NUCLEAR DIVISION

RN-PA-0024

MSA

MATERIAL PRESENTED TO SNPO

IN

SHIELDING TRADE STUDY REVIEW

NERVA Program

Contract SNP-1

23 October 1969

MSA

(Volume I)

Aerojet-General Corporation
Presentation Material

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IN
SHIELDING TRADE STUDY REVIEW

NERVA Program

Contract SNP-1

NUCLEAR ROCKET OPERATIONS

23 October 1969

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CLASSIFICATION CATEGORY

UNCLASSIFIED

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CLASSIFYING OFFICER

Nov. 12, 1969

DATE

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AGENDA

MORNING SESSION

1. SUMMARY REVIEW OF SHIELDING TRADE STUDY
2. RESULTS OF ALTERNATIVE CONCEPT STUDIES AT WANL
3. RESULTS OF ALTERNATIVE CONCEPT STUDIES AT NRO

AFTERNOON SESSION

1. WANL PHASE III TASK RESULTS
2. NRO PHASE III TASK RESULTS
3. DISCUSSION OF SHIELDING IMPACT OF CHANGE ORDER 70-1

TASK BREAKDOWN - PHASE III OF SHIELDING TRADE STUDY

<u>TASK NO.</u>	<u>TASK DESCRIPTION</u>
5	PREPARE INTERIM DOCUMENT ON TASKS 3 AND 4
5.1.W	WANL INPUTS TO TASK 3 AND 4 DOCUMENTATION
6	REVISE CRAM TO REFLECT TD-69-26 AND TASK 4 OUTPUT
6.1.W	WANL REVISION OF NSS CRAM CONTRIBUTIONS BASED ON TD-69-26 AND TASK 4
6.2.W	WANL COMPUTATION OF SHUTDOWN SOURCES IN THE NSS FOR EACH NPRD MISSION
7	COMPLETE ANALYSIS OF TUCKED-IN LINE CONFIGURATION IN MAY CRAM
8	PRELIMINARY DESIGN OF MISSION B DISK SHIELD
9	BENCHMARK MONTE CARLO ANALYSES FOR MISSIONS C, A AND B
10	SYSTEM WEIGHT REDUCTION PROGRAM
10.1	ENGINE SYSTEM AND COMPONENT CONCEPTS
10.2.W	WANL NUCLEAR SUBSYSTEM CONCEPTS
10.3	SYSTEM WEIGHT EFFECTS DUE TO NSS CONCEPTS
10.4	VEHICLE CONCEPTS
10.5	PAYLOAD CONCEPTS
10.6	MATERIALS/SECONDARY GAMMA SOURCE MATRIX
11	SHUTDOWN RADIATION ENVIRONMENT FOR MISSION A WITH AND WITHOUT DISK SHIELD
12.W	WANL STUDY OF INTERNAL SHIELD (MECHANICAL AND NUCLEAR DESIGN)
13	SHIELD WEIGHT SENSITIVITY TO OPERATING PROFILE
14	SHIELD WEIGHT SENSITIVITY TO ERRORS IN RADIATION LEAKAGE PREDICTIONS
15	REDEFINITION OF INTERNAL SHIELD REQUIREMENTS FOR REFERENCE ENGINE

AGC-ND

75K THRUST FULL FLOW NERVA ENGINE

NUCLEAR FLIGHT PROPULSION MODULE
WITH 75,000 LBS THRUST NERVA ENGINE

TANK TOP DOSE FOR ENGINE WITH STEEL OR GRAPHITE NOZZLE SKIRT EXTENSION

ENGINE CONFIGURATION	TANK TOP DOSE (REM)	
	3300 LB INTERNAL SHIELD	3300 LB INTERNAL SHIELD + 10,000 LB ENGINE DISK SHIELD
REFERENCE ENGINE WITH CRES 347 NOZZLE SKIRT EXTENSION AND HAST-C TURBINE EXHAUST LINES	1330	167
REFERENCE ENGINE WITH GRAPHITE NOZZLE SKIRT EXTENSION AND SHORT TURBINE EXHAUST LINES	1000	101

TANK TOP DOSE CONTRIBUTIONS

(DOSE BASED ON TIME INTEGRAL TO 7,500 LB RESIDUAL LH₂ CONDITION)

CONTRIBUTION*	DOSE (REM)	
	3,300 LB INTERNAL SHIELD	3,300 LB INTERNAL SHIELD + 8,300 LB LEAD DISK SHIELD
PRESSURE VESSEL AND REACTOR ASSEMBLY (PVARA)		
DIRECT γ	348	13
SCATTERED γ	443	33
PUMP DISCHARGE LINE AND NOZZLE ASSEMBLY		
DIRECT γ	7	<1
SCATTERED γ	67	36
TOTAL	865	82

* DIRECT CONTRIBUTIONS ARE THOSE WHICH DO NOT INCLUDE SCATTERING IN THE PROPELLANT TANK OR LIQUID OR GASEOUS PROPELLANT. IN THE CASE OF THE PUMP DISCHARGE LINE AND NOZZLE SOURCES THE DIRECT COMPONENT IS THE UNCOLLIDED COMPONENT. THE DIRECT COMPONENT FROM THE PVARA INCLUDES SCATTERING WITHIN THE PRESSURE VESSEL.

**HOT BLEED CYCLE/STEEL DISK ENGINE SHIELD
SHIELD WEIGHT FOR CREW DOSE OF 10 REM FOR
VARIOUS PAYLOAD ATTENUATION FACTORS**

PAYLOAD ATTENUATION FACTOR	SHIELD WEIGHT (LBS)			
	INTERNAL ENGINE SHIELD	EXTERNAL ENGINE SHIELD	SHIELDING AT PAYLOAD	TOTAL
1	3300	10,000	11,600	24,900
3	3300	10,000	6,300	19,600
10	3300	10,000	-	13,300
20	3300	6,300	-	9,600
30	3300	4,300	-	7,600
50	3300	2,100	-	5,400
100	3300	-	-	3,300

NOTES:

- 1. GRAPHITE SKIRT EXTENSION**
- 2. HAST-C TURBINE INLET LINE**
- 3. AI PUMP DISCHARGE LINE**

**HOT BLEED CYCLE/LEAD DISK ENGINE SHIELD
SHIELD WEIGHT FOR CREW DOSE OF 10 REM FOR
VARIOUS PAYLOAD ATTENUATION FACTORS**

PAYLOAD ATTENUATION FACTOR	SHIELD WEIGHT (LBS)			
	INTERNAL ENGINE SHIELD	EXTERNAL ENGINE SHIELD	SHIELDING AT PAYLOAD	TOTAL
1	3300	10,000	10,000	23,300
3	3300	10,000	4,600	17,900
10	3300	8,200	-	11,500
20	3300	5,200	-	8,500
30	3300	3,600	-	6,900
50	3300	1,800	-	5,100
100	3300	-	-	3,300

NOTES: 1. GRAPHITE SKIRT EXTENSION
2. HAST-C TURBINE INLET LINE
3. AI PUMP DISCHARGE LINE

FULL FLOW CYCLE/STEEL DISK ENGINE SHIELD
SHIELD WEIGHT FOR CREW DOSE OF 10 REM FOR
VARIOUS PAYLOAD ATTENUATION FACTORS

PAYLOAD ATTENUATION FACTOR	SHIELD WEIGHT (LBS)			
	INTERNAL ENGINE SHIELD	EXTERNAL ENGINE SHIELD	SHIELDING AT PAYLOAD	TOTAL
1	3300	10,000	10,600	23,900
3	3300	10,000	5,200	18,500
10	3300	8,700	-	12,000
20	3300	5,300	-	8,600
30	3300	3,500	-	6,800
50	3300	1,500	-	4,800
100	3300	-	-	3,300

NOTES: 1. GRAPHITE SKIRT EXTENSION
2. AI PUMP DISCHARGE LINE

FULL FLOW CYCLE/LEAD DISK ENGINE SHIELD
SHIELD WEIGHT FOR CREW DOSE OF 10 REM FOR
VARIOUS PAYLOAD ATTENUATION FACTORS

PAYLOAD ATTENUATION FACTOR	SHIELD WEIGHT (LBS)			
	INTERNAL ENGINE SHIELD	EXTERNAL ENGINE SHIELD	SHIELDING AT PAYLOAD	TOTAL
1	3300	10,000	9000	22,300
3	3300	10,000	3500	16,800
10	3300	7,300	-	10,600
20	3300	4,400	-	7,700
30	3300	2,900	-	6,200
50	3300	1,300	-	4,600
100	3300	-	-	3,300

NOTES: 1. GRAPHITE SKIRT EXTENSION
2. AI PUMP DISCHARGE LINE

**FULL FLOW CYCLE/ENGINE BRIM SHIELD
SHIELD WEIGHT FOR CREW DOSE OF 10 REM FOR
VARIOUS PAULOAD ATTENUATION FACTORS**

PAYLOAD ATTENUATION FACTOR	SHIELD WEIGHT (LBS)			
	INTERNAL ENGINE SHIELD	BRIM SHIELD	SHIELDING AT PAYLOAD	TOTAL
1	7000	6300	8800	22,100
3	7000	6300	3300	16,600
10	6300	4300	-	10,600
20	5300	2400	-	7,700
30	5200	1000	-	6,200
50	4500	-	-	4,500
100	3300	-	-	3,300

NOTES: 1. GRAPHITE SKIRT EXTENSION
2. AI PUMP DISCHARGE LINE

SUMMARY OF SHIELD WEIGHTS FOR MODIFIED APOLLO PAYLOAD - 10 REM

(PAYLOAD ATTENUATION FACTOR OF 3)

<u>ENGINE CONFIGURATION</u>	<u>DATE OF DESIGN REFERENCE</u>	<u>UNIQUE ENGINE FEATURES</u>	<u>ENGINE SHIELD CONFIGURATION</u>	<u>TOTAL SHIELD WEIGHT (LB)</u>
BLEED CYCLE	MAY '69	AL-PDL, HAST-C-TIL & TEL'S CRES-347 - NOZZLE SKIRT AND SKIRT EXTENSION HAST-X - NOZZLE	STEEL DISK	22,700
BLEED CYCLE	SEPT '69	AL-PDL, HAST-C-TIL NO - TEL'S, GRAPHITE SKIRT EXT. HAST-X - NOZZLE, CRES-347 SKT.	STEEL DISK	19,600
BLEED CYCLE	SEPT '69	AL-PDL, HAST-C-TIL NO - TEL'S, GRAPHITE SKIRT EXT. HAST-X - NOZZLE, CRES-347 SKT.	LEAD DISK	17,900
FULL FLOW	OCT '69	AL-PDL, NO TEL'S AND TIL GRAPHITE SKIRT EXTENSION HAST-X-NOZZLE, CRES-347 SKT.	STEEL DISK	18,500
FULL FLOW	OCT '69	AL-PDL, NO TEL'S AND TIL GRAPHITE SKIRT EXTENSION HAST-X-NOZZLE, CRES-347 SKT.	LEAD DISK	16,800
FULL FLOW	OCT '69	AL-PDL, NO TEL'S AND TIL GRAPHITE SKIRT EXTENSION HAST-X-NOZZLE, CRES-347 SKT.	LH ₂ COOLED LEAD BRIM	16,600
FULL FLOW	OCT '69	AL-PDL, NO TEL'S AND TIL GRAPHITE SKIRT EXTENSION HAST-X-NOZZLE, CRES-347 SKT.	CH ₂ COOLED ZrH BRIM	18,600 (ESTIMATED)

TASK 10 - ALTERNATIVE CONCEPTS FOR REDUCING SYSTEM WEIGHT

10.1 ENGINE SYSTEM AND COMPONENT CONCEPTS

1. REGROUP PROPELLANT LINES
2. GRAPHITE TURBINE INLET AND EXHAUST LINES
3. ALTERNATIVE SKIRT EXTENSION CONCEPTS
4. GRAPHITE COMPOSITE NOZZLE DESIGN
5. EXTERNAL NOZZLE SHIELDING
6. NOZZLE REDESIGN TO REDUCE SIZE OF REFLECTOR INLET PLENUM
7. INSERTION OF BORON CONTAINING MATERIAL IN PROPELLANT LINE
8. INSERTION OF BORON CONTAINING MATERIAL IN NOZZLE STRUCTURE AND PLENA
9. NEW SHIELD MATERIALS
10. COMPONENT MATERIAL SUBSTITUTION TO REDUCE NEUTRON CAPTURE
11. LOCAL PROPELLANT LINE SHIELDING

REFERENCE ENGINE LINES
(HOT BLEED/DISK SHIELD/
GAS COOLED SKIRT EXTENSION)

LINE OPTIONS FOR SHIELDING ANALYSIS
(HOT BLEED ENGINE)

	PDL	TIL	TEL
REFERENCE ENGINE	5.0 INCH O.D. TUBING ALUMINUM	4.0 INCH O.D. TUBING HASTELLOY "C"	7.0 INCH O.D. TUBING 347 CRES DUAL LINES
OPTION "A" CONFIGURATION	5.0 INCH O.D. TUBING INCONEL 718	3.0 INCH O.D. TUBING HASTELLOY "C"	10.0 INCH O.D. TUBING 347 CRES SINGLE LINE
OPTION "B" CONFIGURATION	5.0 INCH O.D. TUBING TITANIUM	4.5 INCH O.D. TUBING GRAPHITE	7.5 INCH O.D. TUBING GRAPHITE DUAL LINES
OPTION "C" CONFIGURATION	4.0 INCH O.D. TUBING ALUMINUM	4.5 INCH O.D. GRAPHITE & COOLED B/P ELBOW HASTELLOY "C"	10.5 INCH O.D. TUBING GRAPHITE SINGLE LINE

DISK SHIELD PARAMETRIC DATA
75° TANK
200 IN. SEPARATION DISTANCE

TASK 10.1.7

CROSS SECTION OF PUMP DISCHARGE LINE
WITH 1/8" BORAL INSERT
BORAL WEIGHT = 0.240 LB/IN OF PDL

!

TASK 10.1.10

COMPONENT MATERIAL SUBSTITUTION TO
REDUCE NEUTRON CAPTURE

SECONDARY GAMMA EMISSION
(MEV/SEC-LB X 10^{-13})

<u>MATERIAL</u>	<u>HOT LINE</u>	<u>COLD LINE</u>	<u>PV</u>	<u>NOZZLE</u>	<u>SKIRT</u>	<u>EXTENSION</u>
Ti-5AL-2.5 Sn ELI	--	15.2	20.2	--	--	4.47
HASTELLOY-X	30.6	10.7	--	11.1	16.5	--
HASTELLOY-C	48.8	11.9	--	15.0	--	--
AISI-347	8.03	8.60	--	8.03	12.0	12.0
INCONEL 718	--	15.4	71.7	22.1	--	--
A-286	7.42	8.57	--	--	--	--
AL-7039-T63	--	1.64	4.97	--	3.86	3.86
AL-7075	--	1.31	--	--	--	--
AL-6061-T6	--	--	2.67	--	1.61	1.61
TZM (MO)	--	--	--	--	--	44.5
W	--	--	--	--	--	199.
W-25% RC	--	--	--	--	--	256.
CB-D-14	--	--	--	--	--	34.1
CB-AS-55	--	--	--	--	--	43.5
CB-B-66	91.3	--	--	--	--	70.1
MO	--	--	--	--	--	44.5
AG CARB-100	0.024	--	--	--	0.002	0.002
PALNIRO	--	--	--	197	548	548
MIORO	--	--	--	228	639	639

10.2.W. WANL NUCLEAR SUBSYSTEM CONCEPTS

1. REFLECTOR AFT END SHIELD
2. LOCAL SIDE NEUTRON SHIELD
3. CORE AFT END SHIELD
4. REFLECTOR FORWARD END SHIELD
5. COMBINED REFLECTOR/SIDE SHIELD
6. USE OF POISONED-GRAPHITE TIP ON DOME END OF FUEL
7. COMBINED INTERNAL SHIELD SUPPORT PLATE
8. NEW SHIELD MATERIALS
9. REFLECTOR INLET PLENUM REDUCTION (COMBINED WITH CONCEPT 6 OF SUBTASK 10.1)

10.3 SYSTEM WEIGHT EFFECTS DUE TO NSS CONCEPTS

THIS SUBTASK COVERS THE INCORPORATION OF THE ABOVE NSS CONCEPTS IN THE STUDY OF OVERALL SYSTEM WEIGHT.

AGC-ND

DISK SHIELD CONCEPT - 1136182

AGC-ND

100 IN. DIA. DISK SHIELD CONCEPT 1137102

- 347 CRES SHEET
- LEAD
- GRAPHITE 2% BORATED
- LITHIUM HYDRIDE

AGC-ND

100 IN. DIA DISK SHIELD CONCEPT 1137117

SECTION A-A
SHEAR STRUCTURE

UPPER THRUST STRUCTURE

AGC-ND

100 IN. DIA DISK SHIELD CONCEPT 1137116

- 347 CRES SHEET
- LEAD
- GRAPHITE 2% BORATED
- LITHIUM HYDRIDE

AGC-ND

MISSION "A" LEAD DISK SHIELD
WEIGHT SUMMARY

	TOTAL STRUCTURAL WEIGHT	NON-USEABLE WEIGHT
DRAWING #1137102	1440	285
DRAWING #1137116	1146	520
DRAWING #1137117	1341	426

- CONCEPTS ARE ALL FOR SAME SHIELD MATERIAL CONFIGURATION BUT DIFFER IN THAT EACH CONCEPT IS DESIGNED FOR COMPATIBILITY WITH VARIOUS THRUST STRUCTURE GEOMETRIES.

10.4 VEHICLE CONCEPTS

1. ALTERNATIVE TANK SHAPES
2. PROPELLANT MANAGEMENT
3. USE OF BORON CONTAINING MATERIAL IN PROPELLANT TANK

10.5 PAYLOAD CONCEPTS

1. MINIMIZE SENSITIVE VOLUME
2. RECONFIGURE CAPSULE AND TANK TOP
3. CREW CAPSULE/PROPELLANT TANK SEPARATION
4. MOVEABLE CAPSULE SHIELD
5. USE OF HIGH DENSITY CAPSULE SHIELDS

COMPARISON OF 33 FT DIAMETER TO 22 FT DIAMETER TANK

DISK SHIELD ENVELOPE CURVES - VARIOUS TANK SHAPES

AGC-ND

FERRY MISSION
CONFIGURATION

200 IN. SEPARATION
DISTANCE

PAYLOAD ATTENUATION = 1.0

7500 LB RESIDUAL LH_2
AT END OF FIRING

CREW DOSE, REM

60° TANK -
VARIABLE SEPARATION
DISTANCE

75° TANK -
NO INCREASED TANK WT

SYSTEM WEIGHT, LB (THOUSANDS)

OPTIMIZED SHIELD SYSTEM WEIGHT FOR DISK SHIELD

OPTIMIZED SHIELD SYSTEM WEIGHT FOR DISK SHIELD

CONCLUSIONS

- A Manned Lunar Logistics Vehicle May Be Used With A Typical Nuclear Propulsion Module Without Supplemental Shields.
- Gamma Sources External To The PVARA Are The Primary Contributor To Crew And Tank Top Radiation Environments.
- Multiple Scatter Is The Mechanism By Which Most Radiation Reaches Crew Positions.
- No Single Path For Radiation Controls Crew Environments.
- A 30° (Included Angle) Ellipti-conical Tank Bottom Geometry Is Effective In Reducing Nuclear Module And Spacecraft Radiation Environments.
- Neutrons Make No Significant Contribution To Environments At The Tank Top.
- Nuclear Radiation Energy Deposition In The Propellant Is Minimal.
- The Monte Carlo Method, With Careful Biasing, May Be Feasibly Applied To Multiple Radiation Sources In A Nuclear Module/Spacecraft Of High Geometric Complexity.

LUNAR SHUTTLE 75-K NERVA

PAYLOAD (LB) OUTBOUND/RETURN.		PROPELLANT (LB)
119,000	0.0	274741
44,000	44000	278967
0.0	69000	280437

SYNCHRONOUS SHUTTLE

75-K NERVA

PAYLOAD (LB) OUT/RETURN	PROPELLANT (LB)
102,000/0.0	273,100
38,000/38,000	272,100
0.0/60,000	267,100

ALTERNATE CONFIGURATIONS

CONFIGURATION ANALYSIS SUMMARY

MISSION CLASSES II & IV

$W_p = 285,000 \text{ LB}$

CONFIGURATION CHARACTERISTICS
EST INTEGRATED RADIATION DOSE (REM) (TANK TOP)	11,500	1800	1500	1400	1700	1900
* NEW HARDWARE & TOOLING	1	3	2	3	3	4
DRY WEIGHT** (LB)	78,490	80,490	80,140	81,045	81,910	85,165
*LV IMPACT	2	2	2	2	3	2
*DESIGN/MFG COMPLEXITY	1	3	3	3	3	3
*SR&T	1	3	3	3	2	3
RECOMMENDED CONFIGURATION			✓			

*FACTORS NUMBERED FROM 1 TO 5 WHERE 1 IS LOWEST

**EXCLUDES INTERSTAGE

TANK BOTTOM GEOMETRY COMPARISONS (INTEGRATED RADIATION DOSE LEVELS, RAD)

- DOSE POINT 119 FEET ABOVE CORE CENTER
- 177,000 LB LH₂ PROPELLANT CAPACITY
- 3300 LB INTERNAL ENGINE SHIELD
- 30-MINUTE ENGINE FIRING, 7500 LB RESIDUAL LH₂

	NS-II ELLIPT	75° CONICAL	DUAL CELL - CONICAL	DUAL CELL CYLINDRICAL (PRELIMINARY)	DUAL CELL ELLIPTICAL	MODULAR - SEPARATE
PVARA	5350	810	840	700	670	900
LINES (TEL, TIL) PDL	3140	480	470	420	400	500
NOZZLE, SKIRT AND EXTENSION	2000	280	290	270	250	320
TOTAL (REM)	10,490	1570	1600	1390	1300	1720

TANK GEOMETRY CANDIDATES

CONVENTIONAL

$\sqrt{2}$

60°

75°

UNCONVENTIONAL

TELESCOPE

INTERNAL
BAFFLE

PROPELLANT TANK HEATING
VS SHIELD WEIGHT
(186 IN. SEPARATION DISTANCE)

TOTAL LH₂ HEATING,
Q (BTU/SEC)

MISSION C I
UNMANNED PLANETARY PROBE

AGC-ND

PROPELLANT BOIL OFF VS NUCLEAR ENERGY DEPOSITION INTO TANKS

SINGLE 50 MINUTE BURN, 50 HR COAST

290,000 LBS LH_2 PROPELLANT LOADING PER TANK

37°R INITIAL LH_2 TEMPERATURE

3300 LB INTERNAL SHIELD

PER CENT OF REACTOR POWER VS TIME AFTER SHUTDOWN
 FOR THE 4TH BURN OF MISSION "A"

AGC-ND

TANK TOP
DOSE RATE VS TIME TO EMPTY TANK
75 DEGREE CONICAL BOTTOM

AGC-ND

CUMULATIVE DOSE AT TANK TOP,
50 MINUTE BURN

DOSE VS ENGINE SHIELD WEIGHT FOR REFERENCE ENGINE
WITH STEEL OR GRAPHITE NOZZLE SKIRT EXTENSION

XE-PRIME ENGINE IN EVACUATED TEST
COMPARTMENT OF ENGINE TEST STAND-1

CALCULATED & MEASURED FULL POWER DOSE RATE IN UNITS OF 10^8 REM/HR
FULL POWER (1126 Mw) OPERATION OF XE-PRIME

AGC-ND

CALCULATED AND MEASURED GAMMA KERMA RATES DURING FULL POWER OPERATION ALONG RADIAL MIDPLANE TRAVERSE

XE INTERMEDIATE
POWER MEASUREMENT

△ Li⁷F
○ CaF₂

XE LOW POWER
MEASUREMENT

◇ Li⁷F
□ CaF₂

NOTE: ALL MEASUREMENTS
ARE SCALED UP TO FULL
POWER OPERATION FOR
COMPARISON WITH
CALCULATIONS

AGC-ND

COMPARISON OF MEASURED AND CALCULATED FULL POWER GAMMA DOSE RATES IN BOTTOM OF ENGINE TEST COMPARTMENT

XE PRIME DOSIMETER LOCATION

COMPARISON OF MEASURED AND CALCULATED FULL POWER GAMMA DOSE RATE ALONG SIDE SHIELD

COMPARISON OF MEASURED TO CALCULATED FULL POWER GAMMA DOSE RATE TOP OF ETC

CALCULATED GAMMA RAY DOSE RATE ON LOWER SURFACE OF THE EXTERNAL ENGINE SHIELD

NUCLEAR PROPULSION MODULE WITH 6 MAN MODIFIED APOLLO REENTRY VEHICLE

AGC-ND

REPRESENTATIVE 22 FT DIAMETER PAYLOAD FOR ORBIT TO ORBIT NUCLEAR SHUTTLE

PLAN VIEW OF DECK 1 AND 2 OF MISSION MODULE (ONE WAY SYNCHRONOUS ORBIT MISSION)

SECTION D-D
CREW QUARTERS
DECK #1

SECTION C-C
CONTROL/DINING/RECREATION
DECK #2

AGC-ND

PLAN VIEW OF DECK 3 AND 4 OF MISSION MODULE (ONE WAY SYNCHRONOUS ORBIT MISSION)

AGC-ND

LM/B SPACECRAFT CREW COMPARTMENT
(SCALED TO 22 FT DIAMETER FOR SHIELDING ANALYSIS)

- 1 CONTROL CENTER
- 2 HYDROGEN TANK
- 3 HARD SUIT STORAGE
- 4 OXYGEN TANKS
- 5 ELECTRICAL POWER SYS
RADIATOR
- 6 DOCKING HATCH (SHIELDED)
- 7 ENVIRONMENTAL CONTROL
RADIATOR
- 8 AIRLOCK

AGC-ND

AFTER SHUTDOWN RADIATION ENVIRONMENT FOR DOCKED CONDITION
3300 LB INTERNAL SHIELD, NO DISK SHIELD

AGC-ND

AFTER SHUTDOWN RADIATION ENVIRONMENT FOR DOCKED CONDITION
(3300 LB INTERNAL SHIELD, 10,000 LB DISK SHIELD)

**CYLINDRICAL "WRAP AROUND"
PORTABLE IN-SPACE
MAINTENANCE SHIELD**

- THIS MAINTENANCE SHIELD CONCEPT IS BASED ON THE INCLUSION OF AN ENGINE DISK SHIELD FOR THE FERRY MISSIONS

EXTENDED ANNULAR DISK
PORTABLE IN-SPACE
MAINTENANCE SHIELD

- THIS MAINTENANCE SHIELD CONCEPT IS BASED ON THE INCLUSION OF AN ENGINE DISK SHIELD FOR THE FERRY MISSIONS

SHIELD WEIGHT REQUIRED FOR SPACE STATION OCCUPANCY
(3 REM DOSE IN 30 DAYS)

A. DISK EXTENSION CONCEPT

1.	REACTOR FISSION PRODUCT SHIELD	2400
2.	ENGINE COMPONENT ACTIVATION SHIELD	1000
		<hr/>
		3400 LBS

B. CYLINDRICAL ENCLOSURE CONCEPT

1.	REACTOR FISSION PRODUCT SHIELD	3900
2.	ENGINE COMPONENT ACTIVATION SHIELD	800
		<hr/>
		4700 LBS

NOTES:

1. ALLOWED DOSE IS LIMITED TO 3 REM
2. DOSE RATES ARE INTEGRATED FROM 10 HOURS TO 30 DAYS AFTER ENGINE SHUTDOWN AT A POINT LOCATED 185 FEET FORWARD OF CORE CENTER, 75 FEET FROM THE AXIAL CENTER-LINE (POLAR ANGLE ABOUT 22 DEG)
3. SHIELD WEIGHTS ARE IN ADDITION TO REFERENCE MISSION A DISK SHIELD WEIGHT OF 10,000 LBS
4. DOSE FOR 60 DAY PERIOD IS 3.5 REM COMPARED TO 3 REM DOSE FOR 30 DAYS

PORTABLE SHIELDING REQUIRED FOR STAGE AND ENGINE MAINTENANCE

DISK EXTENSION CONCEPT

DECAY TIME BEFORE MAINTENANCE	SHIELD WEIGHT (LBS)
10 HRS	17,900
1 DAY	15,900
4 DAYS	12,900
10 DAYS	10,700

CYLINDRICAL ENCLOSURE CONCEPT

DECAY TIME BEFORE MAINTENANCE	SHIELD WEIGHT (LBS)
10 HRS	22,100
1 DAY	19,600
4 DAYS	16,000
10 DAYS	13,400

THE ALLOWABLE GAMMA DOSE RATE IS ASSUMED TO BE 500 M REM/HR AT A POINT 10 FEET OFF AXIS AT ENGINE STATION "0"

SHIELD WEIGHTS ARE IN ADDITION TO REFERENCE FERRY MISSION DISK SHIELD OF 10,000 LBS

 INTEGRATED DOSE
 24 HRS TO 30 DAYS
 AFTER SHUTDOWN, REM

 DOSE RATE 24 HRS
 AFTER SHUTDOWN
 REM/HR (*M REM HR)

AFTER SHUTDOWN RADIATION ENVIRONMENT FOR DOCKED CONDITION
 (3300 LB INTERNAL SHIELD, 10,000 LB DISK SHIELD)

NUCLEAR SHUTTLE DEPARTURE FROM PROPELLANT DEPOT

FULL POWER DOSE RATES (REM/SEC)			
	FWD.	RADIAL AT CORE CENTER	AFT.
		CORE CENTER	
100 ft	5.8 (γ) 0.1 (n)	340 (γ) 3400 (n)	210 (γ) 6000 (n)
1000 ft	NEGL.	3.4 (γ) 34 (n)	2.1 (γ) 60 (n)
1 Mile	NEGL.	0.12 (γ) 1.2 (n)	0.08 (γ) 2.2 (n)