On Demand Mobility – Strategic Framework

For NASA HQ
Washington DC
March 8, 2017

AirMarkets Corp
NIA
STARNet
Atlanta Analytics
General Aero Co

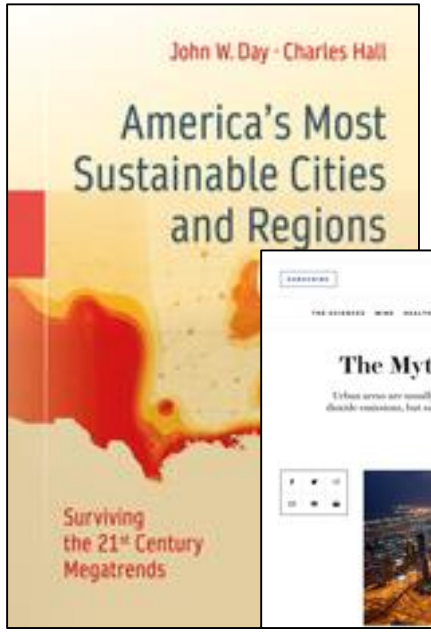
Agenda

- ODM Vision
- Strategic Landscape and Context
- Executive Summary
- NASA Decisions

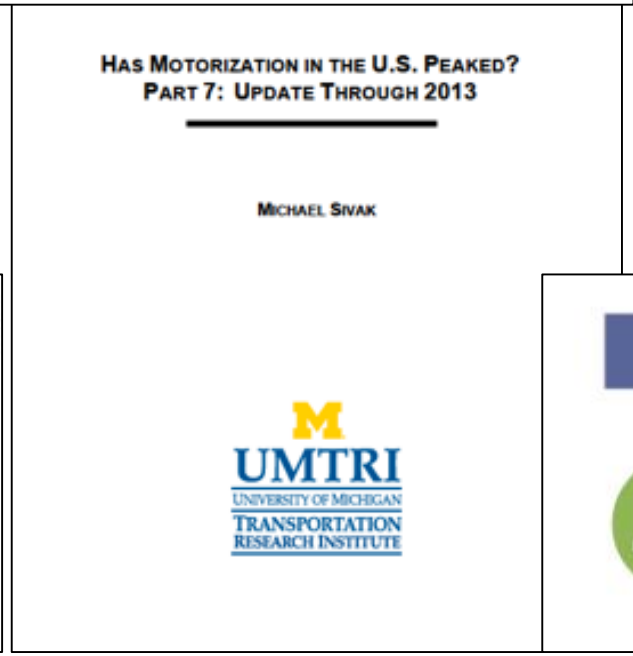
A Vision for On-Demand Mobility

… for anyone to fly from here to there anytime, anywhere …

- The confluence of emerging technologies affecting aviation, along with innovations in business models, will enable on-demand mobility solutions that can transform environmental quality, economic opportunity, accessibility, and travel time, cost, and convenience.
- Many needed technologies can be enabled through the NASA SIP and ODM roadmap outcomes.



- Environment
- Airline Consolidation
- Congestion



ODM Vision

Vision for On-Demand Mobility (for example):

"… air transportation from here to there, anytime, anywhere …"

- Growth in public use of on-demand air mobility (ODM), serving virtually all our nation's communities, would stimulate transformative increases in U.S. productivity.
- NASA is uniquely capable of stimulating the requisite technology advancements enabling on-demand, point-to-point air mobility of persons and goods.
- NASA leadership is needed to communicate the public value proposition for ODM and engage all stakeholders in embracing the opportunities inherent in advancing On-Demand Mobility, including affordable infrastructure.
- ODM vehicle and airspace technologies, including management and operations of ODM services are exportable innovations that will enhance U.S. balance of trade.
- The vision must be codified in policy and strategy to have traction and be effective, enabling legislators, regulators, innovators, investors, and the public to envision a common goal, collaborate on mutual opportunities, and support an ODM Program for the benefits of our nation.

Unprecedented Aviation Innovation Landscape

Companies investing in developing ODM systems and concepts (~30 Public and Non-public).

- A^3 Airbus Ventures (Vahana Sky Taxi Project)
- eHang (eHang-184 Autonomous Aerial Vehicle)
- Airbus Group (E-Fan Project)
- Airbus Group (Urban Air Mobility Division)
- Aeromobil (CTOL Flying Car v3.0)
- Bell Helicopter, Innovation Division (Urban VTOL Vehicle and ConOps Studies)
- DeLorean Company (VTOL Aircraft, U.S. Patent 9085355)
- Embry-Riddle electric propulsion consortium (GE, Textron, Hartzell, et. al.)
- KittyHawk Company (Larry Page Investment – Urban VTOL)
- E-volo Company (Volocopter VC200 Project – Urban VTOL aircraft)
- Joby Aviation (Urban VTOL)
- Lilium Company (VTOL Jet Aircraft)
- Pipistrel (Hydrogen-powered Aircraft – eGenius; Electric VTOL; Regional Commuter – with Chinese investors)
- Siemens Corporation (World Record Electric Motors for Aviation)
- SkyRyse Company (Urban VTOL)
- Terrafugia Company (TF-X VTOL Flying Car)
- Uber Corporation (VTOL Urban Transportation Requirements White Paper)
- Zee.Aero (Larry Page Investment – Urban VTOL)
- Approximately ten other ODM vehicle development projects underway globally, some not yet public
- Numerous Supplier Organizations (Motors; Fuel Cells; Controllers; Avionics; Composite Material Systems; 3D Printing; etc.)

The "disruptive innovation" nature of the ODM concept creates natural investment barriers for extant U.S. industries. The traditional U.S. aviation industry organizations are not leading in early-stage technology consortia.

Strategic Context

Contextual Observations

- **Productivity:** "We are out of big ideas. (WSJ)" – ODM Is a "big idea" affecting U.S. productivity.
- **Economics**: The safe, productive and efficient mobility of people and goods facilitates economic development and enhanced quality of life. Thus, transportation technologies that respond on-demand to society's needs for mobility offer broad, transformational opportunities to improve the wellbeing of U.S. citizens through enhanced domestic and international commerce.
- **Airline Consolidation:** In the U.S. and EU, scheduled air carriers are consolidating services toward larger aircraft, serving larger markets, flying longer legs. In the process, a vacuum in smaller community service exists, thereby diminishing economic opportunity and quality of life for increasing numbers of communities.
- **Congestion**: The growth of congestion in large cities and so-called megaregions has vastly outpaced the ability of highways to meet demand. The consequences in lost productivity and congestion-induced carbon emissions create both a challenge and an opportunity for airborne concepts. Ground infrastructure investments are needed, but will not advance mobility as ODM can.
- **Competitiveness**: U.S. economic competitiveness is at high risk due to international ODM activities. The U.S. needs to lead in "big ideas" like ODM.

Report Topics

Chapter 1: Introduction and Strategic Context.	Bruce J Holmes
Chapter 2: Market Demand.	Roger A. Parker / Laurie Garrow
Chapter 3: Enabling Technologies and Gaps Analysis.	Doug Stanley
Chapter 4: Organizational Contributions and Roles.	Doug Stanley
Chapter 5: Collaboration Options and Resources Alignment	Paul Masson
Chapter 6: Regulatory and Policy Considerations.	Jack Olcott
Chapter 7: Stakeholder Outreach Planning.	Holmes
Summary: Findings and Recommendations.	All hands discussion

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Executive Summary

- *The vision for ODM of enabling the ability "…for anyone to fly from here to there, anytime, anywhere…" creates a compelling public value proposition enabled through a moderate Federal R&D investment vastly leveraged by the private sector.*
- *The latent demand for ODM is large and the ability to satisfy this demand creates significant industrial growth. ODM offers the promise of a cost—effective infrastructure for expanded national mobility.*
- *An ODM vision requires a national strategy and policy to inform the technology, regulatory, partnership, and investment necessary to initiate new and accelerate current activities to keep pace with both national needs and advancing technologies.*
- *The convergence of technologies from outside and from within the aviation sector create new paths to solving long-standing challenges in aviation safety, efficiency, performance, and affordability through ODM investments.*
- *NASA investments in ODM research and technology development would provide the means of delivering air mobility products and services that would support a uniquely significant advancement in American quality of life, economic opportunity, and standard of living.*
- *These investments would preserve the Nation's global leadership in aeronautics and encourage emerging transformations in transportation and distribution systems.*

Executive Summary, concluded

- *NASA should create an ODM-centric project and augment current strategic thrusts to include ODM.*
- *The current NASA ODM Roadmapping activities, while highly effective in assembling an industrial and academic community of practice with a shared vision, require additional components related to secure cyber-physical aircraft connectivity; comprehensive airspace accessibility and services; and air portal infrastructure systems.*
- *Current and proposed ODM technology investments will have significant synergistic benefits to smaller unmanned aerial systems as well as larger general aviation and commercial passenger aircraft.*
- *Collaborations across industry boundaries will transfer ODM advancements in safety and affordability across transportation domains, including air and surface.*
- *Achieving the ODM vision represents significant cultural changes for America.*
- *NASA is in a unique position to play a leadership role in the formation of one or more Innovation-Public-Private Partnerships (I-PPP) to aggregate and leverage the necessary resources from both sectors toward a common public value in future mobility.*

Summary Findings and Recommendations

Findings

- ODM is a "Big Idea" directly impacting U.S. productivity and quality of life.
- The U.S. is at risk of losing out on the leadership opportunity in a global competitive scene.
- ODM R&D would spin out exportable innovations.
- National Policy for ODM would coalesce needed energies, investments, and collaborations.
- Strategic partnering in an I-PPP engaged at C-Suite levels with industry is vital to success.

Recommendations

- Consider socializing a thrifty ODM vision message such as: "*Air transportation from here to there, anytime, anywhere*."
- NASA leadership in timely execution on the ODM strategy is vital.
- Establish partnerships with key industry and government players (auto, UAS, DoE, DoT, FAA).
- Establish ODM Project/Program and Thrust and fund high priority unique technologies.
- Consider establishing an I-PPP with industry to advance technologies/systems.
- Continue studies of demand, configurations, economics, infrastructure, certification, etc. in partnership with industry and government.
- Initiate consumer acceptance studies in collaboration with industry.
- Extend the international market assessment to other regions.
- Take leadership in establishment of National ODM Strategy and Policy.

Discussion

- Actions
- Clarifications
- Decisions and actions
- Follow-on thinking

Thank you!

The full report follows

Purpose

- **Scope**: Assist NASA in developing a strategic framework in which NASA's ODM technology roadmaps create collective public value proposition for the nation.
  - Electric Propulsion and Configuration Integration.
  - Simplified Vehicle Operations.
  - Manufacturing, Integrated Structures and Community Acceptance.
- **Tasks**:
  - Strategic framework context.
  - Market demand indicators
  - Technology gaps assessment
  - Organizational roles and responsibilities
  - Policy and regulatory considerations
  - Outreach planning
- **Deliverable**: A strategic framework document providing NASA with background serving to inform investment decision-making regarding research projects, programs, and strategic thrusts.

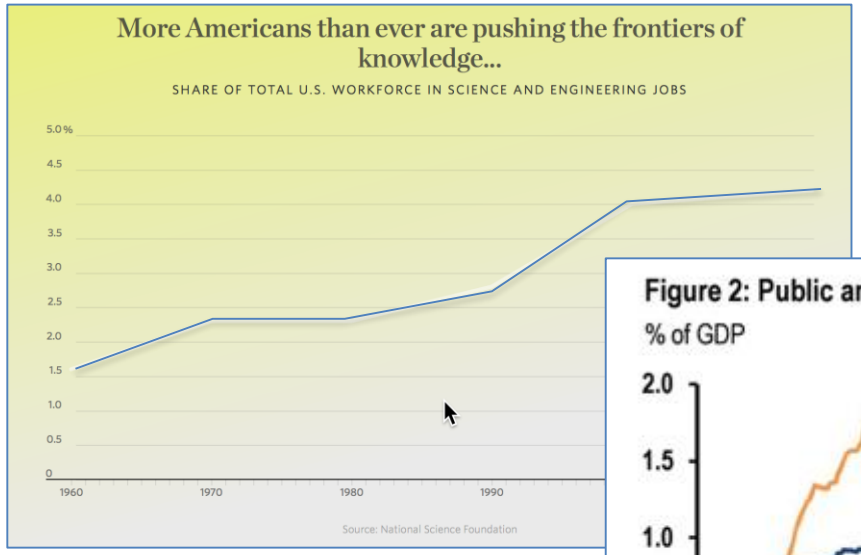
Chapter 1 – Introduction and Strategic Context

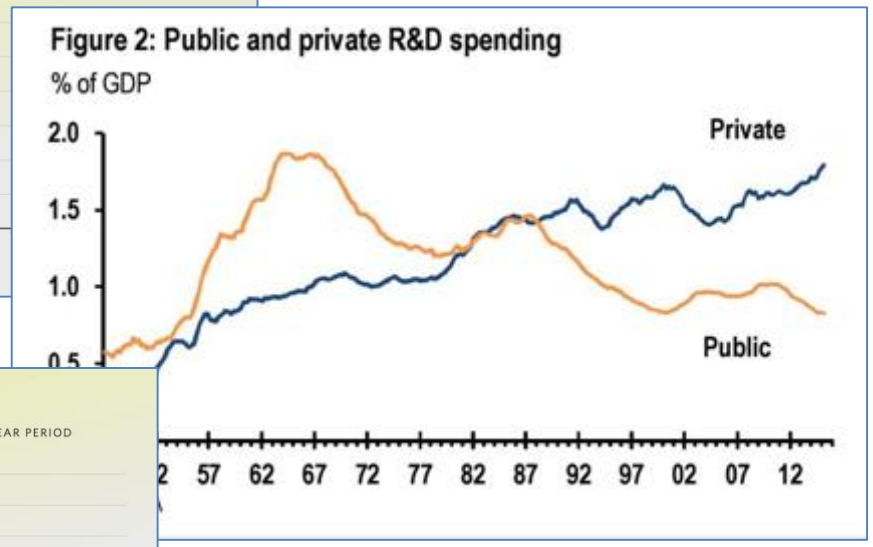
Prelude

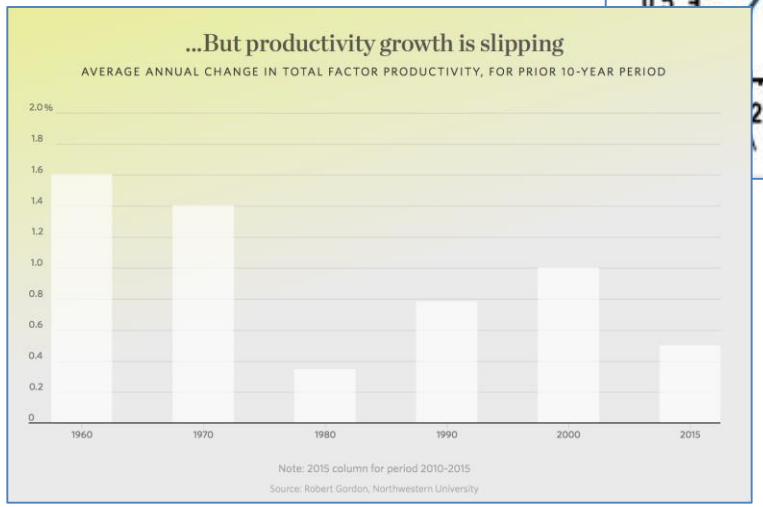
1. Introduction
    - NASA and Industry Perspectives
    - Universal Challenges
    - You Can’t Get There from Here
    - Easy Access to Multiple Markets—the Power of Social Networking Personified
    - Dude, Where’s My Flying Car?
    - Aviation and 1.5 Degrees C
    - External Strategic Context
    - Participants and Contributors
    - International Initiatives
2. Summary
3. Findings and Recommendations

"The Economy's Hidden Problem: We're Out of Big Ideas*"

- The Innovation Paradox *on.wsj.com/innovationseries
- "There is a yawning chasm between what innovation promises for the economy and what it is delivering."
- "Dwindling gains in science, technology and medicine are a hidden drag on economic growth."
- U.S. Labor productivity growth peaked at 3.4% in the 1950's…now averages 0.5%."
- R&D as share of GDP is at an all-time high. There are more scientists and engineers in U.S. than ever. None of this has translated into meaningful advances in Standard of Living.







ODM is a "Big Idea" that directly impacts U.S. productivity.

Strategic Context

Contextual Observations

- The strategic framework for ODM (broadly) is built on the creation of a public value proposition directly affecting U.S. productivity, economic opportunity, international competitiveness, environmental outcomes, and ultimately, standard of living.
- Because ODM (broadly) is, at its core, both a disruptive innovation, and a "platform innovation*", the outcomes will be difficult to predict and quantify with deterministic rigor.
- Traditional and non-traditional industrial domestic and international air mobility investments are increasing.
- Investments in key emerging technologies relevant to ODM safety, performance, and environmental requirements are being made by the automotive, UAS, and aviation companies, as well as governments.
- The path to aircraft cost reduction is complementary to business model innovations that together with reduced operating costs can lower fares into high elasticity market domains.
- ODM investments to date have created fundamentally new aircraft design space.
- U.S. economic competitiveness is at high risk due to international due to international activities.
- Critical need for a focus on ODM airspace operating concepts, for reasons of operating efficiency, piloting considerations in the nearer-term, and autonomy implementation in the longer-term.

*Platform Revolution: How Networked Markets Are Transforming The Economy. G. Parker; M Van Alstyne; S. Choudary

Strategic Context, concluded

- The safe, productive and efficient mobility of people and goods facilitates economic development and enhanced quality of life. Thus, transportation technologies that respond on-demand to society's needs for mobility offer broad, transformational opportunities to improve the wellbeing of U.S. citizens through enhanced domestic and international commerce.
- In the U.S. and EU, scheduled air carriers are consolidating services toward larger aircraft, serving larger markets, flying longer legs. In the process, a vacuum in smaller community service exists, thereby diminishing economic opportunity and quality of life for increasing numbers of communities.
- The growth of congestion in large cities and so-called megaregions has vastly outpaced the ability of highways to meet demand. The consequences in lost productivity and congestion-induced carbon emissions create both a challenge and an opportunity for airborne concepts.
- Globally, as the need for transportation by air increases, commercial aviation is trending toward being one of the largest contributors to future carbon emissions among industrial sectors. As non-aviation industries reduce their carbon footprints, the relative effects of aviation's emissions appear headed toward being a larger part of the global challenge.

*Platform Revolution: How Networked Markets Are Transforming The Economy. G. Parker; M Van Alstyne; S. Choudary

Ch. 1 Findings and Recommendations

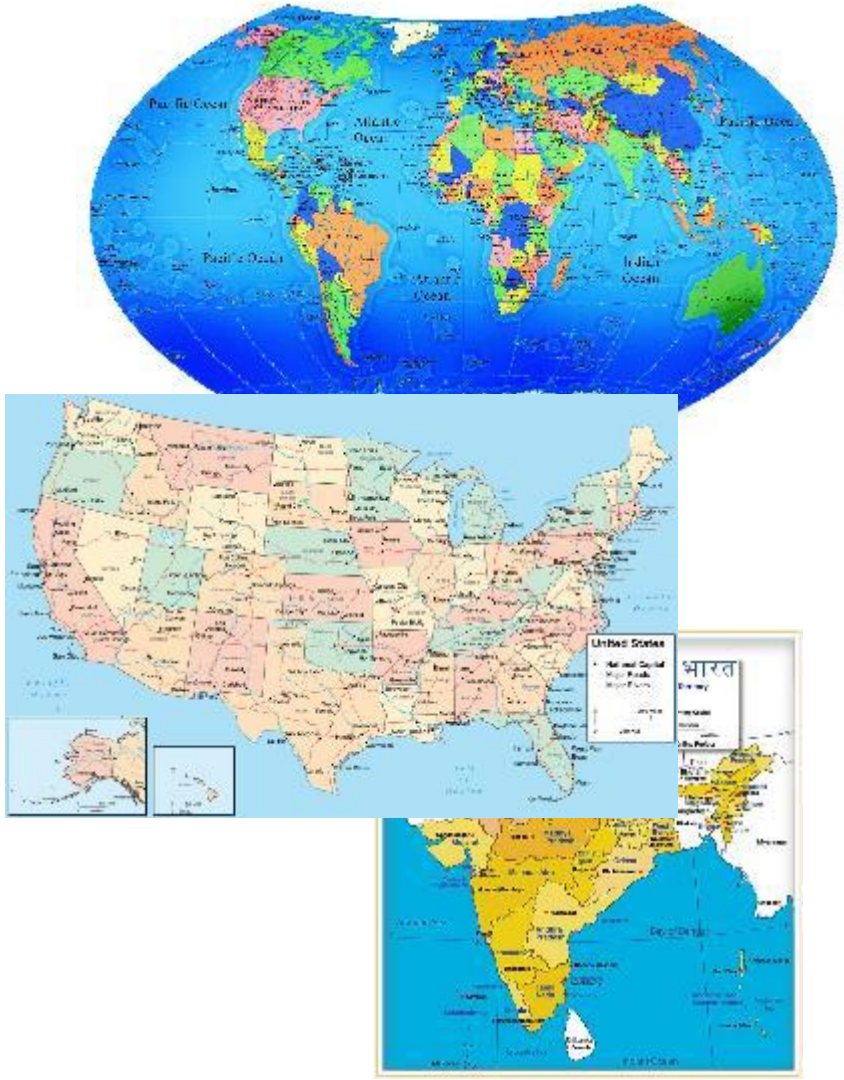
- ***Finding 1.1 –*** *There is a pressing national need for the U.S. to invest in advancements in ODM-related technologies if we are to maintain a competitive international posture in products as well as in regulatory standards.*
- ***Finding 1.2 –*** *The public value proposition posed by the ODM vision includes raised levels of standards of living, productivity, and economic opportunity that derive from an increasingly networked and connected public and their personal and business transport needs.*
- ***Finding 1.3*** *– The opportunity and timing for achieving the ODM vision is significantly enhanced by the convergence of aviation and non-aviation technologies affecting propulsion, autonomy, safety, efficiencies, environment, and affordability.*

- ***Recommendation 1.1*** *– NASA should organize an ODM-centric project, strategic thrust, and partnership plan to address the full breadth of technology domains required for this disruptive innovation to flourish.*
- ***Recommendation 1.2*** *– NASA leadership and championship of the ODM vision including the role of partnerships is vital to the success of the concept.*

Chapter 2 - ODM Demand

1. Introduction and Summary
2. Literature Review
3. The Quantitative Estimation of Air Travel Demand
4. The Definition of ODM and Thin-haul Service
5. Estimates of Demand for ODM Service
6. Estimated of Demand for Thin-haul Scheduled Service
7. Potential for Using New Data Sources to Model Air Travel Demand
8. Forecast Results
9. Autonomous CTOL Air Taxi ODM
10. Autonomous Thin-Haul ODM Commuter
11. Summary of Findings and Recommendations
10. References

Geographic Regions Modeled



- **Global**: The entire world: any air travel in any city pair market in the world that could be served by an aircraft with the defined properties.
- **United States**: Air travel that originates in a city inside the geographic limits of the United States, including Hawaii and Alaska. It does not include US possessions such as Puerto Rico.
- **India**: India has a huge population, but only a small fraction of it is affluent enough to afford air travel. Estimates here are very conservative, since economic growth is substantial.

Prototypical ODM Aircraft

1. CTOL Air Taxi; 2. Thin-Haul Commuter

- Inter-Urban CTOL Air Taxi
  - Hybrid Electric aircraft
  - Capacity: 3 Passenger (2015), 4 Passenger (2035)
  - Speed: 180 knots/hour cruising speed
  - Range: 600 nm maximum range, less 45 nm/carried passenger
  - Fare: $25 base fare + $0.91/nm (2015); $25 base fare + $0.62/nm (2035); fixed fare regardless of party size.
  - Customer Awareness: 10% (2015), 70% (2035)
- Scheduled Thin-Haul Commuters
  - Electric aircraft
  - Capacity: 9 Passenger (2015); 10 Passenger (2035), auto-flight
  - Speed: 275 knots/hour cruising speed
  - Range: 675 nm maximum range, less 25 nm/carried passenger; 400 nm with full passenger load (2015), 375 nm (2035)
  - Per passenger fare: $7.89 base fare + $0.34/nm (2015); $7.89 base fare + $0.32/nm (2035)
  - Customer Awareness: 100%

Autonomous CTOL ODM Air Taxi Findings*

Assuming it is useful to compare future autonomous CTOL air taxi ODM aircraft production needs in the context of current technologically advanced single-engine piston aircraft, the following findings are offered:

- The conservative near-term demand for ODM aircraft production to satisfy projected U.S. consumer trip demand (~2,000 aircraft) is larger than the current U.S. industrial production in General Aviation (~1,000 piston airplanes) (https://www.gama.aero/media-center/industry-facts-and-statistics/shipments-billings)
- In the farther term, the very conservative demand for CTOL air taxi ODM travel increases the demand for aircraft by about 1,000% (10X), to about 20,000 aircraft.
- The global demand for trips (operations) and aircraft to service the demand is about 400% (4X) larger than U.S.-only figures.
- India would experience growth in demand from 2015 to 2035 by about 1,300% (13X) due to advancing economics and ODM technologies.
- The CTOL aircraft performance required to satisfy the distribution of trip lengths appears achievable within the anticipated power- and energy-densities of electric propulsion advances underway today.
- These results do not include Thin Haul Commuter demand or urban VTOL demand for aircraft, which will increase the trip and aircraft demand levels significantly.

*Recognizing that the “disruptive” and “platform-networked” nature of this innovation arena makes forecasting very challenging.

Autonomous ODM Thin-Haul Commuter Findings*

- As context for the Thin Haul demand modeling results:
  - For 2036, the FAA forecasts about 71 million "Itinerant Airport Operations" in the U.S.
    https://www.faa.gov/data_research/aviation/taf/media/taf_summary_fy_2015-2040.pdf
    includes itinerant air carrier, commuter, air taxi, general aviation, and military ops at all airports
  - For 2035, the FAA forecasts U.S. commercial fleet to increase to 8,414
    https://www.faa.gov/data_research/aviation/aerospace_forecasts/media/FY2016-36_FAA_Aerospace_Forecast.pdf
- The expected ~4.2 million trips (operations) in 2035 by Thin Haul represents ~6% of the forecast commercial airline fleet operations.
- The Thin Haul fleet size of about 600 aircraft represents ~7% of the forecast commercial airline transport fleet size. This size of Thin Haul fleet also represents about 150% of an earlier FAA forecast fleet size for regional/commuter aircraft of less than 9 passengers. seats.
  (https://www.faa.gov/data%5Fresearch/aviation/aerospace_forecasts/2005-2016/media/Table29.PDF)
  - Assuming an average ODM aircraft load factor, utilization, and flights/week (See Appendix)
- These conservative results do not account for growth in demand, operations, or fleet size that would be driven by advances in electric propulsion system performance and costs.

*The current regulatory structure is not appropriate for the optimization of ODM aircraft and related business models.

Ch. 2 Findings and Recommendations

- ***Finding 2.1*** *– Passenger demand for air travel and the translation of that demand in to numbers of aircraft required point to a significant expansion of the U.S. small aircraft manufacturing and transportation services industry.*

- ***Finding 2.2*** *– Significant gaps exist in available transportation consumption patterns that are needed to serve as a foundation for improved understanding of how ODM consumers might behave in the future including for example, self-driving cars.*

- ***Recommendation 2.1*** *– NASA should advocate that the U.S. DOT and the FAA initiate new data collection efforts to support the development of future demand models that accurately captures how individuals make travel decisions now and may in the future. The effort should include the emerging modal options such as autonomous ODM.*

Chapter 3 - ODM Enabling Technologies and Gaps Analysis

Prelude

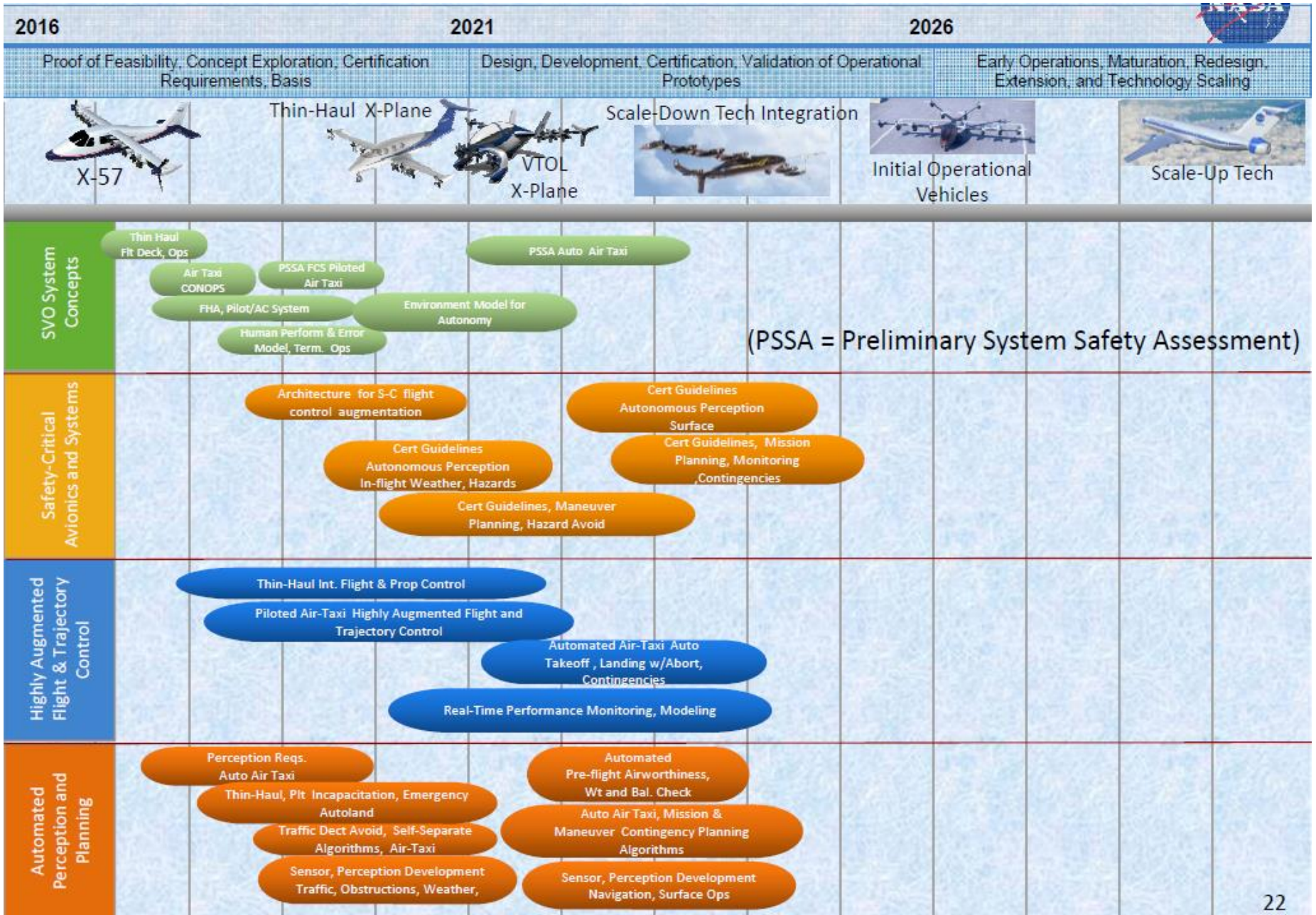
1. Introduction
2. Technology Assessment Process
3. NASA ODM Roadmap Development Summary and Analysis
4. ODM Technology Roadmap Assessment
5. Priorities, Gaps and Recommendations
    - Gaps
    - Proposed NASA ODM Technology Development Approach
    - Strategic Implementation of ODM
6. Summary of Findings and Recommendations

ODM Technology Roadmap Process

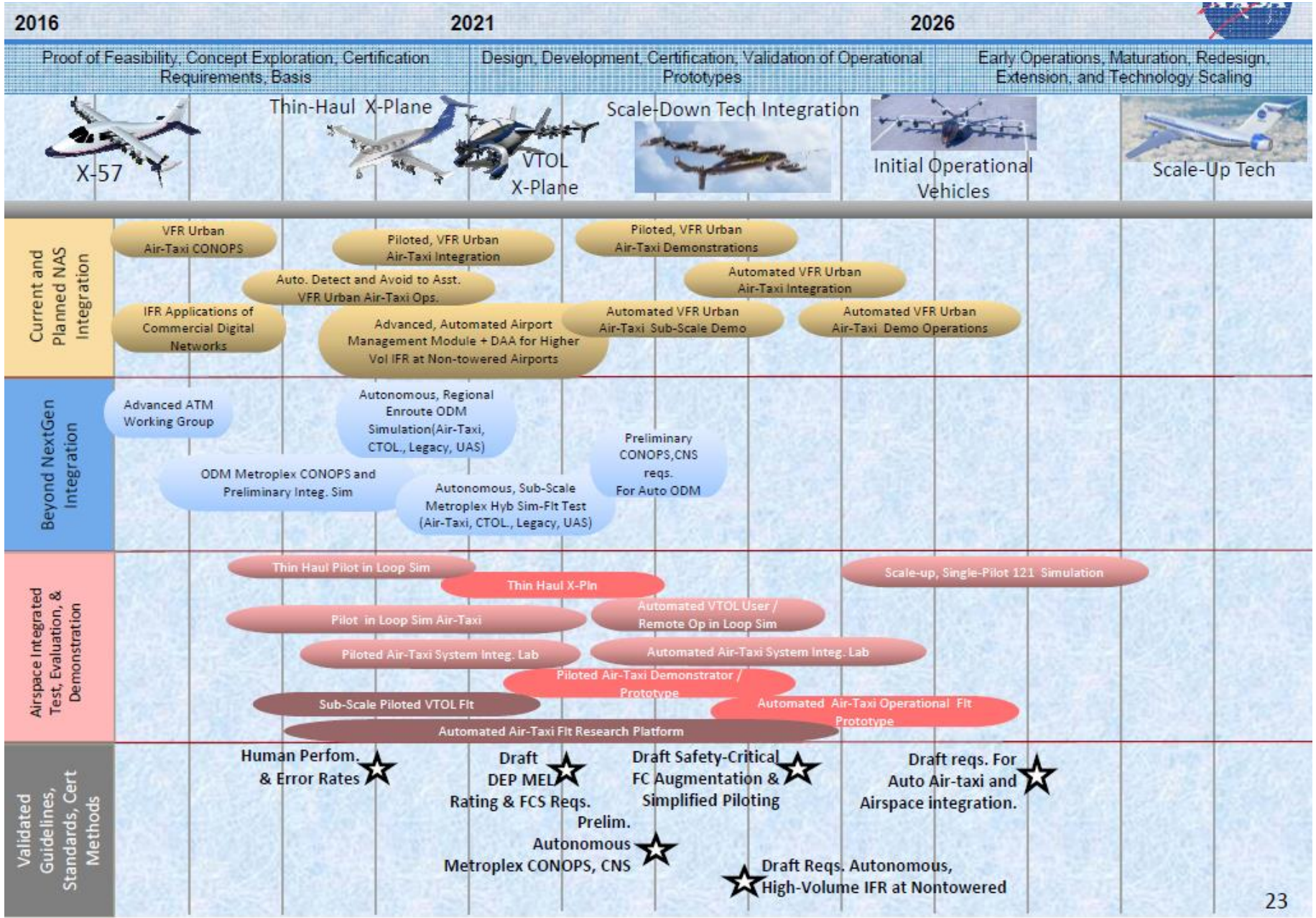
- Conducted Series of NASA-led workshops organized by NIA with key stakeholders
  - On-Demand Mobility Forum, Oshkosh, WI, July 2015
  - On-Demand Mobility Roadmapping Workshop, Kansas City, MO, October 2015
  - ODM and Emerging Technology Joint NASA-FAA Workshop, Arlington, VA, March 2016
  - On-Demand Mobility Report Out, Hartford, CT, September 2016
- Workshop Presentation and Products Posted at: http://www.nianet.org/ODM/roadmap.htm
- Key Stakeholders Present Included: NASA, FAA, Traditional Airframe and Engine Companies, Emerging ODM Companies, Potential Operators, Universities, and Consultants
- Divided Into Three Working Groups to Develop Roadmaps
  - Simplified Vehicle Operations and Airspace
  - Electric Propulsion
  - Manufacturing, Integrated Structures, and Community Impact
- Completed Preliminary Roadmaps for Each of the Three Areas

Remaining Questions:
What Should Priorities Be?
What Gaps Exist?
How Should They Be Filled?
What Role Should NASA's Play?
How Partner With Industry?
How Technologies Scale Up and Down?

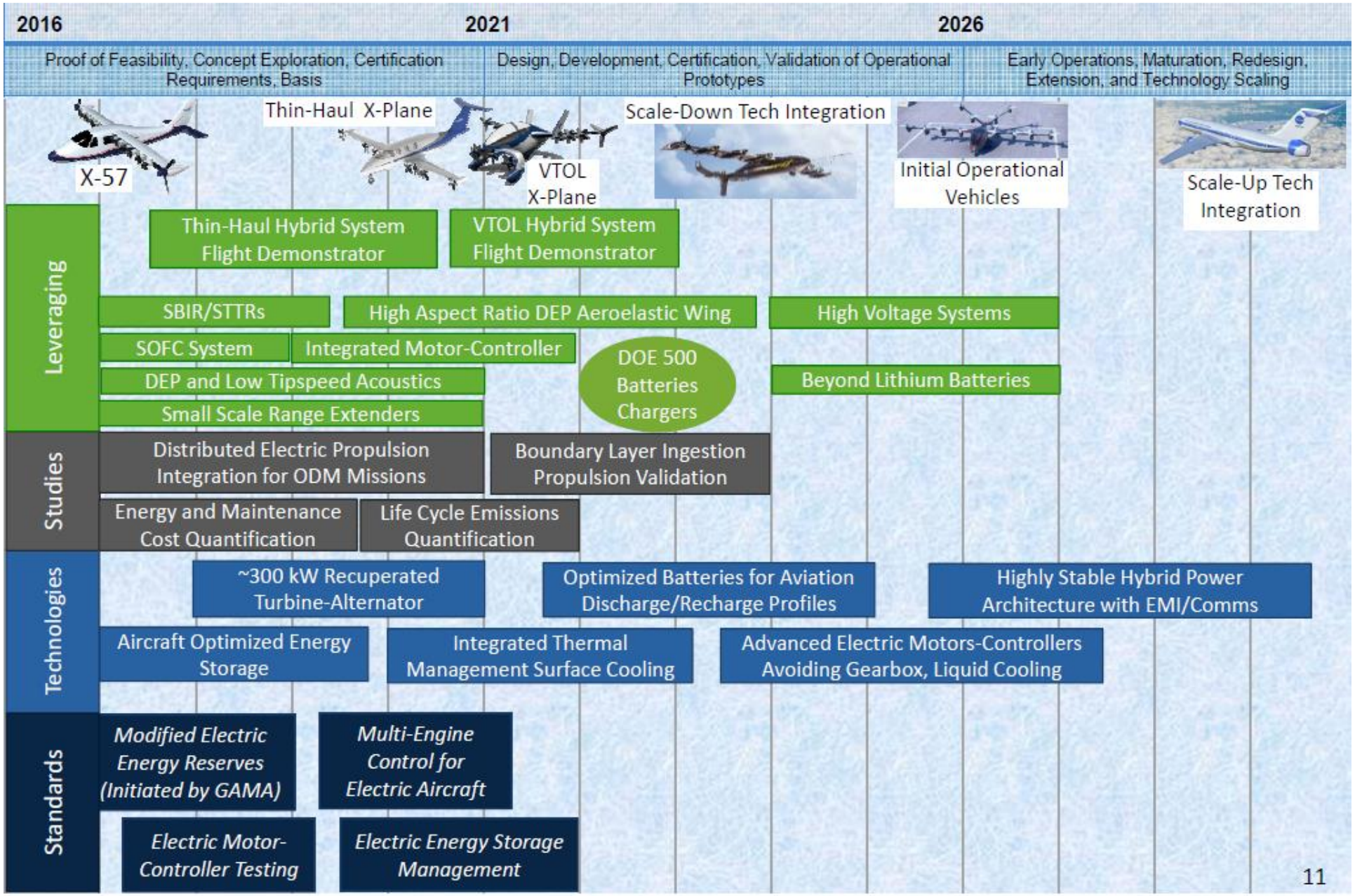
Simplified Vehicle Operations and Airspace (1)



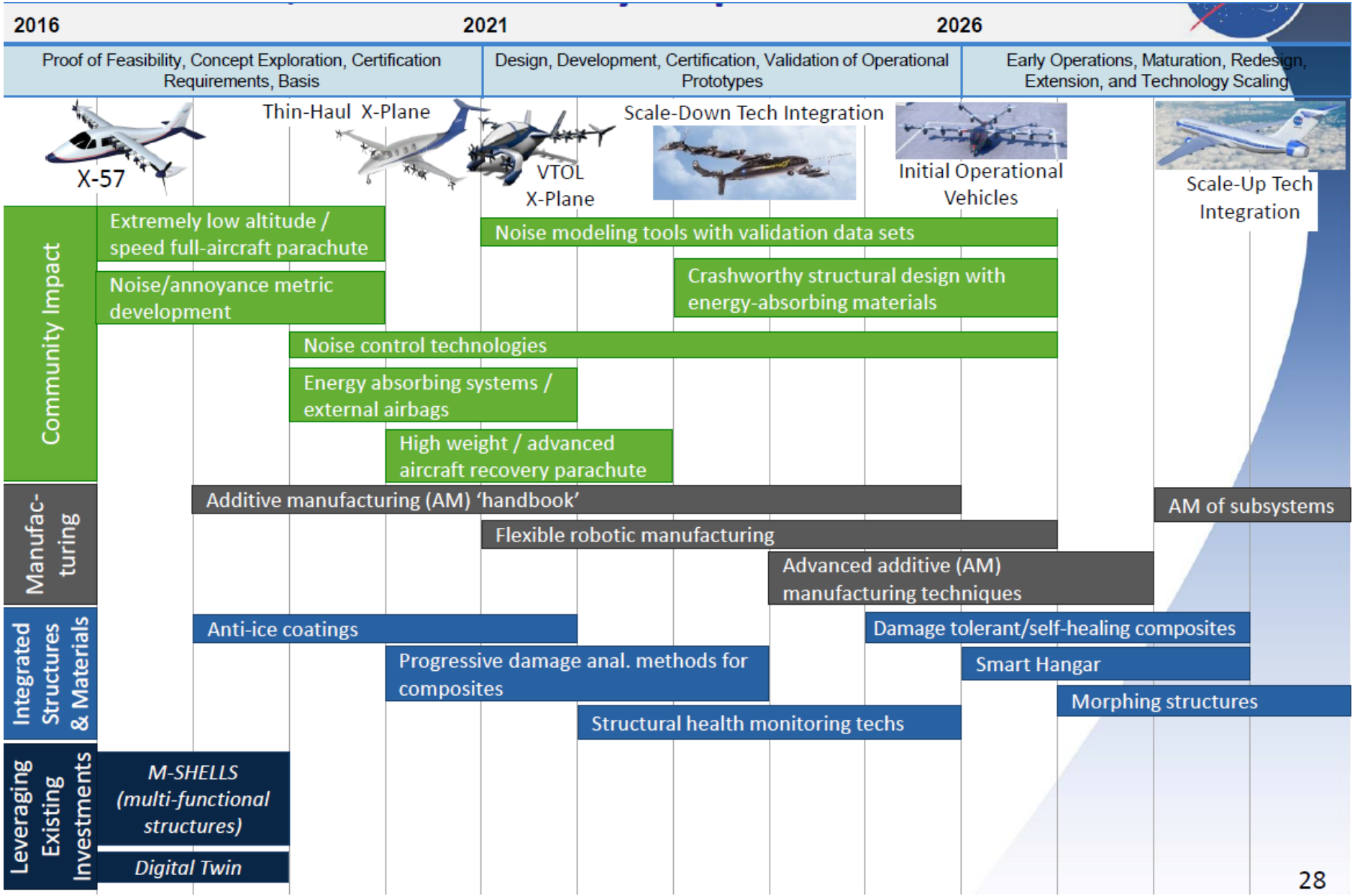
Simplified Vehicle Operations and Airspace (2)



Electric Propulsion



Manufacturing, Integrated Structures, and Community Impact



Identified Technology and Capability Priorities

- Airframe Integrated Distributed Electric Propulsion
- High Specific Energy Long-Life Batteries with Rapid Recharging Capability
- High Voltage Hybrid-Electric Power Systems and Range Extenders with Low EMI Interference
- Adaptive High-Reliability Electric Motor Control Systems
- Multifunctional Structures/Thermal Management/Energy Storage Systems
- Electric Propulsion Standards (Reserves, Control, Charge Management, Testing)
- Highly Augmented Flight and Trajectory Control With Efficient On-Demand Routing and Sequencing
- Highly Reliable Automated Detect, Sense and Avoid Systems That Allow Critical Human Intervention
- Beyond NextGen Airspace Systems Able to Accommodate Orders of Magnitude More Vehicles
- Certification For Autonomous Operations
- Low-Altitude Full Aircraft Parachutes and Energy Absorbing Emergency Recovery Systems
- VTOL Advanced Noise and Propeller Control Technologies and Modeling
- Damage Tolerant, Self-Healing, Smart and Morphing Structures with ISHM
- Anti-Ice Coatings and All-Weather Systems
- Flexible Robotic and Additive Manufacturing

Roadmap 1 - EP
Roadmap 2 - SVO
Roadmap 3 - MISC

Technologies and Capabilities Not Addressed

- Trusted Communications/Cybersecurity
- Airspace Architectures/Flight Rules for ODM
- Consumer Acceptance/Human Factors Assessments – Ride Quality, Acoustics, Perceived Safety
- Vertiport / Vertistop Infrastructure – Including Rapid Charging Stations
- Smart/Reliable Sensors to Enable Autonomous Operations and Self Separation
- On-Board Weather Detection and Robust Adaptation
- Air Vehicle Design Optimization (Speed, Range, Payload) as a Function of Latent Demand Characteristics
- High-Data-Rate Connected Aircraft for Airspace Operations
- System and Subsystem Certification Requirements
- Robust Control Architectures to Engine-Out, Gusts, Weather, Obstacle Avoidance, Etc.
- Human/Machine Interfaces for Emergency Pilot/Passenger Intervention
- Intermodal Network Real-Time Optimization Architectures and Approaches
- Active Noise Control and Acoustic MetaMaterials For Cabin and External Noise Abatement
- “Pilot” Training/Certification

We need to assess each of these technologies
against the framework of NASA’s role in “Lead, Follow, or Collaborate.”

How Technologies Scale Up and Down

- Many Required Technology Investments Have Synergy With Commercial Aircraft Needs
  - High Specific Energy Long-Life Batteries with Rapid Recharging Capability for Auxiliary Systems
  - Hybrid Electric Propulsion/Power Systems
  - Higher Levels of Autonomy for Reduced Crew Operations
  - Multifunctional Structures/Thermal Management/Energy Storage Systems
  - Highly Augmented Flight and Trajectory Control With Efficient On-Demand Routing and Sequencing
  - Damage Tolerant, Self-Healing, Smart and Morphing Structures with ISHM
  - Anti-Ice Coatings and All-Weather Systems
  - Flexible Robotic and Additive Manufacturing
  - Trusted Communications/Cybersecurity
  - High-Data-Rate Connected Aircraft for Airspace Operations
- Almost All Required Technology Investments Have Synergy with UAS Systems Needs and Will Benefit This Important US Industry; ODM Vehicles Will Likely be used as Large Cargo-Carrying UAS in Addition to Passenger Vehicles
  - Build on Airspace/Autonomy Lessons Learned from Cargo-Carrying UAS
  - Build on UAS Lessons Learned Relative to Local Regulations (e.g., Noise/VTOL Infrastructure) and Public Acceptance
  - Different Certification Requirements due to Human Passengers/"Pilots"
- The Thin Haul ODM requirements may offer the most relevance for scale-up to larger commercial aircraft applications.
- The urban VTOL requirements may offer the most relevance for scale-down to smaller vehicle applications (as well as being enabled from the bottom up).

Ch. 3 Findings and Recommendations

- ***Finding 3.1 –*** *The current NASA-led ODM Roadmaps are an excellent starting point for joint technology development within NASA and the ODM community.*
- ***Finding 3.2 –*** *The process used to develop the NASA-led ODM Roadmaps was inclusive, collaborative and thorough, and they led to the establishment of a large, diverse ODM community of practice.*
- ***Finding 3.3 –*** *Several gaps exist in the current ODM roadmaps as identified in this chapter, with the most critical being in the area of cybersecurity and trusted communication.*
- ***Finding 3.4 –*** *Investments in ODM technologies and capabilities will have many scale-up benefits to commercial and general aviation aircraft and scale-down benefits to small and large UAS.*

- ***Recommendation 3.1*** *– NASA should establish a separate ODM project and alter Strategic Thrust 6 to be an ODM/Autonomy/UAS Strategic Thrust*
- ***Recommendation 3.2*** *– NASA should host a workshop and establish strategic partnerships with key automotive companies and organizations developing standards and technologies for autonomous vehicles due to the tremendous synergy with ODM.*
- ***Recommendation 3.3*** *– NASA should host a workshop and establish strategic partnerships with the DoE and key battery and automotive companies developing high-energy-density battery technologies and charging systems and standards due to the tremendous synergy with ODM.*
- ***Recommendations 3.4*** *– Consistent with the approaches outlined in Chapter 5, NASA should consider establishing a non-profit-led Investment Public-Private Partnership (IPPP) with key ODM-related companies and government agencies to coordinate ODM technology and system development.*
- ***Recommendation 3.5*** *- Given the limited NASA budget available and the number of key stakeholders, we recommend NASA conduct an immediate, comprehensive analysis to determine which activities ARMD should lead versus leverage versus collaborate.*

Chapter 4 – Organizational Contributions and Roles

Prelude

1. Introduction
    - Existing Stakeholders, Collaborators and Contributors
    - Industry Organizations
    - Trade Associations, Professional Societies, and NGOs
    - Governmental Organizations (U.S.)
    - Governmental Organizations (International)
    - Academic and FFRDC Organizations
      (including Federally Funded Research and Development Centers)
2. Potential International Collaborators
3. Organizational Issues
4. Options for Leveraging Organizational Cooperation
5. Summary of Findings and Recommendations

Proposed Role for NASA ARMD

- ODM Technology Development and Capability Requirements Similar in Many Ways to Supersonics
  - Promising But Untested Markets
  - Major Systems Certification/Regulation Issues Exist (e.g., Noise, Airspace, Propulsion)
  - Technological Hurdles Exist that NASA Can Help Overcome (e.g., Noise, Propulsion, Airframe Integration)
  - NASA has Unique Systems Analysis and Configuration Modeling Capability/Expertise
  - Flight Test Demonstrators are necessary
  - Motivated US Industry Partners Exist and Want NASA's Help
  - International Competition, Balance of Trade Issues Exist
- <u>Consider Making Strategic Thrust and Program Like Supersonics</u>
  - With Close Coupling to Other Programs for Many Technology Needs (e.g., Rotorcraft, Structures/Materials, Environmentally Responsive Aviation, Acoustics, Autonomy)
- ODM Involves Unique Issues (Local Infrastructure, Autonomous Operations, Ride-Share, Airspace)
- Other Partners will Have Lead Role on Much of Work (FAA – Airspace/Certification, DOE/Industry – Batteries, DoT/Automotive Industry – Autonomy/Sensors, State/Local Communities – Infrastructure)
- Collaboration arrangements Are EXTREMELY Important to Success
  - Consider some form of Public-Private Partnership
  - High-Speed Research or AGATE and RITA Programs Could Be Analogies

Proposed Roles of Other Partners

- ODM Will Benefit from Confluence of Technologies/Capabilities Being Developed by Others
- DOT/Automotive Industry Investments in Autonomous Automobile Technologies
  - Sensors, Algorithms, Cybersecurity, Human/Machine Interfaces, Path Optimization Within Traffic Networks, Connected Vehicles, Highly Reliable Architectures, Certification, Regulation
- DOE/Automotive/Power Industry Investments in Batteries and Energy Mgmt Technologies
  - High Specific Energy Long-Life Batteries, Rapid Recharging Capability, High Voltage Hybrid-Electric Power Systems, Smart Energy Storage and Management Systems
- UAS Industry Investments
  - Autonomy, Sensors, Algorithms, Cybersecurity, Electric VTOL Propulsion, Configuration Approaches, Connected Vehicles, Airspace Integration Regulations Leadership
- Uber Investments and Expertise in Ridesharing Algorithms, Networks, Economics, Customer Experience
- Other NASA Technology Investments in Related Areas
  - Rotorcraft, Structures/Materials, Environmentally Responsive Aviation, Acoustics, Autonomy, Etc.
- FAA Can Track and Learn from Other Country's Best Practices for UAS Airspace Integration
  - Europe, Australia, China, Singapore, Israel, etc,
  - Need to Get "Ahead of the Curve"

NASA/FAA Can Closely Follow These Investments through Partnerships and Limit Investment to Focused Areas Not Already Being Addressed

Ch. 4 Findings and Recommendations

- ***Finding 4.1 –*** *Challenges posed by international competitiveness in technologically advanced smaller aircraft for more widespread inter- and intra-urban public transportation create conditions leading to the potential loss of U.S. global leadership in aviation.*
- ***Finding 4.2*** *– The opportunities posed by unprecedented industrial developments in the ODM space, combined with synergistic emerging technologies create conditions in which NASA investments in research and technology development can secure U.S. global leadership in aviation for years to come.*
- ***Finding 4.3*** *– The convergence of autonomy, automation and connected vehicle technologies along with the ever-increasing demand for increased mobility and decreased congestion, present an opportunity for our nation to be the global leader in transformation of transportation through ODM advancements.*
- ***Finding 4.4*** *– Technologies alone will not enable fulfillment of the ODM vision. The systemic nature of this vision commands a national sharing of and commitment to its achievement.*

- ***Recommendation 4.1*** *– NASA should create a focused effort in ODM research and technology development. The need for a focused program is clear in order to maintain U.S. technological, market, and regulatory leadership.*
- ***Recommendation 4.2*** *– NASA should lead in the collaborative development of ODM technology through one or more Innovation-Public Private Partnerships (I-PPP) involving industry, academia, states, regulators, operators, and investors.*

Chapter 5 – Public/Private Collaboration Options and Resource Alignment

Prelude

1. Introduction and Background
    - Collaboration Options and the Role of Objectives and Requirements
2. Four Collaboration Options
3. Criteria for Selecting an Option
    - Stakeholders
    - Executive-Level Commitment
4. Technology Alignment
5. Resource Alignment
6. Assessing Partnership Options Against Criteria
7. Findings and Recommendations

Collaboration Options

- **Government directed, industry advised**- Government directed and majority funded programs and projects through one or more organizations chosen by government managers with industry input.

- **Joint strategic partnership**- Government/industry/academia coordination through a joint task force or executive group to decide on different levels of co-funding for projects/programs through multiple organizations.

- **Joint alliances or consortiums**- Government/industry/academia membership in a single alliance or consortium organization that decides on different levels of co-funding for project/programs that achieve an agreed upon goals.

- **Industry-led, government participant**- Industry led coordination of government/industry/academia through a single alliance or consortium to decide on different levels of co-funding.

Collaboration Option Selection Criteria

- **Political & policy objectives**- What are the policy objectives to be satisfied?
- **Stakeholder Organizations**- What organizations must be engaged as direct versus indirect stakeholders?
- **Strategic level commitment**- What commitments must be secured from stakeholder senior managers?
- **Technology alignment**- What existing technology development programs must be aligned with the project/program plan?
- **Resource commitments**- What external resources (funding, personnel, facilities) must be committed to achieve the project/program objectives?
- **Cultural compatibility**- What degree of cultural compatibility among stakeholders is necessary?
- **Legal & Operational Requirements**
  - What legal authorities are required to incent stakeholder commitment?
  - What operational procedures are necessary to implement the legal authority?

Ch. 5 Findings and Recommendations

Finding 5.1 *– Four collaboration options relevant to ODM include those that engage multiple economic sectors in working teams across several technology areas to generate certified technology that is commercially adopted, resulting in advances supporting transportation systems solutions* support.

Finding 5.2 – *Based on our options analysis, we have identified two of the four as the most suitable for and ODM (I-PPP). These recommendations include a) a Joint Strategic Partnership; and b) a Joint Consortium.*

Recommendation 5.1 *– NASA should organize a formal assessment of the two recommended alternatives for an I-PPP: either a Joint Strategic Partnership, or a Joint Consortium.*

To be clear, there is a distinction between "partners" as "technology sources" versus as full commercialization partners. "ODM commercialization partners" would including organizations that satisfy the following intersecting requirements: 1) technology sources; 2) strategically aligned; 3) capable of spending their own/internal resources on R&D; 4) are cultural compatibility; 5) have the legal capacity to enter R&D cost/rights sharing agreements; and 6) are operationally compatible.

Chapter 6 – National Policy and Regulatory Considerations

Prelude
1. Introduction
2. Growth Despite the Absence of Policy
3. Tragedy Preempts Policy
4. Additional Thoughts
5. Policy is Needed Now
6. Vision Aligns Constituencies
7. ODM Involves Many Constituents
8. Operator and Stakeholder Interviews and Regulatory Considerations
    - Response
9. Regulatory Restraints vs. Regulatory Enablers
10. Policy Must Reflect Vision and Facilitate Progress
11. Establishing New Processes
    - Relevant Regulations Needed
12. Seeking Consensus
13. Essential Areas for ODM Development and Operation
14. Summary
15. Findings and Recommendations

Chapter 6-Policy Considerations

Vision for On-Demand Mobility

- Growth in public use of on-demand air mobility (ODM), serving virtually all of our nation's communities, would create significant domestic benefits for our nation.
- ODM vehicle and airspace technologies, including management and operations of ODM services, are exportable innovations that will enhance U.S. balance of trade.
- NASA is uniquely capable of stimulating technology advancements that enable a transformational advancement in the on-demand air mobility of persons and goods.
- NASA leadership is needed to communicate the public value proposition for ODM and engage all stakeholders in embracing the opportunities inherent in advancing the technologies for On-Demand Mobility.
- The vision must be codified in Policy to have traction and be effective. A National ODM Policy will enable legislators, regulators, innovators, and the public to envision a common goal, collaborate on mutual opportunities, and support an ODM Policy, for the benefits of our nation.

"In order to lead a country or a company, you've got to get everyone on the same page …. Jack Welsh, Former CEO GE

Chapter 6-Policy Considerations

6.1 National Policy Considerations for ODM

- Why Policy Is needed
  - Implementing On-Demand Mobility involves many different constituencies within the public and private sectors
  - Efficient and effective integration of those constituencies requires an encompassing Policy that focuses the diverse capabilities of different constituencies

- Lack of U.S. policy on air transportation yielded inefficient allocation of resources and lost opportunities
  - While controlled flight was developed in the USA, Europe lead in commercial and military aviation
  - Air transportation in the USA was shaped by accidents and market forces

Opportunities were missed or diminished by our nation's lack of an air transportation policy.

Chapter 6-Policy Considerations

6.1a Aligning Constituents to Implement ODM Technologies.

- Technologies in several disciplines will pace development of On-Demand Mobility. e.g.:
  - Propulsion innovations.
  - Autonomy and automation.
  - Materials and manufacturing.
  - Precision 4-D navigation and related issues involving management of airspace.
  - Integration of piloted, semi- autonomous and autonomous vehicles within the national air transportation system.
  - Digitally connected, networked air vehicles.
- Concurrence at many levels among disperse groups is needed to implement On-Demand Mobility.
  - Legislators, regulators, manufacturers, investors, service providers, operators, passengers, advocacy groups.
  - Government agencies such as NASA, FAA, TSA, EPA, NOAA.

Policy is essential to garner support among constituents that must agreed to support ODM.

Chapter 6-Policy Considerations

6.2 Operator and Stakeholder Interviews and Regulatory Considerations

- Policy is the focal point for viewing community interest and participation in On-Demand Mobility
  - Leaders in Air Charter and Business Aviation offered input regarding ODM opportunities and enabling technologies
  - Many of the interviewees are attempting to provide ODM services and would likely be the early adopters of ODM concepts
- Operators and Stakeholders expressed similar needs and aspirations, with emphasis on key areas
  - Implementation of technologies that enable greater traffic density while reducing pilot workload and human monitoring of traffic
  - Direct routing between departure and destination regardless of city size or location
  - Reduced time and cost of certification
  - Regulations that reflect the benefits of new technology and are not constrained by existing limitations and regulations

Policy will facilitate development of appropriate regulations that support safety while encouraging development of On-Demand Mobility and its benefits to the nation

International Considerations

- China is on a strategic, long-term path that represents both market opportunities and an economic competitiveness risk for the U.S.
- EU firms are making significant strides in ODM-relevant innovations in aircraft, propulsion, avionics, and manufacturing, with scale up and down ambitions.
- The Government in India is promoting development of airport infrastructure for air taxi and charter transportation.

Z-Park Sky Innovations
General Aviation Industrial Alliance
| 中 | 关 | 村 | 蓝创通航产业联盟

And many others

Chapter 6-Policy Considerations

Summary

- Lack of national policy on air transportation has negatively affected progress in air transportation
- Failure to formulate and articulate ODM policy will impede or negate significant opportunities
- Support among contributing constituents requires NASA's Vision and Leadership expressed as Policy

Ch. 6 Findings and Recommendations

- ***Finding 6.1****—Aviation development in the U.S.A. was shaped primarily by market forces and response to accidents.*
- ***Finding 6.2****—The U.S.A. does not have a definitive policy on air transportation.*
- ***Finding 6.3****—Entities likely to develop or operate advanced vehicles for On-Demand Mobility believe that existing regulations will impede and potentially prevent the implementation of On-Demand Mobility.*
- ***Finding 6.4****—A clear vision that is easily imagined, reinforced by a memorable message and memorialized in policy, is a powerful force for coalescing constituents to advance new ideas.*

- ***Recommendation 6.1****—NASA should propose an overarching policy for implementing the vision of On-Demand Mobility that provides air transportation from here to there, anytime, anywhere.*
- ***Recommendation 6.2*** *– NASA, together with a body of stakeholders should identify a comprehensive set of ODM policy issues and sponsor a policy research effort to determine the impact of alternative policy options. In this way, informed policy decisions can be made*
- ***Recommendation 6.2****—NASA should convene representatives from the broad spectrum of stakeholders that would benefit from On-Demand Mobility, with the goal of supporting the development of an appropriate regulatory framework for ODM vehicle manufacture, certification and operation.*
- ***Recommendation 6.2.1*** *– The Fractional Ownership Aviation Rulemaking Committee that developed FAR Part 91k, and the General Aviation Safety Committee that provided leadership for enhanced survivability of Part 23 aircraft, are examples of committee formulation and action that NASA should facilitate.*
- ***Recommendation 6.2.2*** *– NASA should include diverse representation from traditional and non-traditional stakeholders that would participate in and benefit from On-Demand Mobility.*

Chapter 6-Policy Considerations

Recommendation 6.3 *– NASA should support the following Policy Statement:*

Whereas existing technology is capable of significantly expanding the use of airspace for the safe, productive and efficient use of aerial vehicles, whether piloted, semi-autonomous or fully autonomous, either scheduled or on-demand, it is the policy of the U.S. government to support innovation, development, and implementation of aircraft and Air Traffic Management systems that facilitate On-Demand Mobility.

Chapter 7 – Stakeholder Outreach Planning

1. Introduction
2. Stakeholder and Participant Outreach Workshops Plan
3. Outreach Planning Schedule and Resource Requirements
4. Venues
5. Summary
6. Findings and Recommendations

Stakeholder Outreach Plan

Chapter 8

- 8.1 Identify and document candidate outreach workshops to engage the broader community of stakeholders and participants in promoting and contributing to the ODM vision. Include stakeholder domains in state and local aviation officials; airport authorities; travel and entertainment industry; transportation security community; aircraft manufacturers and suppliers; economic development organizations; and others.
- 8.2 Document a draft schedule and resource requirements for executing an outreach initiative for these stakeholders and contributors, including sharing of ODM demand analytics at the regional and local levels, as well as infrastructure gap considerations. Include these plans in the final report under "Recommendations for Further Work."

Outreach – Domains and Candidate Venues

Stakeholder Domains

- Economic development organizations
- State and local aviation officials
- Airport authorities
- Land-Use authorities
- Travel and entertainment industry
- Transportation security community
- Aviation services and suppliers

Candidate Venues

- National and Selected State/Regional Economic Development Conferences
- American Association of State Highway Transportation Officials Conferences (AASHTO)
- Transportation Research Board Annual Convention
- NBAA BACE Convention
- Airports Council International (ACI) Convention
- Travel and Tourism Research Association (TTRA) Conference
- Workshops custom designed for stakeholder domain-specific interests

Candidate Participation on Outreach Workshop Planning Committee and Agenda

Planning Committee Candidate Organizations

- NASA HQ ARMD
- FAA Office of Strategic Planning and Policy Analysis
- https://www.fcc.gov/strategic-planning-%26-policy-analysis
- DOT
  - Volpe National Transportation Systems Center https://www.volpe.dot.gov
  - Office of the Assistant Secretary for Transportation Policy https://transportation.gov
- Leading ODM industry executives and trade associations
- National Business Aviation Association (NBAA), https://www.nbaa.org
- National Air Transportation Association (NATA),
- http://nata.aero
- General Aviation Manufacturers Association (GAMA) http://www.gama.aero
- U.S. Chamber of Commerce, https://www.uschamber.com
- U.S. Economic Development Administration (EDA), https://www.eda.gov
- National Rural Economic Development Institute (NREDA), http://www.nreda.org

Candidate Workshop Agenda Topics

- ODM Vision
- ODM Public Value Proposition
- ODM Safety and Environmental Considerations
- Stakeholder Domain-specific Implications for ODM operations and services
- Breakout Discussion Groups on Strategic Implications
  - Political
  - Legal
  - Environmental
  - Operational
  - Economic
  - Societal
- Plenary Reporting by Discussion Groups
- Action Planning

Ch. 7 Findings and Recommendations

***Finding 7.**1 – Workshops and other gatherings of stakeholders have been successful in addressing programs affecting a broad community of implementers and beneficiaries.*

***Finding 7.2** – NASA has a history of organizing and facilitating large-scale programs requiring input from a diverse community of stakeholders*

***Recommendation 7.1** – NASA should assign a facilitator for planning workshops and similar interactions with a broad community of obvious and latent stakeholders that would be engaged in On-Demand Mobility.*

***Recommendation 7.2** – NASA should assume a leadership position in the overall ODM outreach program and facilitate participation by other government agencies as well as private industry.*

Appendices

Appendix 1: Literature Review Annotated Bibliography

Appendix 2: The Models Used by the AirMarkets Simulation

- The Trip Generation Model (TGM)
- Trip Distribution Model (TDM)
- The Discrete Choice Model of Travel Options
- The Probability of Demand in a Given Time Period

Appendix 3: The AirMarkets Simulator

Appendix 4: The Price Curve for Air Travel