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?

images from www.nasa.gov

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

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

ROTOR-ROTOR INTERACTIONS
performance, vibration, handling qualities
aircraft arrangement
vibration and load alleviation

Quadrotor + Electric

Tiltwing + Turboelectric

ROTOR-WING INTERACTIONS
conversion/transition
interactional aerodynamics
flow control

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

Side-by-side + Hybrid

Lift+Cruise + Turboelectric

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

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

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

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

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”

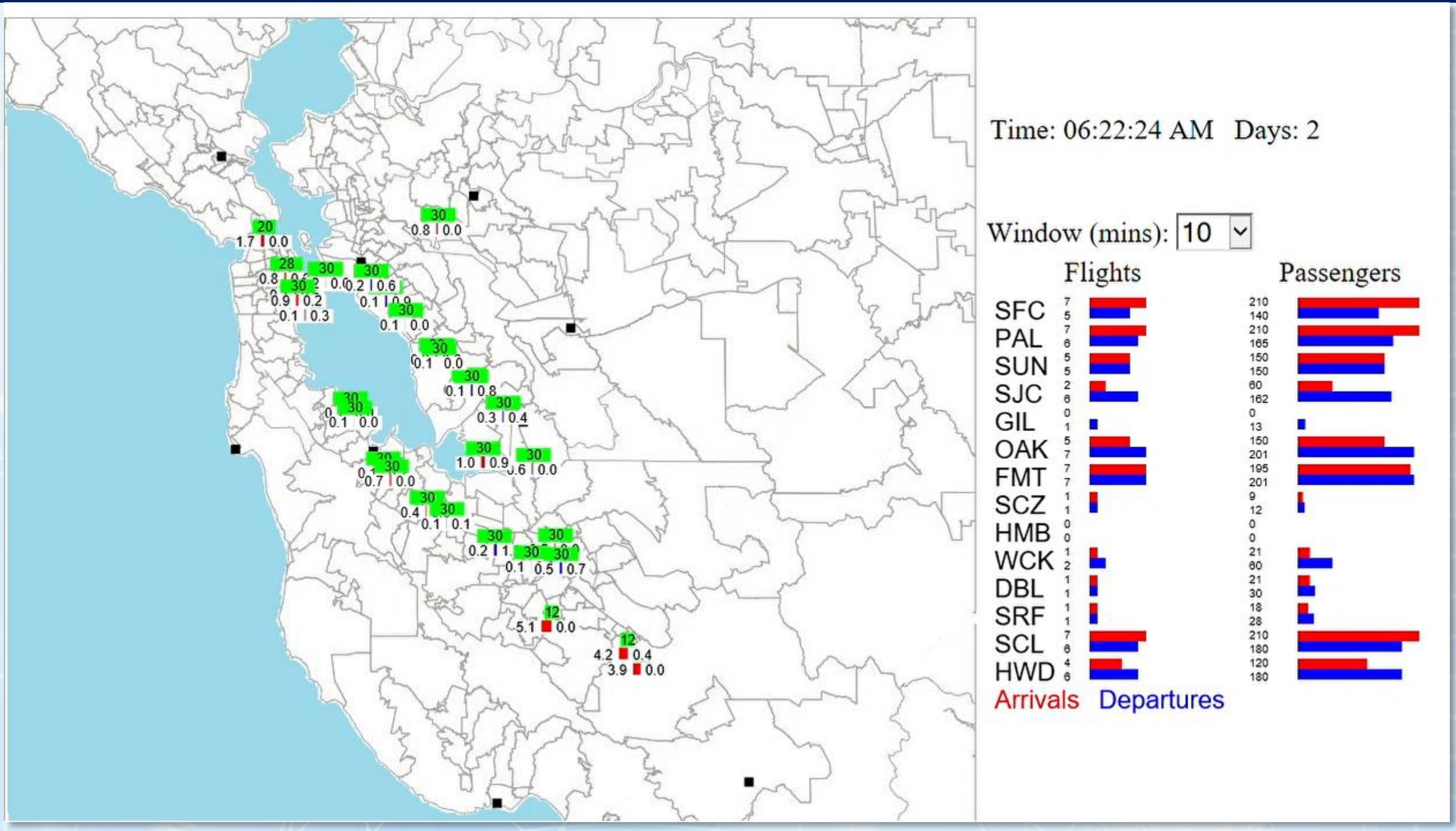
Side by Side “Vanpool”

Lift+Cruise “Air Taxi”

Tilt Wing “Airliner”

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

UAM Traffic Simulations for the SF Bay Area

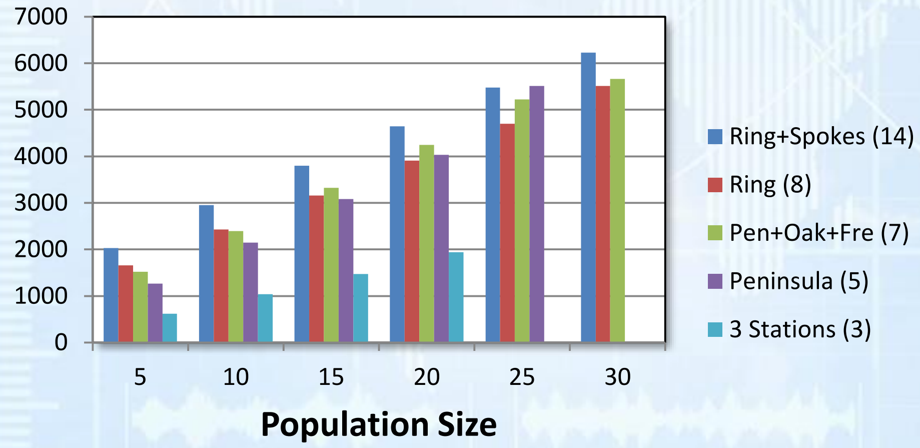


UAM traffic animation serving 30K passengers in one day, 60 Dep/hr

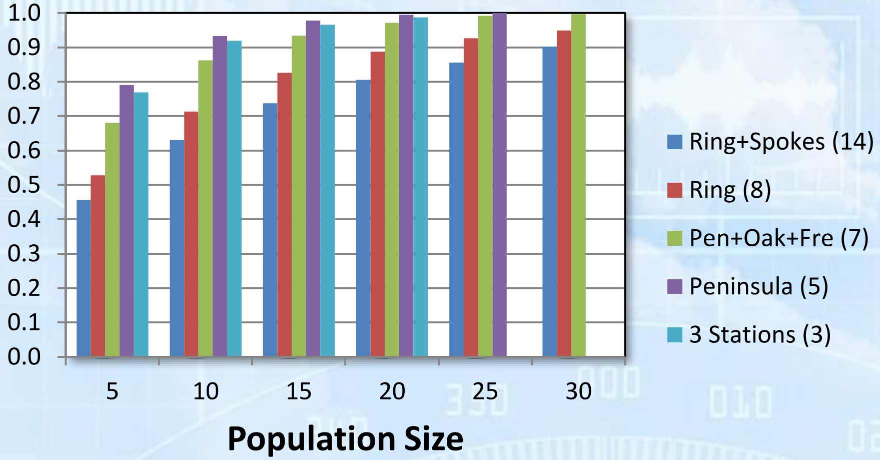
NASA/TM-2017-218356

UAM Traffic Simulations for the SF Bay Area

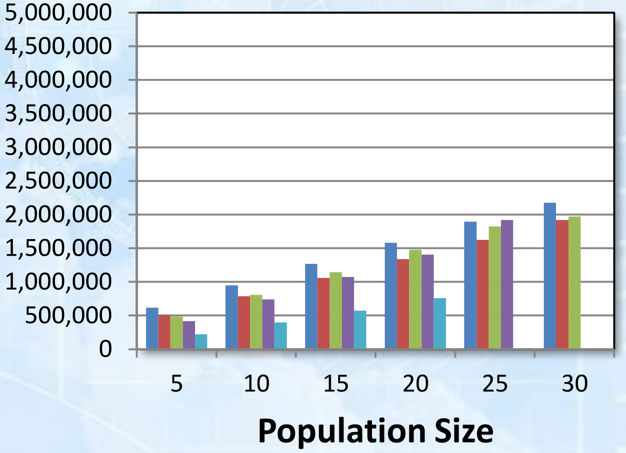
Number of Flights per Day



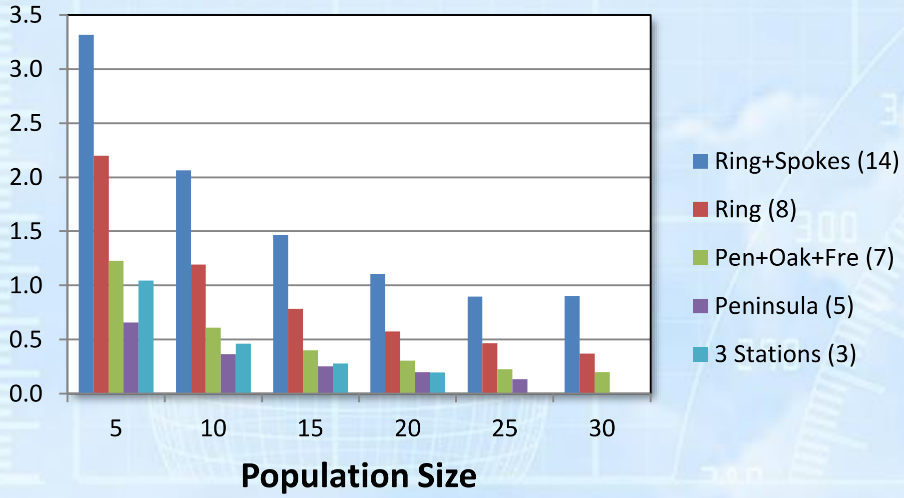
Average Load Factor



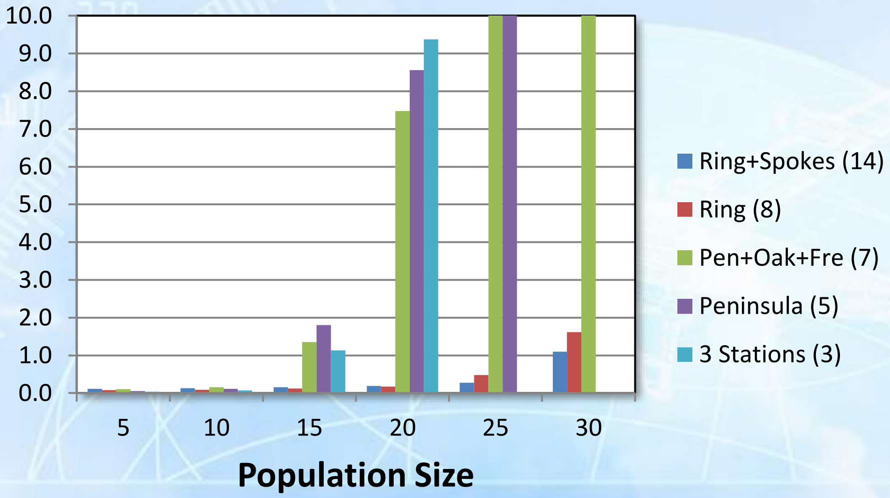
Total Energy Use in kW-h: Battery



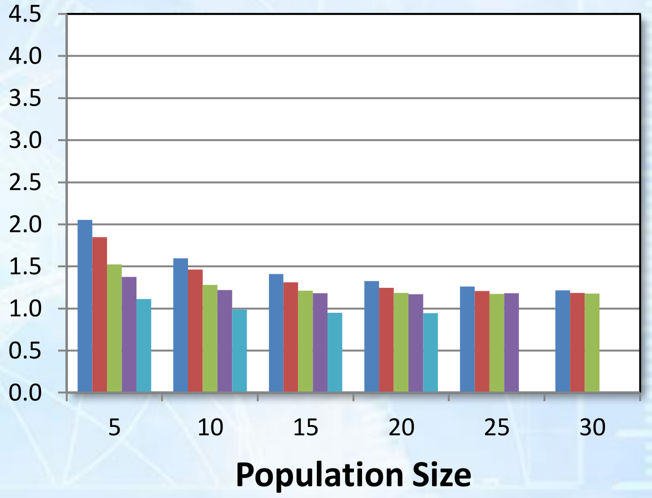
Average PX Queue Delay in Minutes



Average Flight Departure Spacing Delay in Minutes

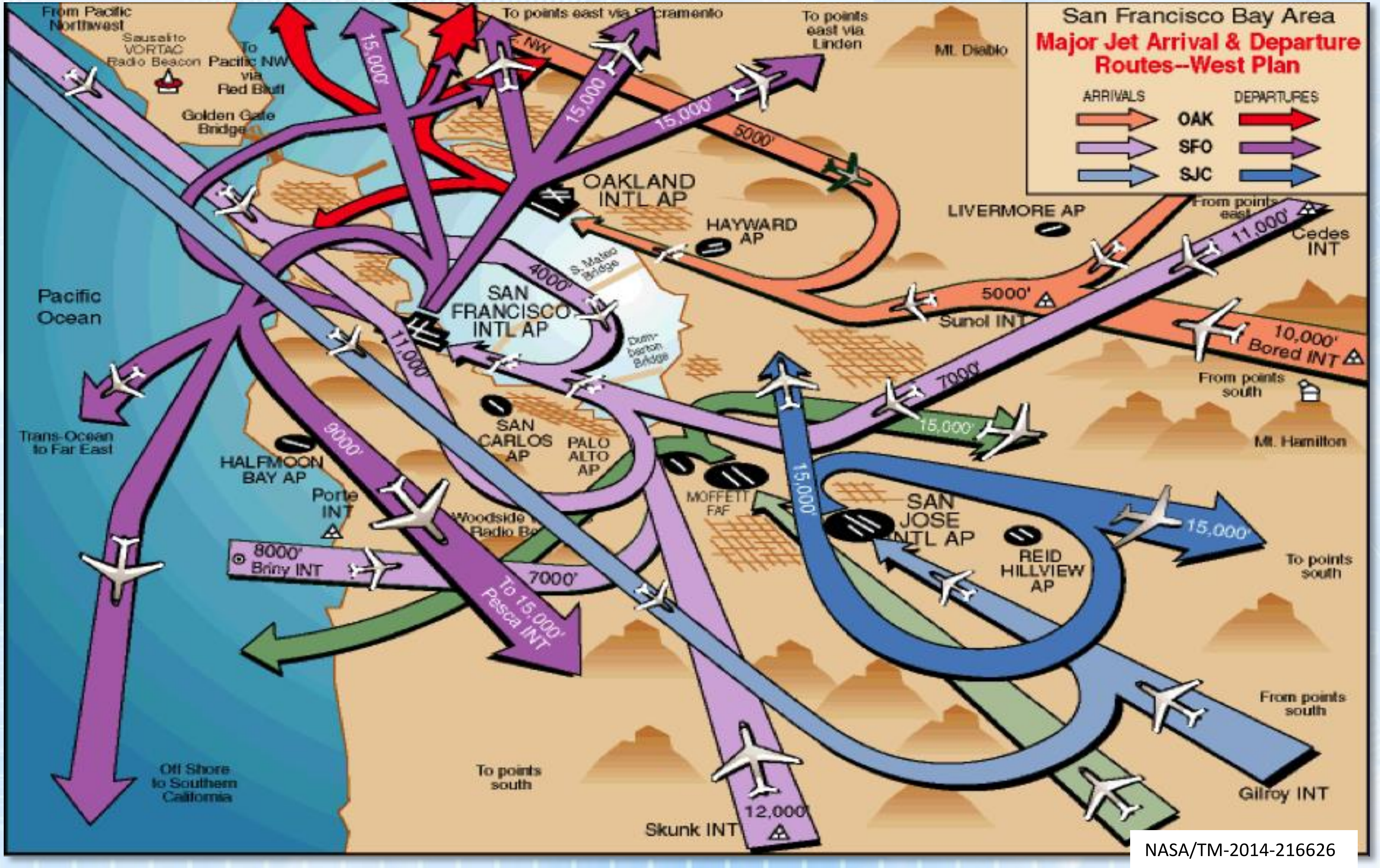


kW-h/(PX-mile): Battery



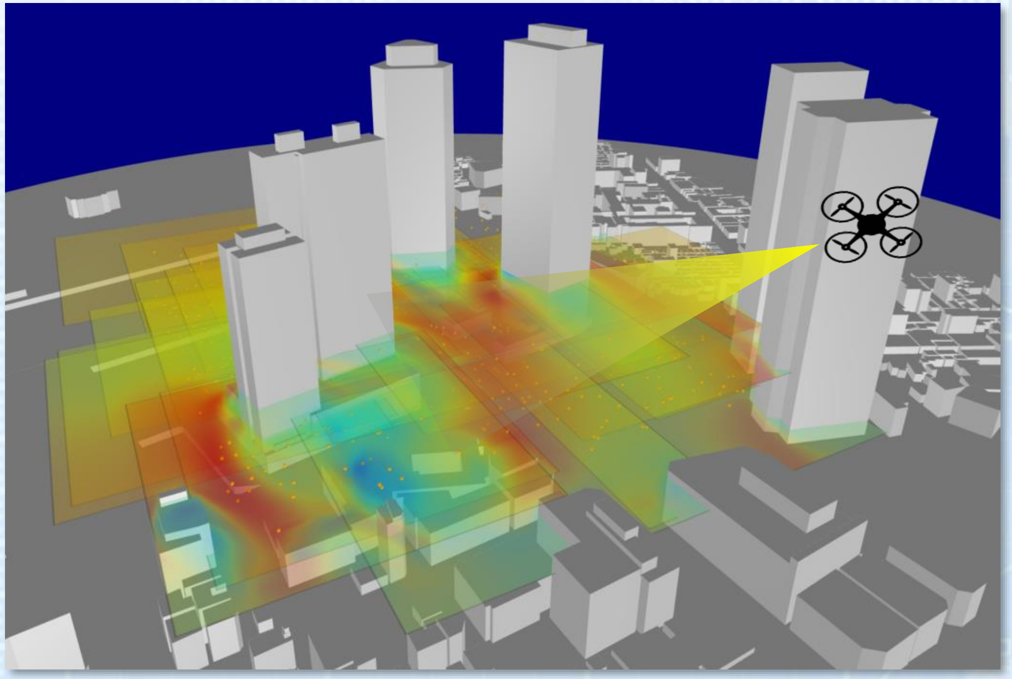
NASA/TM-2017-218356

UAM Air Traffic Interactions will be complex



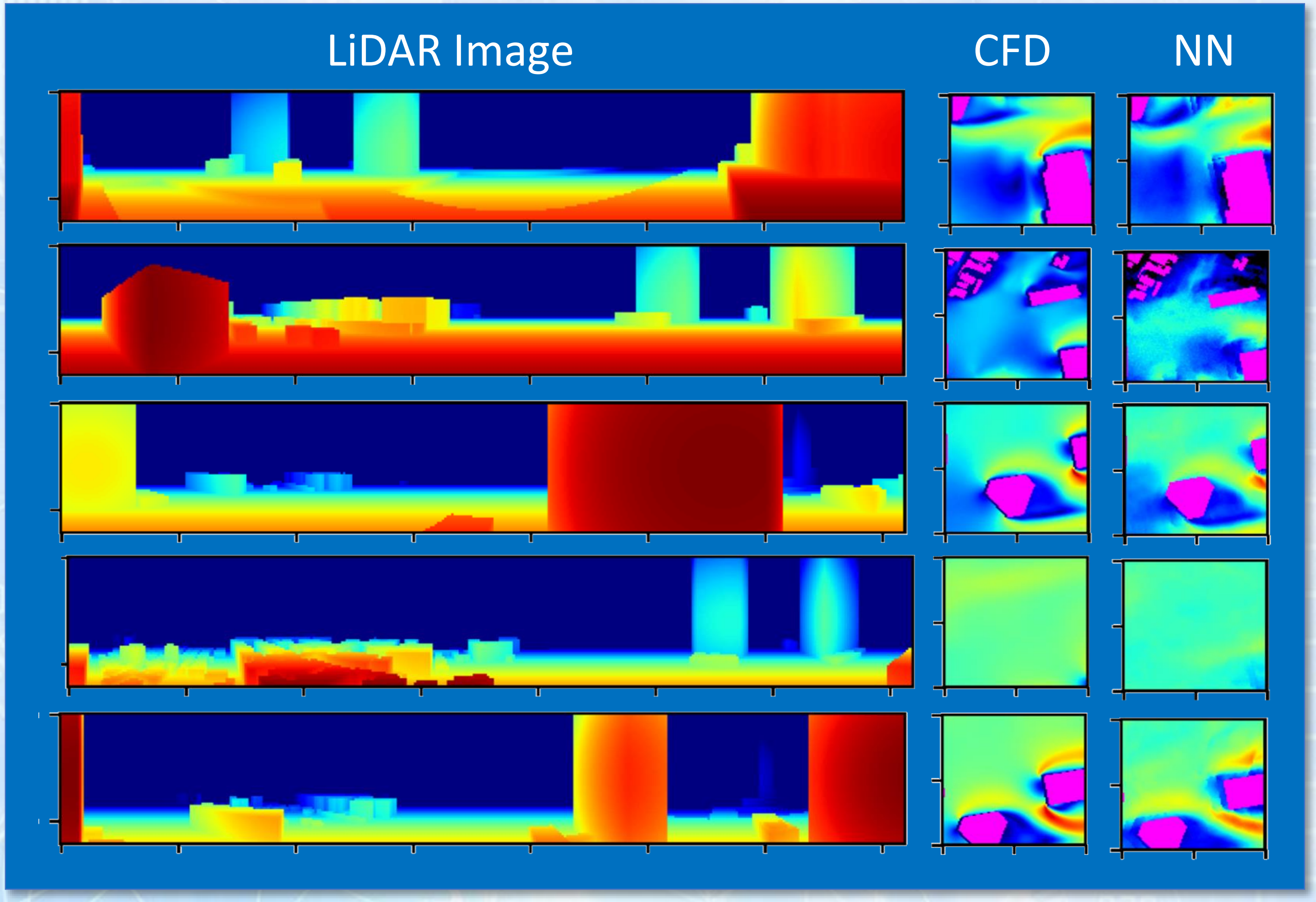
NASA/TM-2014-216626

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

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

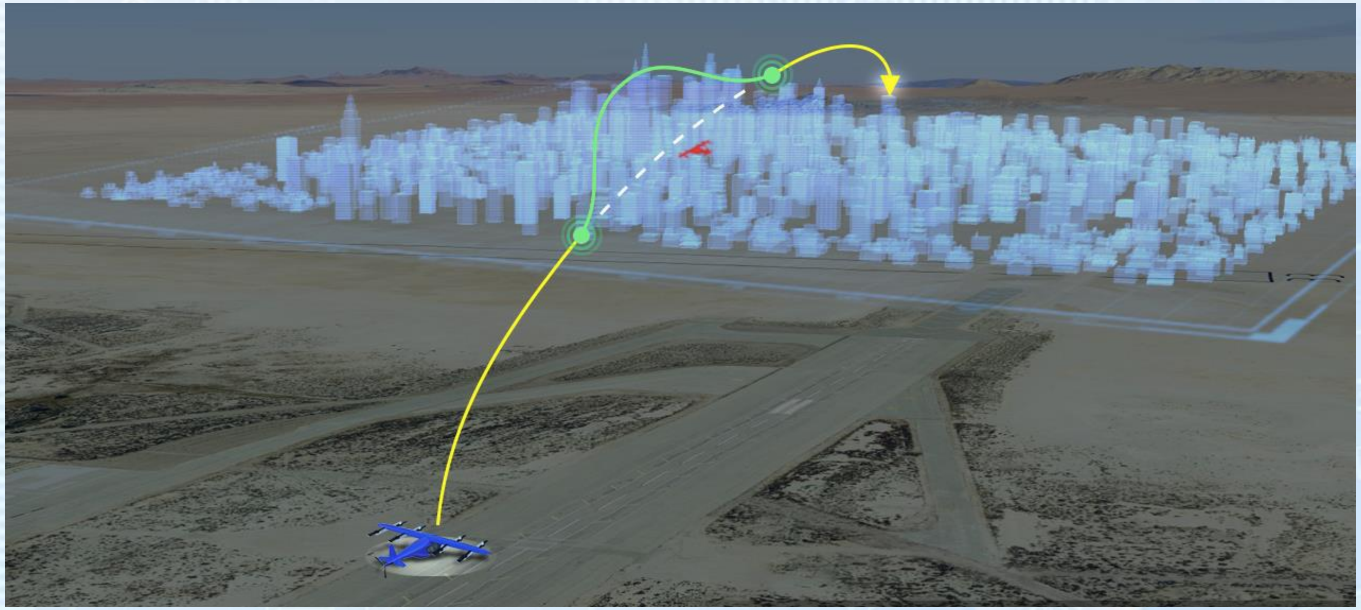
- Controls (and transition)
- Autonomy
- Structures
- Rotors
- Noise
- Manufacturing
- Traffic and network management
- Vertiport designs and operations
- Communications
- Safety and Security

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+)

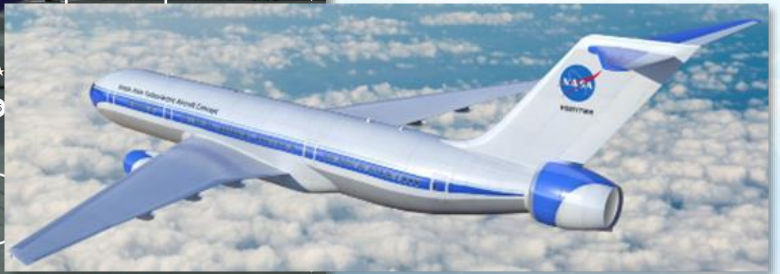


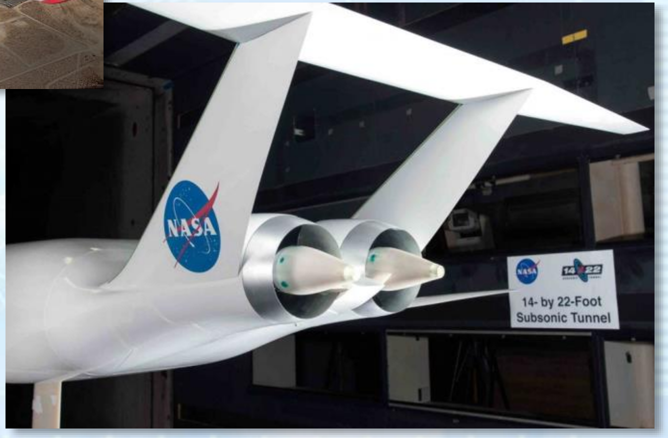
Davis Hackenberg, AAM Project Manager, NASA

- 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



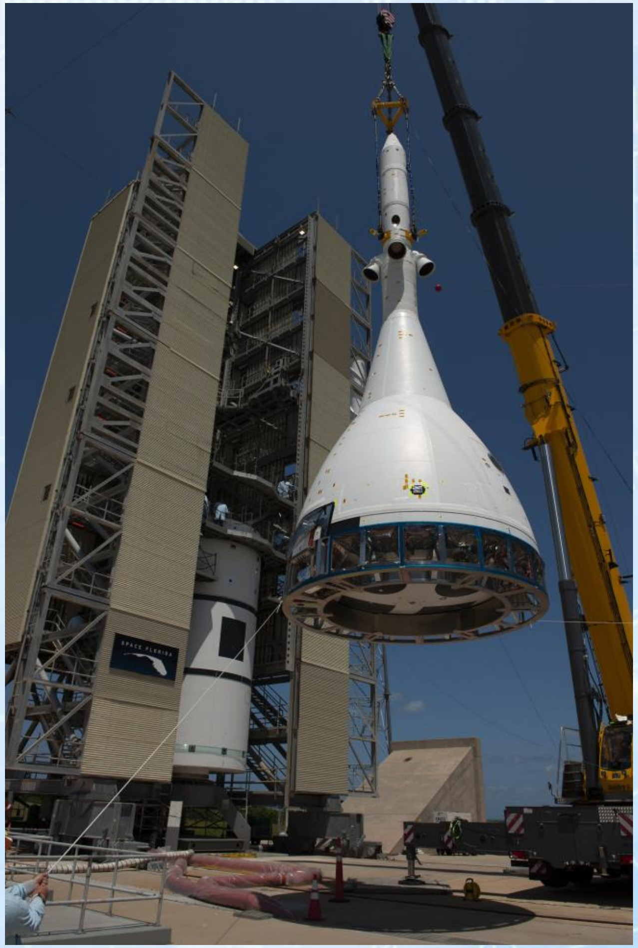


images from www.nasa.gov

The Transonics Revolution gets us to space

- Recent Orion Ascent Abort-2 Test at Mach 1.2

Testing in Ames 9x7 WTs



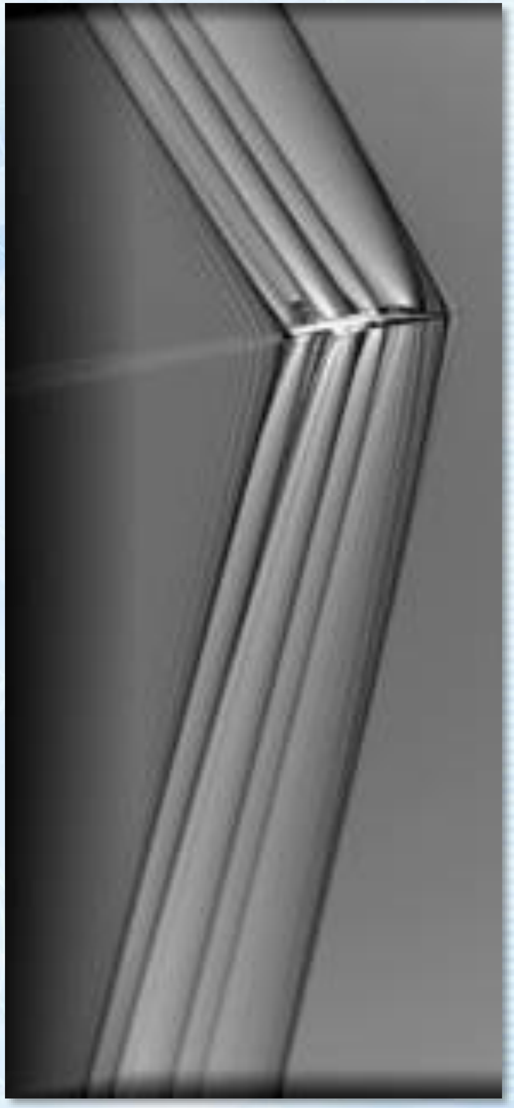
Assembly at KSC

Successful test July 2, 2019

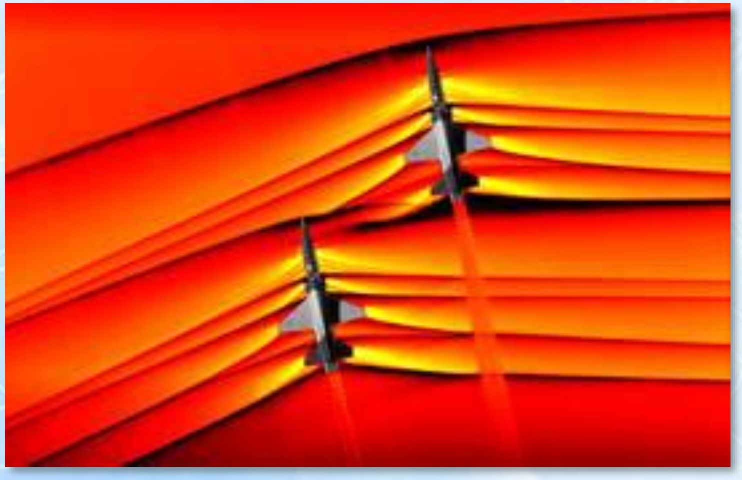
images from www.nasa.gov

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



Boom and Aerion images from corporate websites, others from www.nasa.gov

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

images from www.nasa.gov

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