Development of a Soldier Wearable Power System (WPS)

2015 Joint Service Power Exposition

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CERDEC/CPI/Power/Power Sources

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APPROVED FOR PUBLIC RELEASE

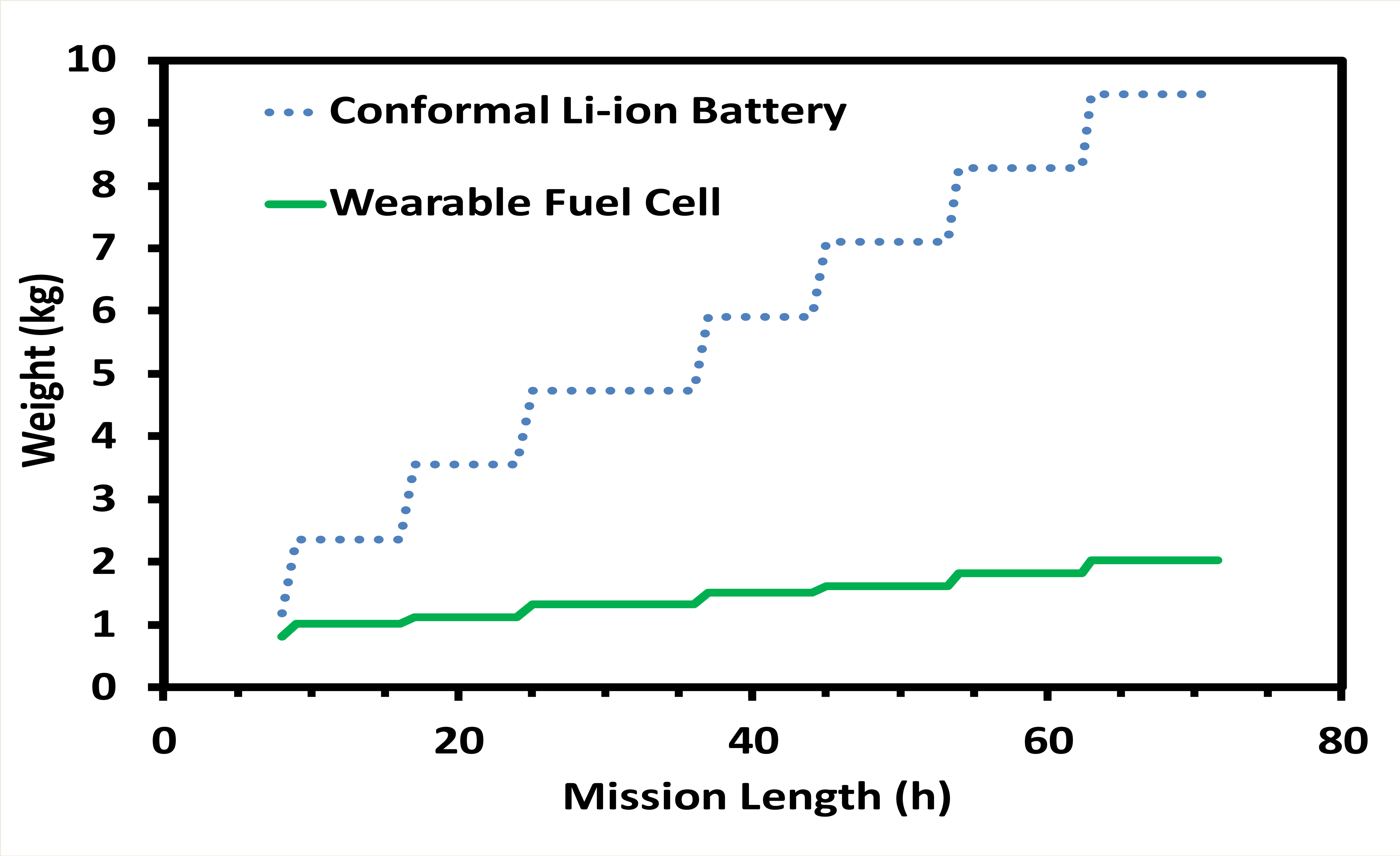
Introduction

Purpose

- Development of a Wearable Power System that provides power to all soldier borne equipment via Integrated Soldier Power & Data System.
- 1st Gen (2012)

Product Payoff

- Physical weight burden reduction (>4X) vs. batteries for dismounted soldier extended missions (72 h)
- Provides wearable power in a fightable footprint
- Provides power in a centralized power configuration
- Alternative to Conformal Wearable Battery



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Why Alane ?

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Different materials available for energy storage

Technology	EDAB	NH3 Borane	Na Silicide	Na Borohydride
Fuel Energy Density (Wh/kg)	3697	6722	3025	7058
Cartridge (Wh/kg)	490	800	133	587
Comments	Pentaborane byproduct	Ammonia byproduct	Low energy density	Difficult reaction control

Selected Alane (AlH_3) based on high energy density, high H_2 product purity and H_2 generation process

$$2AlH_3 \xrightarrow{\Delta} 2Al + 3H_2$$

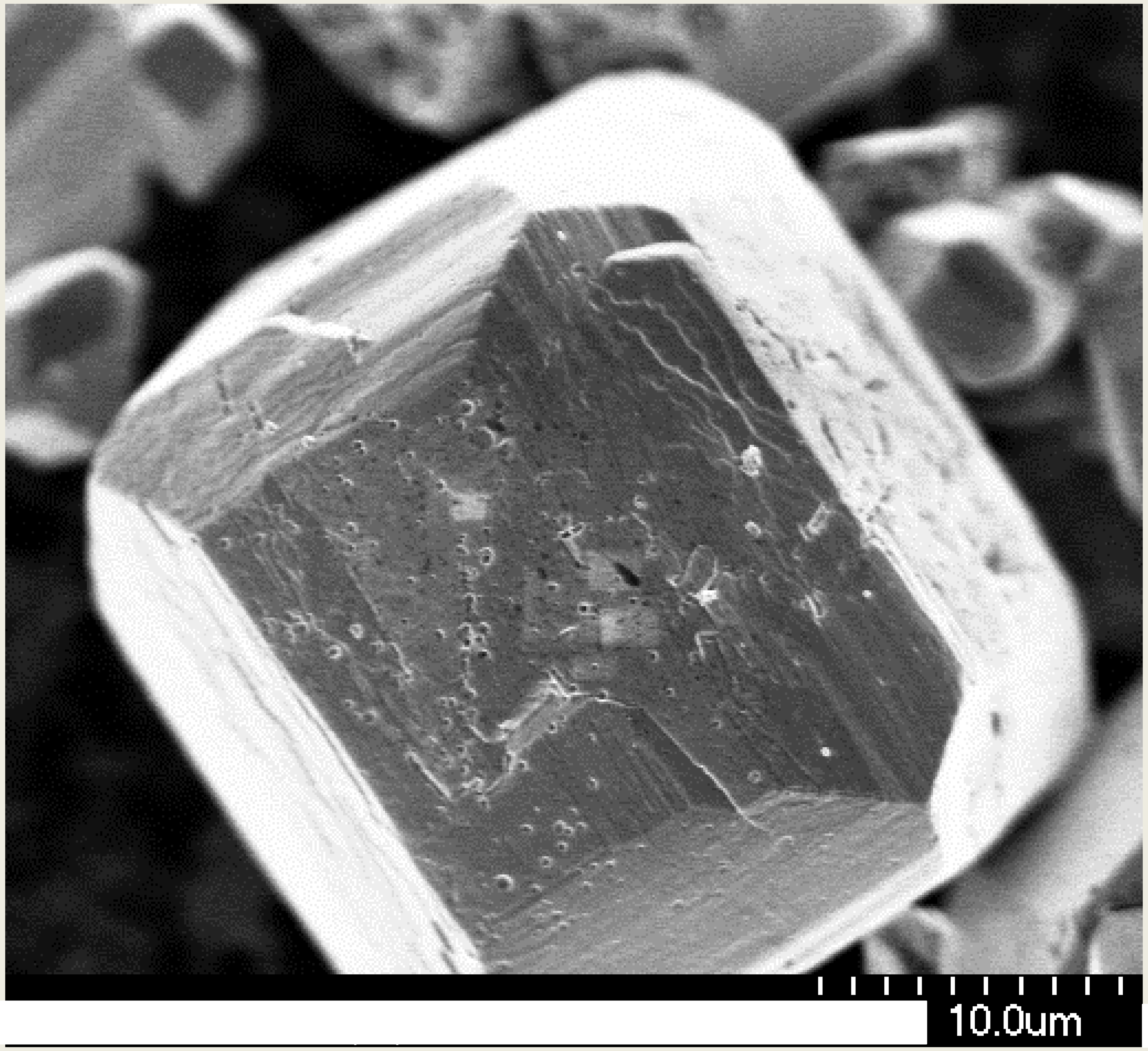
$\Delta H = 6.6$ kJ/mol H_2

Technology	RMFC	DMFC	AlH3
Fuel Energy Density (Wh/kg)	2907	5538	3361
Cartridge Wh/kg	485	780	800
System Power Density (W/kg)	22	13	29
System Vol. Power Density (W/l)	23	11	32
TRL	TRL 8	TRL 8	TRL 6

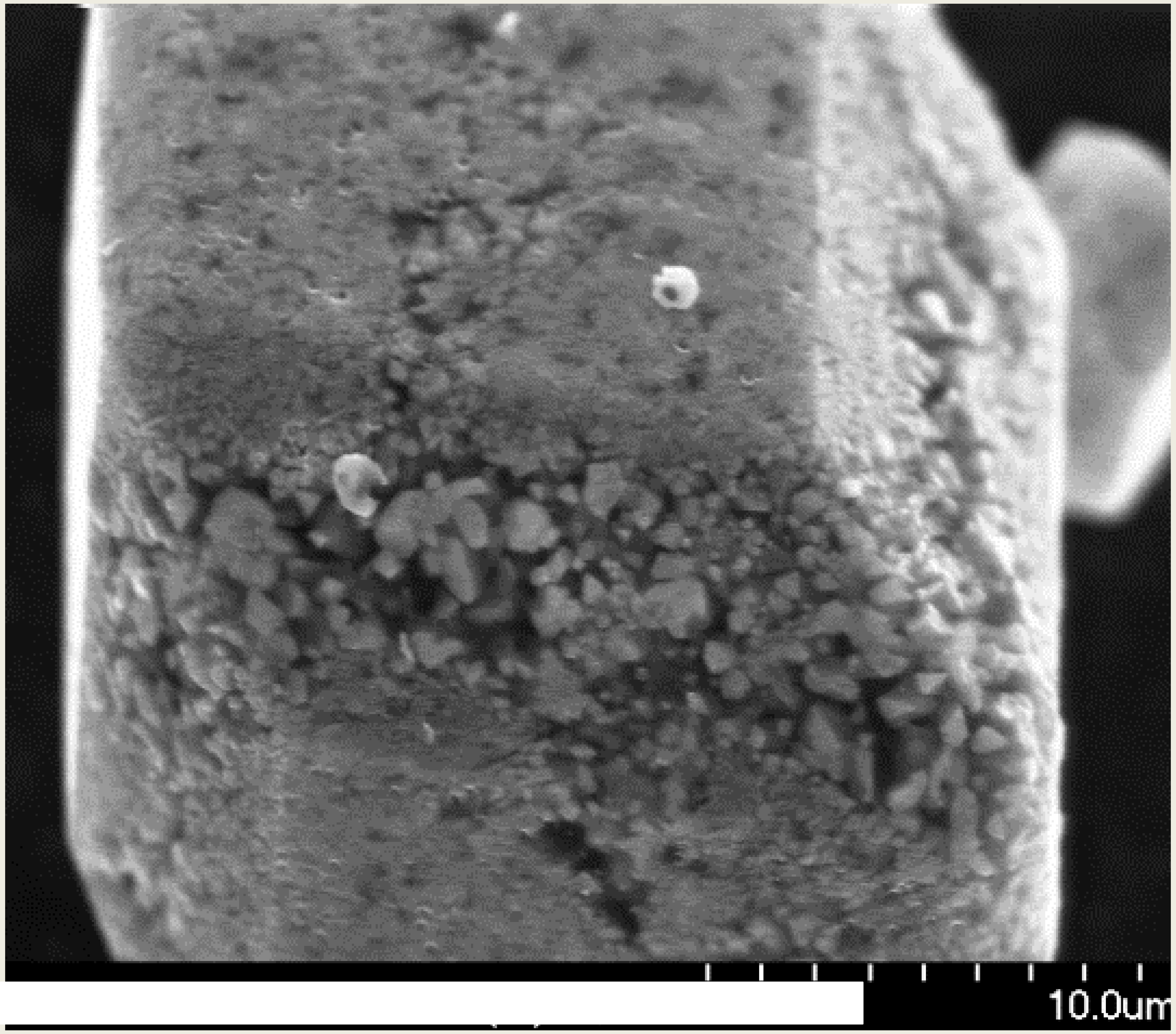
With commercial partner have developed AlH_3 systems that are promising

What is Alane ?

Fresh Alane (AlH_3)



Spent Alane (Al)



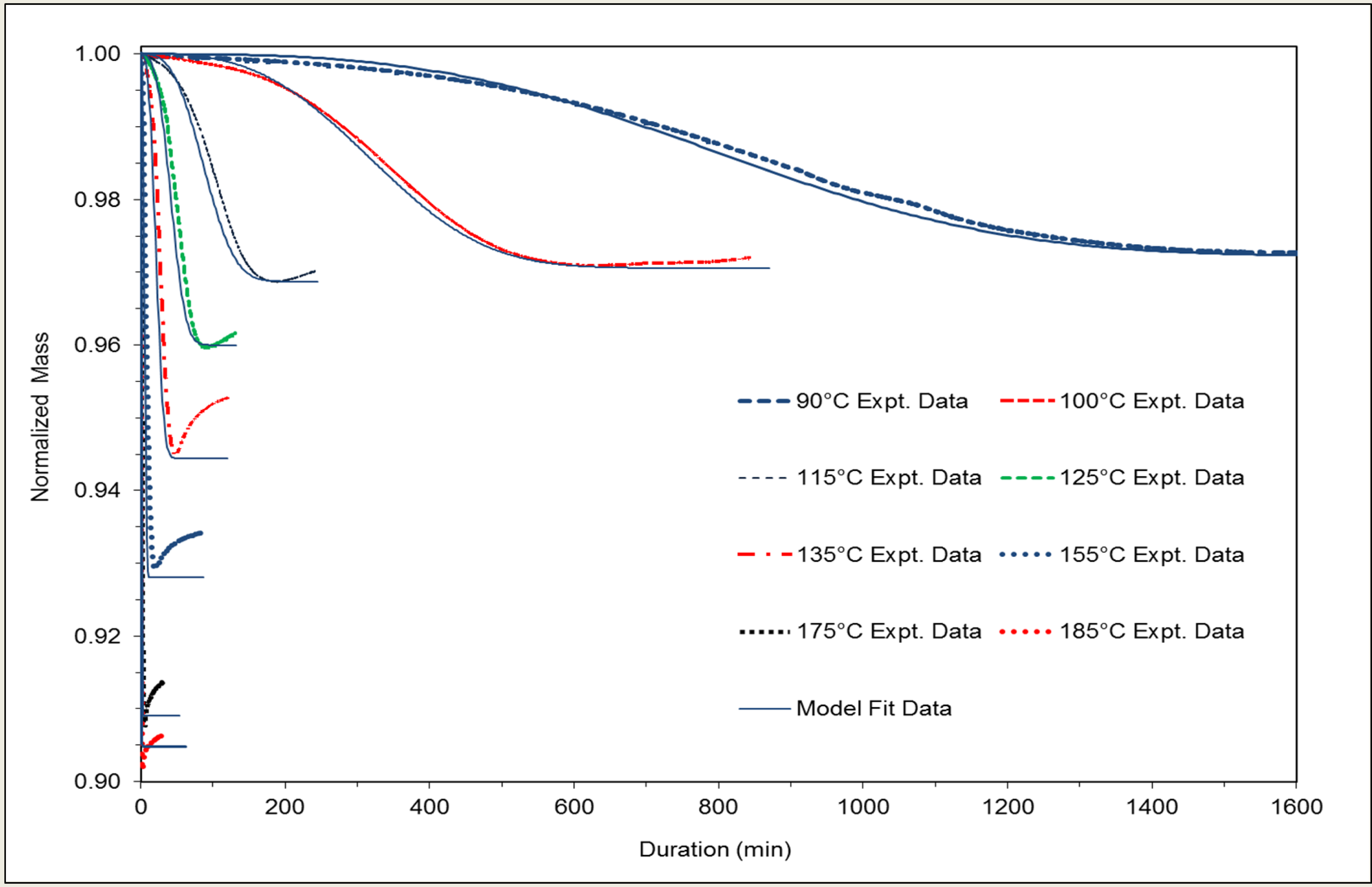
SEM imaging showing Alane (α-AlH_3 phase) material

Spent material retains cubic shape but is porous due to H_2 release

Energy from Alane

H_2 production (Energy) from AlH_3 decomposition

With temperature (heating) can control H_2 production following load demand.



Isothermal desorption data at different temperatures as a function of time. Solid lines are model fits. (T. Thampan et al. 2015).

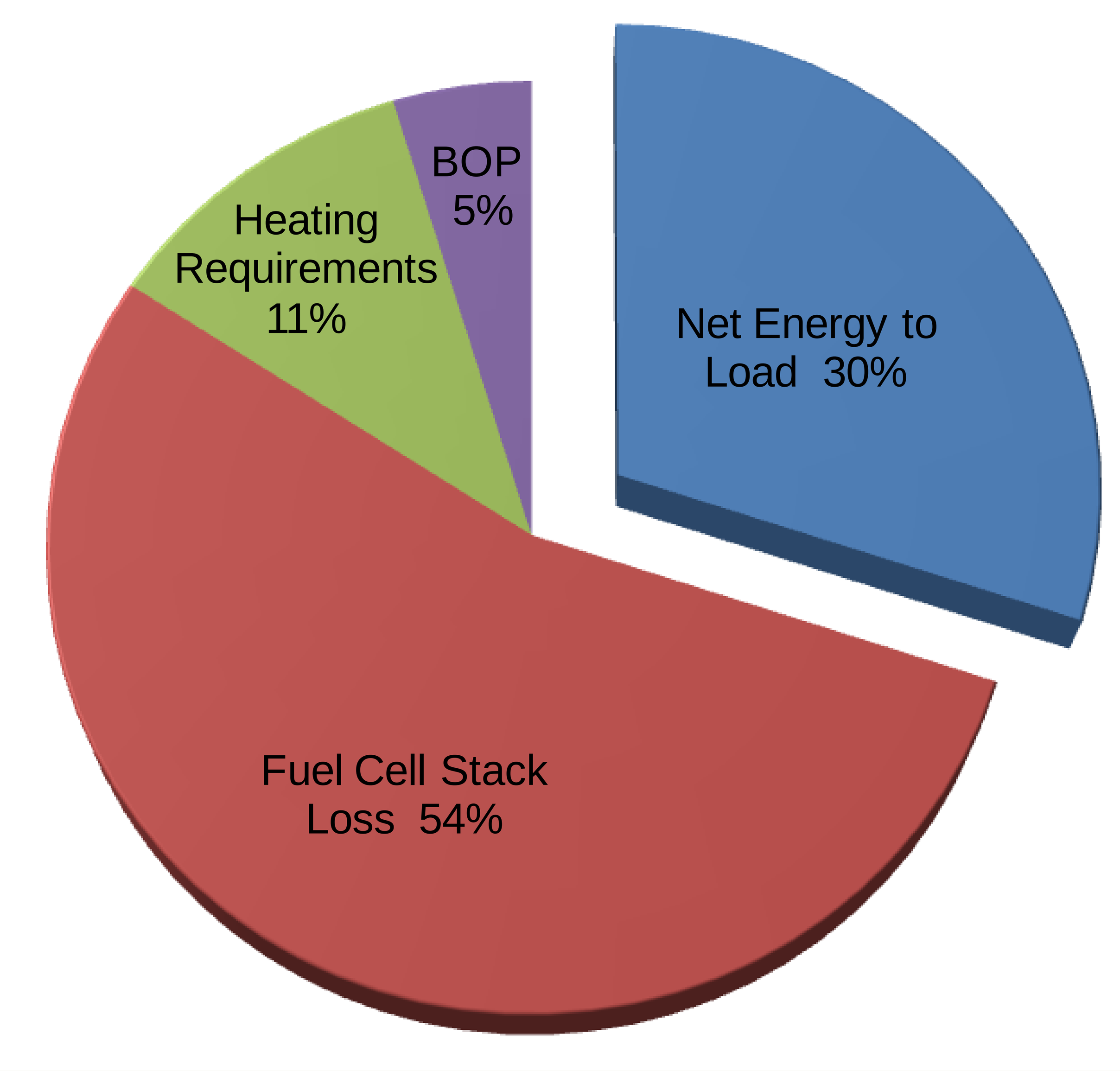
System Prototype

AlH_3 cartridge with PEM fuel cell system was instrumented with electrical, temperature sensors

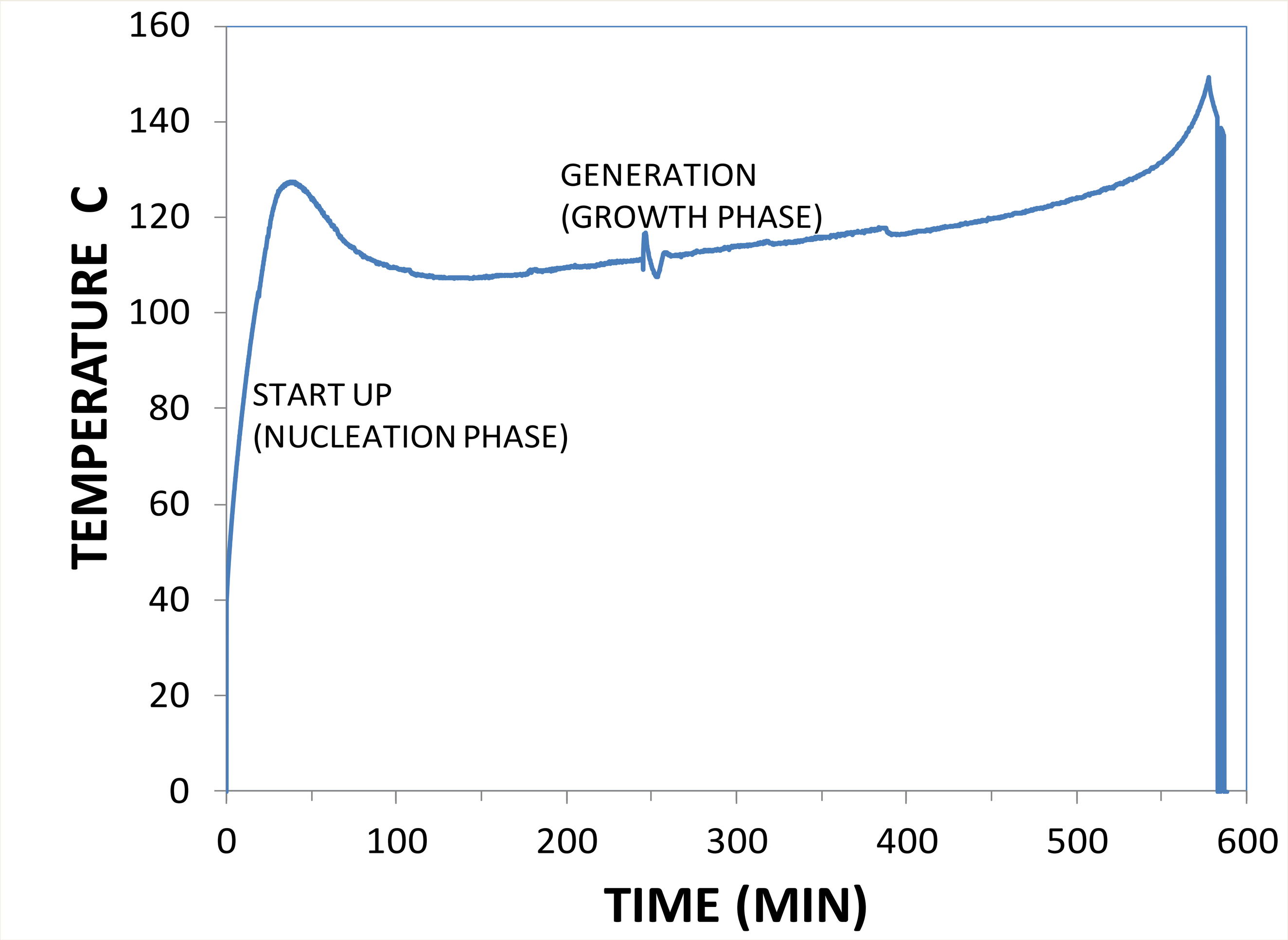
Despite high internal temperature, external temperatures remain low

Although H_2 generation from Alane requires of heating ~ 30% net energy demonstrated

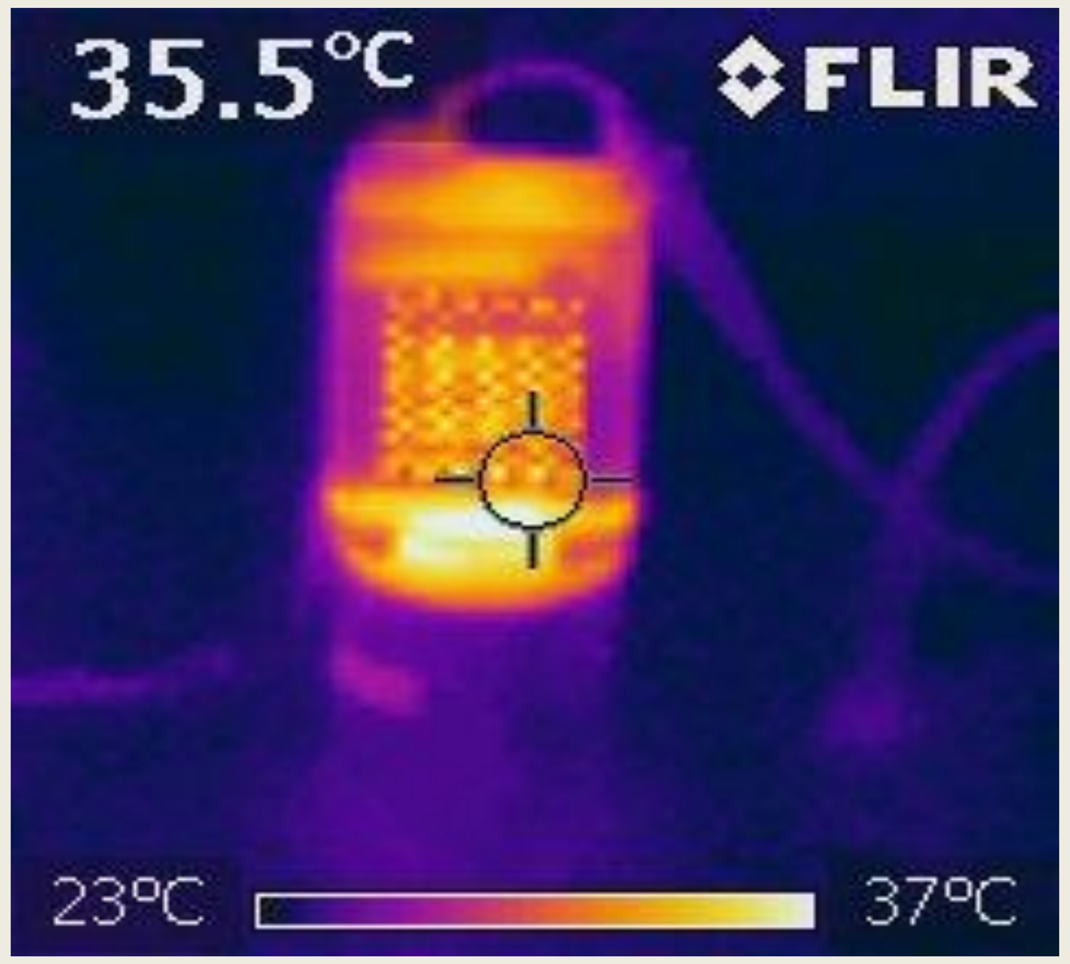
Prototype battery charger



System Energy Balance



Internal cartridge temperature



Surface temp. are touch safe

Wearable System

With industrial partner developed 1st Gen wearable system

Parameter	Demonstrated
Power (W)	20
Peak Power and Duration	35 W for 10 min
Energy Density for 24 hr mission	385 Wh/kg
Dry Weight (kg)	0.698
Volume (mL)	622
Form Factor	Thickness of 3.8 cm
Environmental Operating Temperature Range	Up to 45°C
Orientation	Operation: any orientation

Volume: 62 cm^3
Weight: 68 g
ED: ~800Wh/kg

(T. Thampan et al. 2014).

Soldier Wearable

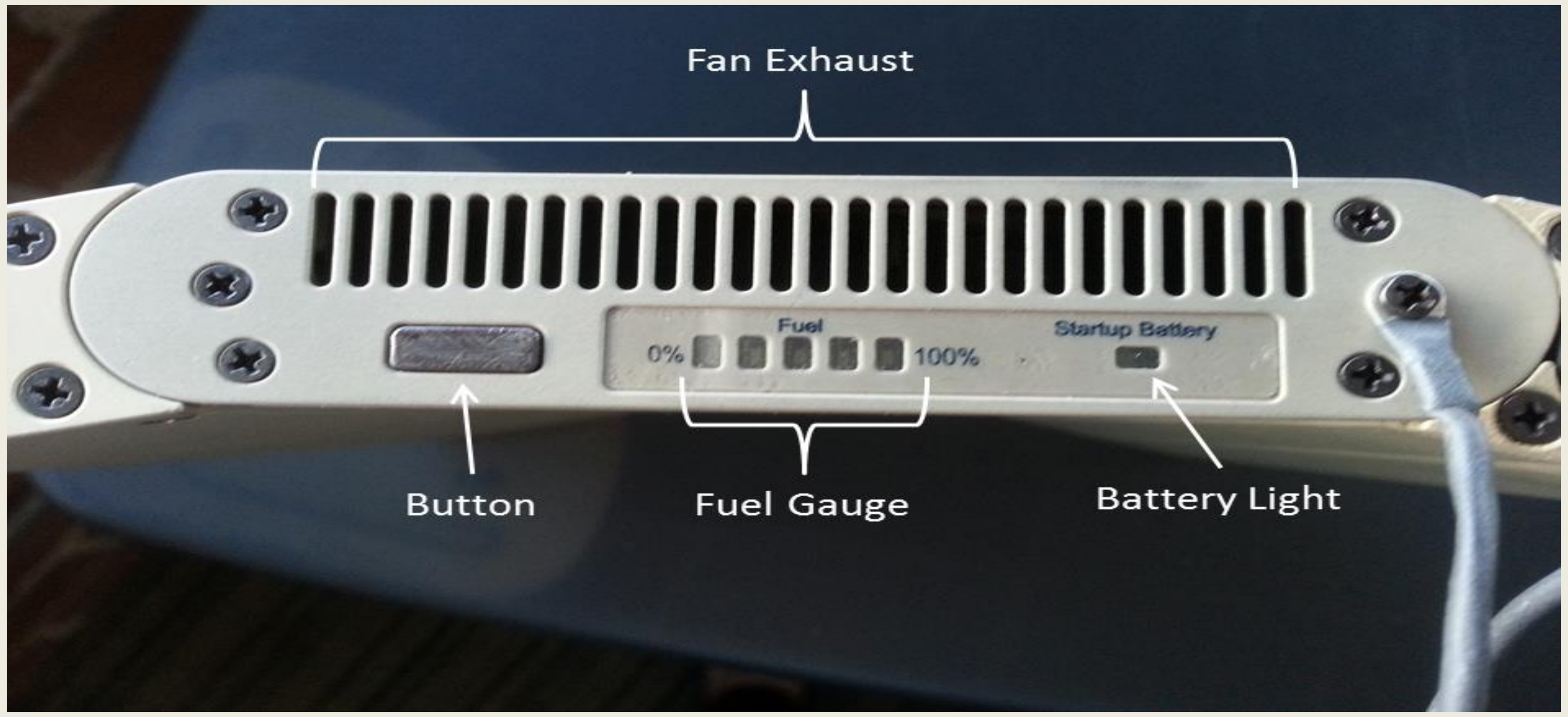
Developed next gen. system based on feedback

AlH_3 cartridge compartment with one quarter turn to open / close

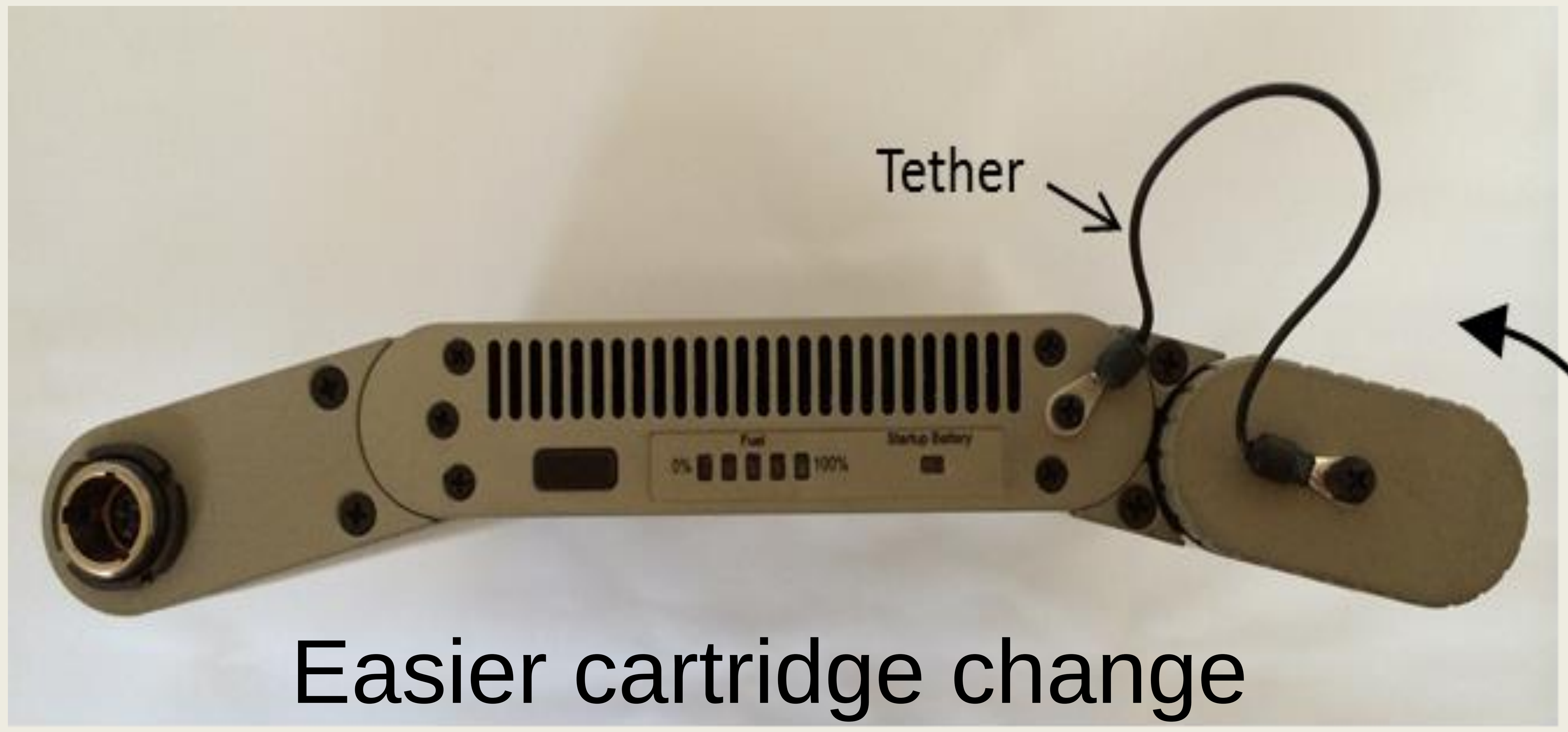
Battery Compartment - allows energy harvesting.

Flexible form factor

Larger Fuel Cartridge



Smaller thickness profile



Easier cartridge change

One quarter turn to open/close

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Thermal Images

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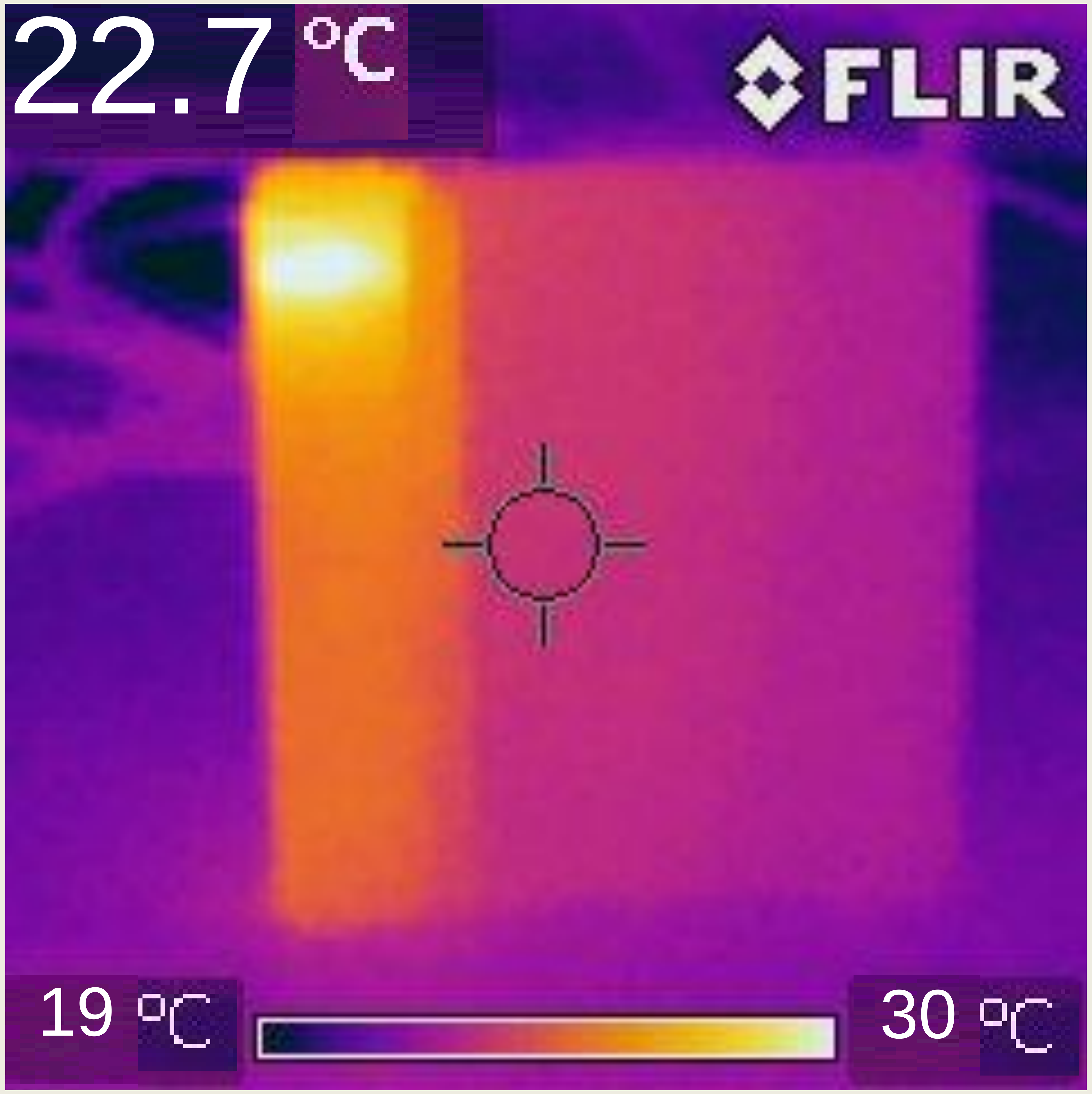
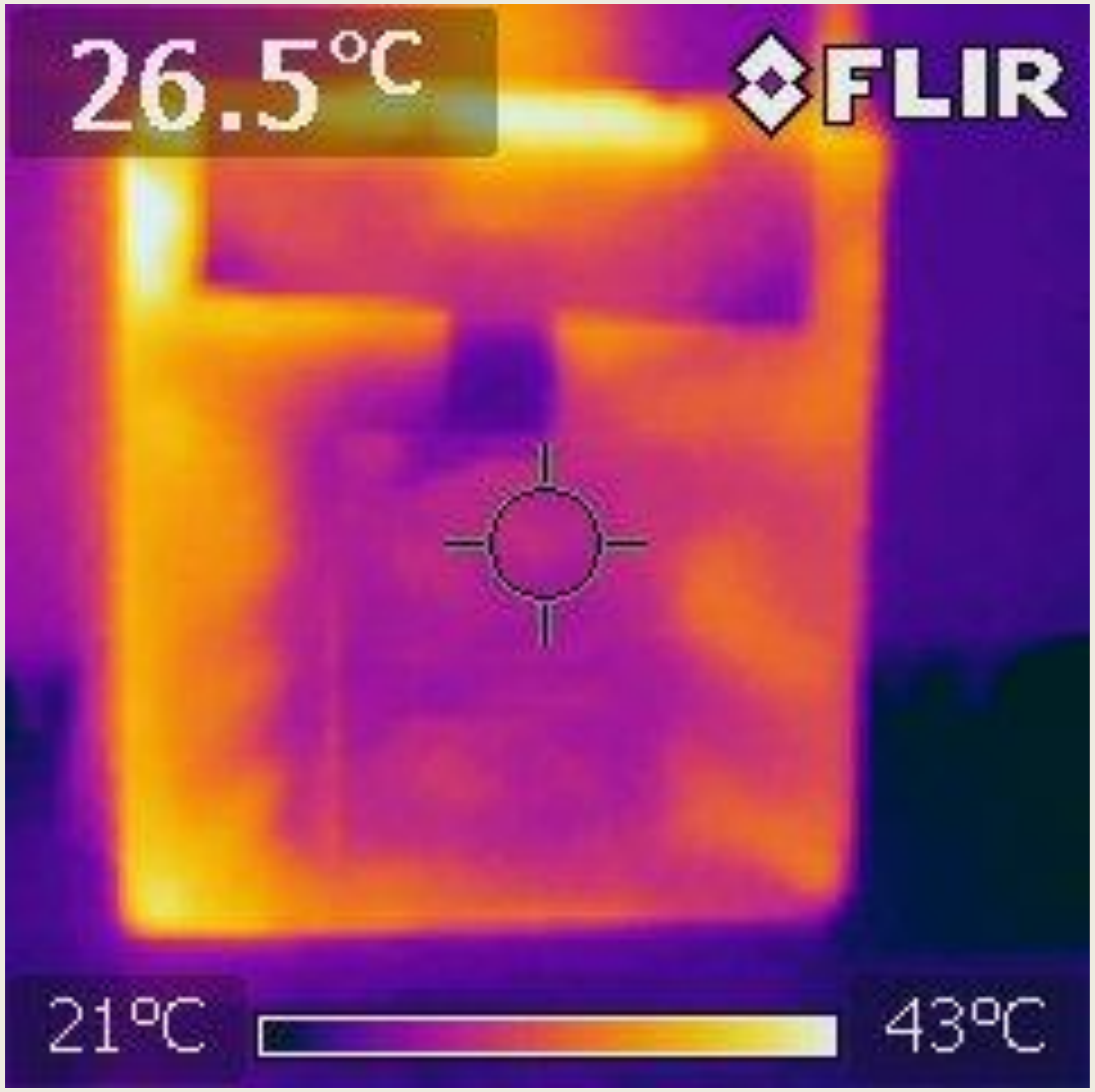


System Operating



System Operating in pouch

Hottest temp is 43 C /109 F in pouch due to limited cooling, still safe to touch

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Performance Data

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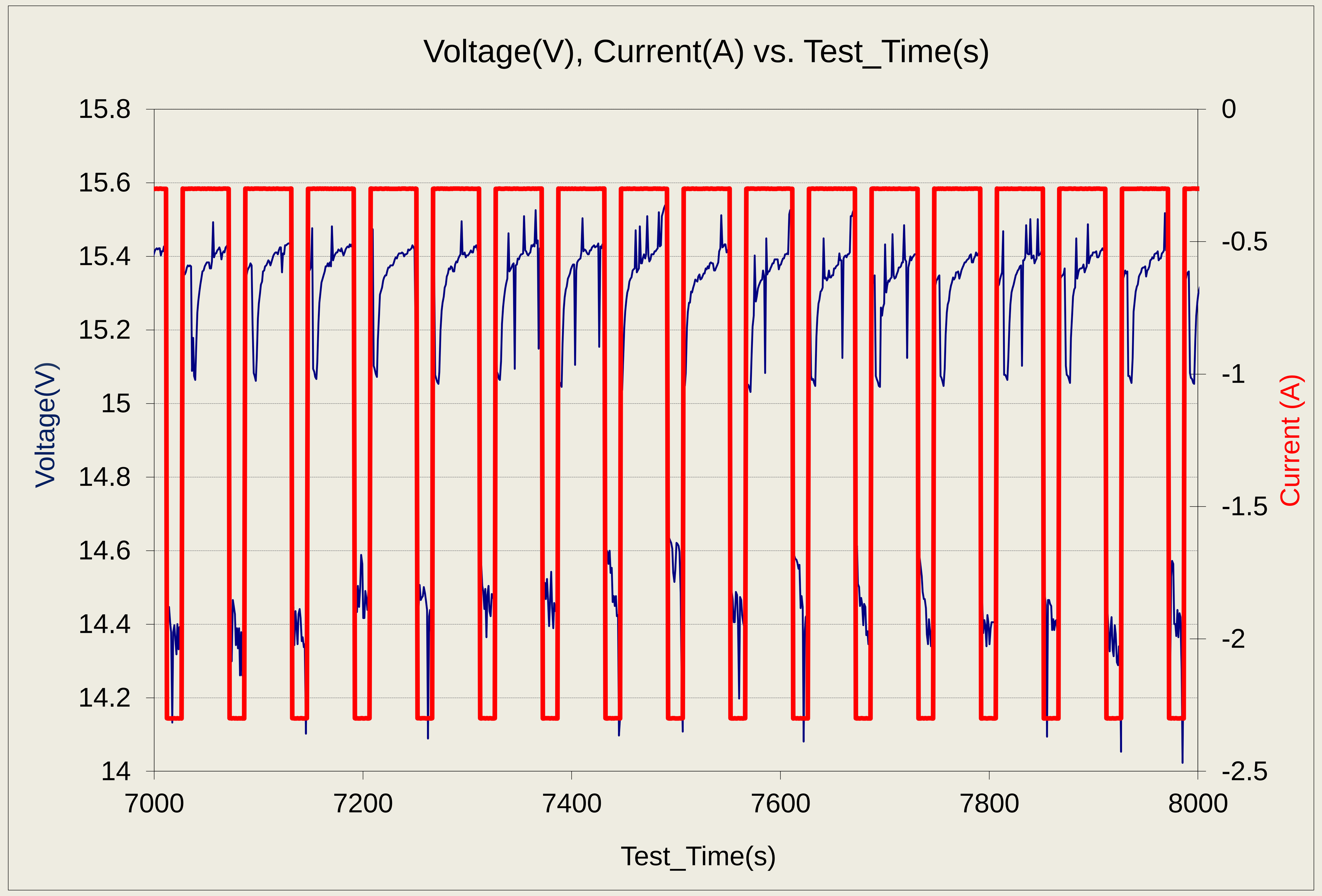
<u>Tests included:</u>

Constant load

In pouch + Constant load

In pouch + Cycle load



Cartridge energy is ~ 600 Wh/kg (measured) vs. 800 Wh/kg (rigid systems)

Test	Current (A)	Average Voltage (V)	Power (W)	Cartride Energy (Wh)	H2 yield
Constant Load	1.3	14.4	18.72	61 / 64	77%
Constant - Load / Pouch	1.3	14.5	18.85	56 / 66	81%
Cycle Load Pouch	0.3 / 2.3	14.8	4.5 / 34	53 / 66	88%

Preliminary cartridge ballistic testing was done. Test results provided confidence in a safe wearable system.

Soldier Evaluation

- Form factor was acceptable and lightweight
- Could be mounted in various vest locations and orientations
- Operated all end items through the use of a power manager and also battery eliminator
- "Relatively" quiet operation
- Cartridge change out was preferred vs battery change out

System can be worn under other equipment

Flexible, thin system

Rigid system

System worn in gap formed from normal arm position

System Meas. Vs Obj.

Parameter	Objective	WPS Achieved Performance*
Power (W)	≥ 20	20
Peak Power and Duration	35 W for 10 min	35 W for 10 min
Dry Weight Target (kg)	≤ 0.5	0.912 kg
Volume (mL)	≤ 650	743
Form Factor	Thickness < 0.7”	Thickness 0.81” (L-7”,W-8”)
Environmental Operating Temperature Range	-20°C to +55°C	Up to 45°C
Orientation	Transportation: any orientation, Operation: any orientation	Operation: any orientation

* Performance of initial, conservative prototype to prove form-factor. Follow-on effort underway to harden system and restore specified performance

Conclusions

Summary:

– Passed objective targets for nominal power, peak power, start up time
– Passed threshold requirements for weight, volume, thickness
– System is able to load follow while maintaining H_2 fuel control
– System can operate in a Molle pouch with an external temperature that is safe for wearable application

Follow On

– Cartridge energy density to be improved
– Improved prototype systems to be delivered 2015 Q4