

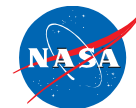


NASA Aeronautics

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Aeronautics Research Mission Directorate

Global Growth in Aviation

Opportunities and Challenges



2017

4 BILLION
PASSENGER TRIPS

2036

7.8 BILLION
PASSENGER TRIPS

Bombardier /
Canada

Airbus /
Europe

Irkut /
Russia

Comac /
China

Embraer /
Brazil

41,030
New Aircraft Deliveries
\$6.1 Trillion
Market Value

Asia-Pacific
Market is Nearly
40%
of New Aircraft
Deliveries

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

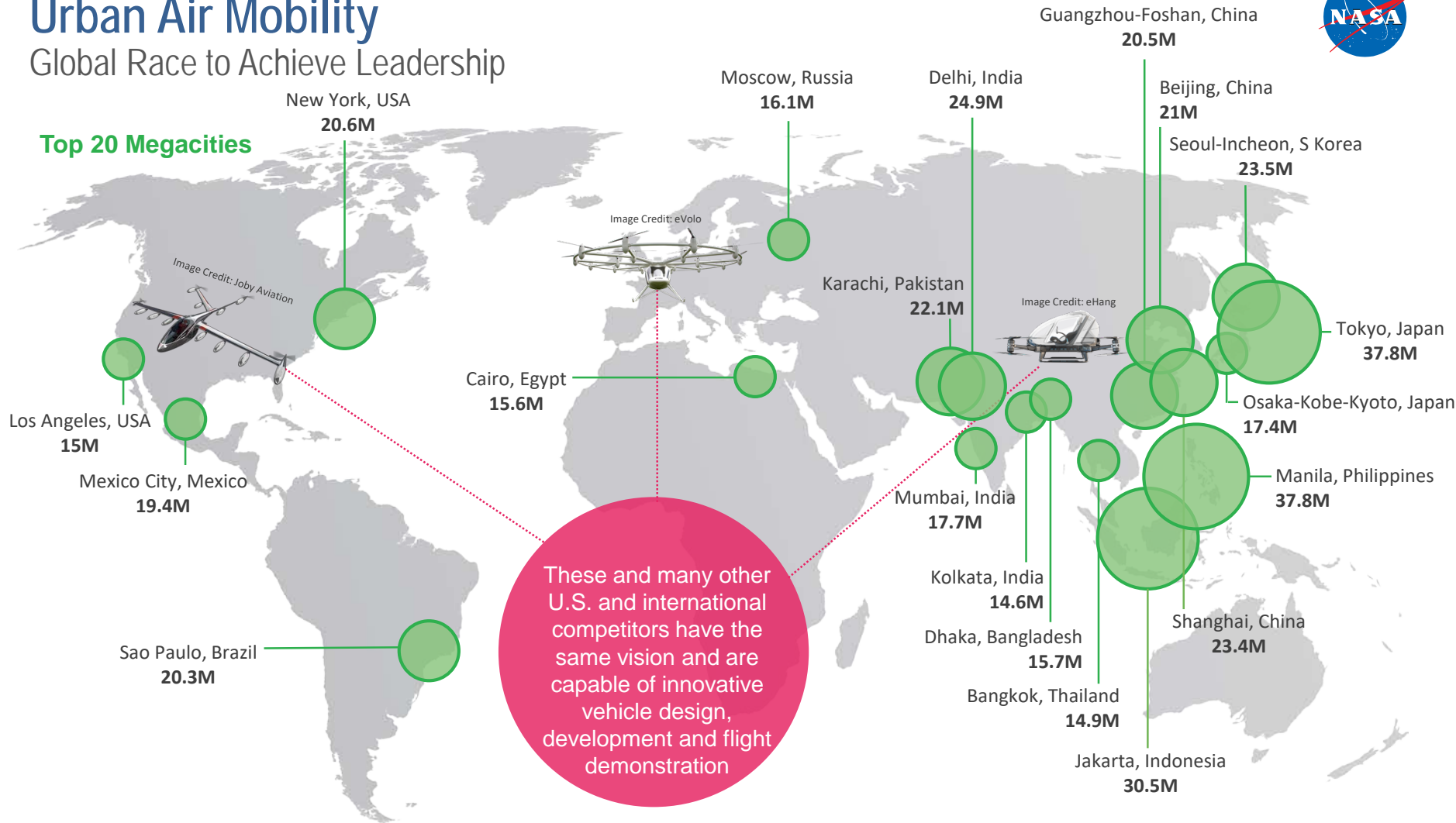
● Global Competitors

Urban Air Mobility

Global Race to Achieve Leadership



Top 20 Megacities



Large projected market—McKinsey analysis of demand by 2030 in 15 major U.S. cities:

- 500 Million annual UAS package deliveries
- 750 Million annual passenger trips

Extrapolation to the global market would likely increase demand by 5 to 10x



MASSIVE CONGESTION

Emerging Aviation Markets



Urban Air Mobility Example



Ehang - China



E-Volo - Germany



Aurora - US



Joby - US

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

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

- Ability to safely certify innovative aviation technologies and configurations
- Achieving equitable community noise standards
- Enabling safe airspace access at high densities
- Achieving safe vertiport infrastructure standards

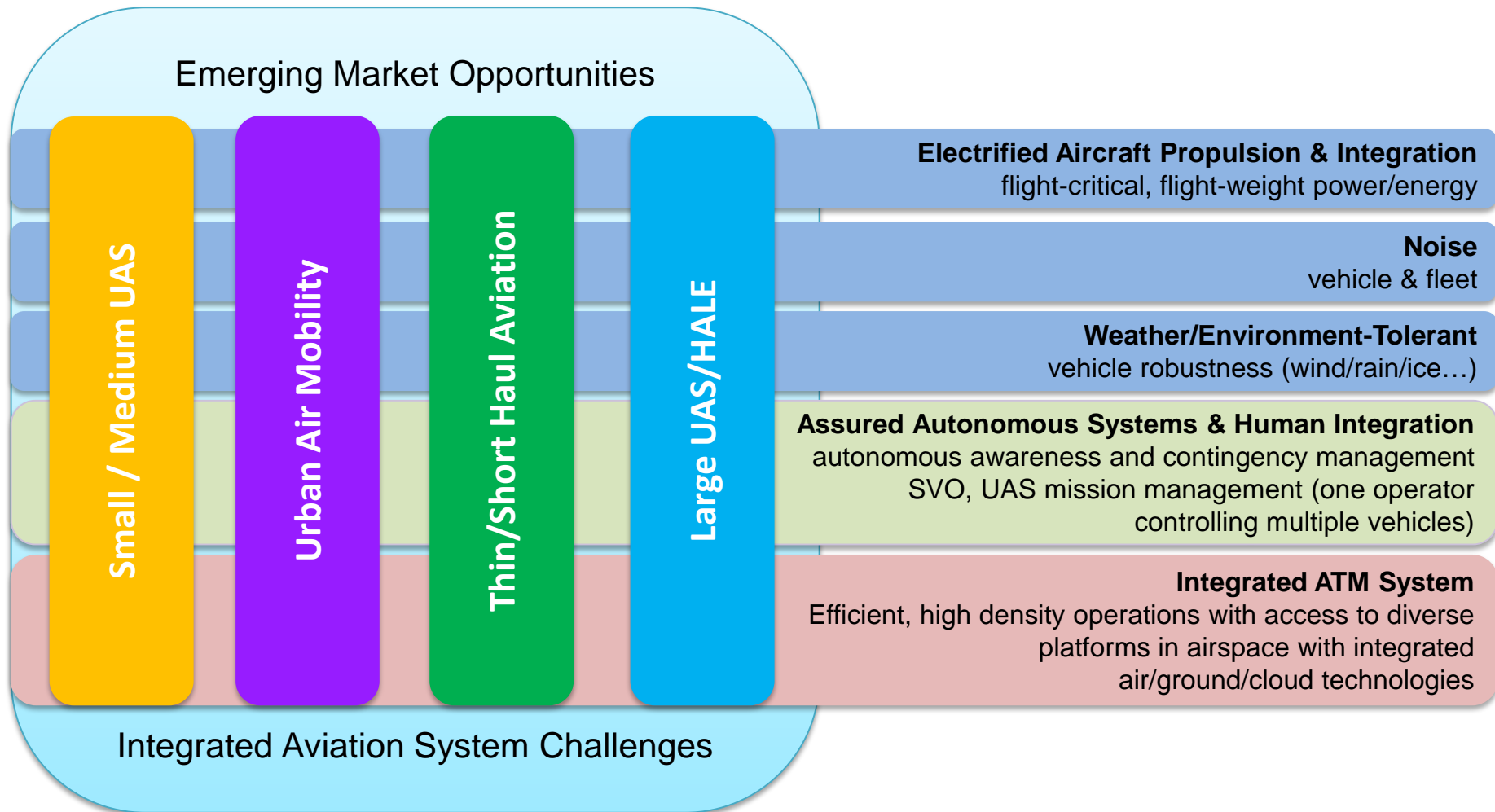
**Most demonstrations and early market adoption are happening overseas.
The U.S. must lead or fall behind.**

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

Emerging Markets - Integrated Challenges



NASA ARMD Programs pivoting to address complex challenges



UAS Traffic Management (UTM) Technical Capability Levels (TCLs)



CAPABILITY 1: DEMONSTRATED HOW TO ENABLE MULTIPLE OPERATIONS UNDER CONSTRAINTS



- Notification of area of operation
- Over unpopulated land or water
- Minimal general aviation traffic in area
- Contingencies handled by UAS pilot

Product: Overall concept of operations, architecture, and roles

CAPABILITY 2: DEMONSTRATED HOW TO ENABLE EXPANDED MULTIPLE OPERATIONS



- Beyond visual line-of-sight (BVLOS)
- Tracking and low density operations
- Sparsely populated areas
- Procedures and “rules-of-the road”
- Longer range applications

Product: Requirements for multiple BVLOS operations including off-nominal dynamic changes

CAPABILITY 3: FOCUSES ON HOW TO ENABLE MULTIPLE HETEROGENEOUS OPERATIONS

2018

- BVLOS of sight/expanded
- Over moderately populated land
- Some interaction with manned aircraft
- Tracking vehicle to vehicle, vehicle to UTM, and internet connected

Product: Requirements for heterogeneous operations

CAPABILITY 4: FOCUSES ON ENABLING MULTIPLE HETEROGENEOUS HIGH DENSITY URBAN OPERATIONS

2019

- BVLOS
- Urban environments, higher density
- Autonomous vehicle to vehicle, internet connected
- Large-scale contingencies mitigation
- Urban use cases

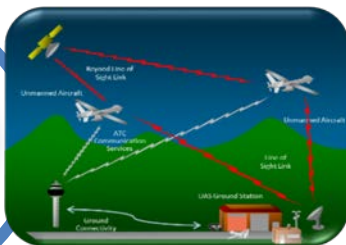
Product: Requirements to manage contingencies in high density, heterogeneous, and constrained operations

Project Goal

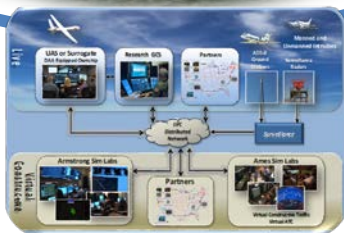
Provide research findings, utilizing simulation and flight tests, to support the development and validation of DAA and C2 technologies necessary for integrating Unmanned Aircraft Systems into the National Airspace System



**Technical Challenge-DAA:
Detect and Avoid (DAA)**



**Technical Challenge-C2:
Command and Control (C2)**

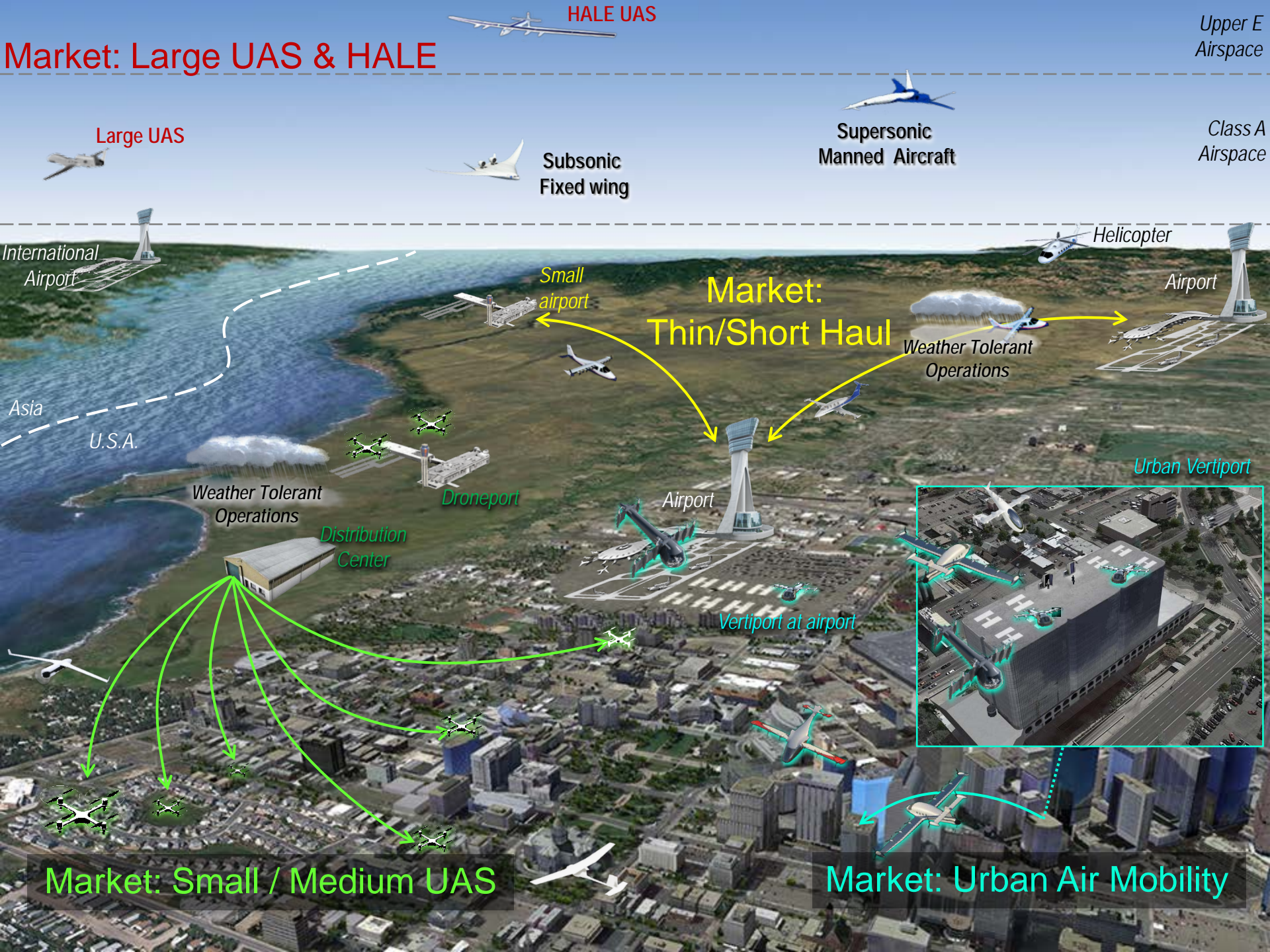


**System Integration and
Operationalization (SIO)**



FROM SONIC BOOM TO
SONIC "THUMP" OVER LAND

Market: Large UAS & HALE



A New Era of Flight is Emerging



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

- **Unmanned Aircraft Systems (UAS) Integration into NAS**
- **UAS Traffic Management (UTM)**
- **Electric Aircraft**
- **System Wide Safety**
- **Low Boom Supersonic Flight**

Interesting Questions to Ponder



Is Google building an autonomous car or a big, multi-functional computer on wheels?

F-22: 1.7 million lines of software code

B787: 6.5 million lines of software code

M-B S class: 20 million lines of software code

2009 report



After 110 years since Ford Model T was first introduced, software is the driving force, not hardware, for creating new markets in automotive industry

Interesting Questions to Ponder

Is Uber in taxi business or sophisticated IT business?

What industrial sector is Google in?

What is Amazon's main product?

Progressive companies are coming up with innovative business models that are enabled by their core technologies. – traditional classification of business line does not apply anymore

Why do we think aviation industry would not face these changes in coming years or decades?