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SYSTEMS RESEARCH AND PLANNING DIVISION

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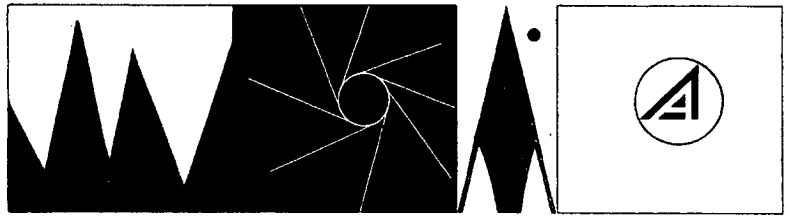

AEROSPACE CORPORATION

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VAULT NUMBER

D18796

TITLE MOL RENDEZVOUS

AEROSPACE CORPORATION

PRESENTATION

AUTHOR L. M. WEEKS DATE OCT. 15, 1964

AUDIENCE DR. B. P. LEONARD, DR. W. C. WILLIAMS,
S. M. TENNANT, C. L. OLSON

LOCATION E. S. O.

DISTRIBUTION CONTROLLED BY L. M. WEEKS

DOWNGRADED AT 3 YEAR INTERVALS;
DECLASSIFIED AFTER 12 YEARS.
DOD DIR 5200.10

MJO: 5107-10
CCC: 2130

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BRIEFING

MOL RENDEZVOUS

OUTLINE

SIAMESE TWIN ALTERNATIVE
EXPERIMENT - RESUPPLY - 60 DAYS
DOCKING CONSIDERATIONS
MOL RELIABILITY ESTIMATES
PRESENT INTEGRAL LAUNCH EXTENSIONS
TITAN III GROWTH POTENTIAL
THE INTEGRAL LAUNCH WITH TITAN III GROWTH
SOME RENDEZVOUS PAYLOAD - DURATION CONFIGURATIONS
A RENDEZVOUS RELIABILITY ESTIMATE
MOL RENDEZVOUS MISSION MECHANICS
IMPACT OF RENDEZVOUS ON TEST AND OPERATIONS
AN EXPERIMENT ALLOCATION
MOL RENDEZVOUS INCREMENTAL COST ESTIMATE
A COST-EFFECTIVENESS COMPARISON OF RENDEZVOUS AND INTEGRAL LAUNCH
IMPROVING LAUNCH VEHICLE CAPABILITY
SOME SUMMARY RENDEZVOUS CONSIDERATIONS
CONCLUSIONS ON MOL RENDEZVOUS
SOME OTHER NATIONAL SPACE PROGRAMS
RECOMMENDATIONS AND ACTION ITEMS

MOL RENDEZVOUS

RENDEZVOUS ALTERNATIVES

A. SIAMESE TWIN

B. EXPERIMENT - RESUPPLY - 60 DAYS

MOL RENDEZVOUS

ALTERNATE A

SIAMESE TWINS

OBJECTIVE:

- TRADE ONE CREW MEMBER
- KEEP ONE CREW MEMBER ON ORBIT 45 TO 60 DAYS
- ONE SET EXP. FIRST 30 DAYS (3000#)
- ANOTHER SET EXP. SECOND 30 DAYS (~ 2000#)

CONFIGURATION:

- BAREST MINIMUM CHANGE TO MOL
- NO UMBILICAL OR COMPATIBLE DISPLAYS BETWEEN TARGET AND CHASER
- QUALIFIED SUB-SYSTEMS TO ONLY 30 DAYS

RENDEZVOUS ALTERNATE A (SIAMESE)

TARGET VEHICLE

- STANDARD MOL CONFIGURATION PLUS
  - / DOCKING RING AND SHELL
  - / RADAR TRANSPONDER
  - / TUNNEL TO CHASER VEHICLE
- APPROXIMATE 3000# EXPERIMENTS

RENDEZVOUS ALTERNATE A (SIAMESE)
CHASER VEHICLE

- STANDARD MOL CONFIGURATION PLUS
  - / 450 FPS EXTRA IN TRANSTAGE
  - / 50 FPS DOCKING IN LABORATORY
  - / FORK AND SHELL DOCKING (MALE)
  - / GEMINI B RADAR
  - / GEMINI B COMPUTER OPERATIVE IN RENDEZVOUS MODE
  - / TUNNEL
  - / OPTICS AND/OR TV FOR TERMINAL RENDEZVOUS AND DOCKING
- APPROXIMATELY 2000 POUNDS EXP. PAYLOAD

RENDEZVOUS ALTERNATE A

SIAMESE TWIN - EXTRA VEHICULAR

MOL RENDEZVOUS

ALTERNATIVE B

LARGE EXPERIMENT (NAVY ?)

AND

RESUPPLY - 60 DAYS

MOL RENDEZVOUS

MISSION

ALTERNATE B

OBJECTIVE:

- TO SHOW MILITARY MAN CAN OPERATE EQUIPMENT ON ORBIT ~60 DAYS

CONFIGURATION: (TAIL TO TAIL DOCKING)

- TARGET VEHICLE
  - / 60 DAY QUALIFIED ECS, EXPERIMENTS
  - / FEMALE DOCKING, TUNNEL, DISPLAYS FOR DOCKED CONFIGURATION
  - / 3000# EXPERIMENTS (NAVY)
- CHASER VEHICLE (RESUPPLY)
  - / 45 TO 60 DAY QUALIFIED SUBSYSTEMS
  - / MALE DOCKING, TUNNEL, DISPLAYS, ETC.
  - / ~400 FPS EXTRA FUEL IN TRANSTAGE
  - / ~100 FPS DOCKING FUEL IN LABORATORY
  - / ~1000# ADDITIONAL EXPERIMENTS

RENDEZVOUS

TARGET VEHICLE CONFIGURATION

ALTERNATE B

- STANDARD MOL CONFIGURATION PLUS
  - / DOCKING RING AND SHELL
  - / RADAR TRANSPONDER (AGENA TARGET)
  - / TUNNEL TO CHASE VEHICLE
  - / DISPLAYS TO MONITOR CHASER VEHICLE
  - / CONTROLS TO MONITOR CHASER VEHICLE
  - / 60 DAY QUALIFIED ECS, EXPERIMENTS
  - / TWO WAY VOICE LINK TO CHASER
  - / TWO WAY DATA LINK TO CHASER
- APPROXIMATELY 3000# EXPERIMENTAL PAYLOAD
  - / (SAY) NAVY EXPERIMENT

RENDEZVOUS

CHASER VEHICLE CONFIGURATION

ALTERNATE B

- STANDARD MOL CONFIGURATION PLUS
  - / 45 TO 60 DAY QUALIFIED ECS, POWER, ATTITUDE, EXPERIMENTS
  - / 400 FPS EXTRA FUEL IN TRANSTAGE
  - / 100 FPS EXTRA DOCKING FUEL IN LABORATORY
  - / ~1000# EXPERIMENTS DIFFERENT FROM CHASER VEHICLE
  - / EXPENDABLES FOR 45 DAYS DOCKED
  - / FORK AND SHELL DOCKING (MALE)
  - / GEMINI B RADAR INSTALLED
  - / GEMINI B COMPUTER OPERATIVE IN RENDEZVOUS MODE
  - / TUNNEL AND DISPLAYS TO OPERATE DOCKED CHASER
  - / OPTICS AND/OR TV FOR TERMINAL RENDEZVOUS AND DOCKING

MOL RENDEZVOUS

OPERATION

ALTERNATE B

TARGET

- NIGHT-LAUNCH
- OPERATES EXPERIMENTS FOR 15 DAYS
- TRIMS TO ALTITUDE FOR RENDEZVOUS COMPATIBLE ORBIT (31/2)
- PREPARES FOR RENDEZVOUS
- TERMINAL RENDEZVOUS AND DOCKING ASSIST TO CHASER

CHASER

- LAUNCH (DAYLIGHT 15, 17, 19, 21 DAYS LATER)
- LAUNCH ON FIXED AZIMUTH (WINDOW ~15 MINUTES)
- STAYS IN PHASING ELLIPSE (80 TO 160 N. M.)
- KILLS OUT OF PLANE ERROR
- KILLS PHASING
- COMPUTES AND EXECUTES FINAL RENDEZVOUS MANEUVER
- COMPLETES TERMINAL RENDEZVOUS AND DOCKING

MOL RENDEZVOUS

OPERATION (cont.)

TARGET AND CHASER DOCKED

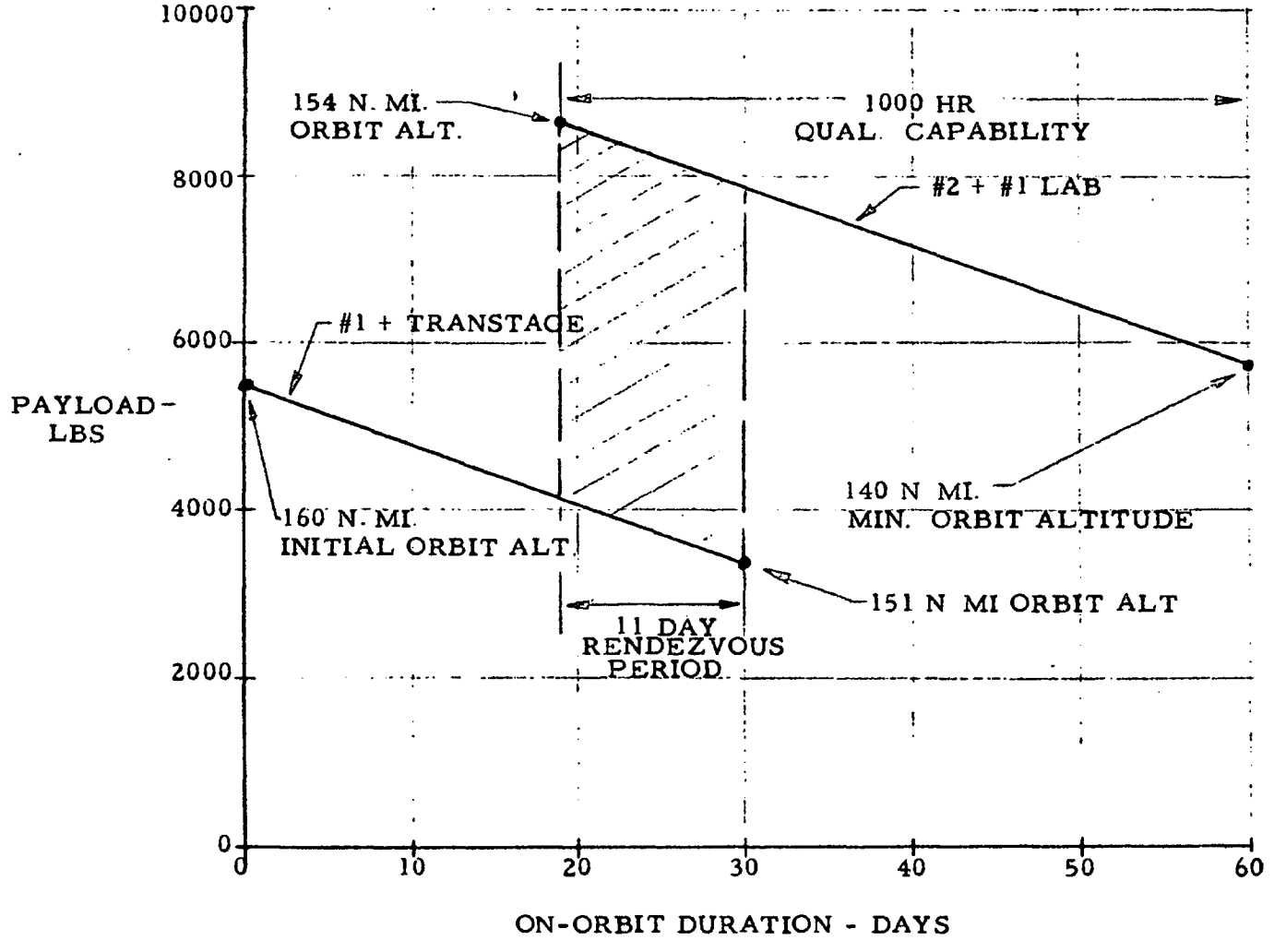
- BOTH CREWS ASSESS SITUATION
  (POWER, ECS, ATTITUDE FUEL, EXPERIMENT STATUS)
- CREWS PREPARE TO SEPARATE AND DE-ORBIT
  APPROPRIATE CREW AND GEMINI B
- SEPARATE LABORATORIES (IF APPROPRIATE)
- ONE CREW CONTINUES TO OPERATE EXPERIMENTS IN
  LABORATORIES #1 AND #2
- MONITOR AND OPERATE
  - / DUAL ATTITUDE SYSTEM
  - / DUAL ECS SYSTEM
  - / DUAL POWER SYSTEM
  - / REMAINING GEMINI B

LOAD ANALYSIS - RENDEZVOUS

BASELINE	TARGET VEHICLE			CHASE VEHICLE
205			COMMUNICATIONS	
	18		VOICE	18
	45		INSTRUMENTATION	20
	100		DATA MGT.	
	8		TLM XMITTERS	
	12		COMMAND	
	22		TRACKING	—
		205		38
236			ATTITUDE CONTROL	
	59		25% DUTY CYCLE	
362			EC/LS (SHIRT SLEEVE)	
	207.5		ATM CONTROL	
	87.5		THERMAL CONTROL	
		295		87.5
150			GEMINI	150
120		120	LIGHTING	
250	250		EXPERIMENTS	
110	110		COMPUTER	
		360		
60		60	DISPLAY	
60		60	MISCELLANEOUS	60
1,553	1,159		TOTALS	335.5

MOL RENDEZVOUS CONFIGURATION

PAYLOAD VS. ON-ORBIT DURATION
- o SUBSYSTEMS QUALIFIED TO 1000 HR.
- o NO ORBIT MAINTENANCE



DOCKING KIT

WEIGHT ESTIMATE

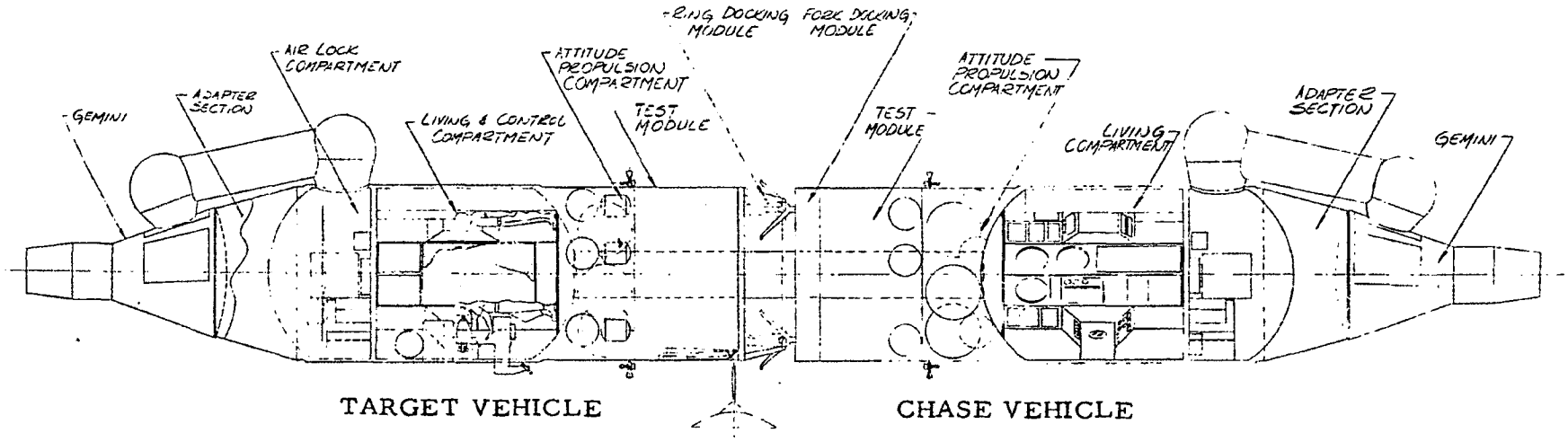
ITEM	TARGET VEH. (LBS)	CHASE VEH. (LBS)
SHELL STRUCTURE	410	410
TRANSTAGE SEPARATION PROVISIONS	35	35
TUNNELS AND SEALS	44	44
N_2 TANKAGE AND SUPPORTS	--	65
0_2 AND N_2 PLUMBING	10	10
PROVISIONS FOR CRYOGENIC MANIFOLDING	150	150
DOCKING MECHANISM SUPPORTS (ARMS)	90	--
DOCKING ARM ASSEMBLY (4)	80	--
RING SEGMENTS (4)	--	30
DOCKING CONTROL PACKAGE AND PLUMBING	6	--
INSTALLATION PROVISIONS	10	4
ELECTRICAL DISTRIBUTION (HARNESS ASSEM.)	15	17
MONITOR & CONTROL (HARNESS ASSEM.)	30	30
ELECTRICAL DISTRIBUTION (UMBILICAL)	15	--
MONITOR & CONTROL (UMBILICAL)	15	--
CONTROL & MONITORING INSTRUMENTATION	60	60
REMOTE TV CAMERAS	--	40
RENDEZVOUS RADAR & CONTROLS	--	120
HATCHES & MECHANISM	20	20
TOTAL KIT WEIGHT	990	1,035

MOL RENDEZVOUS AND DOCKING WEIGHT PENALTIES

ITEM	TARGET VEH. △ W (LB)	CHASE VEH. △ W (LB)
o HARDWARE △WT.		
REMOVE TEST SECTION	-410	-410
ADD DOCKING SECTION	910	795
CONTROL & MONITORING INSTRUMENTATION	60	60
HATCHES & MECHANISMS	20	20
RENDEZVOUS RADAR & CONTROLS (GEM. B)	-	120
REMOTE TV CAMERAS	-	40
NET HARDWARE TOTAL	580	625
o EXPENDABLES △W (NITROGEN LEAKAGE MAKE-UP)	-	85
o PROPELLANT △ W		
PLANE & PHASE CHANGE (TRANSTAGE - 450 FPS)	-	1120
FINAL DOCKING (LABORATORY - 50 FPS)	-	150
TOTAL △ W	580	1980

DOCKING CONSIDERATIONS

IMPACT OF DOCKING ON BASELINE VEHICLE



TARGET VEHICLE CHASE VEHICLE

- ESTIMATED WEIGHT PENALTY

  FOR RING AND FORK CONCEPT (CONSIDERED A REPRESENTATIVE SYSTEM)

  - TARGET VEHICLE

. RING ASSEMBLY AND SHELL STRUCTURE	250
. CREW TRANSFER AND HATCH	110
. UMBILICAL CONNECTION PROVISIONS	10
TOTAL	370 LBS

  - CHASE VEHICLE

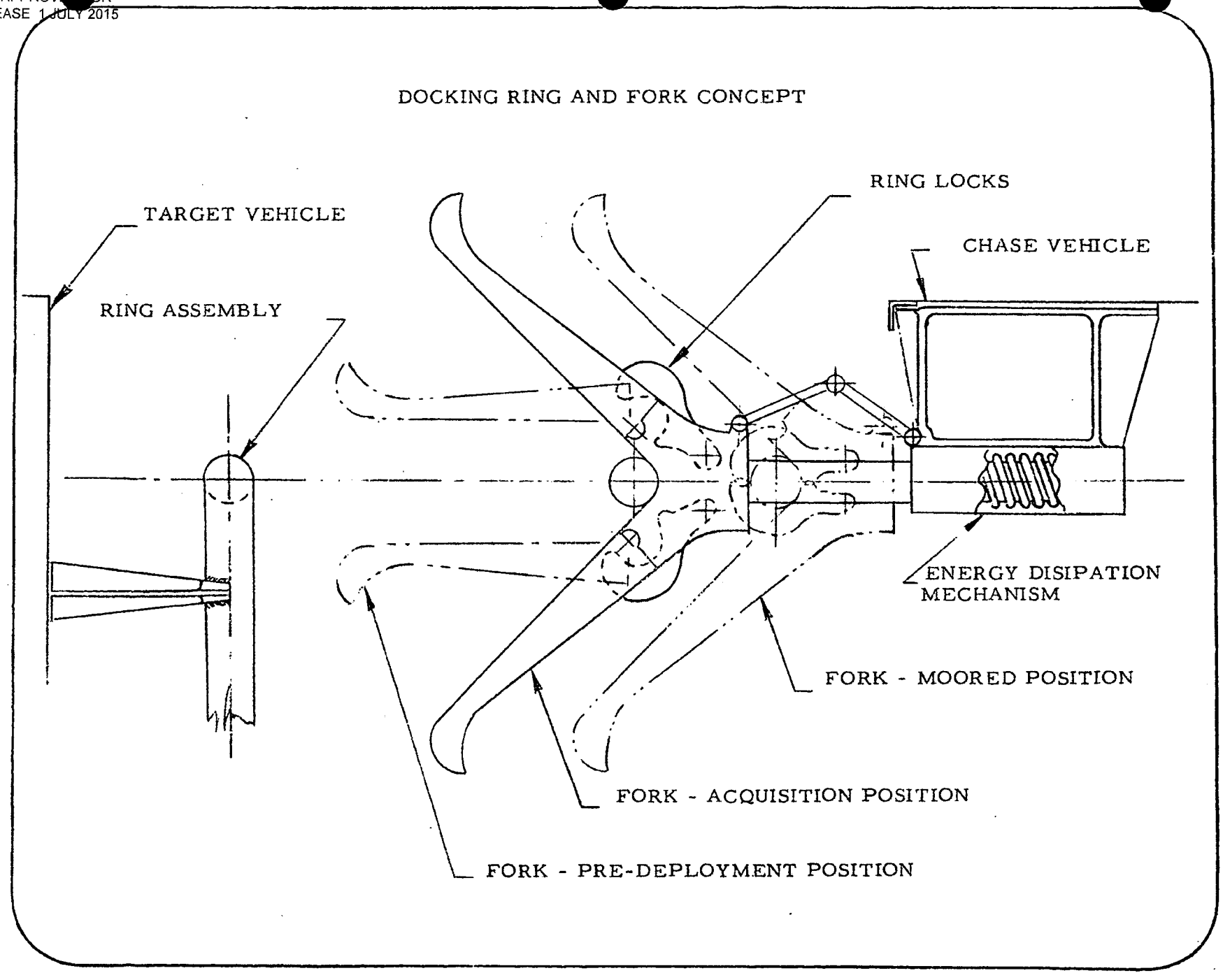
. FORK ASSEMBLY AND SHELL STRUCTURE	320
. CREW TRANSFER AND HATCH	110
. UMBILICAL AND CONNECTION PROVISIONS	30
TOTAL	460 LBS

IMPACT OF DOCKING ON BASELINE VEHICLE

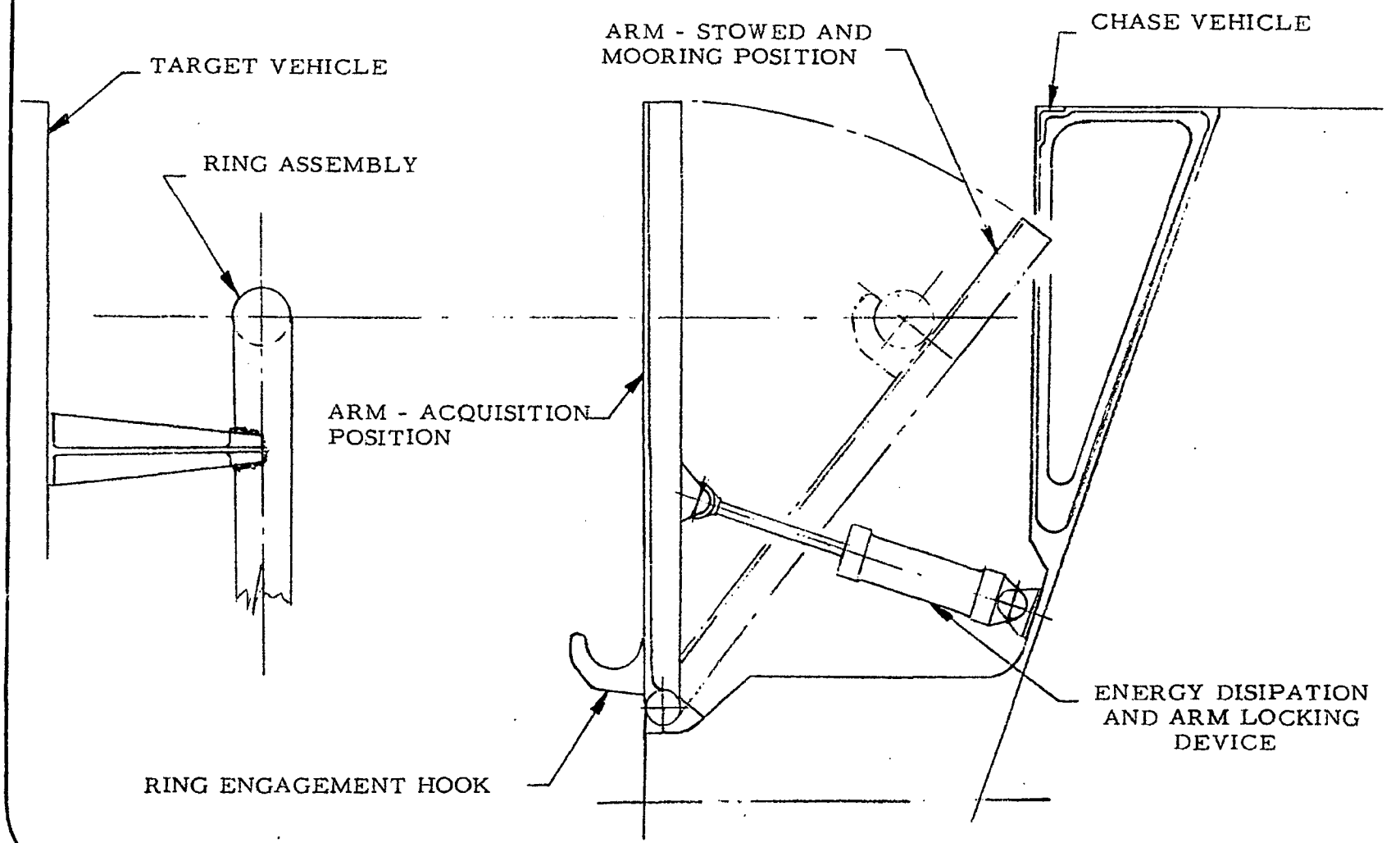
- BASELINE DOCKING CONCEPT
  - TAIL - TO - TAIL SELECTED OVER OTHER METHODS
    - REQUIRES MINIMUM MODIFICATIONS TO GEMINI
    - PROVIDES FOR EASY CREW TRANSFER BETWEEN VEHICLES
    - HAS MINIMUM ON-ORBIT DRAG CONFIGURATION
    - DOCKING MANEUVER IS CONSIDERED RELATIVELY SIMPLE
    - PROVIDES UNENCUMBERED SEPARATION OF GEMINI FROM LABORATORY VEHICLE

- DOCKING SYSTEM REQUIREMENTS
  - DISSIPATE IMPACT ENERGY WITH LOW ACCELERATIONS
  - IMMEDIATE ACQUISITION OF OTHER VEHICLE
  - ACCURATE CENTERING AND ALIGNMENT
  - POSITIVE LOCKING TOGETHER OF VEHICLES
  - FAST AND RELIABLE RELEASE

- CONCEPTS PROPOSED
  - RING AND FORK MECHANISM (MAC)
    - PASSIVE RING ON TARGET VEHICLE
    - ACQUISITION FORK AND ENERGY DISSIPATION DEVICE ON CHASE VEHICLE
  - RING AND MOVABLE ARM MECHANISM (MMC)
    - PASSIVE RING ON TARGET VEHICLE
    - ACQUISITION ARM AND ENERGY DISSIPATION DEVICE ON CHASE VEHICLE



DOCKING RING AND ARM CONCEPT

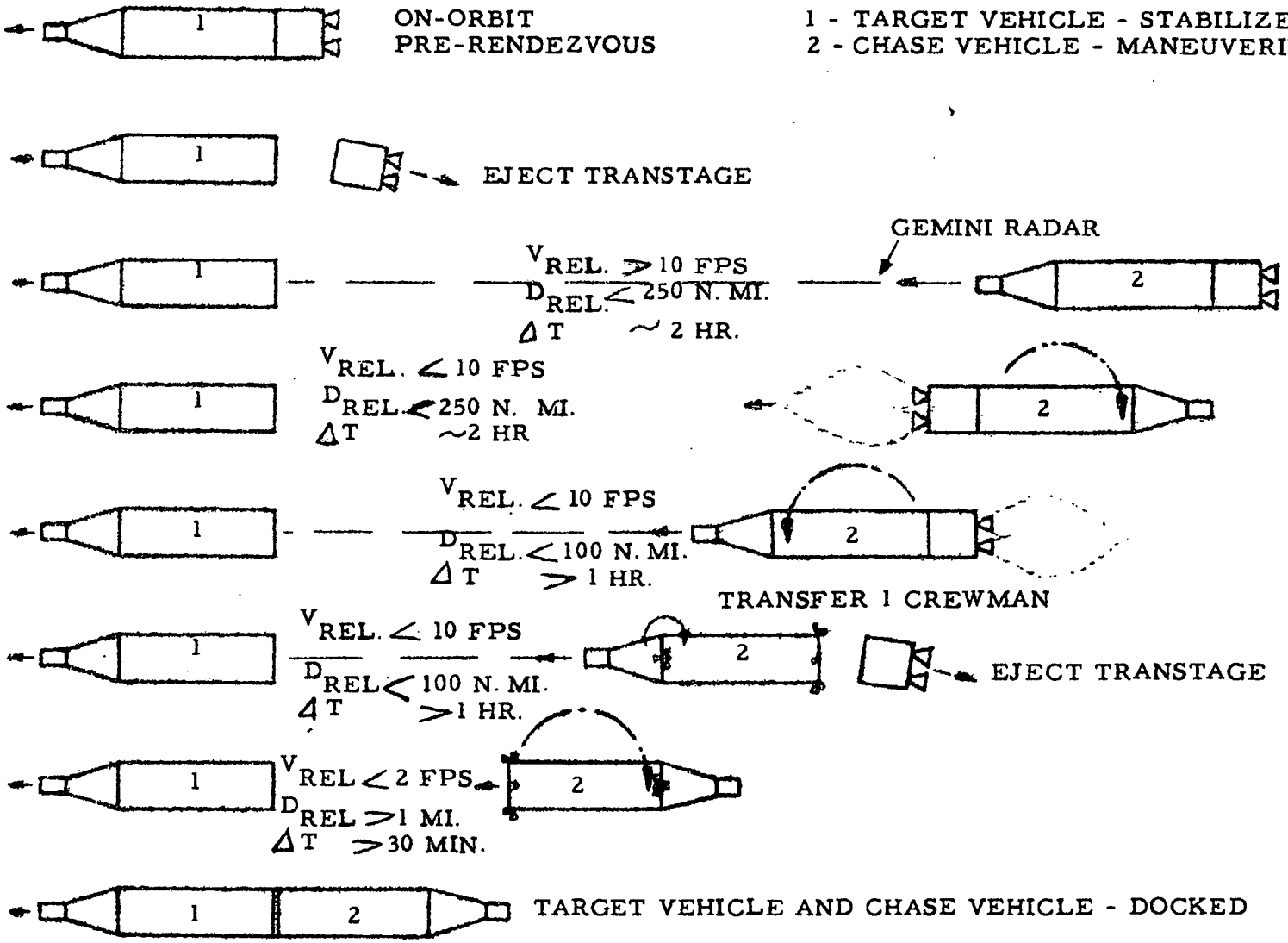


MOL WEIGHT SUMMARY
RENDEZVOUS CONFIGURATION

		TARGET VEHICLE		CHASE VEHICLE
GEMINI B + RETRO		6,000		6,000
LAB		7,910		8,920
STRUCTURE	2,840		2,840	
RCS	560		560	
ELECTRICAL POWER (FUEL CELL)	2,100		2,100	
COMMUNICATIONS	200		200	
ECS	950		950	
INSTRUMENTATION	130		130	
PERSONNEL ACCOMMODATIONS	740		740	
DOCKING RING + PROVISIONS (TARGET)	390			
DOCKING FORK + PROVISIONS (CHASE)			1,400	
DISCRETIONARY PAYLOAD		5,490		4,480
SPARE PARTS + MAINT. EQUIPMENT	140		140	
ACS PROPELLANTS	260		260	
SERVICE ITEMS	1,760		1,760	
EXPERIMENT-WEIGHT AVAILABLE	3,330		2,320	
CONTINGENCY		2,000		2,000
ON-ORBIT WEIGHT		21,400		21,400
EXPENDABLES RATE (FOR 30 DAY MISSION)	70#/DAY			

RENDEZVOUS

TERMINAL DOCKING PHASE CONCEPT



MOL

THE RELIABILITY (EFFECTIVENESS)

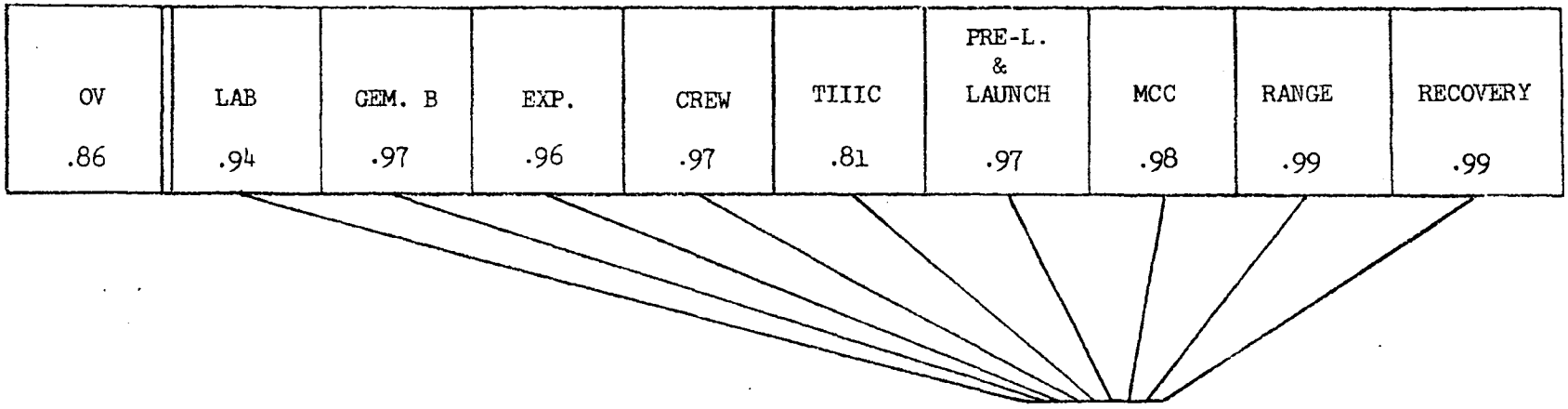
ESTIMATES

EFFECTIVENESS ALLOCATIONS

	OV (Derived)	Lab.	GEMINI B	Experiments	Crew & Crew Equip.	TITAN III C	Pre-Launch & Launch Opn's.	Mission Control	Range Support	Recovery FORCES	π PARA.
SAFETY (NO CASUALTY)	.9918	.9994	.9858	.9997	.9959	.9969	.9980	.9968	.9988	.9989	.9712
PRELAUNCH	$9^3$88	9^5	9^4	9^5	9^4	9^3	9^3	9^4	9^5	----	.9976
BOOST	$9^2$38	9^4	$9^2{}_5$	9^4	9^3	($9^2$8)	9^3	9^3	9^4	9^5	.9897
ORBITAL	$9^2$82	($9^3$5)	9^4	9^4	9^3	9^4 *	----	9^3	9^4	9^5	.9971
DEORBIT	----	----	$9^2{}_5$	---	9^3	----	----	9^3	9^3	9^5	.9920
RECOVERY	----	----	$9^2{}_5$	----	9^3	----	----	9^4	----	9^3=	.9929
MISSION COMP. (NO ABORT)	.9561	.9889	.9829	.9890	.9919	.8293	.9850	.9963	.9992	.9989	.7752
PRELAUNCH	$9^3$7	9^4	9^4	9^5	9^4	9^3	.99	$9^3{}_5$	9^4	----	.9881
BOOST	.983	9^3	(.99)	9^3	$9^2{}_5$	(.831)	$9^2{}_5$	9^3	$9^3{}_5$	9^5	.8123
ORBITAL	.973	(.99)	$9^2{}_5$	.99	9^3	9^3 *	----	9^3	9^4	9^5	.9719
DEORBIT	----	----	9^3	----	9^3	----	----	9^3	9^4	9^5	.9969
RECOVERY	----	----	9^3	----	9^3	----	----	9^4	----	9^3	.9969
DES. ADEQUACY (NO DEGRAD)	.9171	.9499	.9987	.9790	.9834	.9880	.9890	.9928	.9939	.9949	.8752
PRELAUNCH	$9^3$3	9^5	9^4	9^5	$9^3{}_5$	9^3	.99	9^4	9^5	----	.9883
BOOST	$9^2$69	9^4	9^3	9^3	9^3	.99	9^3	9^3	$9^2{}_5$	9^5	.9799
ORBITAL	.9206	.95	9^4	98	.99	9^3 *	----	$9^2{}_5$	9^3	9^5	.9151
DEORBIT	----	----	9^4	----	9^4	----	----	9^3	9^4	9^5	.9987
RECOVERY	----	----	9^3	----	$9^2{}_5$	----	----	9^4	----	$9^2{}_5$	.9889
π SEGMENTS AVAILABILITY	.8696 9^2	.9387 9^3	.9676 9^3	.9679 $9^2{}_5$	.9714 9^3	.8167 $9^2{}_5$	.9722 $9^2{}_5$	.9859 9^3	.9919 $9^2{}_5$	.9927 $9^2{}_5$	
SEGMENT E	.8609	.9378	.9667	.9629	.9704	.8126	.9673	.9849	.9869	.9877	.6392

* TRANSTAGE AFTER INJECTION (π = .9989, A = 9^3)

EFFECTIVENESS ALLOCATION



SYSTEM EFFECTIVENESS .64

PROGRAM EFFECTIVENESS > .85
(3 SUCCESSES IN 6 MANNED MISSIONS)

FIGURE 10

THE PRESENT INTEGRAL LAUNCH EXTENSIONS

ALT.

- α • CREW DURATION WITH EXPERIMENTS
- β • THE RADIOISOTOPE THERMO-ELECTRIC GENERATOR EXTENSION (RTG)
- γ • THE POWER DOWN APPROACH
- δ • THE SEVERE WEIGHT CONTROL APPROACH

INTEGRAL ALT. α

CREW DURATION WITHOUT EXP.

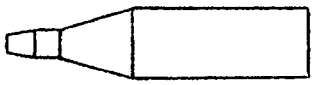
- PRESENT MOL CAN GO ~60 DAYS WITH ~400 # EXP.
- BIOMEDICAL ONLY
- PRESENT MOL CAN LOAD 60-DAY EXPENDABLES IN MOL

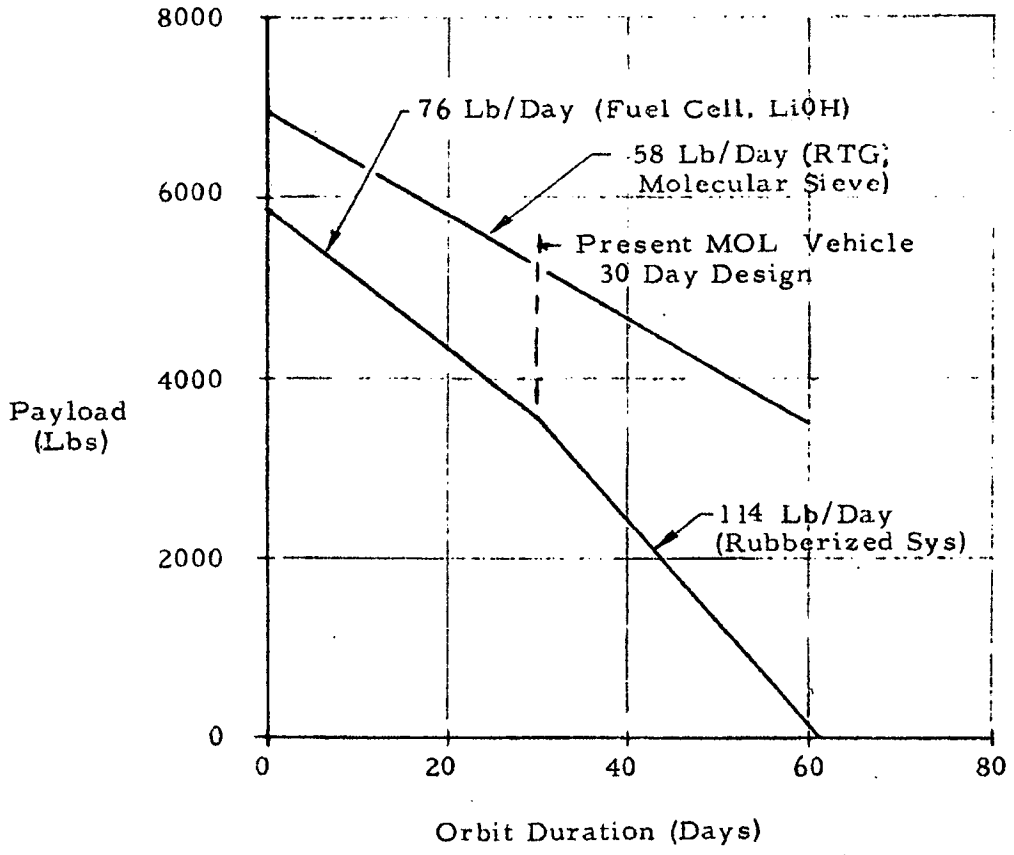
PRESENT 30-DAY - SYSTEM RELIABILITY ~ .64

60-DAY - REQUIRES MUCH IMPROVEMENT
(MAINTENANCE - ETR)

BASELINE MOL - EXTENDED DURATION
PAYLOAD VS. ORBIT DURATION

o Integral Launch





ALT. B

RTG EXTENSION

- 2500 # EXP. (NAVY?)
- 60 DAYS
- MOLECULAR SIEVE

PROBLEMS

RELIABILITY FOR 60 DAYS

RTG DEVELOPMENT - 30 TO 50 M$
- 30 TO 40 MONTHS

ALT. 8

THE POWER-DOWN APPROACH

LABORATORY ELECTRICAL LOAD ANALYSIS

LOAD	WATTS				
	STANDBY	AVE.	MIN.	PEAK	EMERGENCY
COMM., INSTR., DATA MGT.	171	205	171	367	171
ATTITUDE CONTROL	232	232	232	260	0
LIGHTING	60	120	60	120	60
E.C. & L.S.	420	540	420	655	420
DISPLAY	5	10	5	15	5
MISCELLANEOUS	30	60	30	90	0
GEMINI	200	200	100	600	400
EXPERIMENTS	136	250	136	976	0
TOTAL	1,254	1,617	1,154	3,092	1,056

ALT. 8

THE POWER-DOWN APPROACH

	MOL AVE. PWR.	POWER DOWN
COMM. INSTR. & DATA MGMT.	205	100
ATTITUDE CONTROL	232	100
LIGHTING	120	80
ECS AND LSS	540	320
DISPLAY	10	10
MISCELLANEOUS	60	60
GEMINI B	200	200
TRANSTAGE	200	---
EXPERIMENTS	250	100
	1,817 WATTS	970 WATTS

SÁVING OF 670 #

ALT. σ

BACKGROUND

EXPENDABLES FOR BASIC MOL VEHICLE

(30 DAY + 10% 160 N.M. ORBIT ALT.)

2 MAN CREW

ITEM	EXPENDABLE (LBS)	TANKS, ETC. (LBS)
PROPELLANTS	360	128
REACTANTS		
O_2	1,103	347
H_2	138	307
ATMOSPHERE		
PRIMARY O_2	340	132
SECONDARY (H. P.) O_2	21	68
LITHIUM HYDROXIDE AND ACTIVATED CHARC.	215	25
WATER	16	4
WATER PURIFYING CHEM.	3	---
FOOD	121	12
CLEANING TISSUES	12	2
DISPOSABLE CLOTHING	12	2
TOTAL	2,341	1,027
RATE OF EXPENDITURE	78 LBS/DAY	34 LBS/DAY
"RUBBARIZED" EXPENDABLES	112 LBS/DAY	

ALT. 8

THE POWER-DOWN APPROACH

- SAVE 670# ON ELECTRICAL POWER

- DRIFT 1/2 TIME TO SAVE ATT. FUEL

  SAVE 300 #

- WEIGHT SAVING

	1ST 30 DAYS	2ND 30 DAYS
POWER	670	670 + 330
ATTITUDE	300	300 + 120

TOTAL

- EXPERIMENTAL PAYLOAD FOR 60 DAYS

  APPROXIMATELY 2800#

ALT. 8

SEVERE WEIGHT CONTROL APPROACH

- PRESENT WEIGHT MARGIN IS ~3000 #
- PRESENT COST/LAUNCH ~$70,000,000
- PRESENT EXP. PAYLOAD ~3500 #
- VALUE OF # SAVED ≅ 20,000 $/#
- NON-RECURRING MAXIMUM PERMISSIBLE COST
  ≅120,000 $/# (6 LAUNCHES)
- VALUE OF WATT SAVED ≅ 10,000 $/WATT (30 DAY)
  20,000 $/WATT (60 DAY)
- NON-RECURRING MAXIMUM PERMISSIBLE COST
  ≅ 60,000 TO 120,000 $/WATT
- ATTRACTIVE WEIGHT SAVINGS POSSIBILITIES
  ~ 400 # FUEL CELLS
  ~400 # MAGNESIUM STRUCTURES

MOL FUEL CELL POWER SYSTEM SUMMARY

	PRATT AND WHITNEY		GENERAL ELECTRIC		ALLIS CHALMERS
	"Apollo" (400 Hr.)	1,000 Hour	"Gemini" (400 Hr.)	1,000 Hour	1,000 Hour
WEIGHT (LBS.)	4110	3472	3360	2982	2741
VOLUME ($FT.^3$)	156.8	131.6	112.4	102.8	93.8
DEVELOPMENT FUNDING TO DATE	≈34 M		≈20 M		≈4.5 M
HARDWARE STATUS	Qual. In Dec. 64	Proposal to NASA	Qual. In Oct. 64	Presently In Life Test	In Design (Funded)
PRODUCTION CAPABILITY	Production Facilities Producing "Apollo" F.C.		Production Facilities Producing "Gemini" F.C.		?

BASELINE: "GEMINI" FUEL CELL

ALT. 8

1,000 HOUR FUEL CELL STATUS

GENERAL ELECTRIC

FUEL CELL TEST PROGRAM

STACK	AVE. LOAD AMPS/STACK	COOLANT INLET TEMP. °F.	TEST HOURS	COMMENTS
83	3K	75	820	9-25-64 STILL ON TEST
84	5K	75	446	9-25-64 STILL ON TEST
82A	5	75	648	9-25-64 STILL ON TEST
R4	5/15	75	735	9-25-64 S TILL ON TEST
R3	5	62	891	9-25-64 STILL ON TEST
224	5	75	900	9-25-64 STILL ON TEST
241	5	75	785	9-24-64 FAILED
257	5	75	692	9-25-64 STILL ON TEST
SECTION				
11	3.1	75	715	0.2 VOLTAGE DROP STILL ON TEST

ALT. 6

SEVERE WEIGHT CONTROL APPROACH

SUMMARY

- 60 DAY POSSIBLE WITH EXP. PAYLOAD
  - NOW 400 #
  - PLUS 3000 # MARGIN
  - PLUS 400 # FUEL CELLS
  - PLUS 400 # MAG. STRUCTURE

    4200 #

IF HALF (2100#) COULD BE REALIZED A REASONABLE 60-DAY MISSION RESULTS

INTEGRAL LAUNCH SUMMARY

(α, β, γ, δ)

- CREW DURATION - 400 # EXP.

  MINIMUM CHANGE TO MOL

- RTG - 2500 # EXP.

- POWER DOWN - 2800 # EXP.

- WEIGHT CONTROL - 2100 # EXP.

- A NUMBER OF POSSIBLE APPROACHES SEEM TO EXIST TO OBTAIN 60 DAYS WITH EXPERIMENTS WITHOUT THE USE OF RENDEZVOUS

TITAN IIIC GROWTH POTENTIAL

VEHICLE CONFIGURATION	MINIMUM PERFORMANCE PAYLOAD - LB	
	EAST AMR 100 N. M. ORBIT	SOUTH PMR 100 N. M. ORBIT
STANDARD TITAN IIIC	23, 800	19, 550
TITAN IIIC/6 SEGMENT SOLID MOTORS	28, 830	23, 520
TITAN IIIC/7 SEGMENT SOLID MOTORS	31, 450	25, 700
TITAN IIIC/156 IN. MOTORS	39, 700	32, 700

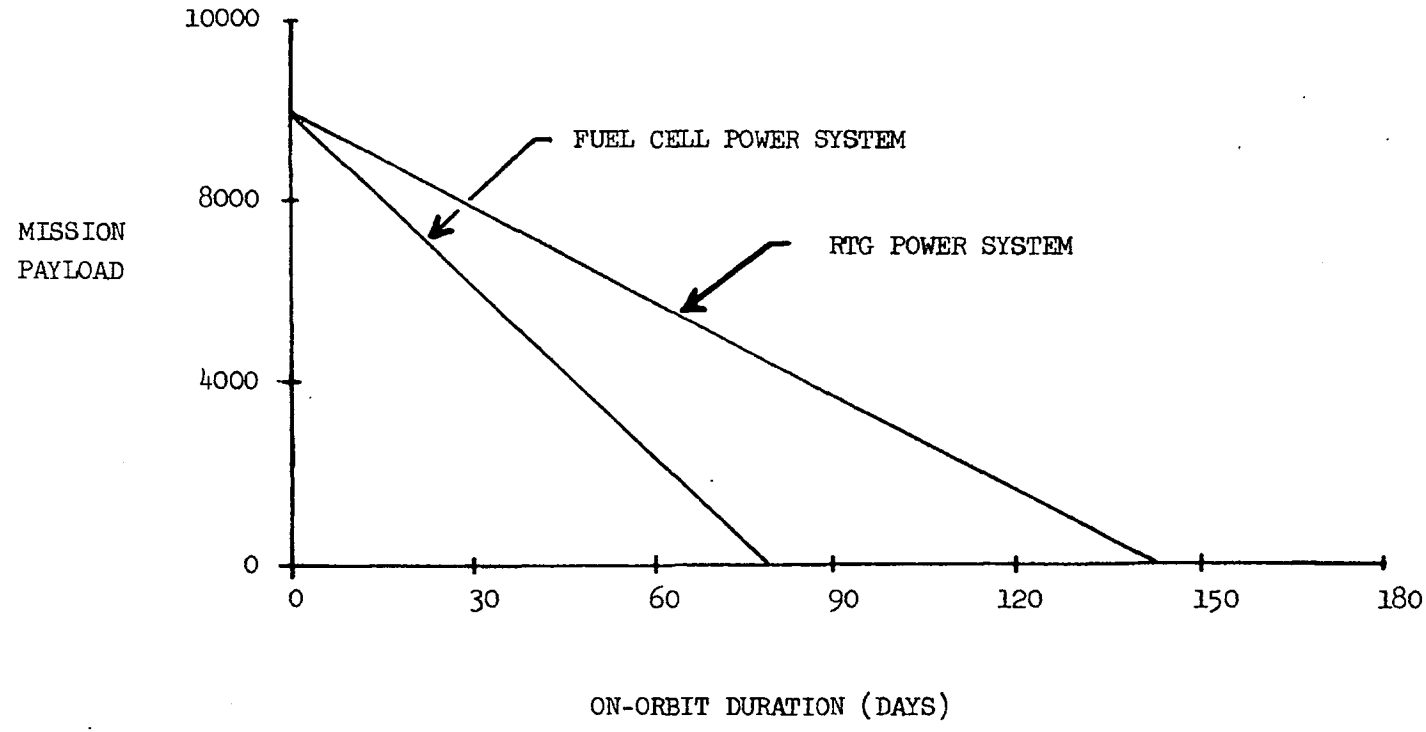
INTEGRAL LAUNCH

WITH

GROWTH TITAN III

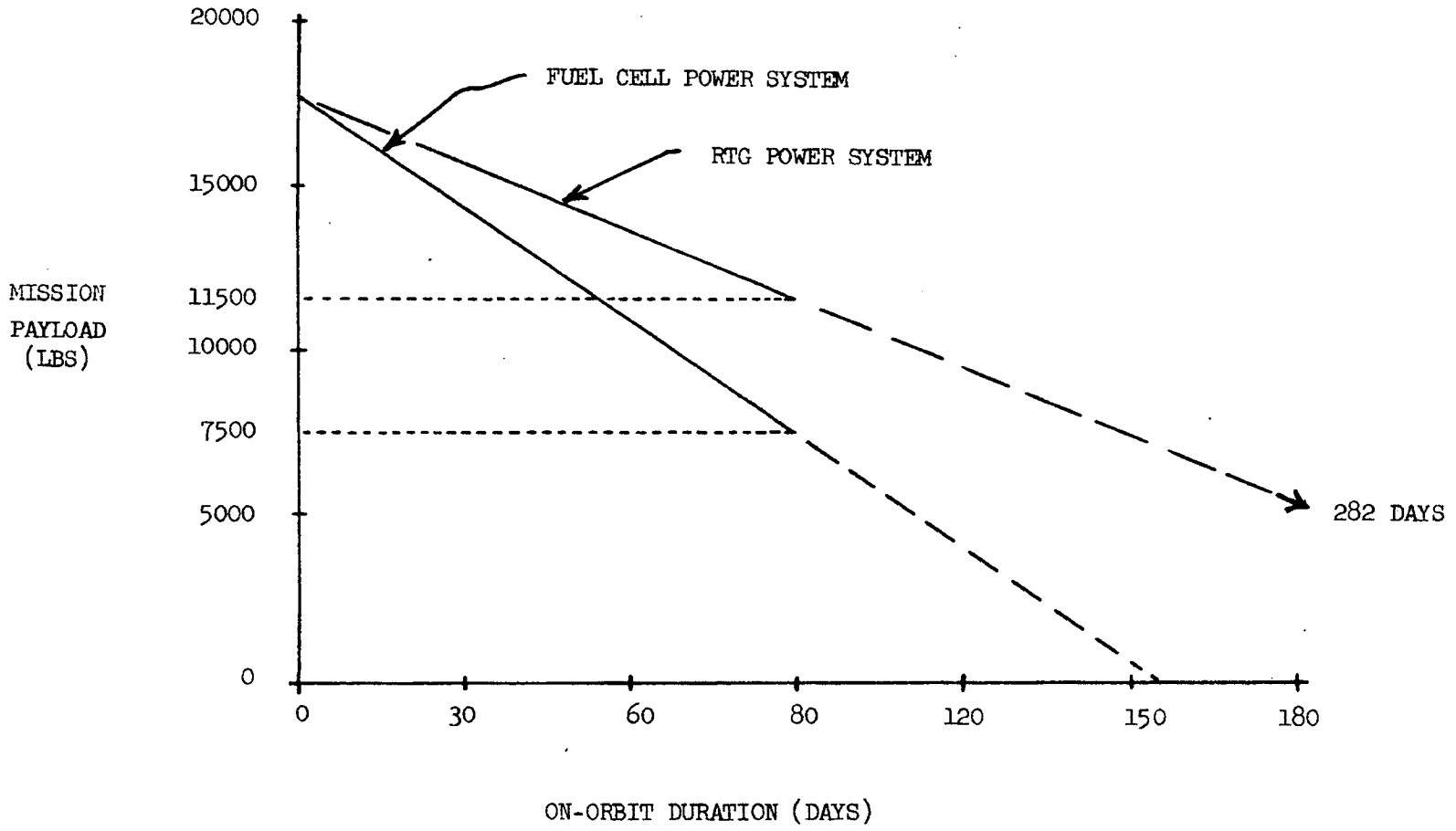
M O L G R O W T H

- INTEGRAL LAUNCH
- POLAR ORBIT (160 N. Mi.)
- 7 SEGMENT SRM



M O L G R O W T H

- INTEGRAL LAUNCH
- POLAR ORBIT (160 N. Mi.)
- 156 in. SRM



INTEGRAL LAUNCH - T III GROWTH

SUMMARY

- 11,500# MISSION EQUIPMENT
- 90 DAYS

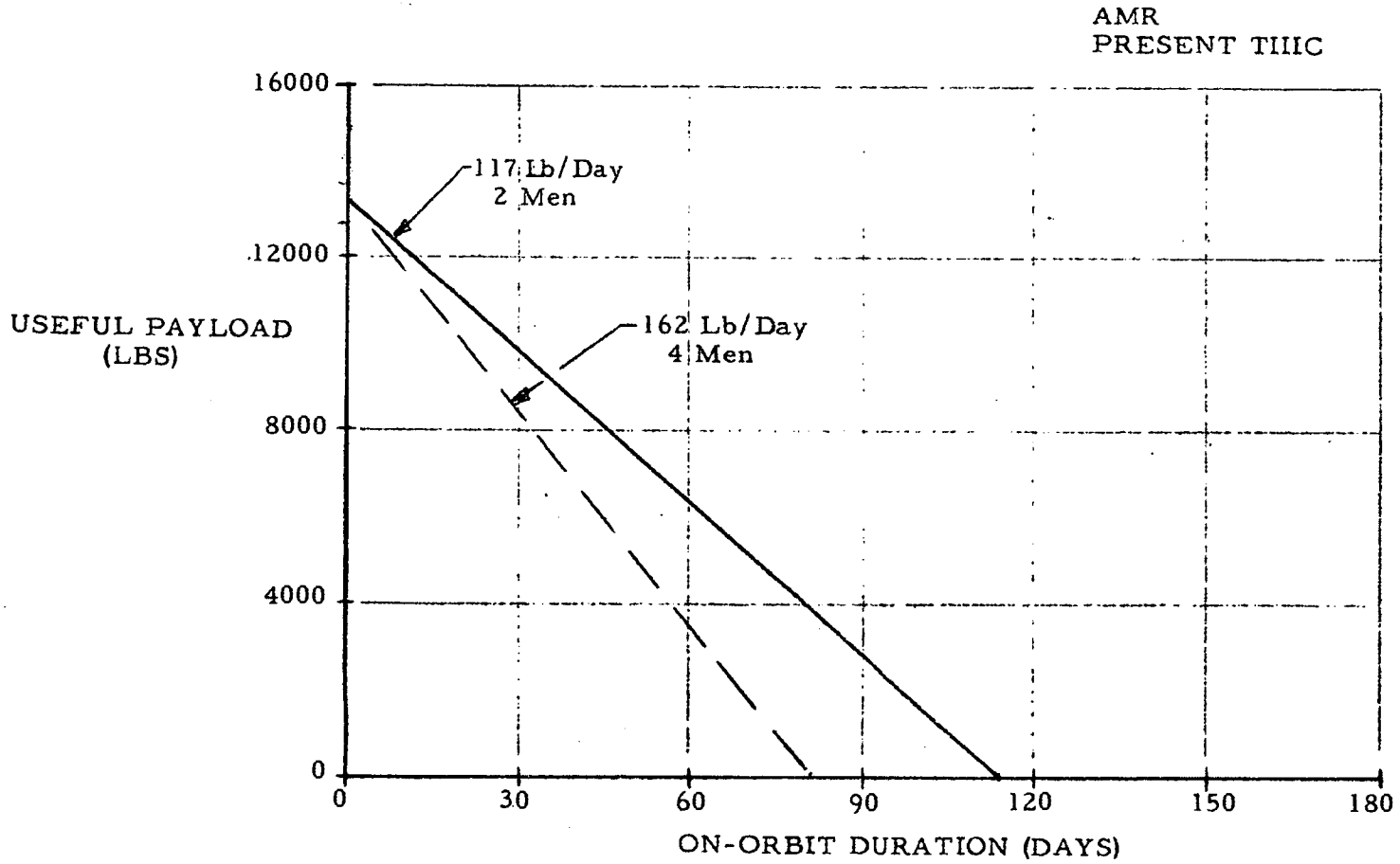
THIS CONFIGURATION SEEMS ATTRACTIVE BOTH AS AN INTEGRAL LAUNCH PROGRAM AND AS A FIRST LAUNCH OF A RENDEZVOUS PROGRAM

SOME RENDEZVOUS PAYLOAD - DURATION

CONFIGURATIONS

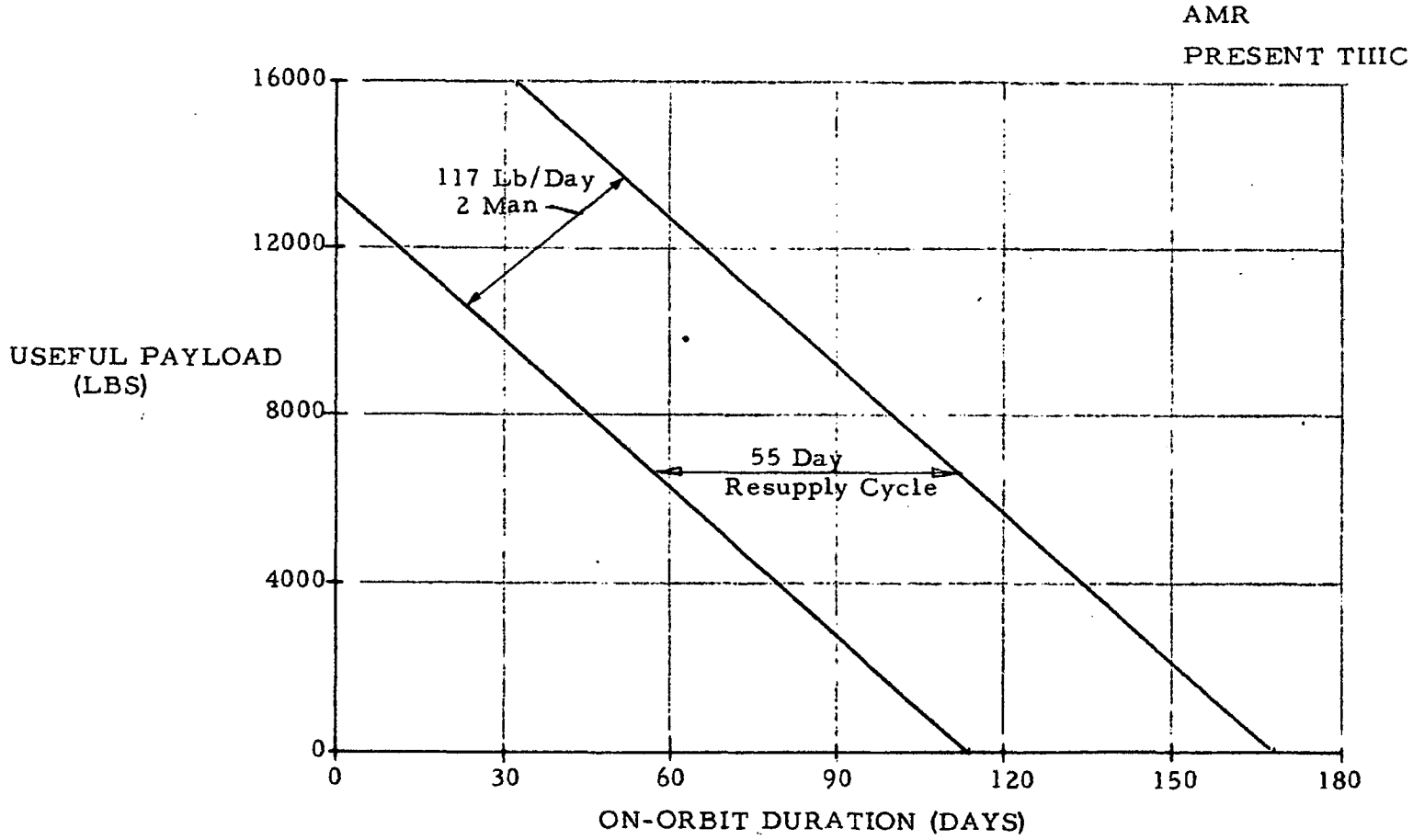
PAYLOAD vs ON-ORBIT DURATION

- DUAL LAUNCH MISSION



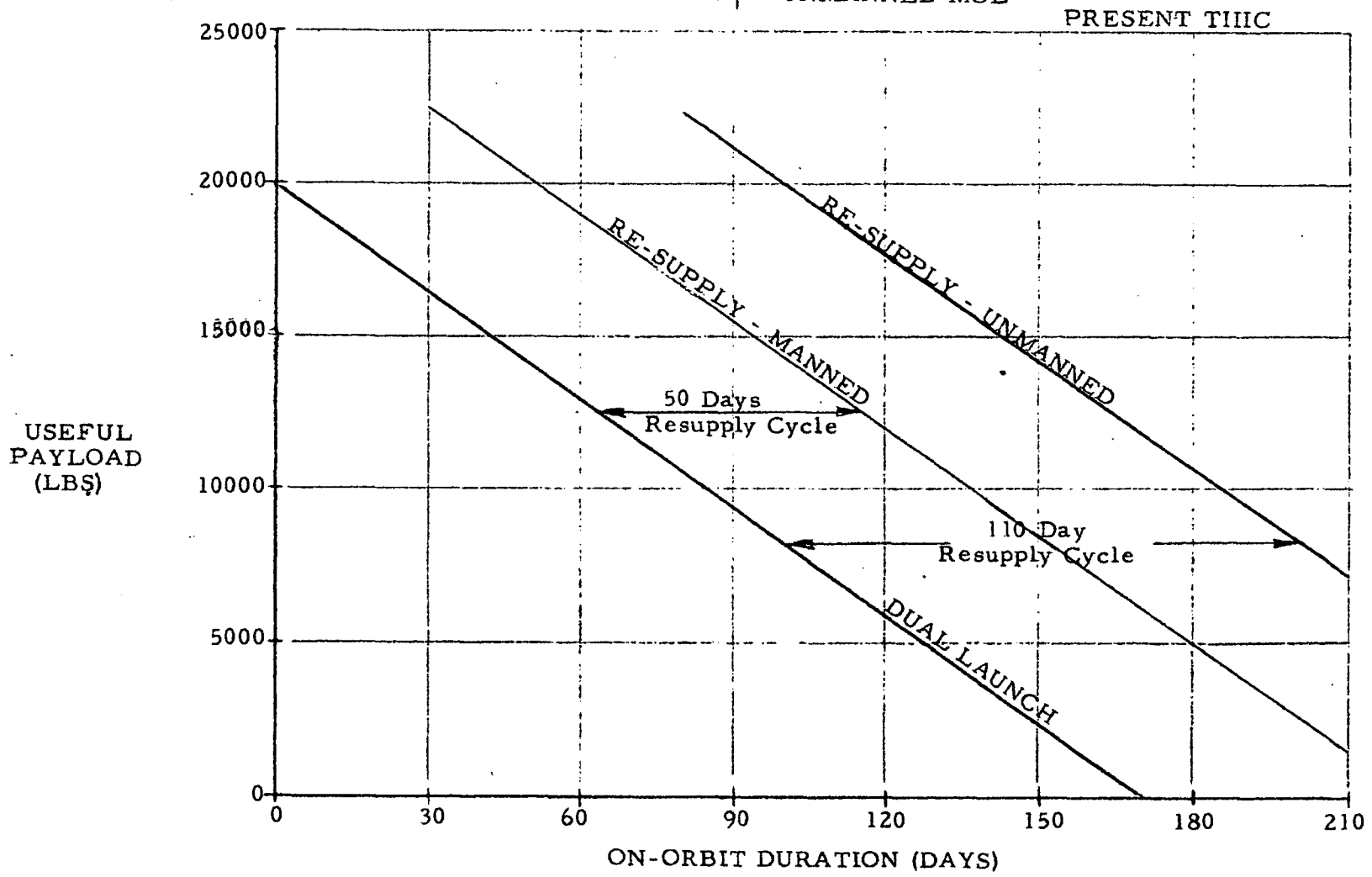
PAYLOAD vs ON-ORBIT DURATION

- RE-SUPPLY MISSION

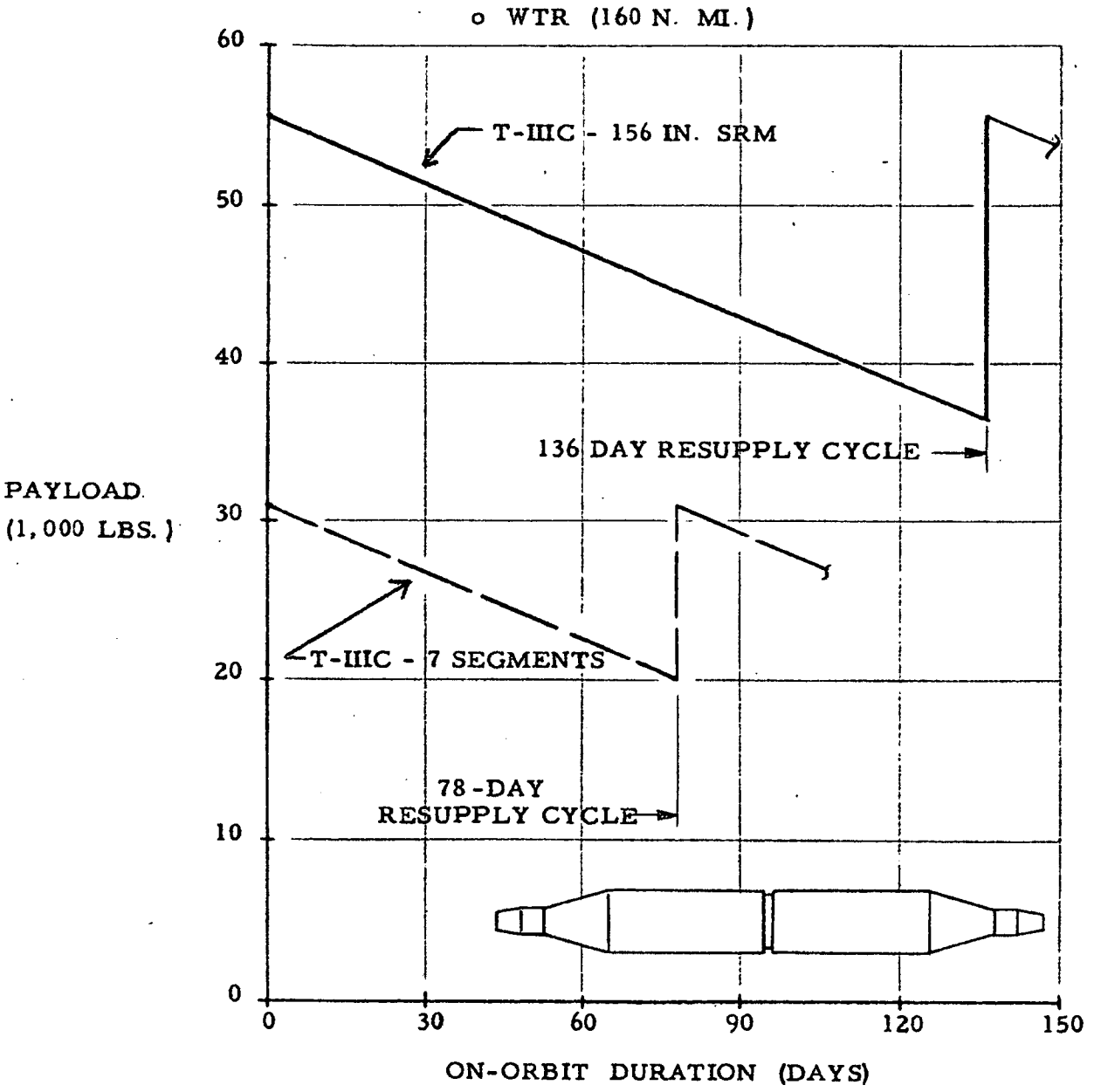


PAYLOAD vs ON-ORBIT DURATION
• AMR MISSION

MOL ← → UNMANNED MOL



MOL RENDEZVOUS CONFIGURATION PAYLOAD CAPABILITY



A RENDEZVOUS RELIABILITY ESTIMATE

	TARGET	CHASER
LAUNCH VEHICLE	.81	.81
LAB. (30 DAYS)	.94	.94
GEMINI B	.97	.97
CREW	.97	.97
PRE-LAUNCH AND LAUNCH	.97	.97
LAUNCH IN 15 MINUTE WINDOW	---	.97 SAY
RENDEZVOUS AND DOCK	---	.95 SAY
	.69	.64

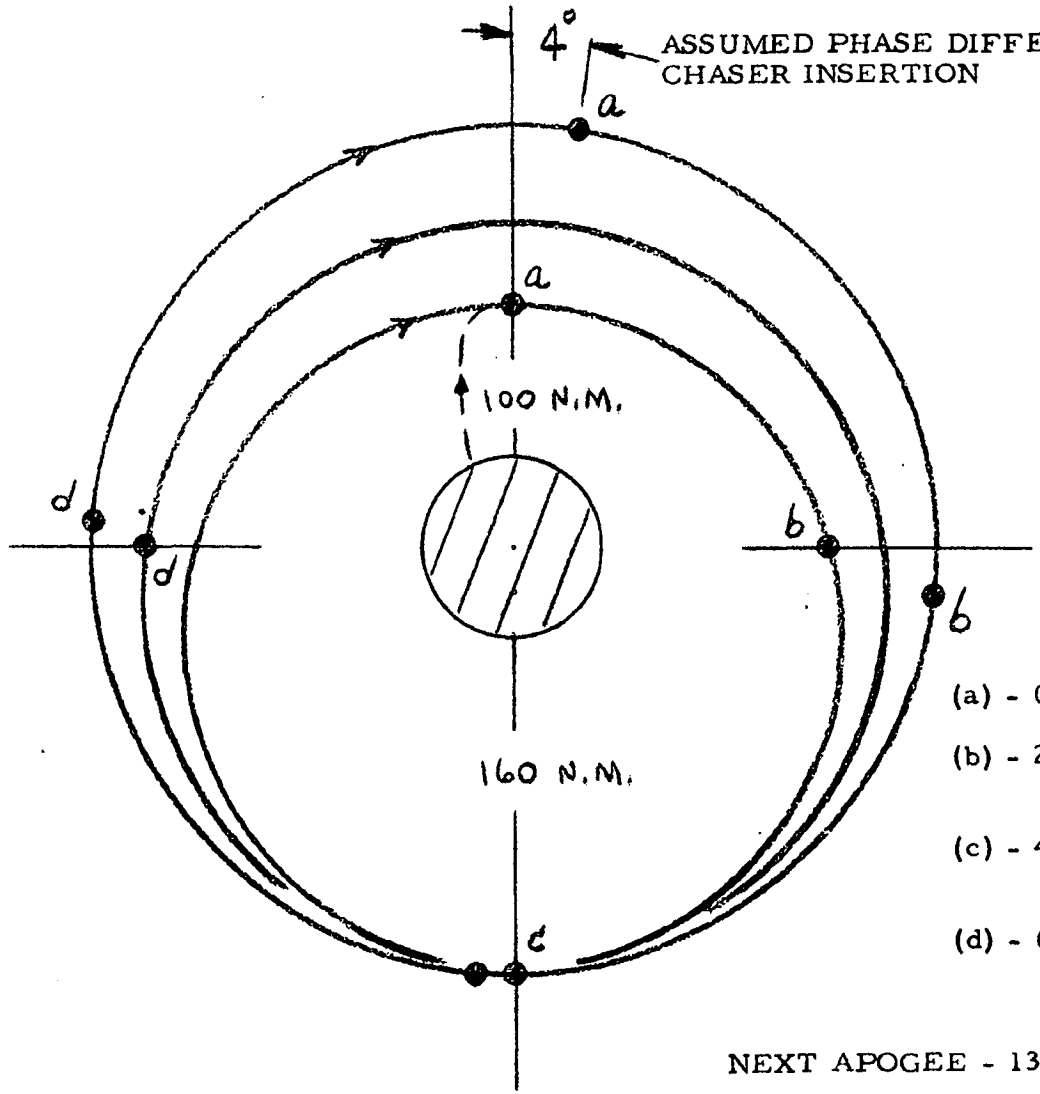
COMBINED
.44

EXP., MCC, RANGE, RECOVERY OMMITTED

MOL RENDEZVOUS MISSION MECHANICS

- PROCEDURES
- LAUNCH WINDOWS
- GROUND SUPPORT
- CONCLUSIONS
- RECOMMENDATIONS FOR FURTHER WORK

RENDEZVOUS PROCEDURES

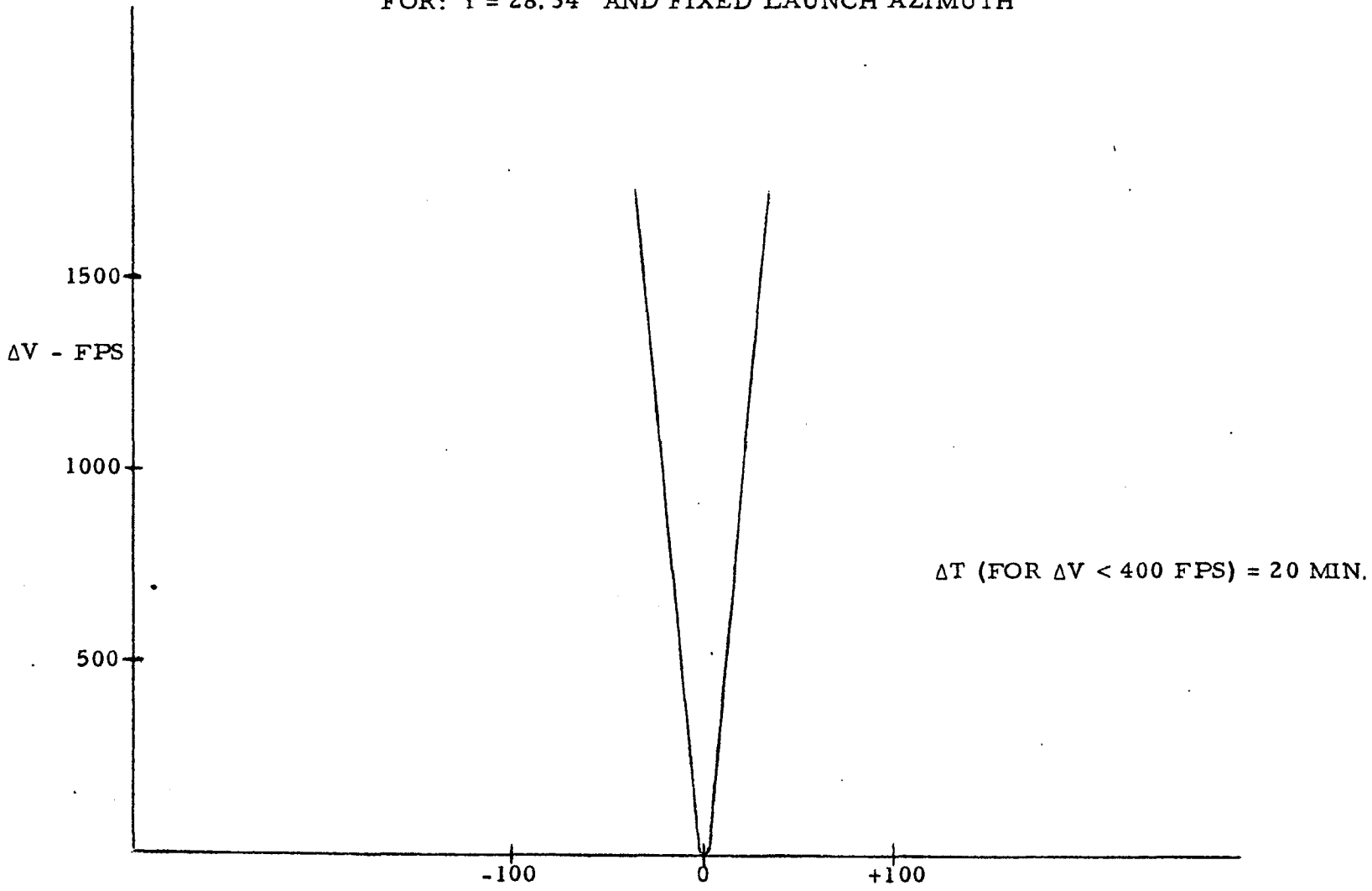


(a) - 0 MIN. - CHASER INSERTED
(b) - 22 MIN. - CHASER MAKES PLANE CHANGE
(c) - 45 MIN. - FIRST APOGEE; CHASER CHANGES ORBIT
(d) - 65 MIN. - CHASER BEGINS CLOSURE CORRECTIONS

NEXT APOGEE - 135 MIN. - CATCH-UP

PLANE CHANGE ΔV REQUIREMENTS

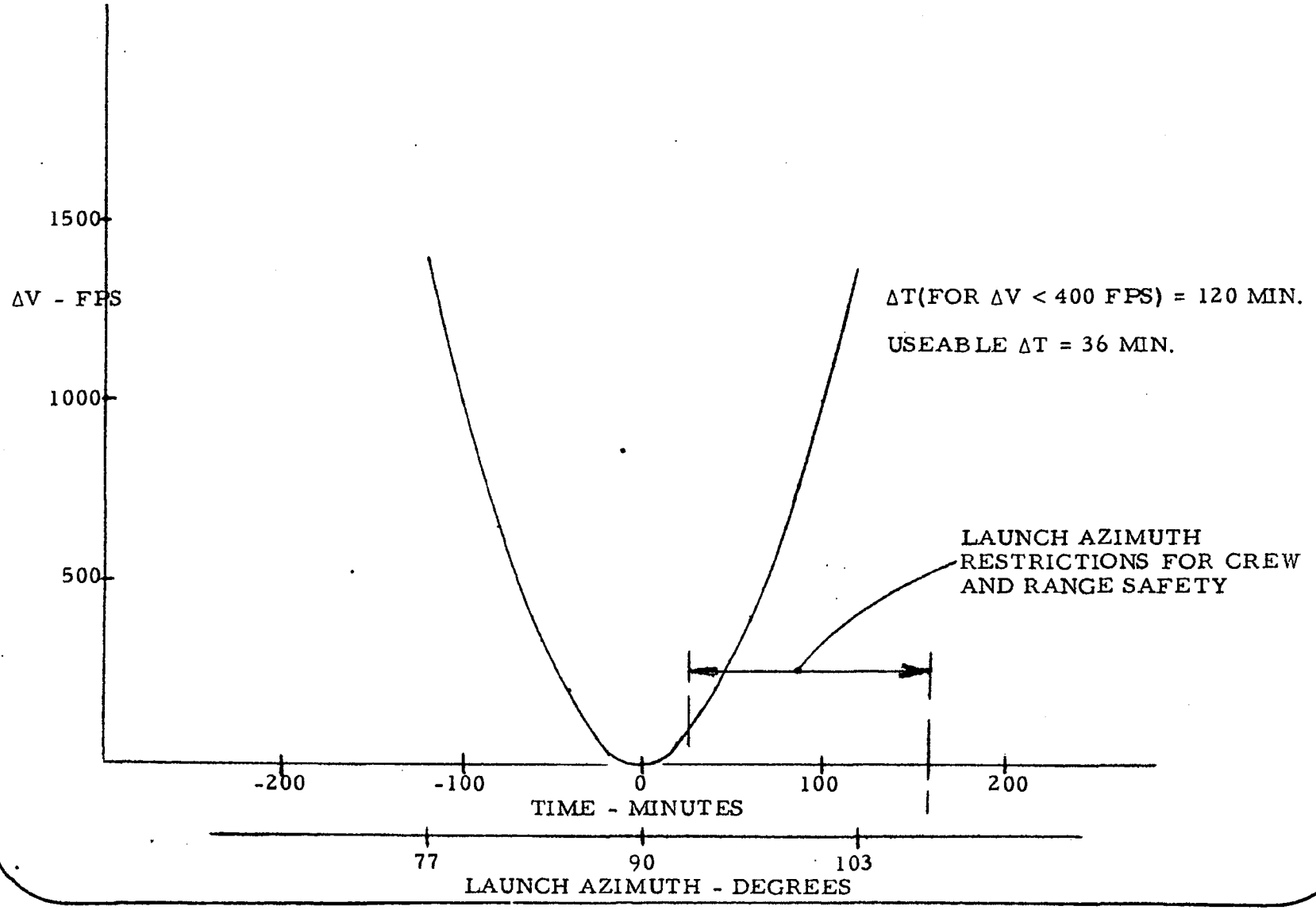
FOR: $i = 28.34^{\circ}$ AND FIXED LAUNCH AZIMUTH



ΔT (FOR ΔV < 400 FPS) = 20 MIN.

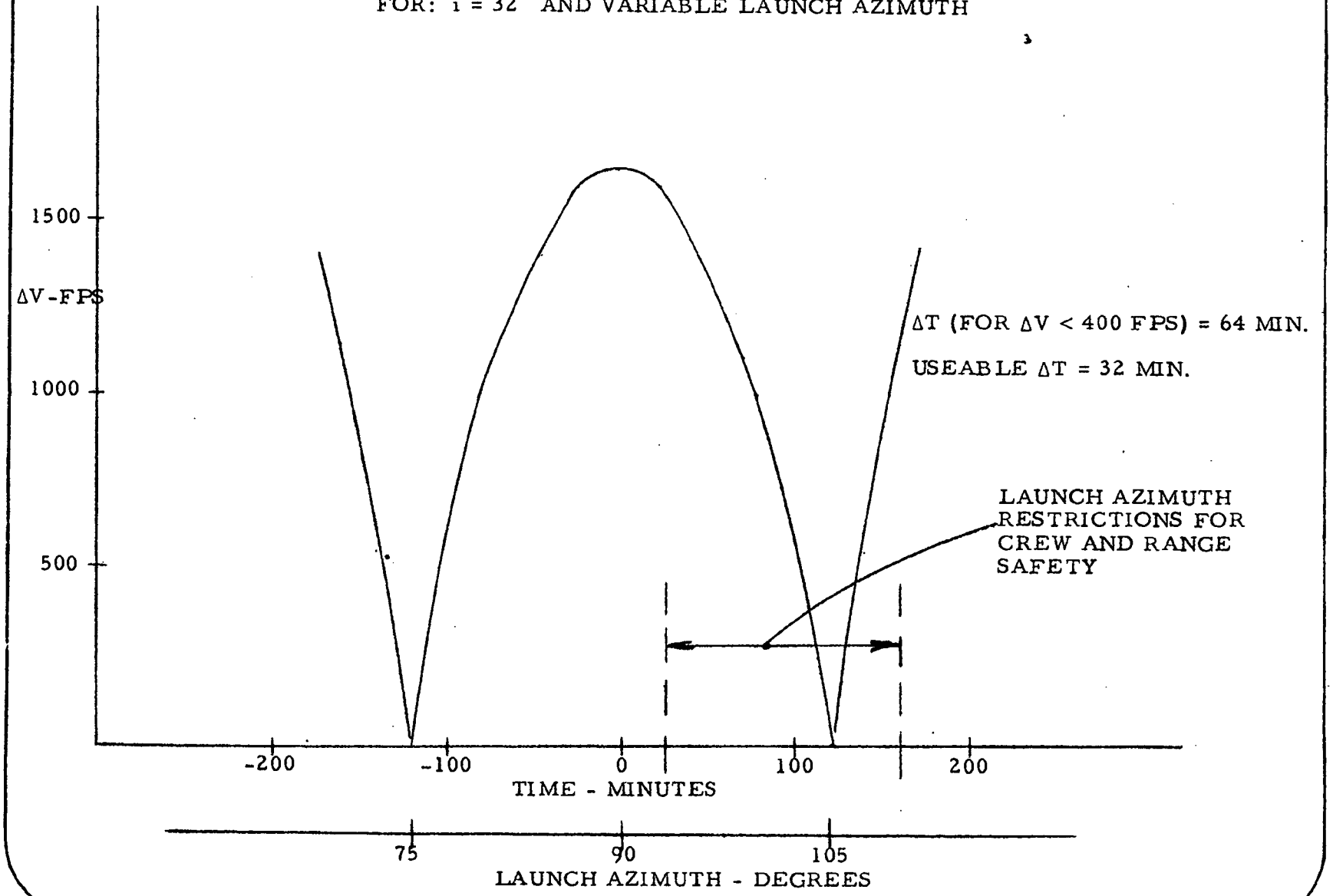
PLANE CHANGE ΔV REQUIREMENTS

FOR: i = 28.34° AND VARIABLE LAUNCH AZIMUTH



PLANE CHANGE ΔV REQUIREMENTS

FOR: i = 32° AND VARIABLE LAUNCH AZIMUTH



LAUNCH WINDOWS IN 30-DAY PERIOD

FOR i = 28.34°; ΔV (PLANE CHANGE) = 400 FPS

LAUNCH FROM ETR

	MAXIMUM TIME TO CATCH-UP			
	1 DAY	2 DAYS	3 DAYS	5 DAYS
AVERAGE NUMBER OF LAUNCH-DAYS	≈18	≈25	30	30
AVERAGE LENGTH OF LAUNCH WINDOW (MIN.)	≈12	≈17	≈21	36
RANGE OF LAUNCH WINDOWS (MIN.)	0-17	0-36	0-36	36 (CONSTANT)
% NIGHT LAUNCHES				
- A. M. TARGET LAUNCH	≈70%	≈70%	≈70%	≈70%
- P. M. TARGET LAUNCH	≈30%	≈30%	≈30%	≈30%

RENDEZVOUS WINDOWS

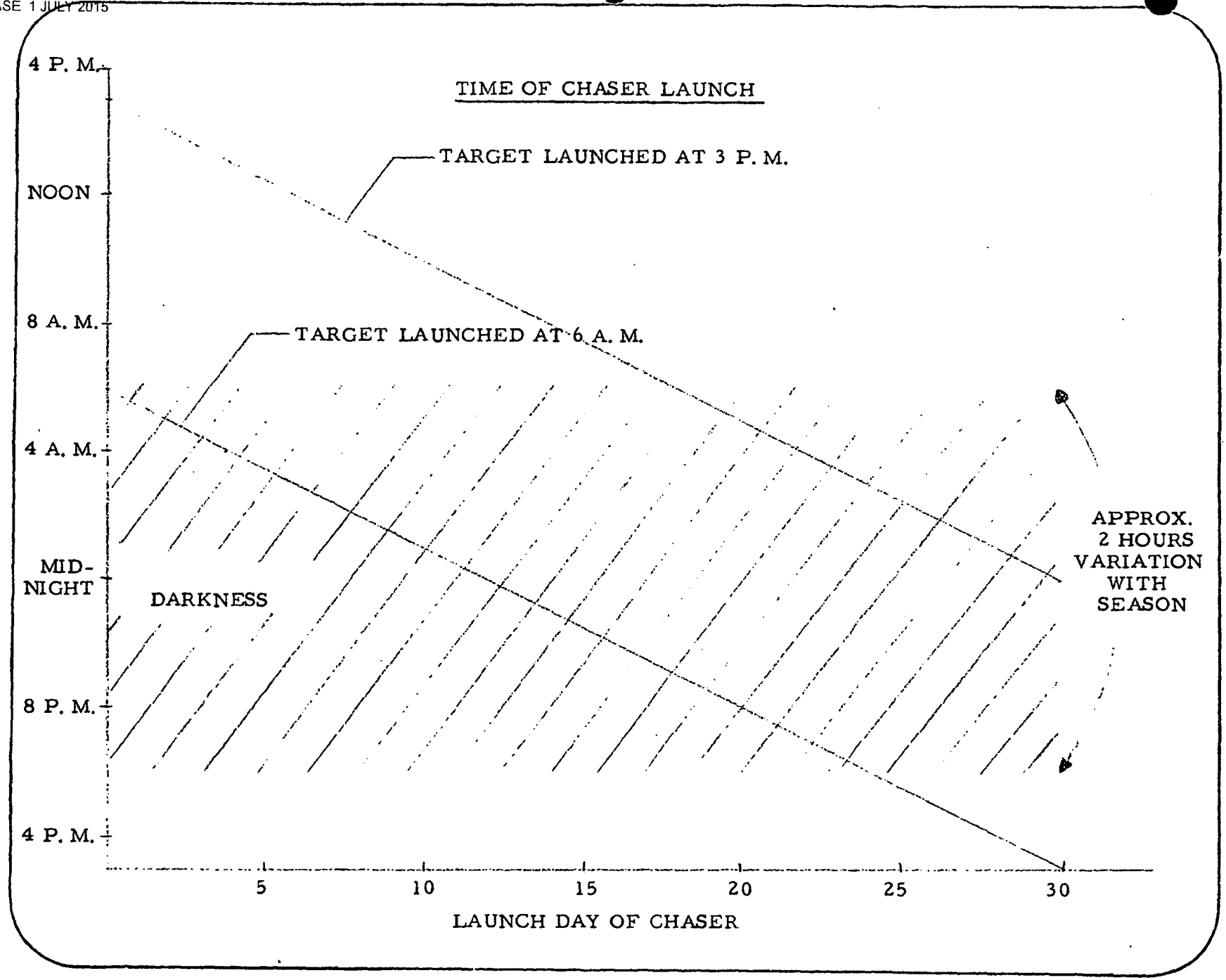
ALLOWABLE PLANE CHANGE ΔV = 400 fps

30 DAY PERIOD

	VARIABLE LAUNCH AZIMUTH $i = 28.34^{\circ}$ *	FIXED LAUNCH AZIMUTH $i \cong 32^{\circ}$ **
TYPICAL NUMBER OF LAUNCH DAYS		
FOR 1 DAY CATCH-UP	18 DAYS	10 DAYS
FOR 2 DAY CATCH-UP	25 DAYS	17 DAYS
FOR 3 DAY CATCH-UP	30 DAYS	22 DAYS
FOR 5 DAY CATCH-UP	30 DAYS	30 DAYS
TYPICAL LENGTH OF LAUNCH WINDOWS		
FOR 1 DAY CATCH-UP	12 MIN.	8 MIN.
FOR 2 DAY CATCH-UP	17 MIN.	9 MIN.
FOR 3 DAY CATCH-UP	21 MIN.	11 MIN.
FOR 5 DAY CATCH-UP	36 MIN.	13.5 MIN.
MAXIMUM WINDOW LENGTH		
FOR 1 DAY CATCH-UP	17 MIN.	13.5 MIN.
FOR 2 DAY CATCH-UP	36 MIN.	13.5 MIN.
FOR 3 DAY CATCH-UP	36 MIN.	13.5 MIN.
FOR 5 DAY CATCH-UP	36 MIN.	13.5 MIN.

* BEST TARGET PLANE INCLINATION FOR MAXIMUM WINDOWS.

** FOR 106° LAUNCH AZIMUTH - ASSUMING RANGE AND PILOT SAFETY RESTRICTIONS ON LAUNCH AZIMUTH.



GROUND SUPPORT

- PROVIDE TIME AND AZIMUTH OF LAUNCH
- PROVIDE CHASER REQUIRED INSERTION CONDITIONS
- DETERMINE IF DIRECT ASCENT IS POSSIBLE
- PROVIDE DATA FOR PLANE CHANGES
  - / TIME OF THRUSTING
  - / ATTITUDE FOR THRUSTING
  - / ΔV REQUIRED
- PROVIDE DATA FOR ALTITUDE ADJUSTMENTS
- DETERMINE CATCH-UP POINT AND PROVIDE PHASE ADJUSTMENT DATA TO CHASER
- PERFORM CLOSURE CALCULATIONS SIMILAR TO AIRBORNE COMPUTER AND PROVIDE CHECKPOINTS TO PILOTS

E&L

GROUND EQUIPMENT

- WORLD-WIDE TRACKING NETWORK
- LARGE HIGH-SPEED, GENERAL PURPOSE COMPUTER
- COMMUNICATION LINKS TO PILOTS AT DIVERSE POINTS
- ROLL PROGRAM A. G. E.
- POSSIBLE ADDITIONAL LAUNCH PAD
  / IF CHASER LAUNCHED WITHIN 8 DAYS OF TARGET

CONCLUSIONS

- RENDEZVOUS FEASIBLE WITH REASONABLE TOTAL ΔV (600 - 800 FPS)
  / TOTAL $\Delta V = \Delta V_1$ (FOR PLANE CHANGE) + ΔV_2 (CLOSURE MANEUVERS)
- VARIABLE LAUNCH AZIMUTH DEEMED NECESSARY
- TIME TO CATCH-UP CAN BE LONG (UP TO 5 DAYS)
- ON-TIME LAUNCHES IMPORTANT (WITHIN A FEW MINUTES)
- EITHER TARGET OR CHASER WILL BE LAUNCHED AT NIGHT IN MAJORITY OF CASES
- GROUND SUPPORT REQUIREMENTS MAJOR
- NEED CAPABILITY OF MODIFYING ROLL PROGRAM FEW MINUTES BEFORE LAUNCH

RECOMMENDATIONS FOR FURTHER STUDY

- REVIEW CLOSURE TECHNIQUE AND DETERMINE ΔV REQUIREMENTS FOR THIS PHASE
- STUDY ON-TIME LAUNCH CAPABILITY OF TITAN IIIC
- REVIEW AND ESTABLISH ACCURATELY THE LAUNCH AZIMUTH RANGE AND PILOT SAFETY RESTRICTIONS
- ASSESS IMPACT OF LONG CATCH-UP TIMES
- ASSESS IMPACT OF NIGHT LAUNCHES
- DETERMINE REQUIRED TRACKING STATIONS LOCATIONS
- INVESTIGATE COSTS AND DIFFICULTIES OF IMPLEMENTING VARIABLE ROLL PROGRAM ON TITAN IIIC
- DETERMINE ACCURATELY LAUNCH WINDOWS FOR VARIOUS LAUNCH DAYS

IMPACT OF RENDEZVOUS ON TEST AND OPERATIONS

- DEVELOPMENT AND QUALIFICATION TESTS OF RENDEZVOUS EQUIPMENT
- EXTENDED LIFE TESTS OF ON-ORBIT EQUIPMENT
- RENDEZVOUS AND DOCKING SIMULATOR AND TRAINER
- DUAL MISSION SIMULATORS - ACCELERATED TRAINING
- DUAL VIB CAPABILITY, AGE AND CREWS
- PROBABLY DUAL PAD CAPABILITY
- DUAL MCC DISPLAYS, EQUIPMENT AND CREWS
- COMPUTING CAPABILITY FOR RENDEZVOUS
- ADDITIONAL ON-ORBIT TELEMETRY SUPPORT EQUIPMENT AND CREWS
- ADDITIONAL RECOVERY FORCES
- POSSIBLE USE OF MASA IMCC
- POSSIBLE SATURATION OF NASA ENVIRONMENTAL FACILITIES

AN EXPERIMENT ALLOCATION

EXPERIMENTS NOS.	FLIGHT NOS. 1	2	3	4	5 R	6	7 R	8
P - 1, 2, 3			402	402	402	402	402	402
P - 4						660		660
P - 5			250	200	150	120	150	120
P - 6			670		670		670	
P - 7			605	605				
P - 8					340		340	
P - 10				385		385		385
P - 11			35	35	35	35	35	35
P - 12			400	400	300	400	300	400
P - 13						698		
GPE			505	505	505	505	505	505
ACTUAL			2867	2532	2402	3205	2402	3205
AVAILABLE			3500	3200	2400	3200	2400	3500
AVAILABLE SECONDARY			633	660	0	0	0	295

TOTAL SECONDARY ALLOCATION = 1596

SOME SUMMARY RENDEZVOUS CONSIDERATIONS

- END OBJECTIVE OF MOL SHOULD BE 90 DAY RECONN. MISSIONS OUT OF PMR
- SERIOUS PAYLOAD LOSS

  #2 MANEUVERING - 3600# TO 2100# (VERY NARROW WINDOW)
  #1 TARGET - 3600# TO 3100#
- MANEUVERING VEHICLE (#2) PROBABLY UNDESIREABLE FOR SIGNIFICANT EXPERIMENTS
- TWO LAUNCH PADS
- TWO CELLS OF ITL
- TWO DISPLAY ROOMS ETC. @ MMC (OR IMCC)
- MOL MUST BE DESIGNED TO WORK BOTH INTEGRALLY AND DOCKED
- TESTING 92 FOOT DOCKED MOL'S IS A PROBLEM
- 6 FLIGHTS FOR 30 DAY QUALIFIED ASTRONAUTS IS ADEQUATE
- 60 DAYS IS PROBABLY AMBITIOUS FOR 6 LAUNCH PROGRAM - PARTICULARLY TO GET ALL "13" EXPERIMENTS ACCOMPLISHED
- 60 DAY CAPABILITY IS PROBABLY BEST ACCOMPLISHED BY EXTENSIONS OF PRESENT MOL CAPABILITY.
- 156" SOLIDS CAN GET 11,500# OF SENSORS FOR 90 DAY MISSIONS

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MOL RENDEZVOUS INCREMENTAL COST ESTIMATE

		$ x 10^6
DESIGN & DEVELOPMENT		
LABORATORY:	DOCKING MODULE	41
	ENVIRONMENTAL CONTROL	3
	ELECTRICAL POWER	10
	STABILIZATION CONTROL	2
	TEST SECTION REMOVAL	24
	TOTAL LABORATORY	80
GEMINI B:	RENDEZVOUS RADAR & CONTROLS	2
	TOTAL DESIGN & DEVELOPMENT	82
HARDWARE PROCUREMENT & OPERATIONS		
	LABORATORY	2
	GEMINI B	3
	LAUNCH SUPPORT	1
	TOTAL HARDWARE PROC. & OPS.	6

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		$ x 10^6
PROGRAM SUPPORT		
FLIGHT HARDWARE SPARES		1
AGE:	DUPLICATE SET T III-C	70
	DUPLICATE SET GEMINI	14
	DUPLICATE SET LABORATORY	24
	PECULIAR TO RENDEZVOUS	6
	AUTOMATION	60
	TOTAL AGE	174
AGE SPARES		23
TRAINERS		2
EXTENDED RECOVERY		1
MISSION CONTROL:	IMCC	10
	NETWORK SUPPORT	20
DOCUMENTATION		10
	TOTAL SUPPORT	241
TOTAL PROGRAM		329

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MOL RENDEZVOUS INCREMENTAL COST ESTIMATE

EXPLANATION OF METHODOLOGY

I. DESIGN & DEVELOPMENT

A. LABORATORY - TOTAL CHANGE TO LABORATORY ASSUMED TO BE OF SUFFICIENT MAGNITUDE TO BE CONSIDERED AS ENTIRE SPACECRAFT DEVELOPMENT TYPE EFFORT. ESTIMATE WAS DETERMINED ON DOLLARS PER POUND BASIS USING DATA ON APOLLO, GEMINI, MECURY, AND DYNA-SOAR PROGRAMS. BREAKDOWN INTO SUBSYSTEMS RATIOED ACCORDING TO WEIGHT BREAKDOWN.

B. GEMINI B - DERIVED FROM 12/18/63 ESTIMATE WHERE PROVISION WAS INCLUDED FOR REMOVAL OF INDICATED ITEMS.

II. HARDWARE PROCUREMENT & OPERATIONS

A. LABORATORY - ESTIMATE WAS DETERMINED ON DOLLARS PER POUND BASIS USING DATA ON APOLLO AND DYNA-SOAR PROGRAMS.

B. GEMINI B - DERIVED FROM 12/18/63 ESTIMATE, ADDING BACK PREVIOUSLY DELETED ITEMS.

C. LAUNCH SUPPORT - PREVIOUS ESTIMATE RATIOED UP ACCORDING TO INCREASE IN HARDWARE COST.

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MOL RENDEZVOUS INCREMENTAL COST ESTIMATE

III. PROGRAM SUPPORT

A. FLIGHT HARDWARE SPARES - 20% FACTOR BASED ON GENERAL MISSILE AND SPACE SYSTEM EXPERIENCE.

B. AGE - DUPLICATE T III-C, GEMINI AND LABORATORY EQUIPMENT + EXTRA FOR RENDEZVOUS + ADDITIONAL FOR AUTOMATION + FACILITIES.

C. AGE SPARES - 20% FACTOR AS STATED FOR FLIGHT HARDWARE.

D. TRAINERS - BASED ON RATIO OF GEMINI MISSION SIMULATOR COST TO PRODUCTION VEHICLE COST.

E. EXTENDED RECOVERY - PREVIOUS ESTIMATE RATIOED UP ACCORDING TO INCREASE IN NUMBER OF DAYS.

F. MISSION CONTROL - 1/2 OF HOUSTON MCC PLUS 1 ADDITIONAL TRACKING STATION.

G. DOCUMENTAION - 3% OF ALL OTHER ELEMENTS OF TOTAL PROGRAM INCREMENTAL COST BASED ON APOLLO EXPERIENCE.

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A COST-EFFECTIVENESS COMPARISON OF RENDEZVOUS AND INTEGRAL LAUNCH

	INTEGRAL LAUNCH	RENDEZVOUS
MISSION LAUNCH COSTS (70 M$ EACH)	30 DAY EXP.	60-DAY SIAMESE
RELIABILITY	.64	.44
COST/PROBABLE SUCCESS	110 M$/SUCCESS	320 M$/SUCCESS

IMPROVING LAUNCH VEHICLE CAPABILITY

- HOW MUCH WOULD IT BE WORTH TO IMPROVE TITAN III

EXP. PAYLOAD (AMR)

T-IIIC	3,500 #	70 M$/LAUNCH	
6 SEG.	8,500 #	71 M$/LAUNCH	(ESTIMATE)
7 SEG.	11,000 #	72 M$/LAUNCH	(ESTIMATE)
156"	19,000 #	75 M$/LAUNCH	(ESTIMATE)

THEREFORE,

T-IIIC	$20,000/#
6 SEG.	$ 8,300/#
7 SEG.	$ 6,600/#
156"	$ 4,000/#

PRESENT PRIMARY EXPERIMENTS ~ 20,000# INCLUDING DUPLICATION

T-IIIC	REQUIRES	6	LAUNCHES	@	70	=	420 M$
6 SEG.	REQUIRES	3	LAUNCHES	@	71	=	213 M$
7 SEG.	REQUIRES	2	LAUNCHES	@	72	=	144 M$
156"	REQUIRES	2	LAUNCHES	@	75	=	150 M$

3 1

IMPROVING LAUNCH VEHICLE CAPABILITY

THEREFORE, FOR THE MOL PRIMARY EXPERIMENTS ONE COULD IN THEORY AFFORD TO PAY:

200	M$	TO DEVELOP 6 SEGMENT TITAN III
275	M$	TO DEVELOP 7 SEGMENT TITAN III
270 TO 325	M$	TO DEVELOP 156 INCH TITAN III

CONCLUSIONS ON MOL RENDEZVOUS

- THE RELIABILITY OF THE PRESENT "COMPLETE" MOL MISSION IS PROBABLY NOT MUCH GREATER THAN 0.65. (THIS GIVES ~.85 FOR 3 OR MORE SUCCESSES IN THE 6 LAUNCH PROGRAM
- THE RELIABILITY OF A RENDEZVOUS MISSION IS PROBABLY~0.45. (THIS GIVES ~.85 FOR ONE OR MORE SUCCESSES IN A 3 x 2 = 6 LAUNCH PROGRAM)
- REASONABLE MODIFICATIONS APPEAR TO BE POSSIBLE TO EXTEND THE PRESENT MOL INTEGRAL LAUNCH TO 60 DAYS
- THE IMPACT ON EXPERIMENT ALLOCATION AND RELIABLE EXPERIMENT ACCOMPLISHMENT IS VERY SERIOUS
- THE PAYLOAD LOSS IS 500 TO 2500 POUNDS
- THE IMPACT ON THE GROUND FROM ALMOST ALL ASPECTS OF OPERATION IS SERIOUS
- INTERJECTING 2 NEW CONFIGURATIONS INTO A 6-LAUNCH PROGRAM IS EXTREMELY AMBITIOUS
- THE FINAL OPERATIONAL MISSION CONFIGURATION IS NOT YET FIRM ENOUGH TO DO EXTENSIVE MISSION PLANNING
- NO DOLLAR ESTIMATE HAS YET BEEN MADE OF THE IMPACT OF RENDEZVOUS ON THE PROGRAM
- IT IS ESSENTIALLY IMPOSSIBLE TO GET ENOUGH RENDEZVOUS LAUNCHES IN SUCH A FEW LAUNCHES TO BE TRULY MEANINGFUL
- MOL WOULD CONTRIBUTE QUITE SUCCESSFULLY IF 3- 4, -5 or 6 CREWS WERE FULLY QUALIFIED FOR 30-DAY MISSIONS

1.5.1

SOME OTHER NATIONAL SPACE PROGRAMS

FAILURES	SUCCESSES
DYNASOAR	X-15
SAINT	MERCURY
RANGER	TELSTAR
MIDAS	TRANSIT
VANGUARD	TIROS
	SYNCOM
	VOSTOK

SURVEYOR ?
GEMINI ?
APOLLO ?

LESSON: AVOID OVER-AMBITIOUS PROJECTS???

RECOMMENDATIONS AND ACTION ITEMS

- ELIMINATE REND. FROM PRESENT 6 FLIGHT PROGRAM
  - / SPEC.
  - / PROGRAM TEST PLAN
  - / ETC.
- INSIST THAT INDUSTRY SHOW THEIR DESIGN APPROACH FOR FOLLOW-ON REND. FLIGHTS.
  - / SPEC. ADDENDUM?
- INSIST THAT INDUSTRY SHOW THEIR DESIGN TO REACH 60 DAYS BY EITHER INTEGRAL OR REND. LAUNCH.
- STUDY VIGOROUSLY THE RECONN. MISSION FOR APPLICABILITY OF "PRESENT" HARDWARE. LAY REQUIREMENTS ON MOL WHEN "FIRM".
- STUDY FLY-BY MISSION FOR APPLICABILITY OF "PRESENT" MOL HARDWARE.
- CONTINUE TO STUDY ALL FOLLOW-ON MOL MISSIONS.
  - / NASA REQUIREMENTS
  - / RECONN. REQUIREMENTS
  - / FLY-BY REQUIREMENTS
  - / OTHER REQUIREMENTS

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