The Future of Vertical Flight: How Do We Get There?

www.eVTOL.news/news

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VTOL Innovators – Then and Now

1st AHS Banquet
1944

1st eVTOL Workshop
2014
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

Join us today: www.vtol.org
A 75+ Year Legacy

- VFS has a long history of advocacy and leadership
  - Helped establish NASA-Army Joint Office, Nat’l Rotorcraft Technology Center (NRTC), Centers of Excellence, RITA/VLC
  - Worked with NASA and DoD to save the NFAC wind tunnel

- Provided major support to transformative initiatives
  - Joint Strike Fighter/F-35B STOVL Lightning II
  - V-22 Osprey tiltrotor

- Providing major foundational support to new transformative initiatives
  - Future Vertical Lift (FVL)/Joint Multi-Role (JMR)
  - Electric and hybrid-electric VTOL (eVTOL)

VFS Works to Advance Vertical Flight!
V-22 only new U.S. military rotorcraft design fielded in past 30 years; CH-53K in service in 2023-2024

All other deployed designs are 30-50 years old
- UH-1 Huey first flight 1956; Chinook 1961; Black Hawk 1975; Apache 1976
- Many 1960s airframes are still flying!
- CH-53K only new design in acquisition process
- OH-58 Kiowas in service from 1969 to 2017
**Investments in RDT&E Needed for Next Generation Capabilities**

**1st Gen**
- R-6, H-21
- Airspeed <100 kts
- Reciprocating Engines
- Wood Rotor Blades
- Mechanical Controls
- No Survivability

**2nd Gen**
- UH-1, AH-1
- Airspeed <130 kts
- Turboshaft Engines
- Metal Rotor Blades
- Improved Flight Controls
- Metal Structure
- Reduced Vulnerability
- Passive Survivability
- Countermeasures
- Crashworthiness
- Weapons Integration

**3rd Gen**
- UH-60, AH-64, CH-47
- Airspeed >150 kts
- Efficient Engines
- Advanced Blade Design
- Fly-By-Wire Flight Controls
- Composite Structures
- Improved Survivability
- Limited Open Systems Architecture (OSA)

**4th Gen**
- RAH-66, CH-53K
- Airspeed >170 kts
- Advanced Engines
- Fly-By-Wire Flight Controls
- Improved Avionics
- Reduced IR Signatures
- Active Survivability
- Countermeasures
- Improved Crash Safety

**5th Gen**
- FVL, MUX, FTUAS
- Airspeed >200 kts
- Multi-Speed Engines/Transmissions
- Fly-By-Wire Flight Controls
- Individual Blade Control
- Common, Resilient Digital Backbone (Modular Open Systems Architecture)
- Advanced MUM-T (supervised autonomy) and Optionally Crewed Vehicle
- Advanced ASE
- Active Crash Safety Systems
- Holistic Situational Awareness & Decision Aiding
- Degraded Visual Environment

**Generations**
- 1st Gen: 1940-1960
- 2nd Gen: 1960-1980
- 4th Gen: 2000-2020
- 5th Gen: 2020-2040

**Investments in RDT&E Needed for Next Generation Capabilities**

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5 Capability Sets from Light to Ultra Heavy
- Plus advanced unmanned programs

Joint Multi-Role (JMR) Technology
Demonstrations – 30,000 lb-class (13.6 t)
- Bell V-280 Valor and Sikorsky-Boeing SB>1 Defiant
- *US industry has invested ~$1B in JMR at 4:1 government spending*

Currently 3 Capability Sets in planning
- **CS1** (Light): Army’s Future Attack Reconnaissance Aircraft (**FARA**) to replace Kiowa Warriors
- **CS2** (Medium): Navy to replace Seahawks/Fire Scouts with **FVL Maritime Strike**
- **CS3** (Medium heavy): Army’s Future Long-Range Assault Aircraft (**FLRAA**) to replace Black Hawks; Attack/Utility Replacement Aircraft (**AURA**)
Sikorsky Boeing SB>1 Defiant
JMR Demonstrator
Future Attack Reconnaissance Aircraft (FARA)
Sikorsky S-97 Raider for FARA
Compounds & Tiltrotors

Sikorsky-Boeing SB>1 Defiant™ (2019)
30,000 lb (13.6 t) class

Sikorsky S-97 Raider™ (2015)
11,000 lb (5 t)

Sikorsky X2 Technology™ Demonstrator (2008)
5,500 lb (2.5 t)

Bell Helicopter V-280 Valor (2017)
30,000 lb (13.6 t) class

Leonardo (with Bell) AW609 (2003)
16,800 lb (7.6 t)

Bell Boeing V-22 Osprey (1989)
52,600 lb (23.8 t)
Clean Sky 2: Next Gen Civil Tiltrotor (NGCTR)
Clean Sky 2: Leonardo NGCTR Demonstrator

- New Wing (no dihedral and no swept) Integration (T-WING)
- Advanced empennage configuration (LITFTE)
- Innovative fuel system (DigiFuel & DEFENDER)
- Mast tilt for control improvement (LH)
- Distributed FCS system (LH)
- New control laws (LH)
- Flow through engine
- Splitted gearbox architecture to support non tilting engine (LH)
Clean Sky 2: Airbus RACER
Civil rotocraft production is expected to dip again near term, but longer-term growth expected:

- 2019: $5.6B / 1,100 aircraft
- 2030: $8.6B / 1,400 aircraft
- +53% in production value
- +25% in units (more expensive civil rotocraft)
Forecast International’s global Platinum Forecast database:

**Military rotorcraft production** expected to continue slow decline:
- 2019: $14.8B / 615 aircraft
- 2030: $12.3B / 448 aircraft
- -17% in production value
- +27% in units (more expensive military rotorcraft)
Vertiflite Covers Advanced VTOL (including eVTOL)
Electric & hybrid electric propulsion enable new possibilities for:

- Regional/Rural Air Mobility (RAM)
- Urban Air Mobility (UAM)/Air Taxis
- Urban Cargo Delivery/Disaster Relief
- Personal Air Vehicles
- Ultralights
- Personal Flying Devices
- Urban Package Delivery
eVTOL Ultralights Are Flying In the US/Canada

- Flight experience offerings
- Ultralights under FAR Part 103 do not require certification
- Less than 254 lb (115 kg) plus 30 lb per float plus parachutes, etc.
- Restricted in speed, overflights, etc.
- Opener and Kitty Hawk have made 20,000+ flight each!

Like flying jet skis!

Kitty Hawk Flyer (<254 lb)
Hoversurf Scorpion (<254 lb)
Opener BlackFly (310 lb)
LIFT Aircraft Hexa (462 lb)
Jan 2020 Unveilings

- Bell unveils all-electric Nexus 4EX at CES
- Hyundai unveils S-A1 eVTOL concept at CES and pledges $1.5B for UAM
- Joby Aviation’s Series C investment led by Toyota with $394M. Total = $720M overall.
Electric Helicopters?

- Eliminate complex rotors!
  - Cyclic, collective, swashplate
  - Transmissions, gearboxes, shafting, hydraulics, etc.
- Distributed Electric Propulsion
  - Replace single complex system with multiple simple thrusters
- Get on a wing for efficiency
  - Higher speed, longer range
- Environment
  - Noise, noise, noise!
  - "Tailpipe" emissions

- Sikorsky “Firefly” Project (2010)
  - Conversion of S-300C to electric power
Advancements in electric motors
+ Advancements in batteries
+ Advancements in computer modeling and simulation
+ Advancements in composites
+ Low cost manufacturing
+ Movement to performance regs
+ Tech innovations
+ Tech investments > $2B

= Enabling new configurations and new innovations
“The Hype Cycle”

- Peak of Inflated Expectations
- Trough of Disillusionment
- Slope of Enlightenment
- Plateau of Productivity

"The Hype Cycle"

ATTENTION:
The eVTOL Revolution Needs YOU!


www.eVTOL.news
Will the eVTOL Revolution Succeed?

- eVTOL must have low direct operating costs and seat mile costs to be successful
- Batteries will continue to improve
  - Drones: 1.5M drones registered in US (Jan 2020) and 162,000+ registered drone operators.
  - EVs: Tesla Model S started in 2012, now all car companies have electric cars. Much lower operating costs vs. fuel-burning cars.
  - Look at your laptop or cell phone today compared to 10 & 20 years ago
- Cost: eVTOL aircraft will be much cheaper/easier to manufacture, for much higher production rates/reduced costs vs. helicopters (but cars?)
- Noise: much lower, allowing more operations in higher density locations

*Potential for step-change in utilization by improved cost, noise & speed*
Uber Elevate

- **Uber Elevate & VFS**
  - Unveiled at eVTOL Workshop in Sep 2016
  - Summits April 2017, May 2018, June 2019

- **Developing an “Ecosystem”**
  - Partnerships with cities, real estate companies, aircraft manufacturers, and EV charger companies, etc.
  - Connecting innovators, investors, regulators, technical experts, media

- **Small aircraft, but high barriers**
  - Technical, regulatory, environmental, *economic*, infrastructural and cultural

Uber plans test flights in 2020 and operational service in 2023!
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!
The Electric VTOL News
www.eVTOL.news

- World eVTOL Aircraft Directory
  - Everything from the silly to the serious
- **253** aircraft (as of 4 Feb 2020)
  - 97 Vectored Thrust
  - 37 Lift + Cruise
  - 54 Wingless (multicopters)
  - 46 Hover Bikes/Flying Devices
  - 19 eHelos & eGyros
- 188 eVTOL companies/designers
- 230+ VFS articles on eVTOL
- Timeline, maps, company directory, educational videos, etc.
eVTOL Online Resources

- Electric VTOL News
  - www.eVTOL.news
  - www.facebook.com/electricVTOL
  - www.twitter.com/electricVTOL
  - www.youtube.com/VTOLsociety
  - www.instagram.com/VTOLsociety
  - www.vimeo.com/VTOLsociety

- Also
  - Electric VTOL eNewsletter
  - eVTOL News videos
  - eVTOL video presentations (100+ hours)
  - eVTOL short course videos (20 hours)
VFS eVTOL Events

- **Transformative Vertical Flight 2020 @ San Jose, California, Jan. 21–23, 2020**
  - 7th Annual Electric VTOL Symposium
  - 500 attendees, 17 exhibitors, 11 sponsors, NASA tour

- **2nd Workshop on Electric VTOL Infrastructure**
  - Glassboro, NJ, March 17-19, 2020
  - Supporting FAA Tech Center, Atlantic City
  - City planners, architectural firms, utilities, etc.
  - www.vtol.org/infrastructure

- **76th Annual Forum, Montreal, May 19-21, 2020**
  - 1,400 rotorcraft & eVTOL engineers, scientists and leaders from industry, academia and governments
  - ~250 technical papers, ~75 panelists, ~75 exhibitors
  - www.vtol.org/forum
Final Fly Off
Feb 27-29th @ Moffett Federal Airfield
NASA Ames Research Center
Moffett Field, CA, USA
www.GoFlyPrize.com
Where We Are Now

First hover
2011 e-Volo VC1 (Karlsruhe, Germany)

First public demos
2019 Volocopter 2X
Mercedes-Benz Museum (Stuttgart)

Capable product
2019 Concept Volocopter VoloCity

Advanced product
TBD
eVTOL Supply Chain Challenges (1)

- Need 10,000 eVTOLs/year. Aerospace supply chain not prepared for this!
  - Even with those quantities, the automotive supply chain will not be interested
  - Commercial vehicle (i.e. trucks) and military ground vehicle suppliers are more closely aligned in terms of volume and possibly reliability/environment

- Required electronics content will be a challenge
  - High volume (low cost) suppliers will struggle to meet aero requirements (energy density, power density, etc.)
  - Commonality and flexibility across platforms can provide some relief

- Electric motors, controllers & batteries all require “rare-earth” raw materials (Lithium, Cobalt, Neodynium, Samarium, etc.)
  - Limited sources ... from sometimes “undesirable” nations
  - Other industries are also increasing the use of these materials (automotive, industrial, power grid, etc.)
eVTOL Supply Chain Challenges (2)

- Novel materials / processes will be used in the development of the infrastructure
  - Current heliports typically do not see the volume of traffic anticipated by UAM
  - Lighting, surface treatment, etc. will require advancement to deal with this volume of traffic.
  - Substation required for charging demands ("grocery store" equivalent power for each aircraft)

- Efficiency will be key in maintaining the fleet load factor and utilization
  - Delivery of electrical power to the aircraft (infrastructure design & Mfg.)
  - Charging of the aircraft ( vertiport design/mfg.)
  - Passenger em-/deplaning (aircraft design/mfg.)
  - Optimization vs. commonality
Use of performance-based standards to show means of compliance will be effective in reducing the complexity of design/mfg.
  – Industry is still not sure how to achieve this

Getting AS9100 certified will be required
  – There are no shortcuts or comparable documentation sets in ground vehicle

Testing methodology is very different from ground vehicle

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 Workshop: April 7 @ NASA Langley
    nari.arc.nasa.gov
eVTOL Workforce

- Helicopter industry has a shortage of pilots, mechanics, etc.
  - 2018 HAI/North Dakota study indicated a shortfall of 7,649 helicopter pilots and 40,613 mechanics in the U.S. between 2018 and 2036.

- Rotorcraft industry needs more engineers
  - Huge new military and civil rotorcraft development programs — need thousands of more rotorcraft engineers in the coming decade-plus
  - Competition is fierce for rotorcraft grads and experienced professionals

- eVTOL needs more pilots, engineers, mechanics, etc.
  - 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
  - Need 500-1,000 engineers to develop each eVTOL to certification, then upgrades
  - First generations of eVTOLs will be piloted. Need 50,000 pilots ... at least temporarily.
  - Instead of A&P mechanics, do we need A&E’s?

- Need a National eVTOL Strategy for workforce, infrastructure, batteries, etc.
The Electric VTOL Revolution is on track for 2023

“There are 1,000 reasons why eVTOL won’t work — we have to find solutions to all of them to find the path that does work”

eVTOL is the intersection of aerospace, automotive, electric, AI, drones, etc.

To invent to a new industry, it will take everyone’s efforts

VFS is leading eVTOL efforts

- It takes a village
- It takes a town
- It takes a city
- It takes a county
- It takes a state
- It takes a nation
- It takes a society
- It takes the world
- It takes you

Join us!
VFS is the global Vertical Flight Society
- We are helping to shape the future of vertical flight!
- $Billions going into new military & civil high-speed/long range rotorcraft
- Find out more at www.vtol.org

Significant funds being invested in electric VTOL (> $2.5B)
- 2nd Infrastructure Workshop: March 17-19 near Philly
- 250+ concepts — significant work in hybrid/electric VTOL aircraft
- The explosive interest in drones is being repeated with manned eVTOL
- The Electric VTOL Revolution is transformative like the turbine engine
- Find out more at www.eVTOL.news