Tiltwing Validation Test: Conceptual Design and Research Objectives

Siena K. S. Whiteside and Brandon L. Litherland

Aeronautics Systems Analysis Branch, NASA Langley Research Center

Revolutionary Vertical Lift Technology (RVLT) Project

Advanced Air Vehicle Program, NASA Aeronautics Research Mission Directorate

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Outline

1. Motivation
2. Tiltwing UAM Reference Vehicle
3. Tiltwing Validation Test
4. What's Next

ASAB
AERONAUTICS SYSTEMS ANALYSIS BRANCH

siena.k.whiteside@nasa.gov

Motivation: Quiet and Efficient Urban Air Mobility (UAM)

Technical Challenge: "Tools to Explore the Noise and Performance of Multi-Rotor UAM Vehicles"

GAP

- Assessment of <u>noise impact of UAM vehicles on the community</u>
- Exploration of feasible <u>noise mitigation strategies</u>
- Assessment of <u>vehicle performance requirements</u> imposed by low-noise designs.

OBJECTIVE

Develop, demonstrate, validate, and document a set of conceptual design tools capable of assessing the tradeoffs between UAM vehicle noise and efficiency.

UAM Reference Vehicles

↓

Validation Tests

components of the reference vehicles

↓

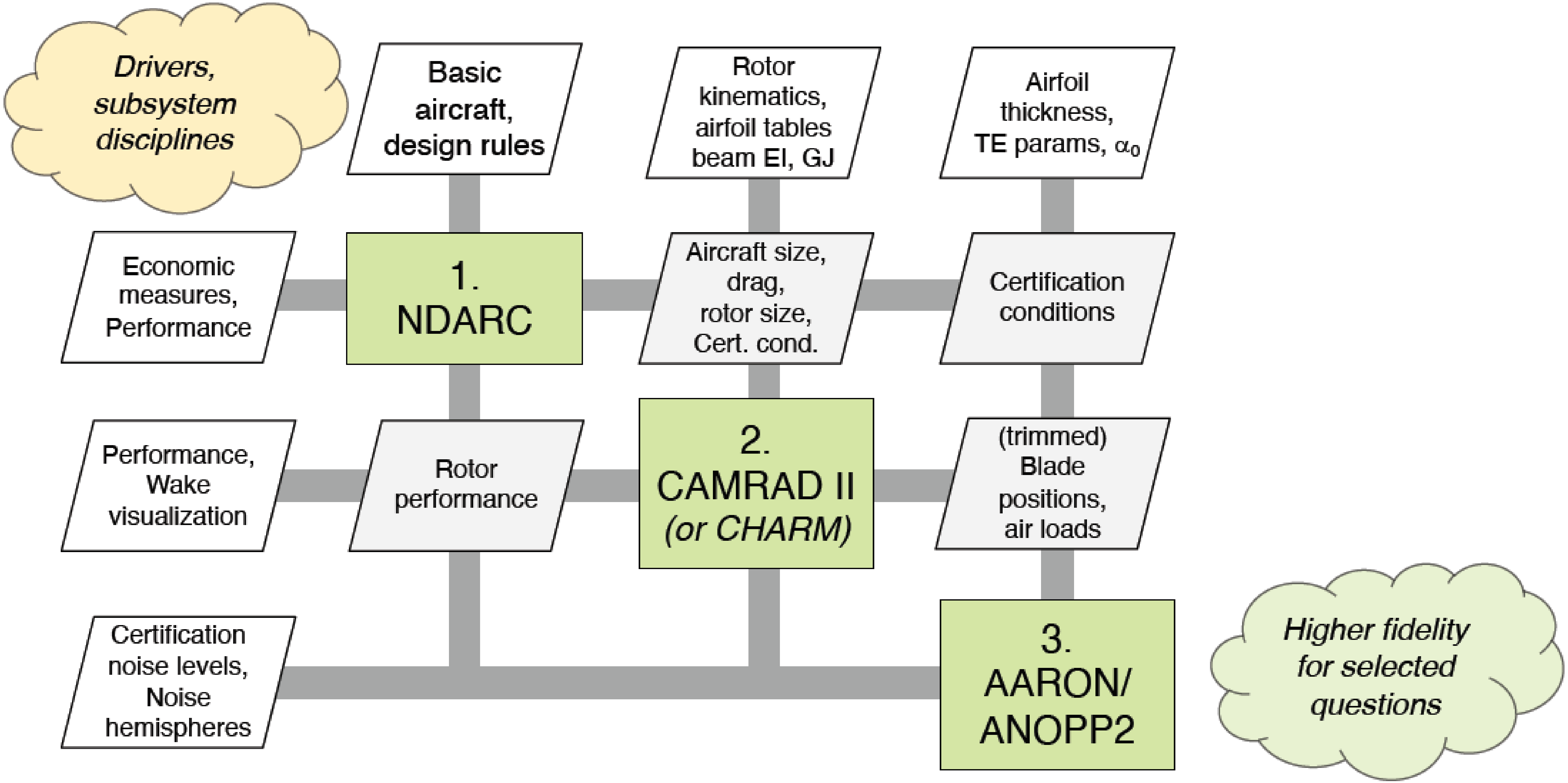
Improve Tools

↓

Community Workshops

Validation Test Plan: https://ntrs.nasa.gov/citations/20210022605

RVLT Conceptual Design Toolchain

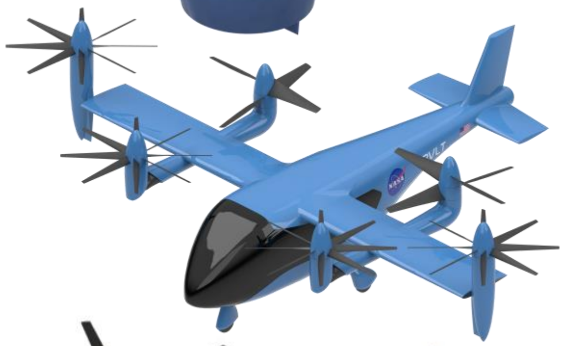


Silva, C., Johnson, W., "Practical Conceptual Design of Quieter Urban VTOL Aircraft," Vertical Flight Society 77th Annual Forum & Technology Display, Virtual, May 10–14, 2021, ntrs.nasa.gov/citations/20210014173.

siena.k.whiteside@nasa.gov

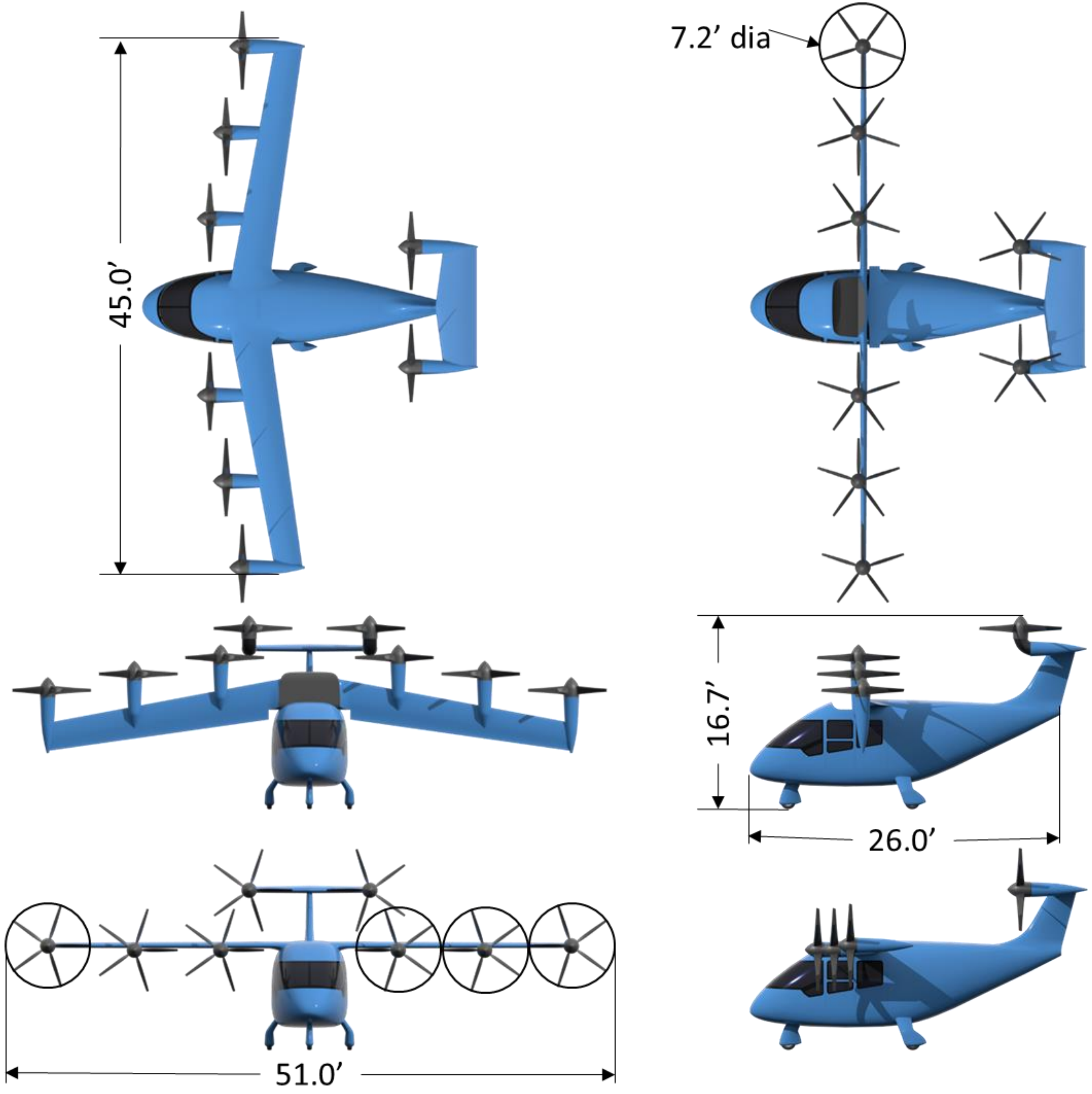
NASA UAM Reference Vehicles

sacd.larc.nasa.gov/UAM



Tiltwing Reference Vehicle

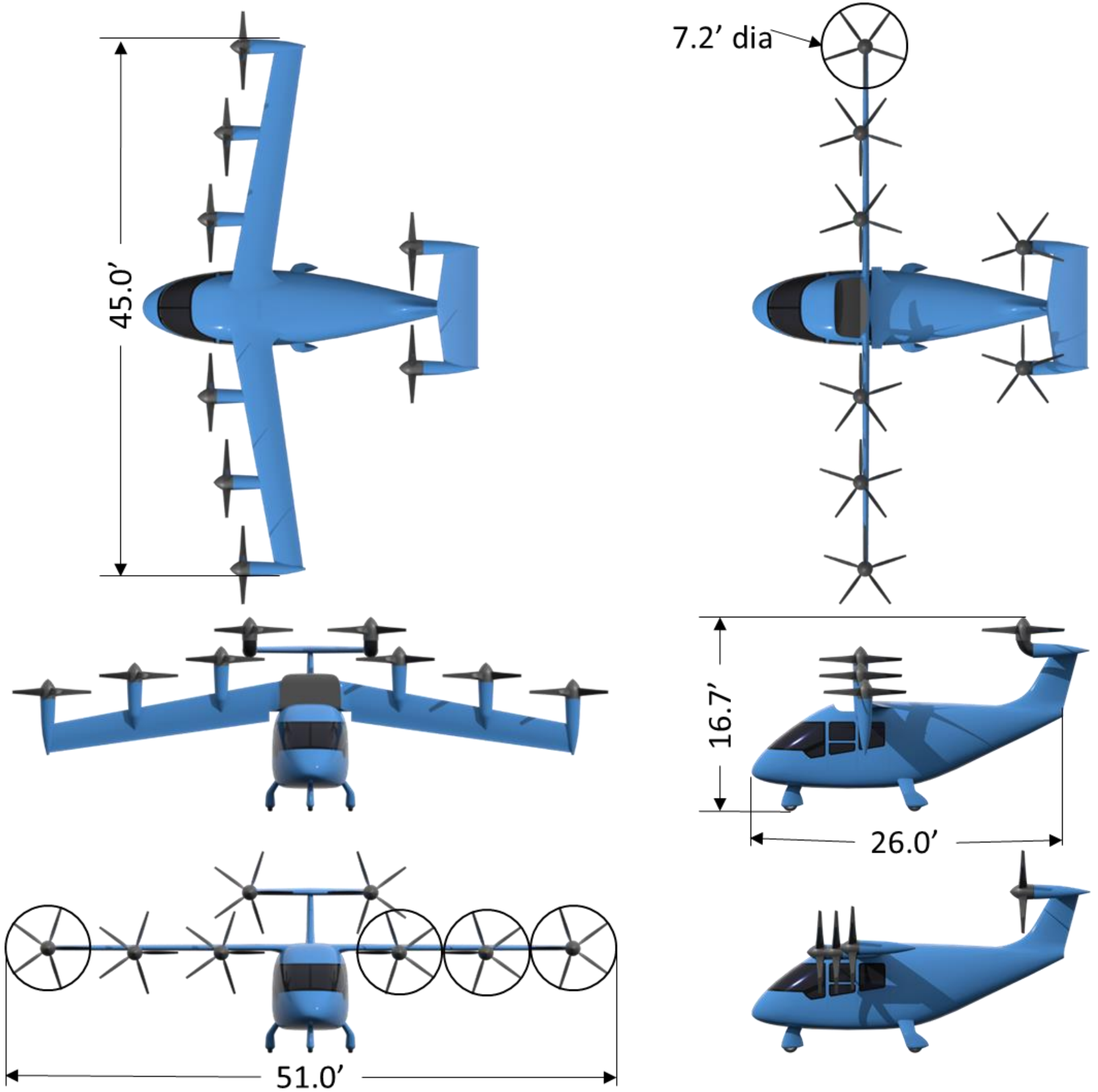
- Tilting Main Wing
  - 18% thick GA(W)-1 Airfoil
  - 10° sweep, 70% taper
  - 25% trailing edge flap
- 6 Main Wing Proprotors
  - 5 blades, collective control
  - 0.75 radius ahead of wing
  - Laterally tangential
  - Longitudinally staggered
  - Inboard nacelles below wing chord
- Fixed Horizontal Tail
  - 2 Tilting Proprotors



Whiteside et al, “Design of a Tiltwing Concept Vehicle for Urban Air Mobility,” NASA TM-20210017971, 2021, https://ntrs.nasa.gov/citations/20210017971.

Tiltwing Reference Vehicle: Research Interests

- Conversion aerodynamics
- Acoustical characteristics in all phases of flight
- Phasing of proprotors
- Design optimization of proprotors
- Active or passive high-lift devices



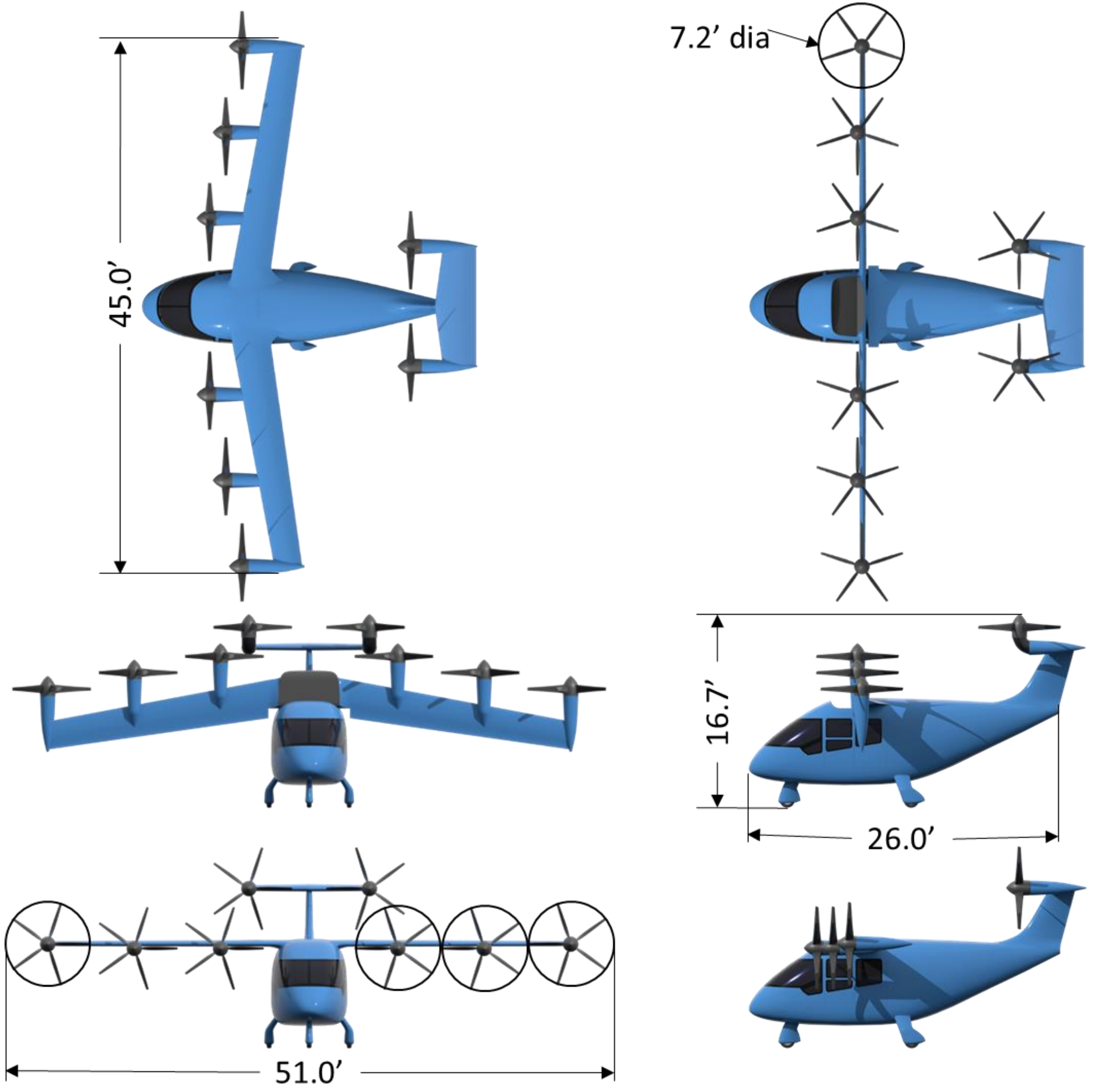
Tiltwing Validation Test: Prioritized Objectives

Primary Objectives

- Effect of proprotor vertical and horizontal spacing on performance and acoustics
- Effect of number of proprotors on performance and acoustics

Secondary Objectives

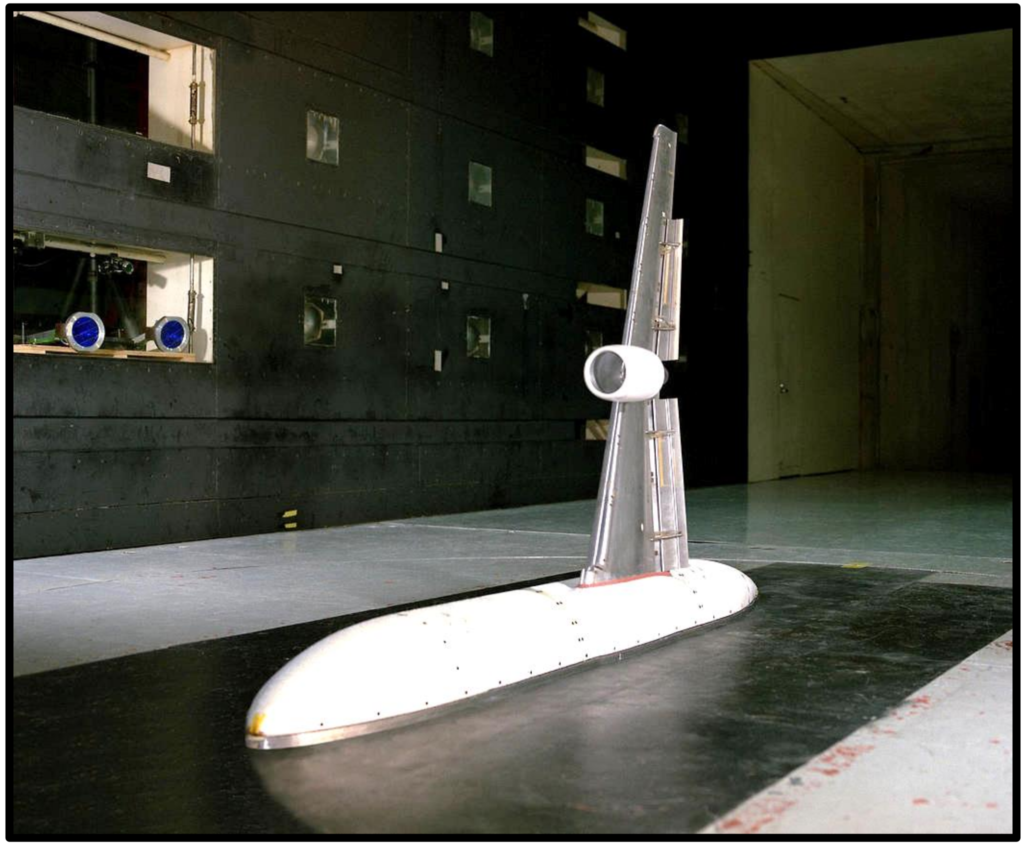
- Effect of proprotor phasing on acoustics
- Insight into conversion



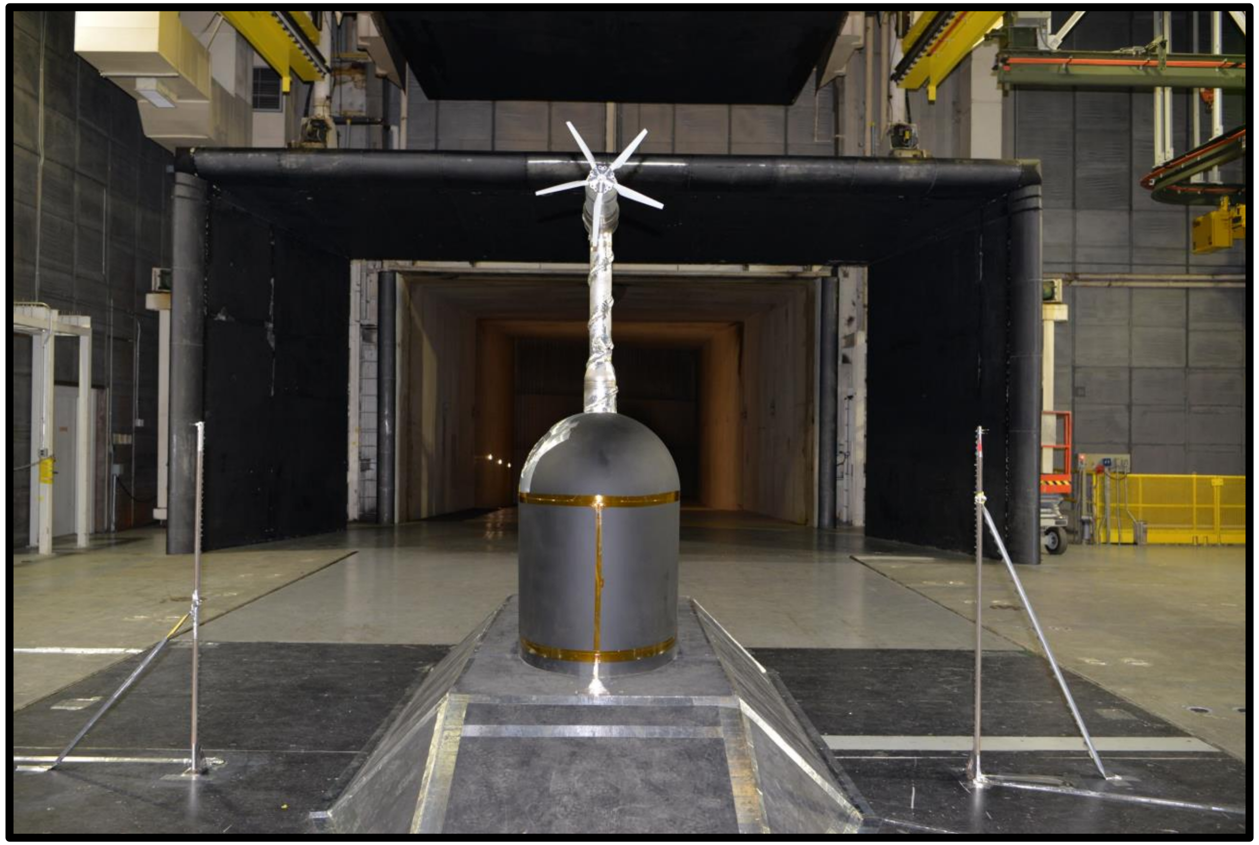
siena.k.whiteside@nasa.gov

NASA Langley 14- by 22-Foot Subsonic Tunnel

- 14.4 ft high x 21.75 ft wide x 50 ft long
  - Closed test section: aerodynamic performance
  - Open test section (floor-only): enables acoustic treatment



Closed test section



Open test section (2 ft dia proprotor)

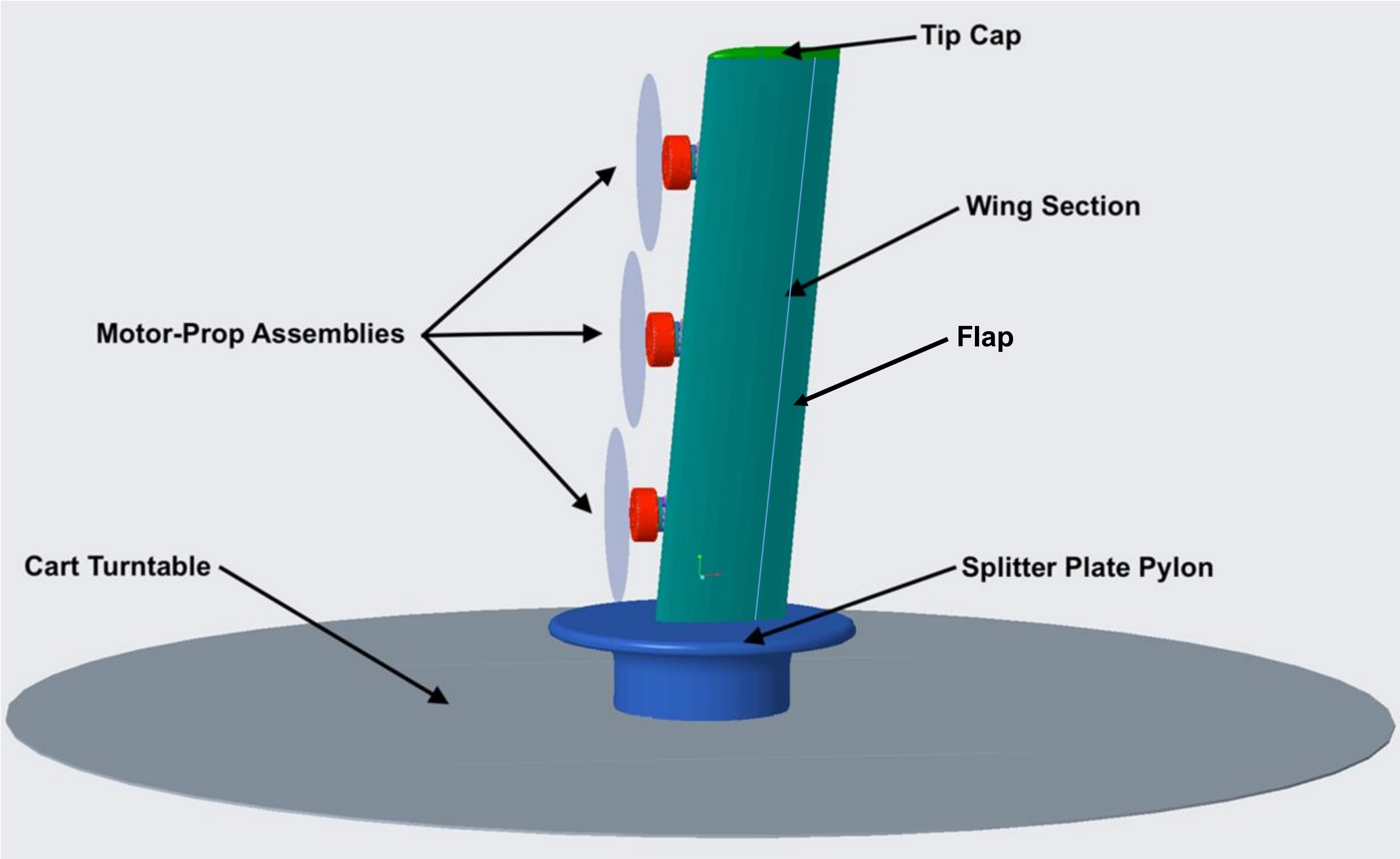
Tiltwing Validation Test: General Layout

Semispan wing

- 78 in span (wing section)
- 18 in chord (constant)
- 17% thick GA(W)-1 airfoil
- 5° sweep
- 30% fowler flap
- 744 pressure taps

3 Proprotors

- 24 in diameter
- 5 blades, collective control
- XV-15 derived design
  (work in progress)
- CW and CCW spin directions
  (6 proprotors total)



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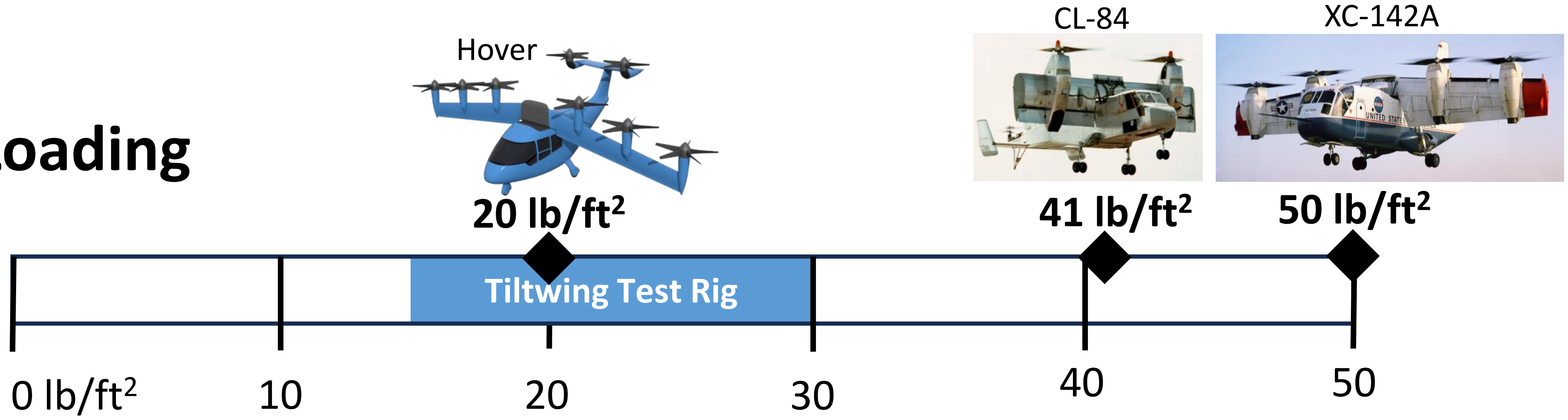
UAM Reference Vehicle vs. Wind Tunnel Model

Hover Disk Loading

15 - 30 lb/ft²

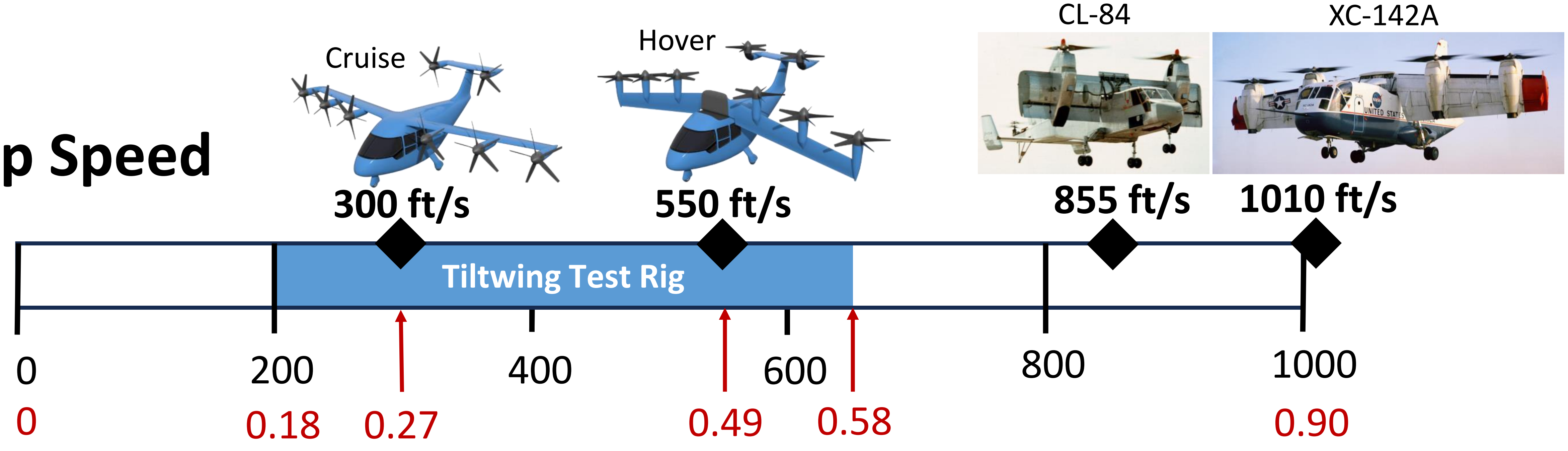


Proprotor Tip Speed

200 - 650 ft/s

Speed (ft/s)

Mach (SLSD)



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UAM Reference Vehicle vs. Wind Tunnel Model

Ratio of wing chord to proprotor diameter

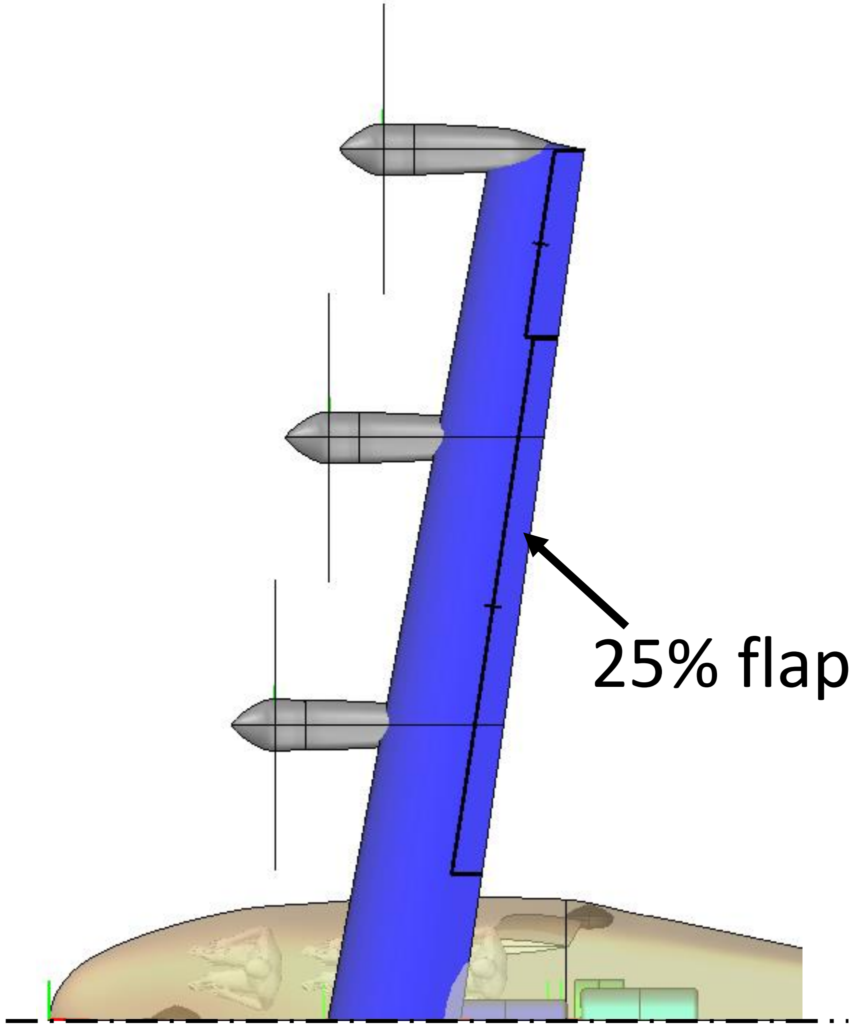
CL-84

0.5

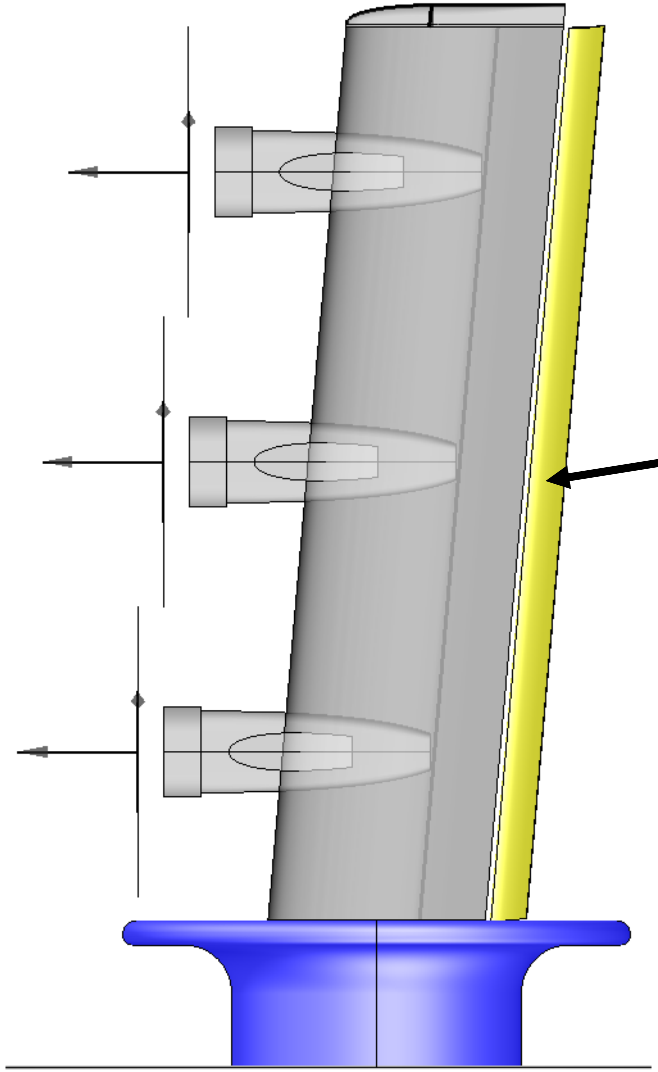
XC-142A

0.5

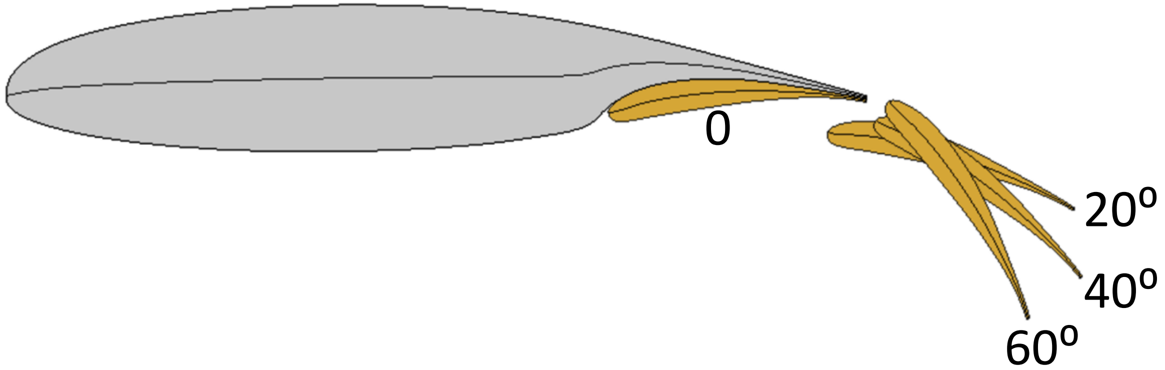
0.4



0.75



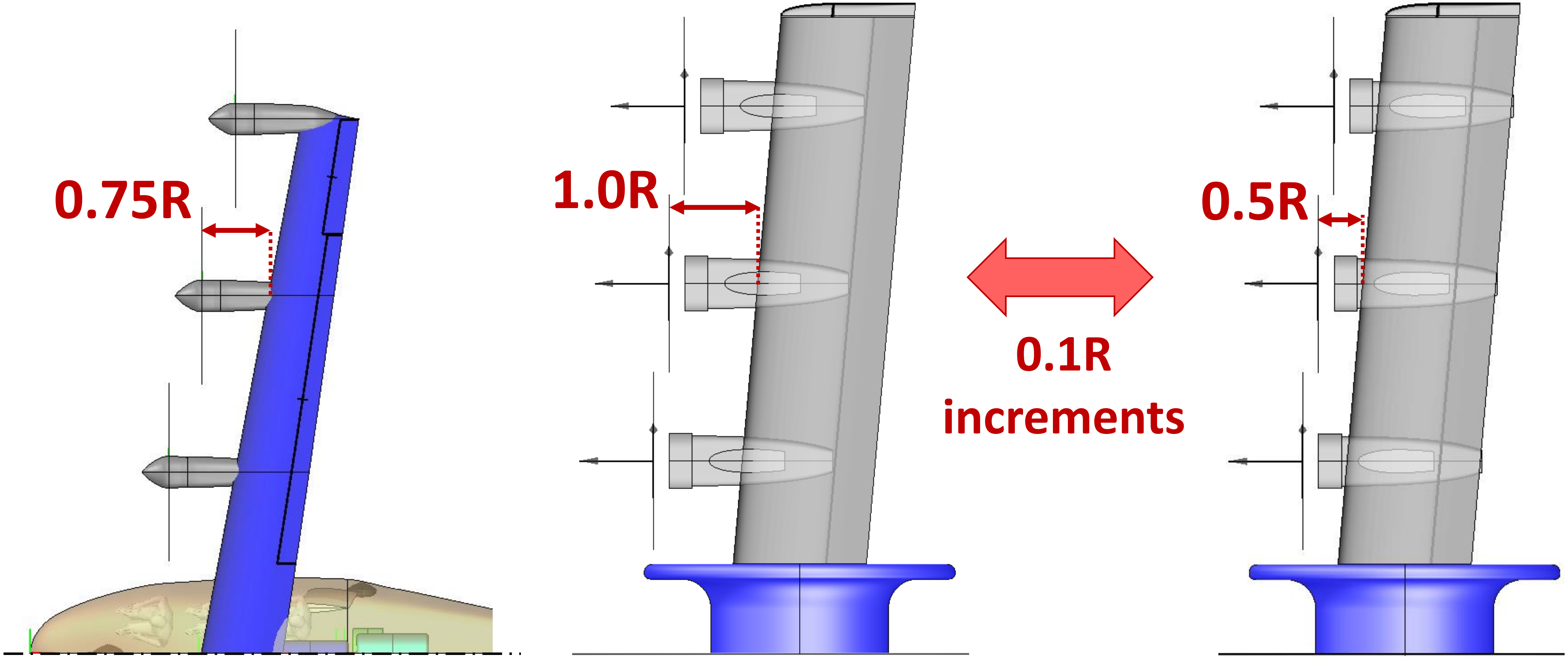
30% fowler flap
[0, 20, 40, 60 deg deflections]



UAM Reference Vehicle vs. Wind Tunnel Model

Proprotor Chordwise Position

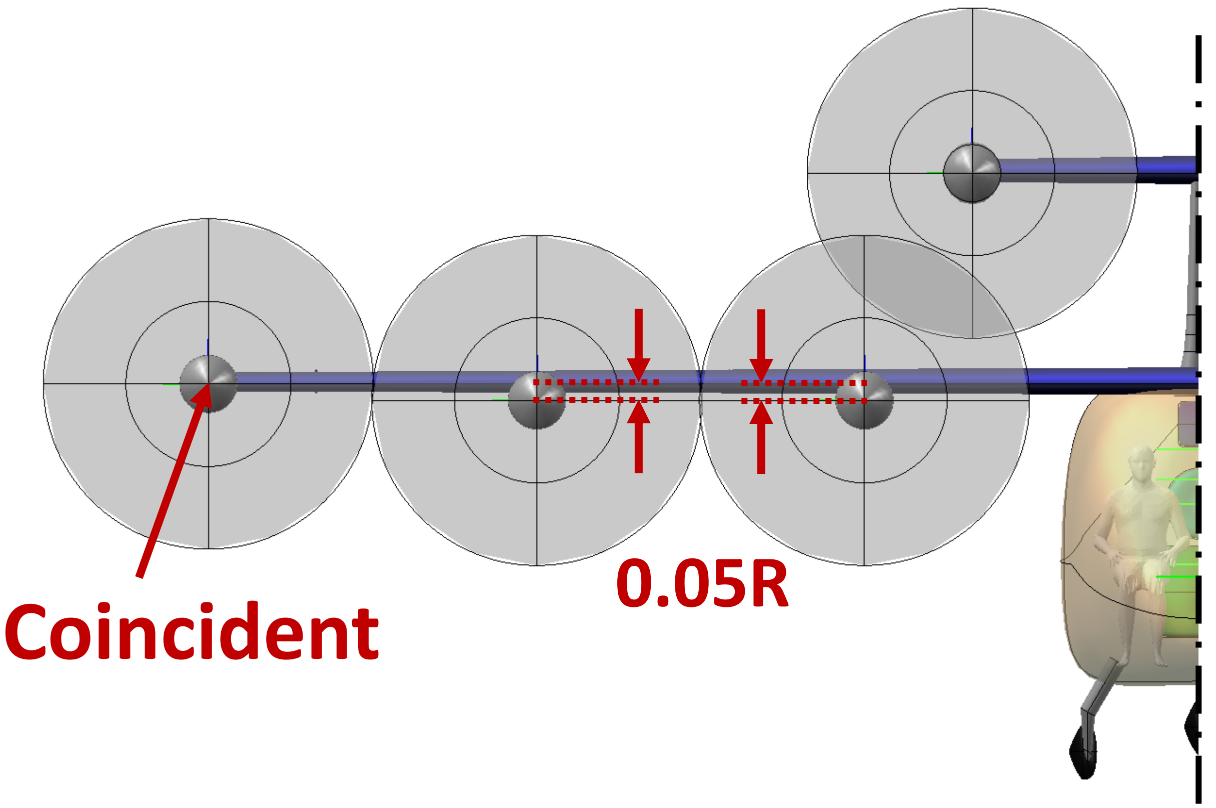
R = Proprotor Radius

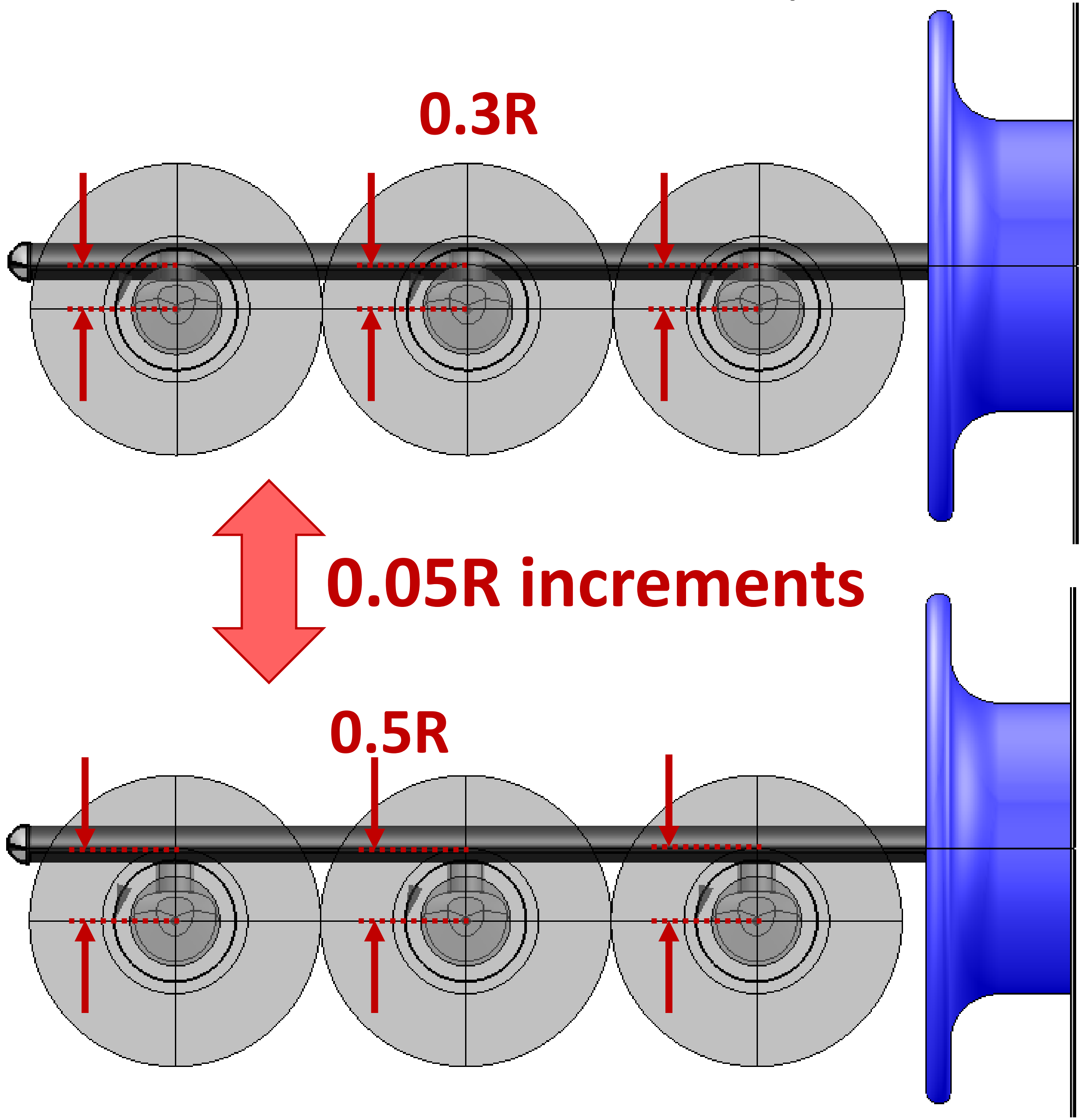


UAM Reference Vehicle vs. Wind Tunnel Model

Proprotor Vertical Position

R = Proprotor Radius

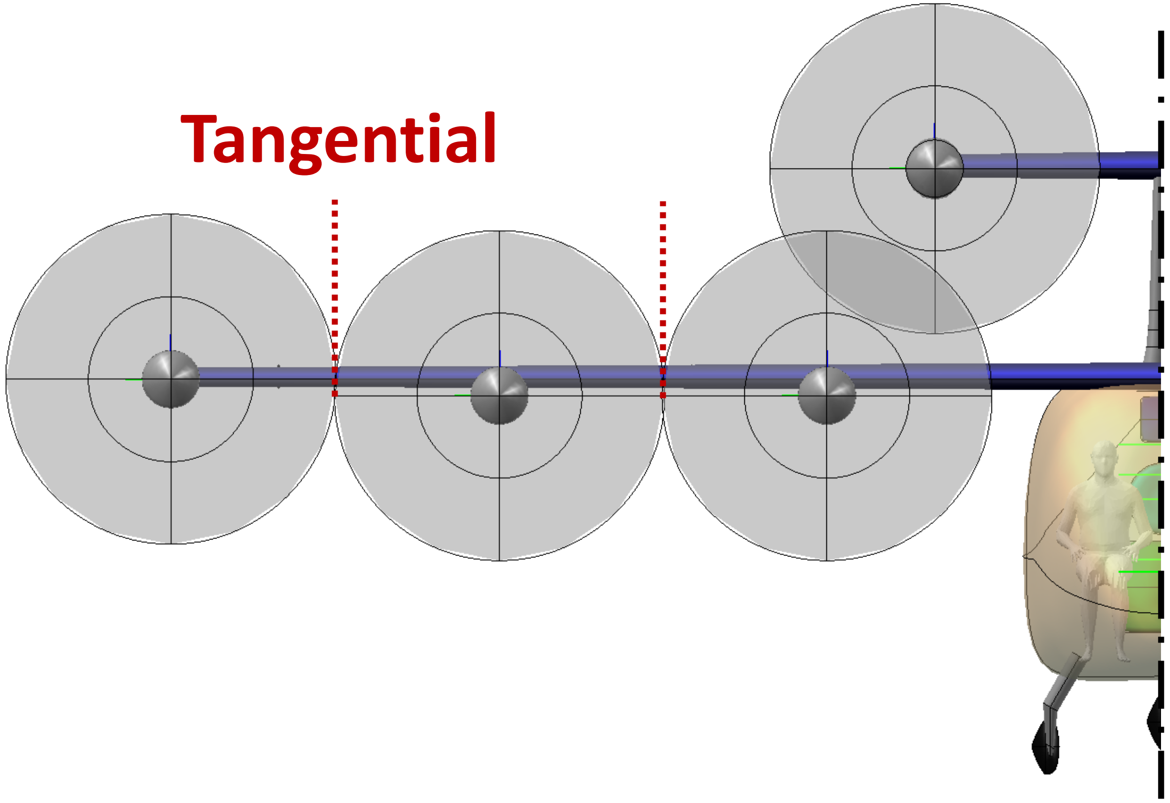


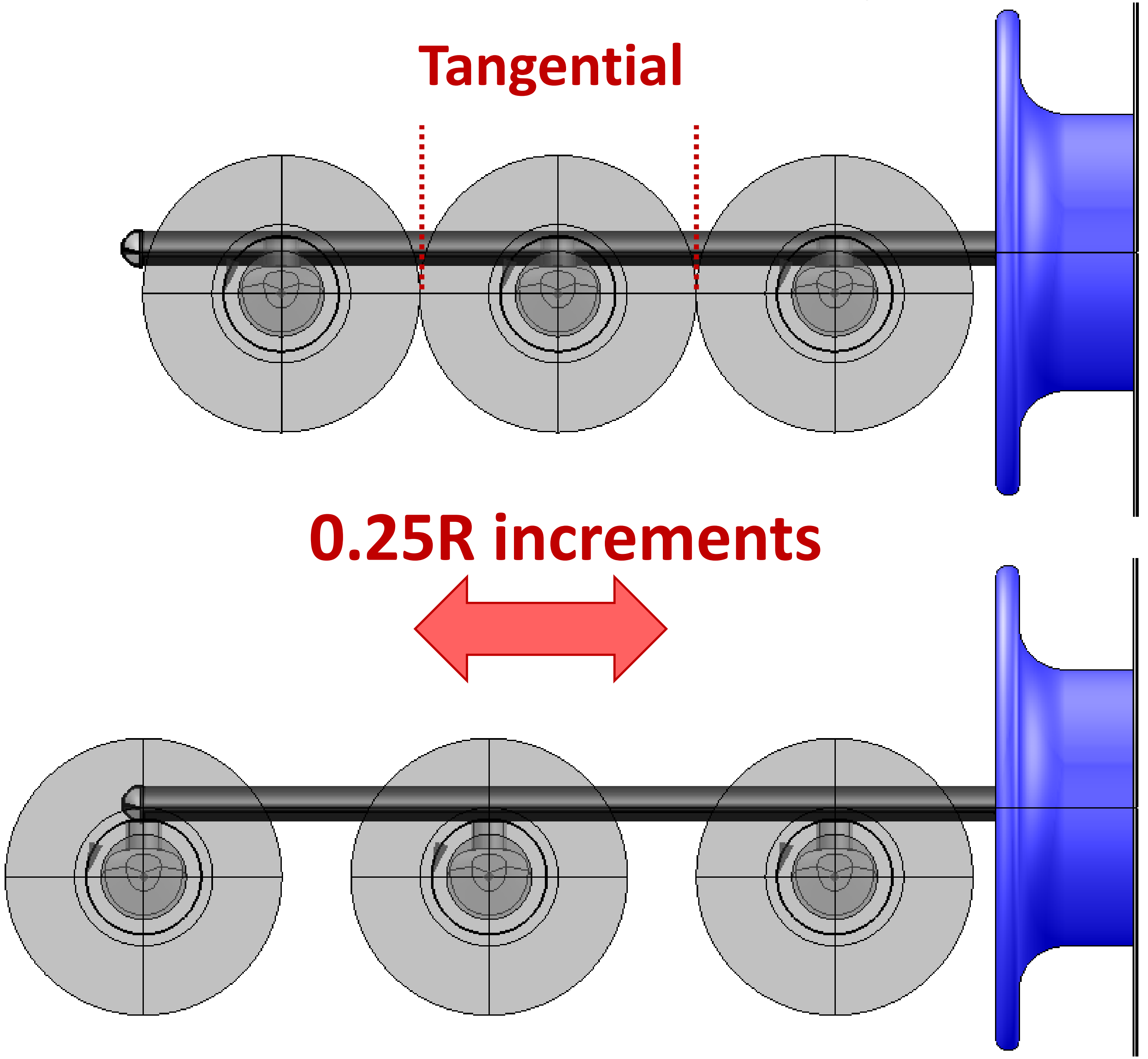


UAM Reference Vehicle vs. Wind Tunnel Model

Proprotor Spanwise Position

R = Proprotor Radius





What’s Next?

- Test matrix design of experiments: predict and prioritize test conditions of interest
- Wind tunnel model completion and delivery to NASA
- Rotor Test Cell: model preparation and shakedown
- 14- by 22-Foot Subsonic Tunnel:
  - Shakedown, aero performance (8 weeks)
  - Acoustics (16 weeks)

Throughout: publication of geometries, test plans, analysis models, and data for community benefit.

Acknowledgments & Points of Contact

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Points of Contact

- Technical Lead: Norman Schaeffler
- Co-PI for Acoustics: Nikolas Zawodny
- Co-PI for Conceptual Design: Siena Whiteside
- Aero analyses: Brandon Litherland, James Jensen
- Design of experiments: Christopher Thurman

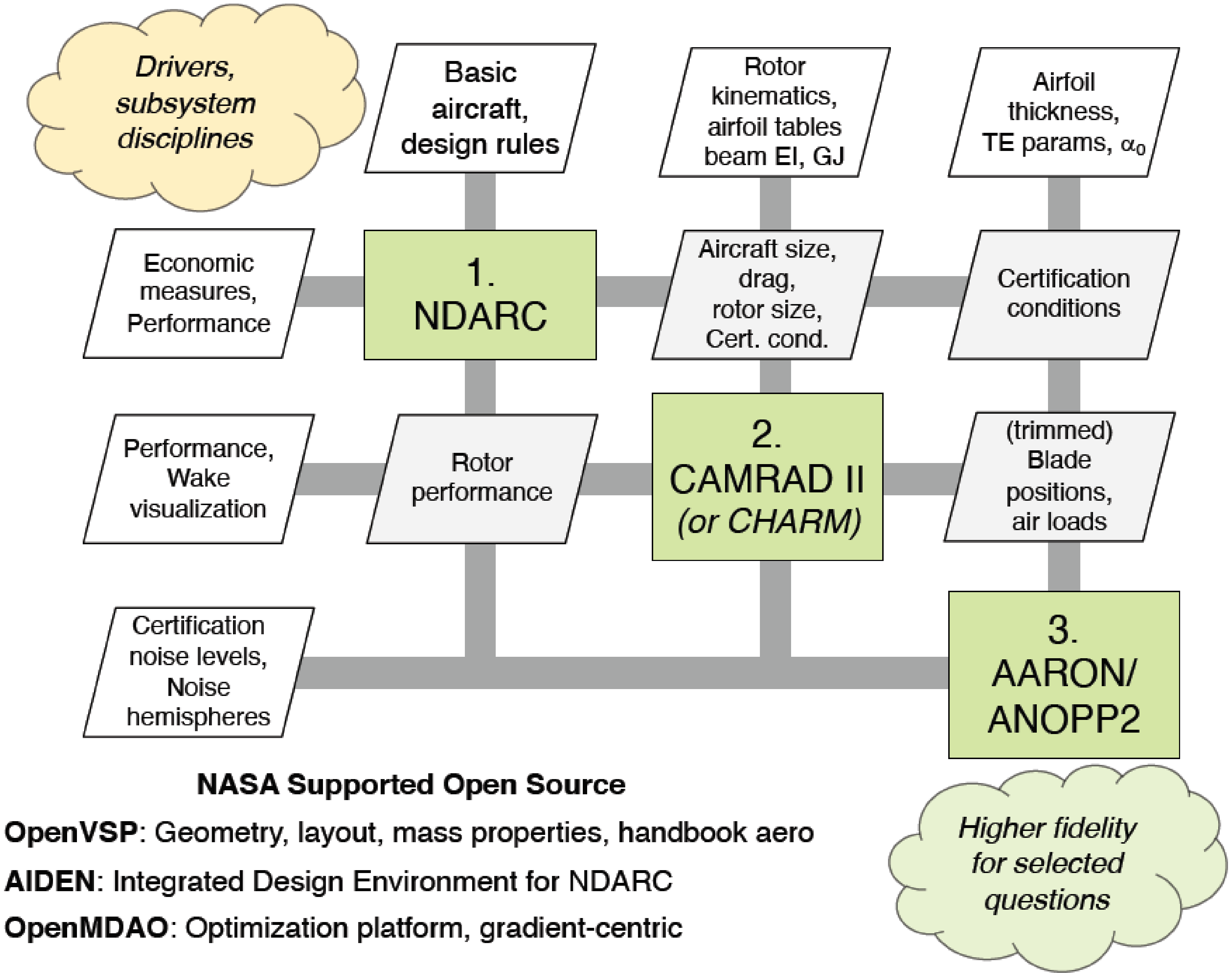
siena.k.whiteside@nasa.gov

Thank you!

Questions & Comments?

siena.k.whiteside@nasa.gov

RVLT Conceptual Design Toolchain



NASA Supported Open Source

OpenVSP: Geometry, layout, mass properties, handbook aero

AIDEN: Integrated Design Environment for NDARC

OpenMDAO: Optimization platform, gradient-centric

NASA Software

NDARC: Aircraft Design and Analysis

RCOTOOLS: Interface and utilities for connecting codes in Python and connecting to OpenMDAO

AARON/ANOPP2: Noise analysis

ALPINE: Python interface between NDARC and OpenVSP

FlightCODE: Flight dynamics model generation and handling qualities design/assessment

Chimera Grid Tools: Grid generation for CFD

Commercial Tools

CAMRAD II: Rotorcraft comprehensive analysis

CHARM: Rotorcraft comprehensive analysis

IXGEN/VABS: Rotor blade cross-sectional structural analysis

AFTGen: Rotor blade airfoil aerodynamic table generation

NPSS: Turbine engine and electric motor design and analysis

M4SS/NASTRAN: Airframe structural analysis

Rhinoceros: Refine geometry for CFD grid generation and visualization