



The Future of Vertical Flight

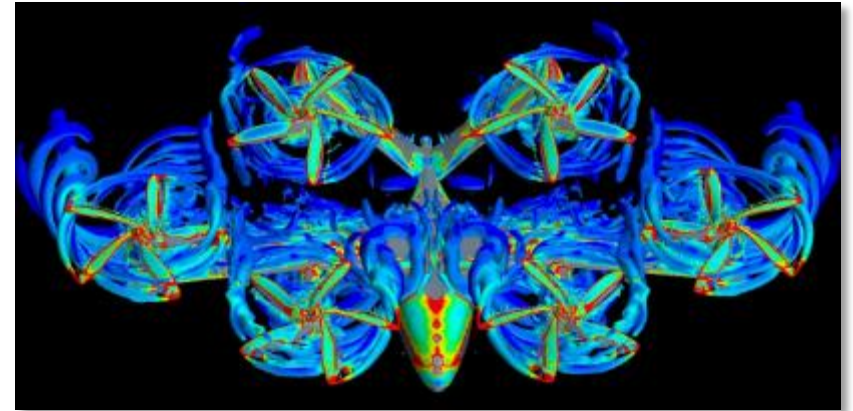


Mike Hirschberg, Executive Director
The Vertical Flight Society
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What is The Vertical Flight Society?

- 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



CFD of Joby S4, Aug 2015



VFF Scholarship Winners at Forum 71, May 2015

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)



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 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

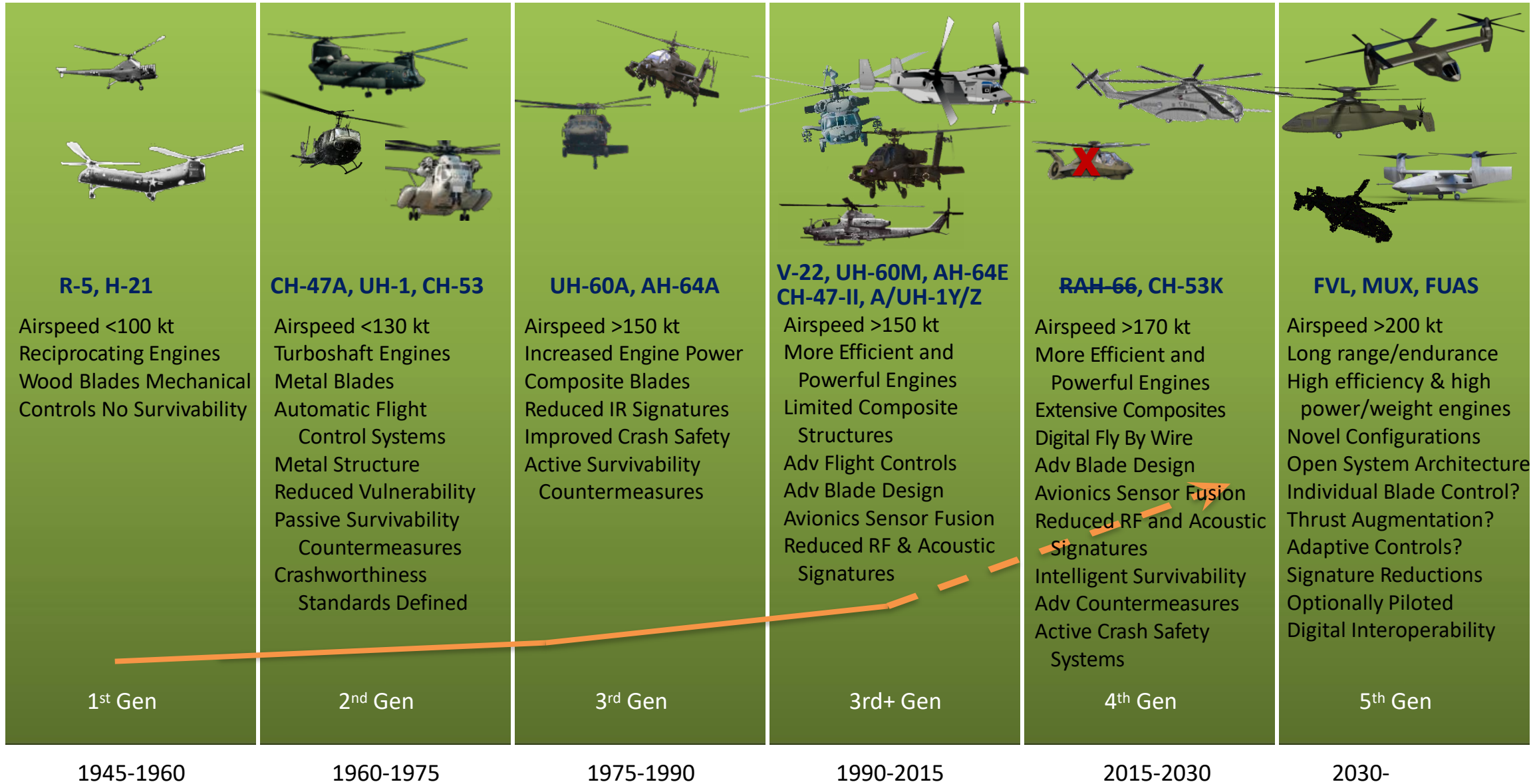


CH-53K King Stallion



Rotorcraft Generations

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



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	Medium			Heavy
<p>All Air Vehicles have common...</p> <ul style="list-style-type: none"> • Cockpit • FACE/JCA • Training • Requirements • Reduced overhead • Mission flexibility • Sustaining • Maintaining • Repair parts and components 				
<p>Capability Set 1</p> <p><u>Missions:</u></p> <ul style="list-style-type: none"> • Reconnaissance • Attack • Security • CCA/CAS • Surface Warfare • Direct Action • Maritime Interdiction Operations 	<p>Capability Set 2</p> <p><u>Missions:</u></p> <ul style="list-style-type: none"> • Reconnaissance/Attack • Security • CCA/CAS • MEDEVAC • Surface Warfare • Direct Action • Anti Submarine Warfare • CSAR • Maritime Interdiction Operations • Mine/Counter Mine 	<p>Capability Set 3</p> <p><u>Missions:</u></p> <ul style="list-style-type: none"> • Mine/Counter Mine • MEDEVAC • Air Assault • Logistics • HA/DR • Amphibious Assault • NEO 	<p>Capability Set 4</p> <p><u>Missions:</u></p> <ul style="list-style-type: none"> • MEDEVAC • Air Assault • Logistics • HA/DR • Amphibious Assault • NEO 	<p>Capability Set 5</p> <p><u>Missions:</u></p> <ul style="list-style-type: none"> • MEDEVAC • Air Assault • Logistics • HA/DR • Amphibious Assault • NEO
<ul style="list-style-type: none"> • Army • Marines • US Special Operations • Navy • Coast Guard (DHS) 	<ul style="list-style-type: none"> • Army • Marines • US Special Operations • Navy • Coast Guard (DHS) 	<ul style="list-style-type: none"> • Army • Marines • US Special Operations • Navy • Coast Guard (DHS) 	<ul style="list-style-type: none"> • Army • Marines • US Special Operations • Navy 	<ul style="list-style-type: none"> • Army • Marines • US Special Operations • Navy

Future Vertical Lift (FVL)

- **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



Future Attack Reconnaissance Aircraft (FARA)

- 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 JMR Demonstrator



Sikorsky-Boeing SB>1 Defiant



X2™ Technology



Bell V-280 Valor JMR Demonstrator

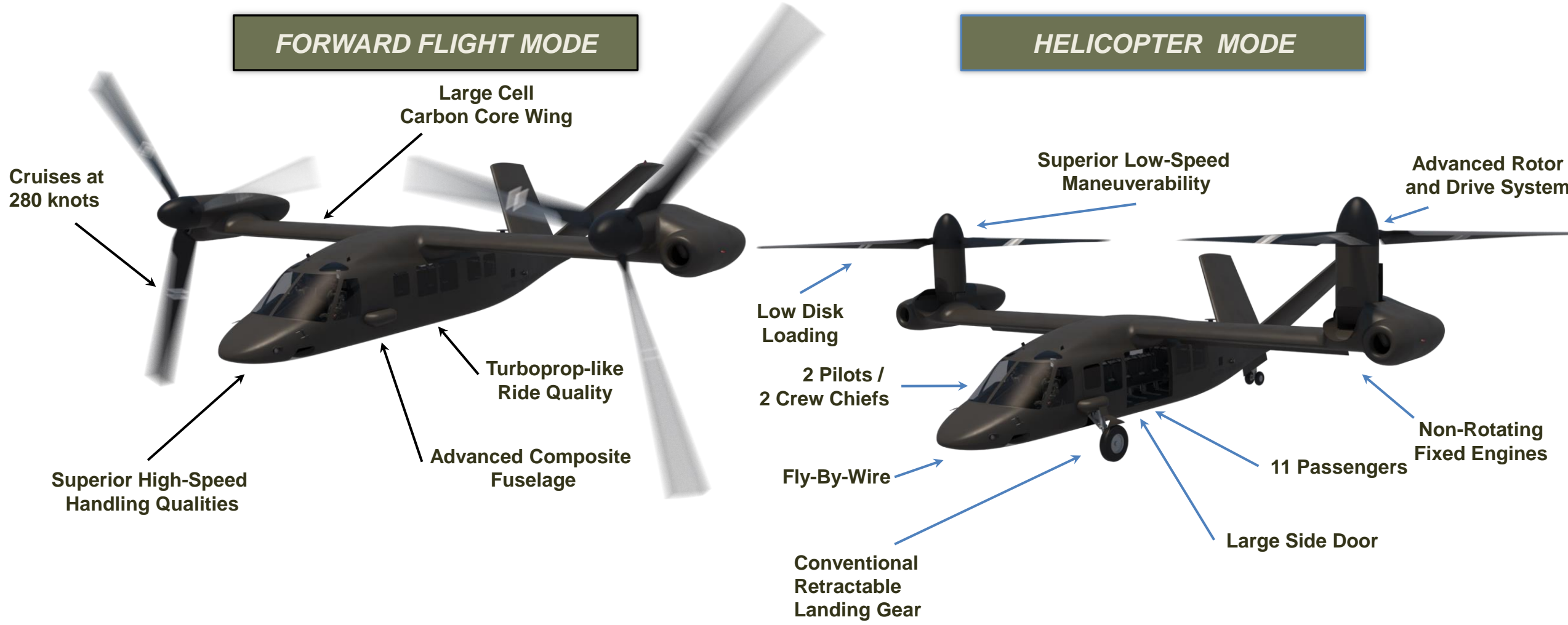


Bell V-280 Valor



FORWARD FLIGHT MODE

HELICOPTER MODE



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)

AW609 Civil Tiltrotor



Clean Sky 2: Next Gen Civil Tiltrotor (NGCTR)



Clean Sky 2: Airbus RACER



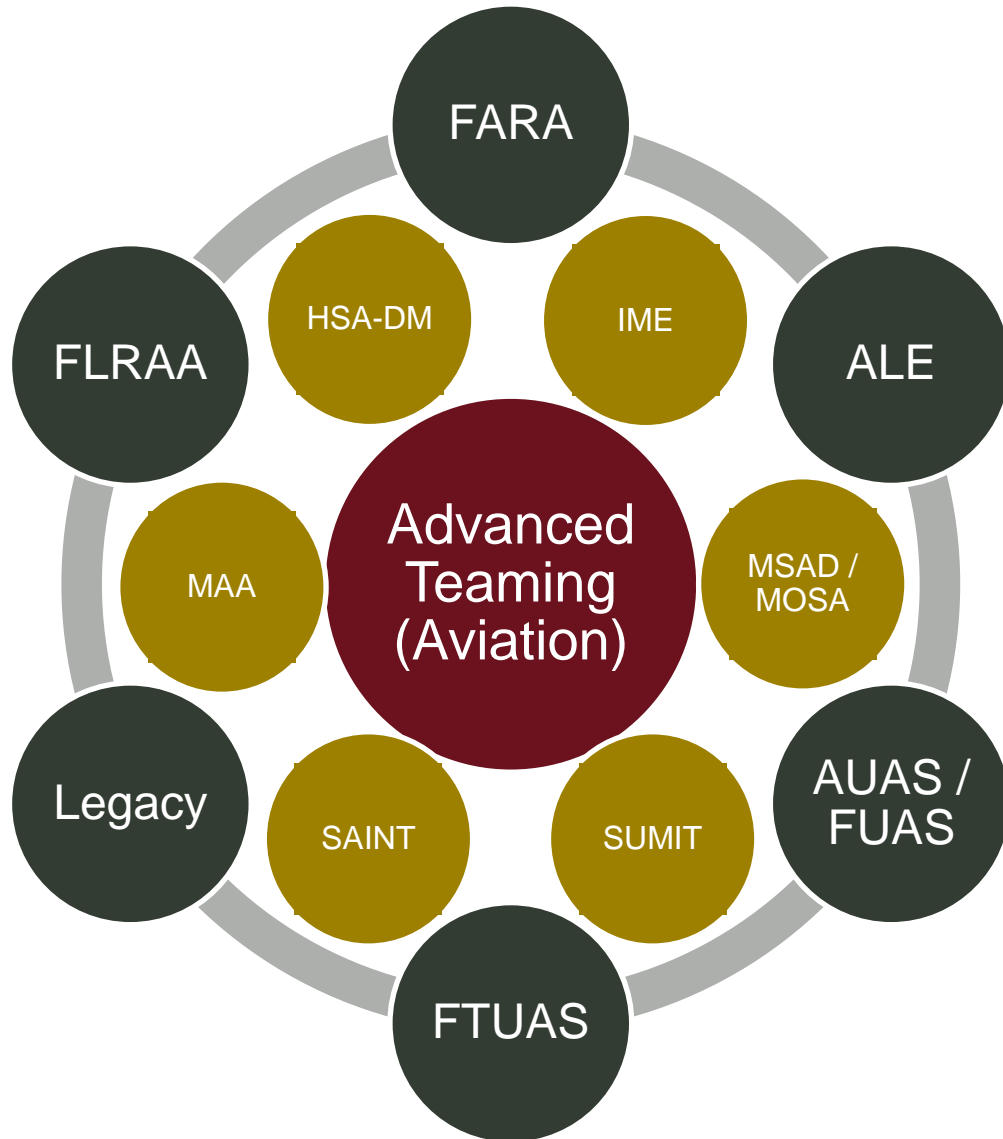
US Army Acquisition Reorganization

Big Changes in Army Modernization

- 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

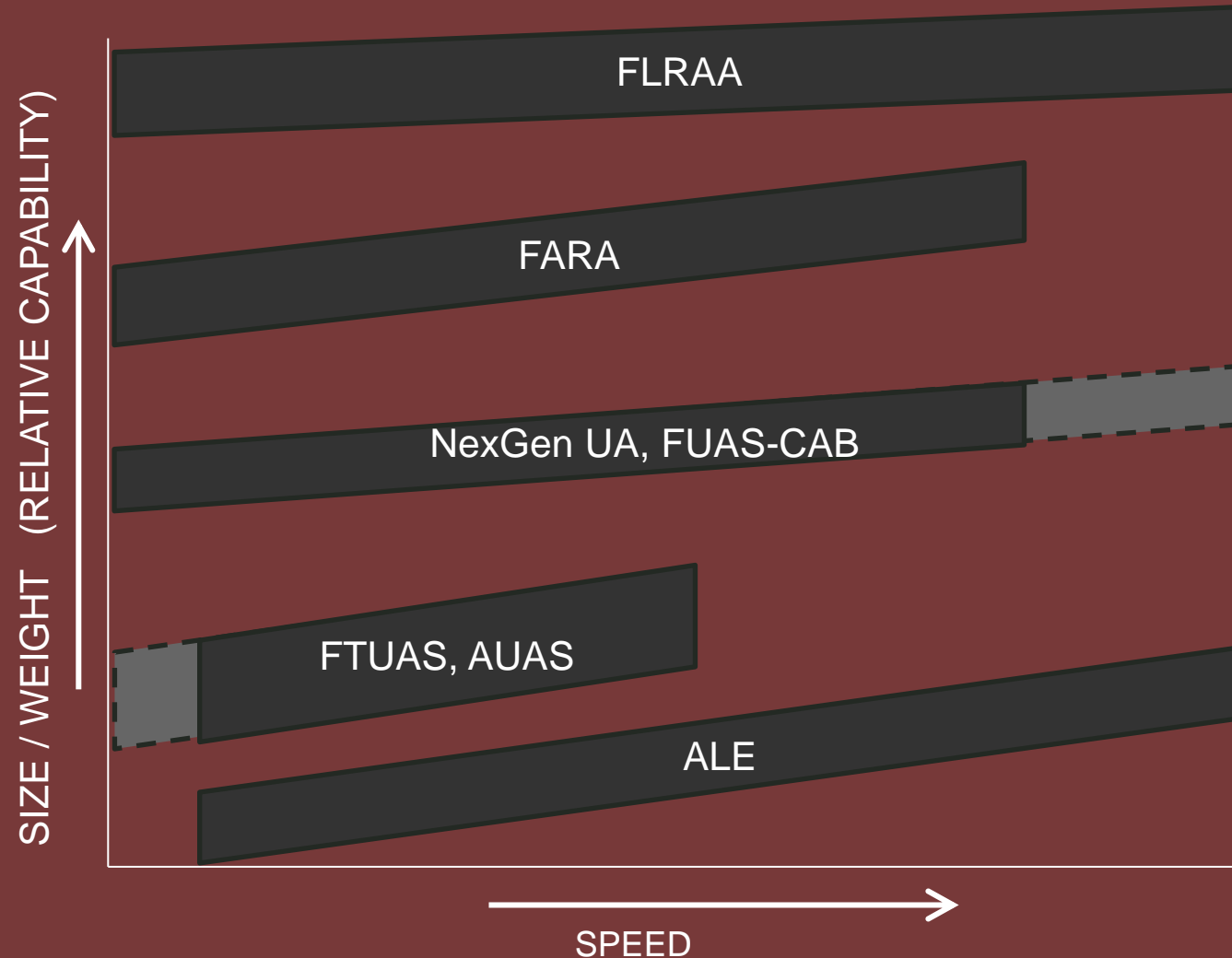
“Whoever can handle the quickest rate of change is the one who survives.”

- COL(ret) John Boyd

Relative Capability Bins

Increasing:

- Performance (Range, Endurance)
- Useful Load
- Resident Autonomy
- Achievable Effects (Lethal, MFEW)
- Cost / Complexity

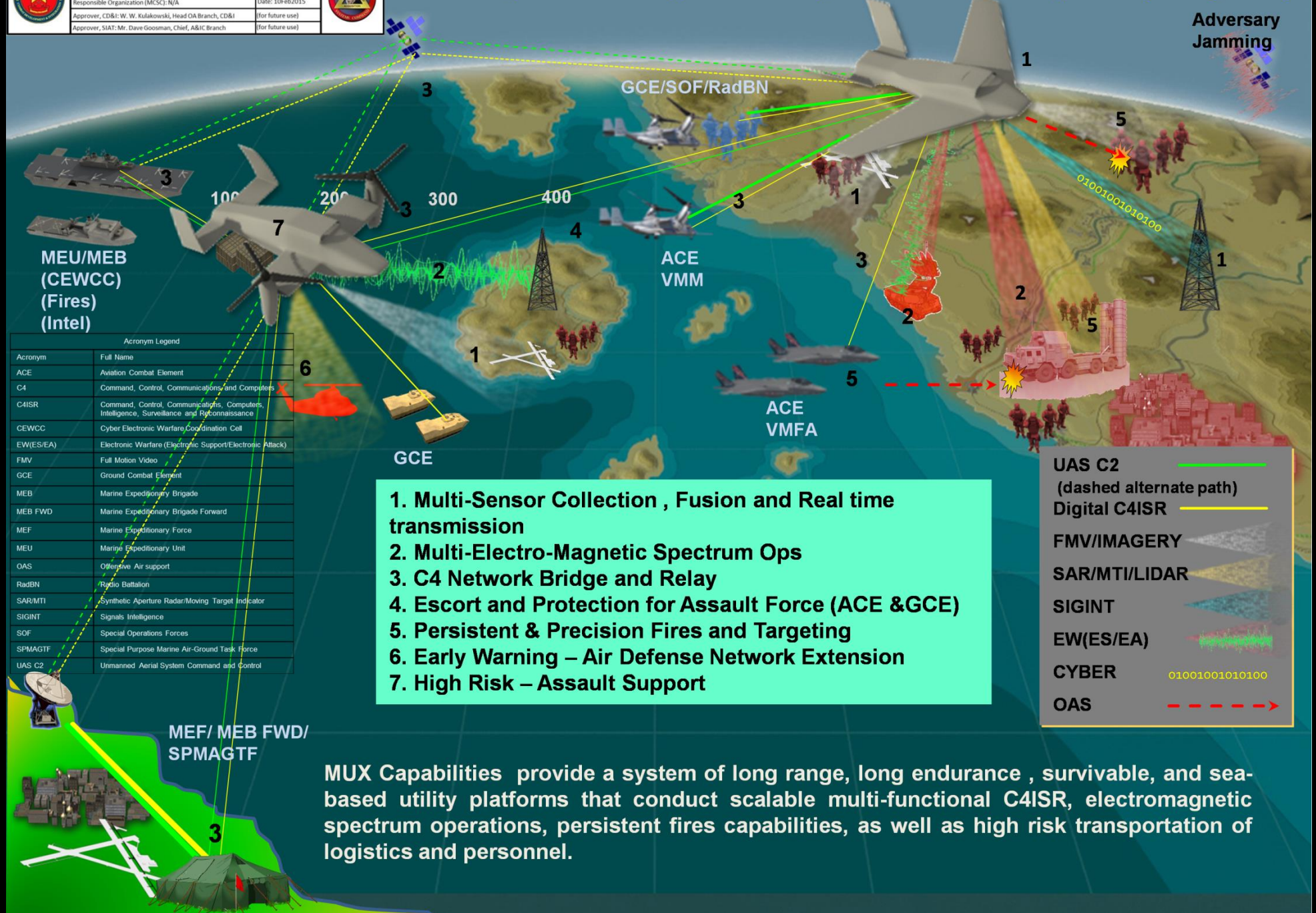


- MUX: Marine Air-Ground Task Force (MAGTF) UAS — Expeditionary
- Joint Requirements Oversight Council (JROC) Initial Capabilities Document (ICD) approved Oct 2016
- Request for Information March 2018
- Early Warning, ISR, EW, Comms Relay, Offensive Air Support, Aerial Escort, Cargo/Logistics
- Capabilities
 - 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

MUX Capabilities High-Level Operational Concept Graphic (OV-1)



Acronym Legend	
Acronym	Full Name
ACE	Aviation Combat Element
C4	Command, Control, Communications and Computers
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance
CEWCC	Cyber Electronic Warfare Coordination Cell
EW(ES/EA)	Electronic Warfare (Electronic Support/Electronic Attack)
FMV	Full Motion Video
GCE	Ground Combat Element
MEB	Marine Expeditionary Brigade
MEB FWD	Marine Expeditionary Brigade Forward
MEF	Marine Expeditionary Force
MEU	Marine Expeditionary Unit
OAS	Offensive Air support
RadBN	Radio Battalion
SAR/MTI	Synthetic Aperture Radar/Moving Target Indicator
SIGINT	Signals Intelligence
SOF	Special Operations Forces
SPMAGTF	Special Purpose Marine Air-Ground Task Force
UAS C2	Unmanned Aerial System Command and Control

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

UAS C2	
(dashed alternate path)	
Digital C4ISR	
FMV/IMAGERY	
SAR/MTI/LIDAR	
SIGINT	
EW(ES/EA)	
CYBER	
OAS	

MUX 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

Heavier, Hybrid



Electric Helicopters?



- Not this!
- Cars were not buggies with mechanical horses

- 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
- + Change in FAR Part 23
- + Tech innovations
- + Tech investments > \$1B
- = All enable new configurations and new innovations



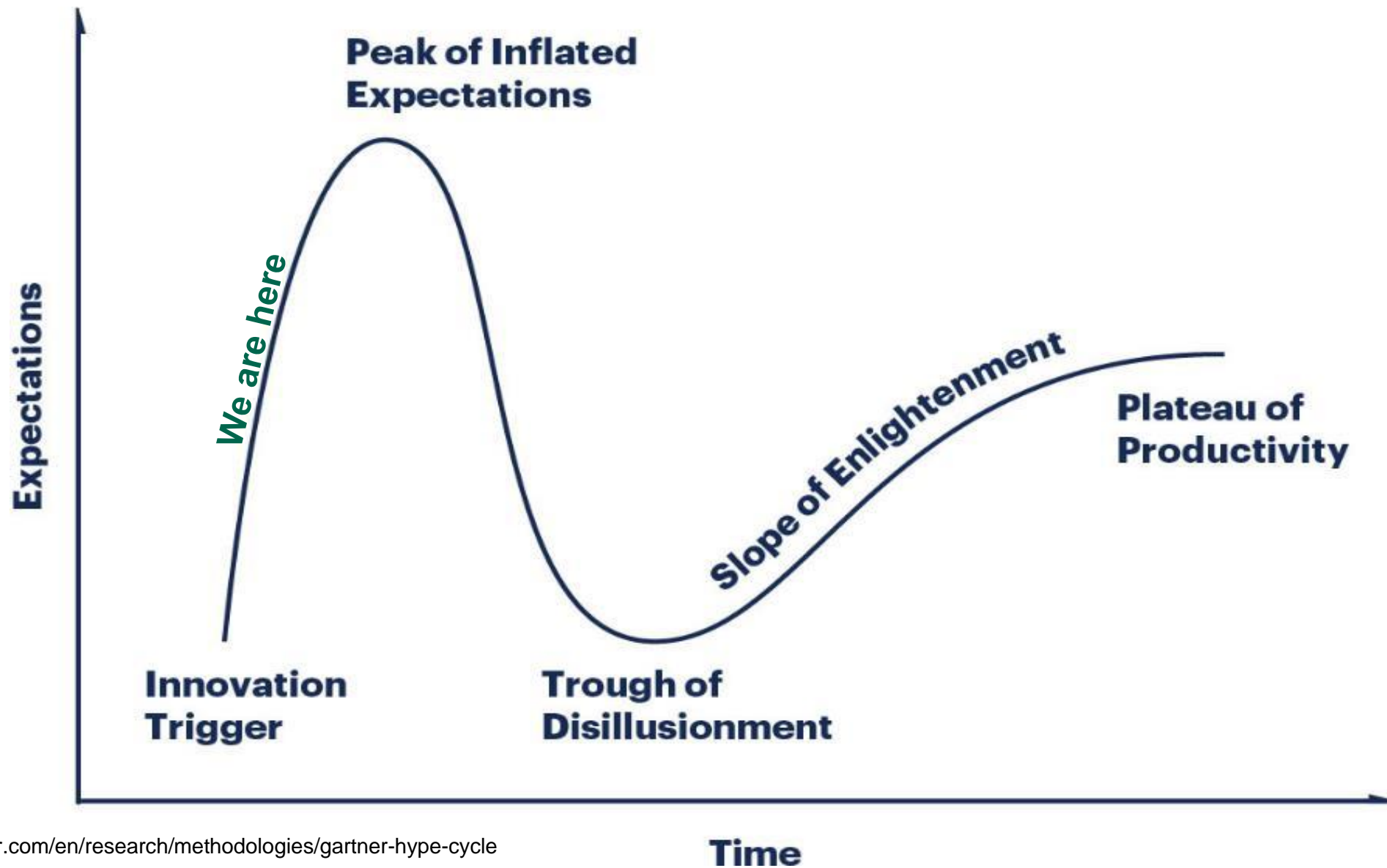
Joby Motors 10 kW (2010)

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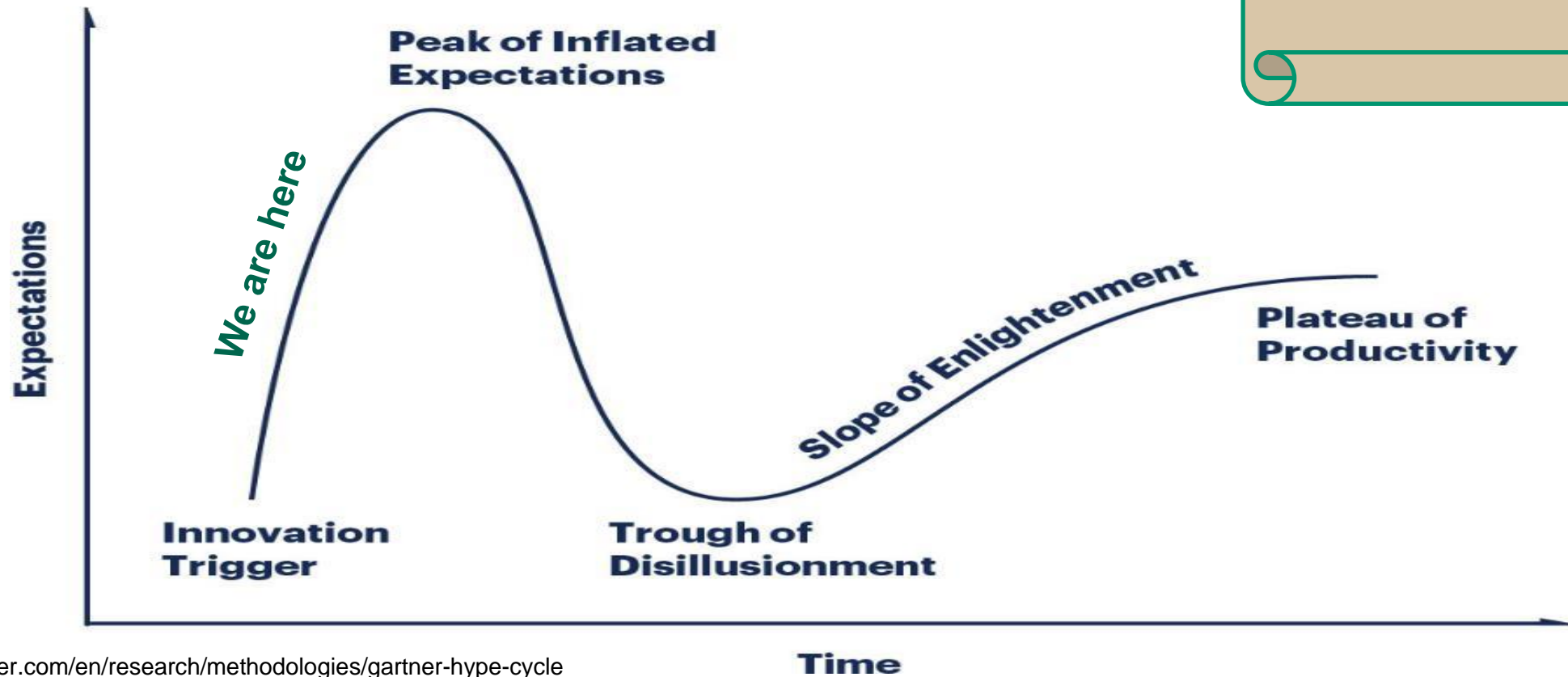


“The Hype Cycle”



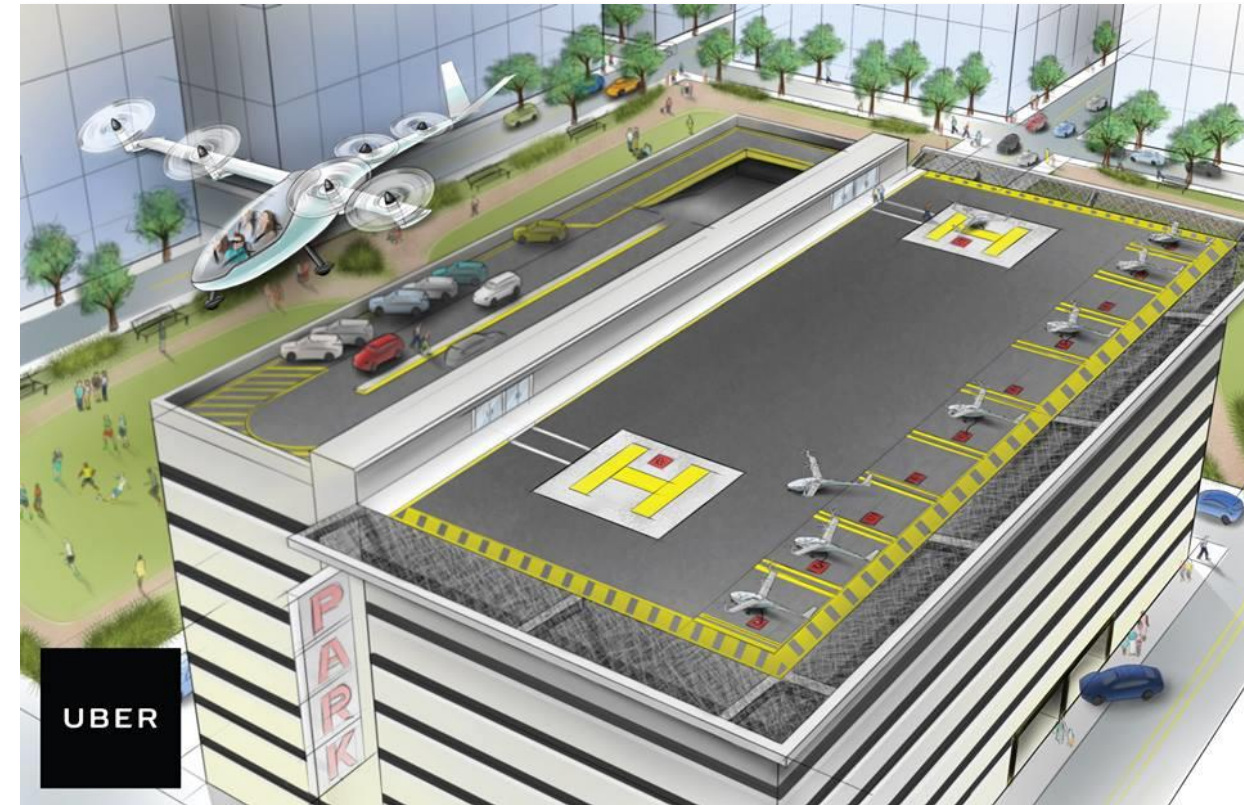
“The Hype Cycle”

The eVTOL Revolution Needs YOU!



Uber Elevate

- **Uber Elevate**
 - 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, 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

Uber Elevate: 5 Aircraft Partners



Aurora Flight Sciences



Bell



Pipistrel



Embraer



Karem Aircraft

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)

Summary



- 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!



Questions?



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