



Storage at the Threshold: Beyond Lithium-ion Batteries

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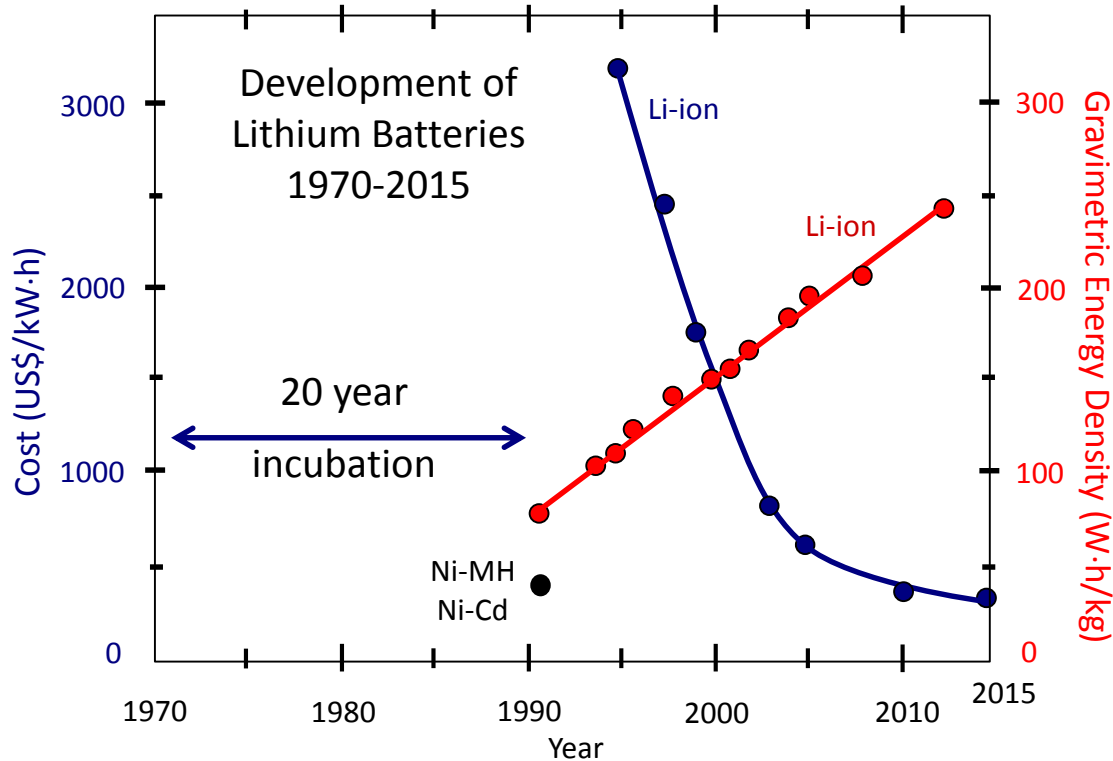
Outline

Electric vehicles: Lithium-ion may be competitive but not transformative

Electricity grid: Storage challenges and opportunities are richer, more diverse and less explored

JCESR: A new paradigm for beyond Lithium-ion R&D

Lessons from Lithium-ion Batteries



Long incubation period

Lithium-ion battery of 1991 looked nothing like the 1970s vision

Many (most) good ideas fail

Multiple paths forward are critical

Crabtree, Kocs, Trahey, MRS Bulletin 40, 1067 (2015)

1971 Conceptualization
1991 Commercialization

Transportation Challenges

- Driving range: hundreds of miles instead of tens of miles
- Fast charging: minutes instead of hours
- Inexpensive: \$20K instead of \$80K
- Cycle life: predictable and commensurate with car life
- Safe: routine and exceptional circumstances - car crash in the rain?

Reduced cost addresses some but not all challenges

Tesla Model 3 and GM Bolt: \$35K/200 mile cars

- Driving range: 200 miles - good
- Fast charging: unchanged
- Inexpensive: \$35K, not \$20K – few percent market penetration, like Prius
- Cycle life: unchanged
- Safety: unchanged

Lithium-ion batteries may be competitive, but not transformative

Electricity Grid Challenges

Storage offers new services beyond conventional reach

- Break historic constraint of real-time balancing of generation and demand
- Firm fluctuations in renewable wind and solar
- Time-shift excess night-time wind and afternoon solar to peak evening demand
- Combine with intelligence and distributed resources to personalize electricity services for customer needs: interlocking macro- and micro-grids

Grid challenges and opportunities are richer, more diverse and less explored than transportation

The grid of the future will not look like the grid of the past

JCESR: Beyond Lithium-ion Batteries for Cars and the Grid

Vision

Transform transportation and the electricity grid with high performance, low cost energy storage

Mission

Deliver electrical energy storage with five times the energy density and one-fifth the cost of today's commercial batteries within five years

Legacies

- **A library of the fundamental science** of the materials and phenomena of energy storage at atomic and molecular levels
- **Two prototypes, one for transportation and one for the electricity grid**, that, when scaled up to manufacturing, have the potential to meet JCESR's transformative goals
- **A new paradigm for battery R&D** that integrates discovery science, battery design, research prototyping and manufacturing collaboration in a single highly interactive organization

TRANSPORTATION

\$100/kWh

400 Wh/kg 400 Wh/L

800 W/kg 800 W/L

1000 cycles

80% DoD C/5

15 yr calendar life

EUCAR

GRID

\$100/kWh

95% round-trip efficiency at C/5 rate

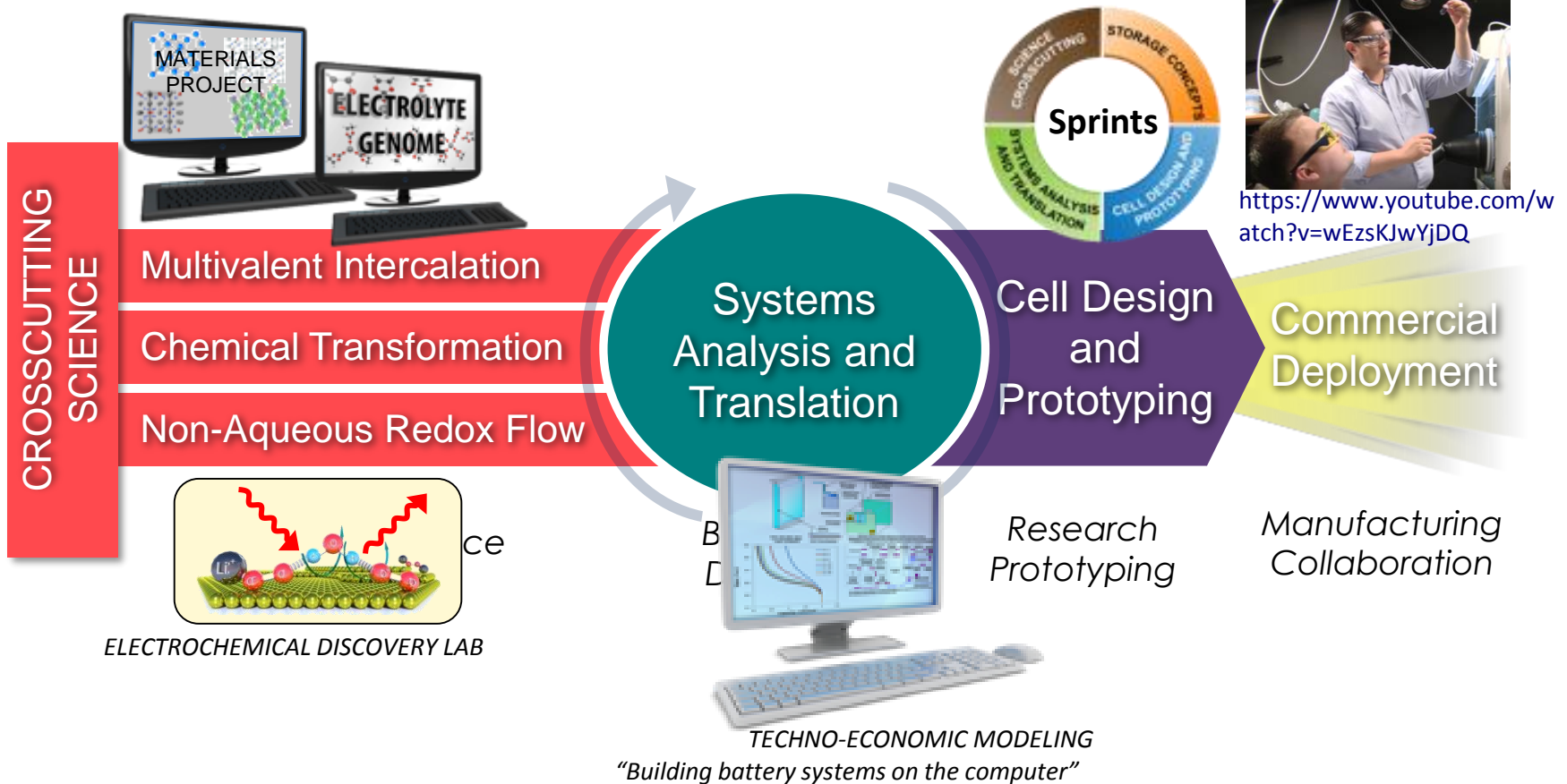
7000 cycles C/5

20 yr calendar life

Safety equivalent to a natural gas turbine



JCESR Creates a New Paradigm for Battery R&D



A single highly interactive organization

Focus exclusively on beyond lithium ion

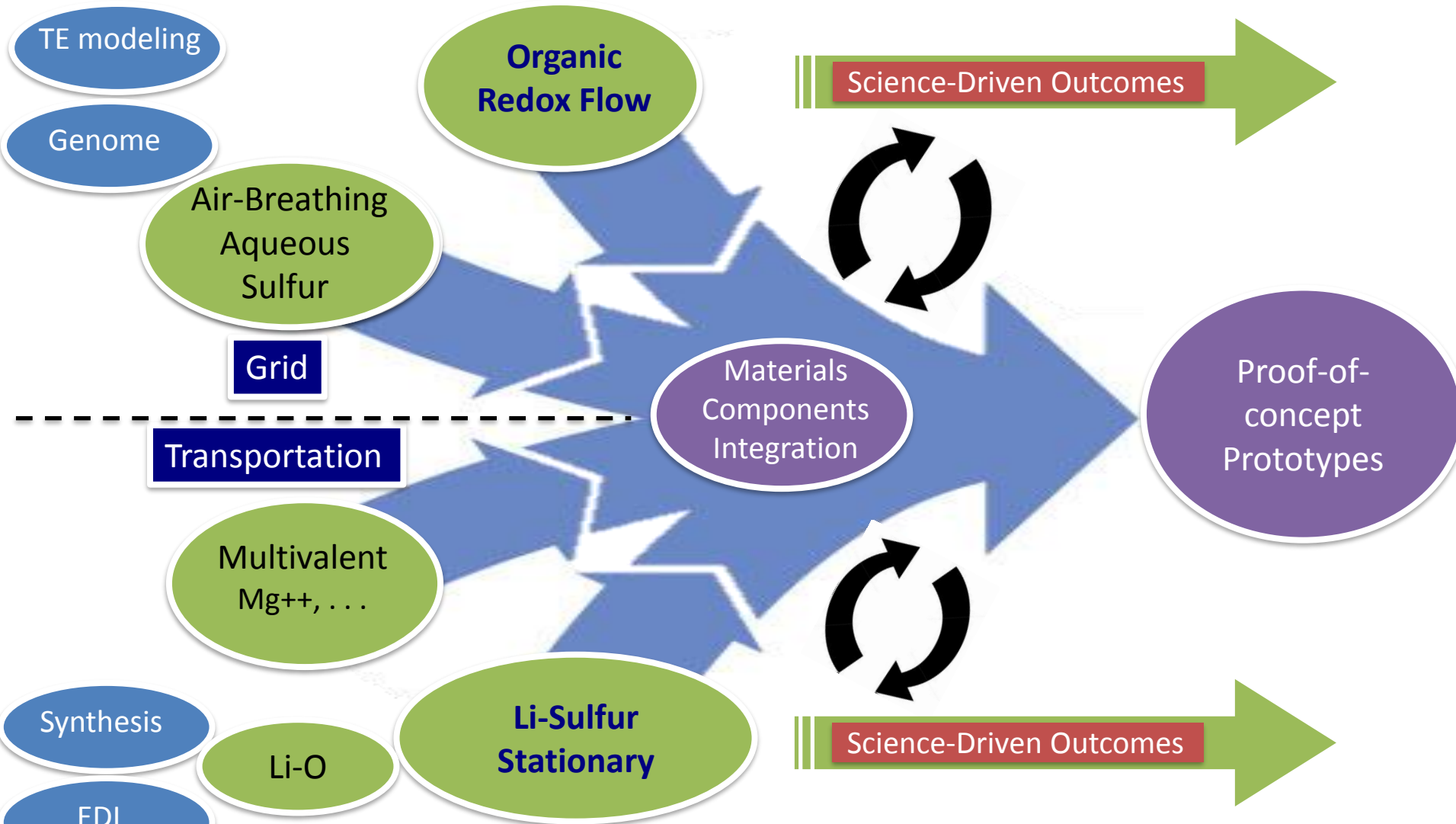
JCESR Team



20 Institutional Partners, 180-200 Researchers



Four Prototype Targets



Final Prototype Targets Selected Jan 2016

JCESR Spins Out Two Startups

Blue Current



Nitash Balsara, Alex Teran and Joe DeSimone (UNC)
Inorganic-polymer hybrids for Li anode batteries
Villaluenga et al, PNAS 113, 52, (2015)

Sepion



Robin Johnston, Michel Fouré, Brett Helms and Peter Frischmann

Lightweight energy storage for the electrification of flight

Li et al, Nano Lett. 15, 5724 (2015)

*Best All-around Team
Bay Area I-Corps competition*

Engaging the private sector
Training next generation entrepreneurs
Building JCESR relationships

Further Reading



JCESR Website
Interactive, visual, engaging
www.jcesr.org

[Why Energy Storage May Be the Most Important Technology in the World Right Now](#)

Forbes Apr 1, 2016

[Frontiers of Energy](#)

Nature Energy Jan 11, 2016

Ten experts, including JCESR's George Crabtree, share their vision of coming energy challenges

[Perspective: The Energy Storage Revolution](#)

Nature Oct 28, 2015

How next-generation storage can change the car and the grid



[Why We Need A Revolution in Energy Storage](#)

PBS Jan 5, 2016

[Lithium Batteries: To the Limits of Lithium](#)

Nature Oct 28, 2015