NASA Aeronautics Update to the ASEB

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Aeronautics Research Mission Directorate
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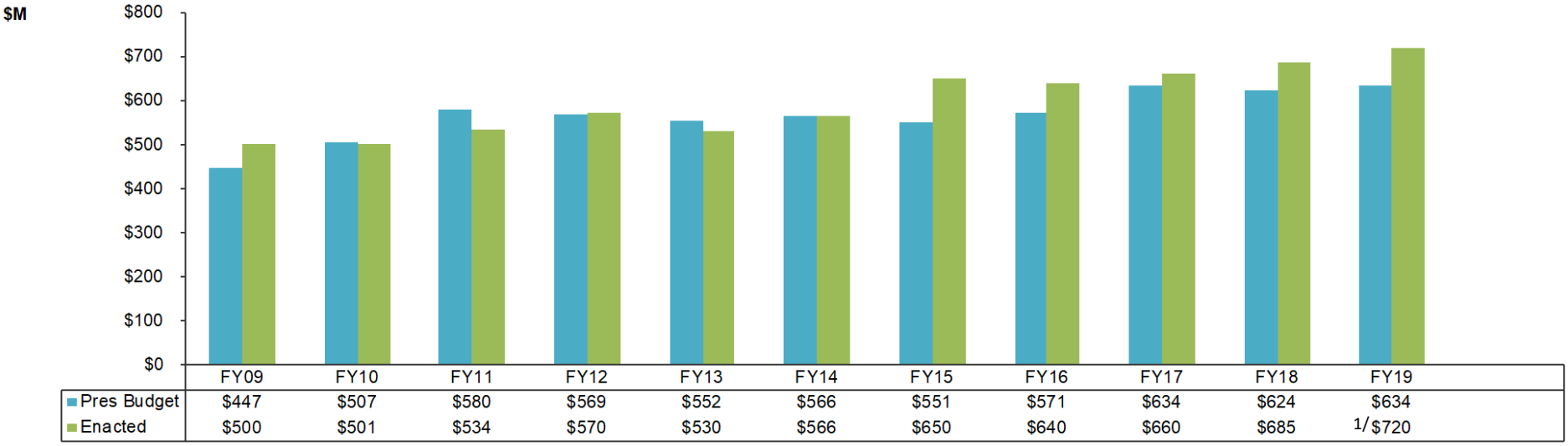
ARMD Budget Trend (FY 2009 to FY 2019)

- Beginning in FY 2015, Congress has consistently appropriated funding up to 18% over the President's budget.
- Congress has been fully supportive of NASA Aeronautics Strategy
  - FY 19 Senate and House Appropriations Reports (House Report 115-704, Senate Report 115-275) fully fund ARMD's proposed content, and both conference reports call for higher levels of funding than the FY19 PBR.
  - The proposed companion bills titled Aeronautics Innovation Act (S.2977 and H.R. 3033) states, "NASA Aeronautics Research Mission Directorate's 6 strategic thrusts are effective and necessary research areas for the development of next generation aeronautics technology that will preserve the United States lead in the global aviation industry."



	FY09	FY10	FY11	FY12	FY13	FY14	FY15	FY16	FY17	FY18	FY19
Pres Budget	$447	$507	$580	$569	$552	$566	$551	$571	$634	$624	$634
Enacted	$500	$501	$534	$570	$530	$566	$650	$640	$660	$685	1/ $720

1/ FY19 enacted amount represents the average of the House and Senate mark ups

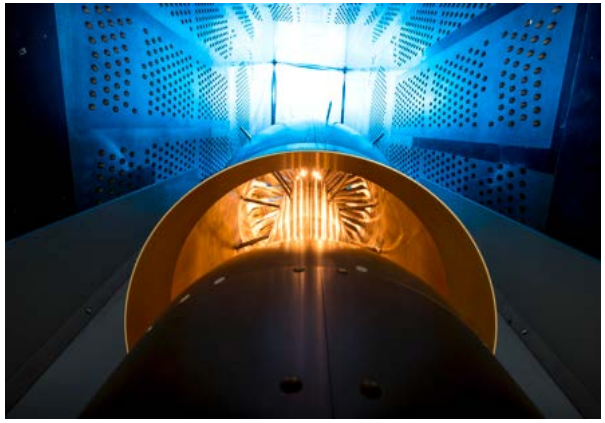
Building the NASA Aeronautics Strategic Implementation Plan

Analysis and Stakeholder Dialogue – 2013 Rollout, 2017 Update

Key Trends (Not Exhaustive)	Aviation Mega-Drivers	Analysis & Community Dialogue	Community Vision
Increasingly Urbanized World Rising Global Middle Class Driven by Asia-Pacific Urban Transportation Increasingly Congested	GLOBAL MOBILITY	 **Industry / Gov't Execs What's Needed?**	Safe, Efficient Growth in Global Operations Innovation in Commercial Supersonic Aircraft
Continuing Pressure to Reduce Noise and Local Air Quality Impacts Aviation Industry Sets Challenging CO_2 Reduction Goals through Mid-Century	ENVIRONMENTAL CHALLENGES	 **Industry / Gov't SMEs What's Possible?**	Ultra-Efficient Commercial Aircraft Transition to Alternative Propulsion and Energy
Networked Com and Sensors, Embedded Artificial Intelligence, and Big Data Converging with Traditional Systems and Technologies On-Demand Service Models Disrupting Traditional Industries	TECHNOLOGY CONVERGENCE	 **Systems Analysis**	In-Time System-Wide Safety Assurance Assured Autonomy for Aviation Transformation

Project Performance Delivers Relevant, High Value Results

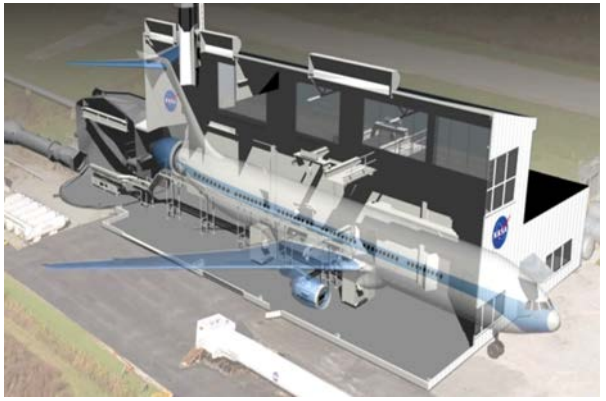
Delivers our commitments for American technical leadership



Boundary Layer Ingestion Test

UTM National Flight Campaign

Sonic Boom Propagation Flight Experiments



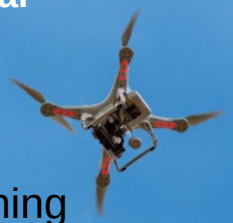
NASA Electric Aircraft Testbed (NEAT) Facility

Juncture Flow Validation Experiment

ATM Tech Demo - 1 FIM Tech Transfer

A New Era of Flight is Emerging

NASA Aeronautics' vision and leadership have stimulated national and international aviation and non-aviation communities to pursue a new era of aviation



NASA led the U.S. community with the UAS Traffic Management (UTM) & UAS in the NAS projects

- Integration of commercial systems is now beginning to emerge
- UTM is now the accepted concept all over the world

Urban Air Mobility (UAM) is fast on the heals of UAS integration

- U.S. industry looking for NASA leadership now to help overcome key barriers

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Industry innovation in the reemergence of supersonic flight is underway

- NASA must sustain aggressive schedule to complete overland supersonic noise database and enable overland supersonic flight

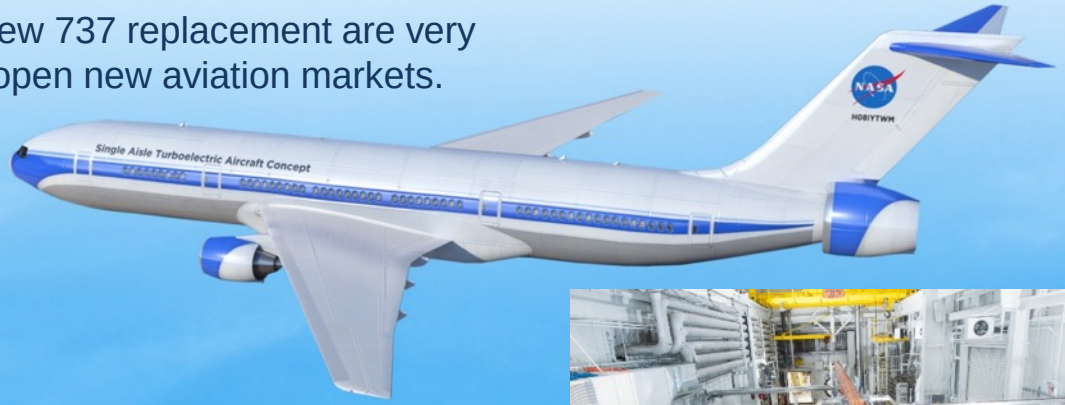
NASA studies, research and advancements in Electric Aircraft have led to an acceleration of U.S. industry interest and investment

- Focused effort to bring MW level power and propulsion to flight demonstration is now a high priority for future generation air transport


Market: High Altitude, Long Endurance UAS
Upper E Airspace
Market: Large Transport & Large UAS
Supersonic Aircraft
Class A Airspace
Subsonic Aircraft
Market: Thin/Short Haul
Asia
U.S.A.
Market: Small / Medium UAS
Market: Urban Air Mobility

New Technologies Will Be the Differentiator to Continued Market Leadership

Technologies that will open the door to a new 737 replacement are very applicable to smaller aircraft and will help open new aviation markets.



2036 Forecast

41,030
New Aircraft Deliveries

$6.1 Trillion
Market Value

78%
of New Aircraft Deliveries are Single Aisle Class (including Regional Jets)

The Single Aisle Aircraft market is the largest economic driver in aviation – but a new design for this market will require substantial performance advancements

- Performance must show significant improvement
- Must be able to build new aircraft at very high rates
- Must be affordable to build and operate

A suite of technologies will be needed:

- Light weight, very efficient wings
- Novel Propulsion-Airframe integration concepts
- Advanced structures
- Small core turbine engines
- More electric propulsion

More electric propulsion has been identified as a potential game changer

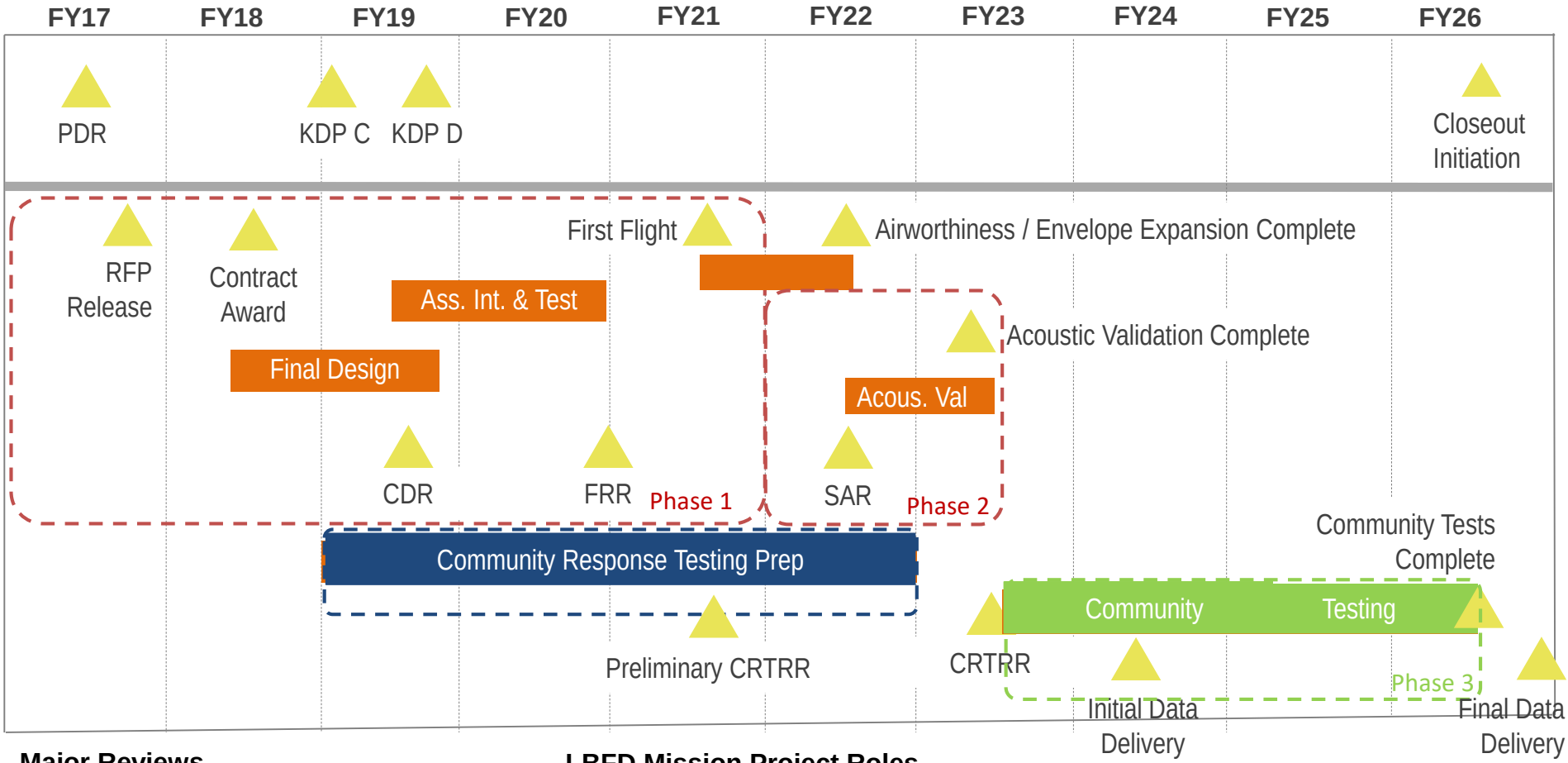
- Allows new architectures and flexibility in design and operation
- Potential for significant efficiency improvement
- 1MW machines have been identified as a “sweet spot” for aviation use
- This is a very challenging problem to be developed and validated

State of available technologies is not sufficient	NASA has made good progress in these areas but more work needed	Increased importance due to convergence of technical progress and industry pull

Low Boom Flight Demonstrator (LBFD) Mission

- **LBFD Project:**
  - Awarded aircraft design/build contract
  - On track for baselining Project in Q1 FY19 (KDP C)
  - First flight planned for Q3 FY21
- **CST Project:**
  - Continues to mature signature analysis and uncertainty quantification tools
  - Flight activities using NASA F/A-18 to support Community Response Testing planning and maturing the design of experiments
    - Flight testing in Galveston, TX during November 2018 will build on successful flight campaigns at AFRC (2011) and KSFC (2017)
- **FDC Project:**
  - Initial planning for LBFD Phase 3 Flight Operations complete
  - Flight assets to support in-flight data measurement and chase identified

LBFD Mission Life Cycle



Major Reviews

PDR, Preliminary Design Review
CDR, Critical Design Review
FRR, Flight Readiness Review
SAR, System Acceptance Review
CRTRR, Community Response Testing Readiness Review

LBFD Mission Project Roles

LBFD Project – A/C development, envelope expansion and acoustic validation

CST Project: Analysis Tools, Community Response Methodology & Validation
FDC Project: In-flight Data Measurement Tools

FDC Project: Flight Operations
CST Project: Community Response Data Gathering and Analysis

Emerging Aviation Markets

Global Race to Achieve Leadership

Urban Air Mobility

Ehang - China

E-Volo - Germany

Kitty Hawk Cora – U.S.

Many other U.S. and international competitors have the same vision and are capable of innovative vehicle design, development and flight demonstration.

The race to capture the market will be won based on…

1. Developing the ability to certify innovative aviation technologies and configurations
2. Achieving equitable community noise standards
3. Enabling safe airspace access at high densities
4. Achieving safe vertiport infrastructure standards

But most demonstrations and early market growth are overseas – all four key issues are easier to manage in many other countries. The U.S. must lead or fall behind.

NASA is adjusting its portfolio to address these issues, support FAA and industry to accelerate U.S. competitive posture, and do it through a technically sound, sustainable and scalable approach.

Urban Air Mobility Rapidly Developing

Just in This Year……..

- 2nd Uber Elevate Summit in L.A.
  - Attended by well over 1,000 people with Uber announcing the new 6th vehicle development partner, Karem Airacrft in addition to the five existing partners (Aurora Flight Sciences, Embraer, Bell, Pipistrel Aircraft, and Mooney)
- Boeing announces formation of Boeing NeXt at Farnborough Air Show to take a lead position in Urban Air Mobility
  - Leverage Boeing HorizonX and acquisiton of Aurora Flight Sciences to accelerate progress
- Rolls Royce and Aston Martin announced plan to develop UAM vehicles at Farnborough Air Show
- Airbus formed a new UAM business unit in May
- Japanese government announced a plan to invest $40M to accelerate UAM development
  - Boeing, Bell, and Uber are participating.
- Well funded new entrants continue vehicle development and flight test
  - Kitty Hawk Cora, Joby S4, Terrafugia TF-2, Lilium Jet, etc

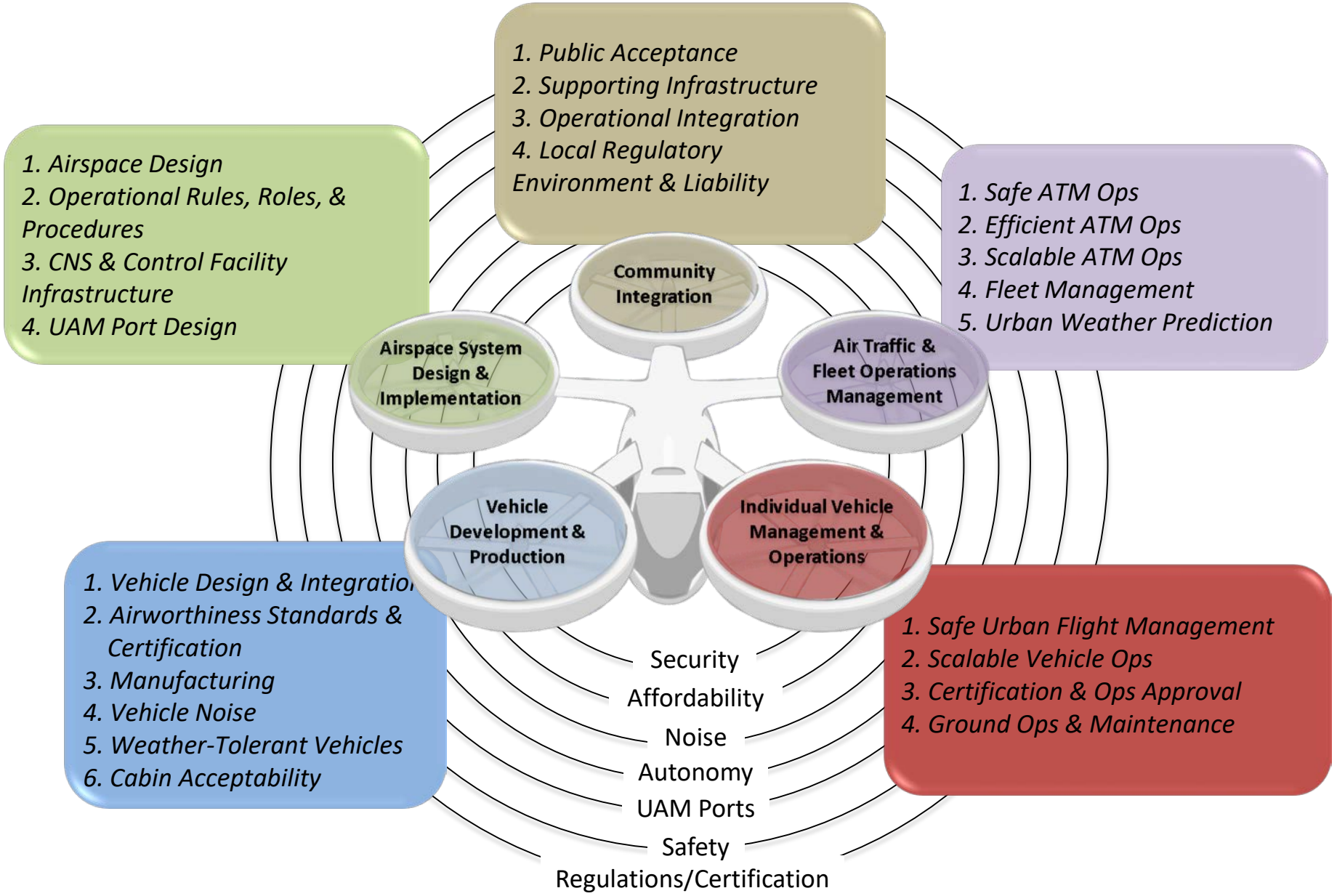
UAM Community is developing rapidly and seeking NASA leadership

NASA Leadership in Urban Air Mobility

- Demonstrated community leadership with UTM and UAS in the NAS
- Major market studies with McKinsey and Booz Allen
- ARMD led systems studies and industry roadmapping activities
- Formation of National Academies Aeronautics Research and Technology Roundtable (ARTR) focused on UAM
- Cross Program and Center Coordination was chartered
  - Urban Air Mobility Coordination and Analysis Team (UCAT)
  - Achieved significant progress in developing ARMD UAM strategy and planning UAM Proving Ground and Grand Challenge series
  - First Grand Challenge planned for FY 2020
- Industry Day planned for Nov 2018
- Programs/Projects actively pivoting research portfolio to address key UAM Issues
  - ATM-X, SWS, RVLT, etc

UAM Community is developing rapidly and seeking NASA leadership

UAM Framework and Barriers



Grand Challenge Series Framework

Vehicles

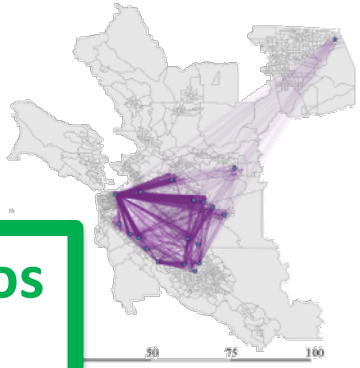
functional UAM vehicles with threshold level of demonstrated airworthiness

NASA Systems & Interfaces

ATM-X UAM ATM, "Testbed/LVC"

Airspace Management

airspace and air traffic management technologies and services (FAA ATM + UTM) built and simulated to a threshold level of UAM ATM requirements



Common Safety and Integration Scenarios

airworthiness processes, realistic UAM scenarios, and a range(s) designed in concert with the FAA to support UAM testing

Stakeholder Integration

societal integration and acceptance of UAM Operations including public acceptance, supporting infrastructure, operational integration, standards organizations, the local regulatory environment, etc.

Industry Provided

NASA Provided

Ecosystem Wide Support

Laying the Ground Work for Aviation in 2040

- The global aviation system of 2040 is emerging today – new companies and new systems built on advanced technologies pioneered by NASA and strengthened by steady U.S. investment
- NASA Aeronautics well positioned to collaborate with U.S. industry to pioneer the future of aviation
  - Will develop and demonstrate key enabling technologies in close partnership with the U.S. aviation industry to transform subsonic airliners market
  - Will develop and demonstrate key enabling technologies in full partnership with the Urban Air Mobility community to ensure the U.S. leadership in opening a scalable, safe, efficient, and environmentally acceptable market - This new capability will reduce ground-based traffic congestion, improve local air quality, and transform urban areas
  - Will deliver scientifically acquired data of community response to low sonic boom to the international and U.S. standard and rule making organizations (e.g., ICAO, FAA) to usher in a renewed supersonic flight for flying public