The Future of Vertical Flight

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The Vertical Flight Society
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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** and eVTOL to **STOVL** (everything vertical except rockets)
- **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 in vertical flight
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
  - 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!**
Aging U.S. Military Fleet

- V-22 only new U.S. military rotorcraft design fielded in past 30 years; CH-53K in service in 2020?
- 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
CH-53K King Stallion

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Rotorcraft Generations

1st Gen (1945-1960)
- R-5, H-21
  - Airspeed <100 kt
  - Reciprocating Engines
  - Wood Blades
  - Mechanical Controls
  - No Survivability

2nd Gen (1960-1975)
- CH-47A, UH-1, CH-53
  - Airspeed <130 kt
  - Turboshaft Engines
  - Metal Blades
  - Automatic Flight Control Systems
  - Metal Structure
  - Reduced Vulnerability
  - Passive Survivability
  - Countermeasures
  - Crashworthiness Standards Defined

3rd Gen (1975-1990)
- UH-60A, AH-64A
  - Airspeed >150 kt
  - Increased Engine Power
  - Composite Blades
  - Reduced IR Signatures
  - Improved Crash Safety
  - Active Survivability Countermeasures

3rd+ Gen (1990-2015)
- V-22, UH-60M, AH-64E
  - CH-47-II, A/UH-1Y/Z
  - Airspeed >150 kt
  - More Efficient and Powerful Engines
  - Limited Composite Structures
  - Adv Flight Controls
  - Adv Blade Design
  - Avionics Sensor Fusion
  - Reduced RF & Acoustic Signatures

4th Gen (2015-2030)
- RAH-66, CH-53K
  - Airspeed >170 kt
  - More Efficient and Powerful Engines
  - Extensive Composites
  - Digital Fly By Wire
  - Adv Blade Design
  - Avionics Sensor Fusion
  - Reduced RF and Acoustic Signatures
  - Intelligent Survivability
  - Adv Countermeasures
  - Active Crash Safety Systems

5th Gen (2030-)
- FVL, MUX, FUAS
  - Airspeed >200 kt
  - Long range/endurance
  - High efficiency & high power/weight engines
  - Novel Configurations
  - Open System Architecture
  - Individual Blade Control?
  - Thrust Augmentation?
  - Adaptive Controls?
  - Signature Reductions
  - Optionally Piloted
  - Digital Interoperability

Modified from slide presented on Rotorcraft Generations at AHS Forum 66 in Phoenix, AZ, 12 May 2010.

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US Military: VTOL Capability Gaps

- **Performance shortfalls**
  - Speed, range, payload, endurance, altitude

- **Unexploited autonomy/collaboration**
  - Significantly increased mission effectiveness remains untapped

- **Unacceptable survivability & situational awareness shortfalls**
  - Safety and threat losses, no common picture

- **Costly sustainment**
  - Supportability, maintainability, reliability and availability

18 years of conflict and DoD studies reveal significant VTOL mission capability gaps
# FVL Family of Systems

## Light
- Cockpit
- FACE/JCA
- Training

## Medium
- Requirements
- Reduced overhead
- Mission flexibility

- All Air Vehicles have common...

## Heavy
- Sustaining
- Maintaining
- Repair parts and components

### Capability Set 1
**Missions:**
- Reconnaissance
- Attack
- Security
- CCA/CAS
- Surface Warfare
- Direct Action
- Maritime Interdiction Operations

### Capability Set 2
**Missions:**
- Reconnaissance/Attack
- Security
- CCA/CAS
- MEDEVAC
- Surface Warfare
- Direct Action
- Anti Submarine Warfare
- CSAR
- Maritime Interdiction Operations
- Mine/Counter Mine

### Capability Set 3
**Missions:**
- Mine/Counter Mine
- MEDEVAC
- Air Assault
- Logistics
- HA/DR
- Amphibious Assault
- NEO

### Capability Set 4
**Missions:**
- MEDEVAC
- Air Assault
- Logistics
- HA/DR
- Amphibious Assault
- NEO

### Capability Set 5
**Missions:**
- MEDEVAC
- Air Assault
- Logistics
- HA/DR
- Amphibious Assault
- NEO

- Army
- Marines
- US Special Operations
- Navy
- Coast Guard
- (DHS)

- Army
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- Army
- Marines
- US Special Operations
- Navy

- Army
- Marines
- US Special Operations
- Navy
5 Capability Sets from Light to Ultra Heavy
- Plus advanced unmanned programs Army Future UAS and Navy/Marine MUX

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 and Fire Scouts
- CS3 (Medium heavy): Army’s Future Long-Range Assault Aircraft (FLRAA) to replace Black Hawks
Solicitation released Oct. 3; proposals submitted Dec. 18

6 contract awards June 2019

2 prototypes – flights in late 2022

$750M in government funding + $375M contractor funding = $1.1B

Smaller in size than Capability Set 3 assault aircraft

- ~14,000 lb (6.5 t) and 40 ft (12.2 m) rotor diameter

Operational by 2028

Likely 7 companies competing:

- Airbus Helicopter
- AVX Aircraft/L3
- Bell
- Boeing
- Karem Aircraft
- MD Helicopters
- Sikorsky Aircraft

Improved Turbine Engine (ITE)

- GE T901 @ 3,000 shp selected over ATEC (Honeywell/PW) T900
- Most advanced turboshaft ever
- 25% sfc reduction, 20% longer life
- 10,000 engines for Black Hawk, Apache
Sikorsky S-97 Raider for FARA
Future Vertical Lift (FVL) Concepts for Capability Set 3

- Sikorsky-Boeing SB>1 Defiant
- Bell Helicopter V-280 Valor
- AVX Aircraft CCH
- Karem Aircraft KVL-3 Mustang
Sikorsky Boeing SB>1 Defiant JMR Demonstrator
Sikorsky-Boeing SB>1 Defiant

- **X2™ Technology**
- **Advanced Drive System**
- Lift Offset Co-Axial Rotor
- Crew of four
- Retractable Gear
- Advanced Rigid Rotor System
- Pusher Prop
- Cabin for 12 Combat equipped troops
Bell V-280 Valor

FORWARD FLIGHT MODE
- Large Cell Carbon Core Wing
- Cruises at 280 knots
- Superior High-Speed Handling Qualities
- Turboprop-like Ride Quality
- Advanced Composite Fuselage

HELIOPER MODE
- Superior Low-Speed Maneuverability
- Fly-By-Wire
- Advanced Rotor and Drive System
- Conventional Retractable Landing Gear
- Non-Rotating Fixed Engines
- Large Side Door
- 11 Passengers
- 2 Pilots / 2 Crew Chiefs
- Large Cell Carbon Core Wing
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: Airbus RACER
Army Futures Command stood up July 1, 2018
- 6 priorities with Cross Functional Teams (CFTs)
- Future Vertical Lift (FVL)
  - Future Unmanned Aircraft Systems (FUAS)
  - Future Attack Reconnaissance Aircraft (FARA)
  - Future Long-Range Assault Aircraft (FLRAA)
  - Modular Open Systems Architecture (MOSA)

Combat Capabilities Development Command (CCDC)
- Replaces Research, Development & Engineering Command (RDECOM) as of Jan. 31, 2019

CCDC Aviation & Missile Center
- Replaces Aviation & Missile Research & Development Center (AMRDEC) as of Jan. 31, 2019
Emerging Aviation Ecosystem

“Advanced teaming is the symbiotic effort of manned rotary wing and fixed wing aircraft, unmanned aircraft systems (UAS), ground vehicles, and air launched effects (ALE) to accomplish the full range of multi-domain operational missions with enhanced and distributed situational awareness, greater lethality, and improved survivability.”

Key Platforms
- Future Attack Reconnaissance Aircraft (FARA)
- Air Launched Effects (ALE)
- Advanced or Future UAS (AUAS / FUAS)
- Future Tactical UAS (FTUAS)
- Future Long-Range Assault Aircraft (FLRAA)
- Legacy (H-60, H-64, MQ-1C, etc.)

CCDC A&M Supporting S&T Efforts
- Holistic Situation Awareness and Decision Making (HSA-DM)
- Integrated Mission Equipment (IME)
- Mission Systems Architecture Demonstration (MSAD) / Modular Open Systems Architecture (MOSA)
- Synergistic Unmanned-Manned Intelligent Teaming (SUMIT)
- Survivability Against Integrated and Networked Threats (SAINT)
- Mission Adaptive Autonomy (MAA)
# Unmanned Aircraft Platform Efforts

| Future UAS (FUAS) | • AROC-approved Initial Capabilities Document  
|                  | • FoS including SCI, ALE, FTUAS, AUAS, Cargo UAS, and other capabilities |
| Future Tactical UAS (FTUAS) | • Brigade Combat Team echelon capability (Shadow Replacement)  
|                         | • Expeditionary UAS that meets current ONS  
|                         | • PM UAS selection in progress supporting FORSCOM experimentation |
| Advanced UAS (AUAS) | • Survivable, Lethal and Autonomous;  
|                     | • Optimized for C-IAD in A2/AD as part of Advanced Teaming Ecosystem  
|                     | • Combat Aviation Brigade (CAB) and higher echelon capability |
| Air-Launched Effects (ALE) | • Expendable UA of various form factors tailored for specific effects  
|                         | • DILR, Decoy, MFEW, Lethal Effects; Operate semi-autonomously  
|                         | • Common, open, modular and scalable software/hardware |
| NexGen UAS TD | • S&T Effort to close the gap between legacy manned and UA capabilities  
|               | • Inform requirements and reduce risk for an objective end-state CAB future UA  
|               | • Seeking balanced design beyond Group 3 UA but below FARA capability |

“Whoever can handle the quickest rate of change is the one who survives.”  
- COL(ret) John Boyd
Increasing:
• Performance (Range, Endurance)
• Useful Load
• Resident Autonomy
• Achievable Effects (Lethal, MFEW)
• Cost / Complexity
US Marine Corps MUX

- MUX: Marine Air-Ground Task Force (MAGTF) UAS — Expeditionary
- Joint Requirements Oversight Council (JROC) Initial Capabilities Document (ICD) approved Oct 2016
- Request for Information March 2018
- Early Warning, ISR, EW, Comms Relay, Offensive Air Support, Aerial Escort, Cargo/Logistics
- Capabilities
  - Cruise speed of 200 to 300 kt
  - Combat radius of 350 to 700 nm
  - Internal payload of 3000 to 6000 lb
  - External payload of 3000 to 9000 lb
  - Single air vehicle Time on Station of 8 to 12 hours at 350 nm (radius)
  - Aerial refueling

Bell V-247 Vigilant Full-Scale Mock-Up
1. Multi-Sensor Collection, Fusion and Real time transmission
2. Multi-Electro-Magnetic Spectrum Ops
3. C4 Network Bridge and Relay
4. Escort and Protection for Assault Force (ACE & GCE)
5. Persistent & Precision Fires and Targeting
6. Early Warning – Air Defense Network Extension
7. High Risk – Assault Support

MUF Capabilities provide a system of long range, long endurance, survivable, and sea-based utility platforms that conduct scalable multi-functional C4ISR, electromagnetic spectrum operations, persistent fires capabilities, as well as high risk transportation of logistics and personnel.
The Electric VTOL Revolution

- Electric & hybrid electric propulsion enable new possibilities for:
  - Regional Air Mobility (RAM)
  - Urban Air Mobility (UAM)/Air Taxis
  - Urban Cargo Delivery/Disaster Relief
  - Personal Air Vehicles
  - Ultralights
  - Personal Flying Devices
  - Urban Package Delivery
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

Not this!
- Cars were not buggies with mechanical horses
Advancements in electric motors

+ Advancements in batteries
+ Advancements in computer modeling and simulation
+ Advancements in composites
+ Change in FAR Part 23
+ Tech innovations
+ Tech investments > $1B

= All enable new configurations and new innovations
Why Now?

Advancements in electric motors
+ Advancements in batteries
+ Advancements in computer modeling and simulation
+ Advancements in composites
+ Change in FAR Part 23
+ Tech innovations
+ **Tech investments > $1B**

= All enable new configurations and new innovations
“The Hype Cycle”

- Peak of Inflated Expectations
- Plateau of Productivity
- Slope of Enlightenment
- Trough of Disillusionment
- Innovation Trigger
- We are here

“The Hype Cycle”


The eVTOL Revolution Needs YOU!
Uber Elevate

- 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, EV charger manufacturers, etc.
- Connecting innovators, investors, regulators, technical experts, media

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

VFS www.eVTOL.news website
- 155+ aircraft concepts detailed
- Many missions beyond Uber’s Elevate

www.eVTOL.news
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Uber Elevate: 5 Aircraft Partners

Aurora Flight Sciences

BELL

Pipistrel

Karem Aircraft

Embraer

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Uber Elevate: 5 Key Challenges

1. Flight demos in 2020; operational in 2023
2. Technology: all-electric (not hybrid) for 5 seats (pilot + 4 pax)
3. Infrastructure (physical and ATM/UTM)
4. Pilot shortage vs. autonomy
5. Regulations
eVTOL Ultralights

- 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.
- Flight experience offerings

Kitty Hawk Flyer (<254 lb)  
Hoversurf Scorpion (<254 lb)

Opener BlackFly (310 lb)  
LIFT Aircraft Hexa (432 lb)
We are the global Vertical Flight Society
  – Bringing industry, governments and academia together
  – Get involved! Go to www.vtol.org

Significant advanced rotorcraft developments underway
  – State-of-the-art conventional helicopter developments and AW609 tiltrotor
  – FVL/JMR: advanced compound and tiltrotor — see www.vtol.org/FVL
  – Clean Sky 2: advanced compound and tiltrotor

Significant funds being invested in electric VTOL (~$2B)
  – 155+ companies investing in electric and hybrid/electric VTOL aircraft
  – The explosive expansion in drones may be repeated with manned eVTOL
  – For more info, see www.eVTOL.news

Advancing vertical flight for 75 years!