National Aeronautics and Space Administration

Power for Distributed Planetary Sensors: The Ultra-High Energy, Ultra-High Power Hybrid Battery Pack

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Objectives:

- Design, build, and test a proof of concept ultra-high energy density, ultra-high specific power hybrid power pack.
- Demonstrate specialized non-rechargeable battery cells coupled with supercapacitors can yield high specific energy, high pulse power sources.

Approach:

- A high-power testbed was developed consisting of environmental chambers, electronic load, and sensing electronic components (i.e., shunt resistors, data acquisition units, etc.)
- The software developed allows for pulse-train conditions ranging from currents up to 60A and at durations as low as 1 msec under dynamic mode.
- Hybrid power packs were constructed using two types of high energy primary cells with rechargeable 3V Maxwell Technologies BCAP0310 cells supercapacitors cells.

Results:

- Representative pulse test results of the hybrid power packs shown in Fig. 2 demonstrate the efficacy of the hybrid approach by comparing the pulse-current carrying capability of the two types of primary battery cells with and without the parallel supercapacitor.
  - For 20A current pulse in the battery cell mode, both primary cell voltages polarize roughly 1.5V, which would result in a power bus brown-out condition in a field application.
  - In contrast, when tested in the hybrid battery-supercapacitor configuration, the cell polarization drops to only about 0.2-0.4V, easily meeting the pulse condition with minimal voltage slump.
- The reduction in the hybrid power pack temperature from 20ºC to -10ºC results in only limited reduction in pulse-current carrying capability. As shown in Fig. 3, an increased voltage drop of only ca. 0.2V was observed for the lower temperature operation.
- The hybrid power packs to perform well under pulse chains with longer duration pulses and then recover pack voltage as shown in Fig. 4. After a series of 5s on/off pulse chains for 50s, the hybrid battery pack approached nearly full cell voltage recovery after ca. 3 minutes.
- The hybrid battery packs tested in this study compare very favorably to other flight-qualified primary and rechargeable battery options in terms of specific power, specific energy, and pulse current carrying capability as shown in Table 1.

Figure 1. Experimental testbed control system.

Background:

- Planetary sensor networks take advantage of recently miniaturized sensors and improved low-power avionics.
- These sensor networks require power sources with low mass, yet be able to provide high burst power for sensing and transmit events.
- Conventional batteries are either too low power or too low specific energy.
- There is a strong NASA and non-NASA (e.g. IARPA) technology pull for high power, high specific energy power pack for a wide range of applications.

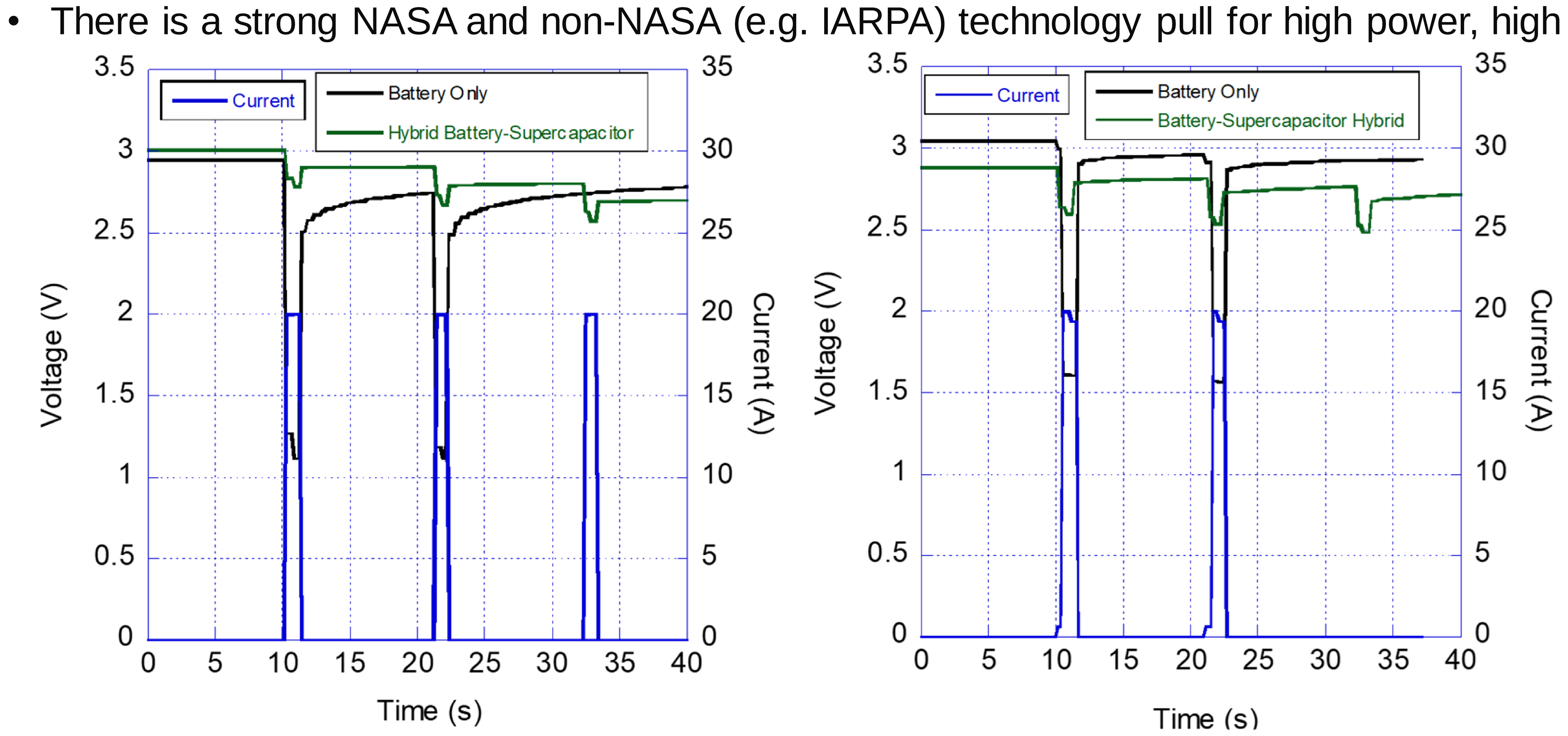

Figure 2. Comparison of pulse discharge capability for battery cells only and battery-supercapacitor hybrid packs; a) Li-CF_x-supercapacitor hybrid, and b) Li-MnO_2+CF_x supercapacitor hybrid..

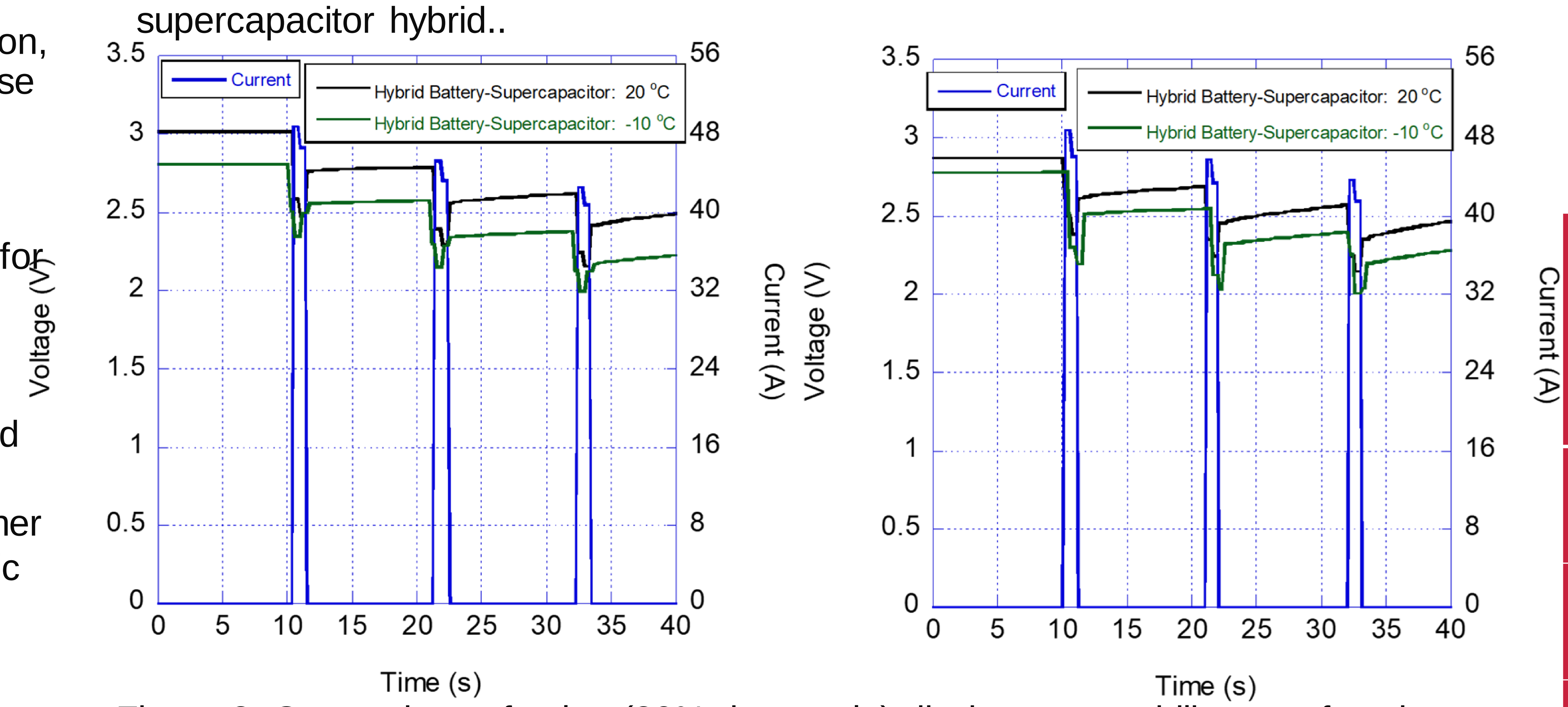

Figure 3. Comparison of pulse (20% duty cycle) discharge capability as a function of temperature for battery cells only and battery-supercapacitor hybrid packs; a) Li-CF_x-supercapacitor hybrid, and b) Li-MnO_2+CF_x supercapacitor hybrid.

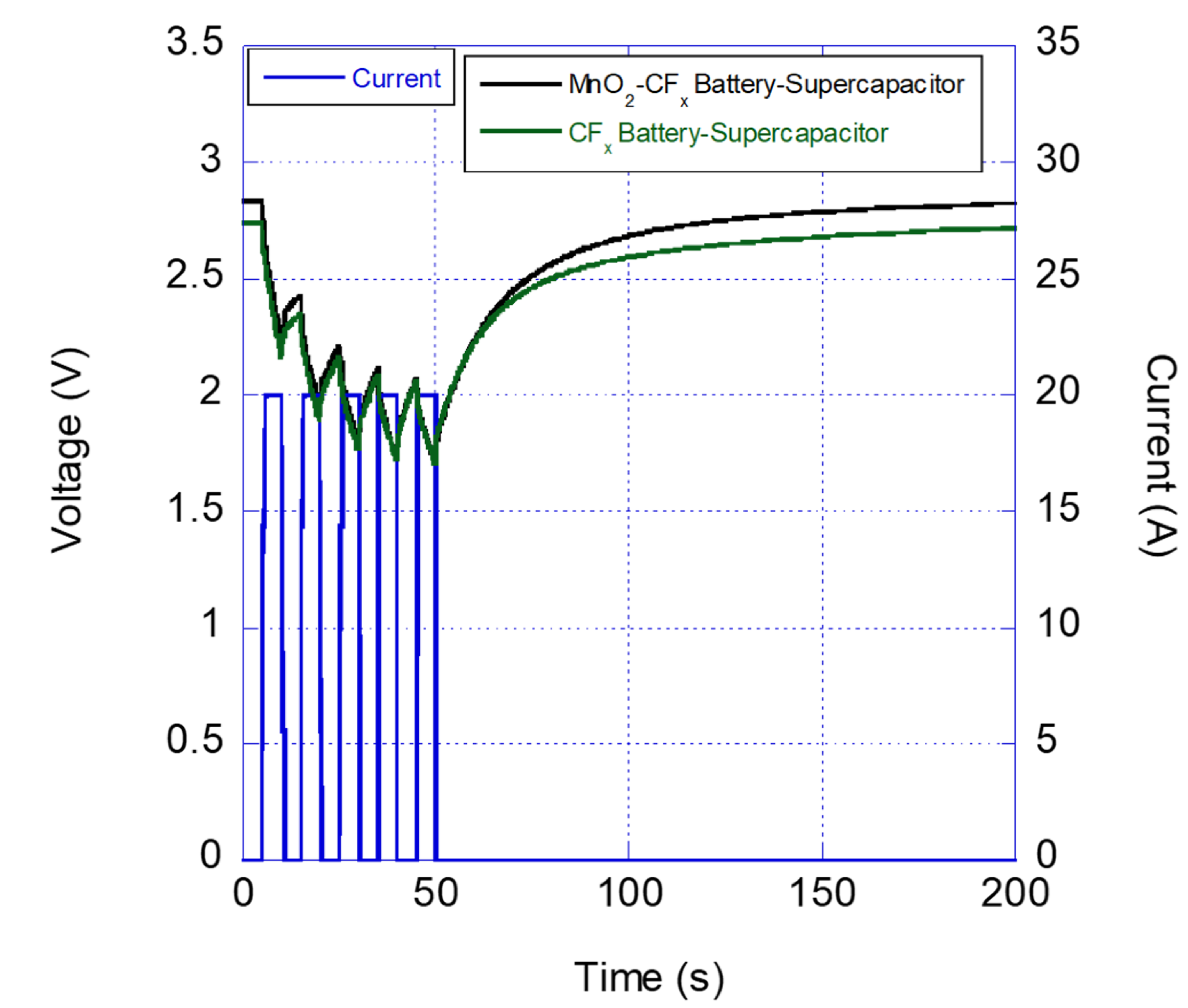

Figure 4. Comparison of long pulse (50% duty cycle) discharge capability for two different primary battery-supercapacitor hybrid packs.

Metric	Flight-Qualified Primary Battery Cell (Saft LO26SX)	Flight-Qualified Rechargeable Battery Cell (LG-Chem MJ1)	Li-MnO_2/CF_x-Supercapacitor Pack (this work)	Li-CF_x-Supercapacitor Pack (this work)
Specific Power (W/kg)	164	742	1143	1373
Specific Energy (Wh/kg)	255	260	363	561
Current Pulse Capability (A)	5	10	100 (manufacturer's specification)	100 (manufacturer's specification)

Table 1. Summary of commercial battery cell and custom battery/supercapacitor hybrid pack performance at +20ºC.

Significance/Benefits to JPL and NASA:

- Successfully developed a high power testbed system.
- Conducted performance comparisons of high power hybrid packs consisting of two different types primary cells and supercapacitors.
- Demonstrated pulse power capabilities of up to 50A with only minimal cell polarization.
- These hybrid power packs exceed the performance of conventional flight-qualified primary and rechargeable battery cells in terms of specific power, specific energy, and current pulse capability
- Hybrid power packs can be operated effectively at reduced temperatures with minimal performance degradation.
- This technology will be useful to a wide range of mission applications including distributed sensors that require small, lightweight energy sources coupled with high power pulse capability.

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