Embracing Innovation in Aviation While Respecting Its Safety Tradition

Parimal Kopardekar, Ph.D.
NASA Senior Technologist for Air Transportation System
Acting Director, NASA Aeronautics Research Institute (NARI)
Parimal.H.Kopardekar@nasa.gov
Daily Flight Demand for All Users in 2025

Uncontrolled Airspace Commercial Space Traffic Management

- Uncontrolled Airspace High-Altitude Unmanned and Manned Traffic Management
- Supersonic Trajectories
- Controlled Airspace: Class A, B, C, D, E
- PAVs
- Uncontrolled Airspace: Class G (ceiling varies, typically 1200 AGL)

Commercial Launches

- Terminal / Metroplex
- ODM
- Swarms
- Pocket Airports
- Low Altitude Urban
- 2.7M UAS at low alt

Alt: 120K & Up
10s to 100s Ops

Alt: 60K & Up
Supersonics: 10s to 100s
Commercial: 25K

Top of Class G
PAVs and ODM: 1K to 37K
UAS: 10K - Millions
GA: 3K+
Connections & communications are internet-based & built on industry standards & protocols
URBAN AIR MOBILITY: SMALL DRONES TO LARGER PASSENGER CARRYING VTOLS
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.
**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

### UTM-LIKE-ATM AIRSPACE OPERATIONS ENVIRONMENT

| High Altitude UTM (Upper E) |
| Conventional Manned Aviation (Class A, B, C, D, E) |
| Urban Air Mobility |
| Low-altitude small UAS |
Current ATM

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

• Human in the epi-center of information integration
• Every data moves through FAA systems for every vehicle
• Each change focused in on domain-specific FAA system

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

UTM-Inspired-ATM

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

Separation

• User or third party services
• Automation addresses off-nominal and contingencies

Automation addresses off-nominal and contingencies

• User participation strategic Separation (e.g., oceanic)

Very little interaction among users, and 3rd party services

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

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

PICS 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!
Connectivity is key

- Availability – real-time and prediction
- Contingencies and emergency
- Fleet optimization
- Priority of certain vehicles
- Schedules at various resources
- Efficient flows and managing disturbances
- Airworthiness
- Health and status
- Performance

Operations center - fleet

Infrastructure resources

Airspace operations

Vehicle

Autonomy alone will not lead to efficiency and large-scale disturbance management. Connectivity is crucial – air/ground/cloud/infrastructure integration will be key.
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

Air Navigation Service Provider
Technology Capability Levels (TCLs)

TCL 1, 2 and 3 (in progress)

- **Nat’l Campaign 1: May 2016**
- **Nat’l Campaign 2: June 2017**
- **TCL 1 demo: August 2015**
- **TCL 2 demo: Oct 2016**
- **TCL3 UAS towards controlled airspace**
- **TCL3 March 2018**

**Participating Orgs**

<table>
<thead>
<tr>
<th>TCL</th>
<th>Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>TCL 1</td>
<td>19</td>
</tr>
<tr>
<td>TCL 2</td>
<td>42</td>
</tr>
<tr>
<td>TCL 3</td>
<td>35</td>
</tr>
</tbody>
</table>
Transformation – Urban Air Mobility

Increasingly autonomous – focused on access, safety and scalability