

UAM Research at NASA (and a dozen other reasons why it's a GREAT time to be an Aerospace Engineer)

John Melton, PhD.

NASA Ames Research Center
Moffett Field, CA 94035
john.melton@nasa.gov

The Aerospace Revolution is Well Underway



- A mini-renaissance in aerospace is occurring at all Mach numbers
- Enhanced Mobility, Greener Transport, Access to Space
 - Subsonic: UAM, electric propulsion, X-57, VTOL/ESTOL, urban operations
 - Transonic: Greener commercial aviation, hybrid propulsion systems, SLS/Orion
 - Supersonics: Low sonic boom demonstrator X-59, NewSpace projects
 - Hypersonics: Planetary reentry (Artemis lunar return), NewSpace
- New multi-physics problems require creative new approaches and novel solutions to hardware, software, and “people”-ware issues

We're ALL aerospace engineers, whether we're AE, ME, EE, CE, CS, or ?ES!

The Subsonics Revolution



- UAS = Unmanned Aerial System (“drones”)
- UTM = UAS Traffic Management
- ***UAM = Urban Air Mobility (urban “air taxis”)***
- Special challenges for VTOL/ESTOL flights
- Urban interactions – noise, winds, clutter
- Vehicle, airspace, and community challenges
- Three sample problems
 - What will these UAM vehicles look like?
 - How will these UAM networks develop?
 - How can we make urban operations safe and efficient?



What is UAM? And Why Now?

- Urban Air Mobility: Enhance overall mobility through the expansion of urban/suburban low-altitude “short”-range VTOL operations
 - New aero-propulsive capabilities provided by propulsive electrification
 - Advances in structures, automation, analysis, computing, and testing
 - Short flight ranges promote “non-traditional” approaches to vehicles and operations



W. Johnson and C. Silva, “Observations from Exploration of VTOL Urban Mobility Designs”, 2018

UAM Vehicles: Not Your Father's VTOL . . .



PROPULSION EFFICIENCY

high power, lightweight battery
light, efficient, high-speed electric motors
power electronics and thermal management
light, efficient diesel engine
light, efficient small turboshaft engine
efficient powertrains

SAFETY and AIRWORTHINESS

FMECA (failure mode, effects, and criticality analysis)
component reliability and life cycle
crashworthiness
propulsion system failures
high voltage operational safety

OPERATIONAL EFFECTIVENESS

disturbance rejection (control bandwidth, control design)
all-weather capability
passenger acceptance
cost (purchase, maintenance, DOC)

PERFORMANCE

aircraft optimization
rotor shape optimization
hub and support drag minimization
airframe drag minimization



Quadrotor + Electric



Side-by-side + Hybrid

ROTOR-ROTOR INTERACTIONS

performance, vibration, handling qualities
aircraft arrangement
vibration and load alleviation



Tiltwing + Turboelectric



Lift+Cruise + Turboelectric

ROTOR-WING INTERACTIONS

conversion/transition
interactional aerodynamics
flow control

STRUCTURE AND AEROELASTICITY

structurally efficient wing and rotor support
rotor/airframe stability
crashworthiness
durability and damage tolerance
High-cycle fatigue

NOISE AND ANNOYANCE

low tip speed
rotor shape optimization
flight operations for low noise
aircraft arrangement/ interactions
cumulative noise impacts from fleet ops
active noise control
cabin noise
metrics and requirements

AIRCRAFT DESIGN

weight, vibration
handling qualities
active control

UAM Vehicles: NASA Concept Vehicles



NASA Concept Vehicles for UAM



Objective: Identify NASA vehicles to serve as references to openly discuss technology challenges common to multiple concepts in the UAM community and provide focus for trade studies and system analysis

Passengers	Range	Market	Type	Propulsion
1	1 x 50 nm	Air Taxi	Multicopter	Battery
	2 x 37.5 nm		Compound	Diesel
2	2 x 50 nm	Commuter Scheduled	Side by Side	Parallel hybrid
4	4 x 50 nm	Mass Transit	Tilt Wing	Turboelectric
6	8 x 50 nm	Air Line	Tilt Rotor	Turboshaft
15			Lift + cruise	Hydrogen fuel cell

Quadrotor "Air Taxi"



Side by Side "Vanpool"



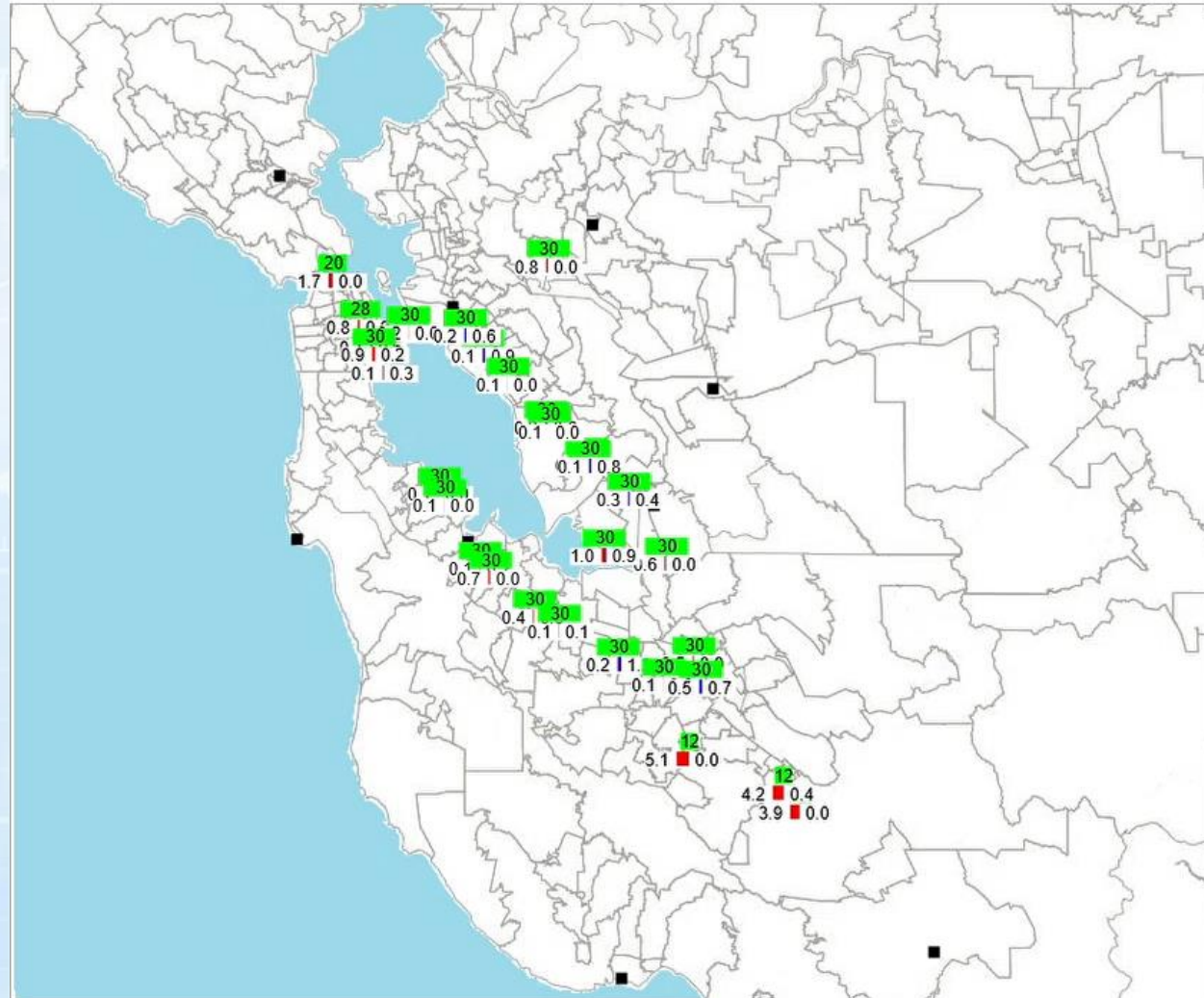
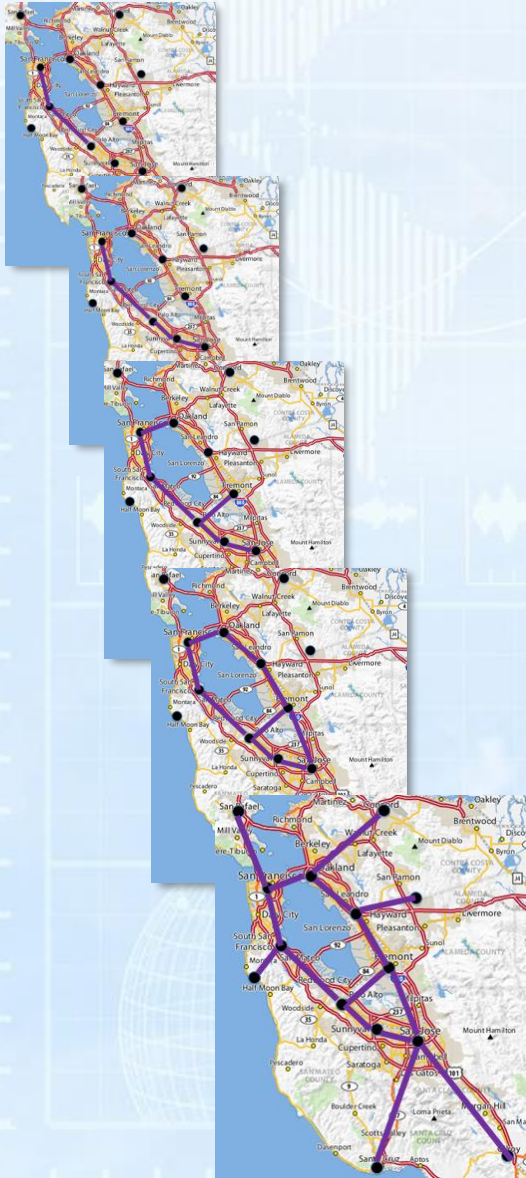
Lift+Cruise "Air Taxi"



Tilt Wing "Airliner"

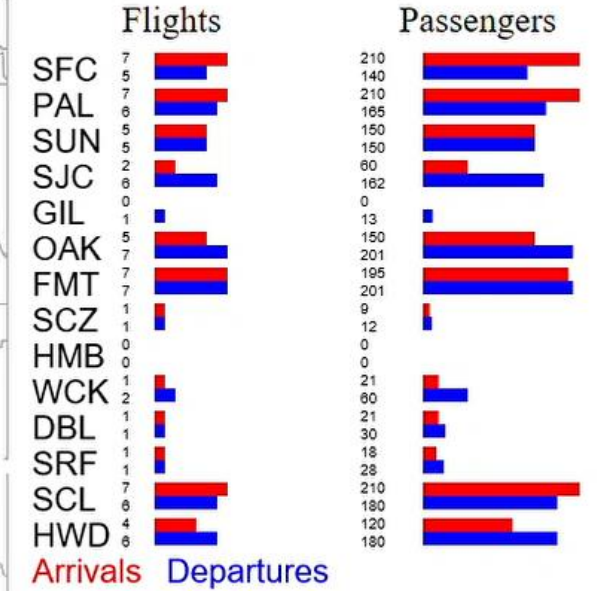


UAM Traffic Simulations for the SF Bay Area



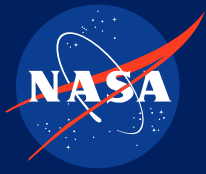
Time: 06:22:24 AM Days: 2

Window (mins):

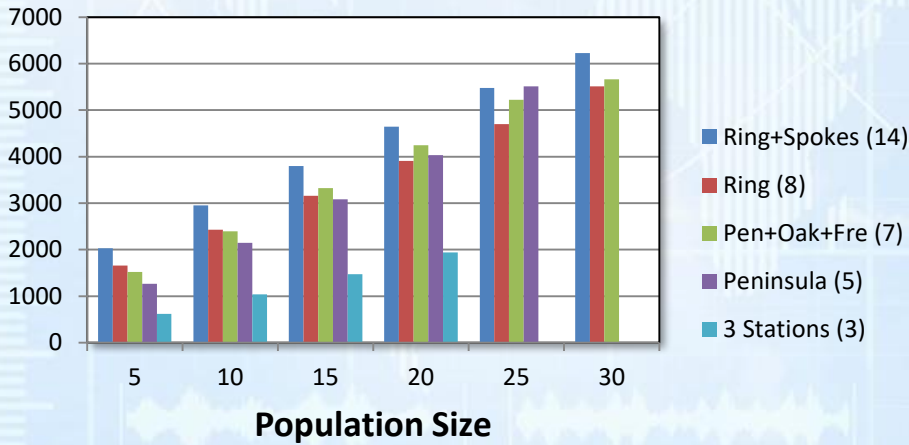


UAM traffic animation serving 30K passengers in one day, 60 Dep/hr

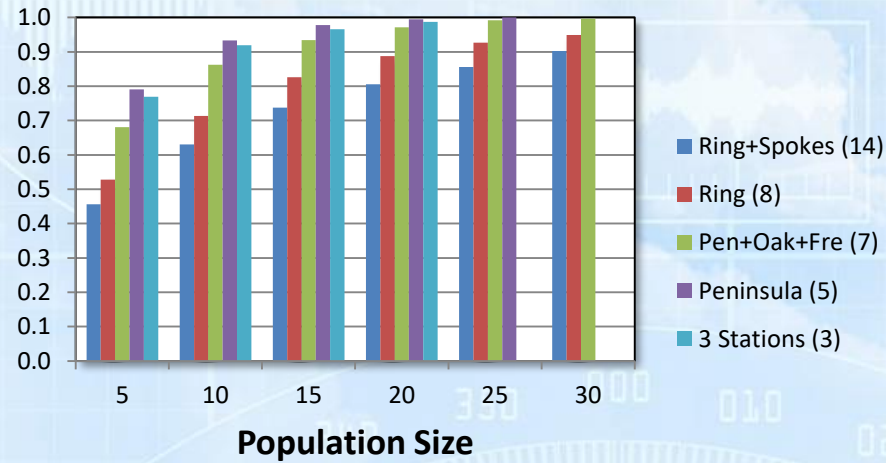
UAM Traffic Simulations for the SF Bay Area



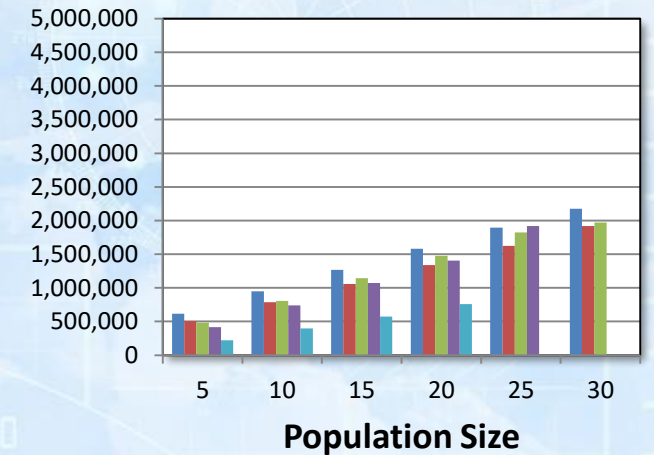
Number of Flights per Day



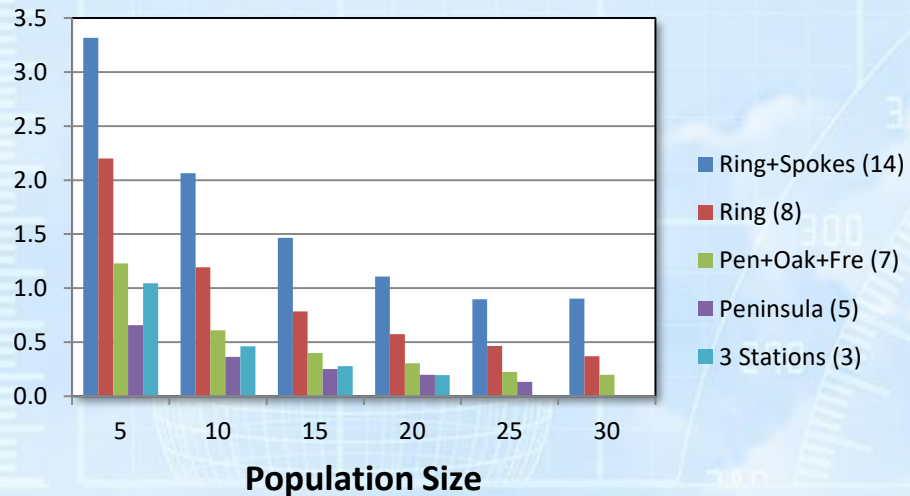
Average Load Factor



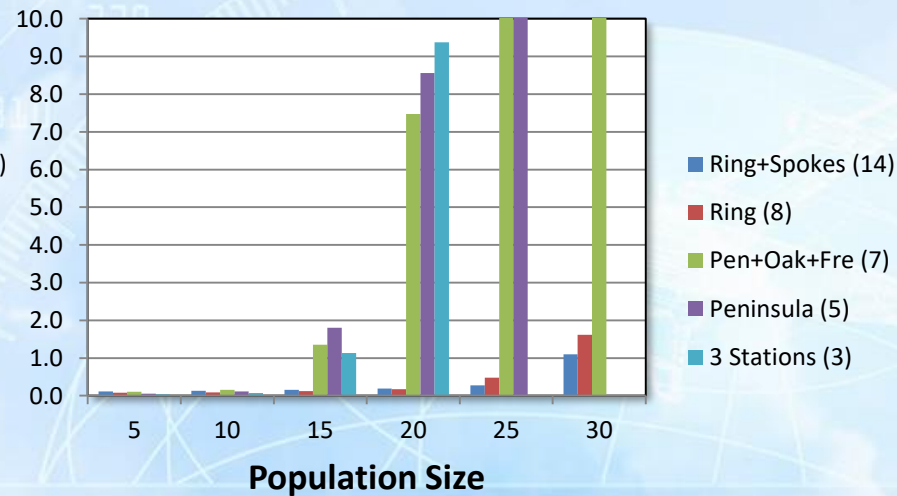
Total Energy Use in kW-h: Battery



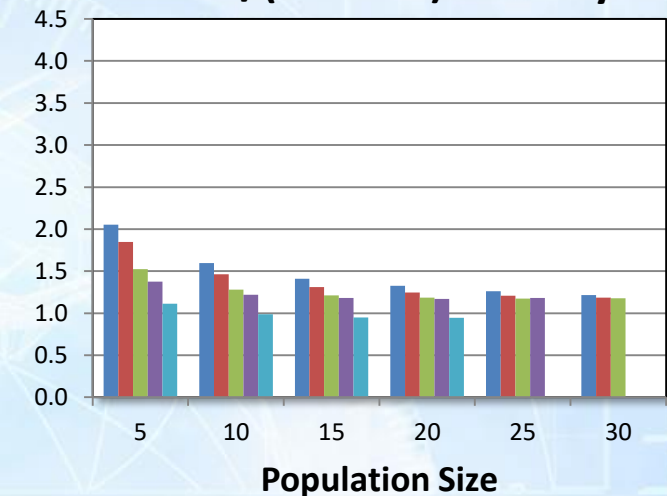
Average PX Queue Delay in Minutes



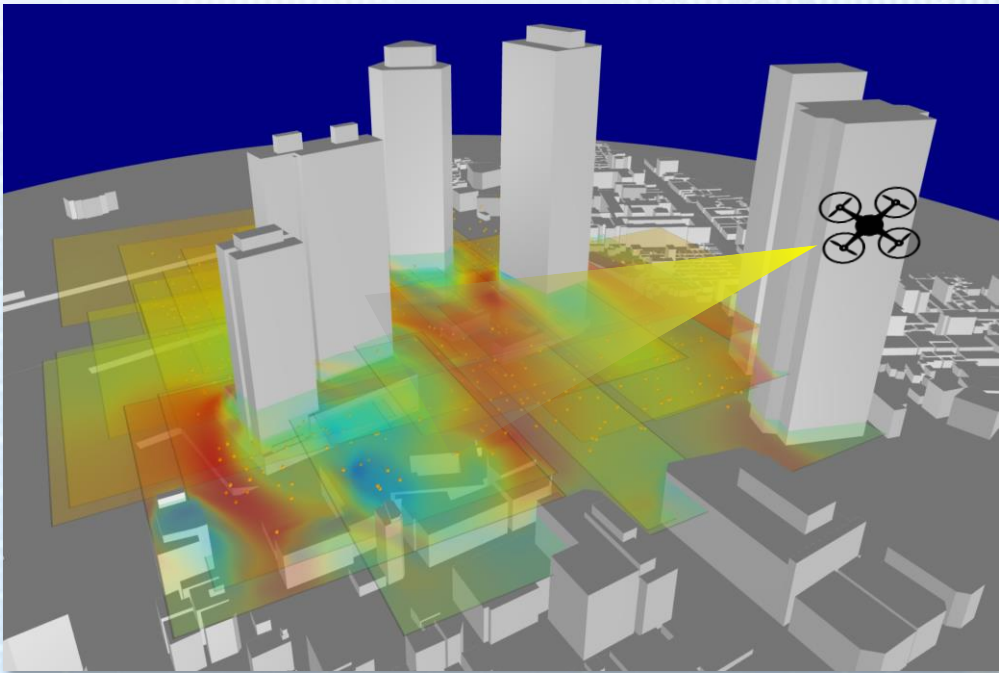
Average Flight Departure Spacing Delay in Minutes



kW-h/(PX-mile): Battery



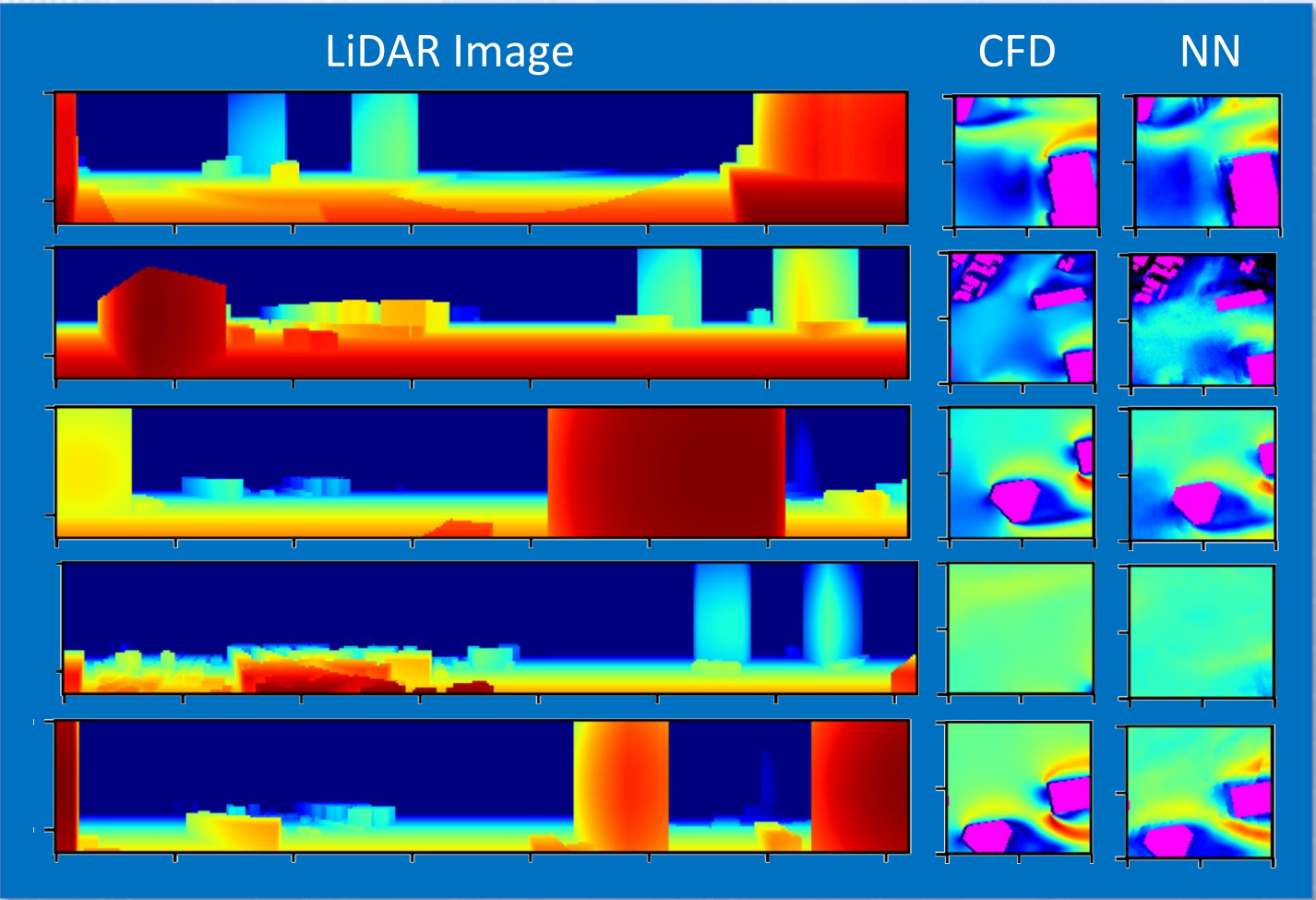
UAM Urban Wind Estimation with Deep Learning



Urban Wind Field used for Deep Learning



Onboard Deep Learning Neural Network



Deep Learning Inputs and Outputs

Other Topics of Ongoing NASA UAM Research



- Controls (and transition)
- Autonomy
- Structures
- Rotors
- Noise
- Manufacturing
- Traffic and network management
- Vertiport designs and operations
- Communications
- Safety and Security

The NASA UAM Grand Challenges (2020+)

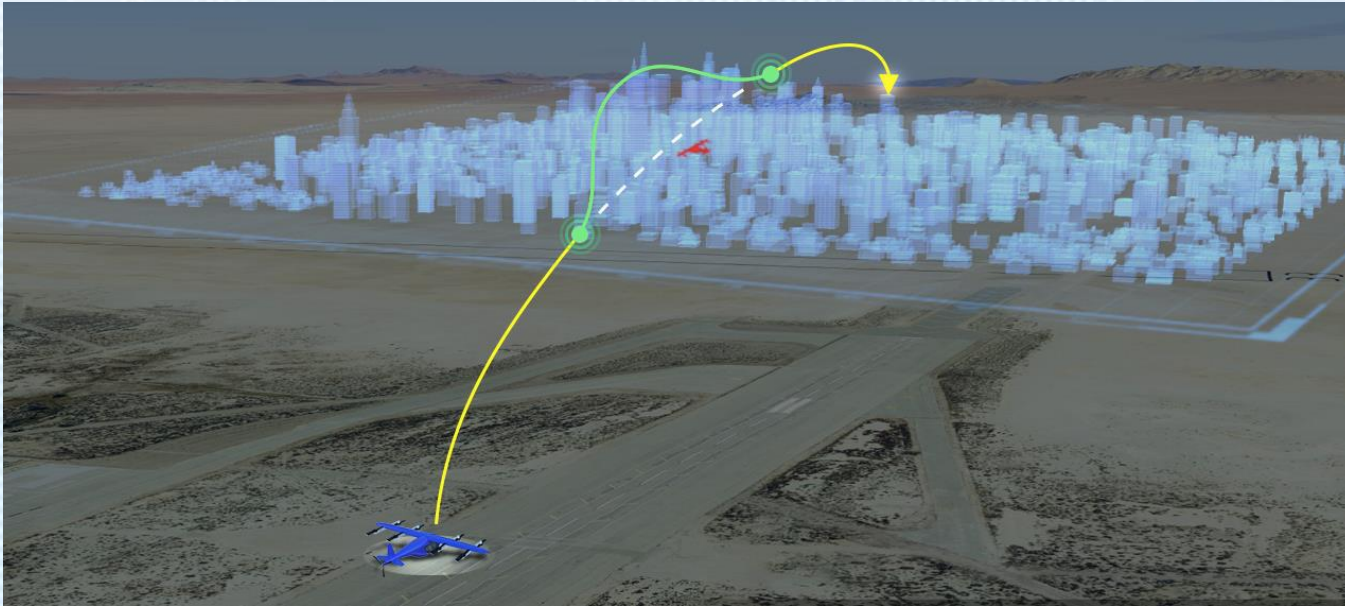


- Flight demonstrations of practical and scalable UAM concepts
- Challenge the industry to execute a variety of safety and integration scenarios
- Share lessons learned
- Benefit of NASA test expertise
- Understand what works (and what doesn't)
- Foster development of standards
- No purse or prize money



Davis Hackenberg, AAM Project Manager, NASA

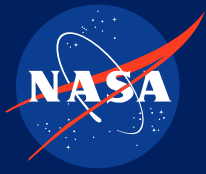
The NASA UAM Grand Challenges (2020+)



Davis Hackenberg, AAM Project Manager, NASA

- Begin testing with real vehicles in virtual/synthetic environments at AFRC
- Understand interfaces and interactions with simulated Air Traffic Systems
- Test real flight hardware within increasingly realistic environments

The Transonics Revolution is just beginning



- Greener aviation has been a long-term NASA goal
- Better L/D, alternative fuels and noise reduction
- Hybrid and electric propulsion systems

NASA AERONAUTICS RESEARCH ONBOARD
DECADES OF CONTRIBUTIONS TO COMMERCIAL AVIATION

- 1 COMPUTATIONAL FLUID DYNAMICS (CFD) ✦ ✧
- 1970s-Today
- 2 AIRBORNE WIND SHEAR DETECTION ✦ ✧
- 1980s-1990s
- 3 DIGITAL FLY-BY-WIRE ✦ ✧
- 1960s-1970s
- 4 TURBO-AE CODE ✦ ✧
- 1990s
- 5 AIR TRAFFIC MANAGEMENT ✦ ✧
 - Center TRACON Automation System (CTAS) - 1990s
 - Traffic Management Advisor (TMA) - 1990s
 - Surface Management System (SMS) - 2000s
 - Future Air Traffic Management Concepts Evaluation Tool (FACET) - 2000s
- 6 LIGHTNING PROTECTION STANDARDS ✦ ✧
- 1970s-1980s
- 7 NASA STRUCTURAL ANALYSIS (NASTRAN) ✦ ✧
- 1960s-Today
- 8 COMPOSITE STRUCTURES ✦ ✧
- 1970s-Today
- 9 GLASS COCKPIT ✦ ✧
- 1970s-1980s
- 10 AREA RULE ✦ ✧
- 1950s
- 11 DAMAGE-TOLERANT FAN CASING ✦ ✧
- 2000s-Today
- 12 JET ENGINE COMBUSTORS ✦ ✧
- 1990s-2000s
- 13 ENGINE NOZZLE CHEVRONS ✦ ✧
- 1990s-2000s
- 14 SUPERCRITICAL AIRFOIL ✦ ✧
- 1960s-1970s
- 15 WIND TUNNELS ✦ ✧
- 1930s-Today

✦ Applies also to general aviation aircraft
✧ Applies also to military aircraft



The Transonics Revolution gets us to space



- Recent Orion Ascent Abort-2 Test at Mach 1.2



Testing in Ames 9x7 WTs



Assembly at KSC

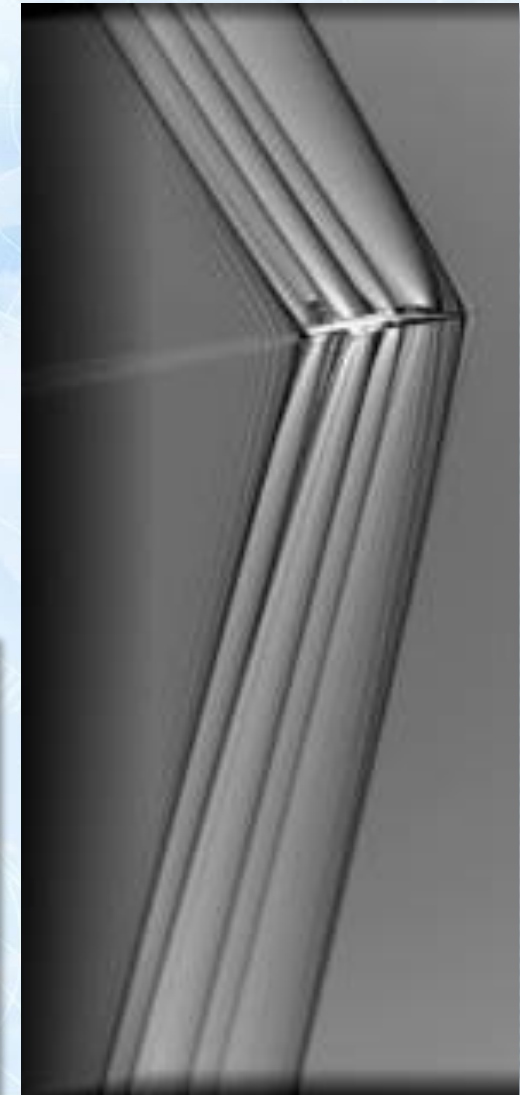


Successful test July 2, 2019

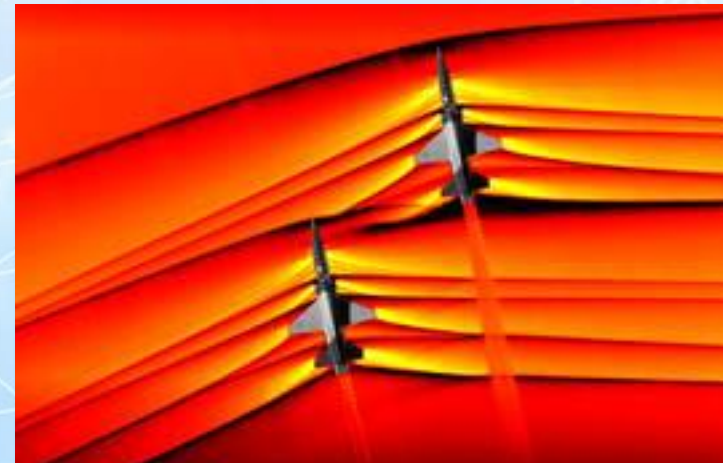
The Supersonics Re-Re-Revolution (Concorde 88)



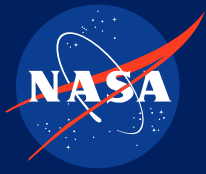
- Low Boom Flight Demonstrator X-59 QueSST (2022)
- Aerodynamics and acoustics of the sonic boom
- In-flight shock visualization
- External Vision System
- Go fast AND go green AND go quietly
- Commercial supersonics



^ Boom / Aerion v



What's next? Definitely more X-vehicles!



- More UAS/UTM testing in Corpus Christi (Downtown Reno in May 2019)
- X-56A flutter testing
- X-57 electric demonstrator testing
- UAM Grand Challenge flights in 2020+
- X-59 QueSST Demonstration flights in 2022



Need more NASA technical info? Check online!



- NTRS (NASA Technical Reports Server) <https://ntrs.nasa.gov>
- STI (Science and Technical Information) <https://www.sti.nasa.gov>
- NTRS includes access to the *entire* NACA Report collections (from 1917 to 1958!)
- NTRS includes most of the key technical reports created on X-planes, Apollo and Shuttle
- Most downloads are professionally scanned, and in convenient pdf format
- Able to tailor search queries to get the results you want
- Searching “UAM” – returned 600 matching records!
- Searching “Urban Air Mobility” – returned 1862 records!
- Searching “Sonic Boom” – returned 3887 records!

And it's all *completely* FREE to download