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Electrification of Aviation – Challenges & Opportunities: “Bannister Moment”

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Electrification of Aviation – Challenges & Opportunities: “Bannister Moment”

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3 historic weeks in the history of electric aviation

Venkat Viswanathan • You
Associate Professor at Carnegie Mellon University, Co-Founder, Aionics, C...
2w •

Next 3 weeks will undoubtedly define the future of electric aviation! Excited to lead a breakout session NASA - National Aeronautics and Space Administration-Office of Energy Efficiency and Renewable Energy (EERE), U.S. Department of Energy workshop this week, organized by Ajay Misra Tien Duong Venkat Srinivasan Simon T. Thompson Amy Jankovsky! The 2019 version of this workshop led to our Nature perspective, https://rdcu.be/daB5F

In early May, excited to talk at Dr. Halle Cheeseman's Bat1K ARPA-E workshop in May! Great piece by Steve LeVine documenting this pivotal moment in 🛬 history.

Steve LeVine • 1st
Batteries, EVs, the future. I run The Electric. Sign up: subscriptions.theinform...
2w • Edited •

Battery researchers—with EVs in the bag—are pivoting to the next big thing: 1,000 wh/kg batteries that can power narrow-body 100-passenger, 700-mile planes. A NASA-DOE workshop begins tomorrow in Cleveland, and Arpa-E follows up with a second workshop in May. The Electric.

Distributed Propulsion: Cubed-Square

	Single	Distributed
Weight ~	D^3	$N_p D_{DEP}^3$
Thrust ~	D^2	$N_p D_{DEP}^2$
Same Thrust: $D^2 = N_p D_{DEP}^2$; $D_{DEP} = D/N_p^{(1/2)}$		
Weight ~	D^3	$D^3/N_p^{(1/2)}$
Same Weight: $D^3 = N_p D_{DEP}^3$; $D_{DEP} = D/N_p^{(1/3)}$		
Thrust ~	D^2	$N_p^{(1/3)} D^2$

Distributed propulsors weighs less than a single propulsor producing the same thrust at the same jet velocity.

Distributed propulsors provide for a larger total fan area and thus lower jet velocity and higher efficiency than a single propulsor with the same total weight

J. Langford, D. Hall, The Bridge, National Academy of Engineering, 21-27

Distributed Electric Propulsion

- **Efficiency:** Lower energy consumption
- **Safety:** No single point of failure
- **Noise:** Lower sound profile
- **Economics:** Reduced maintenance and savings on fuel costs

Credit: eVTOL Innovation

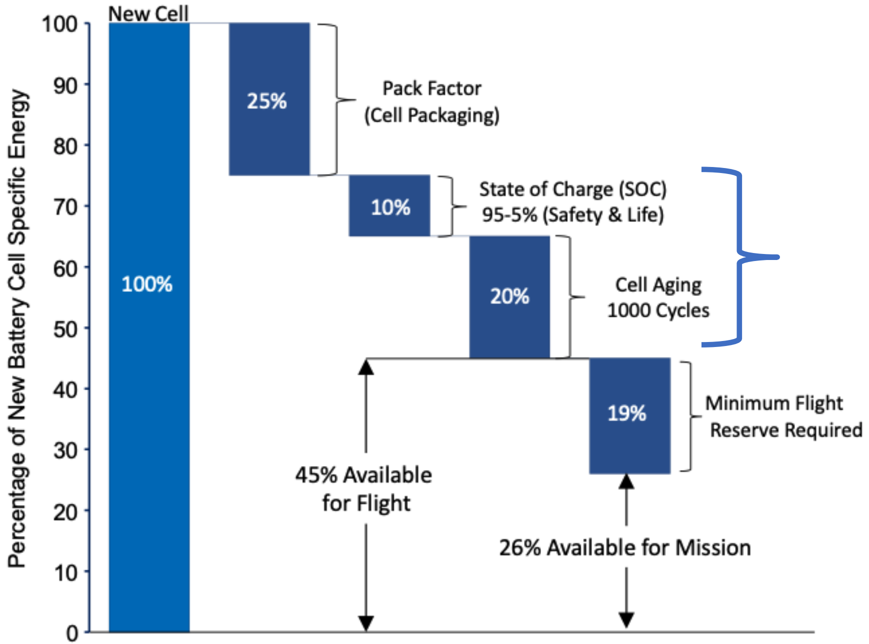
1) Multirotor

2) Lift plus cruise

3) Vectored thrust
3a) tilt rotor
3b) tilt wing
3c) tilt duct

Credit: AAM Reality Index

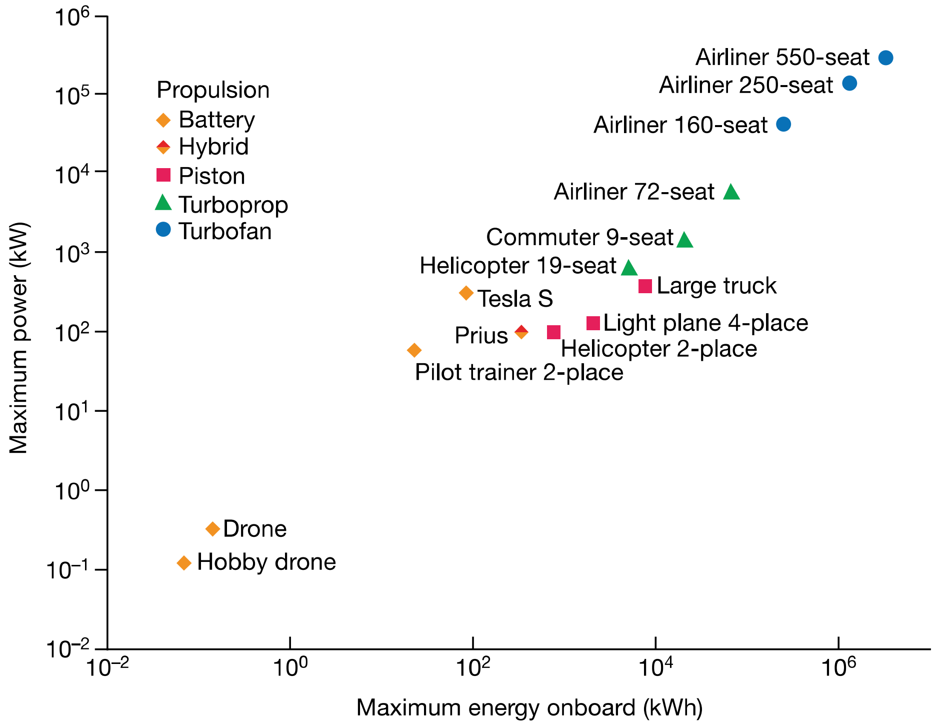
The packaging opportunity

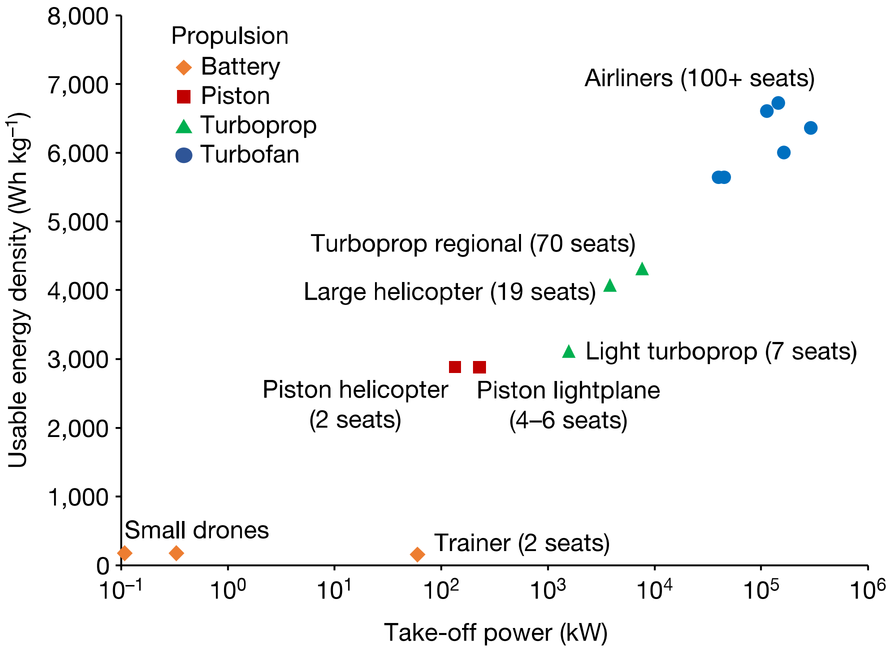


Certified Packs
EASA: 145 Wh/kg (Pipistrel)
FAA: 64 Wh/kg (True Blue Power)

V. Viswanathan, A. Epstein, Y.-M. Chiang, E. Takeuchi, M. Bradley, J. Langford, M. Winter, Nature (2022) 601, 519–525

Energy and Power For Flight





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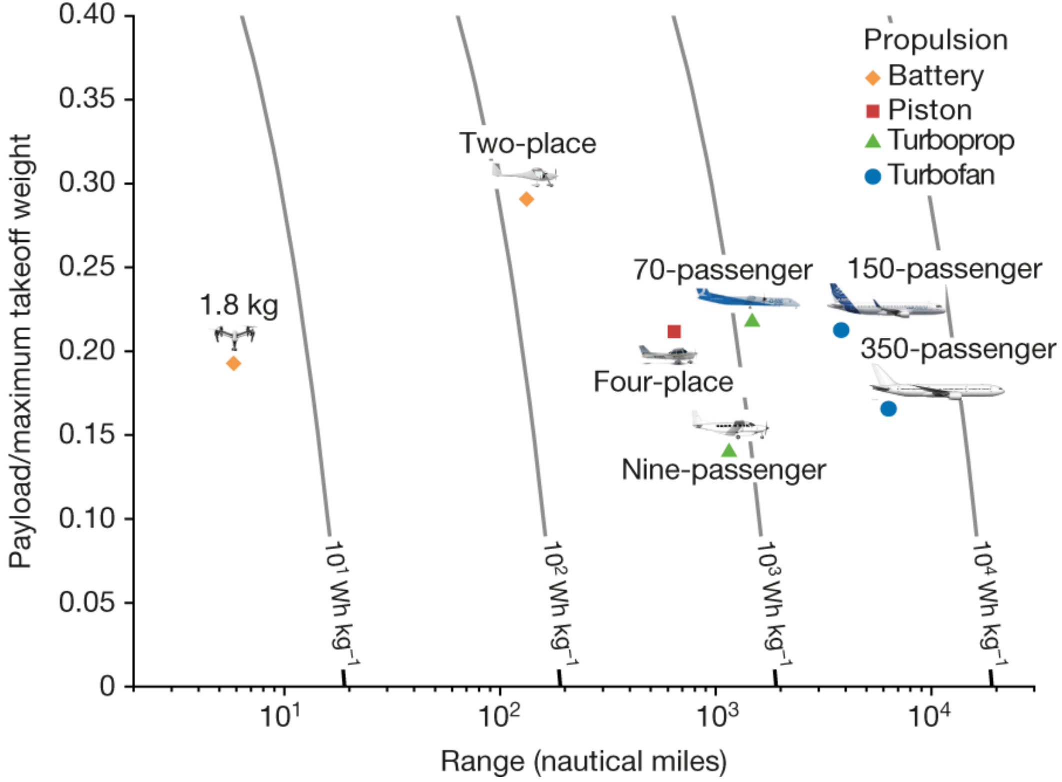
Single-aisle and Twin-aisle



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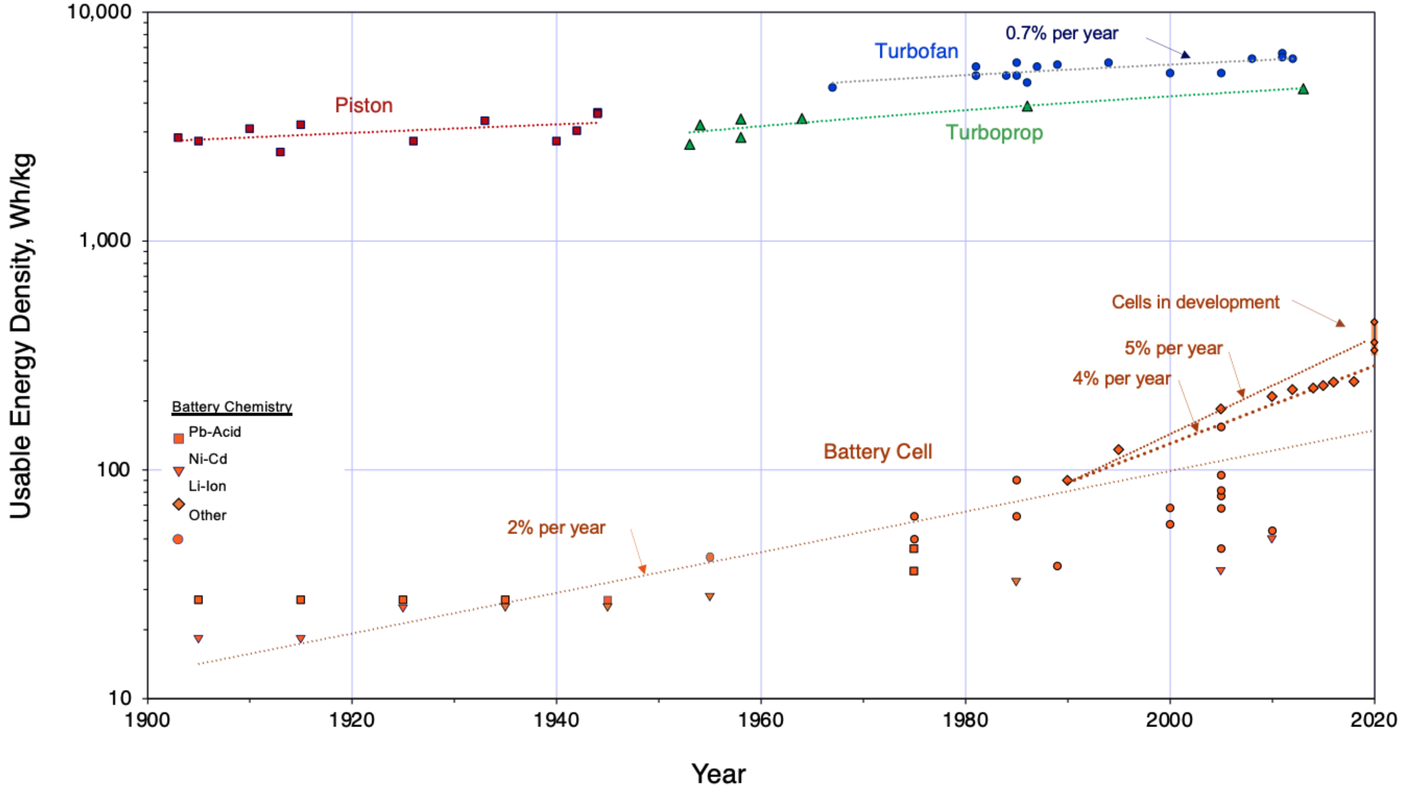
Progress over the last century



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“Bannister Moment”

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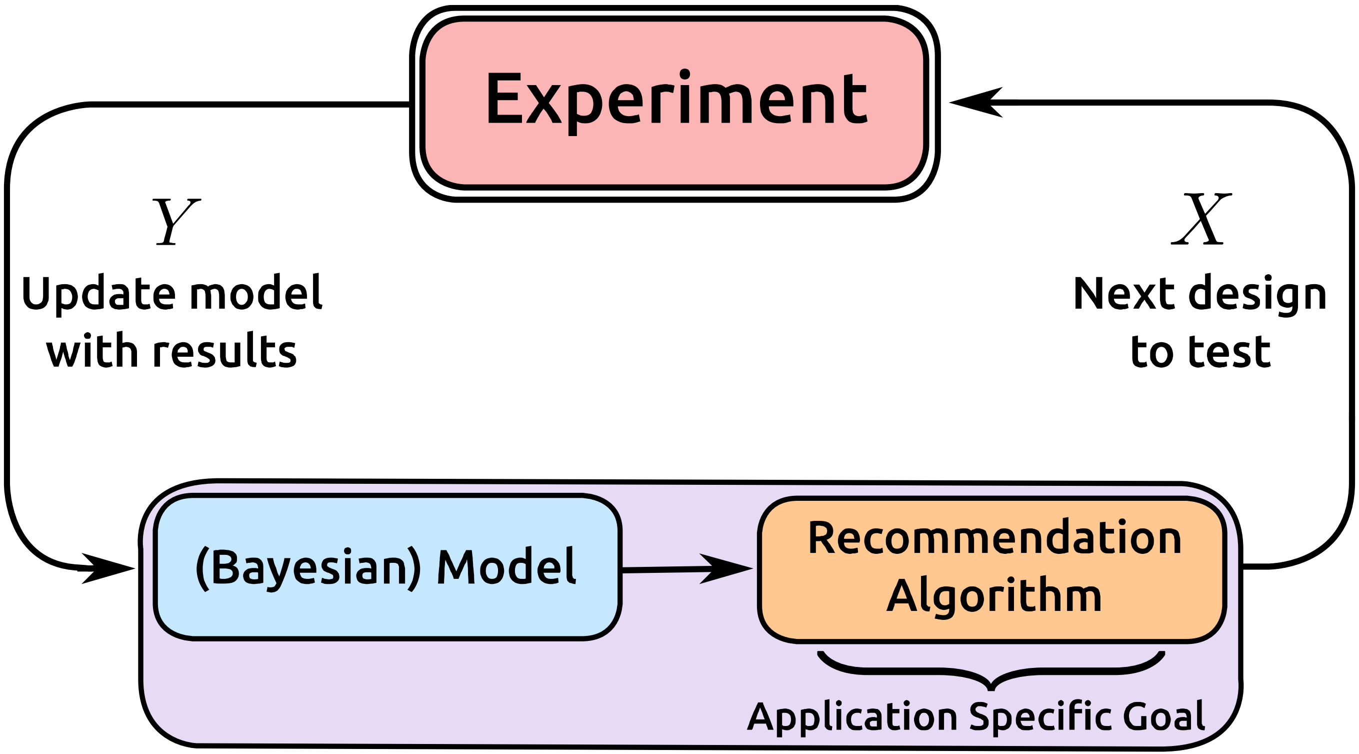
Photograph Credit: Bettmann / Getty

Changing what’s possible

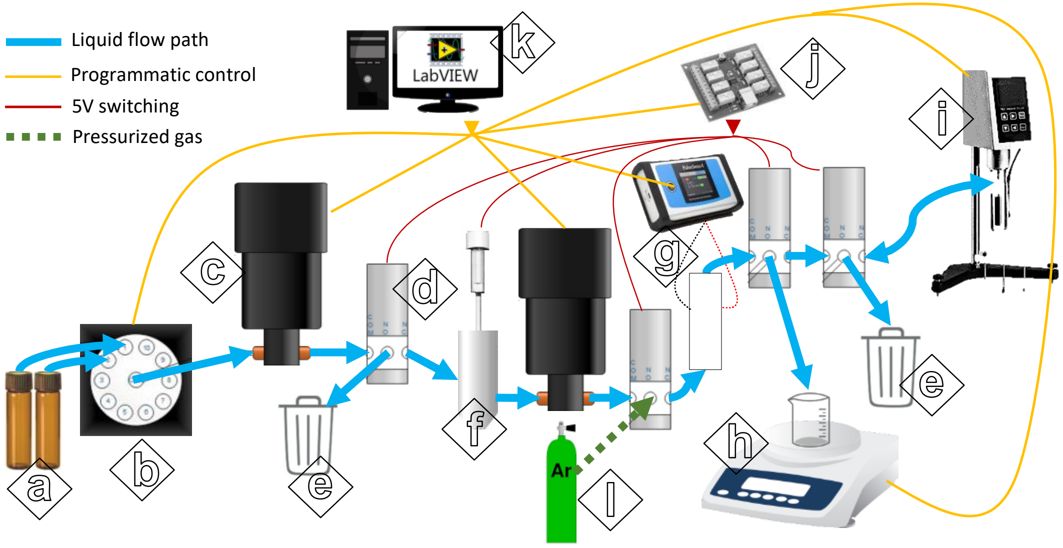
What’s different now?

Three main capabilities

- Machine learning guided-materials design
- Advanced Characterization
- Autonomous Experimentation and Closed-Loop Discovery


Experiment
Y
Update model with results
X
Next design to test
(Bayesian) Model
Recommendation Algorithm
Application Specific Goal

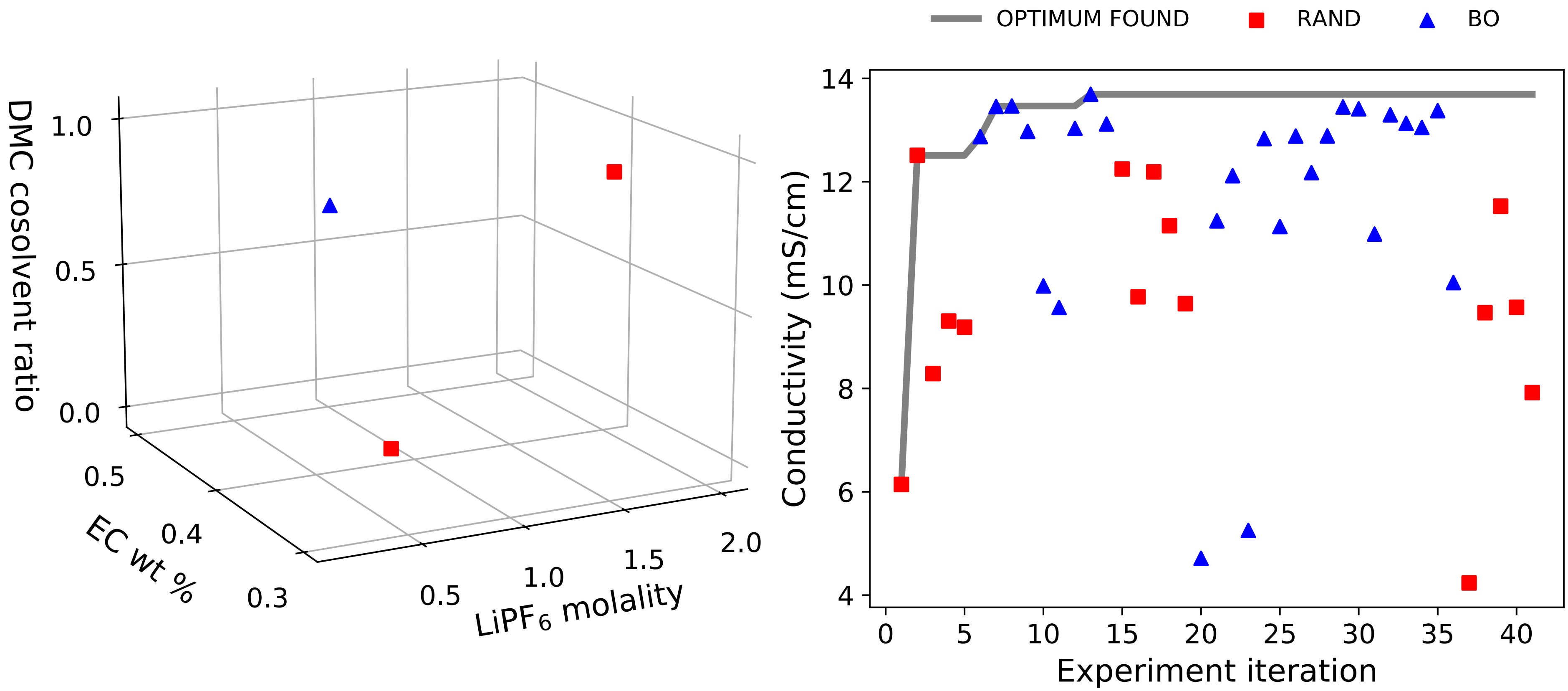
CLIO: our robotic electrolyte test-stand



a: Feeder solution, b: 24-port valve, c: programmatic pumps, d: three-way valve, e: disposal, f: sonicator, g: conductivity chamber to Palmsens4, h: mass balance, i: Brookfield viscometer, j: relay, k: software orchestration, l: Argon gas to clear out

- Mixes multi-component solvent/salt solutions from feeder solutions
- Characterizes conductivity, viscosity, and density of solution
- Controlled over HTTP via a Python class
- Retains samples for follow on cell-testing
- Glovebox and viscometer are temperature controlled

Design space: EC-DMC-EMC-$LiPF_6$ ternary solvent, single salt system



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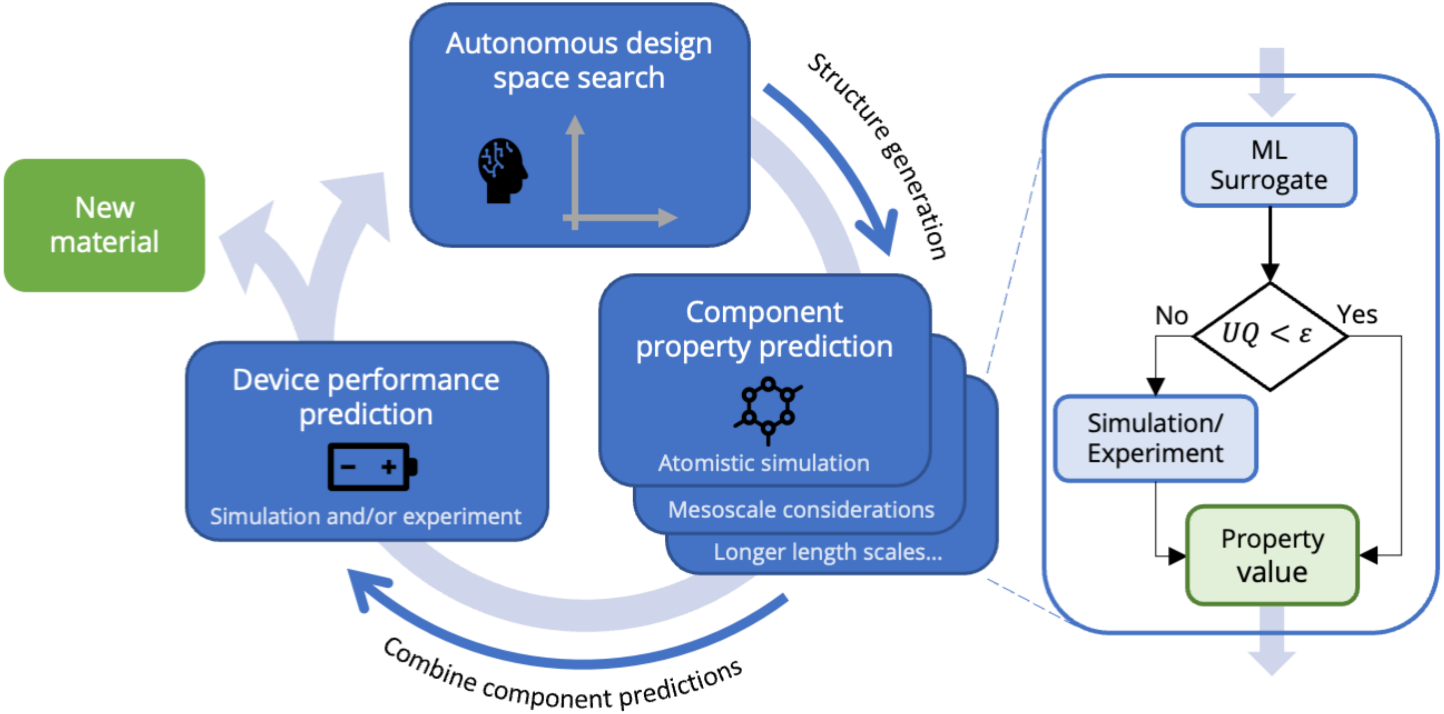
A. Dave, J. Mitchell, S. Burke, H. Lin, J. Whitacre, V. Viswanathan, Nature Communications, 13, 5454 (2022)

Autonomous Materials Discovery



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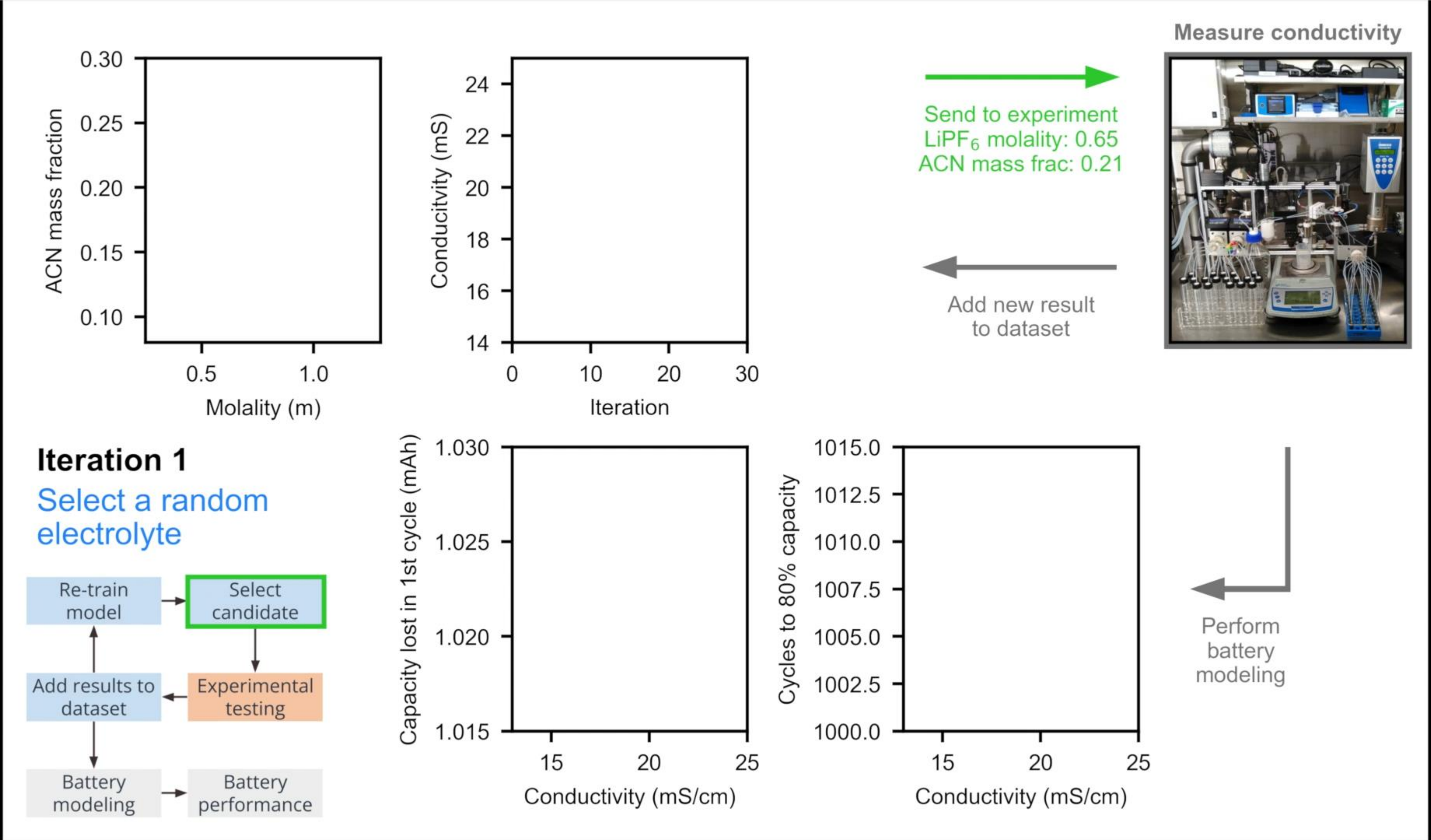
E. Annevelink, R. Kurchin, …, **V. Viswanathan**, *MRS Bulletin*, 47, 1036–1044 (2022)



Measure conductivity
Send to experiment
LiPF6 molality: 0.65
ACN mass frac: 0.21
Add new result to dataset
Perform battery modeling
Iteration 1
Select a random electrolyte
Re-train model
Select candidate
Experimental testing
Add results to dataset
Battery modeling
Battery performance
ACN mass fraction
0.30
0.25
0.20
0.15
0.10
0.5
1.0
Molality (m)
Conductivity (mS)
24
22
20
18
16
14
0
10
20
30
Iteration
Capacity lost in 1st cycle (mAh)
1.030
1.025
1.020
1.015
Cycles to 80% capacity
1015.0
1012.5
1010.0
1007.5
1005.0
1002.5
1000.0
15
20
25
Conductivity (mS/cm)

Rate of Progress

Anode
Li metal

Batt500

IONICS
2017

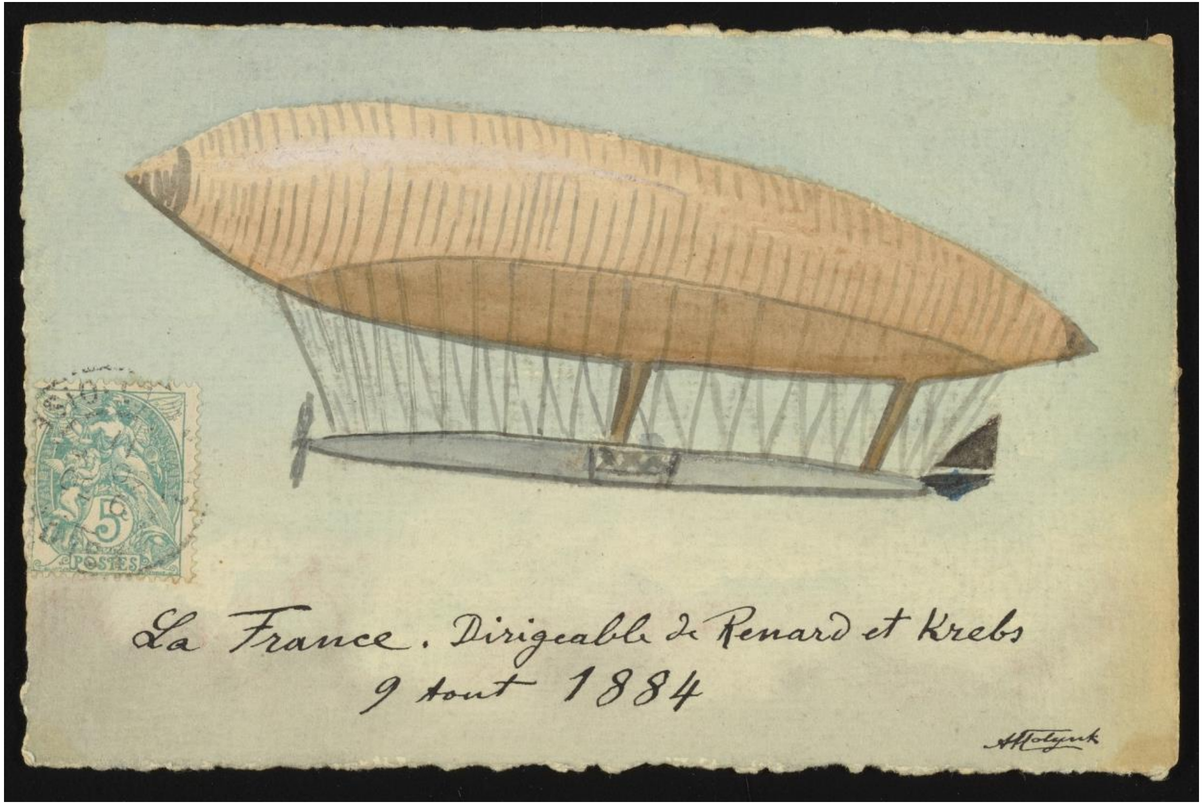
Bat1k
2023

800-1000 Wh/kg
2028

Scaling-up
2030+

One of us will be the "*Roger Bannister*" of Aviation Batteries

What lies ahead?



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Thank you