

Reducing Development and Manufacturing With Scalable Designs

Richard Coffin

Space Power Workshop

*Commoditization of Space: Maintaining Resiliency in the Age
of Faster and Cheaper*

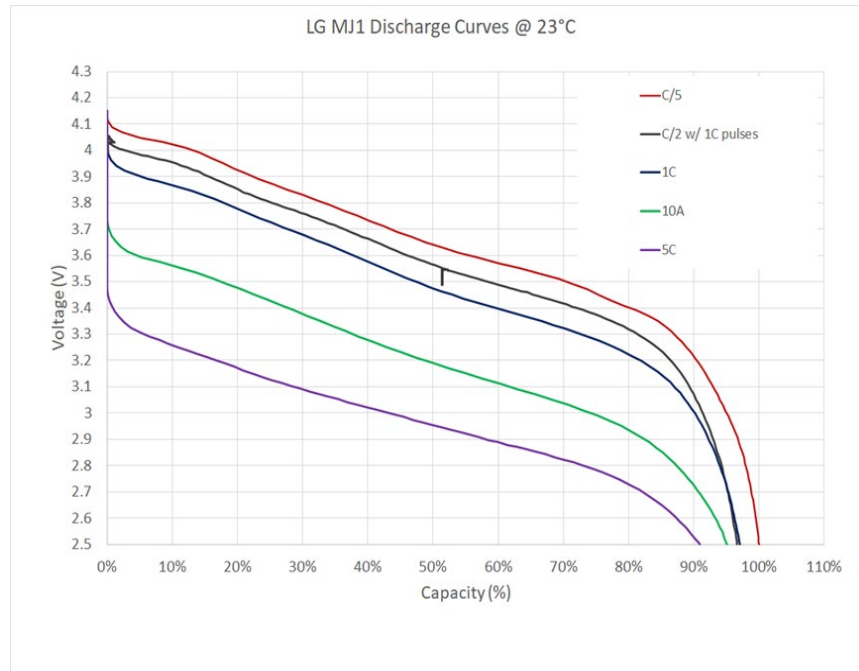


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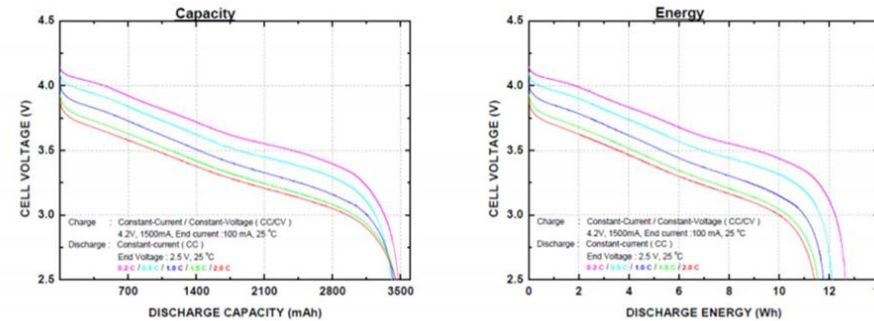
- + Cell Selection
- + Battery / Cell configuration
- + Cell Packs
 - + Open Frame
 - + Mitigated
- + NASA JSC-20793
- + Battery design
 - + Open Frame
 - + Mitigated

Energy Cell – LG INR18650MJ1

- + The cell is capable of 10A rate continuous discharge. The cell has been tested up to 5C by EaglePicher and shows as much as 90% of its capacity is delivered at high rate



LG Chem 18650 MJ1 Cell Performance



Discharge Rate	Capacity		Energy	
	mAh	% vs. 0.2C	Wh	% vs. 0.2C
0.2 C	3480	100 %	12.7	100 %
0.5 C	3411	98 %	12.1	95 %
1.0 C	3428	98 %	11.8	93 %
1.5 C	3452	99 %	11.6	91 %
2.0 C	3451	99 %	11.4	90 %

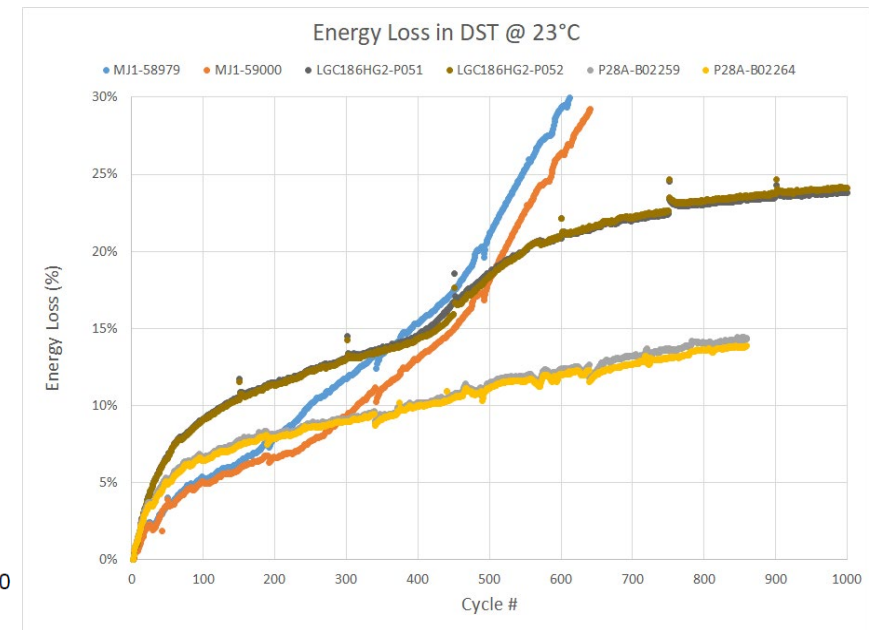
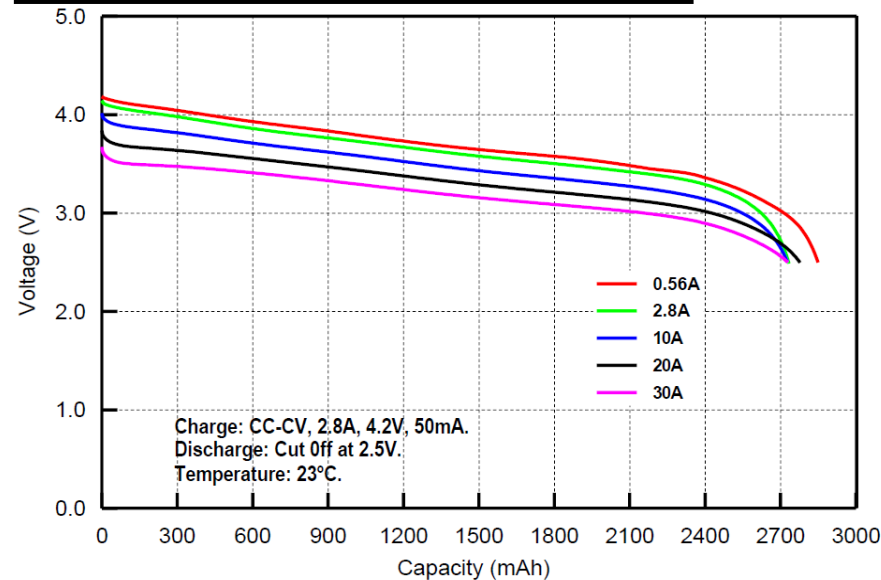
Power Cell – Molicell INR18650P28A

- + The P28A cell is a high-energy cell also capable of high power and rated at 35A continuous discharge (12C). It has been selected by EPT for its high energy, and ability to deliver the energy over a wide temperature range. Because of its high power rating, the P28A cell is well-suited for long life applications, and is expected to maintain stable voltage performance over life.

■ CELL CHARACTERISTICS

Capacity	Typical	2800 mAh
	Minimum	2700 mAh
Cell Voltage	Nominal	3.6 V
	Charge	4.2 V
Charge Current	Standard	2.8 A
	Maximum	8.4 A
Charge Time	Standard	1.5 hr
	Maximum	35 A
Internal Resistance	AC (1 KHz)	20 mΩ (Max)
	DC (10A/1s)	20 mΩ
Ambient Temperature	Charge	0°C to 60°C
	Discharge	-40°C to 60°C
Energy Density	Volumetric	589 Wh/l
	Gravimetric	219 Wh/kg

■ Discharge Rate Characteristics



- + EaglePicher performs cell life testing in-house
- + We test cells for
 - + Storage
 - + Cycling
 - + Multiple levels for DoD
 - + Impedance vs Temperature

Battery Size and Degradation

- + We analyze cells for
 - + Storage
 - + Cycling
 - + DoD
 - + Temperature

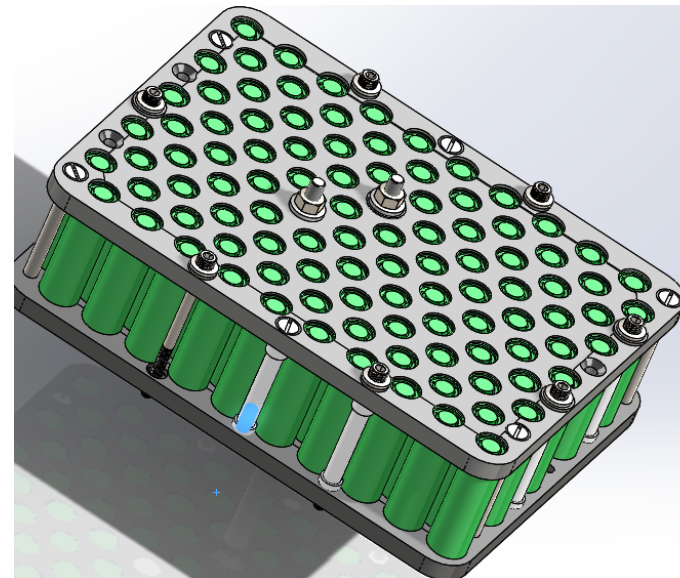
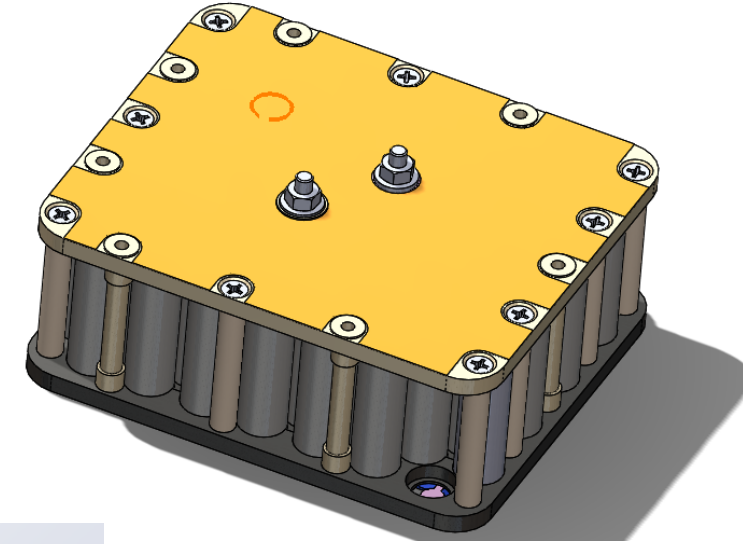
MJ1		
Max Battery Voltage	50	Volts
Min Battery Voltage	30	Volts
Average Discharge Current	80	Amps
Average Discharge Power	500	Watts
Max Battery Voltage	50.4	Volts
Min Battery Voltage	30	Volts
Orbit period	90	Mins
Eclipse Duration	36	Mins
Recharge Duration	54	Mins
Max Average Discharged Energy per cycle	300	Watt-Hours
Max Average DOD of nameplate	33.1%	
Cell Type	MJ1	
Cell energy nameplate	12.6	Watt-Hours
Cell Capacity Nameplate	3.5	Ah
target s-configuration	12	s
target p-configuration	6	p
Total Worst Case Degradation	16.7%	
Pre-mission Degradation	9.6%	
BOL Battery Energy	907	Watt-Hours
EOL Battery Energy	669	Watt-Hours

- + EaglePicher has two distinct types of Cell Pack designs that are proven.
 - + Open frame – Design to support different manufacturing volumes and cost targets
 - + Propagation mitigated (NASA Crew Rated)
- + Sizes and configurations
 - + Designs with less than 16 cells in parallel tend to be 2P or higher packs
 - + Designs with greater than 30P tend to be 1p packs

Open Frame

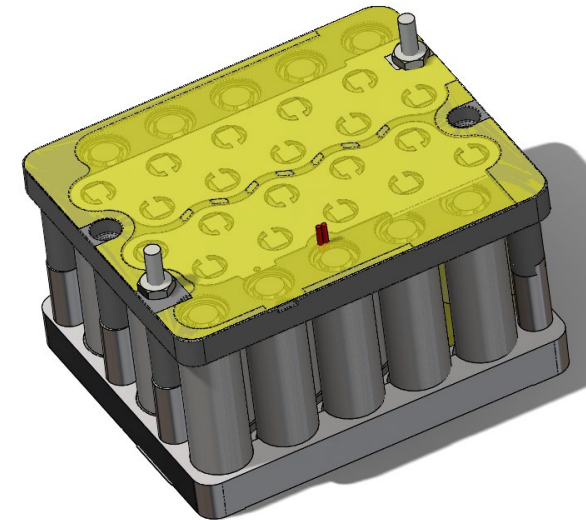
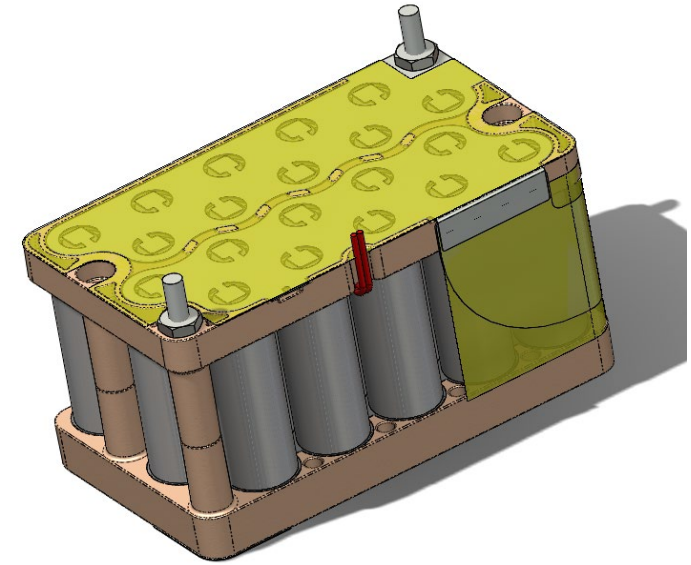
Low Volume

- + Cell Capture Machined Parts
- + Cell Electrical Attachment
- + Assembly Mounting
- + Vibration
- + Shock
- + Standard Cell Spacing
- + Standard Mounting



High Volume

- + Moldable Material selection for capture plates
- + Thermal transfer rates for cells to housing
- + Thermal transfer material that is also electrically isolated



Electrical

- + Cell Attachment
- + Intercell Impedance
- + Current Rating
- + Individual Cell Fusing
- + Pack Electrical Connection

Qualification

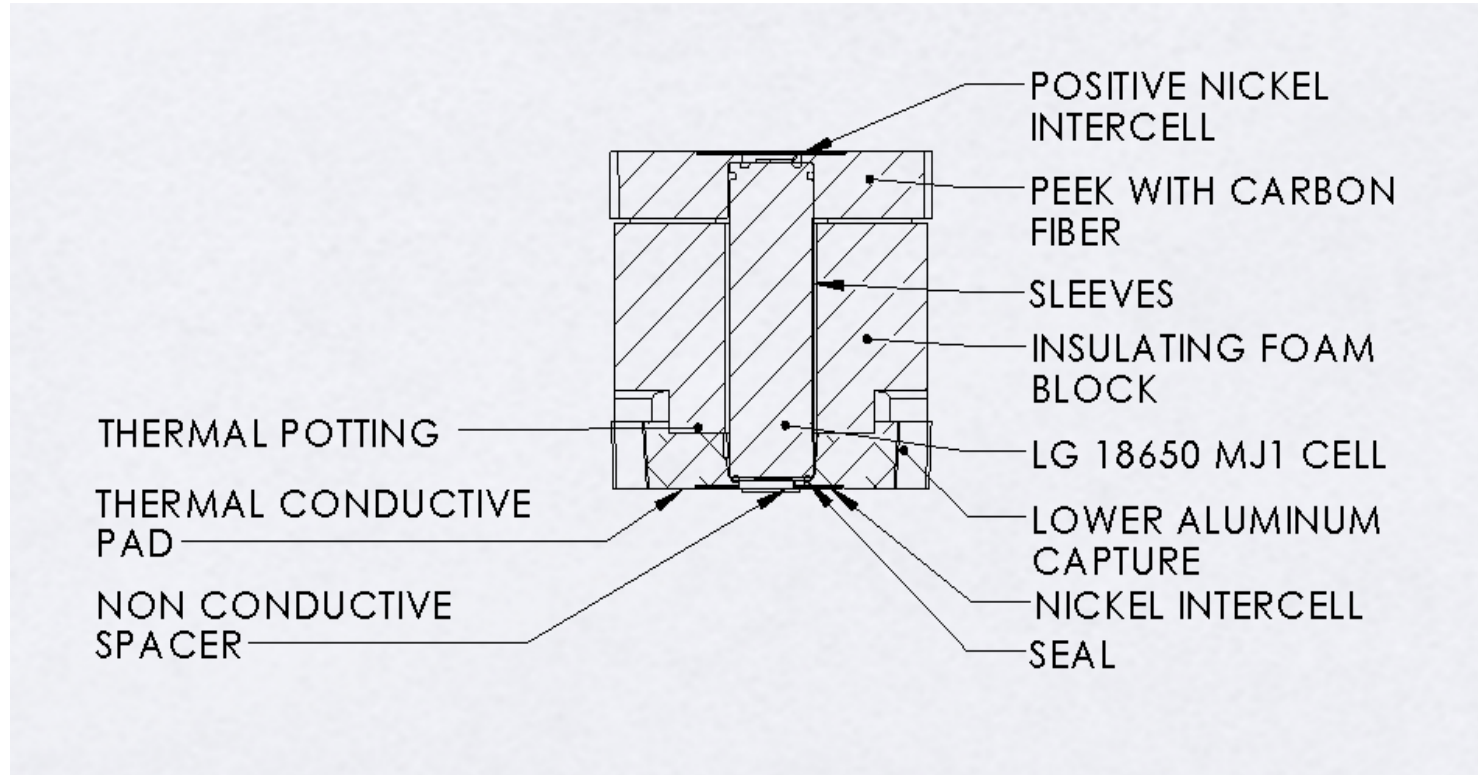
- + Capacity
- + Thermal
- + Impedance
- + Isolation (mounting to Pack voltage)

- + Cell Propagation Mitigation
- + Cell short protection
- + Redundancy
- + Monitoring and Mitigation
 - + Shorts
 - + Over Voltage
 - + Over Temperature
- + Protection from Particle Emissions
- + Control of Gases Emissions



- + Cell propagation mitigation
- + Individual cell short protection
- + High voltage non-metallic pack

Crew Rated Cross Section



Mechanical

- + All the open frame design requirements
- + Reinforce cell walls including spun groove (cap crimp area)
- + Added material for thermal protection
- + Greater cell to cell spacing for thermal and structure
- + Higher temperature materials

Thermal

- + Thermal materials need to function at thermal runaway levels
- + Additional thermal isolation materials
- + Control of vented cell gases along
- + Mitigation for cell vented particular heating other cells in the battery
- + Ability of the battery structure to dissipate the heat generated quickly

Electrical

- + Monitoring of voltage , current and thermal
- + Local method to disconnect
- + Location of electronics to protect from cell outgas and vented particulates
- + Depending on application higher radiation hardness

Pack Summary

- + Open Frame
 - + Smaller
 - + Lighter
 - + Less expensive
- + Mitigated
 - + Larger pack
 - + 20 to 40% higher mass
 - + Additional materials
 - + Higher cost raw material

- + Open Frame

- + Structural

- + Thermal

- + Protection

- + Mitigated

- + Particulate Filters

- + Gas filters

- + Venting mitigation

- + Thermal Management

- + Structural

- + Electronics

- + Volume typically defined by customer
- + Built around Vibration and Shock based on cell packs
- + Thermal analysis to confirm delta thermal from mounting to worst case cell temperature under peak load
- + Enclosed only to protect from external items causing shorts or damage
- + Non-sealed housing with possible location of vent

- + Typical range is 160 to 190 Wh/kg depending upon cell design and chemistry
- + Smaller batteries are lower in Wh/kg
- + Batteries with a center of gravity over 4 in from mounting surface tend to be lower in Wh/kg

Mitigated Design – Battery Structure

- + Volume typically defined by customer
- + Built around Enclosure, Vibration and Shock based on cell packs
- + Thermal analysis to confirm delta thermal from mounting to worst case cell temperature under peak load along with the concerns for cell vented gas
- + Enclosure needs to include filters and vented gas control to limited cell-to-cell propagation

Mitigated Design – Packaging Density

- + Typical range is 140 to 160 Wh/kg depending upon cell format and chemistry
- + Separation of cells packs needs to be greater
- + Propagation mitigation increases structural mass
- + Directing of cell venting increases volume and mass
- + Smaller batteries are lower in Wh/kg
- + Batteries with a cg of over 4in tend to be lower in Wh/kg
- + Location of gas vent can increase mass

Present Technology Status

- + EaglePicher Technologies has been designing and building Space batteries for over 40 years.
- + NASA qualified JSC-20793 designs and crewed missions since 2016.
- + Our recent designs have passed vibration, shock and thermal on first attempt
- + Our NASA rated crew designs have passed propagation testing first time.

- + Designs with higher Wh/kg
- + Designs with higher rate capability
- + Advanced designs with reduced complexity
- + Advanced materials research to improve volume and mass

**Thank-you for listening, If
you have any questions
please contact me.**

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