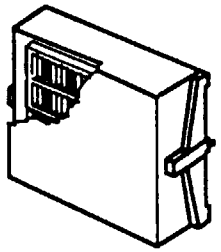


TRANSPORTER
ENERGY STORAGE
SUBSYSTEM

MDESC - L&ES

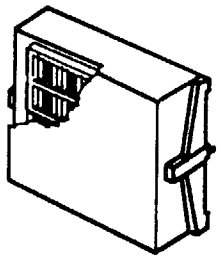
NICKEL-HYDROGEN BATTERY DESIGN FOR THE TRANSPORTER ENERGY STORAGE SUBSYSTEM (TESS)

BY

JOHN R. LAPINSKI
MDESC-L&ES

&

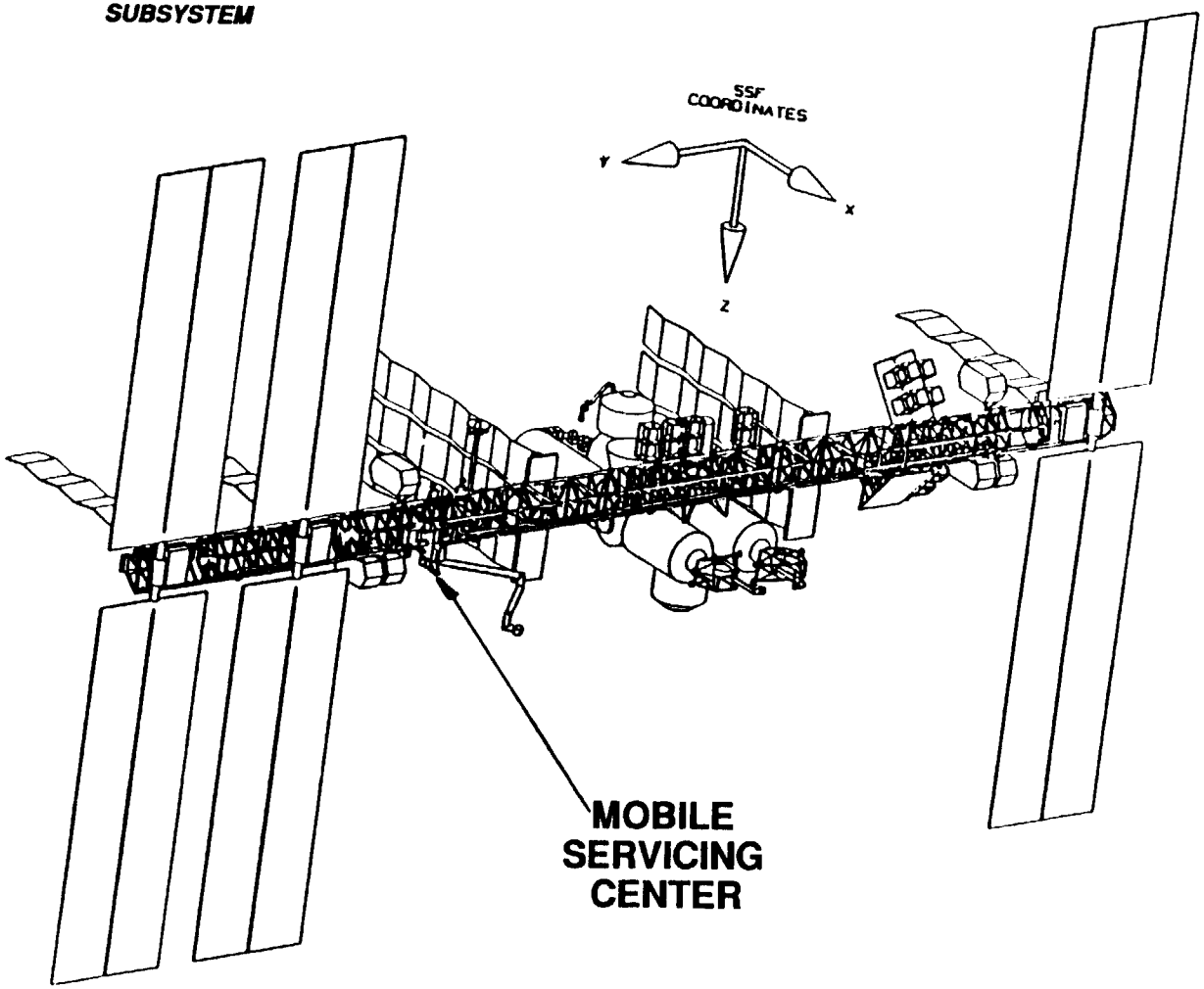
DEBORAH S. BOURLAND
NASA-JSC



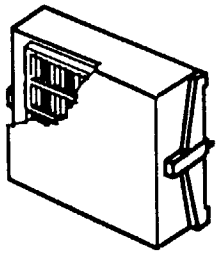
TRANSPORTER ENERGY STORAGE SUBSYSTEM

SPACE STATION FREEDOM - PMC

MDESC - L&ES



- TESS PROVIDES 120 VOLT POWER DURING TRANSLATION OF MOBILE SERVICING CENTER.
- TESS IS RECHARGED USING SPACE STATION 120 VOLT POWER AT BOTH WORK SITES AND HOME BASE.



TRANSPORTER ENERGY STORAGE SUBSYSTEM

TESS IN LAUNCH CONFIGURATION

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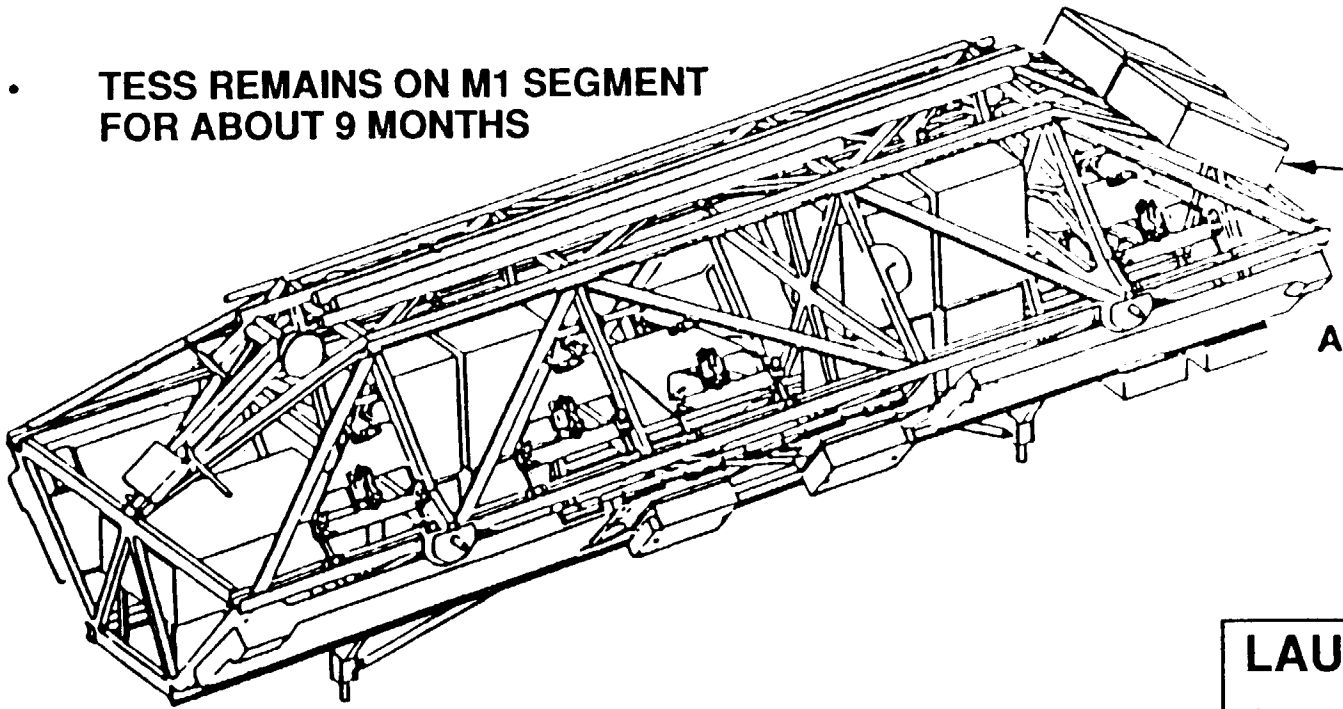
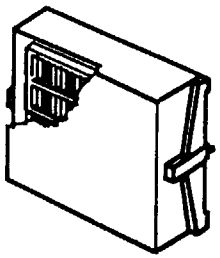
- TESS BATTERY LAUNCHED DISCHARGED AND OPEN CIRCUIT
- TESS REMAINS ON M1 SEGMENT FOR ABOUT 9 MONTHS

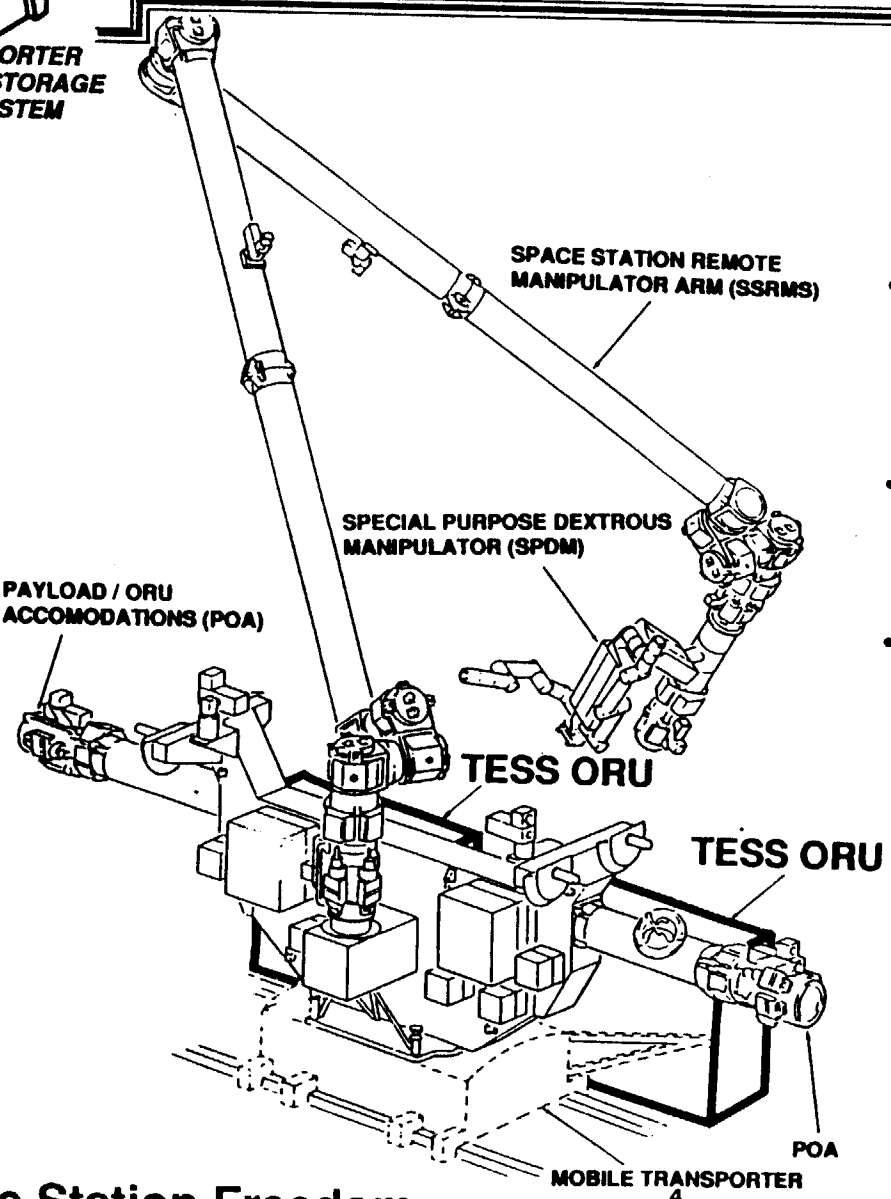


LAUNCH	MB-4
SEGMENT	M1

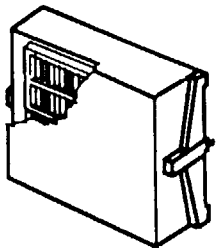
TESS INSTALLED ON MOBILE SERVICING CENTER



TRANSPORTER ENERGY STORAGE SUBSYSTEM



- TESS INSTALLED ON MOBILE TRANSPORTER DURING MB-7 EVA OPERATIONS.
- TESS PROVIDES ABOUT 3.3 HOURS OF MSC TRANSLATION
- TESS PROVIDES REGULATED 120 VOLTS:
  - 10 KW-HR OF ENERGY
  - 3000 WATTS AVERAGE POWER
  - 6000 WATTS PEAK POWER



TRANSPORTER ENERGY STORAGE SUBSYSTEM

TESS ORU LAYOUT

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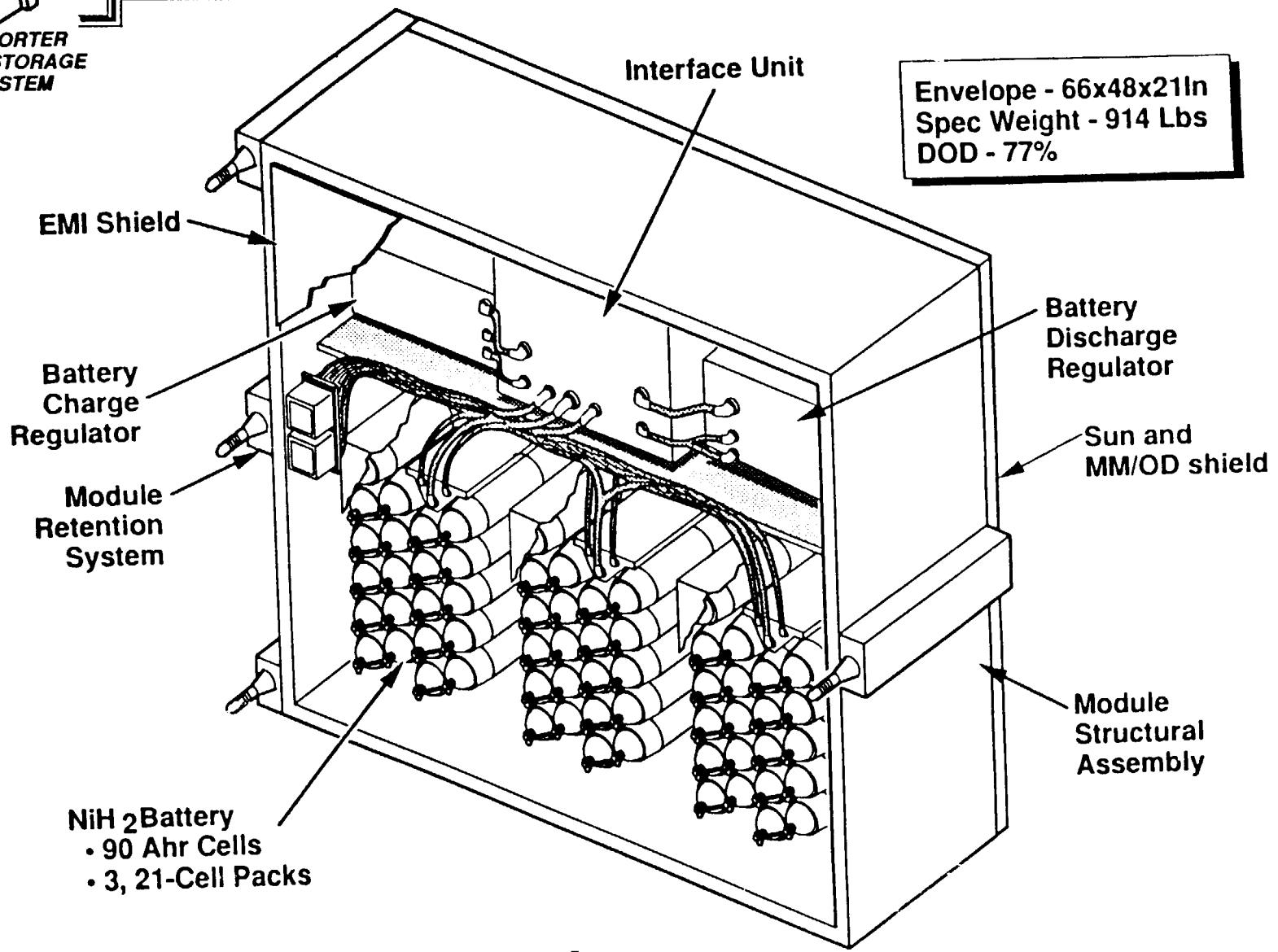
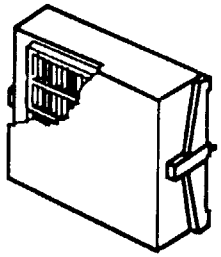




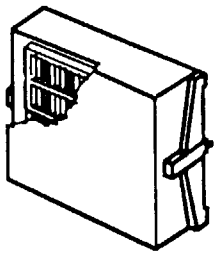
TRANSPORTER ENERGY STORAGE SUBSYSTEM

BATTERY DESIGN REQUIREMENTS

- SUPPORT TESS/MT INTERFACE POWER & ENERGY REQUIREMENTS
  - 3000 WATTS OF AVERAGE OUTPUT POWER AT 120 VOLTS
  - 6000 WATTS OF PEAK OUTPUT POWER AT 120 VOLTS
  - 12,000 WATTS OF FAULT CLEARING POWER
  - 10 KILOWATT-HOURS OF MAXIMUM OUTPUT ENERGY AT 120 VOLTS
  - 7 KILOWATT-HOURS OF NOMINAL OUTPUT ENERGY AT 120 VOLTS

- OPERATIONAL LIFE OF 10 YEARS, THUS 2 REPLACEMENTS OVER SPACE STATION MISSION LIFE OF 30 YEARS.
  - 150 MOBILE SERVICING CENTER MISSIONS PER YEAR
  - 65 % AT NOMINAL ENERGY LEVEL (7 KW-HR), 35 % AT MAXIMUM

- SYSTEM RE[illegible]DANCY, FAIL DEGRADE, FAIL SAFE



TRANSPORTER
ENERGY STORAGE
SUBSYSTEM

BATTERY DESIGN REQUIREMENTS
(CONTINUED)

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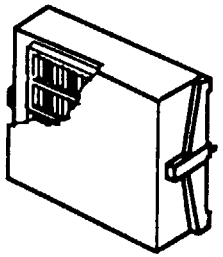
- STRUCTURAL, CELL PRESSURE VESSEL
  - PROOF PRESSURE: 1.5 x MAXIMUM OPERATING PRESSURE
  - ULTIMATE PRESSURE: 3 x MAXIMUM OPERATING PRESSURE

- THERMAL, PASSIVELY COOLED
  - OPERATING: 0 °C TO +25 °C
  - NON-OPERATING: -10 °C TO +35 °C

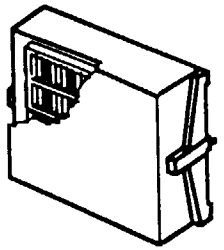


TRANSPORTER ENERGY STORAGE SUBSYSTEM

TESS BATTERY DESIGN

- TWO 63-CELL NICKEL HYDROGEN BATTERIES
  - THREE 21-CELL SUBASSEMBLIES, CONNECTED IN SERIES
  - 90 AMP-HR HUBBLE SPACE TELESCOPE (HST) CELLS, MODIFIED

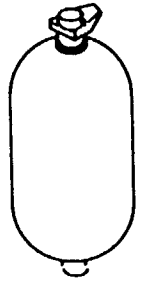
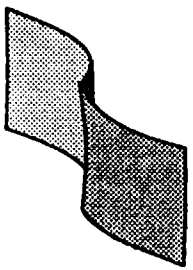
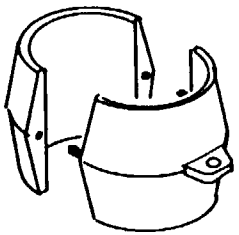
- 21-CELL SUBASSEMBLY
  - WEIGHT: 149 LBS INCLUDING MM/OD COVERS
  - SIZE: 14.9 W x 23.7 L x 13.0 H (INCHES)
  - 3 ELECTRICAL CONECTORS: POWER, INSTRUMENTATION, AND TEST MONITOR
  - CELL ISOLATION: FIBERGLASS WRAP POTTED BETWEEN CELL AND COLLAR
  - BATTERY HOUSING, CELL COLLARS, AND BATTERY COVERS MADE OF ALUMINUM



TESS NICKEL-HYDROGEN BATTERY SUBASSEMBLY DESIGN

MDESC - L&ES

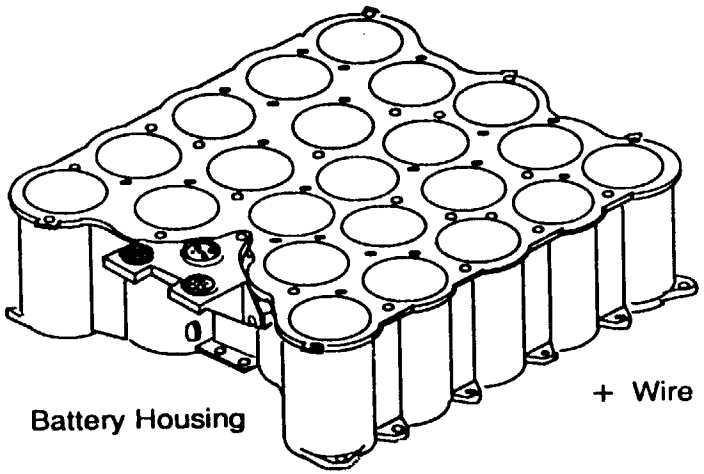
TRANSPORTER ENERGY STORAGE SUBSYSTEM

[ +  + CV-2942 RTV + ] X 21 + CV-2942 RTV +

Cell Supplier = TBD

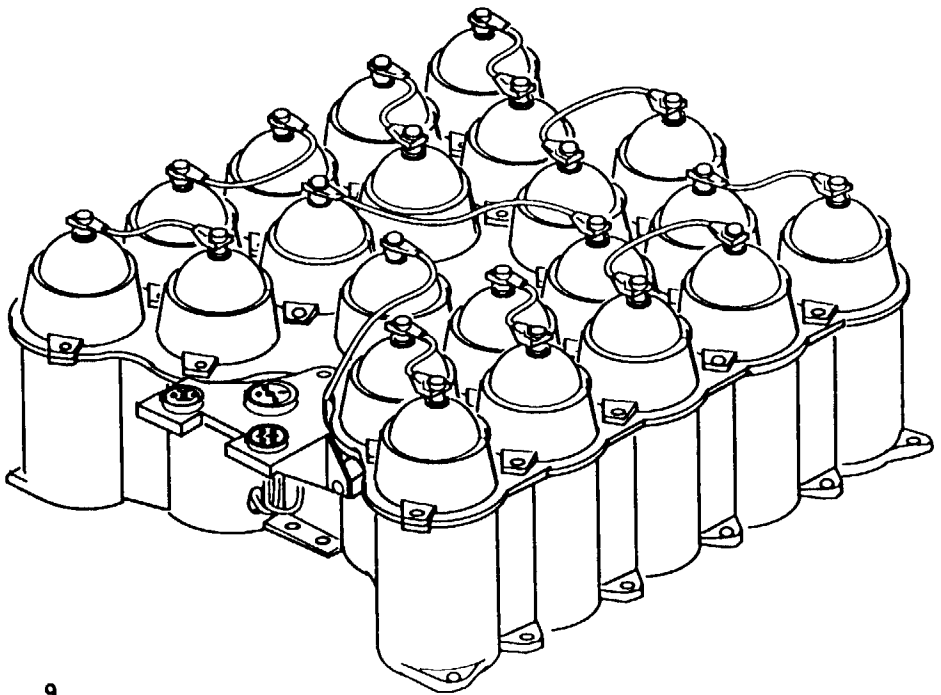
Fiberglass Wrap

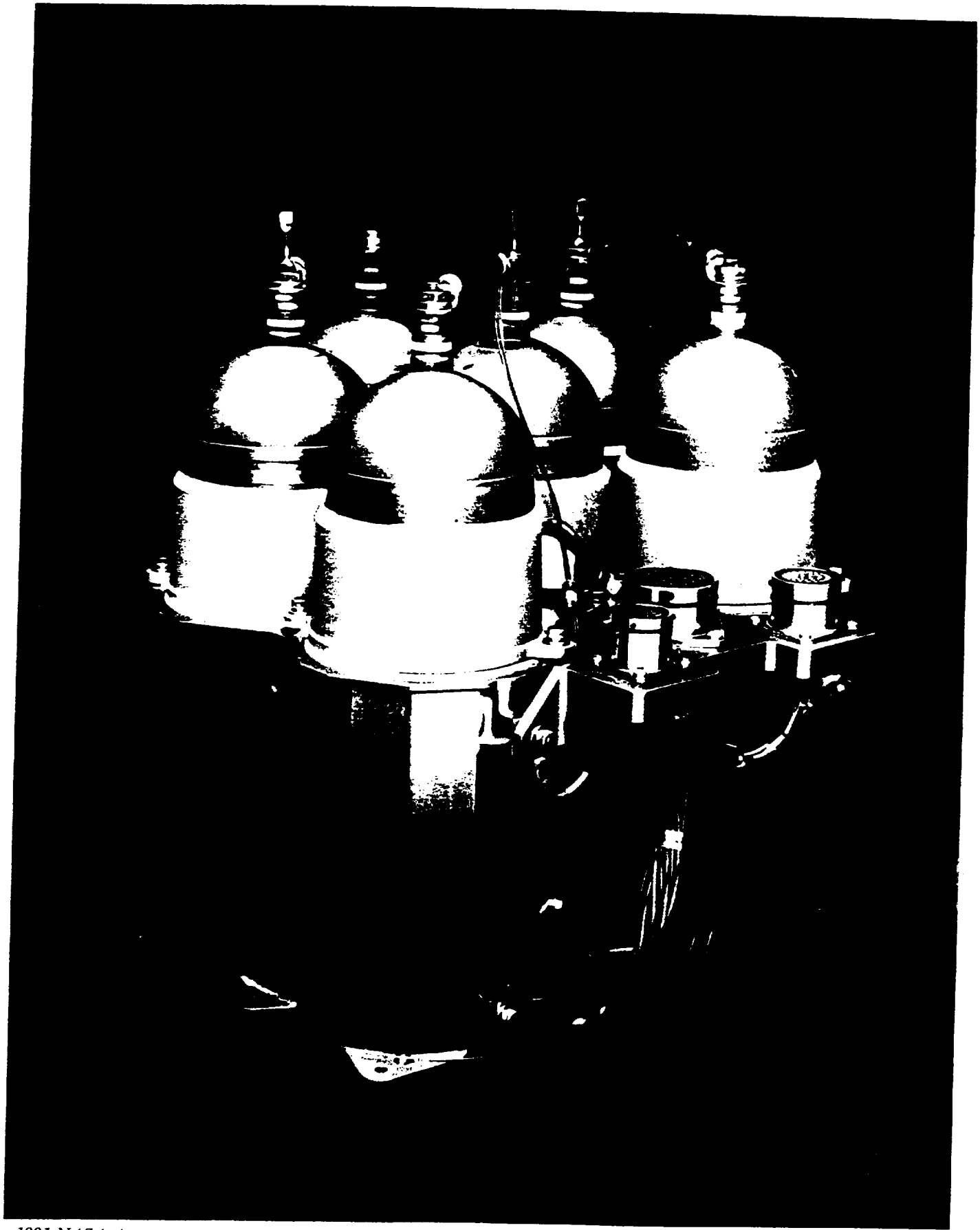
Cell Collars

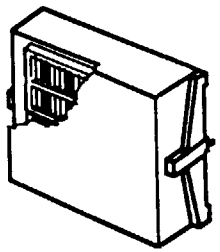


Battery Housing

+ Wire =







TRANSPORTER ENERGY STORAGE SUBSYSTEM

PROOF-OF-PRINCIPLE TESTING OF 6-CELL BATTERY

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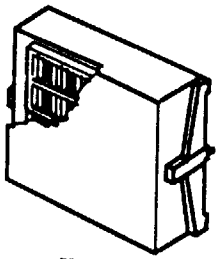
- CELLS ARE USAF/HUGHES 50 AMP-HR DESIGN OF 1985 VINTAGE (40 AMP-HR.)
- ELECTRICAL CHARACTERISTIC TEST WILL NOT PROVIDE DATA RELATIVE TO TESS CELL/BATTERY.
- DISCHARGE EFFICIENCY TESTS WILL VERIFY THERMAL ANALYSIS AND PERFORMANCE OF BATTERY DESIGN AT 10 °C & 20 °C.
  - 1.9 °C GRADIENT ACROSS BATTERY CELL.
  - 1.7 °C GRADIENT FROM CELL TO CELL WITHIN BATTERY.
  - 9.7 °C GRADIENT FROM MIDDLE-OF-CELL (MOC) TO RADIATOR SURFACE (COLDPLATE)
  - TESS BATTERY WILL HAVE A LOWER BATTERY MOC TO RADIATOR GRADIENT DUE TO THE REDUCED HEIGHT (AXIAL/FILL TUBE)
- RANDOM VIBRATION TEST WILL VERIFY STRUCTURAL ANALYSIS AND INTEGRITY OF THIS BATTERY DESIGN.
  - TEST WILL BE CONDUCTED WEEK OF 4 NOVEMBER.

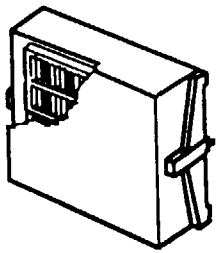


TRANSPORTER
ENERGY STORAGE
SUBSYSTEM

POSSIBLE DOWNSIZING OF TESS

TO SUPPORT

MOBILE REMOTE SERVICER BASE SYSTEM (MBS) REDESIGN



TRANSPORTER ENERGY STORAGE SUBSYSTEM

GROUNDRULES FOR DOWNSIZING TESS

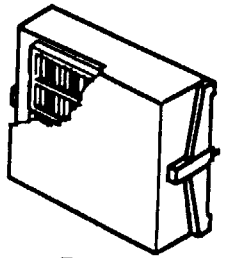
- DESIRED RESULT IS LOWER WEIGHT AND VOLUME OF TESS.
  - SINGLE ORU IS A DESIGN GOAL.

- OPERATIONAL SCENARIOS STILL UNDEFINED.
  - REDUCE OPERATIONAL CONSTRAINTS DURING EVA/EVR MISSIONS

- REDUCTION OF TESS POWER AND ENERGY IS REASONABLE.

	WAS	NOW
- ENERGY LEVEL	10 KWHR	3.4 KWHR
- NOMINAL POWER	3000 W	2300 W
- PEAK POWER	6000 W	3500 W
- TRANSLATION TIME	3.33 HRS	1.50 HRS
- NUMBER OF MISSIONS	150	50

- MAINTAIN CURRENT LEVEL OF TESS RELIABILITY.
  - FAIL DEGRADE, FAIL SAFE

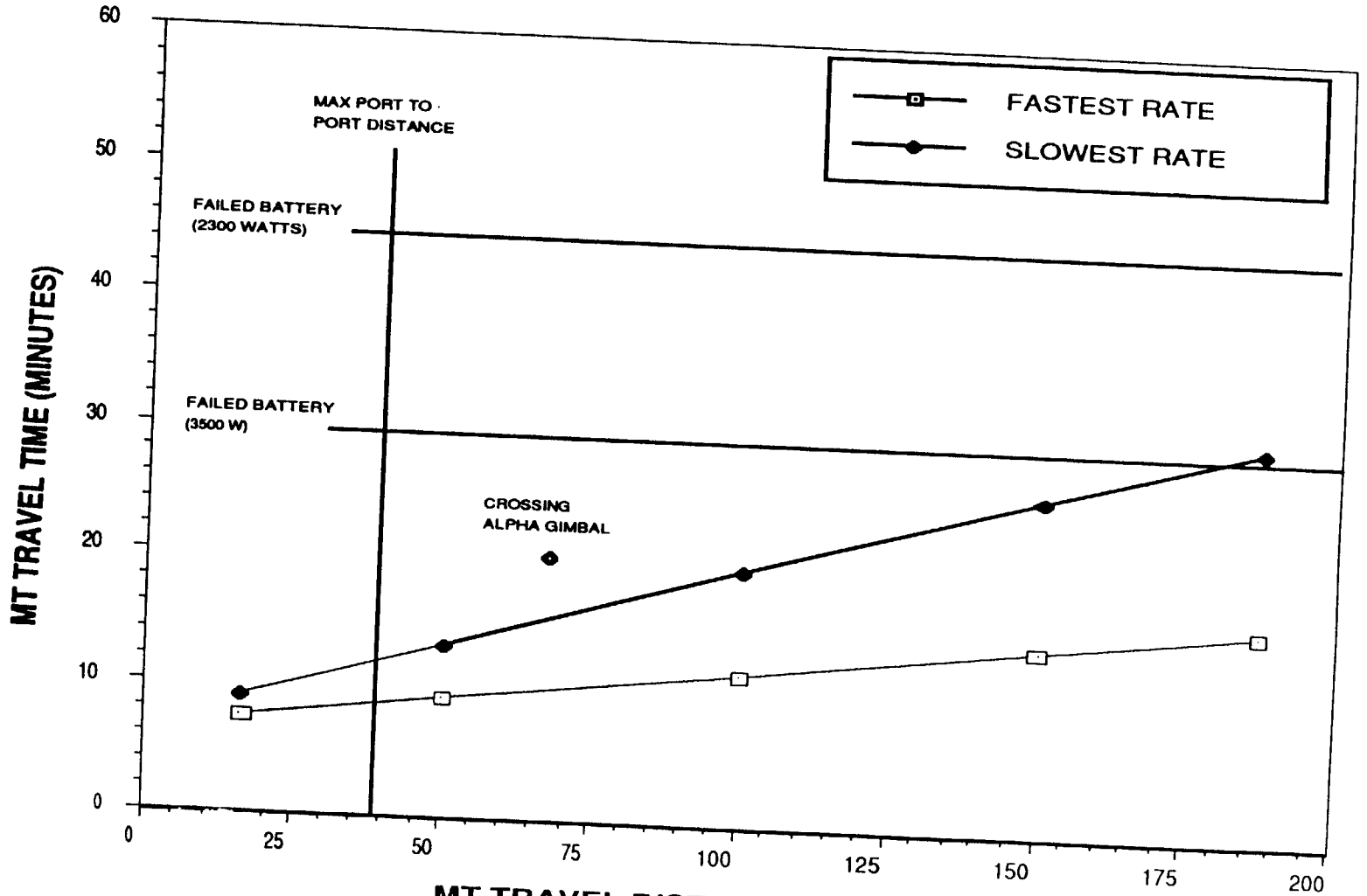


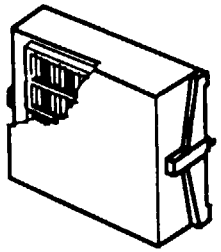
TRANSPORTER ENERGY STORAGE SUBSYSTEM

TRAVEL DISTANCE FOR MT BASED ON TESS SIZE

MDESC - L&ES

BASED ON FAILED BATTERY CONDITION FOR AVERAGE & PEAK LOADS





TRANSPORTER ENERGY STORAGE SUBSYSTEM

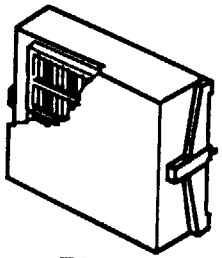
TESS TRANSLATION OUTPUT CAPABILITY

MDESC - L&ES

ASSUMING ONE EVA/EVR MISSION PER DAY.

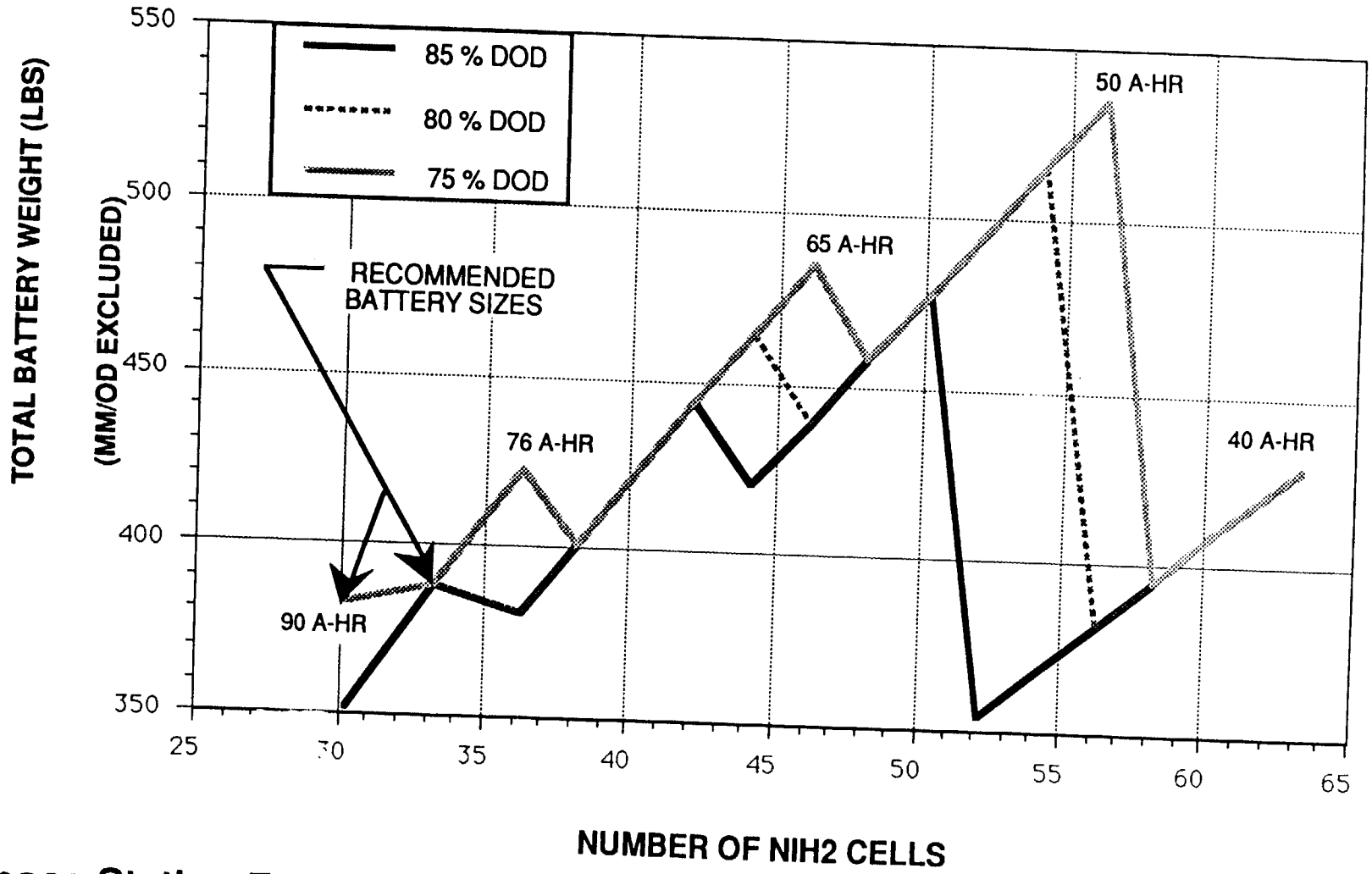
TIMELINE - HOURS 0	6, 8, OR 12	24
EVA/EVR MISSION	**COOLDOWN/RECHARGE/ PREP FOR NEXT EVA/EVR**	
TESS • SUPPLIES 1.5 HRS OF MT TRANSLATION. • SMALL AMOUNT OF COOLDOWN OR CHARGING DURING MBS OPERATIONS. • POSSIBLE INCREASE OF MT TRANSLATION TIME TO 2 HRS.	**TESS** • COOLS AND RECHARGES AS NECESSARY TO BE AVAILABLE FOR NEXT DAY'S ACTIVITIES.	

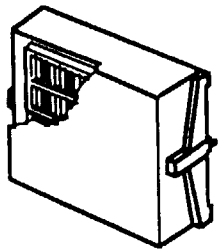
NOTE: TRANSLATION TIMES WILL BE CUT IN HALF FOR FAILED BATTERY CONDITION



TRANSPORTER ENERGY STORAGE SUBSYSTEM

BATTERY SIZING BASED ON MAXIMUM DOD





TRANSPORTER ENERGY STORAGE SUBSYSTEM

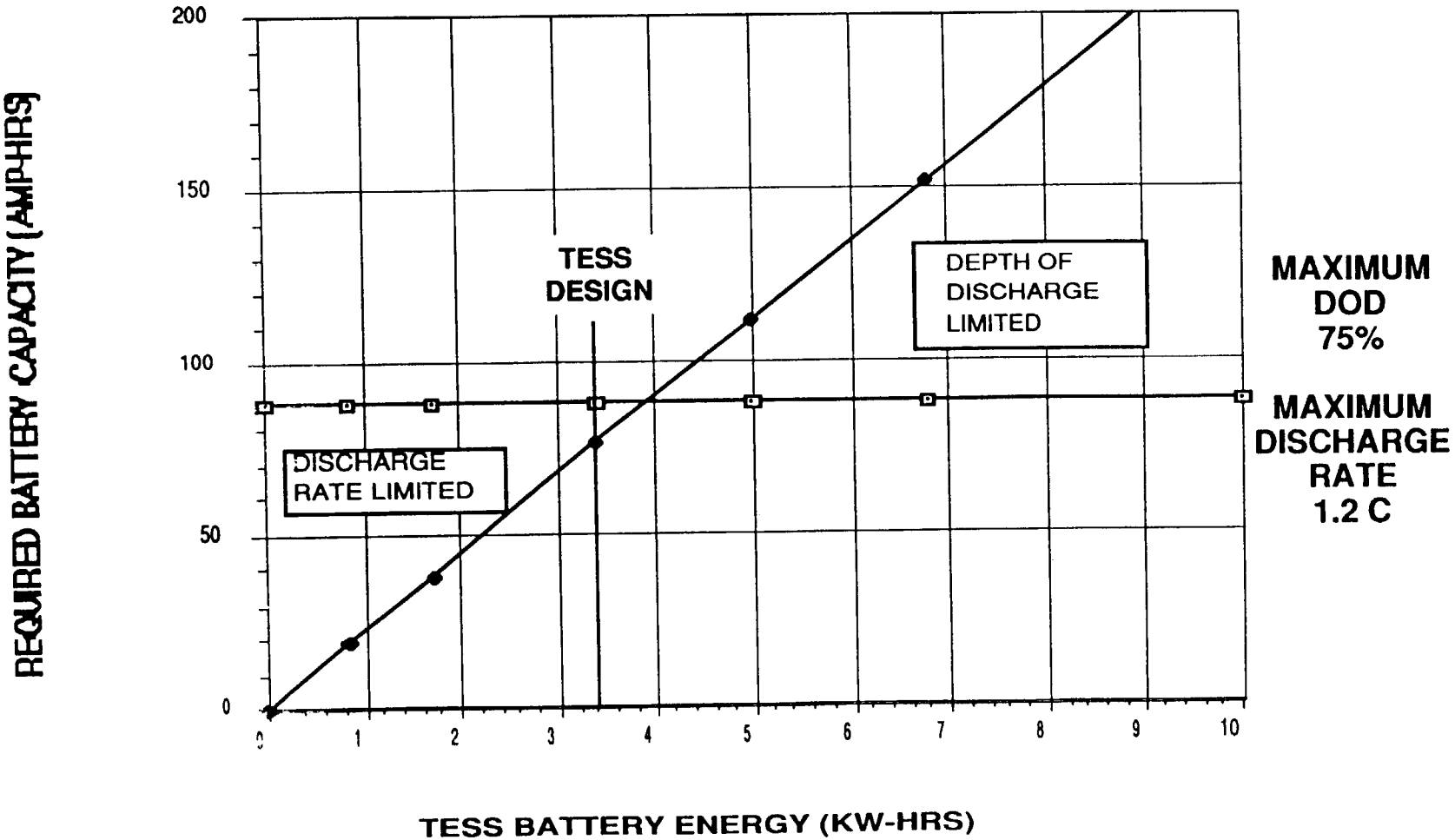
TESS BATTERY WILL BE DISCHARGE RATE LIMITED

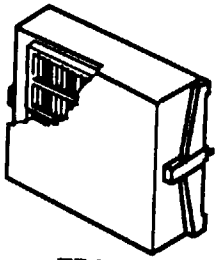
MDESC - L&ES

AVERAGE POWER 2300 W

PEAK POWER 3500 W

33 NIH2 CELL BATTERY

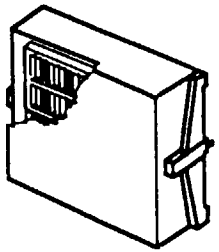




TRANSPORTER ENERGY STORAGE SUBSYSTEM

DOWNSIZED TESS SOLUTION FOR MBS REDESIGN

- REMOVE ONE TESS ORU
- REMOVE 63- CELL, 90 AMP-HR NIH2 BATTERY
- ADD TWO 33-CELL, 90 AMP-HR NIH2 BATTERIES
- CONNECT BATTERIES IN PARALLEL TO OBTAIN REDUNDANCY



TRANSPORTER ENERGY STORAGE SUBSYSTEM

RELATED NIH2 BATTERY CELL TESTING AT NASA-JSC

- OBTAINED 8 HUBBLE SPACE TELESCOPE CELLS FROM NASA-MARSHALL SPACE FLIGHT CENTER
- PAIR CELLS INTO FOUR, 2-CELL TEST PACKS
  - TWO PACKS FOR SSF ELECTRICAL POWER SYSTEM SCENARIOS
  - TWO PACKS FOR TESS SCENARIOS
- ESTABLISH TESS OPERATING SCENARIOS
  - DISCHARGE RATES AND DURATIONS
  - CHARGE RATES AND DURATIONS
  - STANDBY PERIODS OF CONSTANT TRICKLE CHARGE
- TEST PREPARATION IN PROGRESS