



Critical Underlying Needs for The Electric VTOL Revolution



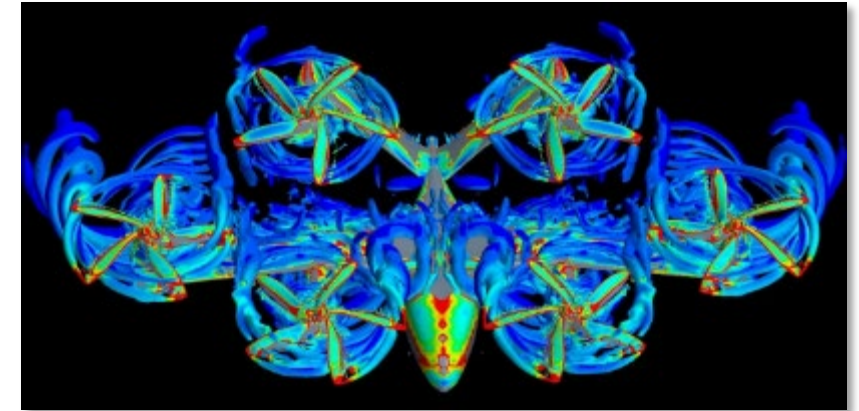
Mike Hirschberg, Executive Director

The Vertical Flight Society

www.vtol.org • www.eVTOL.news

What is The Vertical Flight Society?

- The international **professional society** for those **working to advance vertical flight**
 - Founded in 1943 as the **American Helicopter Society (AHS)**
 - Everything from VTOL **MAVs/UAS** to **helicopters, eVTOL, etc.**
- **Expands knowledge** about vertical flight technology and promotes its application around the world
- Advances **safety and acceptability**
- Advocates for vertical flight **R&D funding**
- Helps **educate and support** today's and tomorrow's vertical flight engineers and leaders
- **Brings together the community** — industry, academia and government agencies — to tackle the toughest challenges



CFD of Joby S4, Aug 2015



VFF Scholarship Winners at Forum 71, May 2015

Join us today: www.vtol.org

5 Key Challenges for eVTOL for UAM

1. **Technology:** batteries, motors, etc. for larger sizes, e.g. pilot + 4 pax
 2. **Infrastructure:** physical and ATM/UTM
 3. **Flying:** Pilot shortage vs. autonomy
 4. **Standards & Regulations:** in development
 5. **Public acceptance:** safety, noise, NIMBY
- + a rush for first mover advantage!*



Airbus 1-seat Vahana
(unmanned)



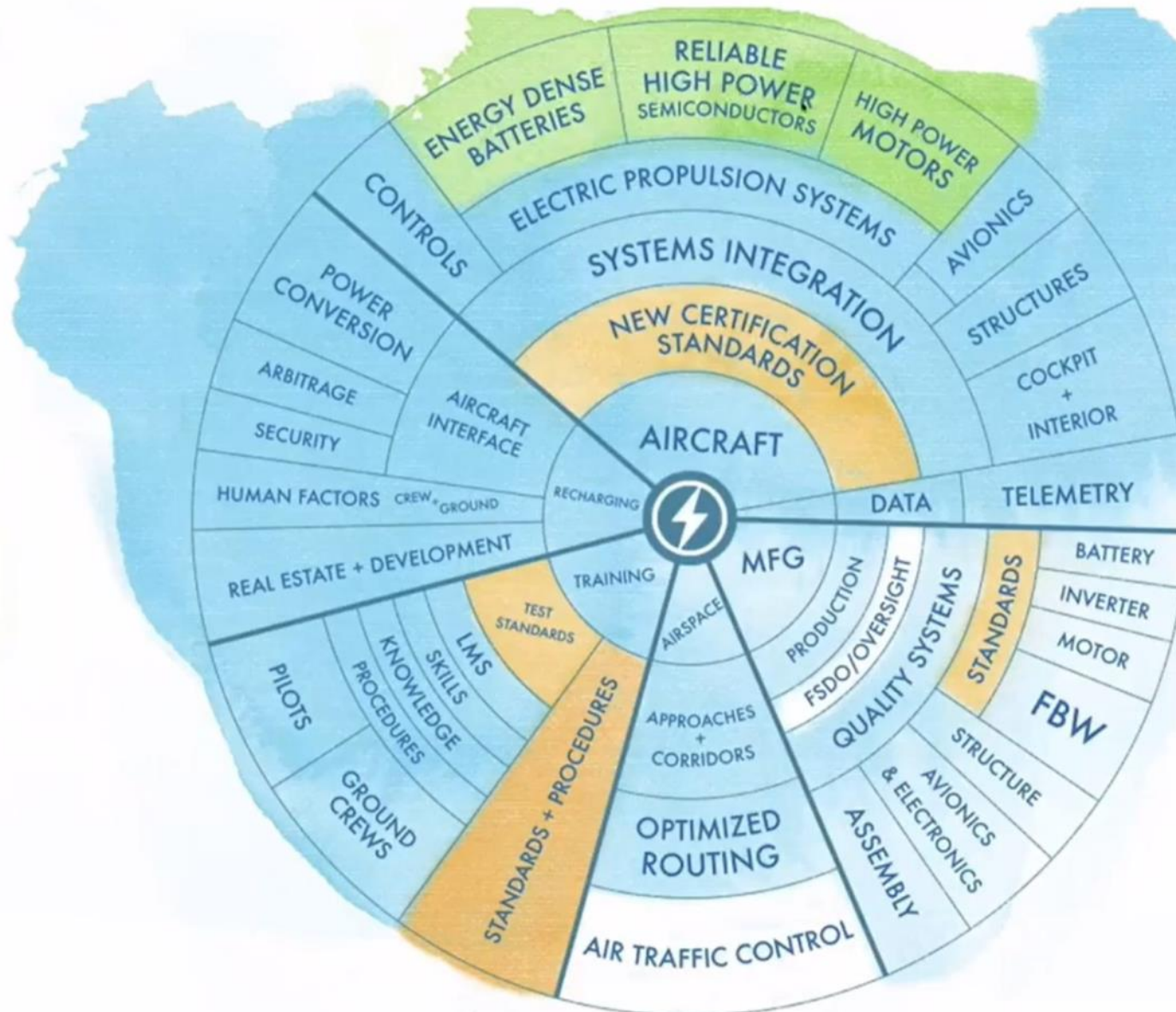
Boeing/Aurora 2-seat Passenger Air Vehicle
(unmanned)



Bell 5-seat Nexus 4EX
(mock-up)



Beta Technologies' Decomposition



Kyle Clark

CEO, Beta Technologies

Underlying Challenges

- NASA's UTM work with FAA has been a gamechanger
- NASA's AAM National Campaign identified many key issues
- Education / workforce / talent pipeline
- Test facilities

Vertical Flight Workforce

www.vtol.org/workforce

- eVTOL needs thousands more engineers!
 - US Army-Navy-NASA-funded Vertical Lift Research Centers of Excellence (VLRCOE) only producing dozens of grad students. Need more government & industry funding for university research/grads!
 - VLRCOEs are inadequately funded for existing demand — need +\$20–50M/yr more funding!
 - Each company needs 500-1,000 engineers to develop each eVTOL to certification (plus next gen)!
- Competition: Helicopter industry needs thousands of more engineers!
 - Huge new military and civil rotorcraft development programs — need thousands of more rotorcraft engineers in the coming decade-plus!
- Talent pipeline is underfunded — zero sum game!
 - Competition fierce for VTOL grads & experienced engineers!

**10,000 additional engineers
needed in the next decade!**

Talent Pipeline is Limiting Factor

www.vtol.org/workforce

- US government must recognize that sustained research investment is required to capitalize on this breakthrough technology
 - Current VTOL-trained graduate student production is a fraction of what is needed for national economic and security needs — risk of outsourcing jobs overseas
 - +\$20M/year govt investment will generate 100 additional VLRCOE graduates
 - The VLRCOEs pipeline is well developed but need to turn on the spigot
- Industry must recognize that workforce is a critical supply chain item
 - If eVTOL industry is investing >\$1B/year in vehicles, industry should invest 2-3%/year in university research to support the talent pipeline
 - An industry venture capital pool could create a human capital risk reduction fund
 - Industry/investor philanthropic funds could support Opportunity Zone projects for university infrastructure/research facilities, etc.

Vertical Lift Research Centers of Excellence

- Established in 1982. Broad collaboration across the US and abroad
 - Inter-center teaming on tasks encompassing aero, design, autonomy and more
 - 16 US universities in 3 centers

Georgia Tech

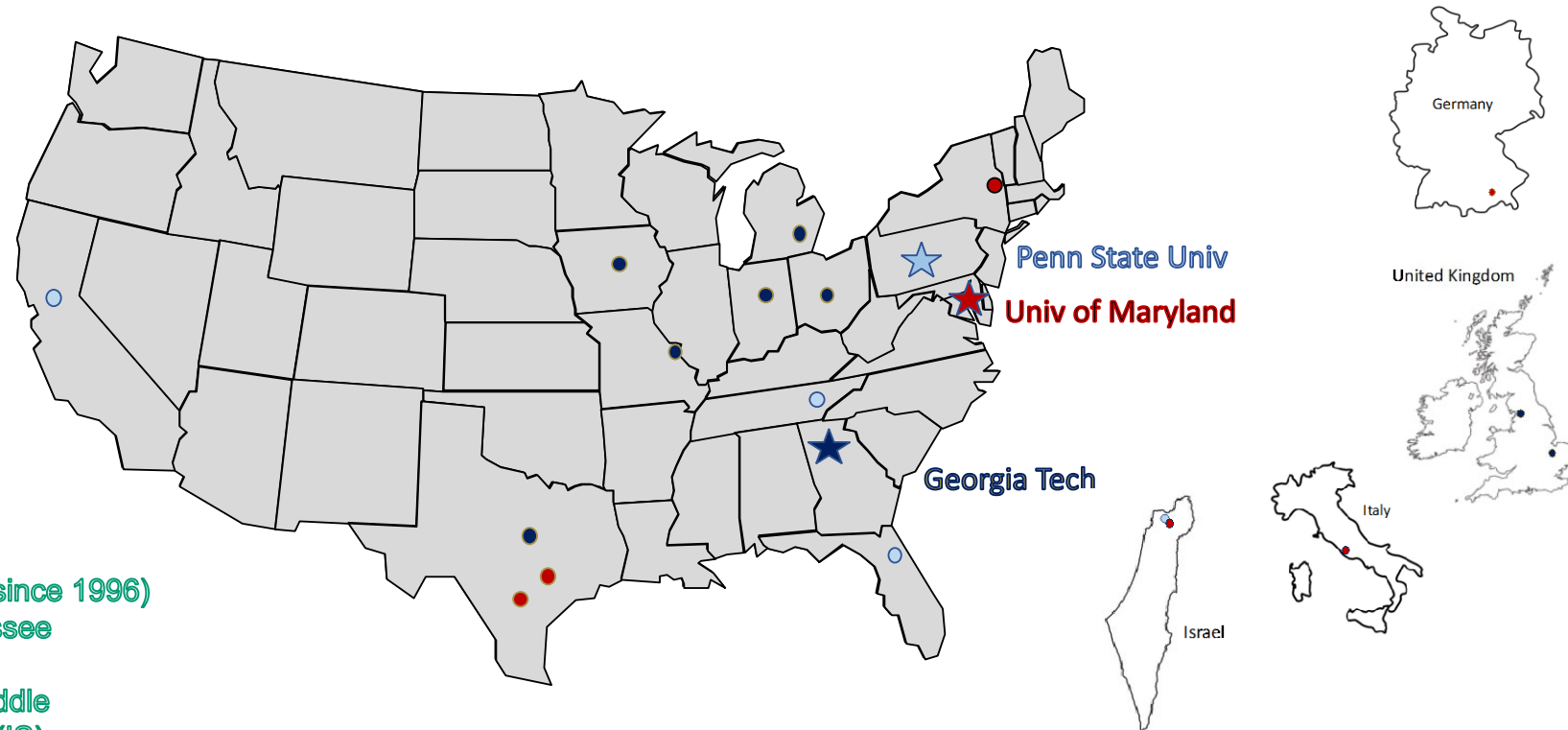
- Univ of MI
- Purdue
- Ohio State
- Washington U (STL)
- U. Texas – Arlington
- Iowa State
- U. Liverpool (UK)
- Cambridge (UK)

University of Maryland

- UT– Austin
- Texas A&M
- US Naval Academy
- RPI
- TU Munich (GR)
- Technion (IS)
- Roma Tre (IT)

Penn State (since 1996)

- U. Tennessee
- UC Davis
- Embry-Riddle
- Technion (IS)



Today's VLRCOE Program

- Total Funding remains at <\$5M/yr Government funds (Army, Navy, NASA)
- Significant cost share provided by University Centers (a challenge with COVID-19!)
- Competitive effort every five years
- Annual reviews of 40-50 government and industry representatives with significant guidance in research roadmaps
- Primarily focused on student support (stipend + medical + tuition)
- Acts as seed funding to attract other Vertical Lift research, ~4-8x
- Agile and innovative educational programs at both undergraduate and graduate levels in all matters related to Vertical Lift, including UAM and eVTOL

Industry-Academia-Collaboration



- Vertical Lift Consortium (VLC) has 200+ members
 - incl. 18 academic and non-profit organizations
- US Army previously had National Rotorcraft Technology Center (NRTC)
 - government-industry collaboration for pre-competitive research
- DoD/NASA should start a National VTOL Technology Center (NVTC)
 - Identify areas of research of interest to large parts of eVTOL industry
 - Universities submit 2-3 year grant proposals
 - \$5M/year, total (50% government, 50% industry) can result in an additional 50-65 trained graduate students joining the eVTOL workforce each year
 - Years 6-10, industry cost-share increase to 75% (government reduces to 25%)
 - Industry contribution 100% for potential IP/licensing rights (need to think about that)

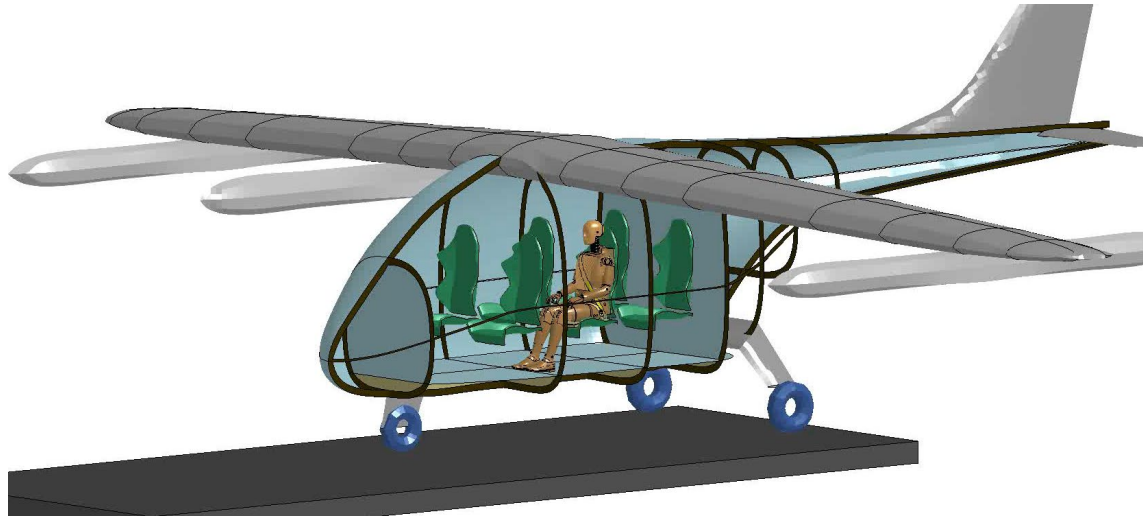
eVTOL Test Facilities Needed

- **Crashworthiness:**
 - Airplanes crash horizontally; rotorcraft crash vertically
 - What about unitized composite structures with lots of battery mass & distributed electric motor masses?
 - *New effort needed to understand eVTOL crash safety*
 - NASA eVTOL Crashworthiness webinar: April 7
nari.arc.nasa.gov/crashworthiness
 - Need to keep the LandIR facility operational
- **What other test facilities are needed?**
 - NASA Langley created City Environment for Range Testing of Autonomous Integrated Navigation (CERTAIN) – what is needed for UAM?



Vehicle Tech – Energy Absorbing (EA) Additions

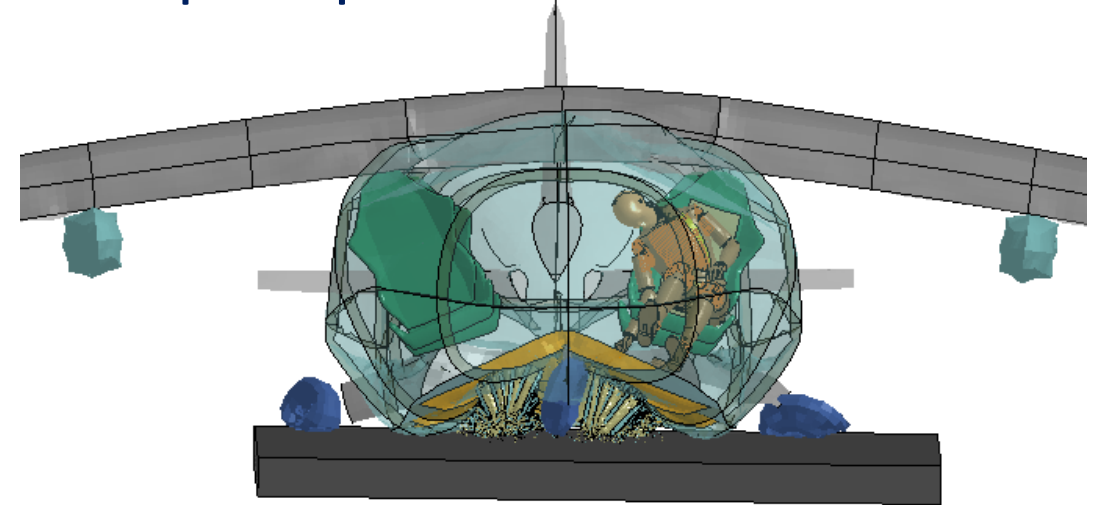
- Using 30 ft/s from NASA Case Study for impact velocity
- NASA RVLT Lift+Cruise baseline vs added occupant protection



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

Putnam, J.B. and Littell, J.D. “Crashworthiness of a Lift plus Cruise eVTOL Vehicle Design within Dynamic Loading Environments.”
To be presented at the Vertical Flight Society International Annual Forum 76, Virginia Beach, Virginia USA, Oct. 6-8, 2020.

Recommendations to Address Underlying Challenges

- NASA's UTM work with FAA has been a gamechanger
- NASA's AAM National Campaign identified many key issues
- Education / workforce / talent pipeline
 - NASA needs to step up and invest more in vertical flight education, e.g. VLRCOEs, University Leadership Initiative (ULI)
- Test facilities
 - NASA should review its test facilities for suitability to support AAM aircraft development