIGHT (LBS)	-	-	56	-	-	68	-	-	100

NOTE: DELETION OF SECURE COMM REDUCES EPS REACTANTS BY 2 POUNDS

COMMUNICATIONS REQUIREMENTS SENSITIVITY STUDY
WEIGHT COMPARISON

FLIGHT MODE	GEOSYNCHRONOUS PAYLOAD (LBS)		
	BASIC NASA (STDN)	BASIC NASA + TDRS (SPREAD SPECTRUM)	FULL CAPABILITY (SGLS + SECURE COMM)
DEPLOY	5187	5143	5026
RETRIEVE	1678	1662	1618
ROUND TRIP	1140	1128	1096

COMMUNICATIONS REQUIREMENTS SENSITIVITY
STUDY PERFORMANCE COMPARISON

COMPONENT	COST ($ X 10^{-3})						NUMBER PER SHIP SET
	DDT & E			RECURRING			
	BASIC NASA (STDN)	BASIC NASA + TDRS (SPREAD SPEC)	FULL CAPABILITY (SGLS + SECURE COMM)	BASIC NASA (STDN)	BASIC NASA + TDRS (SPREAD SPEC)	FULL CAPABILITY (SGLS + SECURE COMM)	
1. CSS X'ceiver	400	1738	1938	100	250	290	1
2. DFS X'ceiver	200	1992	2092	50	200	220	1
3. Aux. X'Mtr	50	704	704	1	43	43	1
4. 5W Power Amp	50	313	313	4	10	10	1
5. 20 W Power Amp	200	290	290	6	25	25	1
6. DFS/CSS B.B. Proc	40	859	859	10	10	20	1
7. DFS Diplexer	8	9	9	3.8	3.8	3.8	2
8. CSS Diplexer	8	10	10	3.4	3.4	3.4	2
9. Antenna Switch	27	27	27	2	2.7	2.7	2
10. DFS Antenna	23	23	23	1	1	1	2
11. CSS Antenna	18	18	18	1	1	1	2
12. Power Splitter	15	15	15	2	2	2	1
13. TV Assembly	350	350	350	250	250	250	1
14. DFS B.B. Proc	-	-	-	-	-	-	-
15. Secure Comm (GFE)	Out	Out	In	Out	Out	In	2
TOTAL COMPONENT COST	1429	6348	6648	445	813	883	-
TOTAL SYSTEM COST (Incl. Wraparound & Integration)	2031	9024	9450	475	867	942	-

COMMUNICATIONS REQUIREMENTS SENSITIVITY STUDY
COST COMPARISON

COMMUNICATIONS REQUIREMENTS SENSITIVITY STUDY

DEVELOPMENT RISK AND TECHNOLOGY ISSUES

- From a Tug viewpoint, the technology exists and there is low risk in providing the transition from the Basic NASA requirements to the full capability communications system.

- The most significant issue involved in growth of the communications capability is the development and operation of the TDRS itself.

COMMUNICATIONS CAPABILITY LEVEL	GROWTH IMPACT						
	DELTA WEIGHT (lbs)	DELTA PERFORMANCE (Geosync Payload - lbs)			DELTA COST ($ X 10^{-3})		RISK
		DEPLOY	RETRIEVE	ROUND TRIP	DDT&E	RECURRING	
BASIC NASA (STDN)	0	0	0	0	0	0	LOW
BASIC NASA + TDRS (Spread Spectrum)	+ 12	- 44	- 16	- 12	+ 6993	+ 392	LOW
FULL CAPABILITY (SGLS + Secure Comm)	+ 44	- 161	- 60	- 44	+ 7419	+ 467	LOW

COMMUNICATIONS REQUIREMENTS SENSITIVITY STUDY

GROWTH IMPACT SUMMARY

8.11.5 - PAYLOAD COMMAND, CONTROL, AND CHECKOUT SENSITIVITY STUDY

OBJECTIVE:

Determine the impact on the baseline 310RE-3A Tug configuration of providing the payload command, control, and checkout function

GUIDELINES AND ASSUMPTIONS:

- The only subsystem area having significant weight or cost impact is the communications subsystem.
- The TV Assembly was assumed to be required for payload monitoring and support only.
- If there is no requirement for payload support, the DFS will be used for both Tug/Ground and Tug/Orbiter communication, but not simultaneously.

STUDY AREAS:

- Weight Impact
- Performance Impact
- Cost Impact
- Development Risk and Technology Issues

COMPONENT	WITHOUT PAYLOAD SUPPORT			WITH PAYLOAD (310RE-3A Baseline)		
	COMPONENT WEIGHT (lbs)	QUANTITY	TOTAL WEIGHT (Lbs.)	COMPONENT WEIGHT (lbs)	QUANTITY	TOTAL WEIGHT (lbs)
1. CSS X'Ceiver				13	1	13
2. DFS X'Ceiver	21	1	21	21	1	21
3. Aux X'Mtr	5	1	5	5	1	5
4. 5W Power Amp	1	2	2	1	1	1
5. 20W Power Amp				3	1	3
6. DFS/CSS B.B. Proc				6	1	6
7. DFS Diplexer	1	2	2	1	2	2
8. CSS Diplexer				1	2	2
9. Antenna Switch	1	1	1	1	2	2
10. DFS Antenna	0.5	2	1	0.5	2	1
11. CSS Antenna				0.5	2	1
12. Power Splitter				1	1	1
13. TV Assembly				12	1	12
14. DFS B.B. Proc	3	1	3			
15. Secure Comm	6	2	12	6	5	30
TOTAL SYSTEM WEIGHT (lbs)	47			100		

NOTE: Elimination of P/L support reduces EPS reactants by 4 lbs.

PAYLOAD COMMAND, CONTROL, AND CHECKOUT SENSITIVITY STUDY

WEIGHT COMPARISON

FLIGHT MODE	GEOSYNCHRONOUS PAYLOAD (lbs)	
	WITHOUT PAYLOAD SUPPORT	WITH PAYLOAD SUPPORT (310RE-3A Baseline)
DEPLOY	5220	5026
RETRIEVE	1691	1618
ROUND TRIP	1149	1096

PAYLOAD COMMAND, CONTROL, AND CHECKOUT SENSITIVITY STUDY

PERFORMANCE COMPARISON

COMPONENT	COST ($ X 10-3)				QUANTITY PER SHIP SET	
	DDT&E		RECURRING			
	WITHOUT PAYLOAD SUPPORT	WITH PAYLOAD SUPPORT	WITHOUT PAYLOAD SUPPORT	WITH PAYLOAD SUPPORT	WITHOUT PAYLOAD SUPPORT	WITH PAYLOAD SUPPORT
1. CSS X'Ceiver		1938		290		1
2. DFS X'Ceiver	2092	2092	220	220	1	1
3. Aux X'Mtr	704	704	43	43	1	1
4. 5W Power Amp	313	313	10	10	2	1
5. 20W Power Amp		290		25		1
6. DFS/CSS B.B. Proc		859		20		1
7. DFS Diplexer		9		3.8		2
8. CSS Diplexer	10	10	3.4	3.4	2	2
9. Antenna Switch		27		2.7		2
10. DFS Antenna	23	23	1	1	1	2
11. CSS Antenna	18	18	1	1	2	2
12. Power Splitter		15		2		1
13. TV Assembly		350		250		1
14. DFS B.B. Proc	583		50	50	1	-
15. Secure Comm (GFE)	IN	IN	IN	IN	2	5
TOTAL COMPONENT COST	3751	6648	346	883	-	-
TOTAL SYSTEM COST (Incl Wraparound & Integration)	5332	9450	369	942	-	-

PAYLOAD COMMAND, CONTROL, AND CHECKOUT SENSITIVITY STUDY

COST COMPARISON

PAYLOAD COMMAND, CONTROL, AND CHECKOUT SENSITIVITY STUDY

DEVELOPMENT RISK AND TECHNOLOGY ISSUES

- DFS hardware exists for STDN or SGLS compatible systems. Existing hardware can be modified to be STDN and SGLS compatible, but not TDRS compatible

- CSS hardware does not exist since no spacecraft has had to communicate with other spacecraft on the same frequency as the ground. New equipment must be developed.

- Elimination of payload support and the associated requirement for CSS equipment would further reduce the risk of an already low risk subsystem.

PAYLOAD SUPPORT LEVEL	GROWTH IMPACT						
	DELTA WEIGHT (lbs)	DELTA PERFORMANCE (Geosynch Payload - lbs)			DELTA COST ($ x 10^{-3})		RISK
		DEPLOY	RETRIEVE	ROUND TRIP	DDT&E	RECURRING	
WITHOUT PAYLOAD SUPPORT	0	0	0	0	0	0	LOW
WITH PAYLOAD SUPPORT (310RE-3A Baseline)	+53	-194	-73	-53	+4118	+573	LOW

PAYLOAD COMMAND, CONTROL AND CHECKOUT SENSITIVITY STUDY

GROWTH IMPACT SUMMARY

8.11.6- ELECTRICAL POWER TO PAYLOAD SENSITIVITY STUDY

OBJECTIVE: DETERMINE EFFECT OF PROVIDING 300 WATT ELECTRICAL POWER TO PAYLOAD DURING TUG DEPLOYMENT AND RETRIEVAL OPERATIONS

STUDY PLAN:

- DETERMINE WEIGHT AND COST IMPACT FOR ADDING REQUIREMENT TO PROVIDE 300W OF PAYLOAD SUPPORT POWER DURING PAYLOAD DEPLOYMENT TO CONCEPT 110A-1

- DETERMINE WEIGHT AND COST IMPACT FOR DELETING REQUIREMENT TO PROVIDE 300W OF PAYLOAD SUPPORT POWER DURING PAYLOAD DEPLOYMENT AND RETRIEVAL FOR OTHER FIVE TUG CONCEPTS

ELECTRICAL POWER TO PAYLOAD SENSITIVITY STUDY

GUIDELINES AND ASSUMPTIONS

- 110A-1 DOES NOT PROVIDE PAYLOAD POWER; ALL OTHER VEHICLES PROVIDE 300 W (28VDC) AT PAYLOAD INTERFACE

- EPS "ON" AND PAYLOAD SUPPORT TIMES FOR SIZING EPS BASELINE:

		110A-1	320AE-3A	ALL OTHER CONFIGURATIONS
- EPS ON TIME	HRS	34	123	117
- PAYLOAD SUPPORT TIME	HRS	-0-	57	100

- PAYLOAD SUPPORT TIME DELTAS:

110A-1	+ 11 HOURS
320AE-3A	- 57 HOURS
ALL OTHERS	-100 HOURS

- PAYLOAD POWER REQUIREMENTS AT TUG POWER SOURCE INCLUDE 10% FACTOR FOR DISTRIBUTION AND CONTROL.

ELECTRICAL POWER TO PAYLOAD SENSITIVITY STUDY RESULTS

OPTION	CONFIG.	ENERGY REQUIREMENT KW-HB			WEIGHT CHANGES - LBS		
		BASELINE	PAYLOAD		ADD	REDUCE	
			Add	Reduce		Reactant	Inert Tank
1	110A-1	18	3.3	-	36	—	
2	410AD-2	94	-	30	-	30.4	9
3A	310-3A→310RE-3A	94	-	30	-	28.6	8.5
3A	320A-3A→320AE-3A	78	-	17	-	16.8	5
3B	310 -3B→310ARE-3B	94	-	30	-	28.6	8.5
3B	510A-3B→510ADE-3B	94	-	30	-	30.4	9

PERFORMANCE AND COST SUMMARY

DELTA TO BASELINE

CONCEPT		PAYLOAD DEPLOY CAPABILITY	UNIT COST	TOTAL PRODUCTION COST
110A-1		- 137 lb	+ $1.9K	+ $405K
410AD-2		+38 lb	- $47K	- $470K
310	310RE-3A	+36 lb	- $47K	- $1130K
320A	320AE-3A	? lb	- $23K	- $552K
310	310ARE-3B	+36 lb	- $47K	- $750K
510A	510ADE-3B	+38 lb	- $47K	- $658K

- o CHANGE IN DDT&E COSTS IS NEGLIGIBLE FOR ALL CONCEPTS
- o PROVIDING 300W PAYLOAD POWER DURING DEPLOYMENT FOR 110A-1 RESULTS IN 137 lb REDUCTION IN DEPLOY CAPABILITY
- o OTHER PERFORMANCE AND COST DELTAS ARE NOT SIGNIFICANT

8.11.7- DESIGN LIFE SENSITIVITY

FACTORS

- o VEHICLE STRUCTURE
  - o TANK FRACTURE MECHANICS
  - o TANK REPLACEMENT
- o VEHICLE EQUIPMENT
  - o LIMITED LIFE
    - - FUEL CELL
    - - MAIN ENGINE
    - - THERMO COATINGS/INSULATION
- o MISSION RELIABILITY
  - o EXPECTED NUMBER OF FLIGHTS
- o TRAFFIC MODEL
  - o EXPENDABLE MISSIONS

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DESIGN LIFE SENSITIVITY (CONTINUED)

VEHICLE STRUCTURE

- o TANK FRACTURE MECHANICS
  - o FLAW GROWTH

    50% FLAW (.008) DOES NOT RUPTURE AT 800 CYCLES
    (EQUIVALENT TO 100 MISSIONS - SCATTER FACTOR - (4))

  - o FLAW DETECTABILITY

    STATE OF ART CAPABILITY -

    0.002 - 0.004 FLAWS USING RADIOGRAPHIC TECHNIQUES -
    (10% SENSITIVITY)

- o TANK REPLACEABILITY

  TANK REPLACEMENT COSTS

$300K	- TANK (410AD-2 TITANIUM)
430K	- INSTALLATION AND CERTIFICATION
$730K	TOTAL

  - o 6 - 8 MONTHS FACTORY FLOW

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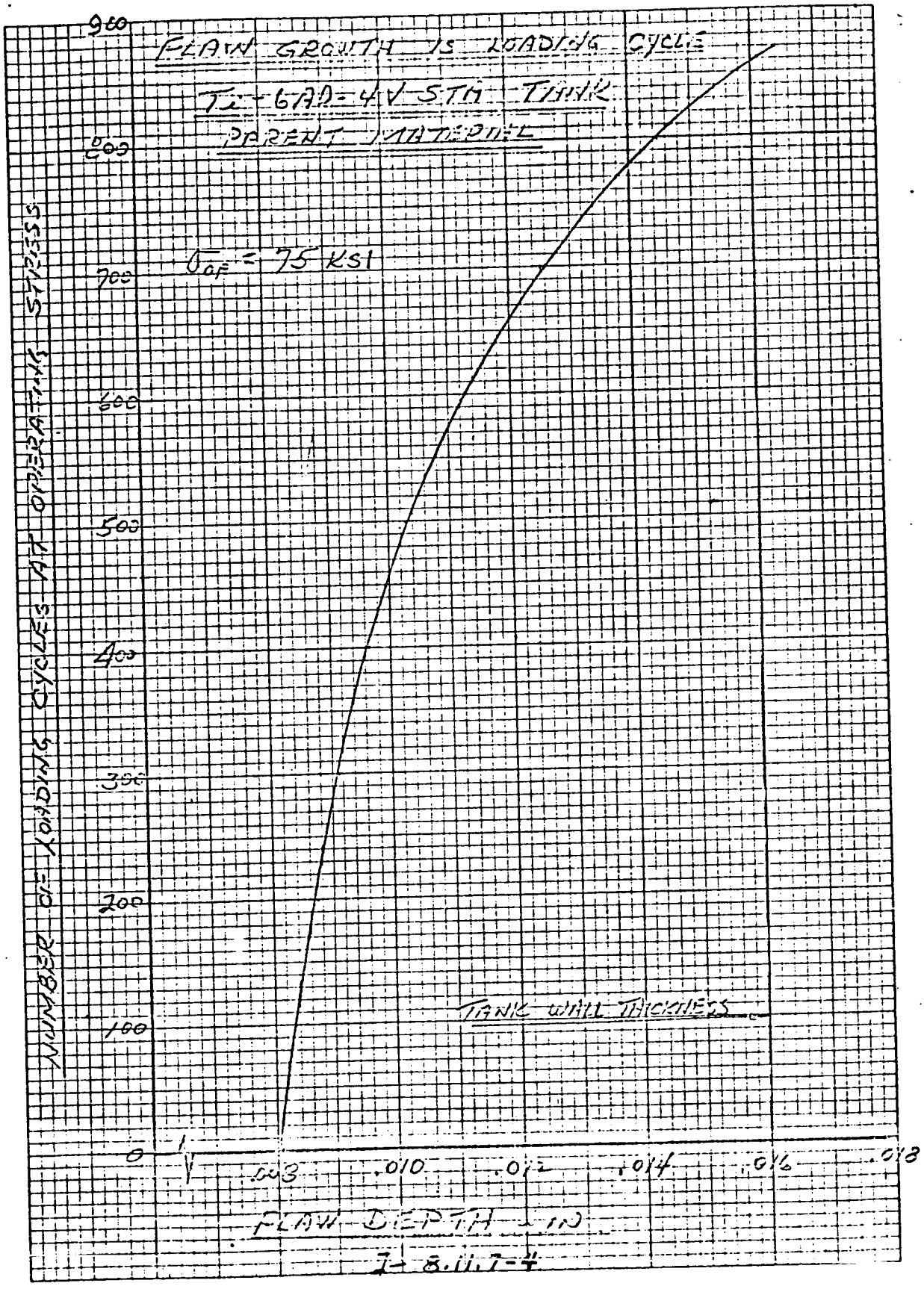
I-8.1.1.7-2

TANK LIFE EVALUATION

MATERIAL	t IN.	OPERATING KSI	K_{IC} KSI IN	K_{TH} KIC	"A" FLAW SIZE - INCHES INITIAL	AFTER 160 CYCLES	AFTER 800 CYCLES
Titanium 6AL-4V STA	0.016	75	44	.70	.008	.0085	.0145
Aluminum 2219-T87	0.039	30.8	36	.70	.0098	.011	.034

T-8117-3



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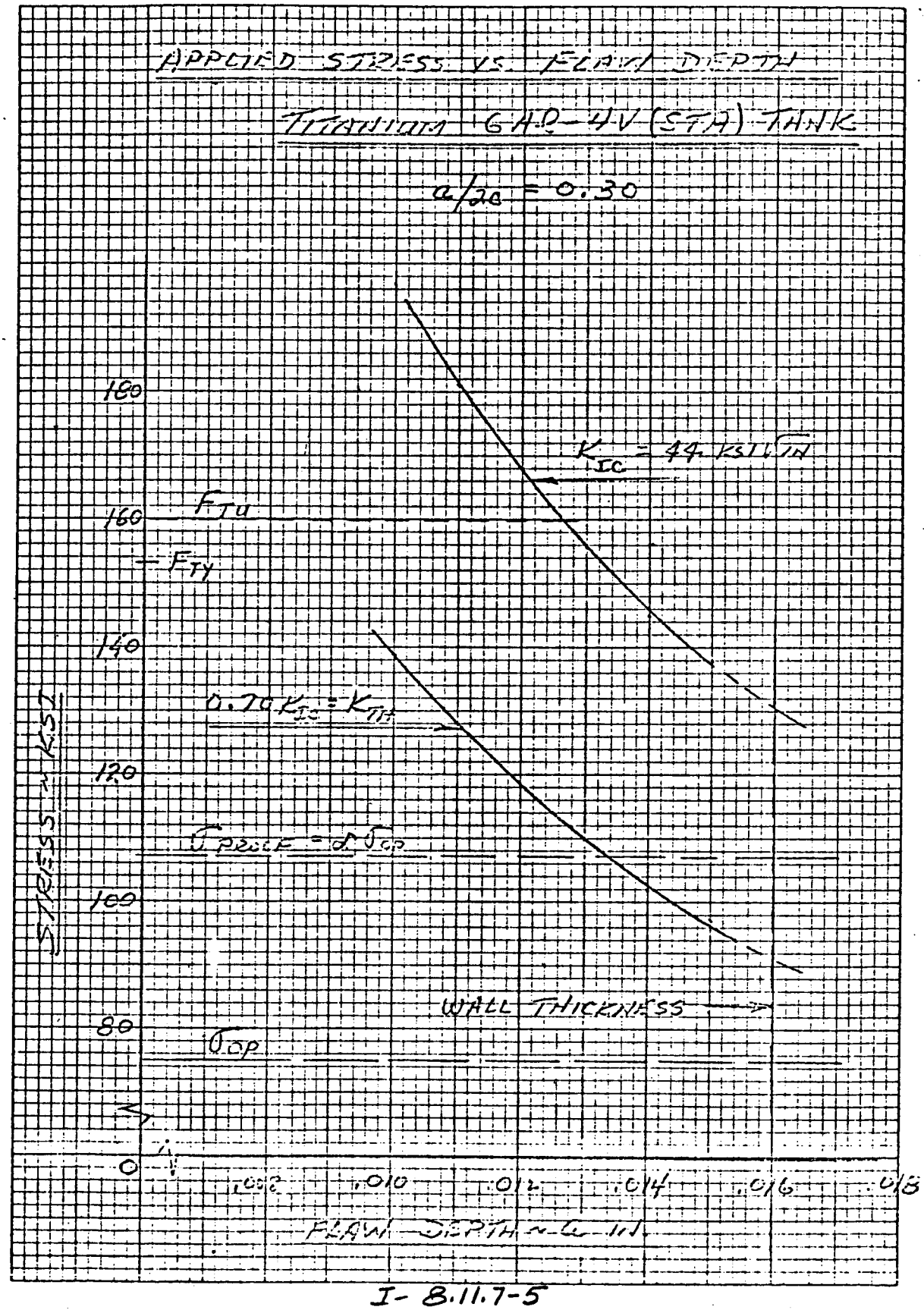
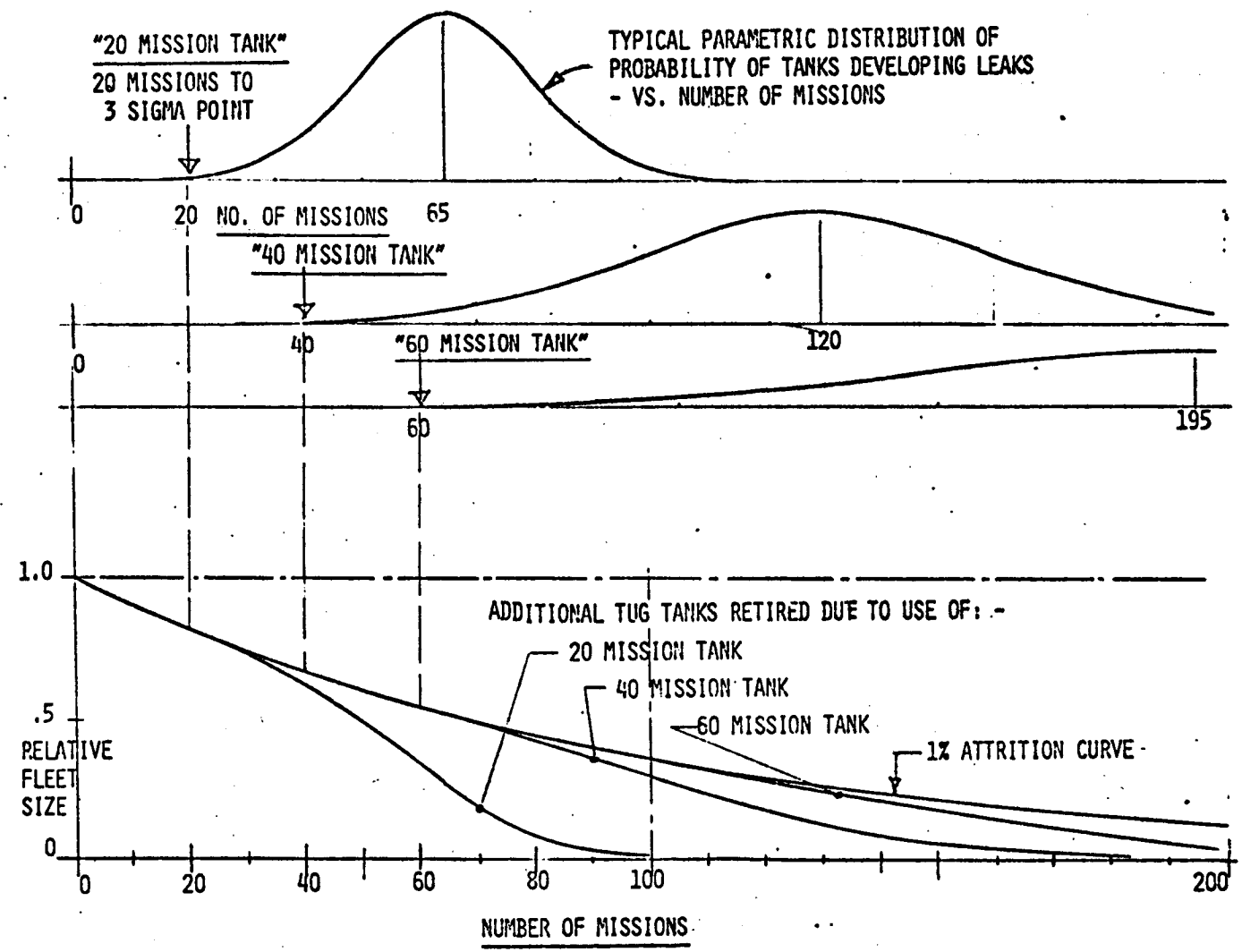
EUGENE DIETZGEN CO.
MADE IN U.S.A.
10 X 10 PER INCH



EUGENE DIETZGEN CO.
MADE IN U. S. A.
NO. 340R-10 DIETZGEN GRAPH PAPER
10 X 10 PER INCH


"20 MISSION TANK"
20 MISSIONS TO
3 SIGMA POINT
TYPICAL PARAMETRIC DISTRIBUTION OF
PROBABILITY OF TANKS DEVELOPING LEAKS
- VS. NUMBER OF MISSIONS
0
20
NO. OF MISSIONS
65
"40 MISSION TANK"
40
120
"60 MISSION TANK"
0
60
195
1.0
ADDITIONAL TUG TANKS RETIRED DUE TO USE OF: -
20 MISSION TANK
40 MISSION TANK
60 MISSION TANK
1% ATTRITION CURVE
.5
RELATIVE
FLEET
SIZE
0
0
20
40
60
80
100
200
NUMBER OF MISSIONS

DESIGN LIFE SENSITIVITY (CONTINUED)

VEHICLE STRUCTURE (CONTINUED)

- ANALYSIS INDICATES THAT TANK DESIGN AND FLAW DETECTION CAPABILITY JUSTIFIES REUSE OF TANK FOR 100 MISSIONS.
- HOWEVER, THERE IS A LACK OF SUBSTANTIATING TEST DATA
- TANK REPLACEMENT IS A VIABLE ALTERNATIVE SINCE COST OF TANK REPLACEMENT REPRESENTS ONLY ABOUT 10% OF VEHICLE REPLACEMENT COST.

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DESIGN LIFE SENSITIVITY (CONTINUED)

VEHICLE EQUIPMENT

LIMITED LIFE -

- o SURVEY INDICATES THAT MOST EQUIPMENTS CAN BE REUSED UP TO 100 MISSIONS WITH CERTAIN PERIODIC TESTS AND/OR OVERHAUL
- o MAJOR LIFE LIMITED EQUIPMENTS
  - FUEL CELL - 30 MISSIONS (EXTENDED TO 100 WITH PERIODIC OVERHAUL)
  - MAIN ENGINE - DESIGN GOAL - 20 MISSIONS WITH 100 MISSION DESIGN LIFE WITH OVERHAULS
  - THERMO COATINGS AND MULTI-LAYER INSULATION 10 MISSIONS (PREDICTED) - EXPERIENCE AND/OR TEST WILL DETERMINE ACTUAL REQUIREMENTS

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LIMITED LIFE SURVEY SUMMARY

SUBSYSTEM/EQUIPMENT	SHELF LIFE LIMIT	Freq/Yrs	ON-VEHICLE MAINTENANCE	Freq	BENCH MAINTENANCE	Freq	DEPOT MAINTENANCE	Freq	REUSE BEYOND 20 MISSIONS: Bench Check	Overhaul	Other	REMARKS
DATA MGT												
Computer												
Mass Memory			Replace Tape	1						Check and/ or Replace Bearings		
Tape Recorder			Replace Tape	1						Check and/ or Replace Bearings		
Data Bus/Formatter												
DAU/Sig Cond												
Hi-Press Sensors			Recalibrate	5					X			
PCM/Sig Cond												
POWER												
Fuel Cell	Seals	10	Nitrogen Purge	1	Yes	2	Yes	5	X	X		Overhaul every 30 Missions
Battery		1										
Cryo Tanks	Seals	10	Check Dewar Vacuum	1	Evacuate Dewar	10						
GN&C												
IMU	Recalibrate	60 days	Recalibrate	1					X	As Req.		
Horizon Scanner	Test	1							X			
MPC Elect									X			
APC Elect									X			
Laser Radar	TBD	TBD	Calibrate	1			TBD	TBD	X	As Req.		
Star Tracker		8	Test	1					X			
Sync Inv Sat Rcvr									X			
Doppler Receiver									X			
Doppler Detector									X	As Req.		
Rate Gyro Assy	TBD											
APS												
Thruster					Catalyst Insp	TBD	Catalyst Repl	TBD		X		
Helium Tank											X	Proof Test
He Latch Solenoid	Seals	2								X		
Shut-Off Valves										X		
Helium Regulator					Adjust	As Req.			X			
Quad Check Valve	Seals	2								X		
Vent Valve										X		
Burst Disc									X			
Relief Valve	Seals	2								X		
Isolation Valve											X	Inspect Bladder
Fuel Tank (w/bladder)	Bladder	2										

SUBSYSTEM/EQUIPMENT	SHELF LIFE LIMIT	Freq/Yrs	ON-VEHICLE MAINTENANCE	Freq	BENCH MAINTENANCE	Freq	DEPOT MAINTENACE	Freq	REUSE BEYOND 20 MISSIONS Bench Check	Overhaul	Other	REMARKS
XPS												
Engine	Seals	2							X			
Helium Tank											X	Proof Test
Pre-Valves	Seals	2							X			
Quick Disconnects									X			
He Iso Valve	Seals	2							X			
Regulators									X			
Relief Valves	Seals	2							X			
Burst Disc									X			
Quad Check Valve	Seals	2							X			
Vent Valve	Seals	2							X			
COMMUNICATIONS												
Receiver									X			
Transmitter									X			
Filter									X			
Filter Control									X			
Diplexer									X			
Ant Transfer Sw									X			
Power Amplifier									X			
Power Splitter									X			
Baseband Processor									X			
Omni Antenna									X			
TV									X			Replace at TBD Life
Aux Transmitter-TV									X			
Power Amp-TV									X			
THERMO												
Multilayer Insulation												Experience (on test) will determine life capability
Thermo Coatings			Recoat	10								
Heat Pipe Radiator												
Fuel Cell Radiation System							X	TBD				

GRUMMAN AEROSPACE SPACE TUG

LIMITED LIFE SURVEY

8-29-73

TYPICAL FORM

Subsystem GNC

Equipment STAR TRACKER

Date 7/3/73

Does this equipment have shelf life limitations?

- [ ] No
- [x] Yes - If yes, describe 50000 Hrs.

Frequency

Does this equipment require any periodic test, adjustment, calibration or maintenance while installed on the Tug?

- [ ] No
- [x] Yes - if Yes, describe periodic task(s) STAR TRACKER PERFORMANCE TEST

Frequency of task (number of missions)

Does this equipment require any periodic bench test, calibration, adjustment or maintenance?

- [x] No
- [ ] Yes - if Yes, describe

Frequency

Does this equipment require periodic overhaul?

- [x] No
- [ ] Yes - if yes, at what frequency?

If the Tug is designed for 20 missions, can we plan on removing this equipment for reinstallation on a new Tug for 20 more missions?

- [ ] No
- [x] Yes - if Yes, what would you recommend to be done between removal and reinstallation?
  - [x] Bench Check
  - [x] Overhaul (IF REQUIRED)
  - [ ] Other - describe

How many times can it be reused? AT LEAST 4

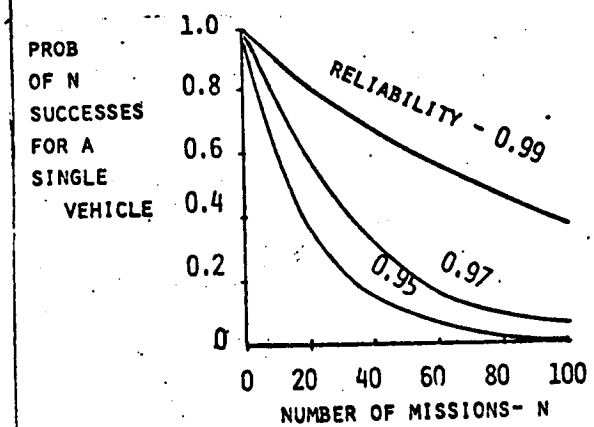
REMARKS:

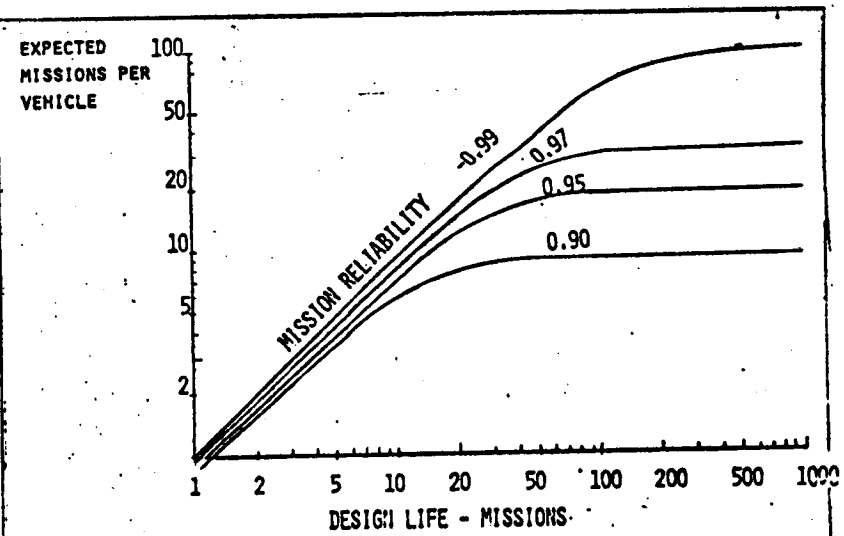
I-8.11.7-11

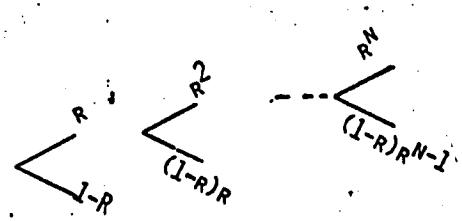
DESIGN LIFE SENSITIVITY (CONT'D)

MISSION RELIABILITY

- EXPECTED NUMBER OF MISSIONS PER TUG IS A FUNCTION OF DESIGN LIFE AND RELIABILITY







$$EM = \frac{R - R^{(N+1)}}{1-R}$$

$$\underset{N \to \infty}{=} \frac{1}{1-R} - 1$$

GRUMMAN

DESIGN LIFE SENSITIVITY (CONTINUED)

TRAFFIC MODEL

VEHICLES REQUIRED AS A FUNCTION OF DESIGN LIFE VS. EXPENDABLE MISSIONS

- 310 → 310RE-3A 351 MISSIONS (17 EXPENDABLE)
- EQUIVALENT TO 310 → 310ARE-3B (10 EXPENDABLE)
- ASSUME ONE LOSS PER 100 FLIGHTS

		DESIGN LIFE		
		20	50	100
NUMBER OF EXPENDABLES	17	24	23	23
	10	23	17	16

GRUMMAN

20 MISSION LIFE (17 EXPENDED)

	79	80	81	82	83	84	85	86	87	88	89	90	TOTAL
310-3A/310RE-3A													
TOTAL FLIGHTS		3	12	17	27	32	42	46	43	40	42	47	351
(PROG BUILD-UP)													
EXPEND				2		4		4	3		3	1	17
VEHICLE 1		2	6	6E									14
2		1	6	7E									14
3				4	15	1E							20
4					12	1E							13
5						14E							14
6						15E							15
7						1	17	2E					20
8							17	3E					20
9							8	12E					20
10								17E					17
11								12	8E				20
12									17E				17
13									17E				17
14									1	17	2E		20
15										17	3E		20
16										6	14E		20
17											17	3E	20
18											6	14R	20
19												17	17
20												13	13
21R													
22R													
23R													
24R													

T-8.11.7-14

G316 REV. 2
8 72 2000

GRUMMAN

UNLIMITED LIFE (17 EXPENDED)

	79	80	81	82	83	84	85	86	87	88	89	90	TOTAL
310-3A / 310RC-3A													
TOTAL FLIGHTS		3	12	17	27	32	42	46	43	40	42	47	351
(PROG. BUILD-UP)													
EXPEND				2		4		4	3		3	1	17
VEHICLE 1		2	6	6E									14
2		1	6	7E									14
3				4	17	1E							22
4					10	1E							11
5						14E							14
6						15E							15
7						1	17	1E					19
8							17	6E					23
9							8	17E					25
10								17E					17
11								5	15E				20
12									17E				17
13									10E				10
14									1	17	4E		22
15										17	4E		21
16										6	17E		23
17											17	17E	34
18												17	17
19												13	13
20 R													
21 R													
22 R													
23 R													

T-8.11.7-15

G316 REV 2
8 72 2000P

GRUMMAN

20 MISSION LIFE (10 EXPENDED)

	79	80	81	82	83	84	85	86	87	88	89	90	TOTAL
310-3A/310RE-3A													
TOTAL FLIGHTS		3	12	17	27	32	42	46	43	40	42	47	351
(PROGRAM BUILDUP)													
EXPEND				2		2		1	1		3	1	10
VEHICLE 1		2	6	6E									14
2		1	6	7E									14
3				4	15	1E							20
4					12	8E							20
5						17	3R						20
6						6	14R						20
7							17	3E					20
8							8	12R					20
9								17	3E				20
10								14	6R				20
11									17	3R			20
12									17	3R			20
13										17	3E		20
14										17	3E		20
15											17E		17
16											17	3E	20
17											2	17	19
18												17	17
19												10	10
20R													
21R													
22R													
23R													

I-8.11.7-16

G316 REV. 4
8 72 2000

GRUMMAN

50 MISSION LIFE (10 EXPENDED)

	79	80	81	82	83	84	85	86	87	88	89	90	TOTAL
310-3A / 310RE-3A													
TOTAL FLIGHTS (PROG. BUILD-UP)		3	12	17	27	32	42	46	43	40	42	47	354
EXPEND				2		2		1	1		3	1	10
VEHICLE 1		2	6	6 E									14
2		1	6	7 E									14
3				4	17	15 E							36
4					10	17 E							27
5							17	17 E	13				34
6							17	17	16 E				50
7							8	12	17	13 R			50
8									10	17	17 E		44
9										10	17 E		27
10											8 E		8
11												17 E	17
12												17	17
13												13	13
14 R													
15 R													
16 R													
17 R													

I-8.14.7-17

G316 REV 2
8 72 2000

GRUMMAN

100 MISSION LIFE (10 EXPENDED)

	79	80	81	82	83	84	85	86	87	88	89	90	TOTAL
310-3A / 310RE-3A													
TOTAL FLIGHTS		3	12	17	27	32	42	46	43	40	42	47	351
(PROG. BUILD-UP)													
EXPEND				2		2		1	1		3	1	10
VEHICLE 1		2	6	6E									14
2		1	6	7E									14
3				4	15	15E							34
4					12	16E							28
5						1	17	17E					35
6							17	17	17E				51
7							8	12	9	17	17E		63
8									17	17	17E		51
9										6	8E		14
10												17E	17
11												17	17
12												13	13
13R													
14R													
15R													
16R													

I-8.11.7-18

GRUMMAN

DESIGN LIFE SENSITIVITY

CONCLUSIONS

COST

TECH - N/A

DDT&E - N/A

FIRST UNIT - N/A

TOTAL PRODUCTION	17	10 ← NO. OF EXPENDED MISSIONS
20 REUSES -	$ 184	177
50 REUSES -	$ 177	135M
100 REUSES -	$ 177	128M

VEHICLE DESIGN

INERT WEIGHT - N/A

P/L Δ WEIGHT - N/A

DEVELOPMENT RISK - ANALYSIS SHOWS THAT SELECTED MINIMUM GUAGE TANK CAPABLE OF 100 MISSIONS

CRITICAL TECH AREAS - PERFORM TESTS TO VALIDATE ANALYSIS

GRUMMAN

I-8.11.7-19

8.11.8 – SPIN STABILIZED PAYLOAD RETRIEVAL SENSITIVITY STUDY

OBJECTIVE: DETERMINE EFFECT ON TUG PROGRAM IF TUG IS REQUIRED TO DESPIN STABILIZED PAYLOADS WHICH ARE CANDIDATES FOR RETRIEVAL

APPROACH

- TOPSS STUDY (FINAL REPORT DATED 5 MARCH 1973) RECOMMENDED THAT REUSABLE DESPIN KIT ON TUG BE UTILIZED TO DESPIN PAYLOADS
- TUG APS WOULD NULL RESIDUAL RATES
- DESPIN KIT WAS ESTIMATED TO WEIGH 90 LB.

RESULTS

- MOST SIGNIFICANT IMPACT IS THAT TUG PAYLOAD RETRIEVAL CAPABILITY IS REDUCED BY 123 LB
- DESPIN KIT WAS ASSUMED TO BE GFE
- TUG/DESPIN KIT INTERFACE IS NOT SIGNIFICANTLY MORE COMPLEX THAN TUG/PAYLOAD INTERFACE
- TUG APS PROPELLANT REQUIREMENTS TO NULL RESIDUAL RATES IS SMALL (LESS THAN 2 LB)
- TUG PROGRAM COST IMPACT IS SMALL. DEVELOPMENT OF GFE DESPIN KIT AND PAYLOAD/DESPIN KIT INTEGRATION WAS NOT ESTIMATED

8.11.9- RENDEZVOUS AND DOCKING SENSITIVITY STUDY

OBJECTIVE: ESTABLISH IMPACT ON STORABLE TUG CONCEPTS OF PROVIDING RETRIEVAL CAPABILITY

APPROACH

- USING CONCEPT 110A-1 (DEPLOYMENT CAPABILITY ONLY) AS A REFERENCE DEFINE THE WEIGHT, DDT&E COST, AND DEVELOPMENT RISK IMPACT OF ADDING RETRIEVAL USING THE FOLLOWING THREE MODES:
  - (1) - ADD RETRIEVAL HARDWARE TO 110A-1 CORE VEHICLE
  - (2) - ADD (1) ABOVE PLUS DEORBIT KICK STAGE
  - (3) - ADD (1) ABOVE PLUS RETRIEVAL DELAY MODULE

GRUMMAN

RENDEZVOUS AND DOCKING SENSITIVITY STUDY

WEIGHT IMPACT

	FLIGHT MODE	PLAIN TUG OPERATION		USING DKS		USING RD.M.	
	ADD REND. & DOCK CAPABILITY		LB		LB		LB
	STRUCTURE		(94)		(108)		(100)
	Outer Shell	Increase Tank Cap.from 56.3 to 59.5K lb.	12	+3	15	+1	13
	Main Frames	Increase Tank Cap.from 56.3 to 59.5K lb.	4	+5	9	+2	6
	Main Tanks	Increase Tank Cap.from 56.3 to 59.5K lb.	12		12		12
	Equipmt Mntg	To Match Incrsd Installed Subsystems	26		36		26
25	1/F - Tug/PL.	Retrieval Mechanism	40	+6	46	+3	43
	PROPULSION		(46)		(65)		(46)
	ACPS - Thrusters	Increase from 16 to 24	18		18		18
10	ACPS-Prop & He Tanks	Increase Capacity from 281 to 454 lb.	24	To 588 lb.	43	To 453 lb.	24
	Pressurization	Increased Main Tank Cap.	4		4		4
	THERMAL		(44)		(44)		(44)
	Heat Dissipation	Increase Rad Cap. (F.C. etc.)	8		8		8
	Insulation	Increased For Longer Duration	36		36		36
	ASTRIONICS		(134)		(154)		(144)
40	Rendezvous & Dock.	Add Laser Radar	40		40		40
	Power -	Chng. Bat.To Mod.F.C.& Cryo Storage -90lb Cap	44		44		44
	Power - Conv $ & Dist.		15	+20	35	+10	25
12	Communications	Add T.V.	12		12		12
10	Communications	Add Talk to P.L. Comm.	23		23		23
97	TOTAL DRY WEIGHT		318		371		334
10	10% CONTINGENCY		32		37		33
*107	DRY WT & CONTINGENCY		350		408		367

WHEN A TUG WITH RETRIEVAL CAPABILITY FLIES "DEPLOY ONLY" MISSIONS SOME ITEMS TOTALING 107 LBS IN WEIGHT & INDICATED THUS:- * CAN BE LEFT ON THE GROUND.

T-8.11.9-2

RENDEZVOUS AND DOCKING SENSITIVITY STUDY

COST IMPACT

	CONCEPT	DDT&E IMPACT ($M)
	BASELINE (110A-1)	0
(1)	ADD RETRIEVAL CAPABILITY	+ 54
(2)	ADD RETRIEVAL CAPABILITY PLUS DKS	+ 90
(3)	ADD RETRIEVAL CAPABILITY PLUS RDM	+ 79

T-8119-3

GRUMMAN

RENDEZVOUS & DOCKING SENSITIVITY STUDY

DEVELOPMENT RISK & TECHNOLOGY

- ADDING RETRIEVAL CAPABILITY TO 110A-1 HAS THE FOLLOWING IMPACT ON DEVELOPMENT RISK:
  - INCREASED MISSION DURATION REQUIRES DEVELOPMENT OF FUEL CELL & CRYO STORAGE TANKS TO REPLACE BATTERY. THESE ITEMS ARE MORE DIFFICULT TO DEVELOP THAN A BATTERY, HENCE INCREASED RISK.
  - FUEL CELLS REQUIRE ACTIVE COOLING LOOPS WITH THEIR ASSOCIATED PLUMBING & VALVES. THESE ITEMS ARE MORE DIFFICULT TO DEVELOP AND ARE INHERENTLY LESS RELIABLE THAN HEAT PIPES, HENCE INCREASED RISK.
  - RETRIEVAL REQUIRES ADDITION OF LASER RADAR WHICH IS A TECHNOLOGY ITEM CURRENTLY UNDER DEVELOPMENT AT ITT.
  - RETRIEVAL REQUIRES TUG/PAYLOAD COMMUNICATIONS, THUS ADDING THE CHANNEL SELECTABLE STATION (CSS) TO THE DEDICATED FREQUENCY STATION (DFS) ALREADY ON 110A-1. THE CSS IS MORE COMPLEX THAN THE DFS, HENCE INCREASED RISK.

- RETRIEVAL REQUIRING DEVELOPMENT OF EITHER A DEORBIT KICK STAGE (DKS) OR A RETRIEVAL DELAY MODULE (RDM):
  - THE DKS IS A STAGE INCORPORATING A SRM WHICH MUST BE ABLE TO SURVIVE 5 YEARS IN SPACE WITHOUT DEGRADATION OF ITS PROPELLANT GRAIN; THIS REQUIRES SUPPORTING TECHNOLOGY INVOLVING INCREASED RISK
  - THE RDM INVOLVES LESS RISK THAN THE DKS SINCE IT UTILIZES EXISTING TECHNOLOGY EQUIPMENT

GRUMMAN

T-8119-4

RENDEZVOUS AND DOCKING SENSITIVITY STUDY

SUMMARY

- ADDING RETRIEVAL CAPABILITY TO A TUG DESIGNED FOR DEPLOYEMENT ADDS AT LEAST 350 LB TO THE DRY WEIGHT OF THE TUG
- ADDED DRY WEIGHT REDUCES DEPLOYMENT CAPABILITY OF TUG BY AT LEAST 900 LB, EVEN WHEN SELECTED RETRIEVAL EQUIPMENT IS LEFT ON THE GROUND
- THE DDT&E COST OF ADDING RETRIEVAL CAPABILITY IS A MINIMUM OF $54M AND COULD BE AS HIGH AS $90M IF A DKS IS REQUIRED TO IMPROVE PAYLOAD RETRIEVAL PERFORMANCE
- DEVELOPMENT OF A LASER RADAR AND A DKS, IF REQUIRED ARE THE KEY TECHNOLOGY ITEMS

GRUMMAN

I-8.11.3-5

8.11.10 – NESTED TANK/SEPARATE TANK SENSITIVITY STUDY

OBJECTIVE: COMPARE TUG 310-3A/310RE-3A NESTED DOME TANK CONFIGURATION WITH EQUIVALENT SEPARATE TANK CONFIGURATION

STUDY AREAS

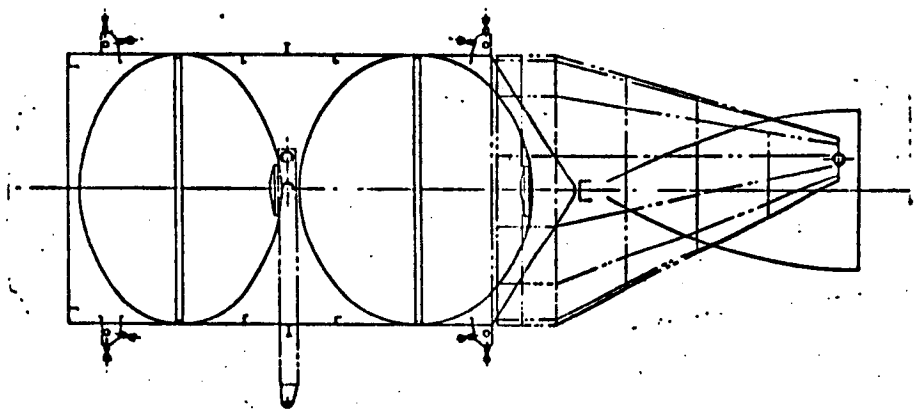
- CONFIGURATION ARRANGEMENT
- WEIGHT COMPARISON
- PERFORMANCE AND COST COMPARISON
- SAFETY CONSIDERATIONS
- MANUFACTURING CONSIDERATIONS
- OPERATIONS CONSIDERATIONS
- DEVELOPMENT RISK AND TECHNOLOGY ISSUES

GRUMMAN

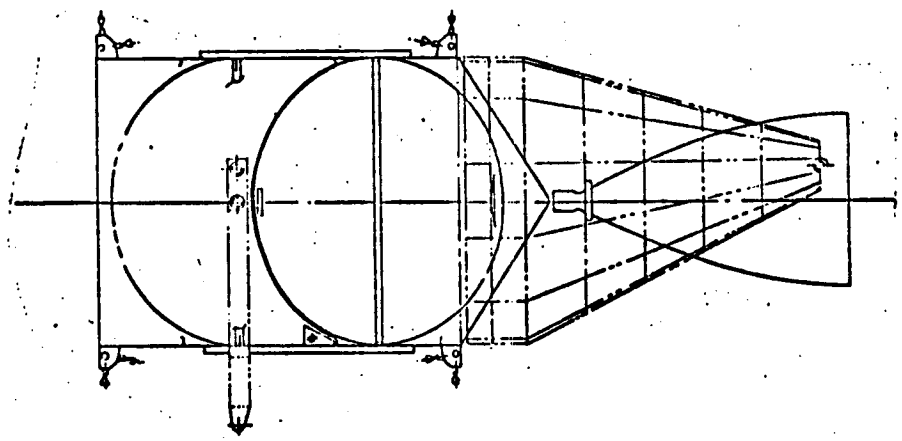
T-8.11.10-1

NESTED TANK/SEPARATE TANK SENSITIVITY STUDY

CONFIGURATION ARRANGEMENTS



SEPARATE TANK



NESTED TANK

GRUMMAN

I-8.11.10-2

NESTED TANK/SEPARATE TANK WEIGHT STUDY

CONFIGURATION 310-3A

- WELDED GORE TITANIUM TANK MATERIAL
- GRAPHITE COMPOSITE HONEYCOMB OUTER SHELL STRUCTURE
- NESTED DOMES SEPARATED BY A NON-METALLIC MESH
- BOTH CONFIGURATIONS SUPPORTED AT THE SAME ORBITER ATTACHMENT LOCATIONS
- THE GEOMETRY AND STRUCTURAL ARRANGEMENT DETAILS FOR THE SEPARATE TANK CONFIGURATION ARE SIMILAR TO TUG 110A-1 WITH WELDED TITANIUM TANKS SUBSTITUTED FOR ALUMINUM TANKS (SPUN ALUMINUM DOMES AND WELDED ALUMINUM CYLINDER) AND COMPOSITE HONEYCOMB SUBSTITUTED FOR THE HONEYCOMB SHELL
- THE SEPARATE TANK CONFIGURATION IS 70 LBS HEAVIER AND 34 INCHES LONGER THAN THE COMPARABLE NESTED DOME CONFIGURATION

CONFIGURATION 110A-1

- THE ALL-ALUMINUM SEPARATE TANK CONFIGURATION IS 129 LBS HEAVIER AND 34 INCHES LONGER THAN A COMPARABLE NESTED DOME CONFIGURATION

GRUMMAN

Storeable Space Tug

Configuration 310 - 3A

Nested Dome/Separate Tank Weight Study

Item	Nested Dome		Separate Tanks	
Structure		(1226)		(1275)
Body Structure		493		629
Shell	244		386	
Frames	217		211	
Latch & APS Support	32		32	
Fuel Tank		255		152
Cylinder Membrane	49		-	
Cylinder Stiffeners	27		-	
Fwd Dome Mesh	12		-	
Fwd Dome	61		55	
Ring	25		23	
Aft Dome	81		74	
Oxidizer Tank		164		169
Fwd Dome	78		82	
Ring	25		24	
Aft Dome	61		63	
Thrust Structure		88		102
Equip. Mounting Struct.		112		112
Meteorite Struct.		26		23
Interfaces-Payload & EOS		73		73
Umbilicals		15		15
Thermal Control		(89)		(97)
Tank Insulation	46		54	
Base Heat Protection	23		23	
Radiators & Heaters	20		20	
Astrionics		(663)		(664)
Propulsion		(697)		(703)
Contingency		(268)		274
Dry Weight		2943		3013

T-8.11.10-5

PERFORMANCE AND COST COMPARISON

CONFIGURATION 310-3A/310RE-3A

PERFORMANCE COMPARISON

- SEPARATE TANK CONFIGURATION RESULTS IN 70LB HIGHER TUG DRY WEIGHT
- THIS RESULTS IN A PAYLOAD PERFORMANCE REDUCTION OF:

  256 LB PAYLOAD DELIVERY CAPABILITY

  96 LB PAYLOAD RETRIEVAL CAPABILITY

  70 LB ROUND TRIP CAPABILITY

COST COMPARISON

STRUCTURES AND THERMAL CONTROL COSTS

	DDT&E	FIRST UNIT COST	AVERAGE UNIT	TOTAL PRODUCTION*	TOTAL PROGRAM
NESTED DOME	$ 16.1M	$ 1.6M	$ 1.0M	$ 23.0M	$ 39.1M
SEPARATE TANK	$ 14.9M	$ 1.5M	$ 0.94M	$ 21.6M	$ 36.5M
DIFFERENCE	+ 1.2M	+ $ 0.09M	+ $ 0.06M	+ $ 1.4M	+ $ 2.6M

* CONCEPT 310-3A/310RE-3A HAS FLEET SIZE OF 23 TUGS

SUMMARY

- EQUIVALENT TRANSPORATION COST = $\frac{\$\ 2.6 \times 10^6}{70\ \text{LB}} = \$\ 37\ \text{K/LB}$
- TUG TRANSPORATION COSTS LESS THAN $ 100 K/LB ARE COST EFFECTIVE OPTIONS
- BASED ON COST/WEIGHT CONSIDERATIONS NESTED DOME TANK CONFIGURATION IS ATTRACTIVE OPTION

GRUMMAN

POTENTIAL TANKAGE HAZARDS/IMPACT

HAZARD	SEPARATE	NESTED
LOSS OF MMH PRESSURE	NOT A TANKAGE PROBLEM	
LOSS OF N_2O_4 PRESSURE	NOT A TANKAGE PROBLEM	VENT MMH TANK
VENT FAILS CLOSED	PROVIDE REDUNDANT VENTS	
EITHER TANK LEAKS	VENT, DRAIN "OTHER" TANK CLEAN UP REQUIRED CONTROL MATERIALS FOR COMPATIBILITY	
BOTH TANKS LEAK	PROVIDE VENT AREA THAT PRECLUDES PRESSURE BUILDUP	LIMITED VENT VOLUME MESH CAUSES TIME DELAY IN MIXING
N_2O_4 IN LINES FREEZE	INSULATE LINES	
INADEQUATE TANK DAMAGE DETECTION	ENTIRE TANK ACCESSIBLE	LIMITED TANK ACCESS WITHOUT DISASSEMBLY

GRUMMAN

SEPARATE TANKS VS NESTED TANKS

SAFETY CONSIDERATION	SEPARATE TANKS	NESTED TANKS
A. FORCED VENTILATION BETWEEN BULKHEADS ON GROUND	PURGE VOLUME BETWEEN TANKS, 194 FT^3, SAMPLE GAS FOR LEAKS	PURGE VOLUME BETWEEN MEMBRANES, 1.5 FT^3, SAMPLE GAS FOR LEAKS
* B. SEPARATE PROPELLANTS TO PRECLUDE MIXING IF SIMULTANEOUS RUPTURE	RUPTURE OF BOTH BULKHEADS CATASTROPHIC	RUPTURE OF N_2O_4 MEMBRANE CATASTROPHIC: RUPTURE OF MMH MEMBRANE ONLY NOT A SAFETY PROBLEM
C. PREVENT EXCESSIVE INTERNAL PRESSURE BY POSITIVE MEANS	OPERATING PRESS. / VENT PRESS. N_2O_4 30-33 PSIA / 33-36 PSIA MMH 18-21 PSIA / 21-24 PSIA	OPERATING PRESS / VENT PRESS. N_2O_4 30- PSIA / 33-36 PSIA MMH 18-24 PSIA / 21-24 PSIA
D. PREVENT PRESSURE RISE MORE THAN 10% OVER NORMAL SYSTEM PRESSURE	10% OPER. PRESS. / VENT. PRESS. N_2O_4 (.1) 33 = 3.3 / 0-3 PSI MMH (.1)(21) = 2.1 / 0-3 PSI	10% OPER. PRESS. / VENT. PRESS. N_2O_4 (.1) 33 = 3.3 / 0-3 PSI MMH (.1) 21 = 2.1 / 0-3 PSI
E. ROUTE LINES WITHIN OWN TANK TO MINIMIZE EFFECTS OF LEAKAGE. IF NECESSARY ROUTE LINES THROUGH INCOMPATIBLES VIA CONTINUOUS CONDUIT, VENTILATE CONDUIT.	LINE FROM FORWARD TANK TO ENGINE, EXTERNAL TO AFT TANK.	LINE FROM FORWARD TANK TO ENGINE IS EXTERNAL TO AFT TANK
F. AVOID LOCATING PROPULSION SYSTEM COMPONENTS IN AREAS WHERE SINGLE FAILURE CAN CAUSE IGNITION	INLET TO ENGINE CRITICAL AREA	INLET TO ENGINE CRITICAL AREA.
G. DRAIN & VENTILATE AREAS INTO WHICH LEAKAGE OR VAPOR MAY SEEP	DRAIN PROVIDED FOR GROUND SAFING OF INTER-TANK VOLUME. CLEANUP REQUIRES FLUSH & PURGE	CLEANUP OF INTER-MEMBRANE VOLUME REQUIRES VEHICLE ROTATE AND HOT GAS PURGE
H. DESIGN VENT SYSTEM TO MINIMIZE EXCESSIVE LIQUID FLOW THROUGH MISUSE OR MALFUNCTION	OPERATIONAL PROCEDURES PRECLUDE EXCESSIVE LIQUID VENTING	OPERATIONAL PROCEDURES PRECLUDE EXCESSIVE LIQUID VENTING

* SIGNIFICANT

GRUMMAN

T-8-110-1

SEPARATE TANKS VS NESTED TANKS - CONT'D

SAFETY CONSIDERATION	SEPARATE TANKS	NESTED TANKS
I. HYPERS SEPARATED BY SINGLE WELD (MSC 00134 #61)	TWO BULKHEADS	TWO BULKHEADS
*J. STRUCTURAL CREVICES WHERE DEBRIS CAN CAUSE LOCAL STRESS CONCENTRATIONS IN TANK SKINS (MSC 00134 #80)	FOUR CREVICES IN VOLUME BETWEEN TANKS	TWO EXTREMELY SMALL CREVICES IN VOLUME BETWEEN TANKS
K. INTERIOR INSPECTION FOR CONTAMINATION OR CORROSION (MSC 00134 #82)	MANHOLES PROVIDED IN EACH TANK	MANHOLES PROVIDED IN EACH TANK
L. PROTECTION OF TANKS FROM DROPPED TOOLS ET AL. (MSC 00134 #138)	ACCESS BETWEEN TANKS POSSIBLE. TETHERED TOOLS USED.	ACCESS LIMITED NORMALLY TO EXTERNAL SURFACE OF TANKS, NO ACCESS TO VOLUME BETWEEN TANKS.
*M. CONTAINMENT AND DISPOSAL OF DANGEROUS FLUIDS (MSC 00134 #239)	VOLUME BETWEEN TANKS VENTED AND DRAINED. DRAIN REQUIRES G FIELD	VOLUME BETWEEN TANKS VENTED. IMPACT OF FULL INTERTANK VOLUME CONSIDERED ONLY A CLEANUP PROBLEM.

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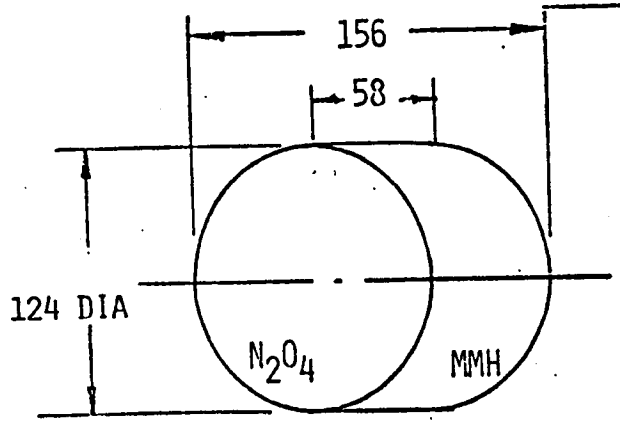
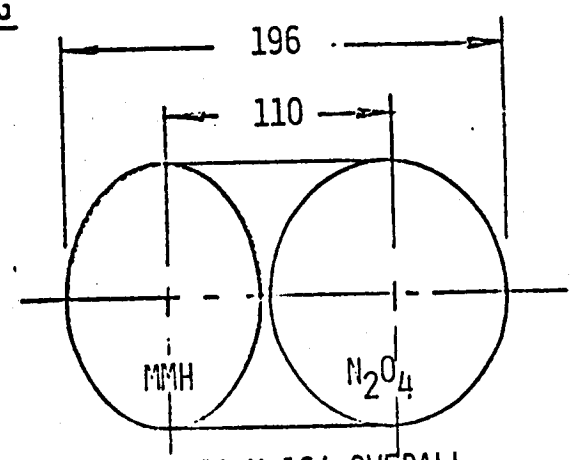
T-8.11.10-8

NESTED DOME TANKS VS. SEPARATE TANKS

MANUFACTURING





10′ DIA X 13′	NOM. SIZE	10′ DIA X 16′ OVERALL
6-4 STA TITANIUM	MATERIAL	6-4 STA TITANIUM
826 FT^3	VOLUME	826 FT^3
419 LB	WEIGHT	321 LB
561 FT^2	WETTED AREA	539 FT^2
.016/.016	GAGES (BASIC))	.016/.016
(1) .016 HEMI -63R	LINER	N.A.
	MFG. METHODS	
(4) WELDED GORE	DOME	(2/2) WELDED GORE
WELDED/BONDED STIFFENERS	CYLINDER	N.A.
2″ DIA X 10′(INCL. LINER)	FEEDLINES	2″ DIA X 18′
ROLL FORGE/MACHINE	RINGS	ROLL FORGE/MACHINE
MLI - 420FT^2	INSULATION	MLI - 540 FT^2
232′	LENGTH OF WELD	178′

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T-8.11.10-9

MANUFACTURE OF SEPARATE VS. NESTED TANKS

FACTORS	NESTED	SEPARATE
o LEAK DETECTION o INSPECTION o REPAIR	o INTERIOR ACCESSIBLE o LEAK LOCATION AND DAMAGE REPAIR o REQUIRES DISASSEMBLY	o ENTIRE SURFACE ACCESSIBLE TO LOCATE LEAKS OR STRUCTURAL DAMAGE AND TO MAKE REPAIRS
o REPLACEMENT	o SIMPLE	o SIMPLE
o HANDLING	o SUSCEPTIBLE TO DAMAGE	o LIGHTER, LESS BULKY TANK HANDLING
o PARALLEL FLOW & SCHEDULE RISK	o SEPARATE MANUFACTURE o FIXTURE REQ'D FOR TESTING o LONGER FLOW TIME	o ASSEMBLE/TEST SEPARATELY o 25% FLOW SAVINGS o INTERCHANGE TKS IF PROBLEMS
o ASSEMBLY AND INSTALLATION	o MECHANICAL FASTENERS o LINE INSTALL FROM OUTSIDE TANK	o MECHANICAL FASTENERS o LINE INSTALL FROM OUTSIDE TANK

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OPERATIONS CONSIDERATIONS

	NESTED	SEPARATE
o VENTING - GROUND - IN FLIGHT	o THROUGH GSE o MAINTAIN DELTA-P	o THROUGH GSE o INDIVIDUAL VENTING
o PROPELLANT LOADING (VERTICAL)	o OXIDIZER LOADED FIRST	o EITHER LOADED FIRST
o PROPELLANT DRAIN	o MMH FIRST	o EITHER
o IN FLIGHT DUMP	o IF BOTH, MMH FIRST o IF ONE, N_2O_4 o MAINTAIN DELTA-P	o NO CONSTRAINTS
o FIRST MISSION SYSTEM PRESSURIZATION	o SAFE DISTANCE FROM ORBITER	

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T-811.10-11

DEVELOPMENT RISK AND CRITICAL TECHNICAL AREAS

RELATIVE TO SEPARATE TANKS

- INSTALLATION AND FITTING OF NESTED DOME MEMBRANE INCREASES WELD/ASSEMBLY COMPLEXITY
- TANKS MUST BE ASSEMBLED AND TESTED AT THE SAME TIME INCREASING MANUFACTURING FLOW TIME AND RISK OF SCHEDULE SLIPPAGE.
- LEAK DETECTION MORE DIFFICULT ON NESTED DOME SURFACES
- INSPECTION OF NESTED DOME SURFACES MUST BE DONE FROM INSIDE TANK
- TESTING OF TANKS MORE DIFFICULT
- DELTA - P REQUIRED FOR NESTED BULKHEAD TO PREVENT STRUCTURAL FAILURE

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T-8.11.10-12

NESTED VS. SEPARATE TANKS

SUMMARY

CONSIDERATIONS	NESTED	SEPARATE
• LENGTH/WEIGHT	✓	
• COST		✓
• COST/WEIGHT EFFECTIVE	✓	
• SAFETY/REQUIREMENT IMPACT		✓
• MANUFACTURING		✓
• OPERATIONS	✓	✓
• TECHNICAL RISK		✓

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7-8.1.1.10-13

8.11.11 – IN-FLIGHT DUMP SENSITIVITY

- DESIGN DUMP SYSTEM FOR MODE III ABORT
- DESIGN FOR DUMP DURING SHUTTLE POWERED FLIGHT ONLY, TO AVOID SIDE TANK OUTLETS AND TAKE ADVANTAGE OF HIGH G LEVEL
- MINIMUM OF 300 SEC. AVAILABLE, DESIGN TO DUMP ENTIRE LOAD IN THIS TIME
- ENLARGE FEED LINES AND GROUND VERTICAL DRAIN LINES TO ACCOMMODATE INCREASED FLOW RATE
- FOR SIMPLICITY, ALL LINES ASSUMED TO HAVE THE SAME DIAMETER
- STUDY CONDUCTED FOR 110A-1, VERY SIMILAR RESULTS EXPECTED FOR OTHER CONFIGURATIONS

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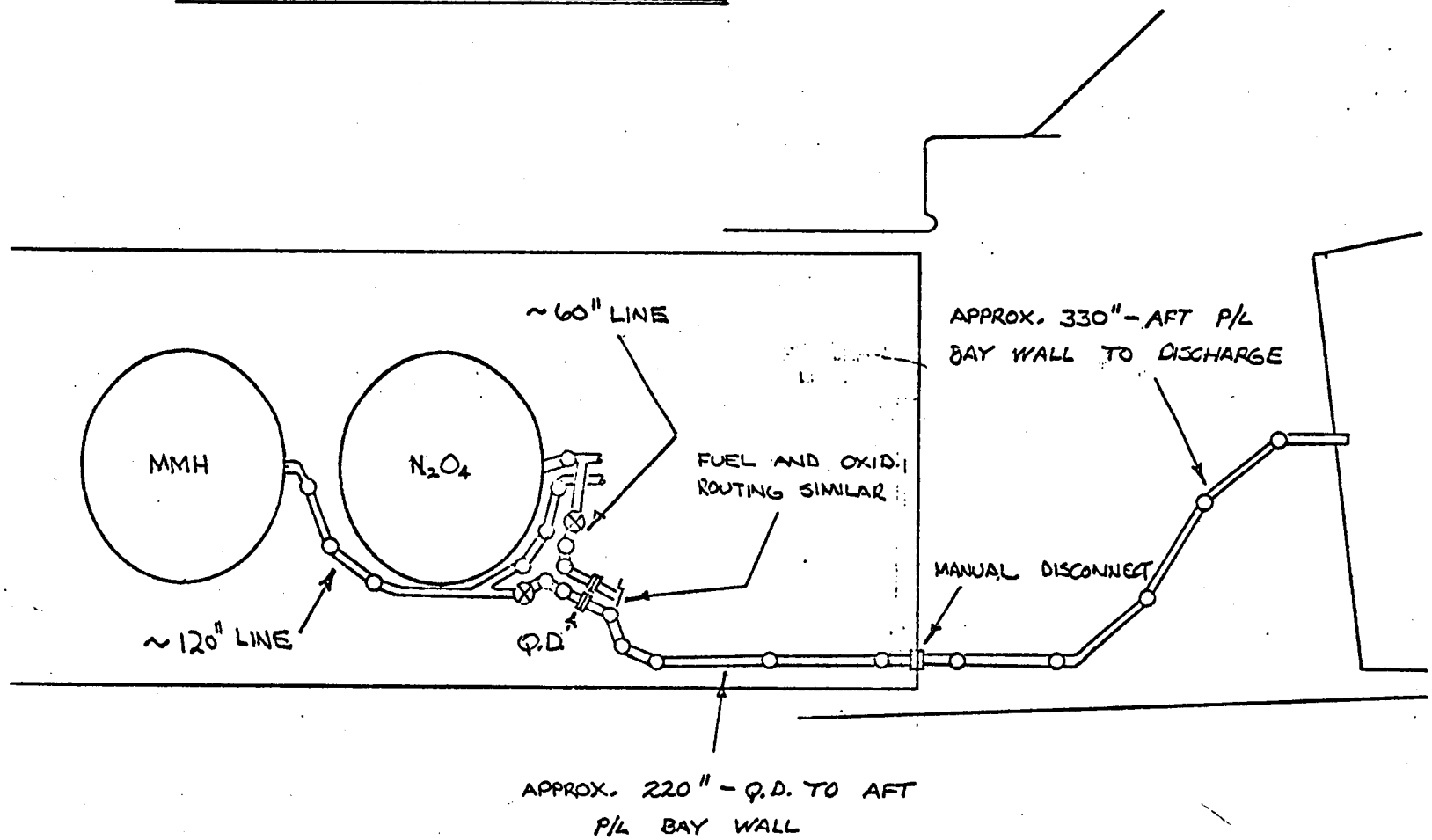
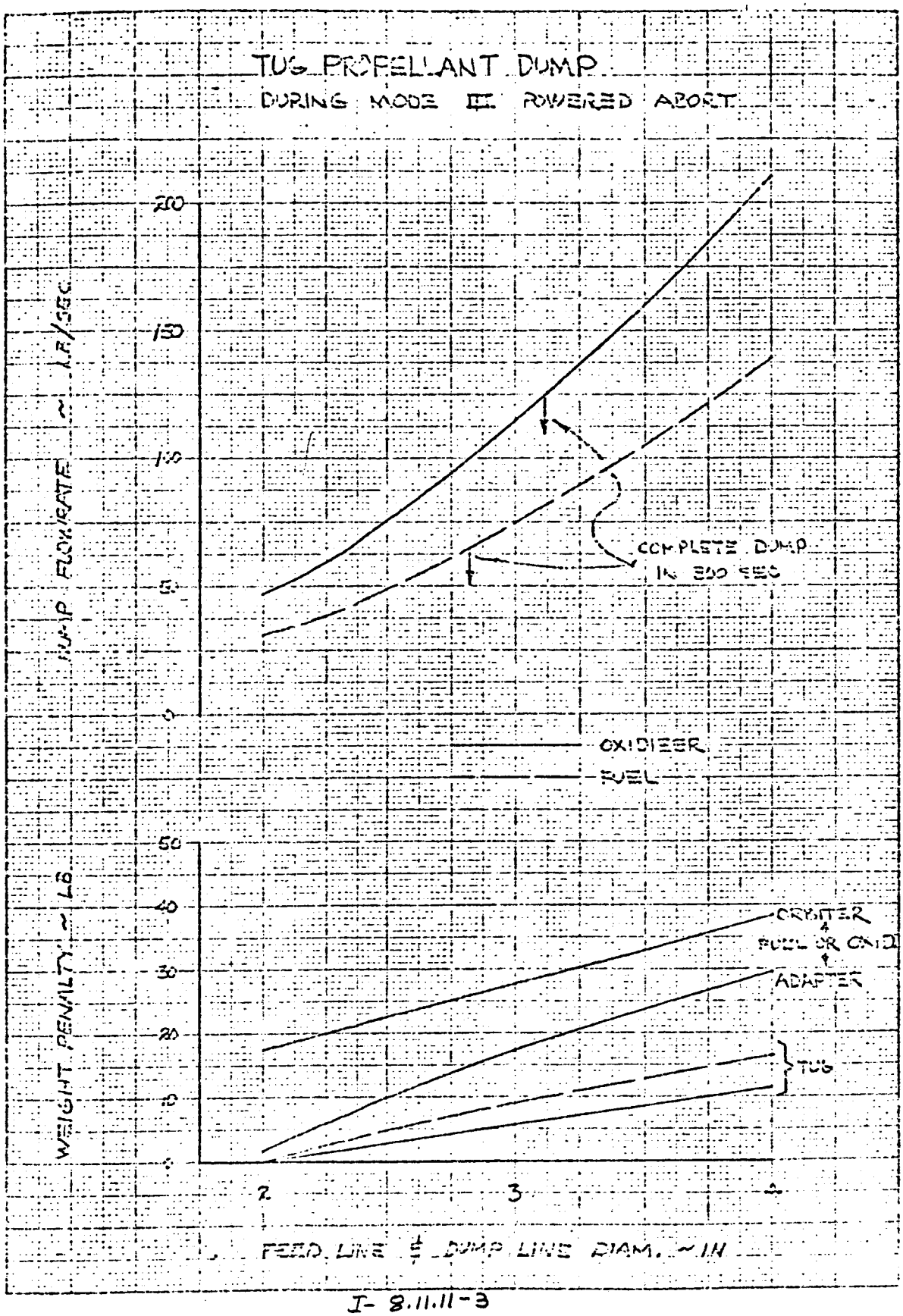
IN-FLIGHT DUMP SCHEME



NOTE: 1) ALL FLUID LINES ASSUMED SAME DIAMETER

2) Q.D.'s REPLACED BY LOW RESISTANCE DESIGNS


TUG PROPELLANT DUMP
DURING MODE III POWERED ABORT
DUMP FLOWRATE ~ LB/SEC
200
150
100
50
0
COMPLETE DUMP IN 300 SEC
OXIDIZER
FUEL
WEIGHT PENALTY ~ LB
50
40
30
20
10
0
ORBITER & FUEL OR OXID & ADAPTER
TUG
2
3
4
FEED LINE & DUMP LINE DIAM. ~ IN

I- 8.11.11-3

IN-FLIGHT DUMP SENSITIVITY

CHANGES TO BASELINE SYSTEM

- FEEDLINE, FILL/DRAIN, ADAPTER, AND SHUTTLE SERVICE LINES INCREASED TO 3.25 IN DIAMETER
- FILL/DRAIN Q.D.'S MUST BE ALL NEW LOW RESISTANCE DESIGN, PRESENT (LM/SPS) DESIGNS HAVE HIGH PRESSURE DROP DUE TO POPPET ARRANGEMENT

FEED SYSTEM WEIGHT PENALTIES

TUG	18 LB. INCREASE
ADAPTER	41 LB. INCREASE
SHUTTLE	60 LB. (TOTAL WEIGHT, PRESENT SYSTEM UNKNOWN)

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ON-ORBIT DUMP

- IF SYSTEM IS DESIGNED FOR MODE III ABORT CAN PROPELLANT BE DUMPED ON A ONCE-AROUND ABORT?

- YES
  - DUMP TIME INCREASED TO 10 MINUTES
  - 5% RESIDUAL WILL REMAIN IN TANKS
  - REQUIRES ONE SHUTTLE RCS ENGINE TO BURN FOR THE 10 MINUTE DUMP (PLUS A 14% DUTY CYCLE ON A NOSE JET TO YAW COMPENSATE)
  - CONSUMES 2000 LB. SHUTTLE RCS PROPELLANT AND 50% DEPLETES ONE AFT RCS MODULE

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VEHICLE WEIGHT SAVINGS

- LANDING WITHOUT PROPELLANT LOAD CAN SAVE TANKAGE AND STRUCTURAL WEIGHT
- ABORT LANDING IS THE CRITICAL DESIGN CONDITION WITH FULL PROPELLANT
- STRUCTURAL WEIGHTS ASSOCIATED WITH THE SENSITIVITY ARE MAIN PROPULSION TANKS, TUG FORWARD SUPPORT FRAME AND TUG/SHUTTLE INTERFACE FORWARD FRAME

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9-11-11-8-I

STRUCTURAL WEIGHT SAVINGS (LB. DECREASE)

TO LAND WITHOUT PROPELLANT

ITEM \ CONFIGURATION	NESTED DOME		SEPARATE TANKS
	(510) ALUMINUM TANKS	(310,410) TITANIUM TANKS	(110) ALUMINUM TANKS
MAIN PROPULSION TANKS	12	5	18
FWD SUPPORT FRAME	39	39	38
TOTAL TUG	51	44	56
ADAPTER	199	199	199

NOTE: DOES NOT INCLUDE CONTINGENCY

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IN-FLIGHT PROPELLANT DUMP

SAFETY ISSUE

- DUMP SYSTEM IS NOT REDUNDANT, CAN WE LAND SAFELY IF IT FAILS?
- TWO FAILURES REQUIRED TO NOT DUMP ALL PROPELLANTS, THREE TO NOT DUMP ANY
- SAFE LANDING IS STILL POSSIBLE WITH FULL TANKS IF OVERLOAD SINKING SPEED IS USED
- WEIGHT PENALTY TO PROVIDE REDUNDANCY IS APPROXIMATELY 25 LB. ON TUG AND 10 LB. ON ADAPTER

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IN-FLIGHT DUMP

WEIGHT SUMMARY (LB. INCREASE)

(110A-1 VEHICLE)

	TUG	ADAPTER	SHUTTLE
FLUID SYSTEMS	+18	+41	+60
STRUCTURE	-56	-199	0
SUBTOTAL	-38	-158	+60
10% CONTINGENCY	- 4	- 16	+ 6
TOTAL	-42	-174	+66
EQUIVALENT TUG WT.*	-42	- 11	+ 4

TOTAL EQUIVALENT
TUG INERT WEIGHT CHANGE - 49 LB.

* USING A 16:1 RATIO FOR ADAPTER AND SHUTTLE EQUIPMENT

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IN-FLIGHT DUMP

COST ANALYSIS

	FLUID COMPONENTS	STRUCTURAL COMPONENTS
Δ DDT&E ($1000)	+300	-700
Δ RECURRING ($1000)	+560	-525
TOTAL	+860	-1225

NET COST SAVINGS = $365,000

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IN-FLIGHT DUMP

SUMMARY

INCORPORATING AN IN-FLIGHT DUMP SYSTEM WILL SAVE 49 LB. EQUIVALENT TUG INERT WEIGHT (HALVE THIS IF REDUNDANCY REQUIRED), AND SAVE $365,000 PROGRAM COST

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8.11.12 - ENGINE SENSITIVITY STUDY

- o EXAMINE THE PERFORMANCE, COST AND PROGRAMATIC IMPACT OF REPLACING THE BASELINE ENGINES WITH SELECTED ALTERNATE ENGINES
  - EXAMINE THE 8096-B2 FOR OPTIONS 2,3
  - EXAMINE THE OME 12 FOR OPTION 1
  - EXAMINE THE CLASS II ENGINE FOR OPTION 2
  - EXAMINE AN OME 7.5/CLASS I PHASED PROGRAM FOR OPTION 3 (310-3A/310RE-3A ONLY)
- o PERFORMANCE, SENSITIVITY GIVEN ON A DELTA PAYLOAD BASIS ONLY, CAPTURE ANALYSIS NOT REITERATED
- o IN PHASED PROGRAM THE PROPELLANT AND HELIUM TANKS REMAIN FIXED DURING PHASING

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ENGINE SENSITIVITY MATRIX

B = BASELINE S = SENSITIVITY EXAMINED

* NOT INCLUDED DUE TO LACK OF PAYLOAD SENSITIVITIES

VEHICLE \ ENGINE	8096-B2	OME 7.5	OME 12	CLASS I	CLASS II
110A-1		B	S		
410AD-2	S			B	S
310-3A	S	S		B	
310RE-3A	S			B	
320A-3A	*			B	
320AE-3A	*			B	
310-3B	S			B	
310ARE-3B	S			B	
510A-3B	S	B			
510ADE-3B	S	B			

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I-8.11.12-2

ENGINE SENSITIVITY STUDY

FACTORS CONSIDERED

- PERFORMANCE
  - RELATIVE ENGINE SPECIFIC IMPULSE
  - INERT WEIGHT DIFFERENCES
    - A) ENGINE WEIGHT DIFFERENCES
    - B) TANK WEIGHT DIFFERENCES DUE TO DIFFERENT PRESSURE REQUIREMENTS (ENG. INLET PRESS. OR FEEDLINE PRESSURE DROP DIFFERENCES)
    - C) TANK WEIGHT DIFFERENCES DUE TO DIFFERENT TANK VOLUMES (BASELINE PROPELLANT LOAD MAINTAINED, MIXTURE RATIO CHANGED)
    - D) HELIUM DIFFERENCES DUE TO TANK VOLUME AND/OR PRESSURE CHANGES
    - E) HELIUM TANK DIFFERENCES
- COST
  - RELATIVE ENGINE DDT&E AND RECURRING COSTS
- PROGRAMMATICS
  - IMPACT OF ENGINE SCHEDULES UPON VEHICLE SCHEDULE
- NONQUANTATIVE FACTORS
  - MAINTENANCE, TECHNOLOGY, RISK, ETC.

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INERT WEIGHT SENSITIVITIES

o HELIUM QUANTITY TO FUEL TANK VOLUME:	.0159 LB/FT^3
o HELIUM QUANTITY TO OXID. TANK VOLUME:	.0205 LB/FT^3
o HELIUM QUANTITY TO OXID. TANK PRESSURE:	.3395 LB/PSI
o HELIUM TANK WEIGHT TO HELIUM QUANTITY:	5.8 LB/LB
o OXIDIZER TANK WEIGHT TO OXID. TANK PRESSURE:	4.55 LB/PSI (110A-1)
	0 LB/PSI (ALL OTHERS)
o VEHICLE WEIGHT TO TANK VOLUME:	1 LB/FT^3

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ENGINE SENSITIVTY STUDY

PRESSURIZATION SYSTEM PARAMETERS

VEHICLE	ENGINE	He WT. (LB)	He TANK WT. (LB)(2 TKS)	He TANK DIAM. (IN)(EA. TANK)	FUEL MDOP (PSIA)	OXID MDOP (PSIA)
110A-1	OME 7.5	13.7	79	22.7	24	34
	OME 12	14.3	83	23.0	24	36
ALL OTHERS (EXCEPT 320)	8096B2	15.7	91	23.7	24	39
	CLASS I	14.2	83	23.0	24	36
	CL. II	15.0	87	23.4	24	37

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ENGINE SENSITIVITY - Δ V LOSSES

- THE 7500 LB. THRUST ENGINE HAS THE FOLLOWING Δ V PENALTIES COMPARED TO THE 12,000 LB. THRUST ENGINES:

	OUTBOUND Δ V PENALTY (FT/SEC)	INBOUND Δ V PENALTY (FT/SEC)
PLAIN DEPLOY, RETRIEVE, ROUND TRIP	+51	+6
AKS DEPLOY, RETRIEVE, ROUND TRIP	+64	+4

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ENGINE DATA

	THRUST LB.	Isp lbf-sec/lbm	M.R.	P_c psia	ϵ	% BELL	L in.	De in.	Wt. lb.	Twall °F
8096B2	12,145	332	1.78	500	244	90	120	62.5	270	- - -
OME 7.5K	7,500	327.2	1.90	150	150	85	120	72	318	
OME 12K	12,000	329.5	1.90	240	150	85	120	72	385	1020
CLASS I	12,000	338	1.90	800	300	102	116	56	268	1500
CLASS II	12,000	344	2.05	1200	300	102	110	46	261	3000

ENGINE	COST ($M)		SCHEDULE (MO.)	
	DDT&E	1ST UNIT	PFC	EFC
8096B2	39.2	0.7	30	39
OME 7.5K	24	0.8	30	42
OME 12K	34	0.8	30	42
CLASS I	59	0.8	42	54
CLASS II	124	1.0	54	66

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PAYLOAD SENSITIVITIES

OPTION	1		2				3A						4A						
GEOSYNCH RETRIEVE C-P(lb)	—		3500				—		2200	—		2200	—		3500	—		3500	
TUG DESIGNATION	110A-1		410AD-2				310-3A		3K RE-3A	320A-3A		320AE3A	310A-3B		310 RE-3B	510A-3B		510ADE3B	
SENSITIVITY	DEPLOY	DEPLOY WITH AKS	DEPLOY	RETRIEVE	ROUND TRIP	DEPLOY WITH AKS	DEPLOY	RETRIEVE	ROUND TRIP		DEPLOY	RETRIEVE	ROUND TRIP	DEPLOY	RETRIEVE	ROUND TRIP	DEPLOY WITH AKS
$\frac{\partial P/L}{\partial W_{FIXED}}$ – P/L TO FIXED WT. (lb/lb)	-3.83	-2.32	-3.4	-1.37	-1.0	-2.4	-3.66	-1.37	-1.0		-3.66	-1.37	-1.0	-3.5	-1.35	-1.0	-2.44
$\frac{\partial P/L}{\partial W_0}$ – P/L TO INITIAL WT. (lb/lb)	.258	.248	.27	.10	.07	.26	.27	.10	.07		.27	.10	.07	.26	.09	.067	.25
$\frac{\partial P/L}{\partial I_{SP}}$ – P/L TO I_{SP} (lb/sec)	117	90.2	97	55	37	93	96	56	37		97	55	37	112	51	36	92
$\frac{\partial P/L}{\partial \Delta V_{OUT}}$ – P/L TO OUTBOUND ΔV (lb/fps)	-1.59	-1.59	-1.6	-.6	-.4	-1.6	-1.6	-.61	-.44		-1.6	-.6	-.44	-1.6	-.6	-.3	-1.5
$\frac{\partial P/L}{\partial \Delta V_{IN}}$ – P/L TO INBOUND ΔV (lb/fps)	-1.21	-.7	-1.2	-.7	-.4	-.8	-1.2	-.7	-.44		-1.2	-.7	-.44	-1.3	-.6	-.4	-.8
$\frac{\partial P/L}{\partial AKS\ \Delta V}$ – P/L TO AKS ΔV (lb/fps)		-.9			-.4	-.7										-.4	-.7

ENGINE SENSITIVITY - PERFORMANCE

	BASE-LINE ENGINE	SENSI-TIVITY ENGINE	Δ ENG. WT. (LB)	Δ OXID. TANK PRESS. (PSI)	Δ PROP. TANK WT. (LB)*	Δ HELIUM WT. (LB)	Δ He TANK WT. (LB)	TOTAL Δ WT. (LB)	ΔI_{sp} (SEC)	Δ P/L PLAIN DEPLOY (LB)	Δ P/L AKS DEPLOY (LB)	Δ P/L RETRIEVE (LB)	Δ P/L ROUND TRIP (LB)	
110A-1	OME 7.5	OME 12	+67	+2	+9.1	+0.6	+3.5	+80	+2.3	+51	+127	-	-	**
410AD-2	CLASS I	8096 B2	+2	+3	+5.0	+1.0	+5.8	+14	-6.0	-633	-595	-349	-236	
410AD-2	CLASS I	CLASS II	-7	+1	-7.0	+0.3	+2.0	-12	+6.0	+626	+590	+346	+234	
310-3A	CLASS I	8096 B2	+2	+3	+5.0	+1.0	+5.8	+14	-6.0	-627	-	-355	-236	
310RE-3A	CLASS I	8096 B2	+2	+3	+5.0	+1.0	+5.8	+14	-6.0	-627	-	-355	-236	
310-3A	CLASS I	OME 7.5	+50	-2	0	0	0	+50	-10.8	-1309	-	-709	-475	**
310RE-3A	CLASS I	CLASS I	0	0	0	0	0	0	0	0	-	0	0	
310A-3B	CLASS I	8096 B2	+2	+3	+5.0	+1.0	+5.8	+14	-6.0	-633	-	-349	-236	
310ARE-3B	CLASS I	8096 B2	+2	+3	+5.0	+1.0	+5.8	+14	-6.0	-633	-	-349	-236	
510A-3B	OME 7.5	8096 B2	-48	+5	+5.0	+1.7	+9.9	-31	+4.8	+745	+616	+327	+225	**
510ADE-3B	OME 7.5	8096 B2	-48	+5	+5.0	+1.7	+9.9	-31	+4.8	+745	+616	+327	+225	**

*DUE BOTH TO MR INDUCED VOLUME CHANGES AND MDOF CHANGES

** INCLUDES EFFECT OF ΔV LOSS DUE TO THRUST CHANGE

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Engine Sensitivities

NON QUANTITATIVE FACTORS

110A-1

The OME 12K engine represents a greater technical risk than the OME 7.5K. The 12K engine requires strengthening of the injector manifolds, prop valves and gimbal ring. The injector manifold volumes must also be increased. The thrust chamber/injector assy. of the 12K engine has a cycle life capability of 300 cycles as compared with 750 cycles for the OME 7.5K. In both cases, the turbo machinery and gas generator are being designed for 300 cycle life capability.

410AD-2

(1) 8096B-2

o The 8096B-2 represents a lower technical risk than the Class I because the gas generator and turbomachinery are the same basic design as the existing 8096 hardware, whereas, the Class I engine is a totally new design.

o The 8096B-2 presents increased operational/contamination problems. During the initial operational phase (1 year) a flush and purge of the engine is required after each flight. Thereafter, it is required every 4th flight. The 8096 S_1O_2 coating on the T/C walls and hydrocarbons from the turbine exhaust represent contamination problems to the cargo bay during reentry. The 8096 engine requires draining and replacing the gear box lube oil after each flight.

The 8096 engine presents a slightly greater post-flight safety hazard in that start tanks contain GN_2 gas at 1000 psi pressure as compared to 1.5 lb of propellant at 50 psi. in the class I engine.

(2) Class II

o The Class II engine represents the highest technical risk of any of the engine designs. It is the only design which requires an advance

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in the state-of-the-art. It is a staged combustion engine operating at 1200 psia Pc and 3000°F combustion chamber wall temp.

o The Class II engine presents increased operational/contamination problems. In order to perform maintenance/refurbishment the turboprop/thrust chamber (which is an in-line configuration) must be removed from the engine mount.

The baseline Class II engine uses Silicone oil to provide the cooling margin required to operate at the wall temp. of 3000°F. The S_1O_2 coating on the T/C walls, which results from its use, presents a contamination problem to the cargo bay during reentry.

The Class II engine presents a slightly greater post-flight safety hazard in that the start accumulators contain 7.5 lb. of propellants as compared to 1.5 lb. for the class I engine

310-3A

Same as 410AD-2, Item (1).

310-3A/310RE-3A OME 7.5K → Class I

Engine/Vehicle Interfaces

o Thrust mount attachment and pump inlet positions are identical. Pump inlet diameters are close enough to be considered identical. Since OME 7.5K has boost pump on ox. side only (Class I has boost pumps on both sides), a 3.5 inch spool piece must be used for the interim vehicle.

o Provisions for gimbal actuator attach points must be included on the interim vehicle for use with the Class I engine. The OME 7.5K is a throat gimballed engine and gimbal actuators are contained within the engine assy.

o There are minor, easily handled, differences in the positions of the fluid and electrical panels.

NOTE: This concept results in the unusual situation of replacing an engine design with superior cycle life capability (T/C life is 750 cycles vs. 300) with one of lesser capability.

310RE-3A, 310-3B & 310ARE-3B

Same as 410AD-2, Item (1).

510A-3B & 510ADE-3B

o The 8096B-2 represents a higher technical risk than the OME 7.5K engine because it includes modifications to the injector, shortening of the combustion chamber and recontouring the nozzle.

o The remaining items are the same as 410AD-2, Item (1) except the OME 7.5K engine also presents a problem of contaminating the cargo bay with hydrocarbons.

ENGINE SENSITIVITY - COST ANALYSIS

VEHICLE	BASELINE ENGINE	SENSITIVITY ENGINE	NO. OF VEHICLES	COST DELTAS FROM BASELINE ($M) AS SUPPLIED NON-REC	AS SUPPLIED REC	PLUS WRAPAROUND NON-REC	PLUS WRAPAROUND REC	TOTAL
110A-1	OME 7.5	OME 12	11	+10	0	+10.8	0	+10.8
410AD-2	CLASS I	8096 B2	10	-20	-.1	-21.6	-.117	-22.4
	CLASS I	CLASS II	10	+65	+.2	+70.2	+.234	+71.8
310-3A 310RE-3A	CLASS I CLASS I	8096 B2 8096 B2	5 18	-20 0	-.1 -.1	-21.6 0	-.117 -.117	-23.5
310-3A 310RE-3A	CLASS I CLASS I	OME 7.5 CLASS I	5 18	-35 +59	0 0	-37.8 +63.7	0 0	+25.9
310-3B 310ARE-3B	CLASS I CLASS I	8096 B2 8096 B2	5 11	-20 0	-.1 -.1	-21.6 0	-.117 -.117	-22.9
510A-3B 510ADE-3B	OME 7.5 OME 7.5	8096 B2 8096 B2	4 10	+15 0	-.1 -.1	+16.2 0	-.117 -.117	+15.1

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ENGINE SENSITIVITY - SCHEDULE IMPACT

BASELINE ENGINE	SENSITIVITY ENGINE	SCHEDULE IMPACT
OME 7.5	OME 12	NO IMPACT
CLASS I	8096 B2	MINOR IMPROVEMENT, ELIMINATES MANUFACTURING WORKAROUND
CLASS I	CLASS II	NO IMPACT, SINCE IT ONLY APPLIES TO A 1983 VEHICLE
CLASS I	OME 7.5/CLASS I	MINOR IMPROVEMENT, ELIMINATES MANUFACTURING WORKAROUND
OME 7.5	8096 B2	NO IMPACT

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ENGINE SENSITIVITY - SUMMARY

VEHICLE	BASELINE ENGINE	SENSITIVITY ENGINE	Δ DEPLOY P/L (LB)	Δ COST ($M)	EQ. INERT WT. (LB)	EQ. TRANS. COST ($/LB)	REMARKS
110A-1	OME 7.5	OME 12	+51	+10.8	-13	831,000	HIGHER RISK, REDUCED LIFE
410AD-2	CLASS I	8096 B2	-633	-22.4	+173	129,000	LESS RISK, MORE MAINTENANCE
410AD-2	CLASS I	CLASS II	+626	+71.8	-171	420,000	HIGHER RISK
310-3A 310-RE-3A	CLASS I	8096 B2	-627	-23.5	+171	137,000	LESS RISK, MORE MAINTENANCE
310-3A 310RE-3A	CLASS I	OME 7.5 TO CLASS I	-1309 TO 0	+25.9	+358	N/A	MINIMUM PHASING PROBLEMS
310A-3B 310ARE-3B	CLASS I	8096 B2	-633	-22.9	+173	132,000	LESS RISK, MORE MAINTENANCE
510A-3B 510ADE-3B	OME 7.5	8096 B2	+745	+15.1	-195	77,000	HIGHER RISK

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T-8.11.12-15

ENGINE SENSITIVITY STUDY - CONCLUSIONS

- o TRANSPORTATION COSTS LESS THAN $100K - $125K/LB INDICATE VIABLE CHANGES
  - 8096B REPLACING OME 7.5 : GOOD CHOICE
  - 8096B REPLACING CLASS I : MARGINAL, CAPTURE ANALYSIS NECESSARY FOR FINAL DECISION
  - OME 12 REPLACING OME 7.5 : BAD CHOICE
  - CLASS II REPLACING CLASS I : BAD CHOICE
- o PHASING OME 7.5 TO CLASS I EASES PRE-1980 DDT&E BY $38M AT A PROGRAM COST PENALTY OF $26M AND A LARGE PHASE I PERFORMANCE DECREMENT.

T-8.11.12-16

GRUMMAN

8.11.13 - USE OF RETRIEVAL DELAY MODULE (RDM) IN OPTION 2

OBJECTIVE: DETERMINE THE COST IMPACT OF UTILIZING A TUG CONCEPT WITH A RDM (SIMILAR TO CONCEPT 310ARE-3B) AS A DIRECT DEVELOPED TUG IN OPTION 2

RESULTS:

CONCEPT	COST ($M) DDT&E	PRODUCTION	OPERATIONS	TOTAL PROGRAM TUG	TUG + SHUTTLE
DIRECT DEVELOPED TUG WITH RDM	336	180	205	721	3569
410AD-2	350	232	207	789	3362
DELTA	-14	-52	- 2	-68	+207

- USE OF TUG WITH RDM IN OPTION 2 RESULTS IN LOWER TUG COSTS BUT HIGHER TUG PLUS SHUTTLE COSTS
- THESE RESULTS ARE SIMILAR TO CONCEPT COMPARISON IN OPTION 3B EXCEPT THAT CONCEPT 510ADE-3B CONTAINED A LOWER TECHNOLOGY, LOWER DDT&E TUG.

GRUMMAN

8.11.14 SENSITIVITY TASK RESULTS SUMMARY

NOTE

- DATA PRESENTED IN PARENTHESIS ( ) INDICATES THAT SENSITIVITY ANALYSIS WAS NOT SPECIFICALLY DONE AGAINST THAT CONCEPT BUT RESULTS ARE BELIEVED TO BE APPLICABLE.

GRUMMAN

SENSITIVITY TASK RESULTS SUMMARY - CONCEPT 110A-1

SENSITIVITY AREA CONCEPT 110A-1	REFERENCE	IMPACT DELTA (REFERENCE)							
		COST - $M				VEH. DESIGN		Dev. Risk	Critical Tech. Are.
		Tech.	DDT&E	First Unit	Total Production	Inert Weight	P/L Del. Wt.		
(1) Autonomy	Level IV								
- Level III		N/A	+4.4	+0.8	+8.8	+25 lbs	-97 lbs	Medium	None
- Level II		N/A	+1.8	+2.4	+26.4	+92 lbs	-305 lbs	High	621B Avail
- Level I		N/A	+3.4	+5.8	+63.8	+1321lbs	-12061lbs	High	Horiz Scan
(2) .97 Reliability - .97/72 Hr/Retrieval - .97/36Hr/Deploy	.97/168Hr/ Round Trip			Not applicable					
(3) 30-Day Servicing Mission	7-day Mission			Not applicable					
(4) Dod Comm. Requirements	NASA Req.			Not applicable					
(5) P/L Command, Control & Checkout	Int w/o capability			Not applicable					
(6) Electrical Power to P/L	0 Watts	N/A	0	+.002	+0.4	+36	-1371bs	None	None
(7) Design Life	20 Reuses	N/A						(Low)	(None)
- 50 Reuses			(0)	(0)	(2)	(0)	(0)		
- 100 Reuses			(0)	(0)	(2)	(0)	(0)		
(8) Spin Stab P/L Retrieval	Int.w/o capability			Not applicable					
(9) Rend. & Docking	Int.w/o R&D	N/A	+54	?	?	+350 lb	-930 lbs	Medium	Laser Radar
(10) Nested Dome vs. Separate Tank	Separate Dome	(N/A)	(?)	?	?	(-1291b)	(+4901b)	(Low)	(None)
(11) In-Flight Propellant Dump	No Dump	N/A	-0.4	+0.004	+0.04	-491b	+1871bs	None	None
Main Engine Selection OME 12K	OME 7.5K	N/A	+10.8	0	0	+80 lb	+1271bs	Medium	None

SENSITIVITY TASK RESULTS SUMMARY CONCEPT 410AD-2

SENSITIVITY AREA - CONCEPT 410AD-2	REFERENCE	IMPACT DELTA (REFERENCE)							
		COST - $M				VEH. DESIGN		Dev. Risk	Critical Tech. Area
		Tech.	DDT&E	First Unit	Total Production	Inert Weight	P/L Del. Wt.		
(1) Autonomy	Level IV								
- Level III		N/A	+14.7	+7.5	+75	+64 lbs	-366 lbs	Medium	None
- Level II		N/A	+9.3	+11.0	+110	+1281lbs	-552 lbs	High	621B Avail
- Level I		N/A	+10.8	+14.1	+141	+1691lbs	-1453 lbs	High	Horiz Scan
(2) .97 Reliability	.97/168Hr/ Round Trip								
- .97/72 Hr/Retrieval		N/A	0	-1.2	-11.8	-61 lbs	+223 lbs	None	None
- .97/36Hr/Deploy		N/A	0	-1.2	-12.3	-67 lbs	+245 lbs	None	None
(3) 30-Day Servicing Mission	7-day Mission	N/A	+8.4	+1.1	+11	+224 lbs	0	Low	None
(4) Dod Comm. Requirements	NASA Req.	(N/A)	(+0.43)	(+0.085)	(+0.75)	(+32 lb)	(-140lb)	Low	None
(5) P/L Command, Control & Checkout	Int w/o capability	(N/A)	(+4.1)	(+0.57)	(+5.7)	(+53 lb)	(-202lb)	Medium	None
(6) Electrical Power to P/L	30 Watts	N/A	0	+0.05	+0.47	+9 lb	-38lb	None	None
(7) Design Life	20 Reuses	N/A						(Low)	(None)
- 50 Reuses			(0)	(0)	(?)	(0)	(0)		
- 100 Reuses			(0)	(0)	(?)	(0)	(0)		
(8) Spin Stab P/L Retrieval	Int.w/o capability			Not applicable					
(9) Rend. & Docking	Int.w/o R&D	N/A	(+90)	?	?	(+408lb)	(-1150lb)	(High)	(Laser Rad + DKS)
(10) Nested Dome vs. Separate Tank	Nested Dome	(N/A)	(-1.2)	(-0.1)	(-0.7)	(+70lb)	(-255 lb)	(Less Risk)	(None)
(11) In-Flight Propellant Dump	No Dump	(N/A)	(-0.04)	(+0.004)	(+0.03)	(-49lb)	(+179 lb)	(None)	(None)
(12) Main Engine Selection	Class I								
8096		N/A	-21.6	-0.1	-1.2	+14 lb	-633 lb	Less Risk	None
Class II		N/A	+70	+0.2	+2.3	-12 lb	+626 lb	High Risk	High Press High Temp

SENSITIVITY TASK RESULTS SUMMARY - CONCEPT 310/310RE-3A

SENSITIVITY AREA	REFERENCE	IMPACT DELTA (REFERENCE)							
		COST - $M				VEH. DESIGN		Dev. Risk	Critical Tech. Are
CONCEPT 310/310RE-3A		Tech.	DDT&E	First Unit	Total Production	Inert Weight	P/L Del. Wt.		
(1) Autonomy	Level IV	N/A	(+14.7)	(+10.9)	(+250.7)	(+ 64 lb)	(-234 lb)	(Medium)	(None)
- Level III		N/A	(+ 9.3)	(+16.0)	(+368.0)	(+134 lb)	(-490 lb)	(High)	(621B Avai
- Level II		N/A	(+10.8)	(+20.5)	(+471.5)	(+169 lb)	(-618 lb)	(High)	(Horiz Sca
- Level I									
(2) .97 Reliability	.97/168Hr/ Round Trip	N/A	(0)	(- 1.2)	(-27.1)	(-61 lb)	(+223 lb)	(None)	(None)
- .97/72 Hr/Retrieval		N/A	(0)	(- 1.2)	(-28.3)	(-67 lb)	(+245 lb)	(None)	(None)
- .97/36Hr/Deploy									
(3) 30-Day Servicing Mission	7-day Mission	N/A	(+ 8.4)	(+ 1.1)	(+25.3)	(+224 lb)	(0)	(Low)	(None)
(4) Dod Comm. Requirements	NASA Req.	N/A	+ 0.43	+0.08	+ 1.7	+ 32 lb	-117 lb	Low	None
(5) P/L Command, Control & Checkout	Int w/o capability	N/A	+ 4.1	+0.57	+13.1	+ 53 lb	-194 lb	Medium	None
(6) Electrical Power to P/L	0 Watts	N/A	0	+0.047	+ 1.1	+ 9 lb	- 36 lb	None	None
(7) Design Life	20 Reuses	N/A						Low	None
- 50 Reuses			0	0	-7	0	0		
- 100 Reuses			0	0	-7	0	0		
(8) Spin Stab P/L Retrieval	Int.w/o capability	N/A	0	0	0	+90 lb	-123 lb Retrieved	Low	None
(9) Rend. & Docking	Int.w/o R&D	(N/A)	(+79)	?	?	(+367 lb)	(-990 lb)	(Medium)	(Laser Rad
(10) Nested Dome vs. Separate Tank	Nested Dome	N/A	-1.2	-0.1	-1.0	+ 70 lb	-255 lb	Less Risk	None
(11) In-Flight Propellant Dump	No Dump	N/A	(-0.4)	(+0.004)	(+0.07)	(-49 lb)	(+179 lb)	(None)	(None)
(12) Main Engine Selection	Class I	N/A	-21.6	-0.1	-2.6	+14 lb	-627 lb	Less Risk	None

8096-B2

SENSITIVITY TASK RESULTS SUMMARY -CONCEPT 320A/320AE-3A

SENSITIVITY AREA CONCEPT 320A/320AE-3A	REFERENCE	IMPACT DELTA (REFERENCE)							
		COST - $M				VEH. DESIGN		Dev. Risk	Critical Tech. Area
		Tech.	DDT&E	First Unit	Total Production	Inert Weight	P/L Del. Wt.		
1) Autonomy - Level III - Level II - Level I	Level IV		NOT APPLICABLE						
2) .97 Reliability - .97/72 Hr/Retrieval - .97/36Hr/Deploy	.97/168Hr/ Round Trip		NOT APPLICABLE						
3) 30-Day Servicing Mission	7-day Mission		NOT APPLICABLE						
4) Dod Comm. Requirements	NASA Req.	(N/A)	(+0.043)	(+0.08)	(+1.8)	(32LB)	?	(LOW)	(NONE)
5) P/L Command, Control & Checkout	Int w/o capability	(N/A)	(+4.1)	(+0.57)	(+13.7)	(+53LB)	?	(MEDIUM)	(NONE)
6) Electrical Power to P/L	0 Watts	N/A	0	+0.023	+0.6	+5 LB	?	NONE	NONE
7) Design Life	20 Reuses	N/A						LOW	NONE
- 50 Reuses			(0)	(0)	?	(0)	(0)		
- 100 Reuses			(0)	(0)	?	(0)	(0)		
8) Spin Stab P/L Retrieval	Int. w/o capability	(N/A)	(0)	(0)	(0)	(-90 LB)	(?)	(LOW)	NONE
9) Rend. & Docking	Int. w/o R&D		NOT APPLICABLE						
10) Nested Dome vs. Separate Tank	Nested Dome		NOT APPLICABLE						
11) In-Flight Propellant Dump	No Dump		NOT APPLICABLE						
12) Main Engine Selection			NOT APPLICABLE						

SENSITIVITY TASK RESULTS SUMMARY - CONCEPT 310A/310ARE-3B

SENSITIVITY AREA concept 310A/310ARE-3B	REFERENCE	IMPACT DELTA (REFERENCE)							
		COST - $M				VEH. DESIGN		Dev. Risk	Critical Tech. Area
		Tech.	DDT&E	First Unit	Total Production	Inert Weight	P/L Del. Wt.		
(1) Autonomy	Level IV								
- Level III		N/A	+14.7	+10.9	+174.4	+64 lb	-143 lb	Medium	None
- Level II		N/A	+ 9.3	+16.0	+256.0	+134 lb	-451 lb	High	6213 Avail
- Level I		N/A	+10.8	+20.5	+328.0	+169 lb	-1330 lb	High	Horiz Scan
(2) .97 Reliability	.97/168Hr/ Round Trip								
- .97/72 Hr/Retrieval		(N/A)	(0)	(-1.2)	(-18.9)	(-61 lb)	(+223 lb)	(None)	(None)
- .97/36Hr/Deploy		(N/A)	(0)	(-1.2)	(-19.7)	(-67 lb)	(+245 lb)	(None)	(None)
(3) 30-Day Servicing Mission	7-day Mission	(N/A)	(+8.4)	(+1.1)	(+17.6)	(+224 lb)	(0)	(Low)	(None)
(4) Dod Comm. Requirements	NASA Req.	(N/A)	(+0.43)	(+.08)	(+1.2)	(+32 lb)	(-117 lb)	(Low)	(None)
(5) P/L Command, Control & Checkout	Int w/o capability	(N/A)	(+4.1)	(+0.57)	(+9.1)	(+53 lb)	(-194 lb)	(Medium)	(None)
(6) Electrical Power to P/L	0 Watts	N/A	0	+0.047	+0.8	+ 9 lb	-36 lb	None	None
(7) Design Life	20 Reuses	N/A						Low	None
- 50 Reuses			0	0	-42	0	0		
- 100 Reuses			0	0	-49	0	0		
(8) Spin Stab P/L Retrieval	Int.w/o capability	(N/A)	(0)	(0)	(0)	(+90 lb)	(-123 lb Retrieved)	(Low)	(None)
(9) Rend. & Docking	Int.w/o R&D	(N/A)	(+79)	?	?	(+367 lb)	(-990 lb)	(Medium)	(Laser Rad
(10) Nested Dome vs. Separate Tank	Nested Dome	(N/A)	(-1.2)	(-0.1)	(-1.1)	(+70 lb)	(-255 lb)	(Less Risk)	(None)
(11) In-Flight Propellant Dump	No Dump	(N/A)	(0.4)	(+0.004)	(+0.05)	(-49 lb)	(+179 lb)	(None)	(None)
(12) Main Engine Selection	Class I	N/A	-21.6	-0.1	-1.8	+14 lb	-633 lb	Less Risk	None

SENSITIVITY TASK RESULTS SUMMARY CONCEPT 510A/510ADE-3B

SENSITIVITY AREA CONCEPT 510A/510ADE-3B	REFERENCE	IMPACT DELTA (REFERENCE)							
		COST - $M				WEH. DESIGN		Dev. Risk	Critical Tech. Area
		Tech.	DDT&E	First Unit	Total Production	Inert Weight	P/L Del. Wt.		
(1) Autonomy	Level IV								
- Level III		(N/A)	(+14.7)	(+7.5)	(+105)	(+641bs)	(-2441bs)	(Medium	(None)
- Level II		(N/A)	(+ 9.3)	(+11.0)	(+154)	(+1281bs)	(-4891bs)	(High)	(621B Avail.
- Level I		(N/A)	(+10.8)	(+14.1)	(+197.4)	(+1691bs)	(-6461bs)	(High)	(Horiz Scan
(2) .97 Reliability	.97/168Hr/ Round Trip								
- .97/72 Hr/Retrieval		(N/A)	(0)	(-1.2)	(-16.5)	(-61 lbs)	(-233 lbs)	(None)	(None)
- .97/36Hr/Deploy		(N/A)	(0)	(-1.2)	(-17.2)	(-67lbs)	(-256lbs)	(None)	(None)
(3) 30-Day Servicing Mission	7-day Mission	(N/A)	NOT	APPLICABLE)			0		
(4) DOD Comm. Requirements	NASA Req.	(N/A)	(+0.43)	(+.08)	(+1.1)	(+32 lb)	(-117 lb)	(Low)	(None)
(5) P/L Command, Control & Checkout	Int w/o capability	(N/A)	(+4.1)	(+0.57)	(+8.0)	(+53 lb)	(-202 lb)	(Medium)	(None)
(6) Electrical Power to P/L	0 Watts	(N/A)	0	+0.047	+0.7	+9 lb	-38 lb	(None)	None
(7) Design Life	20 Reuses	(N/A)						(Low)	(None)
- 50 Reuses			(0)	(0)		(0)	(0)		
- 100 Reuses			(0)	(0)		(0)	(0)		
(8) Spin Stab P/L Retrieval	Int.w/o capability		NOT	APPLICABLE					
(9) Rend. & Docking	Int.w/o R&D	(N/A)	(+90)			(+408 lb)	(-1150 lb)	(High)	(Laser Rad (+DKS)
(10) Nested Dome vs. Separate Tank	Nested Dome	(N/A)				(+129 lb)	(-490 lb)	(Less Risk)	(None)
(11) In-Flight Propellant Dump	No Dump	(N/A)	(-0.4)	(0.004)	(+0.04)	(-49 lb)	(+187 lb)	(None)	(None)
(12) Main Engine Selection	OME 7.5 K	(N/A)	+16.2	-0.1	-1.5	-31 lb	+745	Low	None

8096-B2

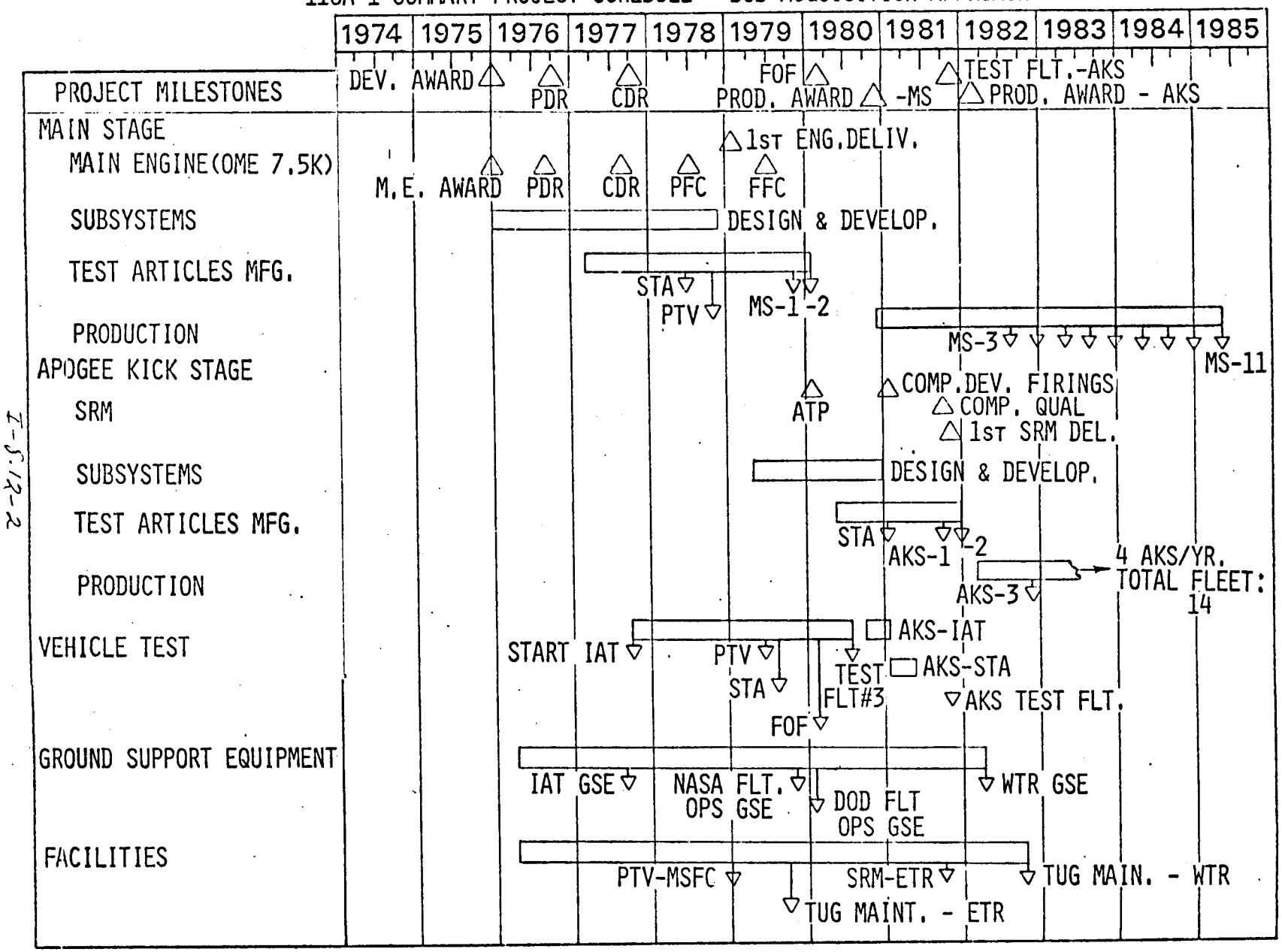
8.12 DOD ACQUISITION APPROACH

110A-1

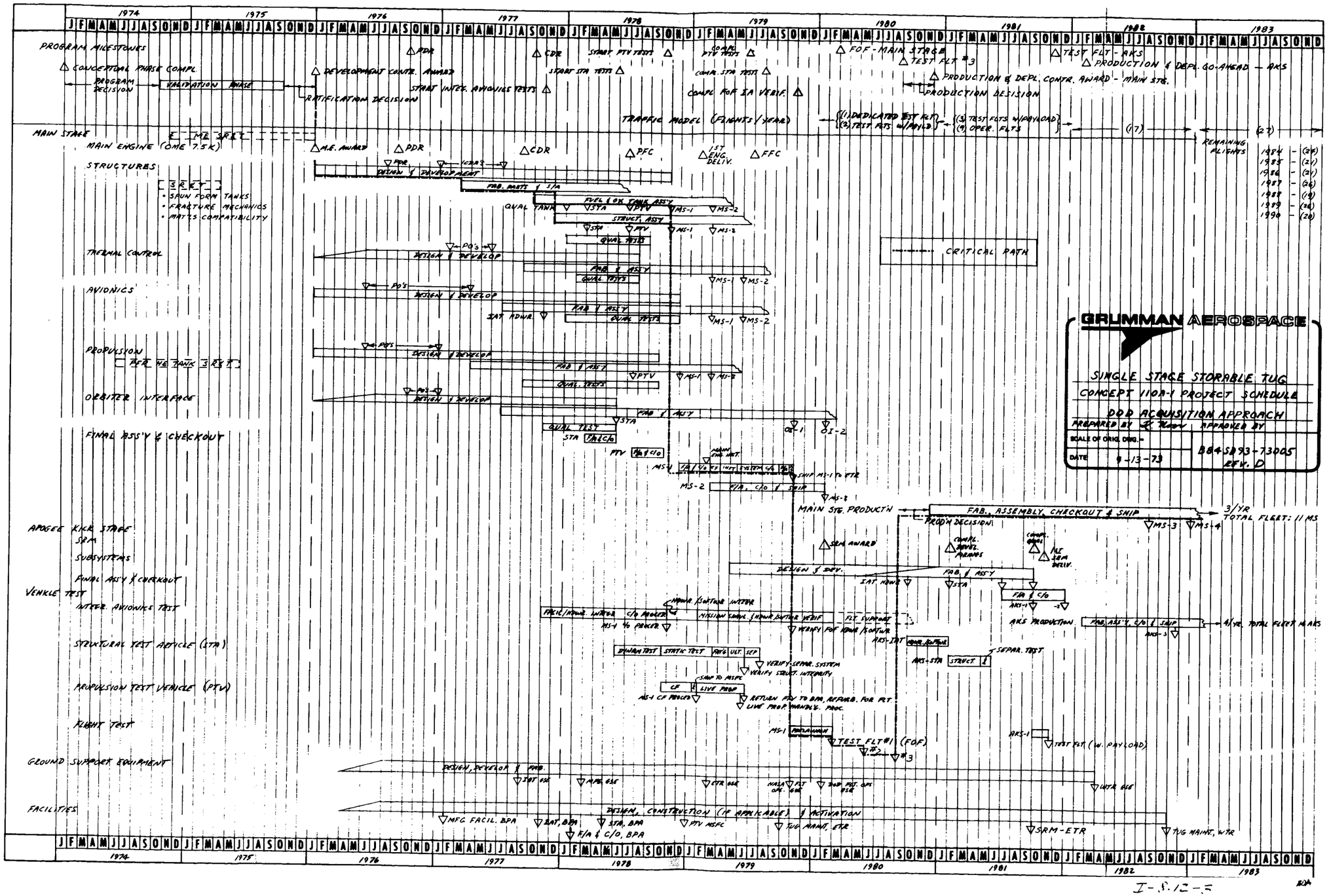
The validation phase serves to validate and refine the program characteristics through study and analysis, hardware development and prototype testing. SR&T activities are also initiated during this phase to assure an orderly progression into the Full Scale Development Phase.

During the Full Scale Development Phase the vehicle test program will be implemented to demonstrate by actual performance testing that the contractual requirements have been met and all major problems have been resolved. The major emphasis at this time is our ground test program which utilizes four major test articles/facilities and mockups. These ground test articles, including the Propulsion Test Vehicle, Structural Test Article, Integrated Avionics and Software Development Facilities and the test programs, are geared to providing assurance of a successful flight test program. The flight test program is the final verification of system design and operational capability and includes a dedicated First Orbital Flight (FOF) without payload followed by operational flights. Flight test data will be acquired on five of these operational flights which have been selected and scheduled to demonstrate Tug capability in a build-up fashion. By the completion of the third flight, however, sufficient confidence will have accrued to verify Tug system capability including ground operations and mission turnaround to allow for a production go-ahead. The Full Scale Development Phase will end after the sixth and last flight test. The two flight test vehicles will continue payload flights during the initial part of the operations Phase. Subsequent flights will be performed by vehicles delivered during the Production Deployment Phase.

110A-1 SUMMARY PROJECT SCHEDULE - DOD ACQUISITION APPROACH



T-S.12-2



1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
PROGRAM MILESTONES
CONCEPTUAL PHASE COMPL.
PROGRAM DECISION
VALIDATION PHASE
DEVELOPMENT CONTR. AWARD
RATIFICATION DECISION
PDR
CDR
START PTV TESTS
START STA TESTS
START INTEG. AVIONICS TESTS
COMPL. PTV TESTS
COMPL. STA TESTS
COMPL. FOF IA VERIF.
FOF - MAIN STAGE
TEST FLT #3
PRODUCTION & DEPL. CONTR. AWARD - MAIN STG.
PRODUCTION DECISION
TEST FLT - AKS
PRODUCTION & DEPL. GO-AHEAD - AKS
TRAFFIC MODEL (FLIGHTS / YEAR)
(1) DEDICATED TEST FLT
(2) TEST FLTS W/PAYLD.
(3) TEST FLTS W/PAYLOAD
(4) OPER. FLTS
(17)
(27)
REMAINING FLIGHTS
1984 - (24)
1985 - (21)
1986 - (21)
1987 - (26)
1988 - (19)
1989 - (26)
1990 - (20)
MAIN STAGE
MAIN ENGINE (OME 7.5K)
M.E. AWARD
PDR
CDR
PFC
1ST ENG. DELIV.
FFC
STRUCTURES
SRKT
• SPUN FORM TANKS
• FRACTURE MECHANICS
• MAT'LS COMPATIBILITY
DESIGN & DEVELOPMENT
FAB. PARTS & S/A
FUEL & OX TANK ASS'Y
QUAL TANK
STA
PTV
MS-1
MS-2
STRUCT. ASSY
QUAL. TESTS
THERMAL CONTROL
PO'S
DESIGN & DEVELOP
FAB. & ASS'Y
QUAL. TESTS
AVIONICS
IAT HDWR.
PROPULSION
PFR HE TANK SRKT
ORBITER INTERFACE
FINAL ASS'Y & CHECKOUT
QUAL TEST
STA
PTV
OI-1
OI-2
CRITICAL PATH
GRUMMAN AEROSPACE
SINGLE STAGE STORABLE TUG
CONCEPT 110A-1 PROJECT SCHEDULE
DOD ACQUISITION APPROACH
PREPARED BY
APPROVED BY
SCALE OF ORIG. DWG. -
DATE 9-13-73
B84SD93-73005
REV. D
MAIN STG. PRODUCT'N
FAB., ASSEMBLY, CHECKOUT & SHIP
PROD'N DECISION
3/YR TOTAL FLEET: 11 MS
MS-3
MS-4
APOGEE KICK STAGE
SRM
SUBSYSTEMS
FINAL ASS'Y & CHECKOUT
VEHICLE TEST
INTEGR. AVIONICS TEST
STRUCTURAL TEST ARTICLE (STA)
PROPULSION TEST VEHICLE (PTV)
FLIGHT TEST
GROUND SUPPORT EQUIPMENT
FACILITIES
SRM AWARD
DESIGN & DEV.
IAT HDWR
STA
AKS PRODUCTION
4/YR. TOTAL FLEET 16 AKS
SEPAR. TEST
TEST FLT #1 (FOF)
TEST FLT (W. PAYLOAD)
DESIGN, DEVELOP & FAB.
DESIGN, CONSTRUCTION (IF APPLICABLE) & ACTIVATION
MFG FACIL. BPA
IAT, BPA
STA, BPA
F/A & C/O, BPA
PTV MSFC
TUG MAINT, ETR
SRM-ETR
TUG MAINT, WTR

I-8.12-5

DOD ACQUISITION APPROACH (AFSCP800-3) 110A-1

Implementing program concept 110A-1 in accordance with DOD full funding requirements (AFSCP800-3) results in a longer development activity plus a delay in the start of production and operations.

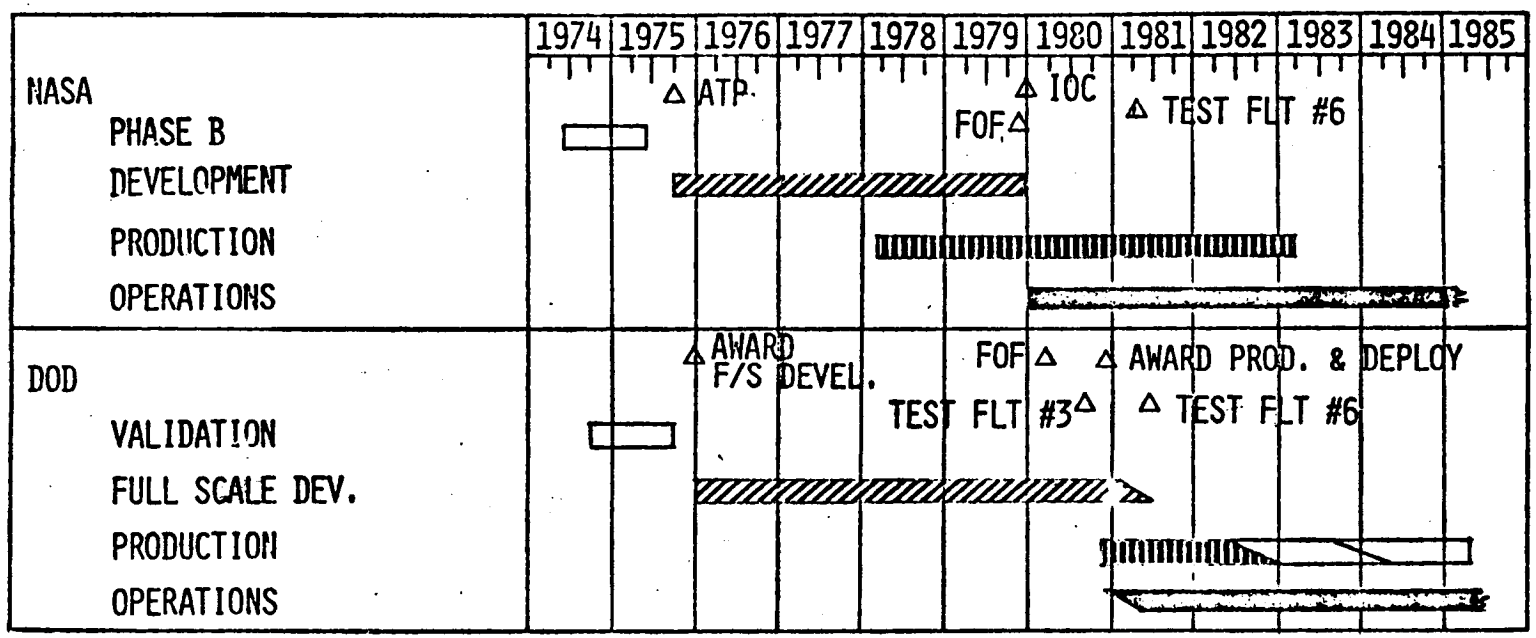
The primary schedule differences between NASA and DOD acquisition programs are as follows:

- DOD Validation Phase constrained to start no sooner than Oct 74 or 3 months after NASA Phase B go ahead.
- Full Scale Development Phase lasts 63 months (1 year longer than the NASA equivalent DDT&E Phase) and includes all test flights (5 of which were costed for NASA as part of initial operations)

In order to obtain DOD approval for full production funding the development program must demonstrate that all performance and operations objectives have been met and related plans for production deployment and operations are well defined.

We have selected the third test flight as the key milestone for demonstrating that all program objectives can be attained. Initial payload deploy operations are performed with the flight test vehicles. The operational fleet will be supplemented with production vehicles as they become available. We recommend that production articles procurement follow a 3 lot buy (3 vehicles per lot) to minimize full funding fiscal requirements.

DOD ACQUISITION APPROACH (AFSCP 800-3) 110A-1



FULL SCALE DEVELOPMENT

- o EXTEND DEVELOPMENT TO INCLUDE 6 TEST FLIGHTS
- o USE FLIGHT TEST VEHICLE FOR INITIAL PAYLOAD OPERATIONS
- o ADD 2ND VEHICLE TO SUPPORT INITITAL OPERATIONS

PRODUCTION/DEPLOYMENT

- o PROVIDE 9 ADDITIONAL VEHICLES (3/3/3-3 LOT BUY)

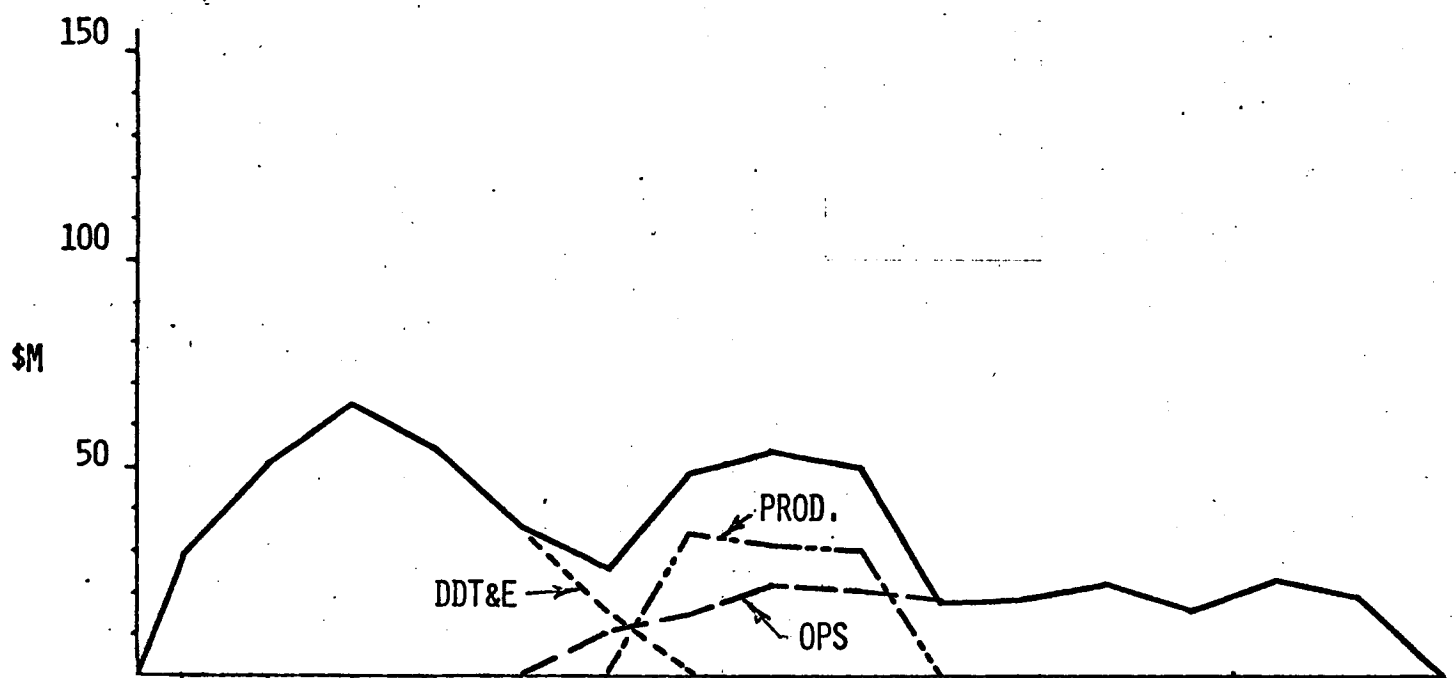
OPERATIONS

- o DELETE 5 TEST FLIGHTS - 213 TOTAL FLIGHTS
- o TOTAL FLEET-11 MAIN STAGES & 14 APOGEE KICK STAGES

GRUMMAN

I-8.12.3-2/3

DOD AQUISITION APPROACH (AFSCP 800-3) 110A-1
ANNUAL PROJECT COSTS



FY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	TOTAL
DDT&E	29	51	64	54	36	17										251
PROD							33	31	30							94
OPS						10	15	22	20	19	19	22	16	23	19	185
TOTAL	29	51	64	54	36	27	48	53	50	19	19	22	16	23	19	530

I-8-12.3-4

8.13 ESTIMATING TECHNIQUE APPLIED

WBS ELEMENT	DDT&E	PRODUCTION	OPN
320-01 Proj. Management	CER's Based on LM Experience	Same as DDT&E	Same as DDT&E
320-02 Syst Eng & Integ	Same as 320-01	Same as 320-01	Same as 320-01
320-03-01 Structure	CER's Lower Level Analysis	Same as DDT&E	N/A
320-03-02 Thermal Insul	Same as 320-03-01	Same as 320-03 -01	N/A
320-03-03 Avionics	Vendor Est/Manpower/Wrap-around	Same as DDT&E	N/A
320-03-04 Propulsion	Gov't Est/Vendor Est/Wrap-around	Same as DDT&E	Same as DDT&E
320-03-05 Orbiter Interface	CER's Vendor Est/Wraparound	Same as DDT&E	N/A
320-03-06 Drop Tanks	N/A	N/A	N/A
320-03-07 Final Assy & C/O	Same as 320-01	Same as 320-01	N/A
320-04-01 Structure	Same as 320-03-01	Same as 320-03 -01	N/A
320-04-02 Thermal Insul	Same as 320-03-02	Same as 320-03 -02	N/A
320-04-03 Avionics	Same as 320-03-03	Same as 320-03 -03	N/A
320-04-04 Propulsion	Same as 320-03-04	Same as 320-03 -04	Same as 320-03-04
320-04-05 Interstage Interface	Same as 320-03-01	Same as 320-03 -01	N/A
320-04-06 Drop Tanks	N/A	N/A	N/A
320-04-07 RDM	Gov't est, CER's Vendor Est, wraparound	Same as DDT&E	Same as DDT&E
320-04-08 AKS	Same as 320-04-07	Same as 320-04 -07	Same as 320-04-07
320-04-09 DKS	Same as 320-04-07	Same as 320-04 -07	Same as 320-04-07
320-04-10 Cache Tank	N/A	N/A	N/A
320-04-11 Final Assy & C/O	Same as 320-03-07	Same as 320-03 -07	N/A
320-05 Logistics	CER's	Same as DDT&E	Same as DDT&E
320-06 Facilities	CER's	Same as DDT&E	Same as DDT&E
320-07 GSE	CER's, and End-item analysis	Same as DDT&E	Same as DDT&E
320-08 Vehicle Test	CER's, Manpower Loading	N/A	N/A
320-09 Launch Ops WTR	N/A	N/A	Manpower Loading
320-10 Launch Ops ETR	N/A	N/A	Manpower Loading

WBS ELEMENT	DDT&E	PRODUCTION	OPN
320-11 Flt Ops DOD	CER's & Manpower Loading	N/A	Same as DDT&E
320-12 Flt Ops NASA	Same as 320-11	N/A	Same as DDT&E
320-13 Ref & Int, 1st TR	N/A	N/A	Manpower Loading
320-14 Ref & Int, 2nd TR	N/A	N/A	Manpower Loading

COST = A (BASE)^B	PROGRAM BASIS	BASE	A DDT&E	A PROD	B DDT&E	B PROD
PROJECT MGMT.	LM	VEH COST	.1	.09	1	1
	LM	LESS ENG.				
SE & E	LM	VEH COST	.13	.08	1	1
		LESS ENG.				
STRUCTURE	LM	WEIGHT				
SPUN AL. TANKS			124	15	.71	.61
TI TANKS			140	24.3	.71	.61
BODY SHELL			25	2.8	.71	.61
THRUST STRUCTURE			5.5	0.4	1	1
METEOROID SHIELD			5.5	.47	1	1
PAYLOAD INTERFACE			37.2	3.4	1	1
PROPULSION						
ACPS THRUSTERS		VENDOR COST	2	1.66	.7	.7
ACPS SUPPORT		VENDOR COST	2.4	1.84		
EPS WIRING	LM	(WEIGHT)	39.7	7	.7	.7
ORBITER INTERFACE, STRUCTURE	LM	WEIGHT	5.5	,4	1	1
FINAL ASSY & C/O	LM	VEH COST	.54	.18	1	1

8.0 SCHEDULES

8.1.1 SUMMARY PROJECT SCHEDULE

Introduction: The Storable Tug Project schedule was developed to identify the principal project phases and to establish schedule estimates for all hardware and soft ware elements in accordance with the Space Tug Work Breakdown Structure.

The Tug Project Schedule depicts major program milestones and presents project activities at level 5 of the WBS. This schedule establishes the planning baseline for development of the Storable Tug System through design, development, manufacturing, ground test, flight test and operations. It integrates all supporting schedules into an overall project level plan and establishes the sequence and interdependency of activities and events required for the development of an operational Space Tug System.

Groundrules and Assumptions: Following are the ground rules and assumptions used for development of the Storable Tug Project Schedule:

- o ATP is October 1975 at the earliest for Options 1 and 3. ATP for Option 2 to be determined by the contractor.
- o Schedule planning is designed to minimize peak annual funding during DDT&E.
- o Main Stage DDT&E requirements consist of the following major test articles:
  - A structural test article (STA) for dynamic, static and fatigue tests.
  - A main propulsion test vehicle (PTV). Following the completion of live propellant testing the PTV will be refurbished and delivered as an operational flight vehicle.
  - One shipset of Avionics hardware for the Integrated Avionics Test (IAT).
  - A flight test vehicle (MS-1).
- o Operational fleet sizes for each project option are based on a study of traffic capture models.
- o Production rate of vehicles is based on avoiding duplication of major structural assembly tooling and minimizing gaps in manufacturing flow.

- Initial operational capability (IOC) is achieved after completion of one test flight (FOF). IOC dates are as follows:

  Option 1 - December 1979
  Option 2 - December 1983
  Option 3 - December 1979 - initial, December 1983 - evolved.

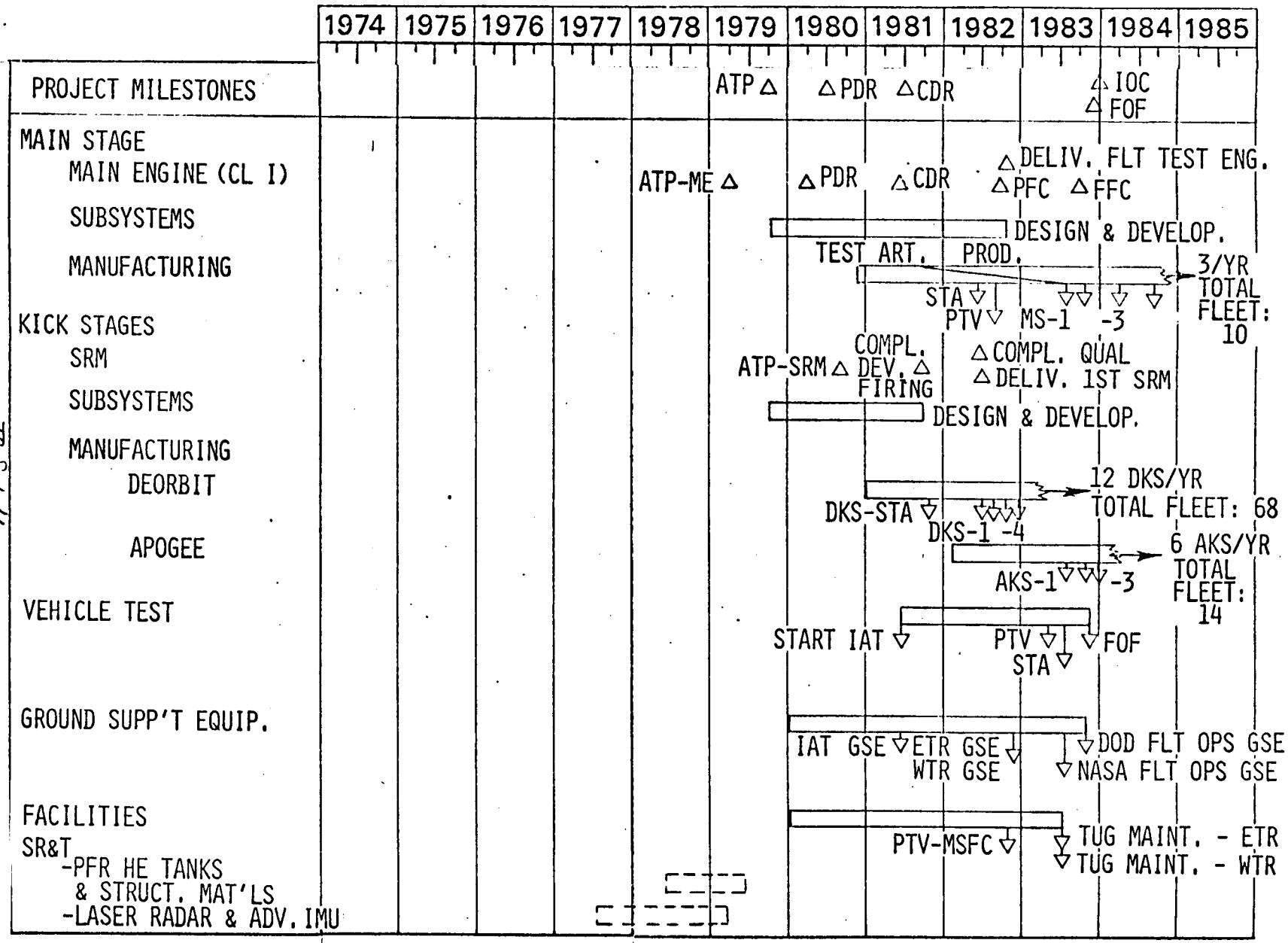
- Maximum number of flights in 1980 is 3, based on the Shuttle traffic model.

Approach: Based on the above groundrules and assumptions a preliminary project milestone schedule was developed to form a baseline for all detail scheduling. Detailed subsystem design and development schedules, manufacturing and factory checkout flows, vehicle test, GSE, facilities, and SR&T Schedules were then developed in conjunction with personnel representing the cognizant management and technical disciplines. These detailed schedules were then summarized and integrated into the Tug Project Schedule through the process of establishing a logical and achievable relationship between the engineering design and development process, procurement of subcontract equipment, hardware fabrication and assembly process and the vehicle test program that minimizes risks and ensures the fulfillment of program objectives. Finally, the major project milestones and activities presented in the Tug Project Schedule were condensed into the Summary Project Schedule.

SUMMARY SCHEDULE - 410AD-2

The primary elements of the 410AD-2 Project Schedule are as described for 110A-1. Authorization to Proceed (ATP) occurs on October 1, 1979 with IOC targeted for January 1, 1984. The design, development and manufacture of the main stage nested dome tanks primarily pace the program. The Class I main engine ATP occurs 6 months before main stage ATP with Final Flight Certification (FFC) occuring two months before main stage first flight. The 410AD-2 main stage major vehicle tests leading to IOC are also as described for 110A-1. Main stage manufacturing begins December 1, 1980 and continues through production of 10 vehicles to support fleet operations. Deorbit Kick Stage (DKS) development begins at the same time as the main stage in order to capture 1986 payload retrieval flights. DKS flights will begin in late 1982 and will be performed with other launch vehicles. Production of Apogee Kick Stages, however, start 13 months after DKS production since AKS operations begin after main stage IOC. DKS vehicle tests start 6 months before the start of main stage vehicle tests and a DKS flight test is planned for September 1, 1982. GSE and Facilities are scheduled to support vehicle test manufacturing ETR/WTR site activation and NASA/DOD Flight Operations Control activations. Both ETR and WTR will be activated to support initial flights in 1983.

410AD-2 SUMMARY PROJECT SCHEDULE

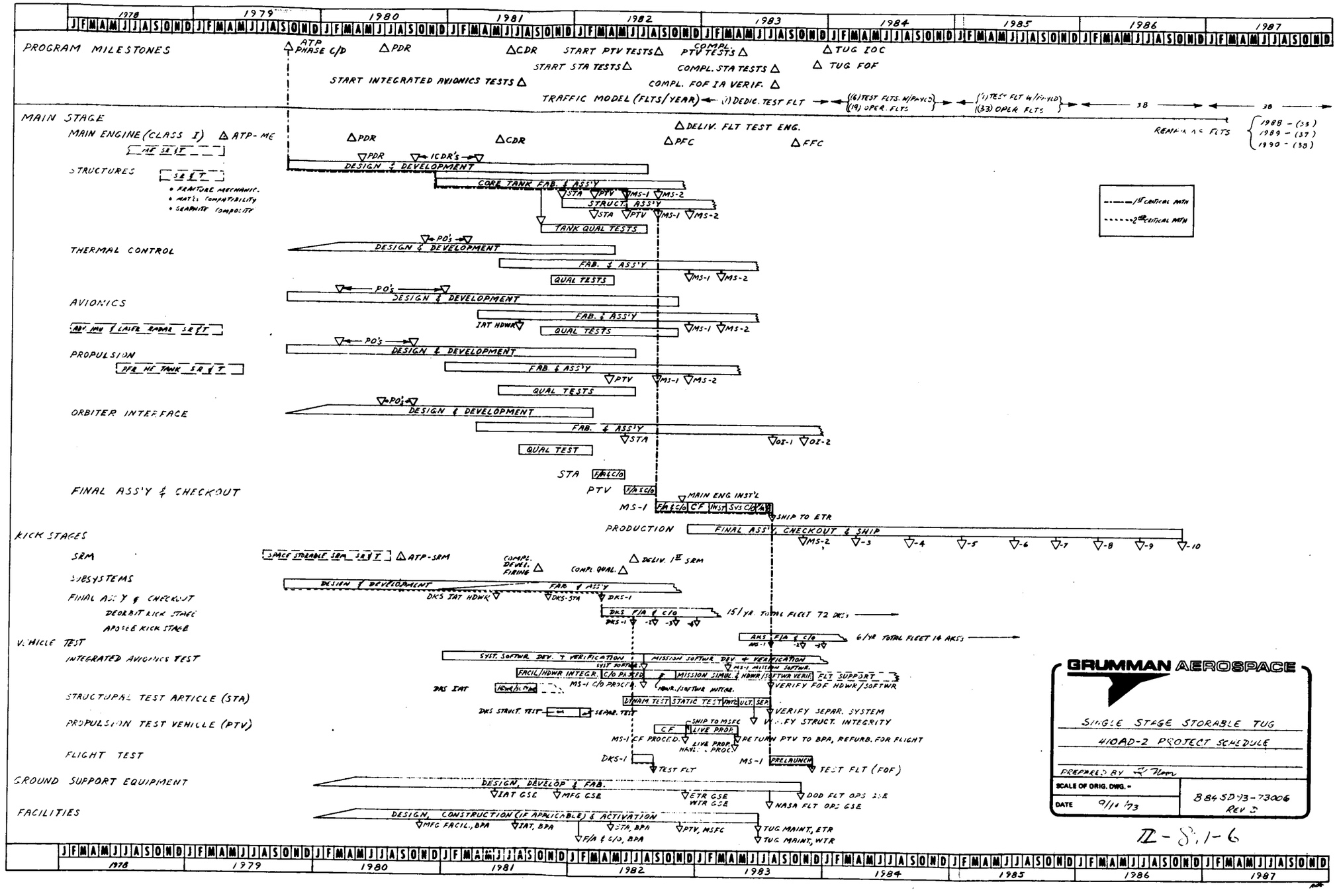


8.1.2 DEVELOPMENT SCHEDULES

8.1.3 PRODUCTION SCHEDULES

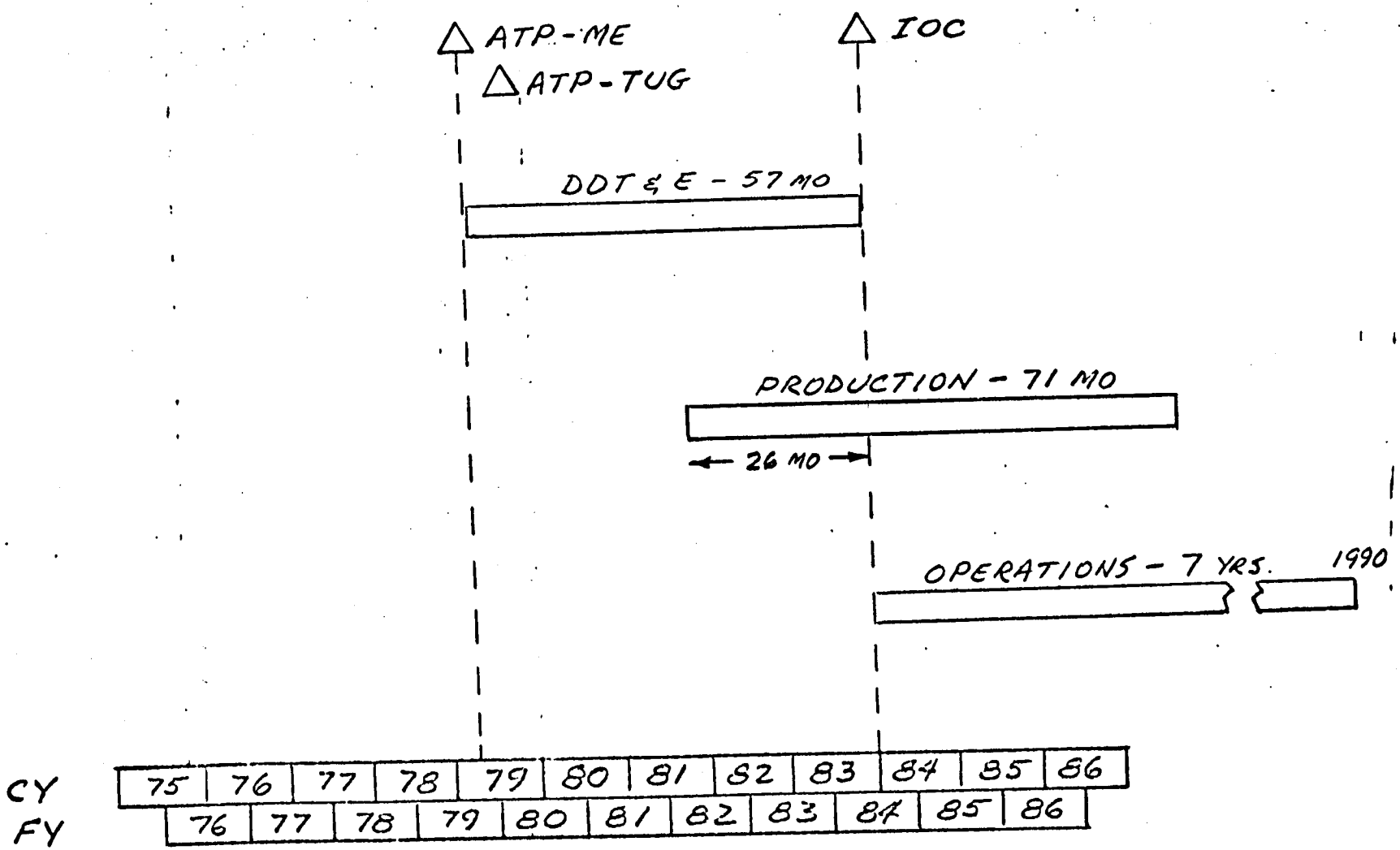
The detailed Project Schedule depicts the total development and production phases for the Main Stage and the Auxiliary Stage(s). The detailed Project Schedule is based on a constraint logic that considers overall program objectives and the detailed interaction of constraints on significant program activities. It provides reasonable margins for development problems and minimizes program front-loading.

The detailed Subsystem Schedules provide an order of magnitude increase in detail from the Project Schedule and depict the subsystem activities in both inhouse and subcontractor areas. Subsystem schedule information is presented at WBS level 6 for Structures, Thermal Control and Orbiter Interface, and at WBS level 7 for Propulsion and Avionics subsystems.

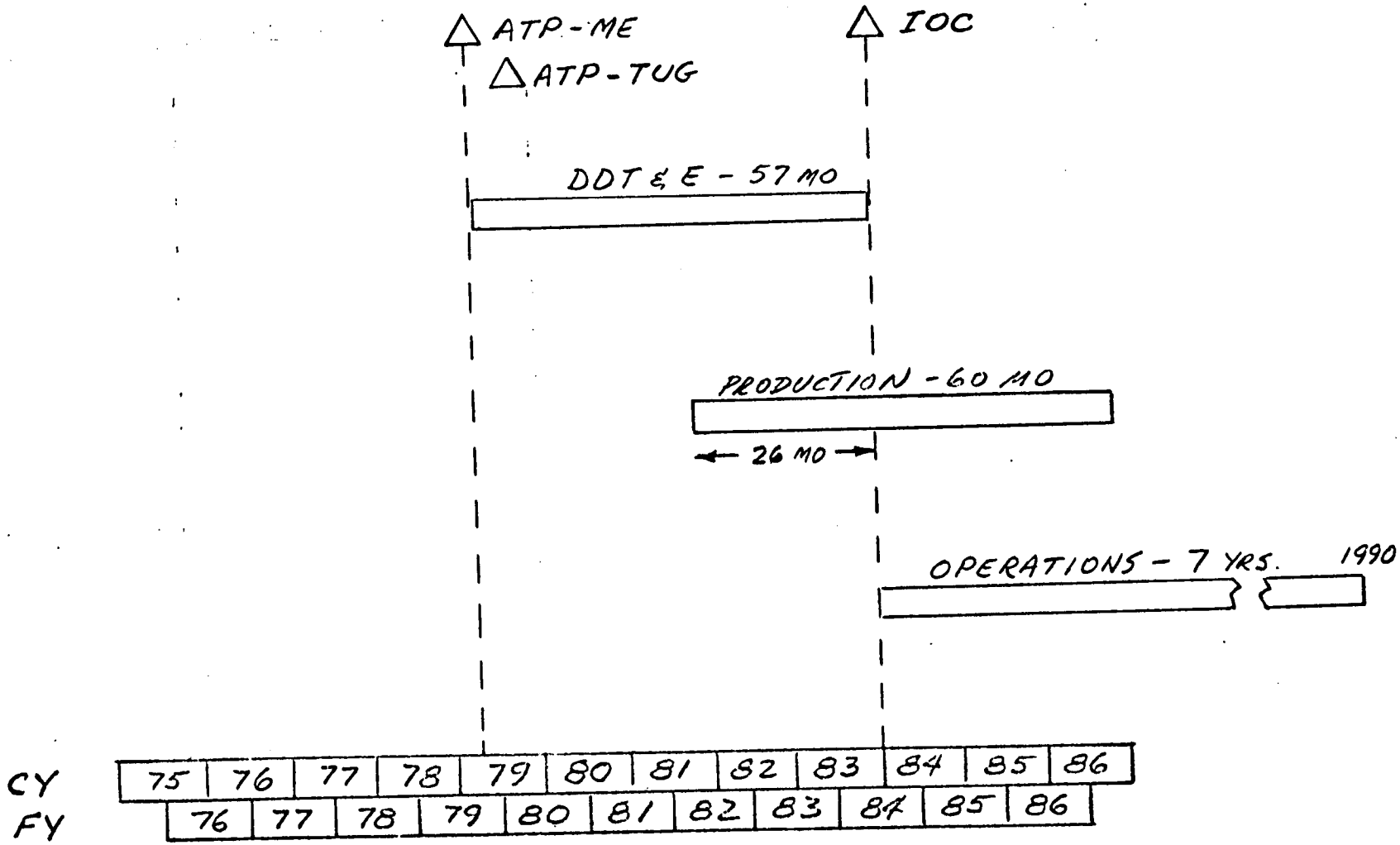

1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
PROGRAM MILESTONES
ATP PHASE C/D
PDR
CDR
START PTV TESTS
COMPL. PTV TESTS
TUG IOC
START STA TESTS
COMPL. STA TESTS
TUG FOF
START INTEGRATED AVIONICS TESTS
COMPL. FOF IA VERIF.
TRAFFIC MODEL (FLTS/YEAR)
(1) DEDIC. TEST FLT
(6) TEST FLTS. W/PAYLD
(19) OPER. FLTS
(1) TEST FLT W/PAYLD
(33) OPER. FLTS
38
38
REMAINING FLTS
1988 - (33)
1989 - (37)
1990 - (38)
1ST CRITICAL PATH
2ND CRITICAL PATH
MAIN STAGE
MAIN ENGINE (CLASS I)
ATP-ME
DELIV. FLT TEST ENG.
PDR
CDR
PFC
FFC
ME SR&T
PDR
ICDR'S
DESIGN & DEVELOPMENT
STRUCTURES
SR&T
• FRACTURE MECHANIC.
• MAT'LS COMPATIBILITY
• GRAPHITE COMPOSITE
CORE TANK FAB. & ASS'Y
STA
PTV
MS-1
MS-2
STRUCT. ASS'Y
TANK QUAL TESTS
THERMAL CONTROL
PO'S
DESIGN & DEVELOPMENT
FAB. & ASS'Y
QUAL TESTS
AVIONICS
AOV IMU & LASER RADAR SR&T
IAT HDWR
PROPULSION
PFR HE TANK SR&T
ORBITER INTERFACE
QUAL TEST
OI-1
OI-2
FINAL ASS'Y & CHECKOUT
F/A&C/O
PTV
MAIN ENG. INST'L
CF
INST
SVS C/O
SHIP TO ETR
PRODUCTION
FINAL ASS'Y, CHECKOUT & SHIP
MS-2
-3
-4
-5
-6
-7
-8
-9
-10
KICK STAGES
SRM
SPACE STORABLE SRM SR&T
ATP-SRM
COMPL. DEMO. FIRING
COMPL. QUAL.
DELIV. 1ST SRM
SUBSYSTEMS
DESIGN & DEVELOPMENT
FAB. & ASS'Y
FINAL ASS'Y & CHECKOUT
DEORBIT KICK STAGE
APOGEE KICK STAGE
DKS IAT HDWR
DKS-STA
DKS-1
DKS F/A & C/O
15/YR TOTAL FLEET 72 DKS
AKS F/A & C/O
6/YR TOTAL FLEET 16 AKS
VEHICLE TEST
INTEGRATED AVIONICS TEST
SYST. SOFTWR. DEV. & VERIFICATION
MISSION SOFTWR. DEV. & VERIFICATION
MS-1 MISSION SOFTWR.
FACIL/HDWR INTEGR.
C/O PROCED.
MISSION SIMUL. & HDWR/SOFTWR VERIF.
FLT SUPPORT
VERIFY FOF HDWR/SOFTWR
STRUCTURAL TEST ARTICLE (STA)
DKS IAT
HDWR/SIMUL
MS-1 C/O PROCED.
HDWR./SOFTWR INTEGR.
DYNAM. TEST
STATIC TEST
PRESS.
ULT.
SEP.
DKS STRUCT. TEST
SEPAR. TEST
VERIFY SEPAR. SYSTEM
VERIFY STRUCT. INTEGRITY
PROPULSION TEST VEHICLE (PTV)
CF
SHIP TO MSFC
LIVE PROP.
MS-1 CF PROCED.
LIVE PROP. HANDL. PROC.
RETURN PTV TO BPA, REFURB. FOR FLIGHT
FLIGHT TEST
DKS-1
TEST FLT
MS-1
PRELAUNCH
TEST FLT (FOF)
GROUND SUPPORT EQUIPMENT
DESIGN, DEVELOP & FAB.
IAT GSE
MFG GSE
ETR GSE
WTR GSE
DOD FLT OPS GSE
NASA FLT OPS GSE
FACILITIES
DESIGN, CONSTRUCTION (IF APPLICABLE) & ACTIVATION
MFG FACIL., BPA
IAT, BPA
F/A & C/O, BPA
STA, BPA
PTV, MSFC
TUG MAINT., ETR
TUG MAINT., WTR
GRUMMAN AEROSPACE
SINGLE STAGE STORABLE TUG
410AD-2 PROJECT SCHEDULE
PREPARED BY
SCALE OF ORIG. DWG. =
DATE 9/14/73
884SD93-73006
REV 3

II-8.1-6

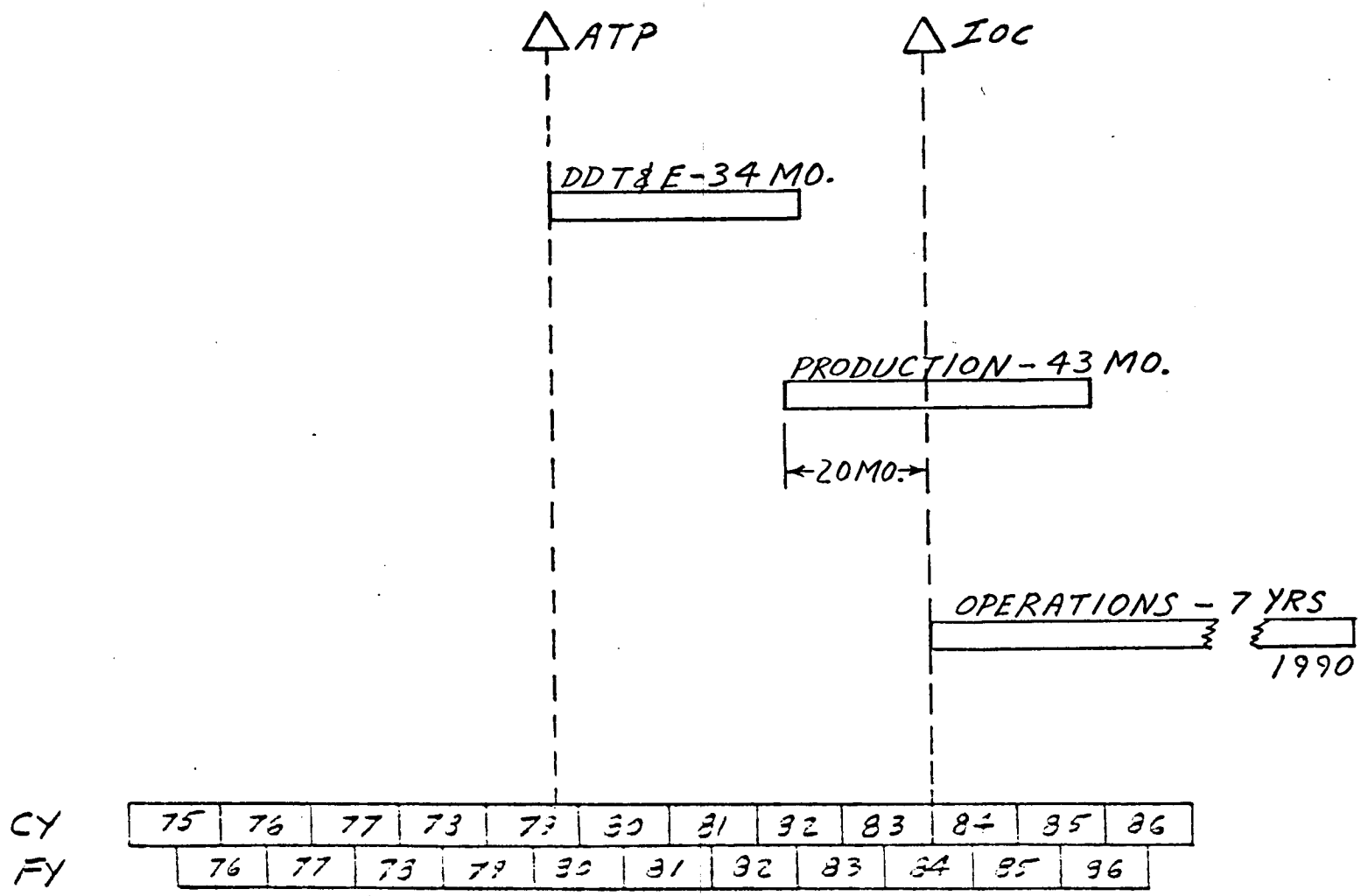
410AD-2 PROJECT SUMMARY



410AD-2 MAIN STAGE

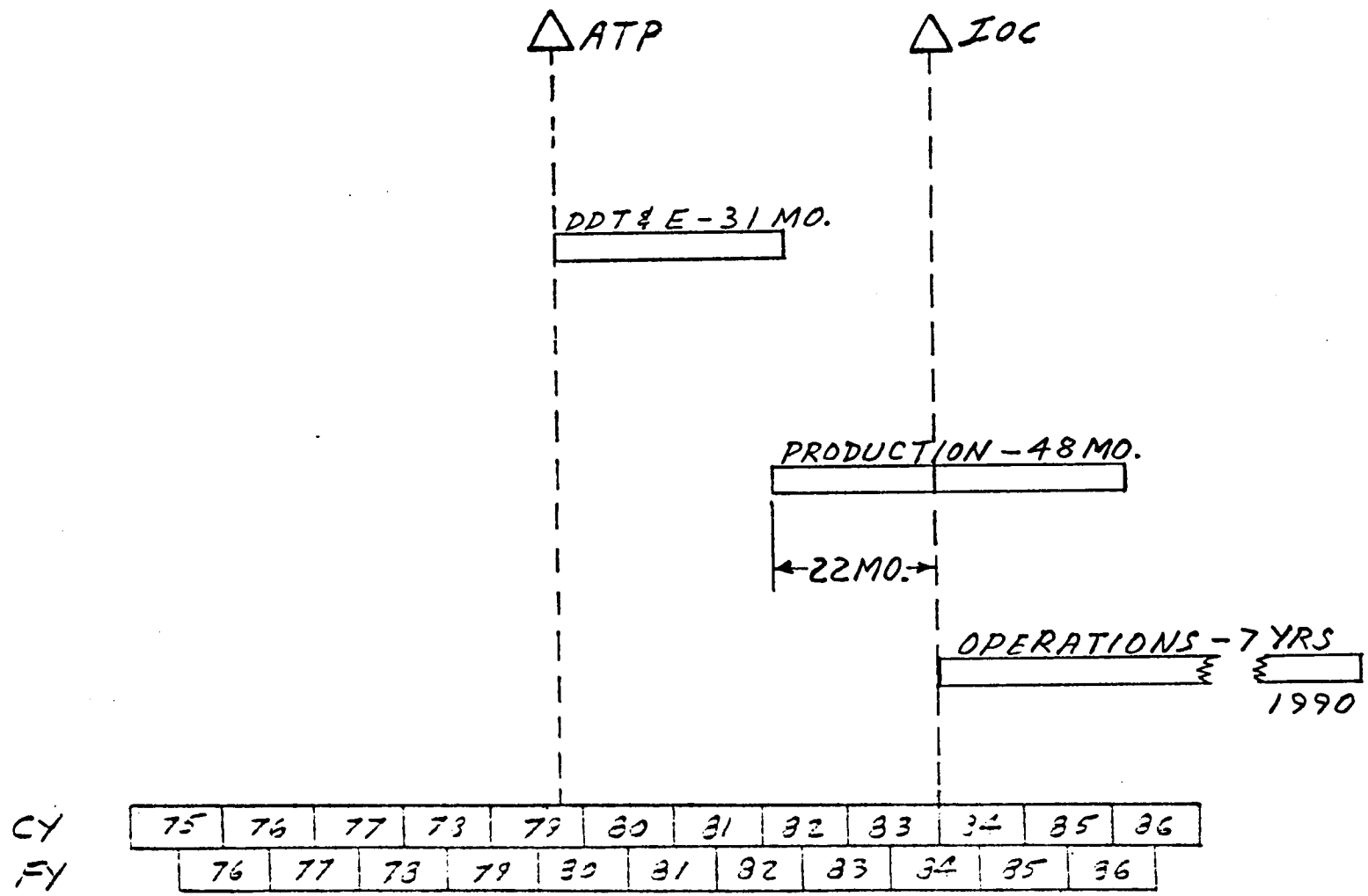


410AD-2 STRUCTURES



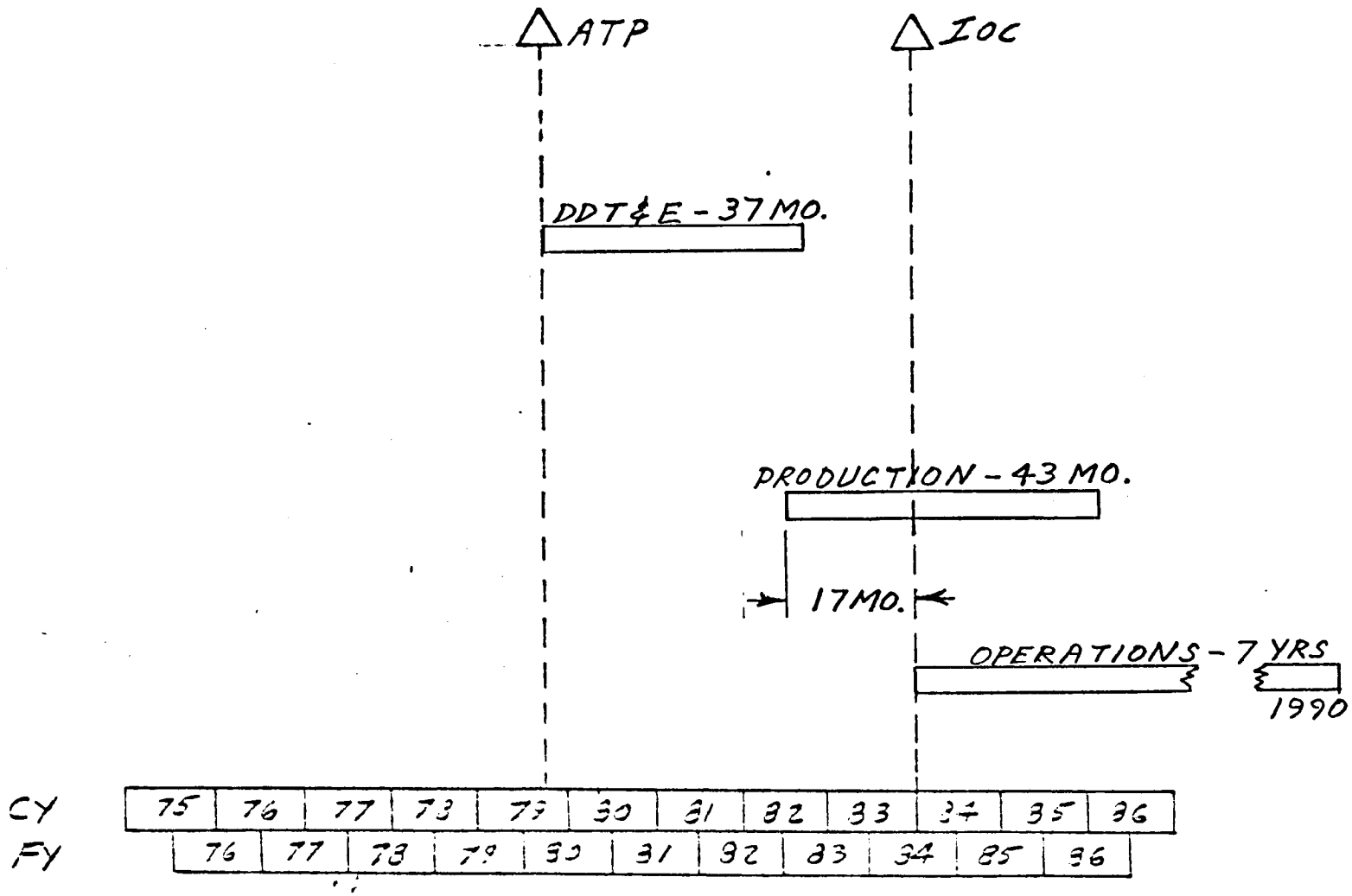
5-18-77

410AD-2 THERMAL CONTROL

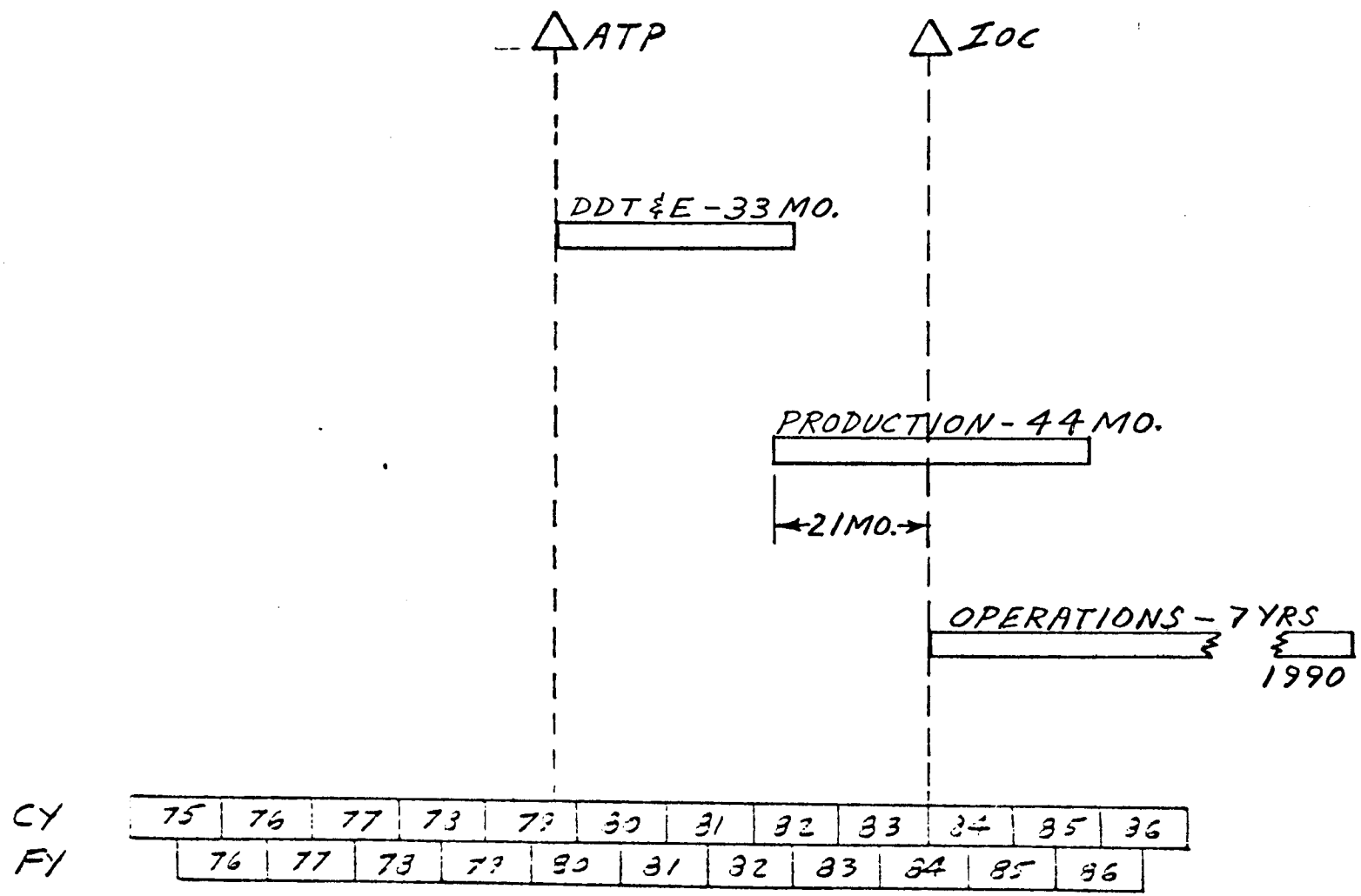


II-8-1-10

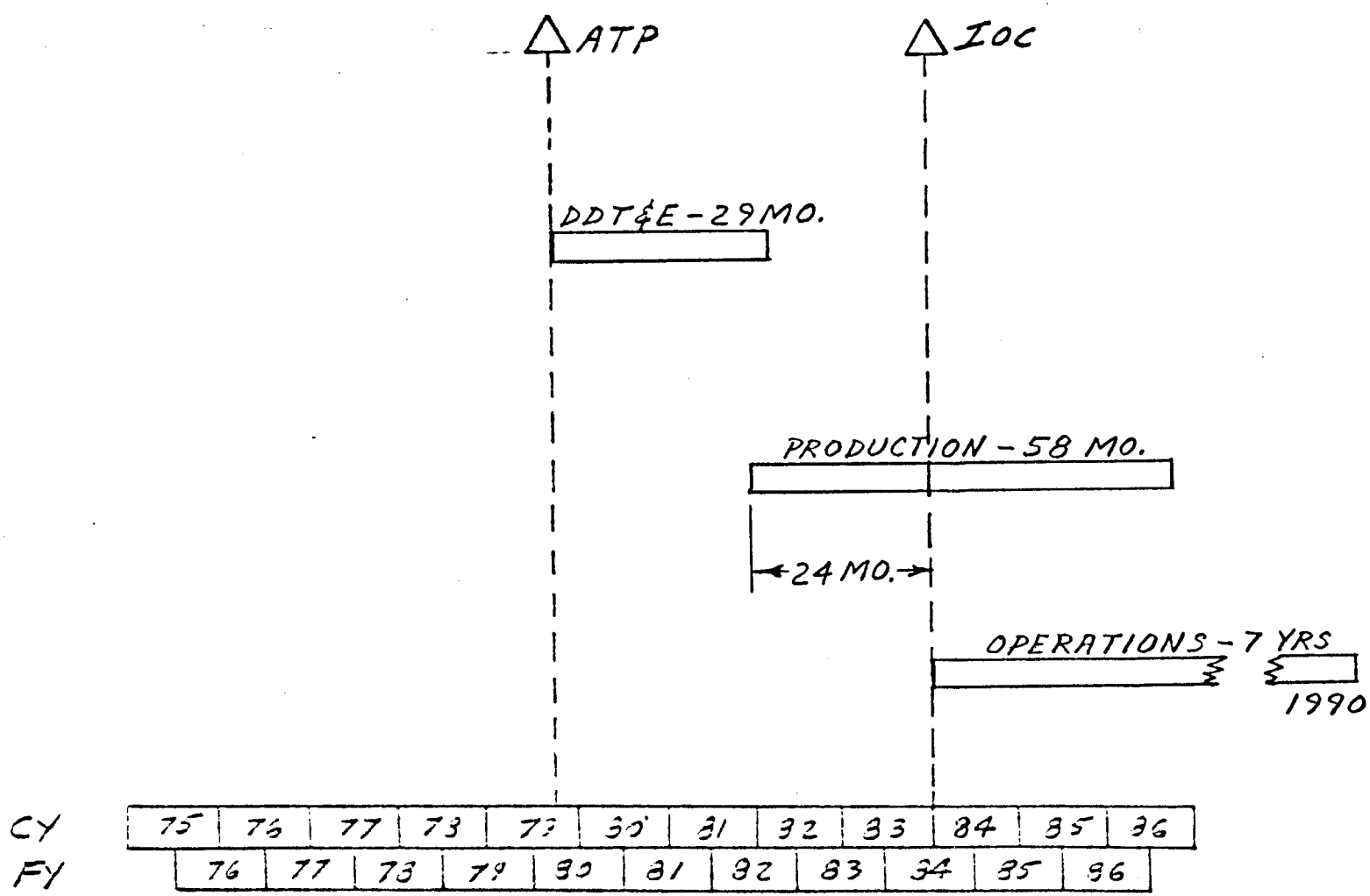
410 AD-2 AVIONICS



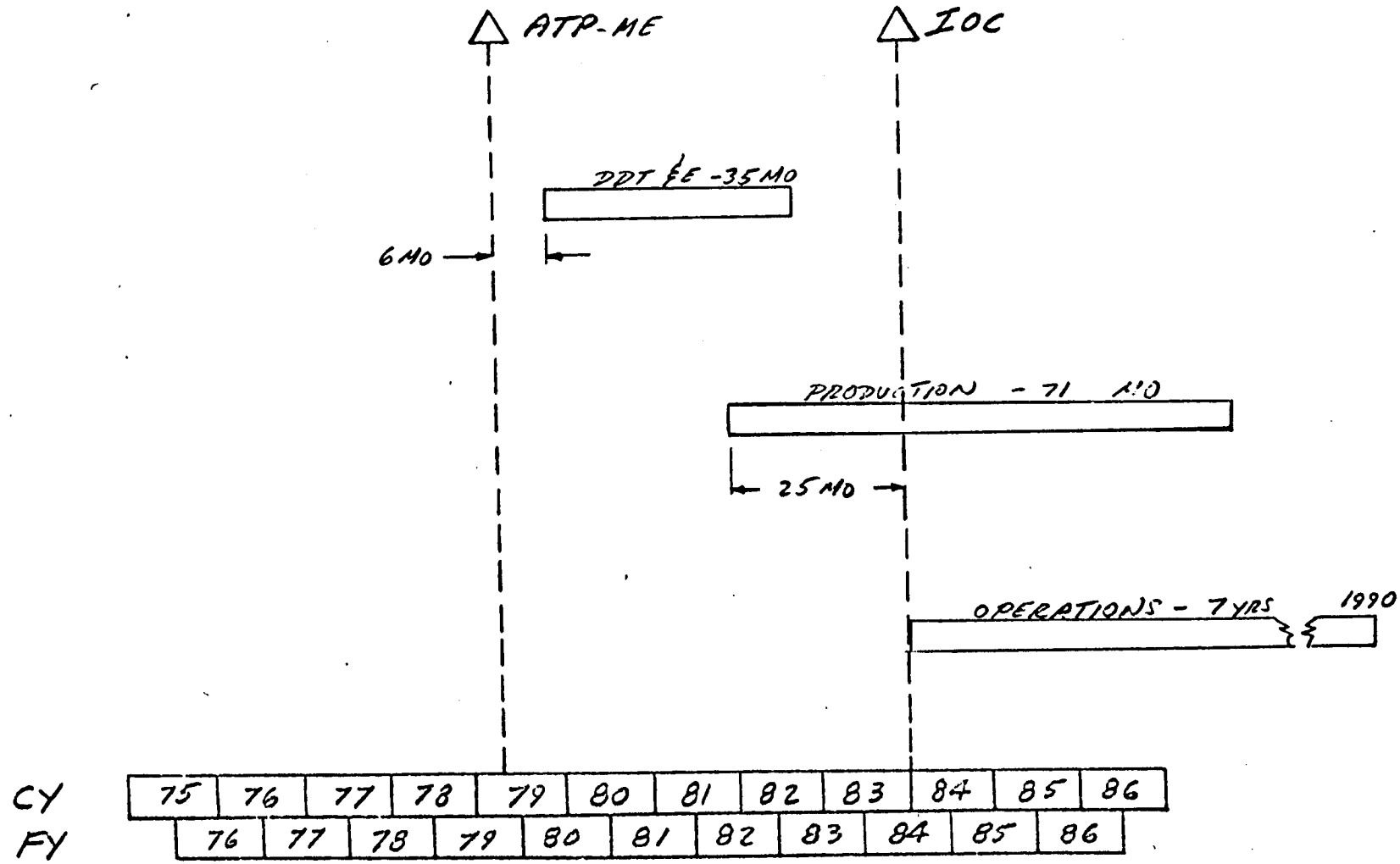
410AD-2 PROPULSION



410AD-2 ORBITER INTERFACE

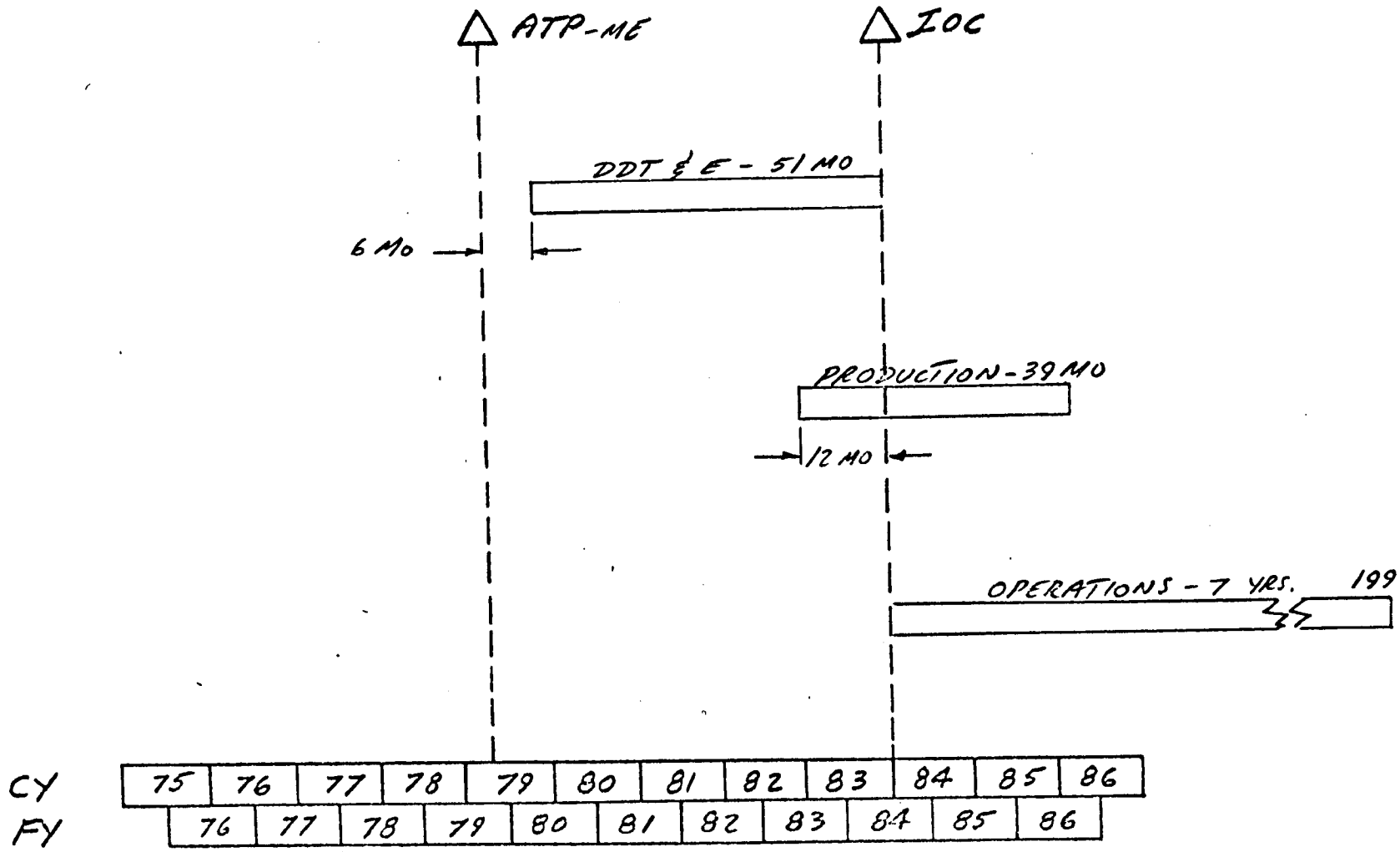


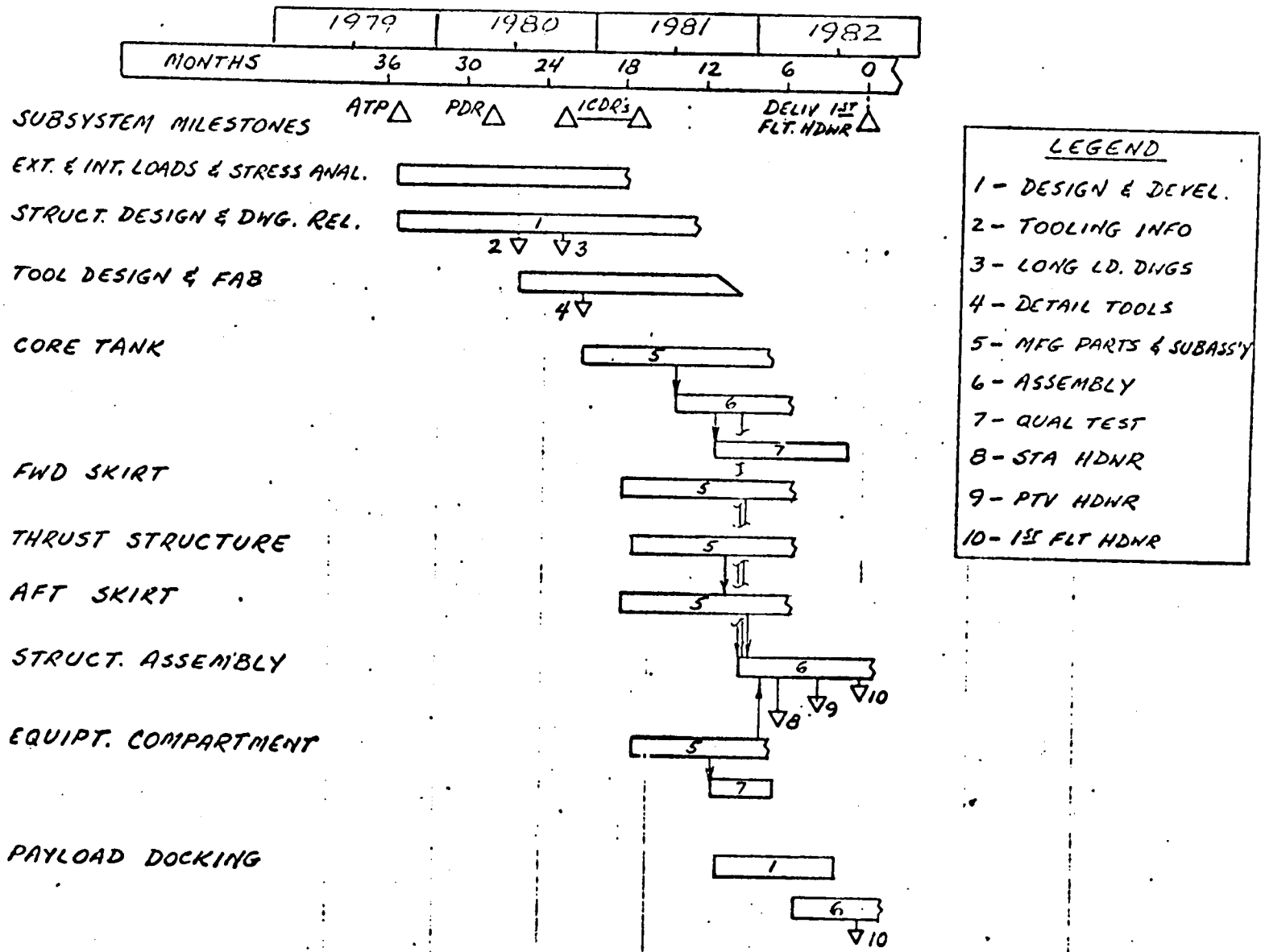
410AD-2 AUXILIARY STAGE - DKS



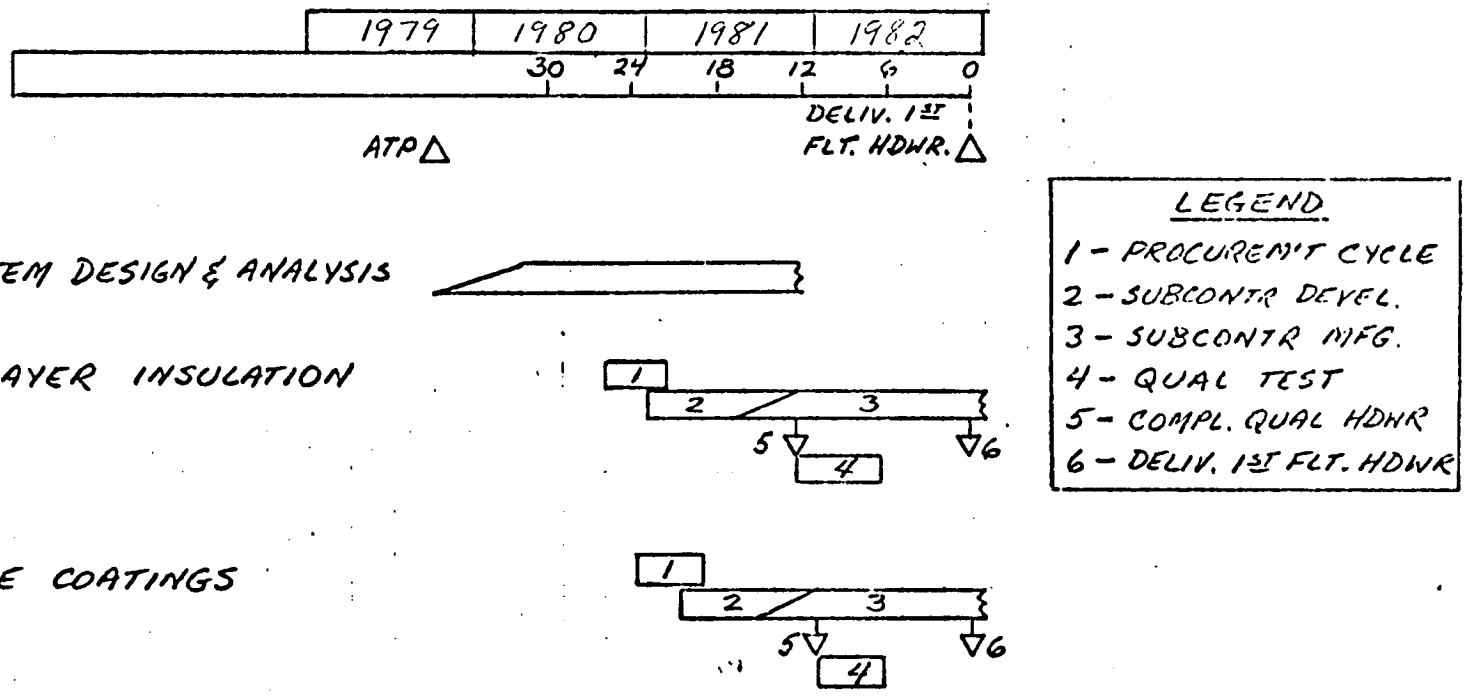
II-2.1-14

410AD-2 AUXILIARY STAGE – AKS

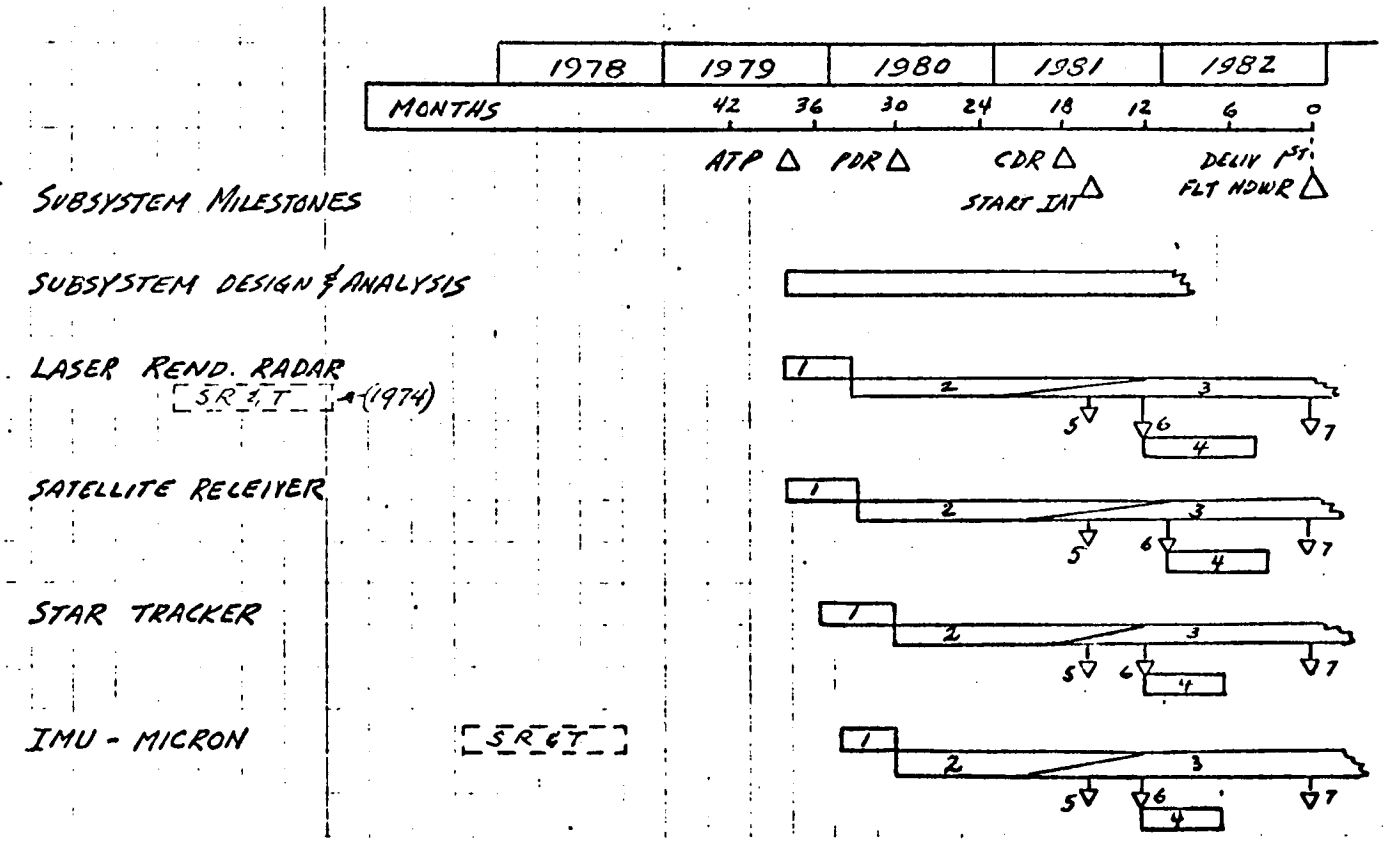




410AD-2 STRUCTURES SUBSYSTEM SCHEDULE



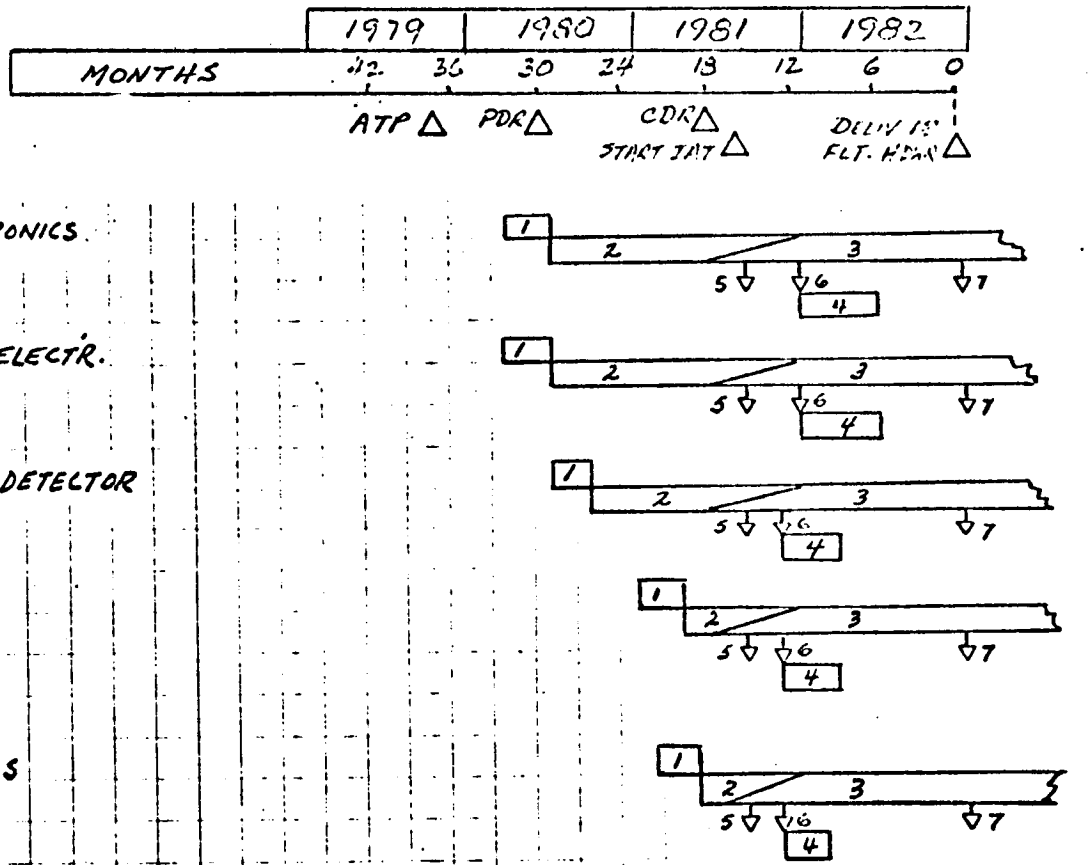
410AD-2 THERMAL CONTROL SUBSYSTEM SCHEDULE



LEGEND
1 - PROCUREMENT
2 - DES & DEVEL.
3 - MFG
4 - QUAL TEST
5 - IAT HDWR
6 - QUAL HDWR
7 - 1ST FLT HDWR

410AD-2 G N & C SUBSYSTEM SCHEDULE

81-1-3-11

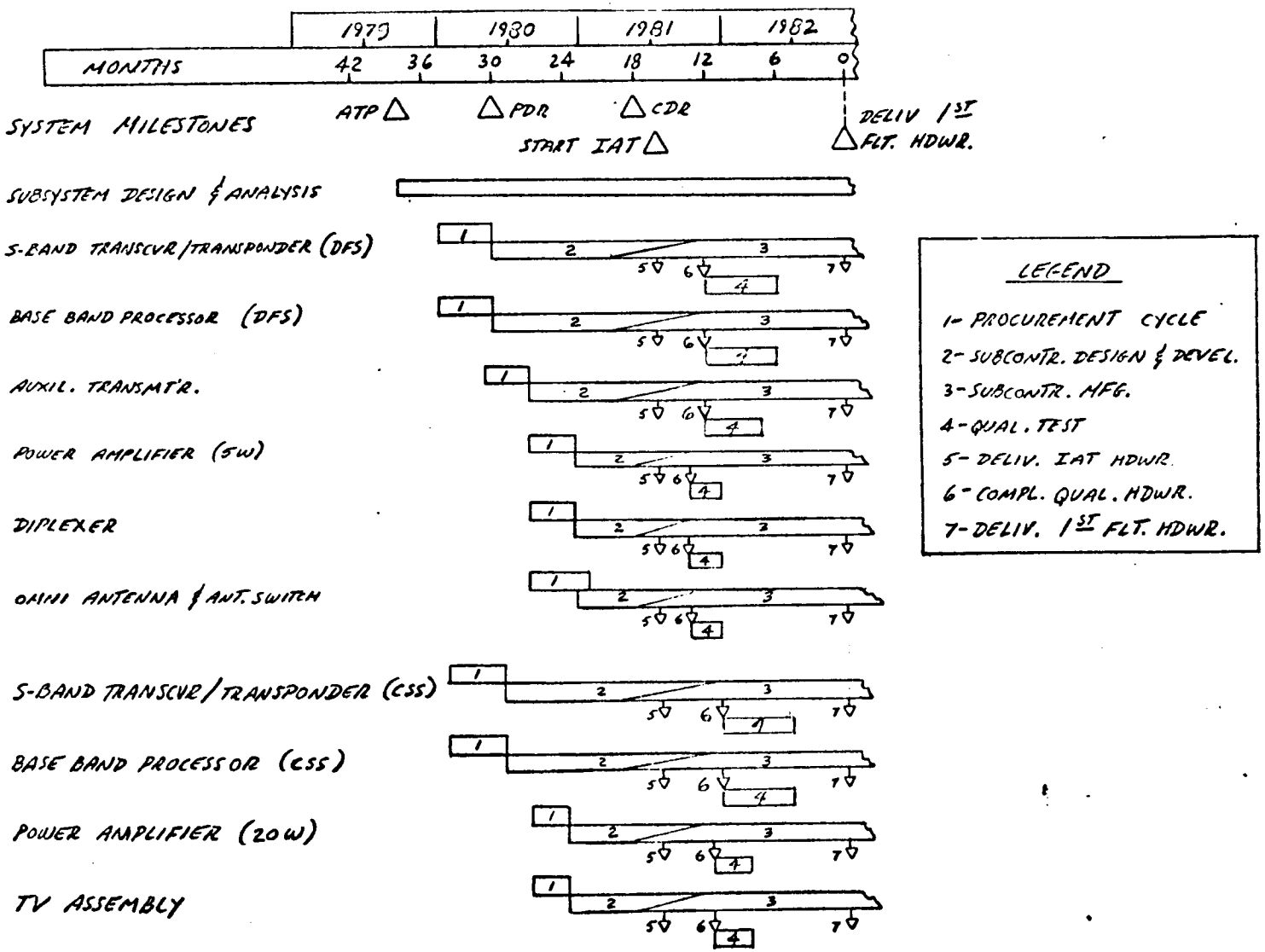


LEGEND

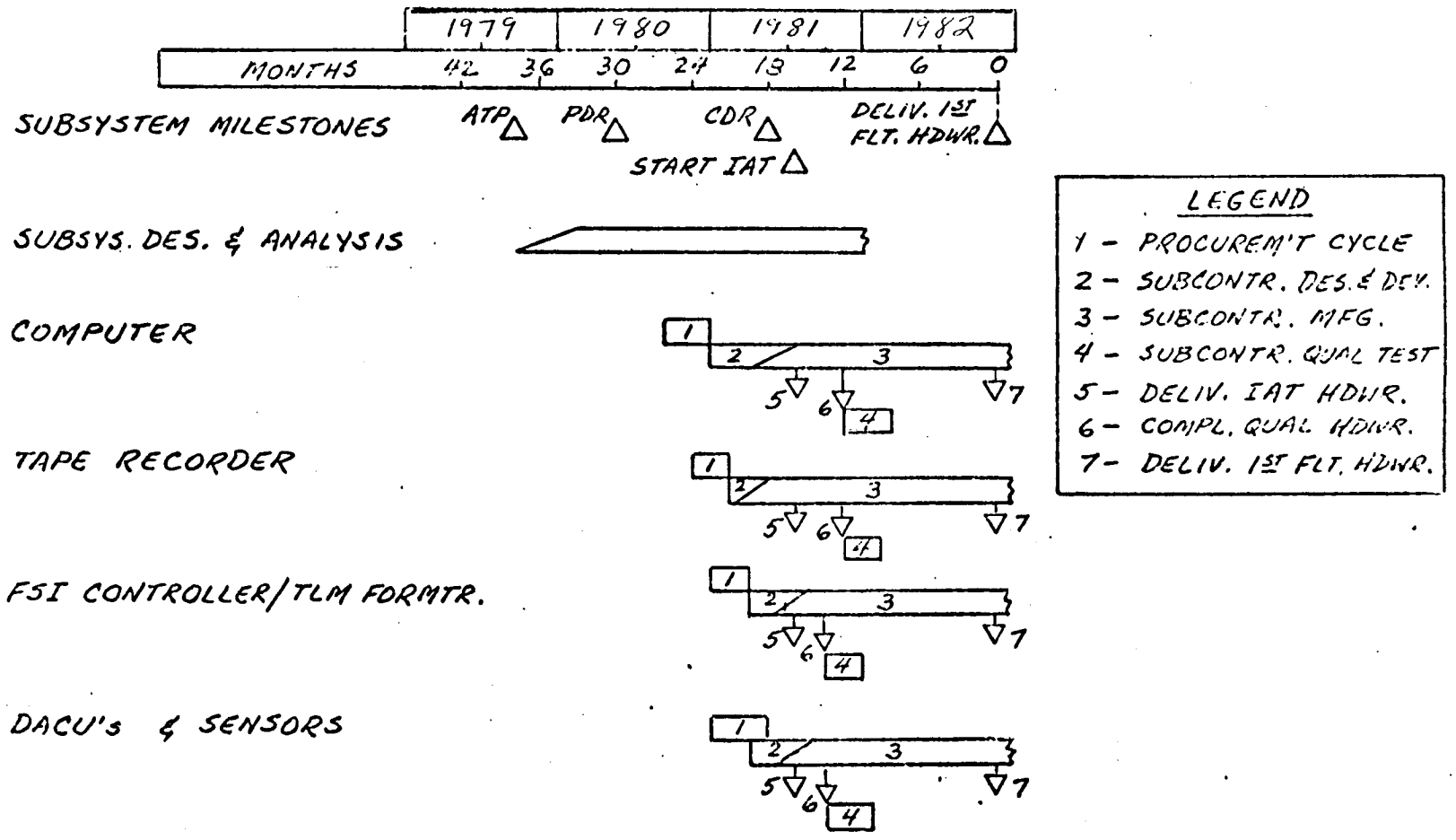
1 - PROCUREMENT
2 - DES & DEVEL.
3 - MFG
4 - QUAL TEST
5 - IAT HDWR
6 - QUAL HDWR
7 - 1ST FLT HDWR

410 AD-2 GN&C SUBSYSTEM SCHEDULE

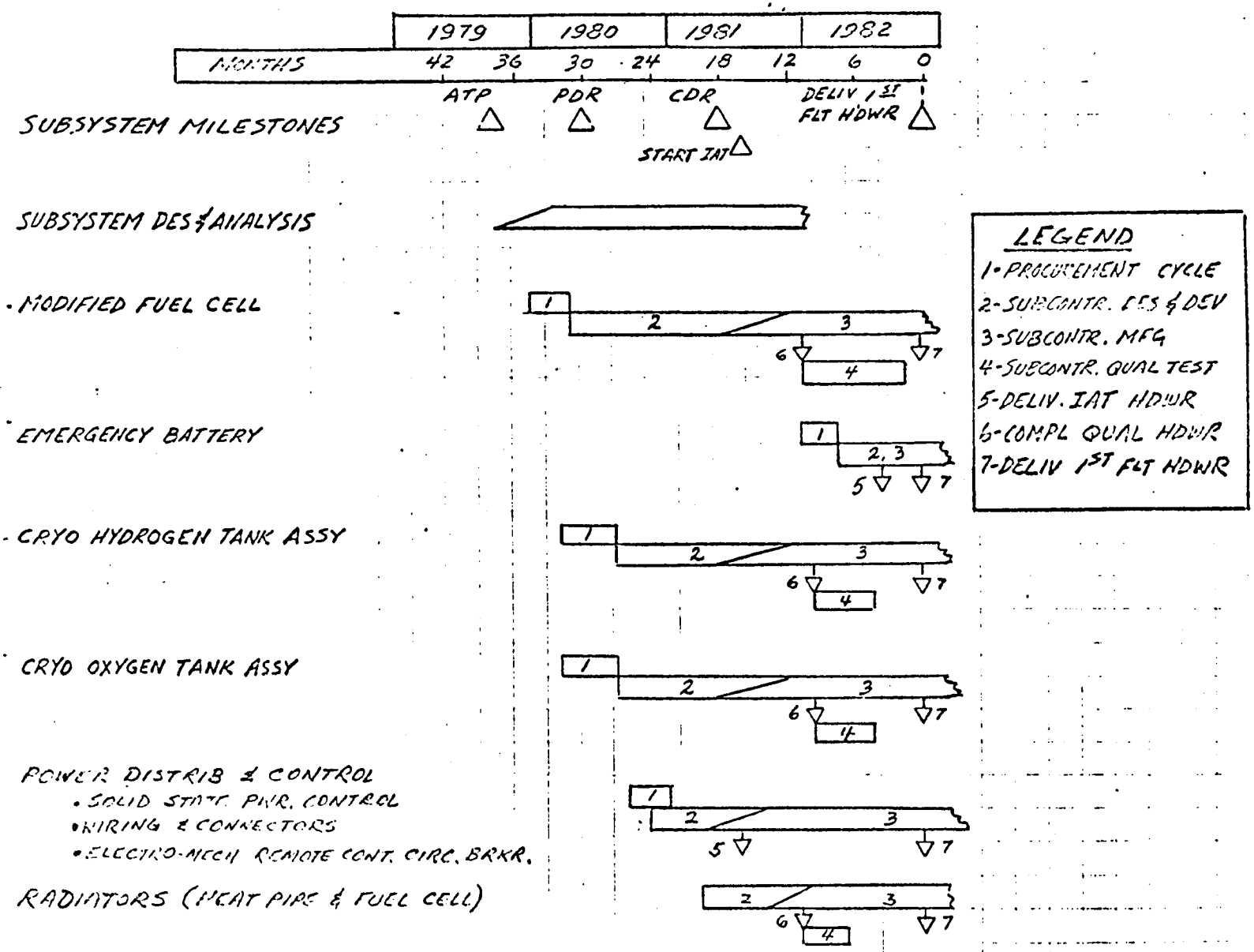
II-8.1-19



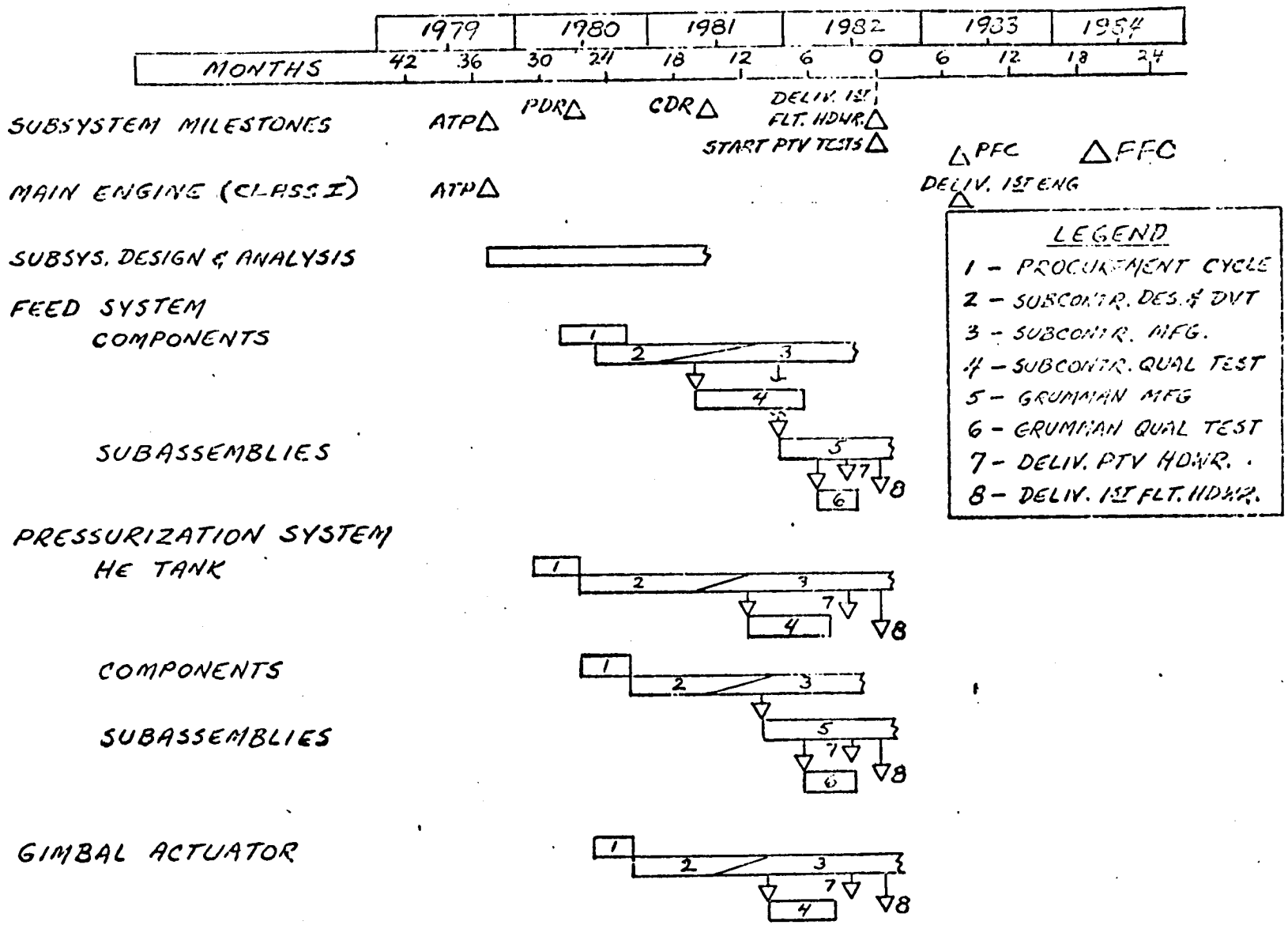
410 AD-2 COMMUNICATIONS S/S SCHEDULE



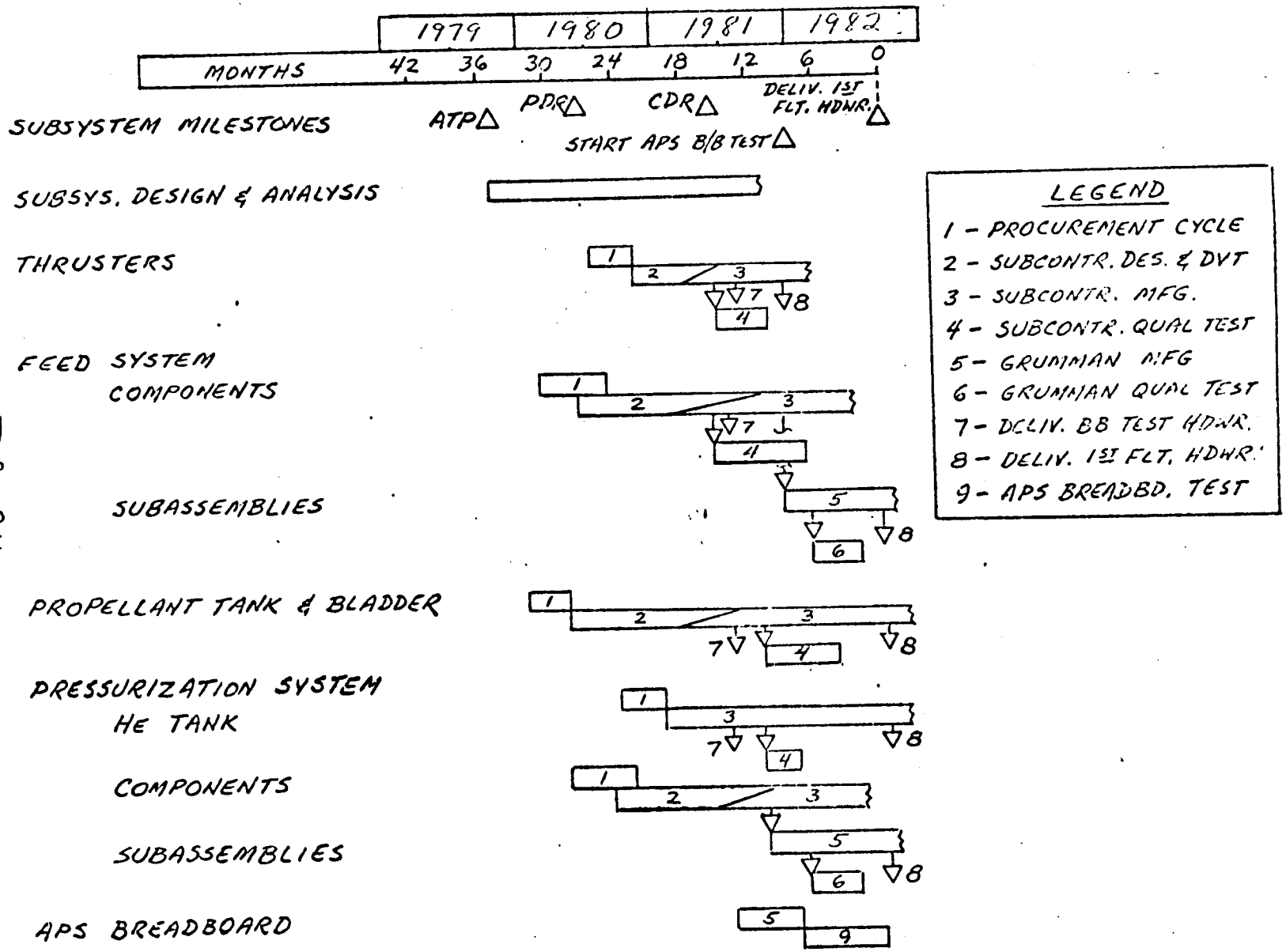
410AD-2 DATA MGT. SUBSYS. SCHEDULE



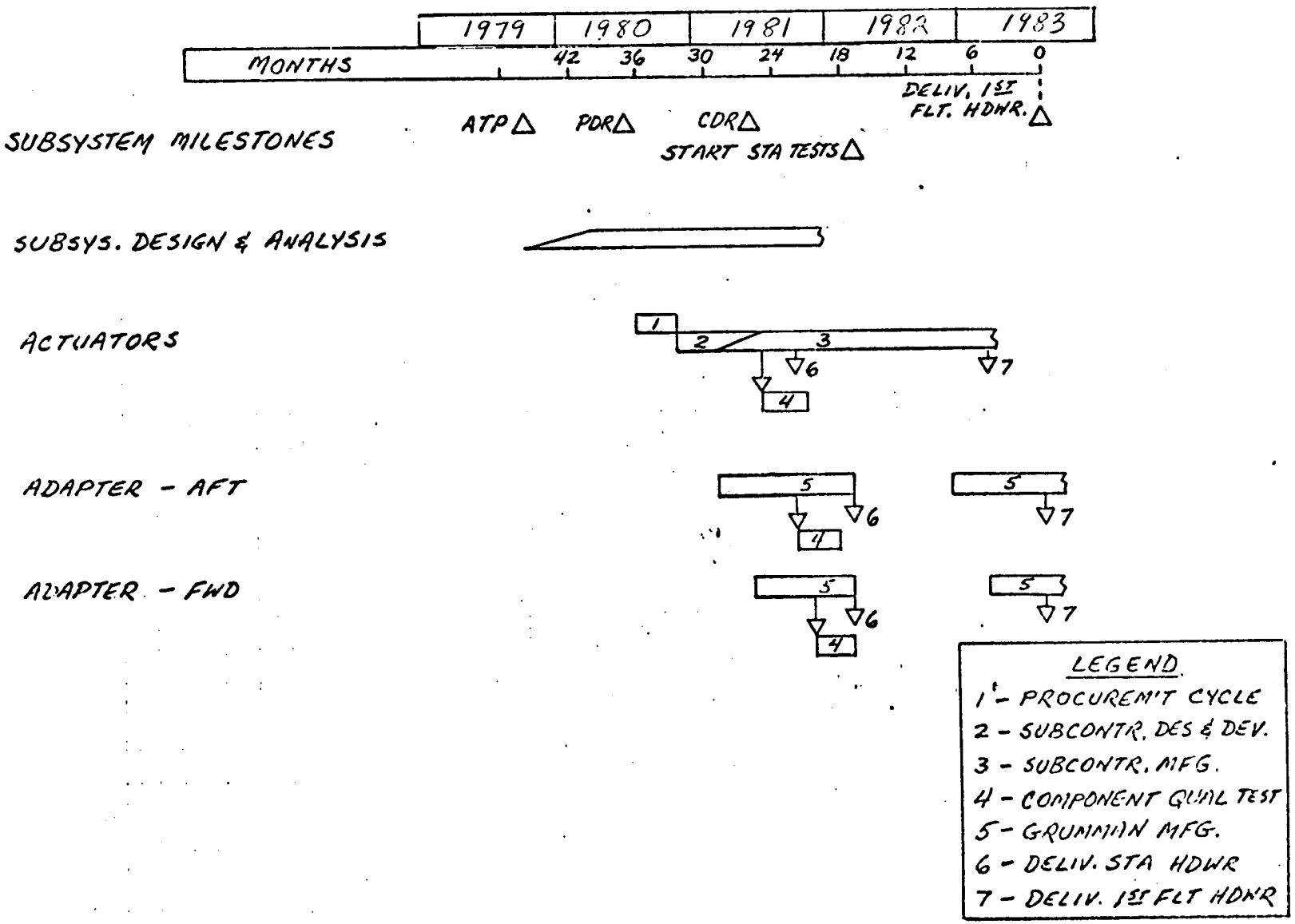
410 AD-2 ELECT. POWER SUBSYSTEM SCHEDULE



4-10AD-2 MAIN PROPULSION SUBSYS. SCHEDULE

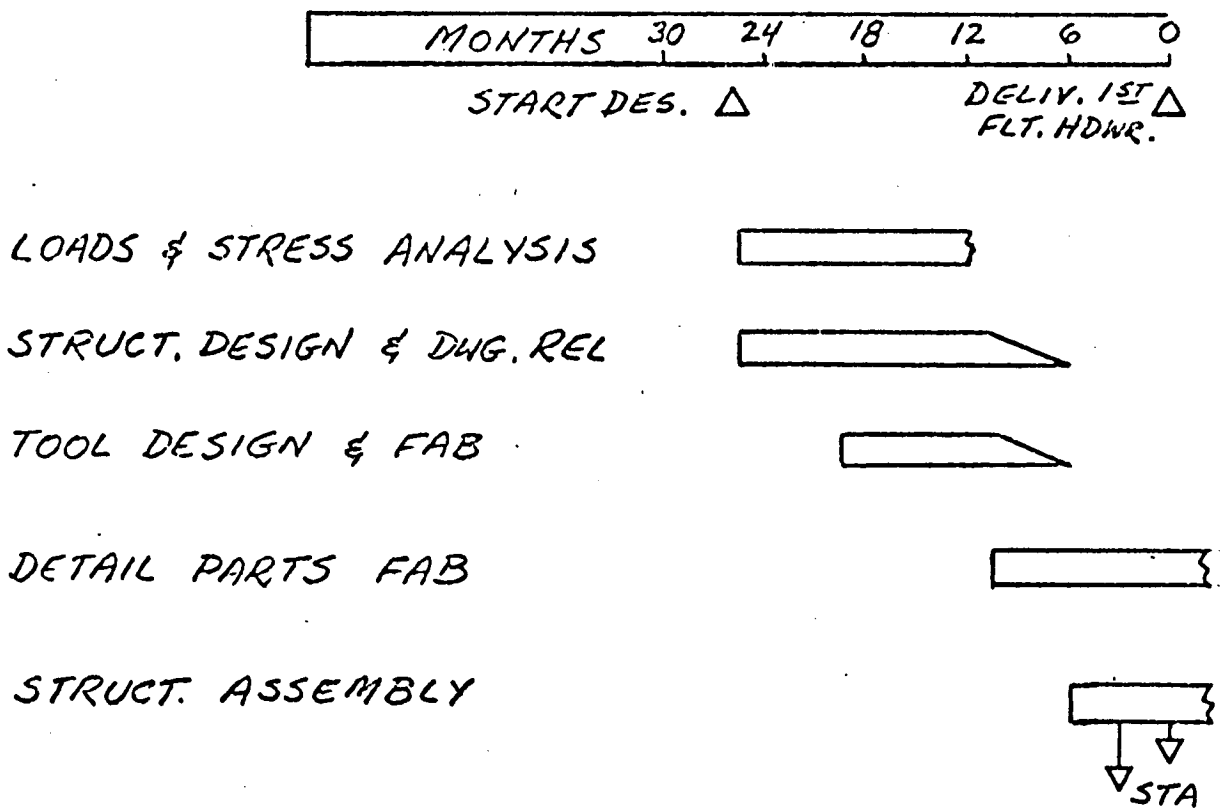


410AD-2 AUXIL. PROPULSION SUBSYS. SCHEDULE

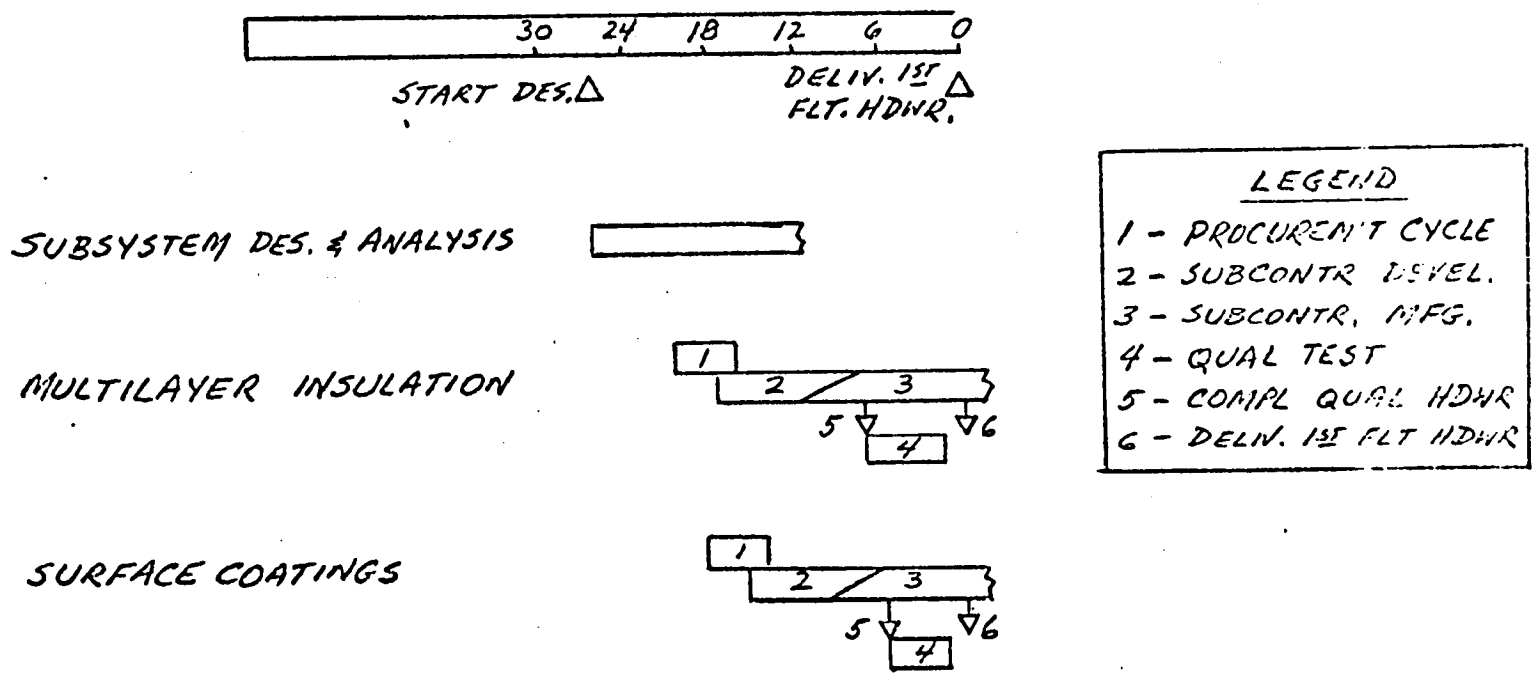


410AD-2 ORBITER INTERFACE SUBSYS. SCHEDULE

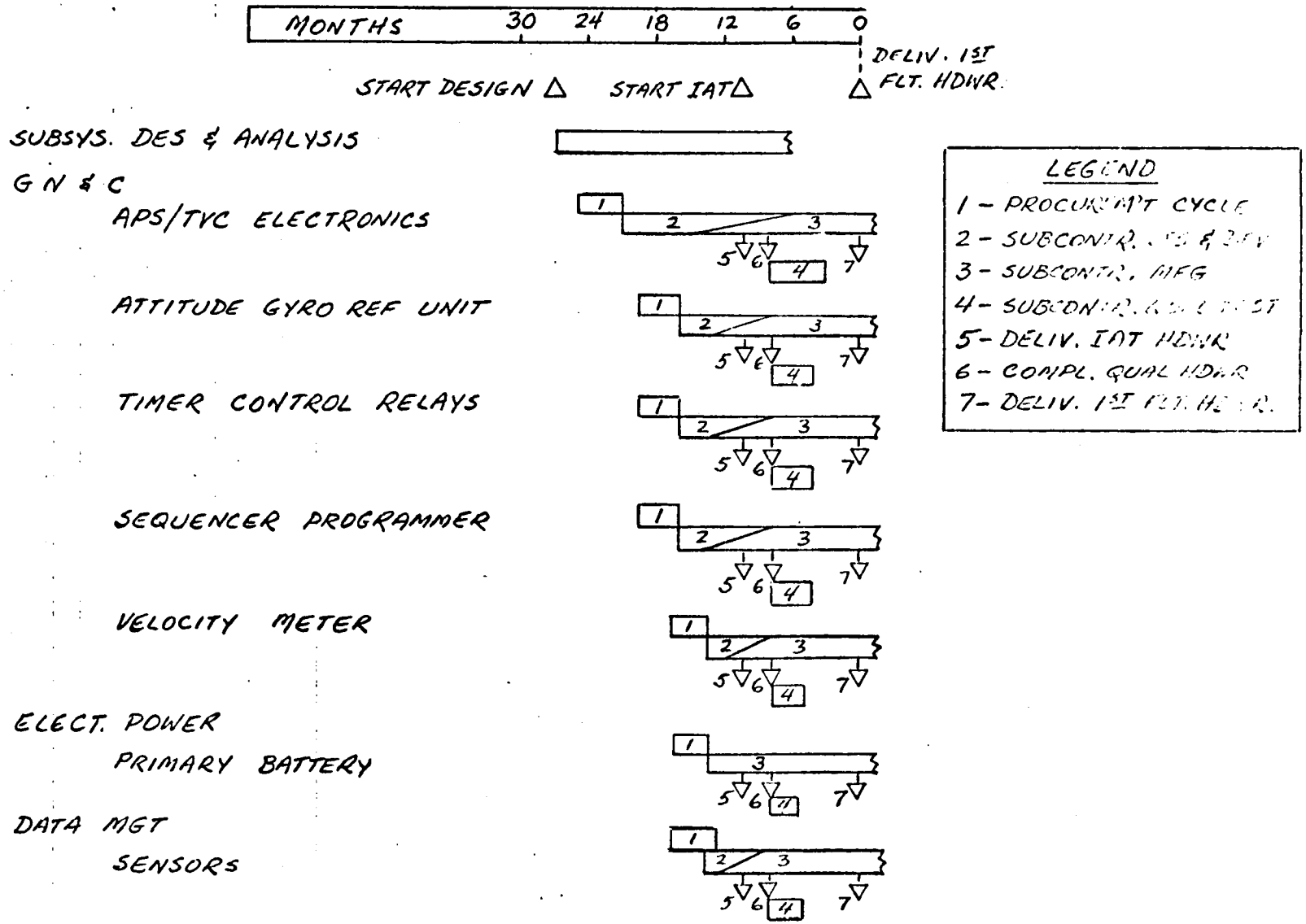
SC-1-3-77



410AD-2 APOGEE KICK STAGE
STRUCTURES SUBSYSTEM SCHEDULE

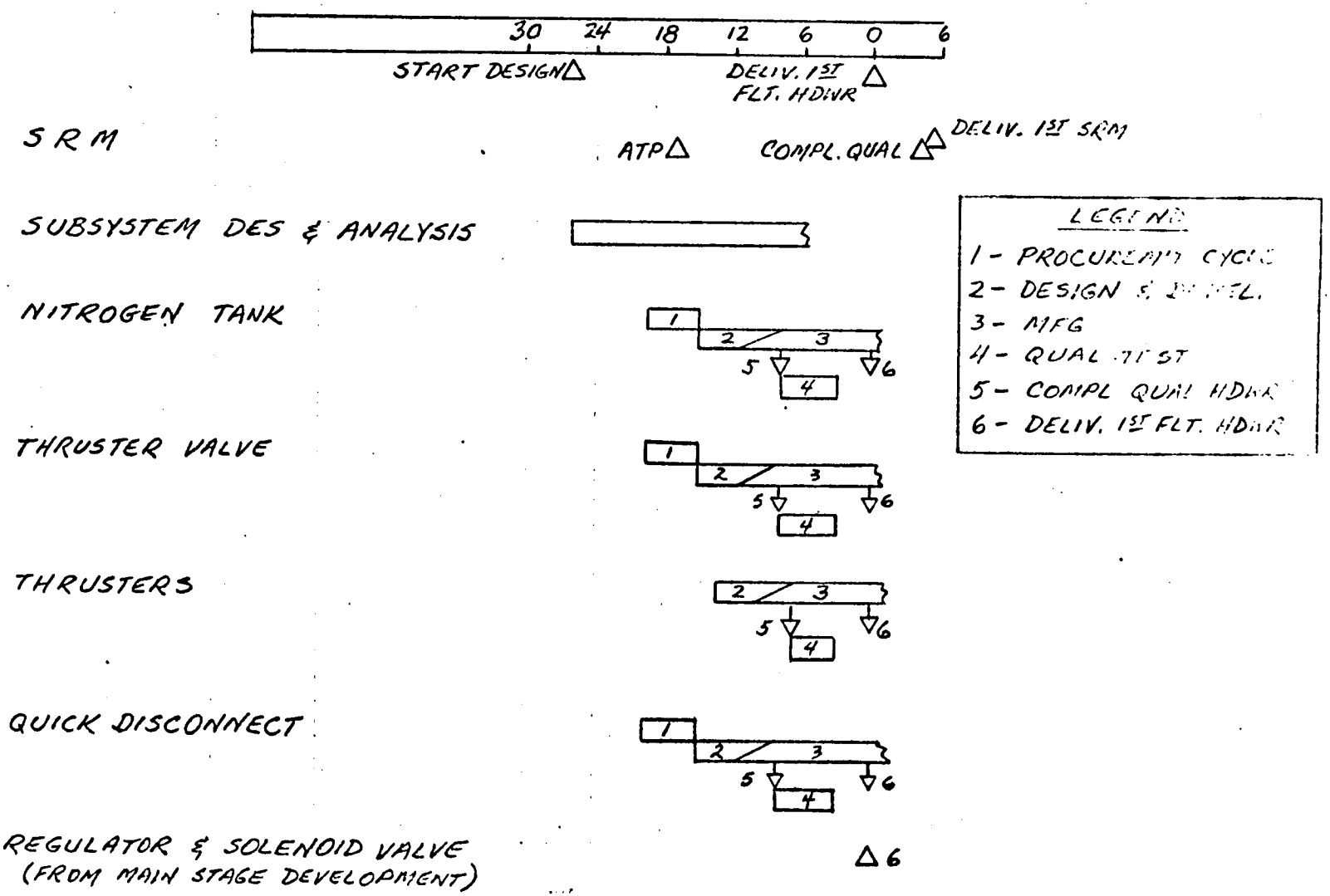


APOGEE KICK STAGE
THERMAL CONTROL SUBSYSTEM SCHEDULE

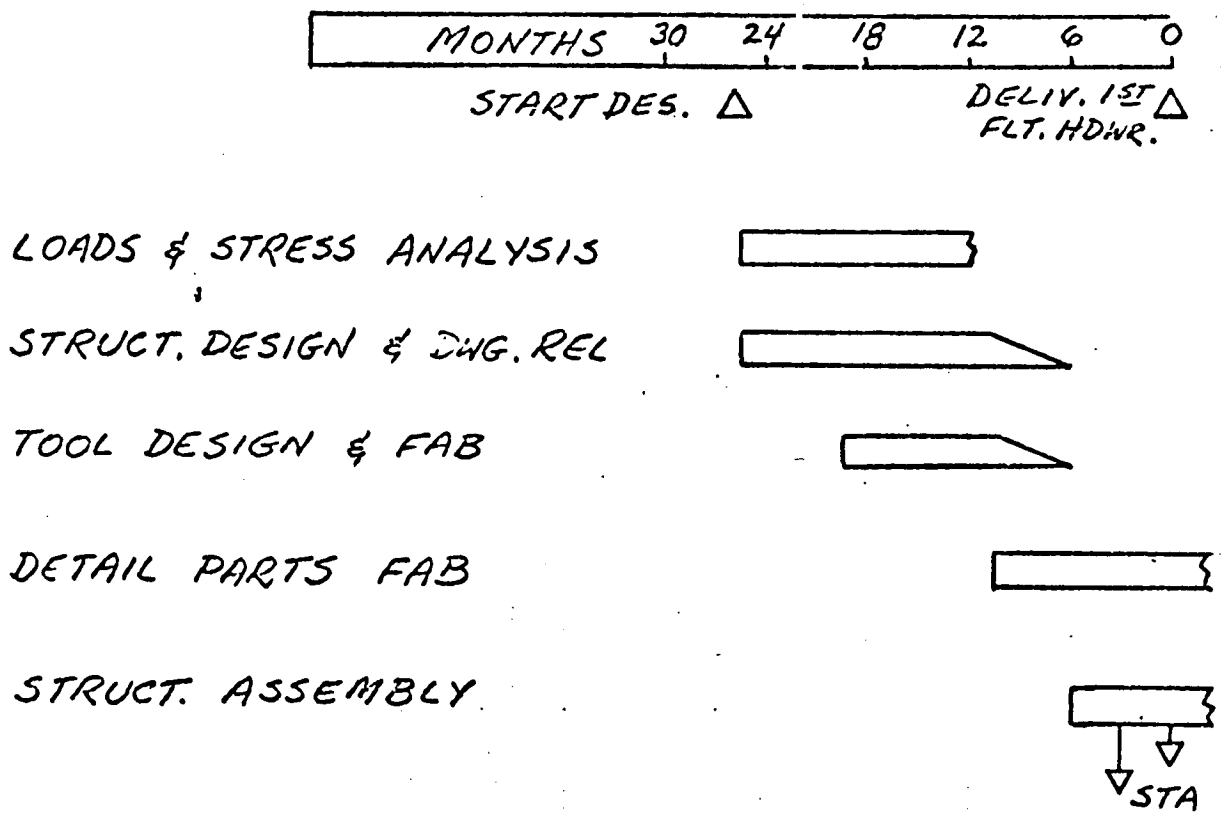


APOGEE KICK STAGE
AVIONICS SUBSYSTEM SCHEDULE

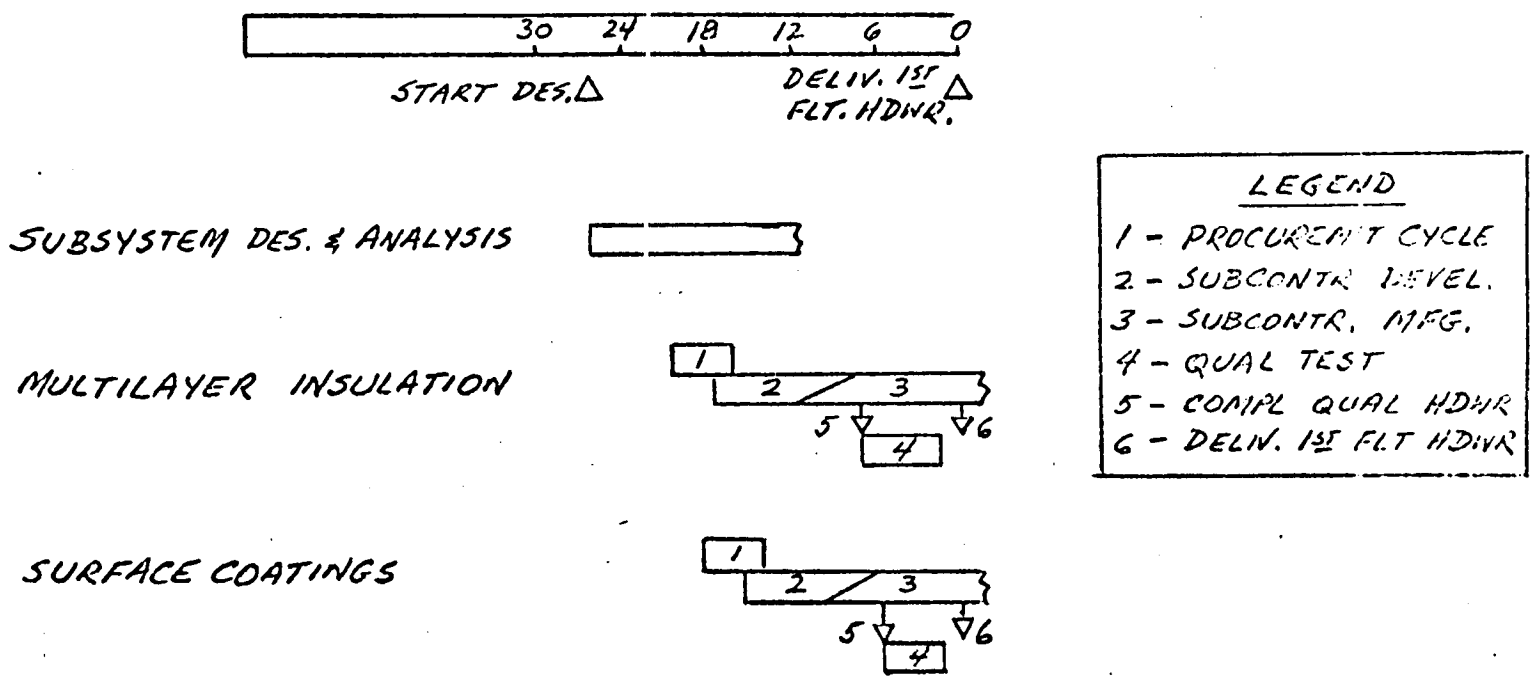
II-8.1-28



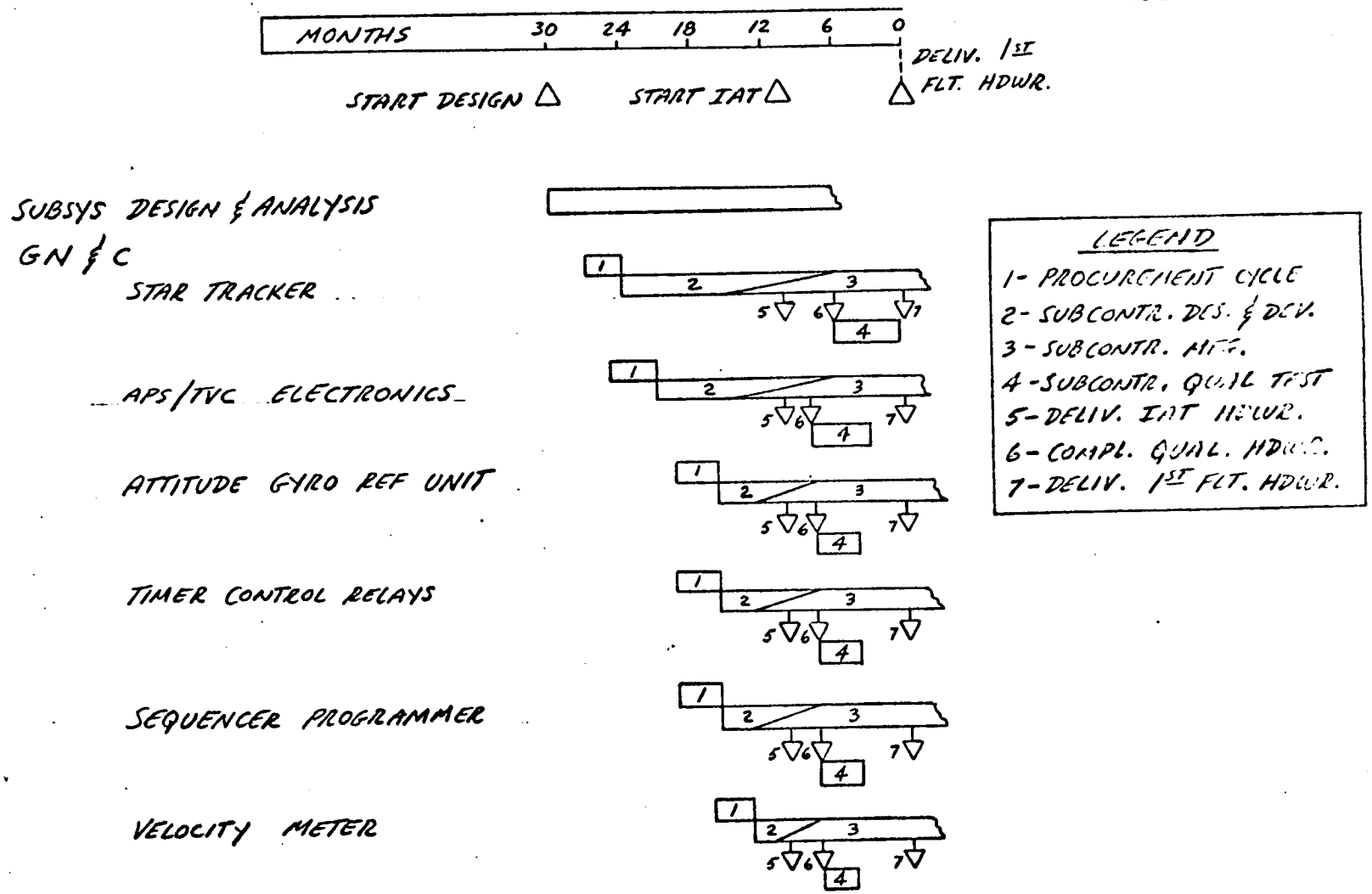
APOGEE KICK STAGE
PROPULSION SUBSYSTEM SCHEDULE



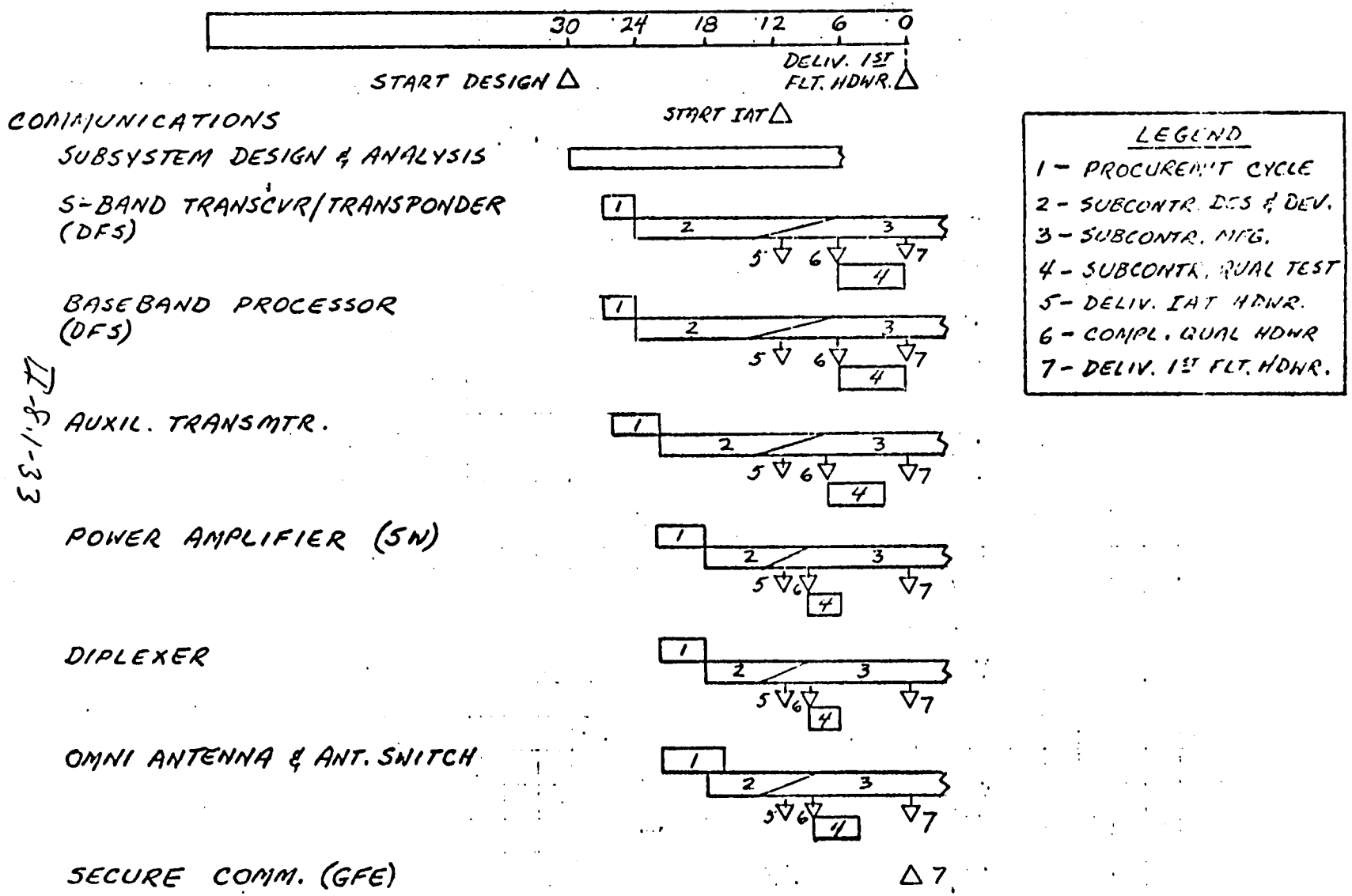
410AD-2 DEORBIT KICK STAGE
STRUCTURES SUBSYSTEM SCHEDULE



DEORBIT KICK STAGE
THERMAL CONTROL SUBSYSTEM SCHEDULE

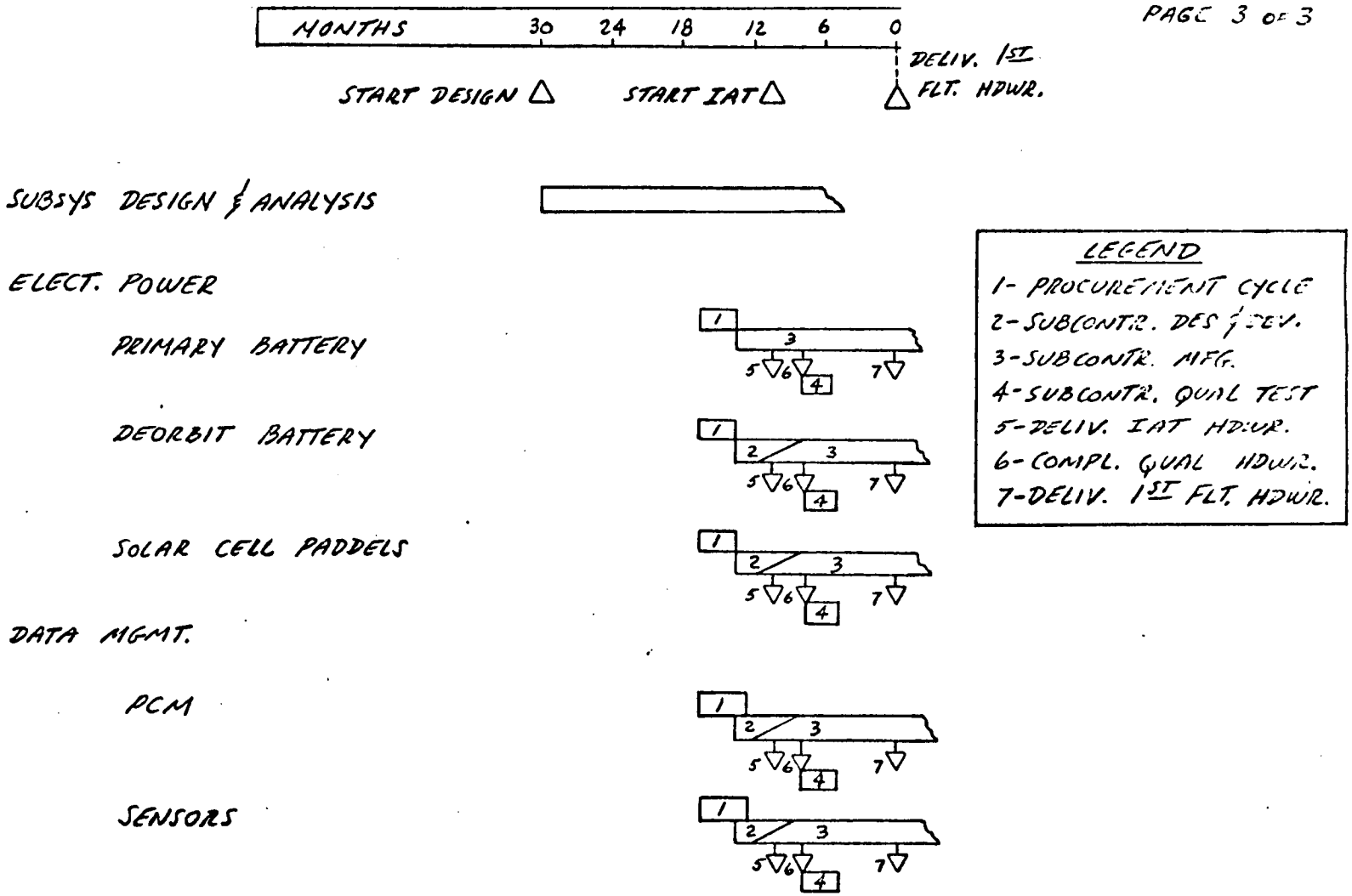


DEORBIT KICK STAGE
AVIONICS SUBSYSTEM SCHEDULE

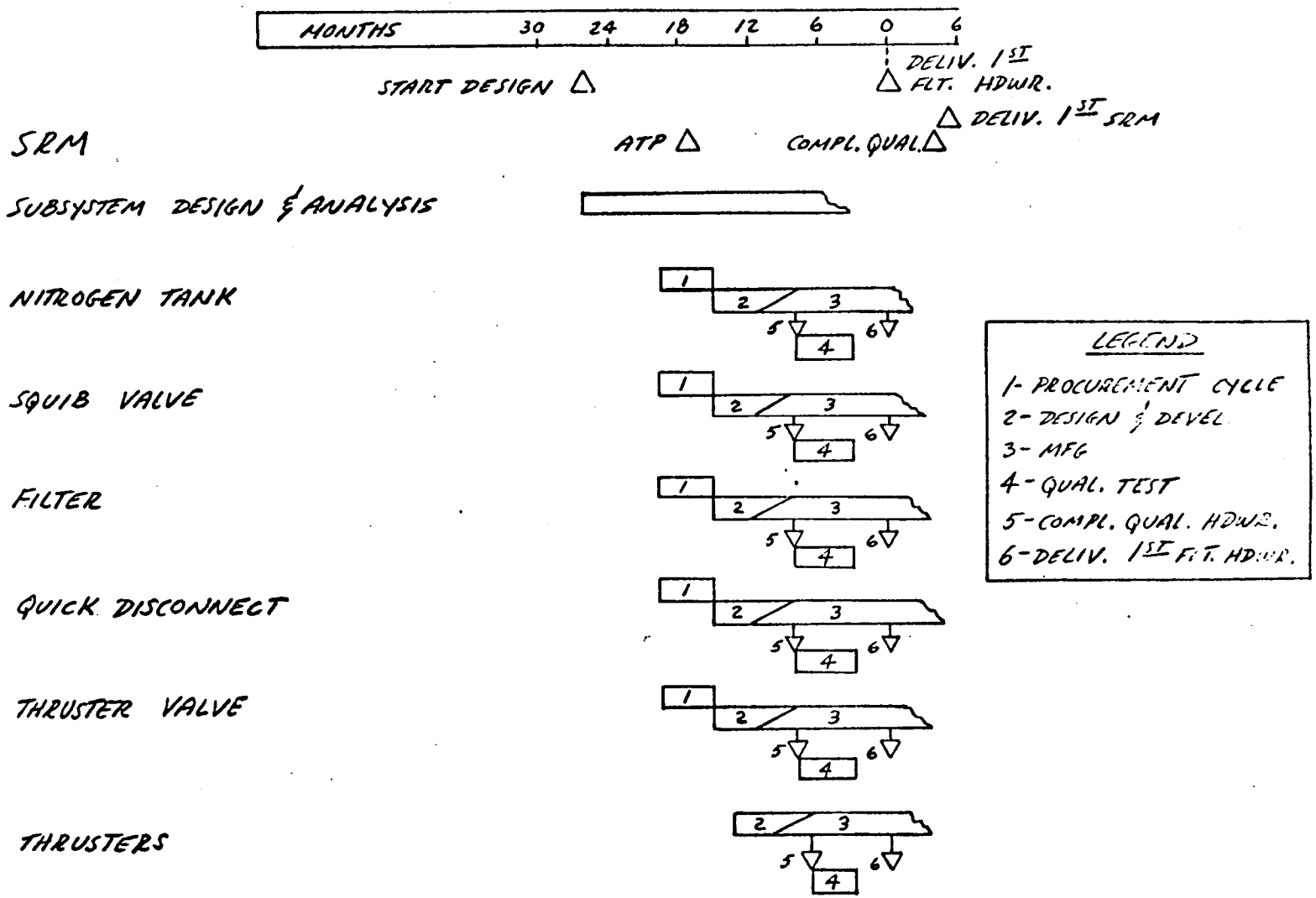


DEORBIT KICK STAGE - AVIONICS SUBSYS. SCHEDULE

II-8.1-33



DEORBIT KICK STAGE
AVIONICS SUBSYSTEM SCHEDULE



DEORBIT KICK STAGE
PROPULSION SUBSYSTEM SCHEDULE

8.1.4 OPERATIONS SCHEDULE

Scheduled and planned for concept 410AD-2, option 2 are 30 launches per year with 12 days between launches. Ground servicing as shown on the programmatics/cost operations schedule from land to launch is 10 tug work days and 9 tug/orbiter work days.

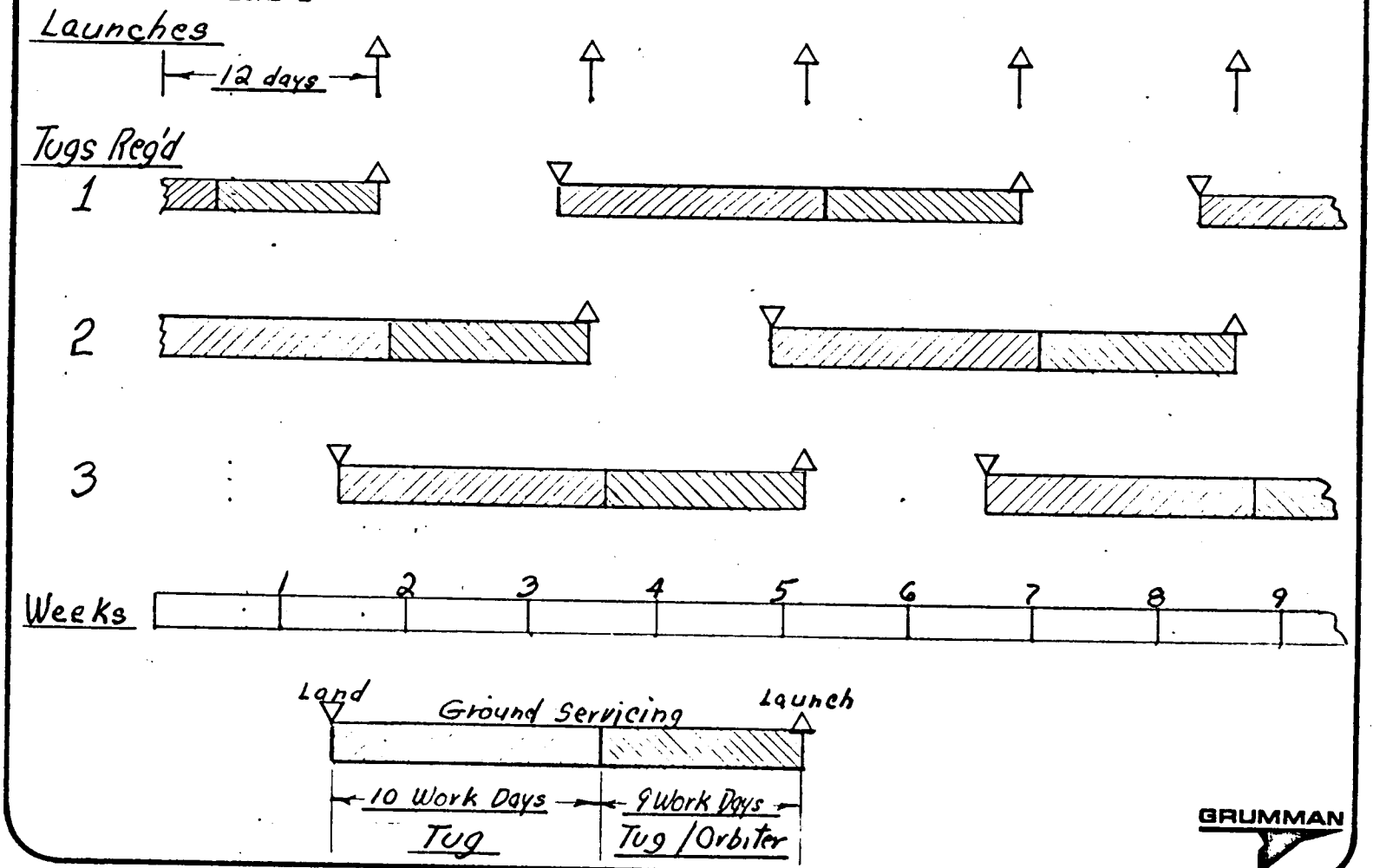
8.1.5 FACILITIES SCHEDULE

Included in the storable space tug facilities schedule for concept 410AD-2 are the various tasks to be completed against major program milestones. The fundamental grouping of these tasks are manufacturing, test, maintenance and refurb-ETR, ETR launch, maintenance and refurb-WTR and WTR launch. Under this tug concept facilities maintenance extends into 1991, with most of design/construction/activation ending by 1983 in support of WTR launch requirements.

PROGRAMMATICS/COST OPERATIONS SCHEDOLE

30 Launches Per Year (ETR)

CONCEPT 410AD-2



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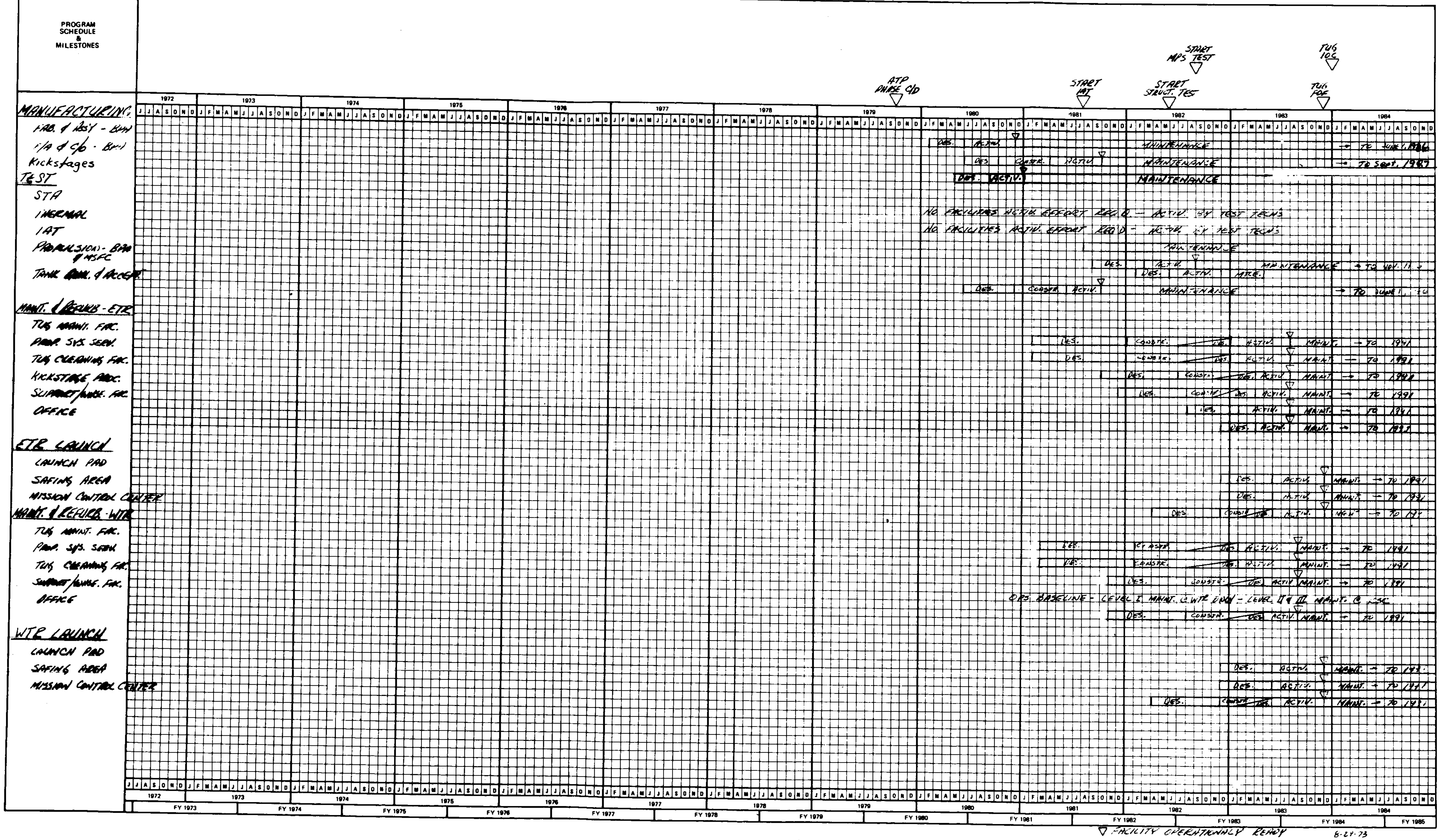
STORABLE SPACE TUG · FACILITIES SCHEDULE - CONCEPT 410AD-2

NASA ACQUISITION PHASE



8.1.6 EVALUATION OF MAJOR SCHEDULE DRIVERS

410AD-2

Our schedule for this project option shows the start of main engine development preceding the Tug ATP by 6 months. This is necessary because of the long development time of the Class I engine (42 months to PFC). Development of the Main Stage subsystems can be achieved in the same overall time span (51 months from ATP to IOC) as for option 1, providing that the SR&T effort for the advanced IMU and the Laser Rend. Radar have been completed prior to phase C/D ATP in October 1979. The critical path for this option may be traced through the following activities:

- Structural design, including the integral, nested tank design.
- Tank fabrication and assembly.
- Vehicle structural assembly.
- Flight test vehicle (MS-1) final assembly, equipment installation and checkout.
- Ship to ETR.
- Prelaunch activity for FOF in December 1983.

Development of the Deorbit Kick Stage will begin concurrently with the Main Stage development in order to make the DKS available for deployment with payloads in 1982, approximately 1½ years prior to the Tug IOC. The Apogee Kick Stage, utilizing common subsystem equipment already developed for the DKS will subsequently be manufactured for deployment in December 1983 (FOF).

8.2 VEHICLE TEST PROGRAM (410AD-2)

8.2.0 Our approach to development of the 410AD-2 Vehicle Test Program is essentially as described in Part I (110A), Paragraph 8.2.0. Since the Deorbit Kick Stage (DKS) must be available for flight approximately fourteen months before main stage first flight, a separate and earlier DKS ground and flight test program is planned. Table 8.2-1 summarizes the design verification approach in terms of test verification requirements and method of requirement satisfaction. Figure 8.2-1 presents a summary schedule of the total 410AD-2 Vehicle Test Program.

8.2.1 Ground Test Articles - Type and Descriptions

8.2.1.1 Propulsion Test Vehicle (PTV)

The 410AD-2 PTV is as described in Part I, Paragraph 8.2.1.1.

8.2.1.2 Structural Test Article (STA)

The description of the main stage STA is the same as that for the 110A-1 and described in Part I, Paragraph 8.2.1.2. The propellant tanks are integral and with nested domes which reduces the overall length to 25 feet.

The auxiliary stage for this configuration is a combined apogee and deorbit kick stage. Its description is otherwise the same as for the 110A-1.

8.2.1.3 Integrated Avionics Testing

8.2.1.3.1 Main Stage Avionics Hardware and Software

Integrated avionics hardware and software testing for the 410AD-2 configuration will be accomplished using an IAT and ASDL facility as described for configuration 110A. However, the 410AD-2 IAT facility and ASDL will have retrieval capability and autonomy level IIB included as part of the initial design.

8.2.1.3.2 Deorbit Kick Stage (DKS)

A breadboard of the DKS wiring and avionics hardware and GSE will be integrated and tested in the main stage IAT facility.

410AD VEHICLE TEST

RETRIEVAL & KICK STAGES INCREASE VEH. TEST BY $16.8M

- o TEST PROGRAM OBJECTIVES:
  - DESIGN VERIFICATION
  - SITE/GSE VALIDATION
  - SYSTEM VERIFICATION
- o GROUND TEST PROGRAM (HARDWARE/OPS = $25.16M)
  - PROP: 1 MS ART. VERIFIES COLD FLOW SYSTEM OPS - REFURBISH TO OPS
  - STRUCT: 2 ART (1 MS & 1 AKS/DKS) VERIFY DYN, STATIC, FATIGUE, SEP - KSC SITE VALIDATION
  - AVIONICS: 2 LABS VERIFY HARDWARE/SOFTWARE
  - MOCKUPS: 2 SOFT & 2 HARD MS & AKS/DKS MOCKUPS SUPPORT DESIGN DEVELOPMENT & MAINTENANCE DEMONSTRATION
- o FLIGHT TEST PROGRAM (HARDWARE/OPS = $24.44M)
  - 1 MS, 1 DKS & 1 AKS VEHICLE
  - 8 FLIGHTS (1 DEDICATED, 7 OPS)
- o TOTAL VEHICLE TEST = $49.60M

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DESIGN VERIFICATION APPROACH

(410AD-2)

	MAJOR VERIF. REQUIREMENT	GRND TEST	FLT TEST
STRUCTURE	STATIC MARGIN	QUAL	VERIFY
	FATIGUE LIFE	QUAL	
	VIBRATION MODES	VERIFY	VERIFY
	VEH/ORB, VEH/PL & VEH/KS SEP.	QUAL	VERIFY
	VEH HDLG & MAINT	DEMO	VERIFY
THERMAL CONTROL	PASSIVE/ACTIVE THERMO SYS PERFORM	QUAL	VERIFY
	TC/GSE SERVICING & MAINT	DEMO	VERIFY
AVIONICS	INTEG HDWR/SFTWR VEH PERFORM	VERIFY	VERIFY
	AVIONIC/GSE C/O & MAINT	DEMO	VERIFY
	VEH SYS INTERFACE (ORB,GRND, KS & PL) PERFORM	VERIFY	VERIFY
PROPULSION	MPS NOM/OFF-NOM PERFORM	QUAL	VERIFY
	MPS/GSE SERVICING & MAINT	DEMO	VERIFY
	APS NOM/OF-NOM PERFORM	QUAL	VERIFY
	APS/GSE SERVICING & MAINT	DEMO	VERIFY
	KS SRM PERFORM	QUAL	VERIFY
ORBITER INTERFACE	STATIC/FATIGUE STRENGTH	QUAL	VERIFY
	VEH/ORB SEP	QUAL	VERIFY
	AVIONIC/FLUID INTERFACE PERFORM	VERIFY	VERIFY
	ABORT SYS PERFORM	QUAL	VERIFY
	VEH HDLG/GSE SERVICE & MAINT	DEMO	VERIFY

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Table 8.2-1

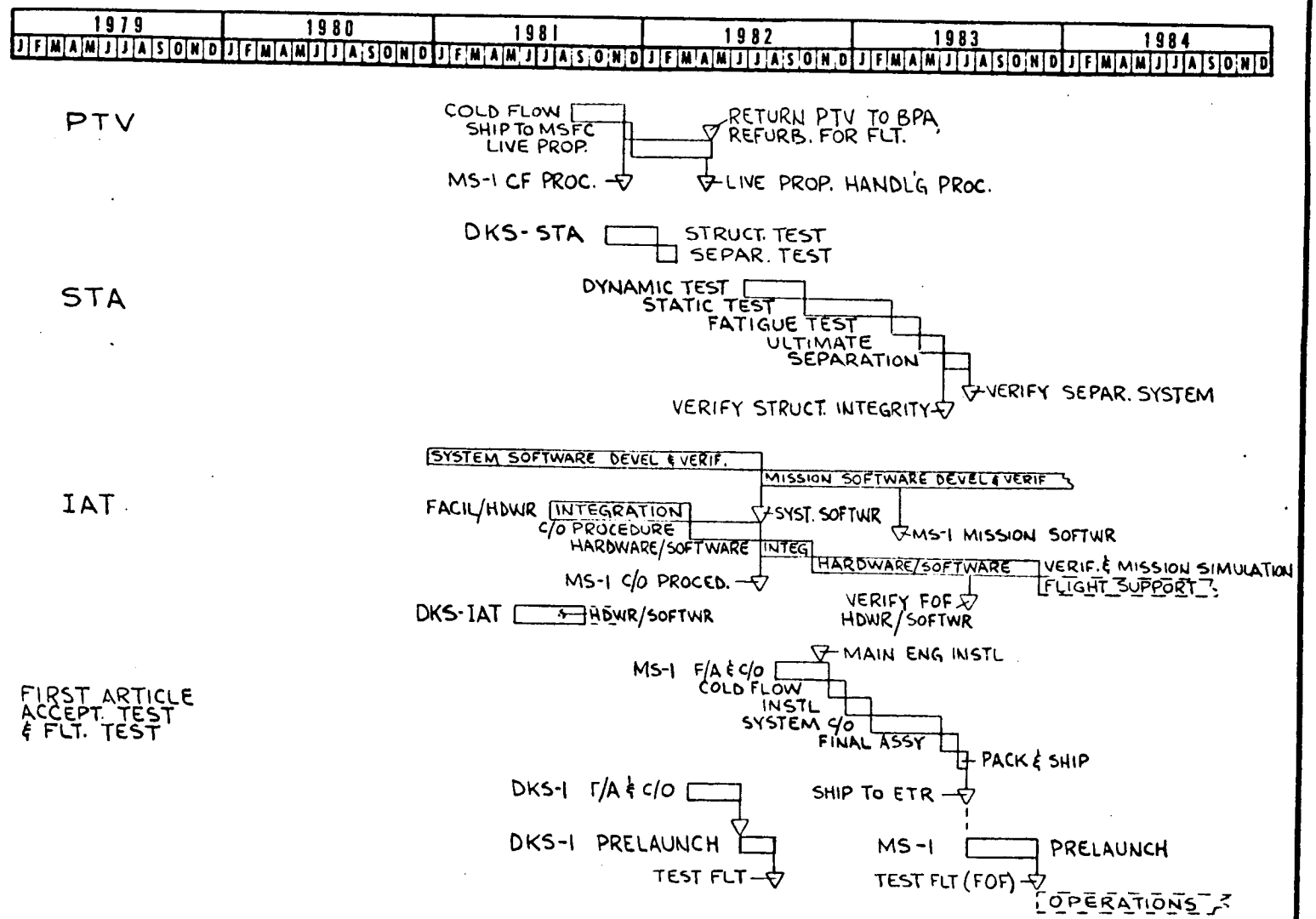


FIG. 8.2-1 410AD-2 VEHICLE TEST SCHEDULE

8.2.1.3.3 Apogee Kick Stage (AKS)

The AKS attitude gyro, velocity meter, sequence programmer, aux. propulsion and thrust vector electronics, instrumentation, and timer/control relays will be the same as for the DKS. Therefore the functional operation of the DKS at these interfaces will be modified to reflect Tug command and control required for the AKS, integrated into the IAT and used as an AKS breadboard for IAT. AKS / Main stage mission software will be developed in the ASDL.

8.2.1.4 Mockups

Mockups will be provided for both the main stage and the kick stages as described in Part I, Paragraph 8.2.1.4. The early deorbit kick stage mockups will be modified and will serve as the later Apogee Kick Stage Mockups.

8.2.2 Flight Test Articles - Description

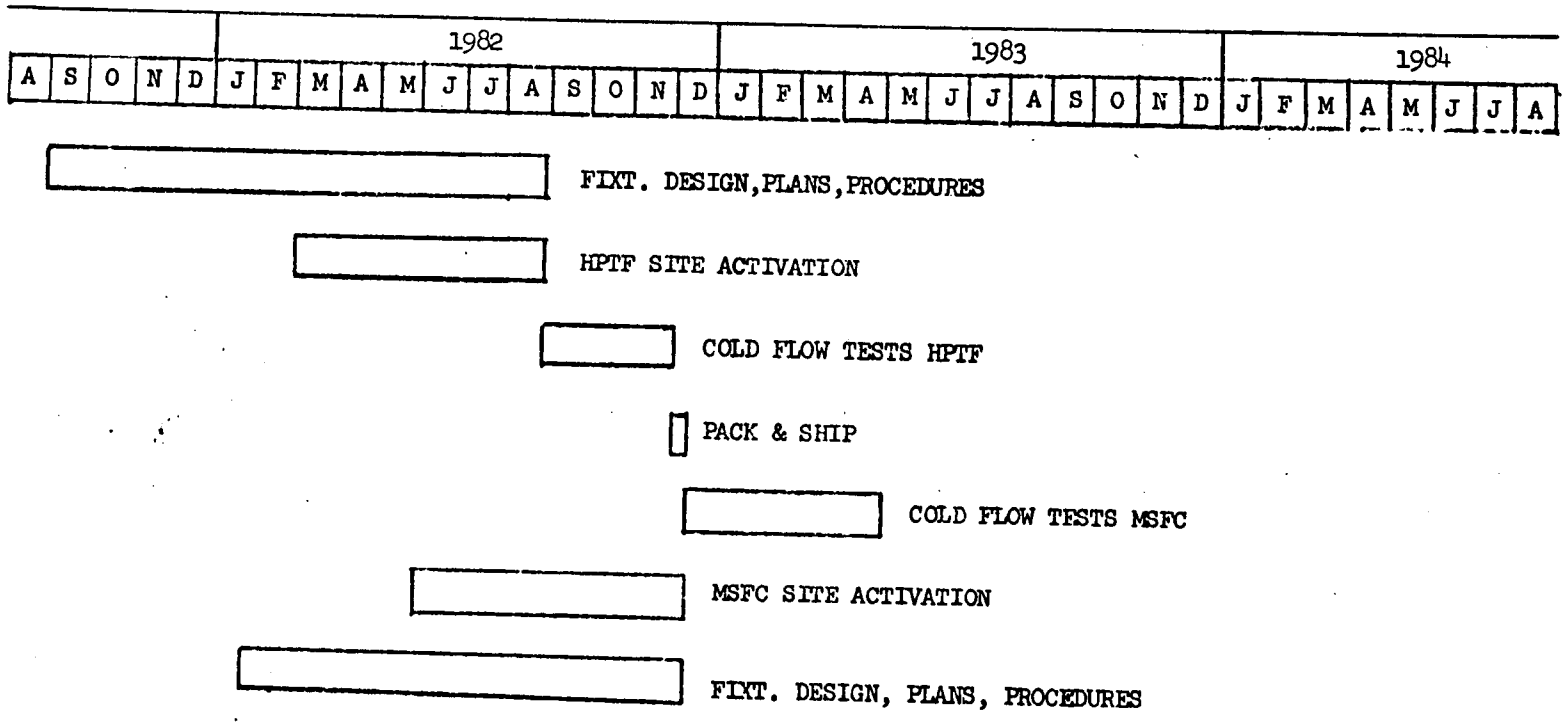
The 410AD-2 main stage flight test article is essentially as described in Part I, Paragraph 8.2.2.1. The deorbit kick stage (DKS) required for the early and separate DKS flight testing will be the first production unit with a DFI system to acquire flight test data. This article must be available for flight test in September 1982.

8.2.3 Ground Test Program

This section describes the major elements of the vehicle ground test program. The test programs described in the following paragraphs include the Propulsion Test Vehicle (PTV), Structural Test Article (STA), Integrated Avionics Testing including software development, and mockups required in support of program requirements.

8.2.3.1 Propulsion Test Vehicle Program

The 410AD-2 Propulsion Test Program is as described in Part I, Paragraph 8.2.3.1. The test schedule and manloading is essentially the same as 110A-1 except it supports the 1983 First Orbital Flight. The test schedule and manloading is shown in Figure 8.2-2. Kick stage SRM development and qualification will be accomplished at the engine contractors facilities as described for 110A-1.



MANPOWER 1 1 2 2 3 6 7 10 16 15 18 24 35 41 44 40 33 29 28 15 7 TOTAL 377 MM

FIGURE 8.2-2 410AD PTV TEST SCHEDULE & MANPOWER

8.2.3.2 Structural Test Article (STA) Program

8.2.3.2.1 Main Stage

The main stage STA program is as described in Part I, Paragraph 8.2.3.2. While the propellant tanks are integral they are again qualified separately from the STA program to allow thorough testing, including burst pressure, without interference with the STA schedule. The STA is used for structural/mechanical interface check-out at the launch site after completion of the test program described for configuration 110A-1. The manloading and test schedule is essentially as shown in Part I, Figure 8.2-3 except that it starts in June 1982.

8.2.3.2.2 Kick Stage

This stage is a combined apogee and deorbit kick stage employing SRM's for propulsion. It is developed 14 months before the main stage for operations with the orbiter or other launch vehicles. The test philosophy is as described in Part I, Paragraph 8.2.3.2.2, as it will be tested with fixtures simulating other payload, main stage or launch vehicle interfaces. The kick stage STA is preserved for additional testing if the need should arise and for structural/mechanical interface checkout at the launch site. The manloading and test schedule for this kick stage is as shown in Part I, Figure 8.2-4 except that it starts in November 1981.

8.2.3.3 Integrated Avionics Test Program

8.2.3.3.1 Main stage Avionic Hardware and Software

The integrated avionics test philosophy and test program for this configuration is basically the same as described in Part I, Paragraph 8.2.3.3. The testing for 410AD-2 will include retrieval avionics hardware and mission software in addition to those tests required for configuration 110A.

Integrated fuel cell reactant tank tests will be required for this configuration and will be performed at the fuel cell subcontractor.

The test schedule and manloading are shown in Figure 8.2-3. It should be noted, however, that DKS development is accomplished early in the program to permit deployment with payloads prior to the availability of the Space Tug.

8.2.3.3.2 Deorbit Kick Stage (DKS)

The test program for the DKS will be similar to that described for the AKS in Part I, Paragraph 8.2.3.3. The major difference is that there is no mission software /hardware tie between the Main stage and the DKS. The test program for the DKS is therefore independent of the MS and consists of breadboard integration, functional verification and GSE and procedures checkout. This will be accomplished in the main stage IAT facility to take advantage of common facility test equipment. The schedule for DKM avionics testing is also shown in Figure 8.2-3.

8.2.3.3.3 Apogee Kick Stage (AKS)

The DKS breadboard will be modified to reflect the AKS configuration and tested in the main stage IAT facility as described for the 110A configuration. Main stage software will include the AKS command and mission requirements. The schedule for AKS avionics testing is also shown in Figure 8.2-3.

8.2.3.4 Mockups

The 410AD-2 mockup program is essentially as described in Part I, Paragraph 8.2.3.4. The DKS mockups, however, must be available in time to support the early development of requirements of the DKS program.

8.2.4 Flight Test Program

This section describes the flight test program for the 410AD-2 configuration. In addition, the section also includes a description of the vehicle level factory and launch site test and checkout approach. In order to maintain continuity the section begins with the checkout and test approach and follows with the discussion of the flight test program.

8.2.4.1 Flight Vehicle Checkout and Test

The philosophy and objectives of the Flight Vehicle Ground test program are the same as those described in Part I, Paragraph 8.2.4.1. The only differences in Factory Testing is the addition of fuel cell checks and the deletion of the RGA-APS Polarity checks (The 410AD-2 doesn't have an RGA Package).

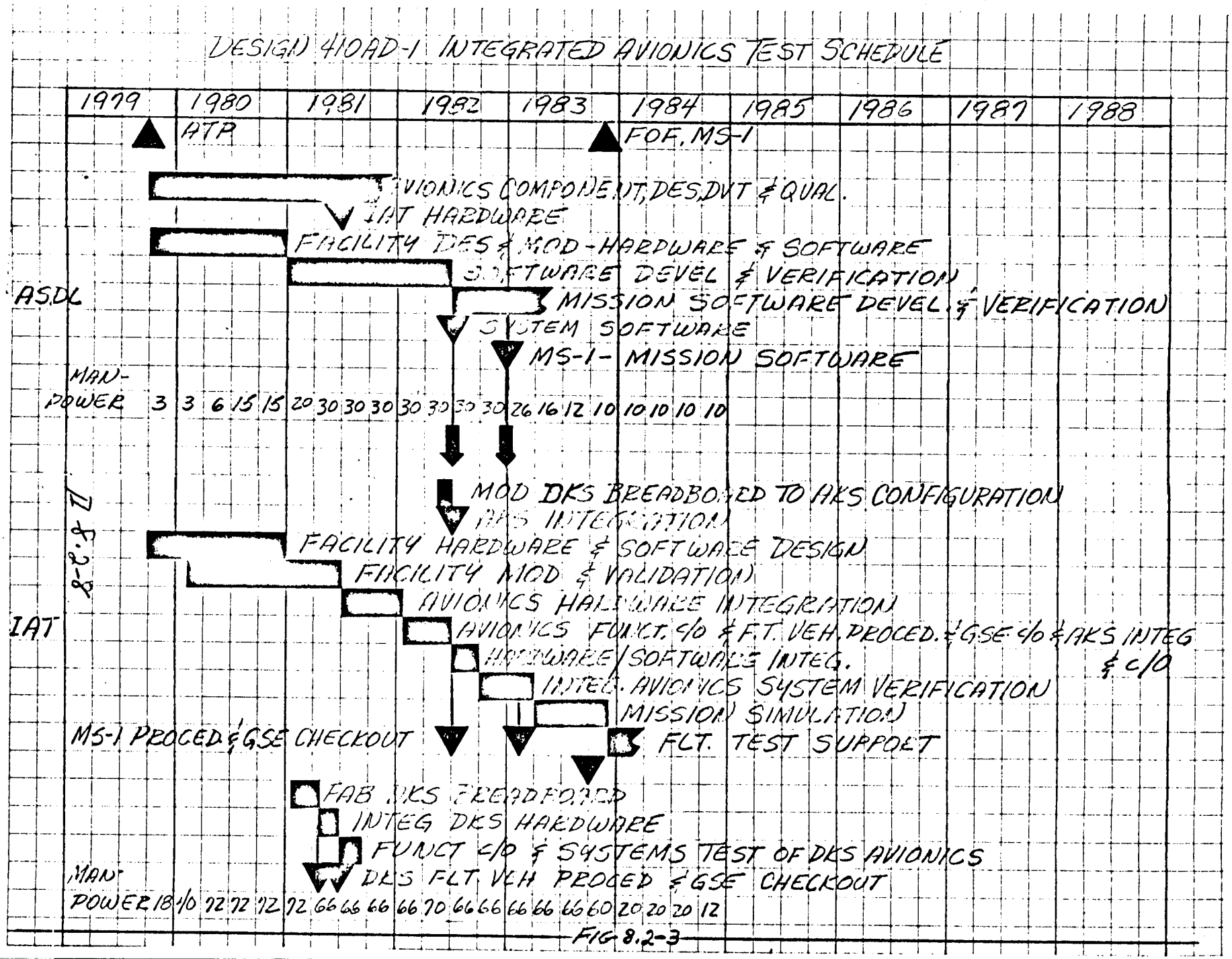

DESIGN 410AD-1 INTEGRATED AVIONICS TEST SCHEDULE
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
ATP
FOF, MS-1
AVIONICS COMPONENT, DES, DVT & QUAL.
IAT HARDWARE
FACILITY DES & MOD - HARDWARE & SOFTWARE
SOFTWARE DEVEL & VERIFICATION
ASDL
MISSION SOFTWARE DEVEL. & VERIFICATION
SYSTEM SOFTWARE
MS-1 - MISSION SOFTWARE
MAN-POWER 3 3 6 15 15 20 30 30 30 30 30 30 30 26 16 12 10 10 10 10 10
MOD DKS BREADBOARD TO AKS CONFIGURATION
DKS INTEGRATION
FACILITY HARDWARE & SOFTWARE DESIGN
FACILITY MOD & VALIDATION
AVIONICS HARDWARE INTEGRATION
IAT
AVIONICS FUNCT. C/O & F.T. VEH. PROCED. & GSE C/O & AKS INTEG & C/O
HARDWARE/SOFTWARE INTEG.
INTEG. AVIONICS SYSTEM VERIFICATION
MISSION SIMULATION
MS-1 PROCED. & GSE CHECKOUT
FLT. TEST SUPPORT
FAB DKS BREADBOARD
INTEG DKS HARDWARE
FUNCT C/O & SYSTEMS TEST OF DKS AVIONICS
DKS FLT. VEH PROCED & GSE CHECKOUT
MAN POWER 18 40 72 72 72 72 66 66 66 66 70 66 66 66 66 66 60 20 20 20 12

FIG 8.2-3

8.2.4.1 Flight Vehicle Checkout and Test (cont'd)

There are two major differences in the prelaunch tests. A longer countdown demonstration is required to allow practice loading of comsumables for the fuel cells, and the AKS/DKS goes through its first prelaunch flow along and not integrated with a main stage as does the AKS with the 110A-1 main stage.

The factory site facilities and equipment requirements are basically the same as those for 110A-1. An additional RF bench is required to test the RF navigation aids, while the Laser radar will require a checkout or calibration unit. Additional GSE is also required in the HPTF for Fuel Cell testing. The special fixture for RGA-APS polarity tests is not required for this concept. Tug operational facilities are used for prelaunch.

Test schedules and manpower requirements are presented in Figures 8.2-4 and 8.2-5 for the MS vehicle and Figure 8.2-6 and 8.2-7 for the AKS/DKS stage.

8.2.4.2 Flight Test Program

The main stage flight test program is essentially as described in Part I, Paragraph 8.2.4. First Orbital Flight (FOF) is a dedicated flight test and deploys a dummy payload only. The test sequence is modified slightly to include a retrieval demonstration using a DKS to serve as the retrieval target.

Since the DKS is developed and flown earlier than the main stage, a separate and dedicated flight test is planned to verify the capability of the DKS to function during and after extended exposure to orbital environments. This flight will occur in mid-1982 and could be accomplished as part of a normal Shuttle launch or by some other means.

There will be a total of eight flights in the flight test program including the dedicated first flight and seven subsequent operational flights. A DFI system will be added to the main stage and kick stage to obtain flight test data during the flight test program. Operational flights included in the flight test program are:

(2) Single payload deploy
(1) Multi payload deploy
(1) Single payload deploy with kick stage
(1) Retrieve
(1) Round trip
(1) Retrieve/round trip with kick stage

The flight test schedule and cost are shown in figure 8.2-8.

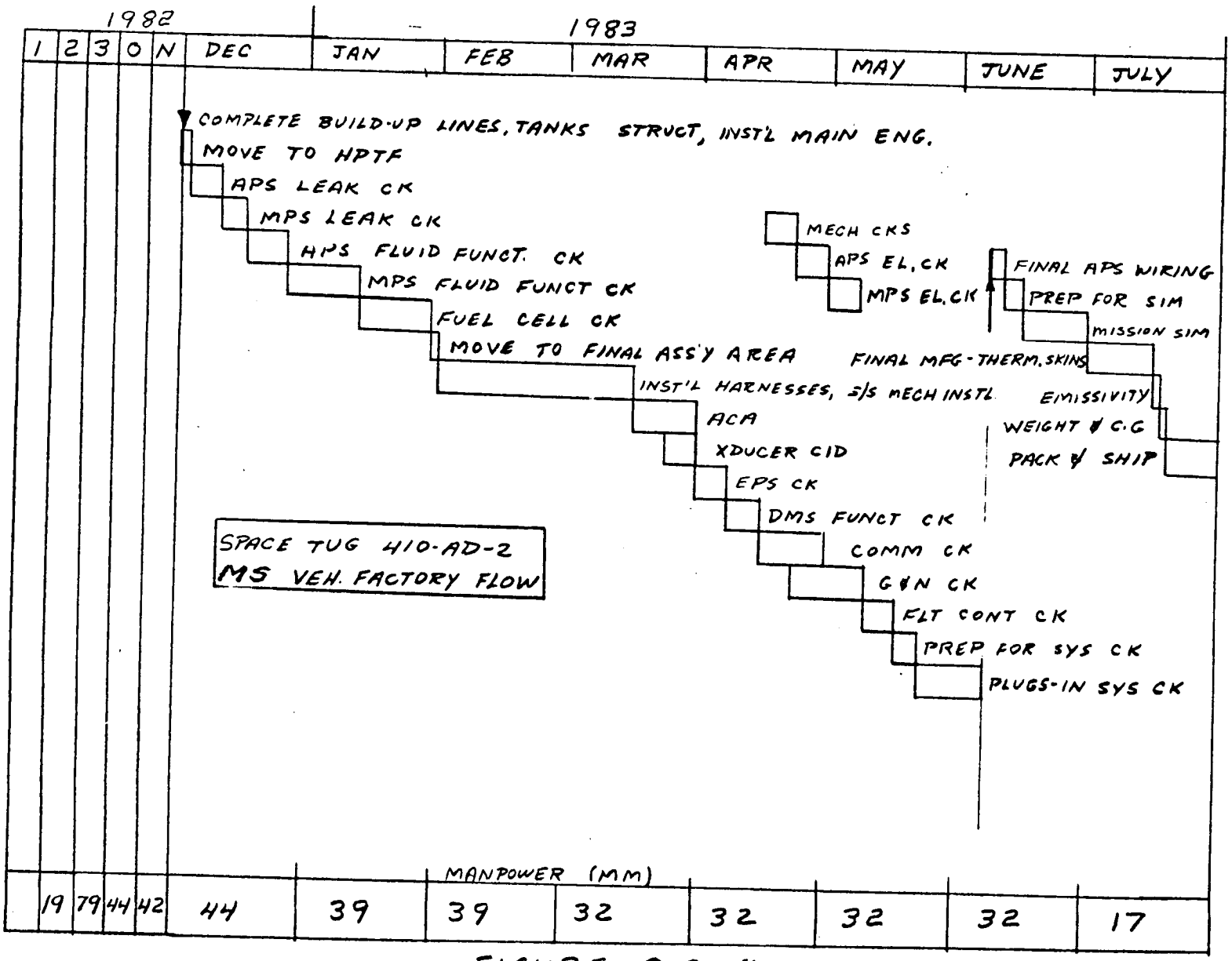


FIGURE 8.2-4

II-8.2-19

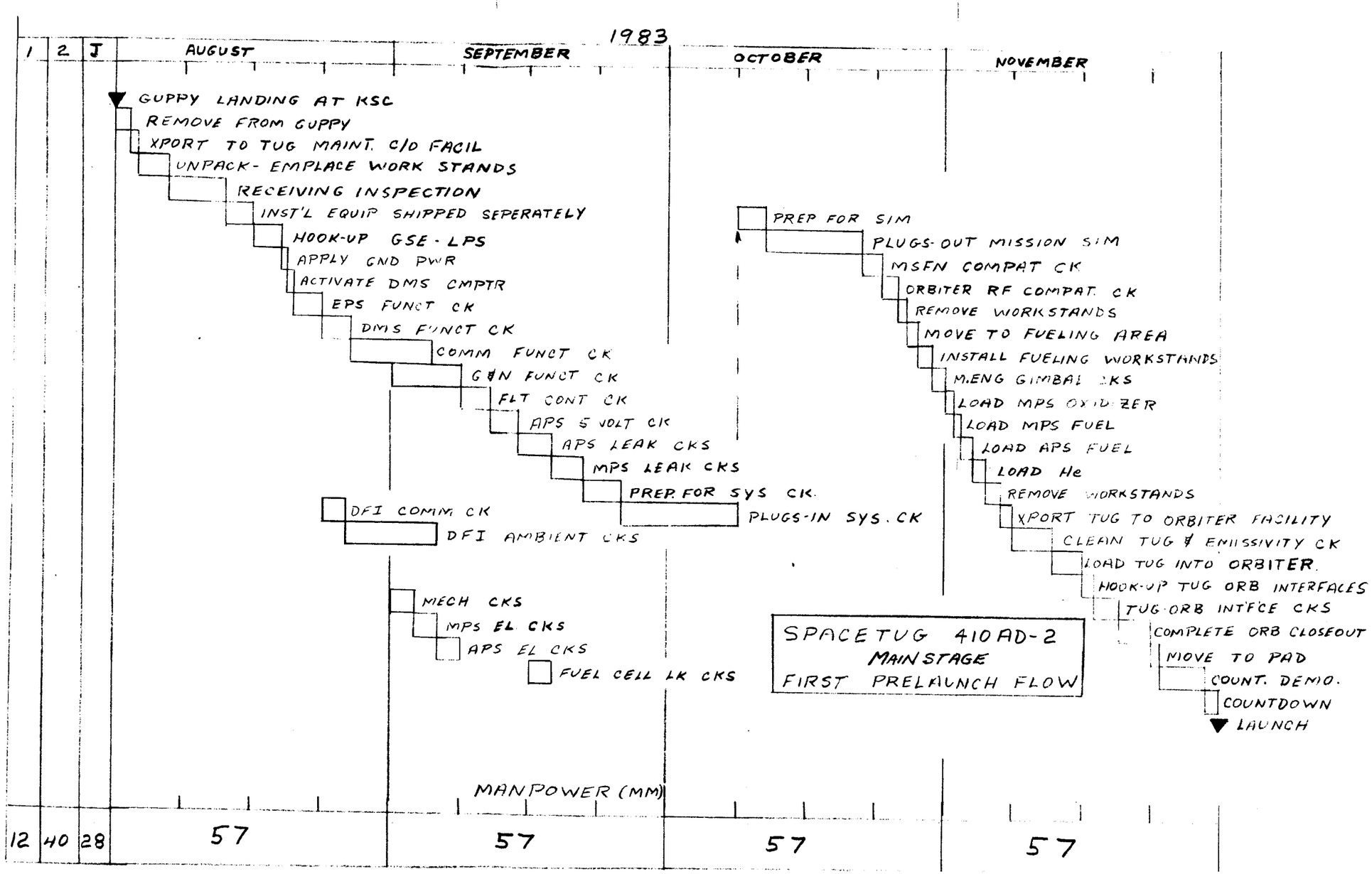

1983
1
2
J
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
GUPPY LANDING AT KSC
REMOVE FROM GUPPY
XPORT TO TUG MAINT. C/O FACIL
UNPACK- EMPLACE WORK STANDS
RECEIVING INSPECTION
INST'L EQUIP SHIPPED SEPERATELY
HOOK-UP GSE - LPS
APPLY GND PWR
ACTIVATE DMS CMPTR
EPS FUNCT CK
DMS FUNCT CK
COMM FUNCT CK
GN FUNCT CK
FLT CONT CK
APS 5 VOLT CK
APS LEAK CKS
MPS LEAK CKS
PREP. FOR SYS CK.
PLUGS-IN SYS. CK
DFI COMM. CK
DFI AMBIENT CKS
MECH CKS
MPS EL CKS
APS EL CKS
FUEL CELL LK CKS
PREP FOR SIM
PLUGS-OUT MISSION SIM
MSFN COMPAT CK
ORBITER RF COMPAT. CK
REMOVE WORKSTANDS
MOVE TO FUELING AREA
INSTALL FUELING WORKSTANDS
M.ENG GIMBAL CKS
LOAD MPS OXIDIZER
LOAD MPS FUEL
LOAD APS FUEL
LOAD He
REMOVE WORKSTANDS
XPORT TUG TO ORBITER FACILITY
CLEAN TUG & EMISSIVITY CK
LOAD TUG INTO ORBITER.
HOOK-UP TUG ORB INTERFACES
TUG-ORB INTFCE CKS
COMPLETE ORB CLOSEOUT
MOVE TO PAD
COUNT. DEMO.
COUNTDOWN
LAUNCH
SPACETUG 410AD-2
MAIN STAGE
FIRST PRELAUNCH FLOW
MANPOWER (MM)
12
40
28
57
57
57
57

FIGURE 8.2-5

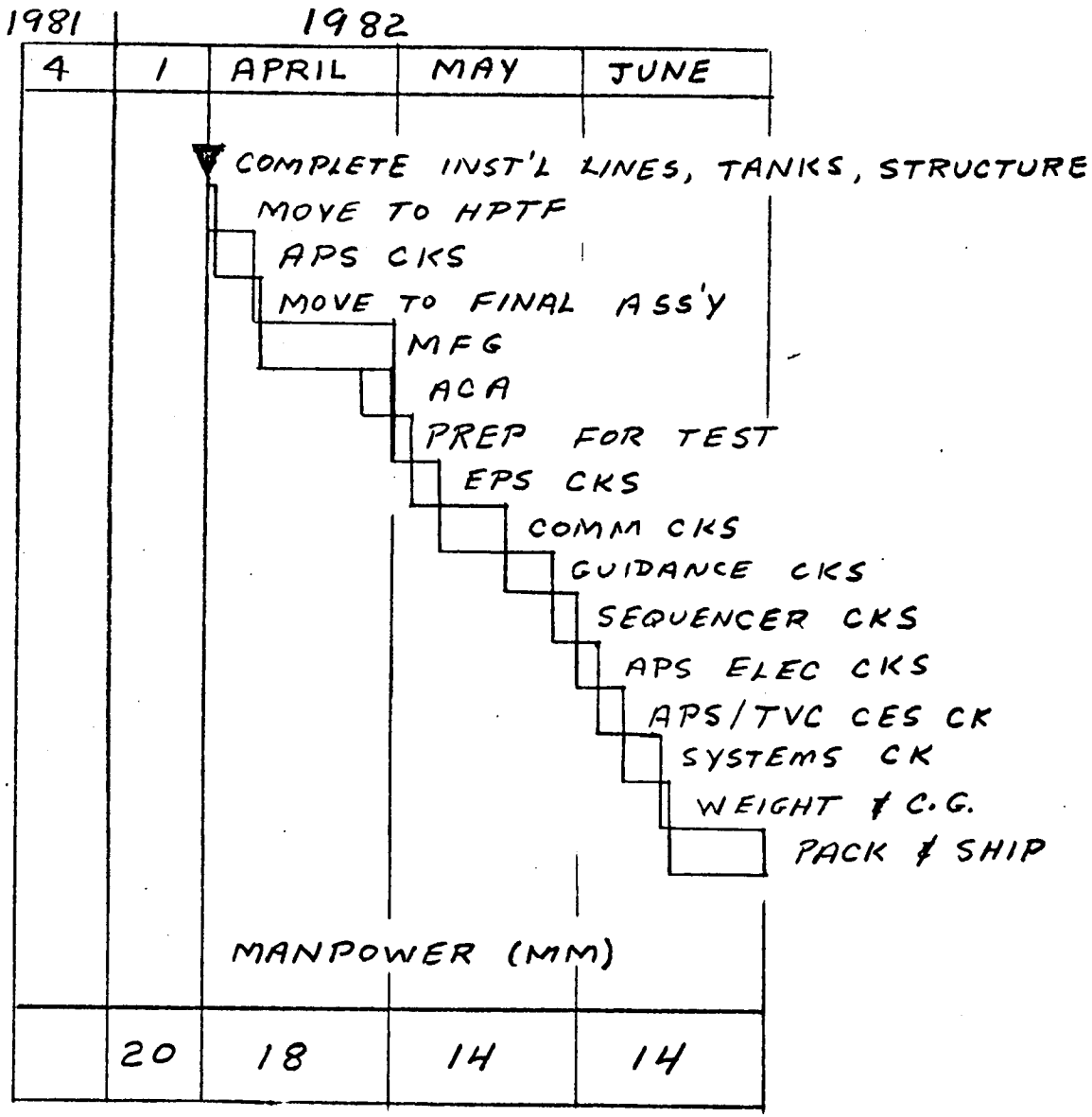


FIGURE 8.2-6

410-AD-2

DEORBIT KICK STAGE FACTORY FLOW

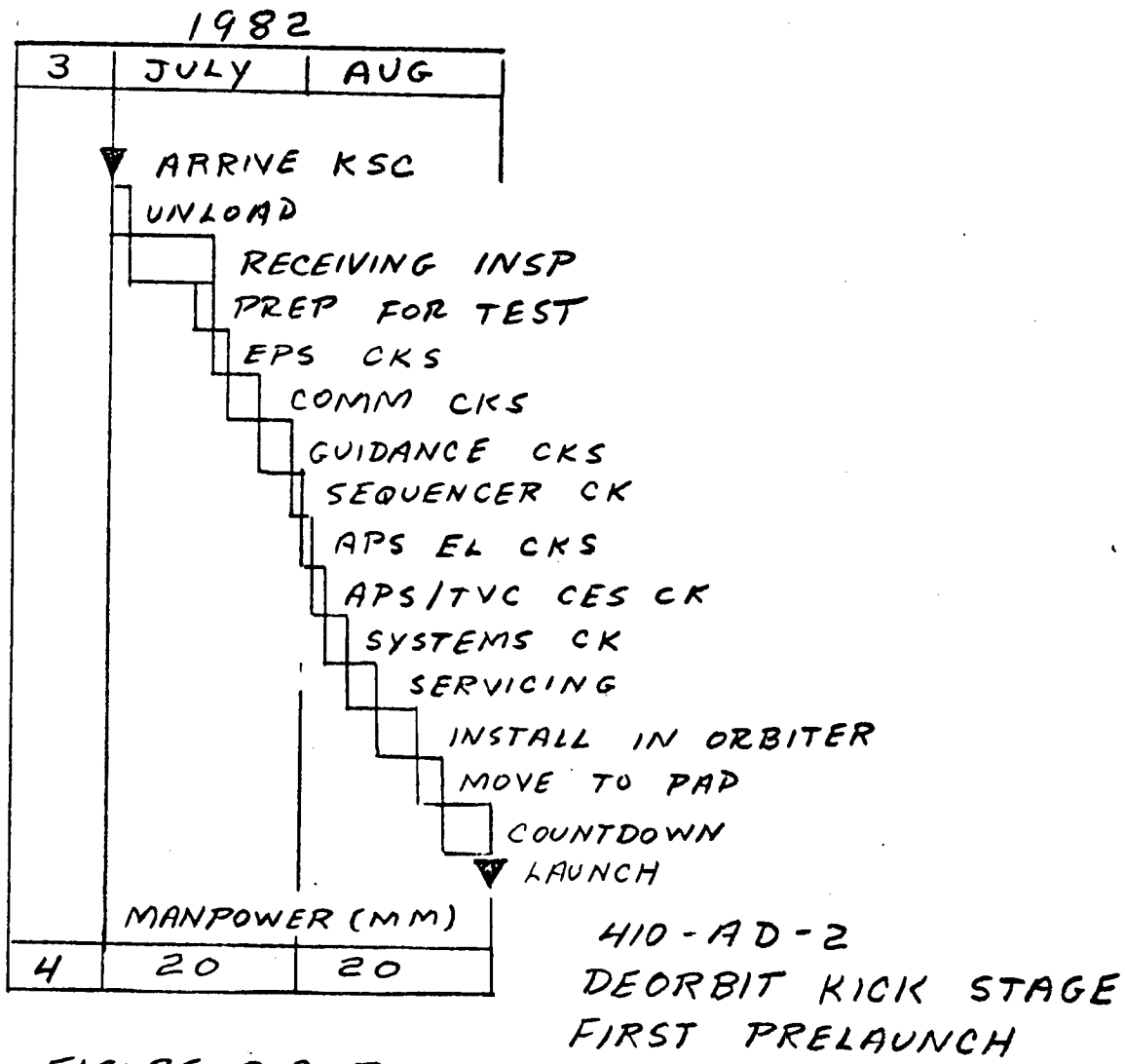
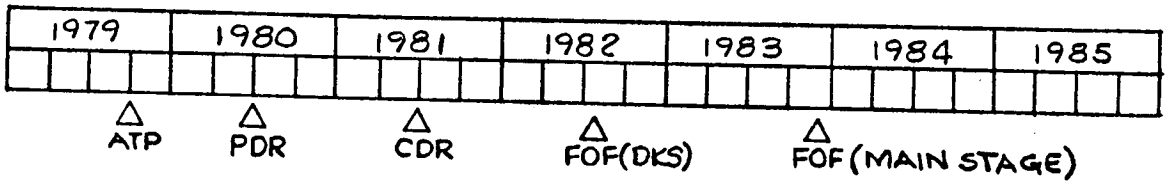
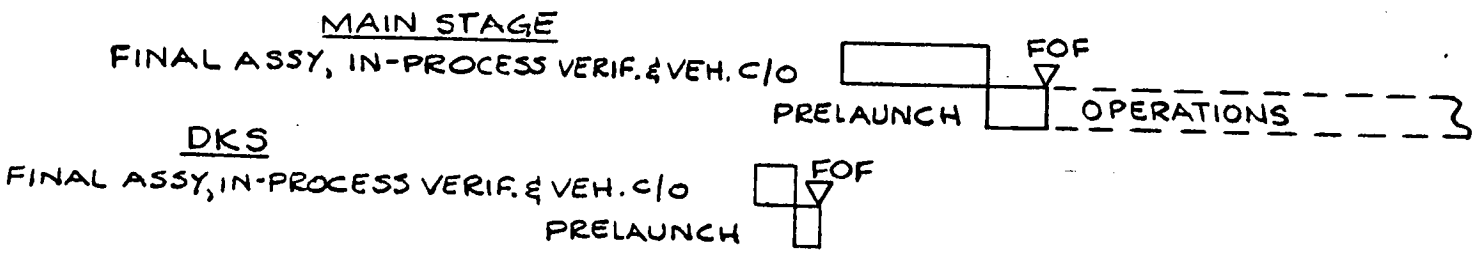

1982
3
JULY
AUG
ARRIVE KSC
UNLOAD
RECEIVING INSP
PREP FOR TEST
EPS CKS
COMM CKS
GUIDANCE CKS
SEQUENCER CK
APS EL CKS
APS/TVC CES CK
SYSTEMS CK
SERVICING
INSTALL IN ORBITER
MOVE TO PAD
COUNTDOWN
LAUNCH
MANPOWER (MM)
4
20
20
410-AD-2
DEORBIT KICK STAGE
FIRST PRELAUNCH

FIGURE 8.2-7





FLIGHT TEST PROGRAM COST

- FLIGHT TEST HARDWARE: 1 MAIN STAGE + DFI
  1 DKS + DFI
- FLIGHT TEST MANPOWER (FOF ONLY)
  - TEST OPS: $3.06M
  - LAUNCH OPS: $3.36M
  - FLIGHT OPS: $3.31M
- CONSUMABLES (FOF ONLY): $62K

FIG. 8.2-8 FLIGHT TEST PROGRAM SCHEDULE (410-AD2)

8.2.5 Impact of Two Year Earlier IOC

A two year earlier IOC accompanied by an identical two year earlier program start (ATP) will generally not impact the Vehicle Test Program. SR&T requirements, however, may affect the development cycle of the advanced IMU utilized in this configuration. Our development cycle for the IMU is based upon a related on going Air Force SR&T activity which is scheduled for completion at the end of 1977. We have proposed further follow-on SR&T activities to refine the technology to Tug requirements. A two year earlier start in the Tug program will necessarily force the follow-on IMU tasks to be also started earlier and in parallel with the Air Force program. This is necessary to ensure that the development cycle through qualification tests may be accomplished on time. This approach will increase program risk and may necessitate an alternate choice in IMU hardware.

8.2.6 Analysis of Test Program

8.2.6.1 Key Elements

The key elements of the Vehicle Test Program are essentially as described in Part I, Paragraph 8.2.6.1. Early development of the Deorbit Kick Stage, however, requires early structural and integrated avionics testing to support the DKS first flight. First flight of the DKS is a dedicated flight test to verify DKS operations after long term orbital exposure.

8.2.6.2 SR&T Assumptions

410AD-2 SR&T requirements are proposed to provide early confidence in an orderly maturity of Tug design, development and manufacturing approaches once the hardware phase of the program begins. Technology requirements, test programs affected and a brief description of the interaction between the SR&T requirements and the test programs affected is summarized in Table 8.2-2.

8.2.6.3 Reusability Demonstration

Reusability Demonstrations for the 410AD-2 are as described in Part I, Paragraph 8.2.6.3.

8.2.6.4 Life Verification Test

Life Verification Tests for the 410AD-2 are as described in Part I, Paragraph 8.2.6.4.

TECHNOLOGY REQUIREMENTS	TEST PROG. AFFECTED	REMARKS
Main engine life and high performance	o GFE eng. devel. prog. o Flight test prog.	Early life verif. of eng. components and area ratio nozzle performance assure phase C/D engine development. PTV is not affected since eng. is not required. FOF could tolerate slightly reduced eng. performance.
PFR helium tank		Early verif. of low weight PFR tank assure maximum tug performance.
Materials compatibility Data	o Tank qual o STA prog. o PTV prog.	Early verif. of material compatibility with MMH and N_2O_4 assures on-time development of main stage tankage including tank qual. STA and PTV testing.
Fracture Mechanics data	o Tank qual. o STA prog.	Early fracture mechanics data allows on-time development of structural subsystem including tankage quals and STA testing.
Heat Pipes	o Flight test prog.	Early verif. of heat pipe design approach allows on-time developments of Thermal Control Subsystem thereby maximizing Tug performance.
Advanced IMU	o Integrated avionics o Flight Vehicle Factory checkout o STA	Early devel. of Advanced IMU will assure on time devel of software and integration procedures in the IAT LAB for FLT VEH buildup and test and accurate simulation for STA prog.
Graphite Composite	o STA Prog.	Early Devel of graphite composite honecomb face sheets assures that STA program progresses as planned.
Laser Radar	o Integrated Avionics o Flight Vehicle factory checkout o STA	Early devel of light weight low power Laser Radar will assure on time development of software and integration procedures in the IAT LAB for FLT VEH buildup & Test and accurate simulation for STA program.
Long Term Space Storable SRM	o SRM Qual	Early verif. of long term space storable SRM on-time development and qual.

Table 8.2-2.

RETRIEVAL CAPABILITY WITH KICK STAGES INCREASE VEH. AVIONICS & FLT TEST BY $16.8M

410AD-2 GROUND TESTS

TEST	TEST ART.	OBJECTIVES	TEST APPROACH
STRUCTURE o MAIN STG (MS) o DEORBIT KICK STAGE (DKS)	o COMPLETE M.S. PRIM. & SEC. STRUCT. INCL. TUG/ORB. & TUG P.L. ADAPTERS o COMPLETE DKS PRIM. & SEC. STRUCT.	o EVAL. DYN., STATIC STRENGTH, SAFE-LIFE & SEPARATION o VERIFY STRUCT./MECH INTERFACES AT LAUNCH SITE	o VIB./ACOUSTIC TESTS o DES. LIMIT STATIC TESTS o STATIC FATIGUE o ULT. STATIC TESTS o SEP. DEMO. o INTERFACE VALIDAT. DEMO. AT KSC.
PROPULSION (MS)	o FLIGHT WT. MAIN STG. STRUCT. o MAIN ENG. SUPPT. S/S LESS ENG. o ENG. SIMUL. UNIT o PTV REFURB. TO FLIGHT OPS.	o DEMO. OPS OF ASSEM. COMPONENTS o DEVELOP C/O & OPS PROCEDURES o VERIFY SERV/HANDLG PROCEDURES o DEMO. SYS. PERF. & CHARACTERISTICS	o COLD FLOW ONLY o REFEREE FLUIDS PHASE - FILL/DRAIN/FLOW TESTS o LIVE PROPELLANTS PHASE - LOAD CONTROL/ ACCURACY - SYS. COMPAT. & DYN. - PERF.SERV./HANDLG. PROCEDURES

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410AD-2 GROUND TESTS

Vehicle Test Program

The vehicle test program for 410AD-2 was developed in a similar manner to that described for 110A-1.

Structural Test Articles

The Structural test program for the 410AD-2 MS is the same as the test program for the 110A-1 MS but is shifted four years later in time. The DKS Structural test article program is basically the same as the MS test program. The AKS structure is the same as the DKS and therefore does not require a separate structural test program.

Propulsion Test Vehicle

The M.S. Propulsion test program for the 410AD-2 configuration is the same as the test program for the 110A-1 except that it is shifted four years later. The DKS propulsion test article program is the same as for the 110A-1 AKS. Since the only difference between the DKS and AKS propulsion system is a reconfiguration in SRM's, no additional AKS propulsion tests are required.

81-E.3-18

410AD-2 GROUND TESTS (CONT'D)

TEST	TEST ARTICLE/FACILITY	OBJECTIVES	APPROACH
INTEGRATED AVIONICS TESTING o INTEG. AVIONICS TEST (IAT) FACILITY - MS - DKS - AKS o AVIONICS SOFTWARE DEVELOPMENT LAB. (ASDL). - MS	o IAT - SHIP SET OF AVIONICS - COMPUTER SIMULATION - SENSOR STIMULUS - FACTORY & LAUNCH GSE o ASDL - COMPUTER FACILITY WITH MATH MODEL SIMULATION OF MS HARDWARE	VERIFY HARDWARE/ SOFTWARE PRIOR TO VEHICLE INSTALLATION & FOF. INCLUDES RETRIEVAL AVIONICS & SOFTWARE	o IAT - SUBSYSTEM INTEG. & END-TO-END FUNCTIONAL VERIFICATION - VERIFY FACTORY C/O PROCED - HARDWARE/SOFTWARE VERIF. - MISSION SIMULATION o ASDL - SOFTWARE DEVELOPMENT
MOCKUPS o MS o DKS o AKS	o WOOD & CARDBOARD MOCKUP OF THE TUG MS, AKS STRUCTURE & DKS INCLUDING EQUIPMENT FOR PDR o WOOD & METAL MOCKUP OF MS, DKS & AKS STRUCT. & EQUIPMENT FOR CDR.	EVALUATE EQUIPMENT ACCESSIBILITY & MAINTAINABILITY. EVALUATE SHUTTLE & PAYLOAD INTERFACE & LINES RUN PRIOR TO FAB OF FINAL HARDWARE	o COMPONENT INSTALLATION o ESTABLISH LINE LENGTHS FOR FINAL HARDWARE FAB o DEMONSTRATE MAINTAINABILITY - ASSESSMENT & DEMOS OF EQUIPMENT CLEARANCES - CONNECTOR & MOUNTING ACCESSIBILITY DEMO - SHUTTLE & PAYLOAD INTERFACE ASSESSMENT

GROUND TEST COST = $25.16M

GRUMMAN

LZ-828-19

410AD-2 GROUND TEST (CONTD)

Integrated Avionics Tests

The MS Integrated Avionics Test program for the 410 AD-2 configuration will be basically the same as for the 110A-1 however, the 410AD-2 IAT facility will include retrieval electronics and Level IIb autonomy hardware. The DKS will be integrated in the same facility as the MS IAT to take advantage of the facility simulation and GSE capability. The DKS will be modified to simulate the AKS for MS-AKS IAT Mission Simulations.

Mockups

The MS mockup for this configuration will be the same as the mockups required for 110A. The DKS will also be mocked up and subsequently modified to serve as AKS mockups.

410AD-2 FLIGHT TESTS

TEST ARTICLE	OBJECTIVES	APPROACH
o MAIN STAGE - 1ST PROD. UNIT INCLUDING DFI o DKS - 1ST PROD. UNIT INCLUDING DFI	o THERMO - VERIFY SYS. THERMAL CONTROL o STRUCT - VERIFY LAUNCH/ORBIT/ ENTRY/LANDING LOADS AND DYNAMICS o PROP - VERIFY MPS/APS o AVIONICS - VERIFY AVIONICS OPS o OPS - EVALUATE TUG/ORB, TUG/KS & TUG/PAYLOAD INTERFACES - EVALUATE SYSTEM PERFORMANCE CAPABILITY - DEMO PAYLOAD DEPLOY & RETRIEVE o DKS - DEMO SYS. PERF. AFTER EXTENDED ON-ORBIT EXPOSURE	o 8 FLT-TEST PROGRAM o FIRST ORBITAL FLIGHT (FOF) COSTED WITHOUT AN OPERATIONAL PAYLOAD - FLOWN WITHIN RETRIEVAL CAPABILITY OF ORB - SEQUENCE INCL: SYS C/O, MPS BURNS, APS C/O, DUMMY PAYLOAD DEPLOY, DEMO RETRIEVE DKS & ORB RETRIEVAL o SUBSQ. FLIGHTS DEPLOY OPERAT. PAYLOADS SELECTED TO DEMO. BUILDUP IN TUG CAPABILITY o ONE DEDICATED FLIGHT TEST OF DKS STAGE IN 1982.

FLIGHT TEST COST = $24.44M

TOTAL VEHICLE TEST = $49.60M

GRUMMAN

II-2.2-21

410AD-2 FLIGHT TESTS

Eight flights are included in the 410AD-2 flight test program. The main stage flight test program is essentially as described for configuration 110A-1. The test sequence is modified slightly to include a retrieval demonstration using a DKS to serve as the retrieval target.

Since the DKS is developed and flown earlier than the main stage, a separate and dedicated flight test is planned to verify the capability of the DKS to function during and after extended exposure to orbital environments. This flight will occur in mid-1982 and could be accomplished as part of a normal Shuttle launch or by some other means.

PART II

8.3 Facilities Plan - Option 2 - Concept 410AD-2

8.3.1 Manufacturing Facility

Same as concept 110A-1 except 34,900 sq. ft. of floor space is required for fabrication and assembly of the TUG.

8.3.2 Test Facilities

Same as concept 110A-1 except 1AT will require 1300 sq. ft. of floor space at JSC.

8.3.3 Operations Facilities

Same as concept 110A-1 except TUG Maintenance Facility at ETR will have 4 horizontal stations in 12,000 sq. ft. addition to the Shuttle OMS Facility. The Kickstage SRM Processing Facility will require 2,800 sq. ft. of floor space.

8.3.4 Impact of 2 Year Early IOC

Examination of the facility schedule in Section 8.1 and the following Facility Funding Requirement Data Sheet indicates that a two year early IOC from December '83 to December '81 with a corresponding two year early ATP would require activation of Manufacturing, Test, ETR and Mission Control facilities two years earlier. Therefore, approximately $4.3 million of facility DDT & E costs must be expended two years earlier. Assuming that WTR would now become operational in 1983 as in the 110A-1 concept, approximately $2.7 million for WTR facilities must be expended one year earlier.

STORABLE SPACE TUG

CONCEPT 410 AD-2

Revision Date 9-7-73

FACILITIES FUNDING REQUIREMENTS 10C DEC. '83 ACQUISITION PHASE NASA

Fiscal Year	'76			'77			'78			'79			'80			'81			'82			'83			'84	'85	'86	'87	'88	'89	'90	'91	TOTALS		
TITLE/WBS # / Level 6 Cat.	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3									DDT&E	PROD	OPS
Manufacturing 320-06-01																																			
Structures														2.0		55.0	28.4	3.6		28.4	27.5			11.8 (22.6) (55.6)	(54.0)	(34.0)	34.2	1.5					156.7	136.1	–
Kickstages	–													5.0			46.6	(12.6)			(25.8)				(15.6)	(25.8)	(25.8)	(25.6)	(6.6)				51.6	176.0	
Sub-Total														7.0		55.0	75.0	16.2		28.4	53.3			60.4	60.4	60.4	60.4	35.3	8.6				208.3	312.1	–
Test 320-06-02																																			
Structural														Existing		Facility			–	No	Facilities			Input	Needed								–	–	–
Thermal														Existing		Facility			–	No	Facilities			Input	Needed								–	–	–
IAT																					1.2			1.3	.9								3.4	–	–
Propulsion																				83.0			27.0	7.5	(7.0)	(1.0)	(.0)	(3.0)					117.5	50.0	–
Total Qual. & Accept.																100.0			20.0		1.0			(1.2)	(1.2)	(.3)	(.3)						121.5	[illegible]	–
Sub-Total																100.0			20.0	83.0	2.2		27.0	10.1	1.2	1.3	10.3	3.0					243.4	[illegible]	–
Maint. & Refurb. - ETR 320-06-03																																			
Tug Maint. Fac.																10.0			[illegible]			560.0	76.0		(7.0)	(22.6)	–	–	–	–	[22.6]	[31.5]	295.0	–	156.9
Prop. Sys. Serv.																25.0			347.0			[illegible]	[illegible]		[illegible]	[illegible]	–	–	–	–	[illegible]	[illegible]	[illegible]	–	64.6
Tug Cleaning																			32.0			321.0	53.1		[illegible]	[illegible]	–	–	–	–	[illegible]	[illegible]	[illegible]	–	[illegible]
Kick Stage Proc.																			14.0			10.0	[illegible]		[illegible]	[illegible]	–	–	–	–	[illegible]	[illegible]	14.6	–	14.3
Support/Whse. Fac.																Shared	Facility						127.0										127.0	–	–
Office																							10.1		[illegible]	–				–	[illegible]	[illegible]	10.0	–	[illegible]
Sub-Total																35.0			553.0			1411.0	34.6		30.6	14.8	–	–	–	–	44.6	22.6	503.8	–	332.0
ETR Launch 320-06-04																																			
Launch Pad																		Shared	Facility				–	5.0									5.0	–	–
Safing Area																		Shared	Facility				2.0	16.0									20.0	–	–
Mission Control Center																			5.0			[illegible]		17.0	12.0	–	–	–	–	–	[illegible]	[illegible]	42.6		17.0
Sub-Total																			5.0			[illegible]	2.0	38.0	12.0	–	–	–	–	–	12.0	[illegible]	127.5	–	17.0
Maint. & Refurb.-WTR 320-06-05																20.0			[illegible]			3,[illegible]	[illegible]		[illegible]	[illegible]	–	–	–	–	[illegible]	[illegible]	[illegible]	–	[illegible]
Tug Maint. Fac.																30.0			[illegible]			[illegible]	38.0		[illegible]	[illegible]	–	–	–	–	[illegible]	[illegible]	1168.0	–	[illegible]
Prop. Sys. Serv.																			31.0			[illegible]	63.6		[illegible]	[illegible]	–	–	–	–	[illegible]	[illegible]	[illegible]	–	[illegible]
Tug Cleaning																																			
Support/Whse. Fac.												Present	Cost	Use/Use	–	Low	I	I	Maint.	S		WTR		only									192.0	–	29.3
Office																16.0			[illegible]	16.0				[3.3]	[7.0]	–				–	[illegible]	[illegible]			
Sub-Total																50.0			70.0			[illegible]	147.6		[illegible]	30.3	–		–	–	30.3	15.1	[illegible]	–	226.1
WTR Launch 320-06-06																		Shared	Facility				–	5.0									5.0	–	–
Launch Pad																		Shared	Facility				2.0	22.0									24.0	–	–
Safing Area																			[illegible]			[illegible]		[illegible]	12.0	–				–	[illegible]	[illegible]	938.0		97.0
Mission Control Center																																			
Sub-Total																			6.0			[illegible]	2.0	34.0	12.0	–				–	12.0	6.0	523.0	–	97.0
TOTALS														7.0		270.0	75.0	16.2	[illegible]	111.4	55.5	[illegible]	113.4	134.5	161.6	119.6	63.6	131.4	107.7	97.1	11.1	61.5	7072.1	1347.3	746.1
																																GRAND TOTAL		8167.5	

COSTS - $000 (1973)

Col. 1 - Design/Construction Costs
Col. 2 - Activation Costs
Col. 3 - Maintenance Costs

00 - DDT & E Costs
(00) - Production Costs
[00] - Operations Costs

T-8.3-2

8.4 Vehicle Manufacturing

This section establishes the manufacturing requirements for the 410AD-2 spacecraft including the assembly sequence, tooling, schedule, manufacturing test, special processes and facilities.

The 410AD-2 spacecraft consists of a main stage and apogee or deorbit kick stages (AKS/DKS). The main stage employs a graphite/epoxy outer shell and nested titanium propellant tanks. The kick stage is structurally the same as the AKS described in Part I and varies only in the number of solid rocket motors and equipment complement required.

8.4.1 Plan/Flow/Time

The manufacturing sequence identifies the major manufacturing tasks from parts fabrication through assembly, installation, checkout and delivery and the manufacturing flow defines the time phasing of these tasks. The calendar relationship of program milestones to tooling delivery, operation sheet planning, work order release and assembly of the major test articles and flight vehicles is shown in a master manufacturing schedule.

8.4.1.1 Main Stage

The assembly breakdown of the main stage is shown in figure 8.4-1 and the description of the major assemblies, equipment installations, and test/checkout operations is provided in Table 8.4-1. The manufacturing flow and master schedule are shown in Figures 8.4-3 and 8.4-4 respectively.

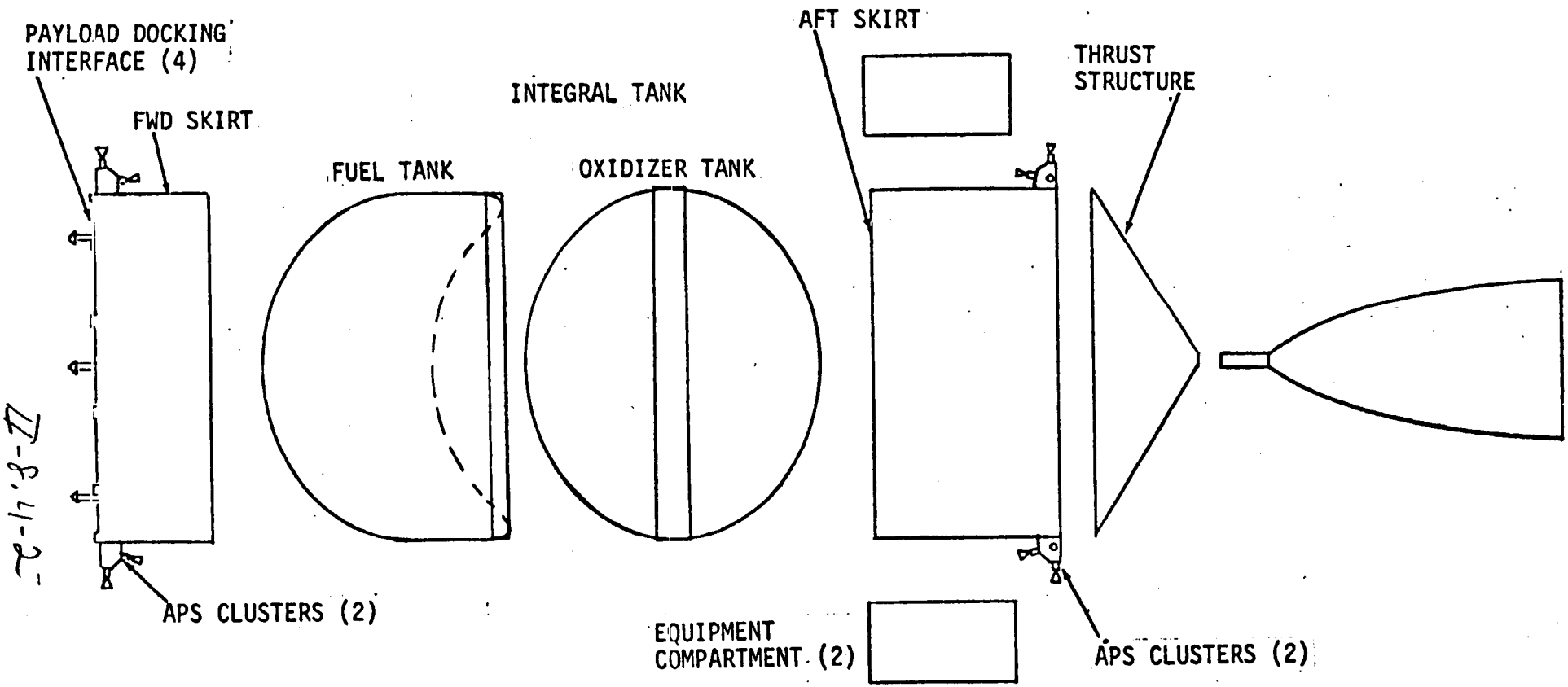


Figure 8.4-1 Assembly Breakdown Main Stage

TABLE 8.4-1

MANUFACTURING SEQUENCE

410AD-2, 310-3A, 310-3B

MAIN STAGE

MAJOR ASSEMBLIES

Forward Skirt Subassembly
- o Outer shell - aluminum honeycomb with graphite epoxy composite skins or stiffened aluminum sheet for 510A-3B
- o Fwd Frame - Payload/kick stage interface & APS support
- o Intermediate Frame
- o Support Frame - Orbiter pick-up

Fuel & Oxidizer Tanks
- o See Nested Dome Propellant Tank Manufacturing Sequence and Fig. 8.4-2

Aft Skirt Subassembly
- o Outer Shell- Aluminum honeycomb with graphite epoxy composite skins or stiffened aluminum sheet for 510A-3B
- o Intermediate Frame
- o Aft Frame - Adapter interface, APS support & thrust structure attachment

Thrust Structure Subassembly
- o Conical shell - stiffened aluminum sheet
- o Fwd ring frame
- o Engine gimbal support
- o Base heat shield

Other
- o Equipment compartment subassembly
- o APS clusters (2 fwd/2 aft)
- o Probe drogue interfaces (4 fwd./4 aft)

STRUCTURAL ASSEMBLY

Join propellant tanks and aft skirt assembly
Install MLI insulation blankets
Join fwd skirt and tank assemblies
Install thrust structure
Install equipment compartment tank supports, equipment shelves and secondary structure

INSTALLATIONS

Main Propulsion System (MPS)
- o Engine - Class I
- o Helium Tank
- o Gimbal actuators (2)
- o Pressurization & propellant feedlines
- o Fill, Vent, Drain Lines
- o Control/Relief valves, filters, regulators, flex joints, quick disconnects, etc.
- o Low level sensors (fuel & OX)

INSTALLATIONS (Cont)

Auxiliary Propulsion System (APS)

- Propellant Tanks (2)
- Helium Tanks (2)
- Thrusters (24) - 25# (310-3A/3B 16 @ 25#)
- Pressurization & Propellant Feedlines
- Fill, Vent, Drain Lines
- Control/Relief Valves, Filters, Regulators, Quick Disconnects, etc.
- Acquisition Bladders
- Thruster Heaters

Thermal Control

- Insulation Blankets - MLI
- Alzak Skins
- Base Heat Shield - Thrust Structure
- Silver Backed Teflon Tape - Saddle Bags
- Radiator & Associated Plumbing

Astrionics

Electrical Power (EPS)

- Fuel Cell
- Cryo Hydrogen Tank
- Cryo Oxygen Tank
- Emergency Battery
- Distribution & Control Boxes
- Cable/Harnesses - Approx. 10,000 ft. & 120 connectors

Guidance, Navigation & Control (GN&C)

- Intertial Measuring Unit (IMU)
- Star Tracker (2)
- Rate Gyro Unit
- Accelerometer
- APS Control Electronics
- Main Engine Control Electronics

Added For Deorbit & Retrieval Missions:

- Laser Rendezvous Radar
- Satellite Receiver
- Doppler Receiver
- "L" Band Antennas (4)
- Combined Doppler Detector

Data Management (DMS)

- Computer (2)
- Controller/TM Formatter
- Data Acquisition Units (3)
- Sensors (190)
- Tape Recorder

(Cont)

INSTALLATIONS (Cont)

Astrionics (Cont)

Communications

- Transciever
- Power Amplifier (2)
- Signal Processor
- Diplexer (2)
- Antenna Switch
- OMNI Antenna (2)
- Aux. Transmitter
- Power Splitter
- TV Assembly

TEST AND CHECKOUT

In-Process Manufacturing Verification

- Fluid Line Leak Checks
- Electrical Harness Continuity, Dielectric and Insulation Resistance
- Dimensions, Finish, Identification and Markings
- Cleanliness
- Workmanship

Acceptance Test

- Cryo Proof Propellant tanks
- Proof/Leak Check Fluid Lines
- Flow Calibration
- Electrical Circuit Functional and EMI
- Thrust Vector and Gimbal Actuator Alignment
- Functional Performance
- Fit & Clearance Checks
- RGA/APS Polarity Test
- Mission Simulation
- Cleanliness Verification
- Weight and CG Determination

PACK AND SHIP

Apply Pad Pressures To Fluid Systems

Install Protective Devices and Covers

Clear Acceptance Paperwork

Install in Shipping Container

MANUFACTURING SEQUENCE

NESTED DOME PROPELLANT TANKS

410 AD-2, 310-3A& 310-3B

TITANIUM

PARTS FABRICATION

Domes (4)
- Stretch form gores (13)
- Trim
- Chimmill
- Trim & Weld Prep

Polar Rings (2)
- Form and Machine

Polar Caps (2)
- Form and machine

Access Covers (2)
- Form and Machine

Cylinder
- Roll Form
- Weld Seam
- Chemmill
- Trim & Weld Prep

Forward Frame
- Machine Roll Ring Forging
- Roll Form Seal Channel
- Weld Channel to Frame
- X-Ray and leak check

"Y" Ring
- Machine Roll Ring Forging

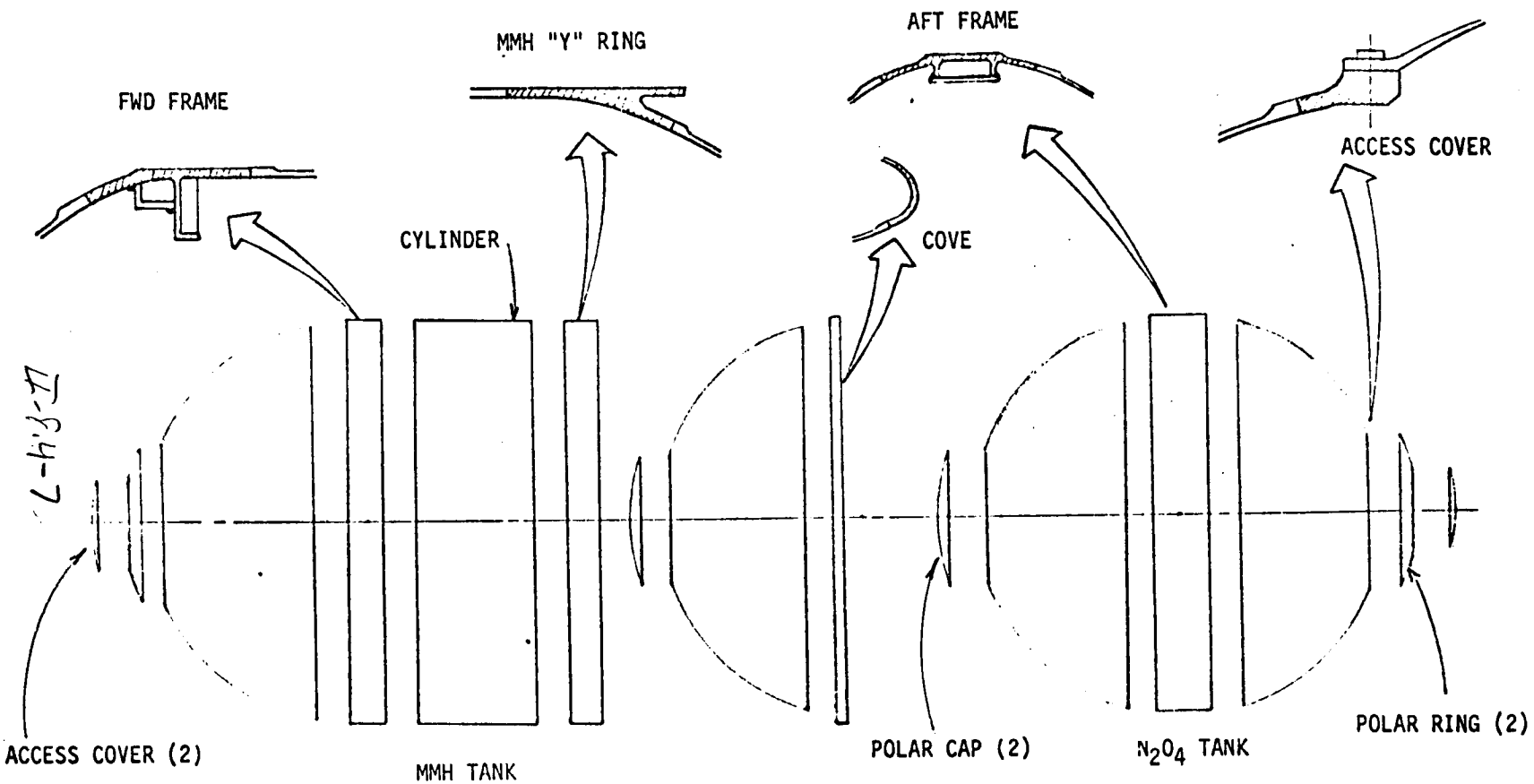
Core
- Press Form Sections (4)
- Chemmill
- Trim & Weld Prep
- Weld Sections

Aft Frame
- Machine Roll Ring Forging
- Roll Form Cover Plate
- Weld Cover Plate to Frame
- X-Ray and Leak Check

Shell Stiffeners
- Brake Form Zee Sections (96)
- Chemmill
- Trim

II-8.41-6

(Cont)



NOTE: ALL DOMES HAVE SAME GEOMETRY AND CAN BE FABRICATED FROM SAME TOOLING
ALUMINUM DOMES ARE ONE PIECE SPINNINGS
TITANIUM DOMES ARE WELDED GORES (13)

TITANIUM - 410AD-1, 310-1, 320A-1
ALUMINUM - 510A-1

Figure 8.4-2 Assembly Breakdown Nested Propellant Tank

MANUFACTURING SEQUENCE

NESTED DOME PROPELLANT TANKS

410 AD-2, 310-3A& 310-3B

TITANIUM

SUBASSEMBLIES

Domes (4)
- Weld (12) gores
- Fit and trim last gore
- Weld last gore
- Trim & weld prep
- Weld polar ring (2) domes only
- Weld cove to lower edge of MMH nested dome
- X-Ray & dye penetrant all welds
- Inspect

Cylinder
- Stake weld longitudinal seam
- Trim & weld prep
- X-Ray, Dye penetrant & inspect

WELDING SEQUENCE

Fuel Tank
- Weld fwd. dome to fwd. frame
- Weld "Y" ring to aft dome core
- Weld cylinder to fwd and aft dome assemblies
- X-ray, dye penetrant & inspect

Oxidizer Tank
- Weld fwd dome to frame
- Weld aft dome to frame
- X-ray, dye penetrant & inspect

FINAL ASSEMBLY

Bond Stiffeners to Cylindrical Section

Install Feed, Vent, Drain Lines

Install Propellant Acquisition Screens

Install Access Covers

Install Propellant Quantity Gaging System (PQGS)

TEST/CHECKOUT

In-Process X-Ray & Dye Penetrant Inspect All Welds

Proof Pressure Test (Cryogenic)

Leak Check

II 8.4-8.

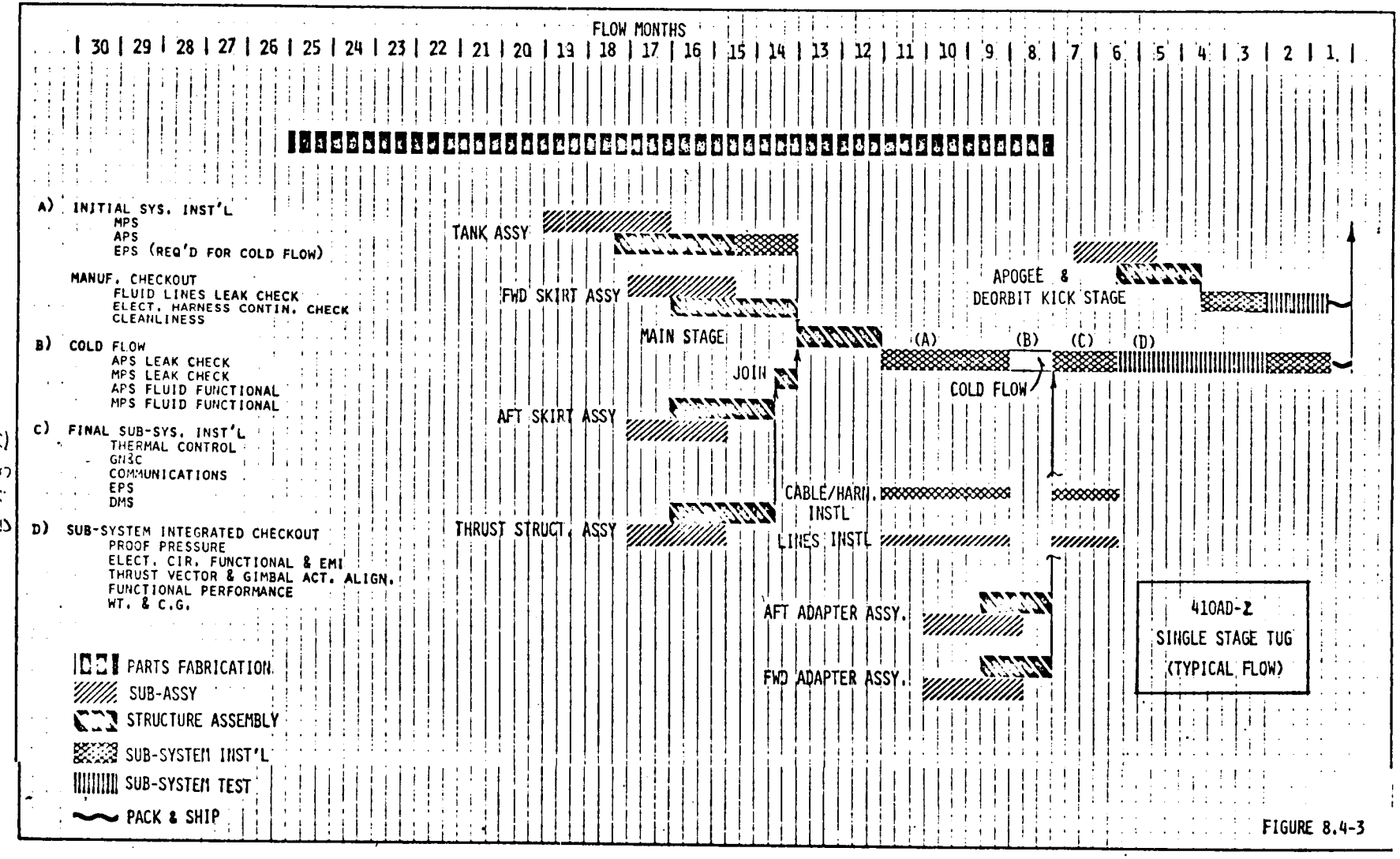

FLOW MONTHS
30 29 28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
A) INITIAL SYS. INST'L
MPS
APS
EPS (REQ'D FOR COLD FLOW)
MANUF. CHECKOUT
FLUID LINES LEAK CHECK
ELECT. HARNESS CONTIN. CHECK
CLEANLINESS
B) COLD FLOW
APS LEAK CHECK
MPS LEAK CHECK
APS FLUID FUNCTIONAL
MPS FLUID FUNCTIONAL
C) FINAL SUB-SYS. INST'L
THERMAL CONTROL
GN&C
COMMUNICATIONS
EPS
DMS
D) SUB-SYSTEM INTEGRATED CHECKOUT
PROOF PRESSURE
ELECT. CIR. FUNCTIONAL & EMI
THRUST VECTOR & GIMBAL ACT. ALIGN.
FUNCTIONAL PERFORMANCE
WT. & C.G.
TANK ASSY
FWD SKIRT ASSY
MAIN STAGE
JOIN
AFT SKIRT ASSY
THRUST STRUCT. ASSY
APOGEE & DEORBIT KICK STAGE
(A)
(B)
(C)
(D)
COLD FLOW
CABLE/HARN. INSTL
LINES INSTL
AFT ADAPTER ASSY.
FWD ADAPTER ASSY.
410AD-2
SINGLE STAGE TUG
(TYPICAL FLOW)
PARTS FABRICATION
SUB-ASSY
STRUCTURE ASSEMBLY
SUB-SYSTEM INST'L
SUB-SYSTEM TEST
PACK & SHIP

FIGURE 8.4-3

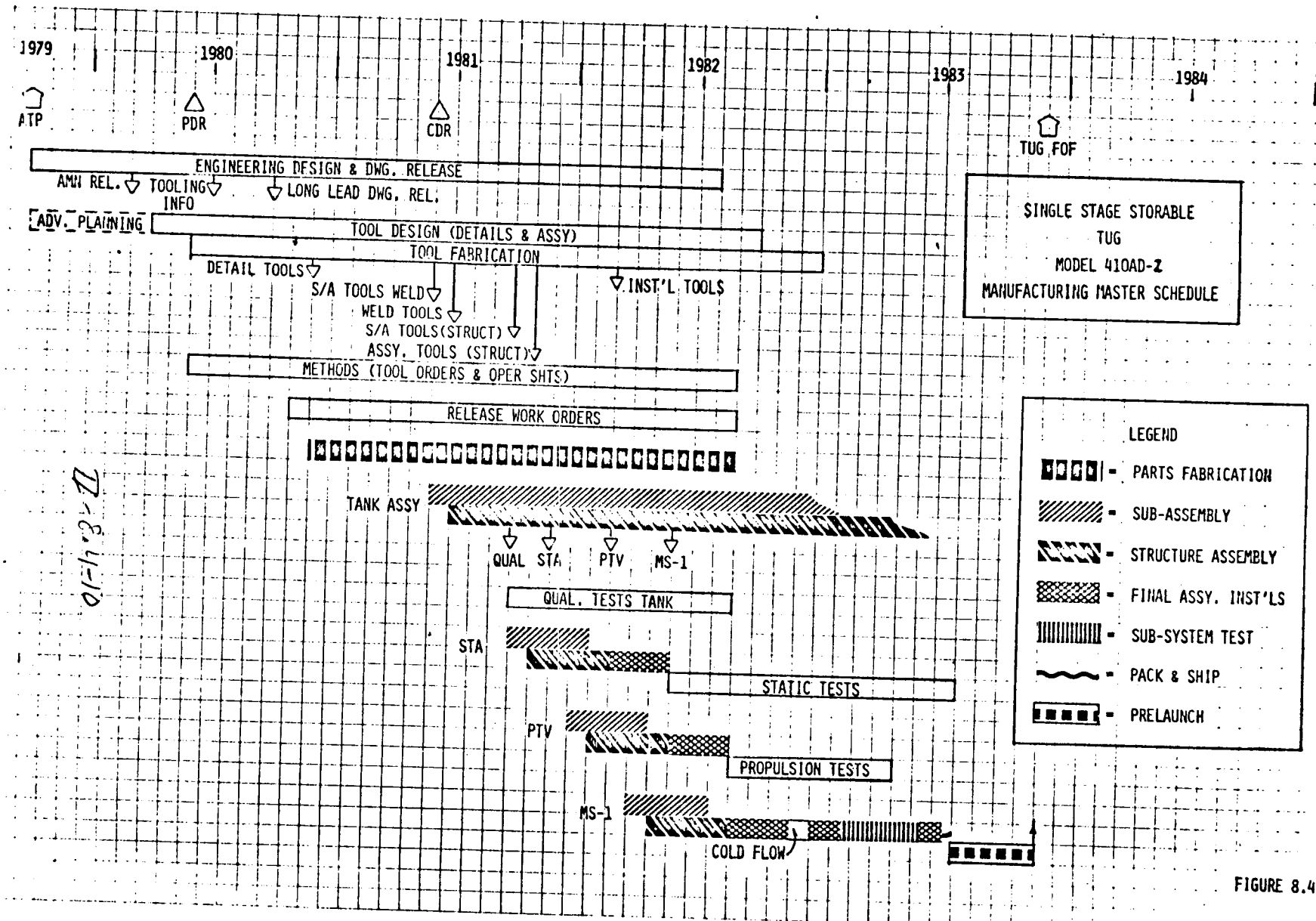

1979
1980
1981
1982
1983
1984
ATP
PDR
CDR
TUG FOF
ENGINEERING DESIGN & DWG. RELEASE
AMN REL.
TOOLING INFO
LONG LEAD DWG. REL.
ADV. PLANNING
TOOL DESIGN (DETAILS & ASSY)
TOOL FABRICATION
DETAIL TOOLS
S/A TOOLS WELD
WELD TOOLS
S/A TOOLS(STRUCT)
ASSY. TOOLS (STRUCT)
INST'L TOOLS
METHODS (TOOL ORDERS & OPER SHTS)
RELEASE WORK ORDERS
TANK ASSY
QUAL
STA
PTV
MS-1
QUAL. TESTS TANK
STA
STATIC TESTS
PTV
PROPULSION TESTS
MS-1
COLD FLOW
SINGLE STAGE STORABLE
TUG
MODEL 410AD-Z
MANUFACTURING MASTER SCHEDULE
LEGEND
PARTS FABRICATION
SUB-ASSEMBLY
STRUCTURE ASSEMBLY
FINAL ASSY. INST'LS
SUB-SYSTEM TEST
PACK & SHIP
PRELAUNCH

FIGURE 8.4-4

TABLE 8.4-2

TOOLING REQUIREMENTS

410AD-2, 310-3A, 310-3B

PART/ASSEMBLY	OPERATIONS	TOOL/GSE
PROPELLANT TANK - TITANIUM		
Domes (4)	Stretch Form Gores (13) Chemmill Trim & Weld Prep Weld Gores Trim Polar Cap & Y Ring Edges Weld polar cap or polar ring as required.	Stretch Die - Heated Chemmill Templates (5) Trim Fixture Weld Fixture (Includes back-up bars, skates, and clamps) Skate Attachment to weld fixture Attachment to weld fixture
Polar Ring (2)	Form Machine	Spin forging - purchased Holding Fixture
Polar Cap (2)	Form Machine	Spin forging - purchased Holding Fixture
Access Covers (2)	Form Machine	Spin Forging - purchased Holding Fixture
Cylinder	Form Weld Chemmill Trim & Weld Prep	Standard Rollers Standard longitudinal stake welder Chemmill template Holding Fixture
Fwd Frame	Machine Roll Forging Form Seal Channel Weld Final Machine	Holding Fixture, NC Tape Standard Rollers Weld Fixture Holding Fixture Above
"Y" Ring	Machine Roll Forging	Holding Fixture, NC Tape
Cove	Form Chemmill Trim & Weld Prep Weld	Press Die Chemmill Templates Trim Fixture Weld Fixture
Aft Frame	Machine Roll Forging Form Cover Plate Weld Final Machine	Holding Fixture, NC Tape Standard Rollers Weld Fixture Holding Fixture Above
Stiffeners	Form Chemmill Trim	Standard Brake Die Chemmill Template Drill & Scribe Template

(Cont)

TOOLING REQUIREMENTS (CONT)

410AD-2, 310-3A, 310-3B

PART/ASSEMBLY	OPERATIONS	TOOL/GSE
PROPELLANT TANK - TITANIUM (Cont)		
Tank Assembly-Fuel	Weld Domes, Cylinder & Y Rings	Weld Fixture (includes mandrel, Back-up bars, clamps and rotating mechanism)
Tank Assembly - Oxidizer	Weld Domes, Cylinder & Y Rings	Weld Fixture (includes mandrel, Back-up bars, clamps and rotating mechanism)
Installation Fixture	Install Propellant Acquisition Screens Fuel Tank	Drill/Installation Fixture
Installation Fixture	Install Propellant Acquisition Screens Fuel Tank	Drill/Installation Fixture
Assembly	Handling	Slings (2) (GSE)
Assembly	Transportation	Dolly(2) (GSE)
FORWARD SKIRT		
Outer Shell	Layup graphite/epoxy skins Roll Form honeycomb core Trim & undercut core Form edge members Bond core & skins	Tape layout templates (4) Standard rollers Saw & trim fixture Standard dies/rollers Bonding fixture - autoclave
Fwd Frame	Form frame members Chemmill	Press blocks (3) Chemmill templates
Intermed Frame	Form frame members Chemmill	Press blocks (3) Chemmill templates
Support frame	Machine roll forging	Holding fixture, NC Tape
Docking Probes (4)	Machine	Holding fixture, NC Tapes
Latches (12 & Ftgs.	Machine	Holding fixtures
Assembly	Assemble shell, frames Docking interfaces, APJ clusters	Assembly fixture
Assembly	Handling and transportation	Standard sling & dolly with adapters

TOOLING REQUIREMENTS (Cont)

410AD-2, 310-3A, 310-3B

PART/ASSEMBLY	OPERATION	TOOL/GSE
AFT SKIRT		
Outer shell	Layup graphite/epoxy skins Form honeycomb core Trim & undercut core Form edge members Bond core & skins	Tape layout templates (4) Standard rollers Saw & trim fixture Standard dies/rollers Bonding fixture - autoclave
Frame	Form members Chemmill	Press blocks (3) Chemmill templates
Aft Frame	Form members Chemmill	Press Blocks (3) Chemmill templates
Docking Drogue Fittings (4)	Machine	Holding fixture
Docking Latches (12) & Fittings	Machine	Holding fixture, NC Tapes
Assembly	Assemble Shell, Frames, Docking interfaces, APS cluster	Assembly fixtures
Assembly	Handling & transportation	Standard sling & dolly with adapters.
THRUST STRUCTURE		
Conical Shell	Roll Form sheet Form stiffeners Chemmill sheet	Standard rollers Standard brake dies Chemmill templates (3)
Engine Suppt.Ftg.	Machine	Holding fixture
Gimbal Fittings	Machine	Holding fixtures (2)
Base Heat Shield	Roll form Alzak sheet	Standard rollers
Assembly	Assemble sheet, stiffeners, fittings, & base heat shield	Assembly fixture
APS CLUSTERS		
Fwd (2)	Machine cluster parts (3)	Holding fixtures (3)
Aft (2)	Weld Machine assembly	Weld fixtures (2) Holding fixture
EQUIPMENT COMPARTMENT		
Sheetmetal Parts	Form Drill & trim	Press blocks & standard Dies Drill & scribe templates & router boards Chemmill templates

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TOOLING REQUIREMENTS (Cont)

410AD-2, 310-3A, 310-3B

PART/ASSEMBLY	OPERATION	TOOL/GSE
EQUIPMENT COMPARTMENT (Cont)		
Fittings	Machine	Holding Fixtures
FLUIDS ASSEMBLIES		
Tubing	Form	Standard bending dies & set-up gages (SUGS)
	Weld connectors	Standard Orbital welding equipment adapters & welding schedules
Assembly	Assemble fluid lines and purchased components such as valves, filters, regulators	Assembly fixtures and standard cryofit and brazing tools.
ELECTRICAL HARNESSING		
	Wire cutting and prep	Standard cutting, stripping, marking tools
	Assembly	Harness boards
INSTALLATIONS		
	Install subassemblies and components	Installation fixtures
FINAL ASSEMBLY		
	Structural Assembly Installations Handling Transportation Shipping	Final assembly fixture Work stand Slings (2) (GSE) Dolly (GSE) Container (GSE)

8.4.3 Facilities

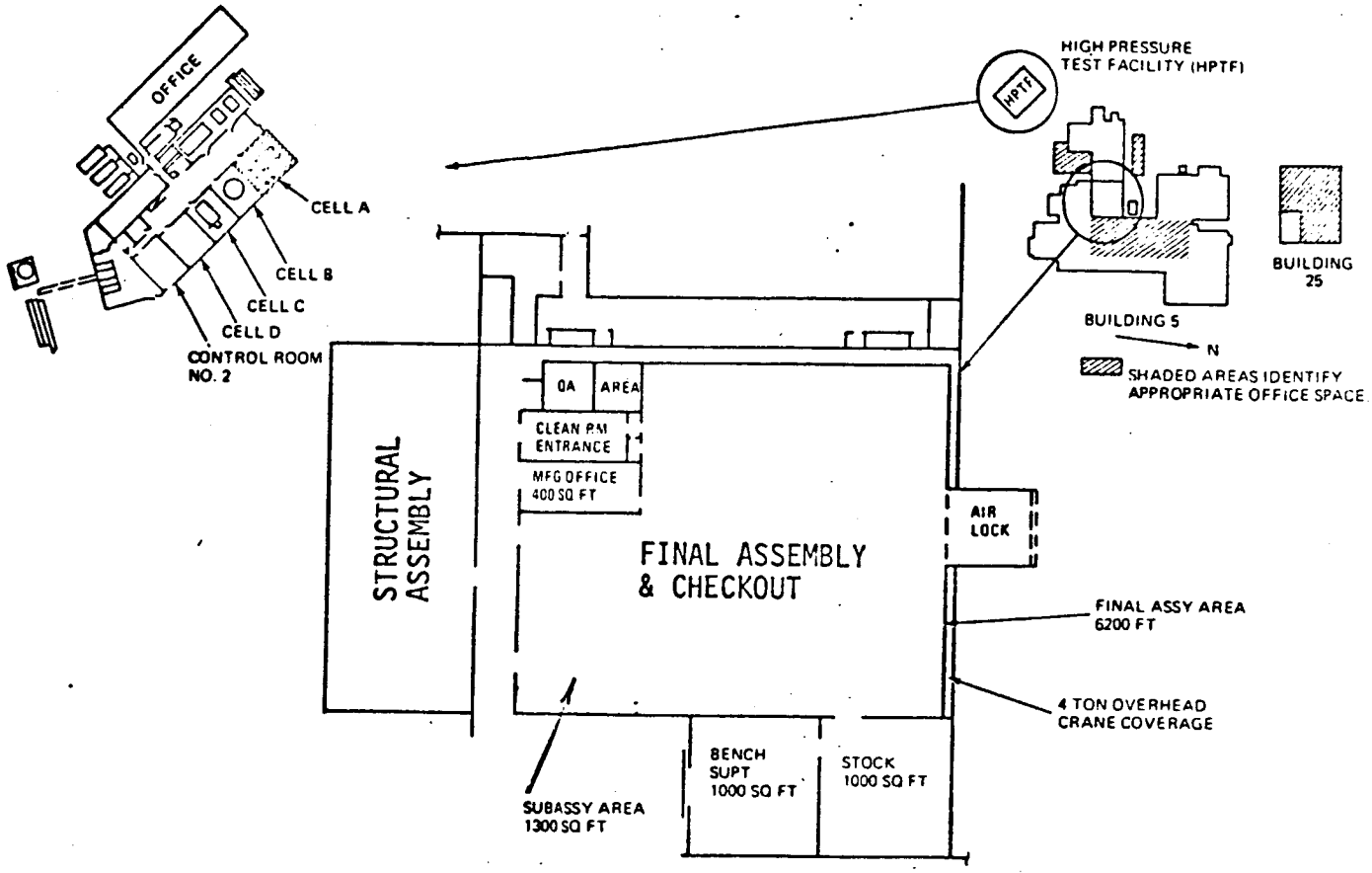
The Tug Spacecraft will be assembled in our existing Plant #5 Spacecraft Assembly Facility. This area, developed for the OAO, has the controlled environment necessary for contamination-free propulsion system assembly and is adjacent to the LM High Pressure Test Facility (HPTF) for fluid system calibration and acceptance test. All structural assembly will be accomplished adjacent to final assembly. The floor plan layout of the area and the floor space requirements are shown in Figure 8.4-5.

Subassembly and acceptance testing of fluid system modules will be accomplished in the Plant #2 Laminar flow clean room which has 4 booths and provisions for component cleaning, tube welding, x-ray inspection and high pressure component test.

The HPTF contains 4 test cells equipped with fluid distribution systems, instrumentation, remote controls and data reduction equipment for safely conducting high pressure fluid system testing.

The propellant tanks will be fabricated in the Plant #3 welding area. This area, developed for LM cabin welding has stake and boom welding equipment and provisions for dye penetrant, X-ray and ultrasonic inspection of pressure vessel quality welds.

Parts will be fabricated in specialized work areas in Plant #2 and #3 such as the press department, chemmilling, heat treat, machine shop and finishing facility.



Final Assembly Facility

FLOOR SPACE UTILIZATION

ACTIVITY	MAIN STAGE	KICK STAGE
FINAL ASSY & C/O	5,900 sq. ft.	10,900 sq. ft.
STRUCT ASSY.	8,300	6,300
TANK ASSY. (PL. #3)	3,800	-
TOTAL	18,000 sq. ft.	17,200 sq. ft.

Figure 8.4-5 II-8.4-17

8.4.4 Special Requirements

8.4.4.1 Critical Processes

Identification and control of critical processes are essential for assuring spacecraft integrity. Grumman corporate procedure M-120 and M-311 discipline the identification and documentation of the control requirement and provide for implementation through detailed shop instructions, inspection procedures and verification records. All processes are validated before being used in production. Personnel are trained, qualified, and certified for performing selected processes.

Our existing Manufacturing Engineering Process Standards (MEPS) for welding, brazing, crimping, finishing, structural bonding, contamination control etc. will apply to the majority of the Space Tug process requirements.

Special attention will be given to defining the critical process requirements for the titanium propellant tanks and the composite honeycomb outer shell.

Ten foot diameter titanium tanks have not been fabricated before and titanium tanks such as the 54" LM tanks are normally fabricated by welding machined forgings. Because of the high cost of developing 10 foot diameter forgings we are proposing to fabricate the tank domes of welded gore sections. Special processes will be required for tolerance control of weld joint fit-up, welding equipment power settings, repair procedures, heat treating, gore forming, chemical milling and finishing.

The outer shell of the spacecraft is designed of honeycomb panels with .012 inch thick graphite epoxy skins. We have extensive composites experience from our aircraft programs but expect that special techniques will be required to fabricate the thin skins which will be layed-up from .0025 inch graphite epoxy tape which is still in the development stage.

8.4.4.2 Vehicle Modification and Repair

In general, minor maintenance and repair of the spacecraft will be accomplished at the operational site. Activities requiring major modification to structure, subsystem installations or MPS tanks which require special tooling or facilities will be accomplished in the final assembly facility in Plant #5 Bethpage.

If extensive modification is required the major structural sections can be disassembled. The forward skirt attaches to the fuel tank frame with mechanical fasteners which can be removed to expose the forward end of the tank. The aft skirt joins the two tanks at the main frame of the aft tank and the fuel tank Y ring. Removing the mechanical fasteners at these points allows separating the tanks and removing them from the structure. To accomplish this level of dis-assembly for tank replacement the vehicle will be designed with mechanical joint connectors such as the Gamah or flange connectors used on LM spacecraft. Raychem cryofit fittings used on F-14 hydraulic systems and brazed fittings used on LM will also be used in applications where replacement or repair of subsystems is anticipated. Electrical harnesses and cables will also have end connectors to allow disconnecting equipment or disassembly of themajor spacecraft sections.

8.4.5 Summary Analysis/Philosophy

The primary manufacturing responsibility in this program phase has been to analyze the various configurations to determine the most cost effective combination of equipment, facilities, resources and schedule required to produce them. Initially the major cost drivers were identified and trade-off studies were conducted to provide inputs to the designers and the costing group. Producibility support was also provided to the designers to assure a cost effective balanced manufacturing program.

The integral titanium nested dome propellant tank is the major cost driver and manufacturing technology challenge in this configuration. We have reviewed Saturn, Titan, Centaur and LM manufacturing methods to establish minimum material gages, fabrication processes, tolerances and assembly procedures. Because of the large diameter (10 feet) we have elected to assemble the tank domes from welded gore sections instead of the usual one piece machined forgings.

Systems installation and checkout is the other main cost driver in this configuration. To reduce the impact of these activities on cost and schedule we will modularize subsystems as much as possible. This allows off-line build-up and parallel flow of the modules such as the helium pressurization unit and APS control valve package to provide better accessibility, more efficient work distribution and man loading, improved workmanship/quality and reduced total flow time. Modularization is of special importance for a reusable vehicle since the entire unit can be removed for maintenance and repair without impacting availability of the spacecraft.

8.4.6 Impact of IOC Date Two Years Earlier

Moving IOC two years earlier to December 1981 will require moving program start (ATP) at least an equivalent time. There is adequate time in the manufacturing schedule to meet the program milestones therefore any stretchout or reduction of elapsed time will be inefficient.

8.4.7 GSE Requirements

Ground support equipment is used to perform acceptance tests in the factory flow and to detect or diagnose malfunctions or monitor the functional performance status of systems, subsystems or equipment. The GSE is listed below and is described in volume 6 appendix E. Special handling equipment associated with manufacturing operations is identified in the tooling section 8.4.2.

Weight and C.G. equipment
LRU handling fixture
Induction brazing unit
Engine dolly
Battery container
Theodolite
Navigation base alignment gage
APS tank dolly
Auxiliary crane control
Vacuum test cart
GN_2 manifold and oxidizer storage unit
Pressurization Maintenance Unit (PMU)
Nitrogen conditioning cart
Transporter GN_2 storage
Cryo and blow-down equipment
Propellant loading control assembly (PLCA)
Propellant system checkout cart
Propellant system helium distribution assembly
Leak detector
APS transfer control assembly
GN_2 regulator unit
Communications test station S-band
Battery charger
Ground power supply
APS valve controller
Load bank
S-band uplink monitor
Communications test station L-band

8.5 SPECIAL PROGRAMMATICS

410AD-2 SPECIAL PROGRAMMATICS

The facing chart summarizes the salient features defined for implementing and managing Program 410AD-2 and indicates specific areas for government participation.

The main factors derived from our analysis of 410AD-2 include: defining the initial flight build up based on initial ground crew launch capability; timing DKS development for concurrent start to capture 1986 retrievals; performing early DKS flights with other launch vehicles; advancing Main Engine go ahead 6 months before the main stage to avoid a critical path; refurbishing the propulsion test article for operational use; and defining a fall back position for every identified risk.

Specific areas for government participation include: establishing Tug/Shuttle interface requirements before Orbiter design freeze; providing payload interface design requirements and mission model data; initiating required activities for Support Research and Technology; providing GFE systems and components (e.g., main engines, and DOD secure comm); supporting propulsion system testing and development and supporting integrated avionics hardware testing and related software development; providing required facilities and performing vehicle ground operations, flight operations and logistic support operations.

410AD-2 SPECIAL PROGRAMMATICS

- o PROGRAM IMPLEMENTATION AND MANAGEMENT
  - FLIGHT BUILD-UP SET BY ETR GROUND CREW LAUNCH CAPABILITY
  - DKS TIMED FOR CONCURRENT START TO CAPTURE 86 RETRIEVALS
  - EARLY DKS FLIGHTS PERFORMED WITH OTHER LAUNCH VEHICLES
  - MAIN ENGINE ATP ADVANCED 6 MONTHS TO AVOID CRITICAL PATH
  - PROPULSION ARTICLE REFURBED FOR FLIGHT
  - FALL BACK POSITION SHOWN FOR EVERY IDENTIFIED RISK

- o AREAS FOR GOVERNMENT PARTICIPATION
  - FIRM TUG/SHUTTLE INTERFACES BEFORE ORBITER PDR
  - PROVIDE PAYLOAD INTERFACE DESIGN REQUIREMENTS & MISSION MODEL DATA
  - INITIATE REQUIRED SR&T
  - SUPPORT SYSTEM TEST - AVIONICS HARDWARE/SOFTWARE, PROPULSION
  - PROVIDE GFE SYSTEMS & COMPONENTS, FACILITIES & LOGISTIC SUPPORT
  - PERFORM VEHICLE GROUND AND FLIGHT OPERATIONS

GRUMMAN

8.6 COST DATA

Included in this report are cost data for DDT & E,Production and Operation Phases of Concept 410AD-2. In sufficing reporting requriements this section is divided as follows:

- Storable Space Tug System Project expected cost--Spares Cost (INT 7 OPS)--First Unit Cost (Data Forms A1,2 and 3, subparagraph No's 8.6.1, 8.6.2 & 8.6.3) (Computer P/O)

- Storable Space Tug Funding Schedules--DDT 7 E,Production and Operations (Data Forms C, subparagraph 8.6.4,8.6.5, 8.6.6 and 8.6.7.

- First Unit Production Cost per WBS (including Avionics to level 7). Main Stage and Auxiliary Stage(s), (subparagraph 8.6.8).

- 410AD-2 Average Cost/Flight (subparagraph 8.6.9).

- Storable Space Tug System Project Cost Estimate data by SOW-DDT & E, Production and Operations. (Data Form T (SOW'S) subparagraph 8.6.10).

- Form B (Technical Characteristics) subparagraph 8.6.11.

CONCEPT 410AD-2

OPTION 2

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STORABLE SPACE TUG SYSTEM PROJECT
EXPECTED COST - SPARES COST(INT + OPS) - FIRST UNIT COST
(COSTS IN 1973 CONSTANT DOLLARS (000))

WBS	LEVEL	EXPECTED COST DDT+E 4	5	6	EXPECTED COST PRODUCTION 4	5	6	INITIAL SPARES	1ST UNIT COST	EXPECTED COST OPN SP/OPS 4	5	6
0100	PROJECT MGMT	12703.			7114.				1104.	2733.		
0110	COST/PERF MGMT		1905.			1067.			166.		911.	
0120	PROJECT DIRECTION		9781.			5478.			850.		911.	
0130	INFO MGMT		1016.			569.			88.		911.	
0200	SYS ENG + INTEGR	15243.			8003.				1242.	5468.		
0210	TUG SYS ENG		12195.						0.		1367.	
0220	SHUTTLE INTERFACE		1524.						0.		1367.	
0230	PAYLOAD INTERFACE		1524.						0.		1367.	
0240	SUST ENG					0.			1242.		1367.	
0300	TUG VEH MAIN STAGE	159634.			87869.			7729.	11113.	12680.		
0310	STRUCTURES		18801.			11223.		1122.	1741.		1122.	
0311	FUEL TNK+SPRT			5651.			3726.	373.	578.			373.
0312	OX TANK +SPRT			6817.			4375.	438.	679.			438.
0313	BODY STRUCT			2511.			931.	93.	144.			93.
0314	THRUST STRUCT			480.			216.	22.	33.			22.
0315	METEOROID SHLD			143.			80.	8.	12.			8.
0316	PAYLOAD INTFCE			3199.			1895.	190.	294.			190.
0317	INSTL,ASSY+C/O			0.			0.	0.	0.			0.
0320	THERMAL INSULTN		149.			1134.		56.	176.		56.	
0321	FUEL TANK INSUL			57.			556.	56.	86.			56.
0322	OX TANK INSUL			92.			578.	0.	90.			0.
0323	PURGE SYS INSUL			0.			0.	0.	0.			0.
0324	CONT SYS			0.			0.	0.	0.			0.
0325	INSTL,ASSY+C/O			0.			0.	0.	0.			0.
0330	AVIONICS		57569.			42263.		4407.	4696.		8265.	
0331	DATA MGMT			5880.			7374.	1220.	819.			2430.
0332	C N + C			24320.			19220.	1920.	2136.			3621.
0333	COMMUNICATIONS			9450.			8482.	516.	942.			924.
0334	INSTRUMENTATION			0.			0.	0.	0.			0.
0335	ELEC PWR			16776.			5137.	751.	571.			1290.
0336	PWR DIST + CONT			1143.			2049.	0.	228.			0.
0337	INSTL,ASSY+C/O			0.			0.	0.	0.			0.
0340	PROPULSION		71049.			18264.		1986.	2181.		3079.	
0341	MAIN ENGINE			59000.			5832.	1760.	800.			2625.
0342	MAIN ENGINE SPT			7563.			3825.	75.	425.			150.
0343	ACPS ENGINE			3000.			5080.	50.	564.			100.
0344	ACPS ENGINE SPT			1486.			3527.	111.	392.			204.
0345	INSTL,ASSY+C/O			0.			0.	0.	0.			0.
0350	ORBITER INTERFACE		6981.			1582.		158.	623.		158.	
0351	STRUCTURE			4900.			675.	68.	266.			68.
0352	INTERFACE PNLS			2081.			906.	91.	357.			91.
0353	PURGE PROVISION			0.			0.	0.	0.			0.
0354	ABORT PROVISION			0.			0.	0.	0.			0.
0355	INSTL,ASSY+C/O			0.			0.	0.	0.			0.

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WBS	LEVEL 4	5	6	4	5	6	INITIAL SPARES	1ST UNIT COST	4	5	6
	EXPECTED COST DDT+E			EXPECTED COST PRODUCTION					EXPECTED COST OPN SP/OPS		
0360 DROP TANKS		0.			0.		0.	0.		0.	
0361 STRUCTURES			0.			0.	0.	0.			0.
0362 THERMAL INSUL			0.			0.	0.	0.			0.
0363 PROP SPRT SYS			0.			0.	0.	0.			0.
0364 INSTL.ASSY+C/O			0.			0.	0.	0.			0.
0370 FINAL ASSY + C/O		5086.			13404.		0.	1695.		0.	
0371 FINAL ASSY			5086.			13404.	0.	1695.			0.
0372 CHECKOUT			0.			0.	0.	0.			0.
0400 TUG VEH AUX STAGE	26394.			102695.			7896.	3485.	7896.		
0410 STRUCTURES		0.			0.		0.	0.		0.	
0411 FUEL TNK+SPRT			0.			0.	0.	0.			0.
0412 OX TANK+SPRT			0.			0.	0.	0.			0.
0413 BODY STRUCT			0.			0.	0.	0.			0.
0414 THRUST STRUCT			0.			0.	0.	0.			0.
0415 METEOROID SHLD			0.			0.	0.	0.			0.
0416 PAYLOAD INTERFC			0.			0.	0.	0.			0.
0417 INSTL.ASSY+C/O			0.			0.	0.	0.			0.
0420 THERMAL INSUL		0.			0.		0.	0.		0.	
0421 FUEL TANK INSUL			0.			0.	0.	0.			0.
0422 OX TANK INSUL			0.			0.	0.	0.			0.
0423 PURGE SYS INSUL			0.			0.	0.	0.			0.
0424 CONT SYS			0.			0.	0.	0.			0.
0425 INSTL.ASSY+C/O			0.			0.	0.	0.			0.
0430 AVIONICS		0.			0.		0.	0.		0.	
0431 DATA MGMT			0.			0.	0.	0.			0.
0432 G N + C			0.			0.	0.	0.			0.
0433 COMMUNICATIONS			0.			0.	0.	0.			0.
0434 INSTRUMENTATION			0.			0.	0.	0.			0.
0435 ELEC PWR			0.			0.	0.	0.			0.
0436 PWR DIST + CONT			0.			0.	0.	0.			0.
0437 INSTL.ASSY+C/O			0.			0.	0.	0.			0.
0440 PROPULSION		0.			0.		0.	0.		0.	
0441 MAIN ENGINE			0.			0.	0.	0.			0.
0442 MAIN ENGINE SPT			0.			0.	0.	0.			0.
0443 ACPS ENGINE			0.			0.	0.	0.			0.
0444 ACPS ENGINE SPT			0.			0.	0.	0.			0.
0445 INSTL.ASSY+C/O			0.			0.	0.	0.			0.
0450 INTERSTAGE INTRFC		0.			0.		0.	0.		0.	
0451 STRUCTURE			0.			0.	0.	0.			0.
0452 SEP SYS			0.			0.	0.	0.			0.
0453 INSTL.ASSY+C/O			0.			0.	0.	0.			0.
0460 DROP TANK		0.			0.		0.	0.		0.	
0461 STRUCTURE			0.			0.	0.	0.			0.
0462 THERMAL INSUL			0.			0.	0.	0.			0.
0463 PROP SPT SYS			0.			0.	0.	0.			0.
0464 INSTL.ASSY+C/O			0.			0.	0.	0.			0.
0470 RDM		0.			0.		0.	0.		0.	

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WBS	LEVEL	EXPECTED COST DDT+E 4	5	6	EXPECTED COST PRODUCTION 4	5	6	INITIAL SPARES	1ST UNIT COST	EXPECTED COST OPN SP/OPS 4	5	6
0471	STRUCTURE			0.			0.	0.	0.			0.
0472	THERM CONT			0.			0.	0.	0.			0.
0473	AVIONICS			0.			0.	0.	0.			0.
0474	PROPULSION			0.			0.	0.	0.			0.
0475	RDM ASSY+C/O			0.			0.	0.	0.			0.
0480	AKS		15340.			15079.		878.	1360.		878.	
0481	STRUCTURE			4940.			3506.	163.	374.			163.
0482	SRM			1680.			2971.	260.	68.			260.
0483	AVIONICS			5000.			5729.	401.	611.			401.
0484	PROPULSION			459.			928.	54.	99.			54.
0485	AKS ASSY+C/O			3261.			1944.	0.	207.			0.
0490	DKS		11054.			87616.		7018.	2125.		7018.	
0491	STRUCTURE			5300.			15034.	775.	400.			775.
0492	SRM			0.			10288.	2428.	68.			2428.
0493	AVIONICS			3185.			45644.	3529.	1214.			3529.
0494	PROPULSION			219.			4465.	286.	119.			286.
0495	DKS ASSY+C/O			2350.			12186.	0.	324.			0.
04100	CACHE TANK		0.			0.		0.	0.		0.	
04101	STRUCTURE			0.			0.	0.	0.			0.
04102	THERM CONT			0.			0.	0.	0.			0.
04103	AVIONICS			0.			0.	0.	0.			0.
04104	PROPULSION			0.			0.	0.	0.			0.
04105	CACHE ASSY+C/O			0.			0.	0.	0.			0.
04110	FINAL ASSY + C/O		0.			0.		0.	0.		0.	
04111	FINAL ASSY			0.			0.	0.	0.			0.
04112	CHECKOUT			0.			0.	0.	0.			0.
0500	LOGISTICS	6328.			6308.				6308.			
0510	TRANSPORT+HANDLG		0.			580.			580.			
0520	TRAINING		6328.			4128.			4128.			
0521	SIM+EQUIPMENT			1950.			1950.		1950.			
0522	GROUND CREW			2178.			2178.		2178.			
0523	FLT OPS CREW			2200.			0.		0.			
0530	WAREHSG+INV CONT		0.			1600.			1600.			

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WBS	LEVEL 4	5	6	4	5	6			4	5	6
	EXPECTED COST DDT+E			EXPECTED COST PRODUCTION			INITIAL SPARES	1ST UNIT COST	EXPECTED COST OPN SP/OPS		
0600 FACILITIES	6557.			156.					748.		
0610 MANUFACTURING		155.			121.					0.	
0611 DES/CONSTR			155.								
0612 ACT/MAINT			0.			121.					0.
0620 TEST		242.			35.					0.	
0621 DES/CONST			242.								
0622 ACT/MAINT			0.			35.					0.
0630 1ST TR MAINT+REF		2914.			0.					332.	
0631 DES/CONST			2914.								
0632 ACT/MAINT			0.			0.					332.
0640 ETR LAUNCH		475.			0.					97.	
0641 DES/CONST			475.								
0642 ACT/MAINT			0.			0.					97.
0650 2ND TR MAINT+REF		2648.			0.					222.	
0651 DES/CONST			2648.								
0652 ACT/MAINT			0.			0.					222.
0660 WTR LAUNCH		523.			0.					97.	
0661 DES/CONST			523.								
0662 ACT/MAINT			0.			0.					97.
0700 GSE	26430.			2910.			1018.		3980.		
0710 MFG GSE		2100.									
0711 HARDWARE											
0712 SITE ACT											
0713 MAINT											
0714 SOFTWARE											
0720 ETR GSE		17730.			0.		0.			1320.	
0721 HARDWARE			15430.			0.	0.				
0722 SITE ACT			2300.								
0723 MAINT			0.								1320.
0724 SOFTWARE			0.								
0730 WTR GSE		0.			2910.		1018.			2660.	
0731 HARDWARE			0.			2910.	1018.				
0732 SITE ACT			0.								
0733 MAINT			0.								2660.
0734 SOFTWARE			0.								

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WBS	LEVEL 4	EXPECTED COST DDT+E 5	6	EXPECTED COST PRODUCTION 4	5	6	INITIAL SPARES	1ST UNIT COST	EXPECTED COST OPN SP/OPS 4	5	6
0740 FL OP NASA		3300.			0.		0.			0.	
0741 HARDWARE			3300.			0.	0.				
0742 SITE ACT			0.								
0743 MAINT			0.								0.
0744 SOFTWARE			0.								
0750 FL OP DOD		3300.			0.		0.			0.	
0751 HARDWARE			3300.			0.	0.				
0752 SITE ACT			0.								
0753 MAINT			0.								0.
0754 SOFTWARE			0.								
0800 VEHICLE TEST	96522.										
0810 GND TEST HARDWARE		12064.									
0811 PTV/BATTLESHIP			2383.								
0812 MAJOR TST ART			9181.								
0813 MOCKUPS			500.								
0820 GND TEST OPS		13100.									
0830 FLT TEST HARDWARE		14648.									
0840 FLT TEST OPS		56710.									
0900 LAUNCH OPS WTR									6704.		
0910 LAUNCH SITE SVC										0.	
0920 TUG/SHUTTLE MATG										580.	
0930 PRELAUNCH C/O										1080.	
0940 COUNTDOWN										34.	
0950 FLUID+GASES										3100.	
0960 POST FLT SAFING										1910.	
1000 LAUNCH OPS ETR									19350.		
1010 LAUNCH SITE SVC										0.	
1020 TUG/SHUTTLE MATG										1168.	
1030 PRELAUNCH C/O										2178.	
1040 COUNTDOWN										70.	
1050 FLUID+GASES										12090.	
1060 POST FLT SAFING										3844.	
1100 FLT OPS DOD	5080								42810.		
1110 MISSION PLAN		4090								13440.	
1120 FLT CONT		420								13620.	
1130 FLT EVALUATION		570								2200.	
1140 FLT SPT SOFTWARE										13550.	
1200 FLT OPS NASA	41840								63000.		
1210 MISSION PLAN		10710								17320.	
1220 FLT CONT		860								15470.	
1230 FLT EVALUATION		540								2360.	
1240 FLT SPT SOFTWARE		29730								27850.	

NOTE
THESE COSTS INCLUDED
IN VEHICLE TEST.

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WBS	LEVEL	EXPECTED COST DDT+E 4	5	6	EXPECTED COST PRODUCTION 4	5	6	INITIAL SPARES	1ST UNIT COST	EXPECTED COST CPN SP/OPS 4	5	6
1300 REF+INT 1ST TR										17232.		
1310	SCHED MAINT+REF										2066.	
1320	UNSCHED MAINT+REF										2164.	
1330	POST MAINT C/O										708.	
1340	TUG/PAYLOAD MATG										1132.	
1350	REF RQMTS PLANNG										162.	
1360	DEPOT MAINT										11000.	
1400 REF+INT 2ND TR										24640.		
1410	SCHED MAINT+REF										4158.	
1420	UNSCHED MAINT+REF										4356.	
1430	POST MAINT C/O										1426.	
1440	TUG/PAYLOAD MATG										2278.	
1450	REF RQMTS PLANNG										322.	
1460	DEPOT MAINT										12100.	
SPACE TUG TOTALS		350212.			215055.			16644.	23252.	207241.		
32A=	350212.	323=	231698.		32C=	207241.		320=	789151.			

II-S.6-8

MOORE BUSINESS FORMS, INC. NO. FORM 1412 T

DEFINITION OF SPREAD

FUNCTION CODES

CODE	DEFINITION
4	Beta Distribution - A = 0.79, B = 0.15 Peak Funding occurs at 28.0% of Time, 73.0% of Dollars consumed at 50% of Time.
6	Beta Distribution - A = 0.68, B = 0.17 Peak Funding occurs at 30.0% of Time, 67.0% of Dollars consumed at 50% of Time.
9	Beta Distribution - A = 0.55, B = 0.05 Peak Funding occurs at 34.0% of Time, 55.0% of Dollars consumed at 50% of Time.
11	Beta Distribution - A = 0.58, B = 0.38 Peak Funding occurs at 34.0% of Time, 67.0% of Dollars consumed at 50% of Time.
16	Beta Distribution - A = 0.47, B = 0.21 Peak Funding occurs at 40.0% of Time, 55.0% of Dollars consumed at 50% of Time.
26	Beta Distribution - A = 0.16, B = 0.45 Peak Funding occurs at 58.0% of Time, 43.0% of Dollars consumed at 50% of Time.

STORABLE SPACE TUG SYSTEM PROJECT SUPPORTING COST DATA FORM A1, A2, & A3 INFORMATION

CONCEPT 410AD-2

WBS	DDT&E FORM A1 Design Rating	Config Rating	Td	Ts	SPD Funct	PRODUCTION FORM A2 No Units	Ref Unit	Config Rating	Td	Ts	SPD Funct	LRN IND	OPERATIONS FORM A3 SPD Funct
0100 PROJECT MGM'T		3			32			3			32		32
0110 Cost/Perf. Mgm't		3			32			3			32		32
0120 Project Direction		3			32			3			32		32
0130 Information Mgm't		3			32			3			32		32
0200 SYS. ENG & INTEG		3			11			3			32		32
0210 Tug Sys Engr		3			11			3					32
0220 Shuttle Interface		3			11			3					32
0230 Payload Interface		3			11			3					32
0240 Sustaining Engr.		3			11			3					32
0310 STRUCTURES	1	4	34	50	4	9	1	4	18	36	4	90%	32
0311 Fuel Tnk & Supt	1	4	34	50	4	9	1	4	18	36	4	90%	32
0312 OX Tnk & Supt	1	4	34	50	4	9	1	4	18	36	4	90%	32
0313 Body Structure		4	34	50	4	9	1	4	18	36	4	90%	32
0314 Thrust Structure	1	4	34	50	4	9	1	4	18	36	4	90%	32
0315 Meteroid Shield	1	4	34	50	4	9	1	4	18	36	4	90%	32
0316 Payload Interface	1	4	34	50	4	9	1	4	18	36	4	90%	32
0317 Installation, Assmbly, D/O													
0320 THERMAL INSULATION	3	3	31	50	16	9	1	3	18	30	4	90%	32
0321 Fuel Tank Insulation	3	3	31	50	16	9	1	3	18	30	4	90%	32
0322 Ox Tank Insulation	3	3	31	50	16	9	1	3	18	30	4	90%	
0323 Purge Syst. Insulation													
0324 Control System													
0325 Instl. Assy & C/Out													
0330 AVIONICS			37	50	4	9	1		20	32	4		32
0331 Data Management	4	4	30	50	4	9	1	4	20	32	4		32
0332 GN&C	1	2	33	50	4	9	1	2	20	32	4		32
0333 Communications	1	2	33	50	4	9	1	2	20	32	4		32
0334 Instrumentation													
0335 Electr Power	3	3	37	50	4	9	1	3	20	32	4		32
0336 Power Dist & Contr	5	4	30	50	4	9	1	4	20	32	4		
0337 Instl. Assmbly & C/O													
0340 PROPULSION			33	50	4	9	1		20	35	4	90%	32
0341 Main Engine (CFE)	1		33	50	4	9	1		20	35	4	90%	32
0342 Main Eng. Supt	5		33	50	4	9	1		20	35	4	90%	32
0343 ACPS Engine	4		33	50	4	9	1		20	35	4	90%	32
0344 ACPS Eng. Supt	4		33	50	4	9	1		20	35	4	90%	32
0345 Instl Assmbly & C/O													

WBS	DDT&E FORM A1 Design Rating	Config Rating	Td	Ts	SPD Funct	PRODUCTION FORM A2 No Units	Ref Unit	Config Rating	Td	Ts	SPD Funct	LRN IND	OPERATIONS FORM A3 SPD Funct
0350 ORBITER INTERFACE	1	4	29	50	9	3	1	4	17	32	4	90%	32
0351 Structures		4	29	50	9	3	1	4	17	32	4	90%	32
0352 Interface Panels		4	29	50	9	3	1	4	17	32	4	90%	32
0353 Purge Provisions													
0354 Abort Provisions													
0355 Instal, Assy & C/O													
0360 DROP TANK		N/A					N/A						
0361 Structures													
0362 Thermal Insulation													
0363 Prop Suppt System													
0364 Instl, Assy & C/O													
0370 FINAL ASSY & C/O		3	20	36	26	9	1	3	11	15	4		
0371 Final Assy		3	20	36	26	9	1	3	11	15	4		
0372 Checkout													

AUXILIARY STAGE

STORABLE SPACE TUG SYSTEM PROJECT SUPPORTING
COST DATA FORM A1, A2, & A3 INFORMATION

WBS	DDT&E FORM A1					PRODUCTION FORM A2						OPERATIONS FORM A3
	Design Rating	Config Rating	Td	Ts	SPD Funct	No Units	Ref Unit	Config Rating	Td	Ts	SPD Funct	LRN IND	SPD Funct
0410 STRUCTURES	N/A					N/A							
0411 Fuel Tnk & Suppt													
0412 Ox Tnk & Suppt													
0413 Body Structure													
0414 Thrust Structure													
0415 Meteroid Shield													
0416 Payload Interface													
0417 Installation Ass'y C/O													
0420 THERMAL INSULATION													
0421 Fuel Tank Insulation													
0422 Ox Tnk Insulation													
0423 Purge Syst Insulation													
0424 Control System													
0425 Instl Ass'y & C/O													
0430 AVIONICS													
0431 Data Management													
0432 C&C													
0433 Communications													
0434 Instrumentation													
0435 Electric Power													
0436 Power Dist & Contr													
0437 Instl Ass'y & C/O													
0440 PROPULSION													
0441 Main Eng (CFE)													
0442 Main Eng Suppt													
0443 ACPS Engine													
0444 ACPS Eng Suppt													
0445 Instl Ass'y & C/O													
0450 ORBITER INTERFACE													
0451 Structures													
0452 Separation System													
0453 Instl Ass'y & C/O													

STORABLE SPACE TUG SYSTEM PROJECT SUPPORTING
COST DATA FORM A1, A2, & A3 INFORMATION

WBS	DDT&E FORM A1					PRODUCTION FORM A2							OPERATIONS FORM A3
	Design Rating	Config Rating	Td	Ts	SPD Funct	No Units	Ref Unit	Config Rating	Td	Ts	SPD Funct	LRN IND	SPD Funct
0460 DROP TANK													
0461 Structure													
0462 Thermal Insulation													
0463 Propulsion Suppt System													
0464 Instl, Ass'y & C/O													
0470 RETRIEVAL DELAY MODULE													
0471 Structure													
0472 Therm Control													
0473 Avionics													
0474 Propulsion													
0475 PDM Ass'y & C/O													
0480 APOGEE KICK STAGE			32	50	4	13	1		28	35	4	90%	32
0481 Structure	1	4	32	50	4	13	1	4	28	35	4	90%	32
0482 SRM	5	4	32	50	4	13	1	4	28	35	4	90%	32
0483 Avionics	4	3	32	50	4	13	1	3	28	35	4	90%	32
0484 Propulsion	4	3	32	50	4	13	1	3	28	35	4	90%	32
0485 AKS Ass'y & C/O	4	3	32	50	4	13	1	3	28	35	4	90%	
0490 DE-ORBIT KICK STAGE			32	50	4	71	1		15	35	4	90%	32
0491 Structure	1	4	32	50	4	71	1	4	15	35	4	90%	32
0492 Therm Control									15	35	4	90%	32
0493 Avionics	4	3	32	50	4	71	1	3	15	35	4	90%	32
0494 Propulsion	4	3	32	50	4	71	1	3	15	35	4	90%	32
0495 De-Orbit Ass'y & C/O	4	3	32	50	4	71	1	3	15	35	4	90%	
04100 CACHE TANK			N/A					N/A					
04101 Structure													
04102 Therm Control													
04103 Avionics													
04104 Propulsion													
04105 Cache Ass'y & C/O													
04110 FINAL ASS'Y & C/O								3	31	35	16		
04111 Final Ass'y								3	31	35	16		
04112 Checkout													

STORABLE SPACE TUG SYSTEM PROJECT SUPPORTING COST DATA FORM A1, A2, & A3 INFORMATION

WBS	DDT&E FORM A1 Design Rating	Config Rating	Td	Ts	SPD Funct	PRODUCTION FORM A2 No Units	Ref Unit	Config Rating	Td	Ts	SPD Funct	LRN IND	OPERATIONS FORM A3 SPD Funct
0510 TRANSP. & HANDLING								3			32		
0520 TRAINING	3				32			3			32		
0521 Simulat & Equip	3				32			3			32		
0522 Ground Crew	3				32			3			32		
0523 Flt. Oper. Crew	3				32								
0530 WAREHOUSE/INV. COST													
0610 MANUFACTURING FACILITIES	3		10	47	6			3			6		
0611 Des/Constr.	3		10	47	6								
0612 Act/Maint								3			6		
0620 TEST FACILITIES	3		35	47	32			3			4		
0621 Des/Constr.	3		35	47	32								
0622 Act/Maint.								3			4		
0630 1st TR MAINT. & REF.	3		42	47	32								32
0631 Des/Constr	3		42	37	32								32
0632 Activ/Maint													
0640 ETR LAUNCH FACILITIES	3		42	47	4								32
0641 Design/Constr.	3		42	47	4								32
0642 Activ/Maint.													
0650 2nd TR MAINT/REF	3		42	47	32								32
0651 Des/Constr	3		42	47	32								32
0652 Activ/Maint.													
0660 WTR LAUNCH	3		42	47	4								32
0661 Des/Constr	3		42	47	4								32
0662 Activ/Maint													
0710 MFG. GSE													
0711 Hardware													
0712 Site Activ													
0713 Maint													
0714 Software													
0720 EAST TEST RANGE	3		35	47	4								
0721 Hardware	3		35	47	4								
0722 Site Activation	3		35	47	4								
0723 Maint													32
0724 Software													

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STORABLE SPACE TUG SYSTEM PROJECT SUPPORTING
COST DATA FORM A1, A2, & A3 INFORMATION

WBS	DDT&E FORM A1 Design Rating	Config Rating	Td	Ts	SPD Funct	PRODUCTION FORM A2 No Units	Ref Unit	Config Rating	Td	Ts	SPD Funct	LRN IND	OPERATIONS FORM A3 SPD Funct
0730 WEST TEST RANGE GSE													
0731 Hardware								3	35	47	4		
0732 Site Activation								3	35	47	4		
0733 Maint.													32
0734 Software													
0740 FLIGHT OPER. NASA	3		43	47	4								
0741 Hardware	3		43	47	4								
0742 Site Activ													
0743 Maint													
0744 Software													
0750 FLIGHT OPER. D.O.D.	3		46	47	4								
0751 Hardware	3		46	47	4								
0752 Site Activ													
0753 Maint													
0754 Software													
0810 GROUND TEST H'WARE	3		31	35	32								
0811 PTV/Battleship	3		31	35	32								
0812 Major Test Art	3		31	35	32								
0813 Mockups	3		31	35	32								
0820 GROUND TEST OPS	3		31	35	32								
0830 Flt Test Hardware	3		31	35	32								
0840 Flt. Test Operi.	3		31	35	32								
0900 LAUNCH OPS WTR													
0910 Launch Site SVC													32
0920 Tug/Shuttle Matg													
0930 PreLaunch C/O													32
0940 Countdown													32
0950 Fluid & Gases													32
0960 Post Flt. Safing													32
1000 LAUNCH OPS ETR													32
1010 Launch Site SVC													
1020 Tug/Shuttle Matg													32
1030 Prelaunch C/O													32
1040 Countdown													32
1050 Fluid & Gases													32
1060 Post Flt. Safing													32

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STORABLE SPACE TUG SYSTEM PROJECT SUPPORTING
COST DATA FORM A1, A2, & A3 INFORMATION

WBS	DDT&E FORM A1					PRODUCTION FORM A2						OPERATIONS FORM A3
	Design Rating	Config Rating	Td	Ts	SPD Funct	Design Rating	Config Rating	Td	Ts	SPD Funct	LRN IND	SPD Funct
1100 FLT OPS DOD												32
1110 Mission Plan												32
1120 Flt/Contr												32
1130 Flt Evaluation												32
1140 Flt SPT Software												32
1200 FLT OPS NASA												
1210 Mission Plan												32
1220 Flt Contr												32
1230 Flt Evaluation												32
1240 Flt SPT Software												32
1300 REF INT 1st TR												32
1310 Sched Maint & Ref												32
1320 Unsched Maint & Ref												32
1330 Post Main C/O												32
1340 Tug/Payload Matg												32
1350 Ref Requirements Planning												32
1360 Depot Maint												
1400 REF INT 2nd TR												32
1410 Sched Maint & Ref												32
1420 Unsched Maint & Ref												32
1430 Post Maint C/O												32
1440 Tug/Payload Matg												32
1450 Ref Requirements Planning												32
1460 Depot Maint												

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STORABLE SPACE TUG SYSTEM PROJECT
FUNDING SCHEDULE DATA BY FISCAL YEAR

DATA FORM C

DDTE (ALL COSTS IN MILLIONS)

FISCAL YEARS

WBS	TITLE	TOTAL	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
100	PROJECT MGMT	12.7	0.0	0.0	0.0	0.0	1.65	2.99	3.19	3.12	1.75	0.0	0.0	0.0	0.0	0.0	0.0	0.0
200	SYS ENG + INTEG	15.2	0.0	0.0	0.0	0.0	2.66	5.09	4.48	2.46	0.56	0.0	0.0	0.0	0.0	0.0	0.0	0.0
300	TUG MAIN STAGE	159.6	0.0	0.0	0.0	0.0	46.27	65.06	37.04	10.48	0.78	0.0	0.0	0.0	0.0	0.0	0.0	0.0
310	STRUCTURE	18.8	0.0	0.0	0.0	0.0	5.76	7.93	4.17	0.94	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
320	THERMAL INSUL	0.1	0.0	0.0	0.0	0.0	0.03	0.05	0.05	0.02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
330	AVIONICS	57.6	0.0	0.0	0.0	0.0	17.65	24.27	12.78	2.87	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
340	PROPULSION	71.0	0.0	0.0	0.0	0.0	21.78	29.95	15.77	3.55	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
350	INTERFACE	7.0	0.0	0.0	0.0	0.0	1.05	1.85	1.78	1.52	0.78	0.0	0.0	0.0	0.0	0.0	0.0	0.0
360	DROP TANK																	
370	FINAL ASSY	5.1	0.0	0.0	0.0	0.0	0.0	1.01	2.49	1.59	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
400	TUG AUX STAGE	26.4	0.0	0.0	0.00	0.00	6.71	10.18	6.55	2.49	0.46	0.0	0.0	0.0	0.0	0.0	0.0	0.0
410	STRUCTURE																	
420	THERMAL INSUL																	
430	AVIONICS																	
440	PROPULSION																	
450	INTERSTAGE																	
460	DROP TANK																	
470	RDM																	
480	AKS	15.3	0.0	0.0	0.0	0.0	3.32	5.52	4.10	1.94	0.46	0.0	0.0	0.0	0.0	0.0	0.0	0.0
490	DKS	11.1	0.0	0.0	0.0	0.0	3.39	4.66	2.45	0.55	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4100	CACHE																	
4110	FINAL ASSY	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
500	LOGISTICS	6.3	0.0	0.0	0.0	0.0	0.82	1.49	1.59	1.55	0.87	0.0	0.0	0.0	0.0	0.0	0.0	0.0
600	FACILITIES	7.0	0.0	0.0	0.0	0.0	1.23	2.04	1.92	1.34	0.42	0.0	0.0	0.0	0.0	0.0	0.0	0.0
610	MANUFACTURING	0.2	0.0	0.0	0.0	0.0	0.03	0.05	0.04	0.02	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
620	TEST	0.2	0.0	0.0	0.0	0.0	0.07	0.10	0.07	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
630	1ST MAIN/REF	2.9	0.0	0.0	0.0	0.0	0.38	0.69	0.73	0.71	0.40	0.0	0.0	0.0	0.0	0.0	0.0	0.0
640	ETR LAUNCH	0.5	0.0	0.0	0.0	0.0	0.10	0.17	0.13	0.06	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0
650	2ND MAIN/REF	2.6	0.0	0.0	0.0	0.0	0.49	0.81	0.83	0.52	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
660	WTR LAUNCH	0.5	0.0	0.0	0.0	0.0	0.16	0.22	0.12	0.03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
700	GND SUPP EQUIP	26.4	0.0	0.0	0.0	0.0	7.83	10.78	5.91	1.72	0.20	0.0	0.0	0.0	0.0	0.0	0.0	0.0
710	MFG GSE	2.1	0.0	0.0	0.0	0.0	0.97	0.92	0.21	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
720	ETR GSE	17.7	0.0	0.0	0.0	0.0	5.43	7.47	3.94	0.88	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
730	WTR GSE																	
740	FLT OPS NASA	3.3	0.0	0.0	0.0	0.0	0.71	1.19	0.88	0.42	0.10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
750	FLT OPS DOD	3.3	0.0	0.0	0.0	0.0	0.71	1.19	0.88	0.42	0.10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
800	VEHICLE TEST	96.5	0.0	0.0	0.0	0.0	0.0	3.43	31.72	40.05	21.32	0.0	0.0	0.0	0.0	0.0	0.0	0.0
810	GND TEST HWRE	12.1	0.0	0.0	0.0	0.0	0.0	3.43	5.03	3.60	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
820	GND TEST OPS	13.1	0.0	0.0	0.0	0.0	0.0	0.0	6.43	6.67	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
830	FLT TEST HWRE	14.6	0.0	0.0	0.0	0.0	0.0	0.0	4.16	6.11	4.38	0.0	0.0	0.0	0.0	0.0	0.0	0.0
840	FLT TEST OPS	56.7	0.0	0.0	0.0	0.0	0.0	0.0	16.10	23.66	16.94	0.0	0.0	0.0	0.0	0.0	0.0	0.0
900	LAUNCH OPS WTR																	
1000	LAUNCH OPS ETR																	
1100	FLIGHT OPS DOD																	
1200	FLIGHT OPS NASA																	
1300	REF + INT TR-1																	
1400	REF + INT TR-2																	
	TOTALS	350.2	0.0	0.0	0.00	0.00	67.18	101.06	92.40	63.21	26.35	0.0	0.0	0.0	0.0	0.0	0.0	0.0

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STORABLE SPACE TUG SYSTEM PROJECT
FUNDING SCHEDULE DATA BY FISCAL YEAR

PROD (ALL COSTS IN MILLIONS) DATA FORM C

FISCAL YEARS

WBS	TITLE	TOTAL	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
100	PROJECT MGMT	7.1	0.0	0.0	0.0	0.0	0.0	0.0	0.93	1.68	1.79	1.75	0.98	0.0	0.0	0.0	0.0	0.0
200	SYS ENG + INTEG	8.0	0.0	0.0	0.0	0.0	0.0	0.0	1.04	1.89	2.01	1.96	1.10	0.0	0.0	0.0	0.0	0.0
300	TUG MAIN STAGE	95.6	0.0	0.0	0.0	0.0	0.0	0.0	14.22	26.87	24.71	16.81	8.84	3.40	0.74	0.02	0.0	0.0
310	STRUCTURE	12.3	0.0	0.0	0.0	0.0	0.0	0.0	1.98	3.70	3.31	2.13	0.99	0.24	0.0	0.0	0.0	0.0
320	THERMAL INSUL	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.15	0.30	0.30	0.23	0.14	0.06	0.02	0.0	0.0	0.0
330	AVIONICS	46.7	0.0	0.0	0.0	0.0	0.0	0.0	5.76	11.62	11.70	8.93	5.45	2.54	0.66	0.0	0.0	0.0
340	PROPULSION	20.2	0.0	0.0	0.0	0.0	0.0	0.0	3.25	6.07	5.43	3.49	1.62	0.40	0.0	0.0	0.0	0.0
350	INTERFACE	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.17	0.36	0.40	0.34	0.24	0.14	0.07	0.02	0.0	0.0
360	DROP TANK																	
370	FINAL ASSY	13.4	0.0	0.0	0.0	0.0	0.0	0.0	2.90	4.83	3.58	1.69	0.40	0.0	0.0	0.0	0.0	0.0
400	TUG AUX STAGE	110.6	0.0	0.0	0.0	0.0	0.0	12.72	25.49	25.80	20.38	13.61	7.87	3.73	1.00	0.0	0.0	0.0
410	STRUCTURE																	
420	THERMAL INSUL																	
430	AVIONICS																	
440	PROPULSION																	
450	INTERSTAGE																	
460	DROP TANK																	
470	RDM																	
480	AKS	16.0	0.0	0.0	0.0	0.0	0.0	3.46	5.74	4.26	2.02	0.47	0.0	0.0	0.0	0.0	0.0	0.0
490	DKS	94.6	0.0	0.0	0.0	0.0	0.0	9.26	19.75	21.53	18.36	13.14	7.87	3.73	1.00	0.0	0.0	0.0
4100	CACHE																	
4110	FINAL ASSY	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.0	0.0
500	LOGISTICS	6.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.82	1.49	1.58	1.55	0.87	0.0	0.0	0.0
600	FACILITIES	0.2	0.0	0.0	0.0	0.0	0.11	0.05	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
610	MANUFACTURING	0.1	0.0	0.0	0.0	0.0	0.08	0.04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
620	TEST	0.0	0.0	0.0	0.0	0.0	0.03	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
630	1ST MAIN/REF																	
640	ETR LAUNCH																	
650	2ND MAIN/REF																	
660	WTR LAUNCH																	
700	GND SUPP EQUIP	3.9	0.0	0.0	0.0	0.0	0.0	0.0	1.12	1.64	1.17	0.0	0.0	0.0	0.0	0.0	0.0	0.0
710	MFG GSE																	
720	ETR GSE																	
730	WTR GSE	3.9	0.0	0.0	0.0	0.0	0.0	0.0	1.12	1.64	1.17	0.0	0.0	0.0	0.0	0.0	0.0	0.0
740	FLT OPS NASA																	
750	FLT OPS DOD																	
800	VEHICLE TEST																	
810	GND TEST HWRE																	
820	GND TEST OPS																	
830	FLT TEST HWRE																	
840	FLT TEST OPS																	
900	LAUNCH OPS WTR																	
1000	LAUNCH OPS ETR																	
1100	FLIGHT OPS DOD																	
1200	FLIGHT OPS NASA																	
1300	REF + INT TR-1																	
1400	REF + INT TR-2																	
	TOTALS	231.7	0.0	0.0	0.0	0.0	0.11	12.77	42.79	57.87	50.88	35.61	20.37	8.67	2.61	0.02	0.0	0.0

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410AD-2 SEP 73

STORABLE SPACE TUG SYSTEM PROJECT
FUNDING SCHEDULE DATA BY FISCAL YEAR

DATA FORM C

OPS (ALL COSTS IN MILLIONS)

FISCAL YEARS

WBS	TITLE	TOTAL	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
100	PROJECT MGMT	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.13	0.29	0.35	0.37	0.38	0.38	0.37	0.31	0.14
200	SYS ENG + INTEG	5.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.26	0.58	0.71	0.75	0.76	0.77	0.74	0.62	0.28
300	TUG MAIN STAGE	12.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.74	1.61	1.90	1.97	2.00	1.97	1.69	0.79
310	STRUCTURE	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.07	0.14	0.17	0.17	0.18	0.17	0.15	0.07
320	THERMAL INSUL	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.00
330	AVIONICS	8.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.48	1.05	1.24	1.29	1.31	1.29	1.10	0.51
340	PROPULSION	3.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.18	0.39	0.46	0.48	0.49	0.48	0.41	0.19
350	INTERFACE	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.01
360	DROP TANK																	
370	FINAL ASSY																	
400	TUG AUX STAGE	7.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.46	1.00	1.18	1.23	1.25	1.23	1.05	0.49
410	STRUCTURE																	
420	THERMAL INSUL																	
430	AVIONICS																	
440	PROPULSION																	
450	INTERSTAGE																	
460	DROP TANK																	
470	RDM																	
480	AKS	0.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.05	0.11	0.13	0.14	0.14	0.14	0.12	0.05
490	DKS	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.41	0.89	1.05	1.09	1.11	1.09	0.94	0.44
4100	CACHE																	
4110	FINAL ASSY																	
500	LOGISTICS																	
600	FACILITIES	0.7	0.0	0.0	0.40	0.15	0.0	0.0	0.0	0.0	0.01	0.02	0.03	0.03	0.03	0.03	0.03	0.01
610	MANUFACTURING																	
620	TEST																	
630	1ST MAIN/REF	0.3	0.0	0.0	0.24	0.09	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
640	ETR LAUNCH	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.01
650	2ND MAIN/REF	0.2	0.0	0.0	0.16	0.06	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
660	WTR LAUNCH	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.01
700	GND SUPP EQUIP	4.0	0.0	0.0	2.90	1.08	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
710	MFG GSE																	
720	LTR GSE	1.3	0.0	0.0	0.96	0.36	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
730	WTR GSE	2.7	0.0	0.0	1.94	0.72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
740	FLT OPS NASA																	
750	FLT OPS DOD																	
800	VEHICLE TEST																	
810	GND TEST HWRE																	
820	GND TEST OPS																	
830	FLT TEST HWRE																	
840	FLT TEST OPS																	
900	LAUNCH OPS WTR	6.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.39	0.85	1.00	1.04	1.06	1.04	0.90	0.42
1000	LAUNCH OPS ETR	19.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.14	2.45	2.90	3.01	3.06	3.01	2.58	1.20
1100	FLIGHT OPS DOD	42.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.51	5.42	6.41	6.66	6.76	6.66	5.72	2.67
1200	FLIGHT OPS NASA	63.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.70	7.97	9.43	9.81	9.95	9.80	8.41	3.92
1300	REF + INT TR-1	17.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.01	2.18	2.58	2.68	2.72	2.68	2.30	1.07
1400	REF +INT TR-2	24.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.45	3.12	3.69	3.84	3.89	3.83	3.29	1.53
	TOTALS	207.2	0.0	0.0	3.30	1.23	0.0	0.0	0.0	0.39	12.28	25.69	30.24	31.43	31.88	31.38	26.90	~~12.52~~ 12
											$30	1.23	29					
											15.7	26.92	30.29					

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FIRST UNIT PRODUCTION COST
PER WBS (INCLUDING AVIONICS TO LEVEL 7)
MAIN STAGE AND AUXILIARY STAGE(S)
(COST IN THOUSANDS)

Concept 410AD-2

WBS	IDENTIFICATION	FIRST UNIT COST LEVEL 1	LEVEL 2	LEVEL 3
0300	TUG VEH. MAIN STAGE	11,113		
0310	STRUCTURES		1,741	
0311	Fuel Tank & Sprt			578
0312	OX Tank & Sprt			679
0313	Body Structure			144
0314	Thrust Structure			33
0315	Metoroid Shield			12
0316	Payload Intface			294
0317	Inst'l Assy & C/O			0
0320	THERMAL INSULTN		176	
0321	Fuel Tank Insul			86
0322	OX Tank Insul			90
0333	Purge Sys Insul			0
0324	Cont Sys			0
0325	Inst'l Assy & C/O			0
0330	AVIONICS		4,696	
0331	Data Management			819
0332	GN&C			2,136
0333	Communications			942
0334	Instrumentation			0
0335	Elec Pwr			571
0336	Pwr Dist & Cont			228
0337	Inst'l Assy & C/O			0
0340	PROPULSION		2,181	
0341	Main Engine			800
0342	Main Engine Sprt			425
0343	ACPS Engine			564
0344	ACPS Engine Sprt			392
0345	Inst'l Assy & C/O			0
0350	ORBITER INTERFACE		623	
0351	Structure			266
0352	Interface PNLS			357
0353	Purge Provision			0
0354	Abort Provision			0
0355	Inst'l Assy & C/O			0
0360	DROP TANKS		0	
0361	Structures			
0362	Thermal Insul			
0363	Prod Sprt Sys			
0364	Inst'l Assy & C/O			
0370	FINAL ASSY & C/O		1,695	
0371	Final Assy			1,695
0372	Checkout			0
0400	TUG VEH. AUX. STAGE	3,485		
0470	RIM		0	
0471	Structure			
0472	Therm Cont			
0473	Avionics			
0474	Propulsion			
0475	RIM Assy & C/O			
0480	AKS		1,360	
0481	Structure			374
0482	Therm Cont			68
0483	Avionics			611
0484	Propulsion			99
0485	AKS Assy & C/O			207
0490	DKS		2,125	
0491	Structure			400
0492	Therm Cont			68
0493	Avionics			1,214
0494	Propulsion			119
0495	DKS Assy & C/O			324
0100	PROJECT MANAGEMENT	2,346		
0200	SYS ENG & INTEGR			
	TOTAL FIRST UNIT COST (Exclusive Logistics)			

LEVEL 7 FIRST UNIT COSTS (AVIONICS)

WBS	IDENTIFICATION	Main Stage	WBS	IDENTIFICATION	Aux. Stage
0330	AVIONICS (MAIN STAGE)	4,696	0400	TUG VEH. AUX STAGE	3,485
0331	DATA MANAGEMENT	819	0470	RIM	0
	Computer	209	0473	AVIONICS	
	Tape Recorder	58		DMS	
	FSI Cont'r/TLM Form.	55		PCM/Sig Cond	
	DACU	105		Sensors	
	Sensors	150		GN&C	
	In-House	242		Attitude Gyro Ref Unit	
0332	GN&C	2,136		Timer/CT'l Relay	
	IMU	200		APS Ct'l Electron.	
	Star Trucker	162		COMMUNICATIONS	
	Hor. Tr.	33		S-Band Xcvr/Xpdr	
	Laser Revo. Radar	400		Baseband Process.	
	Att Ref	20		Aux. Xmtr	
	Doppler Receiver			Pwr Amplifier	
	L-Band Antenna			Diplexer	
	Combined/Doppler Det.			Antenna Switch	
	APS Ct'l Electronics	295		Antenna	
	MS/TVC Ct'l Electron	295		ELEC. POWER	
	In-House	731		Primary Battery	
0333	COMMUNICATIONS	942		Pwr Dist & CT'l	
	S-Band X'CVR/X'PDR	510	0480	AKS	1,360
	Aux. Xmtr	43	0483	AVIONICS	611
	Power AMP	10		DMS	13
	Baseband Processor	50		Sensors	13
	Diplexer			GN&C	300
	Ant Switch			Att Gyro Ref U	100
	Antenna	8		APS/TVC	50
	Power Splitter			Timer/CT'l Relay	50
	GCTA	125		Velocity Meter	50
	In-House	196		Sequence Program	50
0334	INSTRUMENTATION	0		ELEC POWER	69
0335	ELEC POWER	571		Primary Battery	2
	Battery	100		Pwr Dist & CT'l	67
	Emergency Battery	2		In-House	229
	Modified Fuel Cell		0490	DKS	2,125
	Thermal Control	30		AVIONICS	1,214
	Tankage	256		DMS	93
	In-House	183		Sensors	13
0336	PWR DIST. & CT'L	211		PCM	80
0337	INST'L ASSY & C/O	0		GN&C	381
				Attitude Gyro Ref Unit	100
				Timer/CT'l Relay	50
				APS/TVC CT'l Electr	50
				Velocity Meter	50
				Sequence Program	50
				Star Tracker	81
				COMMUNICATIONS	111
				S-Band Xcvr/Xpdr	97
				Baseband Process	
				Aux. Xmtr	1
				Pwr Amplifier	8
				Diplexer	1
				Antenna Switch	2
				Antenna	2
				ELEC. POWER	174
				Primary Battery	6
				Pwr Dist & CT'l	100
				DeOrbit Battery	6
				Solar Cell Pad'S	62
				In-House	455

410AD-Z

AVERAGE COST/FLIGHT
(thousands)

	MODE I REFUSE		MODE II EXTEND TUG		MODE III EXTEND KS	
	NASA	DOD	NASA	DOD	NASA	DOD
Launch Operations	106.34	106.34				
Launch Site Serv & Supt	------	------				
Tug Shuttle Mate & C/O	7.13	7.13				
Prelaunch C/O	13.30	13.30				
Countdown	.42	.42				
Propellants & Gasses	62.00	62.00				
Post Flight Safing	23.49	23.49				
Maintenance & Refurb	598.31	598.31				
Sched Mant & Refurb	25.40	25.40				
Unsched Maint & Refurb	26.61	26.61				
Vehicle Opnl Spares (less Me)	308.84	308.84				
M. Eng. Maint & Refurb	80	80				
M. E. Opnl Spares	38.57	38.57				
Post Maint C/O	8.71	8.71				
Tug/Payload Mate & C/O	13.92	13.92				
Refurb Reqmt Planning	1.98	1.98				
Depot Maint	94.28	94.28				
Total Ground OPS (Launch/Maint/Refb)	704.65	704.65				
Flight Operations	400.29	456.54				
Mission Planning	125.61	125.51				
Flight Control	127.29	112.10				
Flight Evaluation	20.75	17.13				
Flight Supt Software	126.64	201.8				
Operations Support	46.90	46.90				
FSE Maint	2.45	2.45				
Sustaining Eng	22.05	22.05				
Prog Mgt	11.16	11.16				
Transport & Hdlg	2.37	2.37				
Inventory Control & Whseing	6.61	6.61				
Facilities Maint	2.26	2.26				
Expend Veh Avg. Unit Cost			10,000		1250	
Total Cost/Flight	1152	1208	11520		2402	

STORABLE SPACE TUG SYSTEM PROJECT

COST ESTIMATE DATA BY SOW

410AD-2 DDT&E

SUBDIVISIONS OF WORK

WBS ID	NAME	ENGINEERING HRS	ENGINEERING $	MANUFACTURING HRS	MANUFACTURING $	TEST HRS	TEST $	QUALITY ASSR HRS	QUALITY ASSR $	TOOLING/STE HRS	TOOLING/STE $	MGMT AND OTHER HRS	MGMT AND OTHER $	TOTAL HRS	TOTAL $
320	SPACE TUG PROJ		102042.		19424.		120094.		5426.		16689.		86318.		349993.
	MAJ PROC		20880.		10988.		17052.		853.		1421.		65706.		115900.
	IN-HOUSE	4537.	81162.	607.	8436.	7872.	103042.	276.	4573.	922.	15268.	1597.	20613.	15811.	233094.
320-01	PROJECT MGMT		0.		0.		0.		0.		0.		12703.		12703.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	984.	12703.	984.	12703.
320-02	SYS ENGR + INTG		10213.		0.		0.		4573.		0.		457.		15243.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	571.	10213.	0.	0.	0.	0.	276.	4573.	0.	0.	35.	457.	882.	15243.
320-03	SPACE TUG VEH MN		57499.		5041.		18012.		708.		12703.		64671.		159634.
	MAJ PROC		11561.		4719.		3067.		708.		1180.		59657.		80891.
	IN-HOUSE	2569.	45938.	95.	1322.	1142.	14945.	0.	0.	696.	11523.	388.	5014.	4889.	78743.
320-03-01	STRUCTURES		11657.		0.		2820.		0.		3572.		752.		18801.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	652.	11657.	0.	0.	215.	2820.	0.	0.	216.	3572.	58.	752.	1141.	18801.
320-03-02	THERMAL INSUL		82.		0.		30.		0.		30.		7.		149.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	5.	82.	0.	0.	2.	30.	0.	0.	2.	30.	1.	7.	9.	149.
320-03-03	AVIONICS		33305.		4719.		8503.		708.		5596.		4738.		57568.
	MAJ PROC		11561.		4719.		3067.		708.		1180.		2359.		23594.
	IN-HOUSE	1215.	21744.	0.	0.	415.	5436.	0.	0.	267.	4417.	184.	2378.	2082.	33975.
320-03-04	PROPULSION		7701.		0.		3025.		0.		1650.		58672.		71049.
	MAJ PROC		0.		0.		0.		0.		0.		57297.		57297.
	IN-HOUSE	430.	7701.	0.	0.	231.	3025.	0.	0.	100.	1650.	107.	1375.	868.	13751.
320-03-05	ORBITER INTF		3840.		0.		1396.		0.		1396.		349.		6981.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	215.	3840.	0.	0.	107.	1396.	0.	0.	84.	1396.	27.	349.	433.	6981.
320-03-06	DROP TANKS		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-03-07	FINAL ASSEMBLY		915.		1322.		2238.		0.		458.		153.		5085.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	51.	915.	95.	1322.	171.	2238.	0.	0.	28.	458.	12.	153.	357.	5085.
320-04	SPACE TUG VEH AU		16814.		967.		4294.		145.		2613.		1561.		26394.
	MAJ PROC		2369.		967.		628.		145.		242.		483.		4834.
	IN-HOUSE	807.	14445.	0.	0.	280.	3665.	0.	0.	143.	2372.	84.	1078.	1314.	21560.
320-04-01	STRUCTURES		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-04-02	THERMAL INSUL		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-04-03	AVIONICS		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-04-04	PROPULSION		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

STORABLE SPACE TUG SYSTEM PROJECT

COST ESTIMATE DATA BY SOW

410AD-2 DDT&E

SUBDIVISIONS OF WORK

WBS ID	NAME	ENGINEERING HRS	ENGINEERING $	MANUFACTURING HRS	MANUFACTURING $	TEST HRS	TEST $	QUALITY ASSR HRS	QUALITY ASSR $	TOOLING/STE HRS	TOOLING/STE $	MGMT AND OTHER HRS	MGMT AND OTHER $	TOTAL HRS	TOTAL $
320-04-06	DROP TANK		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-04-07	RDM		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-04-08	AKS		9772.		562.		2495.		84.		1519.		907.		15340.
	MAJ PROC		1377.		562.		365.		84.		140.		281.		2810.
	IN-HOUSE	469.	8396.	0.	0.	163.	2130.	0.	0.	83.	1378.	49.	627.	764.	12531.
320-04-09	DKS		7042.		405.		1798.		61.		1094.		654.		11054.
	MAJ PROC		992.		405.		263.		61.		101.		202.		2025.
	IN-HOUSE	338.	6050.	0.	0.	117.	1535.	0.	0.	60.	993.	35.	451.	550.	9030.
320-04-10	CACHE TANK		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-04-11	FINAL ASSEMBLY		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-05	LOGISTICS		6328.		0.		0.		0.		0.		0.		6328.
	MAJ PROC		950.		0.		0.		0.		0.		0.		950.
	IN-HOUSE	301.	5378.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	301.	5378.
320-06	FACILITIES		0.		0.		0.		0.		0.		6926.		6926.
	MAJ PROC		0.		0.		0.		0.		0.		5566.		5566.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	105.	1360.	105.	1360.
320-06-01	MANUFACTURING		0.		0.		0.		0.		0.		124.		124.
	MAJ PROC		0.		0.		0.		0.		0.		124.		124.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-06-02	TEST		0.		0.		0.		0.		0.		242.		242.
	MAJ PROC		0.		0.		0.		0.		0.		194.		194.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	4.	48.	4.	48.
320-06-03	ETR MAINT/REFB		0.		0.		0.		0.		0.		2914.		2914.
	MAJ PROC		0.		0.		0.		0.		0.		2331.		2331.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	45.	583.	45.	583.
320-06-04	ETR LAUNCH		0.		0.		0.		0.		0.		475.		475.
	MAJ PROC		0.		0.		0.		0.		0.		380.		380.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	7.	95.	7.	95.
320-06-05	WTR MAINT/REFB		0.		0.		0.		0.		0.		2648.		2648.
	MAJ PROC		0.		0.		0.		0.		0.		2118.		2118.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	41.	530.	41.	530.
320-06-06	WTR LAUNCH		0.		0.		0.		0.		0.		523.		523.
	MAJ PROC		0.		0.		0.		0.		0.		418.		418.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	8.	105.	8.	105.
320-07	GSE		11187.		12417.		1453.		0.		1373.		0.		26430.
	MAJ PROC		6000.		5303.		0.		0.		0.		0.		11303.
	IN-HOUSE	290.	5187.	512.	7114.	111.	1453.	0.	0.	83.	1373.	0.	0.	996.	15127.
320-07-01	MANUFACTURING		318.		1544.		159.		0.		79.		0.		2100.
	MAJ PROC		0.		511.		0.		0.		0.		0.		511.
	IN-HOUSE	18.	318.	74.	1033.	12.	159.	0.	0.	5.	79.	0.	0.	109.	1589.

STORABLE SPACE TUG SYSTEM PROJECT
COST ESTIMATE DATA BY SOW

410 AD-2 DDTE

SUBDIVISIONS OF WORK

WBS ID	NAME	ENGINEERING HRS	ENGINEERING $	MANUFACTURING HRS	MANUFACTURING $	TEST HRS	TEST $	QUALITY ASSR HRS	QUALITY ASSR $	TOOLING/STE HRS	TOOLING/STE $	MGMT AND OTHER HRS	MGMT AND OTHER $	TOTAL HRS	TOTAL $
320-07-02	ETR		4270.		10873.		1294.		0.		1294.		0.		17730.
	MAJ PROC		0.		4792.		0.		0.		0.		0.		4792.
	IN-HOUSE	239.	4270.	438.	6081.	99.	1294.	0.	0.	78.	1294.	0.	0.	853.	12938.
320-07-03	WTR		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-07-04	FLT OPS NASA		3300.		0.		0.		0.		0.		0.		3300.
	MAJ PROC		3000.		0.		0.		0.		0.		0.		3000.
	IN-HOUSE	17.	300.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	17.	300.
320-07-05	FLT OPS DOD		3300.		0.		0.		0.		0.		0.		3300.
	MAJ PROC		3000.		0.		0.		0.		0.		0.		3000.
	IN-HOUSE	17.	300.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	17.	300.
320-08	VEHICLE TEST		0.		0.		96335.		0.		0.		0.		96335.
	MAJ PROC		0.		0.		13356.		0.		0.		0.		13356.
	IN-HOUSE	0.	0.	0.	0.	6339.	82979.	0.	0.	0.	0.	0.	0.	6339.	82979.
320-08-01	GND TEST HDWR		0.		0.		12064.		0.		0.		0.		12064.
	MAJ PROC		0.		0.		6032.		0.		0.		0.		6032.
	IN-HOUSE	0.	0.	0.	0.	461.	6032.	0.	0.	0.	0.	0.	0.	461.	6032.
320-08-02	GND TEST OPS		0.		0.		12913.		0.		0.		0.		12913.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	986.	12913.	0.	0.	0.	0.	0.	0.	986.	12913.
320-08-03	FLT TEST HDWR		0.		0.		14648.		0.		0.		0.		14648.
	MAJ PROC		0.		0.		7324.		0.		0.		0.		7324.
	IN-HOUSE	0.	0.	0.	0.	560.	7324.	0.	0.	0.	0.	0.	0.	560.	7324.
320-08-04	FLT TEST OPS		0.		0.		56710.		0.		0.		0.		56710.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	4332.	56710.	0.	0.	0.	0.	0.	0.	4332.	56710.
320-09	LAUNCH OPS WTR		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-10	LAUNCH OPS ETR		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-11	FLIGHT OPS WTR		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-12	FLIGHT OPS ETR		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-13	REFB + INTEG WTR		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-14	REFB + INTEG ETR		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

II-3.2-94

STORABLE SPACE TUG SYSTEM PROJECT
COST ESTIMATE DATA BY SOW

41060-2 PROD

SUBDIVISIONS OF WORK

WBS ID	NAME	ENGINEERING HRS	ENGINEERING $	MANUFACTURING HRS	MANUFACTURING $	TEST HRS	TEST $	QUALITY ASSR HRS	QUALITY ASSR $	TOOLING/STE HRS	TOOLING/STE $	MGMT AND OTHER HRS	MGMT AND OTHER $	TOTAL HRS	TOTAL $
320	SPACE TUG PROJ		54497.		105635.		17176.		3408.		16032.		34150.		231698.
	MAJ PROC		9609.		30671.		4533.		1007.		2518.		18752.		67090.
	IN-HOUSE	2440.	44887.	5279.	74964.	837.	13143.	146.	2401.	748.	13514.	1193.	15398.	10642.	164608.
320-01	PROJECT MGMT		0.		0.		0.		0.		0.		7114.		7114.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	551.	7114.	551.	7114.
320-02	SYS ENGR + INTG		5362.		0.		0.		2401.		0.		240.		8003.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	291.	5362.	0.	0.	0.	0.	146.	2401.	0.	0.	19.	240.	456.	8003.
320-03	SPACE TUG VEH MN		18417.		42015.		7726.		602.		6740.		20098.		95598.
	MAJ PROC		4516.		17765.		2710.		602.		1505.		16601.		43700.
	IN-HOUSE	755.	13900.	1708.	24251.	312.	5016.	0.	0.	290.	5235.	271.	3496.	3336.	51898.
320-03-01	STRUCTURES		4074.		4815.		1358.		0.		1481.		617.		12345.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	221.	4074.	339.	4815.	85.	1358.	0.	0.	82.	1481.	48.	617.	775.	12345.
320-03-02	THERMAL INSUL		393.		464.		131.		0.		143.		59.		1190.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	21.	393.	33.	464.	8.	131.	0.	0.	8.	143.	5.	59.	75.	1190.
320-03-03	AVIONICS		8160.		27701.		3704.		602.		2499.		4005.		46570.
	MAJ PROC		4516.		17765.		2710.		602.		1505.		3011.		30110.
	IN-HOUSE	198.	3643.	700.	9936.	62.	994.	0.	0.	55.	994.	77.	994.	1092.	16560.
320-03-04	PROPULSION		1731.		3130.		599.		0.		666.		14123.		20250.
	MAJ PROC		0.		0.		0.		0.		0.		13590.		13590.
	IN-HOUSE	94.	1731.	220.	3130.	37.	599.	0.	0.	37.	666.	41.	533.	430.	6659.
320-03-05	ORBITER INTF		574.		678.		191.		0.		209.		87.		1740.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	31.	574.	48.	678.	12.	191.	0.	0.	12.	209.	7.	87.	109.	1740.
320-03-06	DROP TANKS		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-03-07	FINAL ASSEMBLY		3485.		5227.		1742.		0.		1742.		1206.		13404.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	189.	3485.	368.	5227.	108.	1742.	0.	0.	96.	1742.	93.	1206.	856.	13404.
320-04	SPACE TUG VEH AU		23816.		60732.		9953.		405.		9143.		6542.		110591.
	MAJ PROC		3038.		11950.		1823.		405.		1013.		2025.		20255.
	IN-HOUSE	1129.	20777.	3435.	48782.	505.	8130.	0.	0.	450.	8130.	350.	4517.	5870.	90336.
320-04-01	STRUCTURES		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-04-02	THERMAL INSUL		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-04-03	AVIONICS		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-04-04	PROPULSION		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

II-56-25

STORABLE SPACE TUG SYSTEM PROJECT
COST ESTIMATE DATA BY SOW

410AD-2 PROD

SUBDIVISIONS OF WORK

WBS ID	NAME	ENGINEERING HRS	ENGINEERING $	MANUFACTURING HRS	MANUFACTURING $	TEST HRS	TEST $	QUALITY ASSR HRS	QUALITY ASSR $	TOOLING/STE HRS	TOOLING/STE $	MGMT AND OTHER HRS	MGMT AND OTHER $	TOTAL HRS	TOTAL $
320-04-06	DROP TANK		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-04-07	RDM		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-04-08	AKS		3436.		8763.		1036.		58.		1319.		944.		15957.
	MAJ PROC		438.		1724.		263.		58.		146.		292.		2922.
	IN-HOUSE	163.	2998.	496.	7038.	73.	1173.	0.	0.	65.	1173.	50.	652.	847.	13034.
320-04-09	DKS		20379.		51969.		8317.		347.		7824.		5598.		94634.
	MAJ PROC		2600.		10226.		1360.		347.		867.		1733.		17332.
	IN-HOUSE	966.	17779.	2940.	41743.	433.	6957.	0.	0.	385.	6957.	299.	3865.	5023.	77302.
320-04-10	CACHE TANK		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-04-11	FINAL ASSEMBLY		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-05	LOGISTICS		6308.		0.		0.		0.		0.		0.		6308.
	MAJ PROC		2055.		0.		0.		0.		0.		0.		2055.
	IN-HOUSE	231.	4253.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	231.	4253.
320-06	FACILITIES		0.		0.		0.		0.		0.		156.		156.
	MAJ PROC		0.		0.		0.		0.		0.		125.		125.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.	31.	2.	31.
320-06-01	MANUFACTURING		0.		0.		0.		0.		0.		121.		121.
	MAJ PROC		0.		0.		0.		0.		0.		97.		97.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.	24.	2.	24.
320-06-02	TEST		0.		0.		0.		0.		0.		35.		35.
	MAJ PROC		0.		0.		0.		0.		0.		28.		28.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	1.	7.	1.	7.
320-06-03	ETR MAINT/REFB		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-06-04	ETR LAUNCH		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-06-05	WTR MAINT/REFB		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-06-06	WTR LAUNCH		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-07	GSE		595.		2888.		297.		0.		149.		0.		3928.
	MAJ PROC		0.		956.		0.		0.		0.		0.		956.
	IN-HOUSE	32.	595.	136.	1932.	18.	297.	0.	0.	8.	149.	0.	0.	195.	2973.
320-07-01	MANUFACTURING		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

STORABLE SPACE TUG SYSTEM PROJECT

COST ESTIMATE DATA BY SOW

410 AD-2 PROD

SUBDIVISIONS OF WORK

WBS ID	NAME	ENGINEERING HRS	ENGINEERING $	MANUFACTURING HRS	MANUFACTURING $	TEST HRS	TEST $	QUALITY ASSR HRS	QUALITY ASSR $	TOOLING/STE HRS	TOOLING/STE $	MGMT AND OTHER HRS	MGMT AND OTHER $	TOTAL HRS	TOTAL $
320-07-02	ETR		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-07-03	WTR		595.		2889.		297.		0.		149.		0.		3928.
	MAJ PROC		0.		956.		0.		0.		0.		0.		956.
	IN-HOUSE	32.	595.	136.	1932.	18.	297.	0.	0.	8.	149.	0.	0.	195.	2973.
320-07-04	FLT OPS NASA		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-07-05	FLT OPS DOD		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-08	VEHICLE TEST		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-08-01	GND TEST HDWR		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-08-02	GND TEST OPS		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-08-03	FLT TEST HDWR		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-08-04	FLT TEST OPS		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-09	LAUNCH OPS WTR		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-10	LAUNCH OPS ETR		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-11	FLIGHT OPS WTR		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-12	FLIGHT OPS ETR		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-13	REFB + INTEG WTR		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-14	REFB + INTEG ETR		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

STORABLE SPACE TUG SYSTEM PROJECT

COST ESTIMATE DATA BY SOW

40AD-2 OPN'S

SUBDIVISIONS OF WORK

WPS ID	NAME	ENGINEERING HRS	ENGINEERING $	MANUFACTURING HRS	MANUFACTURING $	TEST HRS	TEST $	QUALITY ASSR HRS	QUALITY ASSR $	TOOLING/STE HRS	TOOLING/STE $	MGMT AND OTHER HRS	MGMT AND OTHER $	TOTAL HRS	TOTAL $
320	SPACE TUG PROJ		126605.		54662.		1877.		1769.		1519.		20809.		207241.
	MAJ PROC		11545.		4866.		578.		129.		321.		11054.		28493.
	IN-HOUSE	7390.	115060.	6095.	49795.	95.	1299.	136.	1640.	99.	1198.	756.	9755.	14571.	178747.
320-01	PROJECT MGMT		0.		0.		0.		0.		0.		2733.		2733.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	212.	2733.	212.	2733.
320-02	SYS ENGR + INTG		3664.		0.		0.		1640.		0.		164.		5468.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	235.	3664.	0.	0.	0.	0.	136.	1640.	0.	0.	13.	164.	384.	5468.
320-03	SPACE TUG VEH MN		2711.		6877.		1069.		100.		914.		1008.		12580.
	MAJ PROC		747.		2938.		448.		100.		249.		498.		4979.
	IN-HOUSE	126.	1964.	482.	3940.	45.	621.	0.	0.	55.	665.	40.	510.	748.	7701.
320-03-01	STRUCTURES		370.		438.		123.		0.		135.		56.		1122.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	24.	370.	54.	438.	9.	123.	0.	0.	11.	135.	4.	56.	102.	1122.
320-03-02	THERMAL INSUL		18.		22.		6.		0.		7.		3.		56.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	1.	18.	3.	22.	0.	6.	0.	0.	1.	7.	0.	3.	5.	56.
320-03-03	AVIONICS		1470.		4909.		645.		100.		446.		695.		8265.
	MAJ PROC		747.		2938.		448.		100.		249.		498.		4979.
	IN-HOUSE	46.	723.	241.	1972.	14.	197.	0.	0.	16.	197.	15.	197.	334.	3286.
320-03-04	PROPULSION		801.		1447.		277.		0.		308.		246.		3079.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	51.	801.	177.	1447.	20.	277.	0.	0.	26.	308.	19.	246.	293.	3079.
320-03-05	ORBITER INTF		52.		62.		17.		0.		19.		8.		158.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	3.	52.	8.	62.	1.	17.	0.	0.	2.	19.	1.	8.	14.	158.
320-03-06	DROP TANKS		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-03-07	FINAL ASSEMBLY		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-04	SPACE TUG VEH AU		1636.		4723.		517.		29.		459.		532.		7896.
	MAJ PROC		217.		853.		130.		29.		72.		145.		1446.
	IN-HOUSE	91.	1419.	474.	3870.	28.	387.	0.	0.	32.	387.	30.	387.	655.	6450.
320-04-01	STRUCTURES		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-04-02	THERMAL INSUL		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-04-03	AVIONICS		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-04-04	PROPULSION		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

II-18-II

STORABLE SPACE TUG SYSTEM PROJECT
COST ESTIMATE DATA BY SOW

410AD-2 OPN'S

SUBDIVISIONS OF WORK

WBS ID	NAME	ENGINEERING HRS	ENGINEERING $	MANUFACTURING HRS	MANUFACTURING $	TEST HRS	TEST $	QUALITY ASSR HRS	QUALITY ASSR $	TOOLING/STE HRS	TOOLING/STE $	MGMT AND OTHER HRS	MGMT AND OTHER $	TOTAL HRS	TOTAL $
320-04-06	DROP TANK		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-04-07	RDM		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-04-08	AKS		182.		525.		58.		3.		51.		59.		878.
	MAJ PROC		24.		95.		14.		3.		8.		16.		161.
	IN-HOUSE	10.	158.	53.	430.	3.	43.	0.	0.	4.	43.	3.	43.	73.	717.
320-04-09	DKS		1454.		4198.		460.		26.		409.		472.		7018.
	MAJ PROC		193.		758.		116.		26.		64.		129.		1285.
	IN-HOUSE	81.	1261.	421.	3440.	25.	344.	0.	0.	29.	344.	27.	344.	582.	5733.
320-04-10	CACHE TANK		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-04-11	FINAL ASSEMBLY		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-05	LOGISTICS		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-06	FACILITIES		0.		0.		0.		0.		0.		748.		748.
	MAJ PROC		0.		0.		0.		0.		0.		598.		598.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	12.	150.	12.	150.
320-06-01	MANUFACTURING		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-06-02	TEST		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-06-03	ETR MAINT/REFB		0.		0.		0.		0.		0.		332.		332.
	MAJ PROC		0.		0.		0.		0.		0.		266.		266.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	5.	66.	5.	66.
320-06-04	ETR LAUNCH		0.		0.		0.		0.		0.		97.		97.
	MAJ PROC		0.		0.		0.		0.		0.		78.		78.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.	19.	2.	19.
320-06-05	WTR MAINT/REFB		0.		0.		0.		0.		0.		222.		222.
	MAJ PROC		0.		0.		0.		0.		0.		178.		178.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	3.	44.	3.	44.
320-06-06	WTR LAUNCH		0.		0.		0.		0.		0.		97.		97.
	MAJ PROC		0.		0.		0.		0.		0.		78.		78.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2.	19.	2.	19.
320-07	GSE		581.		2963.		290.		0.		145.		0.		3980.
	MAJ PROC		0.		1076.		0.		0.		0.		0.		1076.
	IN-HOUSE	37.	581.	231.	1888.	21.	290.	0.	0.	12.	145.	0.	0.	302.	2904.
320-07-01	MANUFACTURING		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

STORABLE SPACE TUG SYSTEM PROJECT
COST ESTIMATE DATA BY SOW

4OAD-2 OPN'S

SUBDIVISIONS OF WORK

WBS ID	NAME	ENGINEERING HRS	ENGINEERING $	MANUFACTURING HRS	MANUFACTURING $	TEST HRS	TEST $	QUALITY ASSR HRS	QUALITY ASSR $	TOOLING/STE HRS	TOOLING/STE $	MGMT AND OTHER HRS	MGMT AND OTHER $	TOTAL HRS	TOTAL $
320-07-02	ETR		193.		983.		96.		0.		48.		0.		1320.
	MAJ PROC		0.		357.		0.		0.		0.		0.		357.
	IN-HOUSE	12.	193.	77.	626.	7.	96.	0.	0.	4.	48.	0.	0.	100.	963.
320-07-03	WTR		388.		1981.		194.		0.		97.		0.		2650.
	MAJ PROC		0.		719.		0.		0.		0.		0.		719.
	IN-HOUSE	25.	389.	154.	1262.	14.	194.	0.	0.	8.	97.	0.	0.	202.	1941.
320-07-04	FLT OPS NASA		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-07-05	FLT OPS DOD		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-08	VEHICLE TEST		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-08-01	GND TEST HDWR		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-08-02	GND TEST OPS		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-08-03	FLT TEST HDWR		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-08-04	FLT TEST OPS		0.		0.		0.		0.		0.		0.		0.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
320-09	LAUNCH OPS WTR		617.		2027.		0.		0.		0.		4060.		6704.
	MAJ PROC		0.		0.		0.		0.		0.		3766.		3766.
	IN-HOUSE	40.	617.	248.	2027.	0.	0.	0.	0.	0.	0.	23.	294.	310.	2939.
320-10	LAUNCH OPS ETR		2794.		9179.		0.		0.		0.		7377.		19350.
	MAJ PROC		0.		0.		0.		0.		0.		6047.		6047.
	IN-HOUSE	179.	2794.	1124.	9179.	0.	0.	0.	0.	0.	0.	103.	1330.	1406.	13303.
320-11	FLIGHT OPS WTR		42810.		0.		0.		0.		0.		0.		42810.
	MAJ PROC		4281.		0.		0.		0.		0.		0.		4281.
	IN-HOUSE	2475.	38529.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	2475.	38529.
320-12	FLIGHT OPS ETR		63000.		0.		0.		0.		0.		0.		63000.
	MAJ PROC		6300.		0.		0.		0.		0.		0.		6300.
	IN-HOUSE	3642.	56700.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	3642.	56700.
320-13	REFB + INTEG WTR		3619.		11890.		0.		0.		0.		1723.		17232.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	232.	3619.	1455.	11890.	0.	0.	0.	0.	0.	0.	133.	1723.	1821.	17232.
320-14	REFB + INTEG ETR		5174.		17002.		0.		0.		0.		2464.		24640.
	MAJ PROC		0.		0.		0.		0.		0.		0.		0.
	IN-HOUSE	332.	5174.	2081.	17002.	0.	0.	0.	0.	0.	0.	191.	2464.	2604.	24640.

II-16-30

SPACE TUG CHARACTERISTICS

410AD-2

		MAIN STAGE	AUXILIARY STAGE
PHYSICAL:	WEIGHT, LB	3411	864
	LENGTH, IN	297	80
	DIAMETER, IN	120	180
TECHNICAL:	REUSABLE	ONE-STAGE	DKS
	AUXILIARY STAGE		AKS/DKS
	PAYLOAD RETRIEVAL	CAPABILITY	
	PROPELLANT CAPACITY, LB	59,500	
	THRUST, LB	12,000	
	ISP, SEC	338	287 & 295
	AUTONOMY LEVEL	IIB	
	RELIABILITY	.9751	.9791

WBS #320-00

GRUMMAN

II-fig-21

MAIN STAGE CHARACTERISTICS

410AD-2

PHYSICAL:	WEIGHT, LB	3411
	LENGTH, IN	297
	DIAMETER, IN	120
TECHNICAL:	REUSABLE SINGLE STAGE	
	PROPELLANT CAPABITY, LB	59,500
	PAYLOAD RETRIEVAL	CAPABILITY
	THRUST, LB	12,000
	ISP, SEC	338
	AUTONOMY LEVEL	IIB
	RELIABILITY	.9751

WBS #320-03

GRUMMAN

VEHICLE TEST CHARACTERISTICS

410AD-2

		MAIN STAGE	AUXILIARY STAGE
PHYSICAL:	PROP. TEST ARTICLE	X	
	STRUCT. TEST ARTICEL	X	X
	INTEG. AVIONICS TEST	X	X
	MOCK-UPS	X	X
	FLIGHT TEST	X	X

TECHNICAL: PTA - COLD FLOW ONLY, NO HOT FIRING

STA - ONE ART FOR DYNAMICS, STATIC & FATIGUE

IAT - SOFTWARE & HARDWARE

MOCK-UPS - WOOD AT PDR, WOOD/METAL AT CDR

FLIGHT TEST - ONE WITHOUT P/L, SEVEN WITH P/L

- ONE DKS ONLY

WBS #320-08

GRUMMAN

STRUCTURAL CHARACTERISTICS

410AD-2

PHYSICAL:	WEIGHT, LB	1288
	LENGTH, IN	297
	DIAMETER, IN	120
TECHNICAL:	TANK CONFIGURATION	NESTED DOME
	TANK CAPACITY, LB	59,500
	MATERIAL	Ti, COMPOSITE H'COMB
	RELIABILITY ALLOCATION	.99900

WBS #320-03-01

GRUMMAN

II-8.6-34

CONFIGURATION 410AD-2 WBS NO. 320-02-01

SUBSYSTEM/COMPONENT STRUCTURE DATE: 7/[illegible]

COMPONENT NAME	DEVELOPMENT STATUS: STATE-OF-THE-ART RATING	DEVELOPMENT STATUS: MONTHS TO QUAL	DEVELOPMENT STATUS: OTHER PROGRAM USAGE	PHYSICAL CHARACTERISTICS: MATERIALS	PHYSICAL CHARACTERISTICS: WEIGHT (LBS)	SIZE: LENGTH (INCHES)	SIZE: WIDTH (INCHES)	SIZE: HEIGHT (INCHES)	VOLUME (CUBIC INCHES)	TECHNICAL CHARACTERISTICS	RELIABILITY: MIN. NO. OF MISSIONS BEFORE COMPONENT BECOMES UNSERVICEABLE	PROGRAMATIC: UNITS PER VEHICLE	PROGRAMATIC: EQUIVALENT UNITS FOR S/S TEST	PROGRAMATIC: EQUIVALENT UNITS FOR MAJOR GND TEST	NOTES
01-Fuel Tanks and Supports	1	44½		Titan.	255	90	120	DIA		Welded Gore Titanium Domes	20	1		2	Tank Leakage Considered Unserviceable
02-Oxid. Tank and Supports	1	44½		Titan.	167	100	120	DIA		Weld Gore Titanium Domes	20	1		2	
03-Body Structure	1	44½		Alum. and Comp.	639	145	120	DIA		Graphite Composite Honeycomb Shell Aluminum Frames	N/A	1		2	Includes Equipment Mounting and Umbilicals
04-Thrust Struct.	1	44½		Alum.	88	35	120 MAX.	DIA		Aluminum Stiffened Sheet	N/A	1		2	
05-Meteoroid Shield	1	44½		Alum.	26	87	126	DIA		Aluminum Sheet	N/A	1	1		
06-Interface	1	46		Alum.	116					Aluminum Machinings and Forgings	N/A	1		2	

DRUMMAN

REPORT
DATE
CODE 20912

THERMAL CONTROL CHARACTERISTICS

410AD-2

PHYSICAL: WEIGHT, LB 89

500 FT^2 GOLDIZED MYLAR MLI

AL BASE HEAT SHIELD

SILVER BACKED TEFLON & ALZAK COATINGS

WBS #320-03-02

GRUMMAN

II-8.6-36

CONFIGURATION 410AD-2 WBS NO. 320-0302-01,02

SUBSYSTEM/COMPONENT THERMAL CONTROL DATE: 8/30/72

COMPONENT NAME	DEVELOPMENT STATUS: STATE-OF-THE-ART RATING	DEVELOPMENT STATUS: MONTHS TO QUAL	DEVELOPMENT STATUS: OTHER PROGRAM USAGE	PHYSICAL CHARACTERISTICS: MATERIALS	PHYSICAL CHARACTERISTICS: WEIGHT (LBS)	PHYSICAL CHARACTERISTICS: SIZE: LENGTH (INCHES)	PHYSICAL CHARACTERISTICS: SIZE: WIDTH (INCHES)	PHYSICAL CHARACTERISTICS: SIZE: HEIGHT (INCHES)	PHYSICAL CHARACTERISTICS: VOLUME (CUBIC INCHES)	TECHNICAL CHARACTERISTICS: POWER (WATTS)	TECHNICAL CHARACTERISTICS	RELIABILITY: EQUIVALENT OPERATING HOURS	RELIABILITY: MTBF (HOURS)	PROGRAMATIC: UNITS PER VEHICLE	PROGRAMATIC: EQUIVALENT UNITS FOR S/S TEST	PROGRAMATIC: EQUIVALENT UNITS FOR MAJOR GND TST	NOTES
THERMAL CONTROL COATINGS	5	0		SBT ALZAK ALCOPING	9		15	0 ft²		0				1			
MULTILAYER INSULATION	3	6		See Mini Spec	46		50	0 ft²		0				1			
FUEL CELL RADIATOR	2	12		See Mini Spec	14		17	ft²						1			
AVIONICS HEAT PIPE RADIATOR	2	12		See Mini Spec	4		4	ft²		0							POWER AMP (20W)
AVIONICS HEATERS	4	6		See Mini Spec	2					7.5/unit				8			COX & COMPANY, NY, NY.
APS HEATERS*	4	6		See Mini Spec	6					20/unit				24			
BASE HEAT SHIELD	5	0		AL	14					0							IDENTICAL TO MICROMETEROID SHIELD
PLUMBING	5	0		AL	2					0							

*CARRIED AS APS WT.

II-8.6-37

GRUMMAN

REPORT DATE CODE 20912

AVIONICS CHARACTERISTICS

410AD-2

PHYSICAL:	WEIGHT, LB	762
TECHNICAL:	AUTONOMY LEVEL	IIB
	RENDEZVOUS & DOCKING	LASER RADAR
	COMMUNICATIONS	DFS/CSS
	COMPUTER CAPACITY	65K WORDS
	FUEL CELL POWER	2.5KW
	RELIABILITY ALLOCATION	.98460

WBS #320-03-03

GRUMMAN

ASSEMBLY [illegible] ED — CORE CONFIGURATION 410AD-2 — WBS NO. 220-03-03-01 — SUBSYSTEM/COMPONENT DMS — DATE: [illegible]

COMPONENT NAME	DEVELOPMENT STATUS: STATE-OF-THE-ART RATING	DEVELOPMENT STATUS: MONTHS TO QUAL	DEVELOPMENT STATUS: OTHER PROGRAM USAGE	PHYSICAL CHARACTERISTICS: MATERIALS	PHYSICAL CHARACTERISTICS: WEIGHT (LBS)	PHYSICAL CHARACTERISTICS: SIZE: LENGTH (INCHES)	PHYSICAL CHARACTERISTICS: SIZE: WIDTH (INCHES)	PHYSICAL CHARACTERISTICS: SIZE: HEIGHT (INCHES)	PHYSICAL CHARACTERISTICS: VOLUME (CUBIC INCHES)	TECHNICAL CHARACTERISTICS: POWER (WATTS)	TECHNICAL CHARACTERISTICS	RELIABILITY: EQUIVALENT OPERATING HOURS	RELIABILITY: MTBF (HOURS)	PROGRAMATIC: UNITS PER VEHICLE	PROGRAMATIC: EQUIVALENT UNITS FOR ENG TEST	PROGRAMATIC: EQUIVALENT UNITS FOR ENG. TEST MAJOR GEN.	NOTES
MAIN STAGE COMPUTER	4	12			15	4.7	5	9.4	244	39	65 KWORDS-16 BITS/WORD	144	12K	2	N/A	1	CDC 469
TIME RECEIVER	5	12	IFI5-3 SIMPLEX		14.5	9	12	2.4	580	8		100	12K	1		1	ODETICS DUS 2100
FSI (CONTROLLER/ TRANSMITTER	4	8	SHUTTLE		18	8	5	16	640	73		144	12K	1		1	RADIATION
DECKS	4	8	"		7	7	4	13	364	21	256 CHANNELS	144	12K	3		1	"
SENSORS	4	8	"		0.2	N/A	N/A	N/A	N/A	0.1				190		10	WHITTAKER TRANSONICS

21-6-69

CONFIGURATION 410AD-2 NOTE 1 AUTOMATIC LEVEL II B WBS NO. 320-03-03-02 SUBSYSTEM/COMPONENT GN & C

REV A 9-[illegible]
DATE: 8-6-72

COMPONENT NAME	DEVELOPMENT STATUS: STATE-OF-THE-ART RATING	DEVELOPMENT STATUS: MONTHS TO QUAL	DEVELOPMENT STATUS: OTHER PROGRAM USAGE	PHYSICAL CHARACTERISTICS: MATERIALS	PHYSICAL CHARACTERISTICS: WEIGHT (LBS)	PHYSICAL CHARACTERISTICS: SIZE: LENGTH (INCHES)	PHYSICAL CHARACTERISTICS: SIZE: WIDTH (INCHES)	PHYSICAL CHARACTERISTICS: SIZE: HEIGHT (INCHES)	PHYSICAL CHARACTERISTICS: VOLUME (CUBIC INCHES)	TECHNICAL CHARACTERISTICS: POWER (WATTS)	TECHNICAL CHARACTERISTICS	RELIABILITY: EQUIVALENT OPERATING HOURS	RELIABILITY: MTBF (HOURS)	PROGRAMATIC: UNITS PER VEHICLE	PROGRAMATIC: EQUIVALENT UNITS FOR S/S TEST	PROGRAMATIC: EQUIVALENT UNITS FOR MAJOR GND TST	NOTES
INERTIAL MEASURING UNIT	1	24			10	6.5	6.5	4.7	200	15				2			(1) USES APOGEE KICK STAGE FOR DEPLOY ONLY MISSION. (2) USES DEORBIT KICK STAGE FOR DEPLOY AND RETRIEVE MISSIONS.
STAR TRACKER	1	24	SHUTTLE		17	15	6 DIA		424	28				1			DOES NOT INCLUDE SUNSHADE (1LB)
LASER RENDEZVOUS RADAR	1	30			40	9 21	9 9	9 6	729 1134	35				1			FOR RETRIEVAL ONLY
SATELLITE RECEIVER	1	30			37	19.5	10.4	7.8	1582	85				1			
DOPPLER RECEIVER	1	12			8	8	7	5	280	10				1			
L BAND ANTENNAS	1	9			0.3	4	4	1	16	—				4			
COMBINER/DOPPLER DETECTOR	1	18			6	7	7	5	245	4				1			
APS CONTROL ELECTRONICS	1	24			18	10	10	5	500	13				2			
ME/TVC CONTROL ELECTRONICS	1	24			10	10	10	3.5	350	15				1			

GRUMMAN

REPORT
DATE
CODE 28912

II-8-6-40

CONFIGURATION 410AD-2(CORE) WBS NO. 320-03-03-03 SUBSYSTEM/COMPONENT COMM DATE: 9-5-7

COMPONENT NAME	DEVELOPMENT STATUS: STATE-OF-THE-ART RATING	DEVELOPMENT STATUS: MONTHS TO QUAL	DEVELOPMENT STATUS: OTHER PROGRAM USAGE	PHYSICAL CHARACTERISTICS: MATERIALS	PHYSICAL CHARACTERISTICS: WEIGHT (LBS)	PHYSICAL CHARACTERISTICS: SIZE: LENGTH (INCHES)	PHYSICAL CHARACTERISTICS: SIZE: WIDTH (INCHES)	PHYSICAL CHARACTERISTICS: SIZE: HEIGHT (INCHES)	PHYSICAL CHARACTERISTICS: VOLUME (CUBIC INCHES)	TECHNICAL CHARACTERISTICS: POWER (WATTS)	TECHNICAL CHARACTERISTICS	RELIABILITY: EQUIVALENT OPERATING HOURS	RELIABILITY: MTBF (HOURS)	PROGRAMATIC: UNITS PER VEHICLE	PROGRAMATIC: EQUIVALENT UNITS FOR S/S TEST	PROGRAMATIC: EQUIVALENT UNITS FOR MAJOR SUBSYSTEM TEST	NOTES
1. S-BAND X'CEIVER/ X'PONDER R'CVR-(2) X'MT-(1)		24			2X4 1X5	7 7	9 8	5 5	315 280	8 34	Spread Spectrum CCIR Interference STDN/SGLS compatible			1			
2. S-BAND X'CEIVER/ X'PONDER R'CVR-(4) X'MTR-(1)		24			4X4 1X5	7 7	9 8	5 5	315 280	8 34	Spread Spectrum CCIR Interference STDN/SGLS compatible			1			
3. AUX. X'MTR		20			5	7	8	5	280	34	Same as (2)			1			
4. POWER AMP.		9			1	3	5	2	30	20	R.F. output of 5W			1			
5. POWER AMP.		15			3	9	5	3	135	100	R.F. output of 20W			1			
6. Base band Processor		24			6	7	7	5	245	4	Same as (1) + (2)			1			
7. Diplexer		9			1	3	7	3	63	—	—			2			
8. Diplexer		9			1	3	7	3	63	—	—			2			
9 Antenna Switch		9			1	3	3	4	36	1	—			2			
10. Antenna		9			.5	3	6	1	18	—	—			2			
11 Antenna		9			.5	3	6	1	18	—	—			2			
12. Power Splitter		8			1	2	2	3	12	—	—			1			
13. TV ASSEMBLY		15			12	18	6	4	432	10	Black + White			1			
15. SECURE COMM		—			6	9	5	4	180	8	—			5			DOD ONLY-GFE

GRUMMAN

REPORT
DATE
CODE 20812

II-S-6-41

TABLE 5.32-A EQUIPMENT LIST

CONFIGURATION 410AD-2 CORE VEHICLE — WBS NO. 320-03-03-05 & -06 — SUBSYSTEM/COMPONENT ELECTRICAL POWER SUBSYSTEM — 8-24-73 REV ① — DATE: 8-9-73

	COMPONENT NAME	DEVELOPMENT STATUS: STATE-OF-THE-ART RATING	DEVELOPMENT STATUS: MONTHS TO QUAL	DEVELOPMENT STATUS: OTHER PROGRAM USAGE	PHYSICAL CHARACTERISTICS: MATERIALS	PHYSICAL CHARACTERISTICS: WEIGHT (LBS)	PHYSICAL CHARACTERISTICS: SIZE: LENGTH (INCHES)	PHYSICAL CHARACTERISTICS: SIZE: WIDTH (INCHES)	PHYSICAL CHARACTERISTICS: SIZE: HEIGHT (INCHES)	PHYSICAL CHARACTERISTICS: VOLUME (CUBIC INCHES)	TECHNICAL CHARACTERISTICS: POWER (WATTS)	TECHNICAL CHARACTERISTICS	RELIABILITY: EQUIVALENT OPERATING HOURS	RELIABILITY: MTBF (HOURS)	PROGRAMATIC: UNITS PER VEHICLE	PROGRAMATIC: EQUIVALENT UNITS FOR S/S TEST	PROGRAMATIC: EQUIVALENT UNITS FOR MAJOR G.S. TEST	NOTES
POWER GENERATION	• MODIFIED FUEL CELL	3	30	SHUTTLE	[illegible] PLATINUM	90	25	15	15	5630	–	RATING: 2.5KW @ 28V, 840W AVG. LOAD OVER 117 HR. MISS.	144	10,000	1	–	1	SELLERS: PEWA, GE REQUIRES AUTO SPACE STARTUP
	• EMERGENCY BATTERY	5	6	..	Ag, Zn Ag	15	9	5	4½	200	–	10 AMP-HR RATED CAP. (½ HR DISCHARGE)	1/2	30,000	1	–	1	SECONDARY SILVER ZINC BATT, SELLER: EAGLE-PICHER
	REACTANT STORAGE (CRYO) • CRYO HYDROGEN TANK ASSY	3	24	GEMINI, APOLLO & SHUTTLE	T2 - INNER T2 - OUTER	66	20" 23"	I. O.	D D	6370	–	MAX PRESS: 350 PSIA; OPERAT. PRES 250 PSIA; 10 LB FLUID CAPACITY, NOMINAL HT LK = 11 BTU/HR	144	500,000	1	–	1	SELLER: AIRESEARCH, BEECH, BENDIX
	• CRYO OXYGEN TANK ASSY	3	24	GEMINI APOLLO & SHUTTLE	INC-718 INNER INC 750 OUTER	68	15 19	I. D. O.D.		3600	–	900 PSIA OPERATING PRESSURE 1000 PSIA - MAX PRESSURE; 80 LB CAPACITY, HT LK = 27 BTU/HR	144	500,000	1	–	1	SELLER: AIRESEARCH, BEECH, BENDIX
POWER DIST & CONTROL	• VEHICLE WIRING	5	–	LM		55	–	–	–		–	6ga, 14ga, 16ga, 20 & 26ga	144	–	SHIP SET		SHIP SET	~ 10,000 FT OF ASSORTED SIZES
	• CONNECTORS	5	–	LM		30	–	–	–	–	–	ASSORTED SIZES	144		"		"	~ 120 MATED PAIRS
	• SUNDRIES (ie CLAMPS, TAPE)	5	–	LM		20						" "	144		"		"	
	• SOLID STATE POWER CONTROLL	5	–			21						90 @ 2amp 17 @ 5amp 60 @ 3amp	144		SHIP SET		SHIP SET	2 ea. each - SELLER: LEACH CORP
	• ELECTO-MECH RCCB	3	12	LM		9						2 @ 20amp 10 @ 100amp	144		"		"	.75 lb each - SELLER: CUTLER-HAMMER
						135	= POWER	D&C	SUBTOTAL									

BAC 322 REV 1 10-69 SH — BRUMMAN — REPORT DATE CODE 26512

PROPULSION CHARACTERISTICS

410AD-2

		MAIN PROP.	AUXILIARY PROP.
PHYSICAL:	WEIGHT, LB	549	188
	ENGINE/THRUSTER	CLASS I	REA 19
	NO. OF ENGINES/THRUSTERS	1	24
TECHNICAL:	FUEL LOAD, LB	20,517	495
	OXIDIZER LOAD, LB	38,983	--
	THRUST, LB	12,000	25
	ISP - STEADY STATE, SEC	338	232
	- PULSING, SEC	--	170
	RELIABILITY ALLOCATION	.99249	.99882

WBS #320-03-04

GRUMMAN

CONFIGURATION 410AD-2

WBS NO. 320-03-04, 320-03-04-01, 320-03-04-02

SUBSYSTEM/~~COMPONENT~~ Main Prop.

REV. 4/1/73

DATE: 8/1/73

MAJOR COMPONENT	DEVELOPMENT STATUS: STATE-OF-THE-ART RATING	DEVELOPMENT STATUS: MONTHS TO QUAL	DEVELOPMENT STATUS: OTHER PROGRAM USAGE	PHYSICAL CHARACTERISTICS: MATERIALS	PHYSICAL CHARACTERISTICS: WEIGHT (LBS)	PHYSICAL CHARACTERISTICS: SIZE: LENGTH (INCHES)	PHYSICAL CHARACTERISTICS: SIZE: WIDTH/DIA. (INCHES)	PHYSICAL CHARACTERISTICS: SIZE: HEIGHT (INCHES)	PHYSICAL CHARACTERISTICS: VOLUME (CUBIC INCHES)	TECHNICAL CHARACTERISTICS: POWER (INPUT/OUTPUT) DATA TRANSFER RATE COMPUTER STORAGE CAP. NUMBER OF CIRCUITS THRUST SPECIFIC IMPULSE	RELIABILITY: EQUIVALENT OPERATING HOURS	RELIABILITY: MTBF (HOURS)	PROGRAMATIC: UNITS PER VEHICLE	PROGRAMATIC: EQUIVALENT UNITS FOR S/S TEST	PROGRAMATIC: EQUIVALENT UNITS FOR MAJOR GND TST	NOTES
Ox Pre-Vlv	4	16	OMS		2.5		3 1/4		60	32 Watts	165	40K	1	1	1	ME - Size increase from 1 1/2" D. (OMS Pu... /Feed Vlv)
Fu Pre-Vlv	4	16	OMS		5		2		42	32 Watts	165	40K	1	1	1	ME - Size increase from 1 1/2" D. (OMS Pu... /Feed Vlv)
Ox F/D QD	4	16	OMS		1.5		2		36		165	50K	1/2	1/2	1/2	ME - Size increase from 1 1/2" D.
Fu F/D QD	4	16	OMS		1.5		2		36		165	50K	1/2	1/2	1/2	ME - Size increase from 1 1/2" D.
Ox F/V QD	4	16	OMS		1		1		12		144	40K	1/2	1/2	1/2	ME - Size increase from 3/4" D.
Fu F/V QD	4	16	OMS		1		1		12		144	40K	1/2	1/2	1/2	ME - Size increase from 3/4" D.
He F/D QD	5	10	OMS		3		5/8		9		156	50K	1/2	1/2	1/2	OTS
Ox F/D Vlv.	5	10	OMS		5		2		12	32 Watts	144	41K	1	1	1	OTS - OMS Dump Valve
Fu F/D Vlv.	5	10	OMS		5		2		12	32 Watts	144	41K	1	1	1	OTS - OMS Dump Valve
He F/D Vlv.	4	16	OMS		5		4/5		24	84 Watts	144	67K	1	1	1	ME - Size increase from 1/2" D. (OMS Eng. Purge Vlv.
He Isol. Vlv.	5	10	LM		2		1/2		16	84 Watts	156	133K	2	1	2	OTS - APS/DPS Latching Sol Vlv.
He Reg	5	16	OMS		5		1/2		80		156	10^6	1	1	1	ME - Reduced press. setting, single stage
He/Fu Reg	5	16	OMS		5		1/2		80		156	10^6	1	1	1	ME - Reduced press. setting, single stage
Ox Burst Dis	5	16	OMS		1.5		5/8		28		165	10^6	1	1	1	ME - Reduced relief setting
Fu Burst Dis	5	16	OMS		1.5		5/8		28		165	10^6	1	1	1	ME - Reduced relief setting
Ox Relief Vl	5	16	OMS		1.5		5/8		20		169	10^6	1	1	1	ME - Reduced relief setting
Fu Relief Vlv	5	16	OMS		1.5		5/8		20		169	10^6	1	1	1	ME - Reduced relief setting
Ox Ck Vlv.	5	10	SPS		3.6		3/4		50		156	10^6	1	1	1	OTS
Fu Ck Vlv.	5	10	SPS		3.6		3/4		50		156	10^6	1	1	1	OTS
Ox Vent Vlv	4	16	OMS		5		5/8		24	84 Watts	168	67K	2	1	2	ME - Size increase from 1/2" D. (OMS Eng. Purge Vlv)
Fu Vent Vlv	4	16	OMS		5		5/8		24	84 Watts	165	67K	2	1	2	ME - Size increase from 1/2" D (OMS Eng. Purge Vlv)
Ox Low-level Sensor	5	16	Titan		2	3	1		2.5	2 Watts	144	TBD	1	1	1	ME - Modified mounting
Fu Low-level Sensor	5	16	Titan		2	3	1		2.5	2 Watts	144	TBD	1	1	1	ME - Modified mounting
Ox Flex Joints	5	10	OMS		0.6		2		36		168		3	1	3	OTS
Fu Flex Joints	5	10	OMS		0.6		2		36		168		5	1	5	OTS
Ox Stub Vlv	5	10	OMS		5		1/2		24	84 Watts	144	67K	1	1	1	OTS - OMS Eng. Purge Vlv.
Fu Stub Vlv	5	10	OMS		5		1/2		24	84 Watts	144	67K	1	1	1	OTS - OMS Eng. Purge Vlv.

LEGEND:
OTS - Off the shelf design
ME - Modified existing design
N - New design

II-5.9-14

CONFIGURATION A10AD-2 | WBS NO. 320-08 04, 320-09-04-01, 320-03-04-02 | SUBSYSTEM/COMPONENT Main Prop. | DATE: 8/21/72

MAJOR COMPONENT	DEVELOPMENT STATUS			PHYSICAL CHARACTERISTICS						TECHNICAL CHARACTERISTICS	RELIABILITY		PROGRAMATIC			NOTES
	STATE-OF-THE-ART RATING	MEETING TO GOAL	OTHER PROGRAM USAGE	MATERIALS	WEIGHT (LBS)	SIZE LENGTH (INCHES)	SIZE WIDTH/DIA (INCHES)	SIZE HEIGHT (INCHES)	VOLUME (CUBIC INCHES)	POWER (INPUT/OUTPUT) DATA TRANSFER RATE COMPUTER STORAGE CAP. NUMBER OF CIRCUITS THRUST SPECIFIC IMPULSE	EQUIVALENT OPERATING HOURS	MTBF (HOURS)	UNITS PER VEHICLE	EQUIVALENT UNITS FOR ENG TEST	EQUIVALENT UNITS FOR MAJOR GND TST	
He Tank	1	22	—		41.5		23.0		571		156	10^6	2	1	2	N- PFR design
Main Eng	1	54	—		266	116	56		280K	170 Watts, 12,000 lb	6	115K	1	17	—	N- Class I
Engine Act	4	15	LM		2.5	5.75	3	4.5	78	90 Watts	10	20K	2	1	—	ME- Increased strength for higher thrust
Ox Horiz Drain Vlv	4	16	OMS		4		1			32 Watts	144	100K	1	1	1	ME- Size decrease from 1½" D (OMS crossfeed valve)
Fu Horiz Drain Vlv	4	16	OMS		4		1			32 Watts	144	100K	1	1	1	ME- Size decrease from 1½" D (OMS crossfeed val.)

54-918-II

WBS NO. 320-03-04, 320-03-04-01, 320-03-04-02

CONFIGURATION 410AD-2 SUBSYSTEM/COMPONENT Main Prop. DATE: 8/21/73

MAJOR COMPONENT	DEVELOPMENT STATUS: STATE-OF-THE-ART RATING	DEVELOPMENT STATUS: MONTHS TO QUAL	DEVELOPMENT STATUS: OTHER PROGRAM USAGE	PHYSICAL CHARACTERISTICS: MATERIALS	PHYSICAL CHARACTERISTICS: WEIGHT (LBS)	PHYSICAL CHARACTERISTICS: SIZE: LENGTH (INCHES)	PHYSICAL CHARACTERISTICS: SIZE: WIDTH/DIA (INCHES)	PHYSICAL CHARACTERISTICS: SIZE: HEIGHT (INCHES)	PHYSICAL CHARACTERISTICS: VOLUME (CUBIC INCHES)	TECHNICAL CHARACTERISTICS: POWER (INPUT/OUTPUT), DATA TRANSFER RATE, COMPUTER STORAGE CAP., NUMBER OF CIRCUITS, THRUST, SPECIFIC IMPULSE	RELIABILITY: EQUIVALENT OPERATING HOURS	RELIABILITY: MTBF (HOURS)	PROGRAMATIC: UNITS PER VEHICLE	PROGRAMATIC: EQUIVALENT UNITS FOR S/S TEST	PROGRAMATIC: EQUIVALENT UNITS FOR MAJOR GND TST	NOTES
ADAPTER EQUIPMENT																
Ox F/D QD	4	16	OMS		2.5		2		36		168	500K	1/2	1/2	1/2	ME - Size increase from 1½"D
Fu F/D QD	4	16	OMS		2.5		2		36		168	500K	1/2	1/2	1/2	ME - Size increase from 1½"D
Ox F/V QD	4	16	OMS		2		1		12		144	40K	1/2	1/2	1/2	ME - Size increase from 3/4"D
Fu F/V QD	4	16	OMS		2		1		12		144	40K	1/2	1/2	1/2	ME - Size increase from 3/4"D
He F/D QD	5	10	OMS		4		5/8		9		156	500K	1/2	1/2	1/2	OTS
Pwr/Act.	1	15	—		2				10	30 Watts	10	20K	4	1	4	N
Ox Flex Joint	5	10	OMS		0.6		2		36		144		2	1	2	OTS
Fu Flex Joint	5	10	OMS		0.6		2		36		144		2	1	2	OTS
SHUTTLE EQUIPMENT																
Ox F/D QD	4	16	OMS		1.5		2		36		168	500K	1/2	—	—	Same as Tug hardware.
Fu F/D QD	4	16	OMS		1.5		2		36		168	500K	1/2	—	—	
Ox F/V QD	4	16	OMS		1		1		12		144	40K	1/2	—	—	
Fu F/V QD	4	16	OMS		1		1		12		144	40K	1/2	—	—	
He F/D QD	5	10	OMS		3		5/8		9		156	500K	1/2	—	—	
Ox Flex Joint	5	10	OMS		0.6		2		36		144		1	—	—	
Fu Flex Joint	5	10	OMS		0.6		2		36		144		1	—	—	

"Ground hardware" Tug QD

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REPORT
DATE
CODE 28912

CONFIGURATION [illegible], 410AD2, [illegible] WBS NO. 500-03-04-03 : 370-03-04-04 Rev A 6/3/73

SUBSYSTEM/COMPONENT Auxiliary Propulsion System (APS) DATE: 5/1/73

COMPONENT NAME	DEVELOPMENT STATUS: STATE-OF-THE-ART RATING	DEVELOPMENT STATUS: MONTHS TO QUAL	DEVELOPMENT STATUS: OTHER PROGRAM USAGE	PHYSICAL CHARACTERISTICS: MATERIALS	PHYSICAL CHARACTERISTICS: WEIGHT (LBS)	PHYSICAL CHARACTERISTICS: SIZE: LENGTH (INCHES)	PHYSICAL CHARACTERISTICS: SIZE: WIDTH (INCHES)	PHYSICAL CHARACTERISTICS: SIZE: HEIGHT (INCHES)	PHYSICAL CHARACTERISTICS: VOLUME (CUBIC INCHES)	TECHNICAL CHARACTERISTICS: POWER (WATTS)	TECHNICAL CHARACTERISTICS	RELIABILITY: EQUIVALENT OPERATING HOURS	RELIABILITY: MTBF (HOURS)	PROGRAMATIC: UNITS PER VEHICLE	PROGRAMATIC: EQUIVALENT UNITS FOR TEST	PROGRAMATIC: [illegible]	NOTES
Helium Tank	5	≤12	–		12.25	12.34	12.34	12.34	850	–	Burst Press = 7500 PSI Operating = 3900 PSI	156	10^6	2			Aerite P/N 6224-1
Helium Filter	5	≤12	LM		0.5					–				1			LSC 310-303-3 (Vacco Ver Co)
Helium Latching Solenoid Valve	4	≤12	LM		2.3					84		156	13×10^6	2			LSC 270-713 (MC Neg)
Regulator, Dual Stage	5	≤12	LM		2.5					–		156	"	1			LSC 310-305-3 ([illegible])
Regulator, Single Stage	4	≤12	–		1.5					–		156	"	1			Mod to dual stage reg.
Hard Check Valve	5	≤12	LM		0.7					–	Proof Press = 600 PSI	156	2000	1			Mod to LSC 310-306 ([illegible])
Burst Disc/Relief Valve	4	≤12	–		1.5					–	Relief Press ≈ 400 PSI	156	10^6/67K	1			Mod to LSC 310-307 (Calmic)
Fill Valve	3	18	–		2.0					70	Proof Press = 600 PSI	156	67000	3			Similar to LSC 310-303 (Marotte) Unidirectional flow valve; higher operating pressure
Propellant Tanks	4	≤12	LM		10.5		12.50	34	3420	–	Burst pressure = 650 PSI	144	10^6	4			Modified LM LCS fuel tank with centrodial bulkheads. Tank wt. included & reduced.
Pressurization Bundles	2	24	–	EPT 10 Equivalent	–					–				4			
Propellant Filter	5	≤12	–		0.5					–				1			
Thruster Isolation Valve	3	18	–		2.0					70	Proof Pressure = 600 PSI	168	67000	8			Same valve as vent valve; same notes apply
Thrusters	4	≤12	–		2.1	11.4	2.7			24	25 LB thrust @ 525 PSI inlet, steady state Isp = 232	144	15×10^6	24			REA 19-3 (Nat'l Lear Standard)
Thruster Heaters	5	≤12	–		0.2					3.5	Maintain catalyst bed at 150°F			24			Submitted for invoicing by Thiokol
Quick Disconnects	5	≤12	–		0.5									3			He fill & drain; Prop fill & drain; Prop fill & vent

Once Shipset

Above

GENERAL NOTE: Tankage based on usable propellant of 450 LB plus 15% contingency.

L-78-7

ORBITER INTERFACE CHARACTERISTICS

410AD-2

PHYSICAL:	WEIGHT, LB	1186
TECHNICAL:	MATERIAL	ALUMINUM
	PIVOT TYPE ADAPTER/DOCKING MECHANISM	
	SERVICE PANELS	GROUND POWER
		INSTRUMENTATION
		ON-PAD EMERGENCY DUMP
		HORIZONTAL PROP. DRAIN
		FUEL CELL REACTANT FILL

WBS #320-03-05

GRUMMAN

II-8.6-48

CONFIGURATION 410AD-2 WBS NO. 320-03-05-01

SUBSYSTEM/COMPONENT ORBITER INTERFACE STRUCT. DATE: 9/17/[illegible]

COMPONENT NAME	DEVELOPMENT STATUS			PHYSICAL CHARACTERISTICS						TECHNICAL CHARACTERISTICS	RELIABILITY	PROGRAMATIC			NOTES
	STATE-OF-THE-ART RATING	MONTHS TO QUAL	OTHER PROGRAM USAGE	MATERIALS	WEIGHT (LBS)	SIZE LENGTH (INCHES)	SIZE WIDTH (INCHES)	SIZE HEIGHT (INCHES)	VOLUME (CUBIC INCHES)		MIN. NO. OF MISSIONS BEFORE COMPONENT BECOMES UNSERVICEABLE	UNITS PER VEHICLE	EQUIVALENT UNITS FOR S/S TEST	EQUIVALENT UNITS FOR MAJOR GND TEST	
01-Rear Adapter	1	44½		Alum.	652	132	120	D		Aluminum Stiffened Sheet and Machinings	N/A			1	Pivot Type Adapter
01-Fwd Frame	1	44½		Alum.	438					Aluminum Trusses and Machinings	N/A			1	
01-Docking Mechanism	1	46		Alum.	96					Aluminum Machinings and Forgings	N/A			1	

63-9'8-II

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REPORT
DATE
CODE 265'2

DEORBIT KICK STAGE CHARACTERISTICS

410AD-2

		PLANETARY	GEOSYNCH
PHYSICAL:	WEIGHT (MAX.), LB	545	864
	LENGTH, IN	80	64
	DIAMETER, IN	180	180
TECHNICAL:	MATERIAL	ALUMINUM	
	INSULATION	GOLDIZER MYLAR MLI	
	PULSE CODE MODULATOR		
	ATTITUDE GYRO		
	S-BAND EQUIP/OMNI ANTENNAS		
	ELECTRICAL POWER	BATTERY & SOLAR CELLS	
	PROPULSION - MAIN	9 SRM'S	6 SRM'S
	- AUX.	12 COLD GAS THRUSTERS	
	RELIABILITY ALLOCATION	.9791	

WBS #320-04-09

GRUMMAN

II-96-50

CONFIGURATION 410 AD-2 WBS NO. 330-04-01

SUBSYSTEM/COMPONENT KICK STAGE STRUCTURE DATE: 9/10/68

COMPONENT NAME	DEVELOPMENT STATUS: STATE-OF-THE-ART RATING	DEVELOPMENT STATUS: MONTHS TO QUAL	DEVELOPMENT STATUS: OTHER PROGRAM USAGE	PHYSICAL CHARACTERISTICS: MATERIALS	PHYSICAL CHARACTERISTICS: WEIGHT (LBS)	PHYSICAL CHARACTERISTICS: SIZE: LENGTH (INCHES)	PHYSICAL CHARACTERISTICS: SIZE: WIDTH (INCHES)	PHYSICAL CHARACTERISTICS: SIZE: HEIGHT (INCHES)	PHYSICAL CHARACTERISTICS: VOLUME (CUBIC INCHES)	TECHNICAL CHARACTERISTICS	RELIABILITY: MIN. NO. OF MISSIONS BEFORE COMPONENT BECOMES UNSERVICEABLE	PROGRAMATIC: UNITS PER VEHICLE	PROGRAMATIC: EQUIVALENT UNITS FOR SIS TEST	PROGRAMATIC: EQUIVALENT UNITS FOR MAJOR GROUND TEST	NOTES
03-Body Structure	1	29		Alum.	363	65	120	DIA		Aluminum Stiffened	N/A	1		1	Payload ≈ 3
06-Payload Interface	1	29			40					Sheet and Fittings		1		1	
03-Body Structure	1	29		Alum.	408	48	120	DIA		Aluminum Stiffened		1		1	Round Trip
06-Payload Interface	1	29			40					Sheet and Fittings		1		1	
03-Body Structure	1	29		Alum.	353	48	120	DIA		Aluminum Stiffened		1		1	Deploy/Retrieve
06-Payload Interface	1	29			40					Sheet and Fittings		1		1	
03-Body Structure	1	29		Alum.	366	48	120	DIA		Aluminum Stiffened		1		1	Double Deploy With
06-Payload Interface	1	29			40					Sheet and Fittings		1		1	Individual Retrieve
03-Body Structure	1	29		Alum.	336	48	120	DIA		Aluminum Stiffened	N/A	1		1	Double Deploy
06-Payload Interface	1	29			40					Sheet and Fittings		1		1	

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PAGE

CONFIGURATION A/DKS

WBS NO. ____

SUBSYSTEM/COMPONENT THERMAL

DATE:

MAJOR COMPONENT	DEVELOPMENT STATUS			PHYSICAL CHARACTERISTICS						TECHNICAL CHARACTERISTICS	RELIABILITY		PROGRAMATIC			NOTES
	STATE-OF-THE-ART RATING	MONTHS TO QUAL	OTHER PROGRAM USAGE	MATERIALS	WEIGHT (LBS)	SIZE: LENGTH (INCHES)	SIZE: WIDTH (INCHES)	SIZE: HEIGHT (INCHES)	VOLUME (CUBIC INCHES)	POWER (INPUT/OUTPUT) DATA TRANSFER RATE COMPUTER STORAGE CAP. NUMBER OF CIRCUITS THRUST SPECIFIC IMPULSE	EQUIVALENT OPERATING HOURS	MTBF (HOURS)	UNITS PER VEHICLE	EQUIVALENT UNITS FOR S/S TEST	EQUIVALENT UNITS FOR MAJOR GND TST	
COATINGS	5	0	LM	PAINT	1	—	150-ft²	—			6 yrs	NA	1	1	NA	
INSULATION	5	6	LM	ML1	4	—	50-ft²	—			6 yrs	NA	1	1	NA	ALUMINIZED MYLAR/NYLON NET
HEATERS	5	3	LM	—	2	NEGLIGIBLE				15 watts/unit	6 yrs		8	1	NA	COX ELECTRICAL HEATERS

II-8.6-52

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REPORT
DATE
CODE 24512

ALL AUTONOMY LEVELS

CONFIGURATION DEORBIT KICK STAGE (DKS)

WBS NO. 320-04-07-03

SUBSYSTEM/COMPONENT DMS

DATE: [illegible]

COMPONENT NAME	DEVELOPMENT STATUS			PHYSICAL CHARACTERISTICS						TECHNICAL CHARACTERISTICS		RELIABILITY		PROGRAMATIC			NOTES
	STATE-OF-THE-ART RATING	MONTHS TO QUAL	OTHER PROGRAM USAGE	MATERIALS	WEIGHT (LBS)	SIZE LENGTH (INCHES)	SIZE WIDTH (INCHES)	SIZE HEIGHT (INCHES)	VOLUME (CUBIC INCHES)	POWER (WATTS)		EQUIVALENT OPERATING HOURS	MTBF (HOURS)	UNITS PER VEHICLE	EQUIVALENT UNITS FOR [illegible] TEST	[illegible] MAJOR [illegible]	
PCM/SIG. COND.	4	5	D72-2 [illegible]		4.6	9	5.5	7	347	9				2	N/A	1	SPACETAC
SENSORS	4	8	SHUTTLE		0.2	N/A	N/A	N/A	N/A	0.1			1M	17	N/A	2	WHITTAKER TRANSONICS

GRUMMAN

REPORT
DATE
CODE 26912

CONFIGURATION DEORBIT KICK STAGE

WBS NO. 320-04-09-03

SUBSYSTEM/COMPONENT GN&C

DATE: 5-3-7[illegible]

COMPONENT NAME	DEVELOPMENT STATUS			PHYSICAL CHARACTERISTICS						TECHNICAL CHARACTERISTICS	RELIABILITY		PROGRAMATIC			NOTES
	STATE-OF-THE-ART RATING	MONTHS TO QUAL	OTHER PROGRAM USAGE	MATERIALS	WEIGHT (LBS)	SIZE LENGTH (INCHES)	SIZE WIDTH (INCHES)	SIZE HEIGHT (INCHES)	VOLUME (CUBIC INCHES)	POWER (WATTS)	EQUIVALENT OPERATING HOURS	MTBF (HOURS)	UNITS PER VEHICLE	EQUIVALENT UNITS FOR S/S TEST	EQUIVALENT UNITS FOR MAJOR GND TST	
ATTITUDE GYRO REFERENCE UNIT	4	12	IMP ITOS		13	10.6	9	DIA.	533	25			2			120 WATTS WARM UP
VELOCITY METER	4	8	IMP ITOS		5.7	5.9	5.5	4.8	156	28			1			40 WATTS WARM UP
AVS/TVC CONTROL ELECTRONICS	1	18			7.6	8.6	7.1	5.5	336	18.5			2			
TIMER/CONTROL RELAYS	4	12	IMP ITOS		3	6	3.4	2.4	49	2			1			
SEQUENCER PROGRAMMER	4	12	IMP ITOS		2	6.4	4.3	2.9	77	6.3			2			
STAR TRACKER	1	24	SHUTTLE		17	15	6	DIA	424	28			2			DOES NOT INCLUDE SUNSHADE (16B)

II-8.6-54

GRUMMAN

REPORT
DATE
CODE 26512

DKS

CONFIGURATION 410AD-2 (ADD ON) WBS NO. 320-03-03-03 9-5-73

SUBSYSTEM/COMPONENT COMMUNICATIONS DATE: 6/4/73

COMPONENT NAME	DEVELOPMENT STATUS: STATE-OF-THE-ART RATING	DEVELOPMENT STATUS: MONTHS TO QUAL	DEVELOPMENT STATUS: OTHER PROGRAM USAGE	PHYSICAL CHARACTERISTICS: MATERIALS	PHYSICAL CHARACTERISTICS: WEIGHT (LBS)	PHYSICAL CHARACTERISTICS: SIZE (each) LENGTH (INCHES)	PHYSICAL CHARACTERISTICS: SIZE (each) WIDTH (INCHES)	PHYSICAL CHARACTERISTICS: SIZE (each) HEIGHT (INCHES)	PHYSICAL CHARACTERISTICS: VOLUME (each) (CUBIC INCHES)	TECHNICAL CHARACTERISTICS: POWER (WATTS)	TECHNICAL CHARACTERISTICS: [illegible]	RELIABILITY: EQUIVALENT OPERATING HOURS	RELIABILITY: MTBF (HOURS)	PROGRAMATIC: UNITS PER VEHICLE	PROGRAMATIC: EQUIVALENT UNITS FOR S/S TEST	PROGRAMATIC: EQUIVALENT UNITS FOR MAJOR GND TST	NOTES
2. S-Band X'CEIVER/X'PONDER R'CVR (4)					4X4	7	9	5	315	8	Spread Spectrum						
X'MTR (1)					1X5	7	8	5	280	34	CCIR Interference STDN/SGLS Compatible			1			
3. AUX. X'MTR					5	7	8	5	280	34	Same as (2) above			1			
4. POWER AMP.					1	3	5	2	30	20	R.F. output of SW			2			
7. DIPLEXER					1	2	7	3	63	—	—			2			
9. ANTENNA SWITCH					1	3	3	4	36	1	—			1			
14. BASEBAND PROCESSOR		24			3	3	3	2	18	2	Same as (2) above			1			
10. OMNI ANT.					.5	3	6	1	18	—	—			2			
15. SECURE COMM.					6	9	5	4	180	8	—			2			DOD ONLY - GFE

II-8.6-55

TABLE 5.3.3-C EQUIPMENT LIST

CONFIGURATION DEORBIT KICK STAGE WBS NO. 320-03-03-05 & 06 SUBSYSTEM/COMPONENT ELECTRICAL POWER SUBSYSTEM DATE: 27 AUG, 1972 REV (1) 13 AUG, 1973

MAJOR COMPONENT	DEVELOPMENT STATUS			PHYSICAL CHARACTERISTICS						TECHNICAL CHARACTERISTICS	RELIABILITY		PROGRAMATIC			NOTES
	STATE-OF-THE-ART RATING	MONTHS TO QUAL	OTHER PROGRAM USAGE	MATERIALS	WEIGHT (LBS)	SIZE LENGTH (INCHES)	SIZE WIDTH (INCHES)	SIZE HEIGHT (INCHES)	VOLUME (CUBIC INCHES)	POWER (INPUT/OUTPUT) DATA TRANSFER RATE COMPUTER STORAGE CAP. NUMBER OF CIRCUITS THRUST SPECIFIC IMPULSE	EQUIVALENT OPERATING HOURS	MTBF (HOURS)	UNITS PER VEHICLE	EQUIVALENT UNITS FOR S/G TEST	EQUIVALENT UNITS FOR MAJOR GND TST	
PRIMARY BATTERY	5	6	—	Ag-Zn	3	7	4	4	102	2 AMP-HR RATED CAPACITY @ 30V; 3 AMP DISCHARGE OVER 0.5 HR	0.5	30,000	1	—	1	MANUALLY ACTIVATED AG-ZN BATTERY SELLER: EAGLE-PICHER
DE-ORBIT BATTERY	4	9	—	Ag-Zn	75	13	8	10	1040	36 AMP-HR RATED CAPACITY @ 30V, 6 AMP DISCHARGE OVER 6 HRS.	6	30,000	1	—	1	REMOTELY ACTIVATED AG-ZN BATTERY SELLER: EAGLE-PICHER
SOLAR CELL PADDLES	4	9	OAO		6	6	SQ. FT			12% EFF n-on-p SILICON SOLAR CELLS, 10 Ω cm.	5 YRS		3	—	—	SOLAR CELLS ON BOTH SIDES OF PADDLE END OF MISSION OUTPUT EACH SIDE ≥ 22W PADDLES RETRACT BEFORE DEORBIT
POWER DIST & CONTROL	5	—	LM		44	-	-			ASSORTED WIRE, CONNECTORS & SOLID STATE POWER CONTROLLERS	5 YRS		SHIP SET	—	SHIP SET	—

II-5.6-56

CONFIGURATION 410 AD-2 WBS NO. 320-04-09-04

SUBSYSTEM/~~COMPONENT~~ MPS (AUX. STAGE) DATE:

COMPONENT NAME	DEVELOPMENT STATUS			PHYSICAL CHARACTERISTICS						TECHNICAL CHARACTERISTICS		RELIABILITY		PROGRAMATIC			NOTES
	STATE-OF-THE-ART RATING	MONTHS TO QUAL	OTHER PROGRAM USAGE	MATERIALS	WEIGHT (LBS)	SIZE: LENGTH (INCHES)	SIZE: WIDTH (INCHES)	SIZE: HEIGHT (INCHES)	VOLUME (CUBIC INCHES)	POWER (WATTS)		EQUIVALENT OPERATING HOURS	MTBF (HOURS)	UNITS PER VEHICLE	EQUIVALENT UNITS FOR S/S TEST	EQUIVALENT UNITS FOR MAJOR GND TST	
SRM #1	3	24	DELTA, BURNER 2 ETC		1880	61	37	—	[illegible] 66K	180	$I_{sp}=287$, $\lambda'=.92$ $\epsilon=34$			1/2/1/4	0	0	ME.-TEM 3 6A OR SVM-4A
SRM #2	3	24	"		1880	75	37	—	[illegible] 83K	180	$I_{sp}=295$, $\lambda'=.909$ $\epsilon=50$			3/6	0	0	M.E.- "
SRM #3	3	24	CTS		1300	69	28	—	[illegible] 43K	180	$I_{sp}=287$, $\lambda'=.909$ $\epsilon=34$			1	0	0	M.E.- TEM 616
SRM #4	3	24	CTS		940	57	28		35K	180	$I_{sp}=287$, $\lambda'=.909$ $\epsilon=34$			3	0	0	ME-TEM 616

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REPORT DATE CODE 285-2

II-8.6-57

WBS NO. 320-03-04-03; 320-03-04-04

CONFIGURATION Deorbit Kick Stage (DKS) SUBSYSTEM/COMPONENT Auxiliary Propulsion System (APS) DATE: 5/3

COMPONENT NAME	DEVELOPMENT STATUS: STATE-OF-THE-ART RATING	DEVELOPMENT STATUS: MONTHS TO QUAL	DEVELOPMENT STATUS: OTHER PROGRAM USAGE	PHYSICAL CHARACTERISTICS: MATERIALS	PHYSICAL CHARACTERISTICS: WEIGHT (LBS)	PHYSICAL CHARACTERISTICS: SIZE: LENGTH (INCHES)	PHYSICAL CHARACTERISTICS: SIZE: WIDTH (INCHES)	PHYSICAL CHARACTERISTICS: SIZE: HEIGHT (INCHES)	PHYSICAL CHARACTERISTICS: VOLUME (CUBIC INCHES)	TECHNICAL CHARACTERISTICS: POWER (WATTS)	TECHNICAL CHARACTERISTICS	RELIABILITY: EQUIVALENT OPERATING HOURS	RELIABILITY: MTBF (HOURS)	PROGRAMATIC: UNITS PER VEHICLE	PROGRAMATIC: EQUIVALENT UNITS FOR S/S TEST	PROGRAMATIC: EQUIVALENT UNITS FOR MAJOR [illegible]	NOTES
Nitrogen Tanks	5	≤12	–	6Al-4V	6.0	9.90			445	–	Burst Press = 7215 PSI Operating = 3600 PSI	117	10^7	2	One Shipset	None	Airite P/N 6435
Squib Valve	5	≤12	–		0.5					80	Normally Closed		10^6	1			LSC 310-302-1
Filter	5	≤12	–		0.5					–			10^6	1			Nitrogen Fill & Vent
Quick Disconnect	5	≤12	–		0.5					–			10^6	1			

General Notes:
1) Assumes DKS use with AKS only; DKS shares the AKS regulator and thrusters.
2) Tanks are sized to provide roll control during deorbit, 72 hrs of wide deadband and 1 hr of narrow deadband control.

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CODE 26312

8.7 FLIGHT SCHEDULES

Included in support of our flight schedule definition for concept 410AD-2 at the following tables:

- Fleet Size and Vehicle Usage
- Kick Stage Usage
- Flight Element Requirements
- Kick Stage Definition
- Payloads Flown
- Flight Operations Buildup
- Programmatic Data Summary
  Storable Tug Concept 410AD-2

410AD-2 FLEET SIZE & VEHICLE USAGE

	1979	80	81	82	83	84	85	86	87	88	89	90	TOTAL
CAPTURE MODEL													
TOTAL FLTS						43	35	38	38	33	37	38	262
PROG BUILD UP MODEL													
ETR REUSE						20	25	28	29	27	25	32	187
EXPEND								1	1		3	1	6
WTR REUSE						5	8	9	8	6	9	5	50
TOTAL FLTS						25	33	38	38	33	37	38	242
											LOST	MISSIONS	+ 3
NATIONAL FLEET													
VEH 1						15	12	8E					
2						10	11	9	4E				
3							8	17	9	6	1E		
4								4	17	10	10E		
5									8	15	7E		
6										2	17	16E	
7											2	17	
8												5	
9 LOST TUG													
10 LOST TUG													
DOD TRAFFIC													
TOTAL FLTS						11	12	17	17	17	14	18	106
											LOST	MISSIONS	+1
DOD FLEET						11	12	17	17	17	14	18	
VEH 1													
2 LOST TUG													

II-8.7-2

1

410AD-2

KICK STAGE USAGE

	401	405A	403	404	405
TYPE	AKS	AKS	DKS	DKS	DKS
NASA FLTS	6	8	12-6=6	12	50-17=33
KS DEPLOY	6	8	12-6=6	12	50-17=33
RETURN	-	-	9-6=3	-	26-17=9
REFURB	-	-	3	-	9
PRODUCTION*	6	8	4	12	26
DOD FLTS			12-2=10		54-13=11
KS DEPLOY	-	-	12-2=10	-	54-13=41
RETURN	-	-	8-2=6	-	33-13=20
REFURB	-	-	6	-	20
PRODUCTION*	-	-	5	-	25

*DKS PROD = TOTAL DEPLOYS - NO REFURBS +20% REFURB (AS BACKUP)

II-4.7.3

FLIGHT ELEMENT REQUIREMENTS OPTION: 2 (410AD-1)

ITEM			CALENDAR YEAR 80	81	82	83	84	85	86	87	88	89	90	TOTAL
SHUTTLE FLIGHTS		TOTAL					24	23	21	21	16	23	20	148
BASIC TUG FLIGHTS	ETK	RECOVERED					18	17	16	14	12	15	15	107
		EXPENDED					2		1	1		3	1	8
	WTR	RECOVERED					4	6	4	6	4	5	4	33
	(TOTAL)						(24)	(23)	(21)	(21)	(16)	(23)	(20)	(148)
KICK STAGES	KS 401						2		2	2				6
	KS 403		5	1		3						3		12
	KS 404									8	4			12
	KS405		5	9	3	7	2	8	5	1	4	3	3	50
	KS405A						1	2		3		1	2	9
	(TOTAL)		(10)	(10)	(3)	(10)	(5)	(10)	(7)	(14)	(8)	(7)	(5)	(89)

NASA TRAFFIC

TABLE 4.3.2.2-5

FLIGHT ELEMENT REQUIREMENTS OPTION: 2 (410AD-2)

ITEM			CALENDAR YEAR 80	81	82	83	84	85	86	87	88	89	90	TOTAL
SHUTTLE FLIGHTS		TOTAL					19	12	17	17	17	14	18	114
BASIC TUG FLIGHTS	ETR	RECOVERED					18	10	12	15	15	10	17	97
		EXPENDED												0
	WTR	RECOVERED					1	2	5	2	2	4	1	17
	(TOTAL)						(19)	(12)	(17)	(17)	(17)	(14)	(18)	(114)
KICK STAGES	KS 403			2		1	3		1	2	1		2	12
	KS 405		7		6	7	7	1	5	6	6	2	7	54
	(TOTAL)		(7)	(2)	(6)	(8)	(10)	(1)	(6)	(8)	(7)	(2)	(9)	(66)

BAS 8-30-73

DOD TRAFFIC

TABLE 4.3.2.2-6

FLIGHT ELEMENT REQUIREMENTS — OPTION: 2 (410 AD-1)

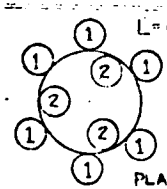
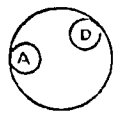
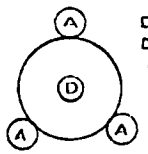
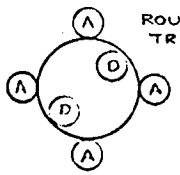
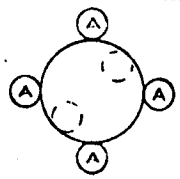
ITEM			CALENDAR YEAR 80	81	82	83	84	85	86	87	88	89	90	TOTAL
SHUTTLE FLIGHTS		TOTAL					43	35	38	38	33	37	38	262
BASIC TUG FLIGHTS	ETR	RECOVERED					36	27	28	29	27	25	32	204
		EXPENDED					2		1	1		3	1	8
	WTR	RECOVERED					5	8	9	8	6	9	5	50
	(TOTAL)						(43)	(35)	(38)	(38)	(33)	(37)	(38)	(262)
KICK STAGES	KS 401						2		2	2				6
	KS 403		5	3		4	3		1	2	1	3	2	24
	KS 404									8	4			12
	KS 405		12	9	9	14	9	9	10	7	10	5	10	104
	KS 405A						1	2		3		1	2	9
	(TOTAL)		(17)	(12)	(9)	(18)	(15)	(11)	(13)	(22)	(15)	(9)	(14)	(155)

COMBINED NASA/DOD TRAFFIC

TABLE 4.3.2.2-7

CONCEPT 410AD-2

KICK STAGE DEFINITION**

KICK STAGE DESIGNATION	GEOMETRY (all stages >10 ft diam. & are 5.5 ft long unless otherwise noted)		PERFORMANCE (geosynch Payload) (lbs)	SRM CHARACTERISTICS INDIVIDUAL WEIGHT (lbs)	NUMBER	TOTAL SRM WEIGHT (lbs)	STAGE INERT WEIGHT (lbs)	TOTAL STAGE WEIGHT (lbs)
KS 401	 L=6'8" PLANETARY	STAGE 1	5000 lbs to ΔV=18400 fps	1880	6	11280	-	11280
		STAGE 2		1880	3	5640	545	6185
		(TOTAL)						(17465)
KS403	 DEPLOY — RTRV	AKS	3920	1880	1	1880	-	1880
		DKS	3920	1880	1	1880	804*	2684
		(TOTAL)						(4564)
KS404	 DOUBLE DEPLOY RTRV	AKS	2770	1880	3	5640	-	5640
		DKS	2770	1300	1	1300	818*	2118
		(TOTAL)						(7758)
KS405	 ROUND TRIP	AKS	2640	1880	4	7520	-	7520
		DKS	2640	1880	2	3760	864*	4624
		(TOTAL)						(12144)
KS405A		AKS Delete 2 DKS from KS 405	6620	1880	4	7520	643*	8163

* ADD 12 lb FOR DOD MISSIONS

** Based on Kick Stage Characteristics, Issue 2, dated 8-29-73

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TABLE 4.3.2.2-8

FLIGHT	PAYLOADS FLOWN		
	1984	1985	1986
1	D-8	D-7	ALL
2	D-8	D-8	
3	D-9	D-8	
4	D-10	R-5 (KS)	
5	D-18	R-5 (KS)	
6	D-18	R-5 (KS)	
7	D-20 (KS)	D1 + R3 (KS)	
8	D-20 (KS)	D2 + R2 (KS)	
9	R-12	D3 + R3 (KS)	
10	R-13	D3 + R3 (KS)	
11	D1 + R1	D3 + R3 (KS)	
12	D1 + R1	D3 + R3 (KS)	
13	D14 + R14	D4 + R4 (KS)	
14	D15 + R15	D6 + R3 (KS)	
15	D-28 (KS)	D7 + R1 (KS)	
16	D-28 (KS)	D11 + R11	
17	D-31 (KS)	D16 + R16	
18	D-31 (KS)	D16 + R16	
19	D37 + D37 + D37	D16 + R16	
20	D39 + D39 + D39	D12 + D14 + R14	
21	R-34	D13 + D15 + R15	
22	D25 + R25	D-30	
23	D25 + R25	D-30	
24	D35 + R35	D40 + D40	
25	D35 + R35	D38 + D38 + D38	
26		D25 + R25	
27		D25 + R25	
28		D27 + R27 (KS)	
29		D33 + R33	
30		D33 + R33	
31		D35 + R35	
32		D35 + R35	
33		SORTIE 41	
34			
FLTS: FLOWN / SCHED	25 / 43	33 / 35	38 / 38
P/L DEPLOY: FLOWN / SCHED	26 / 37	34 / 36	32 / 32
P/L RTRV: FLOWN / SCHED	11 / 27	25 / 27	28 / 28
SORTIES: FLOWN / SCHED	0 / 0	1 / 1	0 / 0

TABLE 4.3.2.2-9 CONCEPT 410AD-2 COSTED FLIGHT BUILDUP

 D-8.7-8

FLIGHT OPERATIONS BUILDUP 410AD-2

The methodology used to establish the 410AD-2 flight buildup is also keyed to achieveing all flights defined by the 100% payload capture analysis after the second year of operations. As in110A-1, the primary factors considered include: NASA defined Shuttle/Tug launch constraints, initial ETR ground crew launch capabilities, and flight mode buildup. In option 2 however, the Shuttle/Tug launch constraints do not apply.

Initial ground crew launch capability is based on a 90% learning factor applied to the minimum ETR ground crew required to support 29 flights in the third year. As a consequence only 20 ETR flights can be achieved in 1984 and 27 in 1985. The minimum WTR ground crew can accomplish all flights planned at WTR.

During the flight buildup period we recommend similiar to 110A-1, that flight crew experience be developed by starting with the simplest flight mode and then progressively introducing the more complex flight modes required for 1986.

Our recommended flight buildup for 410AD-2, including 25 flights in1984 and 33 flights in 1985, encompasses 245 total flights through 1990 or 17 less than 100% payload capture traffic.

410AD-2 FLIGHT OPERATIONS BUILDUP

INPUTS	CY 84	85	86	87	TOTAL FLTS.
	▽ IOC				
o 100% PAYLOAD CAPTURE - ETR+WTR FLTS	43	35	38	38	262
ETR FLTS	38	27	29	30	
o SHUTTLE/TUG LAUNCH CONSTRAINTS - ETR	NONE				
o INITIAL GROUND CREW LAUNCH CAPABILITY - ETR	20	25	29	30	
o TUG FLIGHT MODE BUILDUP					
SINGLE AND MULTI DEPLOY	ALL	ALL	ALL	ALL	
SINGLE DEPLOY WITH KICK STAGE	ALL	ALL	ALL	ALL	
RETRIEVE	ALL	ALL	ALL	ALL	
ROUND TRIP	ALL	ALL	ALL	ALL	
SORTIE	NONE	ALL	ALL	ALL	
RETRIEVE/ROUND TRIP WITH KICK STAGE	NONE	SOME	ALL	ALL	
SINGLE DEPLOY - EXPEND TUG	NONE	NONE	ALL	ALL	
MULTI DEPLOY WITH KICK STAGE	NONE	NONE	NONE	ALL	
RECOMMENDED FLIGHT BUILDUP ETR+WTR FLIGHTS	25	33	38	38	245
ETR FLIGHTS	20	25	29	30	

BUILDUP RATIONALE

- o WTR LAUNCHES CAN BE ACHIEVED
- o ETR LAUNCHES CONSTRAINED BY GROUND CREW CAPABILITY PLANNED FOR 1986
- o PRE 1984 SHUTTLE/EXISTING STAGE EXPERIENCE ALLOWS MORE 1ST YEAR FLIGHT MODES THAN OPTION 1
- o MAXIMIZE GND/FLT CREW LEARNING WITHOUT EXCEEDING DOWN STREAM OPS

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PROGRAMMATIC DATA SUMMARY
STORABLE TUG CONCEPT 410AD-2

PROJECT HARDWARE UTILIZATION (AUTONOMY IIB)

	MAIN STAGE INIT	MAIN STAGE EVOL	ORBITER INTERFACE	AKS 401	AKS 405A	DKS 403	DKS 404	DKS 405
VEHICLE TEST								
PTV		1*	-	-				-
STA		1	1	-				1
1 AT		1	-	1				1
FLT TEST VEH		1*	1*	1				1
VEHICLE OPS								
TEST HDWR CONV		*	*	-	-	-	-	-
NATIONAL FLEET		10	4	6	8	9	12	51
NASA		8	2	6	8	4	12	26
DOD		2	2	-	-	5	-	25
TOTAL FLEET		10		14A		72D		

SHUTTLE FLIGHTS

	TEST	OPERATIONS		
	INIT	INIT	EVOL	TOTAL
ETR	1		195	195
WTR	-		50	50
COMBINED	1		245	245
NASA	1		138	138
DOD	-		107	107

OPNL YEARS

	INIT	EVAL	TOTAL
ETR		7	7
WTR		7	7

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11-23-11

PROGRAM SENSITIVITY TO IOC SHIFT - 410AD-2

Two programmatic options are available for implementing program 410AD-2 with a 2 year earlier IOC. First the baseline schedule could be shifted 2 years and start at October 77 ATP. The second option uses a schedule stretch out from October 75 ATP to the earlier 81 IOC milestone. Both schedule options assume that the original flight build up is advanced. As in 110A-1, we examined the implications of IOC shift with respect to operations, production and development.

IOC delay results in additional payloads captured (66 deployed and 18 retrieved).

Considering vehicle production two different factors should be addressed. They include schedule implications on manufacturing learning and the availability of existing hardware. For the schedule shift option, manufacturing learning can be more efficiently transferred from test article fabrication to vehicle production than in a stretchout situation. However as in 110A-1 the stretch option allows early contractual arrangements for vendor support of existing hardware.

The impact of advancing IOC on development was also reviewed with respect to schedule, type of contractor support available to NASA/DOD for defining Tug/Shuttle systems and interfaces, vehicle test, facilities SR&T and cost. As noted in 110A-1, for the first two years of stretched schedule, Tug/Shuttle systems and interfaces would be defined by the government with support of a prime contractor. This is an important period for assuring that the two vehicles are compatible as illustrated by the Apollo LM/CSM relationship. The impact on vehicle test and facilities are similar for both schedule options. However, it should be noted that the advanced IMU SR&T requirement would conflict with a similar DOD program. This would require a design change to the Carousel IMU. Assuming that the initial period of schedule stretch is devoted to systems engineering studies we estimate that cost of stretch out will be $14M. Peak funding occurs in 1980 and is $119M for the schedule stretch option.

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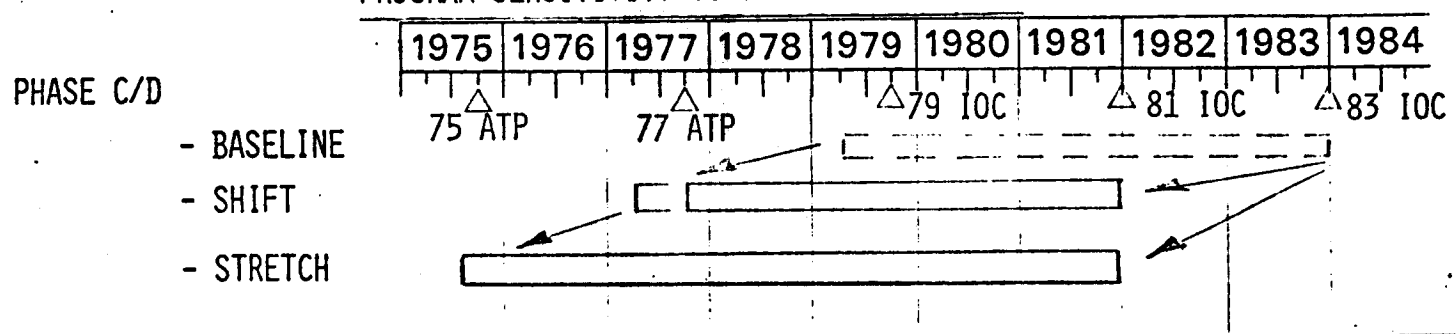
PROGRAM SENSITIVITY TO IOC SHIFT 410AD-2



	SHIFT	STRETCH
OPERATIONS IMPACT		
ADDL PAYLOADS CAPTURES	66 DEPLOY/18 RETRIEVE	66 DEPLOY/18 RETRIEVE
PRODUCTION IMPACT		
MFG TEST ART/PROD LEARN	BEST	FAIR
EXIST HDWAR AVAIL	IMPROVED	BEST
DEVELOPMENT IMPACT		
SCHEDULE	57 MO	75 MO
SYS & INTERFACE DEFN BY	GOVT + STUDY CONTR	GOVT + PRIME CONTR
VEHICLE TEST	2 YR EARLY	2½ YR EARLY
FACILITIES	2 YR EARLY	ADV AS REQUIRED
SR&T	ADV IMU	ADV IMU
DDT&E	350	364
PAF (YR)	151 (80)	119 (80)

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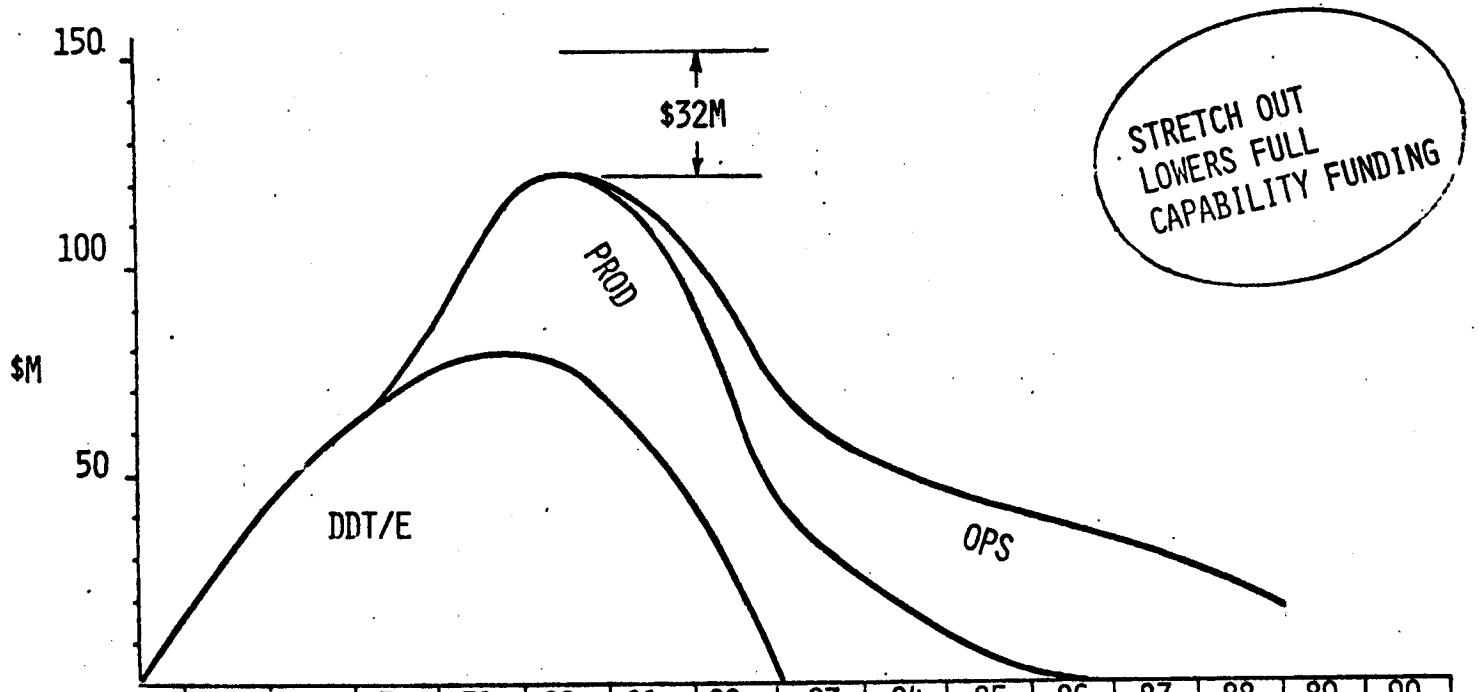
PHASE C/D STRETCH FOR ADVANCED IOC 410AD-2



CY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	
FY	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	
DDT&E	24	42	57	71	76	58	36									364
PROD				13	43	58	51	36	20	9	2					232
OPS							16	27	31	31	32	31	27	12		207
TOTAL	24	42	57	84	119	116	103	63	51	40	34	31	27	12		793

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II-8.8-3

8.9 Risk Assessment

In making an assessment of the risk associated with each configuration in each capability option we have considered the type of technology items associated with each vehicle and the impact that it would have on the program if, for one reason or another, the item would be unavailable and an alternative solution would be required. The impact is defined, usually, in terms of added weight, lost performance and total program cost increase; in some cases the impact can be decreased weight or reduced cost.

It is assumed that all of the weight increases and all of the cost increases will occur simultaneously without benefit of any offsetting decreases in either weight or cost. For example in configuration 110A-1 we have assumed that the +4 lb. weight impact of abandoning spun aluminum tanks in favor of welded aluminum tanks is combined with a $10.0 million cost increase as a result of abandoning aluminum tanks in favor of titanium tanks due to materials compatibility or fracture mechanics issues.

Taking the summation of all the weight increases, these are converted to costs by using the $75K/lb. figure derived when we were first selecting subsystem options for incorporation with 110A-1. The $75K/lb. number represents the last step (actually the slope of the line) in our subsystems synthesis process which provides a curve of Δ weight versus Δ total program costs as we added lighter and more costly subsystems options to achieve a behicle with 3500 lb. deploy capability. In this manner we arrived at a estimate of the costs expected if we had to recover the weight growth.

In similar fashion we then summed all of the potential cost increases, ignoring any offsetting cost decreases, and added these to the dollars representing the weight increases. The 110A-1 has no projected performance loss since it uses the OME 7.5K engine; the assumption is that the basic OME will have been developed to meet its weight, performance and reusability goals for the Shuttle Orbiter. In the case of configurations which use the Class I engine, for example 410AD-2, we have assumed that a 3 second Isp performance loss is possible. To convert this performance loss to costs we use the payload sensitivity factor to loss in Isp (97 lbs/sec), divide this by the payload sensitivity to inert weight and then multiply by $111/lb. to convert it to costs.

Taking all of the costs and adding them together we get a total low cost risk value of $15.3M for 110A-1 which ranges to a high value of 94.3M for 320A-3A/320AE-3A.

410AD-2 RISK ASSESSMENT

TECHNOLOGY ITEM IMPACT	
• CLASS I ENG	-3 SEC ISP
• PFR TANK	+48 LB
• ADV IMU	+30 LB
• GRAPHITE COMPOSITE	+38 LB
• LASER RADAR	COST/SCHED
• SPACE STORABLE SRM	COST/SCHED
• MATERIALS COMPATIBILITY • FRACTURE MECHANICS	+13 LB
• HEAT PIPES	SCHED

VEHICLE SENSITIVITY (DEPLOY)	PLAIN	WITH AKS
$\frac{\partial P/L}{\partial W \text{ FIXED}}$ (LB/LB)	-3.66	-2.66
$\frac{\partial P/L}{\partial ISP}$ (LB/SEC)	97	93

- TECHNICAL RISK
  - POTENTIAL WT IMPACT: +129 LB
  - POTENTIAL ISP LOSS: -3 SEC

  } ≈ 622 LB OF PAYLOAD (W/AKS)
  - OPEN WEIGHT REDUCTION OPTION: ADV. FUEL CELL
- SCHEDULE RISK
  - PROPOSED SR&T PROGRAMS (COMPL PRIOR TO ATP) PROTECT AGAINST SCHEDULE SLIP
  - AVAILABILITY OF 621 B SATELLITES
- COST RISK
  - POTENTIAL Δ COST $23.9M

MODERATE RISK PROGRAM

II-3.4-2

410AD-2 RISK ASSESSMENT

The technology items and their potential impact are shown on the opposite page. If the prestressed filament reinforced (PFR) helium tank fails to meet its goals, a 6A14V titanium tank adds 48 lbs to the vehicle. If the advanced (Micron) IMU is unavailable, a Carousel VB IMU plus a rate gyro unit adds 30 lbs. If the graphite composite shell fails to meet its objectives, an aluminum honeycomb shell adds 38 lbs. The laser radar and space storable SRM are items for which no attractive alternate exists, hence they represent both a schedule and cost risk. If materials compatibility or fracture mechanics data indicate the need to change propellant tank material from titanium to either aluminum or stainless steel, the added weight would be +13 lbs and + 3 lbs respectively. If the heat pipes are replaced by incorporating high heat rejection items on the active loop, there are no weight changes. To recover the weight impact on payload capability due to these possible weight increases, the advanced fuel cell is an open option.

The Class I engine is a new design based on current technology with the exception of the uncertainty in engine life and in the predicted performance with the high expansion ratio nozzles used. It is estimated this engine can miss its performance goals by -3 seconds Isp.

Schedule risk is minimized by the proposed SR&T programs which provide the feasibility of the approach 4 months prior to ATP.

Converting the potential Isp loss and weight increases to a total program cost at a $111K/lb value and adding the potential cost increase items yields a total cost risk of $23.9M for 410AD-2.

RISK ASSESSMENT 410AD-2

BASELINE	ALTERNATIVE	WEIGHT LBS	TOTAL PROGRAM COST, $M
CLASS I ENGINE	NO ALTERNATIVE	-	COST/SCHED RISK
LASER RADAR	RF RADAR PLUS REMOTE TV DOCKING (ALSO A TECHNOLOGY ISSUE), HENCE NO ALTERNATIVE		COST/SCHED RISK
PFR HELIUM TANK	6 Al 4V TITANIUM TANK	+48	+0.97
ADVANCED IMU (MICRON)	CAROUSEL IMU + RATE GYRO UNIT	+30	-3.35
GRAPHITE COMPOSITE SHELL	ALUM. HONEYCOMB SHELL	+38	+0.65
SPACE STORABLE SRM	NO ALTERNATIVE	-	COST/SCHED RISK
TITANIUM TANK (COMPATIBILITY DATA & FRACTURE MECHANICS DATA)	STAINLESS STEEL, OR ALUMINUM	+3, OR +13	TBD
HEAT PIPES	USE ACTIVE LOOP/BYPASS	NONE	NONE

SUMMING HIGHER WEIGHTS & COSTS ONLY ---------- 120 LBS $1.62M

CONVERT WEIGHT TO $ at $111 K/LB ---------- (129 X 111K) ---------- 14.30

CONVERT - 3 ISP TO $ ---------- $(\frac{3 \times 97}{3.66} \times 111K)$ ---------- 7.95

TOTAL COST RISK ---------- $23.87

Section 8.10 Supporting Research and Technology

This section includes a summary matrix chart which identifies all of the SR & T items and where they are applied to each configuration in each capability option.

Following the summary matrix there are individual tables for each configuration which summarize the technology items for that particular configuration and give a very brief synopsis of the type of SR & T program proposed and the estimated funding and schedule requirements. The text following each table is the facing page text prepared for the main presentation.

Following the tables for each configuration, an additional form is filled out for each technology item providing status information, justification for the proposed SR & T program, objectives, technical approach, and a more detailed schedule showing when the proposed program must be completed in order to support the particular configuration.

In dealing with the subject of SR & T we have identified two distinct groups - one where technology is needed and the other where there is no doubt that the technology is available and it is a straightforward engineering task to accumulate data that will preclude making a "false start" where several alternates are under study; we have called the latter group "desired data".

The storable Tug will benefit from the fact that the APOLLO LM program has used similar materials, propellants, equipments and procedures; the Shuttle Orbiter will expand on this data base for the Tug. The low number of identified SR & T items and the modest sums projected are based on the assumption that several existing or planned efforts related to the Shuttle will continue to provide data. These include the planned propellant and materials compatibility testing in support of the Shuttle Orbital Maneuvering Subsystem, its engines, tanks and components both at NASA/WSTF and at the Shuttle contractor's facilities. In addition, we have identified the Air Force funded efforts to develop the advanced Micron IMU for aircraft programs, as an effort which we would build-on rather than to start from scratch.

We have not attempted to detail the SR & T programs required on the Class I engine (with or without the two position nozzle) except to point out the uncertainty associated with the anticipated engine life and the predicted performance of very high expansion ratios within the mixture ratio of interest. The engine contractor will provide the proposed SR & T efforts required on the engine and we will provide comments on same at NASA's request.

The overall "message" which we hope will become obvious to the reader is that there are no real "show-stoppers" among the SR & T items identified.

TECHNOLOGY REQUIREMENTS AND "DESIRED DATA"

		110-A1	410AD-2	310-3A 310RE-3A	320-3A 320AE-3A	310-3B 310ARE-3B	510A-3B 510ADE-3B
S R & T	CLASS I ENGINE, HIGH E PERF		X	X	X	X	
	TWO-POSITION NOZZLE				X		
	LASER RADAR		X	(X)	(X)	(X)	(X)
	PFR HELIUM TANK	X	X	X	X	X	X
	ADVANCED FUEL CELL				X		
	ADVANCED IMU		X	(X)	(X)	(X)	(X)
	GRAPHITE COMPOSITE		X	X	X	X	
	SPUN-FORM ALUM. TANKS	X					X
	LONG TERM SPACE STORABLE SRM		X				(X)
DESIRED DATA	MATERIALS COMPATIBILITY DATA	X	X	X	X	X	X
	FRACTURE MECHANICS DATA	X	X	X	X	X	X
	HEAT PIPE DATA	X	X	X	X	X	X

(X) REQUIRED PRIOR TO GO AHEAD ON EVOLVED TUG CONFIGURATIONS

GRUMMAN

II-3.10-2

410 AD-2 TECHNOLOGY REQUIREMENTS & DESIRABLE DATA

	ITEM	SR&T FUNDS $K	SR&T SCHEDULE MOS.	PROPOSED PROGRAM
SR&T	CLASS I ENGINE	TBD	TBD	HIGH ALT. TESTS TO OBTAIN PERF. DATA ON HIGH ϵ NOZZLE FOR MIXTURE RATIO RANGE
	LASER RADAR	500	12	FAB & TEST LIGHTWEIGHT, LOWER POWER UNIT USING IMPROVED OPTICS & LIGHTER MIRROR DRIVES
	PFR HELIUM TANK	125	12	FAB & TEST 3 TANKS UNDER STATIC & DYNAMIC LOADING: AND ENVIRONMENTAL & COMPATIBILITY TESTS
	ADVANCED IMU	500	18	DEVELOP SOFTWARE FOR REDUNDANCY MGMT AND CALIBRATION OF 2 MULTI-SENSOR TYPE IMU'S
	GRAPHITE COMPOSITE	15	6	FAB GRAPHITE EPOXY HONEYCOMB SAMPLES & TEST IN VARIOUS PLY DIRECTIONS FOR DESIGN DATA
	LONG TERM SPACE STORABLE SRM	100	12	PHYSICAL & BALLISTICS PROPERTIES TESTS ON SAMPLES AFTER VACUUM EXPOSURE
DESIRABLE DATA	MATERIALS COMPATIBILITY DATA	25	6	2219-T87, 2218-T81 & 6Al4VTi; WITH N_2O_4 & MMH UP TO 130°F
	FRACTURE MECHANICS DATA	25	6	2219-T87 & 6Al4VTi; Kic Kth & FLAW GROWTH WITH N_2O_4 & MMH UP TO 130°F
	HEAT PIPES	100	12	FAB & TEST VARIABLE CONDUCTANCE HEAT PIPE RADIATOR & HEADER FOR TURN DOWN RATIO & SHUTOFF HEAT FLUX DATA

GRUMMAN

TECHNOLOGY REQUIREMENTS AND DESIRED DATA - 410AD-2

The upper part of the facing chart contains the supporting research and technology (SR&T) items required for 410AD-2; the lower part of the chart contains what we have termed as "desired data". The distinction between the two is that the "desired data" items do not require technology but are considered straightforward engineering development tasks to produce design data prior to Tug program go-ahead (ATP); this will preclude impacting Tug schedules should the data indicate the desirability of an alternative approach.

Excluding the SR&T on the Class I engine, the total SR&T funds requested for 410AD-2 is $1,390K to be expended over an 18 month period culminating 4 months prior to Tug ATP. The advanced (Micron) IMU) is the long lead item (18 months) also excluding the Class I engine.

4-01-3-77

410 AD-2, 310RE-3A, 320AE-3A, 310 ARE-3B, 510ADE-3B

STORABLE SPACE TUG SUPPORTING RESEARCH AND TECHNOLOGY - Avionics (GN&C)
(Discipline)

TITLE Low Weight/Power, (Rendezvous and Docking) Laser Radar WBS No. 320-03-03-02

STATUS ITT-Gilfillan has been under NASA Contracts since 1964 to design, develop, build, and test various spaceborne laser radar systems. The third generation system will be delivered in late November 1973.

JUSTIFICATION The application of the above developed technology to meet specific space tug rendezvous and docking requirements is desired.

In addition in order to improve the payload capability of the storable tug, low weight Avionics equipments (specifically, low weight/low power laser radar) are required.

OBJECTIVES To design, develop, fabricate, and test a low weight, low power, rendezvous and docking laser radar.

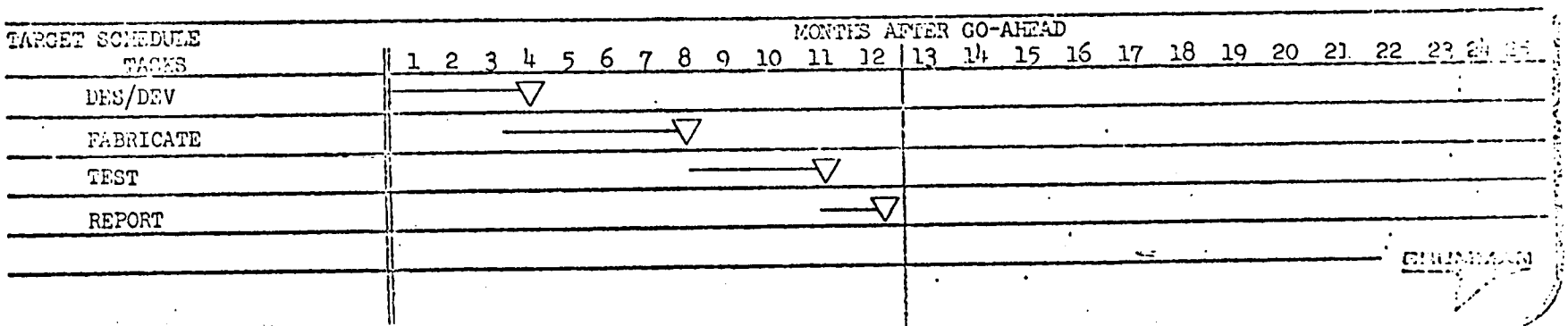
S-018-D

TECHNICAL APPROACH Using Tug requirements, design for light weight, low power by using new components, lighter mirror drives and improved optics

MANPOWER FUNDING $500 K

SPECIALIZED FACILITIES Development and testing at ITT

TARGET SCHEDULE



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STORABLE SPACE TUG SUPPORTING RESEARCH & TECHNOLOGY

DISCIPLINE Astrionics (GN&C) TITLE Low Wt./PW Rend.&Docking Laser Radar WBS 320-03-03-02

TARGET SCHEDULE CY	1973	1974	1975	1976	1977	1978	1979
TUG Ø C/D ATP MILESTONES			1980 TUG△		1982 TUG△		1984 TUG△
TASKS							
Design & Development							
Fabricate							
Test							
Report							

RESOURCE REQUIREMENTS FY	1974	1975	1976	1977	1978	1979	TOTAL
MANPOWER (MAN YEARS)					4	12	16
FUNDING							
a) DIRECT LABOR					100K	300K	400 K
b) EQUIPMENT & MAT'L					20K	40K	60 K
c) FACILITIES					40K	--	40 K
d) OTHER (SPECIFY)							
TOTAL					160K	340K	500 K

SPECIALIZED FACILITIES

TYPE/LOCATION/AVAILABILITY FACILITIES DEV. TIME & COST: Optics bench, dark rooms, test range

II-6.16-6

410AD-2

STORABLE SPACE TUG SUPPORTING RESEARCH AND TECHNOLOGY - Main Propulsion
(Discipline)

TITLE Prestressed Filament Reinforced (PFR) Tanks WBS No. 320-03-04-02

STATUS Structural Composites Industries, Inc. (SCI) and Arde-Portland, Inc. are under contract to LeRC to demonstrate the feasibility of the PFR tanks. This program will result in the construction of a 24 in. diam. Ardeform PFR tank of the type assumed by our study. If successful the basic technology will be proven.

JUSTIFICATION

A PFR ambient helium storage tank is comparable with the weight of a SHe tank and its associated heat exchanger. It provides a simple and less operationally complex system compared to the SHe tank. The PFR tank also provides a leak-before-burst design which results in increased Tug safety.

OBJECTIVES

Design, fabricate, and test 3 to 6 PFR tanks to demonstrate that current manufacturing and quality control techniques are adequate to produce a reliable, low weight tank suitable for containing gaseous helium (or hydrogen and oxygen in the case of fuel cell reactant tanks). The program will resemble a pre-qualification test program which will demonstrate the ability of the PFR tank to undergo the dynamic loading, compatibility, environmental exposure and etc. tests required for acceptance as a flight item.

L-8-10-7

TECHNICAL APPROACH

Fabricate 3 to 6 tanks and subject them to a pre-qualification test program to demonstrate the maturity of the design.

MANPOWER 2 man years FUNDING $125,000

SPECIALIZED FACILITIES

Available at tank manufacturers

TARGET SCHEDULE

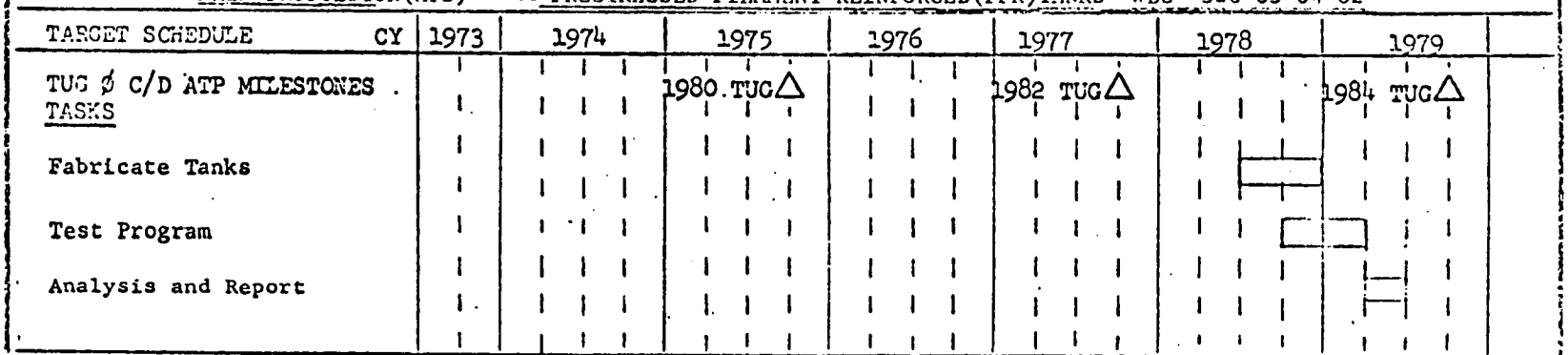
TASKS	MONTHS AFTER GO-AHEAD 1 2 3 4 5 6 7 8 9 10 11 12	13 14 15 16 17 18 19 20 21 22 23 24 25
Fabricate Tanks		
Test Program		
Analysis and Report		

GRUMMAN

410AD-2

STORABLE SPACE TUG SUPPORTING RESEARCH & TECHNOLOGY

DISCIPLINE MAIN PROPULSION (MPS) TITLE PRESTRESSED FILAMENT REINFORCED (PFR) TANKS WBS 320-03-04-02



RESOURCE REQUIREMENTS FY	1974	1975	1976	1977	1978	1979	TOTAL
MANPOWER (MAN YEARS)					1	1	
FUNDING							
a) DIRECT LABOR					$ 38,000	$ 37,000	$ 75,000
b) EQUIPMENT & MAT'L					$ 30,000	$ 20,000	$ 50,000
c) FACILITIES							
d) OTHER (SPECIFY)							
TOTAL					$ 68,000	$ 57,000	$125,000

SPECIALIZED FACILITIES	
TYPE/LOCATION/AVAILABILITY	ARDE, SCI, or Similar
FACILITIES DEV. TIME & COST	None

8-01-2-11

410AD-2, 310 RE-3A, 320 AE-3A, 310 ARE-3B, 510 ADE-3B

STORABLE SPACE TUG SUPPORTING RESEARCH AND TECHNOLOGY - Astrionics (GN&C)

(Discipline) WBS #320-03-03-02

TITLE Advanced (Low Weight) Inertial Measurement Unit for Space Application

STATUS Advanced Lightweight Unit being developed under Air Force Contract. Primarily for aircraft application.

JUSTIFICATION To improve payload capability of a storable tug, low weight Astrionics Equipments are required.

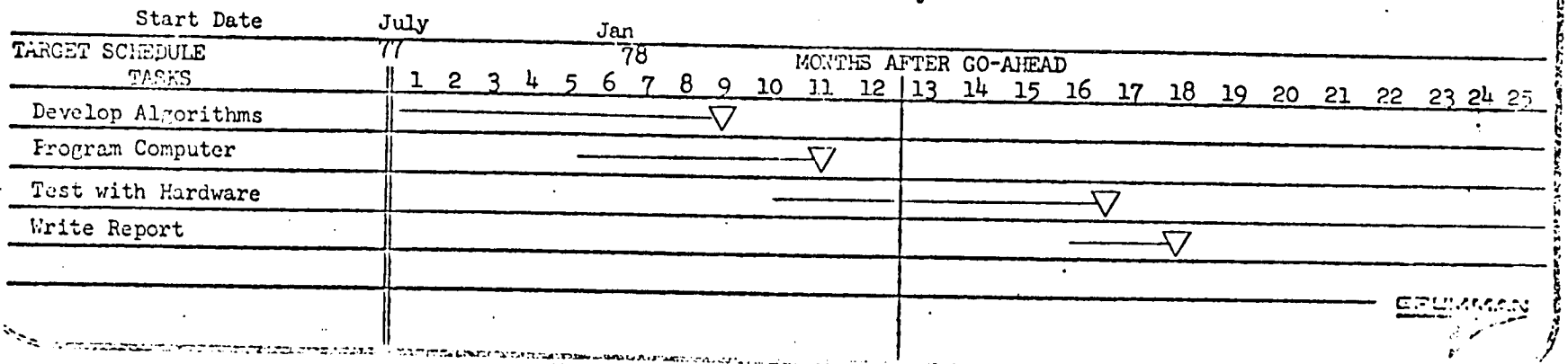
OBJECTIVES To develop the advanced IMU to the point where it can be used in a space application.

TECHNICAL APPROACH
1. Develop software mechanizations for redundancy management.
2. Develop software and procedures for calibration of gyros on the launch pad.
3. Test the software with the hardware in the lab.

MANPOWER

FUNDING $500 K

SPECIALIZED FACILITIES Development and test in subcontractor's facility.



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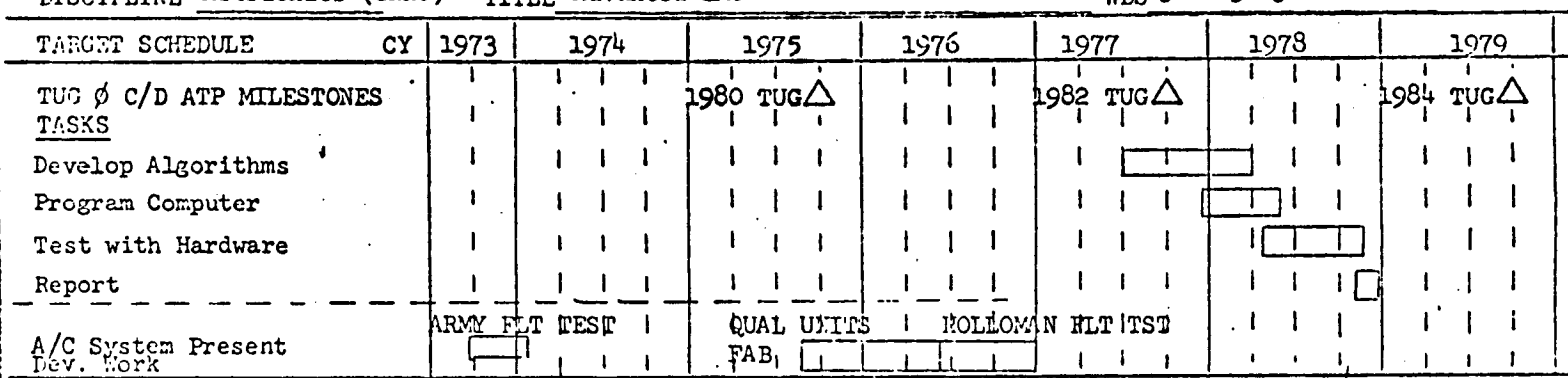
STORABLE SPACE TUG SUPPORTING RESEARCH & TECHNOLOGY

DISCIPLINE Astrionics (GN&C) TITLE Advanced IMU WBS 320-03-03-02



RESOURCE REQUIREMENTS FY	1974	1975	1976	1977	1978	1979	TOTAL
MANPOWER (MAN YEARS)				4	8		12
FUNDING							
a) DIRECT LABOR				100 K	200 K		300 K
b) EQUIPMENT & MAT'L					100 K		100 K
c) FACILITIES Inertial Test Stand					100 K		100 K
d) OTHER (SPECIFY)							
TOTAL				100 K	100 K		500 K

SPECIALIZED FACILITIES
TYPE/LOCATION/AVAILABILITY
FACILITIES DEV. TIME & COST

Development and test at subcontractor's facility.

01-018-11

410 AD-2, 310-3A/310 RE-3A, 320 A-3A/320 AE-3A, 310-3B/310 ARE-3B

STORABLE SPACE TUG SUPPORTING RESEARCH AND TECHNOLOGY - STRUCTURES
(Discipline)

TITLE GRAPHITE/EPOXY HONEYCOMB

WBS No. 320-03-01-03

STATUS Graphite/Epoxy honeycomb is well within Grumman's capability; however, the use of .0025" single ply to achieve a buildup to 0.012 face sheets requires further development.

JUSTIFICATION This design provides the lightest weight shell structure.

OBJECTIVES To establish, by test, design allowables for honeycomb structural components using metallic honeycomb core with graphite/epoxy face sheets utilizing 2.5 mil ply thickness to achieve a total face sheet thickness of 12 Mil.

11-01-8-77

TECHNICAL APPROACH Std. Test specimens will be fabricated using various combinations of ply directions to validate design allowables obtained from classic lamination theory.

MANPOWER Tooling 100 MHRS
Mfg. 400 MHRS M & P 160 HRS.

FUNDING $ 15 K

SPECIALIZED FACILITIES

TARGET SCHEDULE

TASKS	MONTHS AFTER GO-AHEAD 1 2 3 4 5 6 7 8 9 10 11 12	13 14 15 16 17 18 19 20 21 22 23 24 25
Fabricate Test Specimens	⟷	
Test	⟷	
Report	▽	

STORABLE SPACE TUG SUPPORTING RESEARCH & TECHNOLOGY

DISCIPLINE STRUCTURES TITLE GRAPHITE/EPOXY HONEYCOMB THIN GAGES WBS 320-03-01-03

TARGET SCHEDULE CY	1973	1974	1975	1976	1977	1978	1979
TUG Ø C/D ATP MILESTONES			1980 TUG △		1982 TUG △		1984 TUG △
TASKS							
o FABRICATE GR/EP HONEYCOMB USING .0025 PLIES to obtain UP TO 0.012 FACE SHEETS.							
o STANDARD TEST SPECIMENS WITH VARIOUS PLY DIRECTIONS TESTED TO OBTAIN DESIGN DATA							

RESOURCE REQUIREMENTS FY	1974	1975	1976	1977	1978	1979	TOTAL
MANPOWER (MAN YEARS) ½ MAN YEAR							
FUNDING							
a) DIRECT LABOR							
b) EQUIPMENT & MAT'L							
c) FACILITIES							
d) OTHER (SPECIFY)							
TOTAL							

SPECIALIZED FACILITIES

TYPE/LOCATION/AVAILABILITY

FACILITIES DEV. TIME & COST

II-C-10-14

410AD-2

STORABLE SPACE TUG SUPPORTING RESEARCH AND TECHNOLOGY - Main Propulsion (MPS)
(Discipline)

TITLE Long-Term SRM Space Storage

WBS No. 320-04-8-2,9-2

STATUS In 1963, Battelle Memorial conducted long-term space storage tests (hard vacuum, thermal and radiation) on SRM propellants, motor components and assembled motors. The testing was performed on PBAA and polyurethane propellants. Some accelerated thermal testing at -160°F has been conducted by UTC on HTPB during the past year.

JUSTIFICATION Some of the Storable Tug missions use deorbit SRM's; these impose a requirement for long-term space storage (3-6 yrs) on SRM's. The effects of hard vacuum and low temperature on the reliability and performance of the SRM must be considered. Radiation is not a consideration because the payloads requiring deorbit kick stages are not exposed to the Van Allen radiation belt for any significant duration.

OBJECTIVES

To demonstrate that long-term exposure to hard vacuum and low temperature will not affect the performance of present day propellants such as CTPB and HTPB.

D-810-13

TECHNICAL APPROACH

Expose propellant tensile bars, propellant burning strands and propellant additives to thermal vacuum conditions and conduct weight/vapor loss, tensile strength, and burning rate tests after exposure.

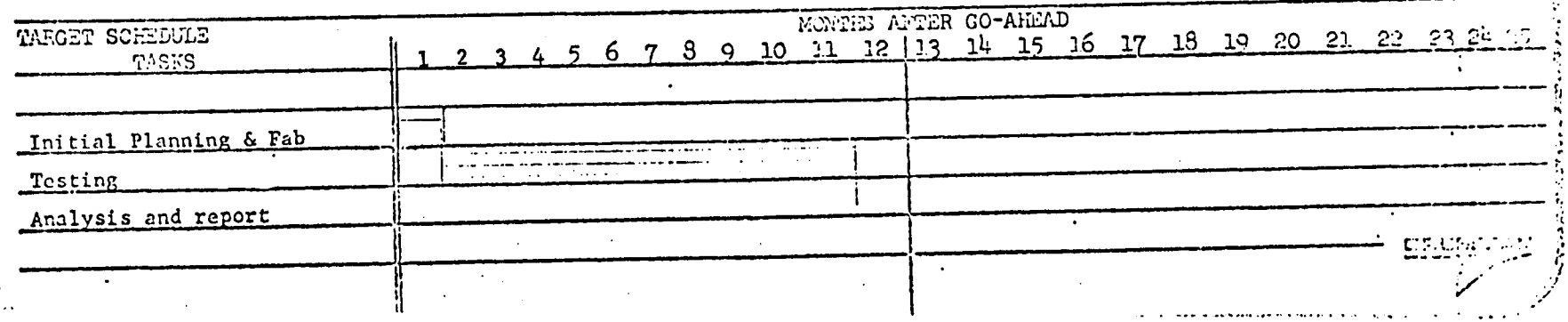
MANPOWER 2 man years

FUNDING Est. $100,000

SPECIALIZED FACILITIES
Available

TARGET SCHEDULE
TASKS

MONTHS AFTER GO-AHEAD



GRUMMAN

410AD-2

STORABLE SPACE TUG SUPPORTING RESEARCH & TECHNOLOGY

DISCIPLINE MAIN PROPULSION (MPS) TITLE LONG TERM SRM SPACE STORAGE WBS 320-04-8-2, -9-2

TARGET SCHEDULE CY	1973	1974	1975	1976	1977	1978	1979
TUG ∅ C/D ATP MILESTONES			1980 TUG△		1982 TUG△		1984 TUG△
TASKS							
Initial Planning & Fab.							
Testing							
Analysis and Report							

RESOURCE REQUIREMENTS FY	1974	1975	1976	1977	1979	1980	TOTAL
MANPOWER (MAN YEARS)					1	2	
FUNDING							
a) DIRECT LABOR					$ 38,000	$ 37,000	$ 75,000
b) EQUIPMENT & MAT'L					$ 12,000	$ 13,000	$ 25,000
c) FACILITIES							
d) OTHER (SPECIFY)							
TOTAL					$ 50,000	$ 50,000	$100,000

SPECIALIZED FACILITIES	
TYPE/LOCATION/AVAILABILITY	Battelle Memorial Inst., Atlantic Research or Similar
FACILITIES DEV. TIME & COST	None

11-8-10-74

ALL TUG VEHICLES

SHORABLE SPACE TUG SUPPORTING RESEARCH AND TECHNOLOGY - Structures
(Discipline)

TITLE Material Compatibility WBS No. 320-03-01-01-02

STATUS Material compatibility of Ti-6AL-4V STA and 2219-T87 Aluminum alloy in the presence of MMH at temperatures up to 150°F is required. Compatibility of N_2O_4 with 2219-T87 is also required.

JUSTIFICATION Compatibility of propellants with tankage material must be assessed to obtain the reuse life of the tanks under cyclic loads.

OBJECTIVES The objective of the program is to obtain the static and fatigue properties of the tankage parent and weldment materials under cyclic exposure to propellants and load.

TECHNICAL APPROACH Static and fatigue properties of candidate materials specimens will be obtained prior to and after exposure to the propellants. Tests will be performed at R.T. and 150°F.

MANPOWER One man-year FUNDING $ 25 K

SPECIALIZED FACILITIES

TARGET SCHEDULE

TASKS	MONTHS AFTER GO-AHEAD 1 2 3 4 5 6 7 8 9 10 11 12	13 14 15 16 17 18 19 20 21 22 23 24 25
Test Plan		
Spec. Fab.		
Test		
Report		

ALL TUG VEHICLES

STORABLE SPACE TUG SUPPORTING RESEARCH & TECHNOLOGY

DISCIPLINE STRUCTURES TITLE MATERIALS COMPATIBILITY DATA WBS 320-03-01

TARGET SCHEDULE CY	1973	1974	1975	1976	1977	1978	1979
TUG Ø C/D ATP MILESTONES			1980 TUG △		1982 TUG △		1984 TUG △
TASKS o FABRICATE & TEST MATERIAL SPECIMENS OF PARENT MAT'L & WELDMENTS TO OBTAIN COMPATIBILITY DATA FOR N_2O_4 & MMH UP TO 200°F. MATERIALS 6AL-4V, 2219-T87 & T-81							

RESOURCE REQUIREMENTS FY	1974	1975	1976	1977	1978	1979	TOTAL
MANPOWER (MAN YEARS) ONE MANYEAR							
FUNDING a) DIRECT LABOR							
b) EQUIPMENT & MAT'L							
c) FACILITIES							
d) OTHER (SPECIFY)							
TOTAL							
SPECIALIZED FACILITIES TYPE/LOCATION/AVAILABILITY FACILITIES DEV. TIME & COST							

III-8.16-16

ALL TUG VEHICLES

STORABLE STAGE TUG SUPPORTING RESEARCH AND TECHNOLOGY - Structure
(Discipline)

TITLE Fracture Mechanics Test Data

WBS No. 320-03-01-01/02

STATUS Fracture mechanics test data for thin gage (.020 to .040) for Titanium 6AL-4V STA and 2219-T87 aluminum alloy exposed to N_2O_4 and MMH at temperatures up to 200°F is not available.

JUSTIFICATION Fracture mechanics data for thin gage tank material are required to assess the fracture mode and life cycle of the tug propellant tanks.

OBJECTIVES The objectives of the program are to obtain K_{ic}, K_{th} and flaw growth data for parent and weldment materials in the induced thermal environment up to 200°F. Data to be obtained prior to and after exposure to the candidate propellants. In addition to fracture mechanics data, NDE techniques are to be employed on the test specimens to assess flaw detection capability.

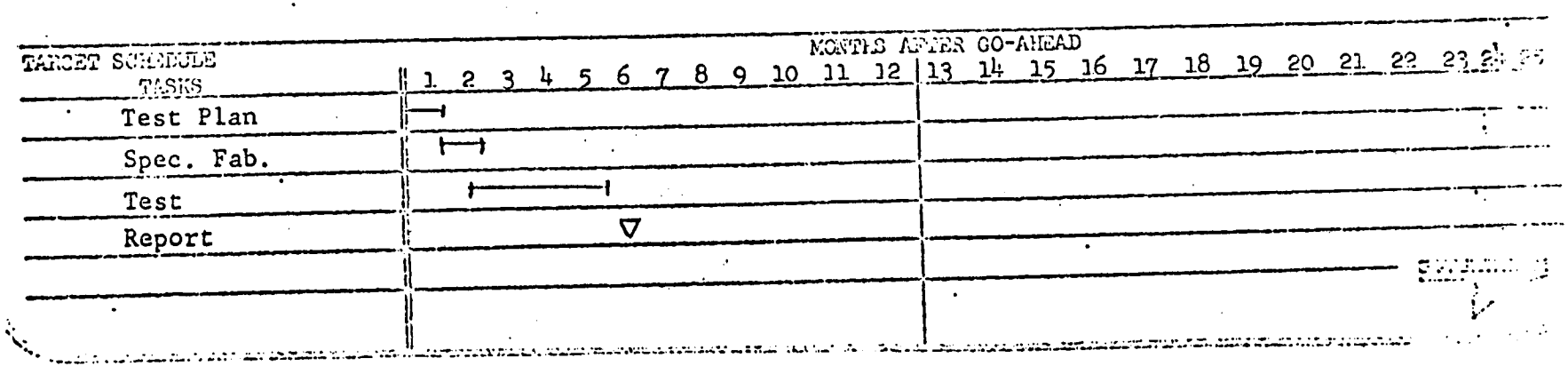
TECHNICAL APPROACH Standard fracture elemental specimens are to be employed. Tests are to be employed. Tests are to be conducted at room temperature and at 150 and 200°F. Surface flaws of various sizes are to be used and NDE techniques are to be employed to document size where practical.

MANPOWER One man-year

FUNDING $25K

SPECIALIZED FACILITIES

TARGET SCHEDULE



ALL TUG VEHICLES

STORABLE SPACE TUG SUPPORTING RESEARCH & TECHNOLOGY

DISCIPLINE STRUCTURES TITLE FRACTURE MECHANICS DATA WBS 320-03-01 = 01/02

TARGET SCHEDULE CY	1973	1974	1975	1976	1977	1978	1979
TUG ∅ C/D ATP MILESTONES			1980 TUG △		1982 TUG △		1984 TUG △
TASKS o FABRICATE & TEST MAT'L SPECIMENS (parent metal & weldments) to obtain K_{IC} K_{TH} & FLAW GROWTH DATA FOR INDUCED ENVIRONMENTS INCL. 200°F. ALSO STATIC & FATIGUE DATA. MAT'LS 6AL-4V & 2219-T87 & T81							

RESOURCE REQUIREMENTS FY	1974	1975	1976	1977	1978	1979	TOTAL
MANPOWER (MAN YEARS) ONE MAN YEAR							
FUNDING a) DIRECT LABOR							
b) EQUIPMENT & MAT'L							
c) FACILITIES							
d) OTHER (SPECIFY)							
TOTAL							
SPECIALIZED FACILITIES TYPE/LOCATION/AVAILABILITY FACILITIES DEV. TIME & COST							

4-6.10-18

110 A-1, 410 AD-2, 310-3A/310 RE-3A, 320 A-3A/320 AE-3A, 310-3B/310 ARE-3B, 670 A-3B/670 ADE-3B

STORABLE SPACE TUG SUPPORTING RESEARCH AND TECHNOLOGY - Thermal Control
(Discipline)

TITLE SPACE TUG HEAT PIPES

WBS No. 320-04-02

STATUS

Heat pipes (HP) are currently being used in both ground and space application. The variable conductance heat pipe (VCHP) principle is particularly attractive for Tug application but requires further development.

JUSTIFICATION

The fuel cell and certain high power density avionics units carried on the Space Tug require active cooling. Trade studies which have examined pumped loop radiators, sublimators and various heat pipes have indicated the obvious merits of the variable conductance heat pipe. A VCHP radiator could interface with the pumped loop heat transport system of the fuel cell, eliminating the cost and complexity of a selective stagnation radiator with its associated unreliable automatic bypass valves. A VCHP header, a heat transport device, could provide for high power density avionics heat transport without recourse to the active loop.

11-8-10-71

OBJECTIVES

Emphasis will be placed on experimentally obtaining the large turn down ratios which appear theoretically achievable and in developing predictive techniques.

TECHNICAL APPROACH

Design, fabricate and test a VCHP radiator and VCHP header and experimentally determine performance with emphasis on turn down ratio and shut off heat flux levels.

MANPOWER 5580 manhours FUNDING $100K

SPECIALIZED FACILITIES

Grumman Thermal Laboratory

TARGET SCHEDULE

TASKS	MONTHS AFTER GO-AHEAD 1 2 3 4 5 6 7 8 9 10 11 12	13 14 15 16 17 18 19 20 21 22 23 24 25
Establish Test Plan	-	
Material Procurement	-	
Design & Fab Test Specimens	———	
Conduct Engineering Tests	———	
Analyse Test Results	———	
Final Report	—	

GRUMMAN

STORABLE SPACE TUG SUPPORTING RESEARCH & TECHNOLOGY

DISCIPLINE _____ TITLE _____ WBS _____

TARGET SCHEDULE CY	1973	1974	1975	1976	1977	1978	1979
TUG Ø C/D ATP MILESTONES			1980 TUG △		1982 TUG △		1984 TUG △
TASKS							
TEST PLAN							
DESIGN & FAB TEST SPECIMEN							
CONDUCT TEST							
ANALYSIS & FINAL REPT							

RESOURCE REQUIREMENTS FY	1974	1975	1976	1977	1978	1979	TOTAL
MANPOWER (MAN YEARS)	1.5	1.5					
FUNDING							
a) DIRECT LABOR							
b) EQUIPMENT & MAT'L	100K						
c) FACILITIES							
d) OTHER (SPECIFY)							
TOTAL							

SPECIALIZED FACILITIES
TYPE/LOCATION/AVAILABILITY
FACILITIES DEV. TIME & COST

GRUMMAN THERMAL LAB, BETHPAGE N.Y., AVAILABLE & FULLY DEVELOPED

II-2-10-80

8.11 SPECIAL COST SENSITIVITIES

REFERENCE:

Due to the size and development of the Special Cost Sensitivities analysis, reference is made herein to Part 1, concept 110A-1, para. 8.11 of Volume 8.

8.13 COST ESTIMATING METHODOLOGY

WBS ELEMENT	ESTIMATING TECHNIQUE APPLIED		
	DDT&E	PRODUCTION	OPN
320-01 Proj. Management	CER's Based on IM Experience	Same as DDT&E	Same as DDT&E
320-02 Syst Eng & Integ	Same as 320-01	Same as 320-01	Same as 320-01
320-03-01 Structure	CER's Lower Level Analysis	Same as DDT&E	N/A
320-03-02 Thermal Insul	Same as 320-03-01	Same as 320-03 -01	N/A
320-03-03 Avionics	Vendor Est/Manpower/Wrap-around	Same as DDT&E	N/A
320-03-04 Propulsion	Gov't Est/Vendor Est/Wrap-around	Same as DDT&E	Same as DDT&E
320-03-05 Orbiter Interface	CER's Vendor Est/Wraparound	Same as DDT&E	N/A
320-03-06 Drop Tanks	N/A	N/A	N/A
320-03-07 Final Assy & C/O	Same as 320-01	Same as 320-01	N/A
320-04-01 Structure	Same as 320-03-01	Same as 320-03 -01	N/A
320-04-02 Thermal Insul	Same as 320-03-02	Same as 320-03 -02	N/A
320-04-03 Avionics	Same as 320-03-03	Same as 320-03 -03	N/A
320-04-04 Propulsion	Same as 320-03-04	Same as 320-03 -04	Same as 320-03-04
320-04-05 Interstage Interface	Same as 320-03-01	Same as 320-03 -01	N/A
320-04-06 Drop Tanks	N/A	N/A	N/A
320-04-07 RDM	Gov't est, CER's Vendor Est, wraparound	Same as DDT&E	Same as DDT&E
320-04-08 AKS	Same as 320-04-07	Same as 320-04 -07	Same as 320-04-07
320-04-09 DKS	Same as 320-04-07	Same as 320-04 -07	Same as 320-04-07
320-04-10 Cache Tank	N/A	N/A	N/A
320-04-11 Final Assy & C/O	Same as 320-03-07	Same as 320-03 -07	N/A
320-05 Logistics	CER's	Same as DDT&E	Same as DDT&E
320-06 Facilities	CER's	Same as DDT&E	Same as DDT&E
320-07 GSE	CER's, and End-item analysis	Same as DDT&E	Same as DDT&E
320-08 Vehicle Test	CER's, Manpower Loading	N/A	N/A
320-09 Launch Ops WTR	N/A	N/A	Manpower Loading
320-10 Launch Ops ETR	N/A	N/A	Manpower Loading

WBS ELEMENT	DDT&E	PRODUCTION	OPN
320-11 Flt Ops DOD	CER's & Manpower Loading	N/A	Same as DDT&E
320-12 Flt Ops NASA	Same as 320-11	N/A	Same as DDT&E
320-13 Ref & Int, 1st TR	N/A	N/A	Manpower Loading
320-14 Ref & Int, 2nd TR	N/A	N/A	Manpower Loading

COST = A (BASE)^B	PROGRAM BASIS	BASE	A DDT&E	A PROD	B DDT&E	B PROD
PROJECT MGMT.	LM	VEH COST	.1	.09	1	1
	LM	LESS ENG.				
SE & E	LM	VEH COST LESS ENG.	.13	.08	1	1
STRUCTURE	LM	WEIGHT				
SPUN AL. TANKS			124	15	.71	.61
TI TANKS			140	24.3	.71	.61
BODY SHELL			25	2.8	.71	.61
THRUST STRUCTURE			5.5	0.4	1	1
METEOROID SHIELD			5.5	.47	1	1
PAYLOAD INTERFACE			37.2	3.4	1	1
PROPULSION						
ACPS THRUSTERS		VENDOR COST	2	1.66	.7	.7
ACPS SUPPORT		VENDOR COST	2.4	1.84		
EPS WIRING	LM	(WEIGHT)	39.7	7	.7	.7
ORBITER INTERFACE, STRUCTURE	LM	WEIGHT	5.5	,4	1	1
FINAL ASSY & C/O	LM	VEH COST	.54	.18	1	1