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MANNED LUNAR LANDING

Operations Analysis And Mode Comparison [U]

MSFC - FPO
June 1, 1962

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NOMINAL PERFORMANCE MARGIN
PRESENT CONCEPTS

	LAUNCH VEHICLE (ΔW)	SPACECRAFT		TOTAL MISSION	
		ΔV	CM+EM ΔW	ΔW ONLY	ΔW +ΔV
EOR	150K +12.5%	7.4%	12,250	14.5%	~ 22%
			2%		
LOR	90K +11%	6.1%	CM+EM 12,600 (5%)	16%	~ 22%
			LEM 5,000 (25%)	36% (4,000)	~ 42%
C-5* DIRECT	90K +11%	5.7%	8700	19.8% (8,000)	~ 25%
			8.8% (8000)		
NOVA DIRECT	150K +6.6%	7.4%	12,250	8.6%	~ 16%
			2%		

(65-716)

* SMALL CAPSULE (8000)

M-MS-G-62-3-62 MAY 26, 1962

SYSTEM CRITERIA

- DEVELOPMENT RISK
  - PERFORMANCE MARGIN
  - MISSION COMPLEXITY
- OPERATIONAL RISK
  - EARLY ACCOMPLISHMENT OF MISSION
  - CREW SAFETY
- COST OF PROJECT
  - TOTAL R&D
  - ACCUMULATIVE COST THROUGH FIRST SUCCESS
- GROWTH POTENTIAL
  - BUILDUP RATE FOR FOLLOW-ON PROJECTS
  - ECONOMY OF CARGO AND PERSONNEL TRANSPORTATION

WEIGHT CAPABILITY
CM & EM
(LAUNCH VEHICLE DESIGN MARGIN
AND VELOCITY RESERVES NOT INCLUDED)

		[illegible] RETURN (LBS.)	H.E.R. AND ΔV = 200 M/S (LBS.)
EOR	12,250	15,300	17,300
LOR (2)	12,600 CM	12,600 CM	12,100 CM
	5,000 LEM	5,000 LEM	5,472 LEM
C-5 DIRECT	8,700	9,210 (1)	9,900
NOVA DIRECT	12,250	15,300	17,300

(1) +10 SEC. Isp IN LR-10 ENGINE
(2) ONLY EARTH STORABLE PROPELLANTS

M-MS-G-62-3a-62 MAY 26, 1962

NOMINAL PERFORMANCE MARGIN
ALTERNATE CONCEPTS
H_2/O_2 RETURN FOR EOR & NOVA, ALL 8,000 LB. CM+EM

	LAUNCH VEHICLE POTENTIAL ΔW	SPACECRAFT		TOTAL MISSION	
		ΔV	WEIGHT CM+EM / ΔW	ΔW ONLY	ΔW +ΔV
EOR	150 K + 22.0%	7.4%	15,300 / 91%	113%	120%
LOR**	90 K + 20.5%	6.1%	CM+EM 12,600 (57%) / LEM 5,000 (25%)	77% (8000) / 45% (4000)	83% / 51%
C-5 DIRECT	90 K + 20.5%	5.7%	9,210* / 15.1%	35.6%	41%
NOVA DIRECT	150 K+ 16.1%	7.4%	15,300 / 91%	107%	114%

*WITH 435s I_{SP} IN LR-10 **NO H_2/O_2

M-MS-G-62-4-62 MAY 26, 1962

MAXIMUM PERFORMANCE MARGIN
ALTERNATE CONCEPTS, THRUST INCREASE and - 200 m/sec ΔV

	LAUNCH VEHICLE	SPACECRAFT		TOTAL MISSION	
	MAXIMUM ΔW	$\Delta V_{RES.}$	WT. CM+EM / ΔW_{MAX}	PROB. $+W_{MAX}$	MAX $+W_{MAX}$
EOR	150K +32%	4.2%	17300 / 116%	148%	152%
LOR*	90K +30.5%	3.0%	CM+EM 12,100 51%	81%	84%
			LEM 5472 37%	67%	70%
C-5 DIRECT	90K 30.5%	2.7%	9900 / 24%	54%	57%
NOVA DIRECT	150K +26.1%	4.2%	17300 / 116%	142%	146%

* NO H_2/O_2

M-MS-G-62-5-62 MAY 26,1962

MAXIMUM PERFORMANCE MARGIN

(1) INCREASE F-1 THRUST RATING TO 1800K (NO CHANGE IN TURBOPUMP)

(2) INCREASE J-2 THRUST RATING TO 212 K (NO CHANGE IN TURBOPUMP)

(3) SHOOT FOR MAXIMUM I_{sp} IN LR 10 ENGINE (440s) AND POSSIBLY OTHER ENGINES.

(4) CONVERT SOME OF THE VELOCITY RESERVES INTO PAYLOAD AS EXPERIENCED IS GAINED IN FLIGHT TEST

(5) REDUCE STAGE CUTOFF WEIGHTS BY PRODUCT IMPROVEMENT PROGRAMS.

MISSION COMPLEXITY

	NUMBER OF MAJOR FUNCTIONS	NUMBER OF MAIN ENGINE IGNITIONS	MEAN RELIABILITY 1st FLIGHT	MEAN RELIABILITY 5th FLIGHT
EOR	38	25	10.0 % / 14.5 %*	20.7 % / 28.2 %*
LOR	34	23	19.1 %	31.7 %
C-5 DIRECT	27	20	21.9 %	34.6 %
NOVA DIRECT	27	23	25.3 %	35.9 %

* WITH SPARE

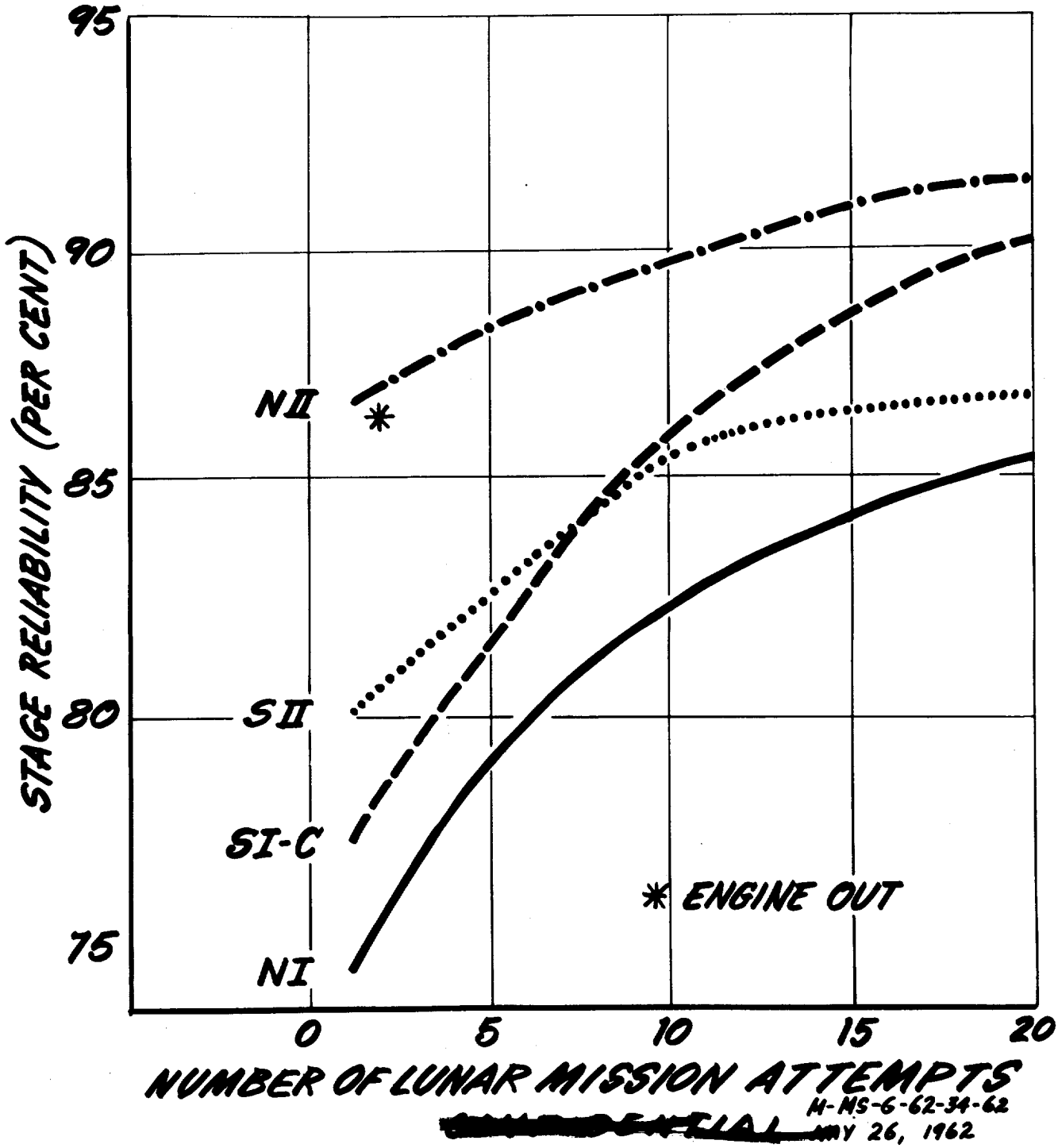
M-MS-G-62-6-62 MAY 26,1962

TIME OF FIRST SUCCESS IS FUNCTION OF:

- MISSION INHERENT RELIABILITY
- MISSION RELIABILITY GROWTH
- DATE OF FIRST ATTEMPT
- FREQUENCY OF ATTEMPTS

[redacted]

STAGE RELIABILITY GROWTH ESTIMATES (LOWER STAGES)



M-MS-6-62-34-62

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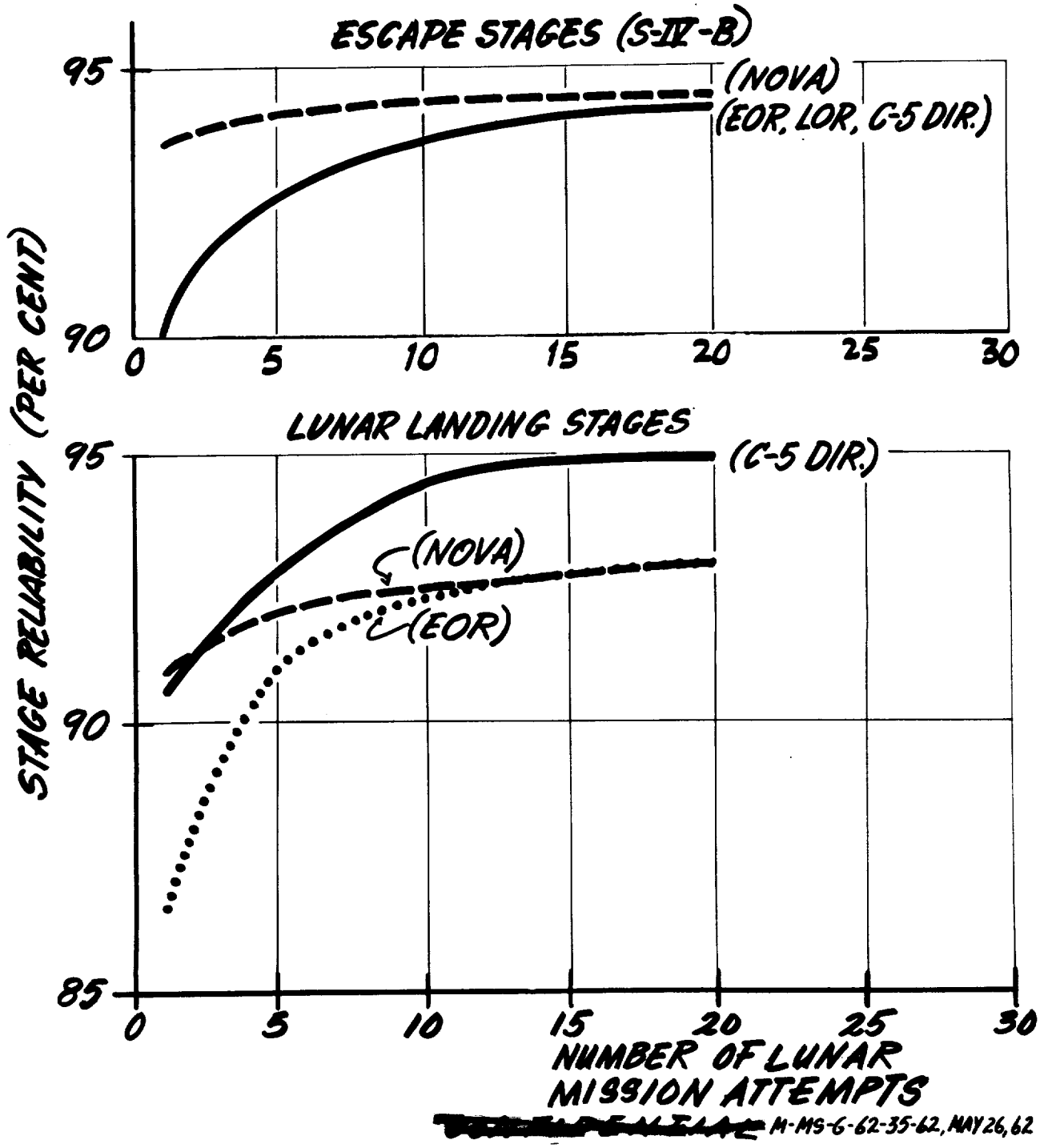
STAGE RELIABILITY GROWTH ESTIMATES (UPPER STAGES)



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INHERENT RELIABILITY ESTIMATES

SMALL STAGES

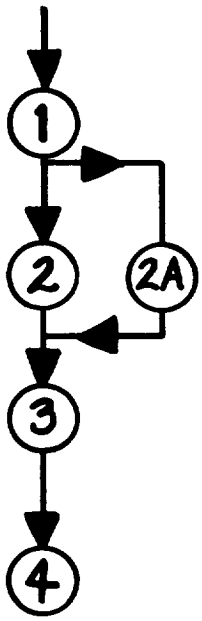
	HOVER STAGE (ES)	LEM (ES)	SM (ES)	SM (HE)
MECH. SYS.	0.987	0.982	0.987	0.987
ELECTR. SYS.	0.989	0.987	0.989	0.988
PROP. SYS.	0.991	0.995	0.995	0.995
SPACE ENVIR. DEGRADATION	0.995	0.990	0.995	0.990
STAGE INHERENT RELIABILITY	0.963	0.955	0.966	0.961

[redacted]

FUNCTIONAL MISSION BREAKDOWN

	ATTEMPT NO1			10			35		
	LO	M	HI	LO	M	HI	LO	M	HI
1. 1ST STAGE BURN									
2. STAGE SEP.									
3. 2ND STAGE BURN									
4. 2ND STAGE SEP.									
.									
.									
.									
. RENDEZVOUS									
. DOCKING									
. LOX TRANSFER									
. CHECKOUT									
.									
.									
.									
25. REENTRY									
26. LANDING									
27. RECOVERY									

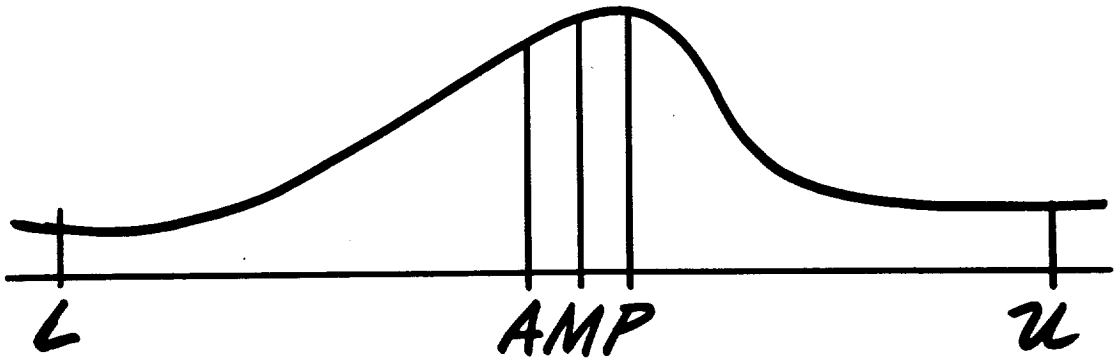
MONTE CARLO ANALYSIS



- MISSION SIMULATION
- RANDOM SELECTION OF STEP RELIABILITY
- RANDOM DETERMINATION WHETHER ATTEMPT FAILS OR SUCCEEDS

INPUTS

(1) ESTIMATED SEQUENCE RELIABILITY



(2) MEAN SEQUENCE RELIABILITY AS FUNCTION OF SUCCESSIVE ATTEMPTS.

MONTE CARLO ANALYSIS

Results:

- NO. of ATTEMPTS TO FIRST SUCCESS
- TIME TO FIRST SUCCESS
- LAUNCH VEHICLES AND SPACECRAFT EXTENDED
- FAILURES AT EACH STEP

THE RESULTS ARE OBTAINED BY SIMULATING the SEQUENCES 2000 TIMES FOR EACH MODE

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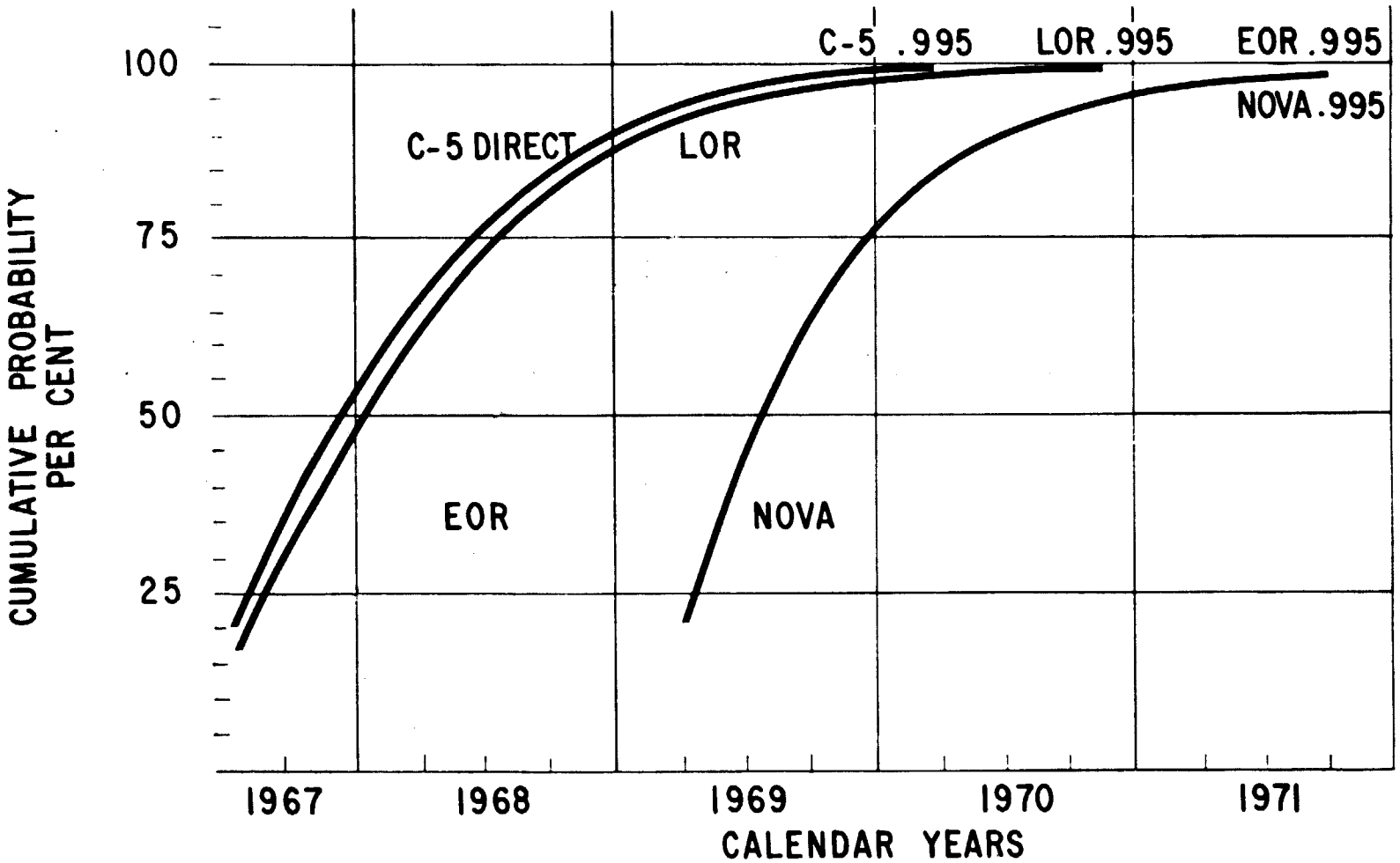
PROBABILITY OF SUCCESS EVALUATION



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M-MS-G 62-7-62
MAY 26, 1962

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PROBABILITY OF SUCCESS EVALUATION

	50% ACCUMULATIVE PROBABILITY	90% ACCUMULATIVE PROBABILITY
EOR	MAY 68 (6)	AUG 69 (16)
LOR	DEC 67 (3)	FEB 69 (10)
C-5 DIRECT	DEC 67 (3)	OCT 68 (8)
NOVA DIRECT	JUN 69 (3)	MAY 70 (8)

M-MS-G-62-8-62 MAY 26, 1962

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CREW SURVIVAL ANALYSIS

PROBABILITY of CREW LOSS:

$$P_{CL} = \Sigma (P_{CL})_i$$

$$(P_{CL})_i = P_{SA} \times P_{SF} \times P_{AF}$$

$(P_{CL})_i$ = PROBABILITY OF CREW LOSS AS RESULT OF FAILURE AT ANY GIVEN STEP

P_{SA} = PROBABILITY THAT STEP WILL BE ATTEMPTED, i.e. PROB. THAT MISSION WILL SUCCEED TO THAT POINT

P_{SF} = PROBABILITY OF FAILURE AT GIVEN STEP

P_{AF} = PROBABILITY THAT ABORT ATTEMPT WILL FAIL

CREW SAFETY

	PROBABILITY OF CREW LOSS — FIRST MISSION ATTEMPT	PROB. OF NO CREW LOSSES — TO 50% PROB. OF MISSION SUCCESS
EOR	18.2 %	54.7 %
LOR	22.0 % BUG 16.1 % CM	47.4 % BUG 59.1 % CM
C-5 DIRECT	17.7 %	55.7 %
NOVA DIRECT	18.0 %	55.1 %

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SYSTEM DEVELOPMENT COST (R&D)
MILLIONS

	LAUNCH VEHICLE AND MODE DEVELOPMENT	SPACECRAFT	TOTAL SYSTEM
EOR	2960	3530	6490
LOR	2770	3070	5840
C-5 DIRECT	2770	2920	5690
NOVA DIRECT	3240	2920	6160

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TOTAL PROGRAM COST THROUGH FIRST SUCCESS
(90% PROBABILITY)
MILLIONS

	OPERATIONAL COST 1 ST ATTEMPT	TOT. OPER. COST TO FIRST SUCCESS (90% CONF.)	TOT. ACCUMULATIVE COST TO FIRST SUCCESS (90%CONF.)
EOR	112.0	1240	7730
LOR	65.7	620	6460
C-5 DIRECT	66.5	510	6200
NOVA DIRECT	83.5	630	6790

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LUNAR BASE BUILDUP ASSUMPTIONS

- BUILDUP BEGINS WITH CY 1970
- LIFE SUPPORT SUPPLIES ARE 2 TONS PER MAN PER YEAR
- CONSTRUCTION MATERIAL REQUIREMENT IS 10 TONS PER MAN CAPACITY
- CONTINUOUS EQUIPMENT SUPPLY REQUIREMENT DURING OPERATION IS 5 TONS PER MAN PER YEAR
- AVERAGE STAY TIME IS 6 MONTHS PER MAN

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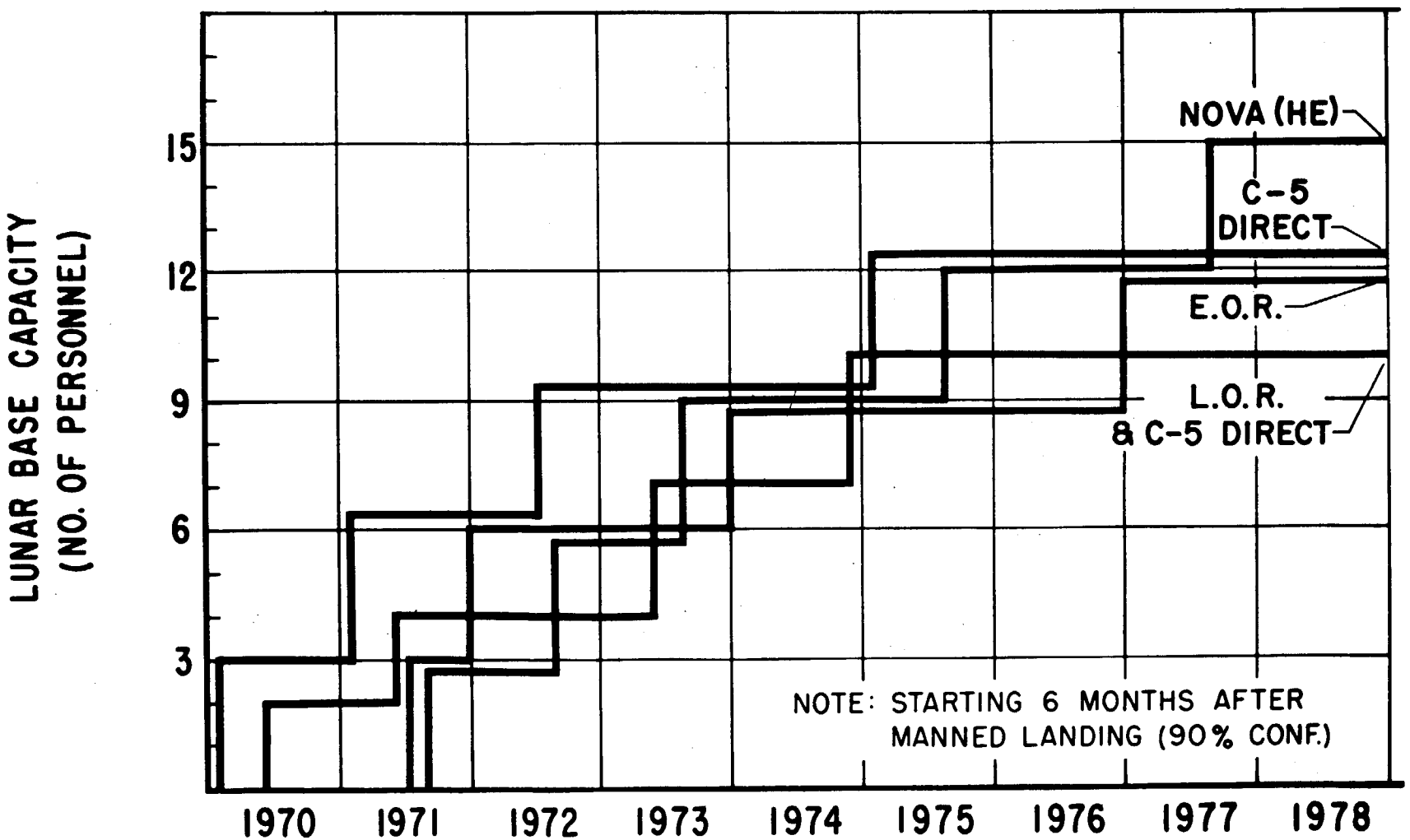
LUNAR BASE BUILDUP RATE (PERSONNEL)



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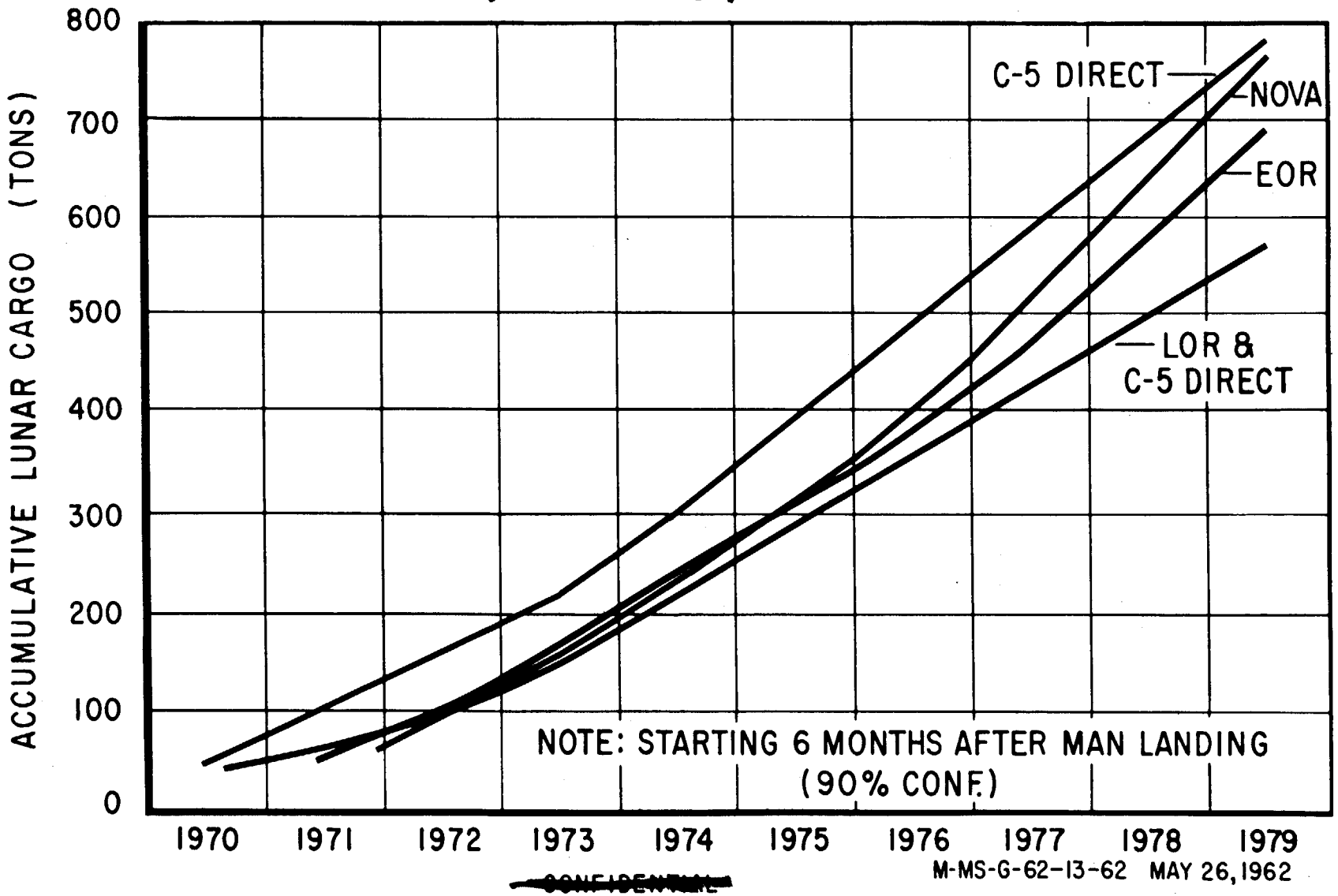
LUNAR BASE BUILDUP RATE (CARGO)



M-MS-G-62-13-62 MAY 26, 1962

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EFFICIENCY OF TRANSPORTATION SYSTEMS FOR LUNAR BASE BUILDUP

AVERAGE COST 1970-1978 / UNIT COST IN 1978	C-5 DIR	EOR	NOVA DIR (S)	NOVA DIR (HE)	LOR & C-5 DIR	LOR & NOVA	EOR & C-5 DIR	EOR & NOVA	C-5 DIR & NOVA
$/LB CARGO	2020 / 1530	2630 / 1910	1900 / 1350	1710 / 1350	2320 / 1715	3910 / 1690	2550 / 1725	3280 / 1925	3790 / 1595
$x10⁶/ROUND TRIP PERSONNEL	14.5 / 12.5	17.8 / 13.9	24.0 / 21.1	11.6 / 9.6	19.1 / 15.7	22.7 / 13.9	20.0 / 13.9	29.3 / 14.0	19.0 / 14.8
$x10⁶/MAN YEAR ON THE MOON	61.4	88.4	86.0	55.4	77.4	118.5	82.4	121.0	100.5

M-MS-G-62-14-62 MAY 26, 1962

TECHNICAL SUMMARY

	TIME TO 1st SUCCESS (90% CONF.)	TOTAL COST TO 1st SUCCESS (90% CONF.)	NOMINAL PERF. MARGIN* (PRESENT CONCEPTS)	$/MAN YEAR ON THE MOON
EOR	AUG 1969	$7,730 x 10^6	22% (12,000 lb)	88.4 x 10^6
LOR	FEB 1969	$6,460 x 10^6	22% CEM (12,000) 42% LEM (4,000)	77.4 x 10^6 *
C-5 DIRECT	OCT 1968	$6,200 x 10^6	25% (8,000)	61.4 x 10^6
NOVA DIRECT	MAY 1970	$6,790 x 10^6	16% (12,000)	55.4 x 10^6

* L.O.R. + C-5 DIRECT FOR CARGO

[redacted]

MODE COMPARISON TABLE

	PERFORMANCE CM+EM (H.E. RETURN) LBS.	PROBABILITY OF SUCCESS ON FIRST ATTEMPT%	TIME TO FIRST SUCCESSFUL LANDING 90% PROBABILITY	PROBABILITY OF CREW LOSS ON FIRST ATTEMPT-%	R&D COST MILLIONS	OPERATIONAL COST TO FIRST SUCCESS (90% PROBABILITY) MILLIONS	SIZE OF LUNAR BASE (NUMBER OF PERSONNEL) 1976	LUNAR MAN-YEAR AVERAGE COST (1970-1979) MILLIONS	CRITICAL DEVELOPMENT PROBLEM AREAS
EOR	15,300	14.5 (W/SPARE)	AUG. 69	18.2	$6490	$1240	12	$88.4	a. EARTH ORBIT RENDEZVOUS b. PROPELLANT TRANSFER c. C-5 LAUNCH VEHICLE d. STANDARD APOLLO CAPSULE
LOR	12,600 5,000 LEM	19.1	FEB. 69	16.1 (CM) 22.0 (LEM)	$5840	$620	10*	$77.4*	a. LUNAR ORBIT RENDEZVOUS b. LEM AND PERSONNEL TRANSFER c. C-5 LAUNCH VEHICLE d. STANDARD APOLLO CAPSULE
C-5 DIRECT	9,210	21.9	OCT. 68	16.7	$5690	$510	12	$61.4	a. HIGH ENERGY RETURN b. LIGHT WEIGHT CAPSULE c. C-5 LAUNCH VEHICLE
NOVA DIRECT	15,300	25.3	MAY 70	18.0	$6160	$630	15	$55.4	a. NOVA LAUNCH VEHICLE b. STANDARD APOLLO CAPSULE

* 8 C-5 DIRECT CARGO

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