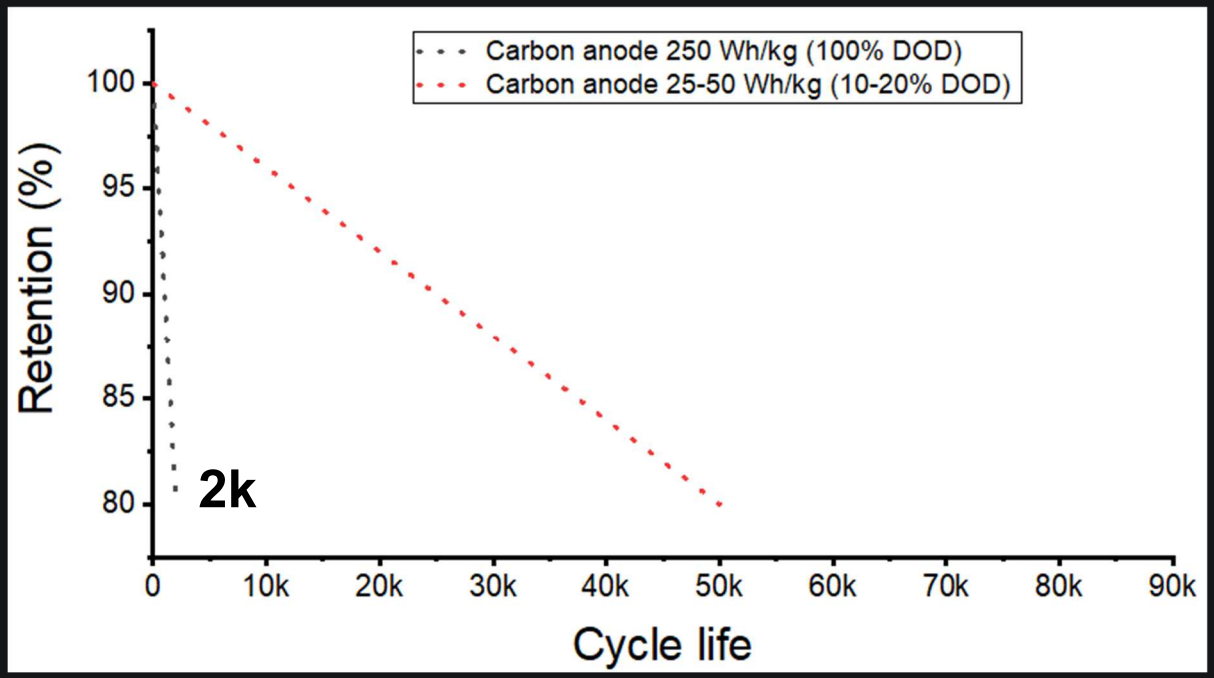
High Performance Li-ion Enabled by Vanadium Oxide Anode: Max Power, Extended Life and Low Temperature Charge Capability

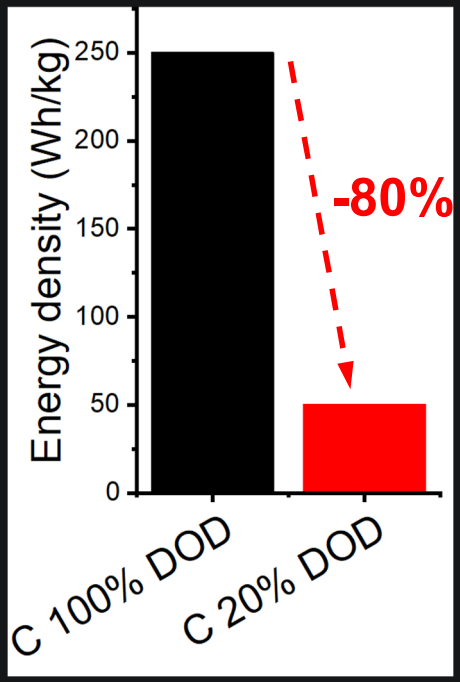
TYFAST

Space Power Workshop 2024

Haodong Liu, Co-Founder and CTO

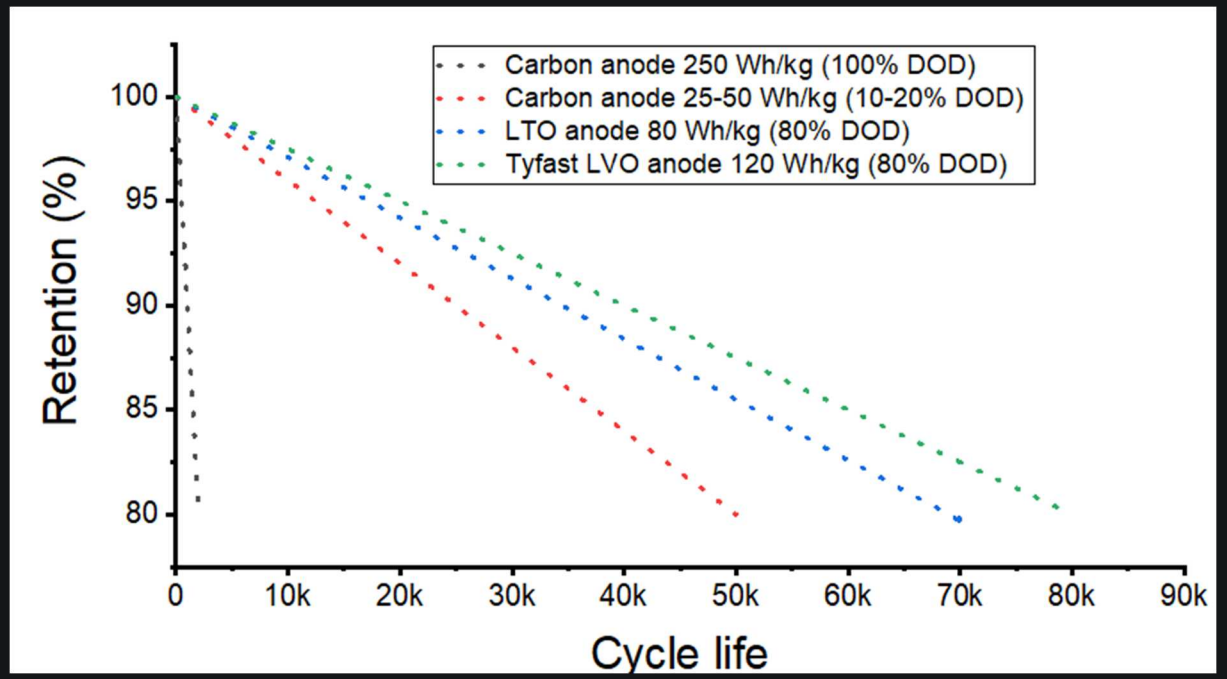
Problem: Carbon Anode Batteries Not Ideal for Space Applications

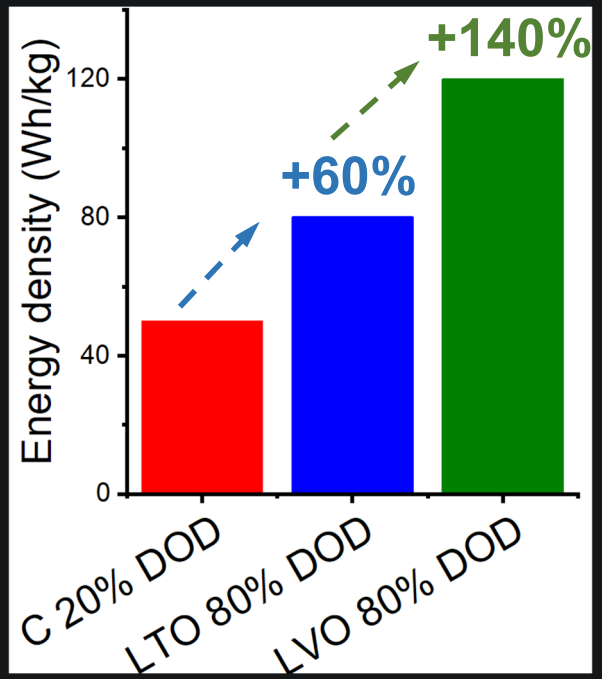




Current carbon anode batteries compromise 80-90% of their energy to attain a 50k cycle life suitable for space applications, resulting in oversizing and increased costs.

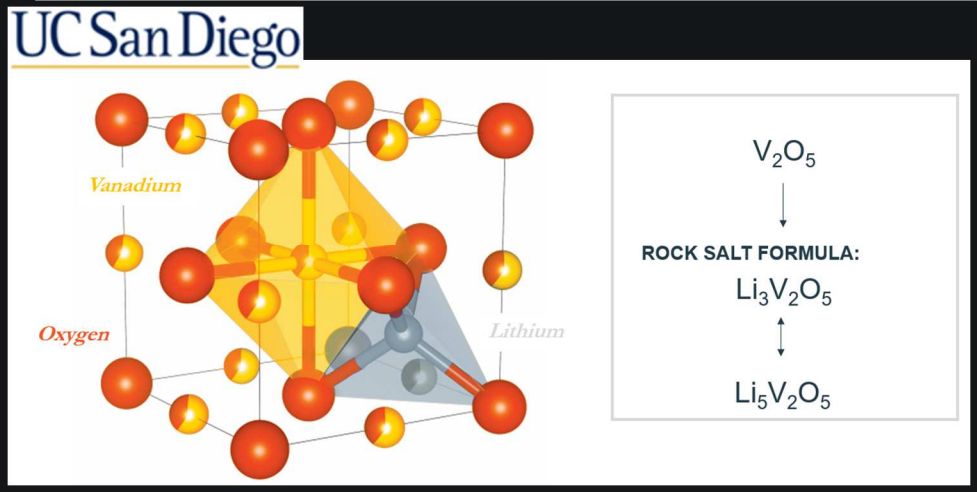
Solution: TYFAST High Performance Battery For Space Applications





Tyfast LVO batteries deliver over 80k cycles of long life coupled with high operational energy density, surpassing space application requirements and enabling reduced sizing and lower costs.

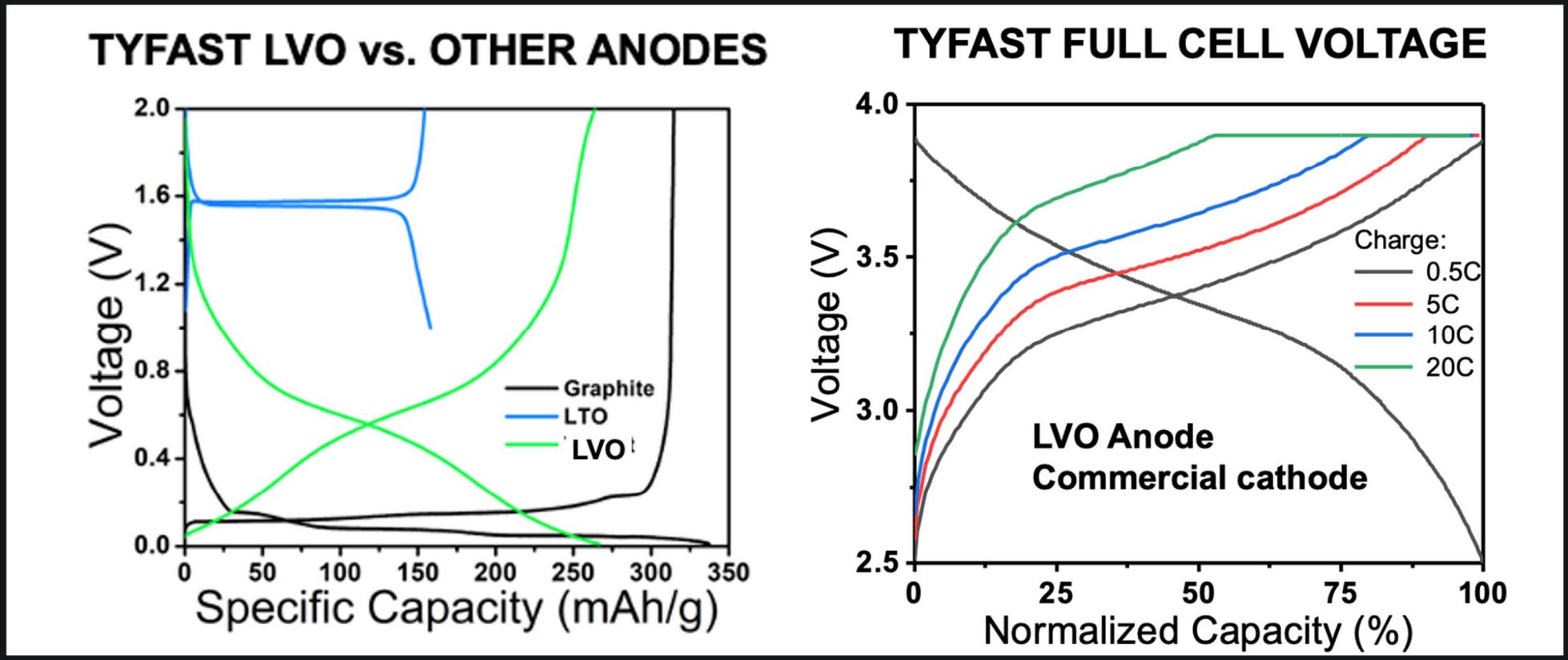
Technology: High Performance Battery Powered by Novel LVO Anode



<u>Sustainability:</u>
10x Battery Life
***Reduces* by 10x**
the Processing, Recycling and Energy Costs and associated Emissions

LVO	⇨	**Lithium Vanadium Oxide (5 patents pending)**
10x Faster Li Transport vs. Graphite	⇨	**<6-mins charging (>10x Power Target)**
5x Lower Volume Expansion vs. Graphite	⇨	**>10,000 Cycle Life (>10x Life Target)** **>80,000 Cycle Life (>80% DOD)**
Metal Oxide Anode	⇨	**Higher Safety, Lower Heat Release**
Raw Material	⇨	**Abundant, 100% Domestic (US Vanadium)**

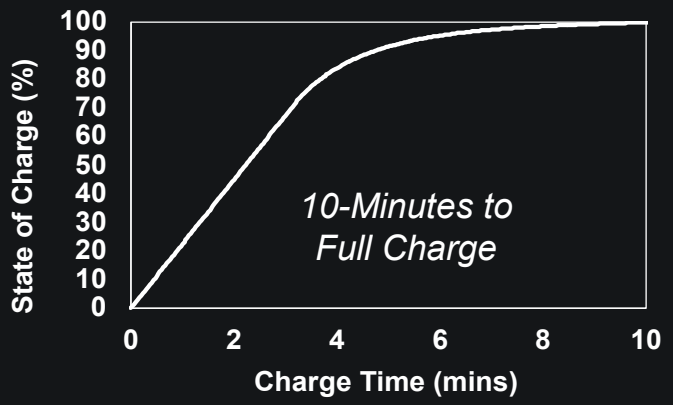
LVO Anode and Cell Voltage



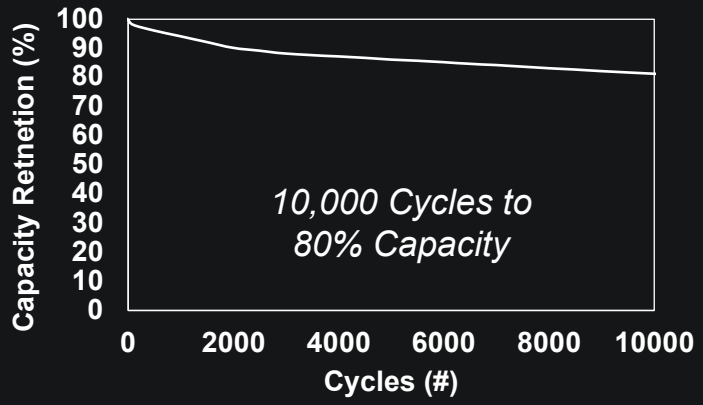
Technical Validation: R&D Cell Performance

COMPLETED:
3rd Party Performance
and Safety Validation

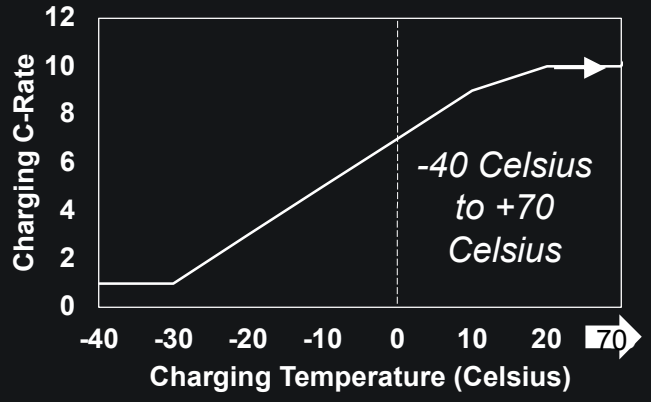
Fast Charging



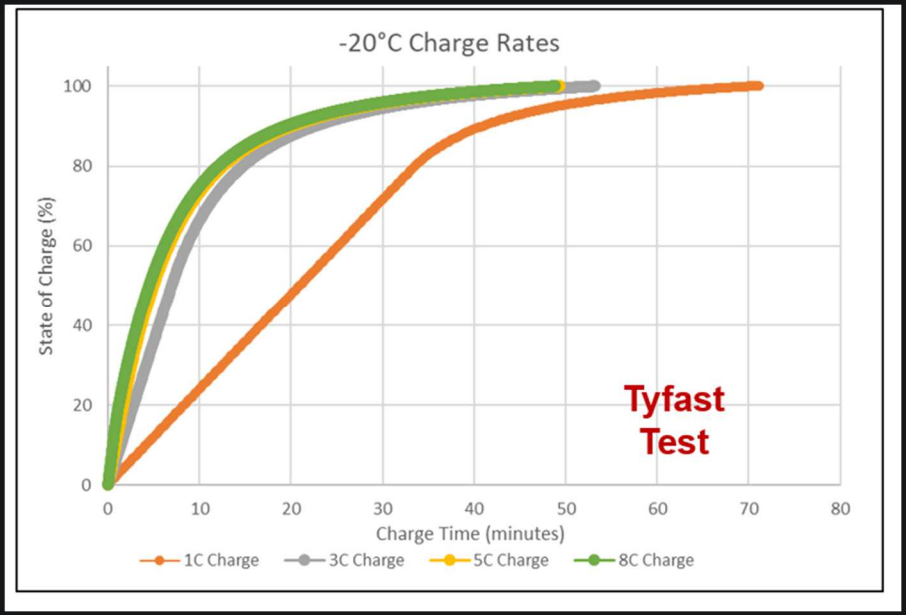
Long Life



All Weather

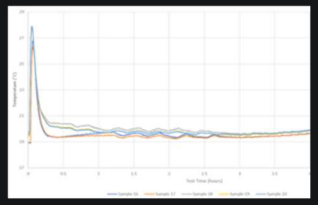
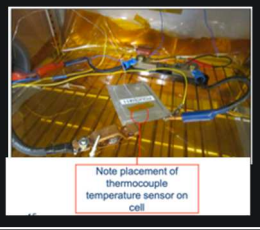
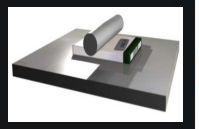


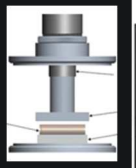
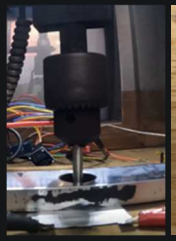
-20 °C Fast Charge Performance



< 20 mins charge from 0-80% at -20 °C

Safety: Passed UL1642 (No Fire or Explosion)

UL1642 Test	Test Result	Test Image/ Description
Abnormal Charging	PASS	• 30C-rate charge to 100% SOC 
Short Circuit	PASS	• 10 mΩ resistance load at 100% SOC 
Impact	PASS	• 20-lb bar dropped from 2ft, 100% SOC  

UL1642 Test	Result	Test Image/ Description
Crush	PASS	• Ram with 3000+224 lbs force applied, 100% SOC  
Nail Penetration	PASS	• 8mm nail at 100mm/sec, 100% SOC  
Thermal Abuse	PASS	• Temp hold at 130 °C for 10 mins 

Technology: LVO Delivers High-Performance & Highest Life Energy

Anode + NMC Cathode	Charging Speed	Charging Below 0 °C	Cycle Life	Energy Density	Life Energy 0-100% SOC
TYFAST LVO* (>3.2V/cell)			>10,000	150-200 Wh/kg 400-500 Wh/L	1.5-2 MWh/kg
Graphite (>3.6V/cell)			>1,000	>250 Wh/kg >600 Wh/L	>0.25 MWh/kg
LTO (<2.5V/cell)			>10,000	<100 Wh/kg <250 Wh/L	<1 MWh/kg
Silicon* (>3.3V/cell)			<1,000	>300 Wh/kg >800 Wh/L	>0.3 MWh/kg
Niobium* (<2.5V/cell)			<10,000	<150 Wh/kg <400 Wh/L	<1.5 MWh/kg

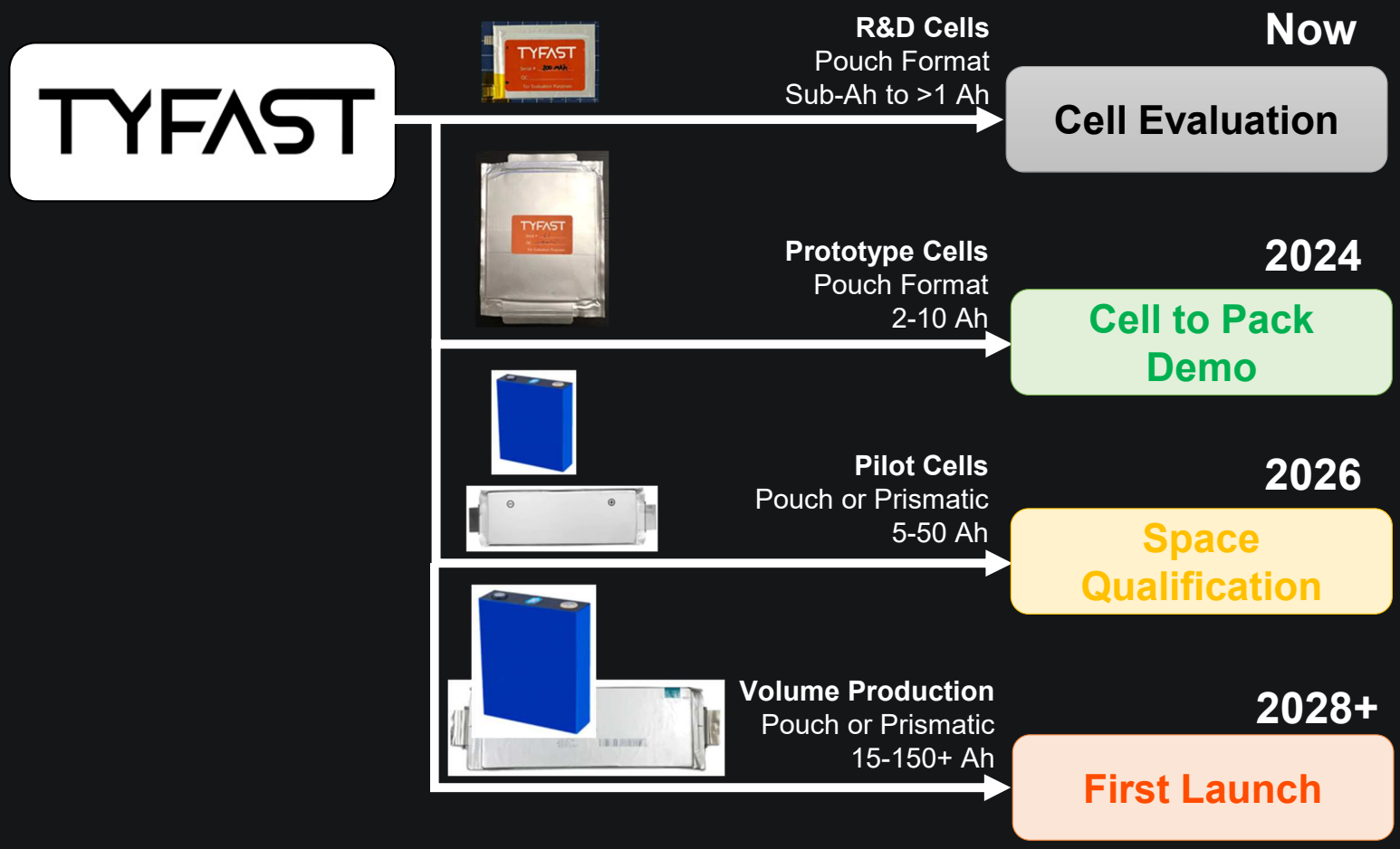
Use Case: Low Earth Orbital Satellites

Tyfast Benefits	Tyfast Li-ion	Current C anode Li-ion	Benefits
Operational Energy (Wh/kg)	120	25-50	60-80% lower weight
Rapid Recharge (min)	<6	30-40	5-7x faster
Operation Temperature (°C)	-46 to 71	-20 to 60	Wider
Discharge Peak Rate	7 to 10	5	1.4-2x higher
>10 Yrs Life (Cycles)	>80,000	~50,000	>1.6x longer
Lifetime Energy (MWh/kg)	9.6	1.25-2.5	3.8-7.6x higher

Tyfast Pouch Cells: R&D and Prototypes

R&D Cell	Prototype Cell
	
0.1 to 1 Ah Pouch Cell	2 to 10 Ah Pouch Cell
1.5 x 2 inches (credit card size)	4 x 6 inches (small notebook)

Timeline: Scaling of LVO Technology for Space Market



Team: Deep Batteries and Commercialization Experience

Leadership

G.J. La O'
CEO & Co-Founder
10+ yrs Battery Development, and Commercialization

PRIMUS POWER · MIT · Berkeley

Haodong Liu
CTO & Co-Founder
10+ yrs Advanced Battery R&D and Co-inventor of LVO

UC San Diego Sustainable Power and Energy Center

Prof. Ping Liu
CSO & Co-Founder
20+ yrs World Leading Battery R&D and Co-inventor of LVO

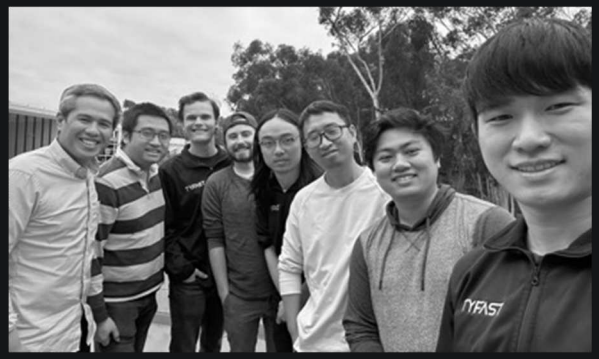
UC San Diego · U.S. Department of Energy · HRL Laboratories · NREL

Advisors

Ryo Tamaki	Li-Battery Cell Manufacturing (GWh), >20 Years at OEMs
Mark Verbrugge	Chief Engineer GM, Vehicle Integration, 37 Years at GM
Ed Williams	Business and Strategy (6 Startups, 3 in Batteries) 3 exits

Activate cyclotronroad — Leading scientific entrepreneurial fellowship program. 106 companies since 2016 with $1.3B funding.

Team



TYFAST

- **High Performance Batteries for Maximized Power and Extended Cycle Life Applications**
- **100% Domestically Sourced Raw Materials**
- **Experienced Team with Battery Development and Commercialization**

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