香港科技大學
THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY

eVTOL, eSTOL and eCTOL

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“It is difficult to make predictions – especially about the future”*

Niels Bohr (and others), Nobel Prizewinner in Physics in 1922

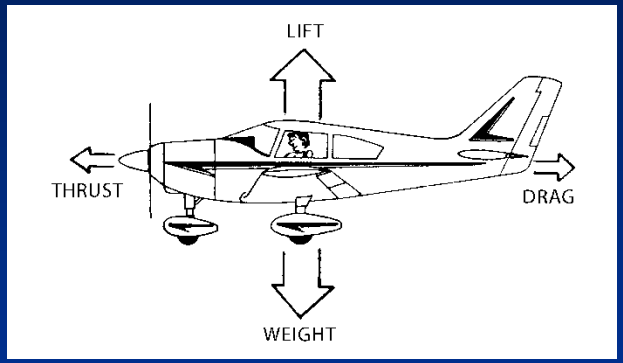
* Old Danish saying

- Background
- Electric-powered Aircraft
  - Vertical Takeoff and Landing (eVTOL)
    - Hybrid-Electric
    - All-Electric
  - Short Takeoff and Landing (eSTOL)
    - Hybrid-Electric
  - Conventional Takeoff and Landing (eCTOL)
    - Hybrid-Electric
    - All-Electric
    - Solar Power
- Air Traffic Control
- Conclusions

This presentation uses the term “electric-powered” in the broadest sense. It includes vehicles with electric motors for which the source of onboard energy includes gasoline, jet fuel, and batteries. Hydrogen is excluded. It would require comparison of direct burn and fuel cells – a topic justifying a separate presentation

Drag Polar

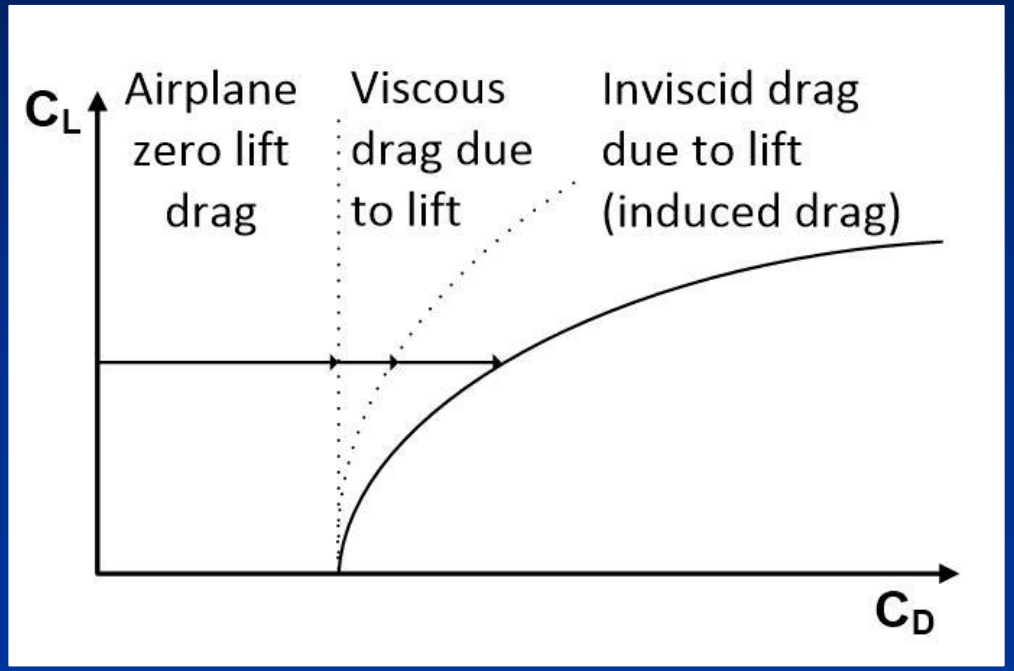
For an airplane, almost half the drag is directly dependent on weight



$$C_D = C_{D_0} + KC_L{}^2$$

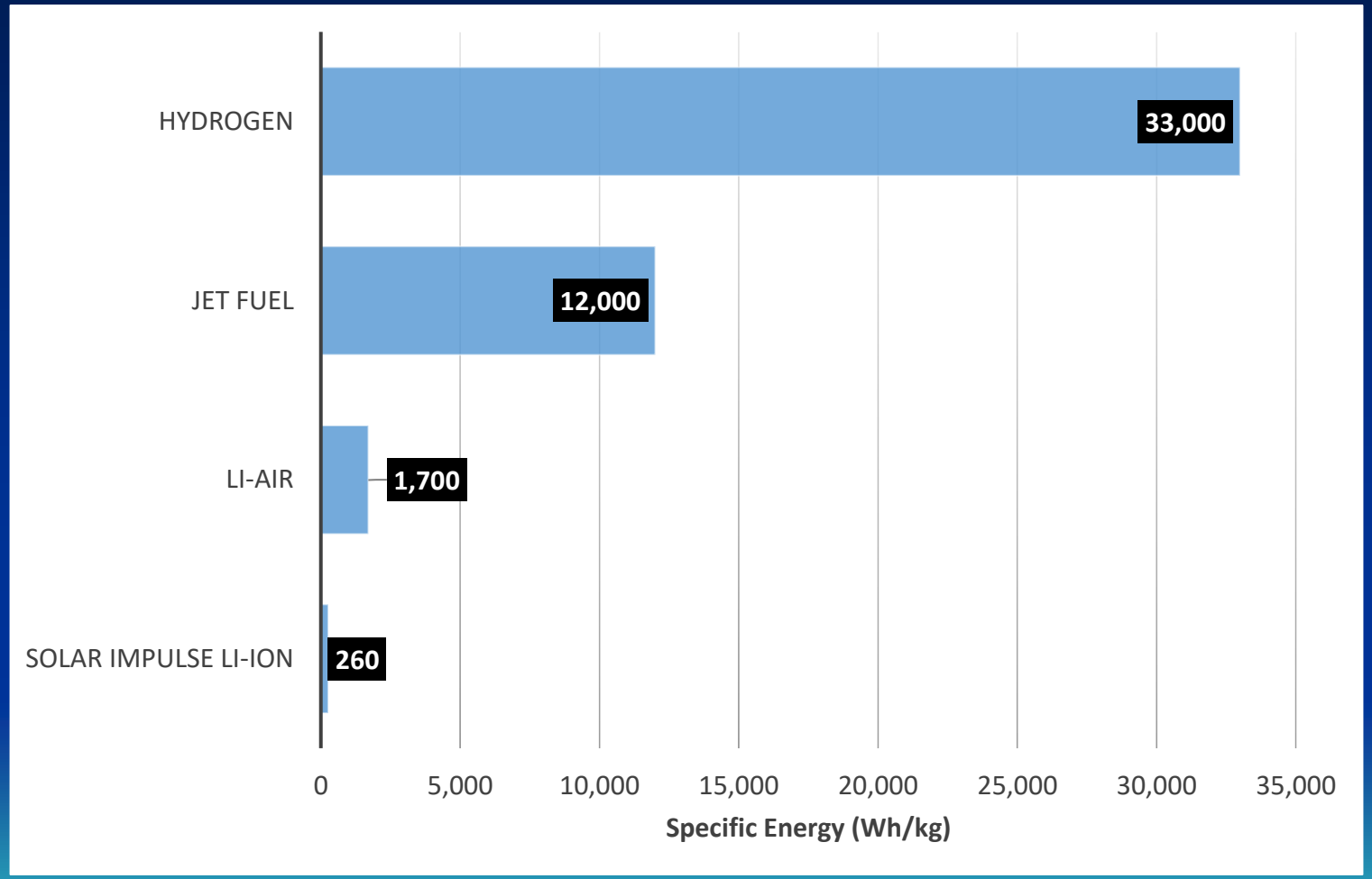
$$where \quad C_L = \frac{L}{\frac{1}{2}\rho V^2 S}$$

$$and \quad L = W$$

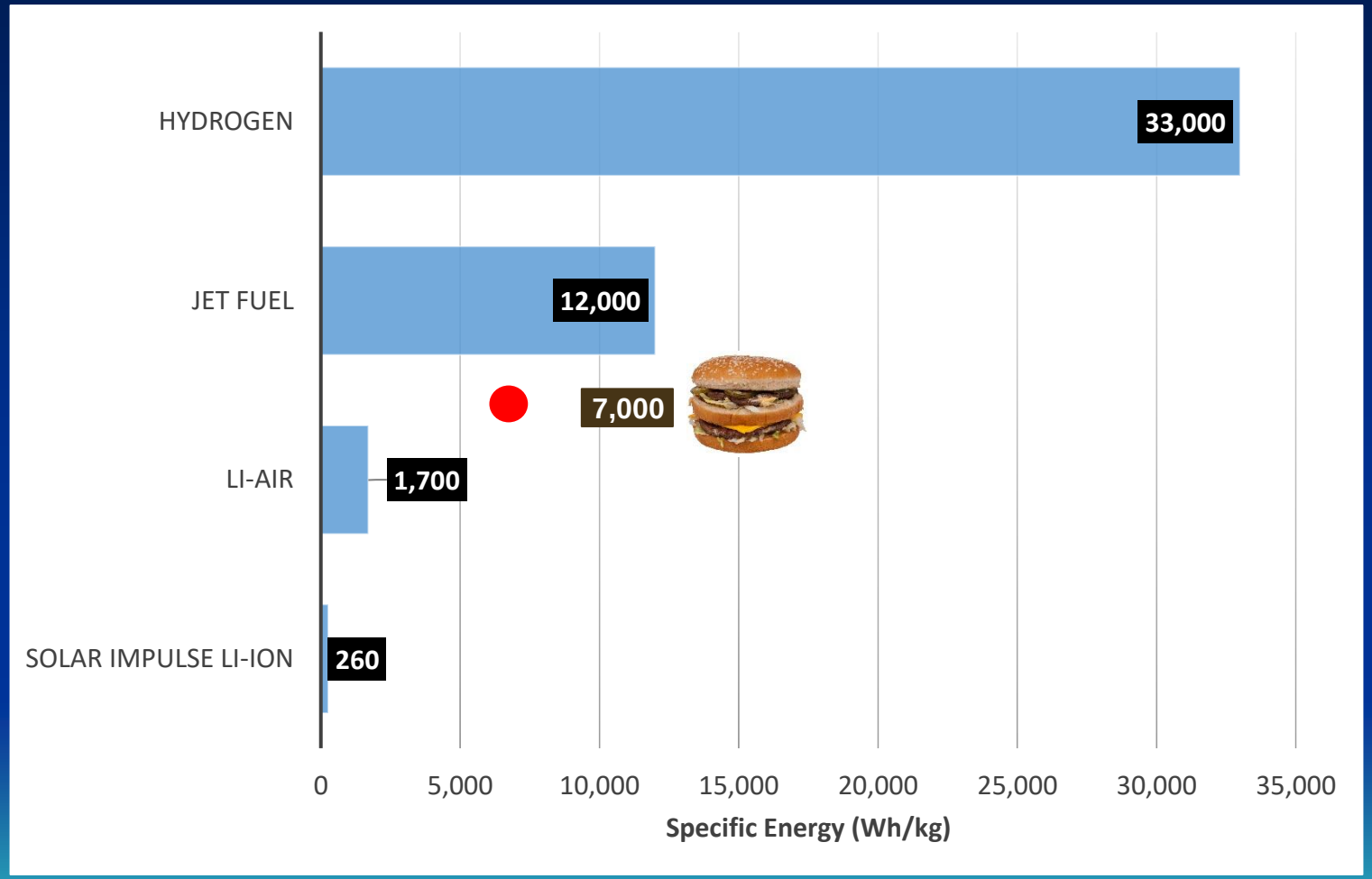


More weight > more lift req'd > more drag > more thrust req'd > more power req'd > more energy req'd > more weight

Energy/Unit Weight is Important



Energy/Unit Weight is Important



https://en.wikipedia.org/wiki/Big_Mac

Batteries aren’t discarded

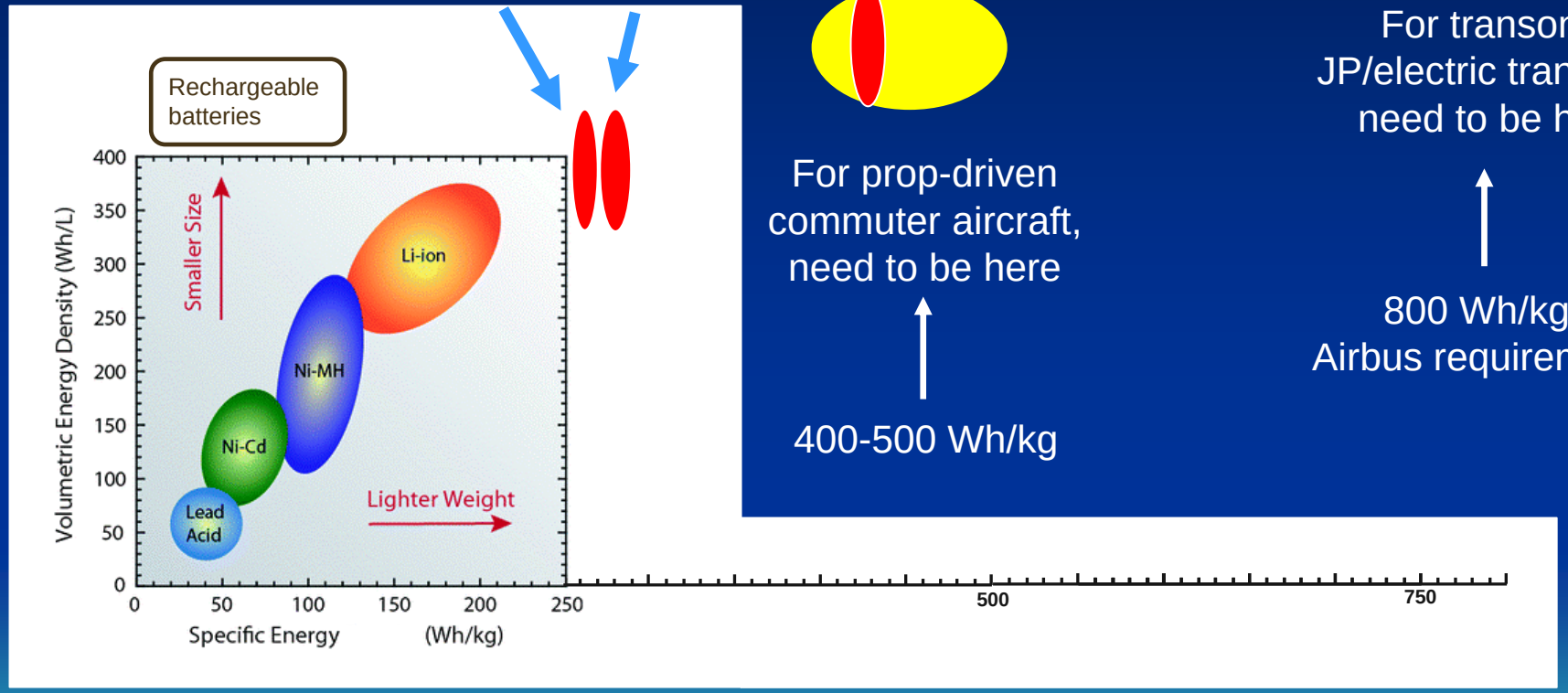
http://www.smartflyer.ch/aircraft/3-side-view/

Battery Specific Energy

Airbus Zephyr (Amprius Li-ion with Si-nanowire anode)

Solar Impulse

Tesla



For prop-driven commuter aircraft, need to be here

400-500 Wh/kg

For transonic JP/electric transport, need to be here

800 Wh/kg
Airbus requirement

http://www.epectec.com/batteries/cell-comparison.html

Engine Maintenance

- Labor hours for oil change almost independent of engine size
- For turbine-powered airplanes, engine maintenance labor cost is a strong function of number of engines, weak function of size of engines

Engine Maintenance

https://www.flickr.com/photos/26436024@N06/3538983970

Airbus A330 1,595 built

https://lentokoneet.wordpress.com/a340-front-view/

Airbus A340 380 built

- For turbine-powered airplanes, two engines better than four

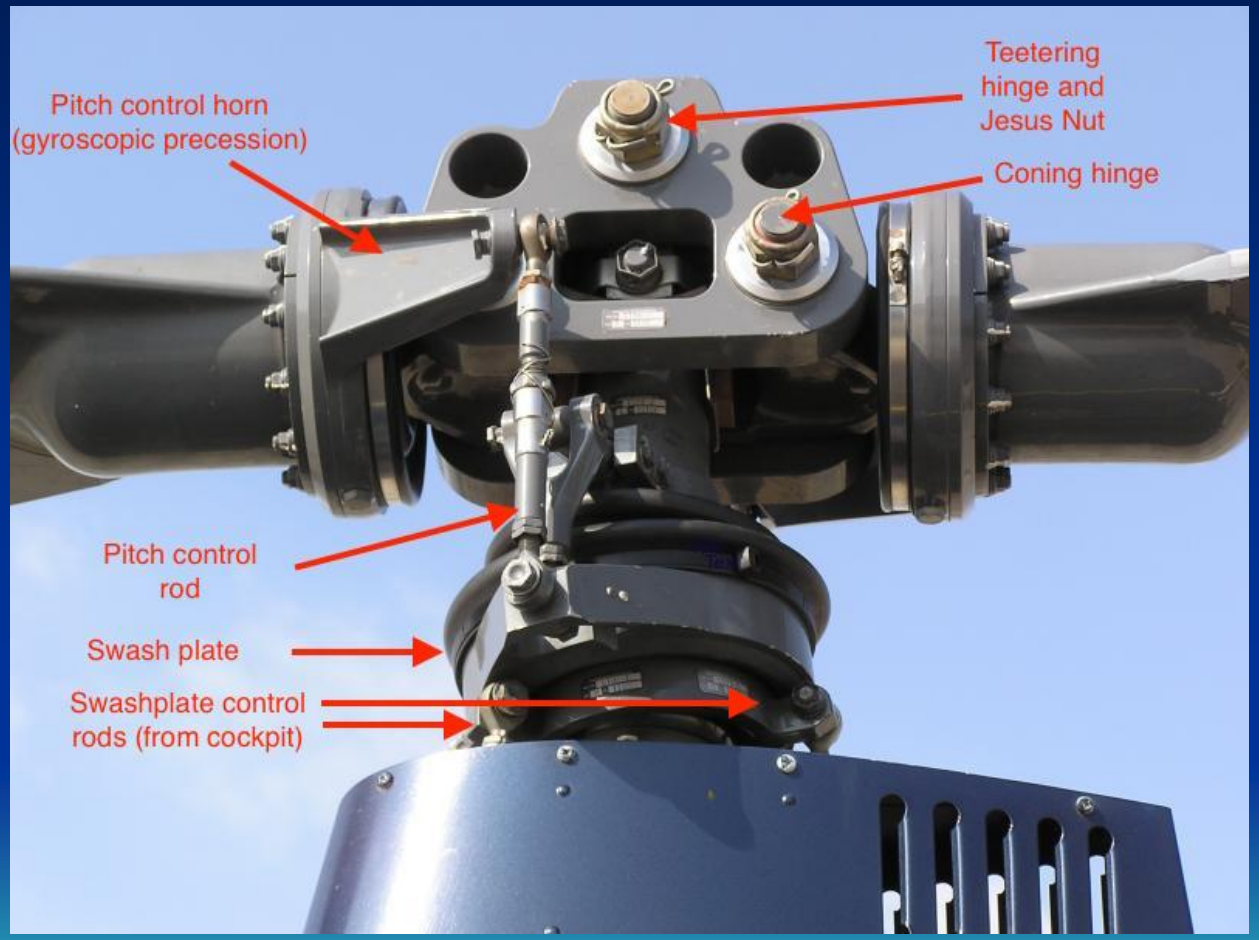
Engine Maintenance

https://www.hansenwholesale.com/emerson-carrera-grande-eco-60-dc-motor

- When did you last change the oil on your ceiling fan?
- For electric power, minimizing number of motors is not important

Helicopter Rotor Hub

- Heavy
- High maintenance
- Requires critical reliability

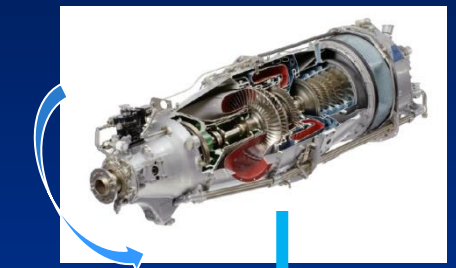


Motor Power/Weight Ratio

- Electric motor has higher power/weight than that of small turboshaft because of turboshaft clearances and Reynolds Number effects

Type	Max. Continuous Power kW	Weight kg (lb)	Specific Power kW/kg
Turboshaft:			
PBS TS 100	180	57 (125)	3.1
P&W PT6B-36A	661	174 (384)	3.8
P&W PT6T-67D	1,182	200 (445)	5.9
Electric:			
Siemens	260	50 (110)	5.2
Siemens E-fan X	2,000	??	>>5.2

- As turboshaft design power decreases, power/weight also decreases



$$\frac{\text{Power}}{\text{Weight}} = \frac{\tau\omega}{1000W}$$

where:
τ = torque (N m)
ω = angular velocity (sec^{-1})
W = weight (kg)

Energy Efficiency

Turboshaft	46%
Electric motor	85%

Propulsive Efficiency η_p

V = air velocity in

V_j = air velocity out

$\dot{m}_a$ = air mass flow rate

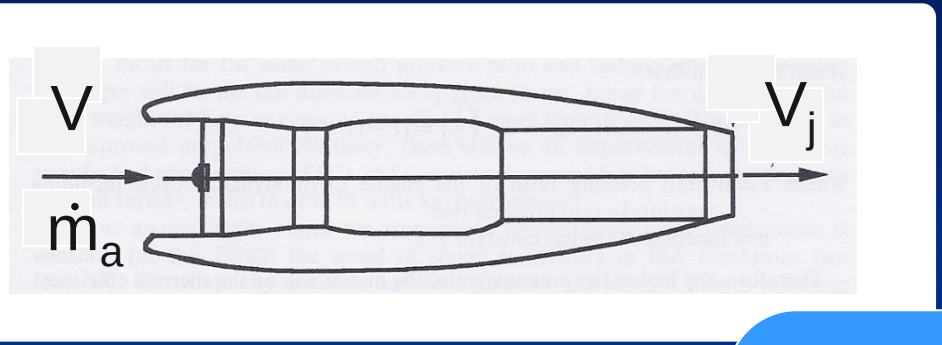
Thrust $F = \dot{m}_a \left(V_j - V \right)$

$$F = \dot{m}_a V \left(\frac{V_j}{V} - 1 \right)$$

$$\text{Propulsive efficiency} = \frac{\text{Useful power}}{\text{Power added}}$$

$$\text{Useful power} = FV = \dot{m}_a V \left(V_j - V \right)$$

$$\text{Power added} = \frac{1}{2} \dot{m}_a V_j^2 - \frac{1}{2} \dot{m}_a V^2$$



$$\eta_p = \frac{\dot{m}_a V \left(V_j - V \right)}{\frac{1}{2} \dot{m}_a \left(V_j^2 - V^2 \right)} = \frac{2V \left(V_j - V \right)}{\left(V_j - V \right)\left(V_j + V \right)}$$

$$\eta_p = \frac{2V}{V_j + V} = \frac{2}{1 + \frac{V_j}{V}}$$

For highest η_p $V_j = V + \Delta V$ where ΔV is as small as possible

But mass flow rate must be large

Caveat – almost all payload-range values in this presentation are goal values. Except for fixed-wing aircraft, almost none of them has been demonstrated in flight

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A Swarm of eVTOL Projects

Now part of Kitty Hawk

No evidence of hardware

Source: teslamotorsclub.com/tmc/threads/will-evtols-take-over-the-commercial-small-helicopter-market.93325/

A Swarm of eVTOL Projects

https://evtol.news/aerofugia-technology-co-ltd-transporter-concept-design

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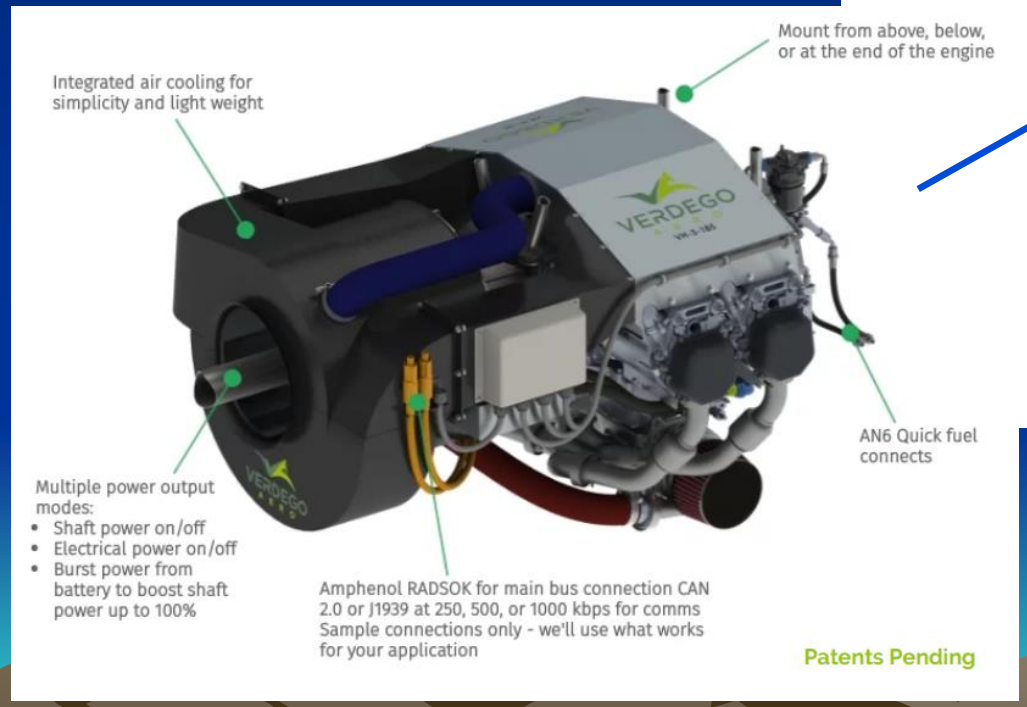
VerdeGo Aero PAT 200

- 2 pax
- Useful load 227 kg (500 lb)
- Max cruise speed 240 km/h (150 mph)
- Energy storage: at present - liquid fuel

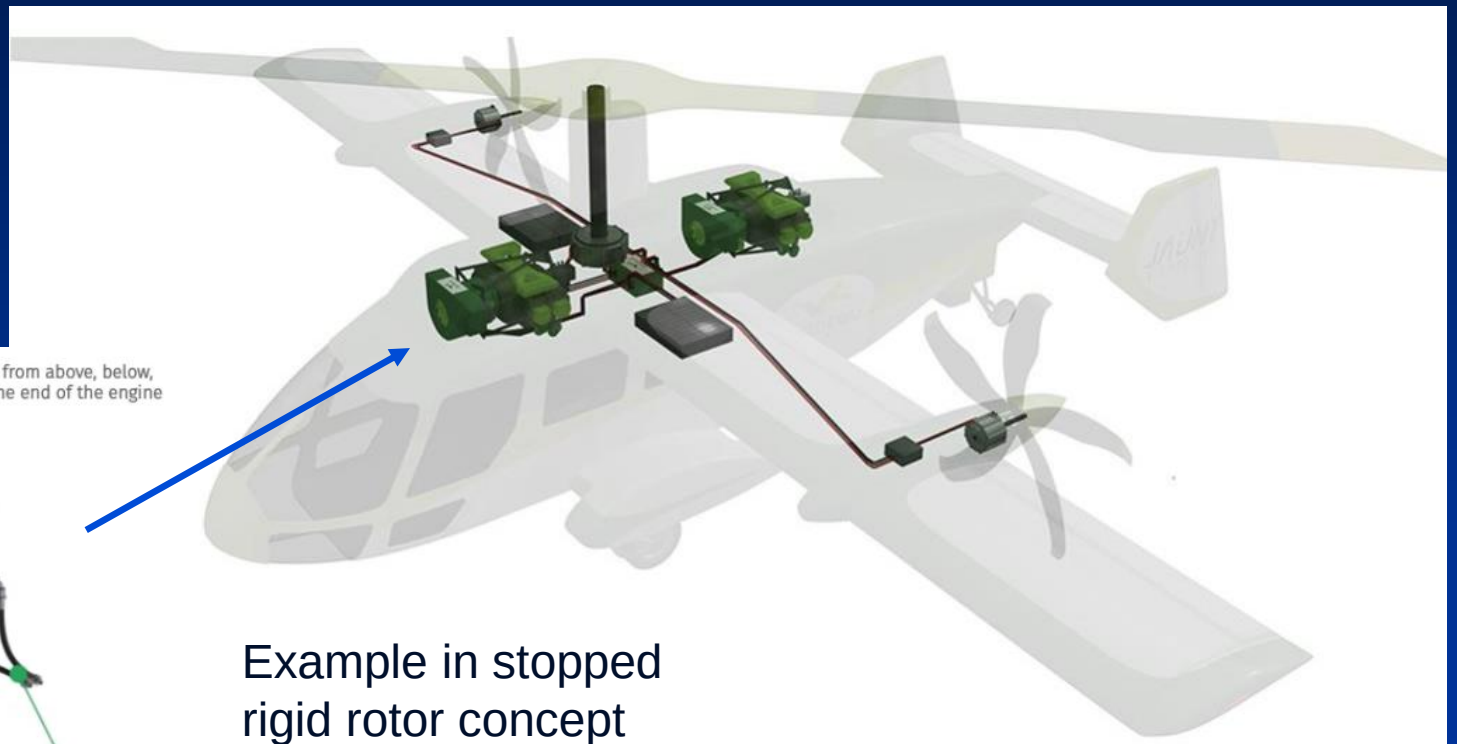
http://evtol.news/aircraft/verdego/

VerdeGo VH-3-185 Hybrid Power System

- SAFRAN SR305 certified diesel aeroengine
- Uses jet fuel or biofuel
- Eventual evolution to all-electric system (maybe)



https://www.verdegoaero.com/copy-of-engineering-services



Example in stopped rigid rotor concept

https://aviationweek.com/special-topics/sustainability/propulsion-providers-hop-accelerating-hybrid-power-train

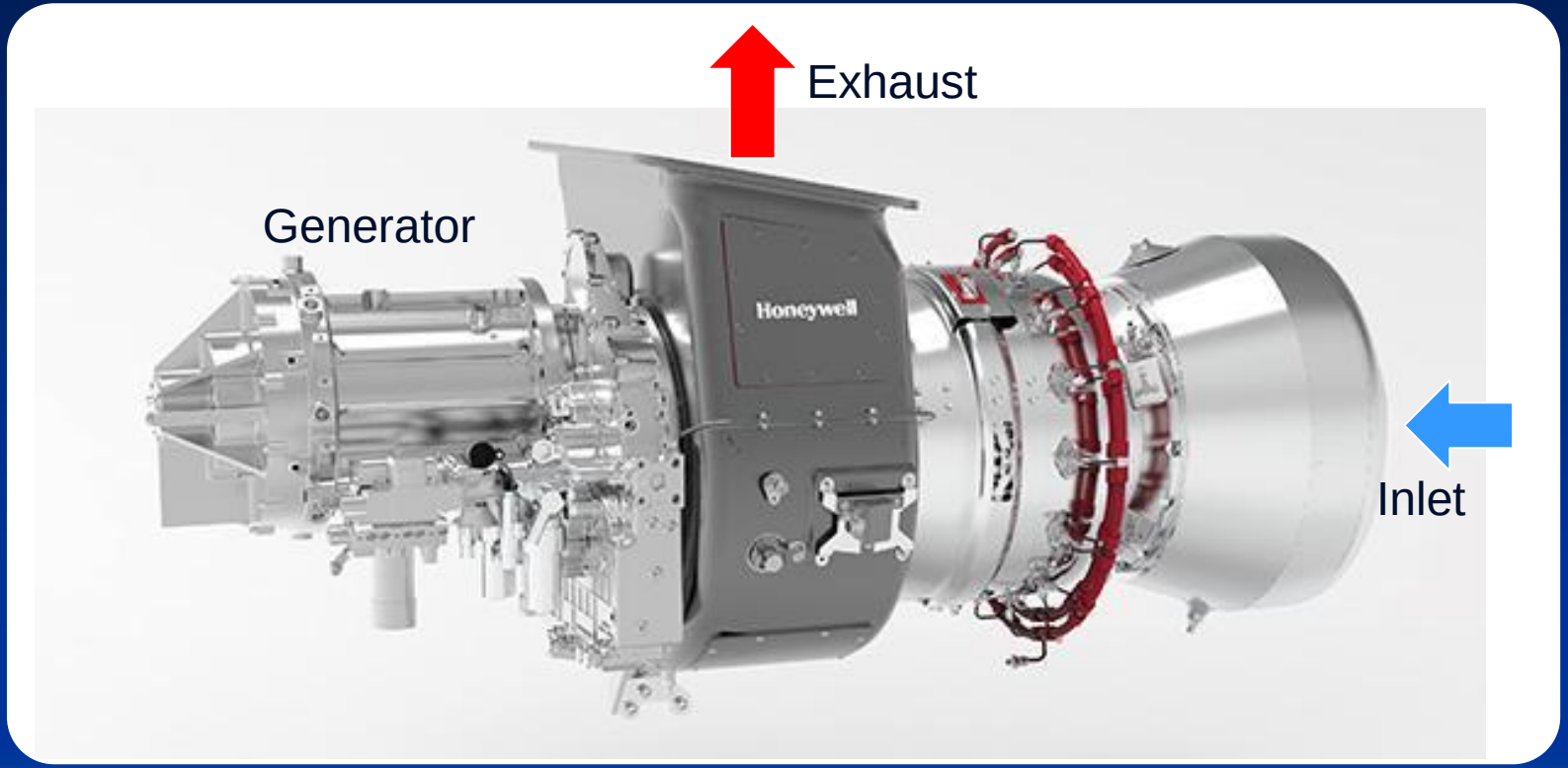
Max continuous power 185 kW
Max burst shaft power 370kW
Currently not battery-powered!!!

VerdeGo Fixed Wing Concept

- Verdego started in 2017
- No full-scale aircraft have been built

Honeywell 1 MW Turbogenerator

- Adapted from HGT1700 APU (on A350) (pneumatic power delivery eliminated)
- Similar developments for PW100 and PT6



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- All-Electric VTOL
  - Fixed vertical nacelles
  - Fixed vertical and horizonal nacelles
  - Rotating and fixed nacelles
  - Rotating nacelles
  - Separate lift and cruise vehicles

Classes of Battery-powered aircraft

Fixed vertical nacelles

Fixed vertical & horizonal nacelles

Separate lift and cruise vehicles

Increasing range

Rotating & fixed nacelles

Rotating nacelles

- All-Electric VTOL
  - Fixed vertical nacelles
  - Fixed vertical and horizonal nacelles
  - Rotating and fixed nacelles
  - Rotating nacelles
  - Separate lift and cruise vehicles

亿航 216

- 16 motors (Ehang 184 has 8)
- Payload: 2 pax (220 kg, 485 lb)
- Range: 35 km (19 nmi)
- Flight time: 21 minute
- V_{max} : 130 km/hr
- V_{cruise}: 100 km/hr
- Ceiling: 3,000 m (9,843 ft)

E-Volo Volocopter

- 18 electrically-driven, fixed pitch 2-bladed propellers
- Approx 97km (52 nmi)
- ~27 minutes endurance/charge
- (1 hour endurance for hybrid propulsion)
- 1-, 2-, or 4-seats
- Partnered with Grab
- MTOGW = 450 kg (1000 lb)
- Battery weight approx. 1/3 TOGW
- Possible, but unlikely, operation at Paris Olympics

Can use multiple propellers driven by electric motors that provide stability, control (and lift augmentation for winged configurations)

Payload: 300-400 kg (660-880 lb)
Range: 100 km (54 nmi)
Cruise speed: 180 km/hr (97 kt)

Payload: Any of six ISO-standard pallets up to 200 kg (330
Range: 40 km (22 nmi)

Most recent funding: $182M in 2022

- All-Electric VTOL
  - Fixed vertical nacelles
  - Fixed vertical and horizonal nacelles
  - Rotating and fixed nacelles
  - Rotating nacelles
  - Separate lift and cruise vehicles

BETA Techologies Package Delivery

https://transportup.com/headlines-breaking-news/vehicles-manufactures/ups-places-order-for-beta-technologies-evtol-eis-in-2024/?ct=t(N_COPY_01)

- 4 lifting props, 1 propulsion prop
- Cargo: 635 kg (1,400 lb)
- Speed: 274 km/hr (148 kt)
- Range: 402 km (217 nmi)
- Battery charge in one hour
- At end of battery life cycle will be used for recharging new batteries and UPS trucks
- Part 23 certification and delivery planned for 2025

Aerofugia (Geely subsidiary) TF-2

- 6 fixed lifting rotors
- 2 tractor propellers
- 1 pusher propellers
- Pilot + 4 pax
- Range: 500 km (270 nmi)

Aerofugia (Geely subsidiary) TF-2

- 2023-02-13 First flight
- 2023-04-13 AE200 certification process started
- 2028 Planned certification

Autoflight

- 10 fixed lifting rotors
- 2 tractor propellers

- Range: > 250 km
- Cruise speed: > 200 km/hr
- Payload: > 350 kg

- 2024-02-27 autonomous flight Shenzhen to Zhuhai (~ 58 km)

- All-Electric VTOL
  - Fixed vertical nacelles
  - Fixed vertical and horizonal nacelles
  - Rotating and fixed nacelles
  - Rotating nacelles
  - Separate lift and cruise vehicles
  - Ducted fan

As of 2023-08-10
Total investment $1.1B

Committed to launching UAM Network in Miami and LA by 2025*

Most Vahana subsystem lead engineers (aerodynamics, flight controls, flight test, avionics) hired by Archer

Forward nacelles pivot into vertical position for takeoff and landing

*Average type certification schedule for FAR Part 23 aircraft is 3 years (https://www.ainonline.com/aviation-news/aviation-international-news/2006-12-18/aircraft-certification-process)

Archer Aviation gets a $1 billion order from United Airlines, on the same day it announces a deal to go public

Last Updated: Feb. 10, 2021 at 3:04 p.m. ET
First Published: Feb. 10, 2021 at 2:05 p.m. ET

By Tomi Kilgore

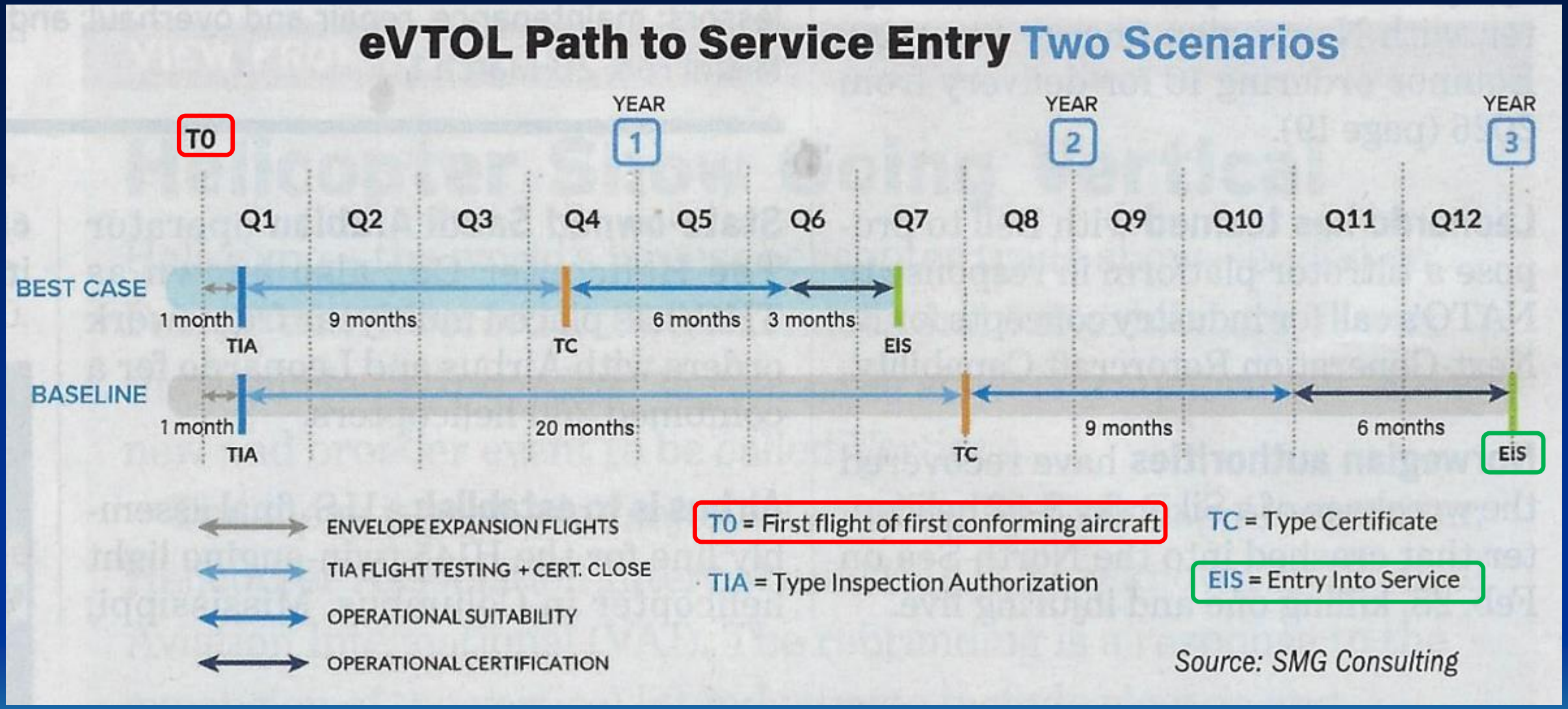
Special Purpose Acquisition Company

6

Archer agrees to merge with SPAC Atlas Crest Investment, to create a public company with an equity value of $3.8 billion

6 fixed nacelles in wake of cruise propellers

Source: marketwatch.com



Baseline scenario is still optimistic

- All-Electric VTOL
  - Fixed vertical nacelles
  - Fixed vertical and horizonal nacelles
  - Rotating and fixed nacelles
  - Rotating nacelles
  - Separate lift and cruise vehicles

Joby Aviation S4

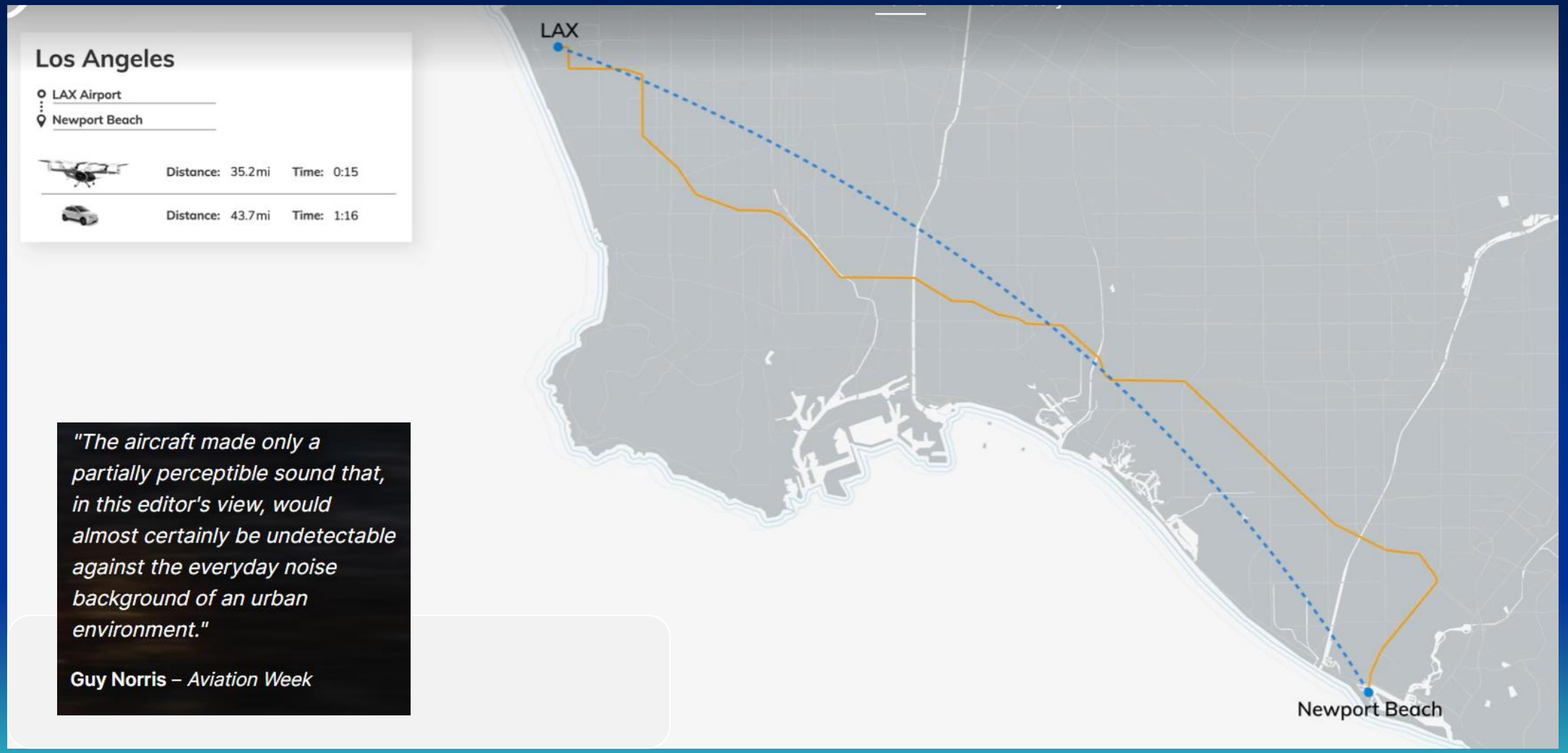
- 2020 design variant
- Additional funding of $594M from Toyota
- 2021-08 SPAC investment of $1.1B
- Planned entry into service in 2025
- Cruise speed of 322 km/hr (174 kt)
- Estimated cost to build $1.3M*
- Estimated DOC: $3/RPM*
- 2022-05 Receives Part 135 certification (still needs Part 91 certification)
- Payload : ~ 1,000 lb (453 kg)
- Range: 157 nmi (291 km)

Aboulafia estimates $4-5M. DOC may be small but capital costs are large (AIAA Aerospace America 2022-04 Gambling on advanced air mobility")

*https://www.forbes.com/sites/jeremybogaisky/2021/08/11/joby-stock-spac-nyse/?sh=5345200b7a41

https://www.jobyaviation.com/

Joby Aviation



"The aircraft made only a partially perceptible sound that, in this editor's view, would almost certainly be undetectable against the everyday noise background of an urban environment."

Guy Norris – *Aviation Week*

Joby Aviation

Agility Prime Works To Deliver eVTOL to USAF Unit in 2025

> eVTOLs COULD ASSIST USAF AGILE COMBAT EMPLOYMENT CONOPS

> GROUND-CHARGING INFRASTRUCTURE COULD BE LIMITING FACTOR

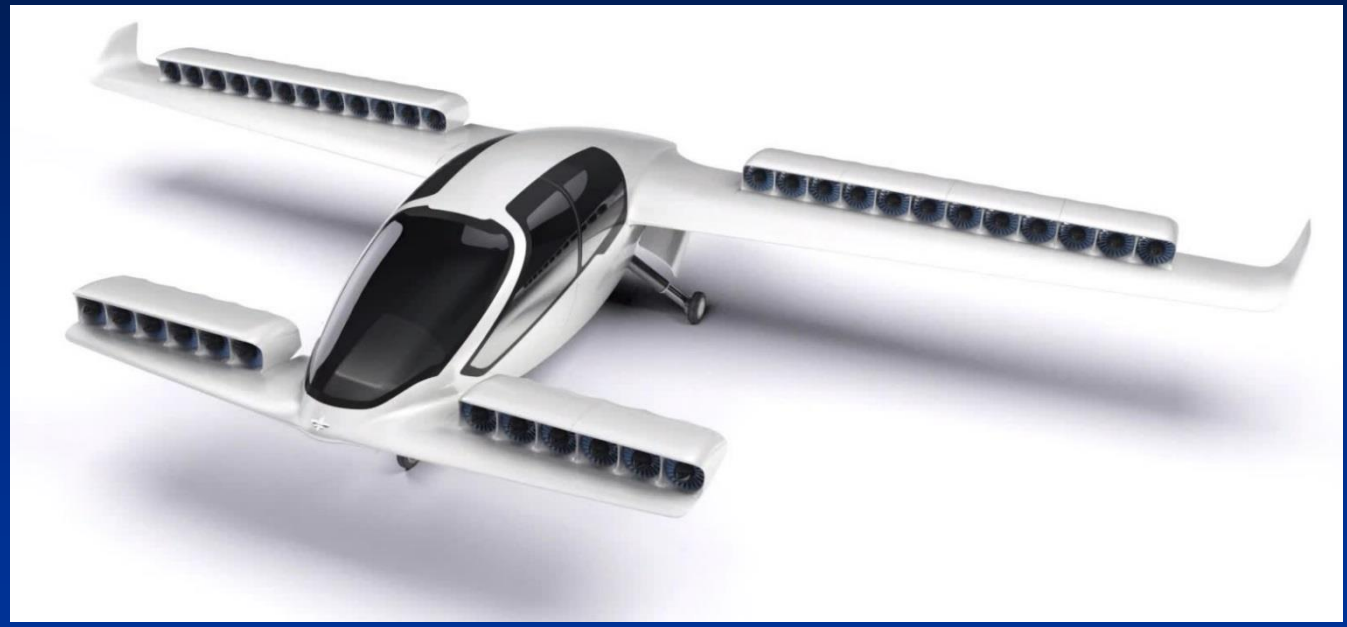
Flight-testing Joby's S4 is a top priority of AFWerx's Agility Prime program.

Garrett Reim Santa Clara, California

Hyundai S-A2 Air Taxi

- Avg trip distance – 22-35 nmi
- Avg cruise speed – > 104 kt
- Number of pax – 4 pax + 1 pilot
- Noise at hover – < 65 dBA
- Noise at cruise – < 45 dBA
- Cruise altitude – 1,500 ft
- Forward rotors pivot up
- Aft rotors pivot down
- Entry into service in 2028

Lilium



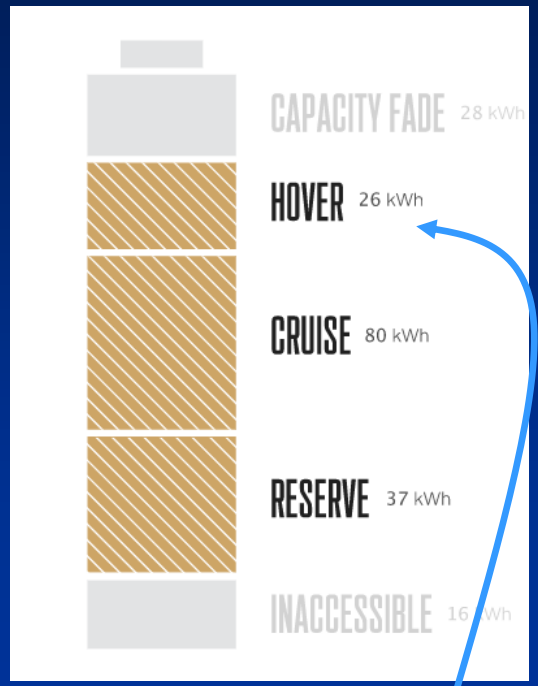
https://lilium.com/technology/

- 2021-03 Receives $830M in SPAC deal valuing company at $3.3B

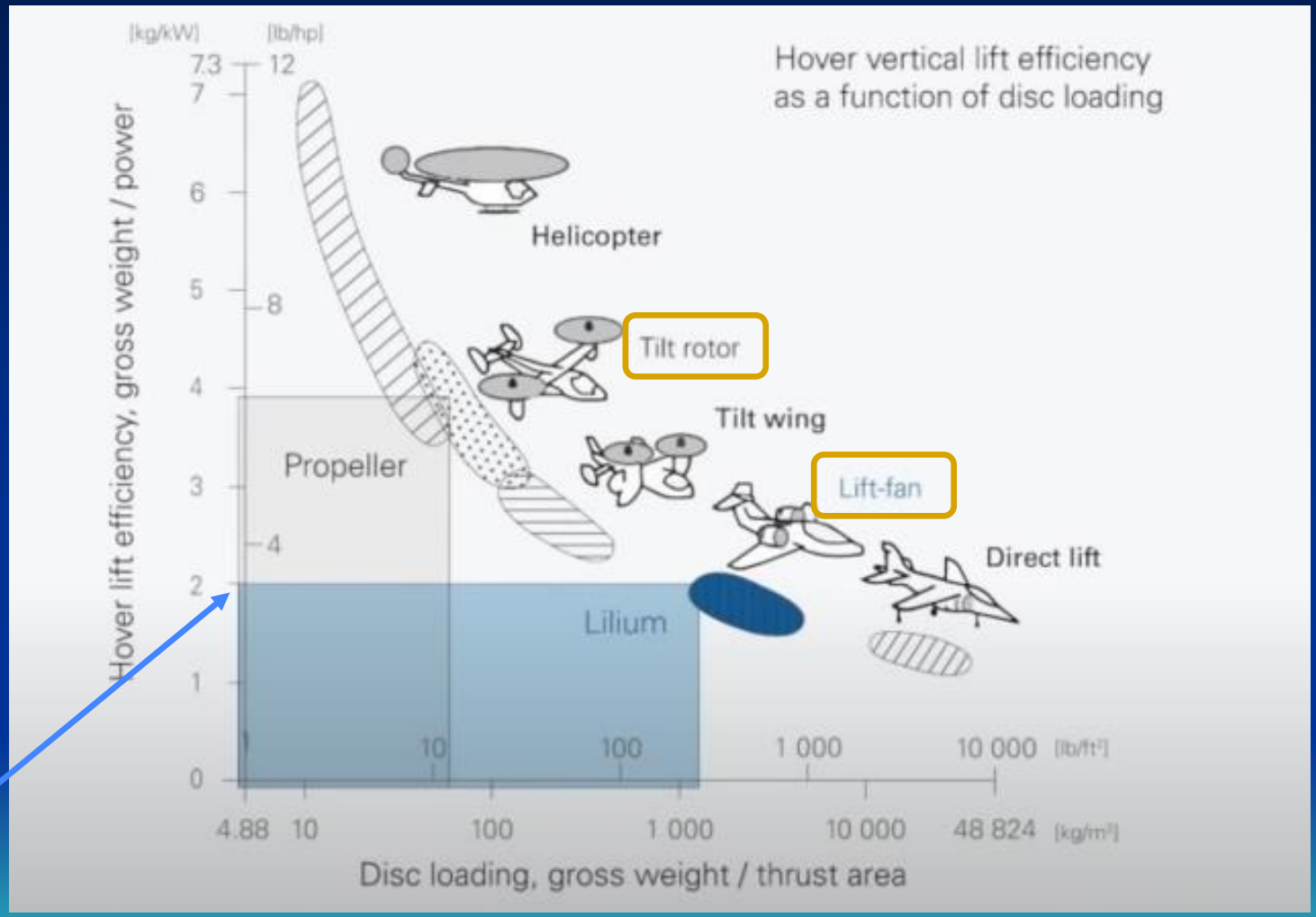
- 36 motors
- 4 pax (5 seats)
- 300 km (160 nmi) range
- 300 km/hr (160 kt) cruise speed

Lilium Jet

Archer mission energy allocation



In hover, Lilium Jet uses twice the energy of tilt rotor configuration



https://www.youtube.com/watch?v=fmiVd-CiNmw&ab_channel=eVTOLInnovation

Opener BlackFly

2017-10 First flight

2021-07 Hover demonstration at EAA Oshkosh

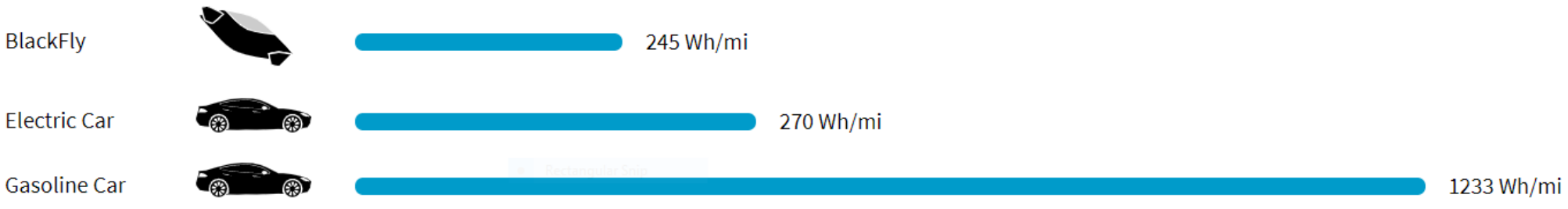
Designer: Marcus Leng
Funded by: Larry Page (Google co-founder)

- Flies under FAR Part 103 (Ultralight)
- No registration
- Max speed: 101 km/h (54 kcas) (FAR 103), 129 km/h (70 kcas) (no limit)
- Range: 32.2 km (17.4 nmi) + 25% reserves

- EW < 142 kg (313 lb) (with battery)
- TOGW = 255 kg (563 lb)
- 8 motors @ 1.8 kg (4 lb) each, 59 kg (130 lb) thrust each
- 1 pax (no license required)

Opener BlackFly

Energy Consumption



Noise

https://www.opener.aero/

Pivotal Helix

2023-10-05 Opener rebranded as Pivotal and Blackfly renamed Helix

- All-Electric VTOL
  - Fixed vertical nacelles
  - Fixed vertical and horizonal nacelles
  - Rotating and fixed nacelles
  - Rotating nacelles
  - Separate lift and cruise vehicles

Talyn Air

Separate vertical lift and cruise functions into two vehicles

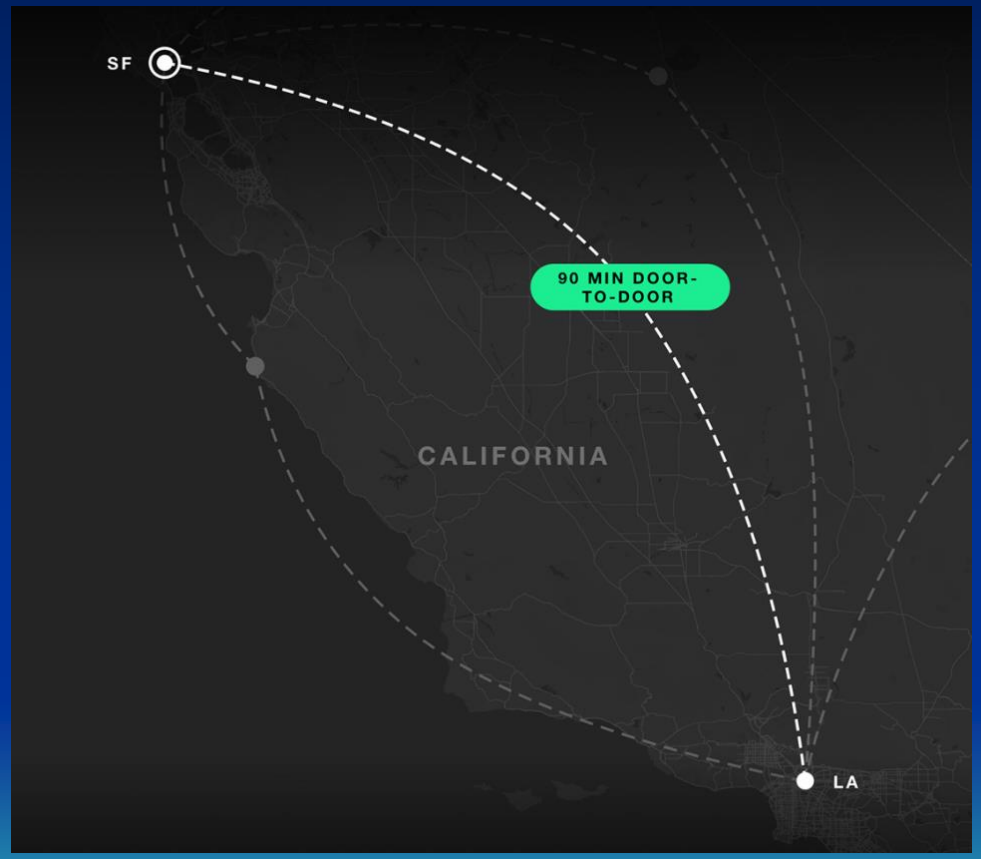
For vertiport landing, lifting drone required at destination

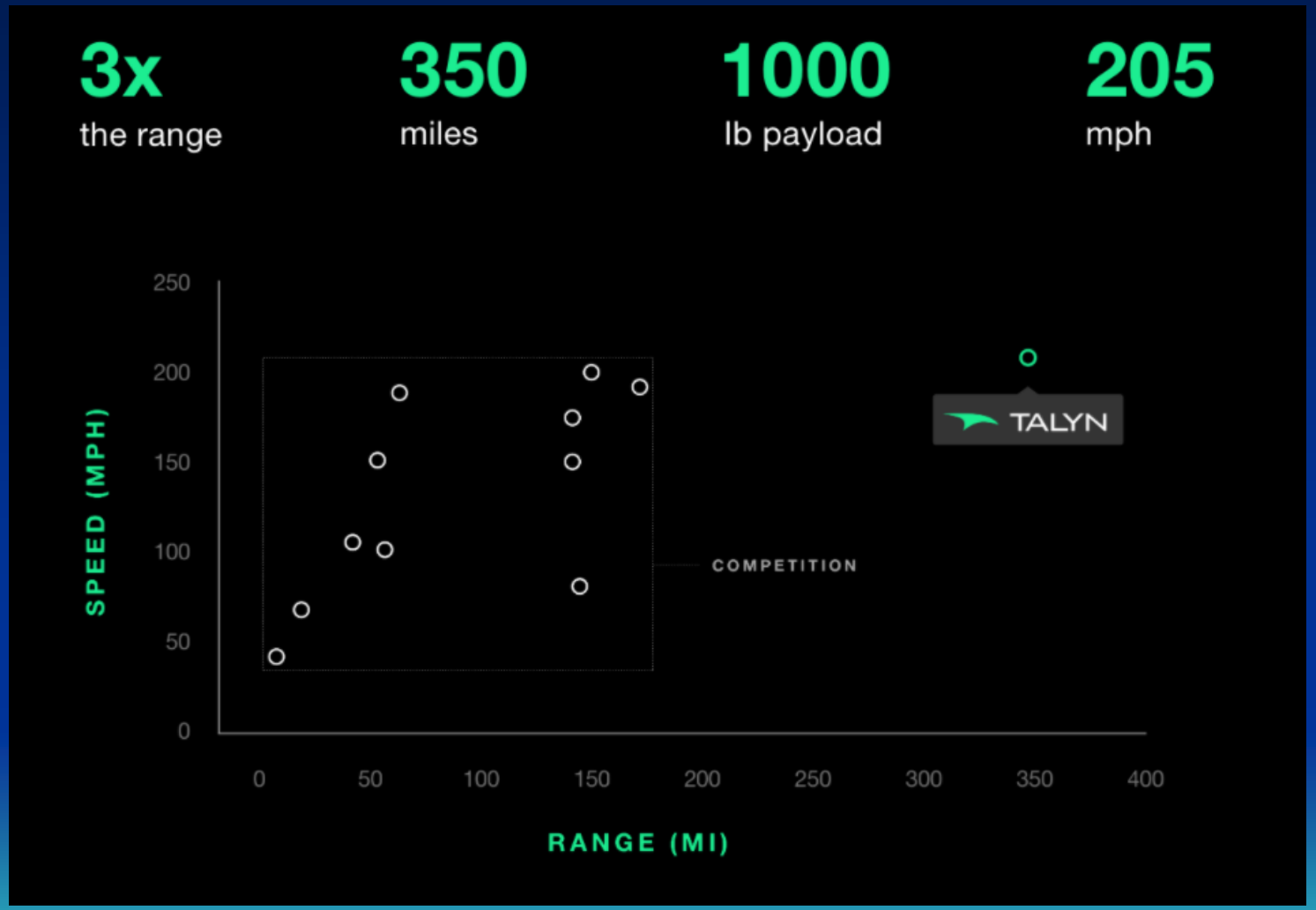
Passenger-carrying cruise vehicle capable of conventional landing if it fails to mate with drone

2023-07-20 Acquired by Ampaire with intention to produce hybrid-electric variant

https://www.futureflight.aero/news-article/2023-07-19/propulsion-system-innovator-ampaire-acquires-evtol-aircraft-developer-talyn

Talyn Air





https://www.talyn.com/#section-2

Ranking the eVTOL Leaders

AAM Reality Index based on

- Entry into service date (i.e., ~ 15 months after type certificate)
- $$ invested
- Cash management
- Potential order book

	2024 Rank	2023 Rank	Change
Volocopter	1	3	2024: Commercial launch in Paris and Rome.
EHang	2	4	2023: China certification; commercial launch.
Joby Aviation	3	1	2023: Pilot production; USAF delivery; crewed flights.
Beta Technologies	4	5	2023: Production start; USAF flight tests. 2024: Dubai flights.
Archer Aviation	5	2	2023: Midnight flight tests. 2024: Crewed flights.
Wisk	6	10	2023: Boeing takes over. 2024: Gen6 prototype to fly.
Eve Air Mobility	7	6	2023: Key suppliers named. 2024: Prototype to fly.
Vertical Aerospace	8	8	2023: First aircraft damaged. 2024: 2nd and 3rd to fly.
Lilium	9	7	2023: Final assembly begun. 2024: Crewed flights.
AutoFlight	10	11	2024: Carryall cargo certification.
Aerofugia	11	—	Carmaker Geely subsidiary. 2023: Flew airworthiness configuration; applied for certification.
Airbus	12	9	2023: Prototype power on. 2024: Flight tests.
Supernal	13	13	2024: Production configuration unveiling; prototype to fly.
SkyDrive	14	—	2023: Production deal with Suzuki. 2024: Flight tests.
Overair	15	12	2024: Uncrewed full-scale demonstrator to fly.

SMG Consulting and Aviation Week
AWST 2024-02-12

Ranking the eVTOL Leaders

COMMENTARY

WHISPER AERO

A pioneer of distributed electric propulsion at NASA and urban air mobility at Uber Elevate and now a proponent of regional air mobility at Whisper Aero, Mark Moore has long experience of and outspoken views on the industry he helped create. Here, Moore offers his electric vertical-takeoff-and-landing industry rankings based on 10 factors he considers critical to developing a successful product.

AWST 2024-02-12

eVTOL Rankings Compared

Manufacturer	Moore	SMG/AW&ST
Joby Aviation	1	3
Archer Aviation	1	5
Airbus	3	12
Supernal	4	13
Wisk	5	6
Vertical Aerospace	6	8
Volocopter	7	1
Lilium	8	9
Aerofugia	9	11
Overair	10	15
Eve Air Mobility	11	7
AutoFlight	12	10
Beta Technologies	13	4
EHang	14	2

Sources: Mark Moore, SMG Consulting and AW&ST

Up 9 places

Down 12 places

Ranking the eVTOL Leaders

Supernal is a division of Hyundai Motor Group

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AWST 2024-02-12

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Airbus	3	12	EU
Supernal	4	13	US
Wisk	5	6	US
Vertical Aerospace	6	8	UK
Volocopter	7	1	EU
Lilium	8	9	EU
Aerofugia	9	11	PRC
Overair	10	15	US
Eve Air Mobility	11	7	Brazil
AutoFlight	12	10	EU/PRC/US
Beta Technologies	13	4	US
EHang	14	2	PRC

Sources: Mark Moore, SMG Consulting and AW&ST

Low Altitude Economic Areas

Though there has yet to be an official definition, economists have generally agreed that it refers to a spectrum of business activities occurring within low-altitude airspace, commonly defined as airspace up to 1,000 meters above the ground.
China Daily 2024-03-14

Aerofugia (Geely): Sichuan
Ehang: Guangdong
Xpeng AeroHT: Guangdong
Geely: Shanghai
Autoflight CarryAll: Shanghai
Digital Eagle: Jiangsu
CATL: Jiangsu

https://www.chinadaily.com.cn/a/202403/14/WS65f2552ea31082fc043bc981.html#:~:text=Though%20there%20has%20yet%20to,1%2C000%20meters%20above%20the%20ground.

Low Altitude Economic Areas

Visit Xpeng Aeroht at https://www.aeroht.com/

The company is headquartered in Guangzhou, Guangdong, with offices in Mountain View, California, United States and Munich, Germany. XPeng stock is publicly traded on the New York Stock Exchange and the Hong Kong Stock Exchange.

Low-altitude economy given all-clear for takeoff

By ZHAO LEI | China Daily | Updated: 2024-03-14 09:38

The X2, a flying car developed by Xpeng Aeroht affiliated with automaker Xpeng, is displayed at the 2023 Smart China Expo in Chongqing in September. Flying cars are predicted to become a major factor in the low-altitude economy in the near future. ZHAO JUNCHAO/FOR CHINA DAILY

- Background
- Electric-powered Aircraft
  - Vertical Takeoff and Landing (eVTOL)
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    - All-Electric
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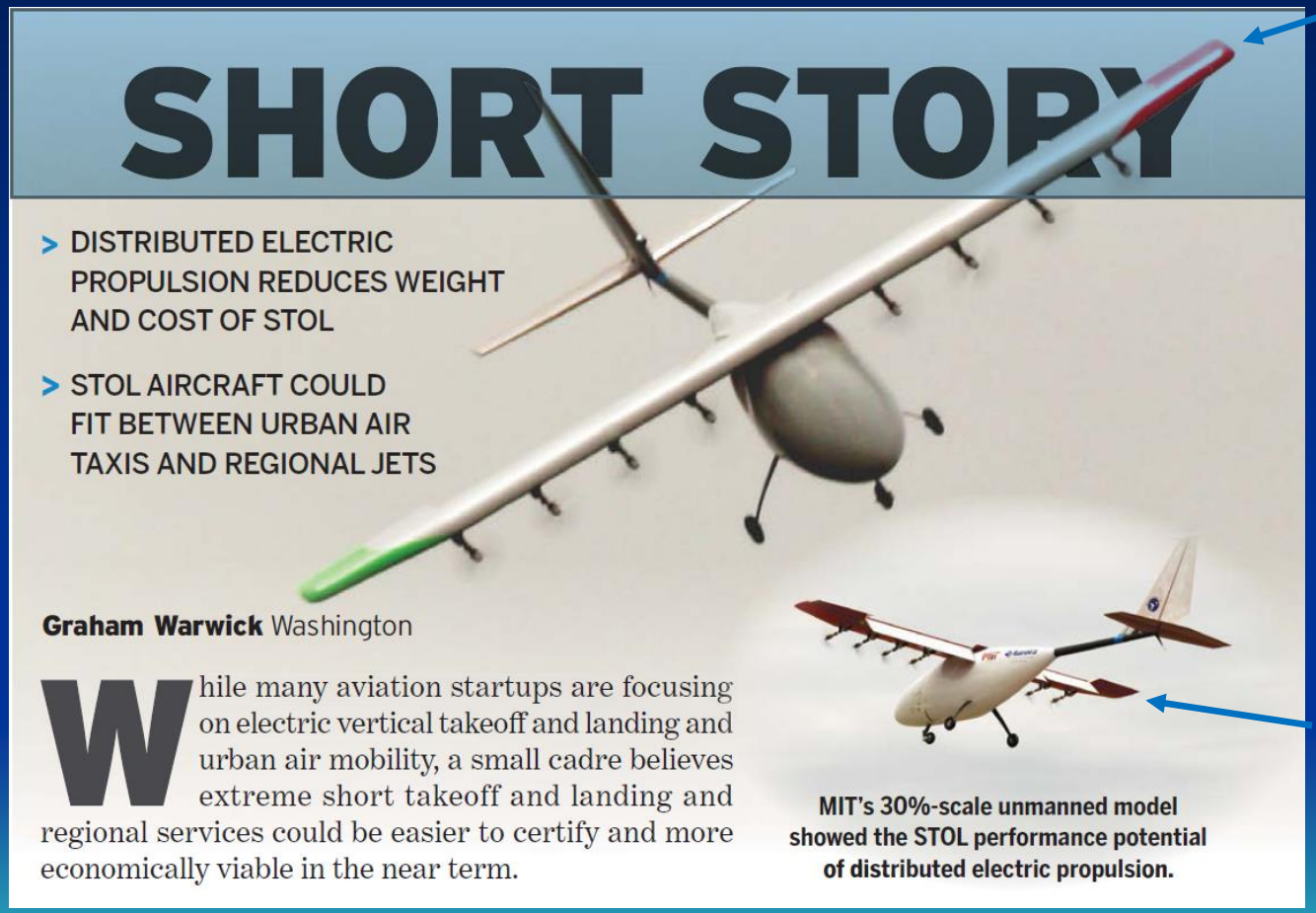
MIT eSSTOL Demonstrator



SHORT STORY

> DISTRIBUTED ELECTRIC PROPULSION REDUCES WEIGHT AND COST OF STOL

> STOL AIRCRAFT COULD FIT BETWEEN URBAN AIR TAXIS AND REGIONAL JETS

Graham Warwick Washington

While many aviation startups are focusing on electric vertical takeoff and landing and urban air mobility, a small cadre believes extreme short takeoff and landing and regional services could be easier to certify and more economically viable in the near term.

MIT's 30%-scale unmanned model showed the STOL performance potential of distributed electric propulsion.

Source: AWST 2020.05.18 Photos: MIT

Good rule for radio-controlled models: paint wingtips different colors, so that ground pilot can tell which way aircraft is headed

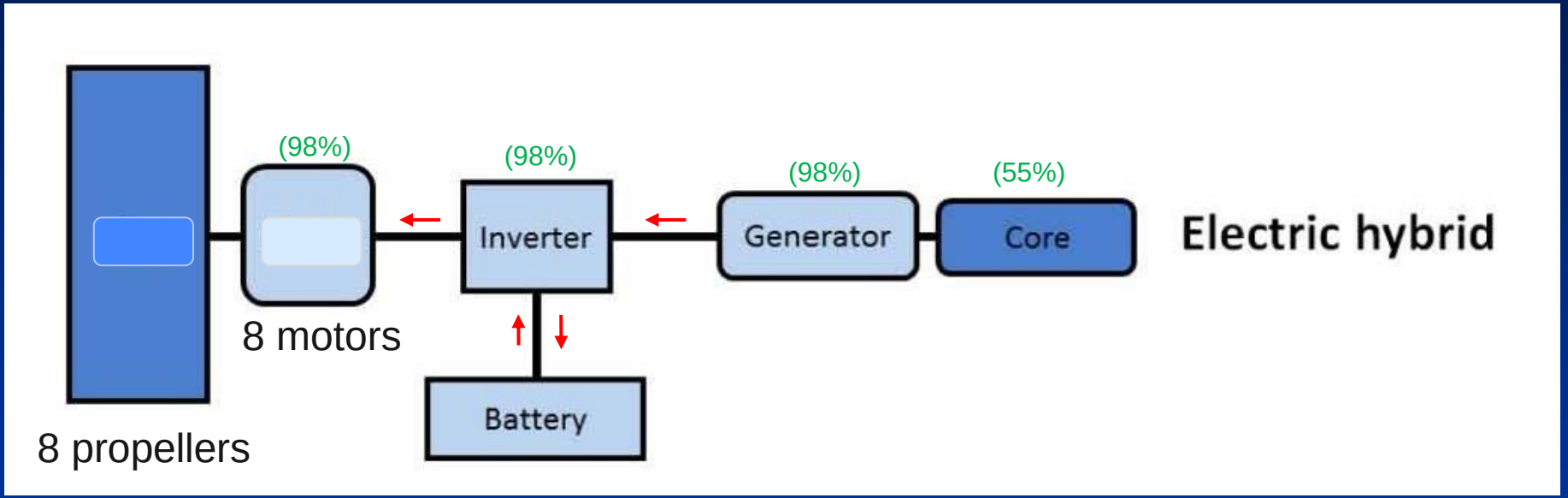
- Funding from Aurora Flight Sciences
- First flight 2019
- TOGW < 18 kg (40 lb)
- Span 9.1 m (13 ft)
- Tested 18 cm (7 in), 5-blade and 23 cm (9 in) , 2-blade props (higher C_L with smaller prop)
- Upwash from shed vorticity from o/b end of flap caused wingtip stall
- Better to use flaperons (drooped ailerons, like Twin Otter) to extend high lift to wingtips

EL-2 Goldfinch Piloted Demonstrator

Source: Flying Magazine

Flight vehicle

Electra Hybrid eSTOL



Source: © Leeham News Bjorns Corner Electric Aircraft Part 2 and 4

According to Electra, the Safran turbogenerator is the heart of the eSTOL's hybrid-electric propulsion architecture. The turbogenerator includes a gas turbine based on Safran's Arrano turboshaft engine driving two GENeUS electric generators, as well as an electrical power management system.

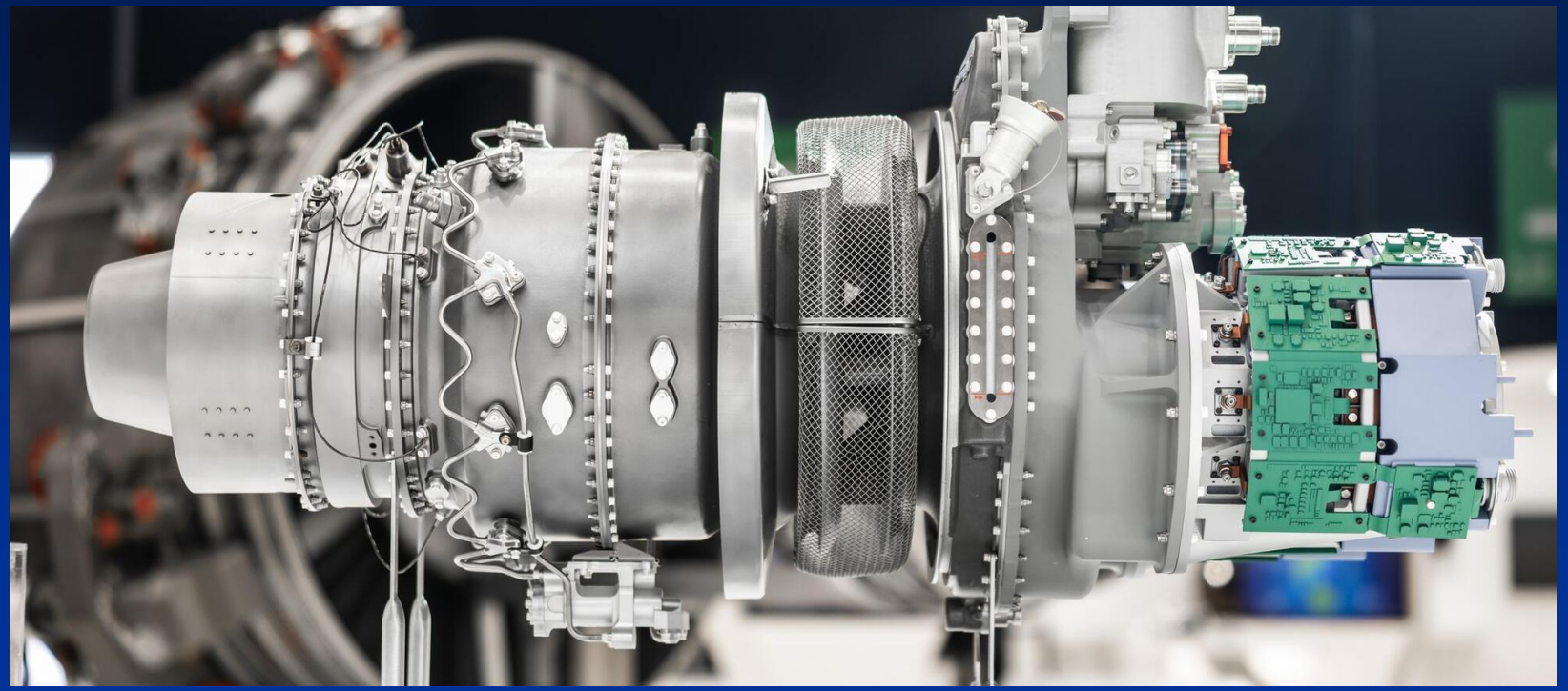
https://www.futureflight.aero/news-article/2023-06-22/safran-turbogenerator-power-electras-full-scale-hestol-prototype

Electra Hybrid eSTOL

Arrano turboshaft

Turboshaft:
Dry weight
175 kg

Length
1.22 m



Two Safran GENeUS electrical generators

Safran Helicopter Engines is supplying a 600-kW turbogenerator for Electra's nine-passenger hybrid-electric short takeoff and landing prototype, which is expected to fly in 2025. (Photo: Safran Helicopter Engines)

https://www.futureflight.aero/news-article/2023-06-22/safran-turbogenerator-power-electras-full-scale-hestol-prototype

Potential Manhattan eSTOL port

Google.com/maps

Using existing Eastside Heliport

https://www.electra.aero/

Electra Hybrid eSTOL

2022-03 USAF awarded MIT Small Business Technology Transfer contract to develop precision landing capabilities for runway-independent operations

https://www.electra.aero/media-blog/electra-mit-secures-usaf-sttr-contract-for-estol-flight-controls-development

Surf Air to Buy 90 eSTOL Electras

- 2024-02-15 Surf Air to provide Aircraft-as-a-Service (Acaas) to other air operators

zadina.barbara@electra.aero

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Ampaire Hybrid-Electric Regional Testbed

- Parallel hybrid
- First flight 2019-05-23
- Personal Airline Exchange (PAX) ordered 50, plus 50 options
- Planned supplemental type certificate
- Test routes on Mokulele Airlines on Maui and Vieques Air Link in Puerto Rico

Source: Ampaire

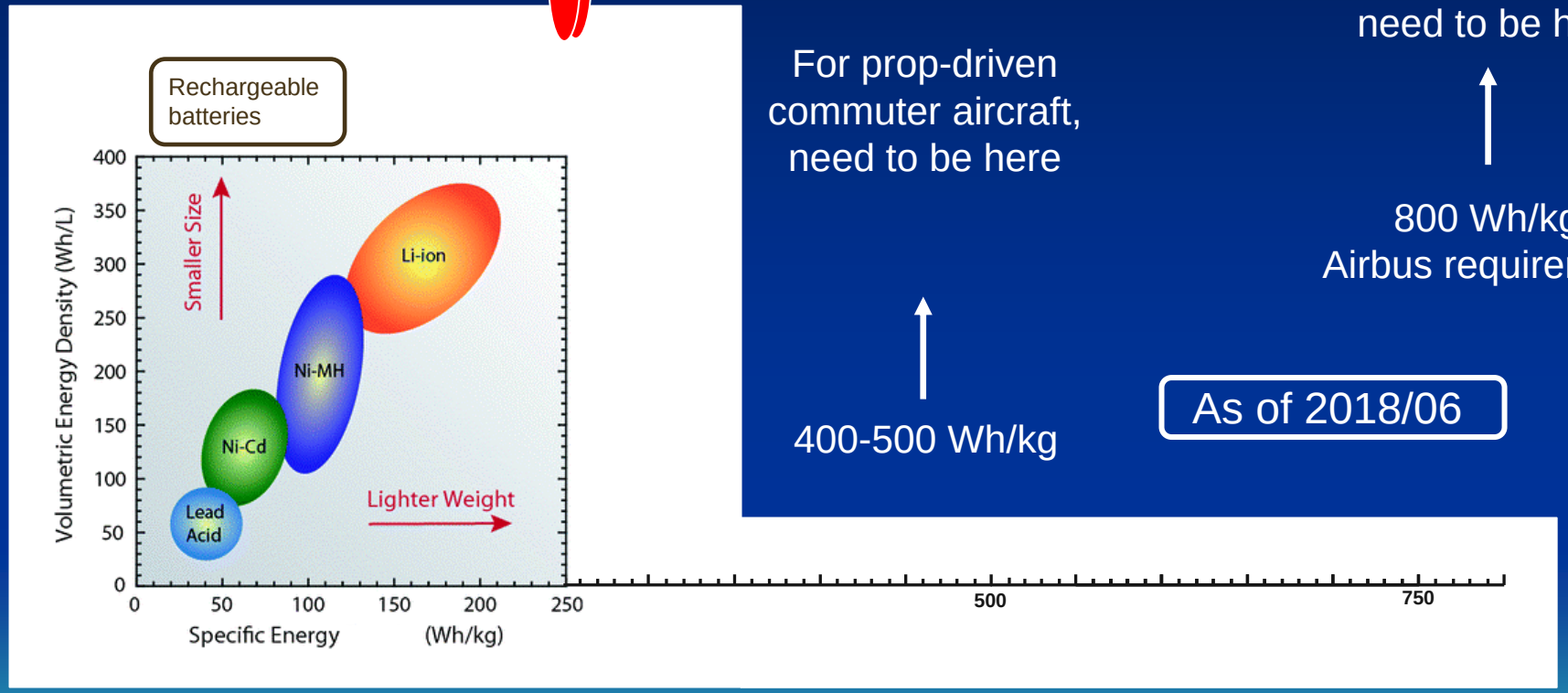
https://www.flyingmag.com/story/aircraft/ampaire-hybrid-electric-trials-begin/

← Cessna 337 Skymaster with Continental IO-360 aft and electric motor forward with 200 Wh/kg Li-ion batteries (normally recharged on field, but could be swapped out)

Battery Specific Energy

Tesla

Solar Impulse



For prop-driven commuter aircraft, need to be here

400-500 Wh/kg

For transonic JP/electric transport, need to be here

800 Wh/kg
Airbus requirement

As of 2018/06

http://www.epectec.com/batteries/cell-comparison.html

Liaoning Ruixiang GA Co. RX1E-A

辽宁锐翔通用飞机制造有限公司

RX1E
Fuel cell + battery

RX1E-A
Battery power only

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Pipistrel Velis Electro

- Based in Slovenia
- 2020-06-10 Receives EASA type certificate for VFR operations
- 2022-03-22 Textron announces purchase of Pipistrel
- Characteristics
  - Powerplant: Pipistrel E-811 (57.6 kW)
  - Energy capacity: 24.8 kWh in two liquid cooled batterie
  - Seats: 2
  - MTOGW: 600 kg (1,323 lb)
  - Cruise speed: 170 km/hr (90 kt)
  - Endurance: 50 minutes with VFR reserves

Hawaii Seaglider Initiative

Wing In Groundeffect (WIG or WIGE) achieves significant reduction in induced drag, with potential for almost doubling range

Developed by Regent Craft
Viceroy model: 12 pax
160 nmi range (300 km)
160 kt (300 km/hr)

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Eviation Alice and Heart Aerospace ES-19

https://cleantechnica.com/2021/07/17/eviation-rolls-out-100-electric-airplane-alices-production-version/

	Alice 9 seat Part 23		ES-19 19seat CS23	
Range, nm	440		200	
	lb	kg	lb	kg
MTOW	16,500	7,484	19,000	8,618
Pax+bags	2,400	1,089	4,180	1,896
Energy	8,200	3,719	6,614	3,000
OEW	5,900	2,676	8,206	3,722
OEW/MTOW	35.8%		43.2%	

https://www.ainonline.com/aviation-news/air-transport/2020-09-23/heart-unveils-electric-propulsion-system-es-19-airliner

Leehamnews.com-Bjorns Corner Sustainable Air Transport Part 4 Reality Checks

For current short-haul aircraft OEW/TOGW ~ 55%

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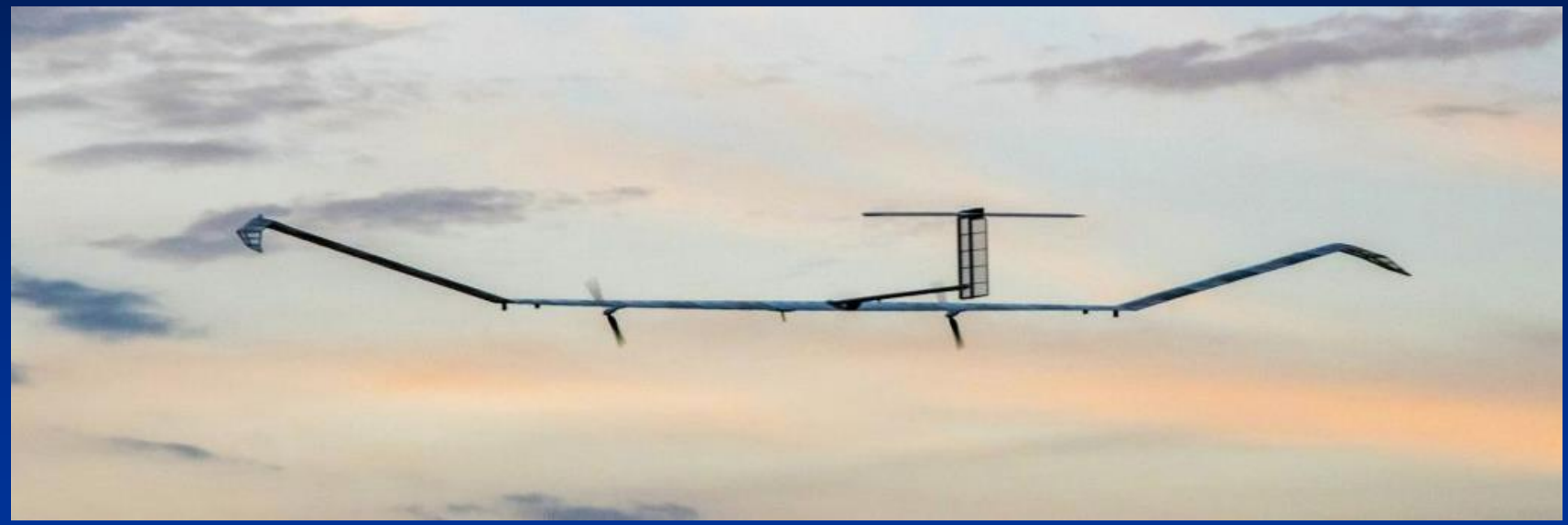
Airbus Zephyr HAPS



- High Altitude Pseudo-Satellite
- First flight: 2018-07-11 to 2018-08-08
- Duration: 26 days
- Amprius Li-ion batteries

- Span: 25 m (82 ft)
- Gross weight: 75 kg (165 lb)
- Daytime cruise alt: 21 km (69,000 ft)
- Nighttime min. alt: 16.7 km (55,000 ft)

- Background
- Electric-Powered Aircraft
- Future Aircraft Energy
- Air Traffic Control
- Conclusions

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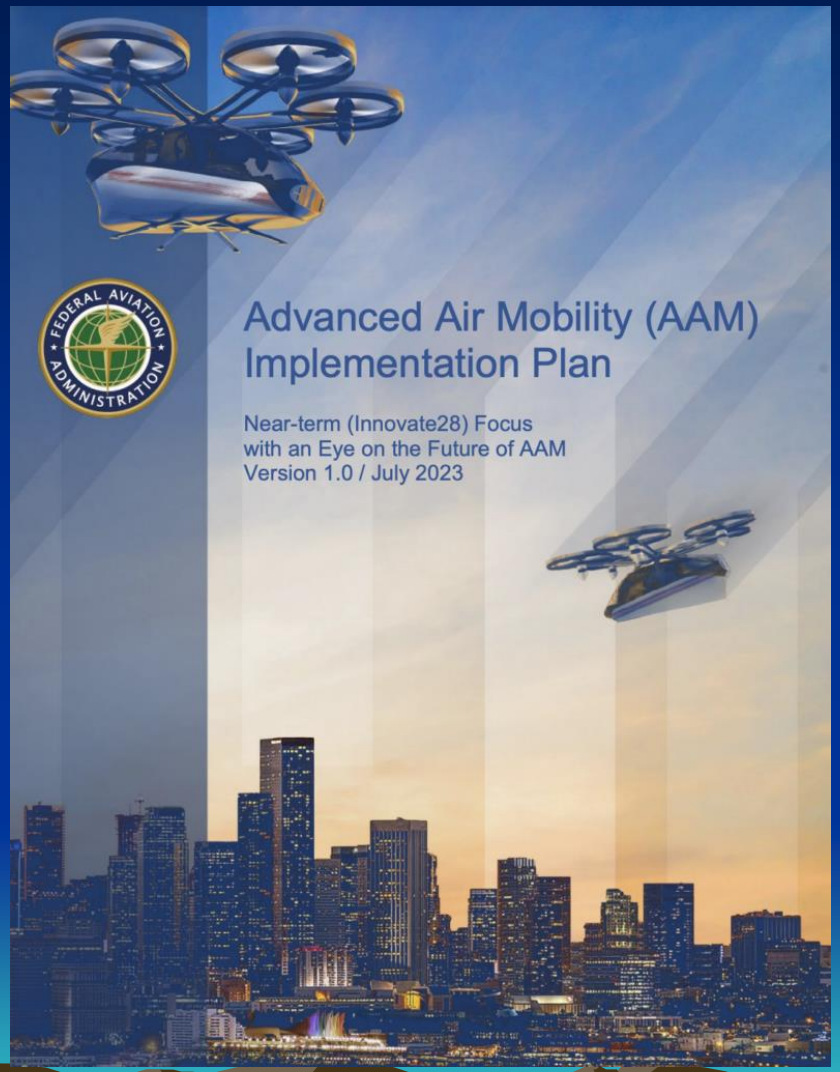
Air Traffic Control



This is the FAA perspective on AAM

Air Traffic Control

This is closer to what it may look like

https://aerospaceamerica.aiaa.org/united-nations-standards-group-increases-focus-on-plans-for-revolutionary-aircraft/?utm_campaign=AerospaceAmericaAMB&utm_medium=email&_hsmi=296462539&_hsenc=p2ANqtz-_iiwzhQt94Nb4V3l9rrdtxHGVgSlvXmiSPPv5fR2KkO1y71SmJ8xNKl-5gyS3zVARKYkO1XQ-PXjZWkYkPLXaylw3alw&utm_content=296462539&utm_source=hs_email

Air Traffic Control

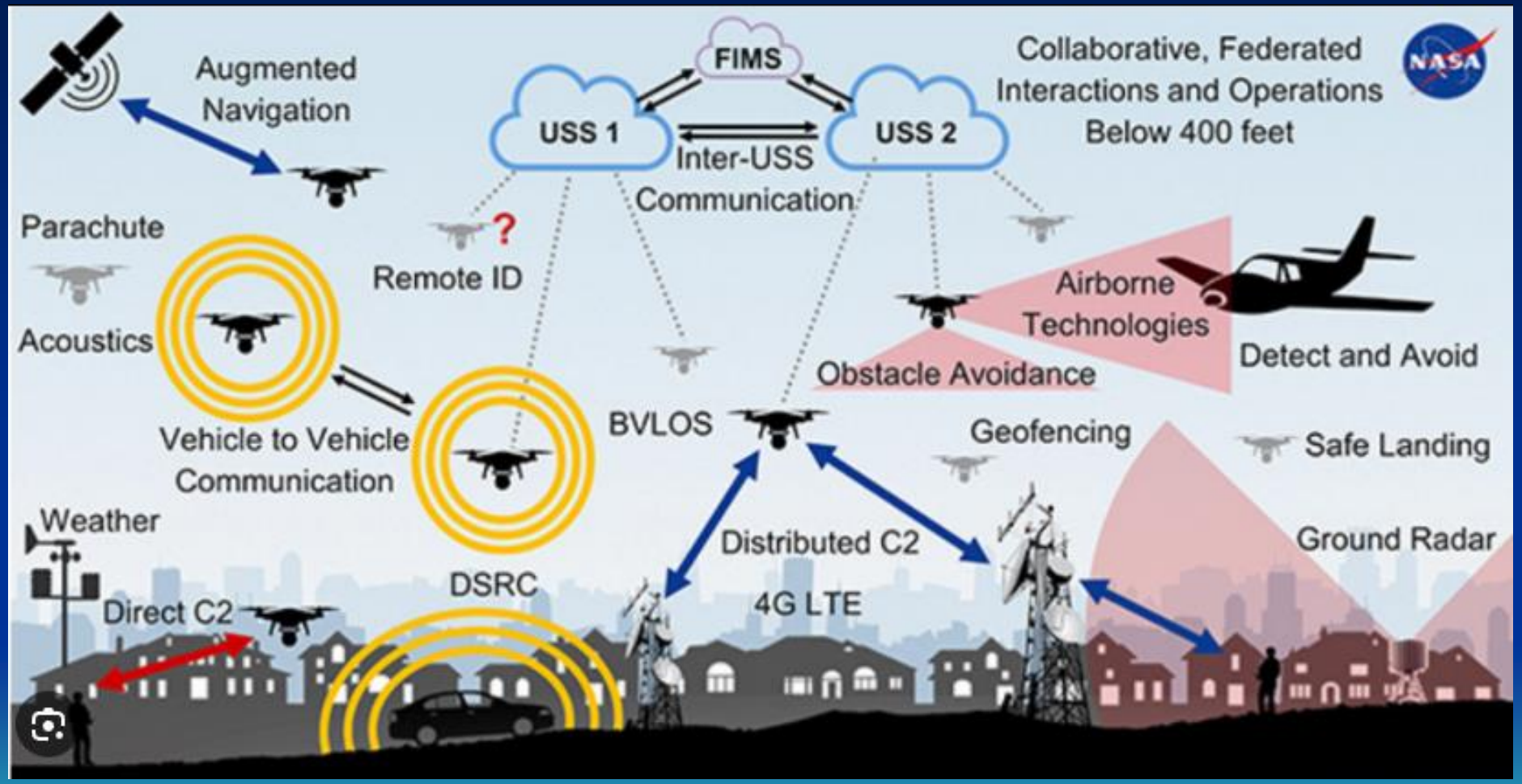
Will we ever own aircraft the way we own automobiles? Market forecasts, a proposed rule from FAA and recent test flights suggest that personal air vehicles could be coming. Aaron Karp tells the story.

BY AARON KARP | aaronkarp74@gmail.com

aerospaceamerica.aiaa.org 2024-02

UAS Traffic Management (UTM)

UAS: Unmanned Aircraft Systems
FIMS: Flight Information Management System
USS: U-Space System (European UTM system)
UTM: UAS Traffic Management
BVLOS: Beyond Visual Line Of Sight
Distributed C2: Distributed Command & Control
4G LTE: 4th Generation Long Term Evolution (mobile phone communications)
DSRC: Dedicated Short Range Communications (e.g. 5G)



Collision Avoidance Software Development

FAA sponsored -

Johns Hopkins University Applied Physics Laboratory

- ACAS Xr (Airborne Collision Avoidance System for small rotorcraft)
  - Designed to avoid imminent collision between two rotorcraft

NASA

- Autonomous Operations Planner
  - Reroutes aircraft around potential collisions that could occur within three minutes in the future

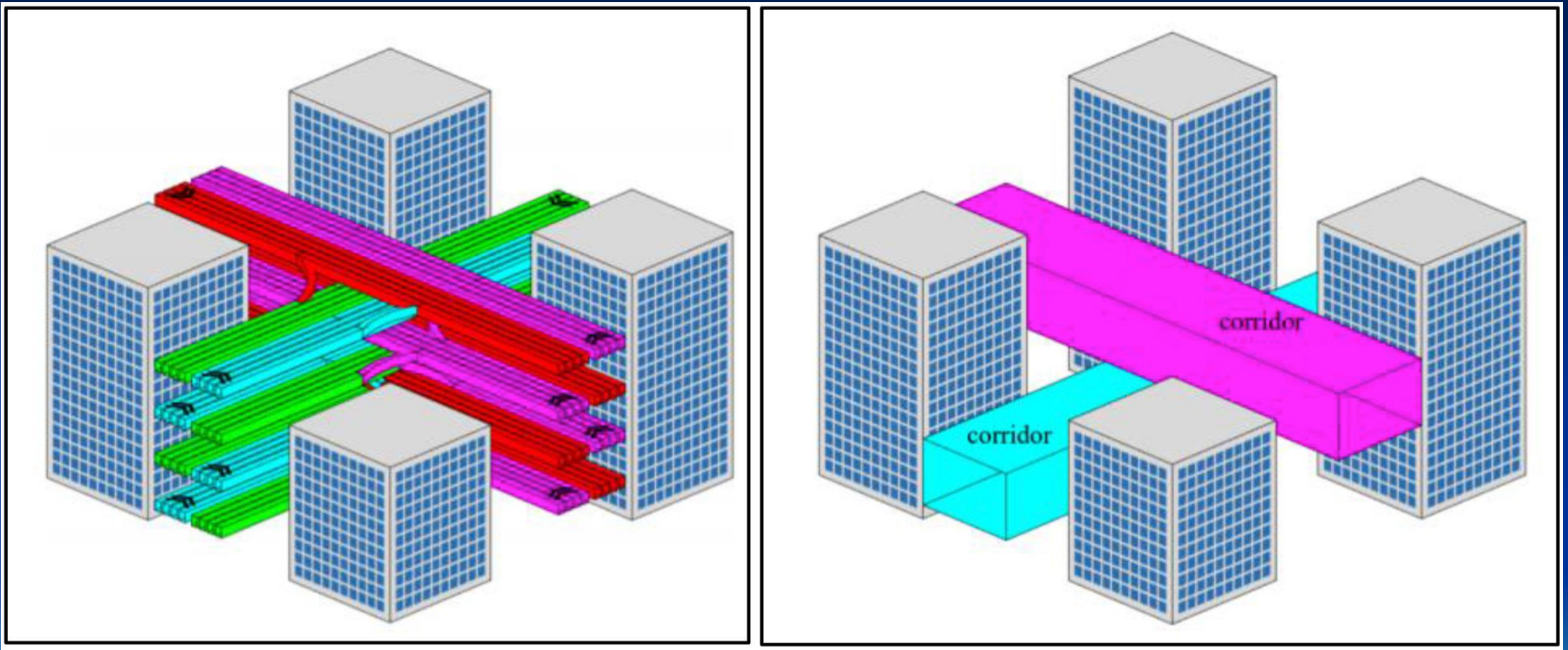
So far, testing only using Sikorsky S-76 and UH-60 Blackhawk, i.e., not tested using AAM vehicles

https://aerospaceamerica.aiaa.org/departments/collision-avoidance-for-air-taxis/

Sikorsky S-76

Sikorsky UH-60

Aerial Traffic Lanes



Aleksandar Bauranov a , Jasenka Rakas b,* Designing airspace for urban air mobility: A review of concepts and approaches, Progress in Aerospace Sciences Volume 125, Elsevier, August 2021, 100726

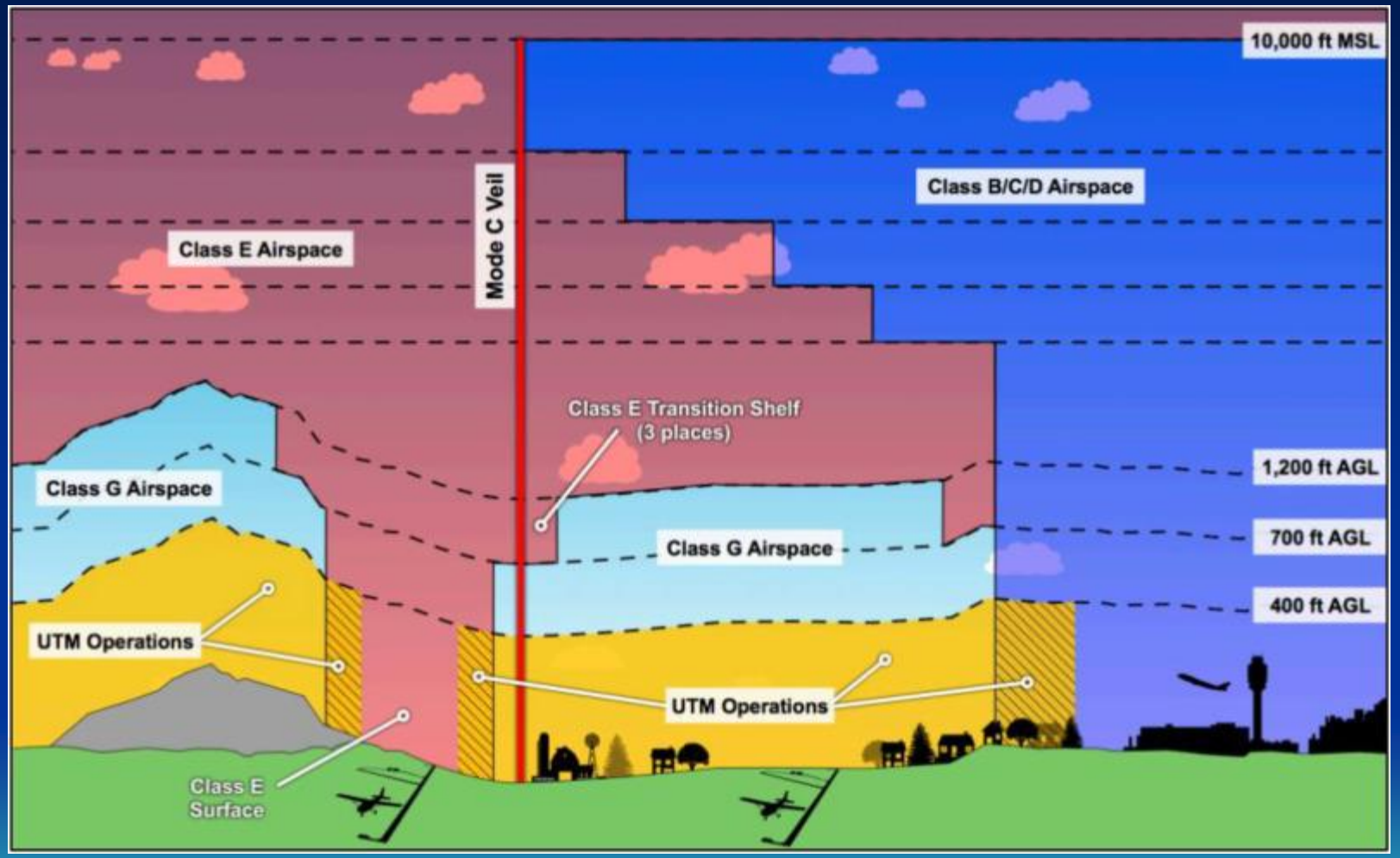
Current FAA Airspace Classification

Aleksandar Bauranov a , Jasenka Rakas b,* Designing airspace for urban air mobility: A review of concepts and approaches, Progress in Aerospace Sciences Volume 125, Elsevier, August 2021, 100726

Dedicated Space for UTM Operations

UTM: UAS Traffic Management

UAS: Unmanned Aircraft System



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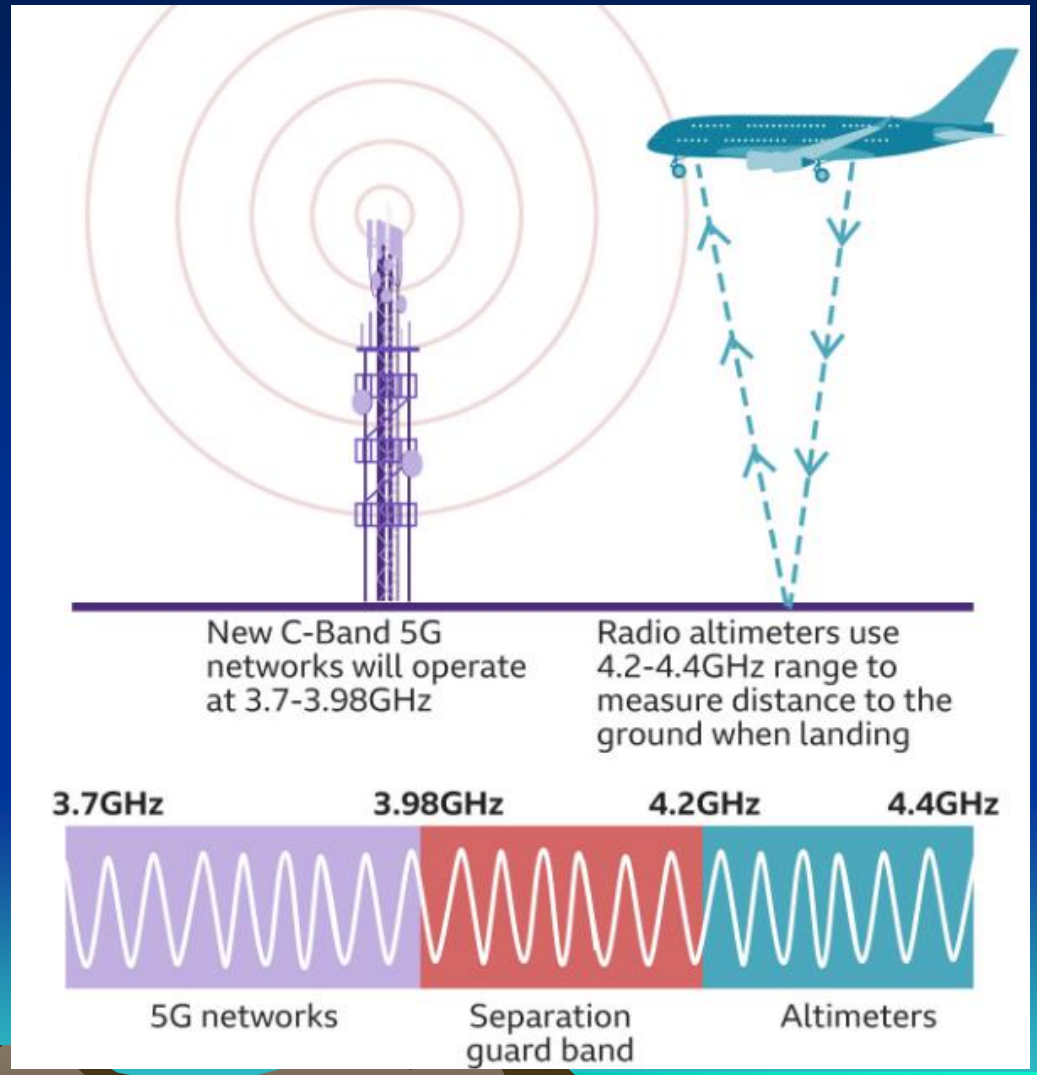
Radio Altimeter – Potential 5G Interference

- In commercial aircraft, radio altimeter can call out height (above ground level) at 10 ft intervals
- In US, concern for inadequate separation between 5G C-band (3.7 – 3.98 GHz) and radio altimeters (4.2 – 4.4 GHz)
- In 2022, AT&T and Verizon agreed not to install 5G towers near airports
- In Europe, 5G services operate between 3.4 – 3.8 GHz (separation guard band is doubled in width)
- In HK, 5G operates at 2.1, 3.5 and 4.7 GHz
- (For comparison WiFi bands are 2.4 GHz and 5 GHz)



https://altair.com/newsroom/articles/Simulation-to-Handle-and-Predict-5G-Interference-During-Aircraft-Landing

5G Vehicle-to-Vehicle Communications

5G will allow new forms of vehicle-to-vehicle (V2V) communications so that in the future, two cars approaching from directions that are perpendicular would allow their onboard computers to determine which vehicle will yield for the other one at the location where their paths will cross

Both Audi and GM expect to begin adding embedded 5G connectivity to select models in the United States in the 2024 model year

https://nmbtc.com/blog/how-5g-standards-will-impact-driving-and-autonomous-vehicles/#:~:text=5G%20will%20allow%20new%20forms,where%20their%20paths%20will%20cross.

https://altair.com/newsroom/articles/Simulation-to-Handle-and-Predict-5G-Interference-During-Aircraft-Landing

5G Vehicle-to-Vehicle Communications

When cars talk with each other, they do it by exchanging data wirelessly over an unlicensed spectrum called the Dedicated Short Range Communications (DSRC) band, using technology similar to Wi-Fi. The FCC has set aside spectrum in the 5.9 GHz band specifically for this purpose, and it is only meant to be used for vehicle-to-everything (V2X) applications. That includes vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), and vehicle-to-pedestrian (V2P) — so cars talking to other cars, to traffic signals, to the phone in your pocket

https://www.theverge.com/2022/2/22/22945823/audi-verizon-5g-connectivity-2024-v2x

https://nmbtc.com/blog/how-5g-standards-will-impact-driving-and-autonomous-vehicles/#:~:text=5G%20will%20allow%20new%20forms,where%20their%20paths%20will%20cross.

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Conclusions

- When batteries may pay off
  - VTOL
    - Small aircraft (small gas turbines and piston engines are less efficient)
    - High density urban setting (rooftop landing pads)
  - Fixed wing
    - Short mission time
    - Hybrid configuration
- General
  - Investors suffering from FOMO (Fear Of Missing Out)

香港科技大學
THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY

Thanks for your interest

Airbus CityAirbus (2021-09 Design)

https://www.airbus.com/en/innovation/zero-emission/urban-air-mobility/cityairbus-nextgen

- Payload: 4 seats total
- Range: 80 km
- Max speed: 120 km/hr
- Started detailed design: 2021
- First flight: 2023

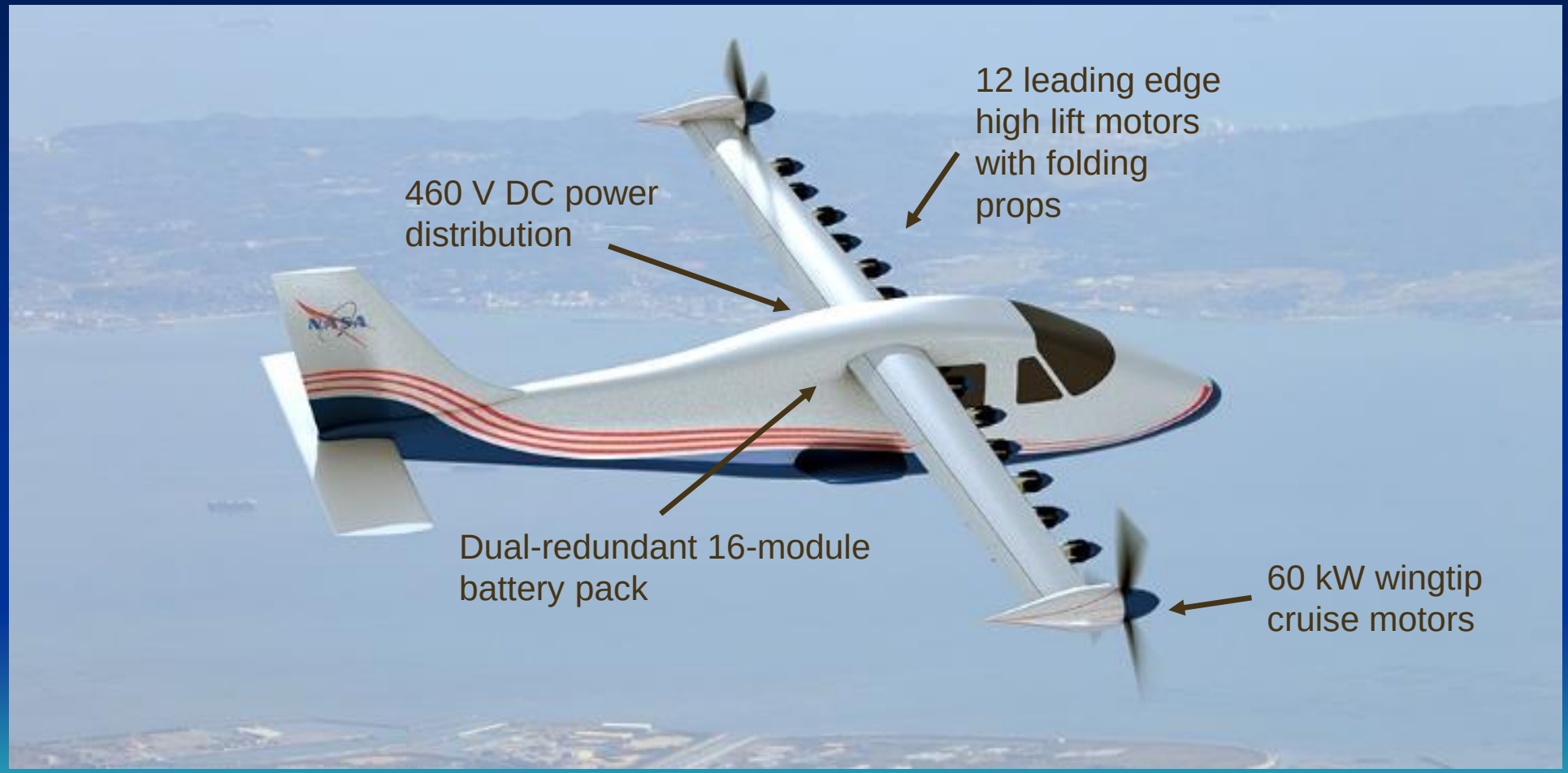
Flight Test on Cessna 208B Grand Caravan

- First flight 2020-05-28
- Replace 647 kW (867 hp) PT6A-114A with 560 kW (750 hp) Magni 500
- Endurance: 30 minutes
- Considering replacing with Li-S batteries or H_2 fuel cells
- For very short missions (overwater**, sightseeing*, training), electric power may be worthwhile

** e.g. Loganair (90 seconds)
*e.g. Harbour Air

https://www.magnix.aero/ecaravan/

NASA X-57 Maxwell



Source: awst.com