Embracing Innovation in Aviation While Respecting Its Safety Tradition

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Connections & communications are internet-based & built on industry standards & protocols
Technology Capability Levels (TCLs)

TCL 1, 2 and 3 (in progress)

<table>
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<tr>
<th>Participating Orgs</th>
<th>TCL 1</th>
<th>TCL 2</th>
<th>TCL 3</th>
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<tr>
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<td>19</td>
<td>42</td>
<td>35</td>
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Transformation – Urban Air Mobility

Increasingly autonomous – focused on access, safety and scalability
URBAN AIR MOBILITY: SMALL DRONES TO LARGER PASSENGER CARRYING VTOLS
Emerging and Heritage Users

- Commercial Space Operations
- Supersonics and Hypersonics
- High Altitude Operations (upper E)
- Subsonic Transport Aviation
- Urban Air Mobility
- Small Unmanned Aircraft Systems

Access
Efficiency
Safety
Scalability

Economy
Affordability
Ubiquitous
FLEXIBILITY WHERE POSSIBLE, STRUCTURE WHERE NECESSARY

AIRCRAFT
- SEPARATION
- LAST/FIRST 100 FT
- ENHANCED FLIGHT RULES

AIR NAVIGATION SERVICE PROVIDER
- DIRECTIVES
- DEMAND/CAPACITY MANAGEMENT
- AIRSPACE CONSTRAINTS MANAGED BY EXCEPTION

"UTM" SYSTEM

OPERATIONS CENTER
- TRAJECTORY PLANNING
- SCHEDULING OPERATION
- DYNAMIC ROUTING
- FLIGHT AND FLEET MONITORING
- CONTINGENCY SUPPORT

SUPPORT SERVICE SUPPLIERS
- WEATHER
- TRACKING
- SEPARATION
- 3D MAPS
- SPACING
- COMMUNICATION

RESEARCH TO DETERMINE SERVICES, PERFORMANCE NEEDS, AUTOMATION CAPABILITIES FOR SCALED OPERATIONS
Connectivity is Key

- Availability – real-time and prediction
- Contingencies and emergency
- Priority of certain vehicles
- Schedules at various resources
- Efficient flows and managing disturbances
- Performance and risk-based
- Scheduling, spacing, separation
- Weather and disturbance management

Autonomy alone will not lead to efficiency and large-scale disturbance management. Connectivity is crucial – air/ground/cloud/infrastructure integration will be key.
### UTM-LIKE-ATM AIRSPACE OPERATIONS ENVIRONMENT

**Space Traffic Management**

- Cooperative
- Intent-sharing
- Digital: data exchanges among operators
- Standardized application protocol interfaces
- Air/ground integrated
- Service-oriented architecture
- Role for third parties

<table>
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<tr>
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<th>Description</th>
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<tr>
<td>High Altitude UTM (Upper E)</td>
<td>Conventional Manned Aviation (Class A, B, C, D, E)</td>
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<td>Urban Air Mobility</td>
<td>Low-altitude small UAS</td>
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Increasingly Autonomous and Connected Operations
All services are provided by the FAA:
- Traffic flow management
- Airspace directives/constraints
- Scheduling, sequencing and spacing
- Separation management
- Off-nominal management
- Every vehicle interaction in real-time

FAA Systems
Humans address off-nominal and contingencies

Very little interaction among users, and 3rd party services

Some services are provided by FAA:
- Airspace directives/constraints
- Resource availability and changes to resources (e.g., arrival/departure rates, resource schedules)

UTM-inspired-ATM

User or third party services

FAA Systems
- Flow management
- Sequencing, and spacing
- User participation strategic Separation (e.g., oceanic)

Automation addresses off-nominal and contingencies

Users collaborate/cooperate for efficiency, intra-user preferences for flights into constrained resources

- Automation in the epi-center of information integration
- New paradigm: digital and connected ecosystems - outside apps, scalability

NASA Unique Role: Architecture, data exchange, service allocation/roles/responsibilities, rules of engagement, service performance requirements, automation for contingency management and disruption handling, machine learning environment and algorithms for continuous improvement, safety assurance, certification/acceptance approaches, and technology transitions
Inter-island Autonomous Cargo Delivery (2025+)

Larger vehicle – single pilot, off-board manager, or fully autonomous depending on vehicle size
Transformation – In stages – Initial Applications
Larger than small drones (~2020+?)

Lowest risk – Grand Canyon or over water deliveries

Mail delivery by mule train in the Grand Canyon

JW Westcott mail delivery by boat

PICTURES FROM USPS.GOV
Future Airspace Operations?

- Scalable – increasingly autonomous
- Cooperative – information needs, and technologies for cooperation among vehicles, and operators, and service providers
- Digital – data exchanges and standardized application protocols
- Resilient – technologies and procedures for faster recovery from disruptions
- Manage by exception – flexibility where possible and structure where necessary
- Safety assurance – in-time data, prognostics, V&V of increasingly autonomous systems
- Air/ground/cloud integrated
- Service oriented architecture – third party

Space Traffic Management

High Altitude UTM (Upper E)

Conventional Manned Aviation (Class A, B, C, D, E)

Urban Air Mobility

Low-altitude small UAS

Airspace operations... ....enabling beyond possible!
Concluding Remarks

• Need for change is real, current systems are not sustainable

• Sense of urgency due to emerging markets and diversity of operations

• Build-a-little-test-a-little and deploy

• Research issues remain – however goal should be "cross the finish line" to improve operations – research is means to an end and not an end in itself

• Highly scaled operations that are affordable and safe
embracing innovation in aviation while respecting its safety tradition