NASA AEROSPACE FLIGHT BATTERY SYSTEMS PROGRAM UPDATE

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1996 NASA AEROSPACE BATTERY WORKSHOP
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BACKGROUND

NASA AEROSPACE FLIGHT BATTERY SYSTEMS PROGRAM - INITIATED IN 1985 TO ADDRESS CONCERNS WITH AEROSPACE BATTERIES

INITIAL CONCERNS - QUALITY, RELIABILITY - PROVIDE BRIDGE BETWEEN DEVELOPMENT AND FLIGHT USE

PROGRAM EVOLVED TO PROVIDE SUPPORT TO NASA ENTERPRISES IDENTIFIED IN RECENT REORGANIZATION

PROGRAM PLAN REVISED TO REFLECT AGENCY'S STRATEGIC PLAN AND SUPPORT FOR NASA ENTERPRISES

The NASA Aerospace Flight Battery Systems Program represents a unified NASA wide effort with the overall objective of providing NASA with the policy and posture which will increase the safety, performance, and reliability of space power systems. The program was initiated in 1985 to address problems experienced with aerospace batteries.

Since the initiation of the program the agency has undergone a reorganization. A strategic plan has been developed to guide the agency over the next 25 years. In the past year, the NASA Aerospace Flight Battery Systems Program has been realigned to be consistent with the NASA strategic plan. The major objectives of the program have been revised to directly support the enterprises that have been identified in the new strategic plan.

BATTERY PROGRAM SUPPORT OF NASA ENTERPRISES

	PRIMARY CUSTOMERS	GOALS	RELEVANCE OF BATTERY PROGRAM
MISSION TO PLANET EARTH ENTERPRISE	Policy Makers Science and Education Communities	Demonstrate new instruments, technologies and procedures - small smart spacecraft and instruments Evolve EOS science and technology and demonstrate new instruments, technologies, and procedures	Evolve new battery technologies that enable MTPE missions Demonstrate battery technologies and advancements
AERONAUTICS ENTERPRISE	Aero Industry US Gov't Agencies	Provide advanced technologies for unpiloted airborne Earth/space observing platforms	Evolve and demonstrate battery technologies to support unpiloted platforms
HUMAN EXPLORATION AND DEVELOPMENT OF SPACE ENTERPRISE	Science and Education Communities Commercial Sectors	Achieve routine space travel Provide safe, reliable, low-cost transportation Operate international Space Station cost effectively	Evolve and validate lightweight battery technologies with improved life & performance, Lower cost batteries
SPACE SCIENCE ENTERPRISE	Science and Education Communities Technology Innovators	Lower cost missions Robotic missions Develop demonstrate and infuse new technology to enable and enhance all missions	Lower cost batteries Lightweight, low volume batteries New technologies to enable missions Cooperative government development, technology transfer to industry

NASA has been reorganized into four major enterprise areas: Mission to Planet Earth, Aeronautics, Human Exploration and Development of Space, and Space Science. Customers and goals have been identified for each enterprise. The chart above also relates the Battery Program to the work in each of the Enterprises. Batteries are critical to the path defined for each of the NASA enterprises.

PROGRAM OBJECTIVES

DEVELOP, MAINTAIN AND PROVIDE TOOLS FOR THE VALIDATION AND ASSESSMENT OF AEROSPACE BATTERY TECHNOLOGIES

ACCELERATE THE READINESS OF TECHNOLOGY ADVANCES AND PROVIDE INFUSION PATHS FOR EMERGING TECHNOLOGIES

PROVIDE NASA PROJECTS WITH THE REQUIRED DATABASE AND VALIDATION GUIDELINES FOR TECHNOLOGY SELECTION OF HARDWARE AND PROCESSES RELATING TO AEROSPACE BATTERIES

DISSEMINATE VALIDATION AND ASSESSMENT TOOLS, QUALITY ASSURANCE, RELIABILITY, AND AVAILABILITY INFORMATION TO THE NASA AND AEROSPACE BATTERY COMMUNITIES

ENSURE THAT SAFE, RELIABLE BATTERIES ARE AVAILABLE FOR NASA's FUTURE MISSIONS

The objectives of the NASA Aerospace Flight Battery Systems Program are listed above.

APPROACH

MAINTAIN CURRENT BATTERY TECHNOLOGY

INCREASE FUNDAMENTAL UNDERSTANDING OF PRIMARY AND SECONDARY CELLS

ESTABLISH SPECIFICATIONS, DESIGN AND OPERATIONAL GUIDELINES FOR PRIMARY AND SECONDARY CELLS AND BATTERIES

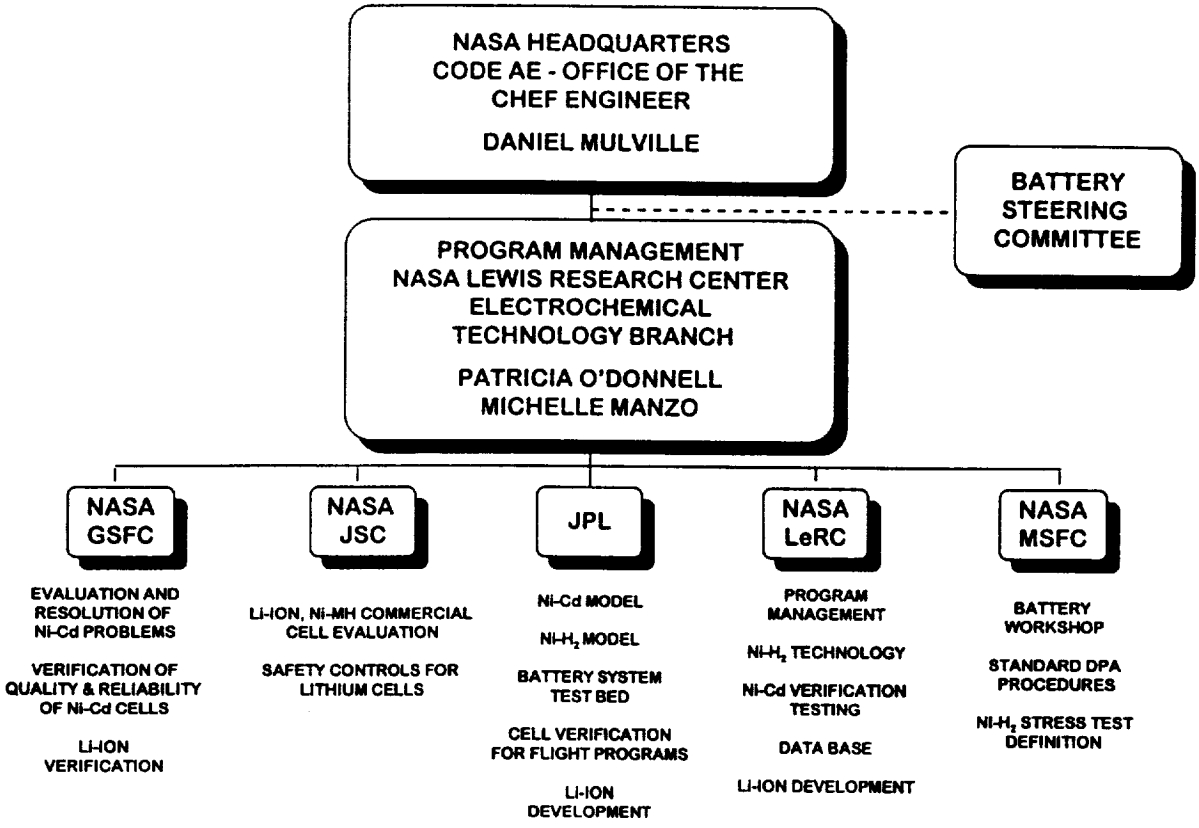
PROVIDE IMPROVED PROCESS CONTROL

OPEN AND MAINTAIN COMMUNICATION LINES WITHIN NASA AND THE AEROSPACE COMMUNITY

The approach to achieving the program objectives involves:

1) maintaining current battery technology;
2) increasing the fundamental understanding of primary and secondary cells;
3) establishing specifications and design and operational guidelines for primary and secondary cells and batteries;
4) providing for improved process control;
5) opening and maintaining communication lines within NASA and the aerospace community

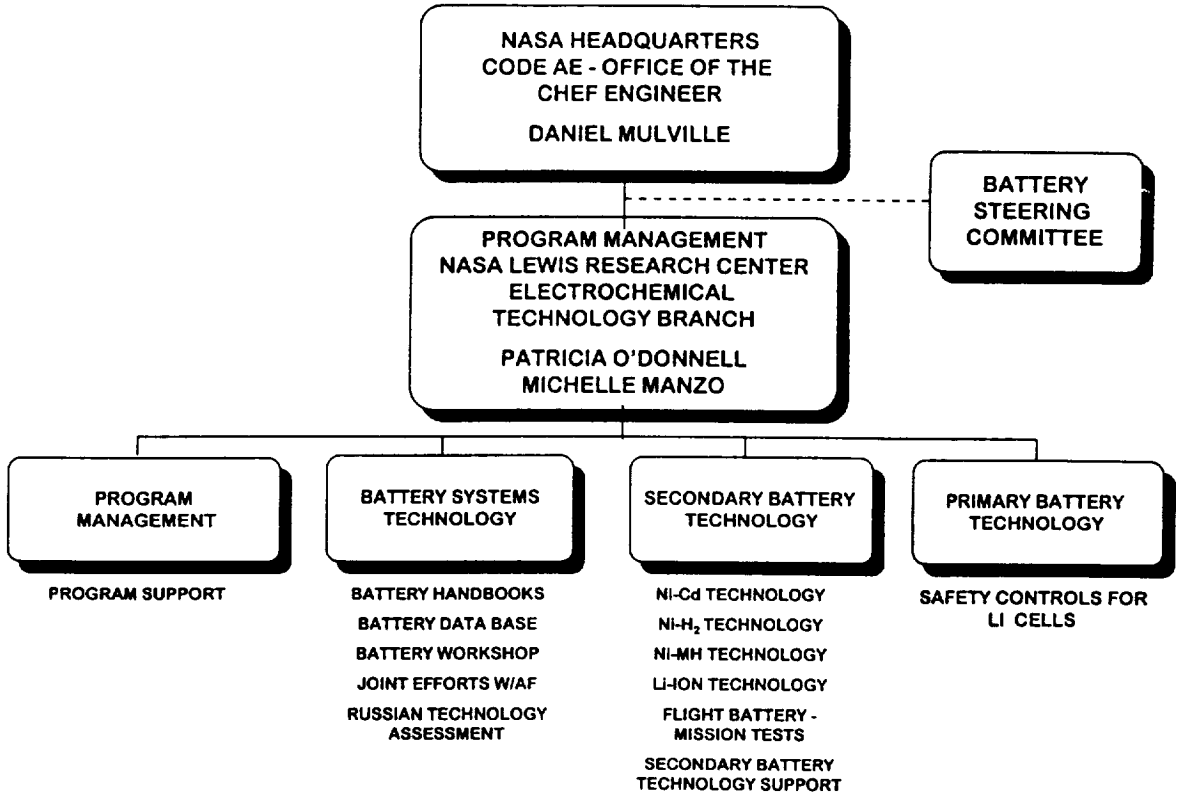
PROGRAM TASK RESPONSIBILITIES



The majority of the NASA centers are involved in the execution of specific tasks within the program. The Lewis Research Center Program Manager has full responsibility for technical management, cost and scheduling of the program. The NASA Lewis Research Center Program Manager also provides continuing coordination with all the NASA centers, Jet Propulsion Laboratory (JPL), NASA Headquarters and the NASA Aerospace Flight Battery Systems Steering Committee.

The NASA Aerospace Flight Battery Systems Steering Committee provides advice on battery issues. The Committee is chaired by the Battery Program manager, membership is comprised of one representative from each of the NASA centers, the Aerospace Corporation, the Air Force, the Navy and the CIA .

PROGRAM ORGANIZATION



This program is designed to enhance the safety, reliability, and performance of NASA's aerospace primary and secondary batteries as well as battery power systems. The NASA Aerospace Flight Battery Systems Program is organized under four major task areas: Program Management, Battery Systems Technology, Secondary Battery Technology, and Primary Battery Technology. The program is sponsored by the Office of the Chief Engineer, Code AE and the NASA Lewis Research Center (LeRC) , as the lead center, has the overall responsibility for management of the program. Dr. Patricia O'Donnell of the Lewis Research Center is the program manager.

BATTERY SYSTEMS TECHNOLOGY TASK

OBJECTIVES:

TO IMPROVE RELIABILITY OF ENERGY STORAGE SPACE POWER SYSTEM DESIGN, INTEGRATION, AND CHECKOUT

ADDRESS SYSTEMS ASPECTS - INTEGRATION OF CELLS INTO BATTERIES AND BATTERIES INTO POWER SYSTEMS

TASKS:

NASA BATTERY HANDBOOKS

BATTERY DATA BASE

NASA BATTERY WORKSHOP

RUSSIAN BATTERY TECHNOLOGY ASSESSMENT

JOINT EFFORTS WITH THE AIR FORCE

The Battery Systems Technology Task addresses the overall systems aspects associated with the integration of cells into batteries and batteries into power systems. The objective is to improve the reliability of energy storage, space power system design, integration, and checkout.

Sub-tasks under the Battery Systems Technology Task are listed above.

NASA BATTERY HANDBOOKS

OBJECTIVE: DEFINE GOOD CONSISTENT PRACTICES FOR THE DESIGN, INTEGRATION AND CHECKOUT, AND TESTING OF PRIMARY AND SECONDARY BATTERY SYSTEMS. PROVIDE GUIDELINES AND REQUIREMENTS TO ENSURE MISSION SUCCESS

NASA HANDBOOK FOR NICKEL-HYDROGEN BATTERIES *

HANDBOOK FOR HANDLING AND STORAGE OF NICKEL-CADMIUM BATTERIES *

PRIMARY BATTERY DESIGN AND SAFETY GUIDELINES HANDBOOK *

GUIDELINES DOCUMENT FOR NICKEL-CADMIUM CELLS

GUIDELINES DOCUMENT FOR NICKEL-HYDROGEN CELLS

GUIDELINES DOCUMENT FOR SILVER-ZINC CELLS

* COMPLETED - PUBLISHED

A number of handbooks has been published since the program was initiated in 1985. Some of the more recent publications are listed above. Present efforts in this area focus on the development of "Guidelines/Checklist" type documents for nickel-cadmium, nickel-hydrogen and silver-zinc technologies.

NASA BATTERY HANDBOOKS

NICKEL-CADMIUM GUIDELINES DOCUMENT - JPL
NICKEL-HYDROGEN GUIDELINES DOCUMENT - LeRC
SILVER-ZINC GUIDELINES DOCUMENT - MSFC

DOCUMENTS TO SERVE AS GUIDELINE AND CHECKLIST FOR THE PROCUREMENT OF CELLS FOR FLIGHT PROJECTS

AID IN DEVELOPMENT OF SPECIFICATIONS FOR PROCUREMENT

RATIONALE FOR SELECTION OF DESIGN FEATURES FOR SPECIFIC APPLICATIONS

REPRESENTATIVE VALUES AND RANGES FOR TECHNICAL SPECIFICATIONS FOR CRITICAL DESIGN PARAMETERS

CONTRACTS WITH AEROSPACE CORPORATION TO PRODUCE DOCUMENTS

The purpose of the guidelines documents is to provide guidance in the areas of overall design considerations, selection of design features /components for specific applications and to provide background for the proper selection of cells for a specific mission.

BATTERY DATA BASE - LeRC

OBJECTIVE: DEVELOP DATA BASE FOR THE DISSEMINATION OF TECHNICAL NOTES, POLICY DOCUMENTATION AND TEST DATA THROUGHOUT THE AGENCY

DATA BASE IS FUNCTIONAL - OPERATION HAS BEEN DEMONSTRATED

OPERATIONAL CYCLE TEST DATA - POST 1990 DATA FROM CRANE TESTING HAS BEEN ENTERED INTO THE DATA BASE AND IS AVAILABLE ON-LINE

LOCKHEED MARTIN TEST DATA IS BEING INCORPORATED INTO DATA BASE

The Battery Data Base subtask addresses a NASA Battery System Data Base Environment to serve the NASA battery community for the dissemination of technical cell cycle data for the testing at Crane. The majority of the NASA cell test data base resides at the Naval Weapons Support Center, Crane, IN. The Crane data has been organized and structured into a battery test data base. Cycle test data for tests run since 1990 is available on-line.

NASA BATTERY WORKSHOP - MSFC

OBJECTIVE: PROVIDE FORUM FOR OPEN COMMUNICATION OF BATTERY RELATED ACTIVITIES

WORKSHOP ADDRESSES TECHNOLOGY STATUS OF ESTABLISHED AND EMERGING TECHNOLOGIES

SUBJECTS COVERED GENERALLY INCLUDE:

RESEARCH AND DEVELOPMENT WORK ON STATE-OF-THE-ART AEROSPACE BATTERY TECHNOLOGIES,

FLIGHT AND GROUND TEST DATA

ON-ORBIT OPERATION AND PROBLEM RESOLUTION EFFORTS

FOCUSED TOPIC TO ADDRESS CURRENT ISSUES RELATING TO AEROSPACE BATTERIES

The NASA Battery Workshop comes under the sponsorship of the NASA Aerospace Flight Battery Systems Program. Previously held at NASA Goddard, the Marshall Space Flight Center has hosted yearly Workshops since December 1990. The workshop serves as a forum for open communication of battery related activities between industry and government.

RUSSIAN BATTERY TECHNOLOGY EVALUATION

OBJECTIVE: DEVELOP SEPARATOR SPECIFICATIONS FOR Ag/Zn CELL DESIGNS BASED ON EVALUATION OF RUSSIAN TECHNOLOGY

NAVY PROGRAM WITH NASA INVOLVMENT

INCORPORATE IMPROVED SEPARATORS IN DOMESTIC CELLS

SEPARATOR ASSESSMENT UNDERWAY
- CYCLE TESTING
- STORAGE TESTING - WET STAND
- DPA

This task was initiated to assess claims of the superiority of Russian Ag-Zn cell technology over domestic silver-zinc technology. In side-by-side tests, Russian cells out-performed cells manufactured in the USA. The tests indicated that the separator may be the component responsible for the improved performance. The present effort is a follow-on to the original evaluation that incorporates candidate separator materials into cells for evaluation. This is a primarily a Navy effort with NASA involvement.

COOPERATIVE EFFORTS WITH THE AIR FORCE

OBJECTIVE: LEVERAGE FUNDS BY COMBINING RESOURCES WITH THE AIR FORCE FOR THE DEVELOPMENT OF EFFORTS TO SUPPORT THE VERIFICATION OF SECONDARY CELLS/BATTERIES FOR AEROSPACE APPLICATIONS.

AREAS OF COMMON INTEREST

COMMON PRESSURE VESSEL (CPV) NICKEL-HYDROGEN BATTERIES

SINGLE PRESSURE VESSEL (SPV) NICKEL-HYDROGEN BATTERIES

INDIVIDUAL PRESSURE VESSEL (IPV) NICKEL HYDROGEN CELLS

SUPER NICKEL-CADMIUM CELLS

DEPENDANT PRESSURE VESSEL (DPV) NICKEL-HYDROGEN BATTERIES

NASA and the Air Force share common interests in aerospace batteries. In order to leverage efforts in these times of shrinking budgets, a Memorandum of Understanding between NASA and the Air Force was signed that permits cooperation in the area of "Joint Spacecraft Battery Verification." Areas of common interest have beer identified as shown on the chart above.

COOPERATIVE EFFORTS WITH THE AIR FORCE

JOINT TASKS

CPV EVALUATION

45AH, 2-CELL CPV'S

AF TEST PLAN WITH NASA INPUT - 3 PACKS - 2 LEO, 1 GEO

Ni-H_2 STORAGE TEST

5 YEAR STORAGE - CYCLE TO COMPARE WITH UNSTORED

SUPER Ni-Cd STORAGE TEST

COMPARISON OF STORAGE TEMPERATURES - 0°C & 20°C AND CELL LOTS

The joint tasks that have been initiated to date are as follows:

CPV Evaluation - The Air Force has 21, 45 Ah, 2-cell CPV's for technology evaluation that are part of the program. The Air Force and NASA have jointly agreed upon the test conditions for the three packs so that the data will be useful to both agencies.

Ni-H_2 Storage Test - NASA is funding the life cycle tests for Ni-H_2 cells that had been stored for five years as part of an Air Force test on the effects of storage on the cycle life of Ni-H_2 cells. The cells are being cycled at the same conditions used for the sister packs that were cycled without storage.

Super Ni-Cd Storage Test - The effects of storage on super-Ni-Cd cells has long been a concern. This task evaluates the effects of storage temperature and cell lot on the capacity and cycle life of super Ni-Cd cells.

SECONDARY BATTERY TECHNOLOGY TASK

OBJECTIVES:

IMPROVE PERFORMANCE, QUALITY, SAFETY AND RELIABILITY OF SECONDARY BATTERY SYSTEMS.

MAINTAIN AND IMPROVE ESTABLISHED TECHNOLOGIES AND AID IN DEVELOPMENT OF EMERGING TECHNOLOGIES

TASKS:

NICKEL-CADMIUM BATTERY TECHNOLOGY
NICKEL-HYDROGEN BATTERY TECHNOLOGY
NICKEL-METAL HYDRIDE BATTERY TECHNOLOGY
LITHIUM-ION BATTERY TECHNOLOGY
FLIGHT BATTERY MISSION TESTS
SECONDARY BATTERY TECHNOLOGY SUPPORT

The Secondary Battery Technology Task was established to improve the performance, quality, safety, and reliability of secondary battery systems. This task is presently structured to maintain and improve established technologies such as nickel-cadmium and nickel-hydrogen, and to aid in the development and assimilation of emerging technologies such as lithium ion and nickel-metal hydride.

The Secondary Battery Technology Task areas are listed on the chart above.

NICKEL-CADMIUM BATTERY TECHNOLOGY
VERIFICATION OF SECONDARY CELLS

OBJECTIVE: PROVIDE INDEPENDENT VERIFICATION OF MANUFACTURING FLIGHT CELLS BY PROCURING AND TESTING REPRESENTATIVE CELLS FROM VARIOUS MANUFACTURERS

FOREIGN CELL EVALUATION - LeRC

SANYO CELLS	25, 35 AH CELLS
SAFT CELLS	21, 50 AH CELLS

ADVANCED Ni-Cd EVALUATION - LeRC, GSFC

SUPER Ni-Cd CELLS	25, 21 AH CELLS
	10, 50 AH CELLS
MAGNUM Ni-Cd CELLS	25, 21 AH CELLS

ALTERNATE SOURCE CELL EVALUATION - LeRC

ACME CELLS	12 EA 18 & 55AH CELLS
	NYLON & PP SEPARATORS

In order to support flight programs and address NASA's future needs with respect to nickel-cadmium cells, the NASA Aerospace Flight Battery Systems Program has a subtask that involves the evaluation of current technology Ni-Cd cells from the following sources: Hughes, SAFT, Sanyo, and Acme.

NICKEL-CADMIUM CELL VERIFICATION

VERIFICATION TEST PLAN

REPEAT PORTIONS OF MANUFACTURERS INSPECTION ACCEPTANCE TESTS

RUN NASA STANDARD ACCEPTANCE TEST PROCEDURE FOR INFORMATION ONLY

PERFORM LIFE CYCLE TESTING

1 PACK	PERFORM V/T CHARACTERIZATION
1 PACK	ACCELERATED GEO
3 PACKS	LEO REGIME @ VARIOUS TEMPERATURES

Cells have been procured in groups of 20-25 and being evaluated according to the plan outlined above. The testing involves a repeat of a portion of the manufacturer's acceptance tests to verify performance, running the NASA Standard Acceptance Test procedure, for information only, to establish a common standard data base among the cells from the various manufacturers, and finally, cycle life testing under a variety of conditions.

NICKEL-CADMIUM CELL VERIFICATION

LIFE CYCLE TEST REGIMES FOR Ni-Cd CELL EVALUATION

TEST/ PACK	DESCRIPTION	DOD (%)	TEMP (°C)	DETAILS OF REGIME
1	V/T CHARACTERIZATION - SHOCK/VIBRATION			V/T CHARACTERIZATION - PROCEDURE
2	STANDARD STRESS TEST	40	20	CHARGE - 1 HR, 0.8C TO V/T LIMIT, TAPER DISCHARGE - 0.8C FOR 30 MINUTES - TO 40% DOD
3	HIGH TEMPERATURE STRESS TEST	40	30	CHARGE - 0.8C TO V/T LIMIT, TAPER DISCHARGE - 0.8C FOR 30 MINUTES - TO 40% DOD
4	LOW TEMPERATURE STRESS TEST	40	0	CHARGE - 0.8C TO V/T LIMIT, TAPER DISCHARGE - 0.8C FOR 30 MINUTES - TO 40% DOD
5	ACCELERATED GEO	80	10	2 WEEK SUN PERIODS/RECONDITIONING TBD

PLAN REQUIRES MINIMUM OF 25 CELLS - IF ONLY 20 CELLS ARE AVAILABLE - THE SAME PACK WILL BE USED FOR TESTS 1 AND 5.

The chart above summarizes the test conditions for the test packs of nickel-cadmium cells.

NICKEL- CADMIUM LEO TEST SUMMARY

11/21/96

PACK ID	VENDOR	DESCRIPTION	CAP (AH)	# OF CELLS ORIG	CONDITIONS DOD (%)	CONDITIONS TEMP (oC)	STATUS CYCLES	COMMENTS
6000A	HUGHES	ADVANCED Ni-Cd - Z/PS	20	5	40	20	28723	Stopped Testing
6001A	HUGHES	ADVANCED Ni-Cd - Z/PS	20	5	40	20	28308	Stopped Testing
6002A	HUGHES	ADVANCED Ni-Cd - PP/PBI	20	5	40	20	25359	Stopped Testing
6003A	HUGHES	ADVANCED Ni-Cd - Z/PBI	20	8	40	20	25219	Stopped Testing
6004A	HUGHES	ADVANCED Ni-Cd - Z/PS	20	8	25	30	25892	Stopped Testing
6005A	HUGHES	ADVANCED Ni-Cd - Z/PS	20	8	40	30	18909	Stopped Testing
6006A	HUGHES	SUPER Ni-Cd - Z/PBI +ADD	20	8	40	20	21601	Stopped Testing
6024S	SAFT		24	5	40	0	39238	
6120S	SAFT	VOS A	20	5	40	20	20900	Stopped Testing
6124S	SAFT	VOS B	24	5	40	20	26091	Stopped Testing
6140S	SAFT		40	5	40	20	19298	
6601S	SAFT	Ni-Cd	50	5	40	0	9611	
6621S	SAFT	Ni-Cd	50	5	40	20	10077	
6631S	SAFT	Ni-Cd	50	5	40	30	10006	Failed at 30, temp reduced to 10
6601R	SANYO	Ni-Cd - advanced cell	35	5	40	0	12752	
6620R	SANYO	Ni-Cd - advanced cell	35	5	40	20	13107	
6621R	SANYO	Ni-Cd - standard cell	35	5	40	20	12705	
6631R	SANYO	Ni-Cd - advanced cell	35	5	40	30	12972	

NICKEL- CADMIUM LEO TEST SUMMARY - CONTINUED

11/21/96

PACK ID	VENDOR	DESCRIPTION	CAP (AH)	# OF CELLS ORIG	CONDITIONS DOD (%)	CONDITIONS TEMP (oC)	STATUS CYCLES	COMMENTS
0020E	EP-CS	Magnum Ni-Cd	21	5	40	20	3988	
0031E	EP-CS	Magnum Ni-Cd	21	5	40	30	3917	
6601E	EP-CS	Magnum Ni-Cd	21	5	40	0	3666	
0020H	EP-CS	Super Ni-Cd	21	5	40	20	4859	
0031H	EP-CS	Super Ni-Cd	21	5	40	30	3938	
0601H	EP-CS	Super Ni-Cd	21	5	40	0	4488	
0018N	ACME	Nylon	18	5	40	20	5338	
0018P	ACME	Polypropylene	18	5	40	20	5337	
0055N	ACME	Nylon	55	5	40	20	5385	
0055P	ACME	Polypropylene	55	5	40	20	5340	
0121M	EP-CS	Magnum Ni-Cd	21	5	40	20	10667	
6122M	EP-CS	Magnum Ni-Cd	10		40	20	13687	
6522M	EP-CS	Magnum Ni-Cd	50		40	20	12982	
0106M	EP-CS	Magnum Ni-Cd	21	5	VAR	0	8004	
6106M	EP-CS	Magnum Ni-Cd	10	5	VAR	0	11645	
6506M	EP-CS	Magnum Ni-Cd	50		VAR	0	12126	

NICKEL-CADMIUM BATTERY TECHNOLOGY

APPLIED NICKEL-CADMIUM TECHNOLOGY - JPL

OBJECTIVE: DEVELOPMENT OF Ni-Cd PERFORMANCE MODEL FOR PREDICTION OF BATTERY PERFORMANCE UNDER SPECIFIED SPACECRAFT OPERATIONAL CONDITIONS

BASED ON FIRST PRINCIPLES

DESKTOP - MACINTOSH VERSION OF MODEL IS UNDERGOING FIELD TESTING

CAPABILITIES SUMARIZED IN *J.ELECTROCHEM SOC* ***143,*** *803* (1996)

CURRENT PLANS INVOLVE THE FOLLOWING REFINEMENTS
- INCLUDE DEGRADATION CAPABILITIES,
- BETTER DEFINED CHEMICAL EQUATIONS,
- MORE SOPHISTICATED ALGORITHMS
- IMPLEMENTATION ON DESKTOP COMPUTERS

The Jet Propulsion Laboratory is responsible for the Applied Nickel-Cadmium Technology subtask. This subtask involves the development of an electrochemical model of the nickel-cadmium system that involves physical, chemical, and electrochemical studies at the component and cell levels. The model will be used to develop an accelerated test which can be used to determine the quality and reliability of flight lot cells without extensive life testing and to predict the performance of a battery from a set of spacecraft operating conditions. The model is scheduled for completion this fiscal year.

NICKEL-HYDROGEN BATTERY TECHNOLOGY

CELL COMPONENT AND IPV DESIGN EVALUATION - LeRC

OBJECTIVE: PROVIDE INDEPENDENT VERIFICATION OF DESIGN AND COMPONENT VARIATIONS TO MANUFACTURING FLIGHT CELLS BY PROCURING AND TESTING REPRESENTATIVE CELLS FROM VARIOUS MANUFACTURES

VERIFICATION OF 26% KOH
- CELLS FROM HUGHES, EAGLE PICHER, GATES, YARDNEY

EVALUATION OF DESIGN FEATURES
- CATALYZED WALL WICK
- CELL STACKING
- ADVANCED DESIGN FEATURES IN ISS DESIGN CELLS
- 350Ah, 5 ½" HUGHES CELL - EVALUATION

EVALUATION OF CELL COMPONENTS
- NICKEL ELECTRODE IMPREGNATION PROCESS
- SEPARATOR
- PASSIVATION OF ELECTRODE PLAQUE

The major goal of the Nickel-Hydrogen Technology subtask is to evaluate design features for incorporation into nickel-hydrogen cells for NASA missions. The Lewis Research Center has responsibility for the Nickel-Hydrogen Technology subtask. Currently, the effects of the NASA advanced design features and the effects of 26% vs 31% KOH, cell design variations including stacking arrangements and impregnation processes are being evaluated in flight cells being tested at Crane.

NICKEL-HYDROGEN CELL TEST STATUS

PACK ID	VENDOR	DESCRIPTION	CAP (AH)	# OF CELLS		CONDITIONS		STATUS CYCLES	DATE	FAILURES
				ORIG	LEFT	DOD (%)	TEMP (oC)			
5000L	HUGHES	26% KOH - AF STANDARD	50	3	0	80	10	-	-	15314,19500,23700
5000L	HUGHES	31% KOH - AF STANDARD	50	3	0	80	10	-	-	3729,4165,11355
5001L	EPI	NASA ADV DESIGN w/ CAT WW	125	3	3	60	10	42792	11/18/96	
5001L	EPI	NASA ADV DESIGN w/o CAT WW	125	3	0	60	10	-		9588,13900,20575
5007L	GATES	26% KOH	65	5	5	60	10	25879	11/18/96	
5007L	GATES	31% KOH	65	5	0	60	10	-	-	10824,10975,11455,12244,12471
5004L	EPI	26% KOH - AQUEOUS	65	3	3	60	10	25787	11/18/96	
5004L	EPI	31% KOH - AQUEOUS	65	3	3	60	10	25787	11/18/96	
5004L	EPI	26% KOH - ALCOHOLIC	65	3	3	60	10	25787	11/18/96	
5004L	EPI	31% KOH - ALCOHOLIC	65	3	3	60	10	25787	11/18/96	
3008L	EPI	BTB DESIGN w/CAT WW	65	3	0	60	10	-	-	10931, 12236, 12236
3008L	EPI	RECIRCULATION	65	3	2	60	10	23700	11/18/96	20100
5006L	YTP	26% KOH	56	3	2	60	10	22862	11/18/96	21907
5006L	YTP	31% KOH	56	3	0	60	10	-	-	12503, 12949, 12949
5002L	EPI	PE FILM/PE PAPER	50	3	0	60	10	0	-	LOW CAPACITY - NO LEO
5002L	EPI	PE FILM/PP FELT	50	3	0	60	10	0	-	LOW CAPACITY - NO LEO
5002L	EPI	ASBESTOS	50	3	0	60	10	-	-	2309,2309,2756
5002L	EPI	PE FILM/ZIRCAR	50	3	0	60	10	-	-	All @ ~6700
5008	HUGHES	PASSIVATED		3		60	10	13195	11/18/96	
5008	HUGHES	NON PASSIVATED		3		60	10	13195	11/18/96	
3002L	EPI	CPV	10	10	9	40	10	12776	11/18/96	CELL REMOVED FOR DPA
3003L	JCI	CPV	50	1	1	35	10	9915	11/18/96	

There are many design variations for nickel-hydrogen cells. The systematic testing being performed in this task is intended to differentiate between the design features and components. Cells from various manufactures with varied design features are being tested. The status of the current tests on cells is summarized above.

NICKEL-HYDROGEN BATTERY TECHNOLOGY

LOCKHEED-MARTIN IPV CELL TESTING

SUPPORT FOR LOCKHEED-MARTIN IPV Ni-H_2TESTS

CELL DESIGN VARIABLES AND TEST HISTORIES MADE AVAILABLE

CELL DATA TRANSFERRED TO CRANE FOR INCORPORATION INTO THE DATA BASE

The life cycle testing at Lockheed-Martin in Denver is the longest running nickel-hydrogen test program. NASA began supporting this program in 1992. In return for this support, all of the information relating these cells has been made available to NASA. This includes the pack histories, cell design information, DPA results and all cycle test data. The cycle test data is being incorporated into the NASA data base at Crane.

LOCKHEED-MARTIN NI-H2 LIFE TEST - CELL CHARACTERISTICS

ONGOING TESTS HIGHLIGHTED

VENDOR	CAP AH	DIA IN	DOD %	TEMP °C	# OF CELLS	STACK CONFIG	KOH %	SEP	SINTER	IMPREG	COMMENTS
EP-J	50	3.5	40	10	16	RECIRC	31	ZIRCAR	DRY	AQUEOUS	
EP-J	50	3.5	40	20	8	RECIRC	31	ZIRCAR	DRY	AQUEOUS	
EP-J	50	3.5	60	10	8	RECIRC	31	ZIRCAR	DRY	AQUEOUS	
EP-J	50	3.5	60	20	4	RECIRC	31	ZIRCAR	DRY	AQUEOUS	
[illegible]											
GATES	50	3.5	40	20	8	RECIRC	31	ZIRCAR	DRY	AQUEOUS	
GATES	50	3.5	60	10	8	RECIRC	31	ZIRCAR	DRY	AQUEOUS	
GATES	50	3.5	60	20	4	RECIRC	31	ZIRCAR	DRY	AQUEOUS	
YARDNEY	50	3.5	40	10	6	RECIRC	31	ASB/ZIR	SLURRY	AQUEOUS	
YARDNEY	50	3.5	60	10	6	RECIRC	26	ASB/ZIR	SLURRY	AQUEOUS	CONST CHG
YARDNEY	50	3.5	60	10	6	RECIRC	31	ASB/ZIR	SLURRY	AQUEOUS	CONST CHG
YARDNEY	50	3.5	60	10	3	RECIRC	26	ASB/ZIR	SLURRY	AQUEOUS	MOD CHG
YARDNEY	50	3.5	60	10	3	RECIRC	31	ASB/ZIR	SLURRY	AQUEOUS	MOD CHG
EP-J	50	3.5	40	10	4	BTB	31	ZIRCAR	DRY	AQUEOUS	COMSAT
[illegible]											
YARDNEY	100	4.5	40	10	4	RECIRC	31	ZIRCAR	SLURRY	AQUEOUS	DUAL STK
[illegible]											

The chart above lists the design features for the cells in the Lockheed-Martin program. Ongoing tests are highlighted.

LOCKHEED-MARTIN NICKEL-HYDROGEN LIFE TEST STATUS

ONGOING TESTS HIGHLIGHTED

MANUFACT-URER	CAP AH	DIA IN	DOD %	TEMP °C	# OF CELLS	CELLS REMAIN	CYCLES	AVG EODV	AVG EOCV	C:D
EP-J	50	3.5	40	10	16	0	42259			
EP-J	50	3.5	40	20	8	0	24309			
EP-J	50	3.5	60	10	8	0	9499			
EP-J	50	3.5	60	20	4	0	5304			
[illegible]										
GATES	50	3.5	40	20	8	0	36612			
GATES	50	3.5	60	10	8	0	10232			
GATES	50	3.5	60	20	4	0	9013			
YARDNEY	50	3.5	40	10	6	0	22318			
YARDNEY	50	3.5	60	10	6	0	10746			
YARDNEY	50	3.5	60	10	6	0	7717			
YARDNEY	50	3.5	60	10	3	0	11018			
YARDNEY	50	3.5	60	10	3	0	8210			
EP-J-COMSAT	50	3.5	40	10	4	0	14691			
[illegible]										
YARDNEY	100	4.5	40	10	4	0	25545			
[illegible]										

The chart above summarizes the status of the ongoing tests in the Lockheed-Martin program. Ongoing tests are highlighted.

NICKEL-HYDROGEN BATTERY TECHNOLOGY

CPV BATTERY EVALUATION

OBJECTIVE: EVALUATE POTENTIAL OF EMERGING CPV TECHNOLOGY TO MEET NASA's FUTURE NEEDS. DEVELOP DATA BASE TO INSURE OPTIMUM BATTERY MANAGEMENT AND SUPPORT FOR MISSIONS

EVALUATION OF 2.5" CPV BATTERIES - LeRC

10, 2 CELL, 10AH CPV BATTERIES EAGLE PICHER
LEO LIFE TEST, 40% DOD, 10°C
12,700 CYCLES - ONE CELL REMOVED FOR DPA

CHARACTERIZATION OF 2.5" CPV BATTERIES - JPL

CHARACTERIZATION/MISSION SIMULATION TESTS ON 2.5"CPV TESTS

JOINT TASK WITH AIR FORCE - 3.5" CPV BATTERIES

21, 2-CELL, 45AH CPV BATTERIES - EAGLE PICHER
3 PACKS - 2 LEO 40% DOD -5 °C, 10 °C, 1 GEO

As NASA missions change to smaller, less expensive satellites with volume and weight concerns, there is a need to incorporate new technologies to meet these needs. CPV batteries are being baselined for a number of NASA missions. This task provides a data base that will aid in insuring optimum battery management for systems using this technology.

NICKEL-HYDROGEN BATTERY TECHNOLOGY

SPV BATTERY EVALUATION - LeRC

OBJECTIVE: EVALUATE POTENTIAL OF EMERGING SPV TECHNOLOGY TO MEET NASA'S FUTURE NEEDS

JOHNSON CONTROLS - SPV BATTERY

28 VOLT, 50 AH BATTERY
35% DOD, 10°C ~10,000 CYCLES
JOINT EVALUATION WITH ISS

As NASA missions change to smaller, less expensive satellites with volume and weight concerns, there is a need to incorporate new technologies to meet these needs. SPV batteries are being considered for future NASA missions. This task provides a data base that will aid in insuring optimum battery management for systems using this technology.

NICKEL-HYDROGEN BATTERY TECHNOLOGY

NICKEL-HYDROGEN MODEL - JPL

OBJECTIVE - DEVELOP A COMPUTER MODEL CAPABLE OF PREDICTING ORBITAL PERFORMANCE OF A NICKEL-HYDROGEN BATTERY USING A CELL LEVEL ELECTROCHEMICAL MODEL BASED ON FUNDAMENTAL PHENOMENA

DEVELOPMENT PARALLELS Ni-Cd MODEL

PRELIMINARY VERSION OF THE MODEL THAT OPERATES ON A PC IS AVAILABLE AND UNDER EVALUATION

PLANS INCLUDE
- CONTINUED VALIDATION AND CALIBRATION
- INCORPORATION OF THERMAL MODEL

JPL is responsible for developing a computer model for nickel-hydrogen batteries that parallels the work done on the nickel-cadmium model.

NICKEL-HYDROGEN BATTERY TECHNOLOGY

DEVELOPMENT OF Ni-H_2 STRESS TEST - MSFC

OBJECTIVE: DEFINE AND VERIFY A STRESS TEST FOR NICKEL-HYDROGEN, COMPARABLE TO THE 40% DOD, 20°C TEST FOR NICKEL-CADMIUM CELLS

60% DOD, 10°C - PRELIMINARY PROFILE FOR THE STRESS TEST

MATRIX DEVELOPED FOR IDENTIFICATION OF TEST CONDITIONS

TEMPERATURE	DEPTH OF DISCHARGE		
20°C	35%	50%	65%
10°C	45%	60%	75%

EAGLE PICHER 48 AH CELLS FOR AXAF
AVERAGE CAPACITY AT 10°C -63.5AH AT C/2, WHERE C=48,

The Marshall Space Flight Center is responsible for the task defining the conditions for a nickel-hydrogen stress test similar to the 40%DOD, 20 °C test currently used for Ni-Cd cells. An analysis of the nickel-hydrogen data base resulted in a preliminary recommendation of 60% DOD, 10°C as the comparable Ni-H_2 test conditions. A matrix has been developed to identify the appropriate test conditions. Eagle Picher 48 Ah cells, similar to those ordered for AXAF are being used in this evaluation.

NICKEL-HYDROGEN BATTERY TECHNOLOGY

DEVELOPMENT OF Ni-H_2 STRESS TEST - MSFC

STRESS TEST STATUS

EARLY FAILURES

65% DOD - 20°C	961-1177 CYCLES
75% DOD - 10°C	1085-1188 CYCLES
60% DOD - 10°C	2037-2400 CYCLES
50% DOD - 20°C	2375-3200 CYCLES

CONTINUING TESTS

35% DOD - 20°C
45% DOD - 10°C

CAUSE OF FAILURES IS UNDER INVESTIGATION

Testing of the cells per the matrix discussed on the previous chart has begun. To date four, of the packs have experienced early failures after less than 3200 cycles. The cause of the failures is under investigation.

NICKEL-METAL HYDRIDE TECHNOLOGY

NICKEL-METAL HYDRIDE TECHNOLOGY EVALUATION

OBJECTIVE EVALUATE POTENTIAL OF Ni-MH TECHNOLOGY TO MEET NASA's FUTURE NEEDS

EVALUATION OF AEROSPACE DESIGN CELLS - LeRC

EAGLE PICHER - 6-10Ah CELLS - 40%DOD, 10°C
- 3 FAILURES - 10000, 14047, 16129 CYCLES
- ONGOING TESTS - 17556 CYCLES

SANYO - 25 - 35Ah CELLS -
- CHARACTERIZATION TESTS COMPLETED
- TO BE RUN IN Ni-Cd VERIFICATION PROFILE

Nickel-metal hydride batteries have the potential to replace nickel-cadmium and in some cases nickel-hydrogen batteries. This task is evaluating this potential. Aerospace design cells from Eagle Picher are on LEO life test at 40% DOD, 10°C. Aerospace design cells from Sanyo are being evaluated in tests that parallel the nickel-cadmium verification tests previously discussed.

NICKEL-METAL HYDRIDE TECHNOLOGY

CHARACTERIZATION OF CELLS FROM OVONICS - GSFC

6.7 Ah CELLS

CALORIMETRIC ANALYSIS, CAPACITY, CHARGE RETENTION

6 CELLS - ACCELERATED GEO CYCLES - 240 CYCLES

LEO CYCLES - 20°C, 40% DOD - 830 CYCLES TO FAILURE

GSFC is responsible for basic calorimetric measurements on nickel-metal hydride cells. Cells from Ovonic Battery Company are being evaluated in LEO and GEO cycle regimes.

NICKEL-METAL HYDRIDE TECHNOLOGY

NI-MH COMMERCIAL CELL EVALUATION - JSC

EVALUATE Ni-MH POTENTIAL FOR EVA's, IVA's FOR SPACE STATION

DETERMINE BEST AVAILABLE COMMERCIAL Ni-MH

EVALUATE CHARGE METHODOLOGY
- BURP CHARGING DEMONSTRATED ADVANTAGES -
  - CHARGE EFFICIENCY, MINIMIZE CHARGE DURATION, INCREASED CAPACITY & CYCLE LIFE

900 - 100% DOD CYCLES WITH SANYO 4/3 A CELLS

Ni-MH DEMONSTRATED GOOD ABUSE TOLERANCE

DEVELOP AND CERTIFY NI-MH BATTERY FOR EMU BACKPACK, ADVANCED HELMET LIGHTS, CUFF CHECK LIST

JSC is evaluating nickel-metal hydride batteries, chargers and charge methods for use in IVA's and EVA's. Replacement of primary batteries with secondary batteries for in-cabin applications on the space shuttle and for the space station has the potential of significant cost savings.

LITHIUM -ION BATTERY TECHNOLOGY

OBJECTIVE EVALUATE POTENTIAL OF Li-ION TECHNOLOGY TO MEET NASA's FUTURE NEEDS. ENABLE TECHNOLOGY DEVELOPMENT FOR AEROSPACE APPLICATIONS

Li-ION TECHNOLOGY ASSESSMENT - JPL

TECHNOLOGY REVIEW - STATUS ASSESSED FOR AEROSPACE APPLICATIONS

EVALUATE COMERCIAL PRODUCTS FROM SONY, SAFT, SANYO, & YARDNEY

DOCUMENTATION OF MANUFACTURING PROCESSES

DEVELOPMENT OF GUIDELINES DOCUMENTS

NASA is evaluating the potential of Lithium Ion technology to meet our future needs. Li-Ion is an enabling technology for many NASA missions. This technology offers the potential for reduced weight and volume.

The preliminary assessment consists of a review of the status of the technology available from the various manufacturers and characterization and life-cycle testing of today's technology.

LITHIUM -ION BATTERY TECHNOLOGY

LITHIUM ION CELL CHARACTERIZATION - GSFC

CHARACTERIZATION, CYCLE TESTING, DPA OF CELLS FROM CURRENT MANUFACTURERS

SAFT - 3.5" CELLS EVALUATED FOR TEMPERATURE EFFECTS ON CAPACITY, VOLTAGE AND SELF DISCHARGE

Li-ION DESIGN DEVELOPMENT - LeRC

IMPROVE ANODE - MODIFY CARBON SUBSTRATES TO FACILITATE Li ION INSERTION AND INCREASE Li CAPACITY

LITHIUM -ION BATTERY TECHNOLOGY

LI-ION COMMERCIALCELL EVALUATION - JSC

INCORPORATION OF NEW TECHNOLOGY BATTERIES INTO GFE EQUIPMENT - LAPTOP COMPUTERS, CAMCORDERS - REQUIRES UNDERSTANDING OF SAFETY ISSUES RELATING TO SPACE USE AND QUALIFICATION OF NEW TECHNOLOGY

OBTAIN COMMERCIAL CELLS - PERFORM EVALUATION
- CHARACTERIZATION,
- CHARGE CONTROL PARAMETERS,
- PERFORMANCE
- THERMAL CHARACTERIZATION
- ABUSE TOLERANCE

FLIGHT BATTERY MISSION TESTS

TOPEX - JPL
MISSION SIMULATION TESTS

MARS GLOBAL SURVEYOR - JPL
20 AH 2-CELL CPV's
STRESS TEST, MISSION SIMULATION, PERFORMANCE VERIFICATION

CLARK SATELLITE SPV DESIGN EVALUATION - LeRC
15AH, 28 VOLT , FLIGHT SPARE, I&T BATTERIES

BATTERY TEST BED - JPL
MISSION SUPPORT - GRO, UARS, EUVE, TOPEX.
MANAGE DIVERGENT CELLS/BATTERIES - FACILITY SIMULATE MPS POWER SYSTEM

NASA projects are beginning to baseline non-traditional battery systems for future missions. In order to increase the data base on these systems and to provide timely support, these technologies are being investigated as part of the battery program. In many cases these efforts are entered into jointly with the programs or other NASA codes. The test data and experience provide benefits throughout the agency.

SECONDARY BATTERY TECHNOLOGY SUPPORT

DEVELOPMENT OF DPA TEST PROCEDURES - MSFC

OBJECTIVE: DEFINE GENERAL GUIDELINES TO BE FOLLOWED BY FACILITIES PERFORMING DPA PROCEDURES ON NICKEL-CADMIUM AND NICKEL-HYDROGEN CELLS

AVAILABLE PROCEDURES HAVE BEEN EVALUATED

DRAFT GUIDELINES DOCUMENTS HAVE BEEN PREPARED

AEROSPACE WILL WRITE MANUAL

The Marshall Space Flight Center has the responsibility for developing and establishing guidelines for NASA for the performance of destructive physical analyses for Ni-Cd and Ni-H_2 chemistries. Current DPA procedures used in the industry are being evaluated in an effort to identify a standard procedure for the agency. Drafts of the guidelines documents have been prepared.

SECONDARY BATTERY TECHNOLOGY SUPPORT

DEVELOPMENT OF SEPARATOR TEST PROCEDURES - LeRC

OBJECTIVE: DESIGN AND DEVELOPMENT OF UNIFORM RELIABLE TEST PROCEDURES FOR EVALUATING CANDIDATE SEPARATOR MATERIALS FOR Ni-Cd, Ni-H_2 & Ni-MH CELLS

DETAILED PROCEDURES FOR STANDARD TESTS TO EVALUATE SEPARATORS HAVE BEEN DEVELOPED

PUBLICATION BY END OF FISCAL YEAR

The Lewis Research Center has produced a manual that recommends standard separator test procedures. The manual defines improved tests that will more closely evaluate separator characteristics as related to the actual cell environment. Publication of a document containing the recommended test procedures is expected before the end of the fiscal year.

PRIMARY BATTERY TECHNOLOGY TASK

OBJECTIVE:

IMPROVE PERFORMANCE, QUALITY, SAFETY AND RELIABILITY OF PRIMARY BATTERY SYSTEMS

TASK

SAFETY CONTROLS FOR LITHIUM CELLS

The objective of the Primary Battery Technology Task is to improve the performance, reliability and safety of primary battery systems. The Johnson Space Center has primary responsibility for work performed in the primary battery area.

The major task in the primary battery technology area is the development of safety controls for primary Li-BCX Cells.

SAFETY CONTROLS FOR LITHIUM CELLS

OBJECTIVE — INCREASE SHORT CIRCUIT HAZARD TOLERANCE BY REDUCING MOLARITY OF ELECTROLYTE AND THUS REDUCE CAPABILITY TO SUSTAIN HIGH SHORT CIRCUIT CURRENT FOR EXTENDED TIME

Li-BCX CELLS FROM WGL - C, D, DD

DETERMINE MINIMUM CONCENTRATION TO MAINTAIN CAPACITY REQUIREMENTS WHILE REDUCING SHORT CIRCUIT CURRENT TO PREVENT VENTING OR RUPTURE

PERFORMANCE, ABUSE, SHELF LIFE DETERMINATIONS AND QUALIFICATION OF CELLS WITH REDUCED ELECTROLYTE LEVELS

LEVELS ESTABLISHED FOR C AND D CELLS, DD EFFORT IS UNDERWAY

Successful implementation of safety controls for Li-BCX cells will result in the elimination of the need to fly the cells with a waiver . The approach used in this task is to reduce the electrolyte concentration to a level that will no longer support a short circuit current and thus prevent cell venting and ruptures.

SUMMARY REMARKS

BATTERY PROGRAM HAS BEEN REALIGNED TO BE CONSISTENT WITH NASA's STRATEGIC PLAN

EMPHASIS HAS SHIFTED FROM RELIABILITY, QUALITY ASSURANCE ROLE TO BROAD SUPPORT FOR NASA ENTERPRISES

BATTERY PROGRAM HAS RESULTED IN INCREASED COMMUNICATION AND COOPERATION AMONG NASA CENTERS AND WITHIN THE AEROSPACE BATTERY COMMUNITY

THE PROGRAM ADDRESSES FLIGHT BATTERY ISSUES RELATING TO NASA's FLIGHT PROGRAMS

The NASA Aerospace Flight Battery Systems Program has been realigned to be consistent with NASA's strategic plan. Emphasis in the program has been shifted to provide broad support for each of the NASA enterprises.

The program has provided for increased communication within the agency and with the battery industry as well. The program addresses flight battery and related flight power system activities which are essential for ensuring safe and reliable performance.