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B70 11021

SUBJECT: Comparison of Nuclear and Chemical Cislunar Shuttles - Case 237

DATE: November 9, 1970

FROM: D. J. Osias

MEMORANDUM FOR FILE

The attached viewgraphs summarizing a comparison between nuclear and chemical powered cislunar shuttles were presented to a group of OMSF and OART personnel on November 6, 1970. The briefing was based upon the performance calculations reported in "Performance Comparison of Nuclear and Chemical Lunar Shuttles," Memorandum for File, B70 08028, August 14, 1970 and included additional material on nuclear shuttle operations and safety. The latter points were the subject of some discussion which resulted in a concensus that more information is necessary regarding implications of the radiation environment and the ability to perform complex operations in space. It was also agreed that a comparison of development and operational costs for these two shuttle concepts should be made to complement the performance studies.

D J Osias

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(NASA-CR-111314) COMPARISON OF NUCLEAR AND CHEMICAL CISLUNAR SHUTTLES (Bellcomm, Inc.) 22 p

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PERFORMANCE COMPARISON OF NUCLEAR AND CHEMICAL CISLUNAR SHUTTLES

NOVEMBER 6, 1970

BACKGROUND

- INTEGRATED PLAN IDENTIFIED 300,000 LB GROSS WEIGHT NUCLEAR CISLUNAR SHUTTLE
- NUCLEAR SHUTTLE DEFINITION STUDIES ASSUME LARGE PAYLOADS, FREQUENT FLIGHTS
- CHEMICAL CISLUNAR SHUTTLE HAS RECEIVED LITTLE ATTENTION

SCOPE

MISSION VARIATIONS

- PLANE CHANGES
- STAGING
- ONE-WAY MISSIONS
- AEROBRAKING

PAYLOADS

120,000 LB OUT	/	20,000 LB RETURN
50,000	/	20,000
20,000	/	20,000

OPERATIONAL CONSIDERATIONS

GROUND RULES FOR PERFORMANCE CALCULATIONS

260 N. MI. CIRCULAR EARTH ORBIT TO 43 N. MI. CIRCULAR LUNAR ORBIT

72 HOUR TRANSFER TIME IS NOMINAL

PLANE CHANGES (IF ANY) DURING RETURN ONLY

CHEMICAL I_{SP} = 460 SECONDS

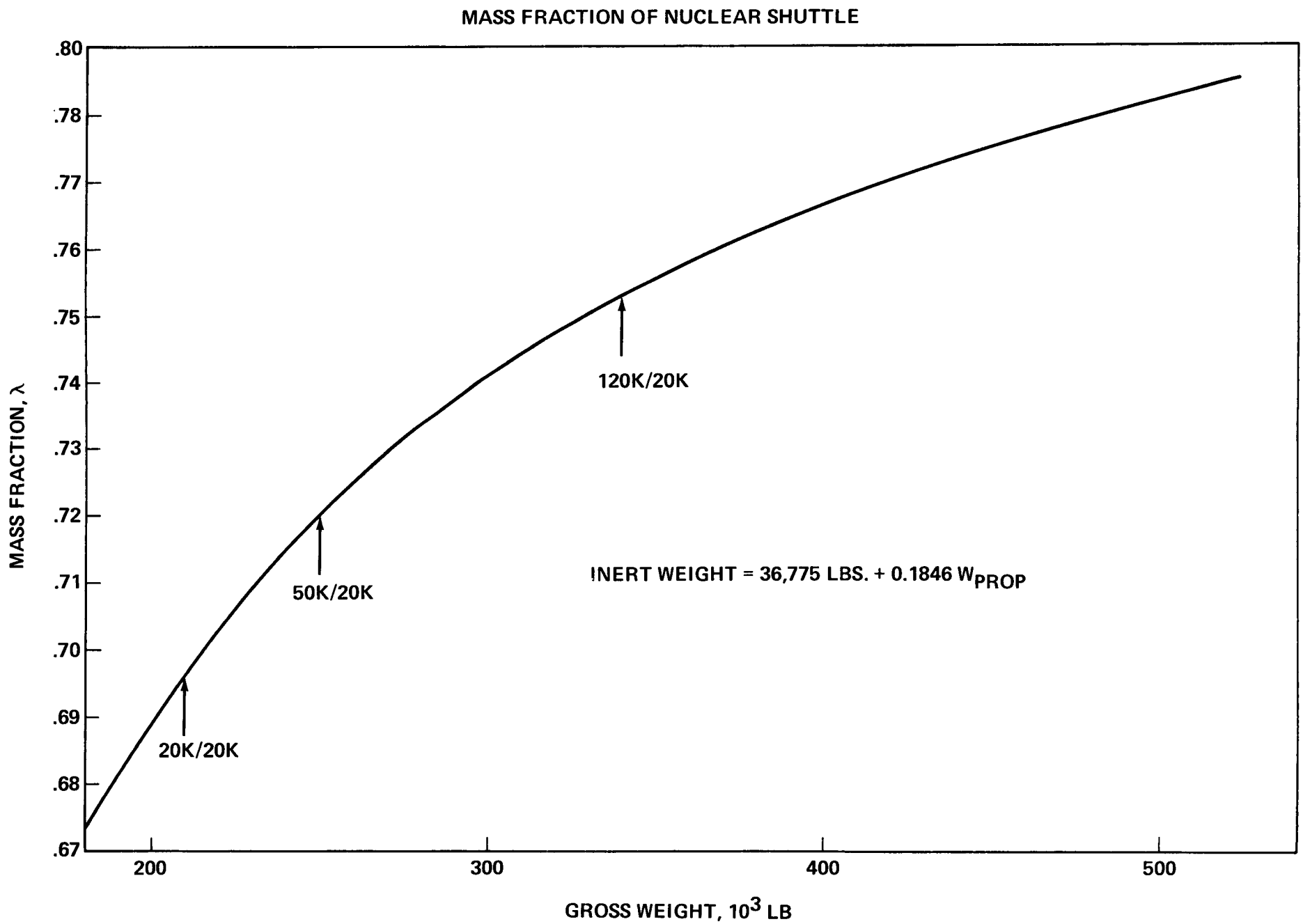
NUCLEAR I_{SP} = 825 SECONDS

AFTERCOOLING ACCOUNTED FOR BY USING AN EFFECTIVE I_{SP} OF 805 SECONDS

GRAVITY VELOCITY LOSSES INCLUDED FOR NUCLEAR SHUTTLES

CISLUNAR SHUTTLE CHARACTERISTICS

	NUCLEAR	CHEMICAL
I_{SP}	825 SEC (805 EFFECTIVE)	460 SEC
λ	0.70 – 0.77 (DERIVED)	0.87 – 0.91 (RANGE STUDIED)
THRUST	75,000 LBS	TO BE DERIVED


MASS FRACTION OF NUCLEAR SHUTTLE
MASS FRACTION, λ
.80
.78
.77
.76
.75
.74
.73
.72
.71
.70
.69
.68
.67
200
300
400
500
GROSS WEIGHT, 10^3 LB
120K/20K
50K/20K
20K/20K
INERT WEIGHT = 36,775 LBS. + 0.1846 W_PROP

MISSION PROFILE VARIATIONS

SINGLE STAGE, NO PLANE CHANGE

SINGLE STAGE , 90° PLANE CHANGE ON RETURN

TWO STAGE, NO PLANE CHANGE

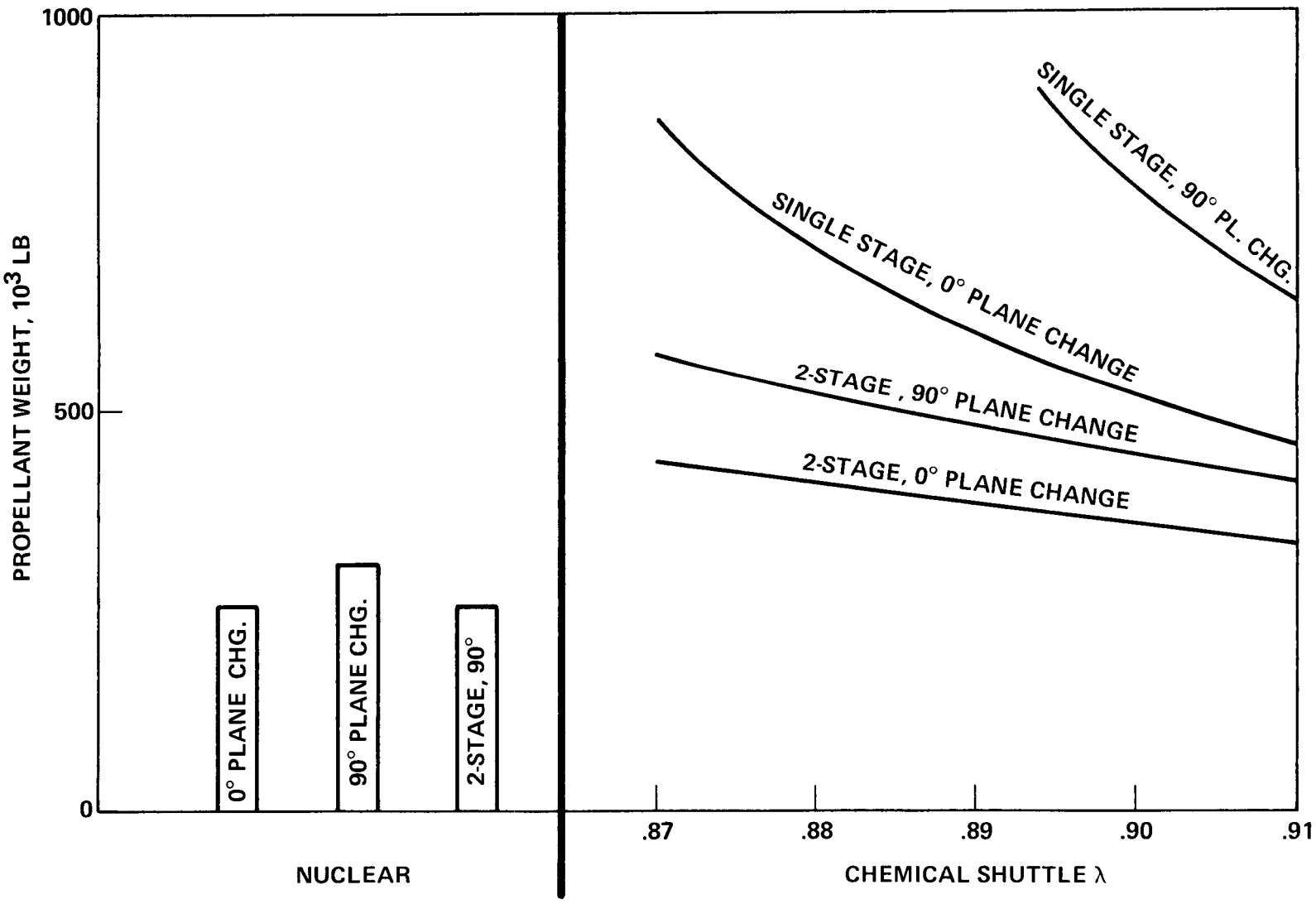
TWO STAGE, 90° PLANE CHANGE

AEROBRAKED CHEMICAL, NO PLANE CHANGE

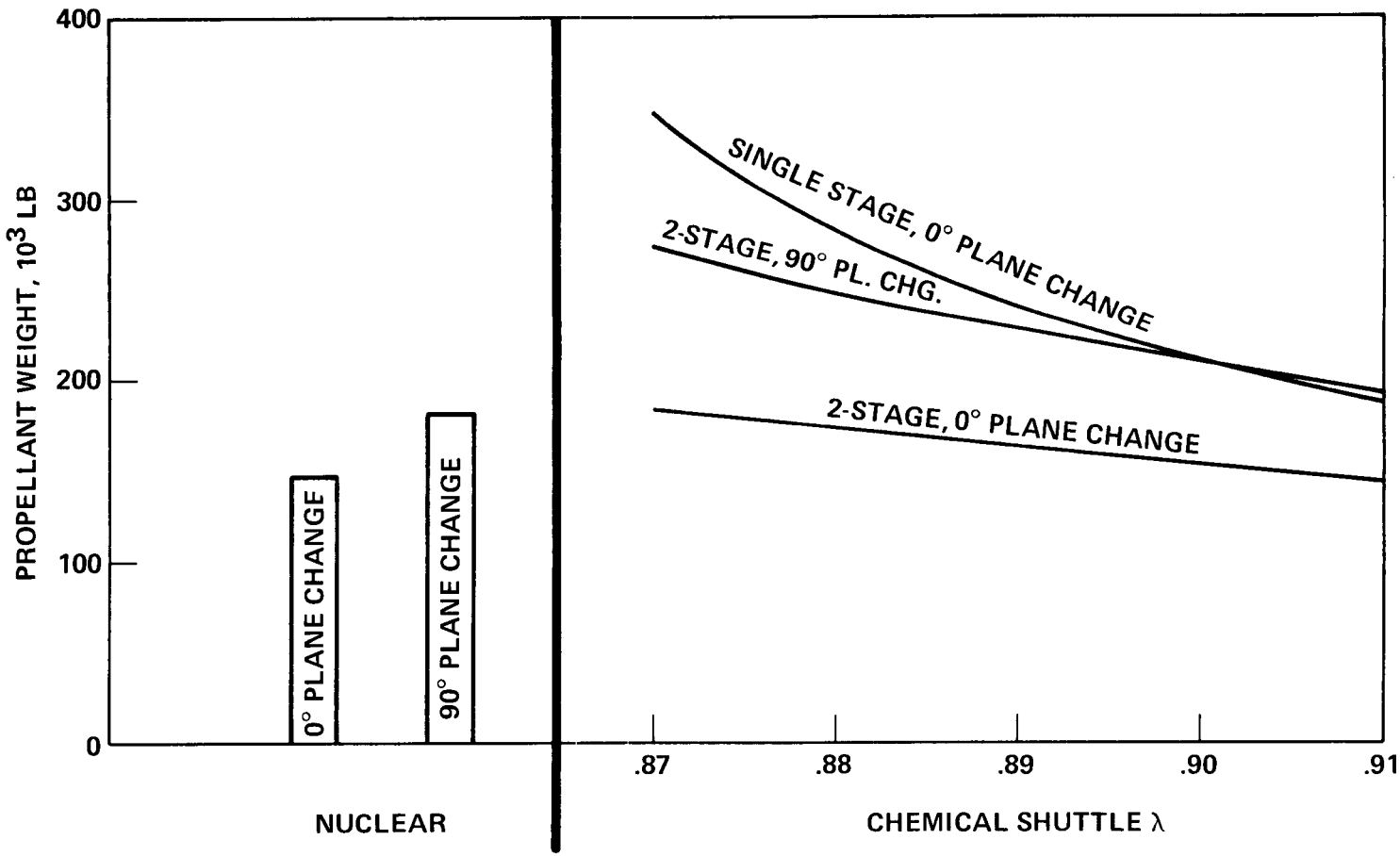
AEROBRAKED CHEMICAL, 90° PLANE CHANGE

ONE-WAY MISSION, 108 HOUR TRANSFER, NO PLANE CHANGE

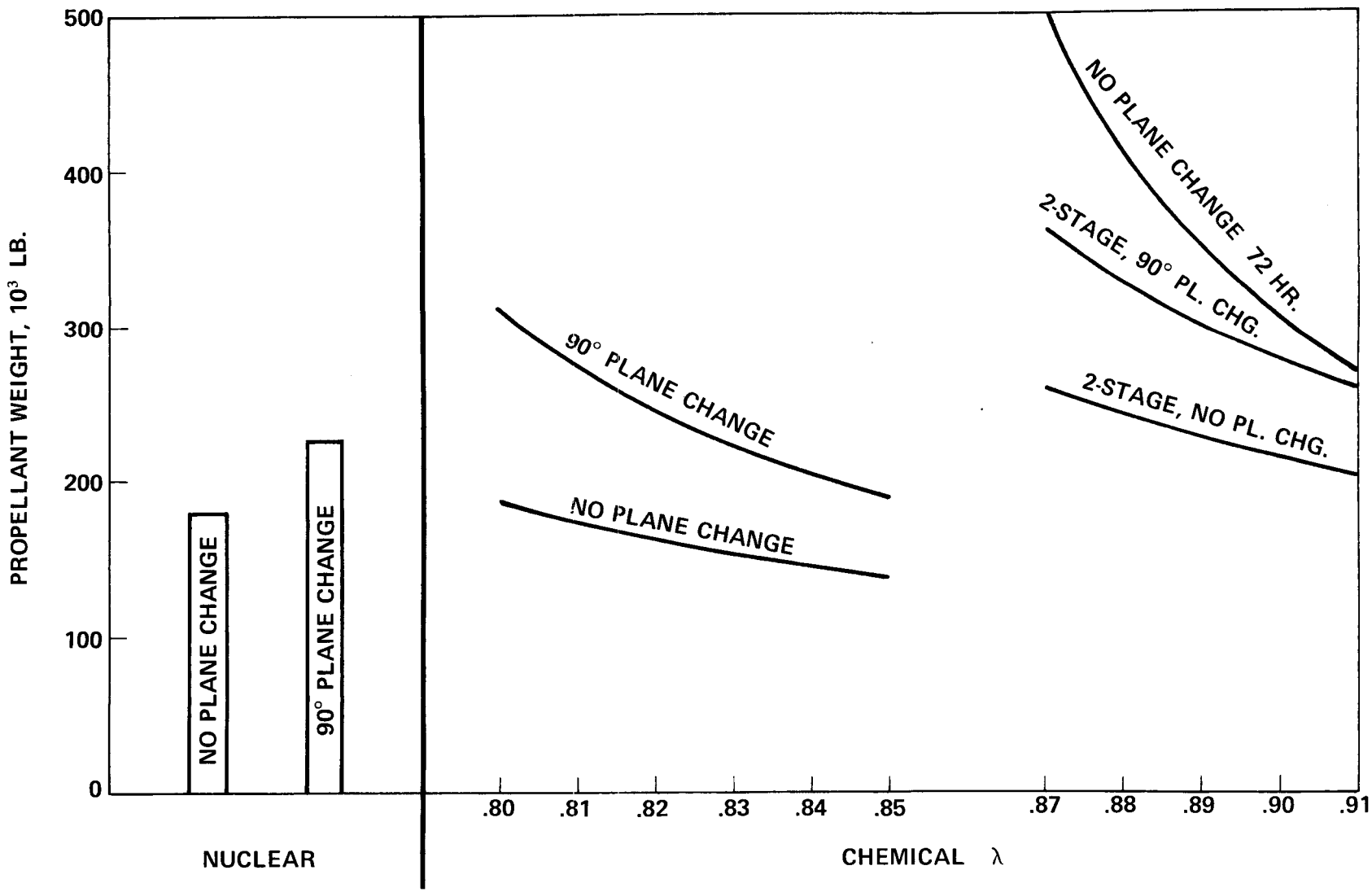
PROPELLANT REQUIREMENTS FOR PAYLOAD OF 120K/20K



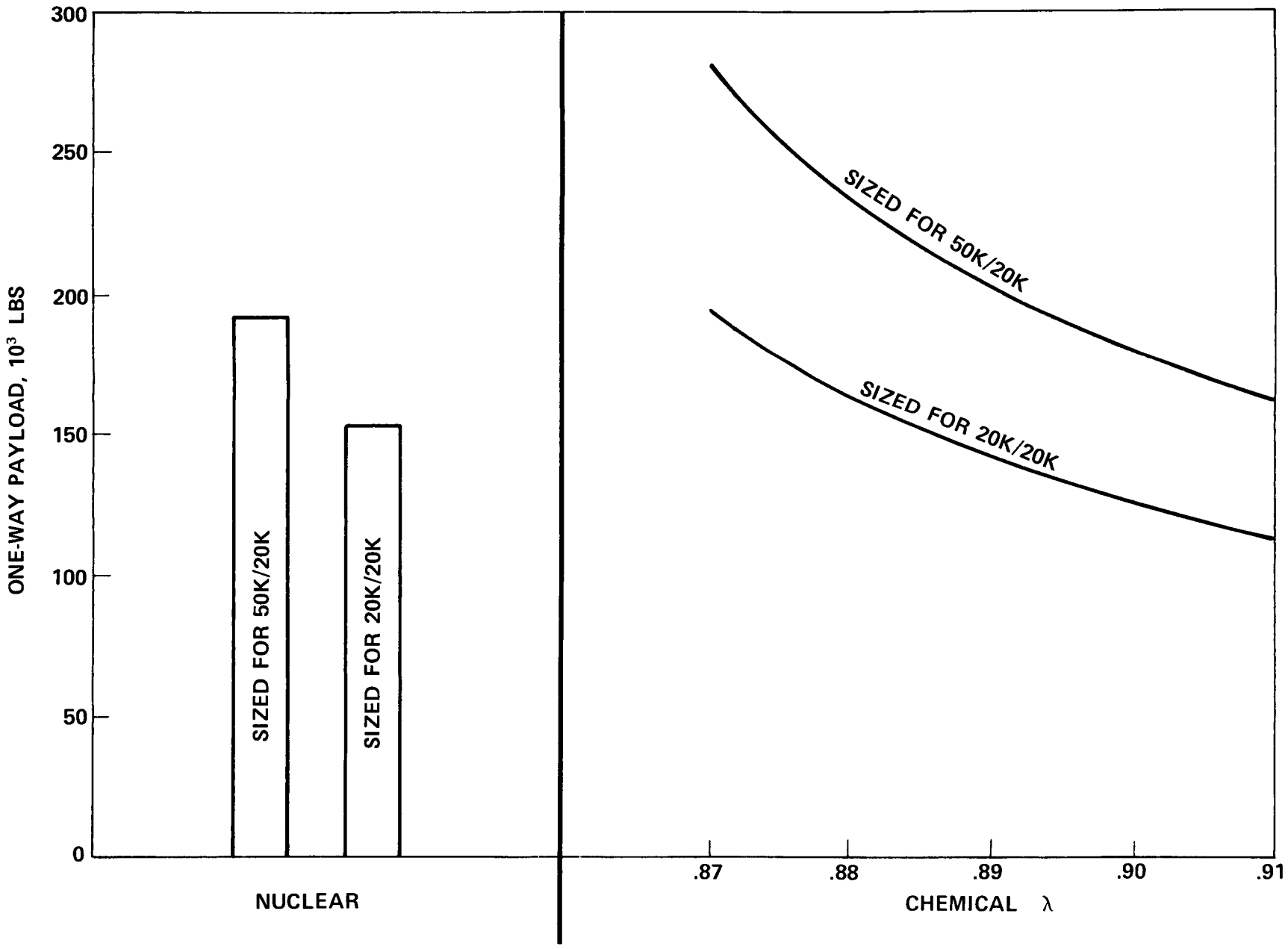
PROPELLANT REQUIREMENTS FOR PAYLOAD OF 20K/20K



PROPELLANT REQUIREMENTS FOR PAYLOAD OF 50K/20K



ONE-WAY PAYLOADS, EXPENDABLE MODE



PERFORMANCE SENSITIVITES

		$\frac{\Delta W_p}{W_p}$ FOR PAYLOADS OF:		
		120/20	50/20	20/20
FOR 10% INCREASE IN INERT WEIGHT	1-STAGE CHEMICAL	0.173	0.176	0.176
	2-STAGE CHEMICAL	0.060	0.060	0.069
	NUCLEAR	0.101	0.111	0.139
FOR 2% DECREASE IN I_{SP}	1-STAGE CHEMICAL	0.106	0.110	0.116
	2-STAGE CHEMICAL	0.058	0.062	0.069
	NUCLEAR	0.078	0.106	0.151

CISLUNAR SHUTTLE PERFORMANCE COMPARISON SUMMARY

- SINGLE STAGE NUCLEAR SHOULD BE COMPARED WITH TWO STAGE CHEMICAL
- STAGED NUCLEAR PROVIDES LITTLE, IF ANY, ADVANTAGE
- NUCLEAR IS SUPERIOR FOR 120 K/20 K PAYLOADS (BY FACTOR OF 1.3 OR MORE)
- SIZING FOR LOWER PAYLOADS (LOGISTICS AND CREW ROTATION) DECREASES NUCLEAR ADVANTAGE
- NUCLEAR PERFORMANCE IS MORE SENSITIVE TO CHANGES IN DESIGN THAN IS TWO-STAGE CHEMICAL PERFORMANCE
- STAGES SIZED FOR LOGISTICS PAYLOAD AND RETURN CAN DELIVER LARGE PAYLOAD ON ONE-WAY MISSION
- AEROBRAKED CHEMICAL (SINGLE STAGE) IS PROBABLY SUPERIOR TO NUCLEAR FOR GROSS WEIGHTS LESS THAN 250,000 POUNDS

CONSIDERATIONS OTHER THAN PERFORMANCE

DEVELOPMENT COSTS

LAUNCH VEHICLES

PROPELLANT RESUPPLY COSTS

SAFETY AND RELIABILITY

ORBITAL OPERATIONS

LAUNCH MODES

CHEMICAL

- REPLACEMENT OF SPACE SHUTTLE SECOND STAGE
- 125,000 LB STAGE OR SMALLER COULD BE CARRIED INTERNALLY BY SPACE SHUTTLE
- DELIVERY BY VEHICLE WITH LARGE LIFT CAPABILITY

NUCLEAR

SINGLE TANK

- SATURN CLASS LAUNCH VEHICLE
- SPACE SHUTTLE BOOSTER WITH EXPENDABLE SECOND STAGE
- ATTACHMENT OF CHEMICAL ENGINE FOR USE AS SPACE SHUTTLE SECOND STAGE

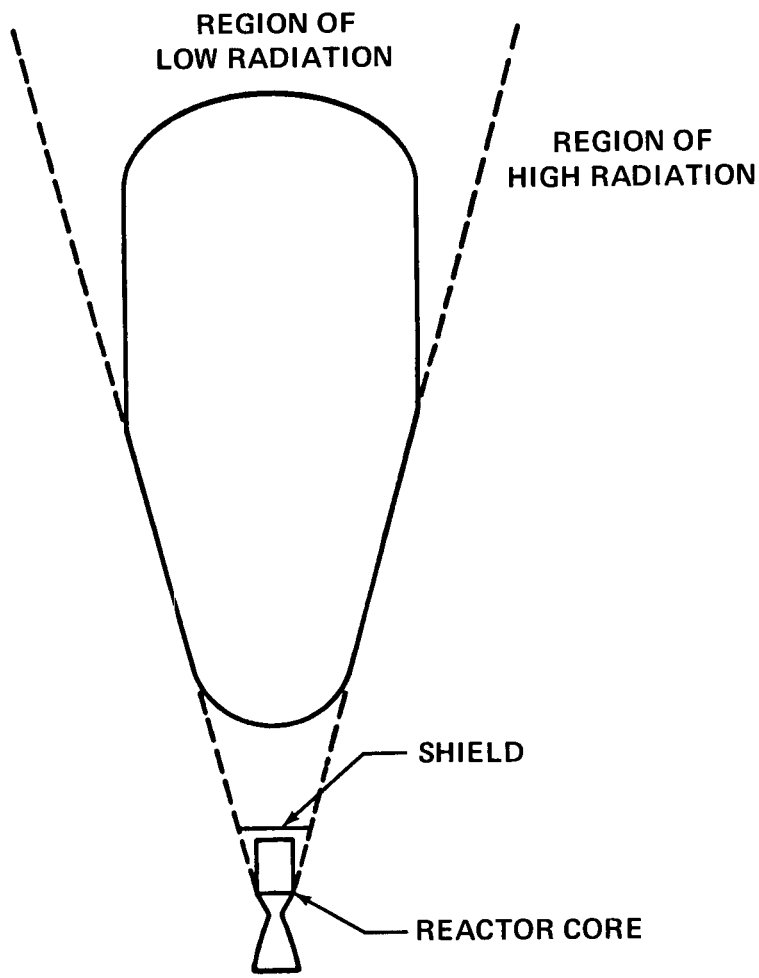
MODULAR

- SEVERAL SPACE SHUTTLE FLIGHTS

ORBITAL OPERATIONS

- RENDEZVOUS, DOCKING, & STATION KEEPING
- TRANSFER OF PROPELLANT, PAYLOAD, & CREW
- MAINTENANCE & REPAIR
- ENGINE REMOVAL & REPLACEMENT
- ENGINE DISPOSAL
- PREVENTION OF UNPROGRAMMED EARTH IMPACT
- EMERGENCY OPERATIONS

SHADOW SHIELDED NUCLEAR SHUTTLE



OPERATIONAL LIMITATIONS ON NUCLEAR SHUTTLE

- NERVA ENGINE CANNOT OPERATE WITHIN 30 TO 100 MILES OF ANOTHER MANNED SPACECRAFT
- ATTITUDE OF NUCLEAR SHUTTLE MUST BE CONTROLLED WHEN NEAR MANNED SPACECRAFT
- APPROACH OF PERSONNEL TO AFT END OF VEHICLE WILL BE IMPOSSIBLE WITHOUT HEAVY, PORTABLE SHIELD (50,000 TO 100,000 POUNDS)
- RENDEZVOUS AND RESUPPLY MUST BE MADE IN FORWARD DIRECTION

POSSIBLE OPERATIONAL PROBLEMS WITH NUCLEAR SHUTTLE

- MAINTENANCE NEAR ENGINE AND REMOVAL OF ENGINE
- DISPOSAL OF DISABLED ENGINE
- DOCKING OF NUCLEAR SHUTTLE WITH SPACE STATION OR PROPELLANT DEPOT

CONCLUSIONS

- SINGLE STAGE NUCLEAR SHOULD BE COMPARED WITH TWO STAGE CHEMICAL
- NUCLEAR OUTPERFORMS CHEMICAL FOR LARGE PAYLOADS
- NUCLEAR ADVANTAGE DECREASES AS PAYLOAD DECREASES
- NUCLEAR PERFORMANCE MORE SENSITIVE TO DESIGN CHANGES
- NUCLEAR/CHEMICAL DECISION MUST WEIGH OTHER FACTORS RELATED TO LAUNCH VEHICLES, ORBITAL OPERATIONS, SAFETY, AND DEVELOPMENT COST
    - COST OF SHUTTLE PROPELLANT FLIGHTS
    - CHEMICAL SHUTTLE REQUIRES STAGING OR AEROBRAKING
    - ORBITAL OPERATIONS WITH NUCLEAR WILL BE MORE DIFFICULT
    - IF SATURN V OR EQUIVALENT NOT AVAILABLE, LAUNCH IS SIMPLER FOR CHEMICAL

BELLCOMM, INC.

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From: D. J. Osias

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