LightningStrike VTOL X-Plane Program

Transformative Vertical Flight Concepts Workshop
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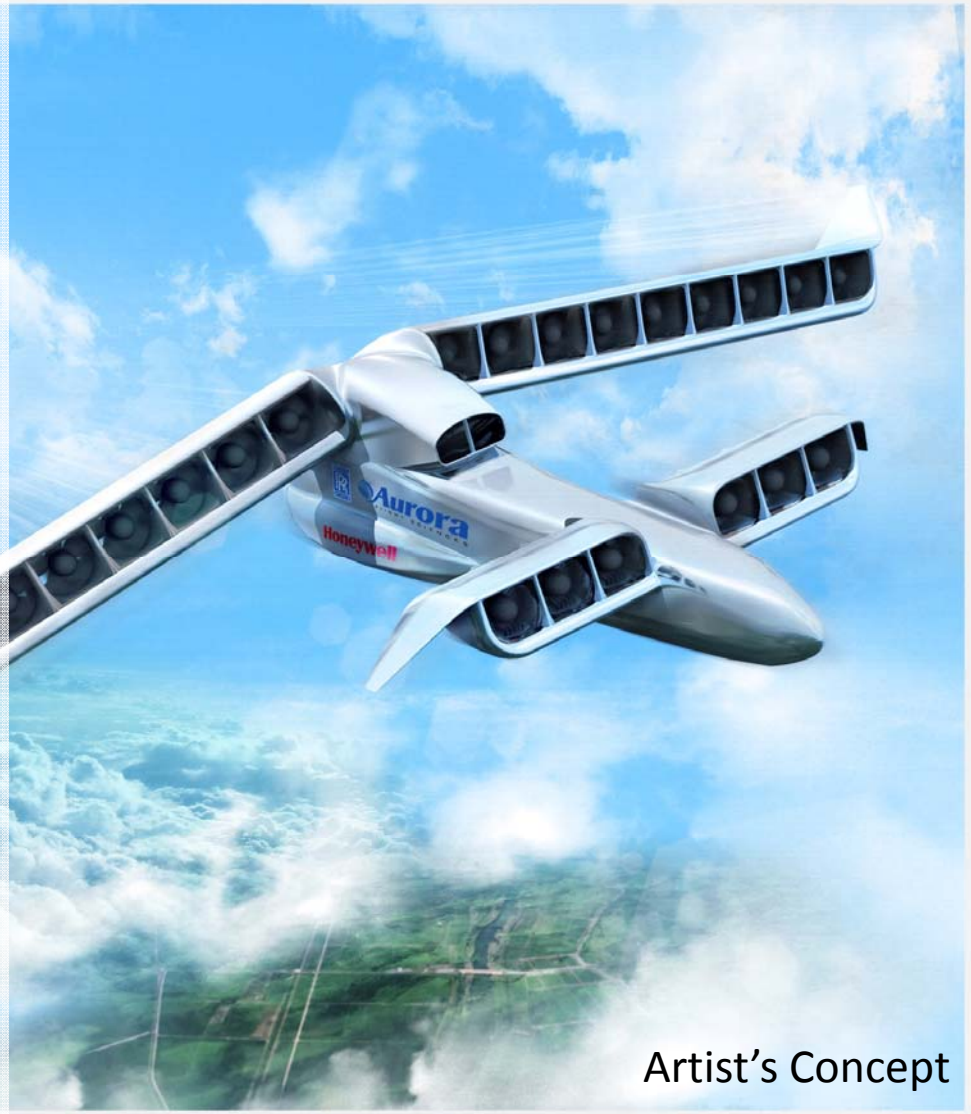
What is LightningStrike?

- Aurora's concept for the DARPA VTOL X-Plane program.
- Hybrid electric distributed propulsion system:
  - Turboshaft-driven gearbox with three 1 MW generators
  - 24 electric motor-driven variable pitch fans
  - Tilt wing, tilt canard
- 3 MW and nearly 10,000 amps flow through this aircraft: enough to power a home subdivision
- Three phase program:
  - Phase 1: 22 month preliminary design phase; PDR in September 2015
  - Phase 2: 21 month detail design, fabrication, and ground test with CDR in Q2FY17
  - Phase 3: 9 month flight test phase
- Our partners: Rolls-Royce LibertyWorks, Honeywell, ThinGap
- Risk reduction test articles include a 20% subscale, 325 lb, electric air vehicle



Artist's Concept

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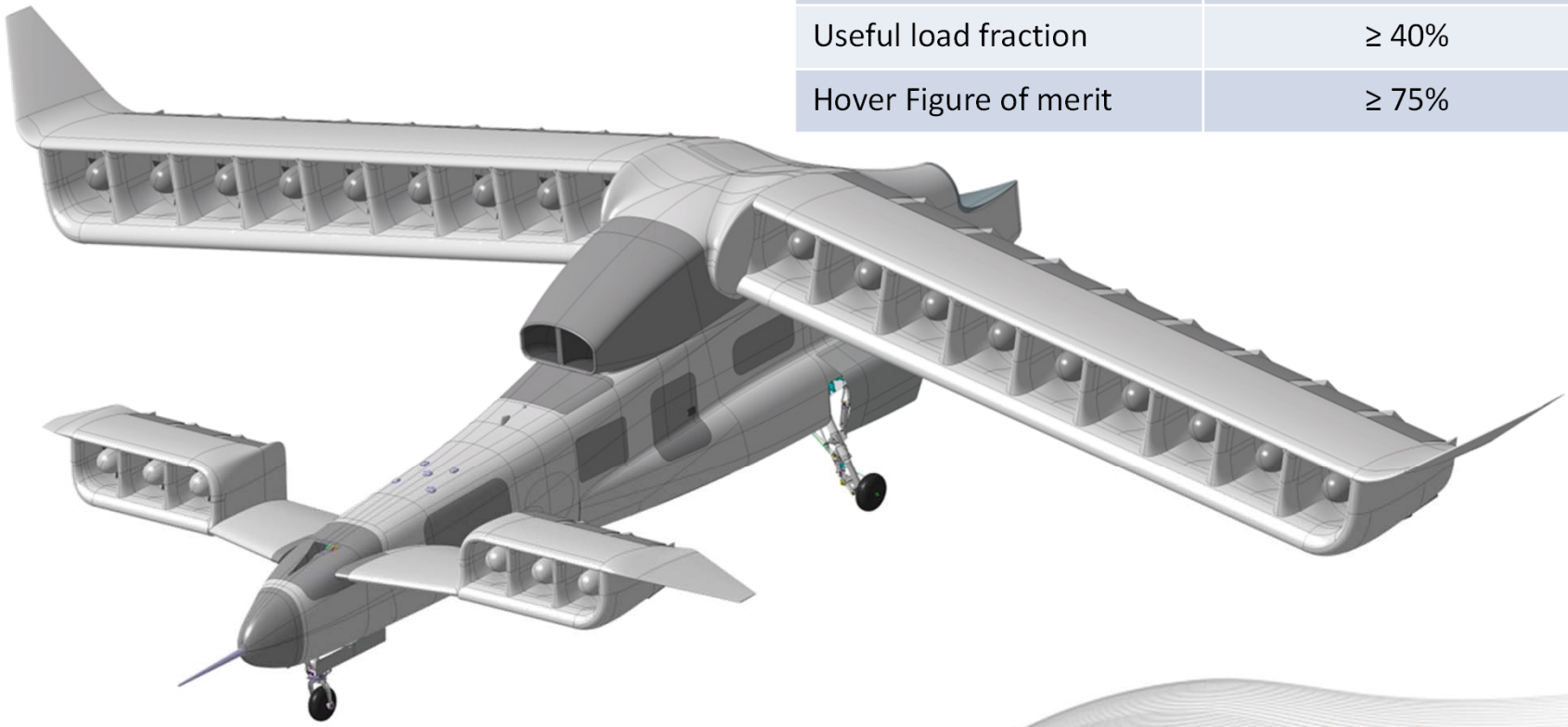
DARPA VTOL X-Plane Objectives

KPPs	
Maximum Airspeed	300-400 KTS
$(L/D)_{effective}$	≥ 10
Takeoff Gross weight	10,000-12,000 lbs
Useful load fraction	≥ 40%
Hover Figure of merit	≥ 75%



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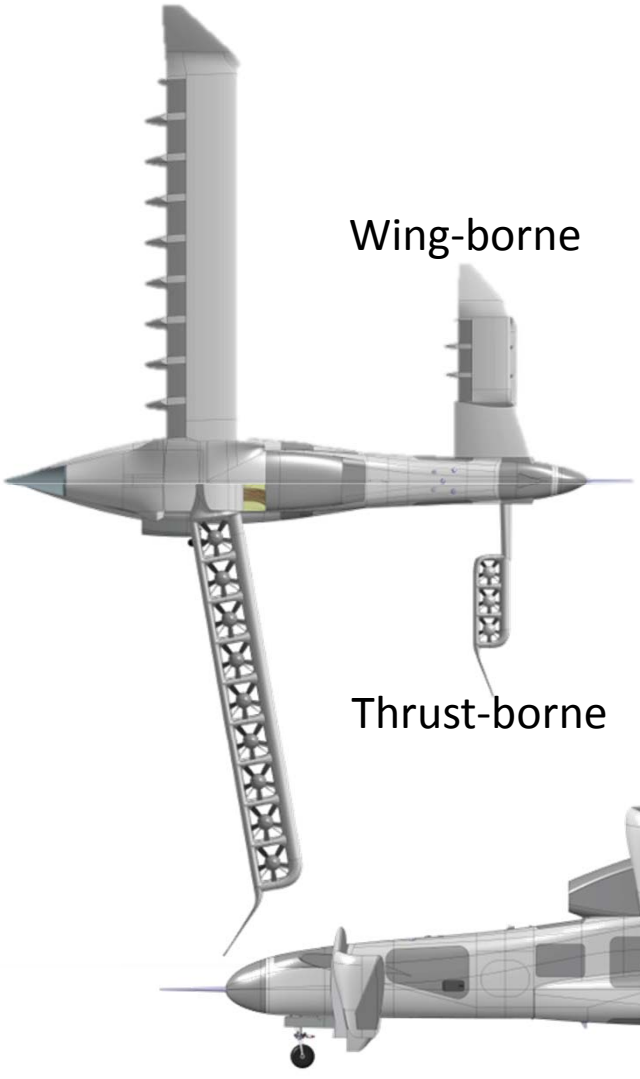
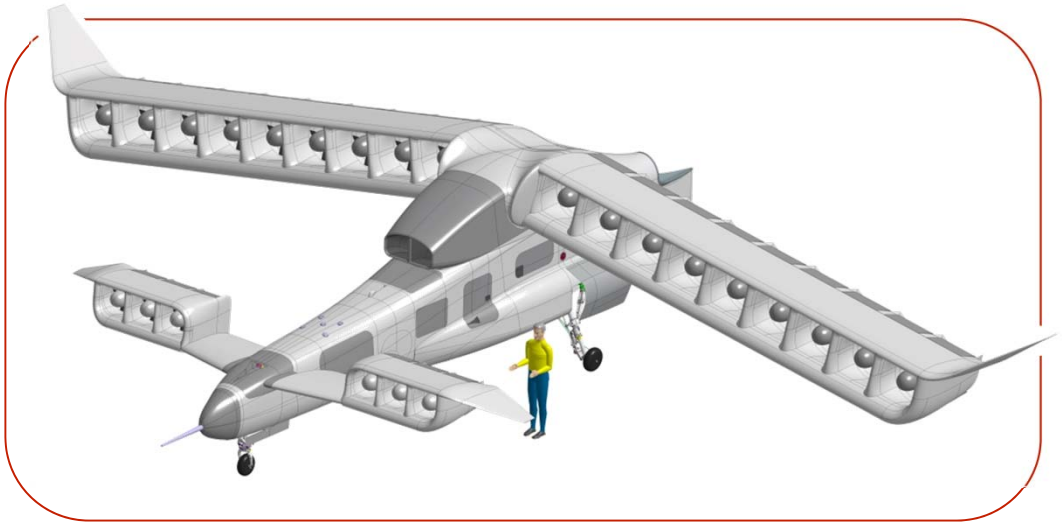
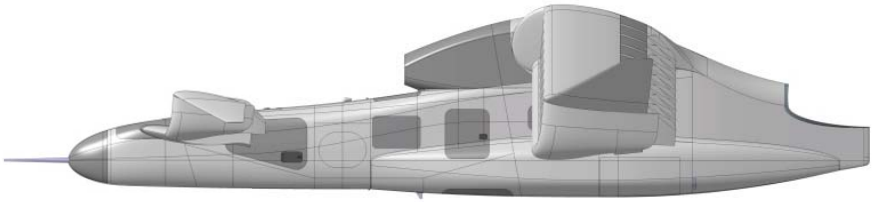
LightningStrike *(Showing Hover/Forward Flight Half-View)*



Wing-borne

Thrust-borne





Wing-borne

Thrust-borne

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“Reuse what you can, design what you must”

Centaur
Ground Control Station

F-22 Hydraulics Common Components

CH-53K Fuel System Common Components

Orion Triplex
Avionics System

MV-22 AE-1107
Turboshaft Engine

S-76
Main and Nose Landing Gear

USN SSC
Engine FADEC

F-35 Oil Cooling Common Components

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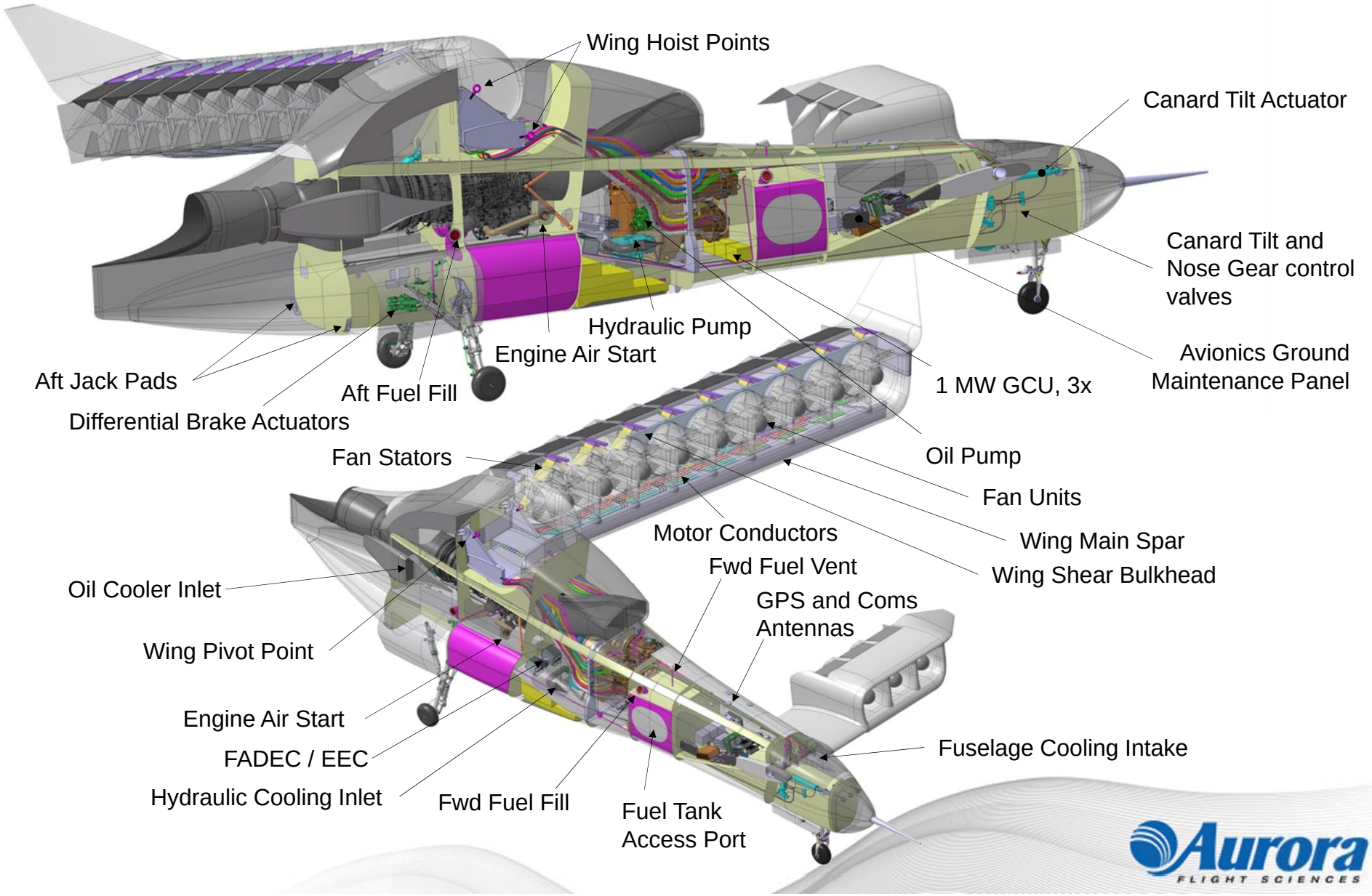
Fuselage General Arrangement



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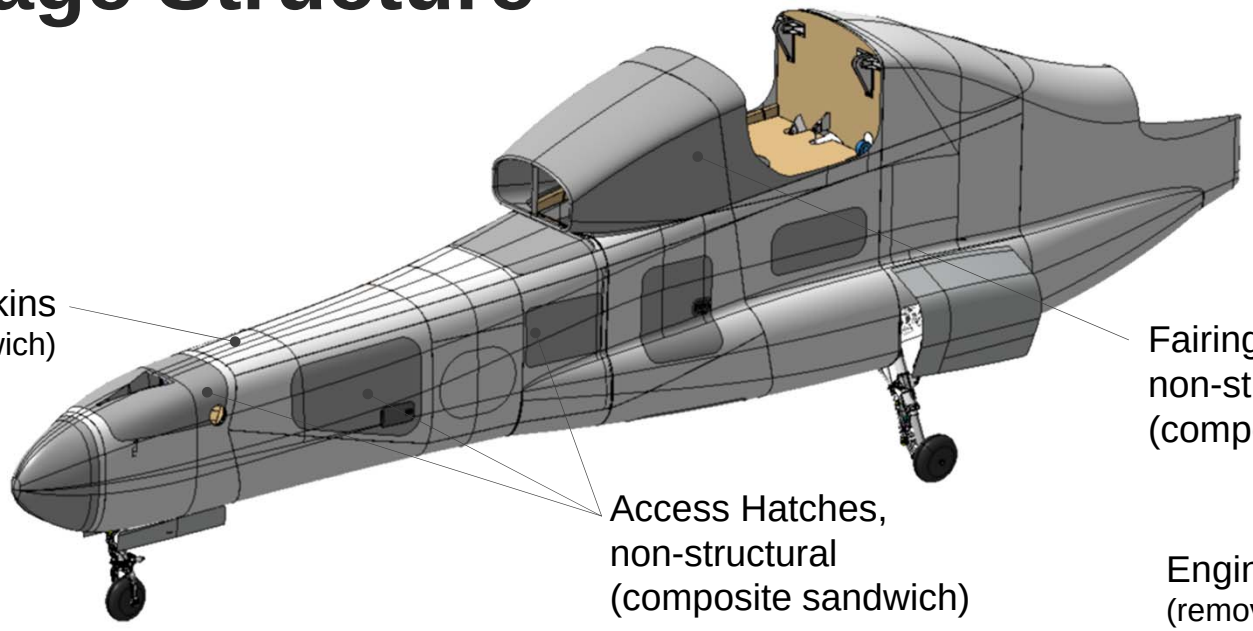
Fuselage Structure

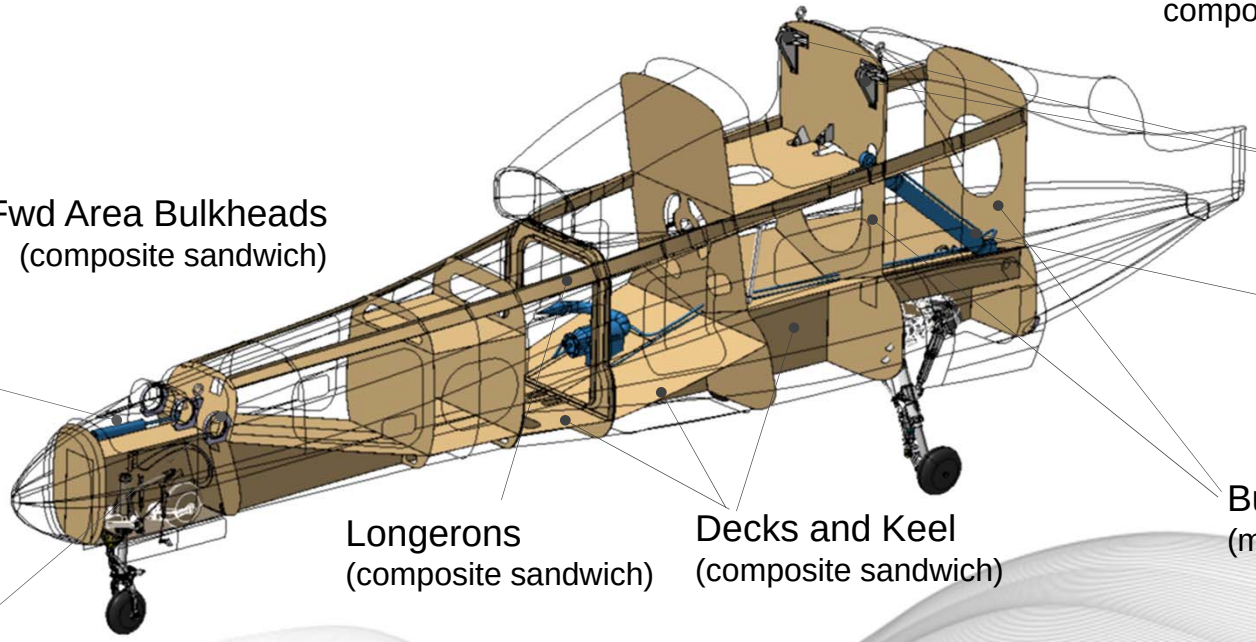


OML Skins
(composite sandwich)

Fairing,
non-structural
(composite sandwich)

Access Hatches,
non-structural
(composite sandwich)

Engine Upper Cover
(removable;
composite sandwich)



Mounts (Pivots),
Wing, Aft
(Aluminum)

Fwd Area Bulkheads
(composite sandwich)

Actuator,
Wing-Tilt

Actuator,
Canard-Tilt

Bulkheads, Aft
(machined metallic)

Longerons
(composite sandwich)

Decks and Keel
(composite sandwich)

Bulkhead,
Canard Mount

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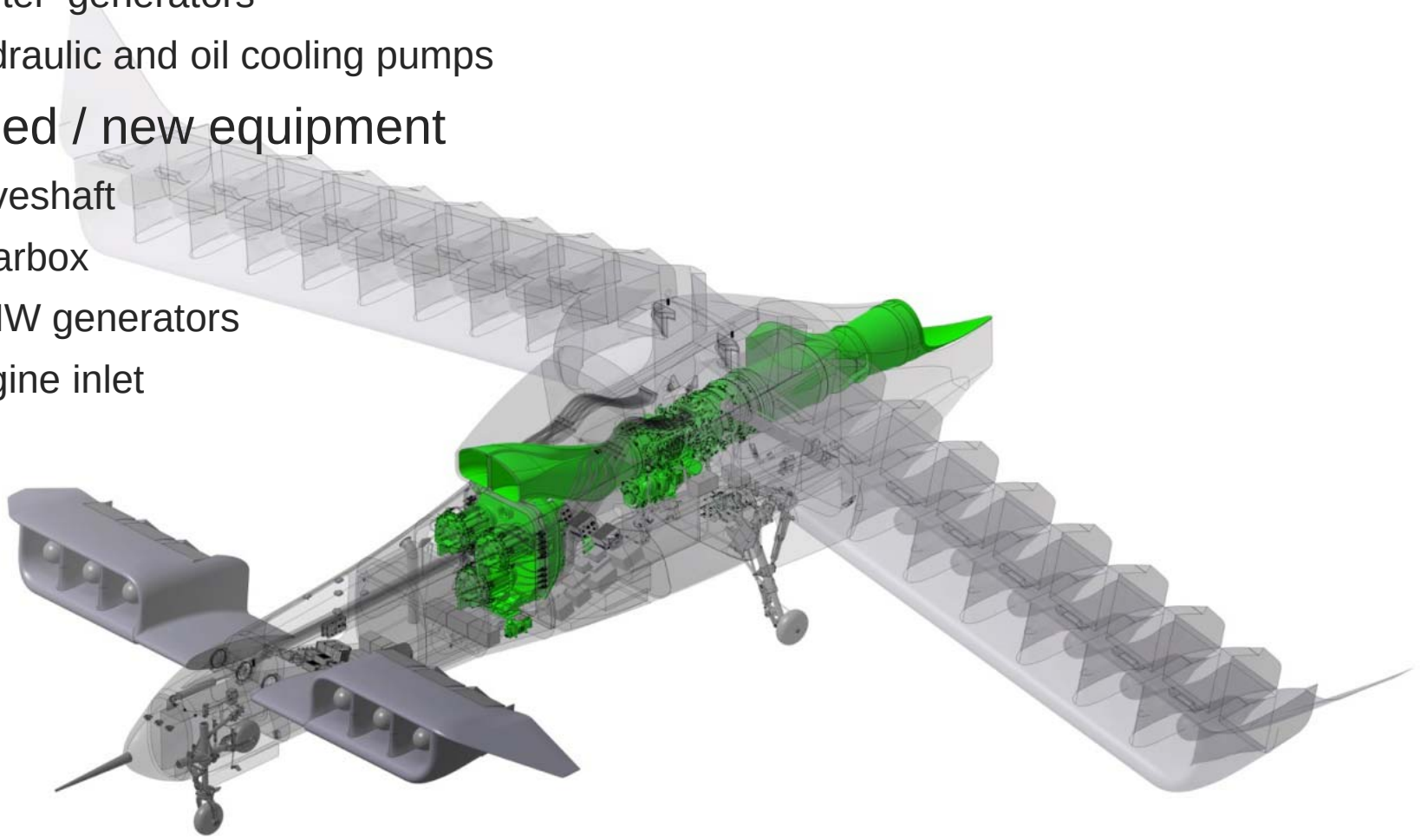
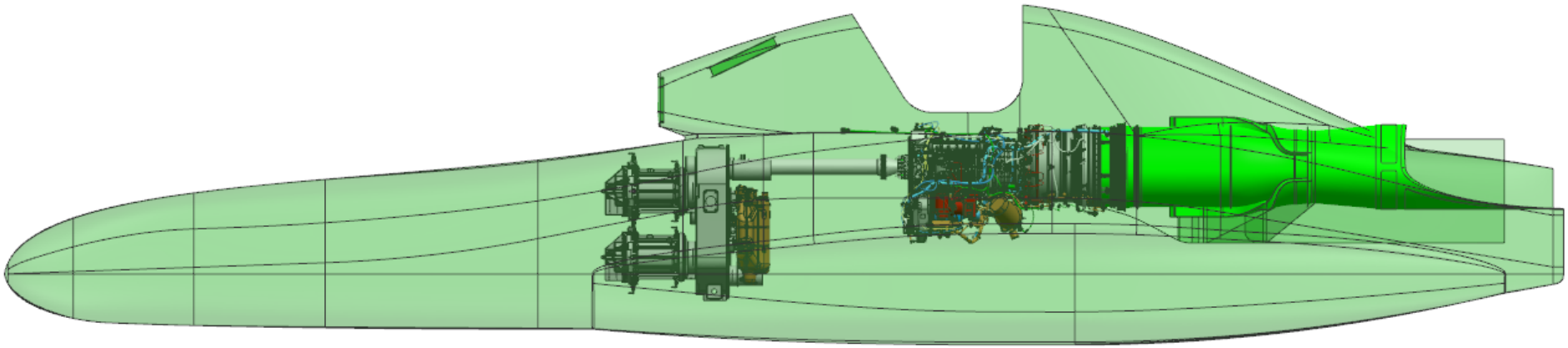
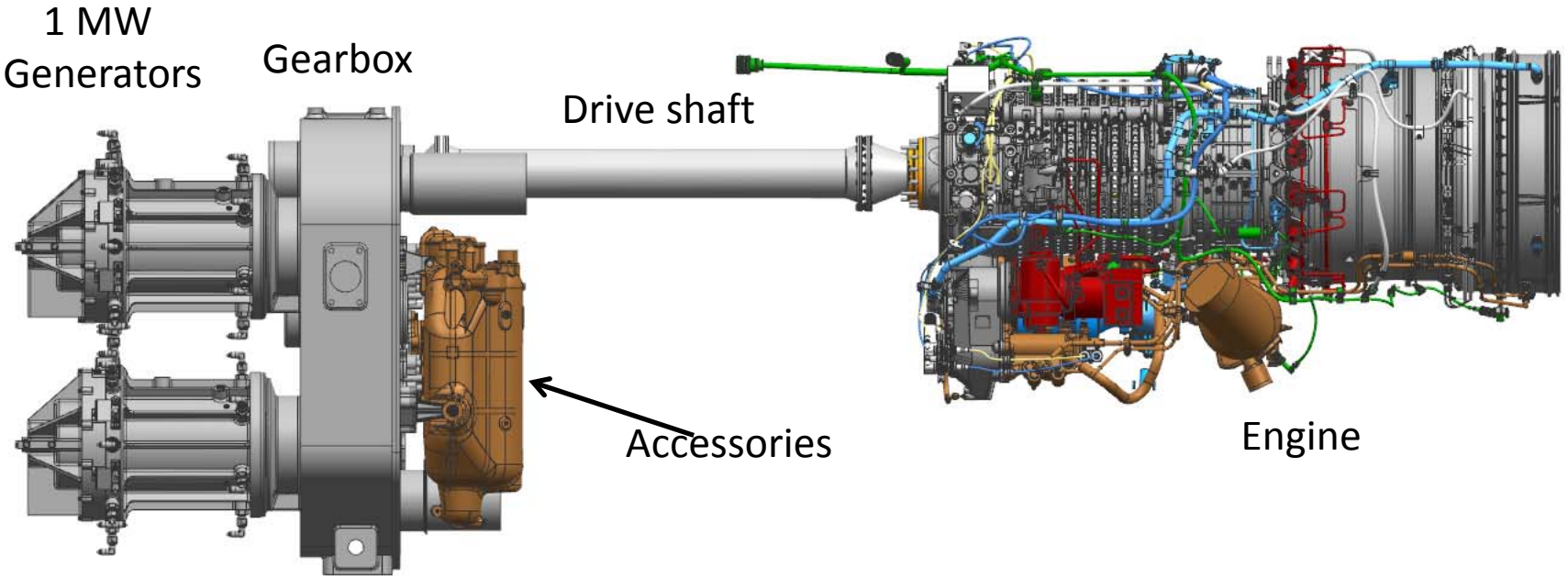
Power-Generation System (PGS)

- Off-the-shelf equipment
  - AE1107C turboshaft engine, V-22 and C-130 heritage
  - “Hotel” generators
  - Hydraulic and oil cooling pumps
- Modified / new equipment
  - Driveshaft
  - Gearbox
  - 1 MW generators
  - Engine inlet



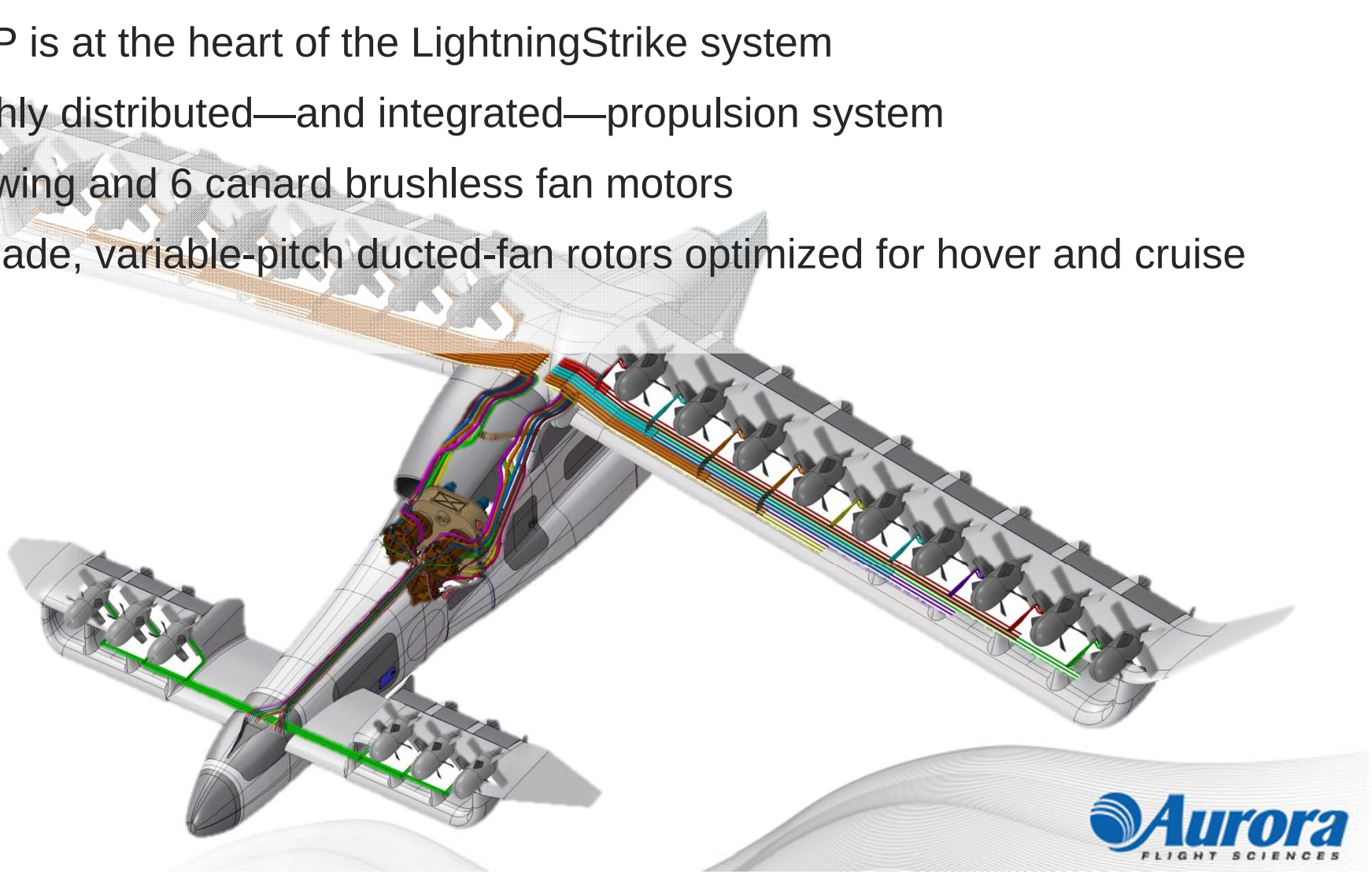
Side-View of the PGS





Electric Distributed Propulsion (EDP)

- EDP is at the heart of the LightningStrike system
- Highly distributed—and integrated—propulsion system
- 18 wing and 6 canard brushless fan motors
- 5-blade, variable-pitch ducted-fan rotors optimized for hover and cruise



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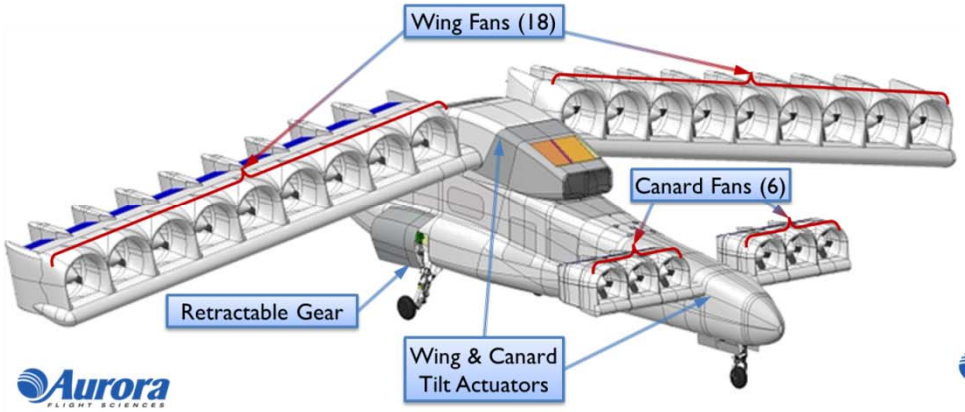
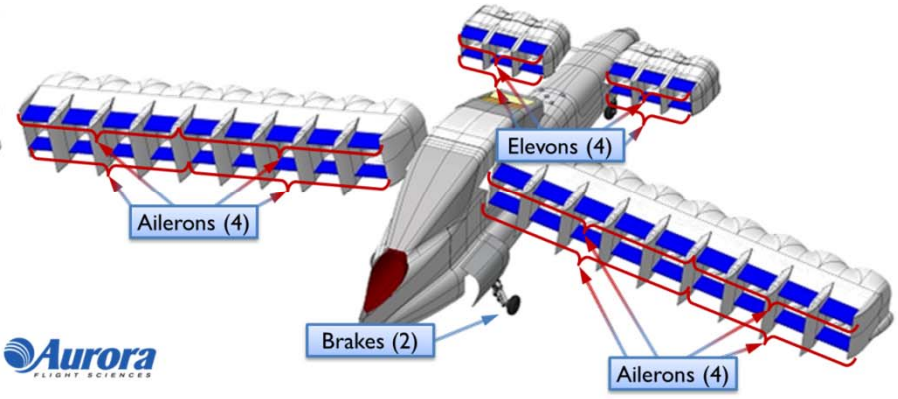
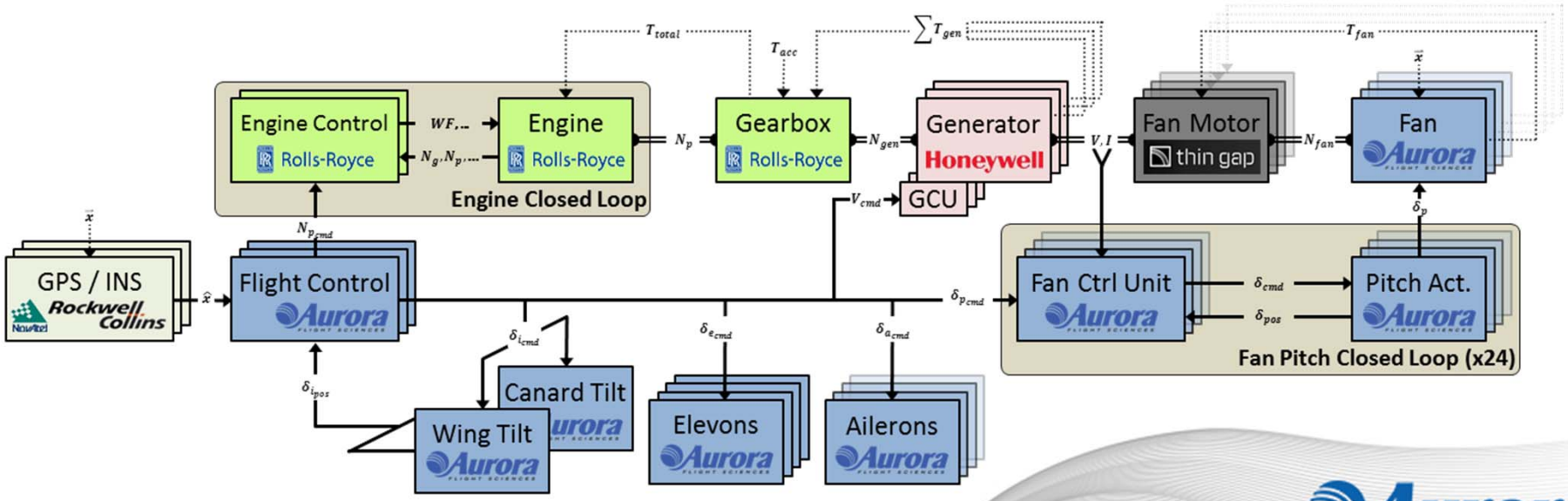
Flight Control System

Over-actuated system – 50 primary effectors available for flight control!







Control Allocation

Thrust-borne and Wing-borne Flight

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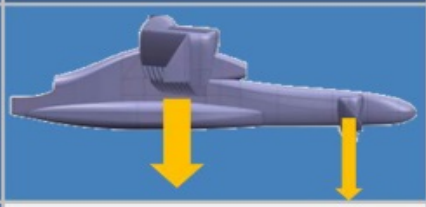
Tilt Orientation			
Pitch Control	Symmetric canard fan thrust via variable fan pitch	Symmetric canard fan thrust via variable fan pitch & symmetric elevon control surfaces	Symmetric elevon control surfaces
Roll Control	Asymmetric wing fan thrust via variable fan pitch	Asymmetric wing fan thrust via variable fan pitch & Asymmetric aileron control surfaces	Asymmetric aileron control surfaces
Yaw Control	Asymmetric aileron control surfaces	Asymmetric aileron control surfaces & asymmetric wing fan thrust via variable fan pitch	Asymmetric wing fan thrust via variable fan pitch
Lift Control	Wing and canard fan thrust via variable fan pitch	Wing and canard fan thrust via variable fan pitch & ganged wing and canard tilt angle	Wing aerodynamics

Major Risk Reduction Tests

- Megawatt generator DVT and endurance test
- Subscale (20%) vehicle demonstrator: configuration, aerodynamics, avionics, flight controls
- Hardware-in-the-loop simulator (HILSim): avionics, flight control system, and software
- “Copper Bird”: motors, motor cooling, variable pitch mechanism, fans, power distribution, and electric distributed propulsion (EDP) dynamics and control (generator-to-fan)
- Gearbox DVT
- “Iron Bird”: end-to-end validation of EDP and power generation system (PGS) systems (turboshaft-to-fan), including AE1107, high-speed shaft, gearbox, generators, “6+2 pack”, accessories, and control hardware/software
- VXP aircraft static load test
- VXP aircraft flight test program

Subscale Vehicle Demonstrator (SVD)

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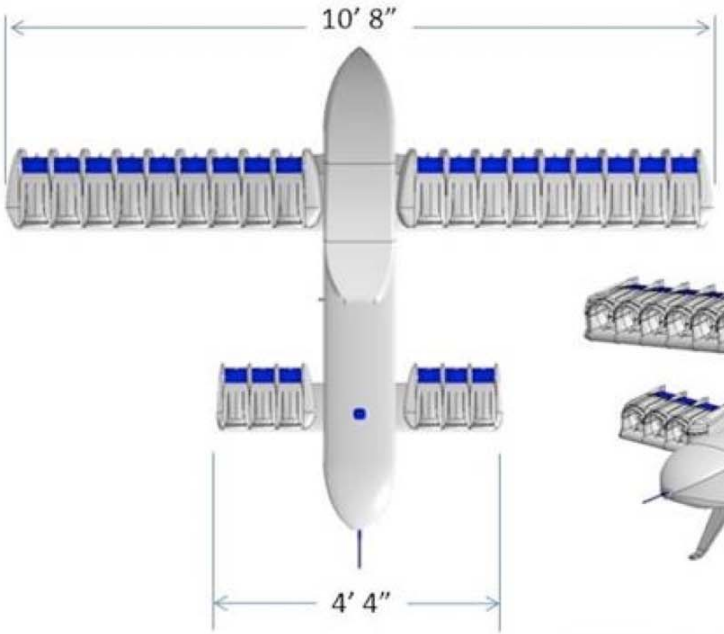
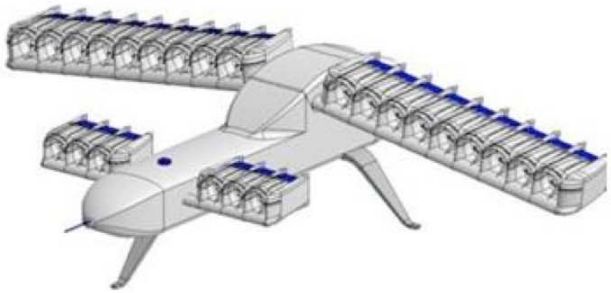
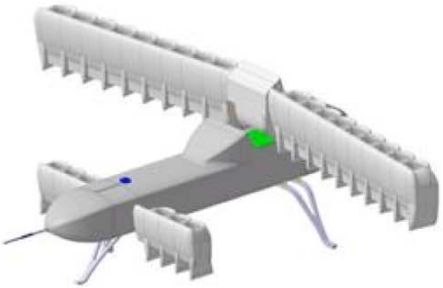
SVD Key Characteristics







Weight ~325 lbs

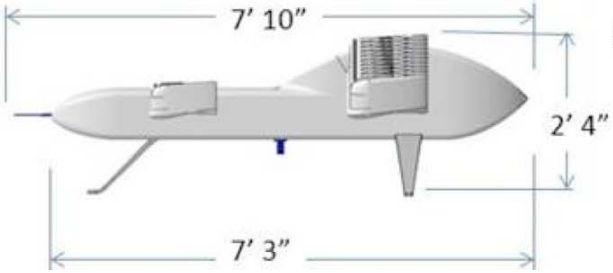
Max speed ~100 kts

Endurance < 5 min

Max altitude 500 ft AGL

Typical altitude ~100 ft AGL or less

Wing & Canard Rotate 90˚



SVD Mitigates Risks in Key Areas

- SVD is the most essential risk reduction activity for the FCS progression to flight testing on the full-scale aircraft
- SVD includes same flight processing hardware and software as the full-scale aircraft
- SVD completed hover and low-speed (up to 20 knots) flight testing this summer.
- SVD will be expanding the flight envelop this fall.

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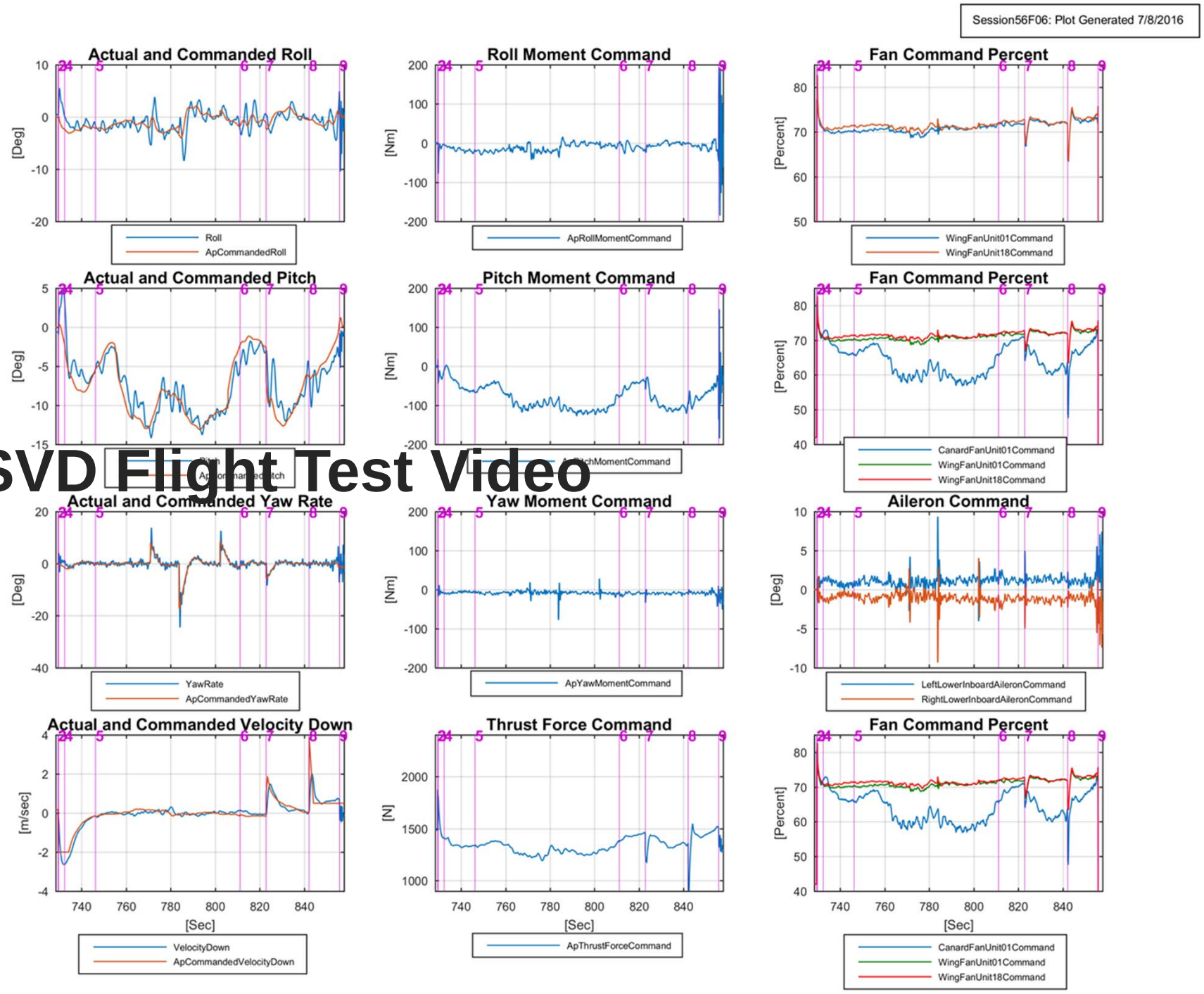

SVD Flight Test Video


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