

NASA

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BATTERY REVIEW BOARD

BATTERY REVIEW BOARD
THE 1992 NASA AEROSPACE BATTERY WORKSHOP
NOVEMBER 19, 1992

THE STORAGE BATTERY IS, IN MY OPINION, A CATCH-PENNY, A SENSATION, A MECHANISM FOR SWINDLING THE PUBLIC STOCK COMPANIES. THE STORAGE BATTERY IS ONE OF THOSE PECULIAR THINGS WHICH APPEAL TO THE IMAGINATION, AND NO MORE PERFECT THING COULD BE DESIRED BY STOCK SWINDLERS THAN THAT VERY SELF-SAME THING....JUST AS SOON AS A MAN GETS WORKING ON THE SECONDARY BATTERY IT BRINGS OUT HIS LATENT CAPACITY FOR LYING...SCIENTIFICALLY, STORAGE IS ALL RIGHT, BUT, COMMERCIALY, AS ABSOLUTE A FAILURE AS ONE CAN IMAGINE.

THOMAS A. EDISON - JANUARY 1883

793 - 20519



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AGENDA

- CHARTER
- MEMBERSHIP
- CHRONOLOGY
- BACKGROUND
- STATEMENT OF THE PROBLEM
- ASSESSMENT/RECOMMENDATIONS FOR NEAR TERM FLIGHTS
- ASSESSMENT/RECOMMENDATION FOR FUTURE ACTIVITIES
- NASA BATTERY STEERING COMMITTEE
- SUMMARY



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NASA BATTERY REVIEW BOARD CHARTER

- REVIEW THE STATUS OF Ni-Cd, Ni-H₂ and Ni- METAL HYDRIDE AEROSPACE BATTERIES WITH EMPHASIS ON RELIABILITY, PRODUCIBILITY AND PERFORMANCE
- DETERMINE BEST DIRECTION FOR FUTURE NASA PROGRAM WITH RESPECT TO THESE SECONDARY BATTERIES



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CHIEF OF THE PROPULSION AND POWER DIVISION

JOHNSON SPACE CENTER

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GSFC



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BOARD CHRONOLOGY

8/19-21/92	BOARD DELIBERATION AND SITE VISIT AT GSFC
8/20/92	SITE VISIT AT COMSAT CORPORATION
8/25/92	BOARD TELECON
8/28/92	SITE VISIT AT LEWIS RESEARCH CENTER
8/31/92	SITE VISIT AT EAGLE-PICHER INDUSTRIES IN COLORADO SPRINGS, CO
9/1/92	SITE VISIT AT JET PROPULSION LABORATORY
9/2/92	SITE VISIT AT HUGHES, ELECTRON DYNAMICS DIVISION IN TORRANCE, CA
9/2/92	SITE VISIT AT AEROSPACE CORP IN LOS ANGELES, CA
9/9/92	SITE VISIT AT MDESC IN ST. CHARLES, MO
9/10/92	SITE VISIT AT EAGLE-PICHER INDUSTRIES IN JOPLIN, MO
9/17/92	SITE VISIT AT GATES IN GAINESVILLE, FL
9/18/92	BOARD DELIBERATION
9/23-25/92	BOARD DELIBERATION
9/25/92	MEETING WITH SAFT PERSONNEL AT GSFC
10/22/92	FINAL REPORT BRIEFING TO ACTING DEPUTY ADMINISTRATOR
11/17/92	ENGINEERING MANAGEMENT COUNCIL
NOV. '92	FEEDBACK TO PARTICIPANTS



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BACKGROUND

- LARGE NUMBER OF APPLICATIONS IN THE 60'S AND 70'S. SIGNIFICANT BATTERY PERFORMANCE ISSUES ENCOUNTERED - MOST APPLICATIONS ABLE TO MANAGE BATTERY PROBLEMS BY REDUCING POWER CONSUMPTION AND MANAGING CHARGE CONTROL
- GSFC IMPLEMENTED GSFC STANDARD SPEC AND GROUND TEST APPROACH FOR THE 20 AH CELLS AND BATTERIES
- 1975 - GSFC CONTRACT WITH FOUR MANUFACTURES (GE, E-P, GULTON, AND YARDNEY) FOR STANDARD 20 AH CELL. ONLY GE (GATES) PASSED CERTIFICATION
- 1976 - MANUFACTURE OF PELLON 2505 SEPARATOR MATERIAL DISCONTINUED- CELL/BATTERY COMPANIES STOCKPILE ENOUGH TO LAST THROUGH THE 80'S
- LATE 1970'S - GSFC 50 AH SPEC FOR STANDARD CELLS AND BATTERIES DEVELOPED
- 1980-85 - MANY PROBLEMS WITH PLATES AND CELLS AT GE. THEIR COMMERCIAL LINE, WHICH ALSO PRODUCES PLATES FOR AEROSPACE APPLICATIONS, WAS SHUT DOWN FOR THREE MONTHS IN SEPTEMBER OF 1984 TO CORRECT DEFICIENCIES
- 1985 - NASA ADMINISTRATOR (MR. BEGGS) REQUESTED AND RECEIVED SURVEY OF BATTERY PROBLEMS - NASA AEROSPACE FLIGHT BATTERY STEERING COMMITTEE ESTABLISHED - BATTERY PROGRAM PLAN ESTABLISHED
- 1986 - GE SOLD TO GATES



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BACKGROUND (CONT.)

- 1985-91
 - BATTERY STEERING COMMITTEE CONVERTED GSFC STANDARD SPEC'S AND MCD TO NASA STANDARDS
 - SEARCH FOR NEW SEPARATOR MATERIAL TO REPLACE PELLON 2505 LED TO DEVELOPMENT OF PELLON 2536 AND 2538
 - Ni-H₂ TECHNOLOGY MATURING - SPACE STATION SELECTED Ni-H₂ BASELINE
 - ADVANCED Ni-Cd TECHNOLOGY MATURING
 - GSFC SELECTED ADVANCED Ni-Cd (9 AH) FOR SAMPEX APPLICATION
 - JPL SELECTED 37 AH ADVANCED Ni-Cd AS BACKUP FOR MARS OBSERVER
 - GSFC SELECTED 50 AH ADVANCED Ni-Cd AS BACKUP FOR EUVE
- 1975-1991
 - LARGE NUMBER OF SUCCESSFUL FLIGHT PROGRAMS (LEO & GEO) UTILIZING NASA STANDARD Ni-Cd BATTERIES (LANDSAT-ERBS, SMM, TIROS)
- 11/91 TO PRESENT
 - PROBLEMS ENCOUNTERED WITH 50 AH CONVENTIONAL Ni-Cd BATTERIES AND CELLS
 - GSFC HAS SELECTED 50 AH ADVANCED Ni-Cd FOR XTE AND TRMM AND 9 AH ADVANCED Ni-Cd FOR FAST AND TOMS



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STATEMENT OF PROBLEM

- INSUFFICIENT/NON REPEATABLE Ni-Cd BATTERY CHARGE/DISCHARGE CYCLE CAPABILITY FOR LEO APPLICATIONS
- EARLIEST FAILURE TO DATE ~ 2000 CYCLES; DIVERGENCE > 200 MV
- WHEN DIVERGENCE OCCURS, TLC (TENDER LOVING CARE) CAN PROLONG THE LIFE. HOWEVER, ON EXISTING IN-FLIGHT SPACECRAFT, THERE IS LIMITED BATTERY CHARGE/DISCHARGE CONTROL CAPABILITY.
- ACCEPTANCE TEST PROCEDURE (ATP) INSUFFICIENT TO SCREEN FOR CYCLE LIFE CAPABILITY - SIGNIFICANT AMOUNT OF TIME REQUIRED TO VALIDATE LIFE CAPABILITY
- GENERAL CONSENSUS IS THAT THE PROBLEM IS WITH NEGATIVE PLATE
- CELL ELECTRICAL BEHAVIOR AND DPA'S (DESTRUCTIVE PHYSICAL ANALYSIS) OF CELLS FROM GROUND TEST SHOW SYMPTOMS OF A FAILED CELL AT THE END OF ITS LIFE
- ROOT CAUSE OF THE FAILURE IS UNKNOWN



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SUMMARY OF PROBLEMS WITH 50 AH STANDARD Ni-Cd

FLIGHT VEHICLES

- GRO
 - TWO MODULAR POWER SYSTEMS (MPS); THREE BATTERIES EACH
 - NOMINAL OPERATION FOR 7 MONTHS (~3000 CYCLES)
 - DEC 91, ~ 80 MV DIFFERENTIAL
 - CURRENTLY -
 - MPS 1: BATTERY 2 OFF LINE > 750 MV
 - BATTERIES 1 AND 3 (STILL ON LINE 150 - 300 MV)
 - MPS 2: NOMINAL FLIGHT PERFORMANCE
- UARS
 - 1 MPS
 - NOMINAL OPERATION FOR 2,000 CYCLES
 - JAN '92 - OCT '92, 80 MV UP TO 400 MV
 - CURRENTLY - APPROXIMATELY 200 MV

GROUND TEST

- GRO
 - CELLS FROM MPS 1 LOT EXHIBIT CELL DIVERGENCE (30 MV) AFTER 6600 CYCLES; THEN IMPROVED
 - CELLS FROM MPS 2 LOT NOMINAL
- UARS
 - CELLS FROM FLIGHT LOT EXHIBIT CELL DIVERGENCE AFTER 2000 CYCLES
 - THREE UARS CELLS DPA'D FROM FLIGHT LOT AT APPROX 5000 CYCLES
 - 2 FROM STRESS PACK (EXCESSIVE MIGRATION IN ONE, OTHER WAS NOMINAL)
 - 1 FROM MISSION SIM PACK (SOFT SHORTS WITH LOCALIZED Cd MIGRATION)



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ACTIVITIES FOR NEAR TERM PROGRAMS UTILIZING CONVENTIONAL Ni-Cd

ASSESSMENT:

- UNCERTAINTY ASSOCIATED WITH LEO LIFE CYCLE CAPABILITY OF ALL NASA STANDARD Ni-Cd CELLS

RECOMMENDATIONS:

- ON-ORBIT VEHICLES IN LOW EARTH ORBIT - MINIMIZE STRESS OF THE BATTERY (TLC)
 - MINIMIZE OVERCHARGE AND AVOID HIGH TRICKLE CHARGE CURRENT - STRONG EVIDENCE THAT THIS ENHANCES LIFE - THIS SHOULD BE DONE ON ALL PROGRAMS UTILIZING NASA STANDARD Ni-Cd BATTERIES
 - CODE S OPERATIONS COMMITTEE APPOINTED BY DR. FISK TO CO-ORDINATE OPERATIONAL ACTIVITIES IS ON-GOING. - DETAILED SUGGESTIONS HAVE BEEN DISCUSSED WITH THAT GROUP
- CONTINUE SEARCH FOR ROOT CAUSE(S)
 - CONTINUE TO PARTICIPATE WITH GOVERNMENT TEAM LOOKING FOR CORRELATION BETWEEN APPARENT GOOD LOTS AND THE PROBLEM LOTS
 - PERFORM CELL DPA'S AT OTHER LOCATIONS
 - MSFC, JPL, LeRC
- RE-EVALUATE PLANNED LAUNCHES UTILIZING ALREADY MANUFACTURED NASA STANDARD Ni-Cd BATTERIES
- PERFORM 2 YEAR CELL STRESS TEST OR A MISSION SIMULATION TEST ON FLIGHT LOT CELLS PRIOR TO FLIGHT



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PRESENT PROJECTS SCHEDULED TO USE NASA STANDARD Ni-Cd

PROJECT	LAUNCH DATE	RESOLUTION	# CYCLES REQUIRED
WIND (26.5A-II)	12/93	7 ECLIPSE ORBIT. EVALUATING PLATE, CELL AND BATTERY DATA, BUT SHOULD BE ACCEPTABLE	7
POLAR (26.5A-II)	8/94	<300 ECLIPSE ORBIT. EVALUATING PLATE AND CELL DATA, BUT SHOULD BE ACCEPTABLE	300
GOES (12A-II)	12/93, 12/94, 98, 99	GEO ORBIT. CONV. Ni-Cd ACCEPTABLE PROVIDED TEST DATA IS ACCEPTABLE	<1000
TDRSS (40A-II)	1/93, 1/95	GEO, PLATE FABRICATED PRIOR TO 1987. CONV. Ni-Cd ACCEPTABLE. CELL PACKS IN TEST	<1000
NOAA I (26.5A-II)	3/93	BATTERIES MANUFACTURED FROM LOT 14 PLATES; SAME AS NOAA D (16 MONTHS IN ORBIT), ONE BATTERY ON H (FOUR + YEARS IN ORBIT); 22 MONTH SUCCESSFUL LIFE TEST. ACCEPTABLE FOR FLIGHT.	10,000
NOAA J (26.5A-II)	'94	22 MONTH MISSION SIM TEST IN PROGRESS; EVALUATING POSSIBLE USE OF SAFT OR SUPER Ni-Cd	10,000
NOAA K (47A-II)	'95	24 MONTH MISSION TEST WILL BE DONE; EVALUATING SUPER Ni-Cd (POSSIBLY M.O.), SAFT Ni-Cd AND Ni-H ₂ AS ALTERNATIVES	10,000
ACTS	6/93	GEO ORBIT MISSION OF APPROXIMATELY 4 YEARS USING 2 NASA STANDARD 19 AH Ni-Cd at 50% DOD WITH RECONDITIONING AND INDIVIDUAL CELL VOLTAGE MONITORING AVAILABLE	400



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OTHER NEAR-TERM NASA PROGRAMS REQUIRING SECONDARY BATTERIES

PROGRAM	CELL MANF	BATTERY MANF	TYPE	ORBIT	AH	LAUNCH DATE	COMMENT
GSFC							
FAST	EP-CS	HAC	Su Ni-Cd	LEO	9	8/94	
SWAS	TBD	TBD	Ad Ni-Cd	LEO	21	6/95	
TOMS	EP-CS	HAC	Su Ni-Cd	LEO	9	8/94	
XTE	EP-CS	HAC	Su Ni-Cd	LEO	50	12/95	
TRMM	EP-CS	HAC	Su Ni-Cd	LEO	50	8/97	
ACE	TBD	TBD	TBD	L1	TBD	8/97	
LeRC							
SSF	GATES	LORAL	Ni-H ₂	LEO	81	3/96	6.5 YEARS @ 35% DOD ~36,400 CYCLES
JSC							
TESS	EP-J	MDESC	Ni-H ₂	15-60% DOD FOR .5-1.5 HOURS	78	6/96	4755 CYCLES/ 10 YEARS

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RECOMMENDED DIRECTION FOR FUTURE PROGRAMS

RECOMMENDATION: MAKE SELECTION(S) BASED ON REQUIREMENT TRADE STUDY RESULTS COMBINED WITH MARKET PLACE COMPETITION

- CONVENTIONAL Ni-Cd
- USER BEWARE WITH RESPECT TO NASA STANDARD Ni-Cd CELLS FOR LEO APPLICATION UNLESS ON-GOING ACTIVITY IDENTIFIES ROOT PROBLEM(S) WHICH CAN BE CORRECTED
- ADVANCED Ni-Cd
- ACCEPTABLE FOR FLIGHT USAGE
- QUANTITY OF DATA ON ADVANCED Ni-Cd IS LIMITED AND MORE TESTING SHOULD BE PERFORMED
- GROUND HANDLING/STORAGE PROBLEM NEEDS RESOLUTION
- Ni-H₂
 - EXCELLENT SYSTEM FOR LEO IN TERMS OF CAPABILITY; (CYCLE LIFE, DEPTH OF DISCHARGE, ETC)
- Ni-MH
 - MONITOR PROGRESS OF Ni-MH
- EACH PROGRAM SHOULD PERFORM A SPECIFIC BATTERY QUALIFICATION TEST. ALSO PERFORM A MISSION SIMULATION TEST, AND/OR A CELL STRESS TEST ON FLIGHT LOT CELLS PRIOR TO FLIGHT
- PROVIDE MORE FLEXIBLE CHARGE CONTROL AT A BATTERY LEVEL, e.g. DESIGN CHARGE CONTROL SYSTEMS TO LIMIT OVERCHARGE AND GENERALLY MINIMIZE STRESS ON BATTERY
- DESIGN Ni-Cd SYSTEMS TO ALLOW FOR RECONDITIONING OF BATTERIES IN LEO IF PRACTICAL



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FUTURE CELL/BATTERY PROCUREMENT STRATEGY

ASSESSMENT

- THE CURRENT STRATEGY OF A NASA STANDARD CELL AND BATTERY SPECIFICATION AND NASA CONTROL OF A STANDARD MANUFACTURING CONTROL DOCUMENT FOR Ni-Cd IS UNWARRANTED

RECOMMENDATIONS

- TREAT BATTERY/CELL LIKE OTHER SPACECRAFT COMPONENTS
- LET PRIME OR IN-HOUSE PROJECT OFFICE (S) DECIDE ON SPECIFICATIONS, MCD'S, ETC.
- USE CONTRACT INCENTIVES TO INSURE PERFORMANCE, SCHEDULE, AND LIFE CHARACTERISTICS ARE MET
- BATTERY STEERING COMMITTEE SHOULD REORIENT 8073.1 SPECIFICATION AS A CHECKLIST/HANDBOOK FOR PROCURING CONVENTIONAL Ni-Cd, ADVANCED Ni-Cd, AND Ni-H₂
- RELINQUISH NASA CONTROL OF DASH 87 AND DASH 88 MANUFACTURER'S CONTROL DOCUMENT (MCD)



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FUTURE CELL/BATTERY PROCUREMENT STRATEGY (CONT.)

PRO'S

- PLACES RESPONSIBILITY AND ACCOUNTABILITY WITH THE PRIMES AND THEIR SUBCONTRACTORS
- ALLOWS IMPROVEMENTS DEVELOPED IN COMMERCIAL AND OTHER GOVERNMENT PROGRAMS TO BE INCORPORATED INTO NASA PROGRAMS MORE QUICKLY
- DECREASES RESPONSE TIME FOR NECESSARY MCD CHANGES AT THE VENDOR
- UTILIZES MARKET PLACE FOR COMPETITION
- ALLOWS NASA AEROSPACE CELLS TO BE MORE LIKE COMMERCIAL AND OTHER GOVERNMENT AEROSPACE CELLS
- MORE LIKE HOW WE ARE CURRENTLY OPERATING

CON'S

- POTENTIALLY LESS NASA CONTINUITY BETWEEN PROGRAMS
- POTENTIALLY FEWER LONG TERM BUSINESS ARRANGEMENTS
- BATTERY TEAM IN '85 RECOMMENDED USE OF STANDARDS



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NASA BATTERY PROGRAM

ASSESSMENT:

THE NASA BATTERY STEERING COMMITTEE WAS ESTABLISHED IN 1985 TO PROVIDE FOR AN INTEGRATED, WELL MANAGED NASA AEROSPACE BATTERY PROGRAM. THIS GROUP CONTINUES TO PROVIDE OVERSIGHT FOR THE NASA BATTERY PROGRAM (INITIALLY FUNDED IN 1988) AND PERFORMS AN ESSENTIAL SERVICE FOR NASA AND AEROSPACE BATTERY COMMUNITY

RECOMMENDATIONS:

- CONTINUE BATTERY PROGRAM EVALUATION OF ADVANCED Ni-Cd, NI-H2 AND NI-MH CELLS TO SUPPORT FUTURE NASA MISSIONS
- ABANDON THE NASA STANDARD BATTERY CONCEPT WITH RESPECT TO NASA CONTROL OF THE CELL SPECIFICATION AND THE MANUFACTURING CONTROL DOCUMENT
- REVISE NHB 8073.1 (NASA STANDARD CELL SPECIFICATIONS) TO CELL/BATTERY PROCUREMENT GUIDELINES
- FOCUS ON COORDINATION OF LESSONS LEARNED AND MAINTAINING AND UPDATING AGENCY WIDE BATTERY DATA BASES
- EXPAND CURRENT BATTERY PROGRAM PLAN TO INCLUDE AUTOMATED FLIGHT/GROUND TEST, GOVERNMENT AND INDUSTRY CELL/BATTERY DATA BASE
- PROVIDE INDEPENDENT VERIFICATION OF MANUFACTURING FLIGHT CELLS BY PROCURING AND TESTING REPRESENTATIVE CELLS FROM VARIOUS MANUFACTURERS
- AUGMENT LIFE CYCLE TESTING OF GOVERNMENT OWNED EXISTING SUPER AND CONVENTIONAL Ni-Cd CELLS
- DEVELOP AN APPLICABLE CELL STRESS TEST FOR Ni-H2 and Ni-MH



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SUMMARY

- HISTORICAL REVIEW OF Ni-Cd USAGE INDICATES "GOOD OLE DAYS" WERE ONLY PARTIALLY GOOD
- SEVERAL ON-ORBIT AND GROUND TEST CYCLE LIFE PROBLEMS WITH NASA STANDARD Ni-Cd CELLS - ROOT CAUSE REMAINS ELUSIVE
 - ON-ORBIT CYCLE LIFE CAN BE PROLONGED WITH TENDER LOVING CARE (TLC)
- SIGNIFICANT NUMBER OF NASA STANDARD Ni-cd CELLS ALREADY MANUFACTURED FOR FUTURE APPLICATIONS - EACH PROGRAM IS EVALUATING EXISTING DATA AGAINST SPECIFIC APPLICATION REQUIREMENTS.
- BATTERY CHOICES FOR NEAR-TERM, NEW PROGRAMS INCLUDE Ni-H₂, ADV Ni-Cd, AND CONVENTIONAL Ni-Cd
- CD ENVIRONMENTAL RULING ACCEPTABLE BUT SHOULD EXPECT CONTINUING PRESSURE
- FUTURE APPLICATIONS SHOULD EMPHASIZE Ni-H₂
- NASA POLICY FOR IMPLEMENTATION OF NASA STANDARD CELL AND BATTERY UNWARRANTED - SHOULD ALLOW SPACECRAFT REQUIREMENTS AND MARKET PLACE COMPETITION TO DRIVE SELECTION

