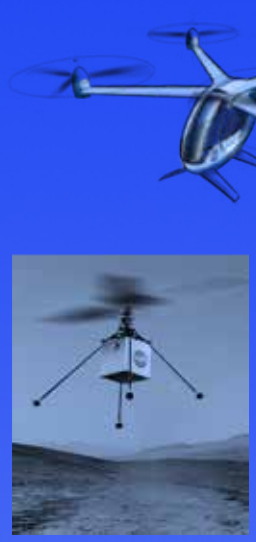
National Aeronautics and Space Administration



NASA's Approach to eVTOL Noise Modeling and Technology Solutions

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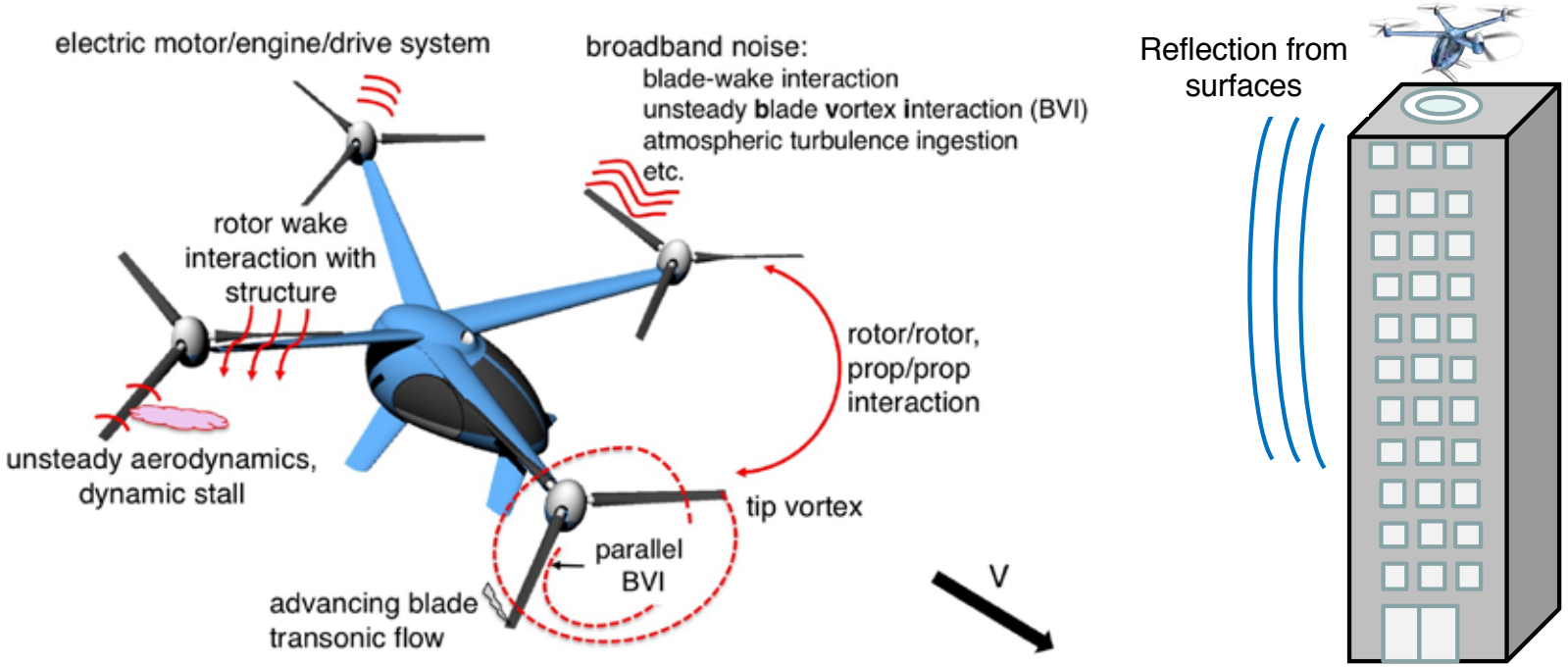
NASA's Approach to eVTOL Noise Modeling and Technology Solutions

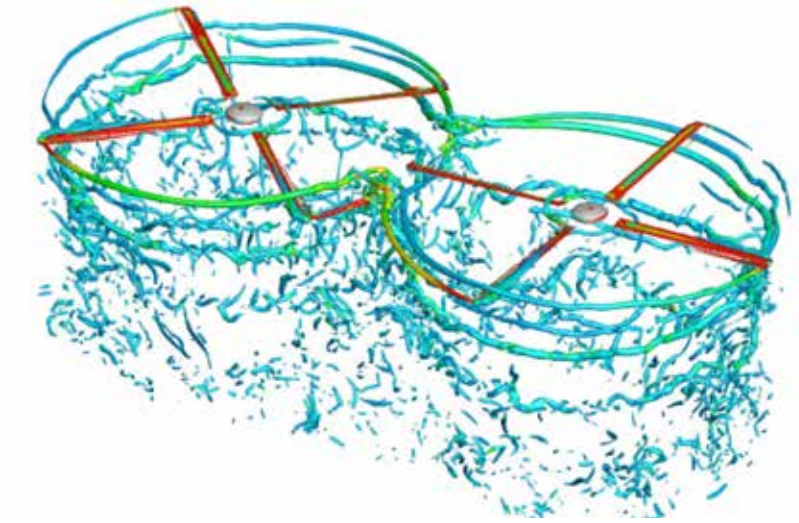
- **Source Noise Modeling, Prediction and Validation**: Many sources of VTOL vehicle noise – difficult to model and validate each source
- **Low-Noise Design Capability**: Vehicle configurations (multi-rotor, multi-motor, unconventional vehicle trim) require higher-fidelity, multi-disciplinary modeling capability to capture important acoustic interactions
- **Low-Noise Flight Path Management and Assessment Tools**: Conventional tools need major modification to model eVTOL operational impact
- **Human Response**: Human response to noise is very difficult to predict and quantify – lower sound levels do not always correlate with reduced annoyance



Noise sources of a representative UAM vehicle configuration

NASA is Using a Multi-Pronged Approach to eVTOL Noise Research (1 of 4)

Source Noise Modeling, Prediction and Validation



Challenges

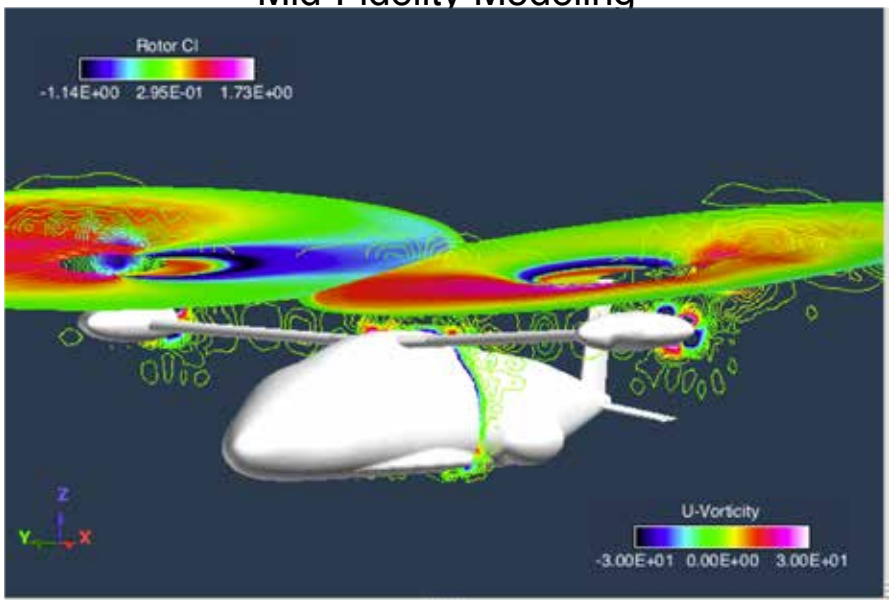
How well can we predict the noise of these vehicles?

- Analysis methods are source and configuration dependent
- Different flight modes (vertical vs forward) require multiple methods
- Aperiodic operations are difficult to model

Technical Approach

- Validate high-fidelity CFD computations using wind tunnel, lab, and field tests of vehicle components
- Simulate aerodynamic interaction effects on noise generation
- Develop high-fidelity modeling capability for trimmed, aperiodic configurations
- Assess capabilities of lower fidelity modeling

Mid-Fidelity Modeling



NASA is Using a Multi-Pronged Approach to eVTOL Noise Research (2 of 4)

Low-Noise Design Capability

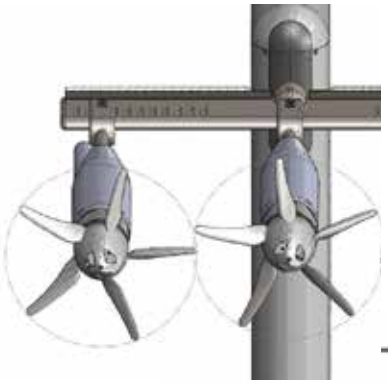
Challenges

How important are installation effects?

- Propulsor-propulsor and propulsor-airframe interactions
- Close-coupling between propulsor and support arms
- Powertrain architecture and integration

Technical Approach

- Use formal optimization to demonstrate design of a low noise rotor blade with performance, structural integrity and anti-icing constraints
- Use component test results and low-fidelity conceptual design approach to assess installation effects, rotor phasing, trim strategies, etc., on acoustics



Prop-Prop Interactions

Rotors positioned to mitigate wake interactions

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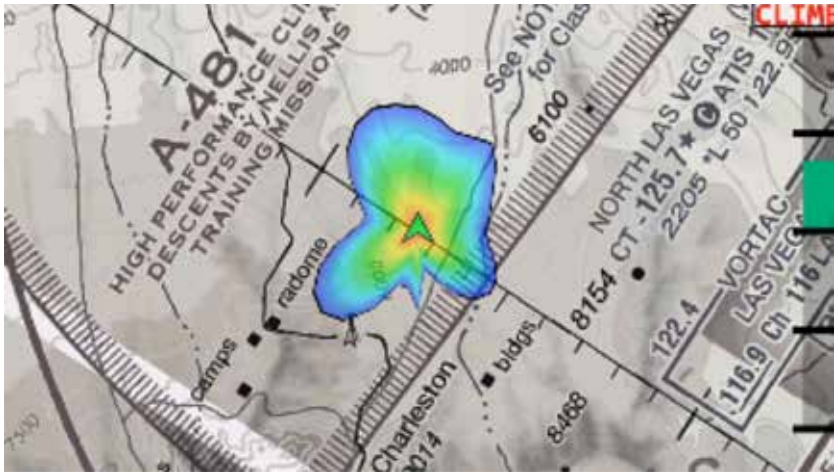
Low-Noise Flight Path Management and Assessment Tools



Challenges

How to quietly operate these vehicles?

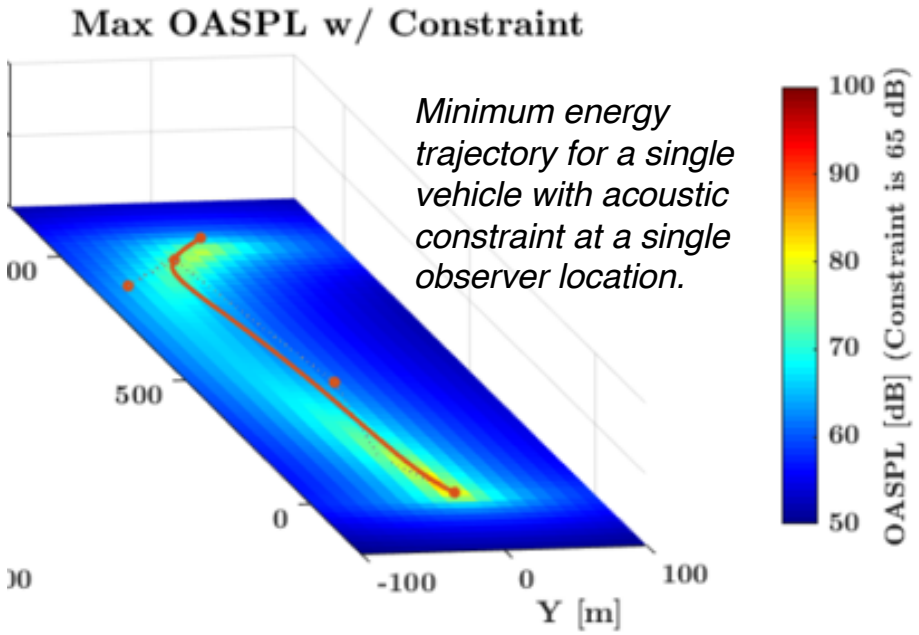
- Low noise guidance and trajectory planning
- Dynamic flight path generation
- Dynamic control of vehicle noise directivity

Does ambient noise affect operations?

- Time of day, indoor vs outdoor
- Number/type of operations

Technical Approach

- Acquire data for low and high fidelity tool validation
- Assess low noise flight profiles and procedures
- Interact with operator community for outreach and education on “flying quieter”
- Develop and demonstrate prototype pilot aid and training tool
- Work closely with the FAA and Helicopter Association International



Descending Turn Movie (29 sec)

NASA is Using a Multi-Pronged Approach to eVTOL Noise Research (4 of 4)

Human Response

Challenges

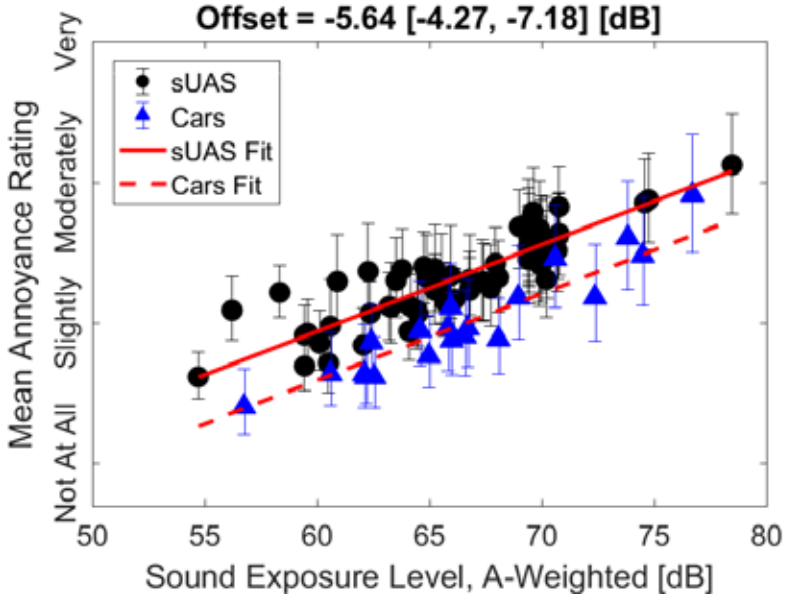
What are appropriate noise metrics and requirements for low annoyance designs?

- Sound quality metrics for annoyance
- Relative importance of non-acoustic factors
- Appropriate dose response measure
- Single event versus multi-event annoyance
- Modifying traditional tools for fleet noise

Technical Approach

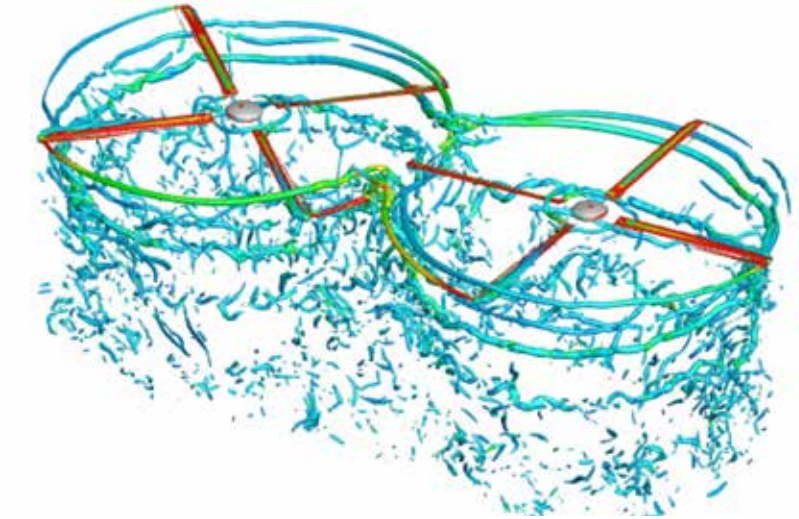
- Determine which noise metric best characterizes human annoyance
- Assess response to measured and low noise design flight acoustic profiles
- Develop method to assess effect of cumulative operations (fleet noise) on community
- Evaluate impact of trajectory changes on community noise footprint

Results from annoyance study

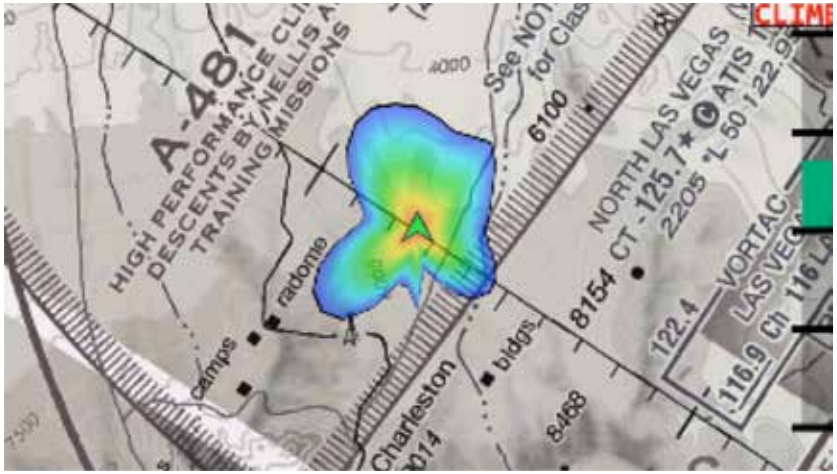


Summary of Approach to eVTOL Noise Research

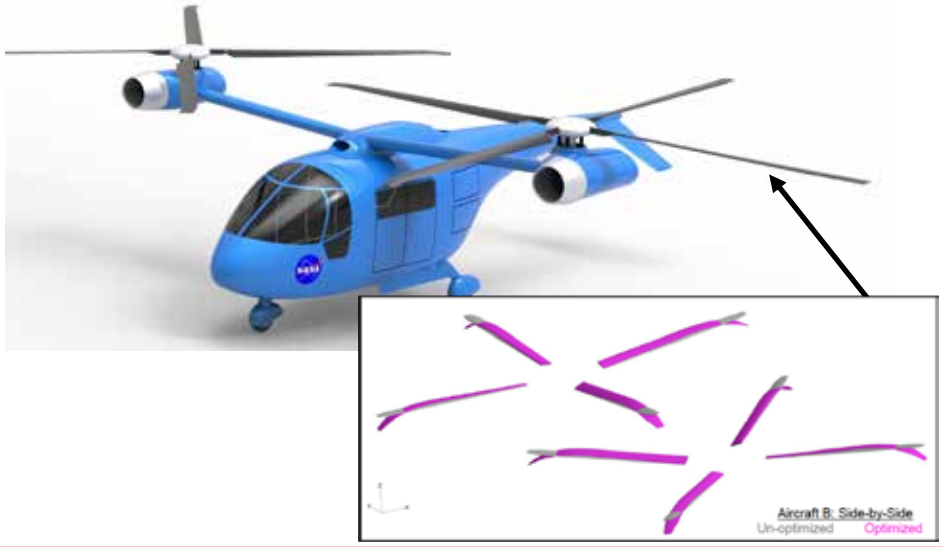
Source Noise Modeling, Prediction and Validation



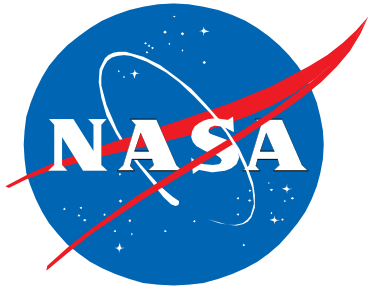
Low-Noise Flight Path Management and Assessment Tools



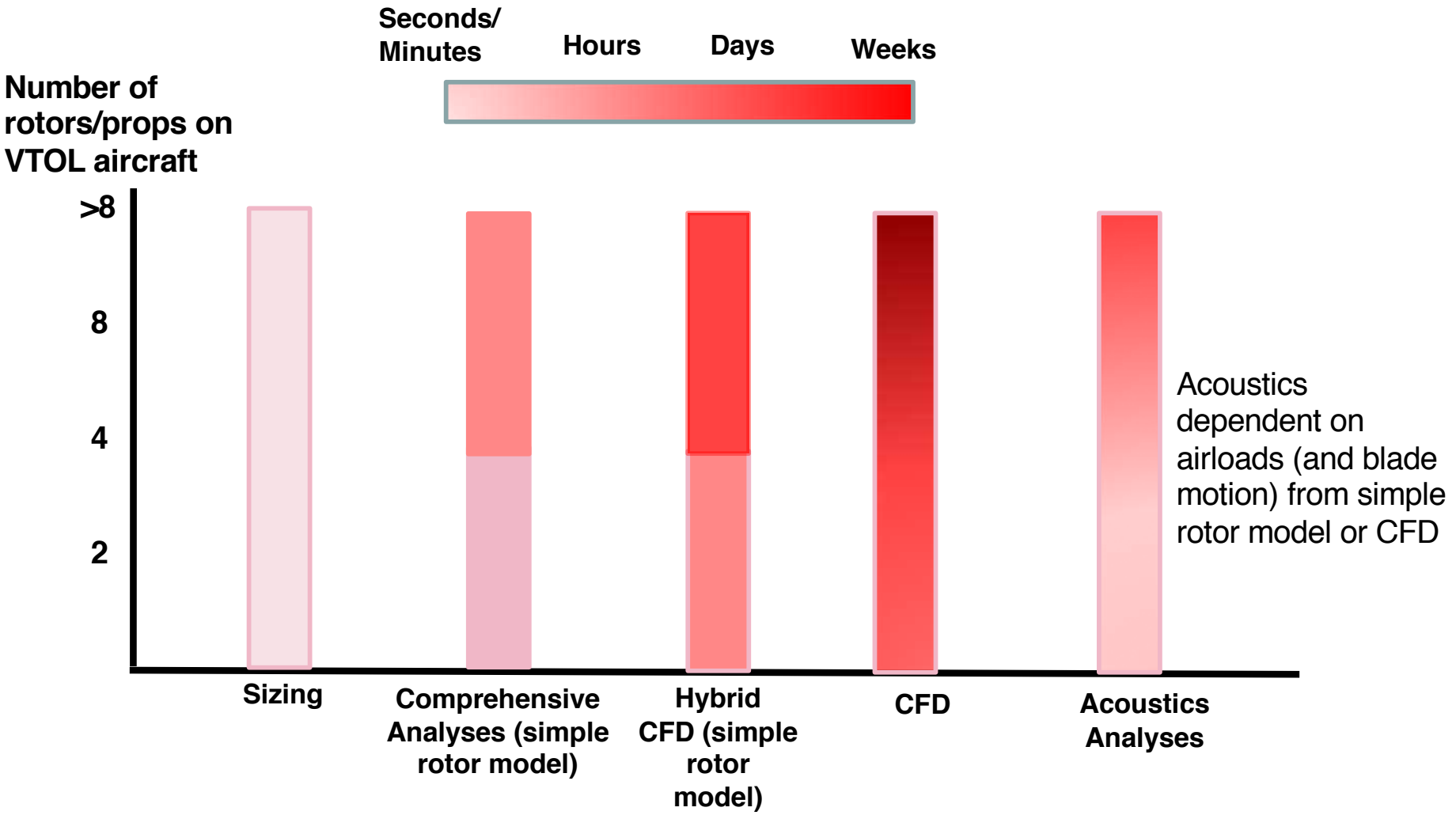
Low-Noise Design Capability



Human Response

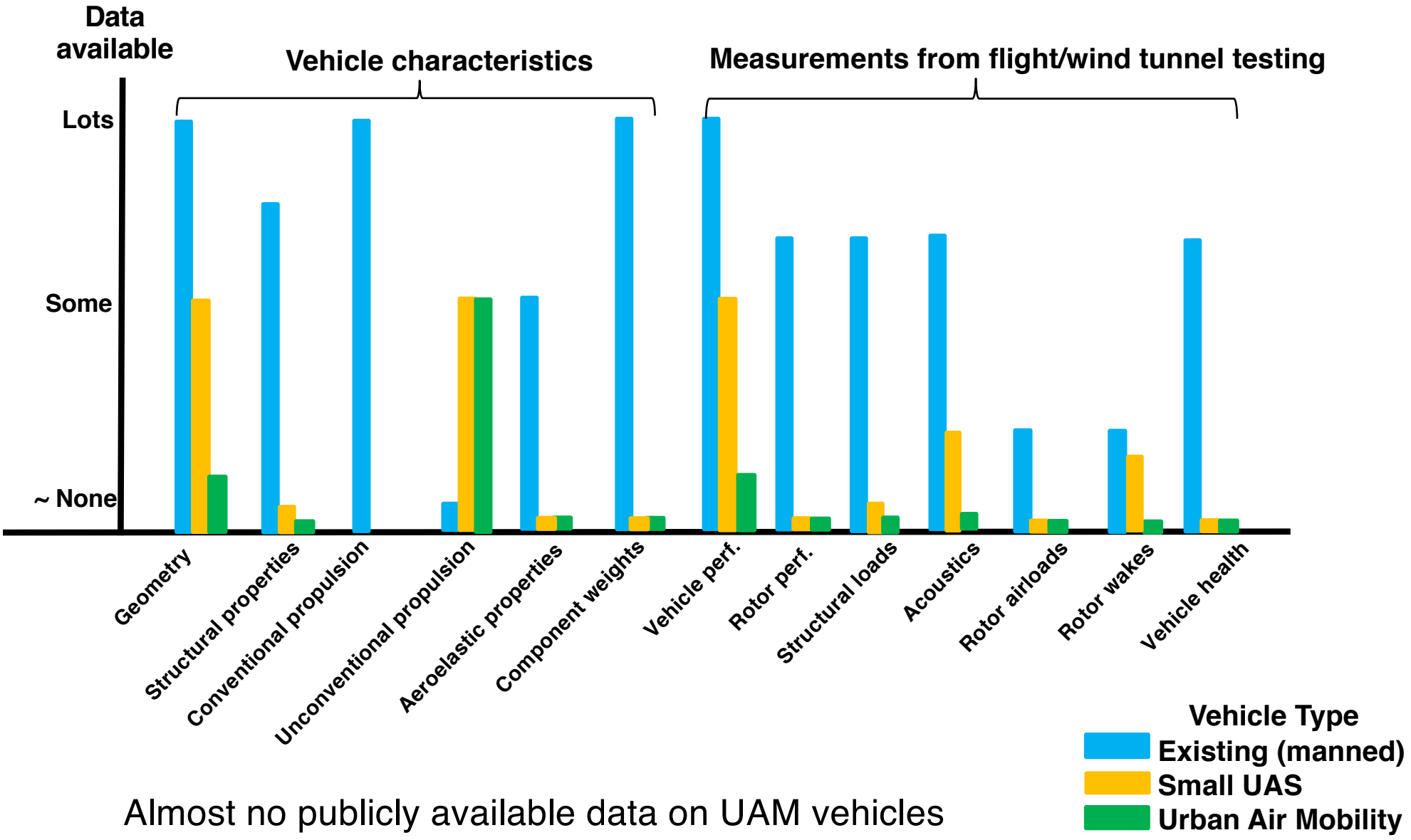

NASA

Execution Times for Rotorcraft Analyses



Most UAM vehicles have > 4 rotors/props

VTOL Aircraft: Validation-Quality Data Availability



Almost no publicly available data on UAM vehicles