Applicability of the LG Chemical 18650 MJ1 Cell for Future Lunar Lander Missions

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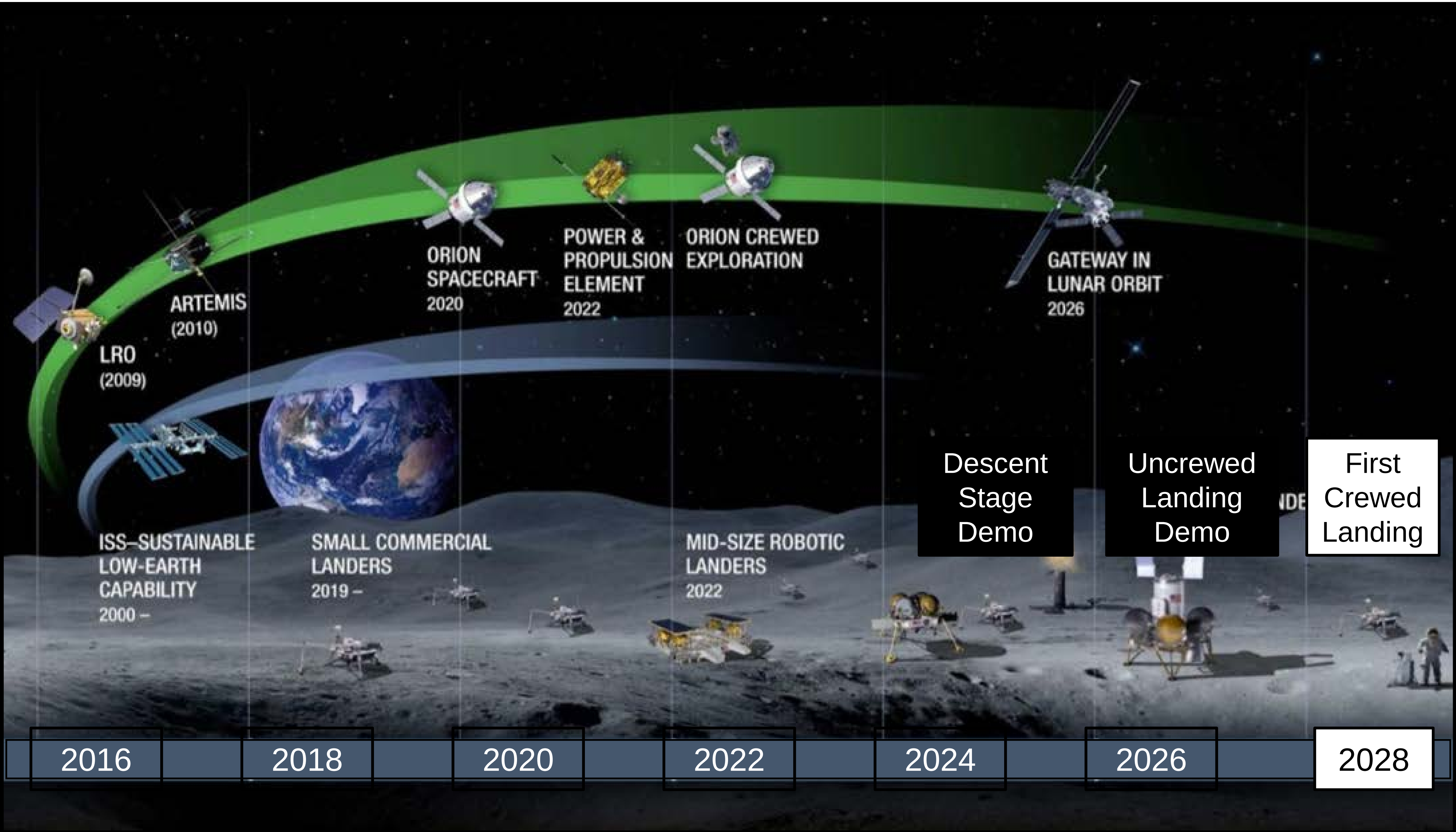
Background

- In 2014 NASA initiated the Lunar Cargo Transportation and Landing by Soft Touchdown (CATALYST) initiative
- Resulted in three Space Act Agreements (SAA); Moon Express Inc., Masten Space Systems Inc. and Astrobotic Technology
- NASA can provide, for example, use of test facilities, design guidance and hardware expertise in all factors of spacecraft design and development
- Glenn Research Center has the lead for electrical power systems

National Aeronautics and Space Administration

Return to the Moon Notional Roadmap



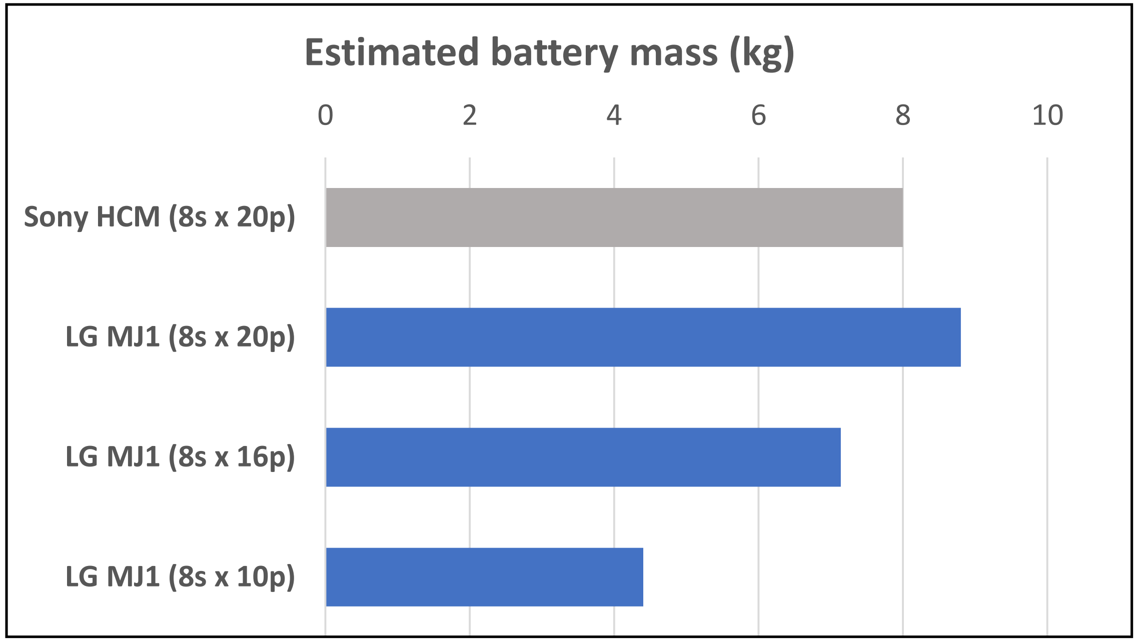
Peregrine Lander

Background

- Astrobotic Inc. Peregrine Lander planned on using a Li ion battery consisting of the flight qualified Sony 18650 HCM cell
  - Flight heritage on LRO, LADEE, LCROSS lunar missions
- However the battery vendor plans on switching to the LG Chem MJ1 cell for future space applications
- NASA GRC initiated a series of characterization and limited cycle tests to verify cell performance over the expected lunar transfer, lunar orbit and surface descent power

MJ1 and HCM Cell Comparison

	Sony HC	LG MJ1
Cell mass (g)	42 g	49 g
Nominal capacity (Ah)	1.44	3.5
Specific energy (Wh/kg)	120	250
Maximum discharge, cont. (A)	1.5	10



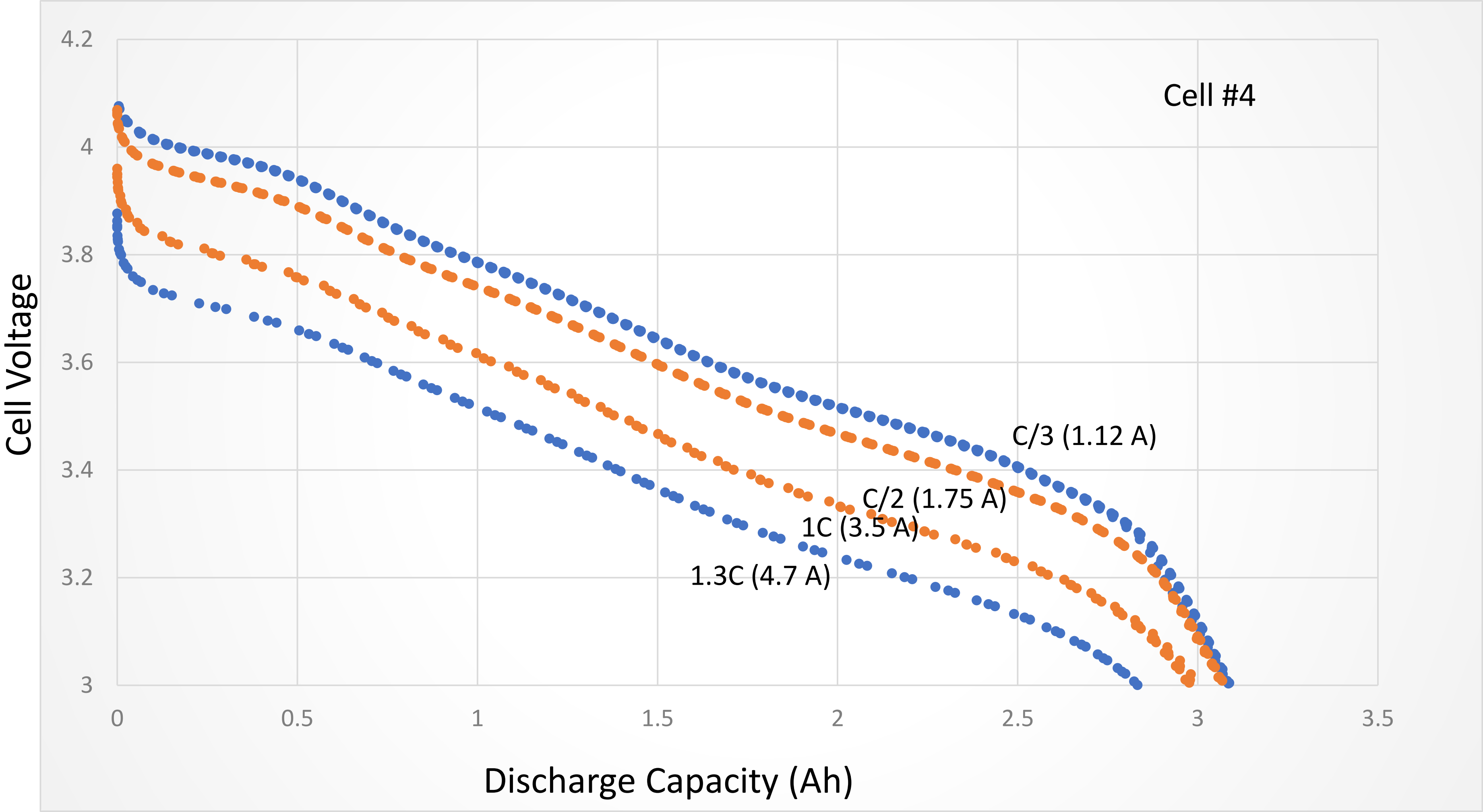
- MJ1 offers ~2 x the energy density for significant mass savings
- Significant increase in discharge rate capability allows simpler bus voltage control avionics

MJ1 Discharge Rate Testing Results

LG MJ1 High Capacity Cell

- Cells charged at C/4 to 4.2 V
  – taper charge to C/20
- Constant-Current Discharge

- All testing at 20°C
- C-rate based on 3.5 Ah nominal capacity



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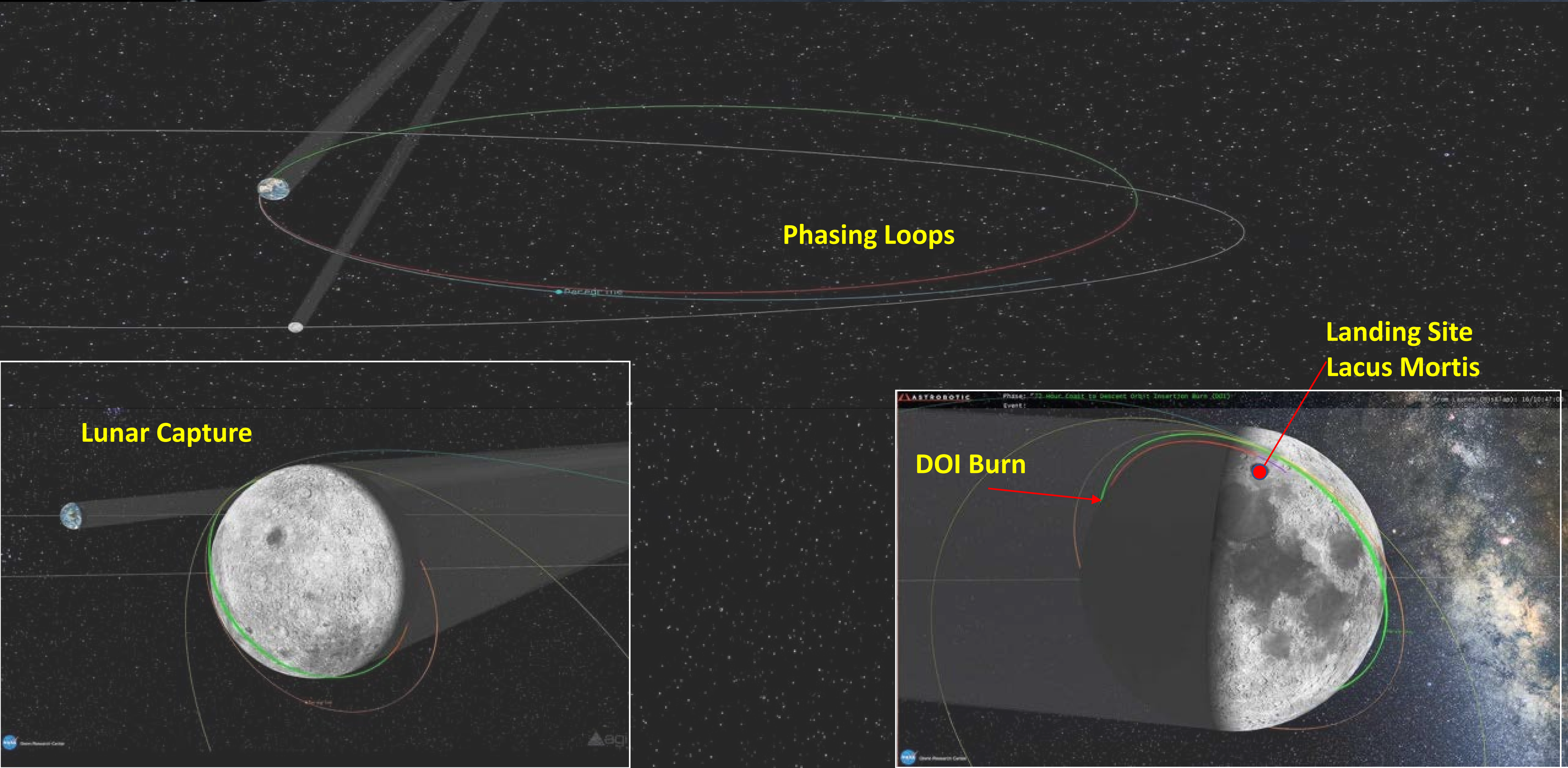
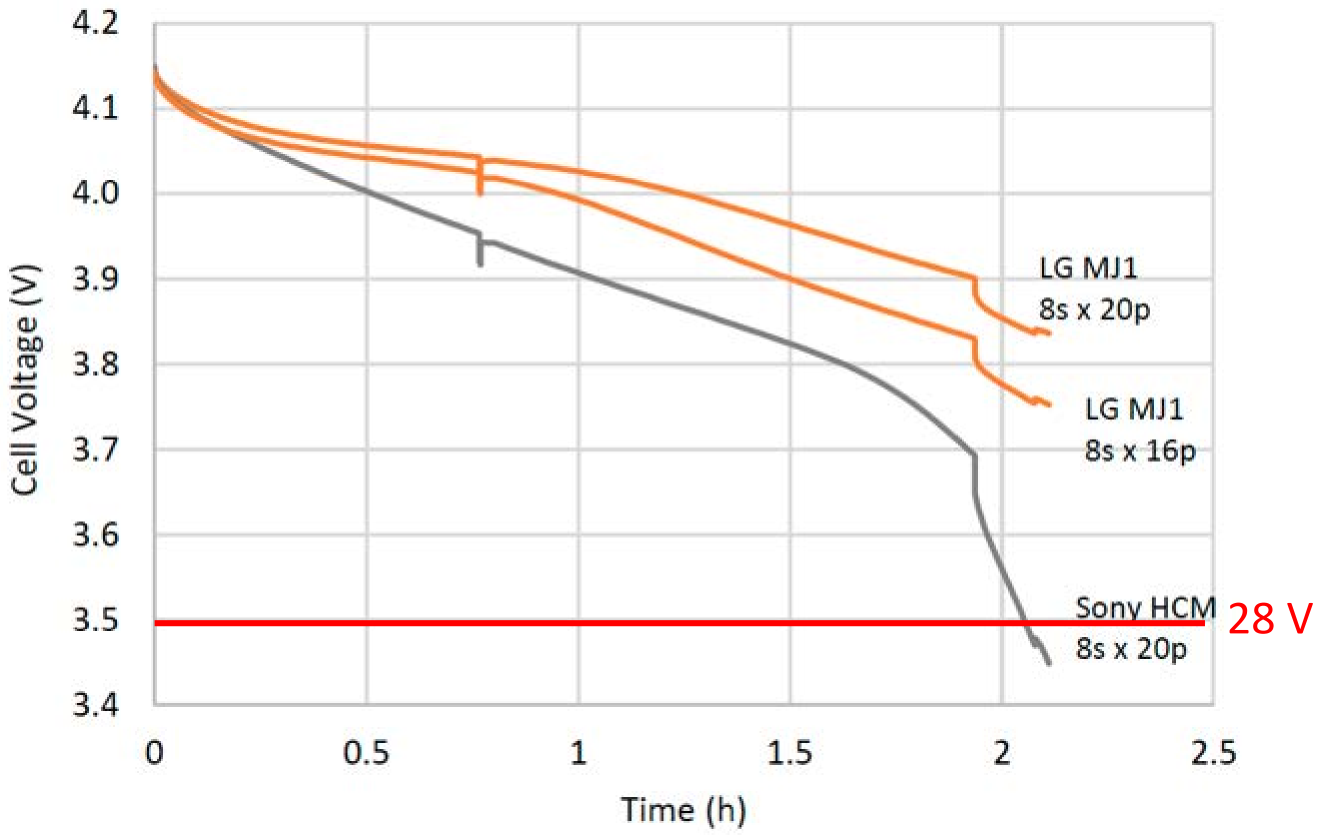
Mission Trajectory Option for Secondary Payload



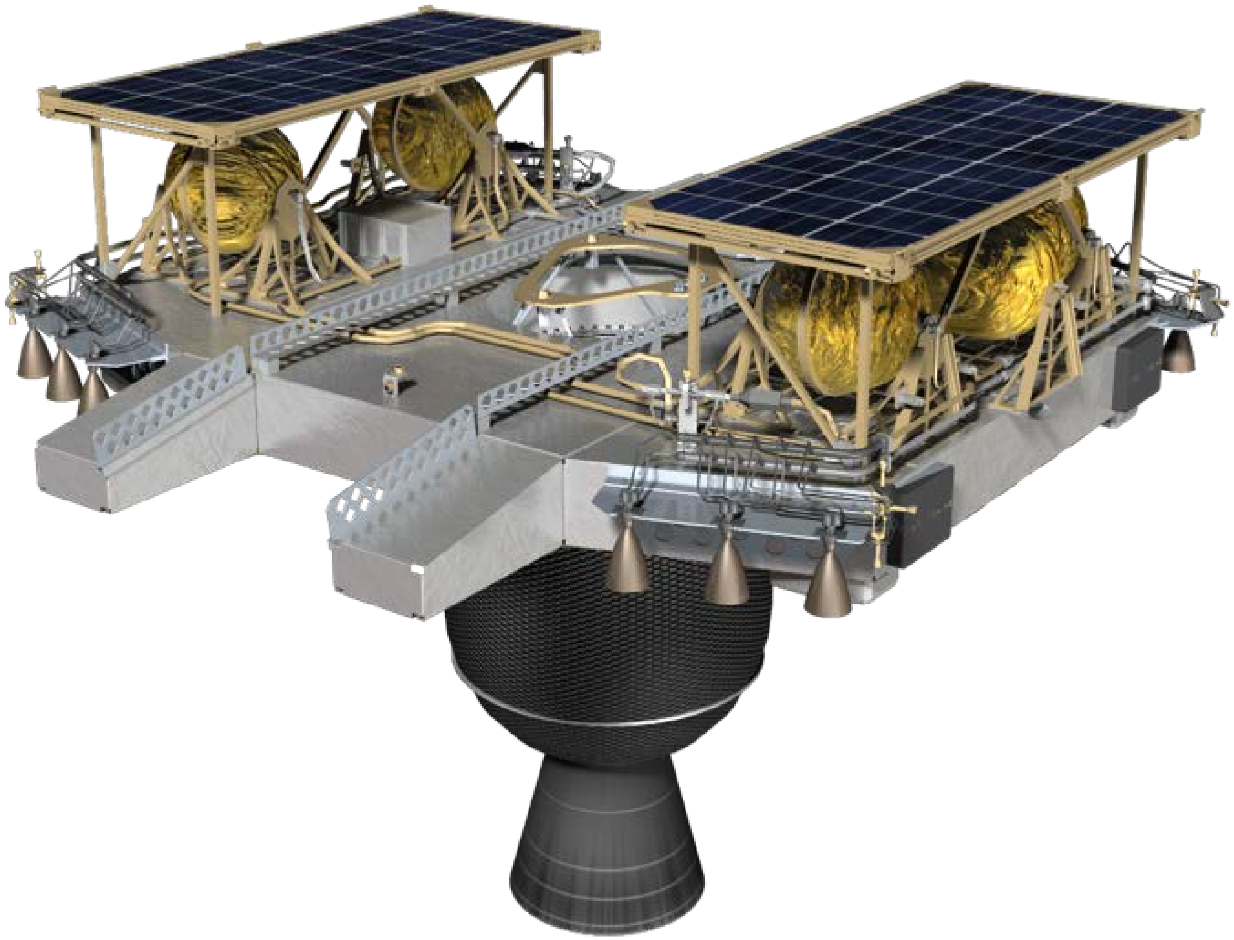
Cell Tests of Peregrine's Power Profile

	duration (h)	Cell (W)	Battery (W)	Battery (Wh)
ORBIT (LOS + eclipse)	0.77	1.64	262.5	201.3
DOI (10-second pulse)	0.003	2.85	456.6	1.3
SLEW MANEUVER	1.17	1.74	279.0	325.5
POWERED DESCENT	0.14	3.07	491.1	69.6
TERMINAL DESCENT	0.033	2.76	441.3	14.7
total	2.11			612.3



MJ1 and HCM Voltage Comparison During Descent

VIPER Lander



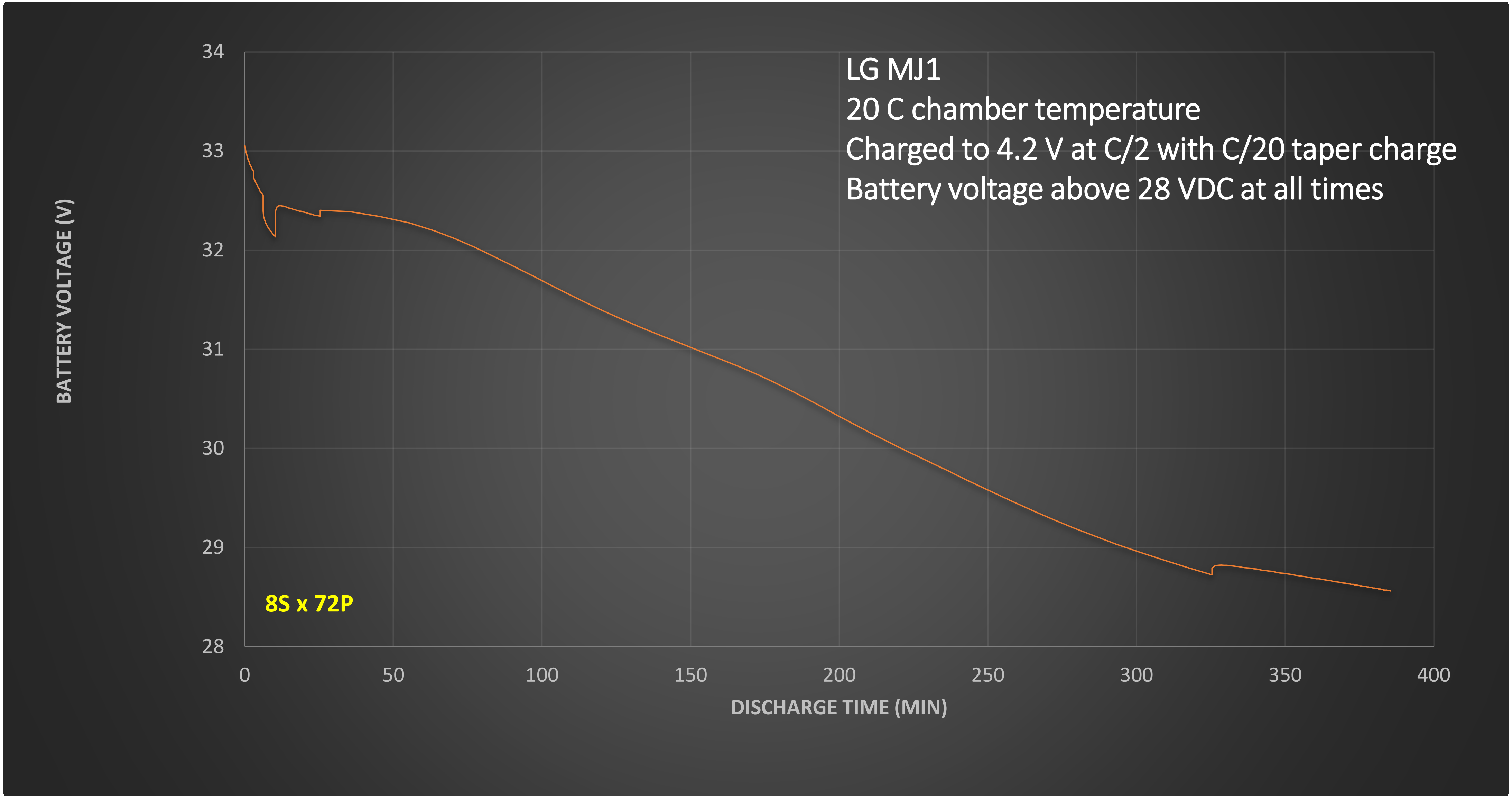
- Lunar Polar Landing
- Direct lunar descent
- Survive ~ 8 hours after landing while rover performs egress
- Demonstrate landing accuracy to within 100 m
- 650 W Array
- 6 kW-hr battery

VIPER Lander Descent Profile

Battery Mode Only (lunar insertion to landing)	Avg Power (W)	Avg Current (A)	Duration (hr)	Energy Used (Whr)	Cumulative Energy Used	Cum DOD (%)	Peak Power (W)	Peak Current (A)	C rate	Notes
Maneuver to SRM burn attitude (3 min)	1237.08	44.18	0.05	61.85	61.85	1.02	1533.48	54.77		chg 5 to 3
SRM burn (2 mins)	1500.98	53.61	0.03	50.03	111.89	1.84	1533.48	54.77		
SRM separation and coast (1 min)	1527.73	54.56	0.02	25.46	137.35	2.26	2742.48	97.95	~C/2.2	Worst Case, Batt V ~31
Vertical descent and landing (4 mins)	2439.58	87.13	0.07	162.64	299.99	4.95	2472.08	88.29		chg 3 to 4
Primary payload services (15 mins)	1116.96	39.89	0.25	279.24	579.23	9.55	1116.96	39.89		
Propulsion Safing (5 hour)	772.85	27.60	5.00	3864.25	4443.48	73.25	1155.96	41.28		
Idle (Rover Egress) (45 mins)	409.22	14.62	0.75	306.92	4750.39	78.31	473.85	16.92		
Deploy Solar Arrays (15 mins)	409.16	14.61	0.25	102.29	4852.68	80.00	490.75	17.53	~C/12	Exp. Battery V ~28
Total battery capacity required				4852.7						
Total battery capacity w/80% @ EOM (217 Ahr)				6065.85						

*VIPER (**V**olatiles **I**nvestigation **P**olar **E**xploration **R**econnaissance)

MJ1 Validation for VIPER Descent and Landing Phase



Key Observations

- Based on preliminary test results, the MJ1 cell performed very well over the mission profile of a typical lunar lander mission
- Superior cell voltage performance allows use of a quasi-regulated bus and simpler power management devices
  - Reduced cost and complexity
- Two fold increase in energy density can provide a significant mass and volume that could be allocated for additional payloads
  - Increased science return or revenue

Thank you for your attention!

Questions?

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