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Lithium Battery Innovations For Projectile Munitions

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Munitions Batteries

Agenda

- Applications
- Battery Characteristics
- Electrochemistries
- Challenges
- Innovations
- Performance Characterization
- Selected Cells
- Selected Batteries
- Summary

Li-Ion FTS Battery
(Device No. G3203B1)

Munitions Batteries

Lithium Battery Applications

Missiles & Space

GALILEO

THAAD

CASSINI HUYGENS

Air Delivered Bombs

JASSM

JDAM

ERGM

Large Caliber Projectiles

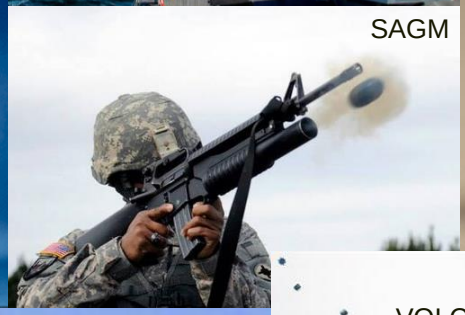
LW30

Medium Caliber Projectiles

MOFA

ETFM

SLAM



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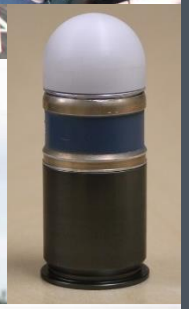


VOLCANO

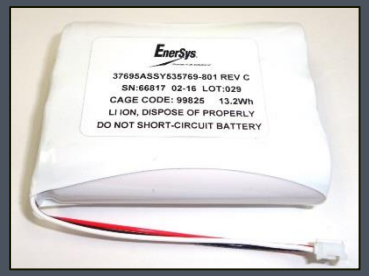
Barrier Munitions

SHIELDER

Whether your application is on the Land, Sea, Air, or Space, EnerSys can provide the power.

Lithium Batteries

Battery Characteristics



Li-Ion Battery

Why use Lithium Batteries?

1. Long Shelf Life

Lithium reserve batteries are unique in their ability to last for over 20 years prior to activation. This long shelf life is made possible by either storing the active materials separately until activation or by storing the active materials in a non-ionically conductive state until activation.

2. Temperature Range

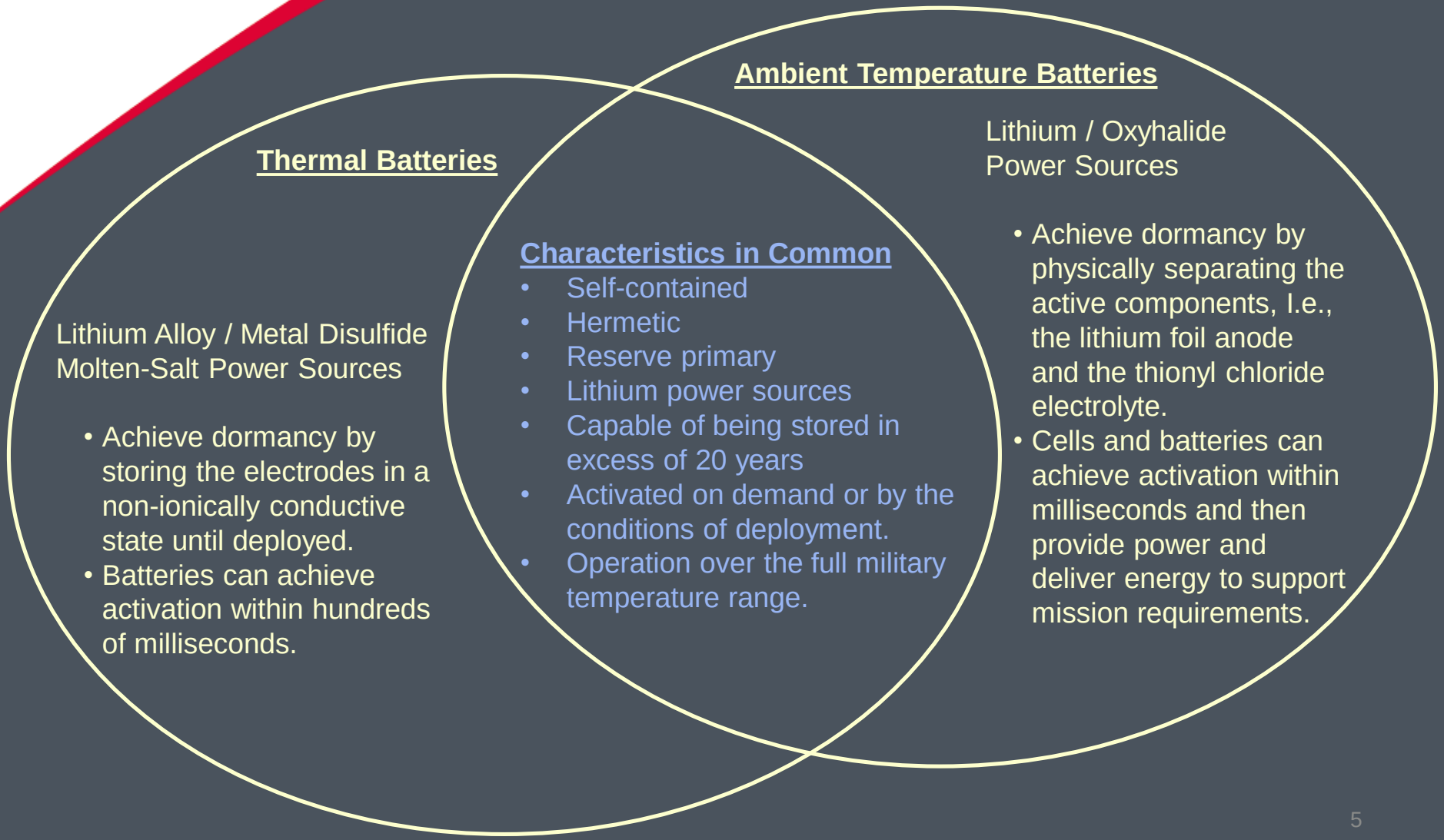
Capable of operation across the full military temperature range (-65˚F to +221˚F/-54˚C to +105˚C).

3. Environmentally Hardened

Our lithium reserve batteries are optimized for operation in high acceleration environments (up to 100,000 g's) and high spin rate (30,000 RPM), applications that ordinary batteries cannot survive.

Munitions Batteries

Battery Characteristics



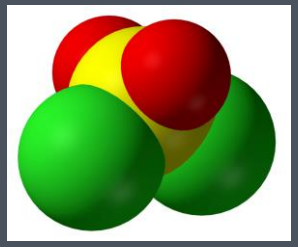
Lithium Batteries

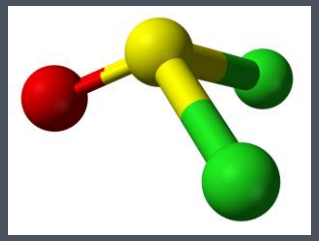
Electrochemical Systems

Li

Products Offered

- Lithium Thermal Batteries
- Lithium Ambient Temperature Batteries
- Lithium-Ion Rechargeable Batteries



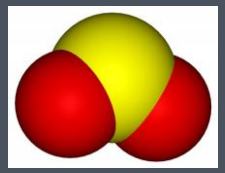


Electrochemical Systems

• Lithium Silicon/Cobalt Disulfide ($LiSi/CoS_2$) • Lithium Silicon/Iron Disulfide ($LiSi/FeS_2$)	High Power Density
• Lithium/Thionyl Chloride ($Li/SOCl_2$) • Lithium/Sulfuryl Chloride (Li/SO_2Cl_2)	High Energy Density
• Lithium/Sulfur Dioxide (Li/SO_2)	
• Lithium/Vanadium Pentoxide (Li/V_2O_5)	Fast Activation Cold Temperature
• Lithium-Ion (various chemistries)	Rechargeable

Automated Manufacturing

- Multiple automated manufacturing lines are used to produce Ambient Temperature Batteries and Thermal Batteries.



Munitions Batteries

Activation Methods

Miniature Piston Actuator

- Batteries can be activated on demand or by the conditions of deployment, such as: ballistic launch, aircraft release, or canister dispense, etc. using one or more of the following methods:

Electric Igniter

M42C Percussion Primer

Method	Initiation
Electric Igniter	Electrical Pulse
Electric Primer	Electrical Pulse
Percussion Primer	Firing Pin, Lanyard
Stab Initiated	Squib, Thumb Screw
G-activation	Launch Acceleration, Target Impact

Dashpot Electrolyte Reservoir

Pyrotechnic Gas Generators

- Batteries can be activated within milliseconds to seconds.

Munitions Batteries

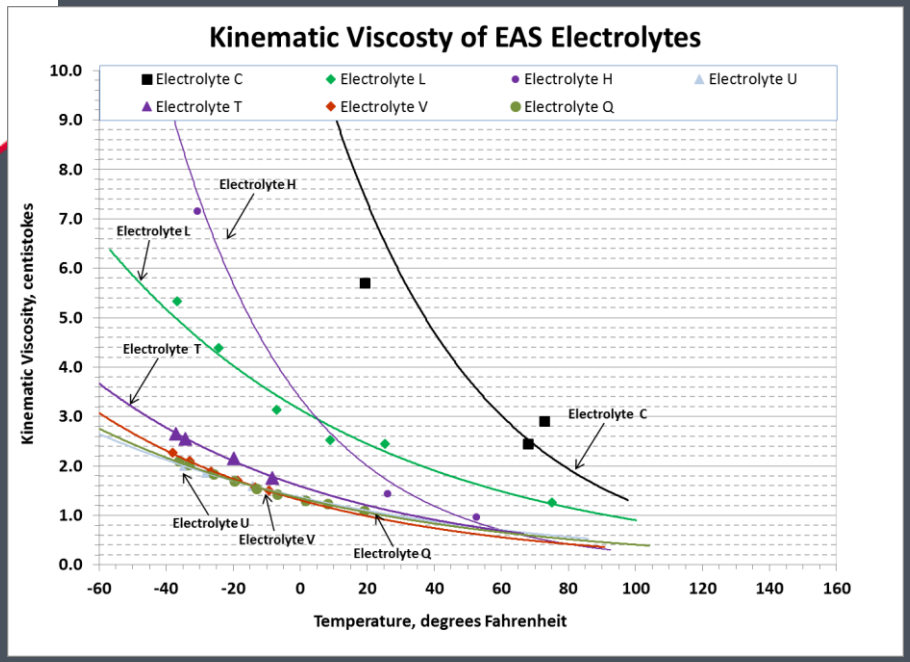
Challenges

	Requirement		Potential Solution
Activation Risetime	Faster Initiation	→	Lower Viscosity Electrolytes
Cold Temp. Performance	Improved Function Cold	→	Electrolytes with Greater Ionic Conductivities
Power Capability	Greater Power	→	Lower Cell Impedance
Deliverable Capacity	Greater Energy	→	Increased Active Material Content

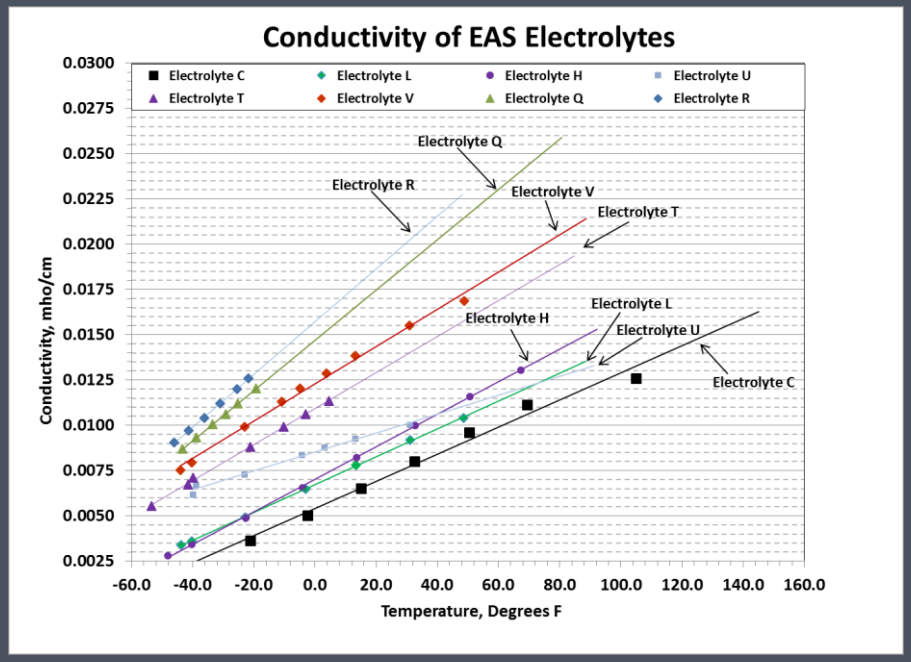
Munitions Batteries

Innovations

Advanced Electrolytes for Improved Cold Temperature Operation



Lower Viscosity Electrolytes



Greater Ionic Conductivities

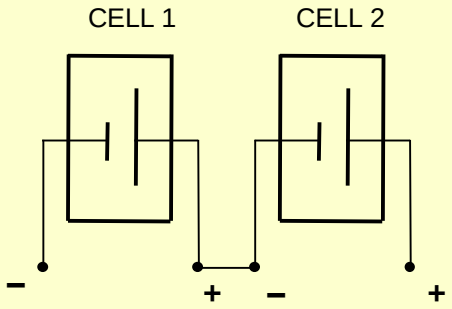
New electrolytes are stable for 20+ year storage! Enhanced cold temp Conductivity and Viscosity give excellent rise time and voltage performance.

Munitions Batteries

Battery Configurations (Liquid Reserve Primary)

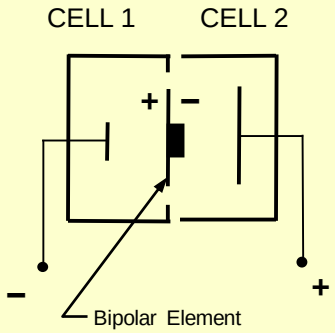
What's the best configuration?

Long Mission Life
High Energy



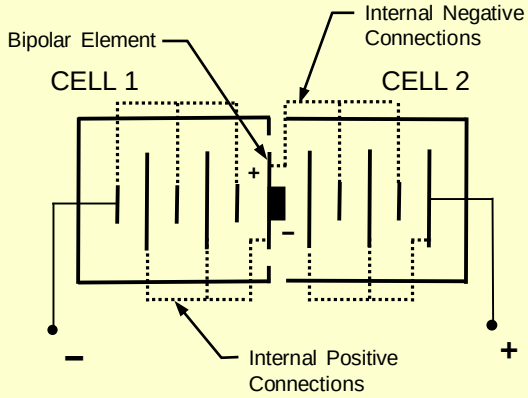
Discrete Unit Cells
Cells consisting of one set of electrodes.

Moderate Power



Bipolar Cells
Cells connected in series using bipolar elements.

High Power



Hybrid Bipolar Cells
Cells with multiple internal parallel connections that are connected in series using bipolar elements.

Performance requirements may be met by selecting the battery configuration most suited to the application.

Munitions Batteries

Design Innovations

State-of-the-art batteries support next generation electronic fuzing in projectile munitions

Advanced Power Source for Medium and Large Caliber Projectiles

G3207A1 - Cell

1S2P Internal Electrode Structure

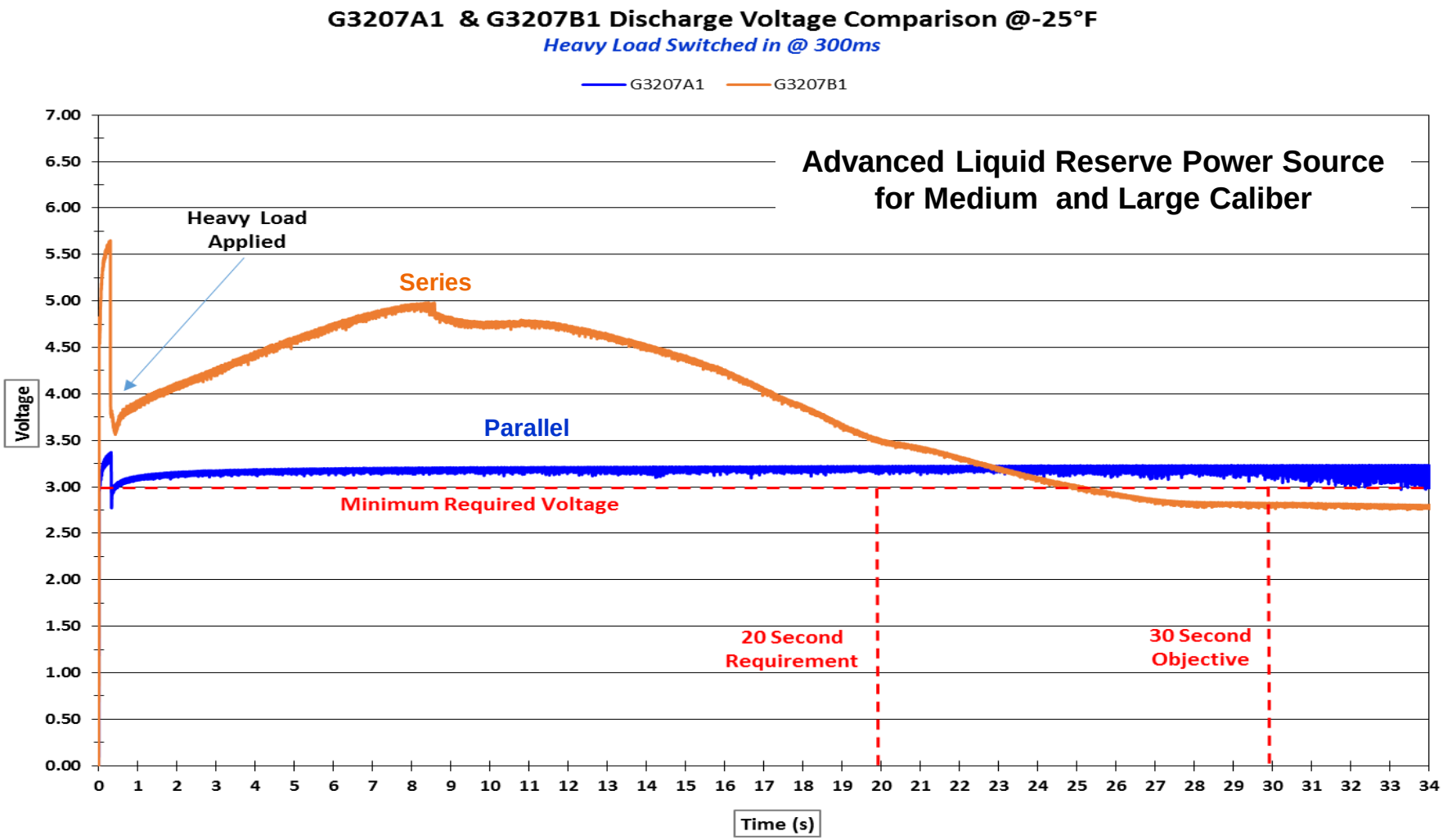
Power Source Size
∅0.450” Max X 0.395” Max Length
(Not including terminal pin)

G3207B1 - Battery

2S1P Internal Electrode Structure

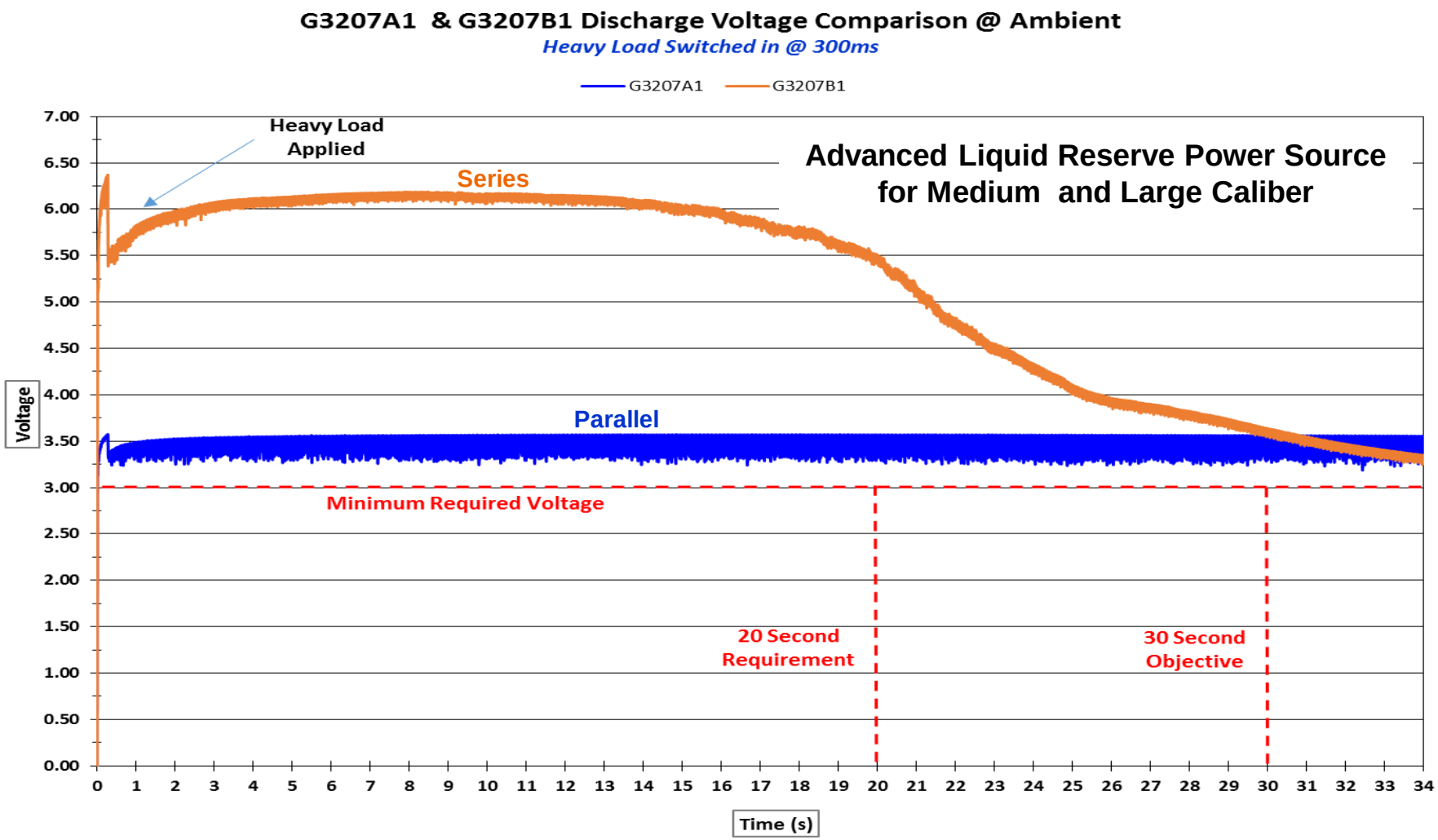
Innovative design allows for parallel or series electrode configurations in same size format. Power source can be configured to meet customers power and energy needs.

EAS – Munitions



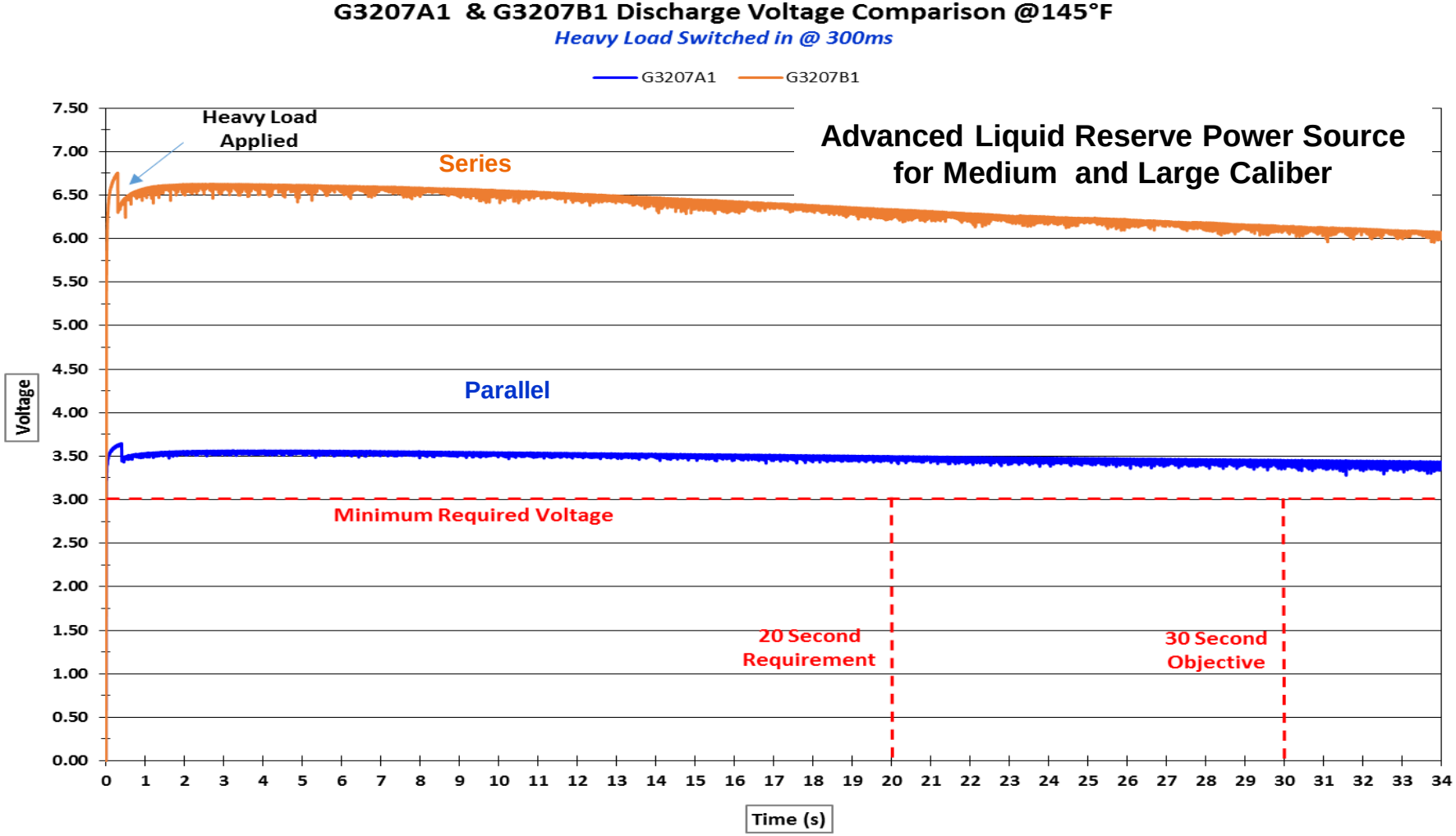
The series configuration provided higher voltage but shorter runtime under identical loading at the worse-case cold temperature extreme.

EAS – Munitions



The series configuration provided higher voltage but shorter runtime under identical loading at room temp ambient.

EAS – Munitions



The series configuration provided higher voltage but shorter runtime under identical loading at the worse-case high temperature extreme.

Munitions Batteries

Design Innovations

State-of-the-art batteries support next generation electronic fuzing in projectile munitions

Advanced Power Source for Next Gen Extended Range Projectiles

G3220A1 - Battery

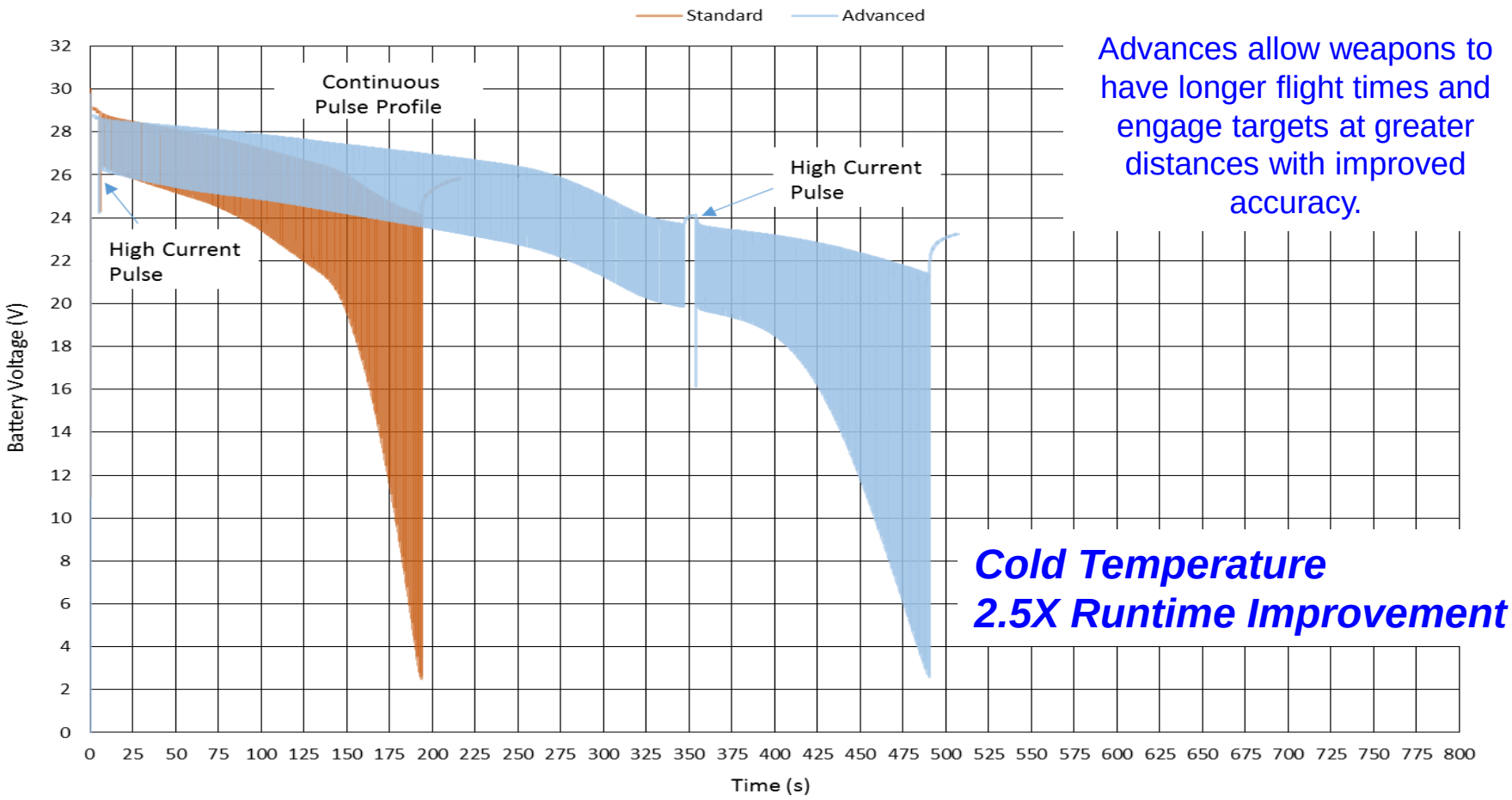
Power Source Size
∅1.50” Max X 3.00” Max Length
(Not including terminal pins)

Thermal Battery Innovations for Extended Runtime

- High Quality Electrode Materials
- State-of-the-Art Electrochemistries
- Advanced Mechanical Designs
  - Designed for Ballistic Launch Survivability
  - Designed for Optimal Thermal Management
- State-of-the-Art Insulation Materials
- Automated Production
  - High Rate Production
  - Consistent Build Quality
  - Repeatable Performance

Extended range capability in efficient battery size.

EAS – Munitions

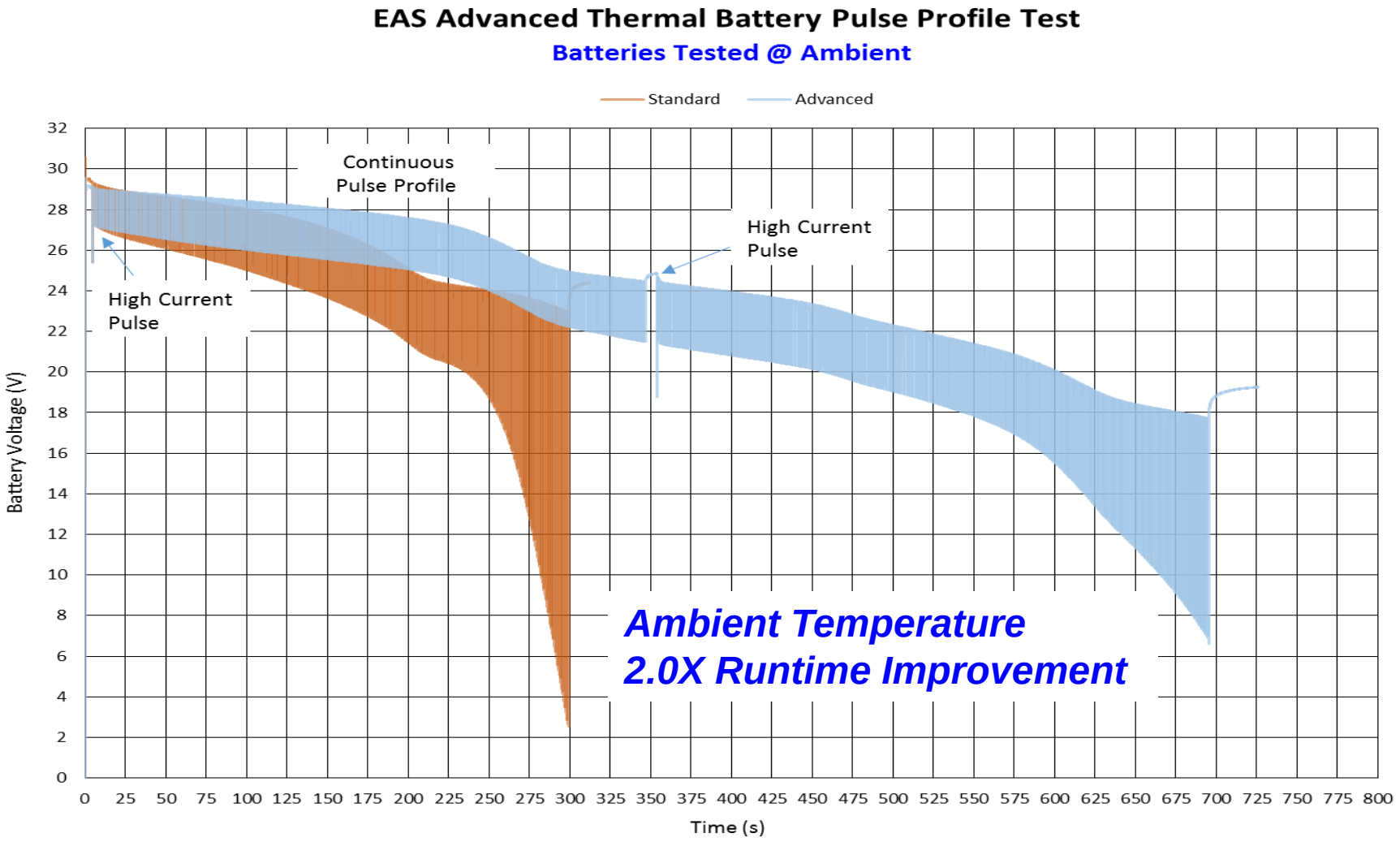


Advances allow weapons to have longer flight times and engage targets at greater distances with improved accuracy.

Cold Temperature
2.5X Runtime Improvement

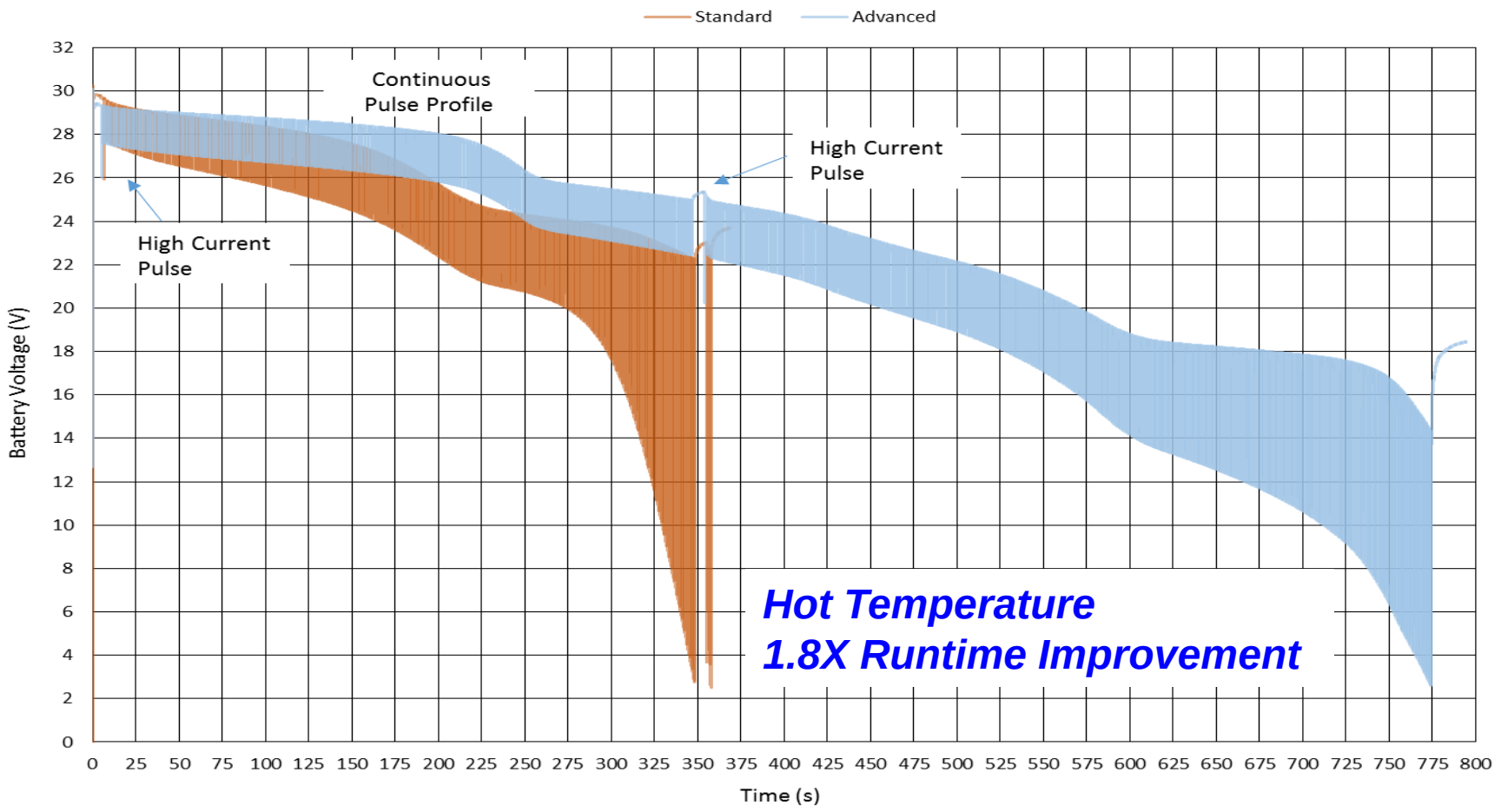
EAS's use of advanced materials, superior electrochemistry, and state-of-the art design resulted in 2.5X runtime improvement at cold temperature extreme.

EAS – Munitions



EAS's use of advanced materials, superior electrochemistry, and state-of-the art design resulted in 2.0X runtime improvement at ambient temperature.

EAS – Munitions



EAS's use of advanced materials, superior electrochemistry, and state-of-the art design resulted in 1.8X runtime improvement at hot temperature extreme.

Ambient Temperature Batteries

Selected Cells







	Sub-munitions	30 mm	40 mm	25 mm	40 mm	Munitions	Artillery
Device Number	G3168B1	G3201B1	G3198B1	G3165D1	G3207A1	G2666B1	G3147A1
Electrochemistry	Li/SO_2Cl_2	$Li/SOCl_2$	$Li/SOCl_2$	$Li/SOCl_2$	$Li/SOCl_2$	$Li/SOCl_2$	$Li/SOCl_2$
Size (in)	Φ.220 x .215	Φ.275 x .325	Φ.319 x .359	Φ.350 x .435	Φ.450 x .395	Φ.500 x .840	Φ.500 x .840
Voltage (V)	2.5 - 4.25	2.0 - 3.8	2.0 - 3.8	2.0 - 3.8	2.0 - 3.8	2.5 - 3.6	2.5 - 3.6
Current (mA)	0.250	20	30	30	50	0.5	0.5
Activation Time(s)	60.0	0.025	0.050	0.050	0.050	0.5	0.8
Run Time (s)	10 days	>30	>30	30	30	10 days	15 days
Capacity (mAh)	2.0	1.5	3.13	3.4	5.2	230	280
Weight (gm)	0.6	.875	1.25	2.0	2.0	5.1	6.2
Acceleration (G)	25,000.	100,000.	100,000.	70,000.	25,000.	7,000.	30,000.
Spin (RPS)	350	1,000.	2,100.	2,100.	300.	Low	500
Activation App.	Stab	Setback	Stab	Setback	Stab/Primer	Stab/Primer	Stab/Primer
Activation Acc. (G)	N/A	50,000.	N/A	8,000.	N/A	N/A	N/A
Applications	Self-Destruct Fuzing	30 mm Projectile Munitions	40 mm Air-bursting Non-Lethal Munitions	20 mm Projectile Fuzing & 84mm Rockets	40 mm Grenade Munitions	Barrier Munitions	Artillery Fuzing & Air Delivered Bombs

EnerSys offers a wide range of state-of-the-art Reserve Lithium/Oxyhalide Cells for medium and large caliber projectile fuzing.

Ambient Temperature Batteries

Selected Batteries

	 40 mm	 120 mm	 120 mm	 155 mm	 Air Delivered	 Projectiles
Device Number	G3207B1	G3153A2	G3153B1	G3158B3	G3161A1	G3177A1
Electrochemistry	Li/$SOCl_2$	Li/$SOCl_2$	Li/$SOCl_2$	Li/$SOCl_2$	Li/$SOCl_2$	Li/$SOCl_2$
Size (in)	Φ.450 x 0.395	Φ1.510 x 1.255	Φ.880 x 1.280	Φ1.500 x .670	Φ1.500 x .670	1.517 x 2.674
Voltage (V)	3.0 – 7.6	20.0 – 40.0	25.0 – 40.0	5.6 – 12.0	5.6 – 12.0	5.5 – 7.5
Current (mA)	50	750	500	350	350	36
Activation Time(s)	0.050	0.025	0.025	0.100	0.100	2.0
Run Time (s)	25	10	20	200	200	14 days
Capacity (mAh)	0.6	20.0	8.0	35	35	350
Weight (gm)	2.0	110.0	51.2	71.0	57.0	80.0
Acceleration (G)	25,000.	55,000.	55,000.	30,000.	30,000.	12,600.
Spin (RPS)	300	Low	Low	500.	Low	Low
Activation App.	Stab/Primer	Setback	Setback	Setback	Primer	Electric
Activation Acc. (G)	N/A	10,000.	10,000.	1,500.	N/A	N/A
Applications	40 mm Grenade Munitions	120 mm Tank Munitions, ES&A Fuzing	120 mm Tank Munitions, ES&A Fuzing	155 mm & 105 mm Artillery Fuzing	Electronic Fuzing, Projectiles, Bombs	Guidance, Data Hold Functions, Projectiles

EnerSys offers a wide range of state-of-the-art Reserve Lithium/Oxyhalide Batteries for medium and large caliber projectile fuzing.

Thermal Batteries

Selected Batteries

Air Delivered

Artillery

Artillery

Mortar

Missile

105 mm

	Air Delivered	Artillery	Artillery	Mortar	Missile	105 mm
Device Number	G3190B2	G3197A3	G3200A1	G3202A1	G3206A1	G3208A1
Electrochemistry	$LiSi/FeS_2$	LiSi/FeS2	$LiSi/FeS_2$	$LiSi/FeS_2$	$LiSi/FeS_2$	$LiSi/FeS_2$
Size (in)	Φ1.50 x 2.380	Φ2.00 x 2.70	Φ1.515 x 1.905	Φ1.00 x 1.436	3.00 x 3.50	Φ1.10 x 2.85
Voltage (V)	22.0 - 32.0	23.8 - 34.0	5.0 – 8.4	11.0 – 23.0	24.0 – 35.0	18.0 - 32.0
Current (mA)	700	5,000.	750	11 W	800	11 W
Activation Time(s)	0.500	0.500	0.500	0.500	1.0	0.250
Run Time (s)	200	150	200	65.5	1,050.	55
Capacity (mAh)	39	412	39	20	730	64
Weight (gm)	250.0	463.0	190	80.0	1,360.0	198.0
Acceleration (G)	30,000.	15,000.	30,000.	11,000.	50.	25,000.
Spin (RPS)	Low	30	366.	50	Low	300
Activation App.	Electric	Electric	Setback	Electric	Electric	Setback
Activation Acc. (G)	N/A	N/A	2,000.	N/A	N/A	2,000.
Applications	Air Delivered Weapons	155 mm Artillery Fuzing	155 mm Artillery Fuzing	Electronic Fuzing, Projectiles, Bombs	Missile Electronics	105 mm Artillery Fuzing

EnerSys offers machine produced Reserve Batteries for high volume applications such as medium and large caliber projectile fuzing.

Munitions Batteries

Summary

- Several innovations were presented in the areas of electrochemistry and battery design that provide enhanced performance and capability for next generation electronic fuzing.
- Selected cells and batteries offering enhanced performance were discussed.
- EnerSys is a $3.0 billion/year American company with munitions battery manufacturing facilities located in Horsham, Pennsylvania and Tampa, Florida.
- EAS has all of the physical assets and facilities required to: design, develop, manufacture, test, and analyze lithium batteries.
- Thank you for your attention.

EnerSys provides high energy density "lithium/oxyhalide batteries" and high power density "thermal batteries" as well as secondary "lithium ion batteries".