# ODM and SVO Related Research & Development

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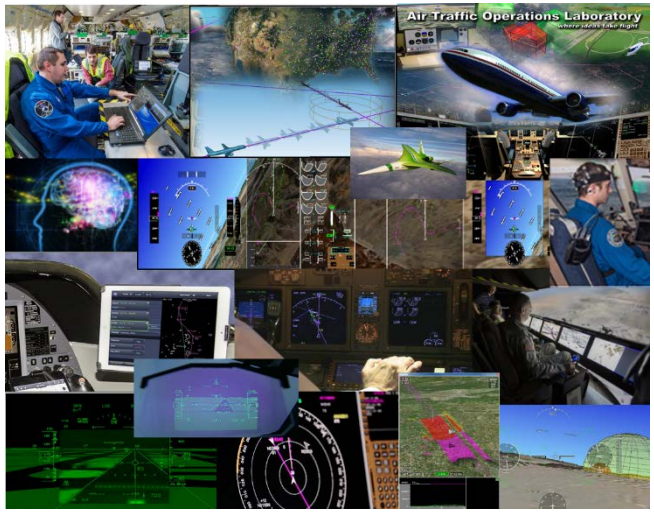


# ODM Barriers

- Substantially Higher Operating Costs
- **Poor Comparative Safety**
- **Onerous Training Requirements**
- Poor Emissions
- **Poor Community Noise**
- **Poor Dispatch & Trip Reliability**
- **Increased Traffic Density of Airspace**
- **Non-traditional NAS Entrance and Exit points**
- **Efficient Routes and Trajectories**

# R&D Toward Removing Barriers

## Barriers

- **Poor Comparative Safety**
- **Onerous Training Requirements**
- **Poor Community Noise**
- **Poor Dispatch & Trip Reliability**
- **Increased Traffic Density of Airspace**
- **Non-traditional NAS Entrance and Exit points**
- **Efficient Routes and Trajectories**

## R&D

- **Intuitive and Adaptive Interfaces**
- **Operator Monitoring**
- **Advanced Alerting and Cueing**
- **Data Analytics for Safety**
- **Autonomous Systems**
- **Function Allocation Schemes**
- **Improved Training**
- **Human-Automation Teaming**
- **Operational Autonomy**
- **Efficient Trajectories and Trajectory Management**
- **New Airspace Architectures**
- **Improved Conflict Detection & Resolution Algorithms**
- **Connected Aircraft Solutions**
- **New Operational Procedures**

# Future Requisite Attributes

Requisite Airspace Attributes

- *On Demand Air Transportation*
  *Anyone can travel anywhere at any time.*
- *Obtaining a pilot's license may for some vehicles / Ops require about the same level of training as is needed to obtain a driver's license.*
- *Air Vehicles Operate Without Need For Pre-authorization.*
- *Point to Point Travel is Possible*
- *Digital data communications*
- *Airspace access for all people.*
- *Fixed ground-based navigation and surveillance systems are minimal, thereby enabling a cost-effective scalable and demand-adaptive infrastructure.*
- *System is robust and resilient.*
- *Traditional airports and Non-traditional airspace entry and exit points*
- *System standards ensure interoperability and safety - do not impede modernization, scalability.*
- *Systems are scalable and demand adaptive.*
- *System takes advantage of increasingly autonomous systems.*
- *The system is at least as safe as today's system, even though it accommodates orders of magnitude more vehicles (>5x).*
- *Almost all traffic control is decentralized and vehicle-centric.*
- *The system is secure, protecting privacy, protecting national security.*
- *All weather operations*
- *Mix of vehicles with mixed avionics equipage*

Ballin, M.G., Cotton, W., and Kopardekar, P., *Share the Sky: Concepts and Technologies That Will Shape Future Airspace Use*. 11th AIAA Aviation Technology, Integration, and Operations (ATIO) Conference, 20 - 22 September 2011, Virginia Beach, VA AIAA Paper No. 2011-6864

# CSAO R&D Swim Lanes

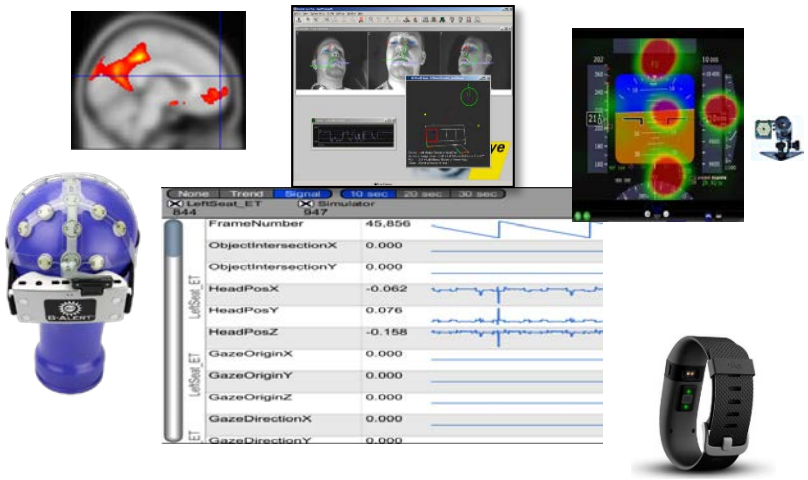
- **Trajectory and Airspace Operations Flexibility**
- **Multi-Agent Teaming**
- **Human-System Interaction**
- **Trust and Certification**

# Trajectory & Airspace Operations Flexibility

- **Flight Deck Trajectory Optimization Tool**
  - Traffic Aware Strategic Aircrew Requests (TASAR)
- **Conflict Detection and Resolution (CD&R) Algorithms**
  - Autonomous Operations Planner (AOP)
- **Vehicle Autonomous Operations**
  - Autonomous Flight Rules (AFR)
- **UAS Detect and Avoid Algorithms/Interfaces**
- **Arrival Spacing Tool and Procedures**
  - Flight deck Interval Management (FIM)
- **Trajectory Based Operations Solutions**
  - Trajectory Management by Constraints
- **Urban Metroplex-like Operations**
  - Autonomous Departure and Arrival Procedures and Technology (ADAPT)


# Multi-Agent Teaming

- **Operator State Monitoring**
  - Channelized/Diverted Attention
  - Optimizing Decision Making
  - Incapacitation




- **Function Allocation Assessments**
  - Separation Assurance Functions
  - Cockpit Roles – Ongoing with FAA OKC

- **Adaptive Automation/Cockpit Interfaces**
  - Collaborative Agent for Path Planning Execution (CAPPE)
  - Cockpit Alerting for Inattentive Operators
  - Traffic Surveillance by Increasingly Autonomous System

- **Connected Aircraft/Vehicles**
  - Dispatch-Aircraft Trajectory Collaboration

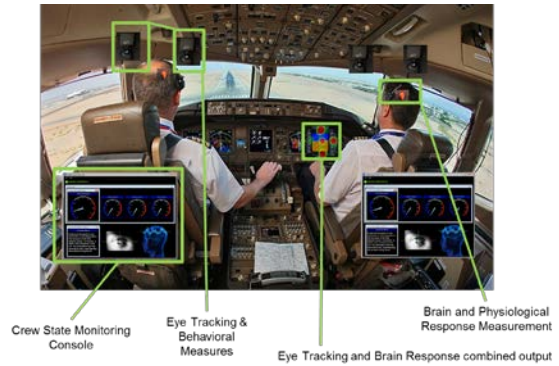
- **Vehicle to Vehicle (V2V) Collaboration**
  - Drone and Rover collaboration
  - V2V Teaming for CD&R

# Human-System Interaction

- **Vision Systems Technologies**
  - Enhanced Flight Vision Systems (EFVS)
  - Synthetic and Enhanced Vision Systems (SEVS)
  - eXternal Vision Systems (XVS)

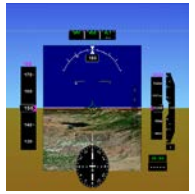
- **Head Worn Displays**
  - Improve Operator's Situational Awareness
  - Augmented Reality

- **Training for Attention Management**
  - Addressing and Improving Operator Self Management
    - Aircraft State Awareness/Instrument Scan
  - Increased Efficiency in Ground Training




- **Advanced and Configurable Cockpit Displays**
  - Vehicle Attitude Awareness and Safety
  - Traffic and Constraint awareness

- **Gesture and Voice Controls**
  - Small UAS Management and Control
  - Voice Activated Cockpit Management System



# Trust and Certification

- **Development of Human-Autonomous System Teaming Metrics**
- **Trusting Non-Deterministic Autonomous Agents**
- **Trust of Humans by Increasingly Autonomous Systems**
- **Assured Algorithms for Trajectory Prediction and CD&R**
- **Certification Considerations for Non-Deterministic and Adaptive Systems**

# How Do We Get to the Future?

***Vehicles*: Manually Piloted / Remotely Piloted / Passengers / Occupants/ Fully Autonomous / Optionally Piloted / Tethered / Flocked / Floating**

*On Demand Air Transportation*
*Anyone can travel anywhere at any time.*

*Air Vehicles Operate Without Need For Pre-authorization.*

*Fixed ground-based navigation and surveillance systems are minimal, thereby enabling a cost-effective scalable and demand-adaptive infrastructure.*

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*Obtaining a pilot's license may for some vehicles / Ops require about the same level of training as is needed to obtain a driver's license.*

Legacy

PAVs

Air Taxi

Helicopters

Autonomous

Cargo

Commercial Air Transport

…personic Vehicles

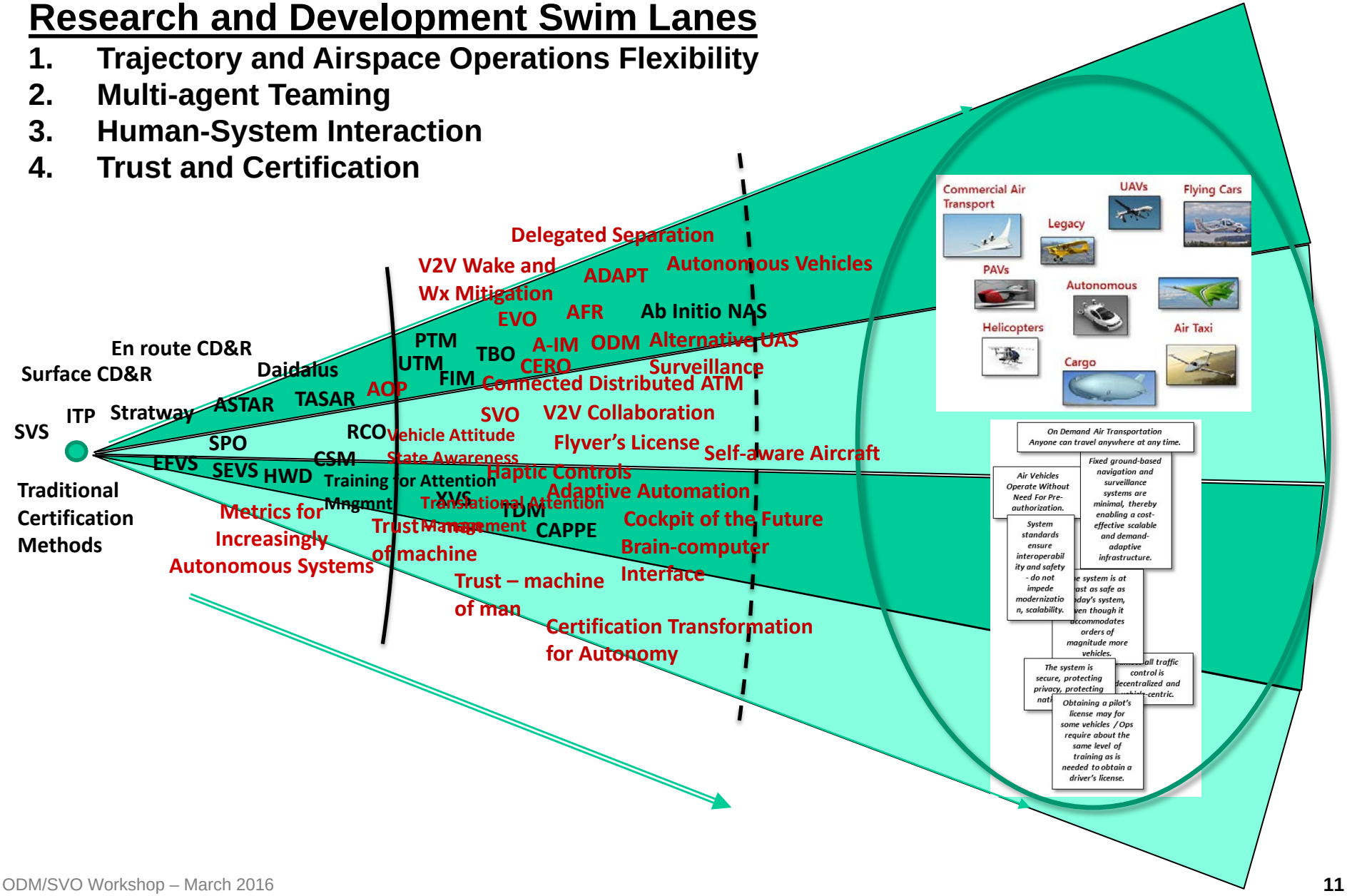
UAVs

**There Are Many Possible Outcomes / Instantiations of What the Future Will Be… We Need To Create Technologies That Can Enable Any Number Of These Possibilities**

# How Do We Get to the Future?

## Research and Development Swim Lanes

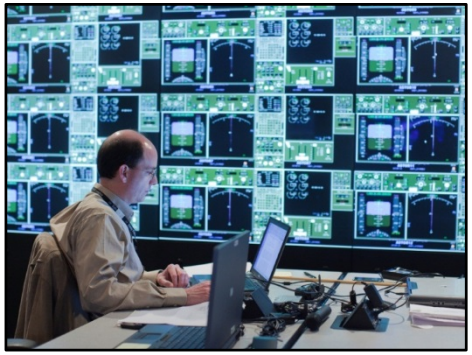
1. Trajectory and Airspace Operations Flexibility
2. Multi-agent Teaming
3. Human-System Interaction
4. Trust and Certification

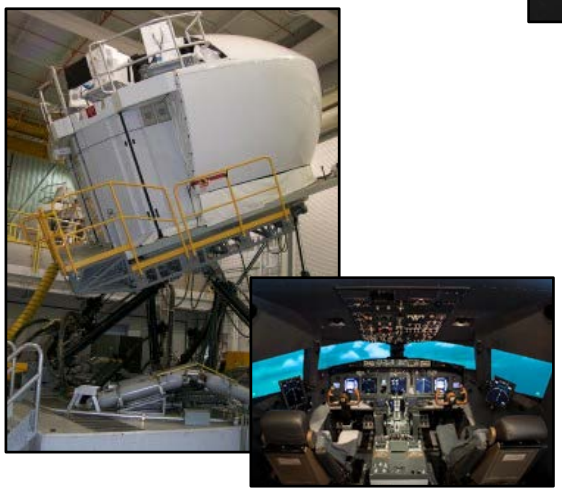


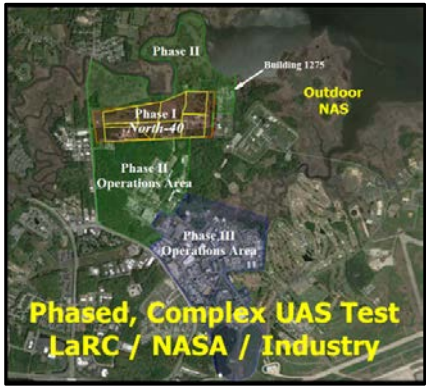
# Where CSAOB Wants to Go With R&D

- **Adaptive Human-Automation Interaction/Teaming**
- **Vehicle Operational Autonomy**
- **Onboard Trajectory Management**
- **Cockpit of the Future**
  - Including for Variably Crewed Vehicles
  - Operator Training and Certification Requirements
- **Connected Aircraft and V2V Collaboration Solutions**
- **Increasingly Autonomous System Solutions for:**
  - Emergency Response Vehicles
  - Thin Haul sized aircraft
  - General Aviation
- **Certification, Trust, and V&V of Complex Systems**
- **Integration of Revolutionary Vehicles into the NAS**
  - sUAS, PAV, VTOL, Supersonic, Fully Autonomous Vehicles
- **Efficient Airspace Solutions and Procedures**
  - Including Trajectory Based Operations
- **Identification, Alerting, and Mitigation of Safety Issues**

# CSAO / LaRC Facilities






# Questions?