JCESR | JOINT CENTER FOR ENERGY STORAGE RESEARCH

An Overview

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Outline

Opportunity: Transportation and Electricity Grid
Vision, Mission, Legacies
Opportunities for Engagement

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Google
Mountain View, CA
January 18, 2014

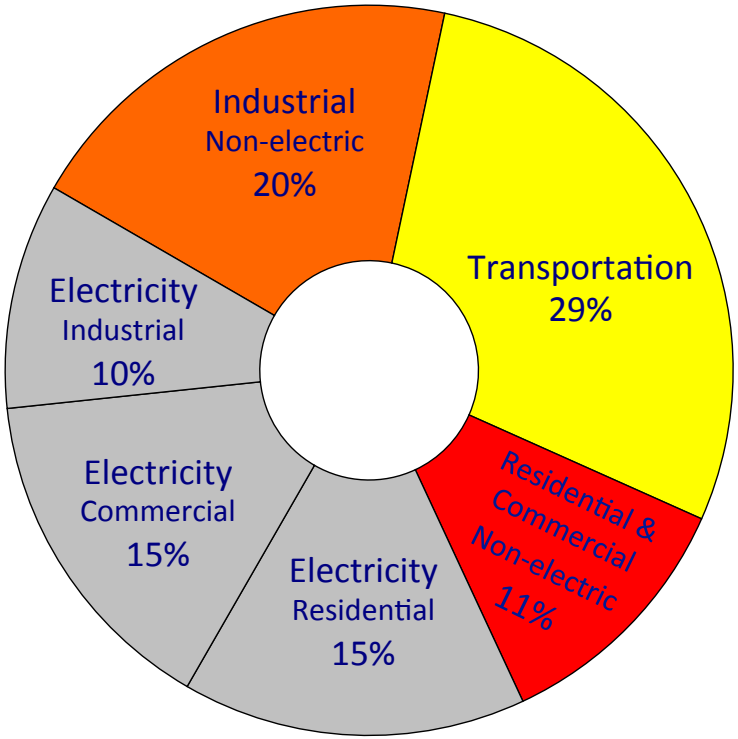
Energy Storage Opportunity

Two biggest energy uses poised for transformational change

Transportation 29%
- Oil → Electricity
- Reduce foreign oil dependence
- Reduce carbon emissions

Electricity 40%
- Coal → Gas → Wind and Solar
- Reduce carbon emissions
- Sustainable energy supply

Energy Demand



EIA Annual Energy Review 2009

The bottleneck for both transitions is inexpensive, high performance electrical energy storage

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JCESR Has Transformative Goals

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

Vision

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

Mission: 5-5-5

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 5-5-5 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

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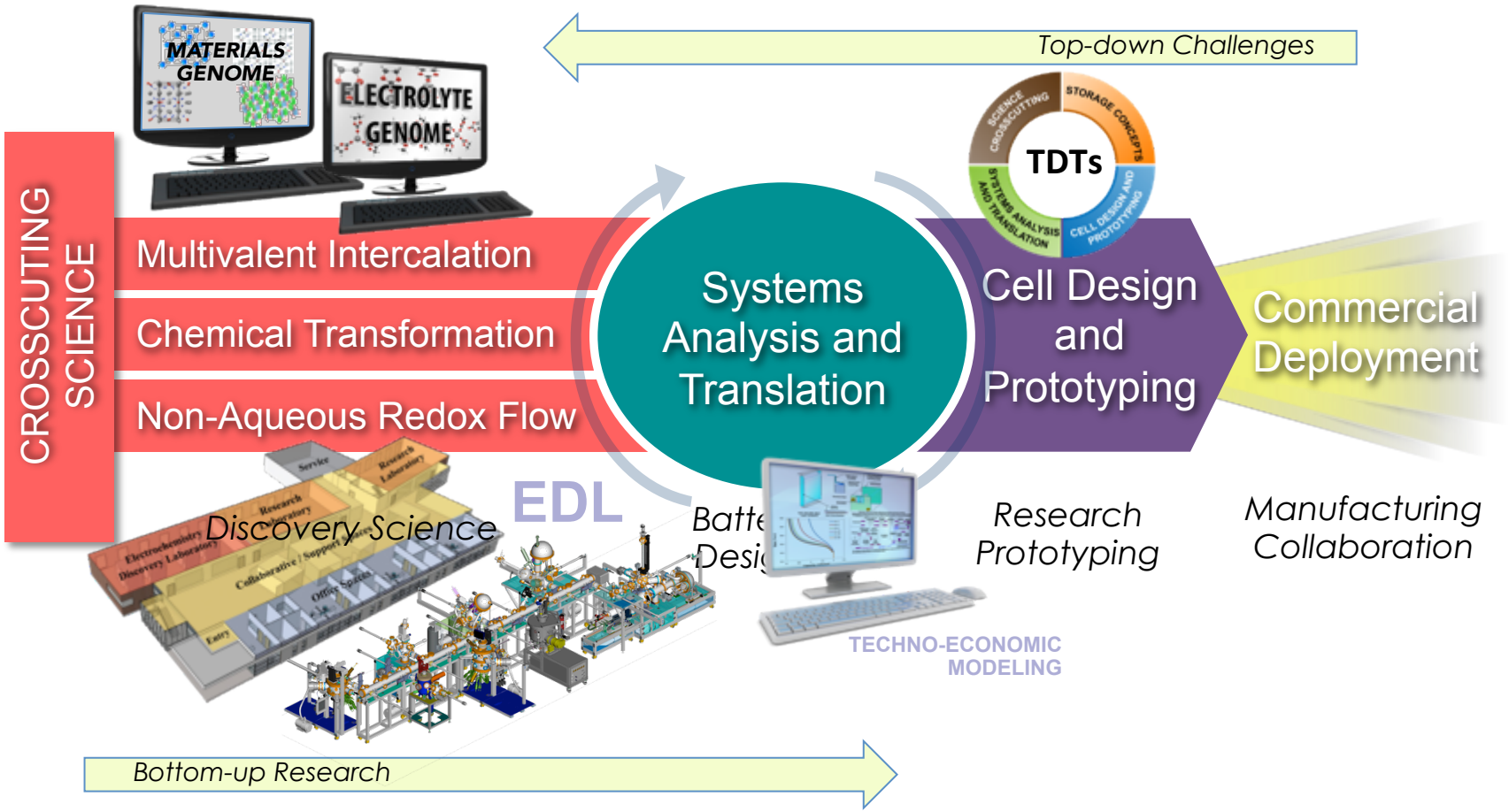
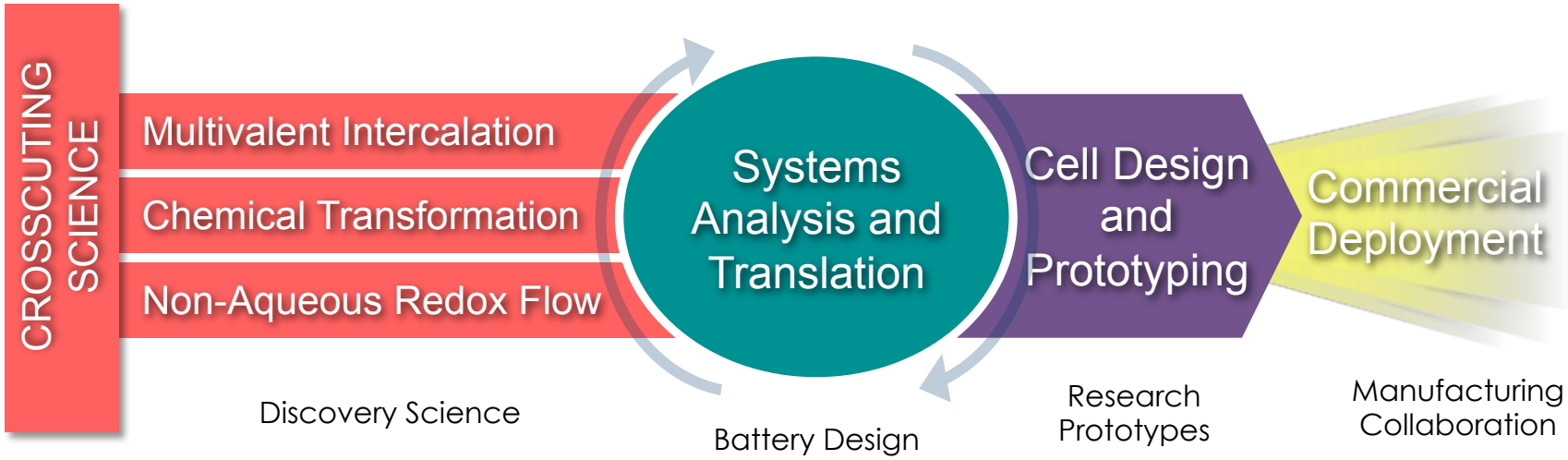
JCESR Creates a New Paradigm for Battery R&D



The JCESR Partner Team



National Laboratories

Argonne

Lawrence Berkeley

Sandia

SLAC

Pacific Northwest

Universities

University of Illinois at Chicago

University of Illinois at Urbana-Champaign

Northwestern University

University of Chicago

University of Michigan

Faculty from
MIT, University of Waterloo,
Harvard, Notre Dame

Private Sector

Johnson Controls (JCI)

Dow

Applied Materials

Clean Energy Trust

Organization Designed for the New Paradigm

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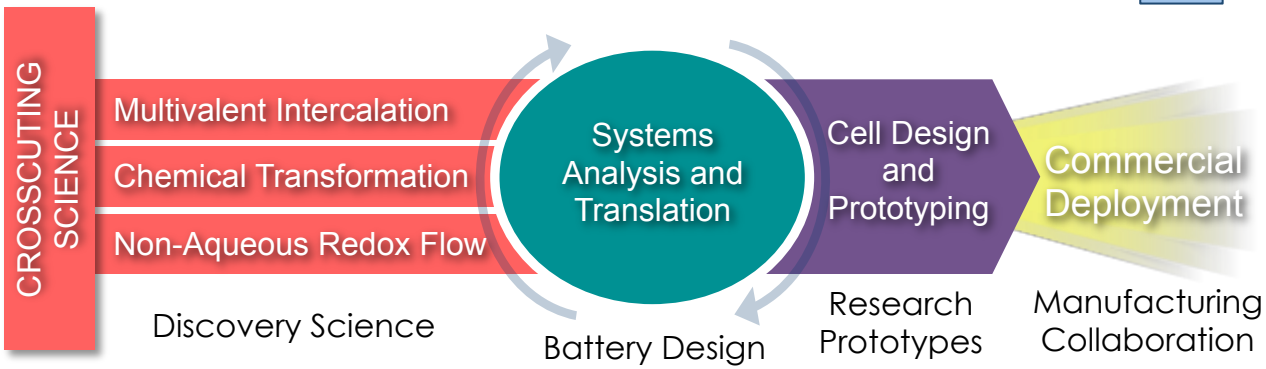
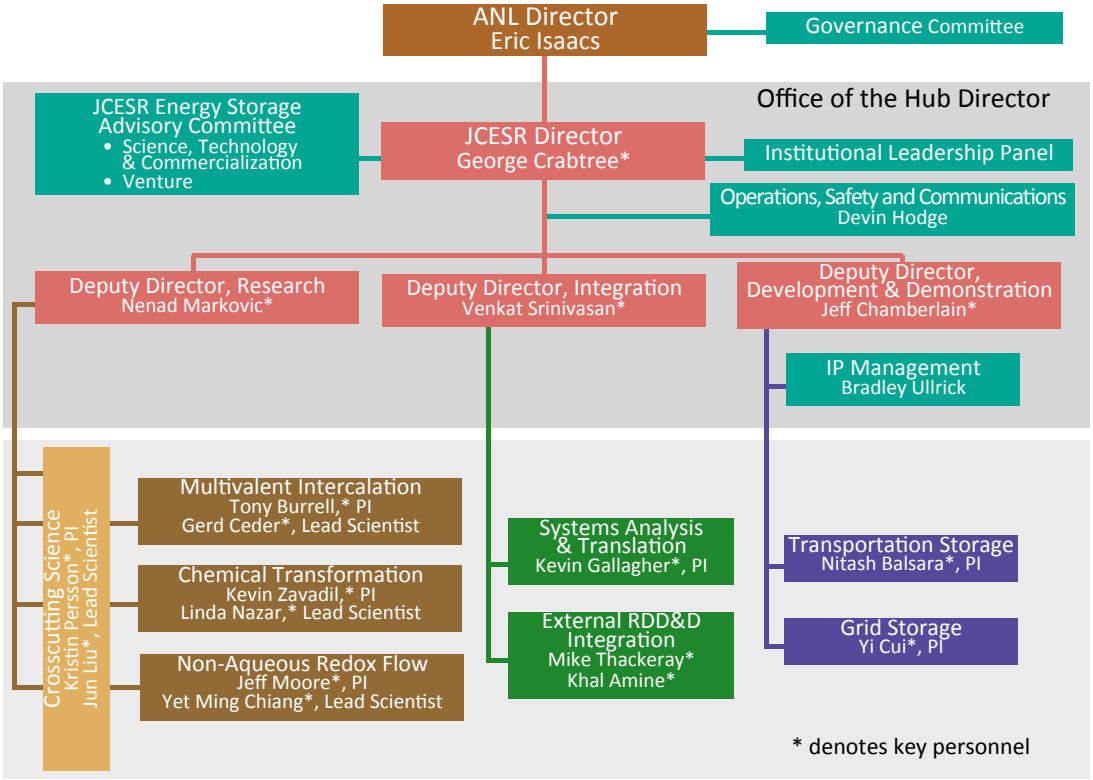


JCESR Without Walls
14 Partner Institutions
- 5 National Labs
- 5 Universities
- 4 Private Sector



Four Advisory Committees

Director

Three Deputy Directors

Seven R&D thrusts
One outreach thrust

Thrust Principle Investigators
Thrust Lead Scientists

⋮

Project scientists, postdocs and graduate students

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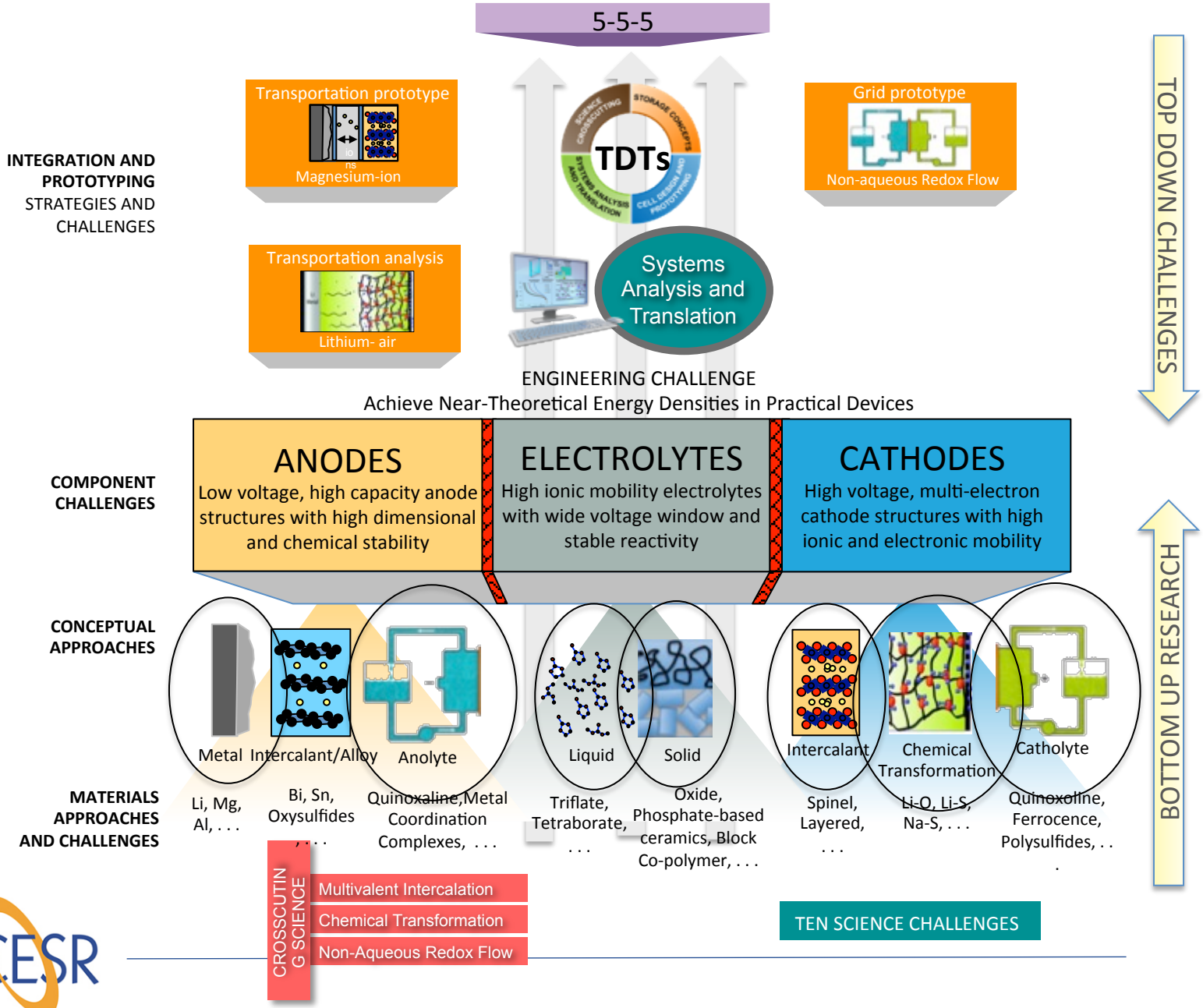
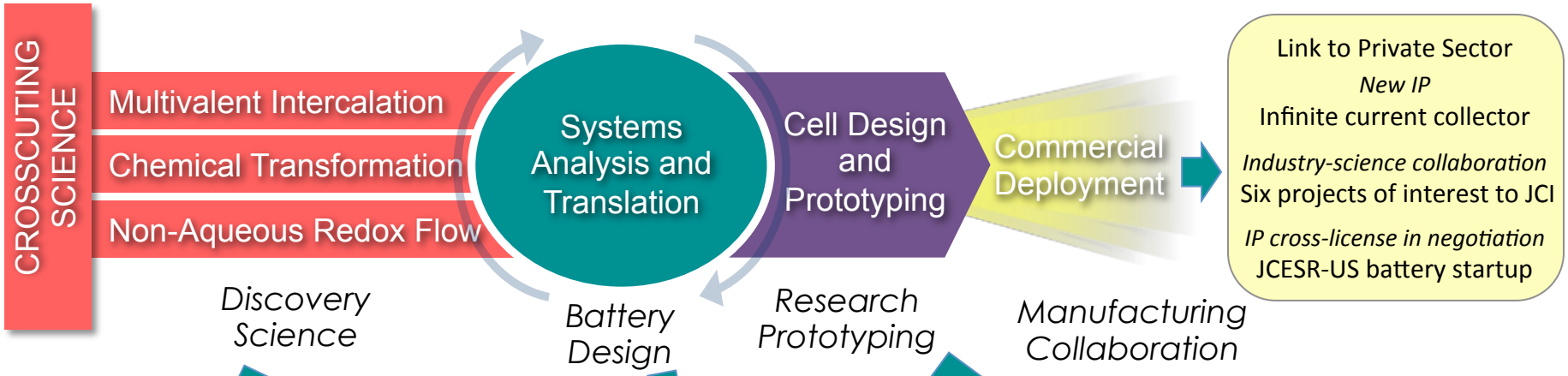
Strategic Roadmap: Capturing the Opportunities and Challenges



JCESR's New Paradigm is Working

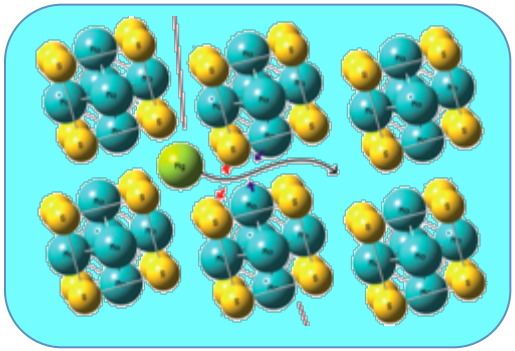


Discovery Science

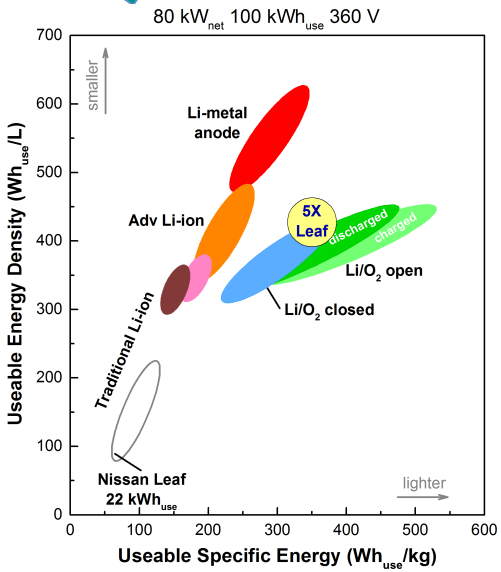
Battery Design

Research Prototyping

Manufacturing Collaboration



Screening by conduction electrons dramatically increases mobility in Chevrel phase cathodes



Lithium-air confirms JCESR vision
Metal anodes key to many paths to 5-5-5

Magnesium ion transportation prototype cycled

Additional highlights on www.jcesr.org

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Definition of “prototype” in JCESR

- JCESR prototypes will serve two purposes
  - Research prototype for Science Legacy
  - Proof-of-concept prototype for Technological Legacy

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- JCESR prototypes will serve two purposes
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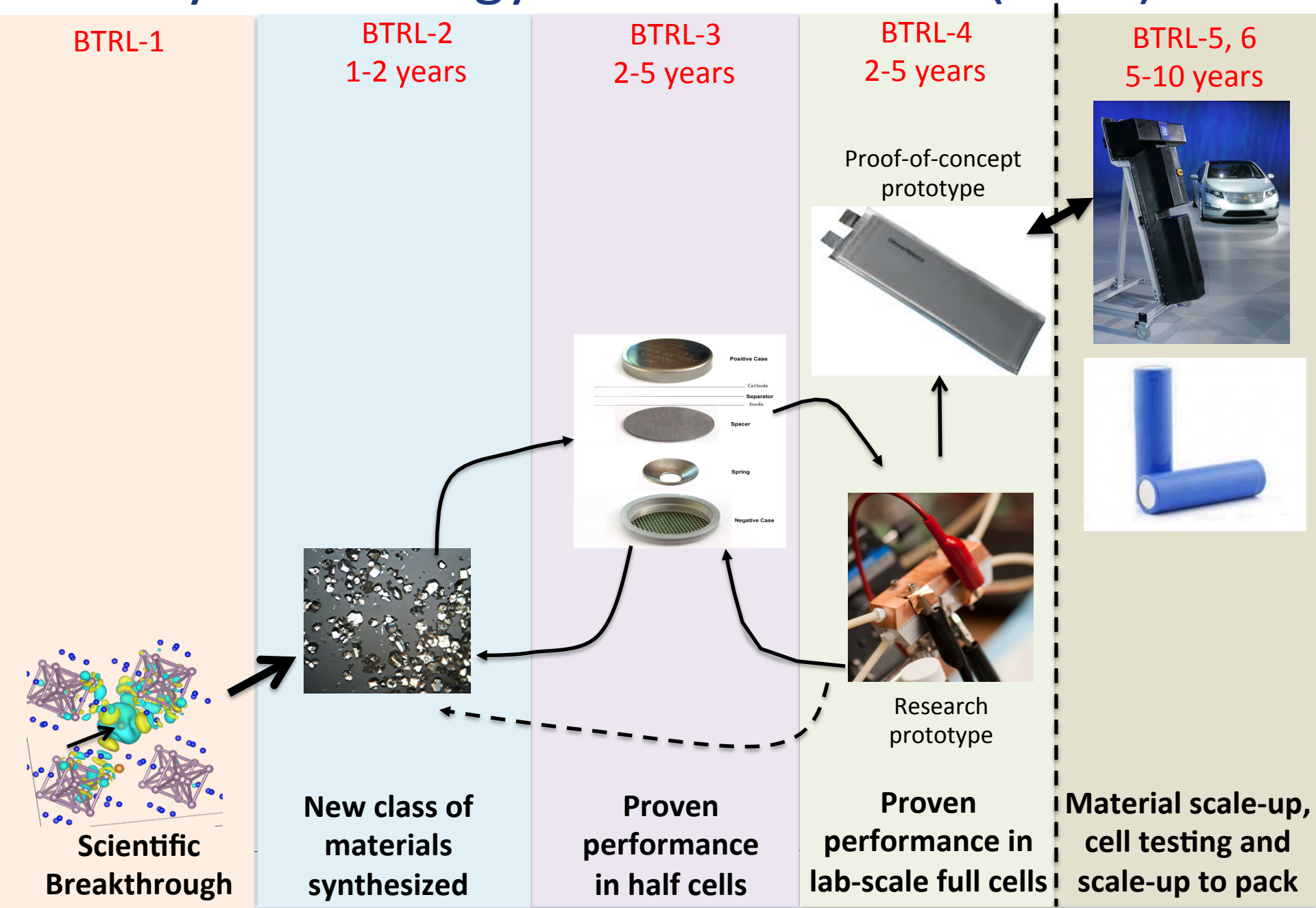
  - Proof-of-concept prototype for Technological Legacy
- Studying the Chemical System (a couple with electrolyte in a cell)
- No defined cell architecture, including physical size of the cell

Battery Technology Readiness Level (BTRL)



Techno-Economic Modeling

BUILDING A BATTERY ON THE COMPUTER

Systems Analysis and Translation

Linking system level goals to materials level values

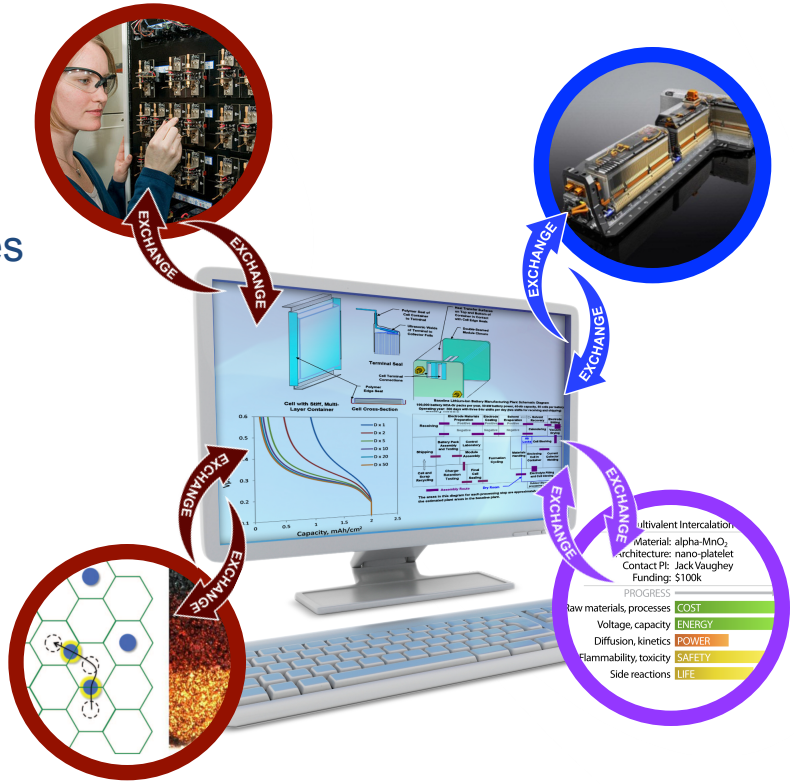
- What cell voltage, capacity, diffusion coefficient, ...etc… are needed to meet JCESR goals?

Directing research dollars to most promising approaches

- Informing JCESR leadership, assessing most promising candidates, creating new Translational Development Teams

Identifying and overcoming barriers to transformational advances

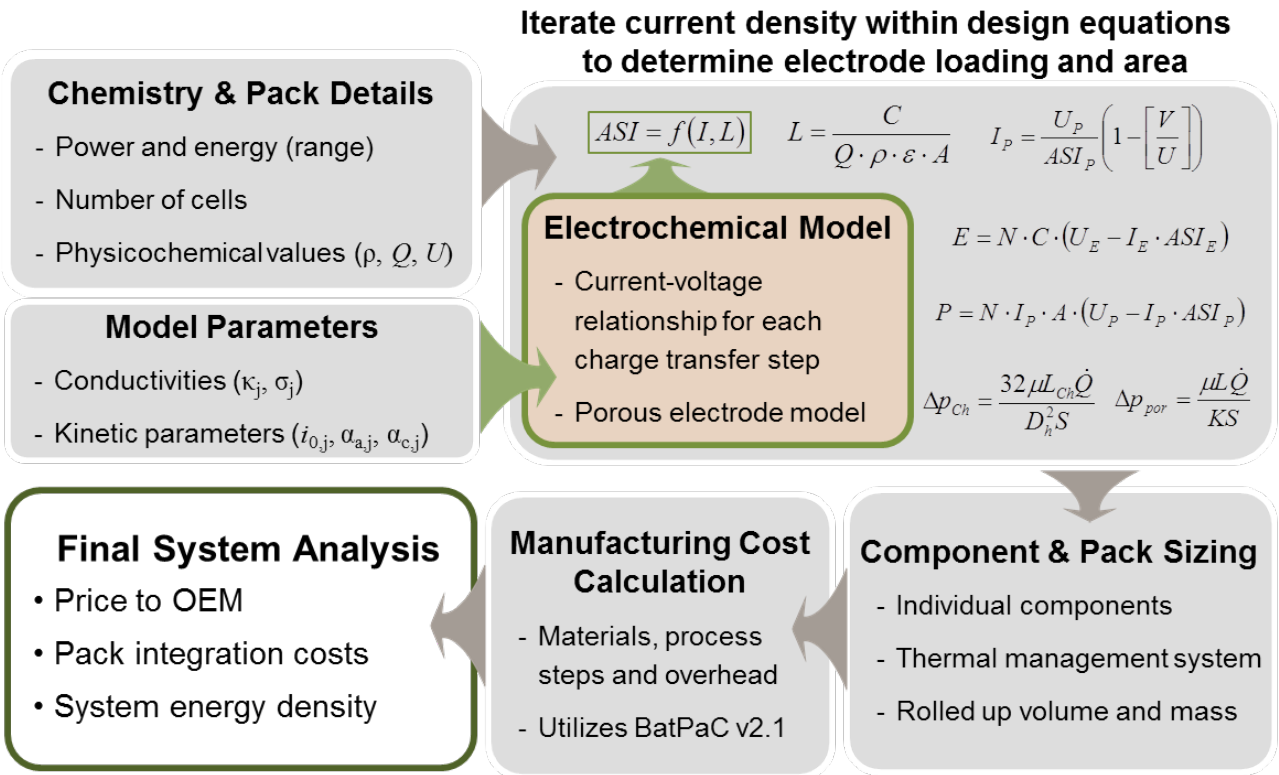
- Across all levels – materials, electrodes, cells, pack/stacks



Technical performance
Manufacturing cost

Process flow of design & cost battery model

- Bottom-up performance and cost model
  - Account for each component necessary to make functioning battery
  - Captures manufacturing cost by building the facility for each battery
- Builds upon BatPaC: Peer-reviewed Li-ion model www.cse.anl.gov/batpac



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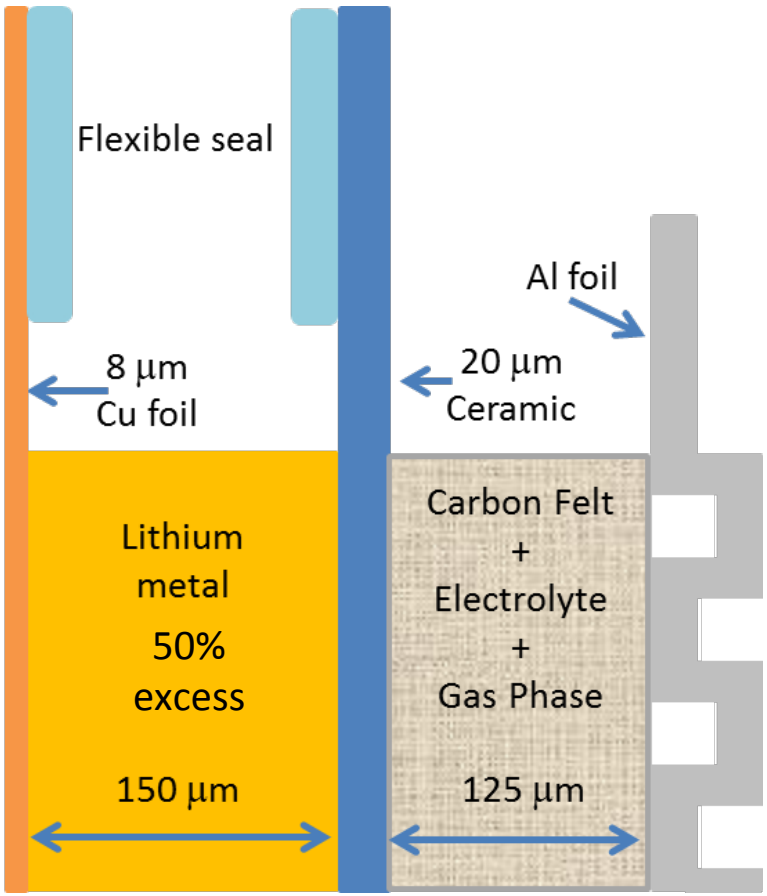
Materials in a single layer of Li/O_2 cell

- Negative electrode
  - Lithium-metal, 50% excess
  - Solid ceramic electrolyte
  - Hermetic, long-lived seal
- Positive electrode
  - Carbon-like porous felt
  - Liquid electrolyte
  - 60 vol% Li_2O_2 at discharge
- Flow-field/positive current collector
  - 0.3 MPa_a Air: corrugated Al foil
    - Sized for 30 kPa pressure drop
    - Optimistically assume 20 um thickness
  - Pure O_2: standard battery Al foil
    - Porosity of electrode is enough



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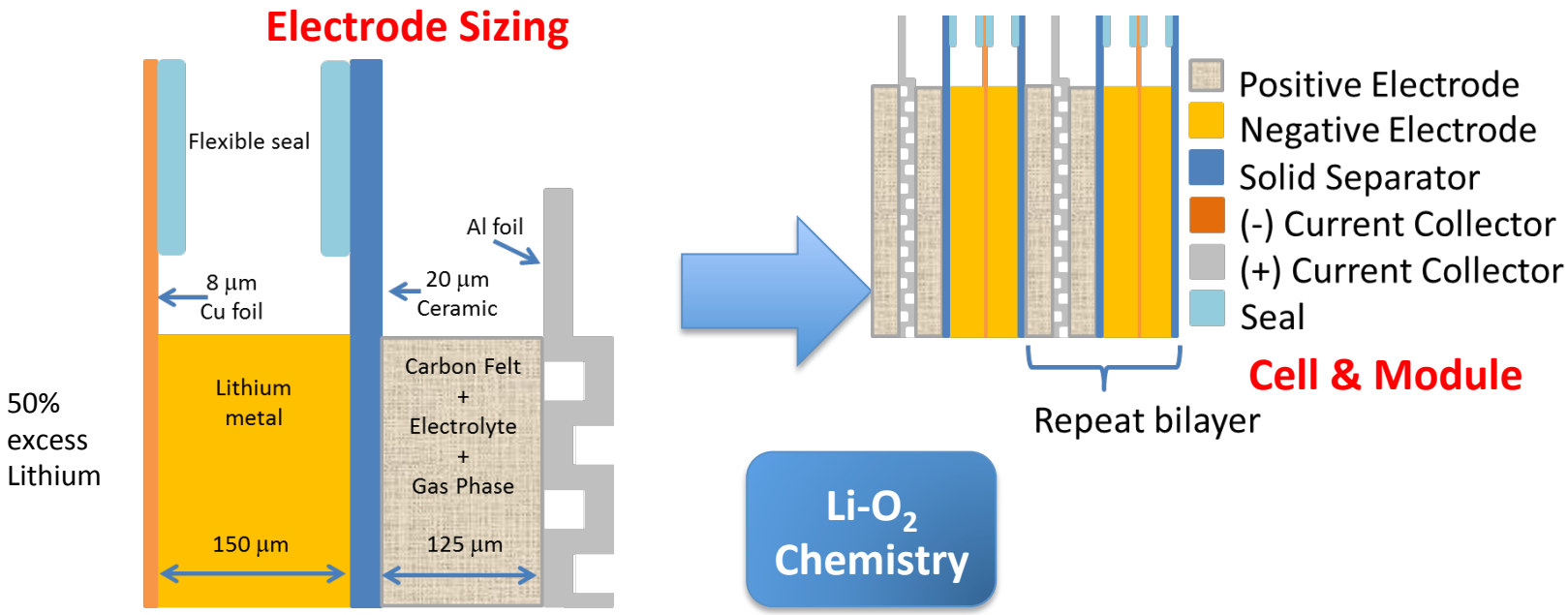
Multiple scales and approaches to design



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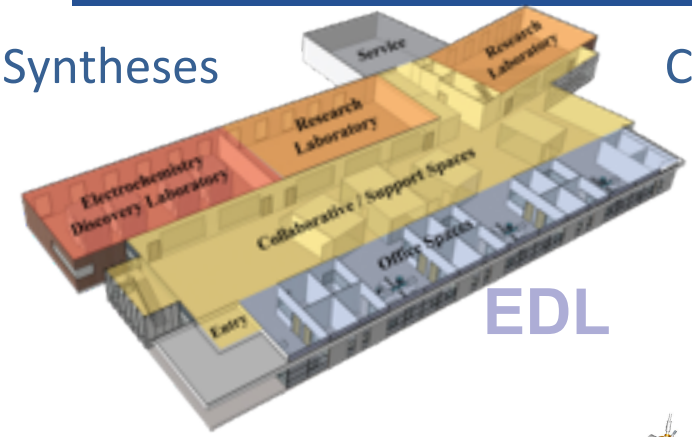
Syntheses

Characterization

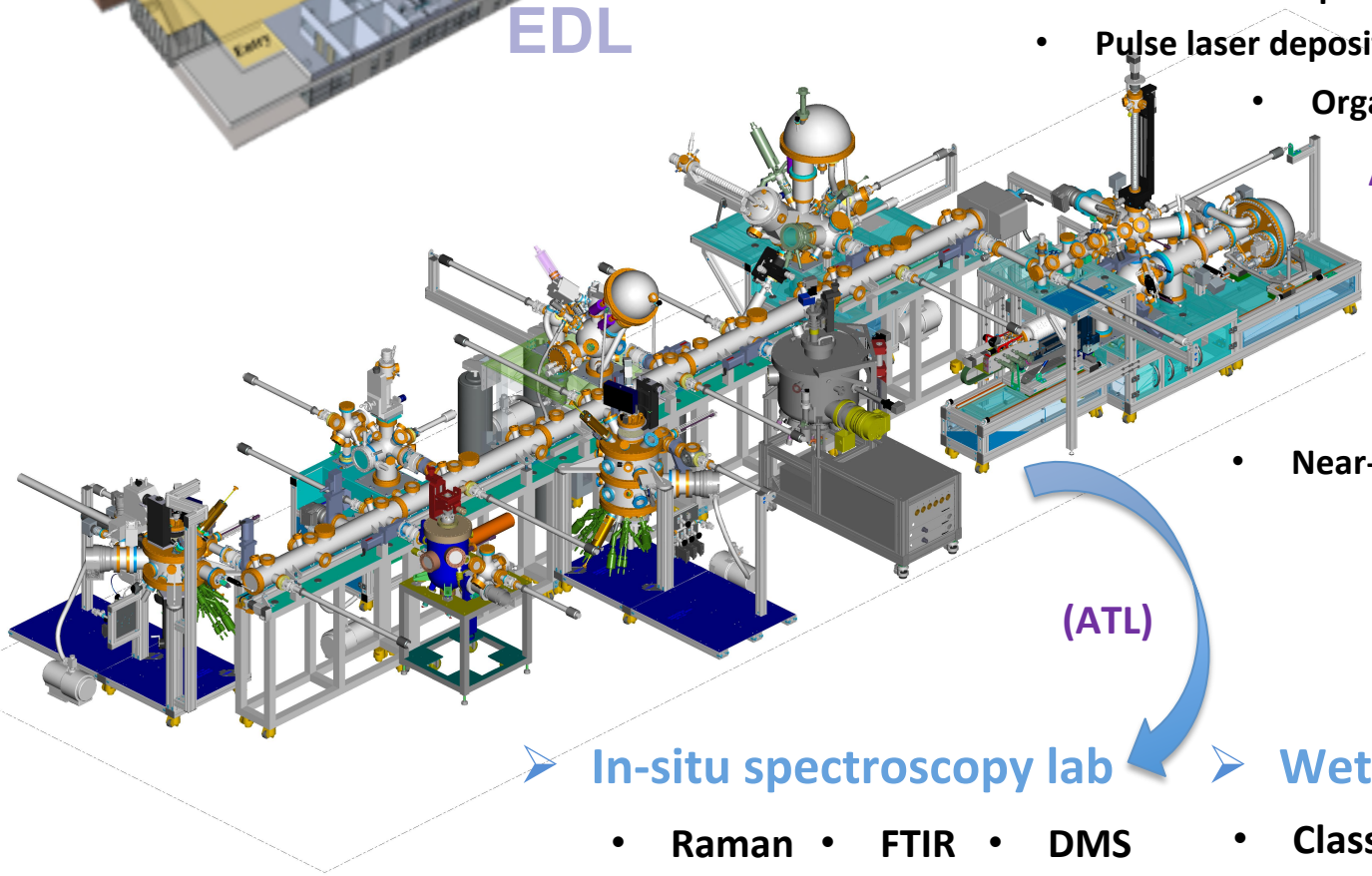


EDL

➢ **High throughput synthesis lab**

- Magnetron sputtering module
- Molecular beam epitaxy (MBE) module
- Pulse laser deposition (PLD) module
- Organic layer (OLD) module

Automated Transfer Line (ATL)



UHV analytical module

- LEED, LEIS, XPS, STM
- Near-ambient pressure AR-XPS module

(ATL)

➢ **In-situ spectroscopy lab**

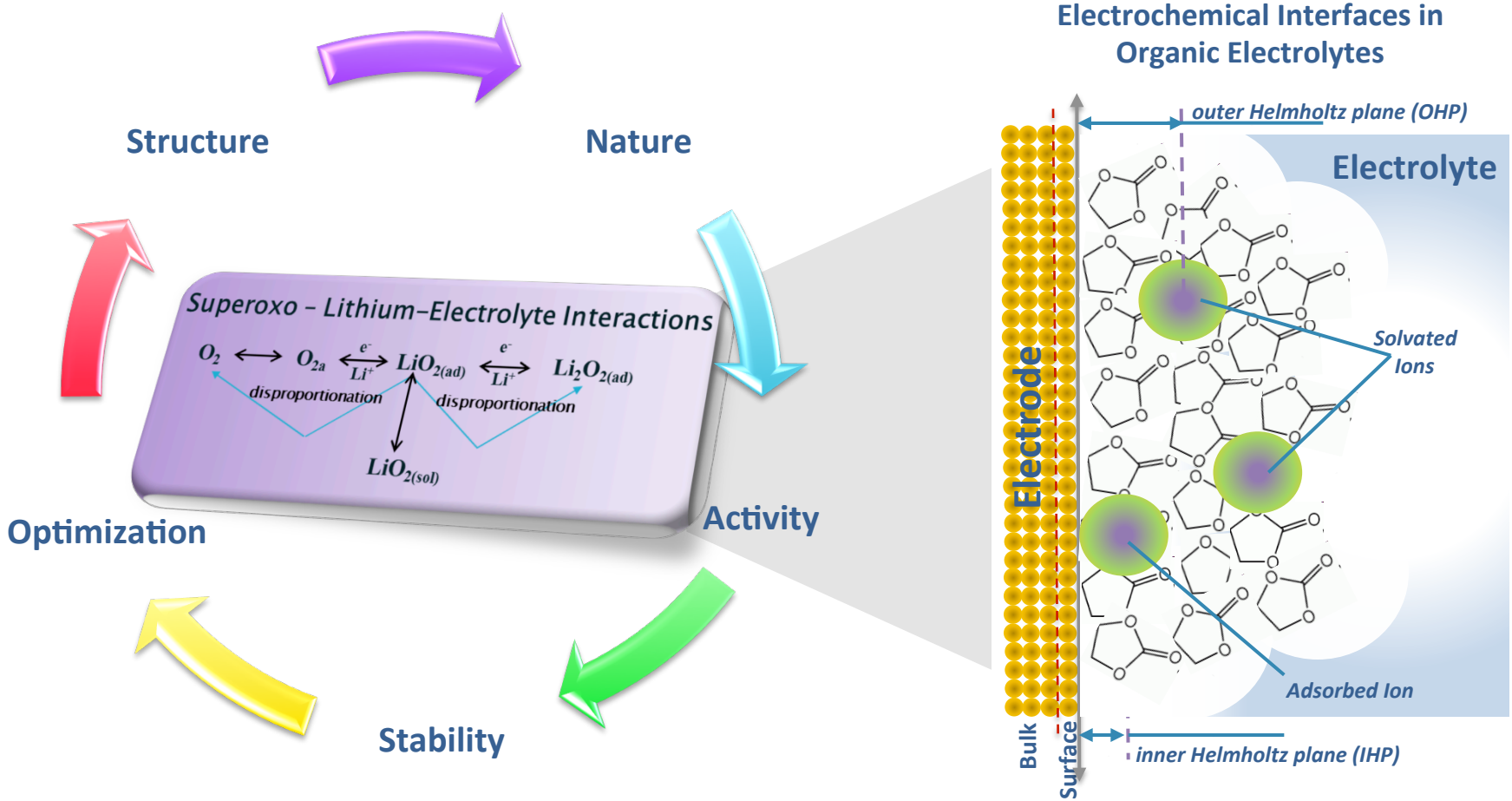
- Raman
- FTIR
- DMS

➢ **Wet electrochemical lab**

- Classical electrochemical methods

Core function -design new materials by applying surface science approach

Understanding and Tailoring Interfacial Properties



Using basic science to unveil reaction pathways; this leads to materials design

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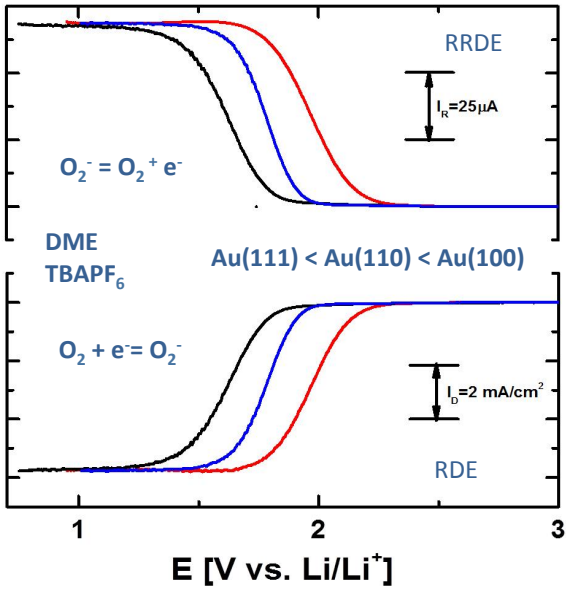
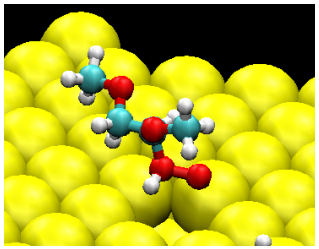
Resolving Fundamental Challenges: Li-free electrolytes

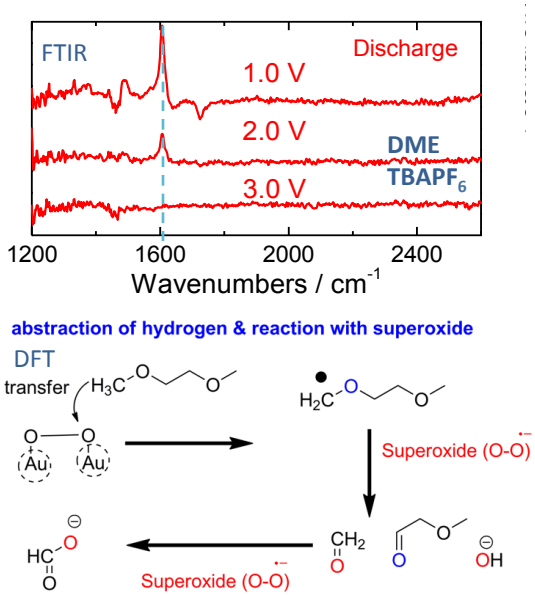


Parasitic reactions:

1) Electrolyte

2) Impurities (H_2O)





RDE: O_2 electrochemistry is structure sensitive in ether-based electrolytes

- Catalysis is important (substrate O_2 interaction)

RRDE: monitoring of intermediates

- O_2^- is stable in Li free electrolytes

FTIR/DFT: the role of superoxide in electrolyte decomposition

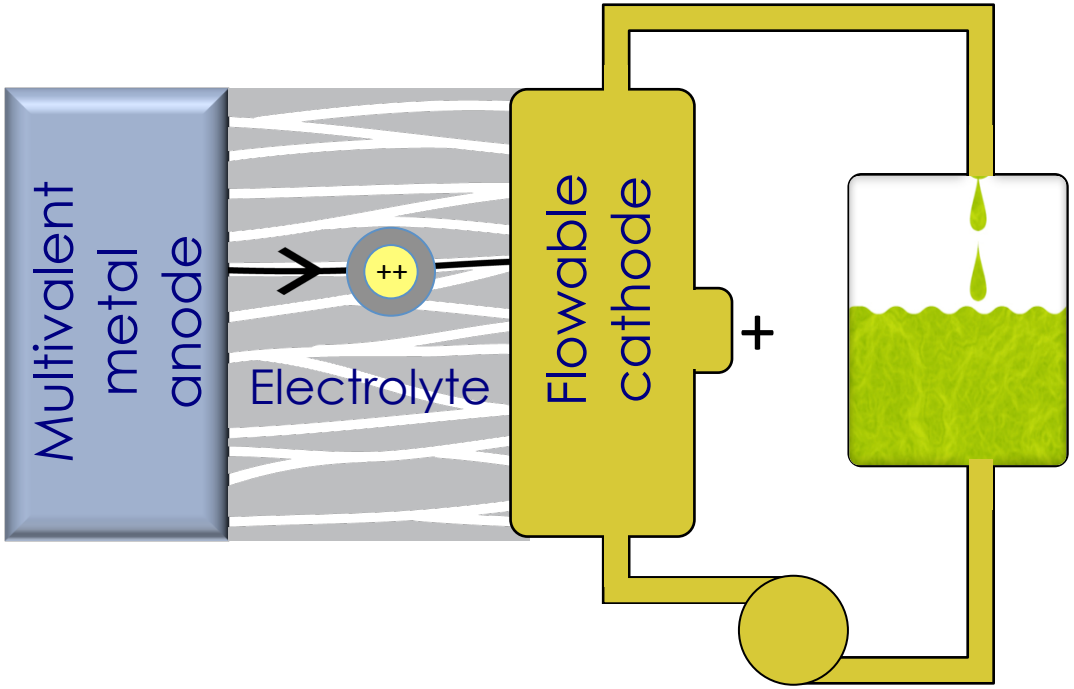
- Bulk O_2^- is unreactive for breaking bonds in an ether molecule
- Hydrogen abstraction by adsorbed superoxide (defects)
- Formate anion observed experimentally and by DFT

Ultimate Battery May Combine Storage Concepts

Multivalent metal anode

High ion mobility in stable electrolyte

Chemical reaction in flowable cathode



JCESR Model

- Mission orientation for the research
- Top-down challenges
- Bottom-up research
- JCESR without walls
- Modify directions due to new information
- Result: integration of science across disciplines and across institutions, aimed together toward the same mission

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How to best engage JCESR?

Why?

- We want to ensure we are working on the relevant problems, as we strive for our targets
- Our work may complement yours
- It's likely your goals are aligned with ours

How?

- Affiliates organization – first meeting this March
  - Contact me, or Brad Ullrick at bullrick@anl.gov

- Directly through a researcher you know in JCESR

Perspective

Vision: **Transform transportation and electricity grid**

Mission: **5-5-5 Five times the energy density, one fifth the cost, in five years**

Nothing less is transformative

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 5-5-5 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

- A bold new approach to battery R&D
- Accelerate the pace of discovery and innovation
- Shorten the time from conception to commercialization