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Energy Storage Commonality Military vs. Commercial Trucks

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There are three distinct requirements for Military Energy Storage:

- ***Starting, Lighting and Ignition***

Batteries provide electric power to start the vehicle power generation (Engines / APUs)

- ***Hybrid Vehicle Boost Acceleration and Regenerative Braking Energy Capture***

In hybrid vehicle powertrains, batteries have the ability to supplement main engine power for burst accelerations.

In addition, batteries can be used to recover wasted energy in vehicle braking

- ***Silent Watch***

Batteries can provide the energy storage capability to power mission equipment with main engine off while the vehicle is stationary



Energy Storage Comparison



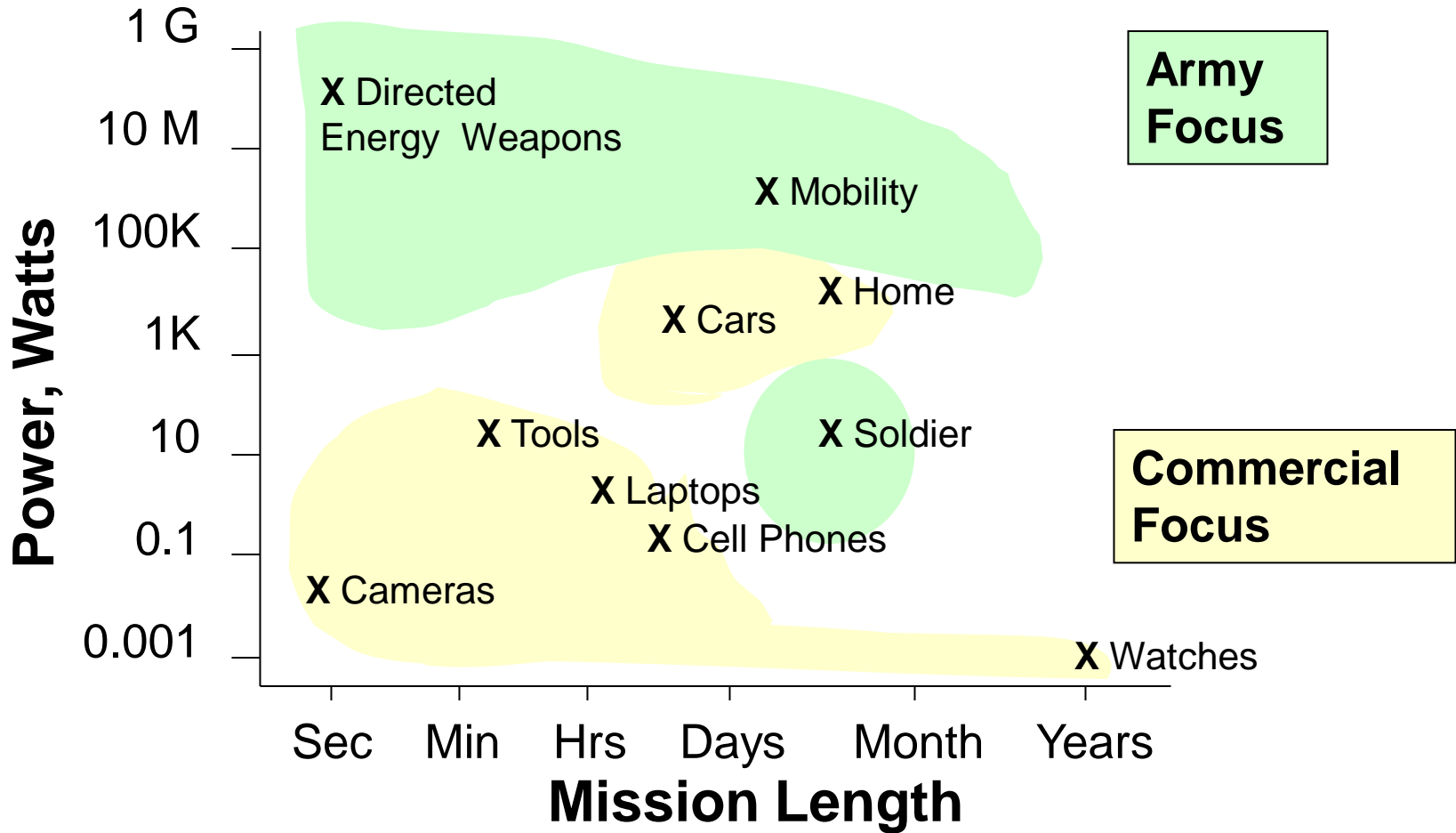
Commonality between Military and Commercial

Military	Commercial
Starting, Lighting, and Ignition	Starting, Lighting, and Ignition
Hybrid Vehicle Boost Acceleration and Regenerative Braking Energy Capture	Hybrid Vehicle Boost Acceleration and Regenerative Braking Energy Capture
Silent Watch	No Idle Laws

Unique Military requirements

- Greater environmental demands such as temperature, vibration, and shock.
- Greater chance of abuse, destruction, or penetration of components.
- Higher power demands.

Army and Commercial Industry Requirements





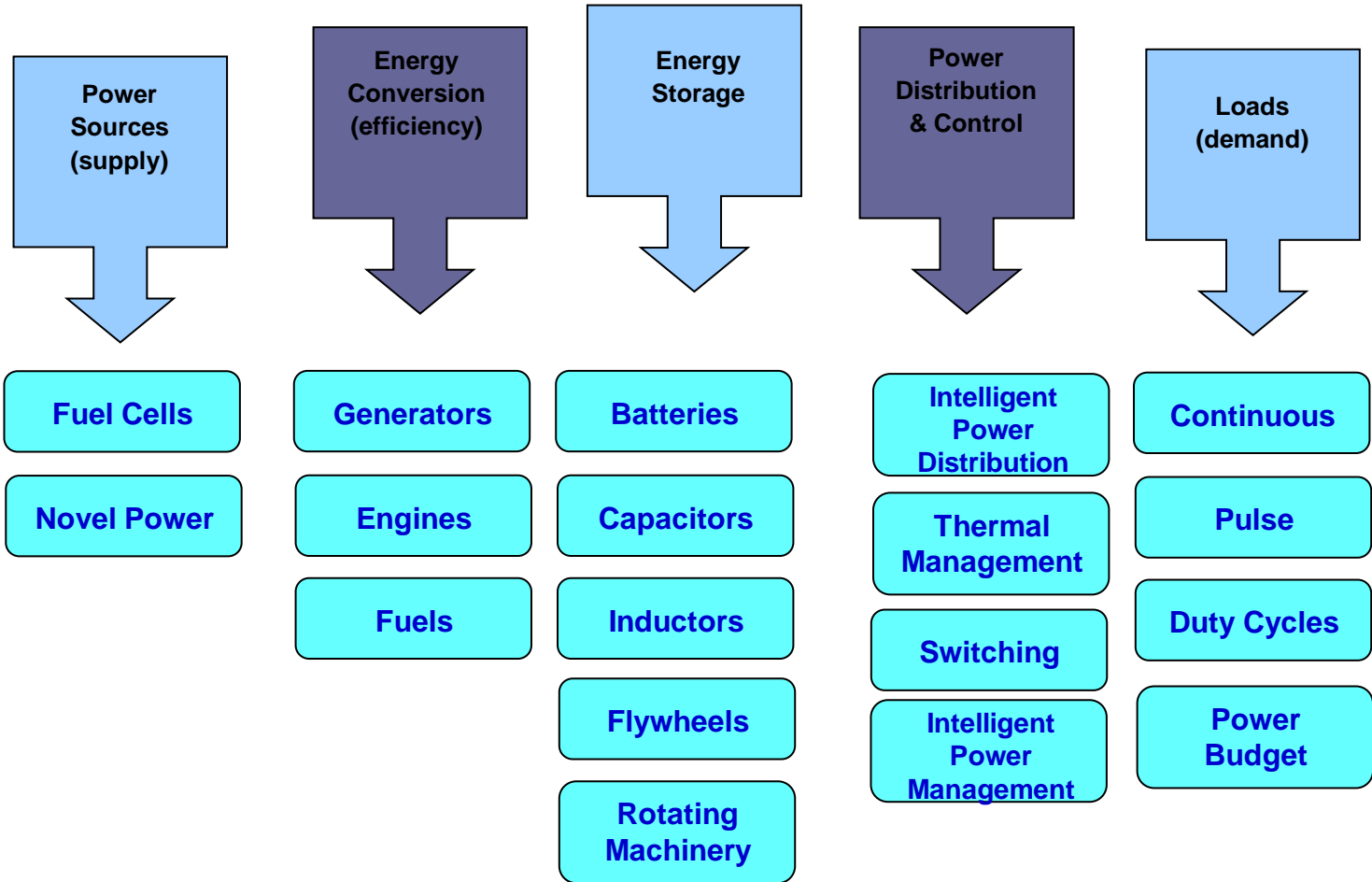
Driving Power Demands



- **Commercial and Military are leveraging a common chemistry and solutions but have very distinct requirements**
- **Silent Watch is one of the most stressing demands driving vehicle capability for energy storage**
- **Battery only solution to high power silent watch is not practical given current state-of-the-art battery and combat vehicle size and weight constraints**
- **Investment path forward requires continued research in advanced batteries and an integrated approach that leverages batteries with advanced power generation sources.**

Total RDECOM investment in the last 6 years has been >~\$150M to support the challenging requirement of high power silent watch for future combat platforms

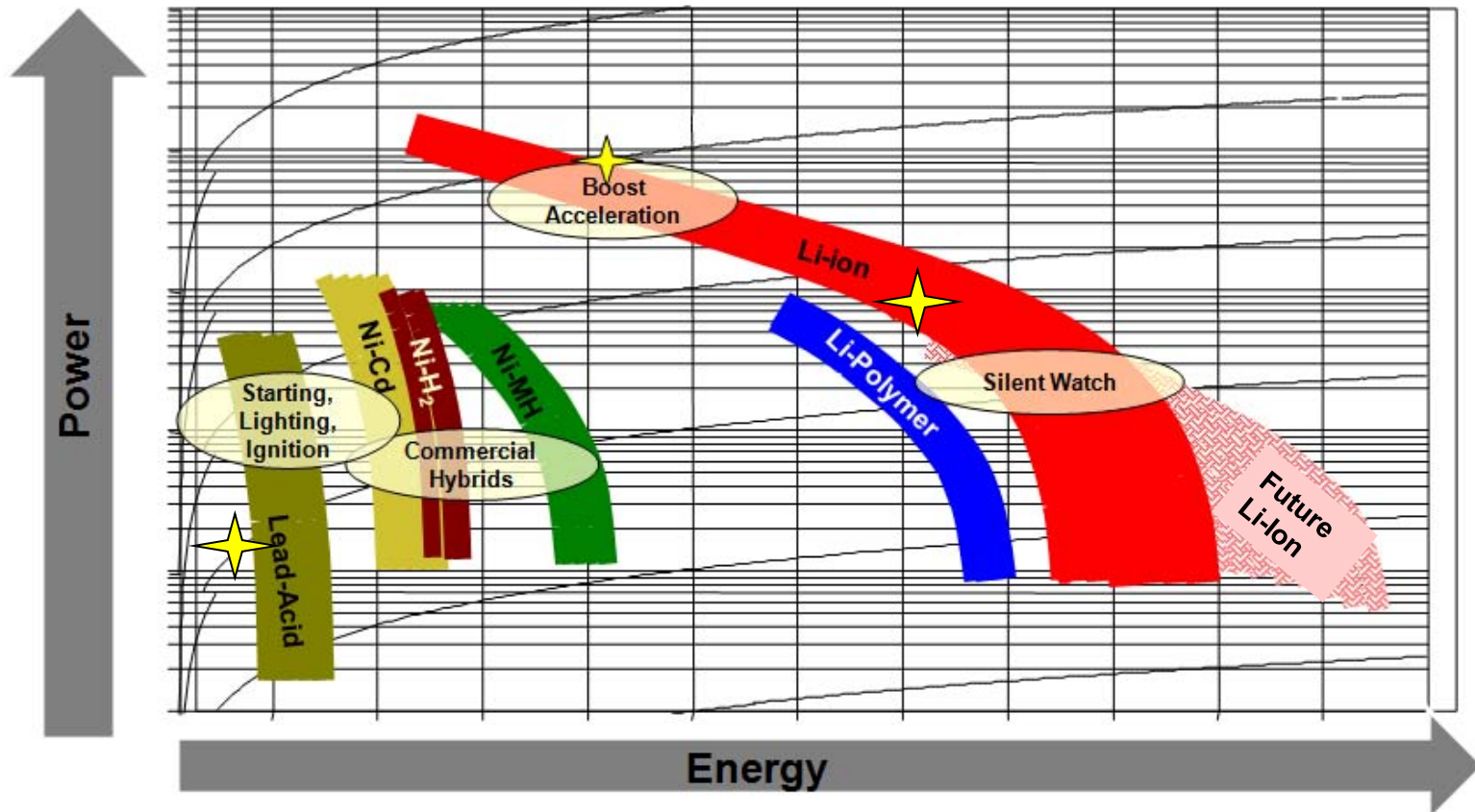
Technology Focus Areas



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Batteries can be optimized for either **power** or **energy** performance. These are fundamentally competing characteristics:

- An **energy battery** is used for silent watch in either a hybrid electric or conventionally driven vehicle and is measured in kW-hrs.
- A **power battery** is used for boost acceleration / regenerative braking in a hybrid electric drive vehicle and is measured in kW.



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Current Systems



Future Systems

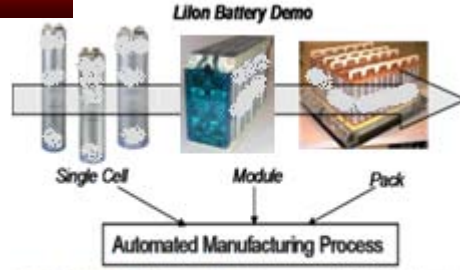
Current Technology



Advanced Lead-Acid



Capacitors for EMA



Testing



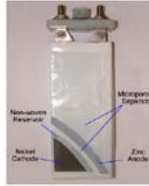
Improvements



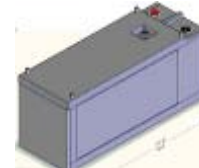
Li-Ion Prismatic Cell



L-i-Ion Battery Module (50V)



NiZn Cell



Li-Ion / Ultracap Hybrid Energy Storage



LFP cathode

•Efforts Supporting Today

- Battery Monitoring Technology development & testing
- Advanced Lead acid battery development
- Battery Ballistic Impact Test & Evaluation
- Battery Pack Integration, Testing & Evaluation
- High-Power/High-Energy Li-Ion Battery Manufacturing
- Ultra High Power Li-Ion Cells for Pulse Power
- Thermal Runaway Studies
- Nickel Zinc Battery Development

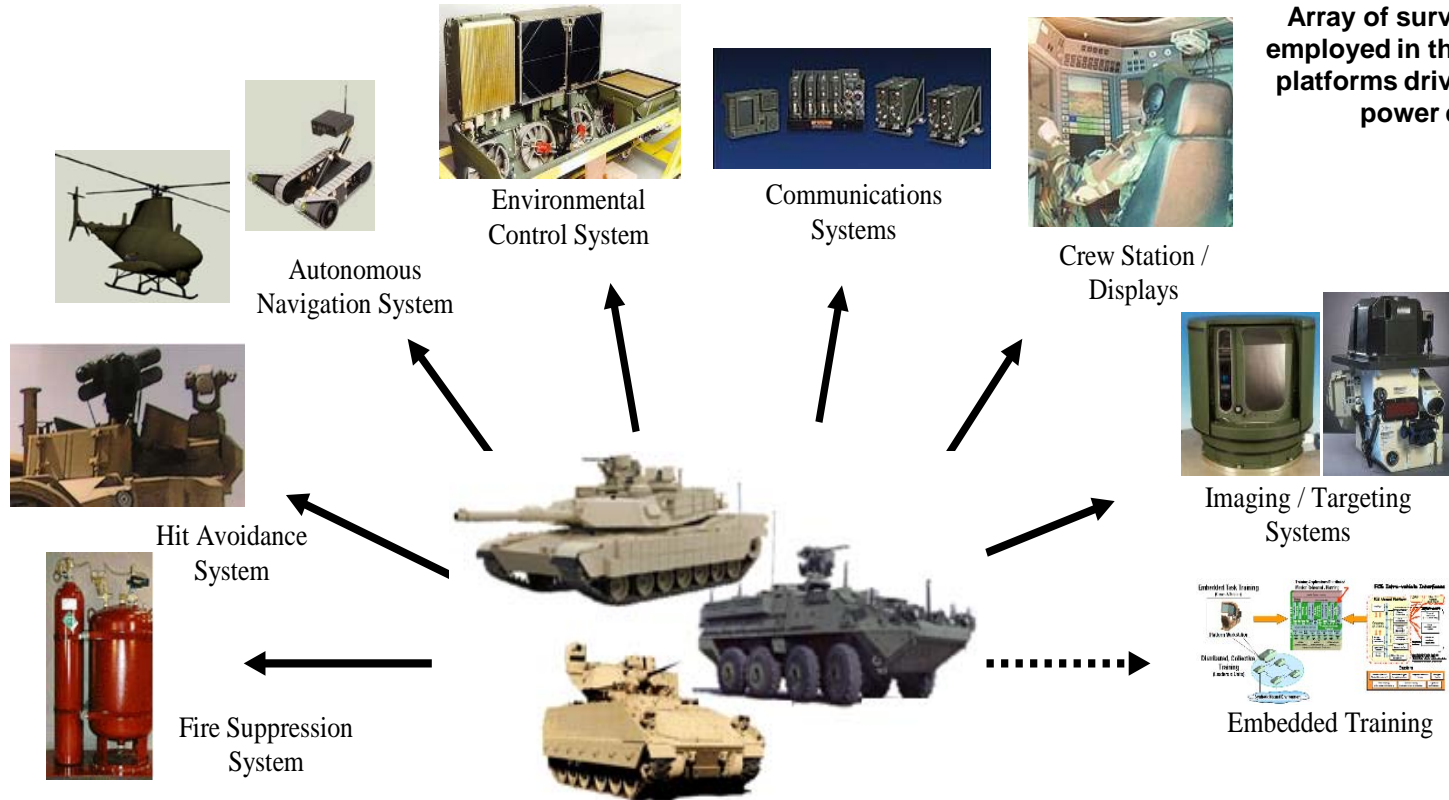
Outlook for The Future

- New Anode, Cathode, and Electrolyte Materials
- Extensive Use of Nano-materials
- Hybrid ES Devices (Batteries & Capacitors)
- High-rate Charging (Minutes vs. Hours)
- Advanced Battery Subsystem Diagnostics
- Reliable Battery Subsystem Prognostics
- >50% Improvement in Energy/Power Density
- Structurally Integrated Batteries

Advanced Batteries are the foundation for hybrid vehicles and technologies

Army Ground Vehicle Power and Energy Challenges

Advanced survivability, weapons and equipment are driving vehicle power demands dramatically higher.



As the Army transitions to the Future Force, significant technical challenges in power and energy must be overcome to enable superior capability

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Thank You



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Backup Slides



Unique Benefit of Hybrid Electric Ground Combat Vehicles:

- Optimized engine performance
- Brake energy recovery
- Greater vehicle design flexibility (Cable connection Engine & battery positions not fixed w/ series)
- Synergy with electric weapons and EM armor

Non-Unique Benefits of Hybrid Electric Ground Combat Vehicles:

- More on-board electrical power for mission equipment
- Potential to reduce vehicle fuel consumption

However,

- High military vehicle electrical requirements won't allow significant duration of engine-off
- Combat vehicles will not benefit from hybrid fuel economy improvement seen in commercial light-duty hybrids due to duty cycle optimization (EPA city/highway)
- Commercial hybrid fuel economy is optimized by other attributes besides the hybrid power train that are not applicable to combat vehicles (aerodynamics, low rolling resistance tires, etc.)

There are significant differences between commercial hybrid vehicles' and military ground combat hybrid vehicles' requirements and operational profiles

- Still many opportunities to leverage commercial investment in hybrid technology

The performance requirements for batteries to meet hybrid military combat are beyond today's state-of-the-art.

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