Challenges for eVTOL Crashworthiness and Barriers to Market Utilization

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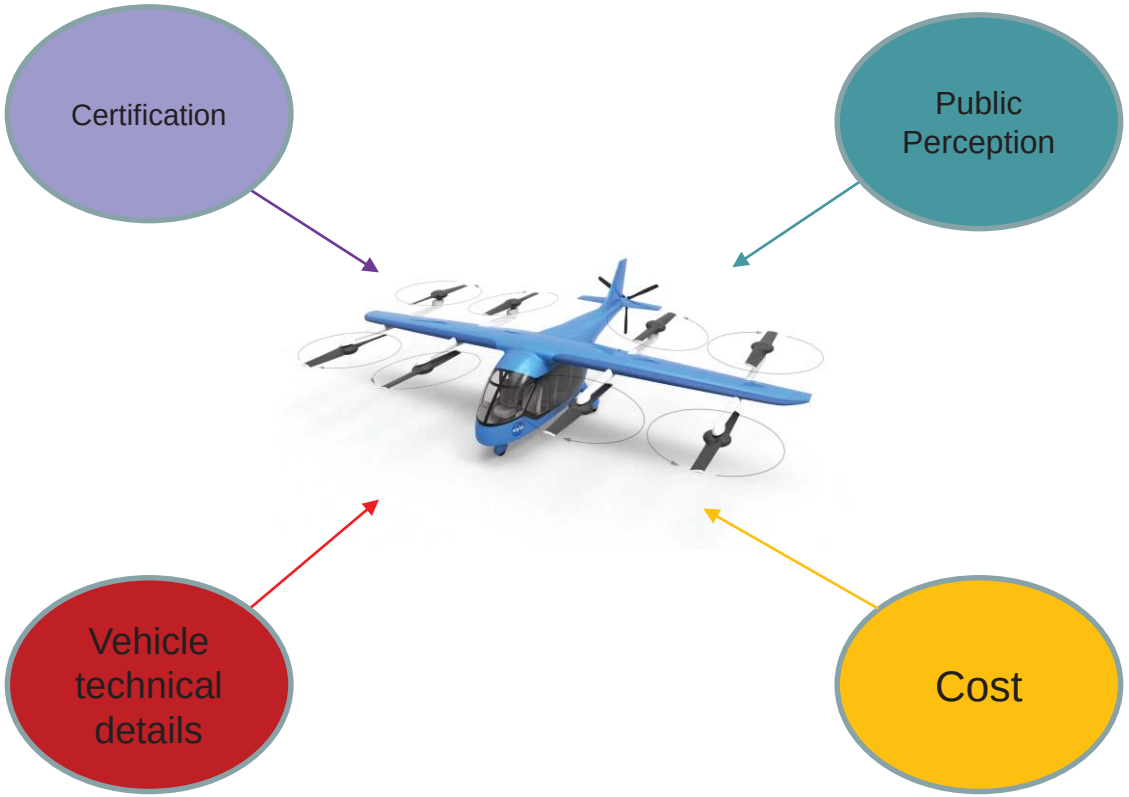


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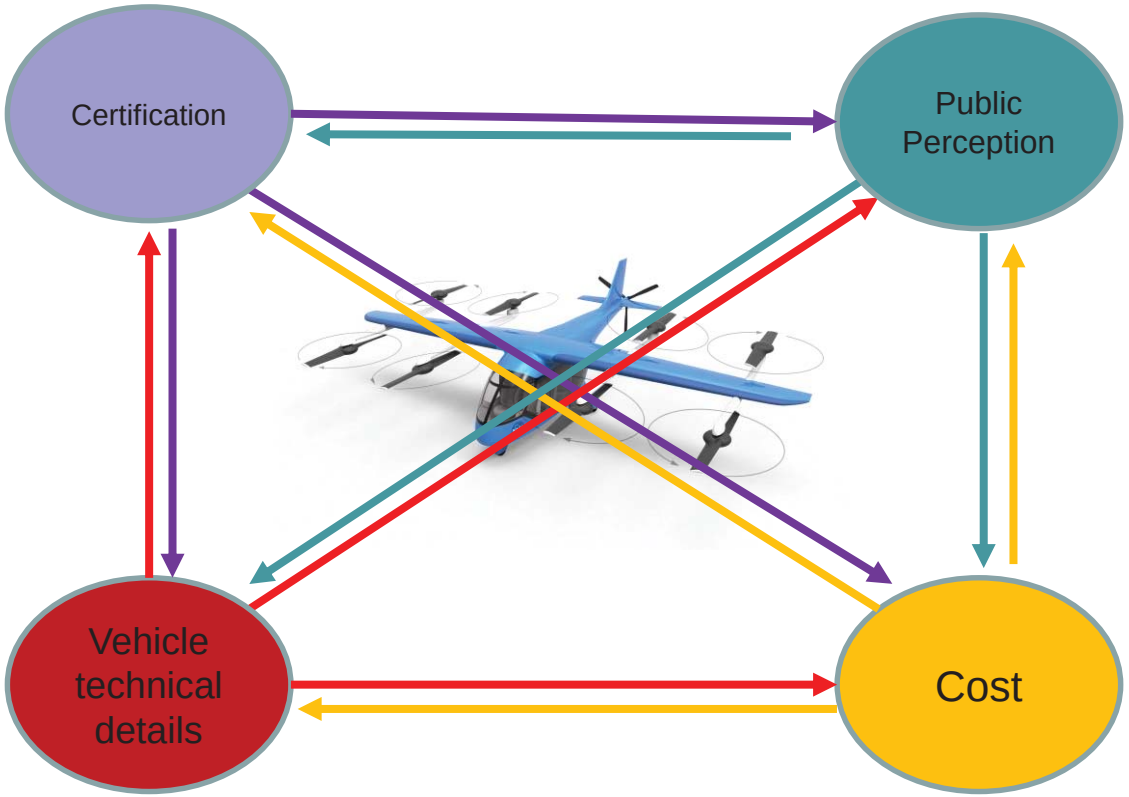


- This session will focus on crashworthiness and occupant protection topics only as barriers to market utilization. *There are many others that are covered in many other sessions*
- We will also not be discussing "*how to avoid crashes*." We will assume we are in a crash situation. *There are many other sessions that cover "how to avoid crashing."*
- My hope that this will the start of an information exchange, along with provide the start of engagements between Regulators, Operators, Researchers and Manufacturers (OEMs) so that market barriers can be overcome.
- My background is crashworthiness research. Specifically, conducting vehicle crash tests with the intent of achieving sufficient occupant protection in various scenarios.
  - I have no inside information on OEMs other that what's publically available
  - I have served on rulemaking committees, however I am not a regulator
  - NASA/Revolutionary Vertical Lift Technology (RVLT) project has interest in expanding research in Urban Air Mobility (UAM) crashworthiness and occupant protection due to technology gaps and regulatory uncertainties that exist
- I have taken many steps to ensure that the information presented is accurate. However, in this industry, things change quickly. If you see something that is potentially out of date, missing or incorrect, please inform me. This is not intentional.

Four topic areas as barriers to flight



Four topic areas as barriers to flight



Market Utilization



- NASA Strategic Framework for On-Demand Air Mobility
  - Demand now and upcoming
    - 3,570,000 trips x 12 min / trip = 714,000 Flight Hours (FH) / year (2015 data)
    - 29,008,000 trips x 12 min / trip = 5.8M FH / year (2035 est)
- UBER Elevate
  - 2,800 FH / year utilization
  - Long term 5000 units produced per year (2030s)
  - 14,000,000 FH / year (assume produced = utilized)
- FAA Part 23 actual data – 213 fatalities in 2016
  - 1.7 fatal / 100,000 FH
- FAA Part 135 actual data – 2 fatal accidents in 2016
  - 0.51 fatal / 100,000 FH

Avenues of Certification

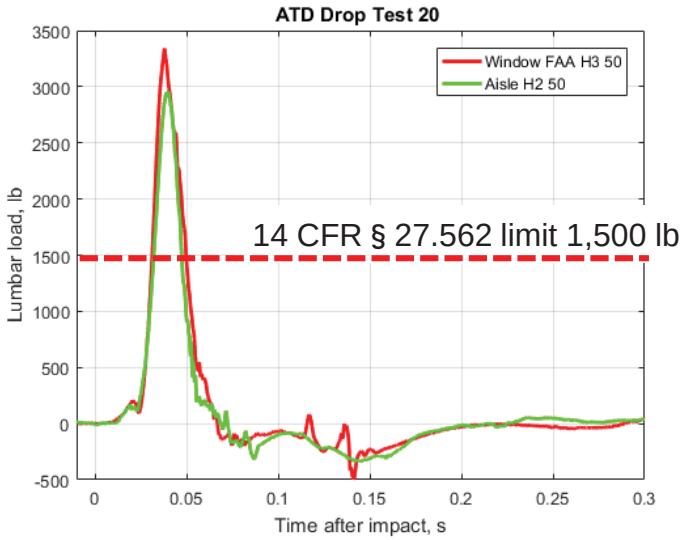


- 2017 - Part 23 Admt 64 – performance based
  - Airframe certification level 2 (2-6 pax)
  - 14 CFR § 23.2270 Emergency Conditions
  - Federal Register 83 FR 21850 lists ASTM F3264 as one (of many possible) accepted MOC
    - ASTM F3264 lists ASTM F3083 applicable document for *"Standard Specification for Emergency Conditions, Occupant Safety and Accommodations"*
  - *Other consensus organizations working on MOC?*
  - *Likely avenue. Will UAM be **based on** Part 23 or **be** Part 23?*
- *ASTM F3083 lists 2 dynamic seat tests based on Part 23*
- *"80% standards exist, 20% new"*
  - *Crash standard for eVTOL different conditions?*
- Others include: Part 25, 21.17(b), MIL-STD-1290A, AC20-146 - Analysis

Vehicle Tech - Case Study

- Case study: A fall from only 14 feet (30 ft/s) has the capability of causing occupant injury if not protected
  - Impact shape from the below test is a current 14 CFR § 27.562 Regulation





Littell, J.D. and M.S. Annett. "The Evaluation of Anthropomorphic Test Device Response under Vertical Loading." Proceedings from the American Helicopter Society International Annual Forum 74, Phoenix, AZ, May 14-17, 2018.

Vehicle Tech –Tech Available

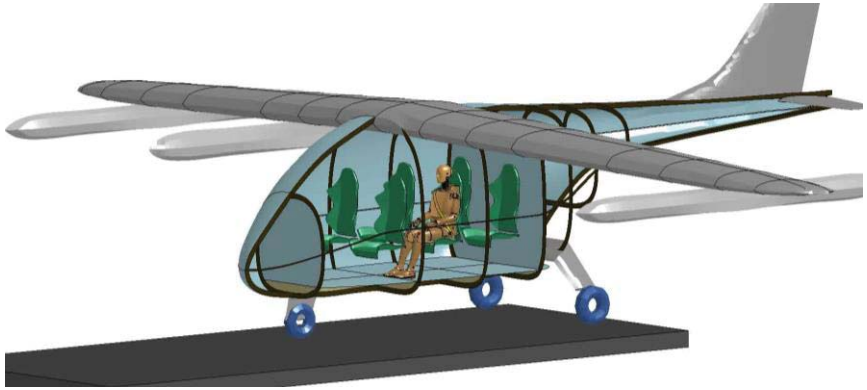
- Ballistic Recovery Systems (BRS)
  - Are these going to work at low alts?
  - Are these going to work at low speeds?
  - Reduce velocity to acceptable limits within vehicle? What is acceptable limit?
- Vehicle Design
  - Energy Absorbing (EA) frame / structure
  - EA landing gear
- External Energy Absorbers
  - Airbags
  - NASA developed Deployable Energy Absorber (DEA)
  - Other “bolt on” systems
- Seat and Restraint systems
  - EA seats via wire-bender or other
  - Seatbelts with airbags
  - Cockpit airbags

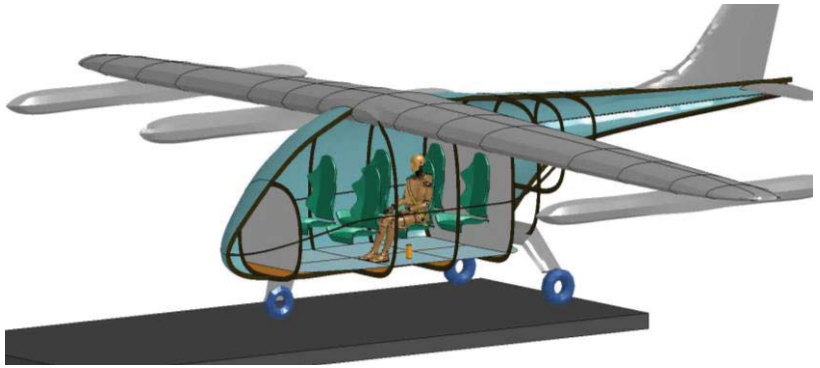




Vehicle Tech – EA Additions

- Using 30 ft/s from NASA Case Study for impact velocity
- NASA RVLT Lift+Cruise baseline vs added occupant protection





Carbon fiber structure
- Non energy absorbing seat
- No other EA structure added

Injury loads approximately 1.5 x injury limits

Carbon Airframe
- Carbon/Kevlar hybrid structure
- Add stroking seat with seat foam
- Add energy attenuating subfloor

Injury loads 20% below injury limits

Vehicle Tech - Batteries



- SAE J2464 – Electric and Hybrid Electric Vehicle Rechargeable Energy Storage System (RESS) Safety and Abuse Testing
  - Shock tests, drop tests, mechanical tests at pack and cell level
  - Pack Level drop test – height 2 m
  - Pack level shock test – half sine, 25 g @15 ms, all axes
- SAE J2929 – Safety standard for Electric and Hybrid Vehicle Propulsion systems utilizing Lithium-based Rechargeable Cells
- UL 2580 - Standard for Safety – Batteries for use in Electric Vehicles
  - Shock test same as SAE J2464 - half sine, 25 g @15 ms, all axes
- ISO 6469-1 – Electrically propelled road vehicles
  - Shock test defined by vehicle type and direction
  - Has conditions for vehicle based test
- If the batteries are tested to 25g @15ms, half sine, and vehicle tested to (for example) 14 CFR § 27.562 – 30 g, 31ms at 60° angle.
  - Part of 20% new/augmented regulations?

Public Perception



- **Automotive**
- 2017 data
- 6.4M accidents
- 34,247 fatalities
- 1.11 fatal / Million miles

- Highest accident #s of all transportation listed
- Most widely used form of transportation

- *Source: US DOT, NHTSA*



- **General Aviation**
- 2016 data
- 1,267 accidents
- 213 fatalities
- 1.7 fatal / 100k flight hours

- Primarily for leisure (not incl. 135) form of travel
- Skilled pilots trained to handle emergencies
- Known risks to pilots

- *Source: NTSB Aviation: data & stats*



- **Driverless Auto**
- Level 2 (partial automation) – 5 fatalities between 2016 and 2019 (1-5)
- Level 3 (full control) – 1 fatality, 2018 (6)
- Minimal implementation currently
- Test phases
- Unknown risks

1 - https://qz.com/783009/the-scary-similarities-between-teslas-tsla-deadly-autopilot-crashes/

2-5 – NTSB accident reports (various)

6 - https://www.ntsb.gov/news/press-releases/Pages/NR20180524.aspx



- **Transport Aviation (Part 121)**
- 2016 data
- 31 accidents
- 0 fatalities
- Safest form of transportation listed
- Public perception of a safe form of travel

- *Source: NTSB Aviation: data & stats*

Public Perception – Final

UAM Market Study – Crown Consulting. https://ntrs.nasa.gov/search.jsp?R=20190026762



- Findings
  - Concerns fall into 5 categories – Safety being one of them
    - Others privacy, job security, environmental threats, noise and visual disruption
  - Consumers cite proven safety records and demonstrations as factors that would most increase their level of comfort
- Crown suggests 3 strategies that could help address public acceptance
  - Technology R&D – establish safety standards, focus on noise abatement and safety systems
  - Unified messaging – address public concerns and emphasize benefits
  - Proactive engagement with concerned groups – identify and reach out to groups with resistance to UAM
- Community Air Mobility Initiative

Crash workshop @ LaRC 2020

