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SECONDARY LITHIUM CELLS FOR SPACE APPLICATIONS

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SECONDARY LITHIUM CELLS/BATTERIES
OUTLINE

(1) JPL PROGRAM GOAL

(2) SPACE APPLICATIONS

(3) JPL PROGRESS

(4) SUMMARY

(5) ACKNOWLEDGEMENTS

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SECONDARY LITHIUM CELLS/BATTERIES

PROGRAM GOAL

- DEMONSTRATE THE FEASIBILITYOF AMBIENT TEMPERATURE SECONDARY LITHIUM CELL TECHNOLOGY BY 1994

- TARGETS
  - 100 Wh/kg
  - 1000 CYCLES (50% DOD)
  - 5 YEAR ACTIVE STORAGE LIFE
  - SAFE

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SECONDARY LITHIUM CELLS/BATTERIES
ADVANTAGES

- 3-4 FOLD INCREASE IN SPECIFIC ENERGY AND ENERGY DENSITY OVER Ni-Cd
- LOW SELF DISCHARGE
- LONG ACTIVE SHELF LIFE

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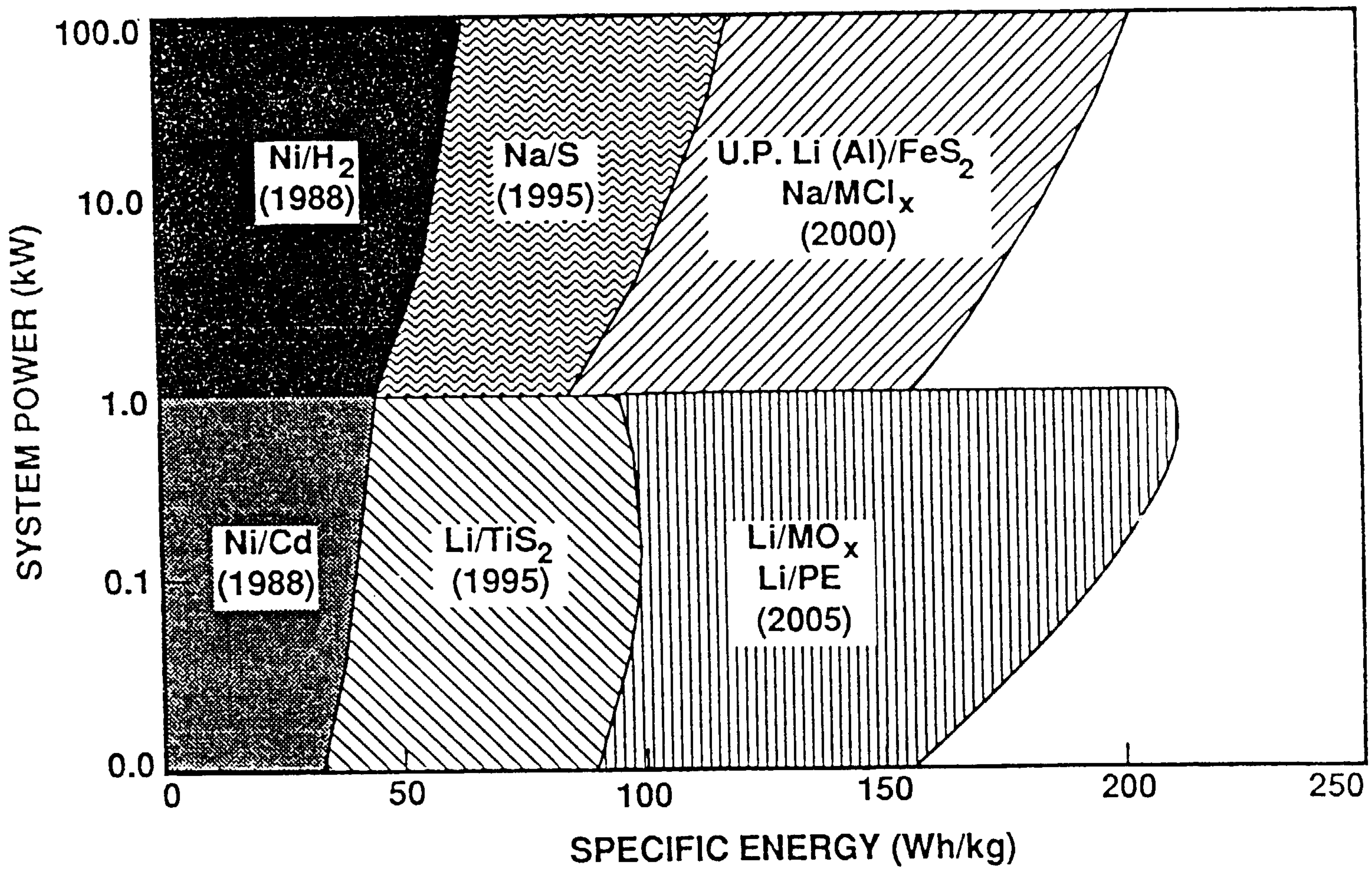
ADVANCED RECHARGEABLE BATTERY PERFORMANCE ENVELOPE



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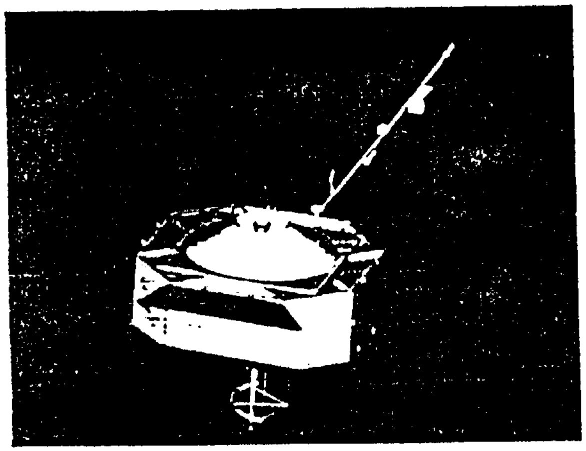
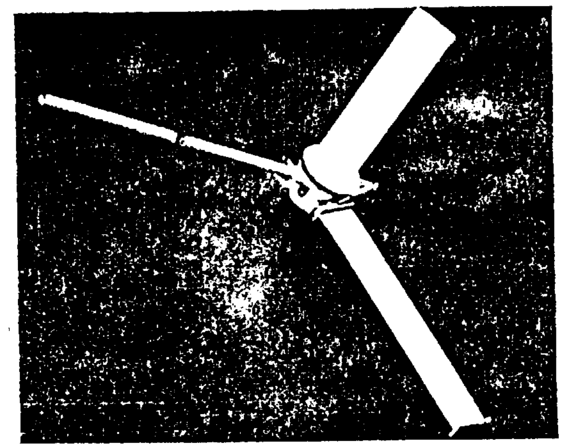
RECHARGEABLE LITHIUM CELL PROGRAM
PROJECTED APPLICATIONS

PLANETARY ORBITERS
(MERCURY ORBITER)

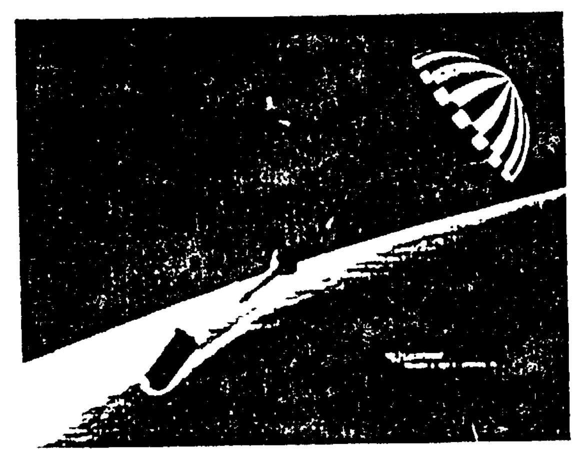


MISSIONS TO COMETS (COMET NUCLEUS SAMPLE RETURN TAIL PROBE)



MARS ROVER

PENETRATORS
(GLOBAL NETWORK MISSION)



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CLASSIFICATION OF SECONDARY LITHIUM CELLS

RECHARGEABLE LITHIUM BATTERY SYSTEMS

ORGANIC ELECTROLYTE SYSTEMS

- $Li-TiS_2$
- $Li-MoS_2$
- $Li-NbSe_3$
- $Li-MnO_2$
- $Li-CoO_2$
- $Li-V_2O_5$

POLYMERIC ELECTROLYTE SYSTEMS

- $Li-TiS_2$
- $Li-V_6O_{13}$
- $Li-CoO_2$

INORGANIC ELECTROLYTE SYSTEMS

- $Li-SO_2-C$
- $Li-CuCl_2$

MOLTEN SALT SYSTEMS

- U.P. $Li(Al)-FeS_2$
- $Li(Al)-FeS$

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SECONDARY LITHIUM CELLS/BATTERIES

SPECIFIC ENERGY OF SELECTED CATHODE MATERIALS

MATERIAL	AVE. V (Volt)	Li EQ.* PER mole	SPECIFIC ENERGY (Wh/kg) THEO.	SPECIFIC ENERGY (Wh/kg) EXP.**	CYCLE LIFE
JPL STUDIES (EXPERIMENTAL CELLS)					
Li-TiS_2	2.1	0.9	473	417	300+
MoS_2	1.9	2.0	717	421	50+
$NbSe_3$	1.8	2.8	412	384	150+
V_6O_{13}	2.2	4.0	636	361	50+
FROM LITERATURE (PROTOTYPE CELLS)					
Li-TS_2	2.1	0.8	473	378	200+
$NbSe_3$	1.8	2.5	412	330	200+
MoS_2	1.7	0.8	272	214	200+
MnO_2	3.0	0.5	855	364	200+
CoO_2	4.0	0.5	1094	465	50+
$CuCl_2$	3.2	2.0	1125	665	140+
SO_2	3.1	1.0	524	524	30+

* EXPERIMENTALLY REVERSIBLE

** EXPERIMENTALLY REVERSIBLE LITHIUM EQ./mole, BINDER AND CONDUCTING DILUENTS WERE TAKEN INTO CONSIDERATION

RECHARGEABLE AMBIENT-TEMPERATURE LITHIUM BATTERIES

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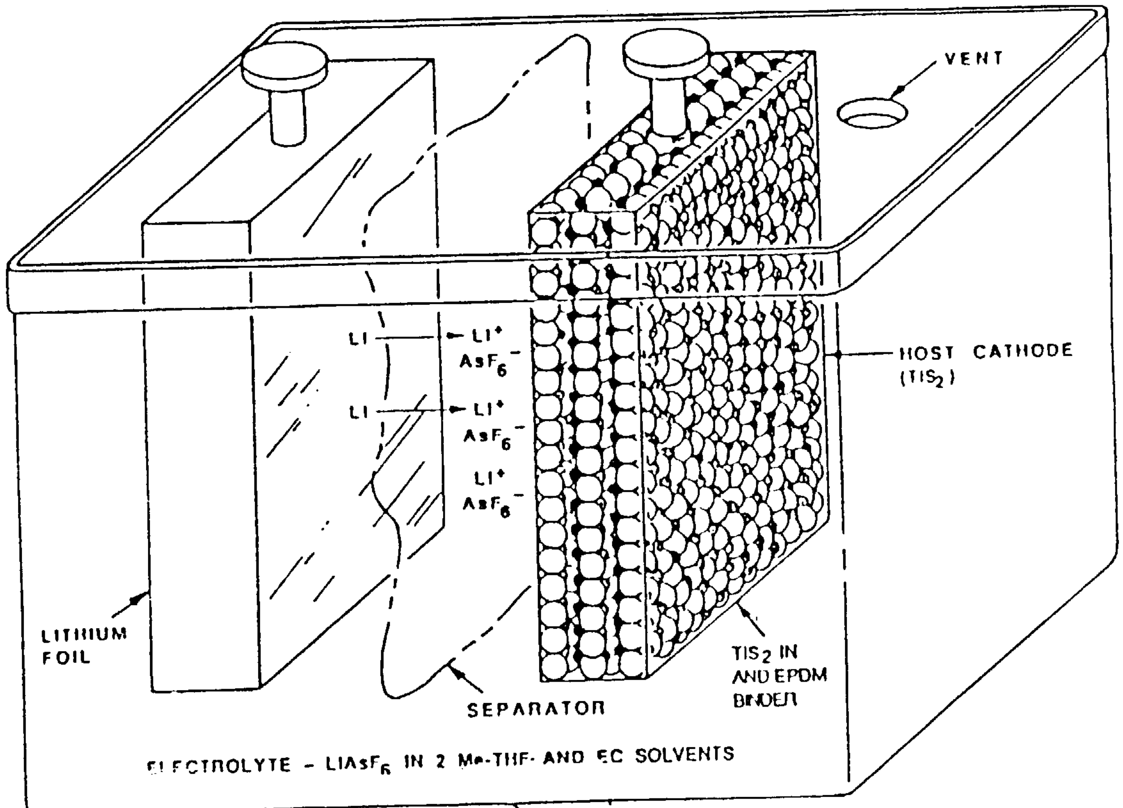
SCHEMATIC DIAGRAM OF A $Li\text{-}TiS_2$ CELL



<u>CELL REACTIONS</u>

DISCHARGE . . LI INTERCALATION (INSERTION)

CHARGE. . . . . LI DE-INTERCALATION (REMOVAL)

$$LI + TIS_2 \underset{C}{\overset{D}{\rightleftharpoons}} LI\text{-}TIS_2$$

<u>ELECTROLYTE</u>

LITHIUM ARSENIC HEXAFLUORIDE ($LIAsF_6$) - SALT

2-METHYL TETRA HYDROFURAN (2-MeTHF) WITH

ETHYLENE CARBONATE (EC) - MIXED SOLVENT

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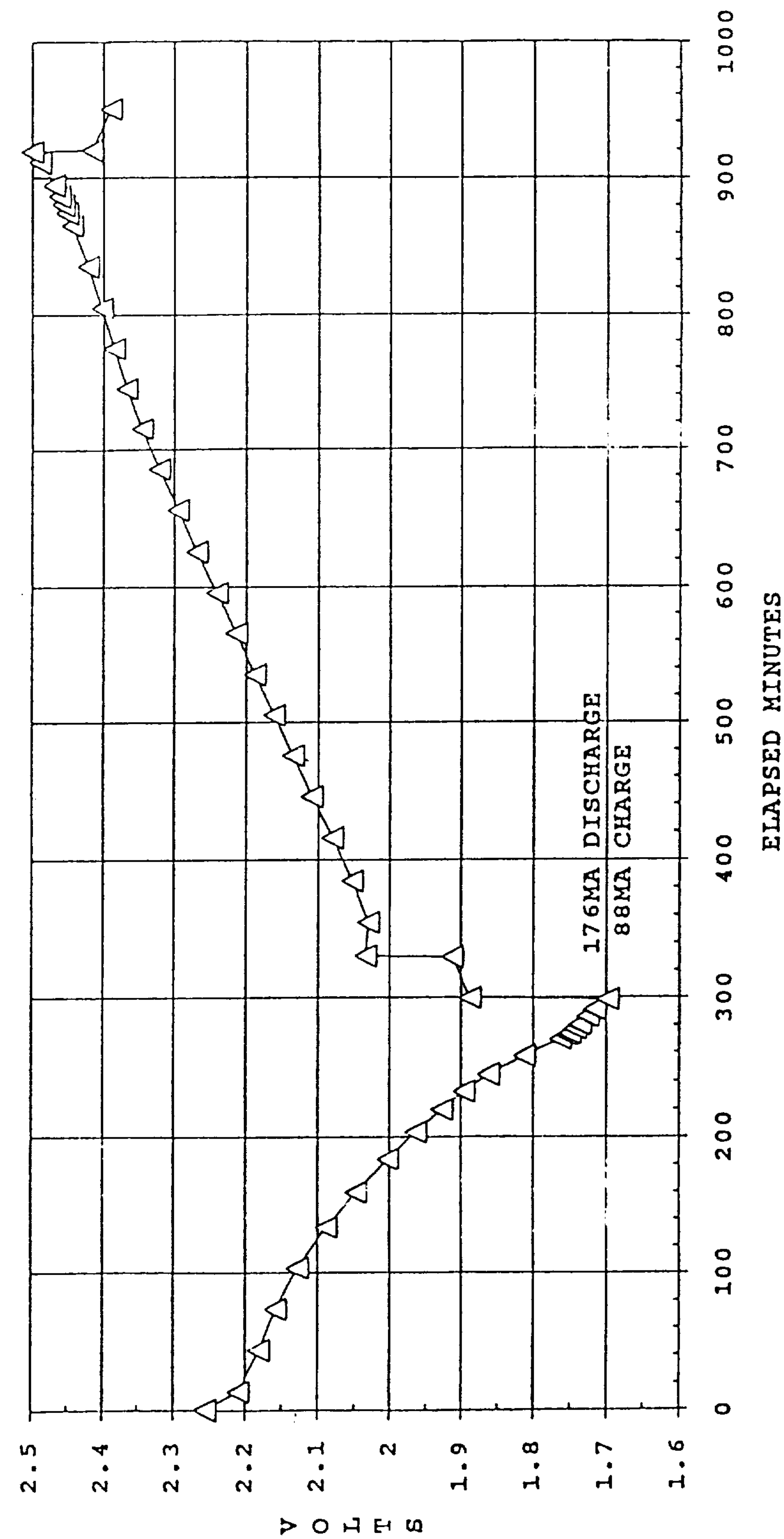
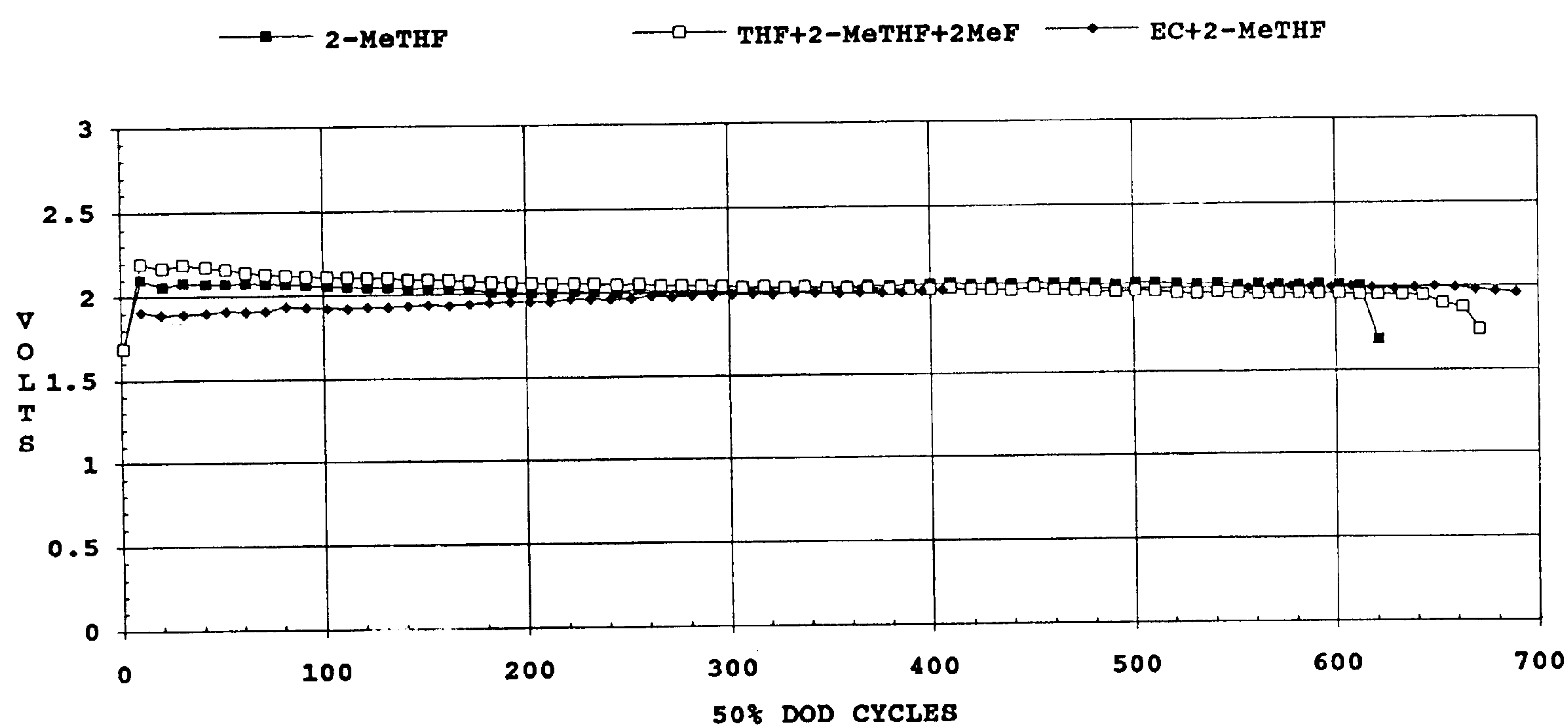
TYPICAL CHARGE/DISCHARGE CURVE FOR 1 Ah Li-TiS_2 CELL



END-OF-DISCHARGE VOLTAGE VS CYCLES FOR JPL FABRICATED LITHIUM-TITANIUM DISULFIDE CELLS



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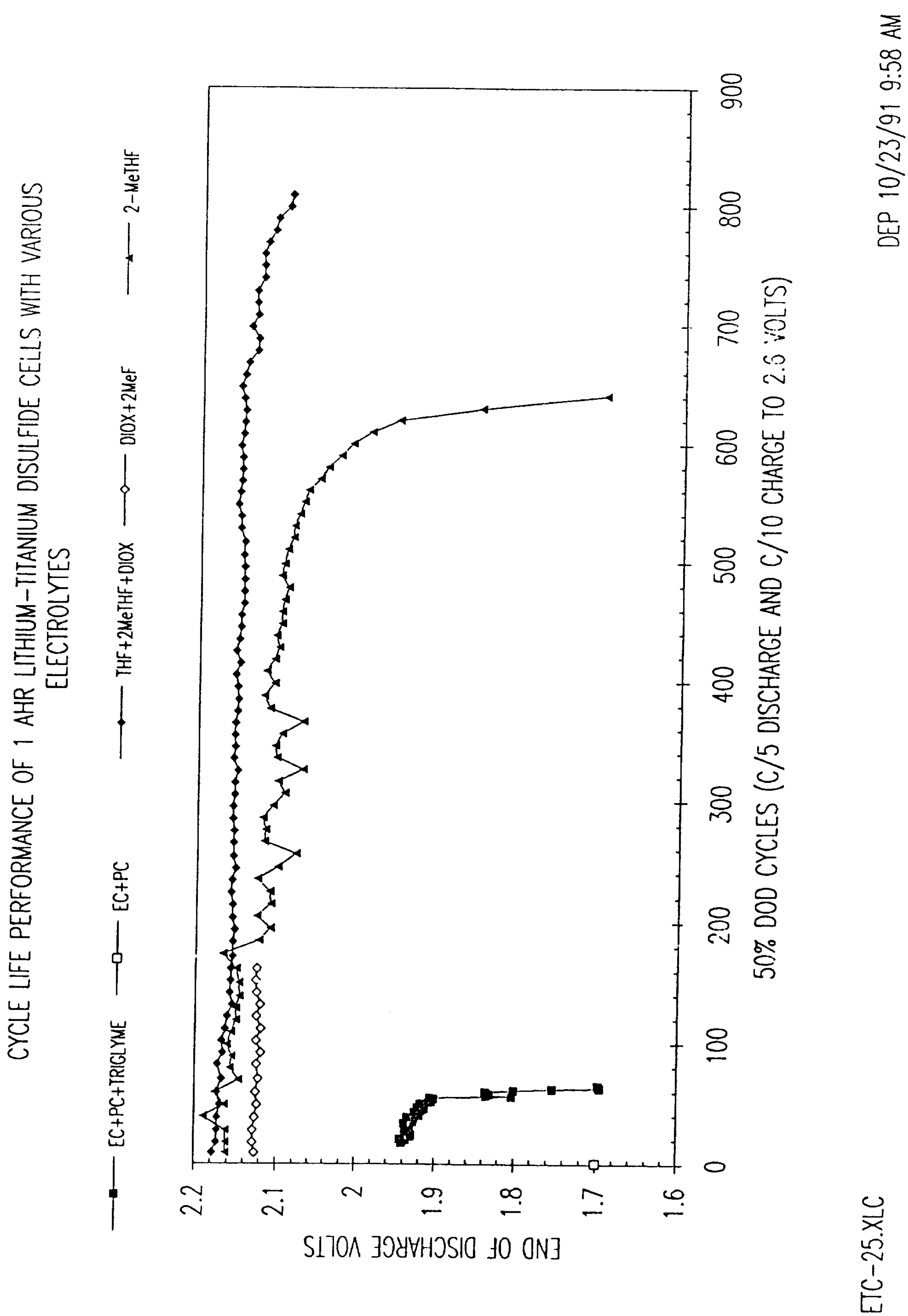

CYCLE LIFE PERFORMANCE OF 1 AHR LITHIUM-TITANIUM DISULFIDE CELLS WITH VARIOUS ELECTROLYTES
EC+PC+TRIGLYME
EC+PC
THF+2MeTHF+DIOX
DIOX+2MeF
2-MeTHF
END OF DISCHARGE VOLTS
2.2
2.1
2
1.9
1.8
1.7
1.6
0
100
200
300
400
500
600
700
800
900
50% DOD CYCLES (C/5 DISCHARGE AND C/10 CHARGE TO 2.6 VOLTS)
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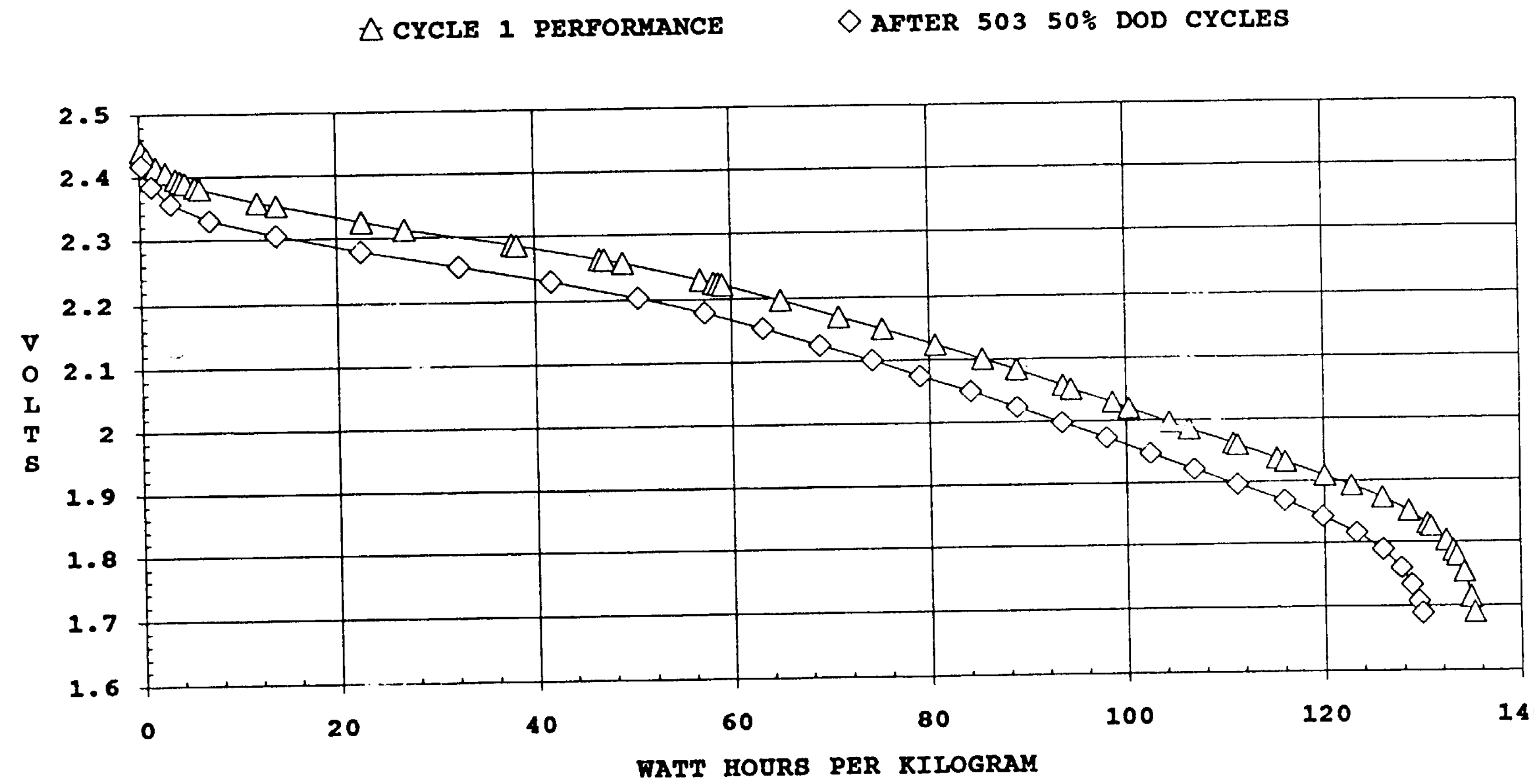
C/5 PERFORMANCE (200MA) OF AA 1 AMPERE-HOUR LITHIUM TITANIUM DISULFIDE CELL



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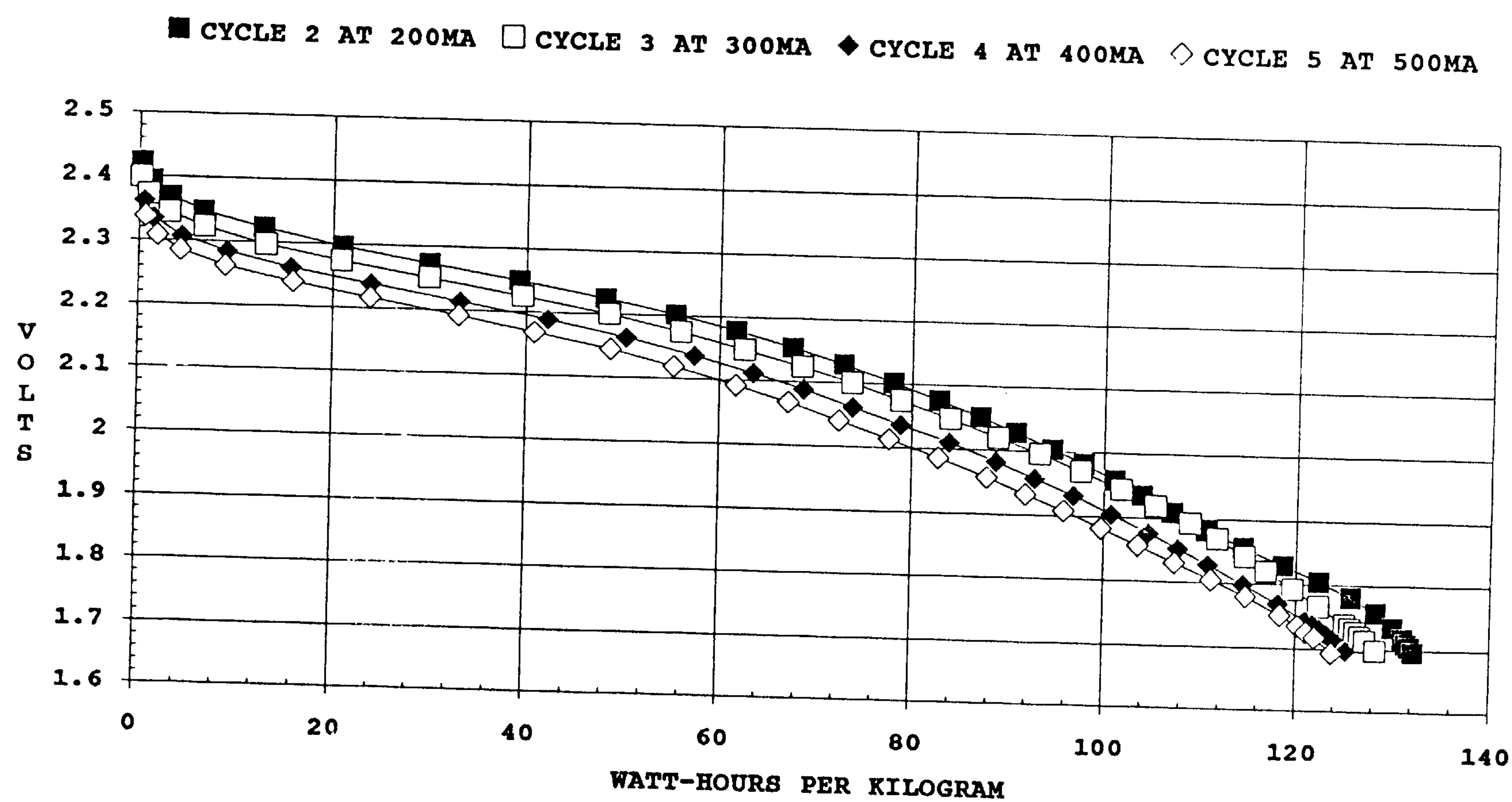
TYPICAL PERFORMANCE OF MANUFACTURED AA 1 AMPERE-HOUR LITHIUM TITANIUM DISULFIDE CELL



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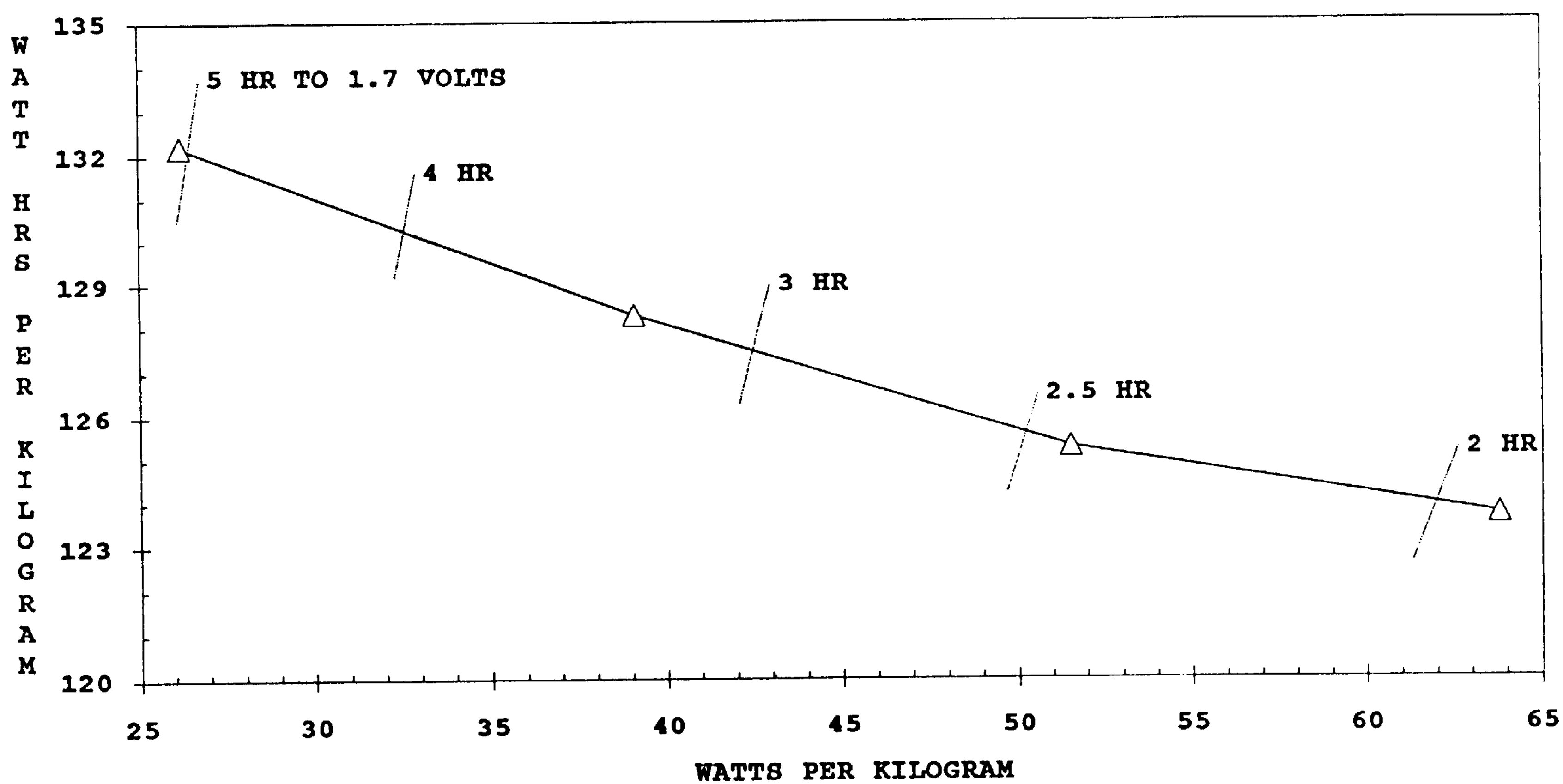
PERFORMANCE OF A TYPICAL MANUFACTURED AA 1 AMPERE-HOUR LITHIUM TITANIUM DISULFIDE CELL



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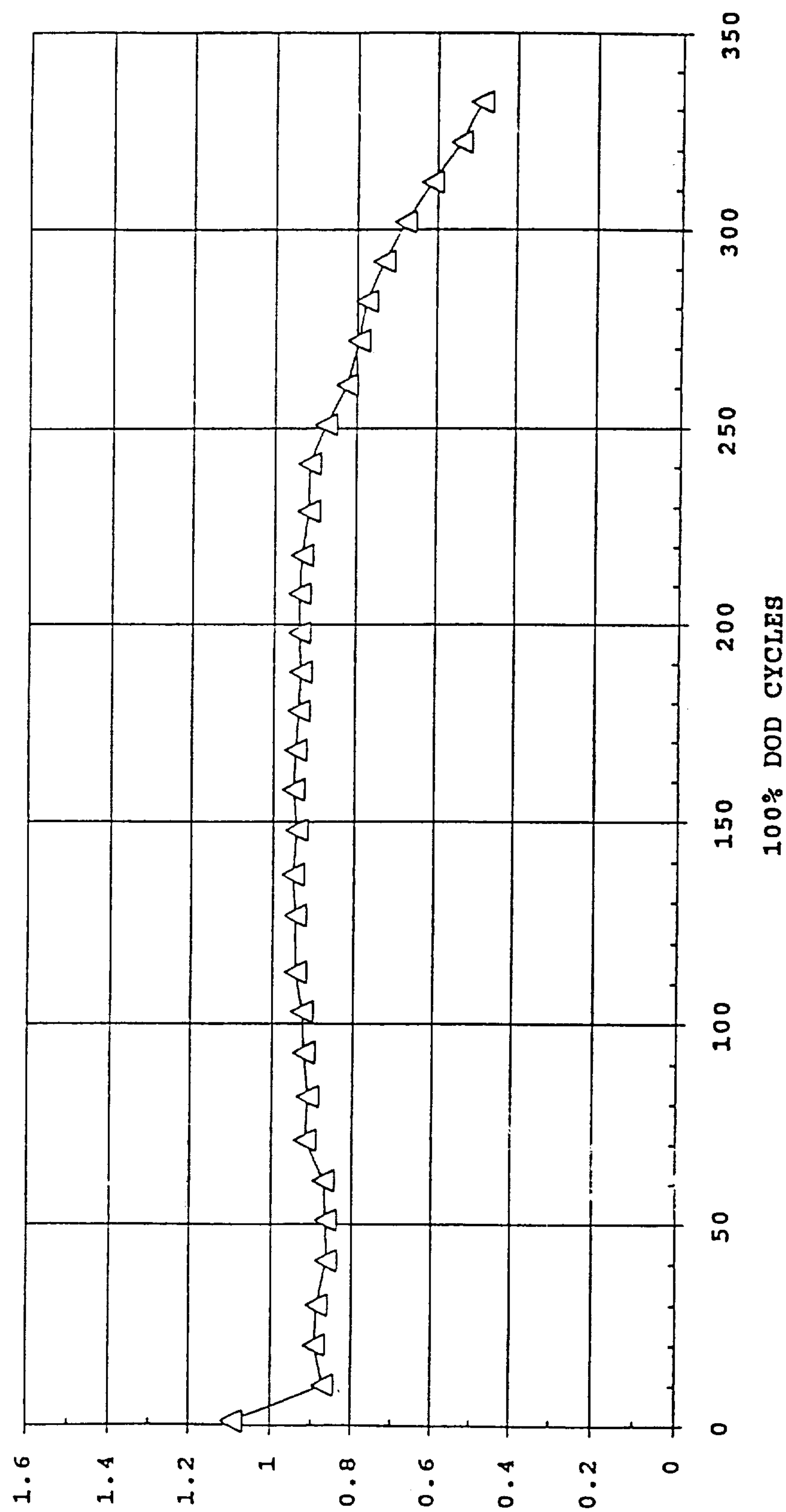
CYCLE LIFE CHARACTERISTICS OF JPL 1 Ah Li-TiS_2 CELL AT 100% DOD



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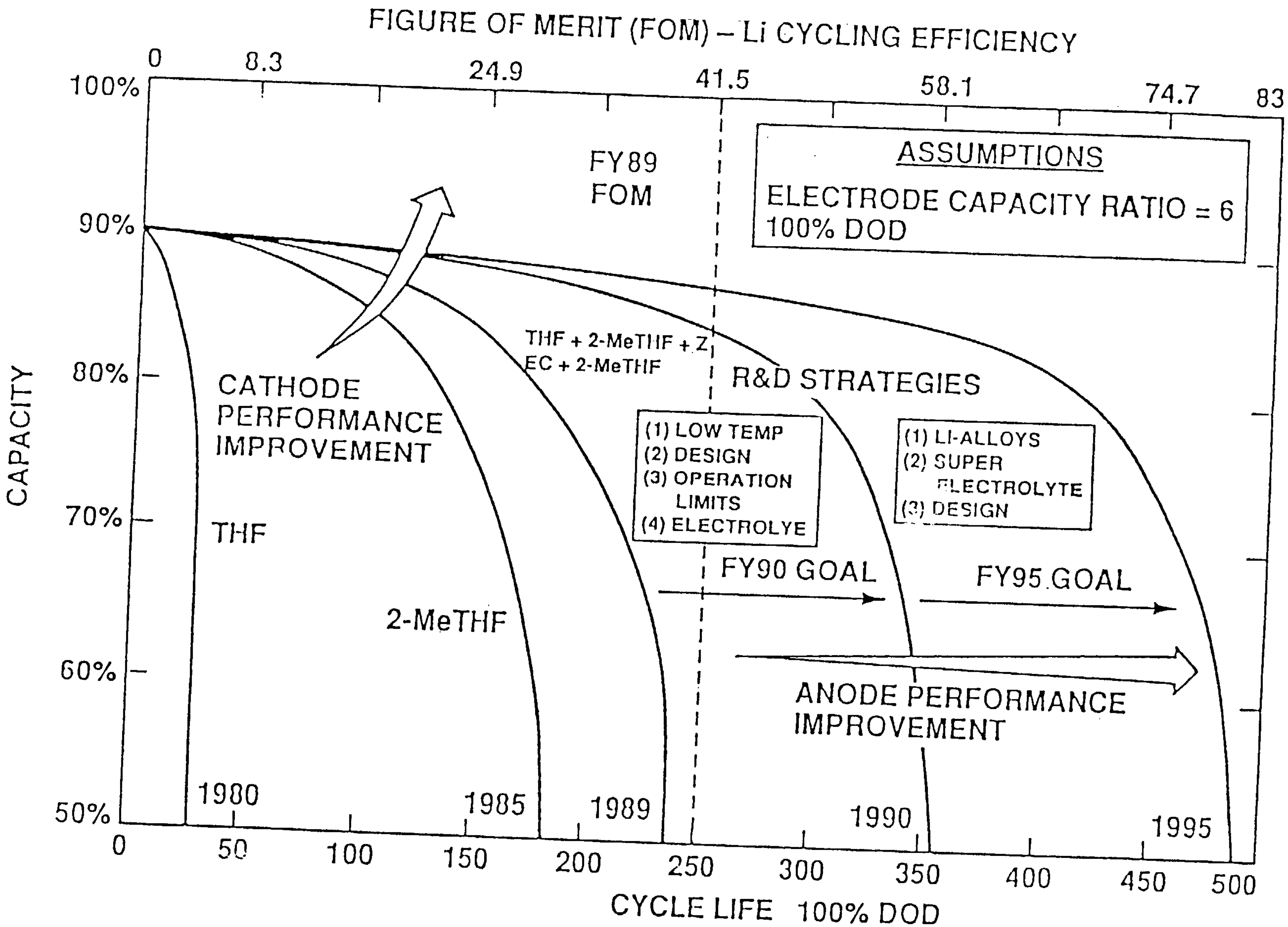
REQUIRED TECHNOLOGY IMPROVEMENTS

IPARAMETER	PRESENT STATUS	NASA REQUIREMENT
CYCLE LIFE	335+ (100% DOD) 650+ (50% DOD)	500 (100% DOD) 1000 (50% DOD)
RATE CAPABILITY	C/5	C/2
CELL SIZE	1 Ah	30 Ah
OVERCHARGE/OVERDISCHARGE	SENSITIVE	TOLERANT
ACTIVE STORAGE	1 YEAR	5 YEARS

RECHARGEABLE LITHIUM CELL PROGRAM

JPL ADVANCES IN $Li\text{-}TiS_2$ CELL TECHNOLOGY



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ALTERNATE Li ANODE MATERIAL STUDIES

EXPERIMENTAL EVALUATION OF SELECTED Li ALLOYS

Material	Stability*	Ave. E vs. Li (mV)	Reversibility** # OF Li		Specific Energy*** (wh/Kg)	
			Estimated	Experimental	Estimated	Experimental
$Li_{1.2}Al$	good	380	1.0	< 0.8	312	300
$Li_{2.85}Cd$	poor	0	2.6	--	322	--
$Li_{4.5}Pb$	good	388	3.5	< 1.5	254	167
$Li_{0.15}C$	good	200	0.15	< 0.08	255	186
$Li_{4.4}Si$	poor	--	--	--	--	--
$Li_{4.3}Sn$	good	411	2.0	< 1.0	243	171
$Li_{1.1}Zn$	good	191	0.6	< 0.12	220	62

* Microcalorimetric and OCV measurements.

** Galvanostatic cycling studies.

*** Calculated based on TiS2 cathode.

SUMMARY OF FINDINGS:

o Li-Si & Li-Cd ALLOYS WERE FOUND TO BE UNSTABLE.

o SELECTED Li-Al and Li-C ALLOY SYSTEMS FOR DETAILED ASSESSMENT.

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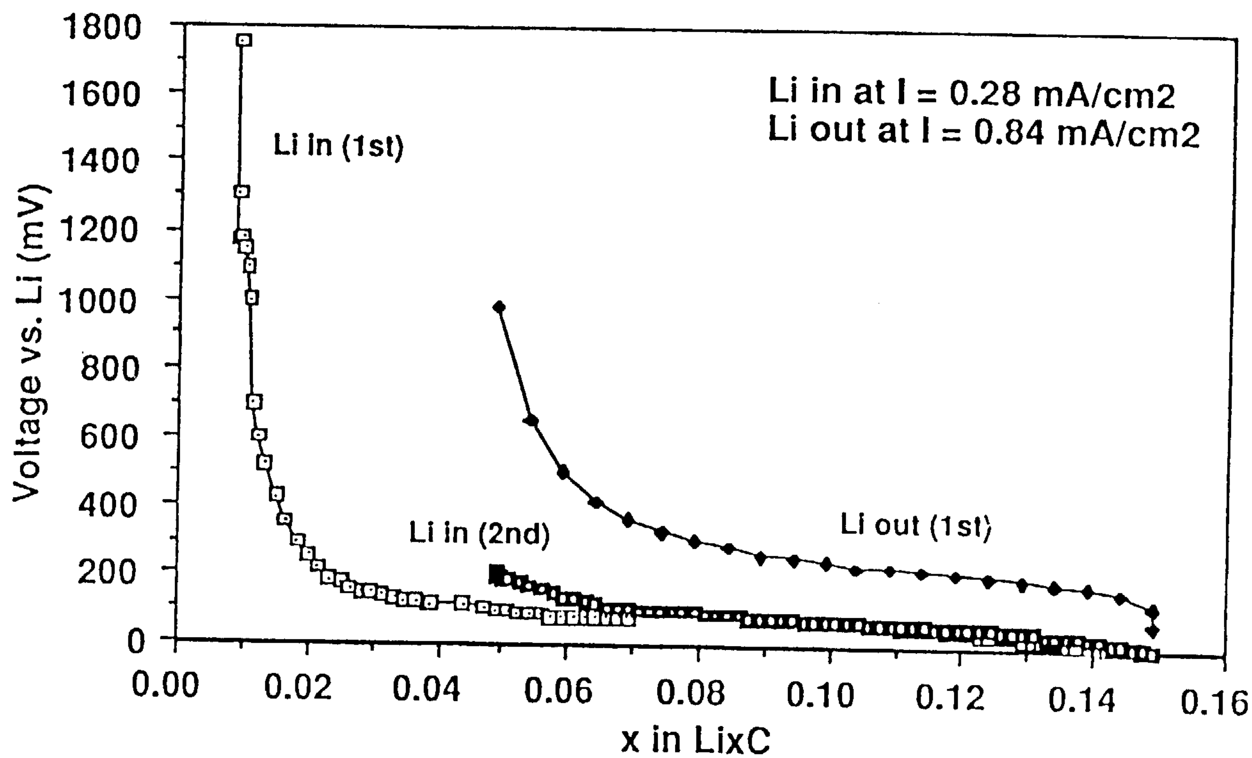
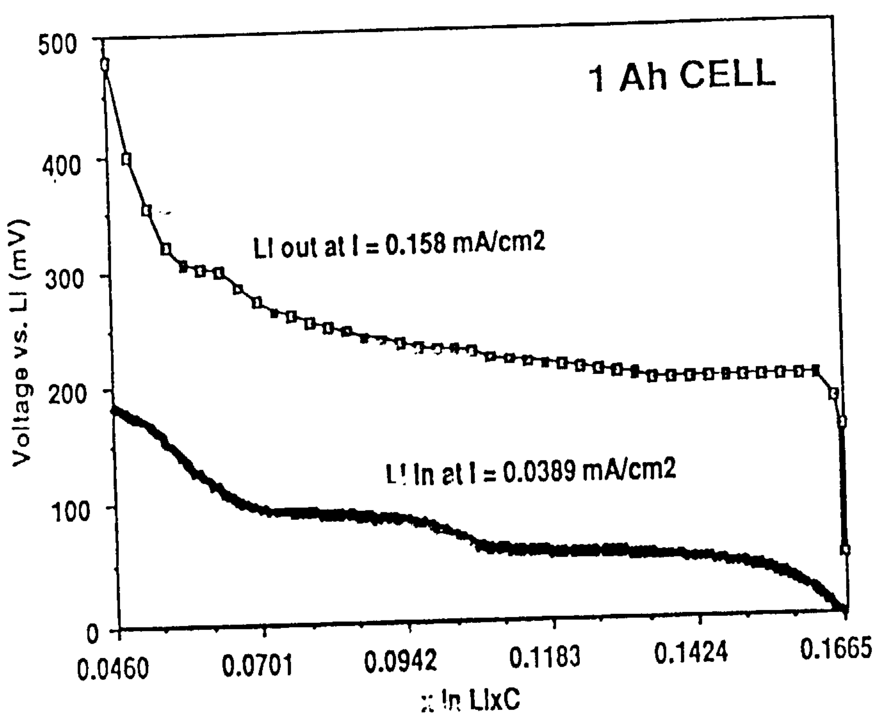
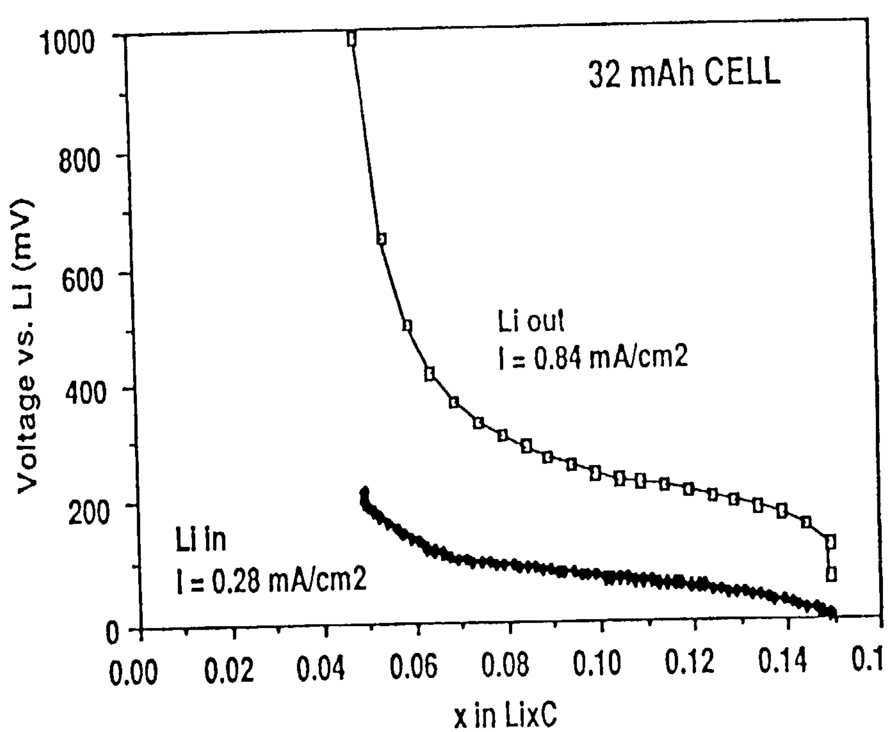
ELECTROCHEMICAL INTERCALATION & DE-INTERCALATION OF Li IN Li_xC



BATTERY SYSTEMS GROUP

COMPARISON OF CHARGE & DISCHARGE CHARACTERISTICS OF 1 Ah & 32 mAh CELLS





BATTERY SYSTEMS GROUP

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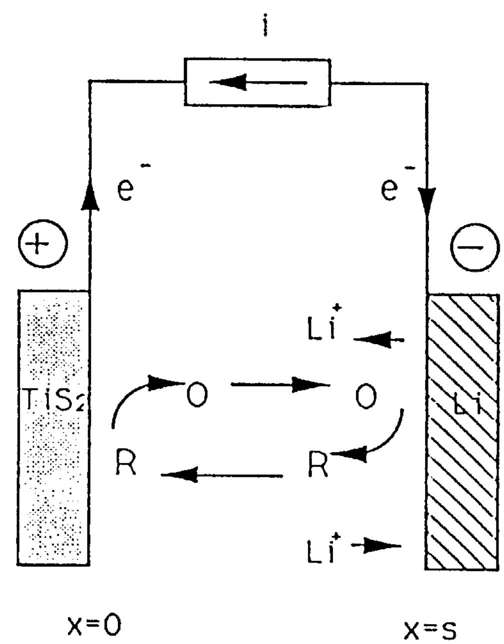
REDOX SHUTTLE APPROACH TO OVERCHARGE PROTECTION



BATTERY SYSTEMS GROUP

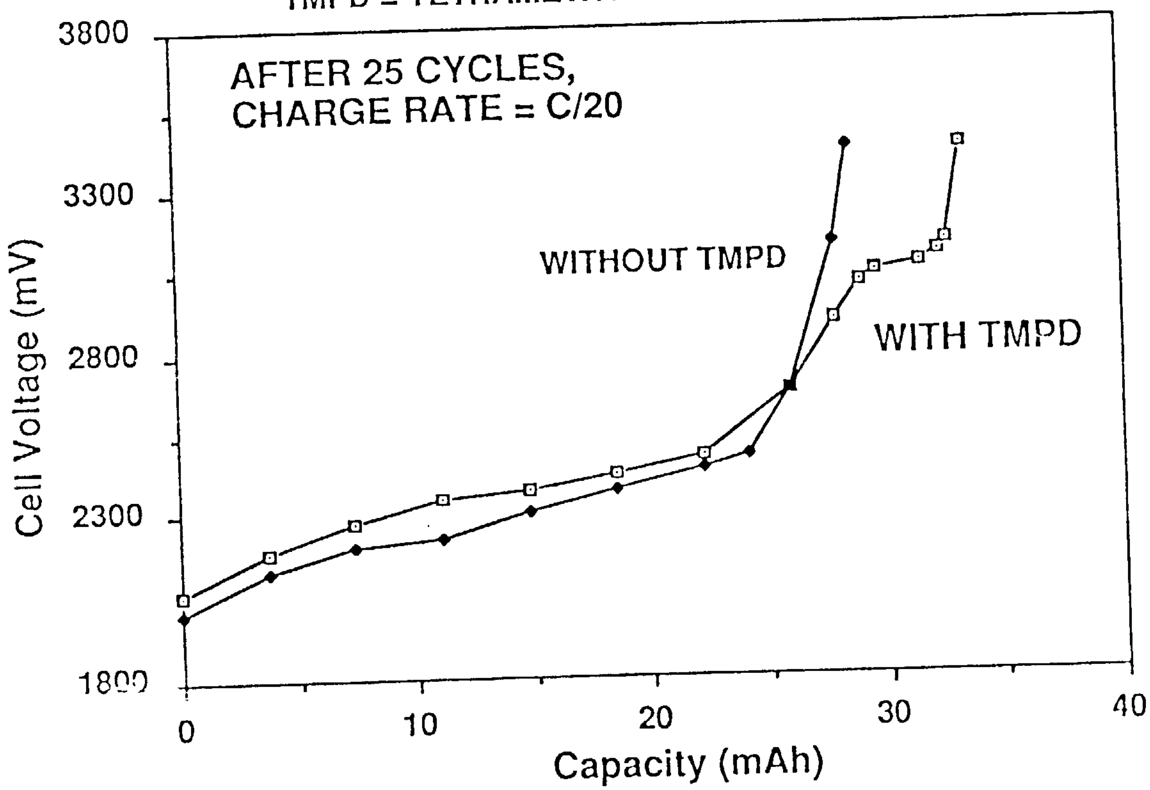
2

CHEMICAL ENERGY CONVERSION (BATTERY) TECHNOLOGY

JPL RECHARGEABLE LITHIUM CELL PROGRAM

STUDIES ON OVERCHARGE PROTECTION

TYPICAL CHARGE CHARACTERISTICS OF Li-TiS2 CELL
TMPD = TETRAMETHYL PHENYLENE DIAMINE



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ANNUAL RTOP REVIEW

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.CONDARY LITHIUM CELLS/BATTERIES
CONCLUSIONS

- SECONDARY LITHIUM BATTERIES ARE SUITABLE FOR PLANETARY MISSIONS REQUIRING
  - HIGH SPECIFIC ENERGY
  - LONG ACTIVE SHELF LIFE
  - LIMITED CYCLE LIFE
- TiS_2 CATHODE MATERIAL MEETS ALL REQUIREMENTS FOR RECHARGABLE Li CELL
  - HIGH INTRINSIC REVERSIBILITY
  - REALIZABLE SPECIFIC ENERGY
- SECONDARY LITHIUM TECHNOLOGY IS STILL EVOLVING
  - LOW CAPACITY CELLS (~1 Ah) DEMONSTRATED
  - > 700 CYCLES (@ 50% DOD) ACHIEVED
- WORK IS IN PROGRESS TO IMPROVE CYCLE LIFE AND SAFETY
  - ELECTROLYTES
  - ALTERNATE Li ANODE
  - SEPARATORS

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SECONDARY LITHIUM CELLS/BATTERIES

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