



## Storage at the Threshold: Beyond Lithium-ion Batteries

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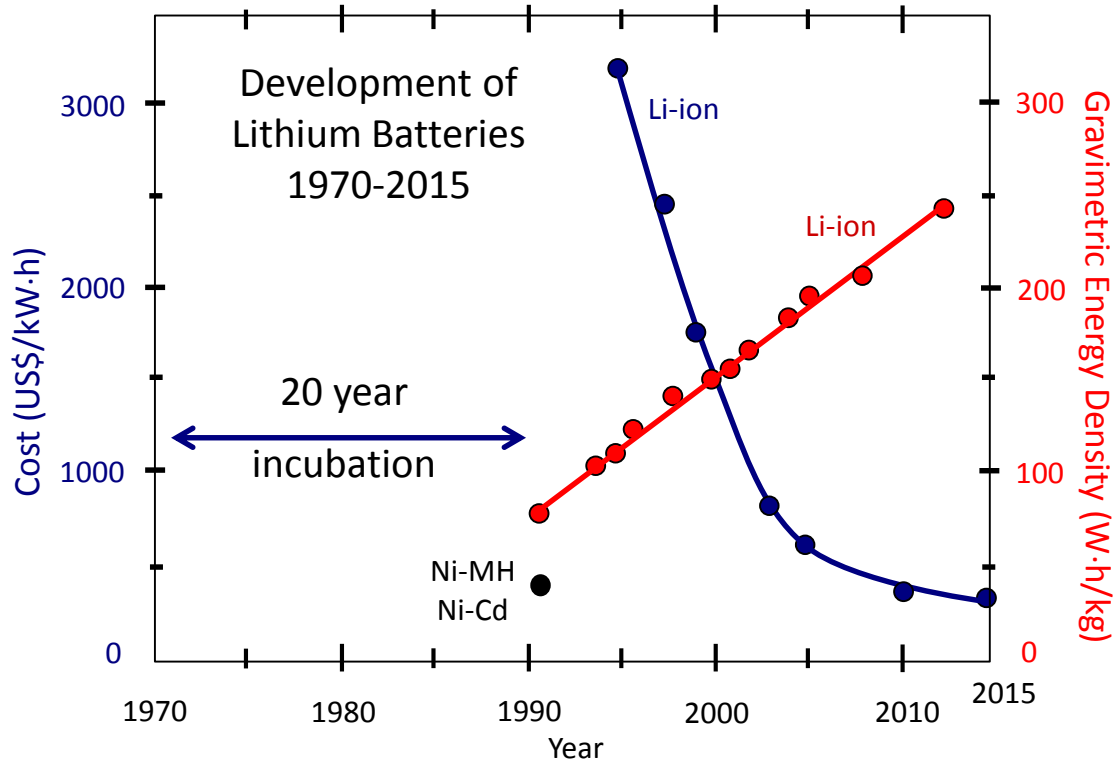
### *Outline*

*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

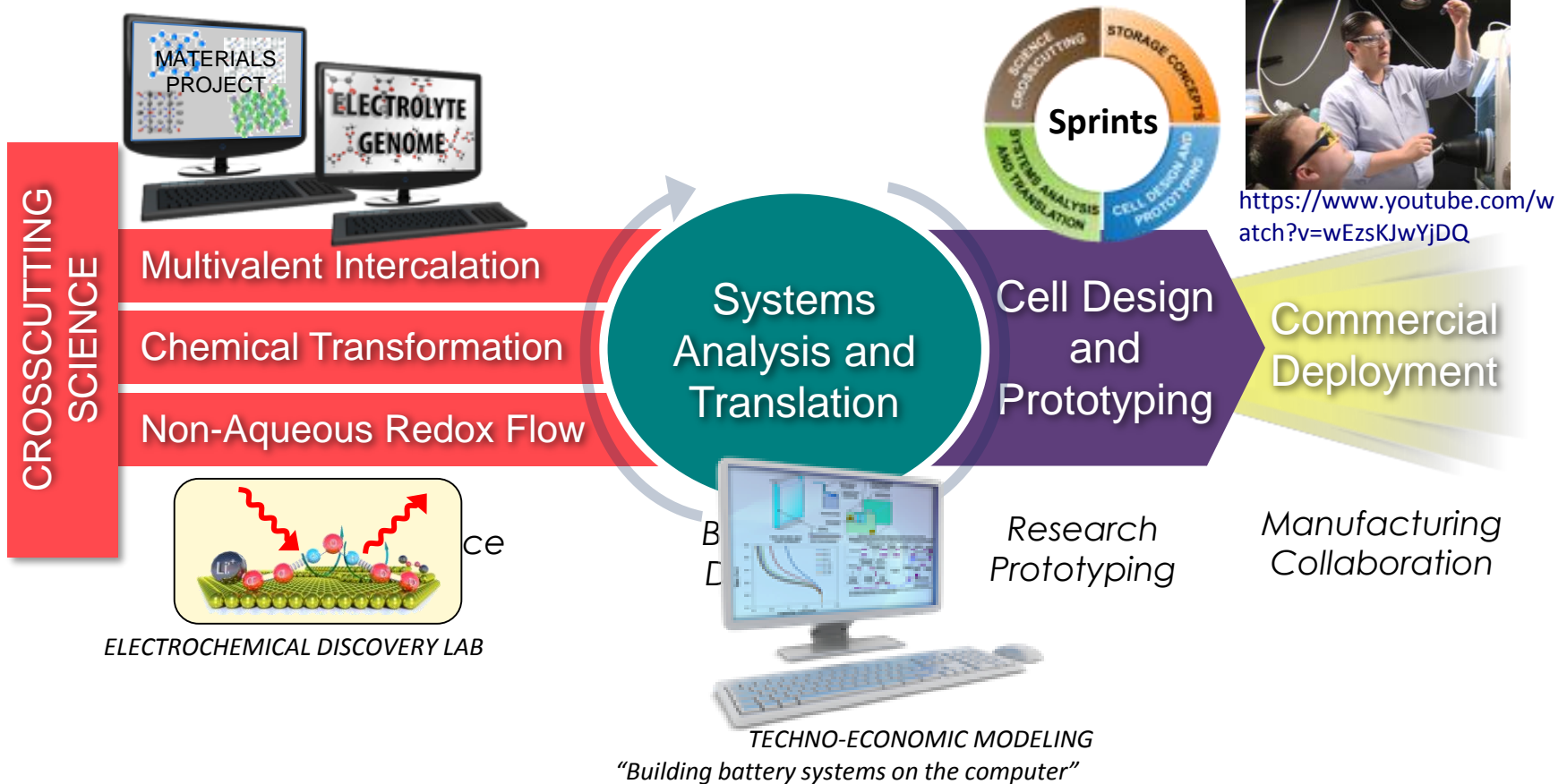
7000 cycles C/5

**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

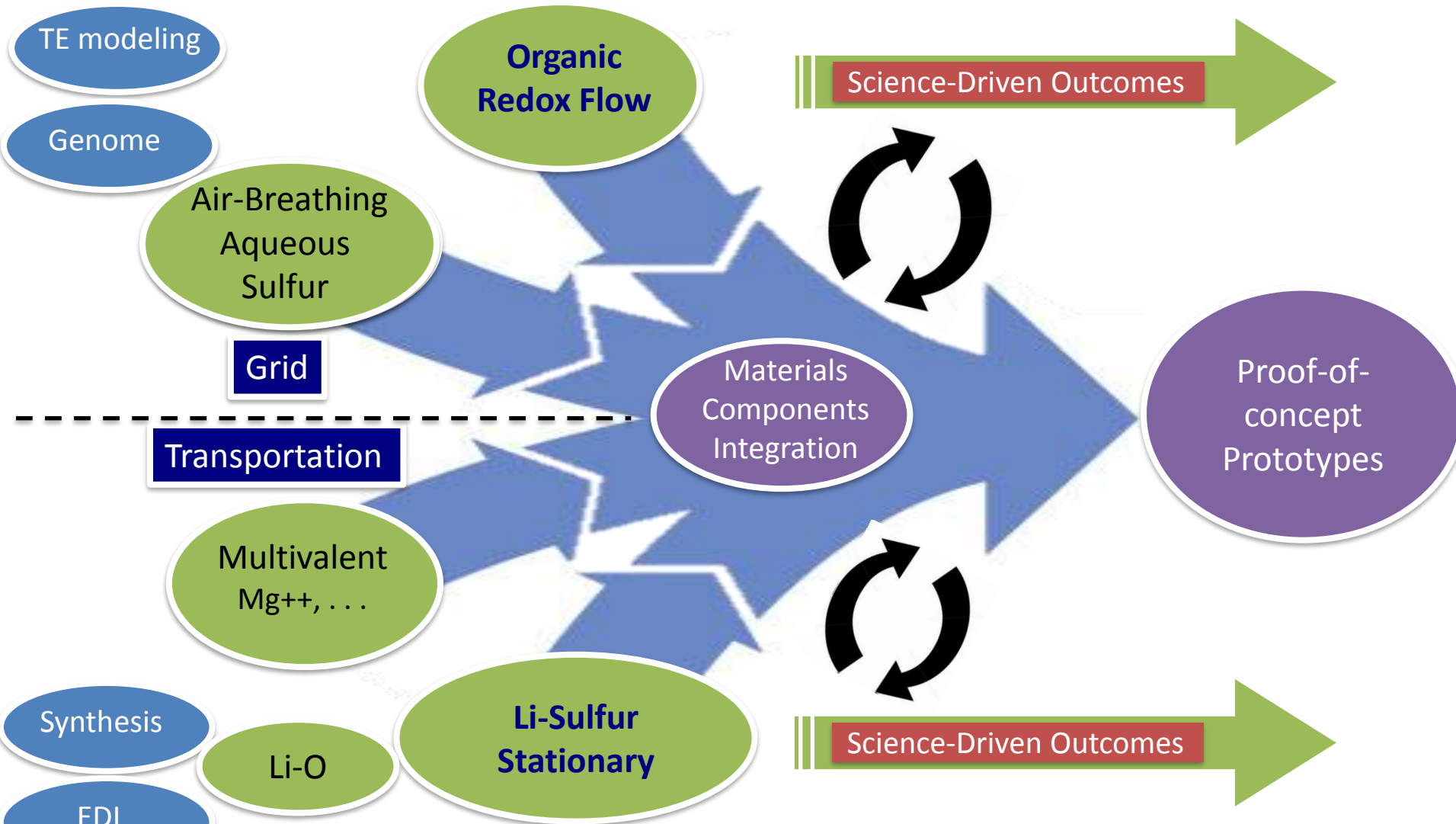
# JCESR Team



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](http://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