

Battery Crashworthiness

Presenter: Dave Stanley

FAA Research Team Members:

Structures and Propulsion Branch

**David Brandt, Elisabeth Davis, Tom
Maloney, Jon Doyle, Dave Stanley**

**Sponsor: Dr. Joseph Pellettierre, Dr. Nazih
Khaouly**



**Federal Aviation
Administration**



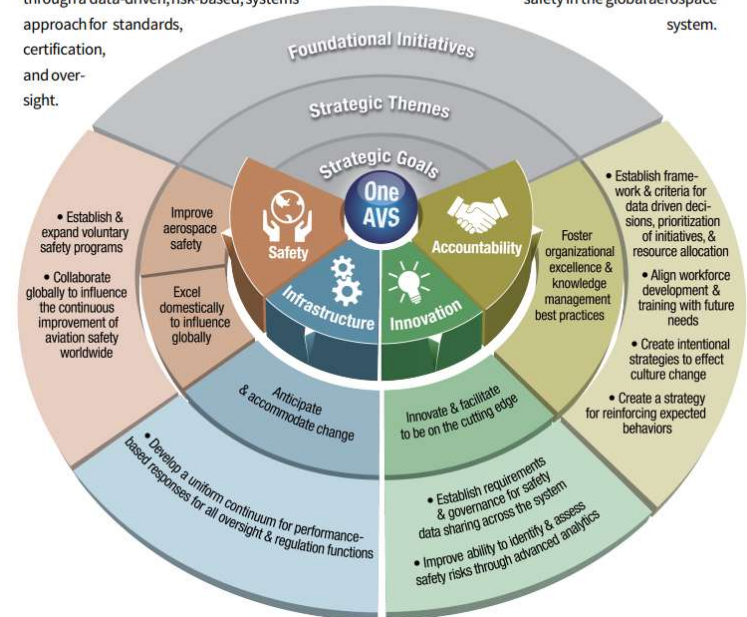
Research Sponsors

- Most research at the Tech Center is evaluated through the lens of Aviation Safety (AVS)
 - https://www.faa.gov/sites/faa.gov/files/about/office_org/headquarters_offices/avs/avs_strategy_508_final.pdf
- AVS sponsors create research questions to fill knowledge gaps within the FAA to meet Four Strategic Goals (Safety, Infrastructure, Innovation, and Accountability)
- The FAA William J. Hughes Technical Center teams work to generate data and transfer knowledge to aid our sponsors in rulemaking decisions

The AVS Strategy

Mission: To provide the safest, most efficient aerospace system in the world through a data-driven, risk-based, systems approach for standards, certification, and oversight.

Vision: We are an innovative organization that achieves excellence and assures safety in the global aerospace system.



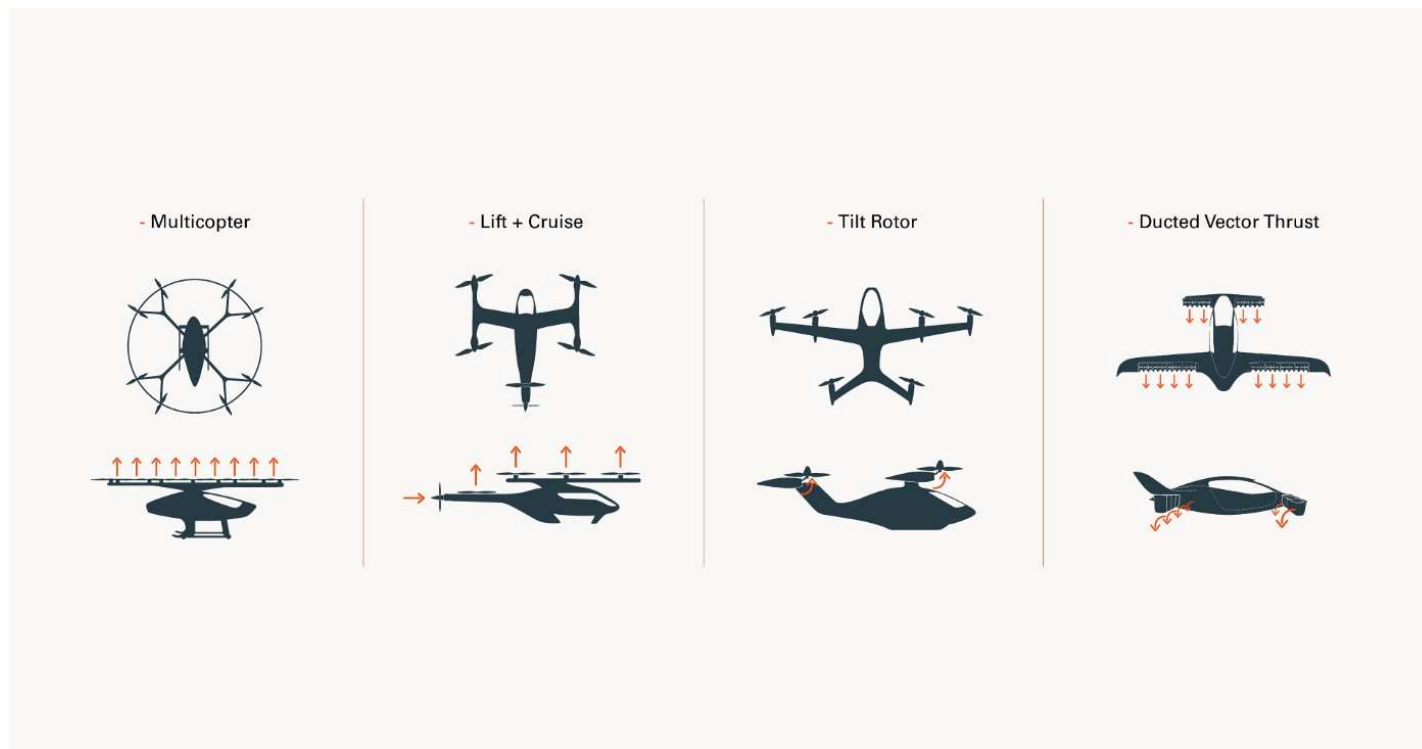
Why does the FAA conduct research?

- **Preparation for applications of new technologies**
 - Actively work to not create burdensome regulations
 - Cannot allow industry to self-certify without oversight
 - Cannot say no to innovation (“Don’t be caught flat-footed!”)
- **To provide proper oversight**
 - FAA needs to understand new technologies
 - Cooperative research is needed to “meet industry at the finish line”
- **Success and expediency by Early Engagement and Cooperative Research with industry groups**
- **All of the above is needed for successful eVTOL integration**



eVTOL Design Concepts

- Multiple eVTOL design architectures that may have battery placement in different locations



Source: Lilium Blog, What it takes to design an aircraft from scratch, 09/24/2020

eVTOL Emergency Landing

- **Part 23 and 27 based on years of service data**
 - Do we consider some wing lift? Autorotation?
- **In what stage of flight is the emergency landing happening?**
- **What constitutes a hard impact?**



Crash Survivability

- **Rotorcraft Occupant Protection Working Group (ROPWG) Final Analysis Report to the ARAC, Revised September 27, 2018**
 - Context : Existing fleet of rotorcraft do not meet current occupant protection requirements of 27/29.561, .562, .785, and .952 since they were certified prior
 - “Most significant hazards to personal survival in a potentially survivable crash are post-crash fire and inadequate upper torso restraint”
 - Recommended retrofitting crash resistant fuel bladders and upper torso restraints
 - Rotorcraft operations overall accident rate is over 30 times of Part 121 air carrier
- **eVTOL needs to have crashworthiness integrated into design**
https://www.faa.gov/regulations_policies/rulemaking/committees/documents/media/ROPWG%20Task%206%20Final%20Report%20Revised%202018-09-27.pdf



Where does eVTOL battery crashworthiness fit?

- **First we need to define the configuration and utilization?**
- **Is 14 CFR § 27.952 - Fuel system crash resistance a fair comparison for battery packs? Is there data that can be produced to verify it is robust enough?**
 - (1) 50 foot drop height onto non-deforming surface
 - (4) Tank must be enclosed in a surrounding structure representative of the installation unless it can be established that the surrounding structure is free of...features likely to contribute to rupture
 - (5) The tank must drop freely and impact in a horizontal position $\pm 10^\circ$.
 - (6) After the drop test, there must be no leakage

Battery Structures

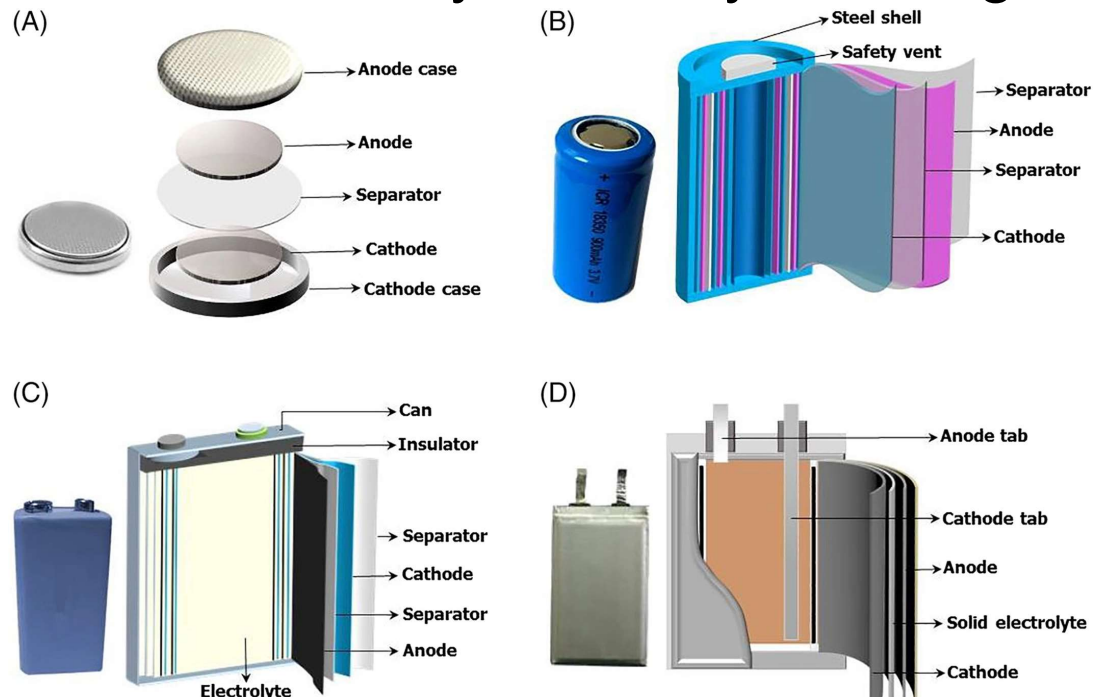
- Different battery structures can behave differently in a crash scenario
 - Propensity for thermal runaway, electrolyte leakage, off gassing, etc.

A) Coin

B) Cylindrical

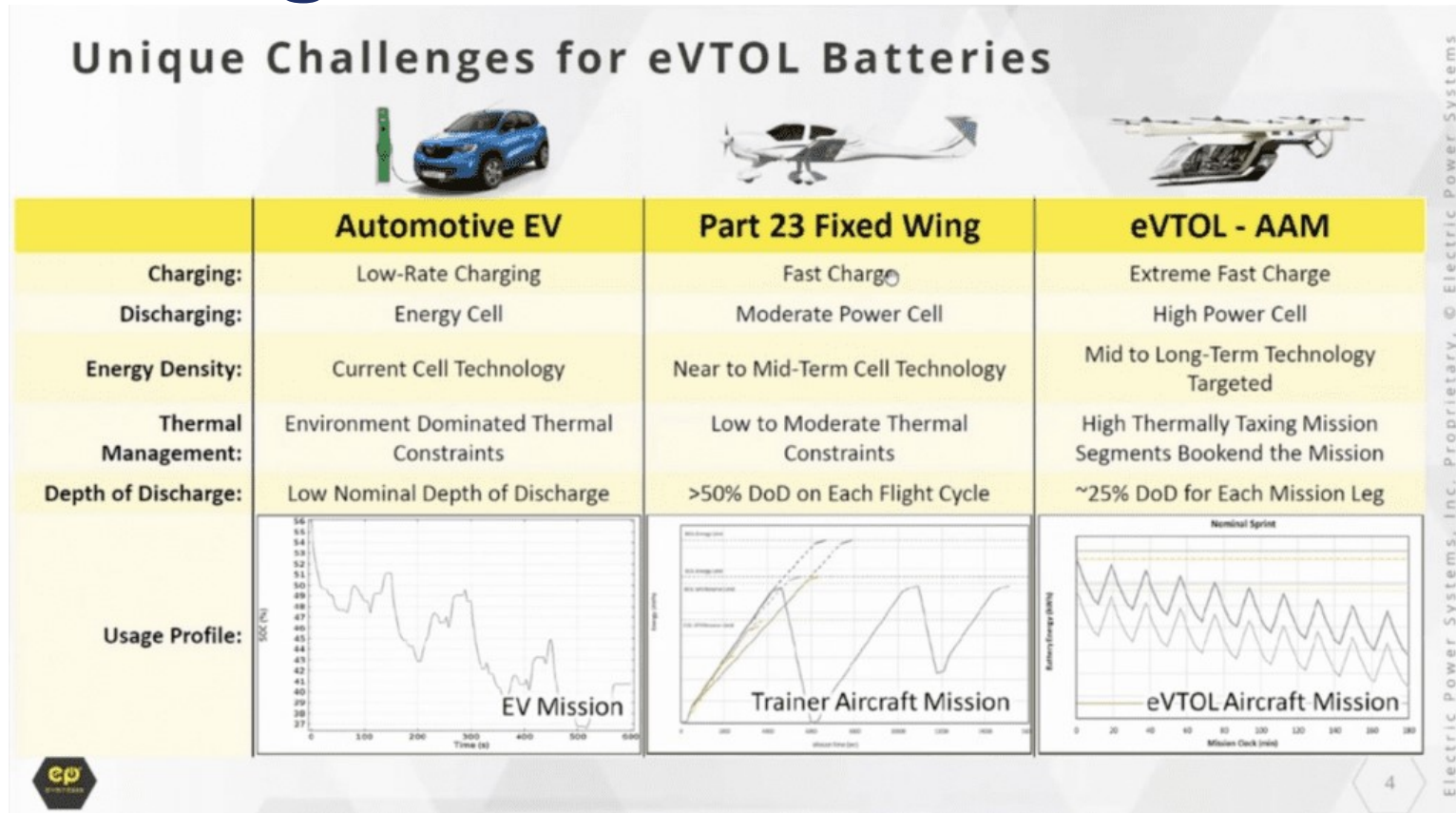
C) Prismatic

D) Pouch



Source: Liang, Y, Zhao, C-Z, Yuan, H, et al. A review of rechargeable batteries for portable electronic devices. *InfoMat*. 2019; 1:6–32. <https://doi.org/10.1002/inf2.12000>

Challenges for eVTOL batteries



- Should we consider reusability after a crash event?

Source: Reichmann, K. Why are Batteries a Problem for eVTOLs? Aviation Today. May 14, 2021.

Battery Specific Research Questions

- **What is the minimum required amount of time to allow egress before hazardous condition?**
- **Will thermal runaway occur at drop tests lower than 50ft?**
- **Can we use measured deformations of the battery (module or cell) to replicate tests?**
- **Does the battery module leak electrolyte following a crash?**
- **What effect does drop height and orientation have on battery crashworthiness? What about reusability?**
- **What constitutes a hard landing? How do we go about return to service?**
- **Is it possible to reuse a battery pack after X hard landings or a crash event?**



Drop Test Tower

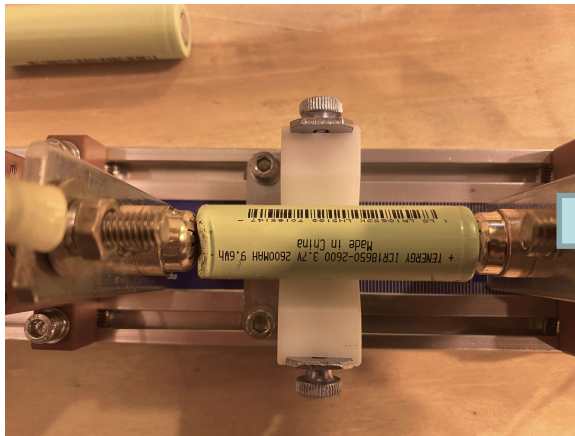
- The FAA William J. Hughes Technical Center is home to a 57' drop test tower
- Conducting drop tests of battery cells, packs and modules to gain a greater understanding of their crash behavior
- Plan on conduction tests on different landing pads (rigid, soft soil, etc)
- Long term goal : drop a generic eVTOL structure with battery pack to identify crashworthiness



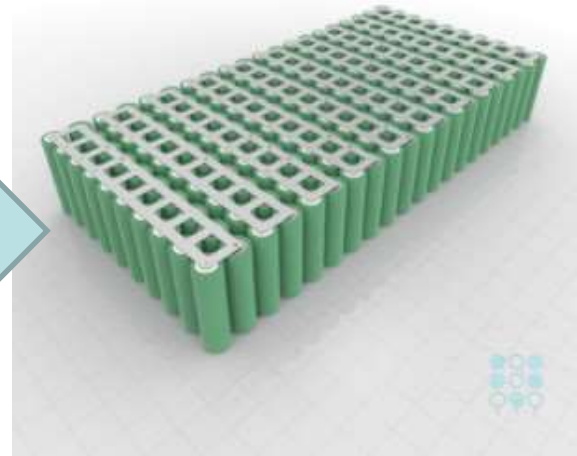
strengths/weaknesses

Post Drop Evaluation

- **Visual Inspection.** Is there quantifiable damage?
- **Complete discharge/recharge cycling** to evaluate electrical performance
- **Starting at cell level, moving to pack and then system**



Cell After Drop



Other Current Work

- **JAMS grant with NIAR (Dr. Gerardo Olivares and Luis Gomez) to assess state of the market for eVTOL design and operation windows**
- **Current grant between FAA/CAMI/NASA (IA1-34337) titled “Aerospace Medical Research Division Biodynamics (AAM-632) Crashworthiness and Occupant Protection of Rotorcraft Structures and Seats in Vertical Takeoff and Landing Research**



Questions?

