



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

www.eVTOL.news/news



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The Vertical Flight Society

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VTOL Innovators – Then and Now

1st AHS Banquet
1944

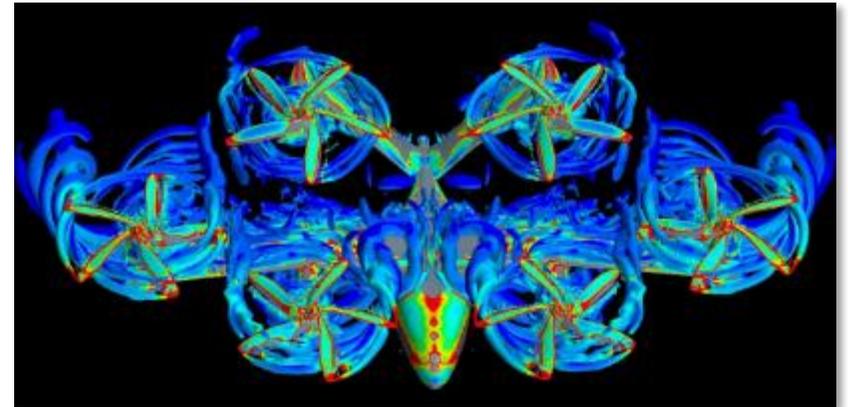


1st eVTOL Workshop
2014



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



CFD of Joby S4, Aug 2015



VFF Scholarship Winners at Forum 71, May 2015

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)



NFAC 40 ft x 80 ft wind tunnel
Courtesy of NASA



Future Vertical Lift (FVL)
Sikorsky-Boeing Defiant and Bell Valor

VFS Works to Advance Vertical Flight!

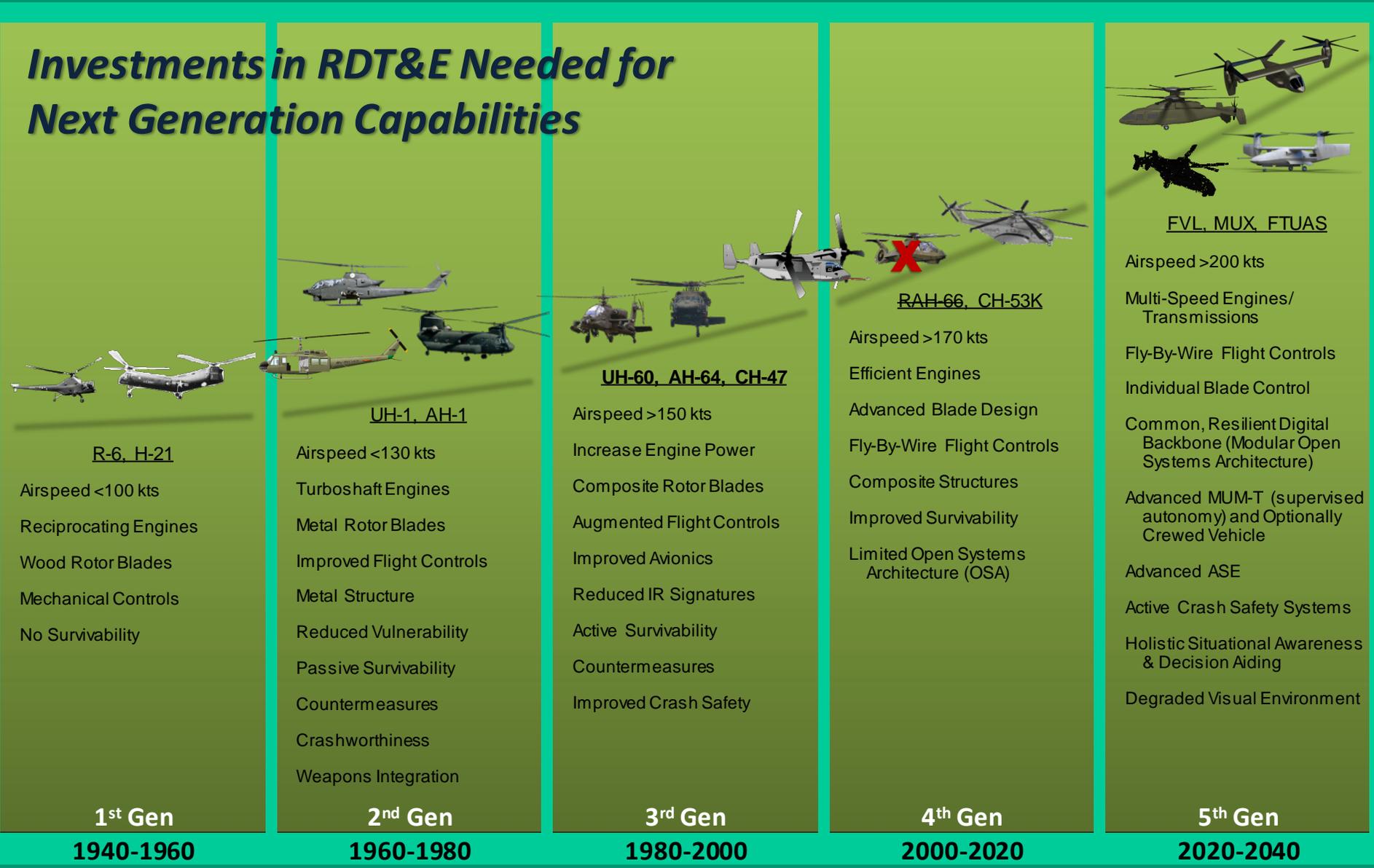
Aging U.S. Military Fleet

- 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



Rotorcraft Generations

Investments in RDT&E Needed for Next Generation Capabilities



Future Vertical Lift (FVL)

- **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 JMR Demonstrator



Sikorsky Boeing SB>1 Defiant JMR Demonstrator



Bell V-280 Valor JMR Demonstrator



Future Attack Reconnaissance Aircraft (FARA)



Boeing
?



Sikorsky S-97 Raider for FARA



Compounds & Tiltrotors

Sikorsky-Boeing SB>1 Defiant™ (2019)



30,000 lb (13.6 t) class

Bell Helicopter V-280 Valor (2017)



30,000 lb (13.6 t) class

Sikorsky S-97 Raider™ (2015)



11,000 lb (5 t)

Leonardo (with Bell) AW609 (2003)



16,800 lb (7.6 t)

Sikorsky X2 Technology™ Demonstrator (2008)



5,500 lb (2.5 t)

Bell Boeing V-22 Osprey (1989)



52,600 lb (23.8 t)

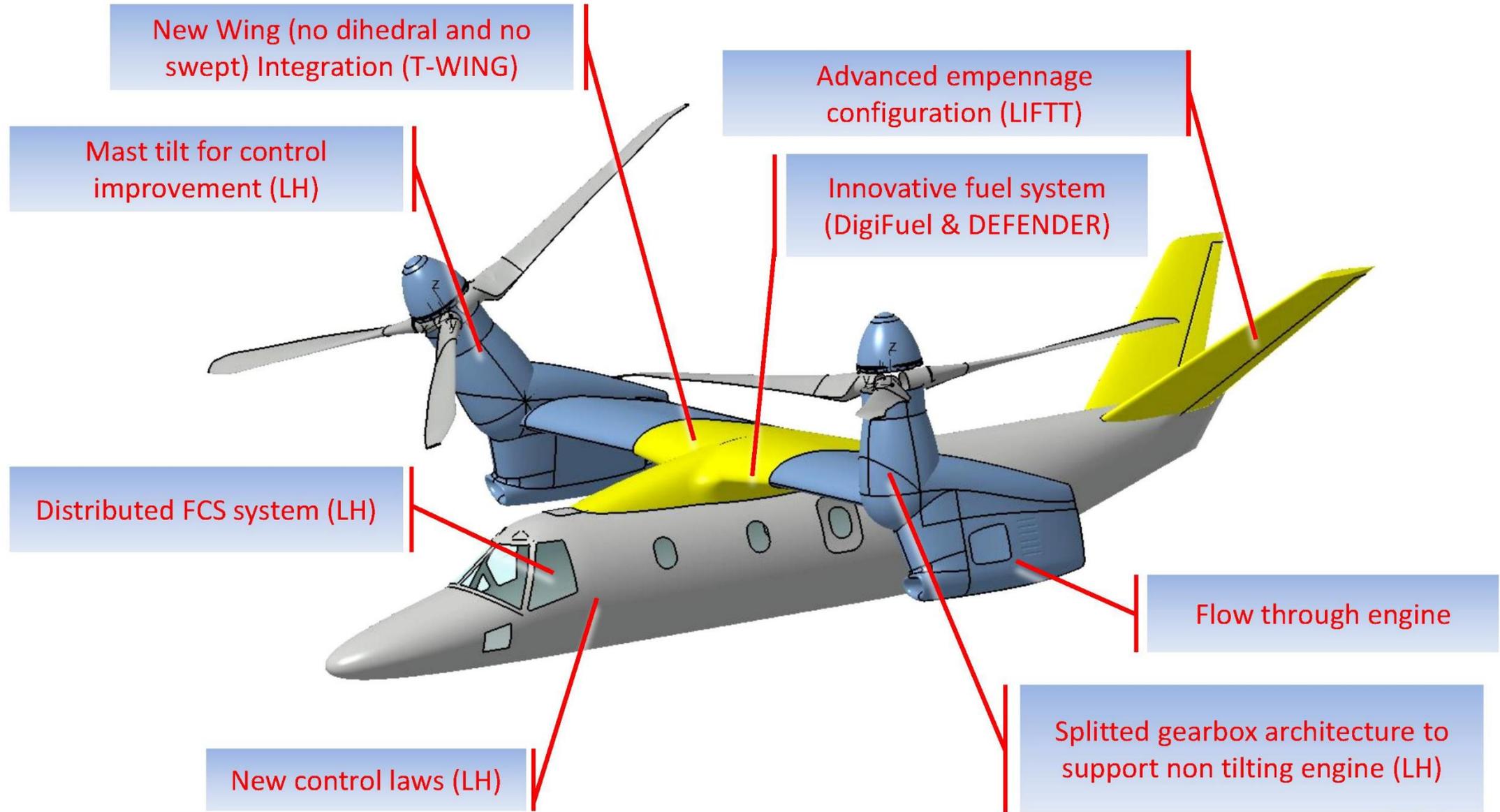
AW609 Civil Tiltrotor



Clean Sky 2: Next Gen Civil Tiltrotor (NGCTR)



Clean Sky 2: Leonardo NGCTR Demonstrator



Clean Sky 2: Airbus RACER



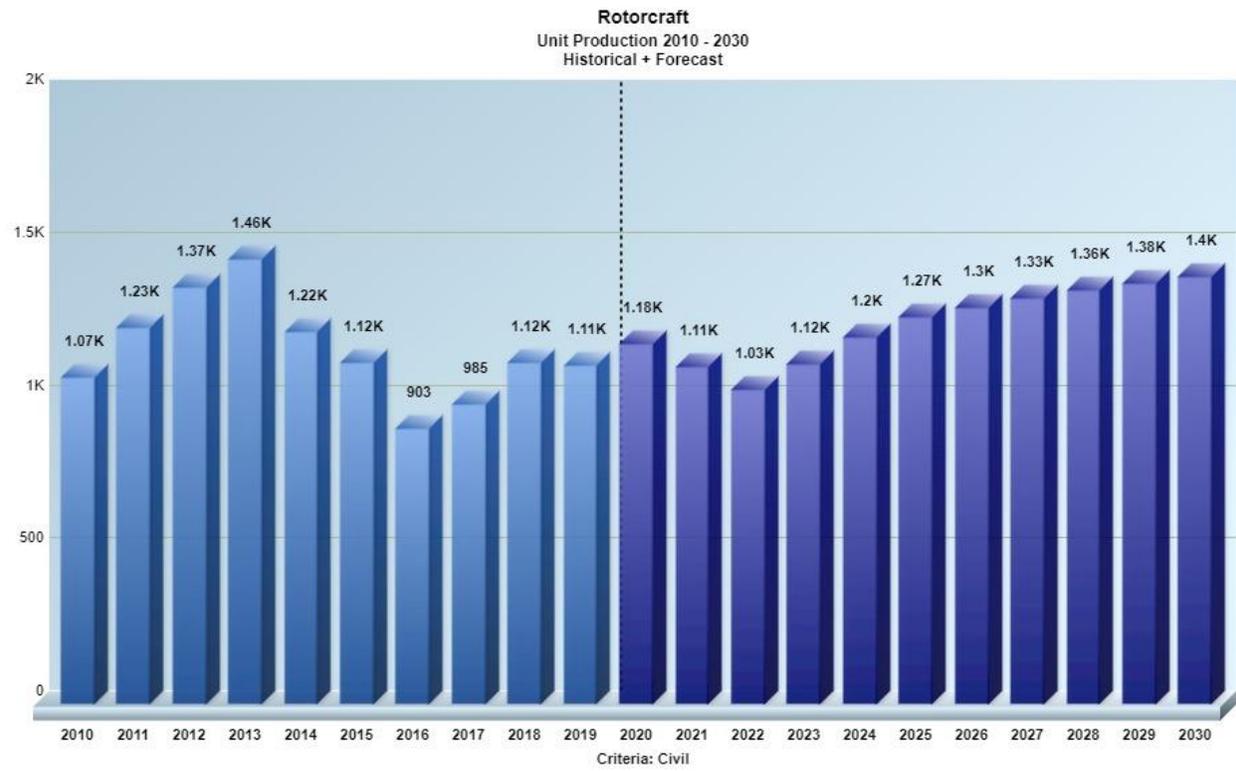
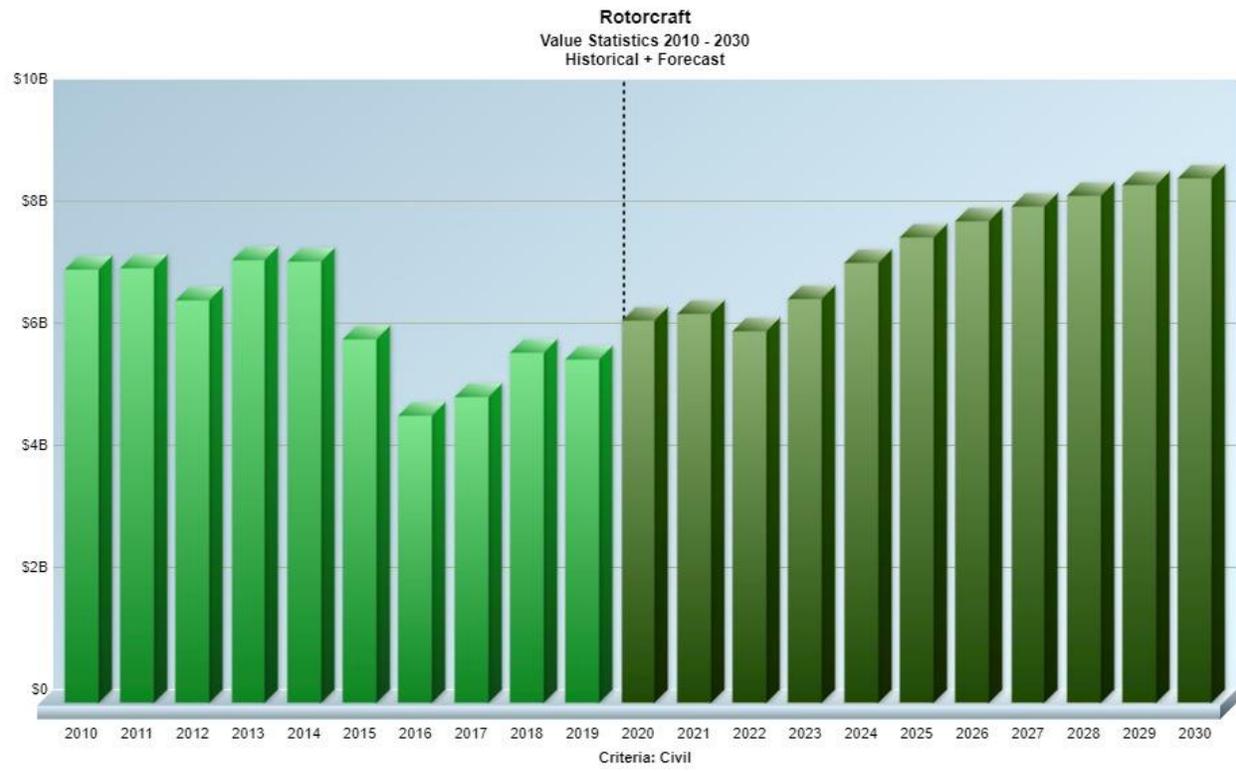
Global Civil Rotorcraft Production

Forecast International's global Platinum Forecast database (does not include eVTOL):



Civil rotorcraft 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 rotorcraft)



Global Military Rotorcraft Production

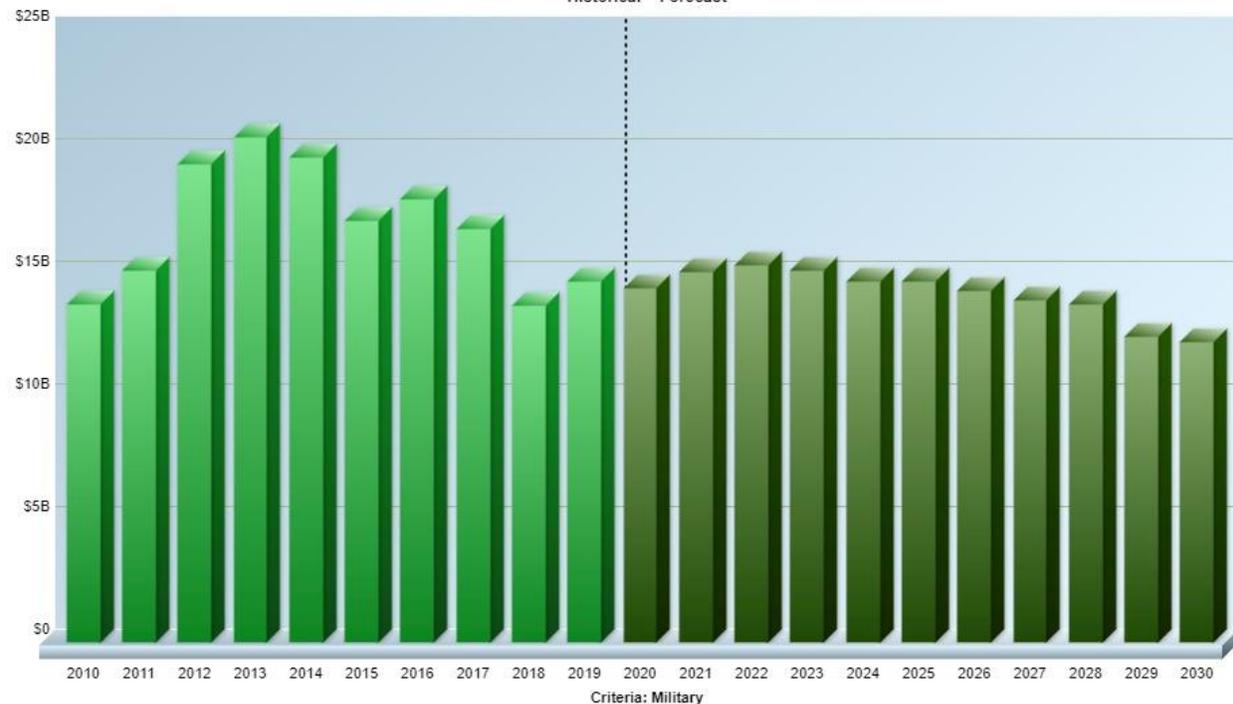
Forecast International's global Platinum Forecast database:

Military rotorcraft production expected to continue slow decline:

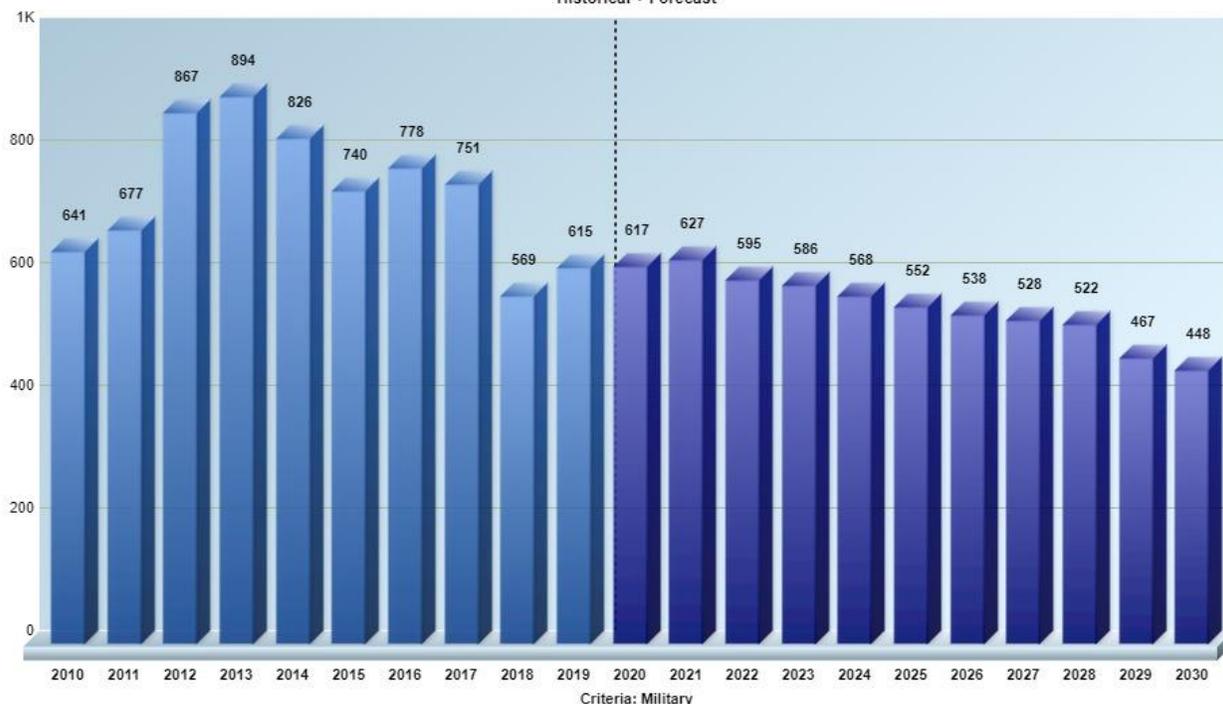
- 2019: \$14.8B / 615 aircraft
- 2020: \$12.3B / 448 aircraft
- -17% in production value
- +27% in units (more expensive military rotorcraft)



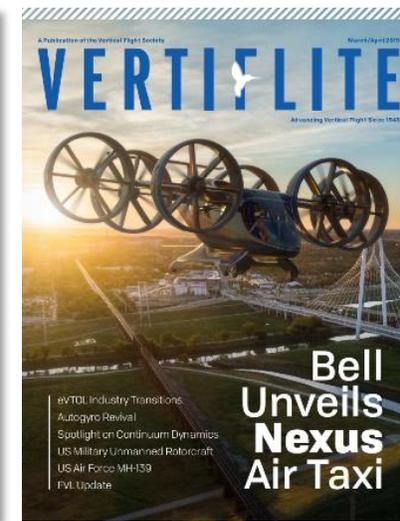
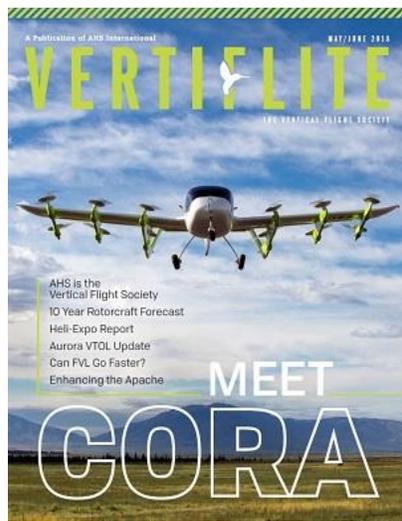
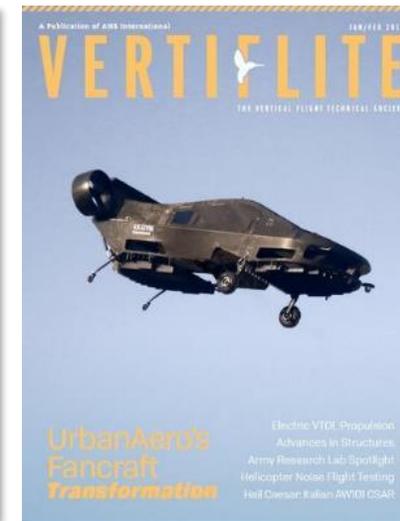
Rotorcraft
Value Statistics 2010 - 2030
Historical + Forecast



Rotorcraft
Unit Production 2010 - 2030
Historical + Forecast



Vertiflite Covers Advanced VTOL (including eVTOL)



The Electric VTOL Revolution

- 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

Heavier, Hybrid



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)



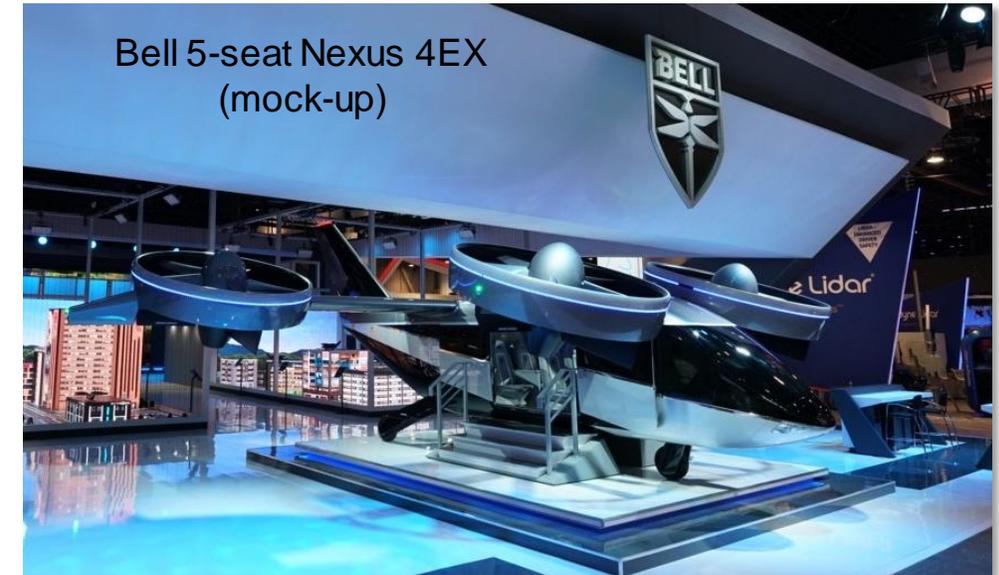
LIFT Aircraft Hexa (462 lb)

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.



Joby Aviation S4 Production Prototype



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



Hyundai S-A1 (mock-up)

Electric Helicopters?

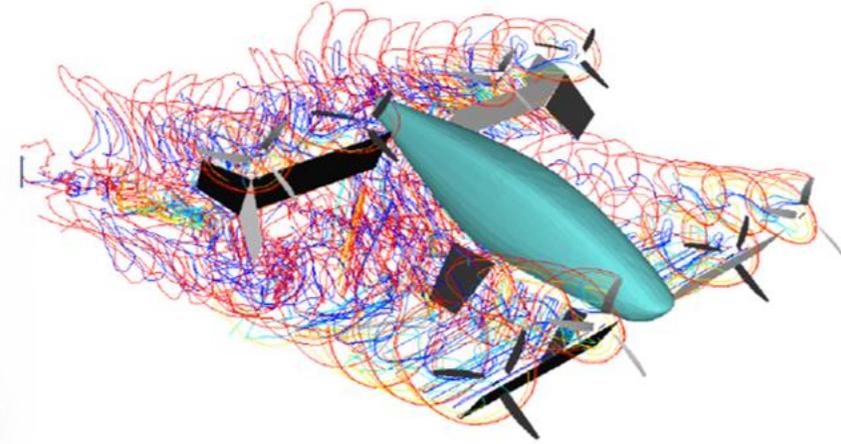


- Sikorsky “Firefly” Project (2010)
 - Conversion of S-300C to electric power

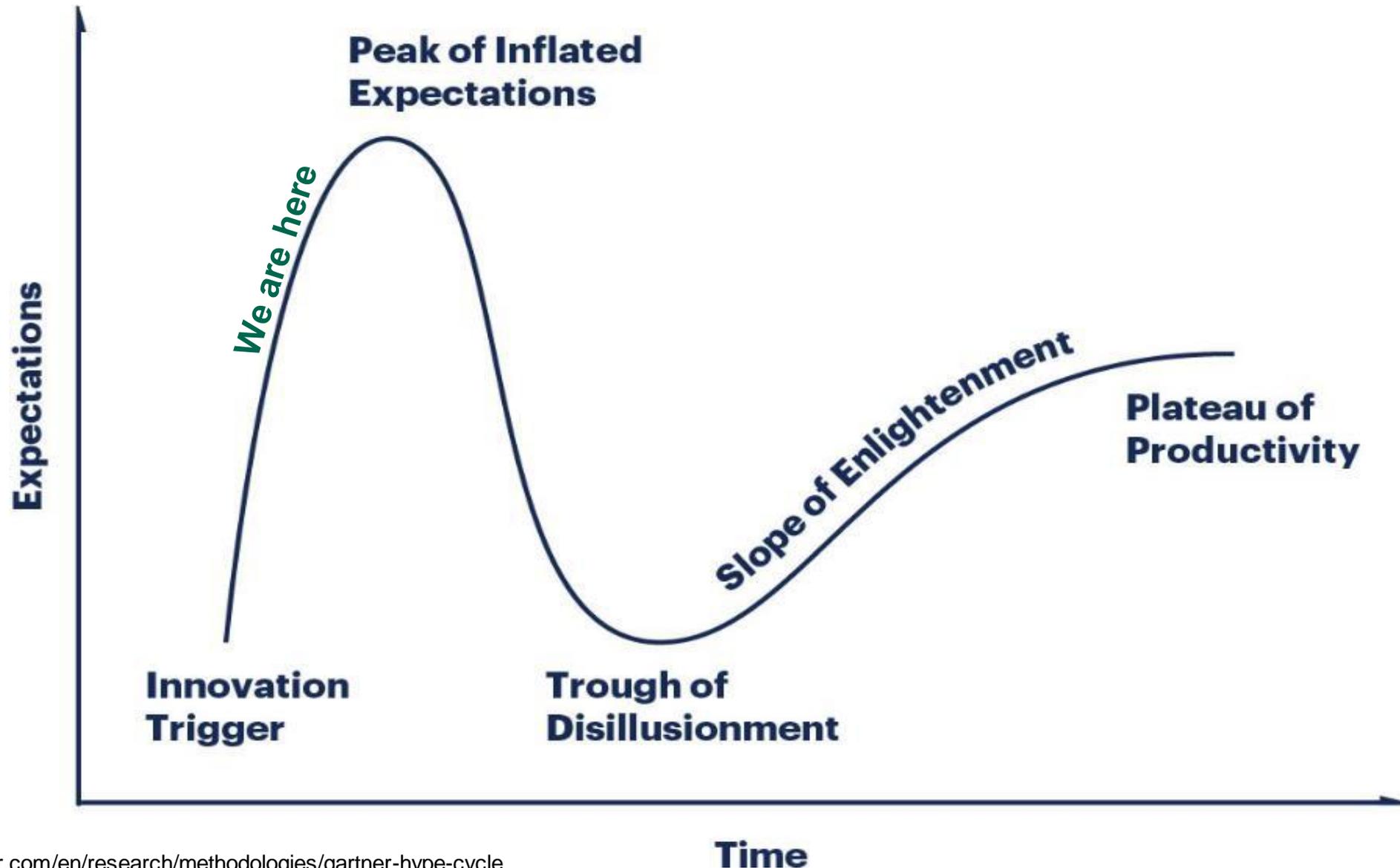
- Eliminate complex rotors!
 - Cyclic, collective, swashplate
 - Transmissions, gearboxes, shafting, hydraulics, etc.
- Distributed Electric Propulsion
 - Replace single complex system with multiple simple thrusters
- Get on a wing for efficiency
 - Higher speed, longer range
- Environment
 - Noise,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

Why Now?

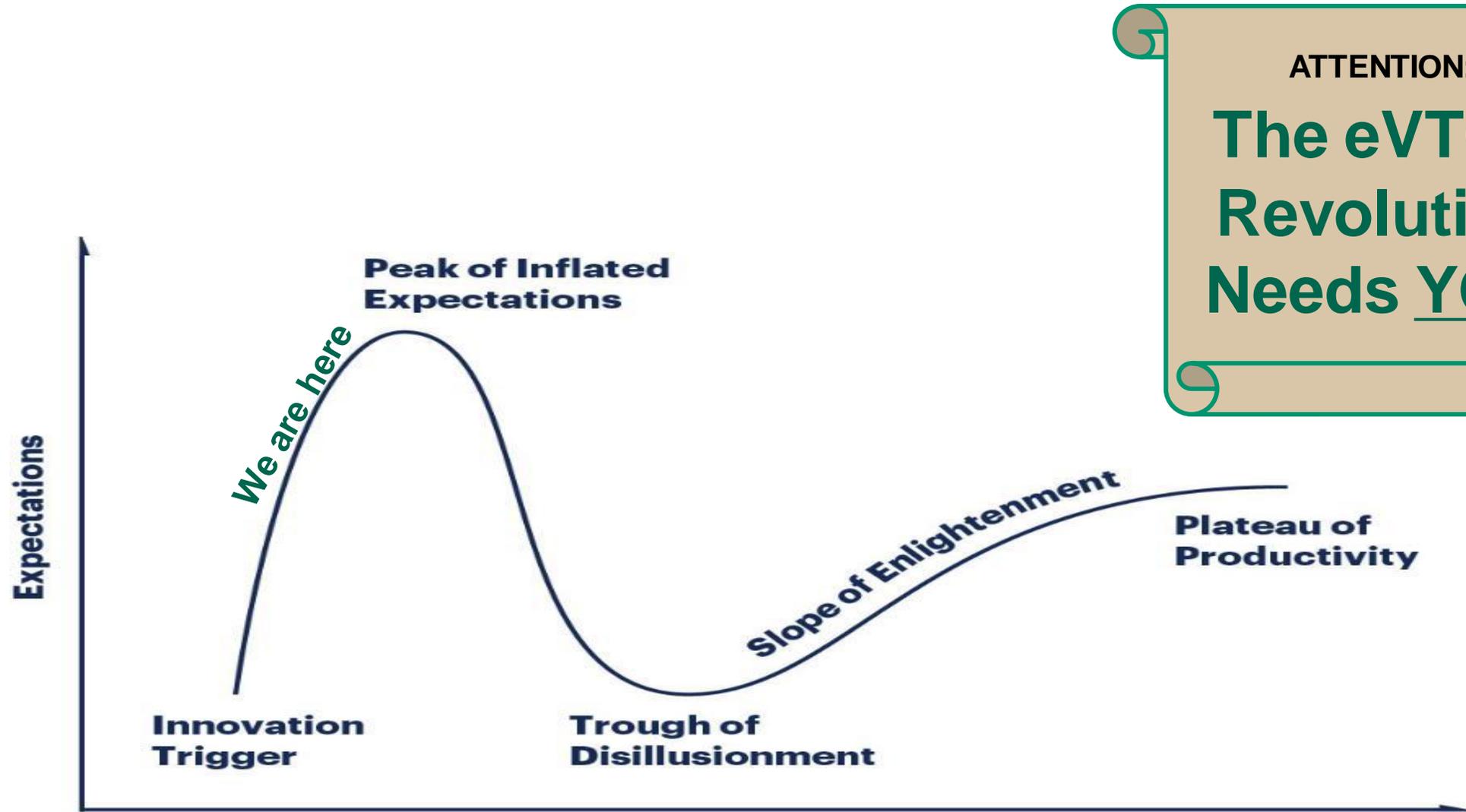
- Advancements in electric motors
- + Advancements in batteries
- + Advancements in computer modeling and simulation
- + Advancements in composites
- + Low cost manufacturing
- + Movement to performance regs
- + Tech innovations
- + Tech investments > \$2B
- = **Enabling new configurations and new innovations**



“The Hype Cycle”



“The Hype Cycle”



ATTENTION:
**The eVTOL
Revolution
Needs YOU!**

Will the eVTOL Revolution Succeed?

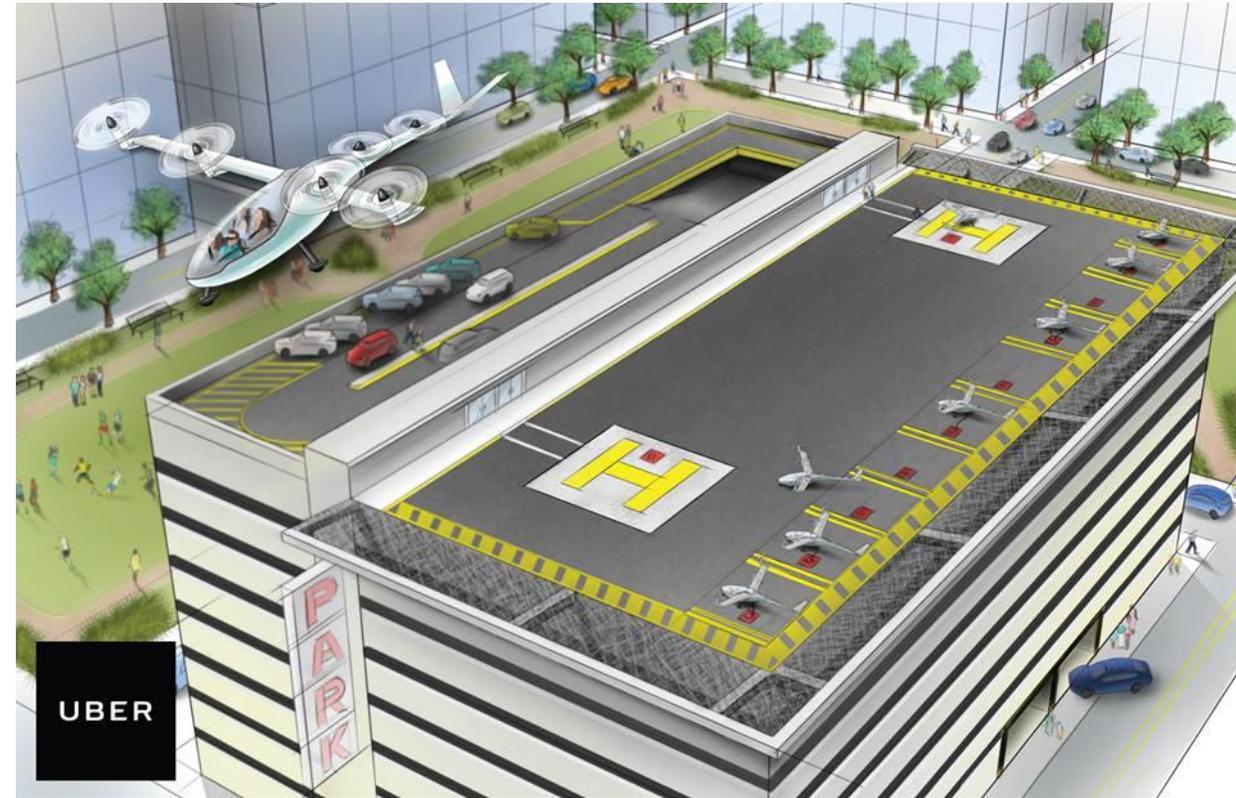
Overair (Karem) Butterfly

- 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
 - White Paper in Oct 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!*



Airbus 1-seat Vahana
(unmanned)



Boeing 2-seat Passenger Air Vehicle
(unmanned)



Airbus 4-seat CityAirbus
(unmanned)



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.



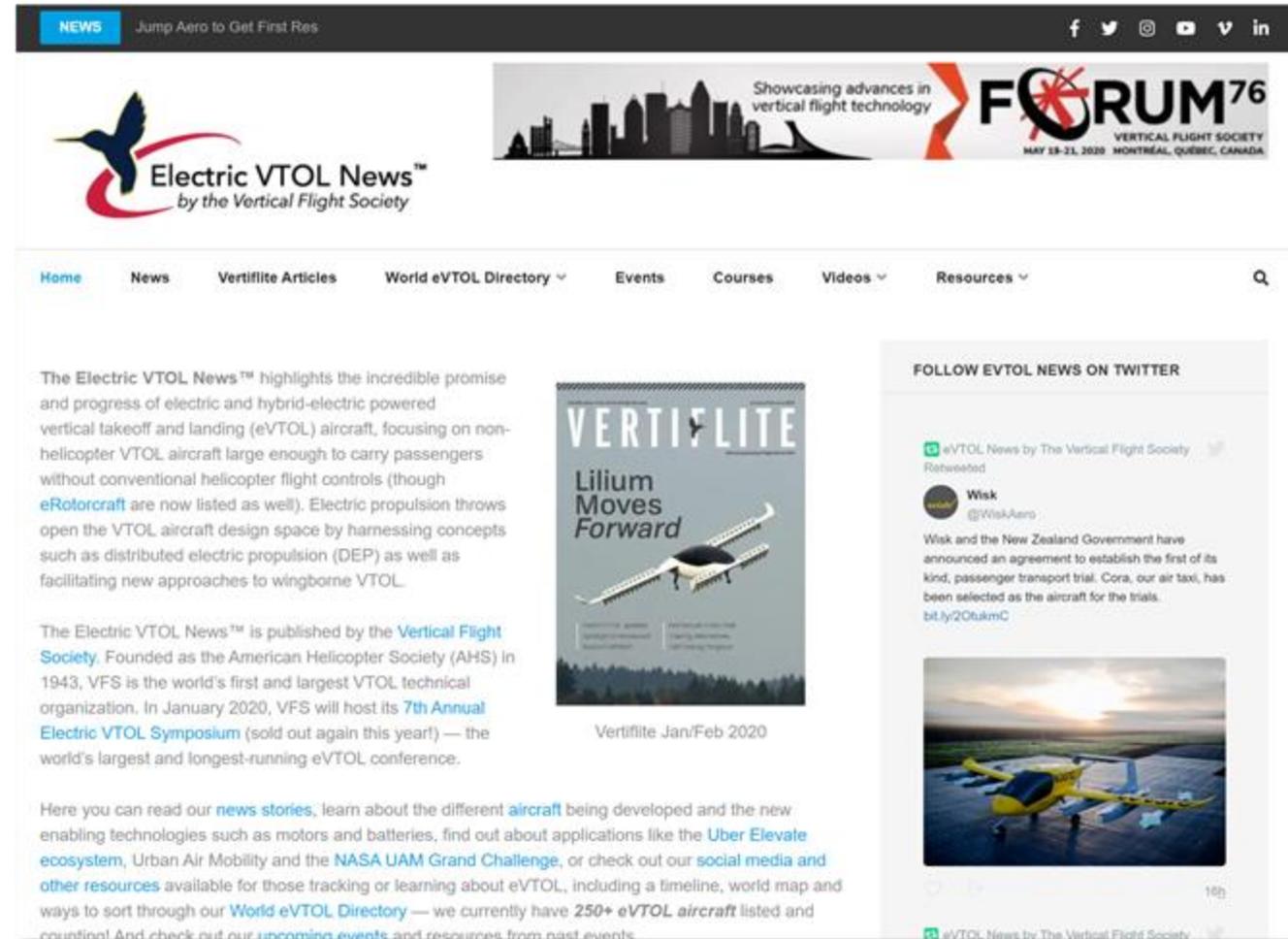
Geely Terrafugia TF-2A (China)



Lilium Jet (Munich, Germany)

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)



The screenshot shows the website for Electric VTOL News by the Vertical Flight Society. The page features a navigation menu with links for Home, News, Vertiflite Articles, World eVTOL Directory, Events, Courses, Videos, and Resources. A featured article titled "Lilium Moves Forward" is highlighted, accompanied by a cover image of a Lilium aircraft. The article text discusses the promise of electric and hybrid-electric powered vertical takeoff and landing (eVTOL) aircraft. A sidebar on the right promotes a Twitter feed for eVTOL News, featuring a tweet from Wisk about a passenger transport trial in New Zealand. The website also includes a banner for the FORUM 76 event, showcasing advances in vertical flight technology.

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



GO FLY

Final Fly Off

Feb 27-29th @ Moffett Federal Airfield
NASA Ames Research Center
Moffett Field, CA, USA
www.GoFlyPrize.com



TEAM SILVERWING PERSONAL FLIGHT
LOCATION NETHERLANDS
DEVICE S1



TEAM AEROXO
LOCATION RUSSIA AND LATVIA
DEVICE ERA AVIABIKE



TEAM TEXAS A&M HARMONY
LOCATION UNITED STATES
DEVICE ARIA



TEAM DRAGONAIR
LOCATION UNITED STATES
DEVICE AIRBOARD 2.0



TEAM TREK AEROSPACE
DEVICE FLYKART 2

Where We Are Now



1907 Cornu (Lisieux, France)



1938 Fw 61
Deutschlandhalle (Bremen)



1967 Bo 105 first flight (Ottobrunn)



2015 H160 (Marignane)

First hover

2011 e-Volo VC1
(Karlsruhe, Germany)



First public demos

2019 Volocopter 2X
Mercedes-Benz Museum (Stuttgart)



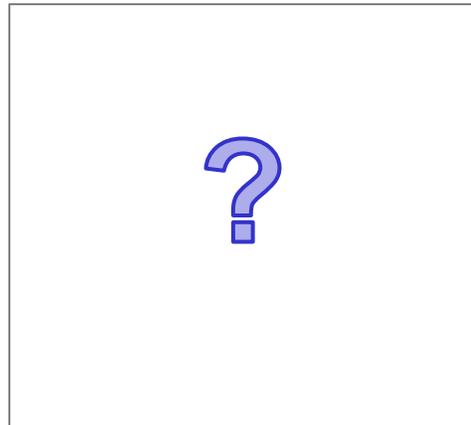
Capable product

2019 Concept
Volocopter VoloCity



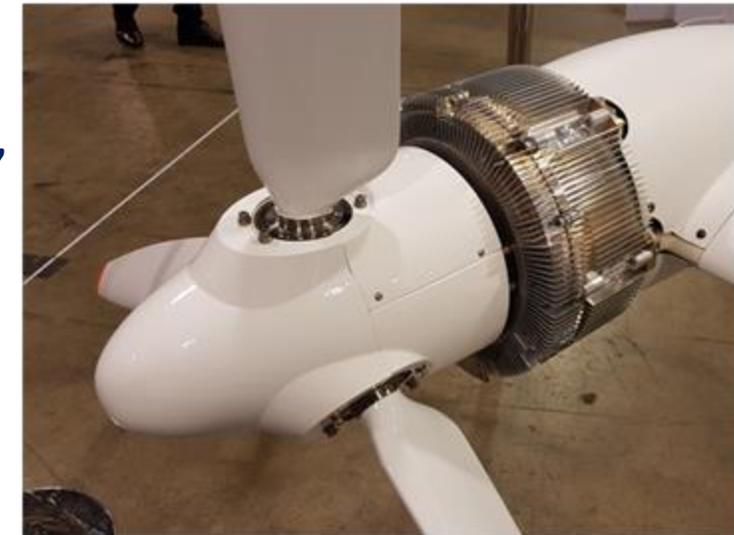
Advanced product

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, Neodymium, 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



eVTOL Supply Chain Challenges (3)

- 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.

What Will It Take?

- 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

- 
- A photograph of an astronaut in a white spacesuit walking on the lunar surface. The astronaut is carrying a large, complex piece of equipment, likely a lunar rover or lander component, on their back. The background shows the dark sky of space and the bright, dusty surface of the moon.
- 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!



Summary

www.eVTOL.news/news

- **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

