

INTERGALACTIC





OUTDATED THERMAL MANAGEMENT IS BLOCKING AEROSPACE PROGRESS

“HOUSTON, WE HAVE A PROBLEM”

Modern aircraft and aerospace systems:

- Generate more heat
- Have smaller space and weight budgets to deal with increased heat
- Need thermal systems that integrate into modern mechanical and electrical systems

Legacy thermal management solutions are not equipped to solve these emerging problems.



BREAKING
DEFENSE

How to ensure readiness of next-generation defense technology: Solving the issue of massive heat

High-performance systems generate tremendous amounts of heat that can compromise missions and make high-tech systems less effective in tactical environments. But there is a solution to this modern-age challenge.



Electric aviation industry grapples with battery cooling



Military-Aerospace
Electronics

LOGIN JOIN

Demands are increasing for high-performance embedded computing in small packages, which creates a huge amount of waste heat. Designers look at sharing responsibilities for electronics cooling from chips to entire systems.

Aerospace and defense systems designers today face an overwhelming task when it comes to electric power control and thermal management. Systems integrators are demanding increased capabilities and ever-smaller packing, and yet these converging forces are conspiring to create staggering amounts of waste heat; there's no end in sight to this trend.



Aerospace
TESTING
INTERNATIONAL



Unlike in other industries, aerospace electronics must survive in some of the world's harshest environments, endure extreme weather conditions and handle regular fluctuations in temperature, airflow and pressure. As a result, the process of estimating how temperature changes and heat flow will impact a device's reliability becomes very complex.

While these challenges have always existed, new trends and innovations are driving further change in the industry — and introducing a whole host of new considerations for aerospace engineers.

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Military & Defence news, analysis, research & data



F-35 cooling issue bill: additional repairs to cost \$38 billion

OUR MISSION IS TO BREAK
HEAT BARRIERS

PURPOSE BUILT FOR TODAY’S THERMAL
MANAGEMENT CHALLENGES

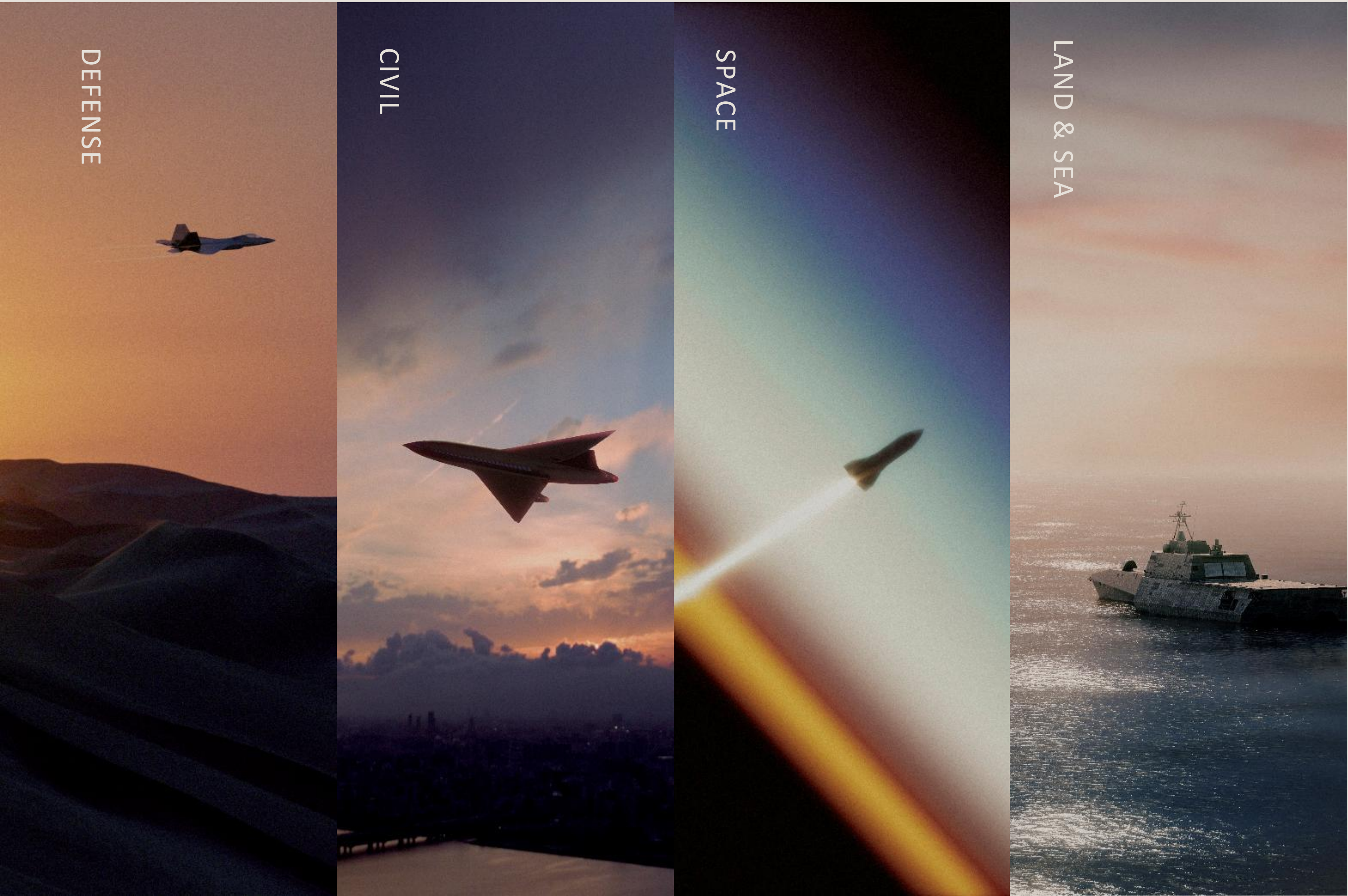
From our founding, we’ve focused on
developing smaller, lighter, and more
flexible thermal management
solutions to integrate with modern
systems and aerospace platforms.



SERVING ALL SECTORS

FLEXIBLE SOLUTIONS FOR AIR,
SPACE, AND BEYOND

Strengths in modernization
and next-generation
aerospace systems and
platforms



- Fixed & rotor wing
- Cabin cooling
- Drones & pods
- Avionics & computing
- Directed energy

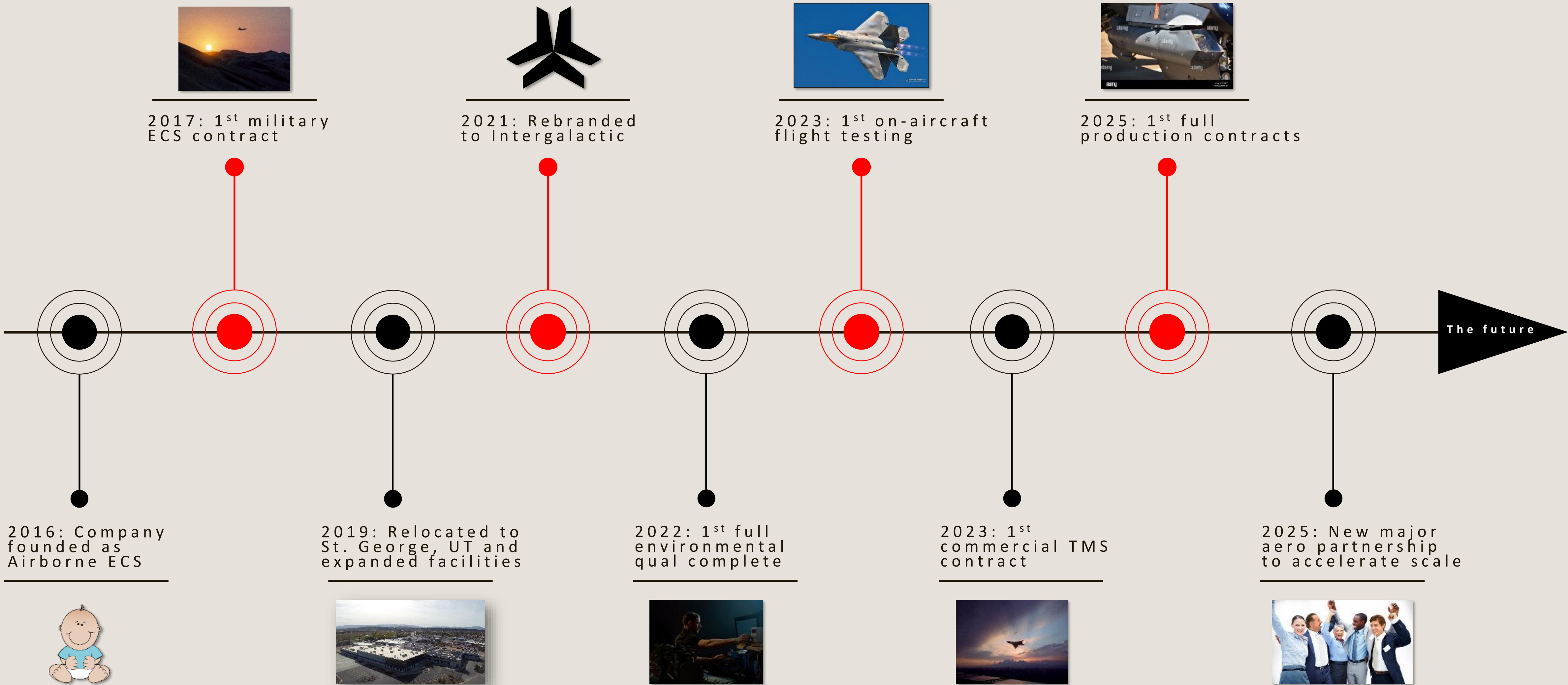
- Commercial
- Urban and regional electric
- Hybrid-electric
- Hydrogen

- Lunar mobility
- Habitation
- Lander systems
- Rocket motors

- Military sea vehicles
- Heavy ground vehicles
- High performance auto
- Industrials

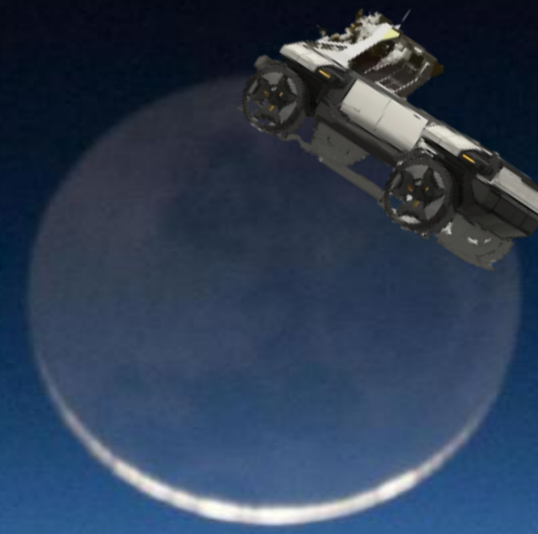


THE INTERGALACTIC JOURNEY

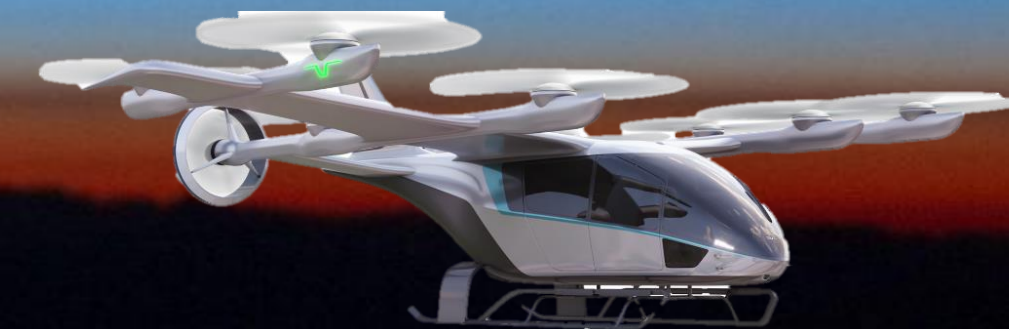


CONSTRAINING THERMAL PROBLEMS IN SPACE AND SKY

New Space



Next Gen Aviation

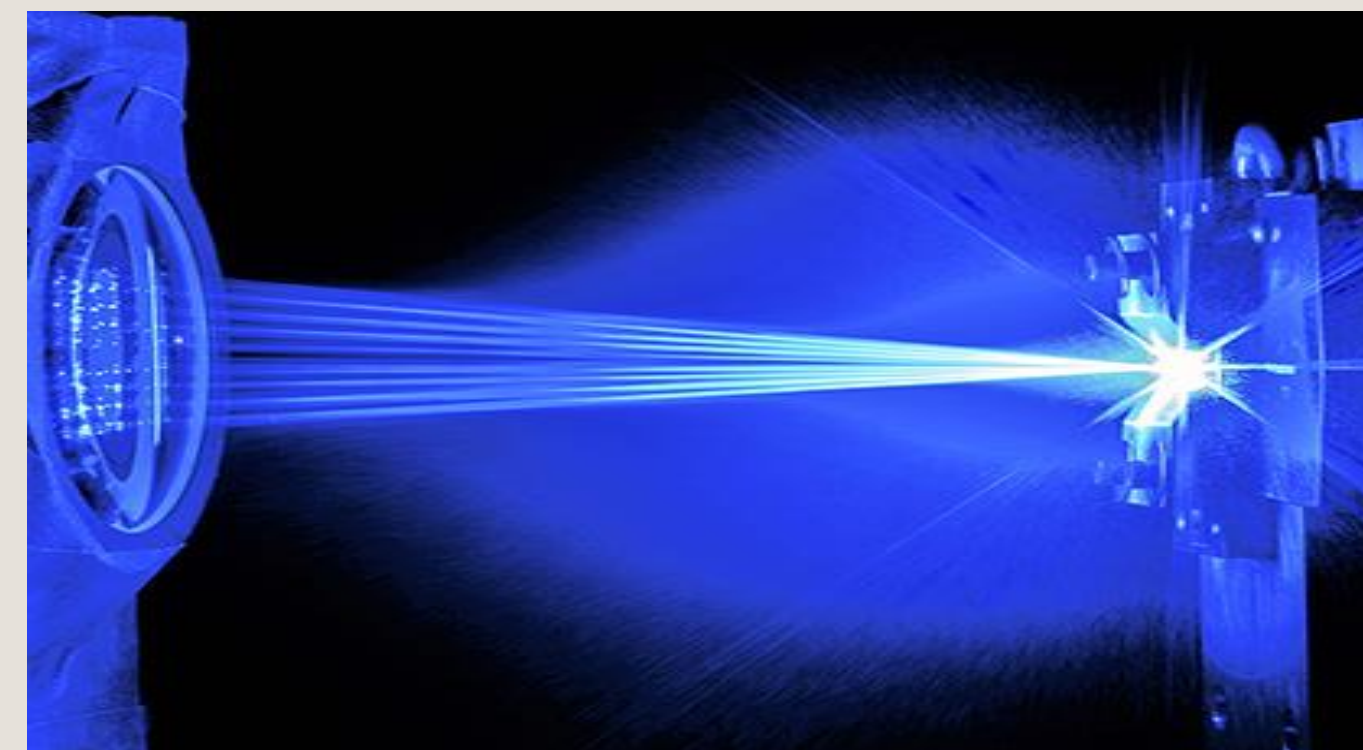


Electric Aircraft



NEXT GEN AVIATION

- Very high loads (25 kW to 100's of kW and increasing)
- Loads exceeding traditional fuel and air thermal sinks
- Rejection to aircraft ram air (in some cases supersonic)
- Desire to miniaturize and package TMS into small form factors
- Severe environments (high temperatures)



Tech Reach Goals for 2060:

- Gigawatt solid state laser
- Nanoradian laser beam-control accuracy and stability
- Miniaturization of laser systems

AFRL "Directed Energy Futures 2060" Report



"Thermal management and power generation are what's currently limiting airborne DEW capability today" – Air Force Research Lab, 2023



ELECTRIC AVIATION



- Motors, electric aircraft systems, occupants (ECS) all need cooling
- Weight directly impacts range and load capacity
- Power draw (efficiency) directly impacts range and weight
- Power source (batteries and/or fuel cells) both generate significant heat and require thermal management to perform
- Fully electric solutions required (no bleed air)

BATTERY SPECIFIC CONSIDERATIONS:

- Batteries generate heat and demand particular temperature (25°C for current Li-Ion, 100°C+ for solid state)
- Thermal management improves energy density (more range per unit weight)
- Isothermal conditions across batteries important for performance and safety (cells within 2-3°C of each other)
- Significant improvement (>50%) in battery life
- Reduced risk of thermal runaway with proper thermal management (safety)

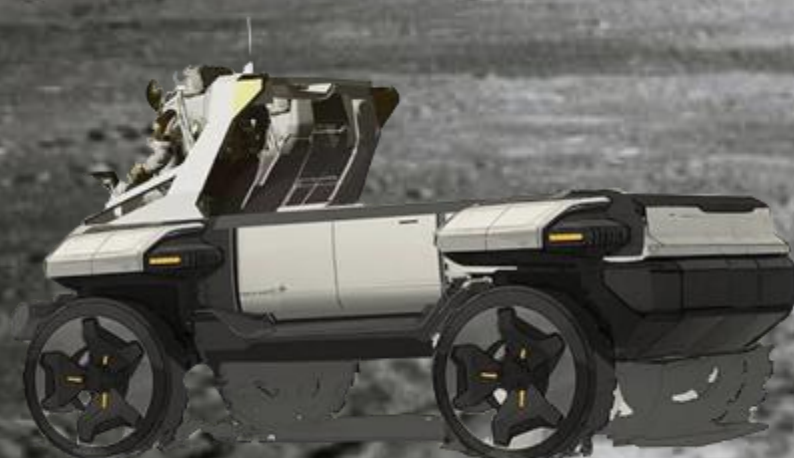


NEW SPACE

- Weight limited by launch payload capacity
- Available power limited

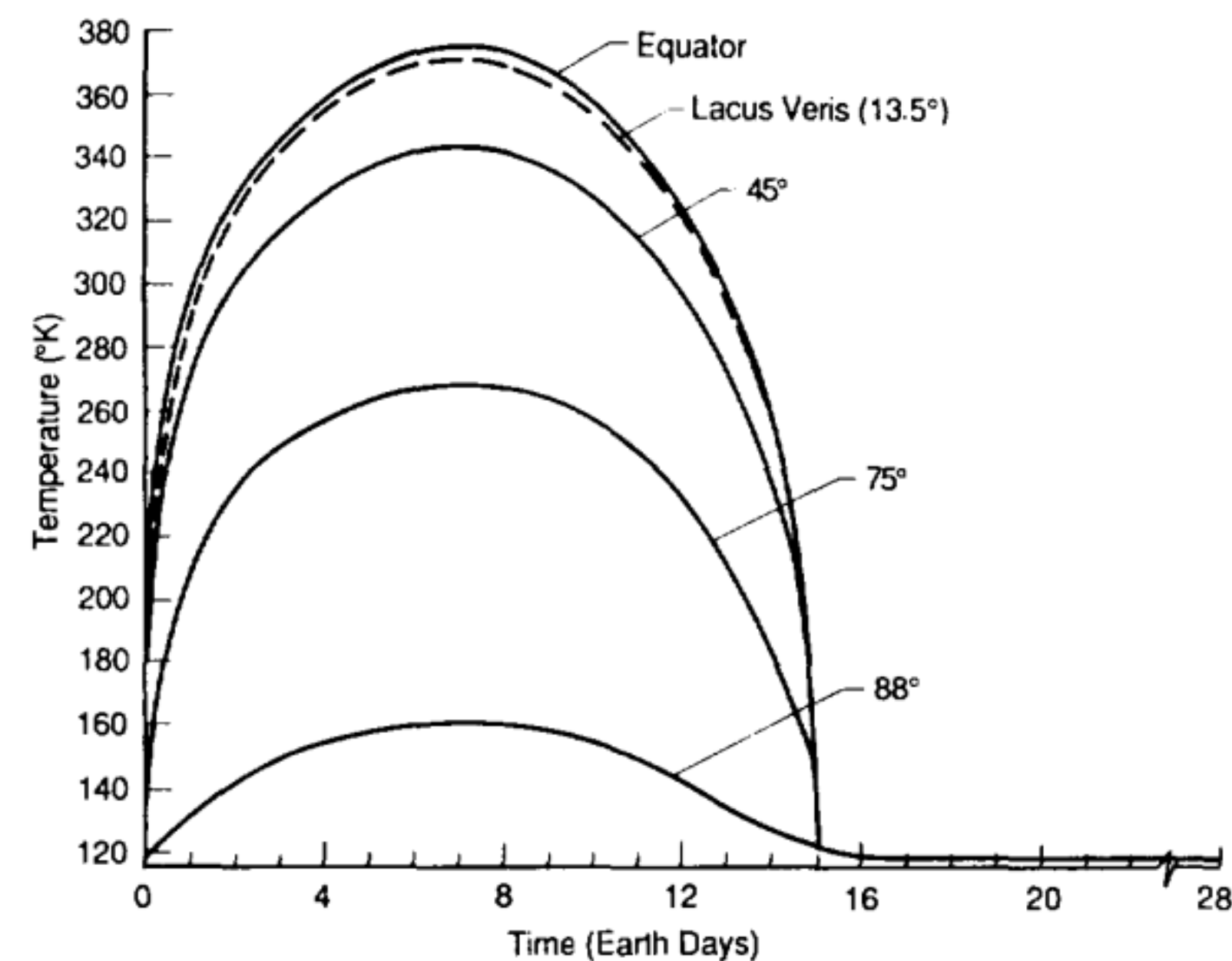


- Extreme cold at night
- Extreme hot during day
- 15 days hot, 15 days cold
- No atmosphere to reject heat to



- Moon dust
- Difficult or impossible to maintain / repair
- High radiation environment
- Reliability critical to mission and/or human life

Moon Day/Night Cycle Temperatures



ENERGY MANAGEMENT SYSTEMS

SPEED & PRECISION VIA DIGITAL ENGINEERING

Shorter development timelines

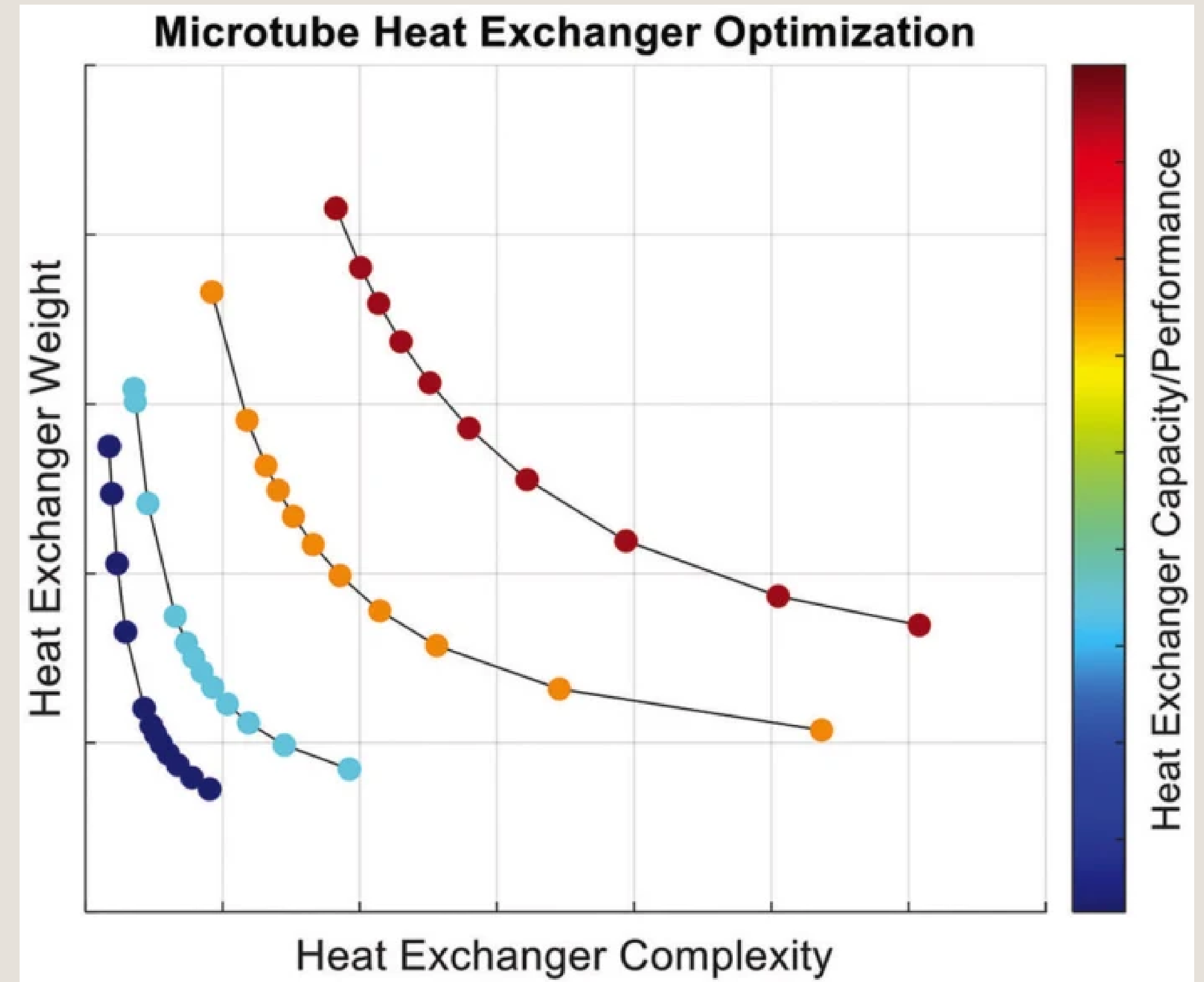
- Eliminates ambiguity and rework compared with designing to flat text requirements
- Faster path to prototyping, testing, and production

Tighter collaboration

- Leaves no optimization opportunities on the table
- Un-silos various subsystems for better overall performance

Easier tradeoff decision-making

- Clearly see pros and cons and pick points that maximize priority benefits



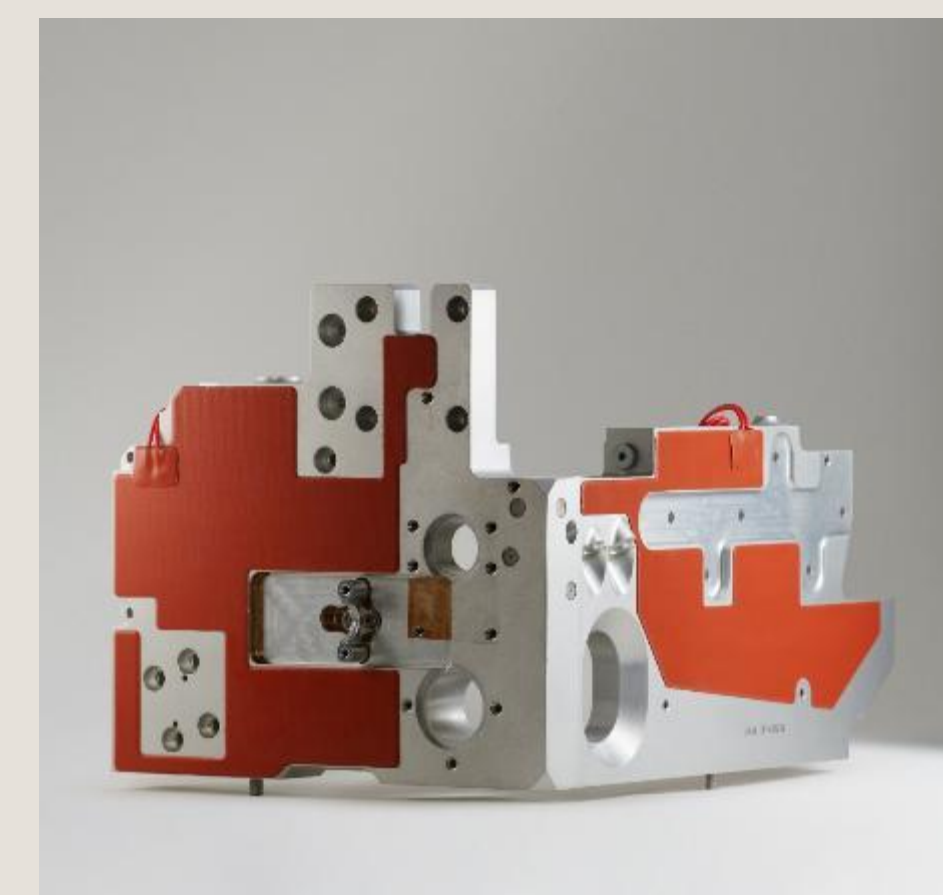
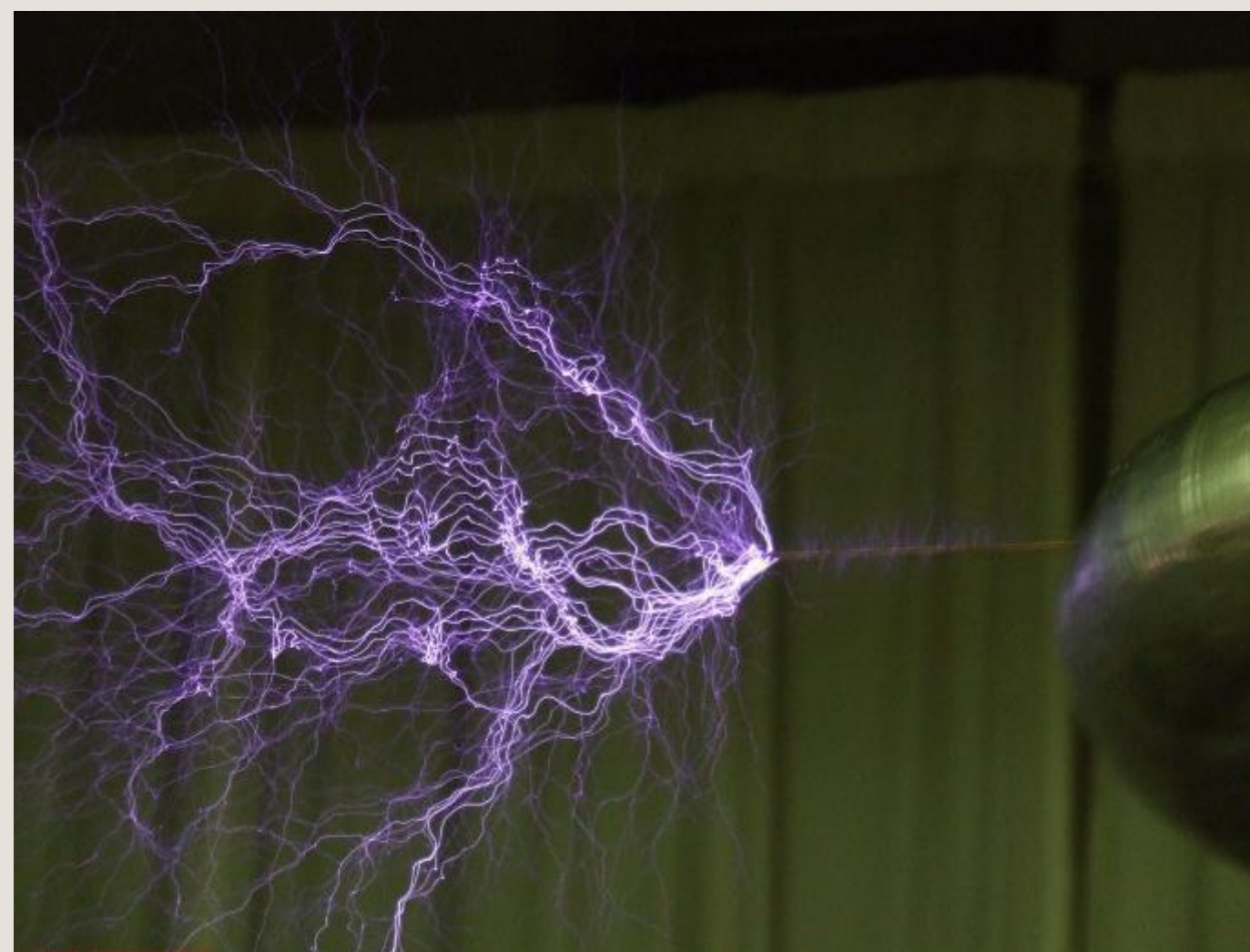
HIGH VOLTAGE HIGH POWER ELECTRICAL SYSTEMS

Native high voltage DC capabilities (no power conversion)

- Designed to accommodate more electric platforms
- Built in test, predictive health management feedback
- Eliminate bleed air for improved engine and air vehicle performance

“Smart” thermal management

- System only cools or heats as needed; variable speed compressor and fans
- Minimize power draw and noise generation based on loads and conditions
- Dynamic feedback loop- “pushed” to end-user



MICROTUBE HEAT EXCHANGER

OUR PATENTED MICROTUBE HX TECHNOLOGY
IS 3X SMALLER & LIGHTER

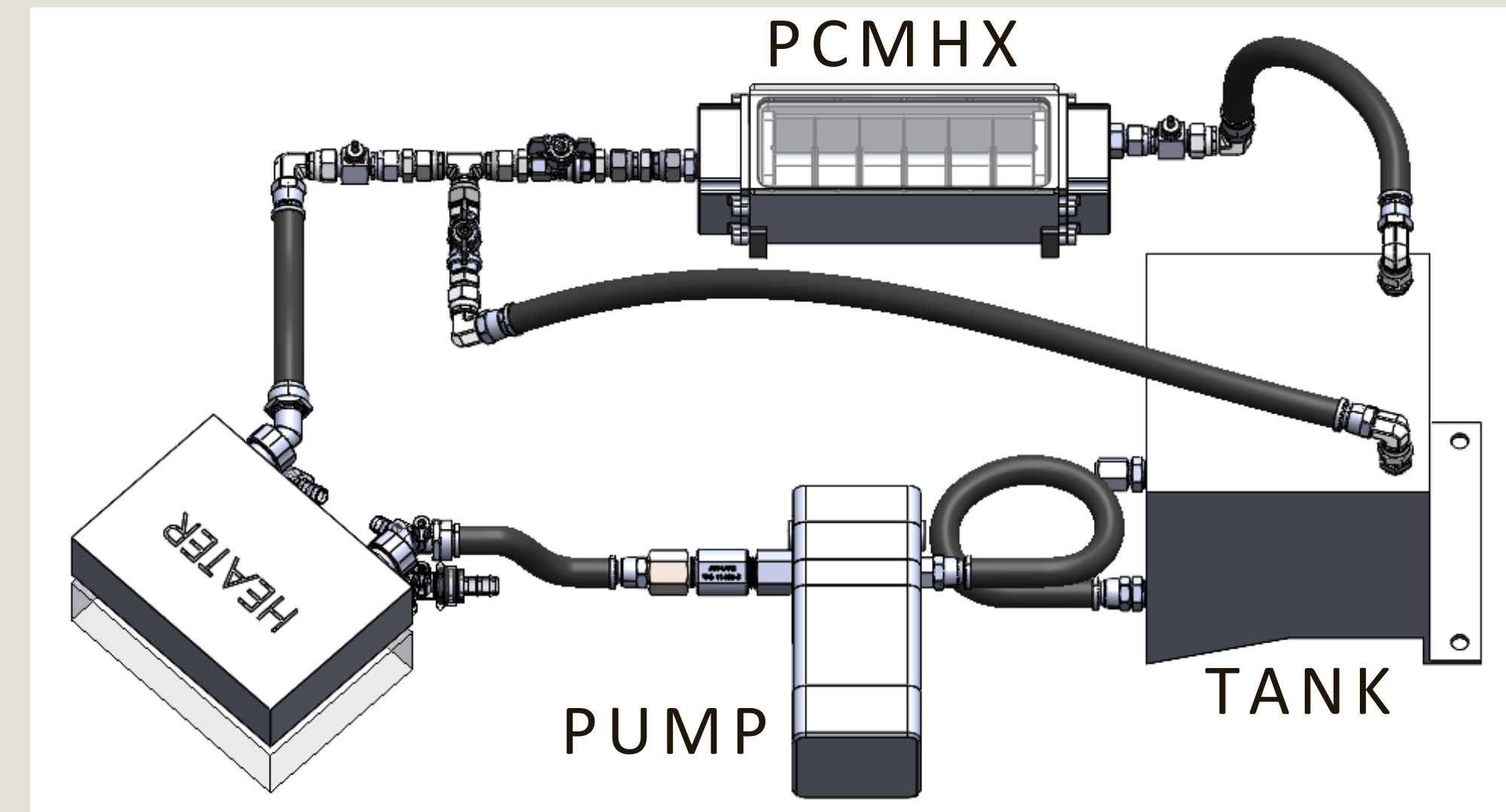
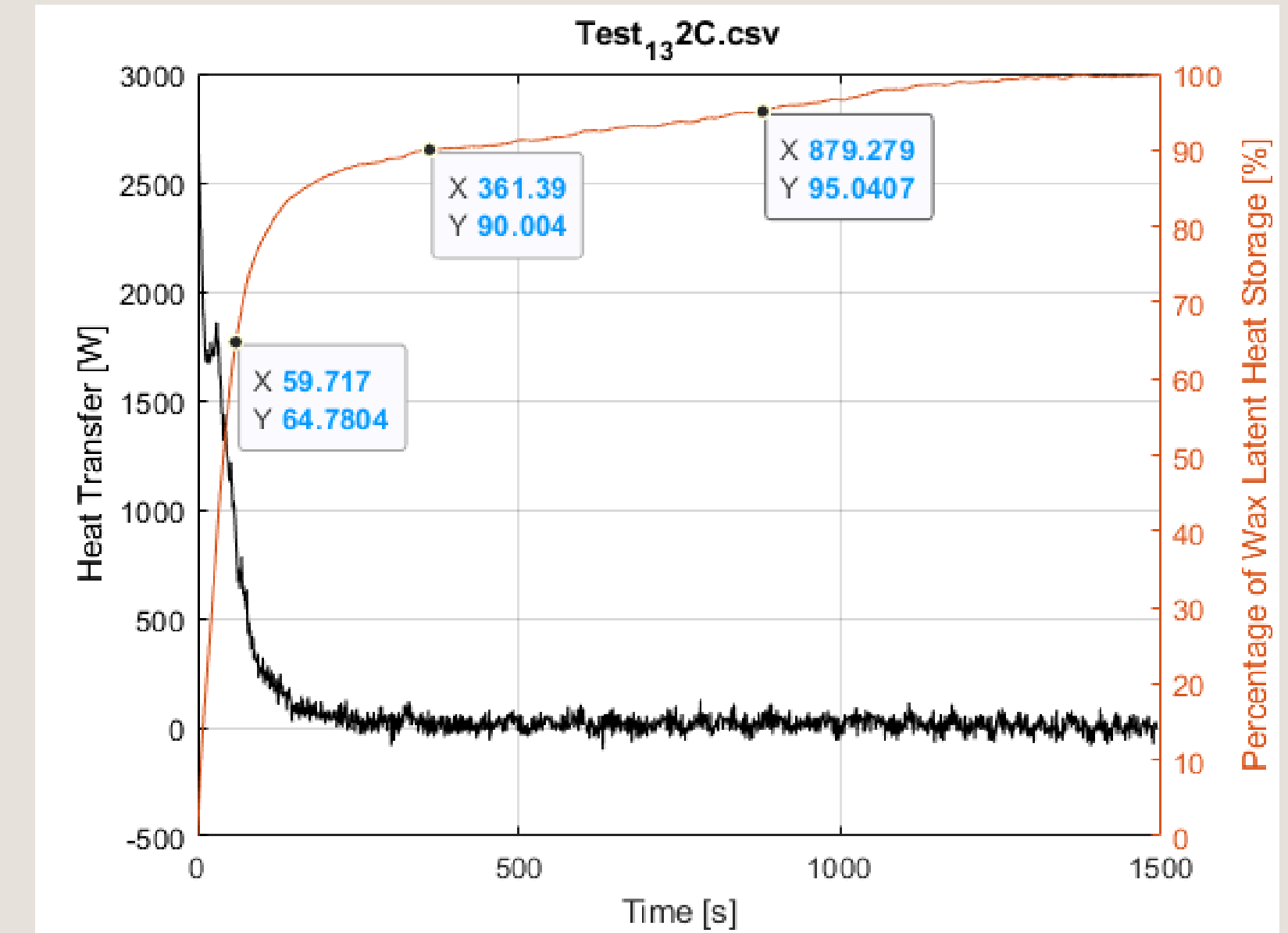
- Best-in-class heat rejection per weight and volume
- World-class size, weight, and pressure drop characteristics vs. traditional brazed plate fin technology
- Proprietary, patented microtube technology
- Precision laser-welded
- Engine, hydraulic, gearbox oil coolers
- Refrigerant evaporator and condensers (air and liquid exchange)
- Liquid-to-air and air-to-air, including air cycle machine heat exchangers
- Low tube and shell side pressure drops reduces compressor, pump, and fan power



PHASE CHANGE MICROTUBE HX

FAST RESPONDING THERMAL STORAGE BATTERY

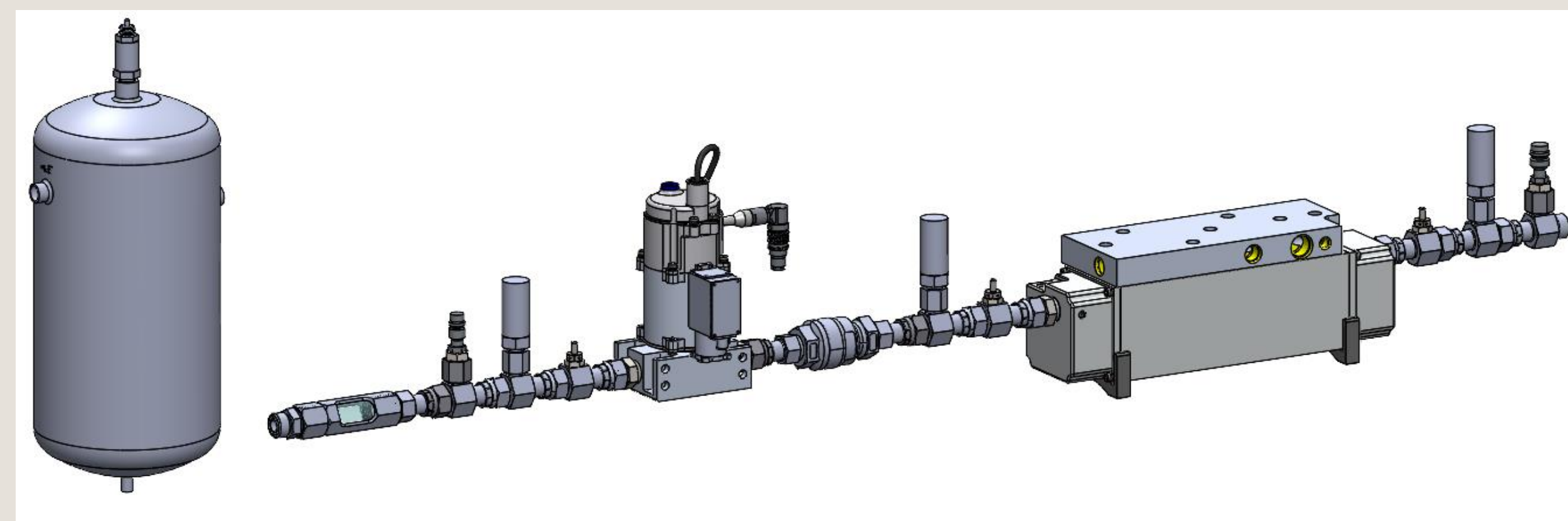
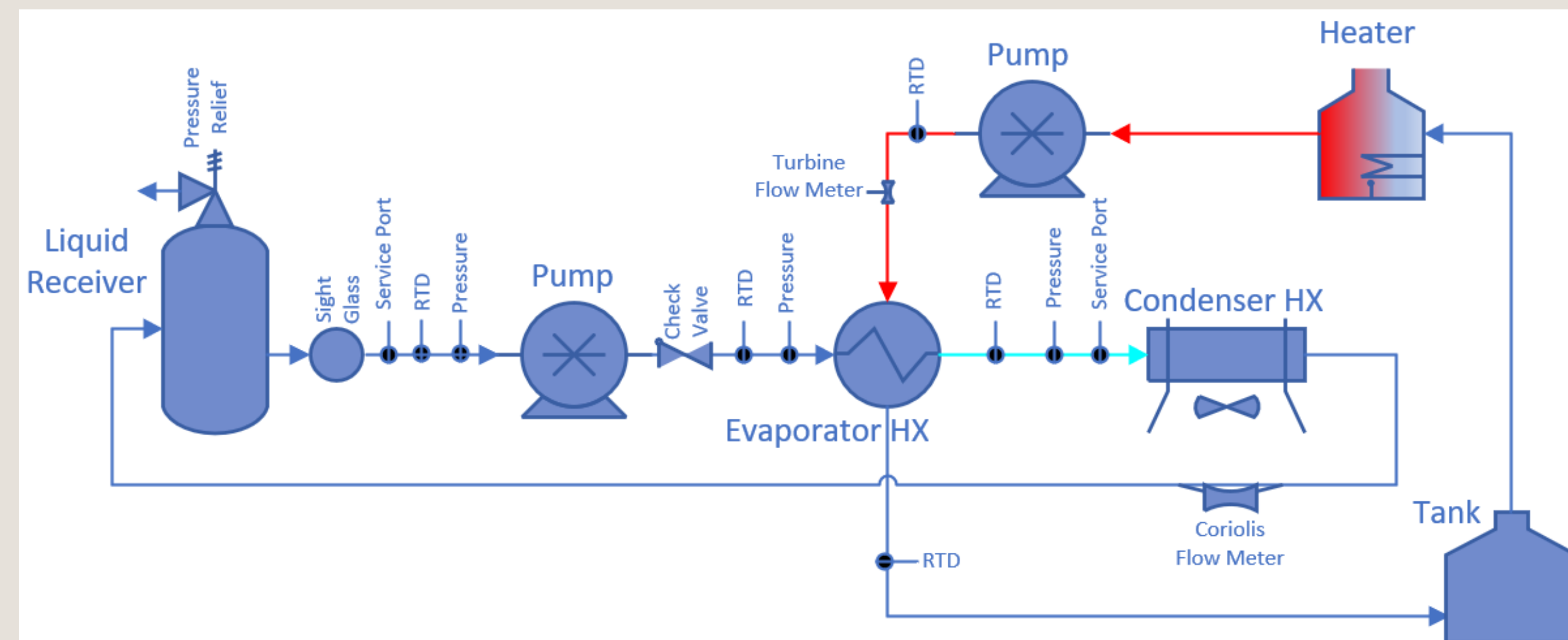
- Utilizes principal benefits of IG's microtube HX for thermal storage
- Flooded shell side of microtube HX with wax phase change material
- Acts as thermal buffer/capacitor against highly dynamic/transient peak loads (such as High Energy Lasers)
- Mitigates transient heat loads from determining TMS sizing which ideally is sized for steady state
- Custom phase-change temperature setpoints available
- Initial testing with OTS HX, HX weight: 6.8 lbs / Wax: 1.415 lbs
- Thermal storage capacity of 150 kJ / Discharge rate of 420W (first 90%)
- TRL 5 currently, with full maturation to TRL6 by late 2023



PUMPED TWO-PHASE COOLING LOOPS

NEXT GEN “LIQUID” COOLING LOOPS

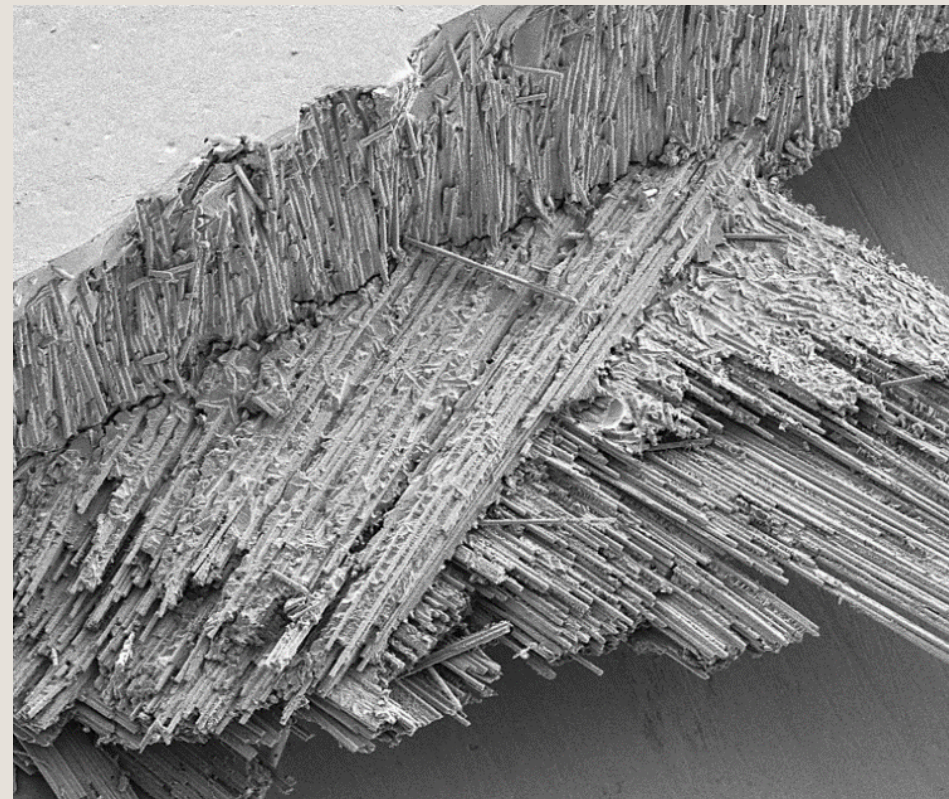
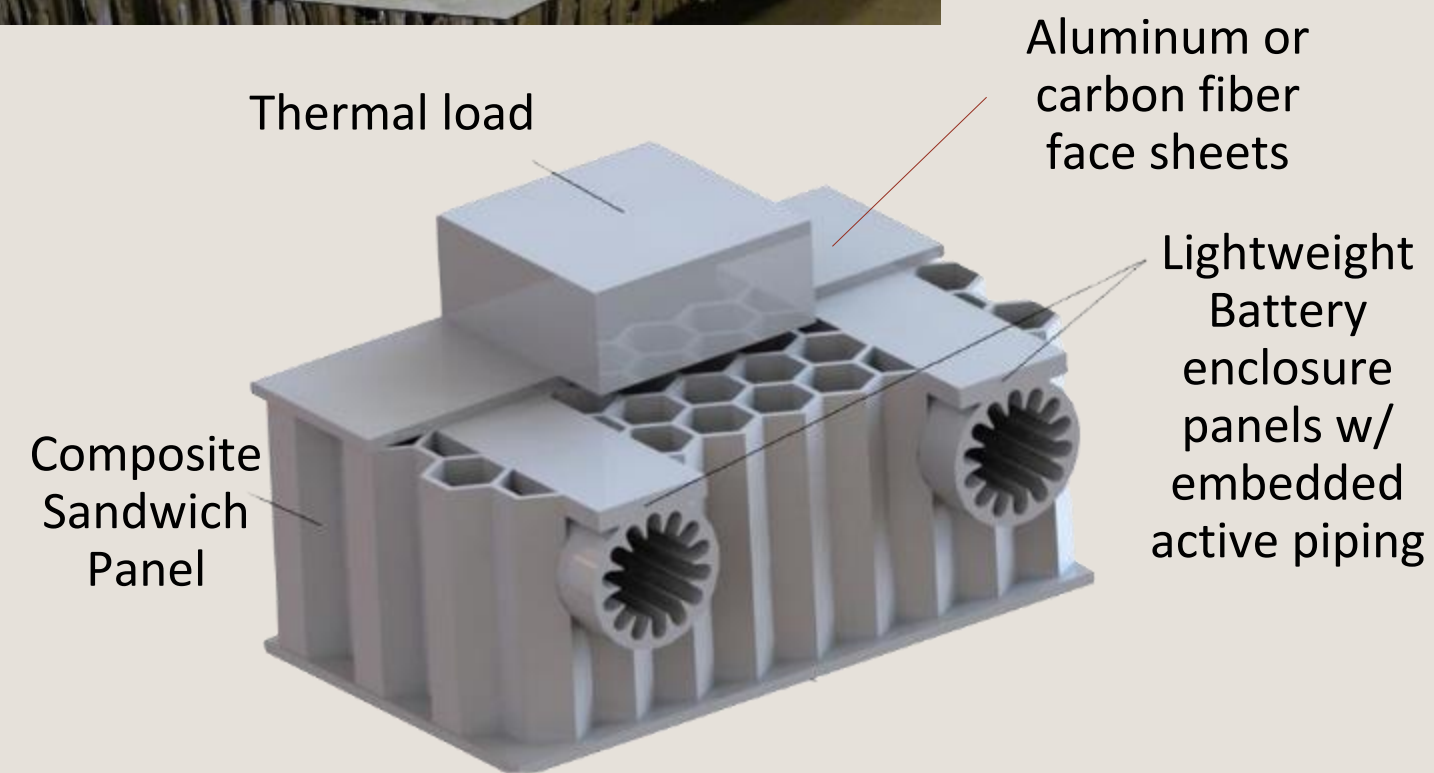
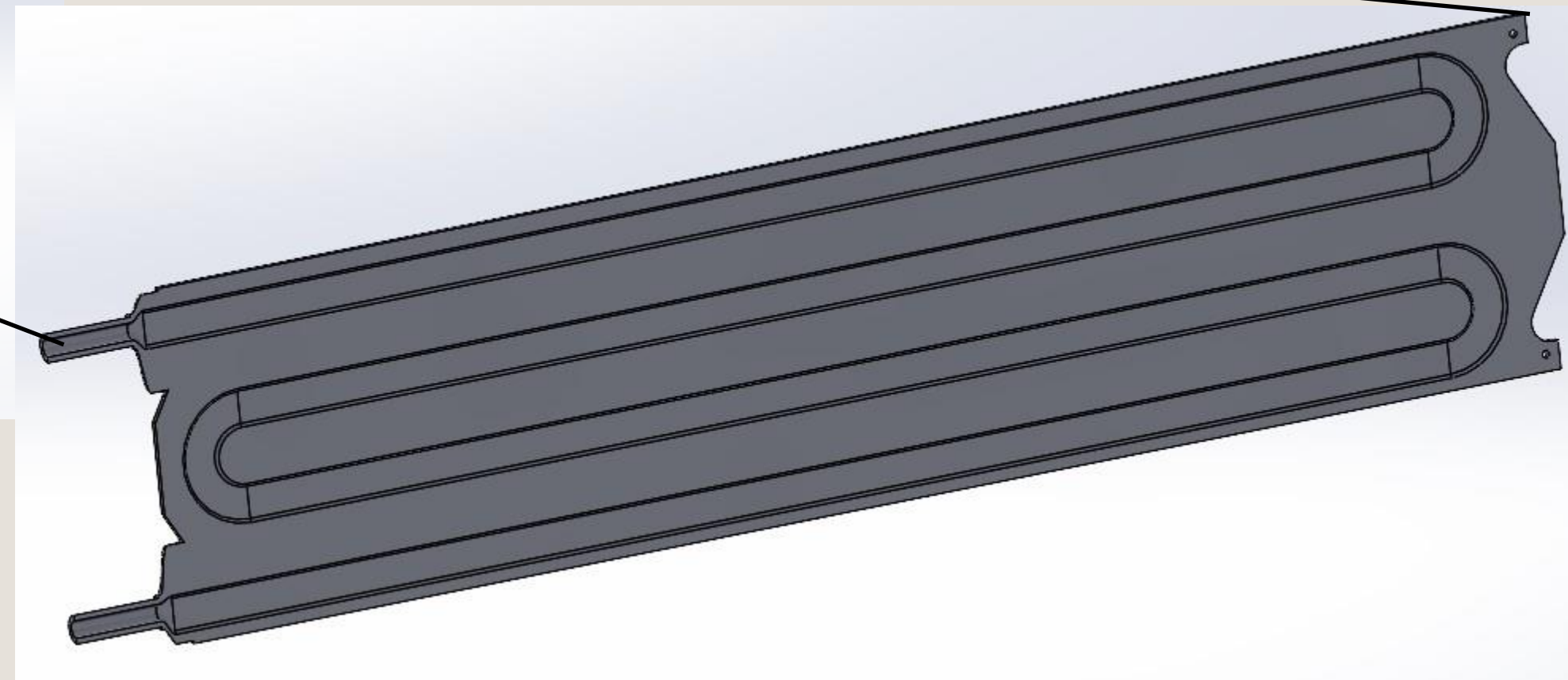
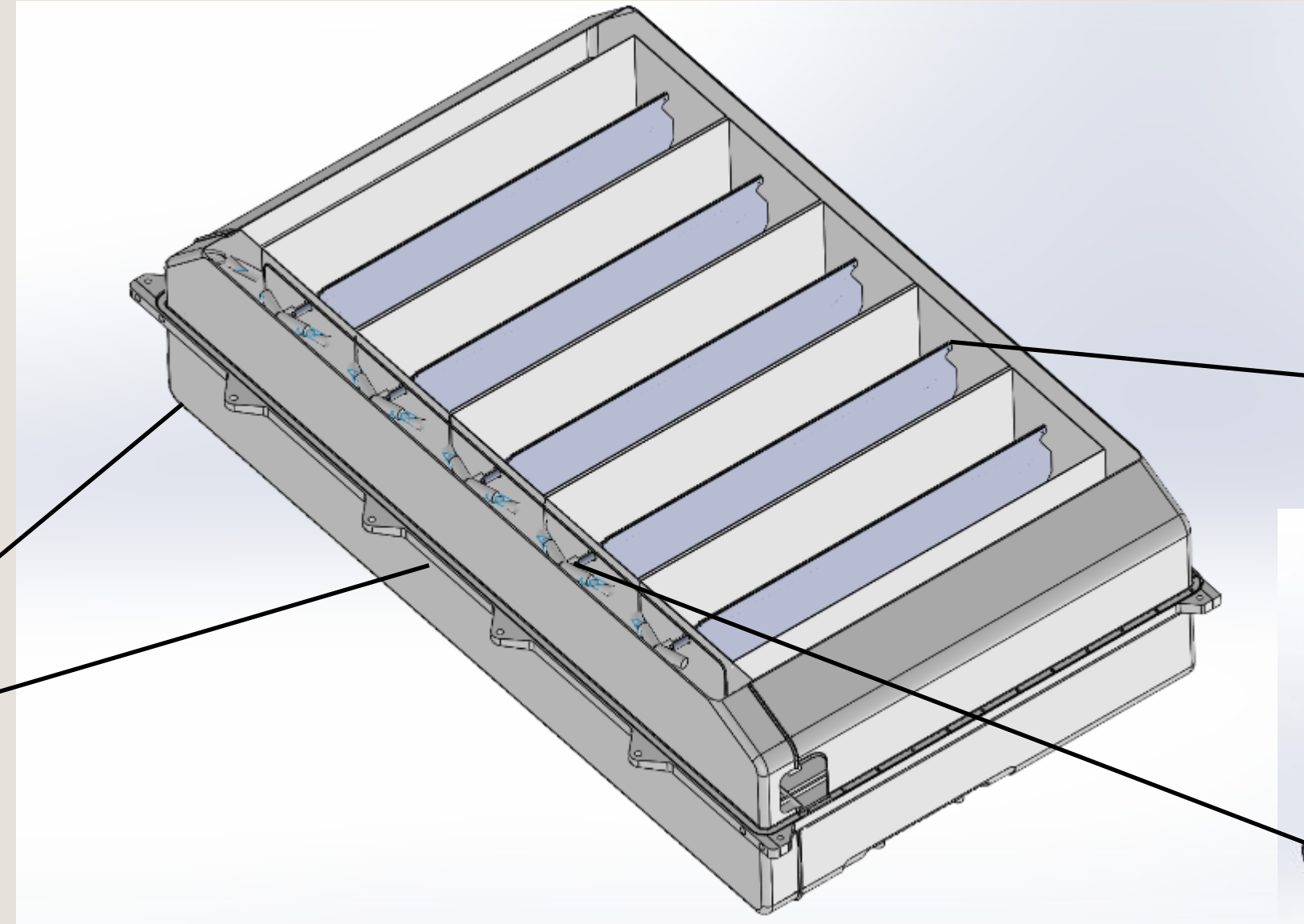
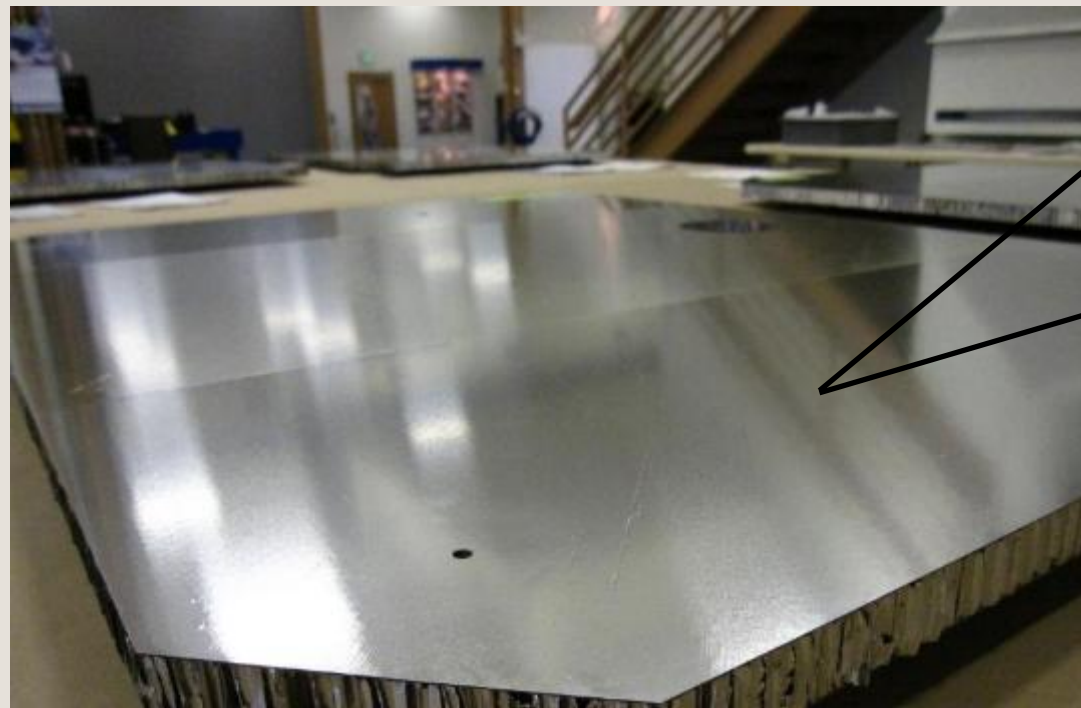
- Utilizes a fluid's latent heat of fusion rather than sensible heat and temperature change
- Nearly an order of magnitude reduction in required mass flow compared to single-phase cooling loops
- Velocity flow reduction is linearly proportional with mass flow
- Pressure drop reduction and required pump head rise follows velocity squared resulting in significant power draw reduction
- Significantly reduces size of pump, tubing, and receiver
- Payload is maintained at nearly a constant temperature (two-phase loop's saturation temperature)
- Initial concept design phase for established space/lunar application
- Full maturation to TRL 6 by mid-2023



COMPOSITE SYSTEMS — Light Weight enclosure and Cold Plates

Battery Enclosure

- 45% Mass savings, increased Structural capabilities



Build up Composite flat Panels (Aluminum Face sheets / Composite Face sheets – lightweight structure with thermal systems built into structure)

Cold Plates – composite

- Two halves of high thermal conductivity, z-axis material. Flat laminate designed for manufacturing, simple to fabricate, simple to machine.
- Thermally conductive adhesive to bonding two plates together

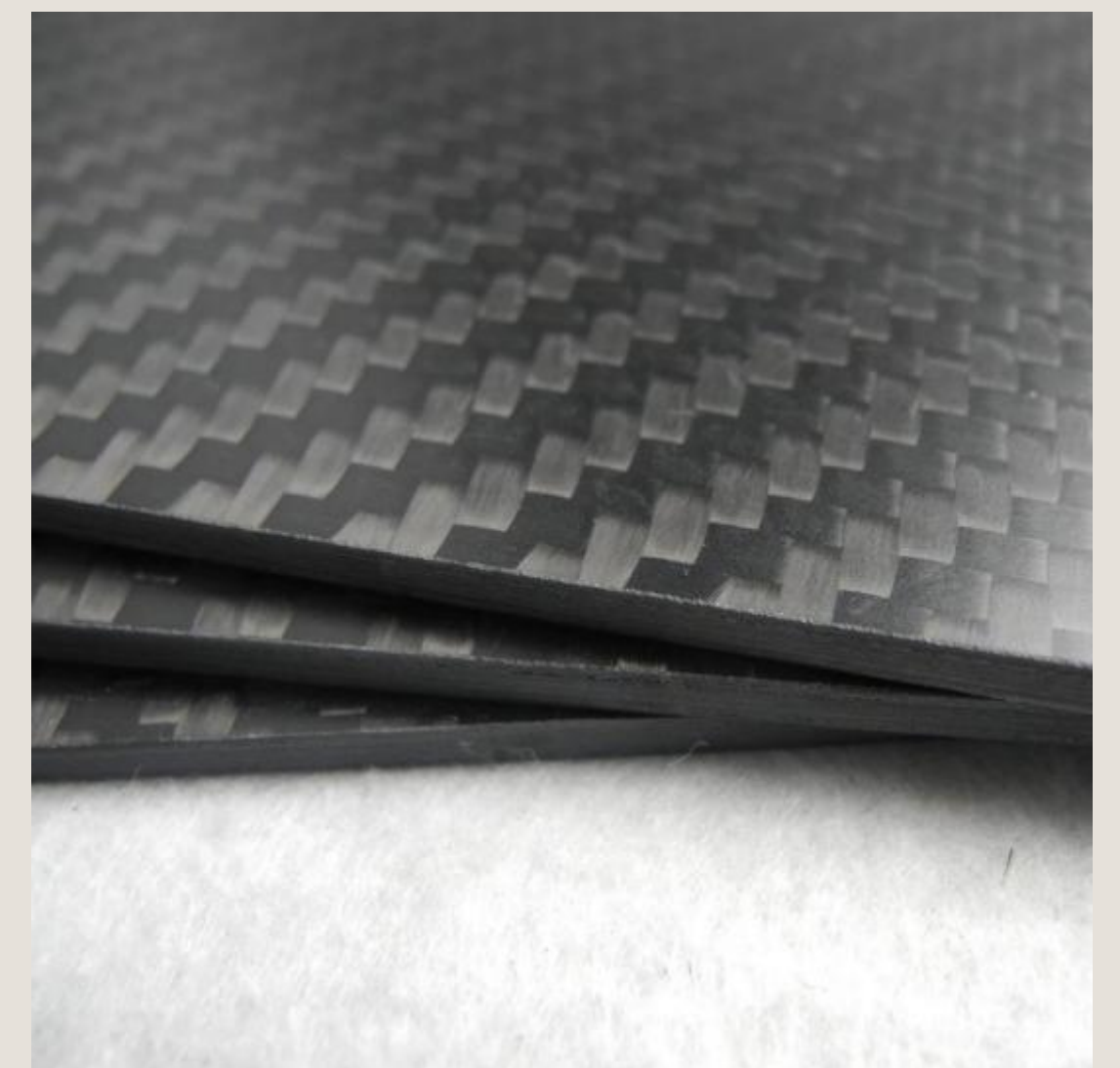
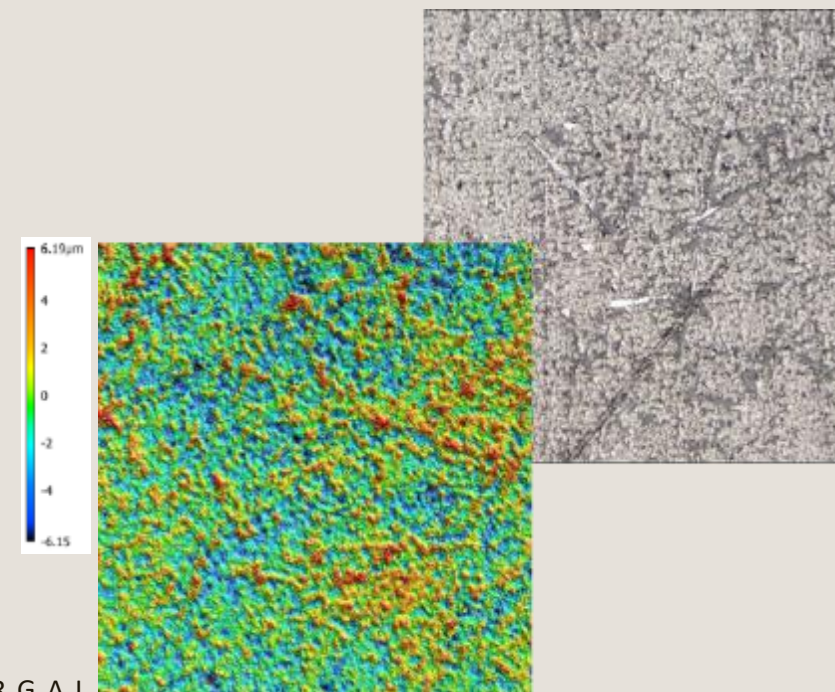
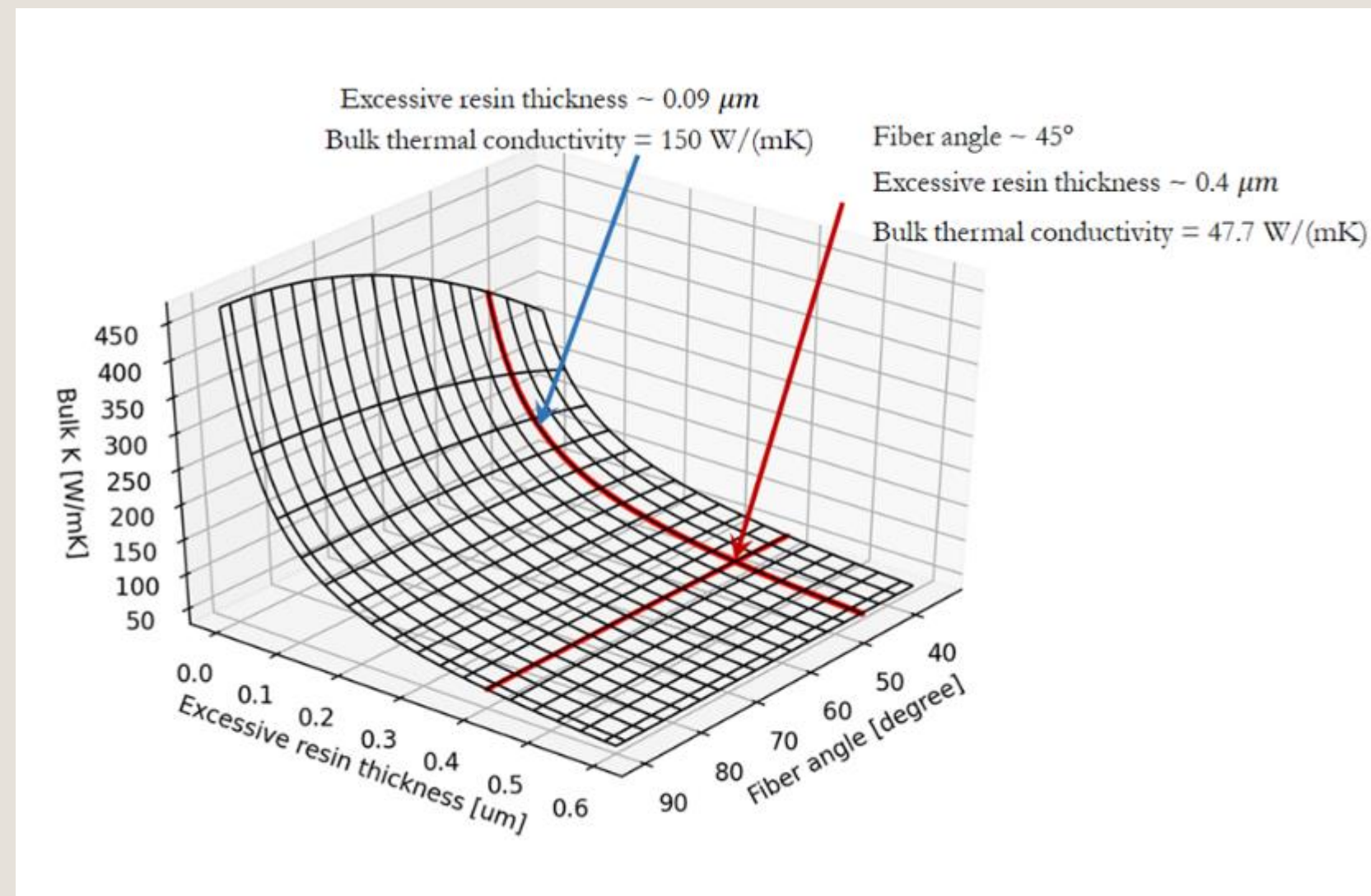
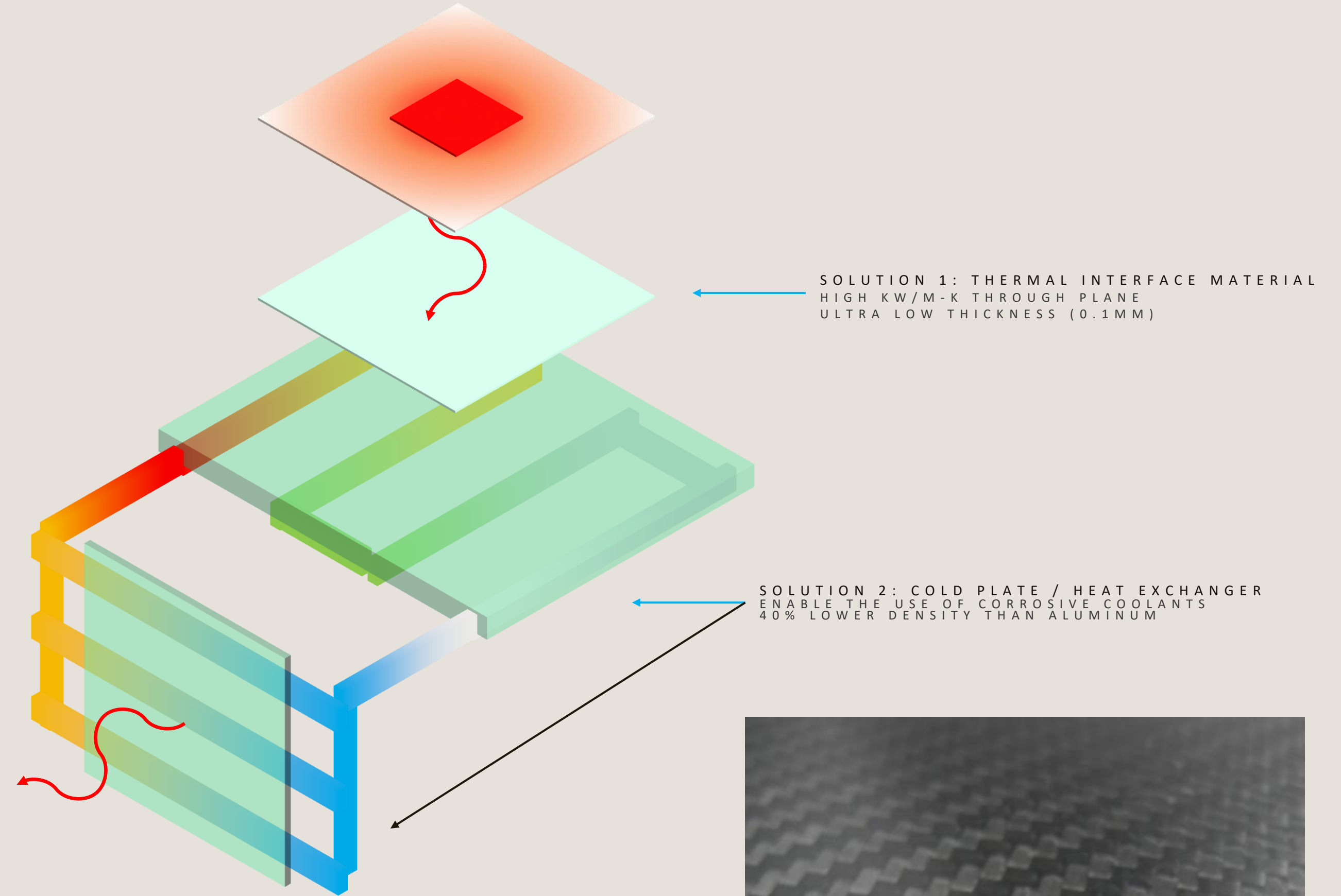
Extreme mass saving option – proposing an integrated thermal system throughout the battery enclosure - composite system



COMPOSITE COLD PLATES AND RADIATORS

IG Carbon Cold Plates & Radiators

- Light weight cold plate option
 - 40% Lower Density than Aluminum
- High thermal conductivity
 - z-Axis Fiber configuration for effective through thickness conductivity
- Structural, scalable



QUESTIONS?



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