SUMMARY OF JPL ACTIVITIES

Paul Timmerman
Subbarao Surampudi
Outline

JPL Program Summary
Ni-H2 Cell Testing
Li-Ion Technology
NASA Telecons
Battery Laboratory
JPL Flight Program Summary

Solar System Exploration

Deep Space 1 - Asteroid Rendezvous
Deep Space 2 - Mars Penetrator
Mars Global Surveyor
Mars Surveyor '98
Stardust - Comet Sample Return
Europa Orbiter - Jupiter Lunar System Explorer
Mars Surveyor 2001
Mars "03 Lander and Rover
JPL Flight Program Summary (cont'd)

Earth Sciences

ACRIMSAT - Active Cavity Radiometer Irradiance Monitor
TOPEX/Poseidon - Ocean Topography Experiment
Jason-1 - Ocean Topography Experiment Follow-On
QuikScat /Seawinds - Ocean Winds Tracking

Astrophysics

Genesis - Solar Dust Return
Deep Space 1

Mission:
Its first destination was the near-Earth asteroid Braille. Deep Space 1 flew by this asteroid on July 28, 1999. The New Millennium Program is conducting to demonstrate new technologies in the environment of space.

Launch:
October 24, 1998 from Cape Canaveral, Florida.

Completion:
Deep Space 1 began thrusting toward Comet Wilson-Harrington less than 36 hours after encountering Braille.

Batteries: CPV NiH2, 12AH, 11-Cell, Dual String
MARS GLOBAL SURVEYOR

Launched 6 Nov. 1996
Regulated Direct Energy Transfer System
  4 Solar Array Panels (2 GaAs, 2 Si) Capable of Generating 667 W @ Aphelion
  2 - 20 Amp-hr Nickel Hydrogen (NiH2) Batteries
  28 Vdc +/-2% Regulated Bus

BATTERY
  2 BATTERIES / 8 NiH₂ CP V'S PER BATTERY
  VOLTAGE MONITORED AT BATTERY AND HALF BATTERY LEVEL
  2 STRAIN GAUGES AND 2 TEMPERATURE SENSORS PER BATTERY
  CHARGE CONTROL: V/T WITH PRESSURE AND AHR INTEGRATION

REGIME
  11 MONTH CRUISE (THREE 40% DOD CYCLES)
  MODIFIED AEROBRAKING (TO MAINTAIN S/A INTEGRITY)
  ~8500 MAPPING CYCLES (29% DOD) AND ~14,000 RELAY CYCLES (24% DOD)
MGS EONV TREND

Voltage (Volts)

Date


- B1 EOD Voltage
- B2 EOD Voltage
MARS SURVEYOR '98

Mars Climate Orbiter
Launch: Dec 10, 1999
Mars Orbit: Sep 23, 1999

Mars Polar Lander
Launch: Jan 3, 1999
Mars Landing: Dec 3, 1999

ORBITER BATTERY REQUIREMENTS 13,500 CYCLES @ 50% DOD
BOTH ORBITER AND LANDER WILL USE 2.5" 2-CELL CPV NiH₂ BATTERIES
16 Amp-Hour capacity (RNHC-16-1, Lot 5)
11 CPVs for the orbiter and 11 CPVs and one IPV for the lander
Rabbit Ear, Teflon coated wall, 31% KOH
LANDER WILL CARRY TWO PROBES FOR THE DS-2 MISSION

Paul.J.Timmerman@jpl.nasa.gov
ELECTROCHEMICAL SYSTEMS GROUP
MARS MICROPROBE DS-2

Mission:
Characterize Martian Sub-surface soil
Aft body plus forebody ~2Kg
Demonstrate Key Technologies for future missions
(low temp performance, flex cabling, Telecom-on-a-chip)

Batteries:
Lithium-Thionyl Chloride
- 80°C Environment
80,000 g shock,
Voltage 6-14 V,
550 mAhr capacity @ -80°
Yardney Technical Products

Paul.J.Timmerman@jpl.nasa.gov
ELECTROCHEMICAL SYSTEMS GROUP
SAFE AMERICA

Lithium/Sulfur Dioxide
Sample Return Capsule Battery
Cell Design Similar To Msp, 96
16 Amp-Hour Capacity (RNC61-1 Lot 6)

2.5" 2-Cell CPV NiH2 Batteries
Battery Design
7 Year Cruise + 1 Year Pre-Launch
Low Cycle Life (~200 Cycles @<71% DOD)
Battery Regime

Sample Return Mission - The Stardust

Using a streamlined, low-cost reentry capsule, Stardust will return to the Earth in January of 2006 and drop off the samples
commanded by the Galileo mission. This Interstellar Dust was first discovered by Voyager in 1993 and later
our solar system from the Interstellar
cometary particles that recently came to
during cruise, Stardust will collect
into comets at the birth of the solar system,
ancient pre-solar Interstellar Grains and
volatiles. The comet samples are made up of
early 2004 and collected cometary dust and
kilometers (62 miles) of the comet Vtld-2 in
mission will fly within approximately 100
Europa Orbiter

Missions:
Explore the Frozen Oceans on Moon of Jupiter and look for signs of Life

Batteries: Cold and Wet

Solar Probe

Mission: This first exploration mission to the Sun's Corona seeks a new understanding of a star by flying through its corona.

Batteries: Hot and Dry
Mars Surveyor 2001
This mission will allow scientists to study the ancient climate and geologic history of Mars, investigate the role water may have played on Mars in the past and search for evidence of ancient life.

The Mars Surveyor 2001 Orbiter
Mission:
It will arrive at Mars on Dec. 10, 2001.
Battery:
NiH2 2.5” CPV RNHC16-1 or 16-9

Mars Surveyor 2001 Rover / Lander
Mission:
Land on Mars on Jan. 27, 2002.
Batteries:
Lander: Li-Ion batteries, 7AH size
Rover: Same Li-SO₄ D-Cells as used in “98

Paul.J.Timmerman@jpl.nasa.gov
ELECTROCHEMICAL SYSTEMS GROUP
ACRIMSAT - Active Cavity Radiometer Irradiance Monitor:

Mission: Study of the Solar Activity
System Contractor: Hughes (in STV)
Launch: 2000
Completion: TBD
Batteries: Ni-H2 ?
TOPEX

PRIME CONTRACTOR - FAIRCHILD
MODULAR POWER SUBSYSTEM / McDac
NASA STANDARD BATTERY (3 x 22 CELL)
50 Amp-Hr CELLS / GATES AEROSPACE
PELLON 2505 SEPARATOR / Eagle-Picher
NONPASSIVATED POS / TEFLOLATED NEG

LAUNCH AUGUST 10, 1992

BATTERY OPERATIONAL STRATEGY

LIMIT PEAK CHARGE TO LESS THAN 24 AMPS
LIMIT RECHARGE RATIO (C/D) TO 105 (+/-3%)
OPERATE AT LOWEST PRACTICAL (V/T 3 FULL SUN, V/T 4 ECLIPSES)
AVOID HIGH CHARGE CURRENTS DURING FULL SUN PERIODS
CURRENT STATUS - OVER 85 MONTHS SUCCESSFUL OPERATION

Paul.J.Timmerman@jpl.nasa.gov
ELECTROCHEMICAL SYSTEMS GROUP
Jason-1

Mission: Follow-up Mission to TOPEX

Spacecraft Contract: ESA/France/AS

Launch: 2000

Completion: TBD

Batteries: Single String Ni-H$_2$ IPV / SAFT
QuikScat/Seawinds

Mission: Microwave radiometry - measuring wind speed and direction over Earth's oceans.

System Contractor: Ball Aerospace

Launch: June 19, 1999
Completion: TBD
Batteries: E.P. CPV Ni-H₂
Genesis

Mission:
Return solar matter for compositional analysis in terrestrial laboratories. Ultra pure materials will be exposed to the solar wind for two years.

System:
This system is to use the New X2000 power subsystem under development at JPL.

Batteries:
RNH16-9, 11 Cell, CPV Ni-H2
GRACE (Gravity Recovery and Climate Experiment) Produce a new model of the Earth's gravity field with unprecedented accuracy every 12 to 15 days for five years. Launch 2001,

System Contract: German

Battery: CPV NiH2
CELL TESTING

Ni-H$_2$

2.5" CPV Characterization - On Going

3.5" CPV Characterization - On Going

MGS Simulation - Over 2300 Cycles

Ni-Cd

Topex Simulation - 21 Occultations on Zero Degree Pack
CPV EVALUATION

TECHNOLOGY STATUS
NUMEROUS BATTERIES FLYING OR BEING BUILT
PREVIOUS MECHANICAL PROBLEMS HAVE BEEN ELIMINATED

MISSIONS USING CPV
NEW MILLENIUM DS-1, MARS '98 (ORBITER AND LANDER), MARS 2001 ORBITER
STARDUST, GENESIS, GRACE, SIRTF, GOES

PROGRAM
PROCURE REPRESENTATIVE SAMPLES FROM FLIGHT LOTS
DEVELOP A PERFORMANCE DATABASE - CHARACTERIZATION TESTS
PERFORM MISSION SIMULATION TESTING
PROVIDE SUPPORT TO PROGRAMS THROUGH TELCONS AND WORKSHOP
FOLLOW DEVELOPMENT OF NEW DESIGNS

Paul.J.Timmerman@jpl.nasa.gov
ELECTROCHEMICAL SYSTEMS GROUP
### 2.5'' CPV DESIGNS

SIZES CURRENTLY MANUFACTURED BY E.P.

<table>
<thead>
<tr>
<th>Design</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>RNHC 4-1</td>
<td>(12 UNITS)</td>
</tr>
<tr>
<td>RNHC 6-1</td>
<td>(77 UNITS)</td>
</tr>
<tr>
<td>RNHC 10-1</td>
<td>(335 UNITS)</td>
</tr>
<tr>
<td>RNHC 12-3</td>
<td>(81 UNITS)</td>
</tr>
<tr>
<td>RNHC 16-1</td>
<td>(147 UNITS)</td>
</tr>
</tbody>
</table>
2.5" CPV EVALUATION

BACKGROUND

HISTORY OF FAILURES DURING VIBRATION AND REDESIGNS

STATUS

OBTAINED THREE (RNHC 10-1) CPV UNITS FROM EAGLE-PICHER
CHARACTERIZATION TESTS IN PROGRESS
INITIAL CAPACITY 11.3 AHR

PLANS

CONTINUE ELECTRICAL CHARACTERIZATION
COMPILE RESULTS AND ISSUE REPORT
20 AH CPV Prorated Battery Discharge for Four Rates
Following 10 degree C/10 16 hour charge
3.5" CPV EVALUATION

3 Cells in MGS Characterization Tests

Insert Information Here

3 Cells in MGS Simulation Test

Provides Mission Leading Information

Shows Characteristic Pressure Decline

Unusual Charge Control Regime Uses VT and Switch to Trickle
MGS Simulation Prorated Battery Voltages

9 Cell CPV Battery Potential

Cycle Number

- V Batt EOC
- V Batt EOD

Paul.J.Timmerman@jpl.nasa.gov
ELECTROCHEMICAL SYSTEMS GROUP
Ni-H2 Modeling

GOALS
DEVELOP A NH₂ BATTERY PERFORMANCE MODEL
MODEL FLIGHT TYPE CELLS WITH INTERNAL DETAILS
COMBINED ELECTROCHEMICAL / ELECTRICAL / THERMAL MODEL

APPROACH
COMPUTATION FLUID DYNAMICS (CFD)
EXCELLENT INDUSTRY SUPPORT (S/W TOOLS)
EASIER TO IMPLEMENT EQUATION THAN PREVIOUS MODELS
QUICK SOLUTIONS PROVIDED
PROVIDES FIRST CONVECTION SOLUTION
EASY TO CHANGED GRANULARITY OF MODEL - DETAILS
Li-Ion ASSESSMENT

OBJECTIVES

GENERATE PERFORMANCE CHARACTERIZATION DATA
IDENTIFY POTENTIAL ISSUES AND WORK TOWARD RESOLUTION
DETERMINE FLIGHT READINESS OF TECHNOLOGY

APPROACH

PARTICIPATE IN THE JOINT AIR FORCE / NASA PROGRAM
CHARACTERIZE CELL PERFORMANCE FROM MULTIPLE VENDORS
DOCUMENT MANUFACTURING PROCEDURES
DEVELOP METHODS/FACILITIES FOR EVALUATION
DEVELOP MODELS FOR BATTERY PERFORMANCE PREDICTIONS
COMMUNICATE FLIGHT INFORMATION TO BATTERY COMMUNITY

Paul J. Timmerman@jpl.nasa.gov
ELECTROCHEMICAL SYSTEMS GROUP
Li-Ion ASSESSMENT

STATUS
BASELINE CHEMISTRY SELECTED WITH LOW TEMP ELECTROLYTE
EVALUATION OF FOUR VENDORS FOR MARS "01 LANDER COMPLETED
YARDNEY SELECTED FOR "01 LANDER BATTERY DEVELOPMENT
EVALUATION OF TWO VENDORS FOR MARS "03 ROVER IN PROGRESS
EXTENDED LIFE CYCLE TESTING AND STORAGE TESTING IN PROGRESS
IMPROVED COMPONENTS RESEARCH ONGOING

PLANS
CONTINUE THE EVALUATION OF CELLS FROM 5AH TO 25 AH INCLUDING:
CONTINUE COLD TEMPERATURE CYCLING
STORAGE / CRUISE TESTING
RATE AND TEMPERATURE EFFECTS / VARIABLE TEMP CYCLING
PULSE TESTING
CHARGE CONTROL DEVELOPMENT
AC IMPEDANCE
FAILURE ANALYSIS

Paul.J.Timmerman@jpl.nasa.gov
ELECTROCHEMICAL SYSTEMS GROUP
BENEFITS ALL PARTIES INVOLVED

GSFC, BERKELEY, JPL PARTICIPATION

ALSO LOOKS AT NEWER EXPLORERS

TOPEX, CBOV, VARS, EUVE

CONCENTRATION IS ON MPS S/C

FUNCTIONING FOR ~ 5 YEARS

TELECON

NASA N-I-CA BATTERY OPERATIONS TELECON

1999 NASA Aerospace Battery Workshop - 1999
TELECONS

Ni-H2 BATTERY OPERATIONS TELECON

NEW ACTIVITY IN 1999
DAVE PICKETT CONSULTS ON CALLS
LARGE PARTICIPATION BY NASA AND CONTRACTORS
DETAILED ANALYSIS OF S/C PERFORMANCE
DISCUSSIONS OF GENERAL INTEREST
ONGOING "WORKSHOP ATMOSPHERE"
PARTICIPANTS BRING IN THEIR ISSUES/QUESTIONS
FLIGHT BATTERY STORAGE PROGRAM

GOALS

DEVELOP FLIGHT BATTERY REUSE PROGRAM

BUILD BATTERY STORAGE FACILITY

COLLECT FLIGHT SPARE BATTERIES FROM FPO’S

MAINTAIN SPARES UNDER QC PROGRAM (FHLP)

PROVIDE BATTERIES TO NEW PROGRAMS - FAST!

BRIDGE THE PROGRAM GAP

Paul.J.Timmerman@jpl.nasa.gov
ELECTROCHEMICAL SYSTEMS GROUP
FLIGHT BATTERY STORAGE PROGRAM

PLAN

- Secure money to buy/lease facility
- Co-operate with flight H/A/W Logistics Prog
- Solicit FPO's for spares
- Maintain spares inventory and logs
- Advertize availability to new programs
- Extract compensation from FPO to fund
BATTERY LABORATORY

STATUS

THREE MACCOR CYCLERS OPERATING
OVER ONE HUNDRED CHANNELS AVAILABLE
LAB OPERATING AT NEAR CAPACITY
BATTLAB SERVER OPERATING
REMOTE CONNECTIONS TO SERVER IN PLACE
ROOM TEMP FACILITY UPGRADE COMPLETED