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Accelerated Thermal Battery Design Through Digital Engineering Tools

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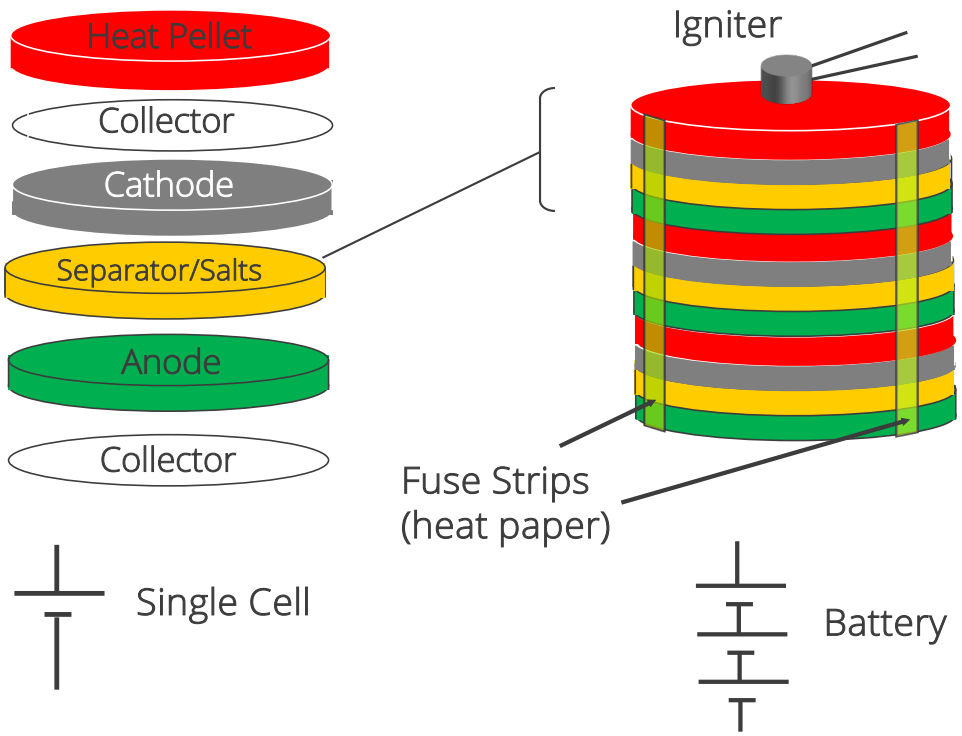
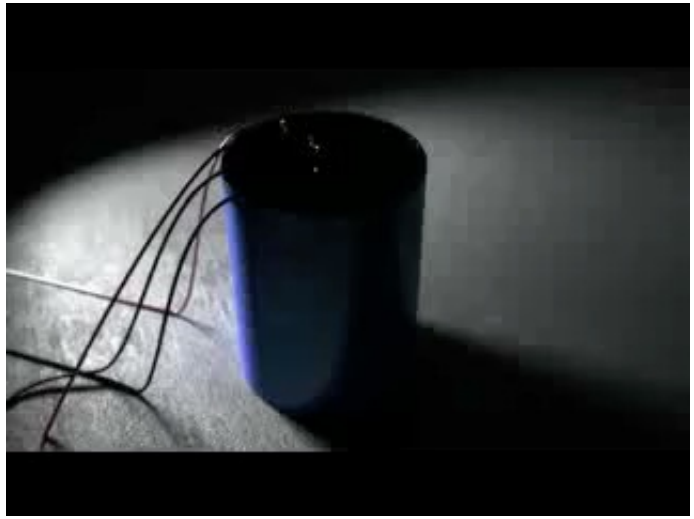
What is a thermal battery?



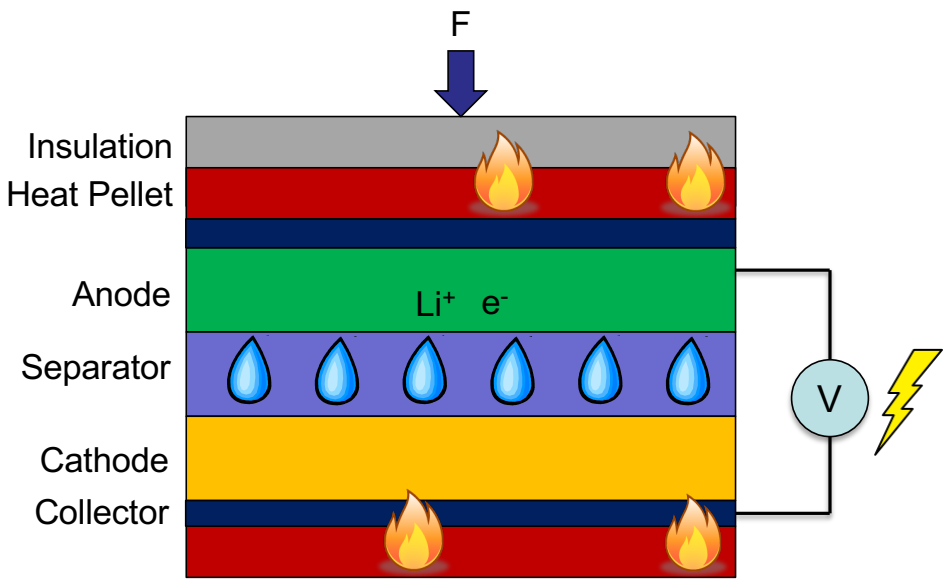


Thermal batteries provide high power density, high reliability, and a long shelf life.

What makes a thermal battery work?

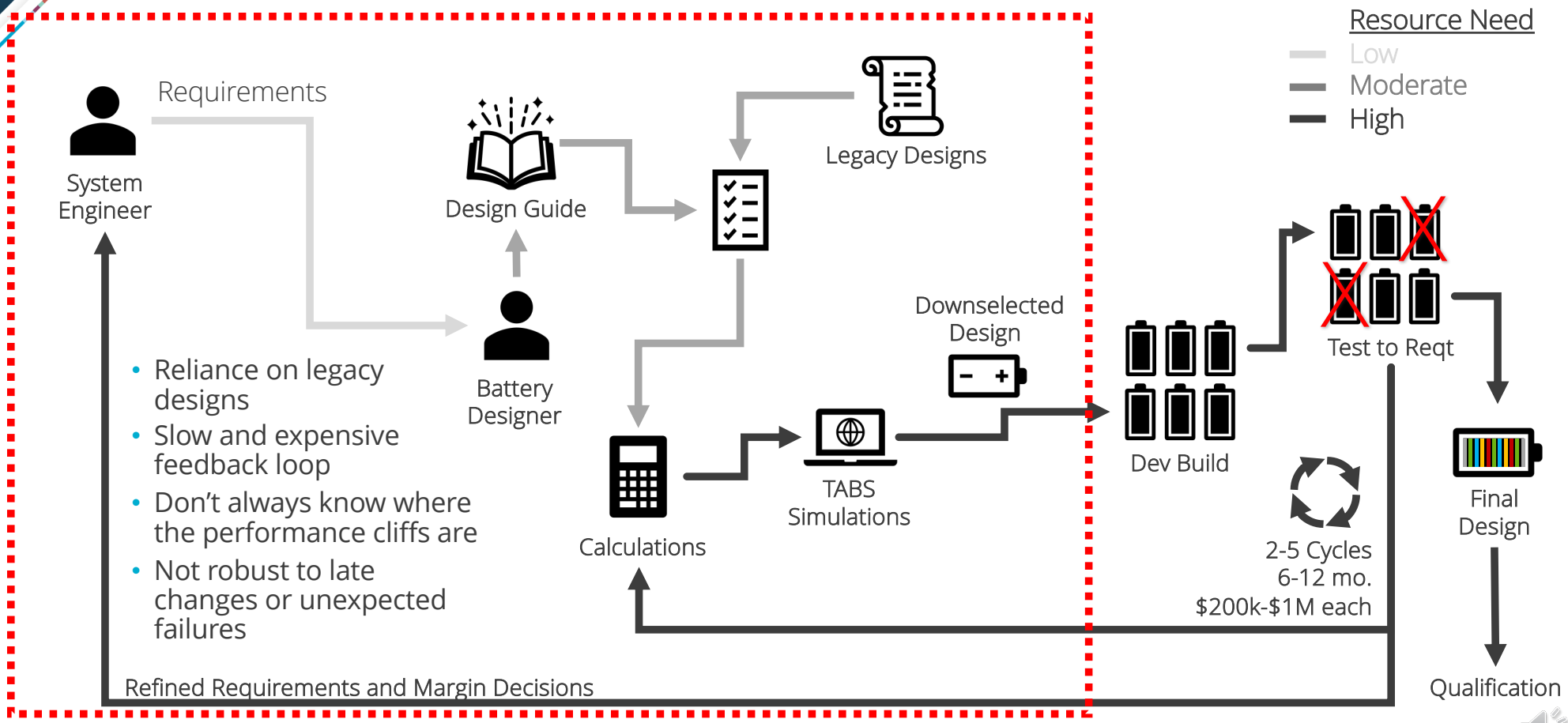
Battery activation is a complicated, multi-step process

- Heat pellet burning
- Thermal diffusion
- Melting and flow of the electrolyte
- Deformation of the separator
- Rebound of the insulation
- Activation



Thermal battery activation is a true multi-physics process!

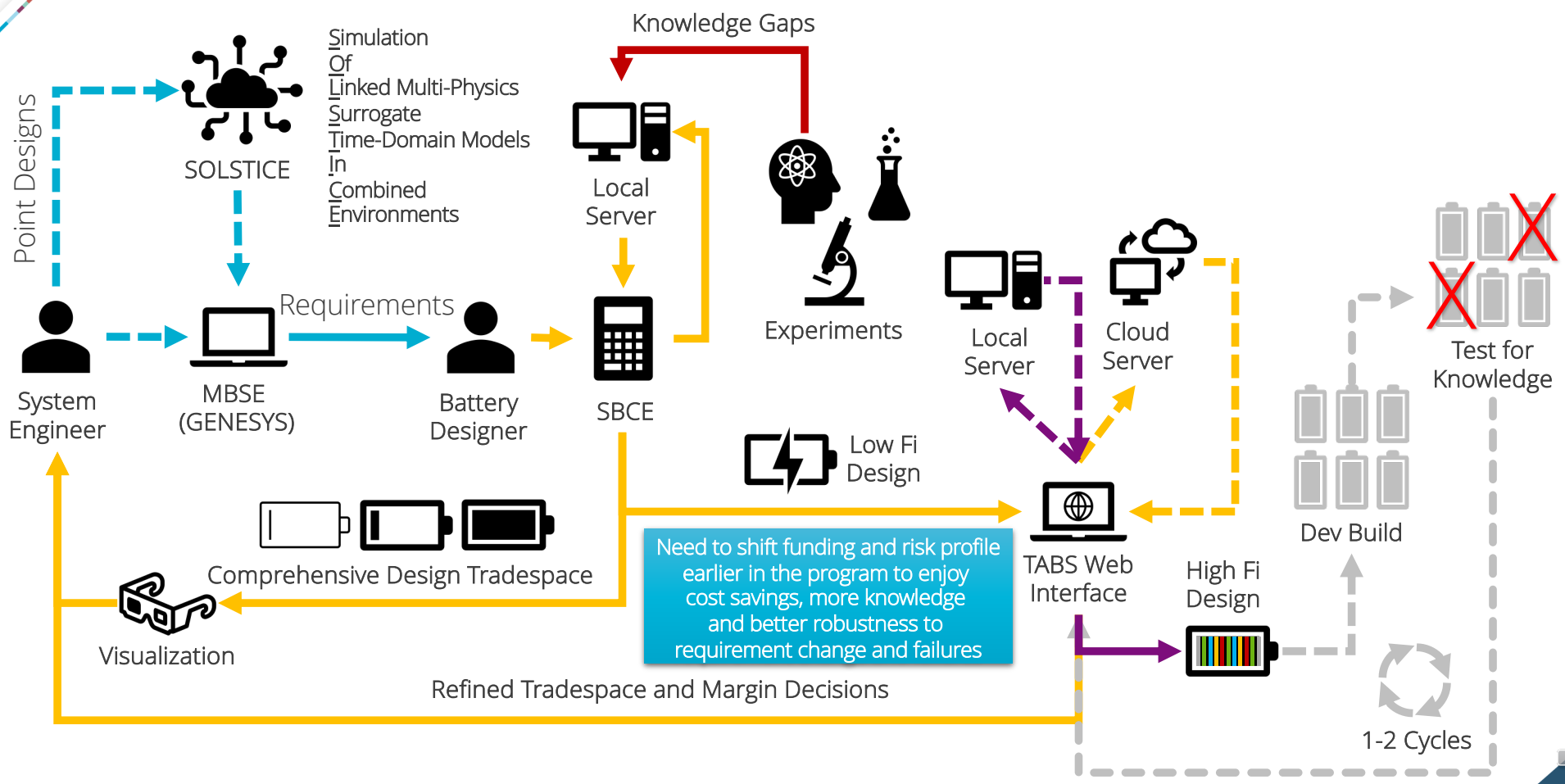
Current state of thermal battery design



- Reliance on legacy designs
- Slow and expensive feedback loop
- Don't always know where the performance cliffs are
- Not robust to late changes or unexpected failures

Current battery design process is nowhere near optimal

Vision for accelerated digital engineering of batteries



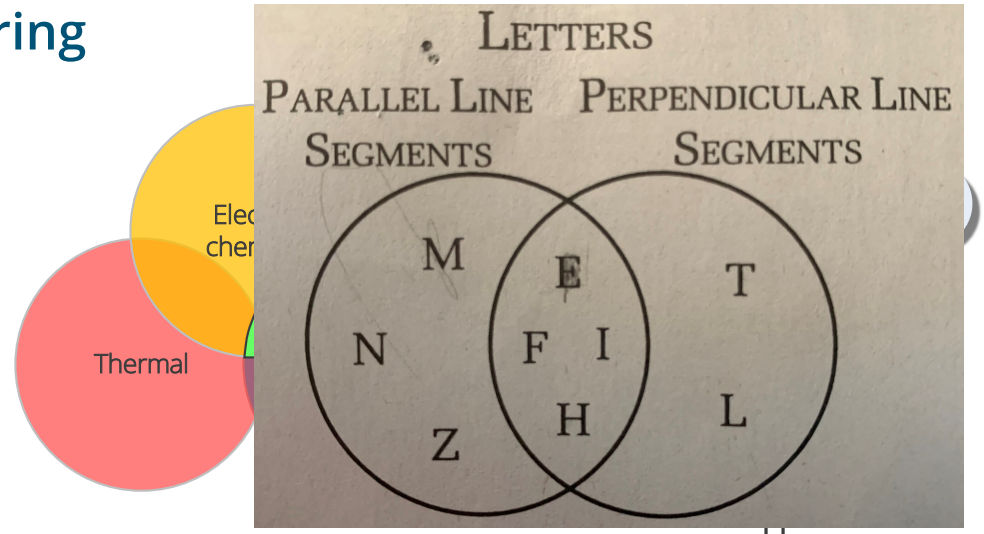
Set-Based Concurrent Engineering

What is SBCE?

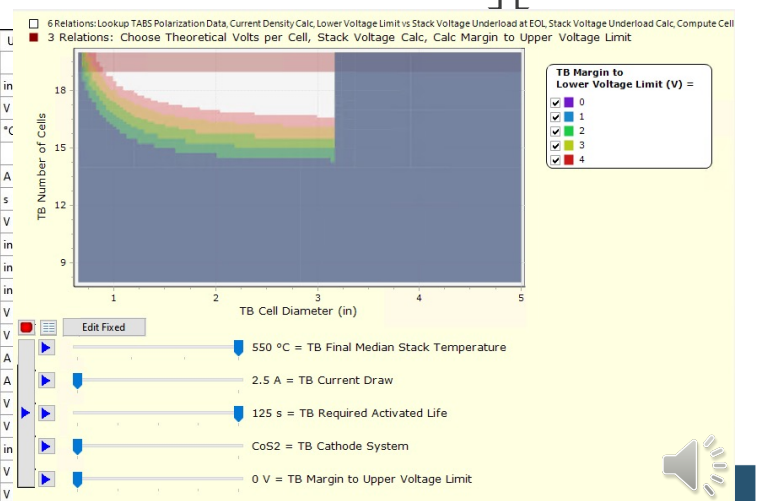
- Set-Based: Finding the set of all feasible solutions given all requirements and constraints
- Concurrent: Convergence of the set of system solutions occurs simultaneously with convergence of the set of subsystem or component solutions
- Thermal Battery team uses software called Success Assured

How does it work?

- Building blocks
  - Requirements, Design Choices, Relations
- Tools
  - Causal Maps (knowledge gaps)
  - Solvers (compatibility)
  - Limit Charts (feasible design space)
- Goals
  - gaining knowledge
  - finding compatible ranges for design variables
  - defining the set of all feasible designs



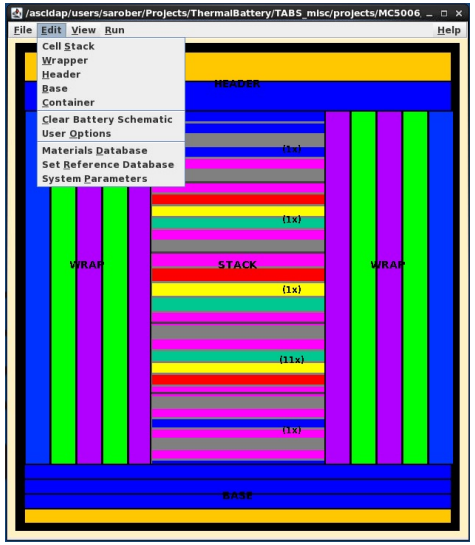
Short	Decision	U
	TB Number of Cells	
	TB Cell Diameter	in
	TB Margin to Lower Voltage Limit	V
<None>	*TB Final Median Stack Temperature*	°C
	TB Cathode System	
	TB Current Draw	A
	TB Required Activated Life	s
	TB Margin to Upper Voltage Limit	V
<None>	TB Anode Thickness	in
<None>	TB Cathode Thickness	in
<None>	TB Separator Thickness	in
	TB Lower Voltage Limit	V
	TB Upper Voltage Limit	V
<None>	*TB Current Density*	A
<None>	*TB Capacity Consumed*	A
<None>	*TB Cell Voltage at EOL*	V
	TB Theoretical Volts per Cell	V
	TB Cell Area	in
	TB Stack Voltage Underload at EOL	V
	TB Initial Stack Voltage	V



TABS: The Thermally Activated Battery Simulator

TABS design principles

- Create a user interface **intuitive to battery designers**, not just for computational scientists
- Be **computationally efficient**, so many design iterations can be explored in a single work day
- Present the user with the most **relevant quantities of interest**, yet enable them to explore more deeply
- Have **demonstrated credibility**, such that the user knows when and how much to trust the solutions



TABS-FB: Full Battery

- Thermal
- WIP: Electrochemical

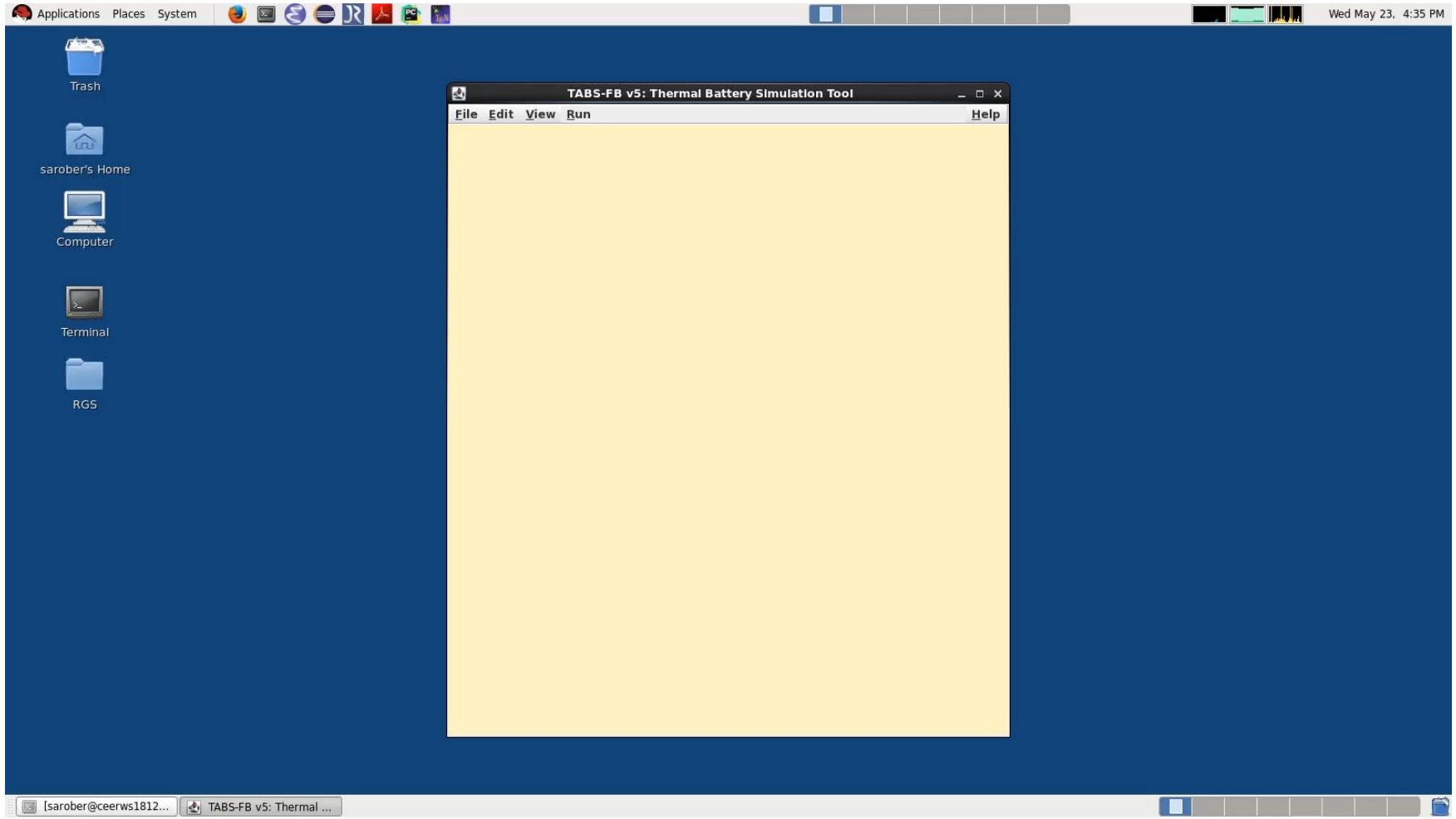
TABS FULL BATTERY

TABS thermal realized impacts

- Saved $3.6M and 13 months of schedule on two recent life extension programs
- Cost savings recouped ASC investments to date
- Enabled first fully virtual battery design for external customer
- Yielded insight into anomalous test behavior

TABS provides battery designers the power to understand how design decisions impact performance

Thermal design analysis in 5 minutes using TABS



So what's wrong with TABS?

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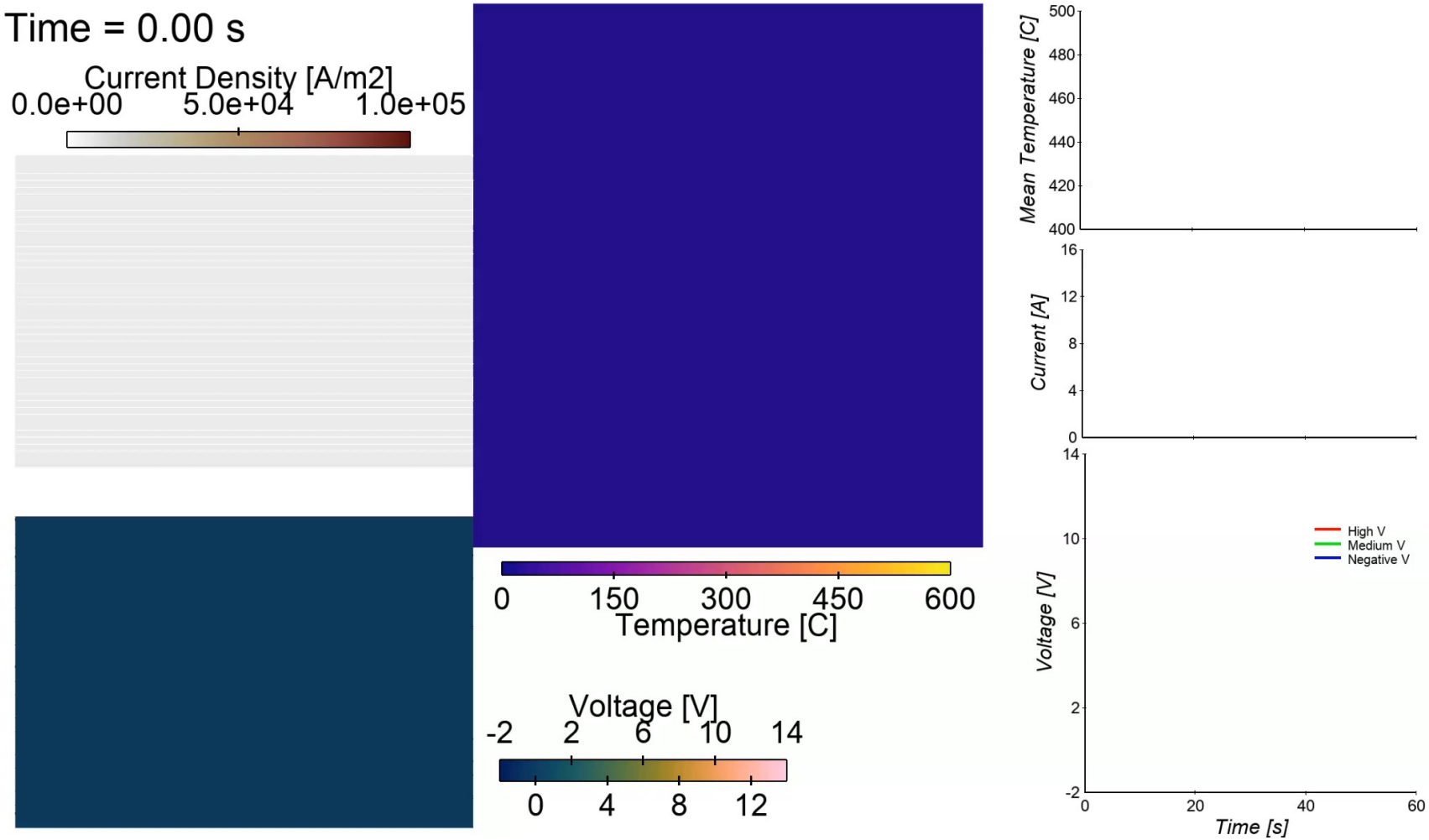
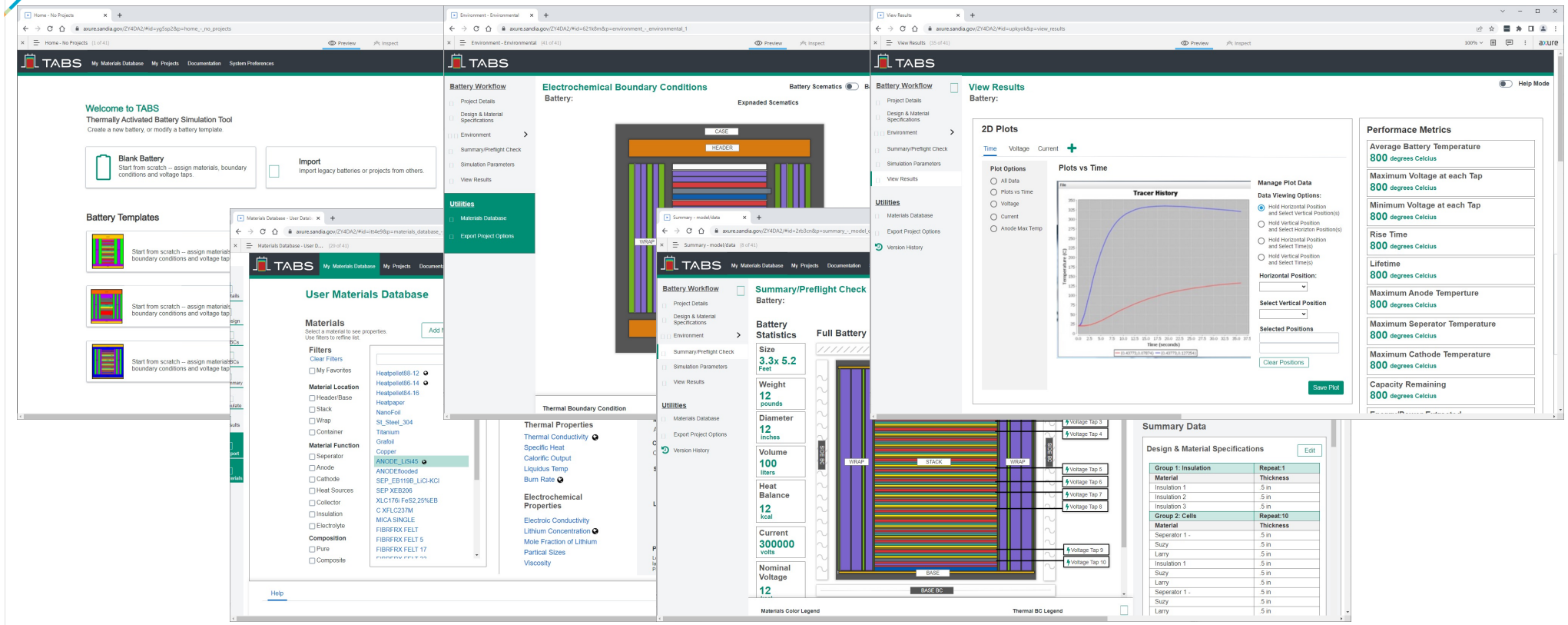
Legacy TABS is powerful and impactful, but not prepared to maximize potential

Full battery electrochemical simulations

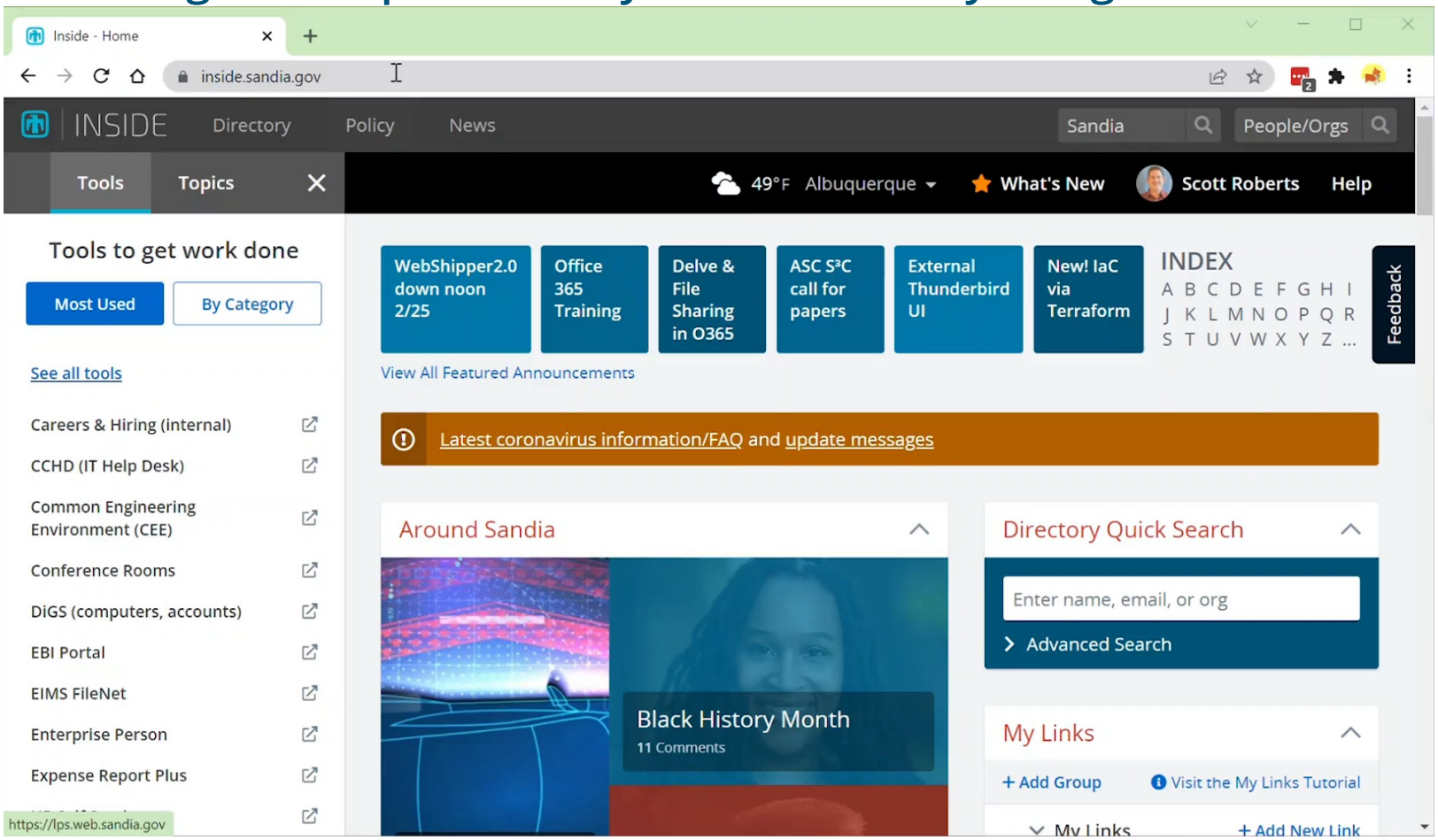


Making TABS a web-based productivity tool for battery designers



UX research teaches us how battery engineers want to interact with TABS

Making TABS a productivity tool for battery designers



Web application with HPC-backed computation will provide more capability with easier access

Fully-Integrated Digital Workflow