Presentation to the UAS COE Public Meeting

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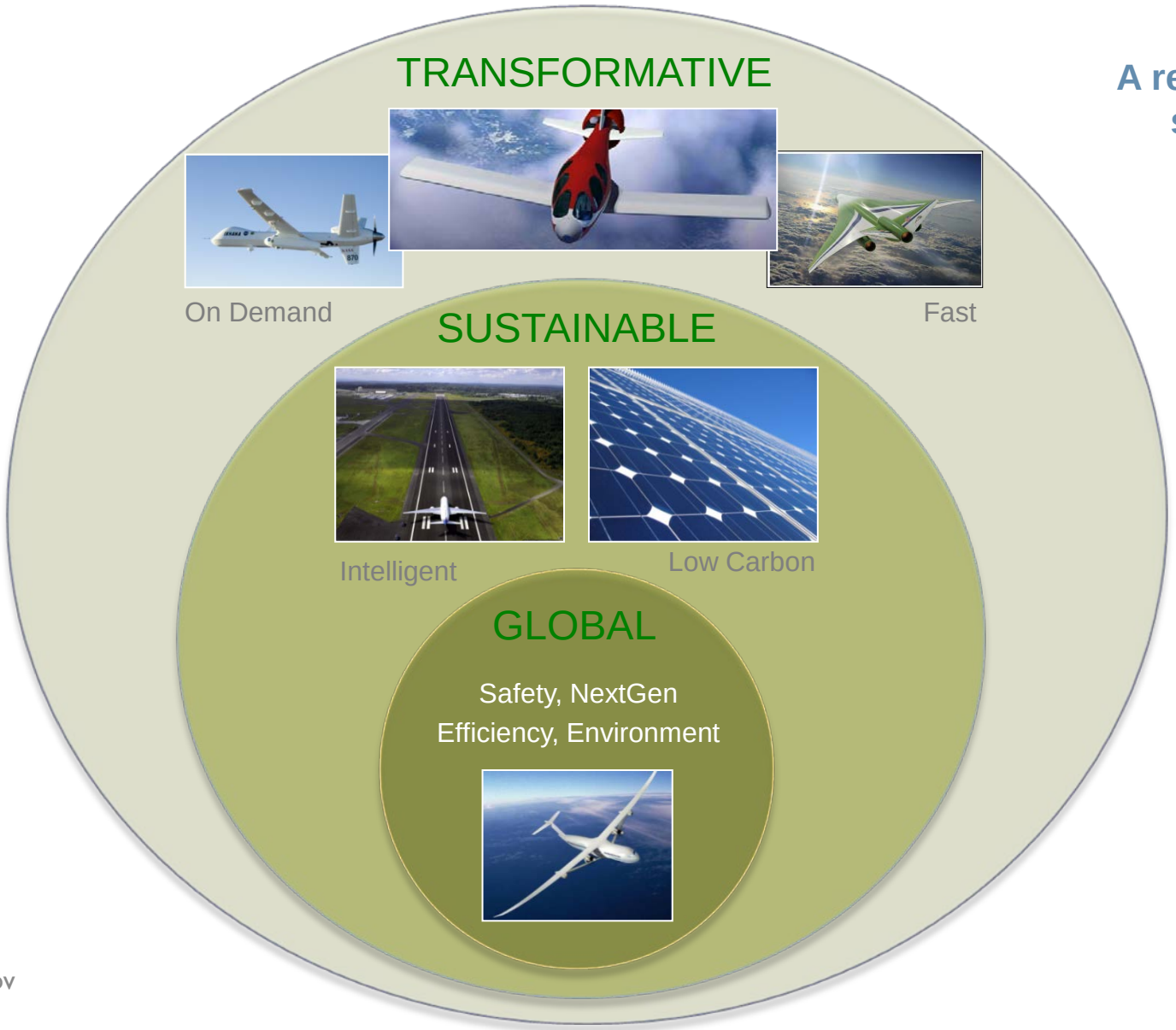
Three Aviation Mega Drivers

Traditional measures of global demand for mobility - economic development, urbanization - are growing rapidly

Severe energy and climate issues create enormous affordability and sustainability challenges

Revolutions in automation, information and communication technologies enable opportunity for safety critical autonomous systems

NASA's Vision for Aviation



A revolution in sustainable global air mobility

NASA Aeronautics Six Strategic Thrusts

Safe, Efficient Growth in Global Operations

- Enable full NextGen and develop technologies to substantially reduce aircraft safety risks

Innovation in Commercial Supersonic Aircraft

- Achieve a low-boom standard

Ultra-Efficient Commercial Transports

- Pioneer technologies for big leaps in efficiency and environmental performance

Transition to Low-Carbon Propulsion

- Characterize drop-in alternative fuels and pioneer low-carbon propulsion technology

Real-Time System-Wide Safety Assurance

- Achieve proactive safety management of the integrated aviation system

Assured Autonomy for Aviation Transformation

- Develop high impact aviation autonomy applications

Assured Autonomy for Aviation Transformation

NASA Role

Enable Safe Application of Aviation Autonomous Systems

Strategies:

- Develop key technologies and information to enable UAS to achieve routine access to the NAS
- Pursue long-term research to solve the major hurdles for the development and safe operation of autonomous systems, such as V&V techniques for highly complex software-intensive systems, and guidelines and technologies for human-autonomy teaming
- Partner with the aviation community on autonomy "challenge problems" to explore real-world issues and support near and mid-term innovation
- Develop and maintain a relevant test environment to support high confidence research and experimentation
- Establish partnerships to leverage accelerating developments in machine learning, robotics and other key autonomy disciplines

Risk Management and Challenges:

- Verification and validation of complex systems will set the pace of progress of implementing safe, autonomous aviation systems
- The inability to implement research in this area could limit the discovery of unknown issues and risks

UAS in the NAS

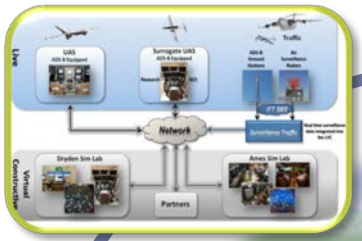
Project Goal, Research Themes, & Technical Challenges

Goal: Provide research findings to reduce technical barriers associated with integrating Unmanned Aircraft Systems into the National Airspace System utilizing integrated system level tests in a relevant environment

Research Theme 1: UAS Integration - Airspace integration procedures and performance standards to enable UAS integration in the air transportation system

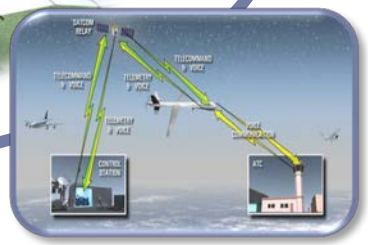
Research Theme 2: Test Infrastructure - Test infrastructure to enable development and validation of airspace integration procedures and performance standards

TC-ITE: Integrated Test & Evaluation



TC-SAA: SAA Performance Standards

TC-HSI: Human Systems Integration



TC-C2: C2 Performance Standards

UAS Integration in the NAS Project
Value Proposition Flow Diagram

NASA UAS-NAS Project Activities

SAA Performance Standards
- Develop SAA Performance Testbed
- Develop SAA Interoperability Testbed
- Conduct SAA Flight Test and MS&A
  - *Perf. Trade-offs*
  - *Interoperability*
  - *Self Separation*
  - *CONOPs*
  - *Well Clear*
  - *Coll. Avoid.*
- Develop SAA Performance & Interoperability Requirements

C2 Performance Standards
- Develop C2 Prototype System
- Conduct C2 Flight Test and MS&A
  - *Data Link*
  - *CNPC Spectrum*
  - *CNPC Security*
  - *LOS*
  - *BLOS*
  - *ATC Interop.*
- Develop C2 Requirements

Human Systems Integration
- Develop Prototype GCS
- Conduct Human Factors (HF) Flight Test and MS&A
  - *Conting. Mngmt*
  - *Pilot Response*
  - *Autonomy*
  - *SAA*
  - *C2*
  - *Displays*
- Develop HF Guidelines for SAA, C2 & GCS

Integrated Test & Evaluation
- Develop LVC Test Infrastructure
- Conduct IHITL Testing
- Conduct FT3 Test Scenarios
- Conduct FT4 Test Scenarios & Mission Based Flight Activity

Certification & Safety
- Analyze Classification Factors for UAS
- Conduct Restricted Category Study
- Analyze Case Study Results

Key Products

- SAA Performance Requirements to inform DAA MOPS
- C2 Performance Requirements to inform C2 MOPS
- SC-228 GCS & HF Whitepapers
- Re-usable Test Infrastructure
- Test Data to support SAA & C2 Standards Devlpmt
- Safety Substantiation Final Report & Safety Metrics Data

Resultant Outcomes

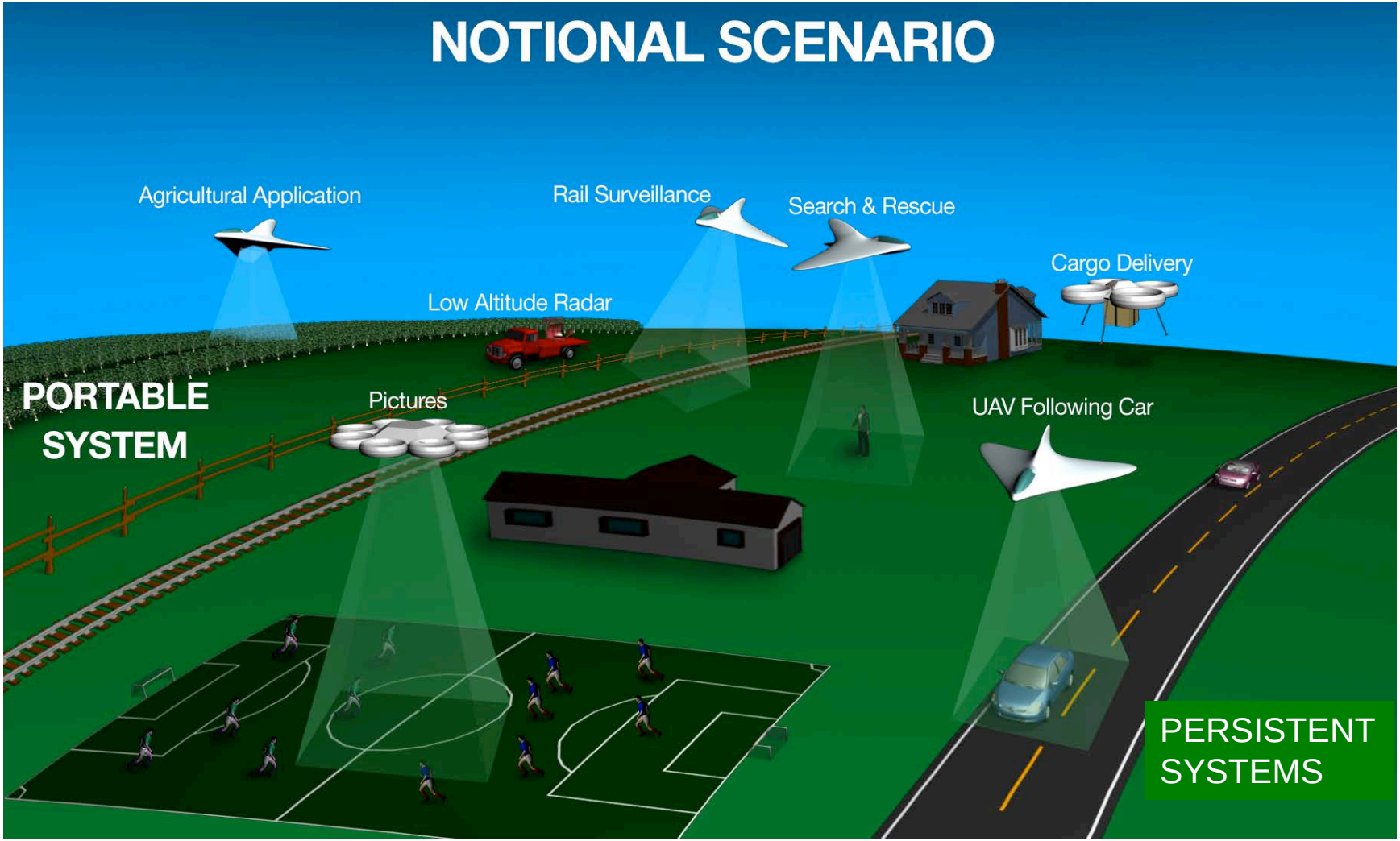
- RTCA DAA MOPS → SAA Technical Standard Order (TSO)
- RTCA C2 MOPS → C2 Technical Standard Order (TSO)
- RTCA DAA MOPS, RTCA C2 MOPS → SAA Technical Standard Order (TSO), C2 Technical Standard Order (TSO)
- Restricted Category Certification Guidance

* Details above do not include project sUAS or autonomy efforts.

UAS Traffic Management (UTM)

- Many civilian applications of Unmanned Aerial System (UAS) are being considered
  - Humanitarian
  - Goods delivery
  - Agricultural services
  - Strategic assets surveillance (e.g., pipelines)
- Many UAS will operate at lower altitude (Class G, 2000 Feet)
  - Other low-altitude uses such as personal vehicles are emerging
- No infrastructure to safely support these operations is available
- Global interest (e.g., Australia, Japan, France, UK, Europe)
- Lesson from History: Air Traffic Management (ATM) started after mid-air collision over Grand Canyon in 1956
- Need to have a system for civilian low-altitude airspace and UAS operations

UTM Applications



UTM Design Functionality

- UAS operations will be safer if a UTM system is available to support the functions associated with
  - Airspace management and geo-fencing (reduce risk of accidents, impact to other operations, and community concerns)
  - Weather and severe wind integration (avoid severe weather areas based on prediction)
  - Predict and manage congestion (mission safety)
  - Terrain and man-made objects database and avoidance
  - Maintain safe separation (mission safety and assurance of other assets)
  - Allow only authenticated operations (avoid unauthorized airspace use)

- Analogy: Self driving or person driving a car does not eliminate roads, traffic lights, and rules
- Missing: Infrastructure to support operations at lower altitudes

Autonomy Strategy Framework

Vision

Autonomy is implemented in harmony with humans to maximize the benefit of aviation to society

Needs

Technologies & Applications

Develop archetypal / model autonomy standards, technologies, functions and mission applications to broadly enable innovation

Trusted Systems Integration

Through the appropriate collaborations and partnerships, address the challenges associated with trust between humans and autonomous systems, including certification, verification and validation, and user/public acceptance.

Architectures, Methods & Metrics

Develop architectures and meta-design tools that enable the efficient and effective creation of joint human-machine cognitive systems

Real World Testbeds

Establish and maintain the relevant environment and testbeds for developing technologies, concepts and architectures and testing autonomous systems

Challenges

Technical (Research to Enable)

Issues such as human-machine collaboration, TEV&V, machine reasoning, sensor integration, etc.

Socio-Policy (Research to Inform)

Issues such as liability, public acceptance, moral decision-making, transformation of human roles/tasks, etc.

Draft UAS / Autonomy Roadmap

	Near (5 years)	Mid (5-15)	Far (15-30)
Outcomes	Autonomy Safety Applications for Passenger Aircraft and/or GA – e.g., *Autonomous Emergency Land*	Autonomous Support Functions for TBO Airspace Operations	Autonomous Systems are Certified and Trusted to Operate Safely in the NAS
	Routine Limited Access for UAS* in the NAS	Autonomy Applications for Passenger Aircraft – e.g., *Single Pilot Operations; Semi-Autonomous GA*	Initial Implementation of Autonomic Airspace
	UAS Traffic Management (UTM) System provides public benefit via short-term applications (e.g., search & rescue, agriculture, etc)	Full Access for UAS* in the NAS	Autonomous discovery and optimization of new aviation missions; and new, more capable aircraft designs through autonomy in design
		Persistent UTM System with Restricted Cert of Fully Autonomous UAS	

*Remotely Piloted

Summary

- Economic Growth
- High Quality Jobs
- Revolutionary Mobility
- Long-Term Sustainability

Urgent Drivers

Innovative Solutions and
High Payoff Technologies