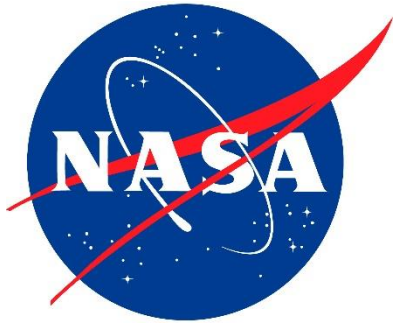

Effect of Mechanical Stress Factors on Large Format Li-Ion Cell Thermal Runaway Characteristics

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235th Meeting of The Electrochemical Society

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* - NASA Lyndon B. Johnson Space Center, Houston, TX, USA; # - LIB-X Consulting, Long Beach, CA, USA

Agenda

- Background
- Cell Thermal Runaway (TR) Trigger Methodology
- Cell Mechanical Compression Test & Analysis
- Summary

NASA Engineering Safety Center (NESC) Initiatives

Developing NASA LIB Best Safety Practices

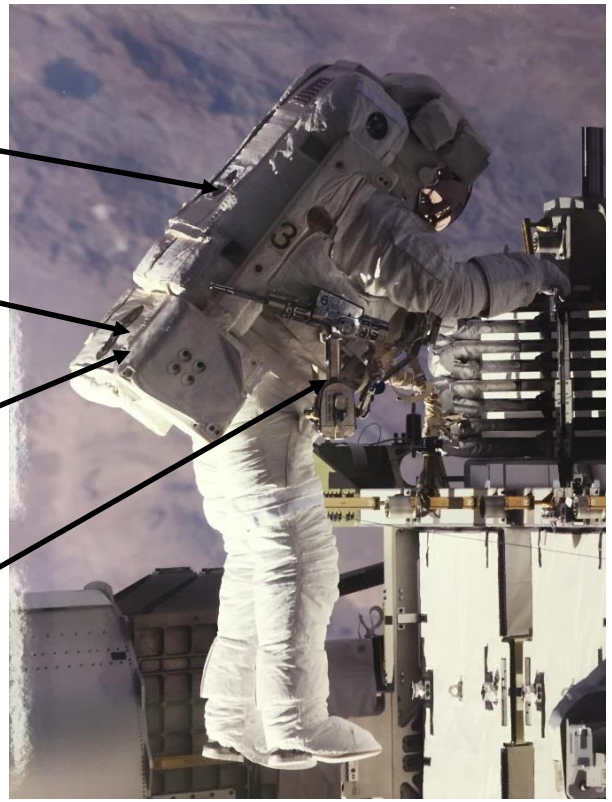
ISS EVA Batteries

Long Life Li-Ion Battery (LLB)

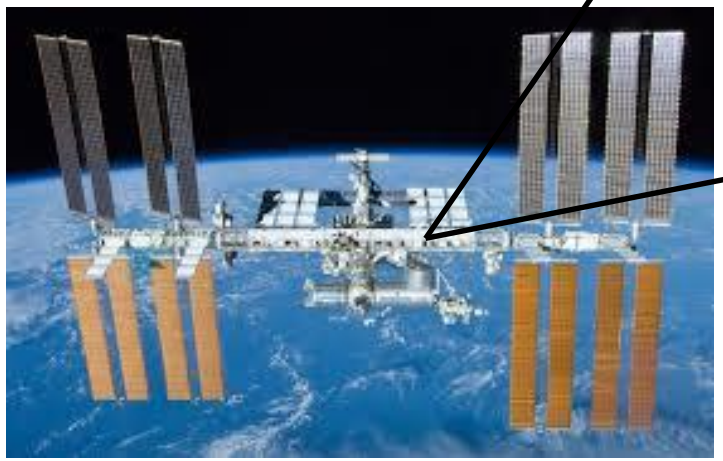
Li-Ion Rechargeable EVA Battery (LREBA)

Simplified Aid For EVA Rescue (SAFER) Battery

Li-Ion Pistol Grip Tool (LPGT)



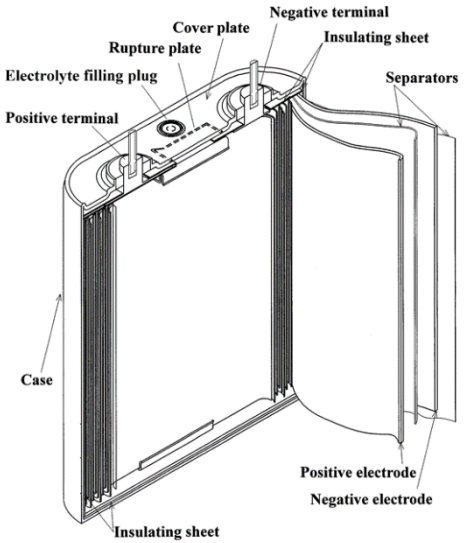
ISS Li-Ion Main Battery ORU

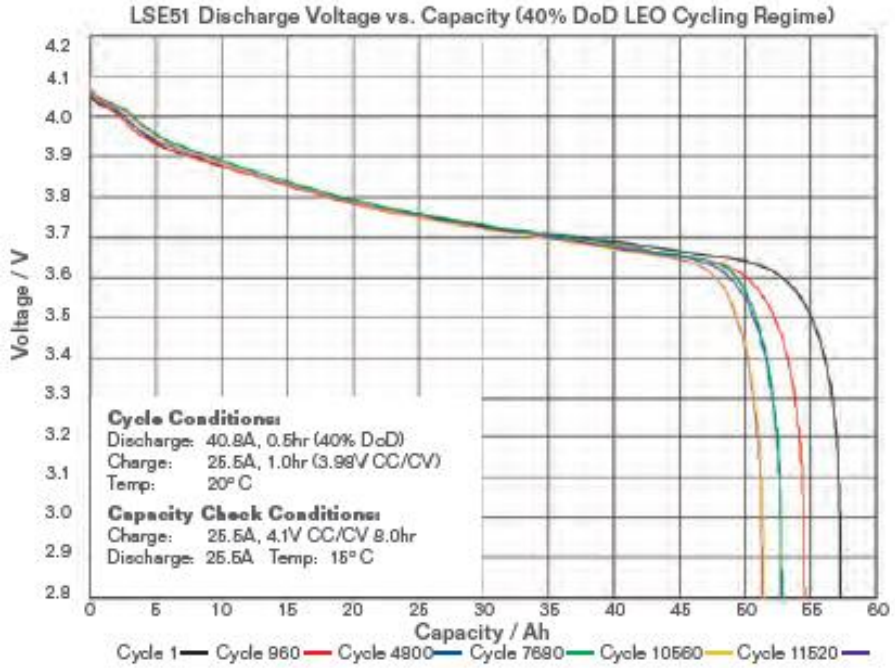


ISS COTS Li-Ion Cell Specification

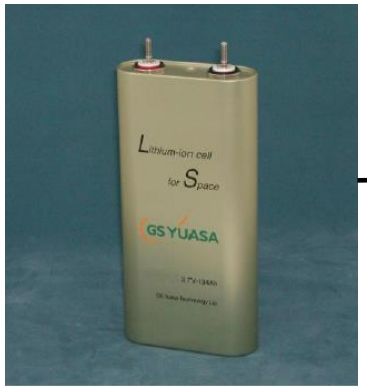
Cell Characteristics	GS Yuasa LSE 134
Chemistry - Gen III	
Cathode	Li Cobalt Oxide (LCO)
Electrical	
Cell Capacity (Nameplate; BoL), Ah	134; 148
Cell Energy (Nameplate; BoL), Wh	496; 548
Specific Energy, Wh/kg	155
Energy Density, Wh/L	349
Nominal Voltage, V	3.7
End of Charge, V	4.1
End of Discharge, V	2.75
Max. Continuous Charge Current, A	67
Max. Continuous Discharge Current, A	134
Max. Pulse Discharge Current (5 s), A	402
Overcurrent Protection	***Yes***
Mechanical	
Dimensions (w x t x h), mm	130 x 50 x 271
Mass, kg	3.53
Volume, L	1.57
Header Vent Device	***Rupture Plate***
Temperature	
Charge, °C	+10 to +35
Discharge, °C	-10 to +35
Storage, °C	-10 to -10

Ref: URL: http://www.gsyuasa-lp.com/

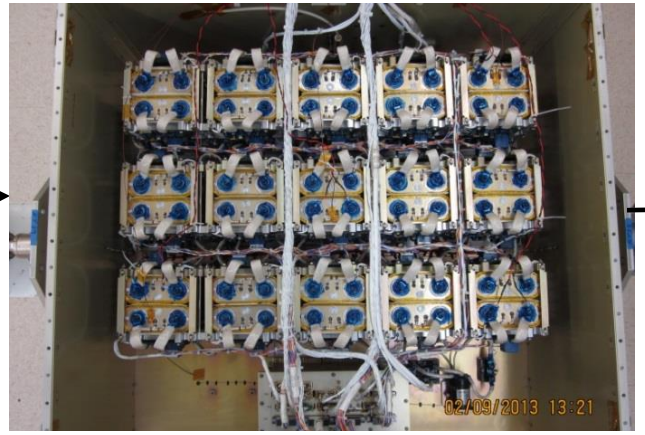




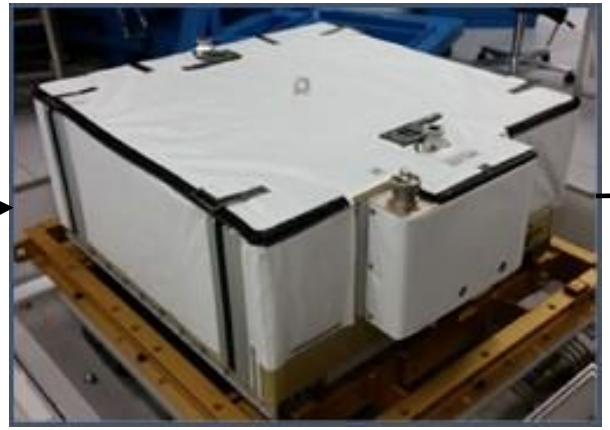
NASA ISS Li-Ion Battery Architecture & Integration



ISS Li-Ion Battery Cell (GS Yuasa LSE134)



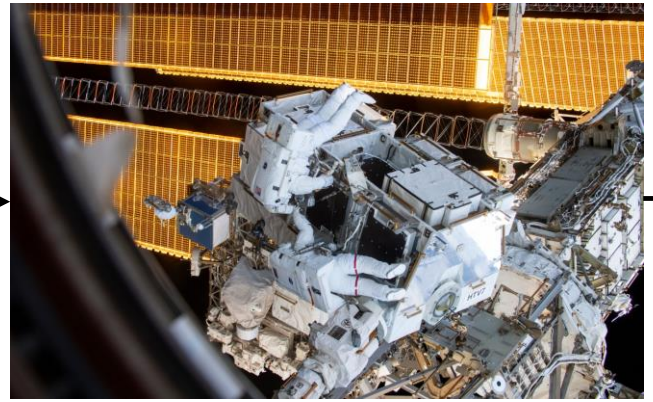
ISS Li-Ion Battery ORU – 1P-30S



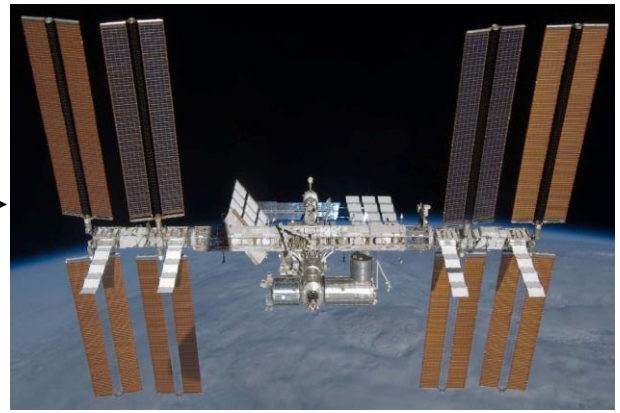
ISS Li-Ion Battery ORU – Cover On

HTV Clean Room – Tanegashima Space Center

HTV6 – Launch



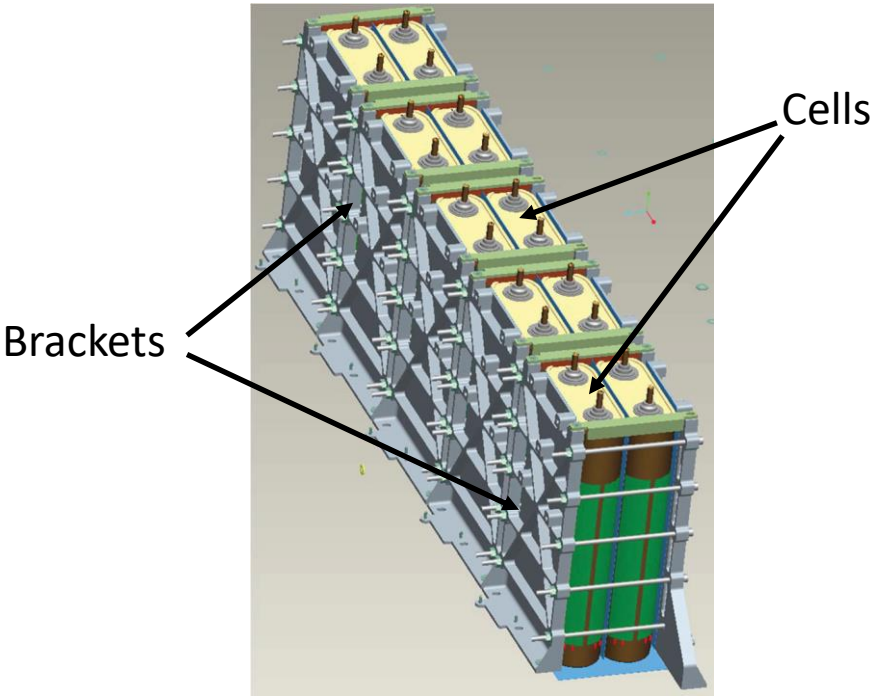
US Astronauts Installation of ISS LIB's



International Space Station

NASA ISS Li-Ion Battery Architecture

LSE134 Li-ion cells (single group)
3 Groups per Battery ORU (10 cells/group)

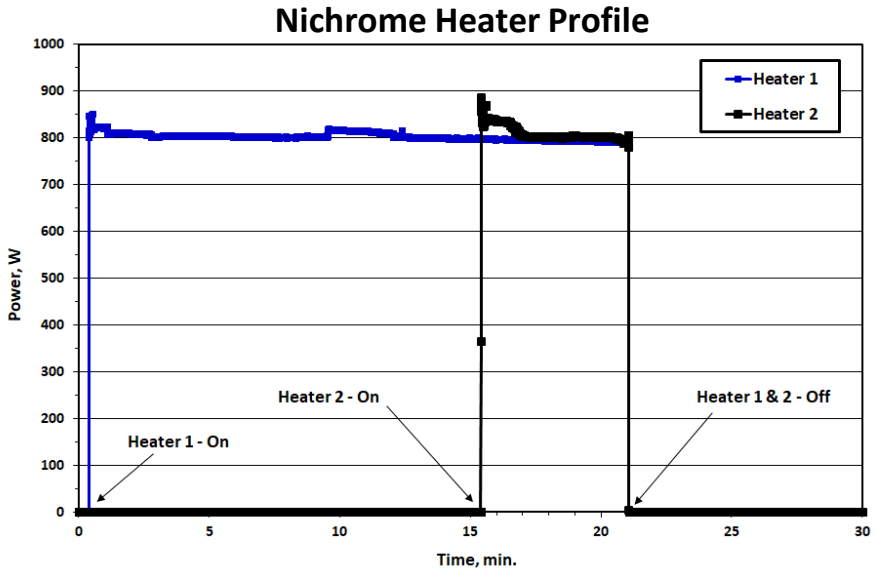


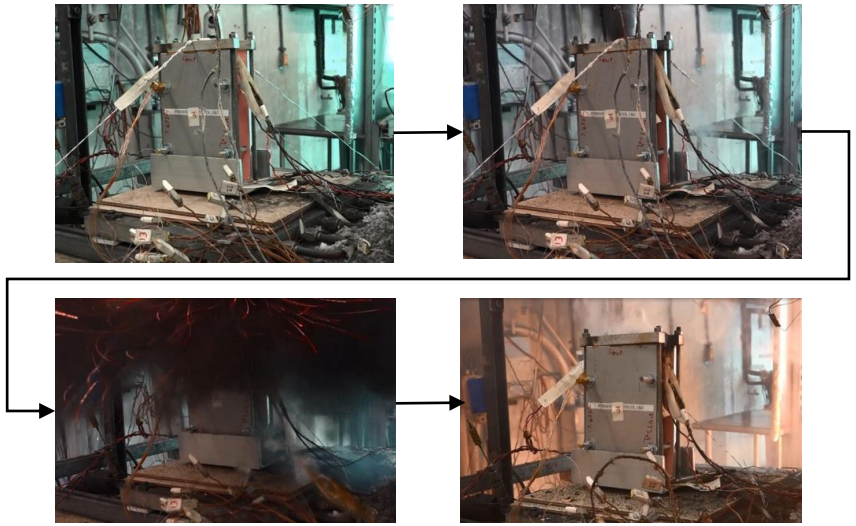
NASA White Sands Test Facility - Thermal Runaway Test Configuration

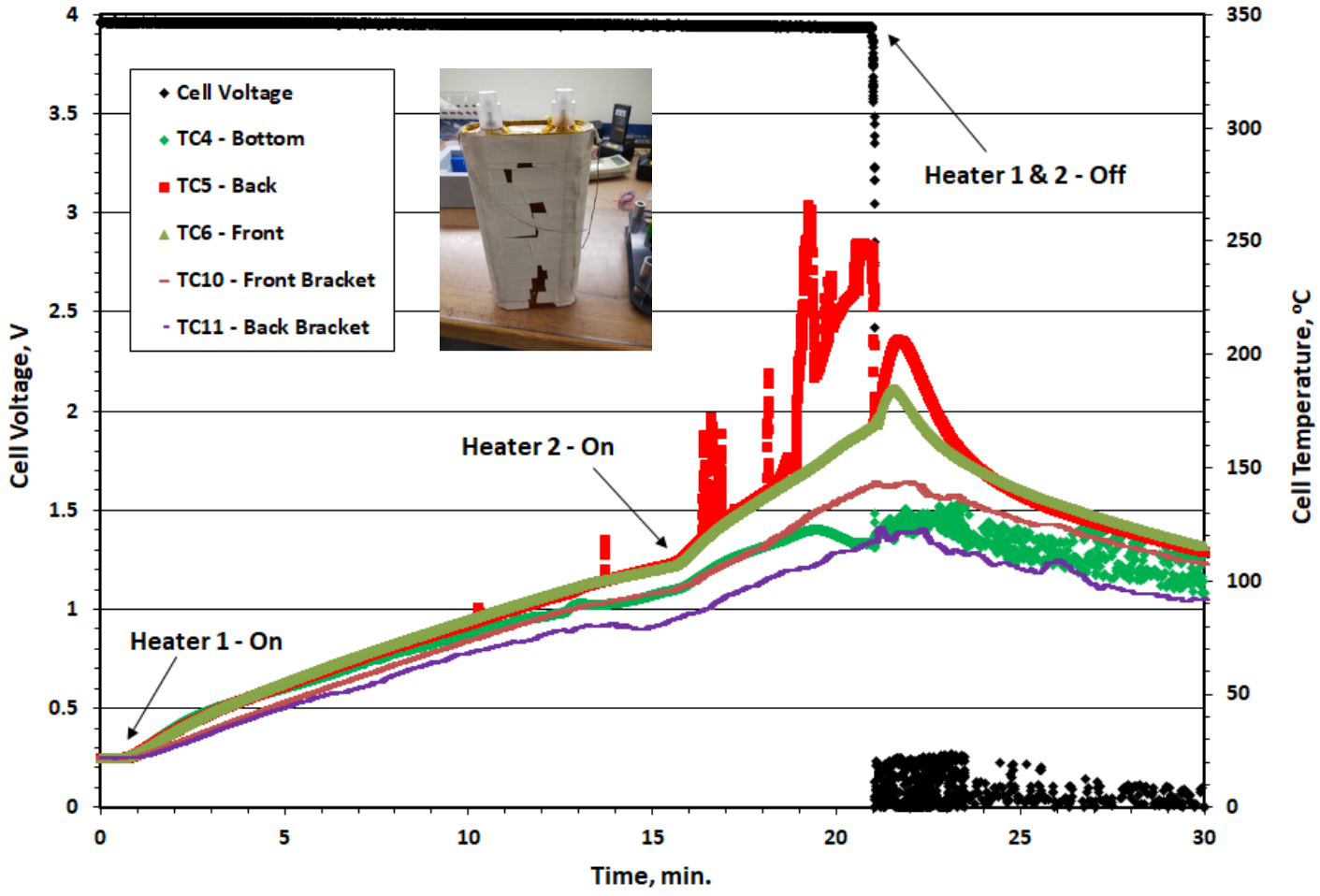
NASA Photo

- 10 screws applied to each cell pair
- 1200 lb. of compression force applied to each cell pair
- Cell compression required to meet launch vibration; thermal baseplate contact; and performance requirements.

Large Cell TR Trigger Heat-to-Vent : Nichrome Wire







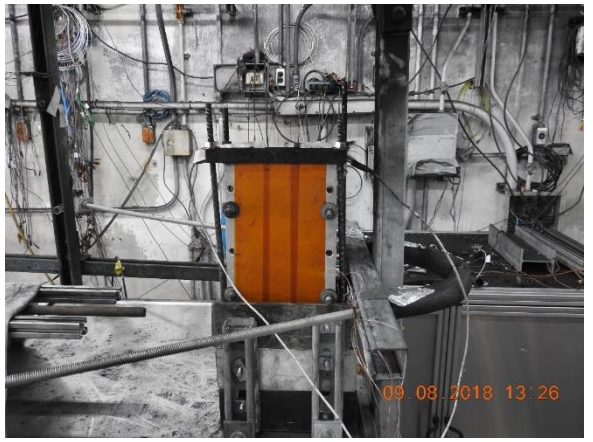
Test Cell Compression Analysis

- Purpose
  - Flight battery loading and test setup
  - Ungreased screws were found to create uncertainty in calculations
- Results
  - 7 in-lb testing less than flight level load
  - 14 in-lb was found approximate to flight load
  - 19 in-lbs found to be greater than flight load

Test Compression Calculation (4 Bolts)

Bolt Dia = 0.375 $k_{PTFE\ Grease}$ = 0.10 - 0.18

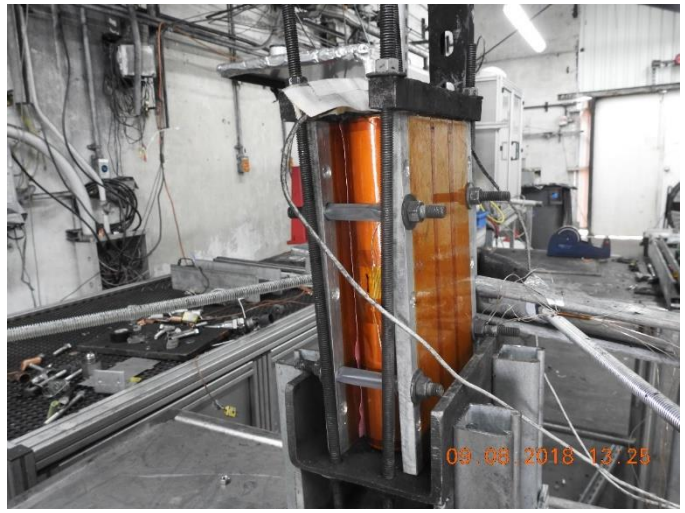
Total Cell Compression	Single Bolt Force	Bolt Torque (in-lbs)		
		Max	Mean	Min
lb	lb	k = 0.18	k = 0.13	k = 0.10
2030	507.5	34.3	24.7	19.0
1900	475	32.1	23.2	17.8
1800	450	30.4	21.9	16.9
1700	425	28.7	20.7	15.9
1560	390	26.3	19.0	14.6
1490	372.5	25.1	18.2	14.0
1400	350	23.6	17.1	13.1
1300	325	21.9	15.8	12.2
1200	300	20.3	14.6	11.3
1150	287.5	19.4	14.0	10.8
1125	281.25	19.0	13.7	10.5
900	225	15.2	11.0	8.4
827	206.75	14.0	10.1	7.8
745	186.25	12.6	9.1	7.0
575	143.75	9.7	7.0	5.4
500	125	8.4	6.1	4.7
415	103.75	7.0	5.1	3.9
300	75	5.1	3.7	2.8
200	50	3.4	2.4	1.9



Flight Compression

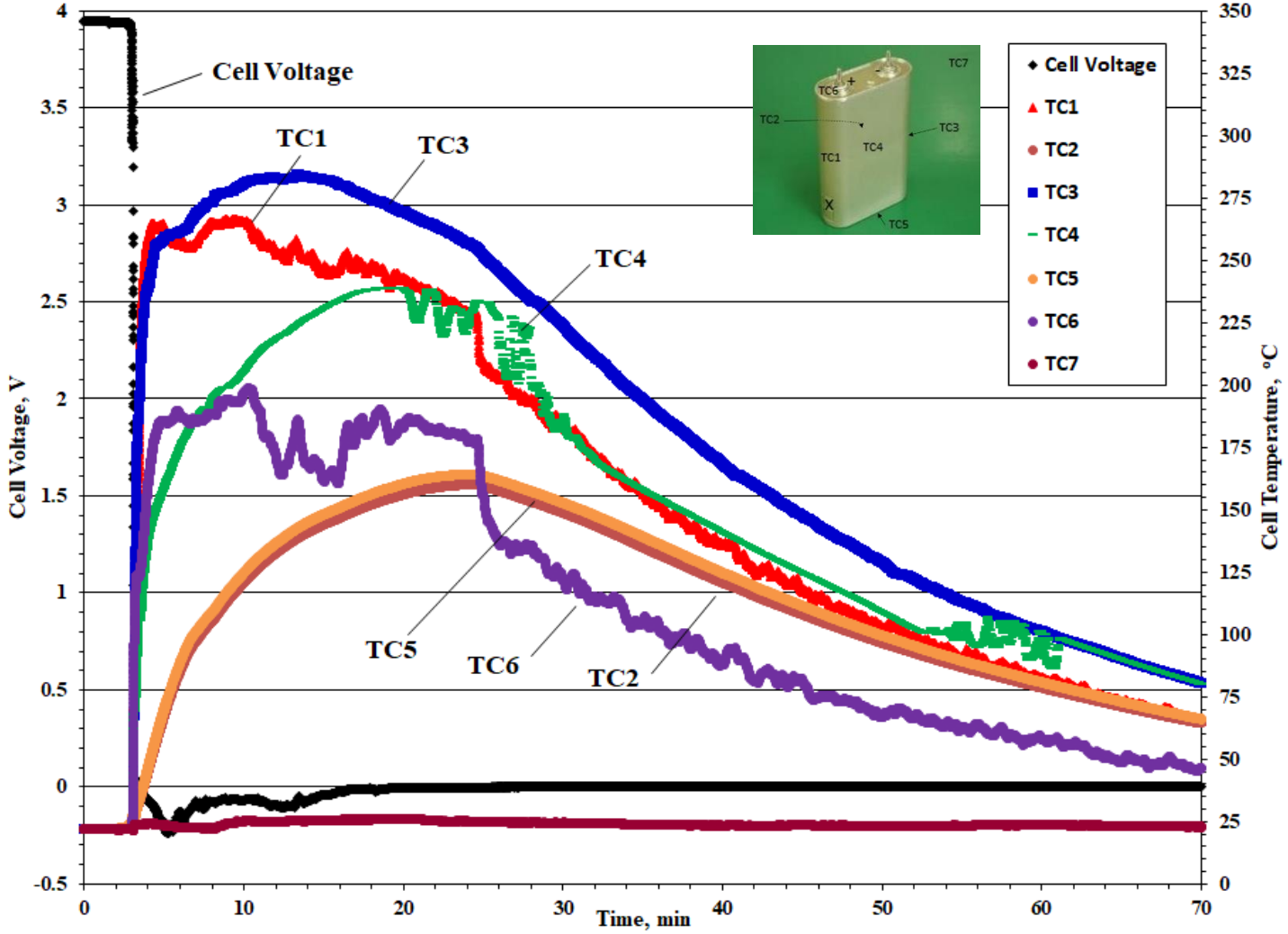
Test Approach & Protocol

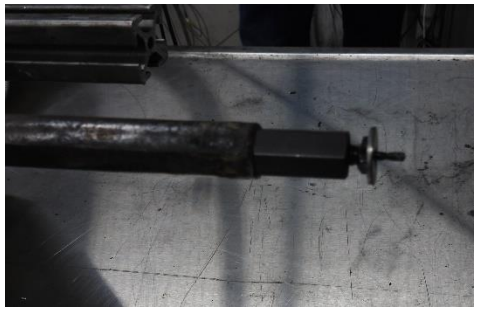
- Cells were clamped following GSY procedure
- Custom drill rig controlled by an operator used for trigger method
  - Drill bit diameter of .1285” with 4/16” max penetration distance
- Video monitoring, IR video, cell temperature, cell voltage, and cell current recorded
- Cells were charged to 3.95V (ISS maximum voltage per cell)
- Tests conducted in ambient environment
- Values of 0, 7, 14, and 19 in-lb of torque were applied to screws.



Cell Thermal Response : 0 in-lb Cell Compression

Cell Jellyroll Ejection - **No**

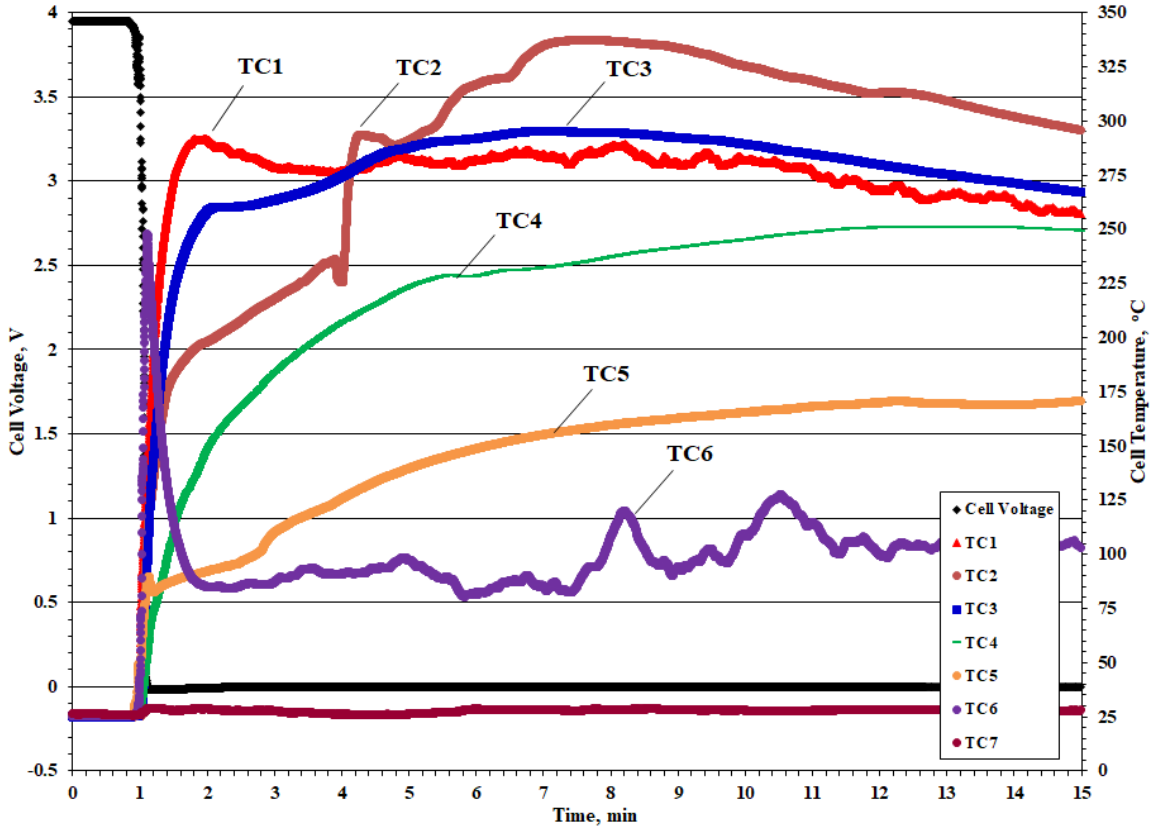




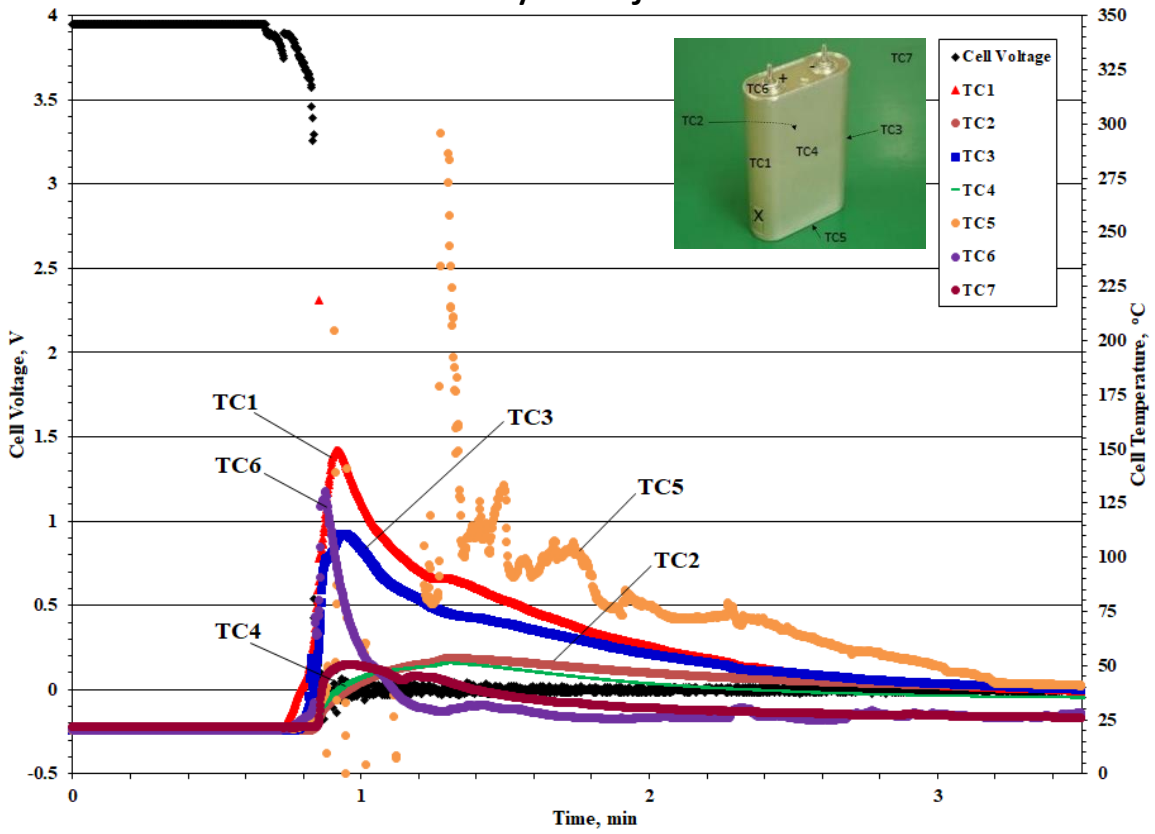
Cell Thermal Response : 0 in-lb Cell Compression

Cell Thermal Response : 7 in-lb Cell Compression

Cell Jellyroll Ejection - **No**

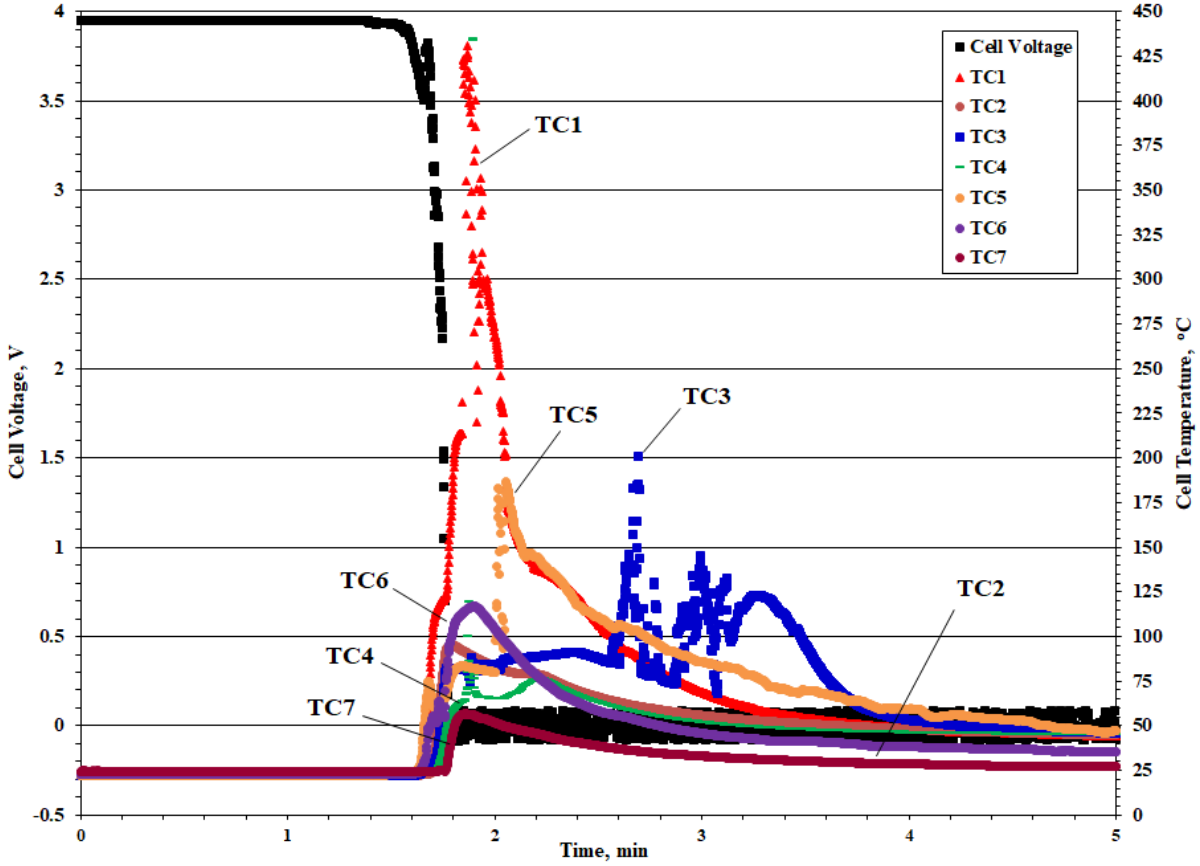


Cell Jellyroll Ejection - **Yes**

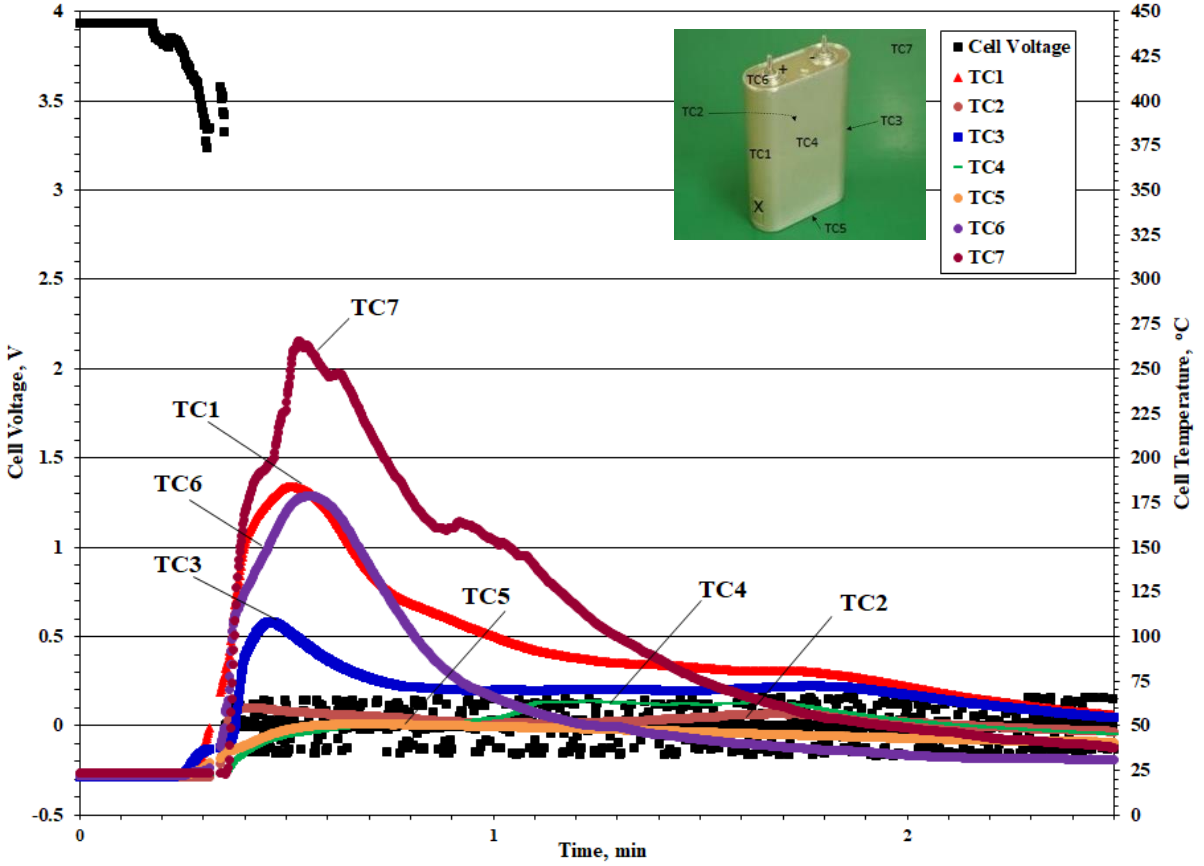


Cell Thermal Response : 14 in-lb Cell Compression

Cell Jellyroll Ejection - **Yes**

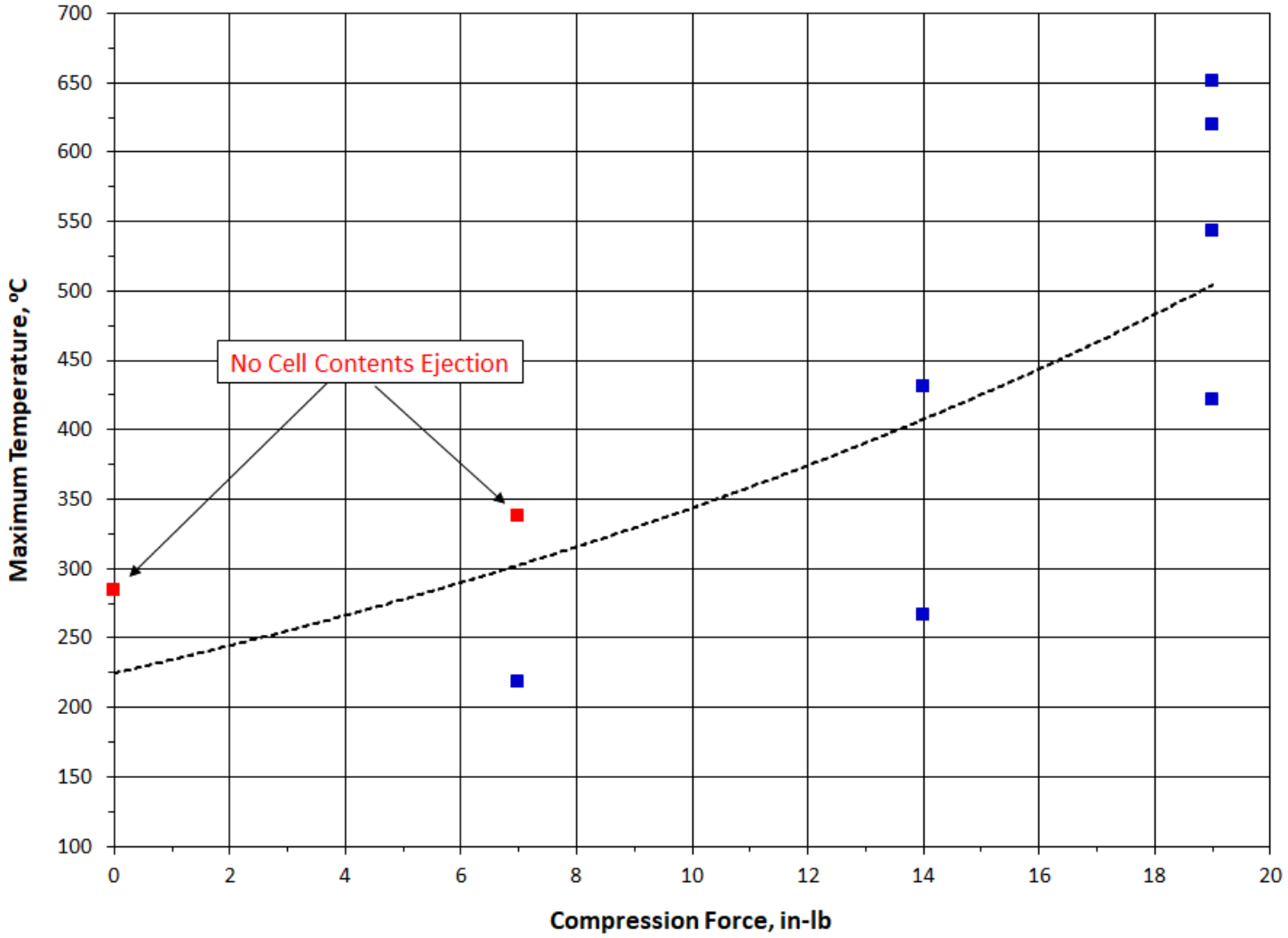


Cell Jellyroll Ejection - **Yes**



Cell Thermal Response : 14 in-lb Cell Compression

Effect of Cell Compression Load on TR Severity



Summary

- Applied Cell Compression Force
  - Necessary to meet spacecraft launch environments and reduce swelling during on-orbit cycling
  - Positive correlation between compression force and severity of thermal runaway
  - Other primary factors affecting thermal runaway severity include cell SoC
- Next Steps
  - Quantify compression forces with flight load cell compression fixture
  - Investigate affects of cell compression on different Li-ion cell designs (vent types, geometry, etc.)

Acknowledgments

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- Mr. Yaramy Trevino and the NASA/JSC Energy Systems Test Area (ESTA) personnel for outstanding test & analysis support

NASA/JSC ESTA Test Facility, Houston, TX, USA

NASA Photo