Behavior of Li Ion Cells in High-intensity Radiation Environments

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Mission Critical Performance Characteristics

- Long calendar life
  - Cruise time of 6-8 years

- Tolerance to high radiation environments
  - 4 M Rad for Europa Orbiter
  - 8 Mrad including the qualification margin
Technology Demonstration Strategy for Radiation Tolerance

- Obtain prototype cells from different aerospace vendors and evaluate radiation tolerance
  - DD cells from SAFT (PC-EC-DMC)
    - High and low dosage rates
  - 7 Ah Prismatic cells from Yardney (EC+DMC+DEC)
    - High and Low Dosage Rates
  - 18650 cells from Sony/AEA/Comdev
    - High and Low Dosage Rates with blanks for both
- Three electrode cells and Li ion cell components
  - Tonin Separator, YTP electrodes and EC:DMC (1:1) electrolyte
RADIATION TOLERANCE TESTS

- Cobalt 60 radiation at low and high dosage rates.
- Radiation levels in increments of 1.5 M rad and test to failure.
- Five cycles at C/5 charge and C/5 (to 4.1 V for three hours) and C/5 discharge to 3.0 V
- EIS in the fully charged state
- Irradiation in the discharged state.
RADIATION TEST FACILITY

- Cylindrical cells
  - Radiation in a direction to the electrodes
- Prismatic cell
  - Radiation in a direction parallel to the electrode plates (to avoid attenuation from the preload fixtures)

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Lithium-Ion Cells for Future Outer Planets Program Applications
Status of Yardney 7 Ahr Cells: Effects of Radiation Testing (High Rate)
Reversible Capacity at 23°C

Yardney 7 Ahr Lithium-Ion Cell
Cell Y081
High Rate Cell

Initial Capacity = 7.1406 Ahr
Capacity after 1.5 M Rad = 6.9361 Ahr (97.14 %)
Capacity after 2.6 M Rad = 6.8018 Ahr (95.25 %)
Capacity after 4.1 M Rad = 6.7464 Ahr (94.48 %)
Capacity after 5.0 M Rad = 6.7172 Ahr (94.07 %)
Capacity after 7.1 M Rad = 6.6637 Ahr (93.32 %)
Capacity after 8.6 M Rad = 6.6315 Ahr (92.87 %)
Capacity after 10.1 M Rad = 6.6179 Ahr (92.68 %)
Capacity after 11.6 M Rad = 6.668 Ahr (93.66 %)
Capacity after 13.1 M Rad = 6.548 Ahr (91.70 %)
Capacity after 14.6 M Rad = 6.496 Ahr (90.55 %)
Capacity after 14.6 M Rad = 6.444 Ahr (90.24 %)

Capacity prior to radiation exposure
• Capacity after 1.5 M Rad radiation exposure
• Capacity after 2.6 M Rad radiation exposure
• Capacity after 4.1 M Rad radiation exposure
• Capacity after 5.0 M Rad radiation exposure
• Capacity after 7.1 M Rad radiation exposure
• Capacity after 8.6 M Rad radiation exposure
• Capacity after 10.1 M Rad radiation exposure
• Capacity after 11.6 M Rad radiation exposure
• Capacity after 13.1 M Rad radiation exposure
• Capacity after 14.6 M Rad radiation exposure
• Capacity after 16.1 M Rad radiation exposure

Discharge Capacity (Ahr)
Cell Voltage (V)
5th Discharge
Lithium-Ion Cells for Future Outer Planets Program Applications
Status of Yardney 7 Ahr Cells: Effects of Radiation Testing (High Rate)
Reversible Capacity at 0°C

Yardney 7 Ahr Lithium-Ion Cell
Cell Y081
High Rate Cell

Initial Capacity at 0°C = 6.457 Ahr (90.43 % of Initial RT Value)
Capacity at 0°C after 1.5 Mrad = 6.0557 Ahr (91.61 % of Initial RT Value)
Capacity at 0°C after 3.0 Mrad = 5.9067 Ahr (92.44 % of Initial RT Value)
Capacity at 0°C after 4.1 Mrad = 5.8329 Ahr (91.69 % of Initial RT Value)
Capacity at 0°C after 5.6 Mrad = 5.9064 Ahr (92.72 % of Initial RT Value)
Capacity at 0°C after 7.1 Mrad = 5.7165 Ahr (90.06 % of Initial RT Value)
Capacity at 0°C after 8.6 Mrad = 5.6927 Ahr (91.58 % of Initial RT Value)
Capacity at 0°C after 10.1 Mrad = 5.7333 Ahr (90.03 % of Initial RT Value)
Capacity at 0°C after 11.6 Mrad = 5.616 Ahr (78.65 % of Initial RT Value)
Capacity at 0°C after 13.1 Mrad = 5.478 Ahr (76.72 % of Initial RT Value)
Status of Yardney 7 Ahr Cells: Effects of Radiation Testing (High Rate)

Yardney 7 Ahr Lithium-Ion Cell
Cell Y081 - High Rate Cell

Capacity Fade Rate (Cycles 1-5) = 0.047%/cycle
Capacity Fade Rate (Cycles 6-7) = 0.122%/cycle
Capacity Fade Rate (Cycles 8-12) = 0.121%/cycle
Capacity Fade Rate (Cycles 13-19) = 0.055%/cycle
Capacity Fade Rate (Cycles 20-29) = 0.136%/cycle
Capacity Fade Rate (Cycles 30-40) = 0.165%/cycle
Capacity Fade Rate (Cycles 41-50) = 0.122%/cycle
Capacity Fade Rate (Cycles 51-60) = 0.163%/cycle
Capacity Fade Rate (Cycles 61-70) = 0.051%/cycle
Capacity Fade Rate (Cycles 71-80) = 0.144%/cycle
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Status of Yardney 7 Ahr Cells: Effects of Radiation Testing (Low Rate)

Reversible Capacity at 23°C

Yardney 7 Ahr Lithium-Ion Cell
Cell Y092
Low Rate Cell

- Capacity prior to radiation exposure
- Capacity after 1.5 M Rad radiation exposure
- Capacity after 3.0 M Rad radiation exposure
- Capacity after 4.5 M Rad radiation exposure
- Capacity after 6.0 M Rad radiation exposure
- Capacity after 9.0 M Rad radiation exposure
- Capacity after 10.5 M Rad radiation exposure
- Capacity after 12.0 M Rad radiation exposure
- Capacity after 13.5 M Rad radiation exposure

Discharge Capacity (Ahr)

Cell Voltage (V)

 Initial Capacity = 7.2568 Ahr
Capacity after 1.5 M Rad = 6.9205 Ahr (95.17 %)
Capacity after 3.0 M Rad = 6.8216 Ahr (94.08 %)
Capacity after 4.5 M Rad = 6.8127 Ahr (93.95 %)
Capacity after 6.0 M Rad = 6.7382 Ahr (92.93 %)
Capacity after 9.0 M Rad = 6.6796 Ahr (92.12 %)
Capacity after 10.5 M Rad = 6.5788 Ahr (90.73 %)
Capacity after 12.0 M Rad = 6.6240 Ahr (91.50 %)
Capacity after 13.5 M Rad = 6.4905 Ahr (89.52 %)
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Status of Yardney 7 Ahr Cells: Effects of Radiation Testing (Low Rate)

Reversible Capacity at 0°C

Yardney 7 Ahr Lithium-Ion Cell
Cell Y092
Low Rate Cell

Initial Capacity at 0°C = 6.478 Ahr (89.40% of Initial RT Value)
Capacity at 0°C after 1.5 MRad = 5.991 Ahr (82.62 % of Initial RT Value)
Capacity at 0°C after 3.0 MRad = 5.884 Ahr (81.15 % of Initial RT Value)
Capacity at 0°C after 4.5 MRad = 5.795 Ahr (79.92 % of Initial RT Value)
Capacity at 0°C after 6.0 MRad = 5.754 Ahr (79.36 % of Initial RT Value)
Capacity at 0°C after 9.0 MRad = 5.659 Ahr (76.95 % of Initial RT Value)
Capacity at 0°C after 10.5 MRad = 5.608 Ahr (77.34 % of Initial RT Value)
Capacity at 0°C after 12.0 MRad = 5.499 Ahr (75.84 % of Initial RT Value)
Capacity at 0°C after 13.5 MRad = 5.455 Ahr (75.23 % of Initial RT Value)
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Status of Yardney 7 Ahr Cells: Effects of Radiation Testing (Low Rate)

Yardney 7 Ahr Lithium-Ion Cell
Cell Y092 - Low Rate Cell

Capacity Fade Rate (Cycles 1-5) = 0.082 %/cycle
Capacity Fade Rate (Cycles 6-7) = 0.169 %/cycle
Capacity Fade Rate (Cycles 8-12) = 0.253 %/cycle
Capacity Fade Rate (Cycles 13-19) = 0.172 %/cycle
Capacity Fade Rate (Cycles 20-26) = 0.226 %/cycle
Capacity Fade Rate (Cycles 27-33) = 0.263 %/cycle
Capacity Fade Rate (Cycles 34-40) = -0.037 %/cycle
Capacity Fade Rate (Cycles 41-47) = 0.172 %/cycle
Capacity Fade Rate (Cycles 48-54) = 0.226 %/cycle
Capacity Fade Rate (Cycles 55-61) = 0.272 %/cycle

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Status of Yardney 7 Ahr Cells: Effects of Radiation Testing
High Rate vs. Low Rate

Yardney 7 Ahr Lithium-Ion Cells
Reversible Capacity vs. Radiation Dosage

$^{60}$Co $\gamma$-rays

- Capacity at Room Temperature (High Rate Cell)
- Capacity at Room Temperature (Low Rate Cell)
- Capacity at 0°C (High Rate Cell)
- Capacity at 0°C (Low Rate Cell)
Little change in the series resistance indicative of small changes in the ionic (electrolyte) and electronic (electrode) conductivities.

Increase in the low frequency impedance (attributed to the cathode kinetics) which might affect the high rate/low temperature performance.
Electrochemical Impedance Spectroscopy
Low Rate

Yardney 7 Ahr Outer Planets
EIS of Radiated Cells
Cell YO92-Low Rate

Temperature = 23°C

• Slightly higher increase in the series resistance compared to the high rate impedance data, may be attributed to ageing.
• Also, marginally higher impedance at low frequencies compared to high rate exposure data, may be attributed to cell ageing.
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Status of SAFT DD-Size Cells: Effects of Radiation Testing (High Rate)

Reversible Capacity at 23°C

SAFT 9 Ahr Lithium-Ion Cell
Cell SO111
High Rate Cell

Temp = 23°C
5th Discharge
Lithium-Ion Cells for Future Outer Planets Program Applications

Status of SAFT DD-Size Cells: Effects of Radiation Testing (High Rate)

Reversible Capacity at 0°C

Initial Capacity at 0°C = 8.394 Ahr (92.25% of Initial RT Value)
Capacity at 0°C after 1.5 MRad = 8.050 Ahr (88.47% of Initial RT Value)
Capacity at 0°C after 2.6 MRad = 8.039 Ahr (88.35% of Initial RT Value)
Capacity at 0°C after 4.1 MRad = 8.056 Ahr (88.56% of Initial RT Value)
Capacity at 0°C after 5.6 MRad = 8.146 Ahr (89.52% of Initial RT Value)
Capacity at 0°C after 7.1 MRad = 7.830 Ahr (86.05% of Initial RT Value)
Capacity at 0°C after 8.6 MRad = 7.781 Ahr (85.11% of Initial RT Value)
Capacity at 0°C after 10.1 MRad = 7.860 Ahr (86.60% of Initial RT Value)
Capacity at 0°C after 11.6 MRad = 7.799 Ahr (85.71% of Initial RT Value)
Capacity at 0°C after 13.1 MRad = 7.824 Ahr (85.99% of Initial RT Value)
Lithium-Ion Cells for Future Outer Planets Program Applications

Status of SAFT DD-Size Cells: Effects of Radiation Testing (High Rate)

Capacity Fade Rate (Cycles 1-5) = 0.034 %/cycle
Capacity Fade Rate (Cycles 10-15) = 0.055 %/cycle
Capacity Fade Rate (Cycles 17-21) = 0.092 %/cycle
Capacity Fade Rate (Cycles 24-28) = 0.030 %/cycle
Capacity Fade Rate (Cycles 31-35) = 0.059 %/cycle
Capacity Fade Rate (Cycles 38-42) = 0.044 %/cycle
Capacity Fade Rate (Cycles 45-49) = -0.018 %/cycle
Capacity Fade Rate (Cycles 52-56) = -0.086 %/cycle
Capacity Fade Rate (Cycles 59-63) = -0.086 %/cycle
Capacity Fade Rate (Cycles 66-70) = -0.086 %/cycle
Lithium-Ion Cells for Future Outer Planets Program Applications

Status of SAFT DD-Size Cells: Effects of Radiation Testing (Low Rate)
Reversible Capacity at 23°C

Reversible Capacity at 23°C

SAFT 9 Ahr Lithium-Ion Cell
Cell SO105
Low Rate Cell

Discharge Capacity (Ahr)

Cell Voltage (V)

Capacity prior to radiation exposure
Capacity after 1.5 M Rad radiation exposure
Capacity after 3.0 M Rad radiation exposure
Capacity after 4.5 M Rad radiation exposure
Capacity after 6.0 M Rad radiation exposure
Capacity after 8.0 M Rad radiation exposure
Capacity after 12.0 M Rad radiation exposure
Capacity after 13.5 M Rad radiation exposure

Initial Capacity = 9.313 Ahr
Capacity after 1.5 M Rad = 9.314 Ahr (100.01 %)
Capacity after 3.0 M Rad = 9.282 Ahr (99.67 %)
Capacity after 4.5 M Rad = 9.2798 Ahr (99.64 %)
Capacity after 6.0 M Rad = 9.2282 Ahr (99.07 %)
Capacity after 9.0 M Rad = 9.1899 Ahr (98.68 %)
Capacity after 12.0 M Rad = 9.2082 Ahr (98.15 %)
Capacity after 13.5 M Rad = 9.1406 Ahr (98.15 %)

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Lithium-Ion Cells for Future Outer Planets Program Applications
Status of SAFT DD-Size Cells: Effects of Radiation Testing (Low Rate)
Reversible Capacity at 0°C

![Graph showing discharge capacity vs. cell voltage with various radiation exposure levels.]

Initial Capacity at 0°C = 8.721 Ahr (93.64% of Initial RT Value)
Capacity at 0°C after 1.5 Mrad = 8.241 Ahr (88.48% of Initial RT Value)
Capacity at 0°C after 3.0 Mrad = 8.224 Ahr (88.30% of Initial RT Value)
Capacity at 0°C after 4.5 Mrad = 8.178 Ahr (87.81% of Initial RT Value)
Capacity at 0°C after 6.0 Mrad = 8.015 Ahr (86.06% of Initial RT Value)
Capacity at 0°C after 9.0 Mrad = 8.105 Ahr (87.03% of Initial RT Value)
Capacity at 0°C after 12.0 Mrad = 8.127 Ahr (87.26% of Initial RT Value)
Capacity at 0°C after 13.5 Mrad = 8.066 Ahr (86.61% of Initial RT Value)
Lithium-Ion Cells for Future Outer Planets Program Applications

Status of SAFT DD-Size Cells: Effects of Radiation Testing (Low Rate)

SAFT 9 Ahr Lithium-Ion Cell
Cell SO105
Low Rate Cell

Initial at 23°C
After 1.5 Mrad (23°C)
After 3.0 Mrad (23°C)
After 4.5 Mrad (23°C)
After 6.0 Mrad (23°C)
After 9.0 Mrad (23°C)
After 12.0 Mrad (23°C)
After 13.5 Mrad (23°C)

Cycling at 0°C
After 1.5 Mrad at 0°C
After 3.0 Mrad at 0°C
After 4.5 Mrad at 0°C
After 6.0 Mrad at 0°C
After 9.0 Mrad at 0°C
After 12.0 Mrad at 0°C
After 13.5 Mrad at 0°C

Discharge Capacity (Ahr)

Capacity Fade Rate (Cycles 1-5) = 0.023 %/cycle
Capacity Fade Rate (Cycles 10-14) = 0.051 %/cycle
Capacity Fade Rate (Cycles 17-21) = 0.083 %/cycle
Capacity Fade Rate (Cycles 24-28) = -0.091 %/cycle
Capacity Fade Rate (Cycles 31-35) = 0.075 %/cycle
Capacity Fade Rate (Cycles 38-42) = 0.059 %/cycle
Capacity Fade Rate (Cycles 45-49) = 0.156 %/cycle
Capacity Fade Rate (Cycles 52-56) = 0.073 %/cycle

Cycle Number

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Lithium-Ion Cells for Future Outer Planets Program Applications

Status of SAFT DD-Size Cells: Effects of Radiation Testing (High Rate)

High vs. Low Rate Dosage

SAFT DD-Size Lithium-Ion Cells
Reversible Capacity vs. Radiation Dosage

\[ \text{Percent of Initial Capacity (\%)} \]

\[ \text{Radiation Dosage (MRad)} \]

- High Rate Cell (SO 111) RT Capacity
- High Rate Cell (SO 111) OC Capacity
- Low Rate Cell (SO 105) RT Capacity
- Low Rate Cell (SO 105) OC Capacity

\[ ^{60}\text{Co } \gamma\text{-rays} \]
Electrochemical Impedance Spectroscopy
Low Rate

SAFT Outer Planets
EIS of Radiated Cells
Cell SO105-Low Rate

Temperature = 23°C

- Initial Measurement
- After Exposure to 1.5 MRAD
- After Exposure to 3.0 MRAD
- After Exposure to 4.5 MRAD
- After Exposure to 6.0 MRAD
- 9.0 Mrad
- 9.0 Mrad-rep

- Similar scatter in the impedance pattern, mainly increase in the series resistance, as in the high dose cells.
- EIS measurements/interpretation may be difficult when the case is polarized (-ve terminal).
SONY 18650-Size (1.2 Ahr) Lithium-Ion Cells (AEA)

Effect of Radiation Upon Cell Performance ($^{60}$Co γ-rays)

Test Assignment

- 0.250 Amp Charge Current (C/5) to 4.1 V
- 0.025 Amp taper current cut-off (C/50)
- 0.250 Amp Discharge Current to 3.0 V
- Temperature = 23°C

Average Capacity = 1.183 Ahr
SONY 18650-Size (1.2 Ahr) Lithium-Ion Cells (AEA)
Effect of Radiation Upon Cell Performance ($^{60}$Co $\gamma$-rays)
High Rate Radiation Test (Test Sample vs. Blank)

0.250 Amp Charge Current (C/5) to 4.1 V
0.025 Amp taper current cut-off (C/50)
0.250 Amp Discharge Current to 3.0 V

Red = Blank
Blue = Radiation Sample

Initial Char. at 23°C
After 1.5 Mrad (23°C)
After 3.0 Mrad (23°C)
After 4.5 Mrad (23°C)
After 6.0 Mrad (23°C)
After 7.5 Mrad (23°C)
After 9.0 Mrad (23°C)
After 10.5 Mrad (23°C)
After 12.0 Mrad (23°C)
After 13.5 Mrad (23°C)
After 15.0 Mrad (23°C)
After 16.5 Mrad (23°C)
SONY 18650-Size (1.2 Ahr) Lithium-Ion Cells (AEA)
Effect of Radiation Upon Cell Performance (⁶⁰Co γ-rays)
High Rate Cell - Reversible Capacity (23°C)
SONY 18650-Size (1.2 Ahr) Lithium-Ion Cells (AEA)
Effect of Radiation Upon Cell Performance ($^{60}$Co $\gamma$-rays)
High Rate Cell - Reversible Capacity (23°C)

SONY 18650-Size Lithium-Ion Cells
0.250 Amp Charge Current (C/5) to 4.1 V
0.025 Amp taper current cut-off (C/50)
0.250 Amp Discharge Current to 3.0 V
Temperature = 23°C

Percent of Initial Capacity (%)

Radiation Dosage (M Rads)

- SX 027 - Cell subjected to radiation
- SX 004 - Blank sample

Combine 41 and 42

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SONY 18650-Size (1.2 Ahr) Lithium-Ion Cells (AEA)
Effect of Radiation Upon Cell Performance \((^{60}\text{Co }\gamma\text{-rays})\)
High Rate Cell - Reversible Capacity (\(0^\circ\text{C}\))

- SONY 18650-Size Lithium Ion Cells
- 0.250 Amp Charge Current (C/5) to 4.1 V
- 0.025 Amp taper current cut-off (C/50)
- 0.250 Amp Discharge Current to 3.0 V
- Temperature = \(0^\circ\text{C}\)

Percent of Initial Capacity (%) vs. Radiation Dosage (M Rads)

- SX 027 - Cell subjected to radiation
- SX 004 - Blank sample
SONY 18650-Size (1.2 Ahr) Lithium-Ion Cells (AEA)
Effect of Radiation Upon Cell Performance ($^{60}$Co $\gamma$-rays)
Low Rate vs. High Rate Cell - Reversible Capacity (23°C)

**Graph:**
- **Discharge Capacity (AHR)** vs. **Radiation Dosage (M Rads)**
- Lines and markers indicate:
  - **SX 027** - Cell subjected to radiation (High Rate)
  - **SX 004** - Blank sample (High Rate)
  - **SX 091** - Cell subjected to radiation (Low Rate)
  - **SX 042** - Blank sample (Low Rate)

**Specifications:**
- 0.250 Amp Charge Current (C/5) to 4.1 V
- 0.025 Amp taper current cut-off (C/50)
- 0.250 Amp Discharge Current to 3.0 V
- Temperature = 23°C
Electrochemical Impedance Spectroscopy

High Rate

Sony/ComDev Outer Planets
EIS of Radiated Cells
Cell SX027-High Rate

Temperature = 23°C

- Increase in the series resistance, may be related to the cell case being Scatter not as much as with SAFT cells.
- The low frequency impedance (attributed to the cathode kinetics) appears be unaffected by radiation exposure.
Changes in the impedance pattern, more specifically on the series resistance are also observed in the control cell, which suggests that the performance decay on storage is significant compared to that occurring on γ-irradiation.
Lithium-Ion Cells for Future Outer Planets Program Applications
Effect of Radiation Upon Cell Performance (High Rate)
Comparison of Cell Design/Vendor - Reversible Capacity at 23°C

![Graph showing the effect of radiation dosage on the percent of initial capacity for different cell designs at 23°C.](image)

**Graph Information:**
- **Title:** High Rate Radiation Dosage Cells
- **Axes:**
  - Y-axis: Percent of Initial Capacity (%)
  - X-axis: Radiation Dosage (MRad)
- **Legend:**
  - SAFT DD-Size (9 Ahr)
  - SONY Blank
  - Yardney 7 Ahr
  - SONY 18650
  - SONY 18650-Size Cell (SX004) - Blank

**Temperature:** 23°C
Lithium-Ion Cells for Future Outer Planets Program Applications

Effect of Radiation Upon Cell Performance (High Rate)
Post-radiation cycling of Yardney Cells at 100% DOD

Yardney 7 Ahr Lithium-Ion Cells
Temperature = 23°C

- Cell Y718
- Cell Y792 (Subjected to 21 Mrad Radiation)

1.4 Amp Charge current (C/5) to 4.1 V
Taper Cut-Off at 0.140 A (C/50)
1.4 Amp Discharge Current (C/5) to 3.0 V

Cell also cycled ~ 100 times prior to life test
Lithium-Ion Cells for Future Outer Planets Program Applications

Effect of Radiation Upon Cell Performance (High Rate)

Post-radiation cycling of SAFT cells at 100% DOD

SAFT DD-Size (9 Ahr) Lithium Ion Cells

Temperature = 23°C

1.800 Amp Charge current (C/5) to 4.1 V
Taper Cut-Off at 0.180 A (C/50)
1.80 Amp Discharge Current (C/5) to 3.0 V

Cell also cycled ~ 100 times prior to life test

Cell SDD18
Cell SD105 (Subjected to 21 Mrad Radiation)
Lithium-Ion Cells for Future Outer Planets Program Applications
Effect of Radiation Upon Cell Performance (High Rate)
Post-radiation cycling of Sony/Comdev cells at 100% DOD

SONY 18650 Size Lithium Ion Cells (AEA)

Temperature = 23°C

- Cell SX061
- Cell SX042 (Blank Cell)
- Cell SX091 (Subjected to 10.5 MRad Low Rate Radiation)

0.25 Amp Charge current (C/5) to 4.1 V
Taper Cut-Off at 0.100 A (C/50)
0.25 Amp Discharge Current (C/5) to 3.0 V

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Summary and Conclusions

- Li ion prototype cells have been subjected to Co-60 radiation exposure to dosage levels exceeding 20 Mrad.
- Lithium ion cells sustain mild capacity loss, more noticeably in low temperature discharges.
  - Capacity loss is independent of the dosage rate
  - Control tests performed on the Sony/Comdev/AEA cells reveal that a significant portion of the capacity loss is due to storage, rather than irradiation, at least until the first 5 exposures.
- Among the three types of cells tested, i.e., Yardney Prismatic 7 Ah cells, SAFT DD cylindrical 9 Ah cells and Sony/Comdev/AEA 18650 cells, SAFT cells have the highest tolerance followed by Sony and Yardney.
- Post-radiation cycling show of Yardney, SAFT and Sony/Comdev cells show no ill effects of radiation on capacity fade rate.
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