Embracing Innovation in Aviation While Respecting Its Safety Tradition

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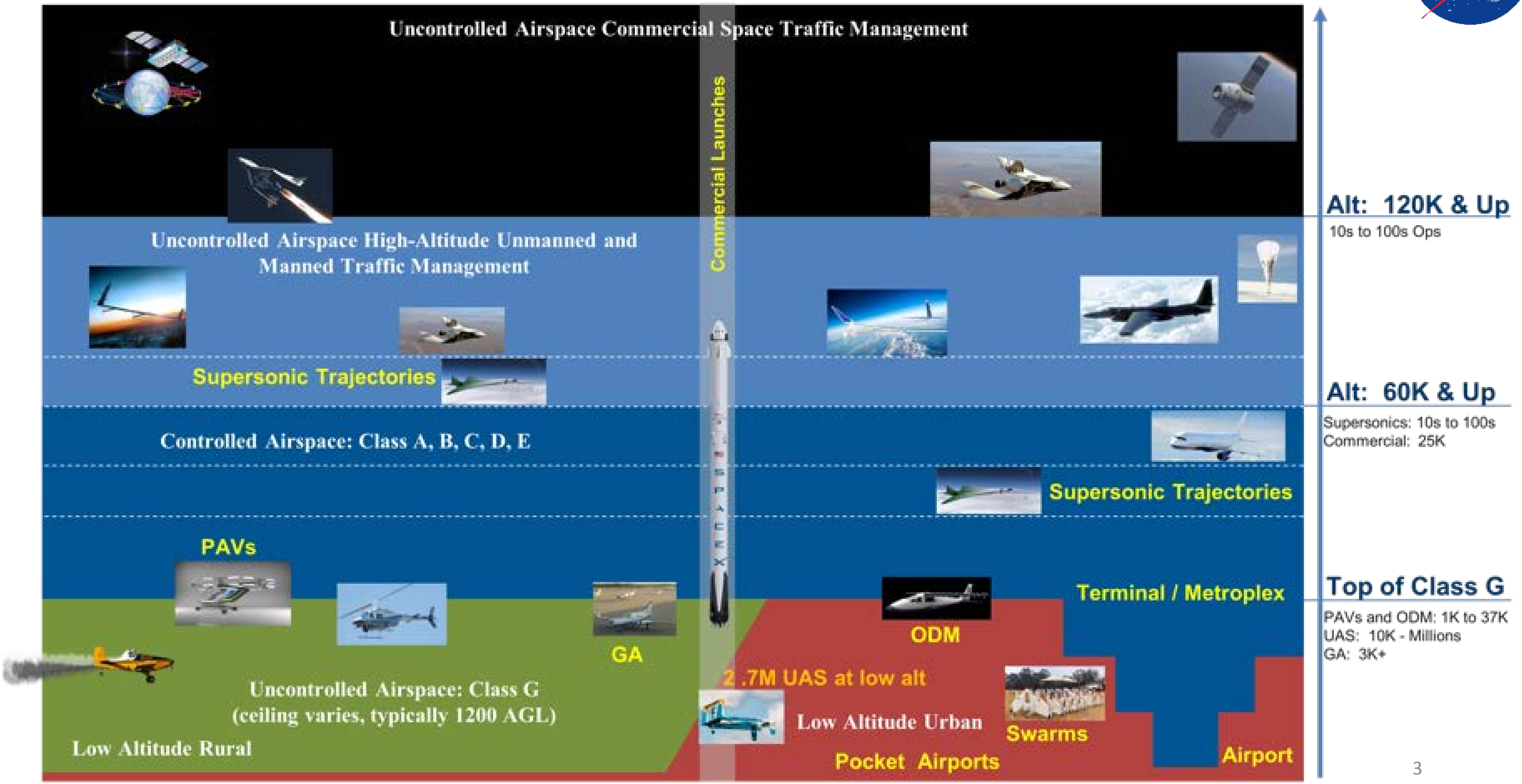
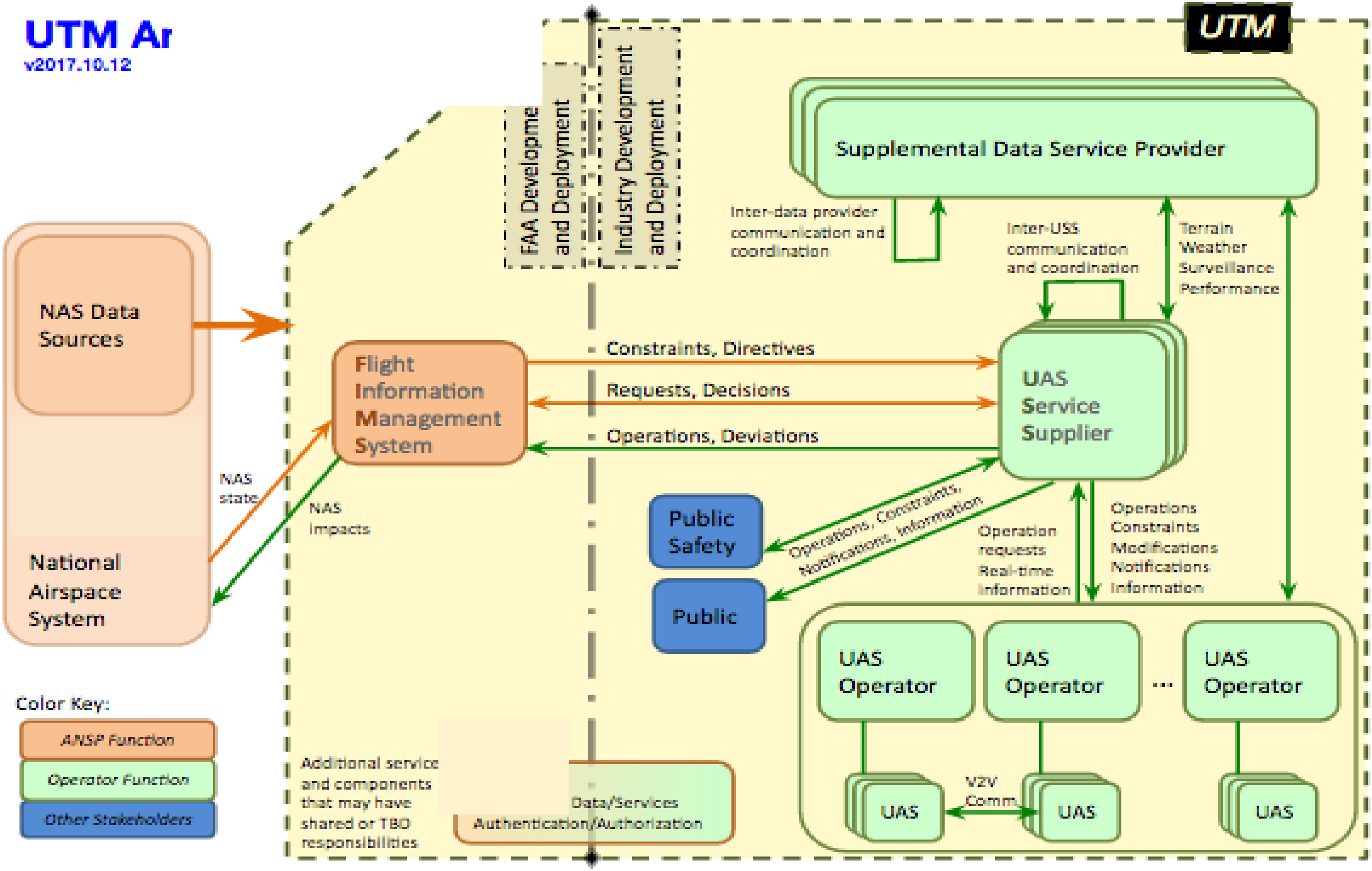
CURRENT AIRSPACE OPERATIONS


Uncontrolled Airspace Commercial Space Traffic Management
Commercial Launches
Uncontrolled Airspace High-Altitude Unmanned and Manned Traffic Management
Supersonic Trajectories
Controlled Airspace: Class A, B, C, D, E
Supersonic Trajectories
PAVs
Terminal / Metroplex
ODM
GA
2.7M UAS at low alt
Uncontrolled Airspace: Class G
(ceiling varies, typically 1200 AGL)
Low Altitude Rural
Low Altitude Urban
Swarms
Pocket Airports
Airport
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+

SMALL UNMANNED AIRCRAFT SYSTEMS

UAS Traffic Management Architecture



*Connections & communications are internet-based & built on industry standards & protocols

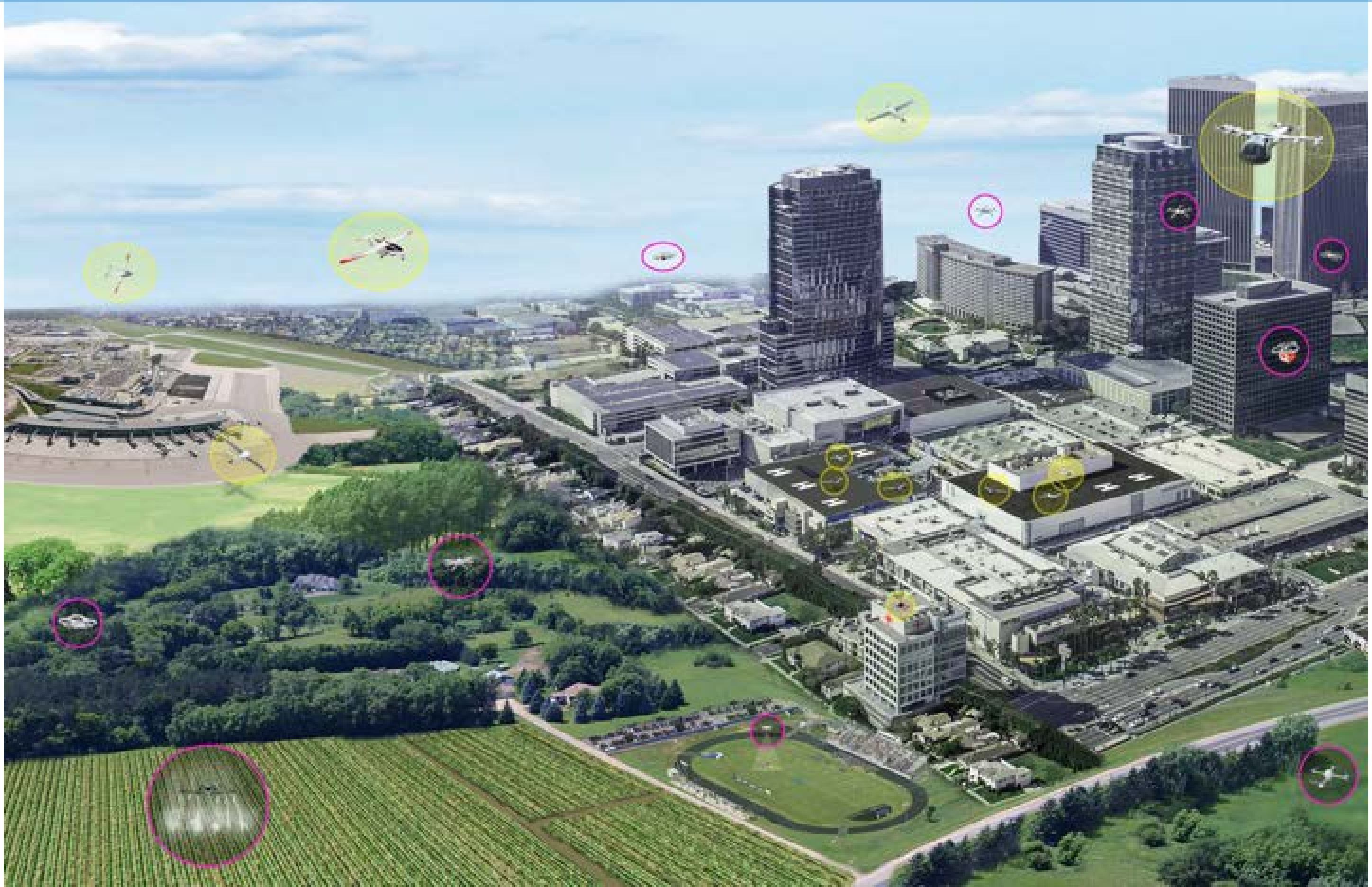
Technology Capability Levels (TCLs)

Participating Orgs	
TCL 1	19
TCL 2	42
TCL 3	35

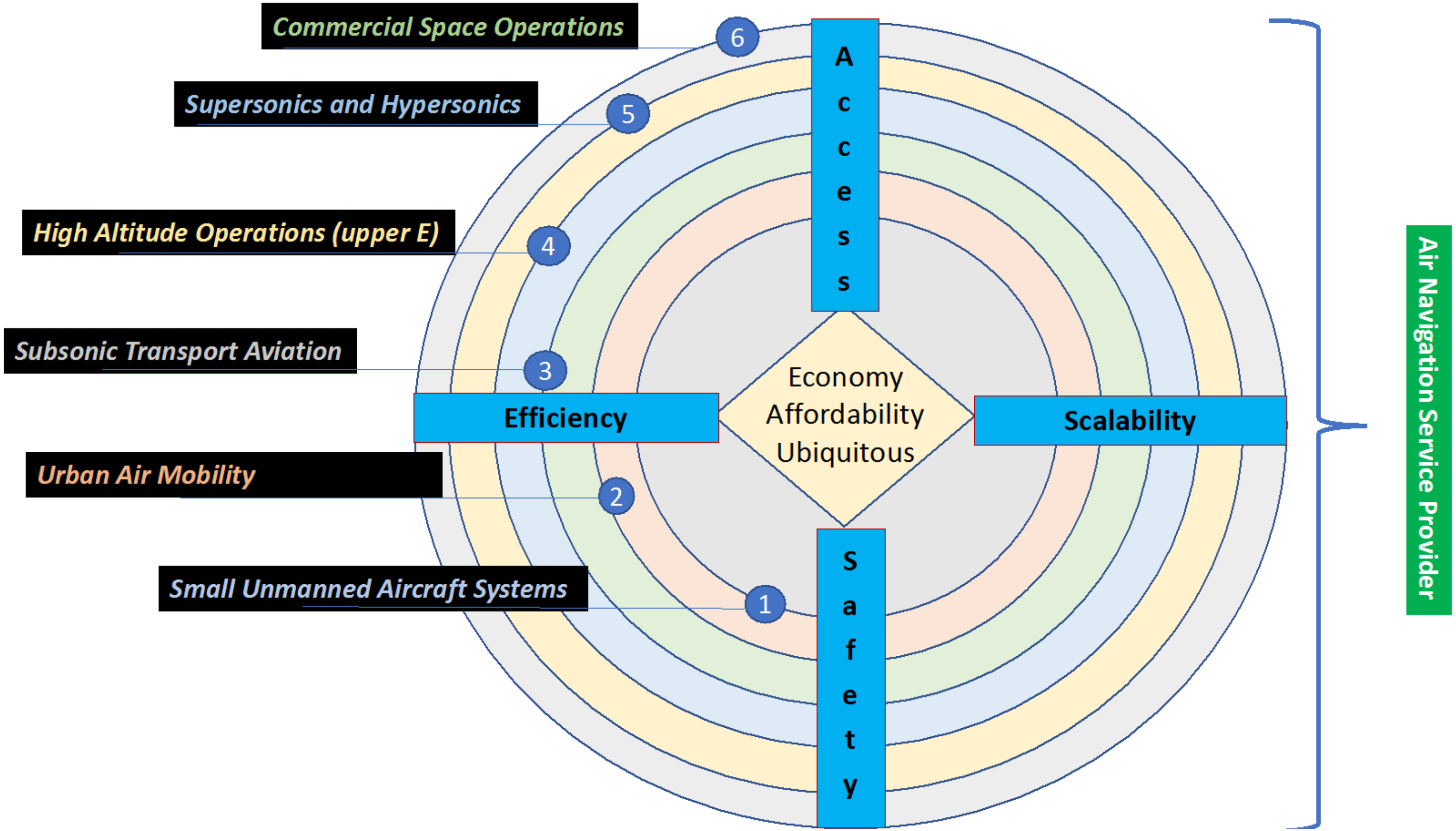
Transformation – Urban Air Mobility

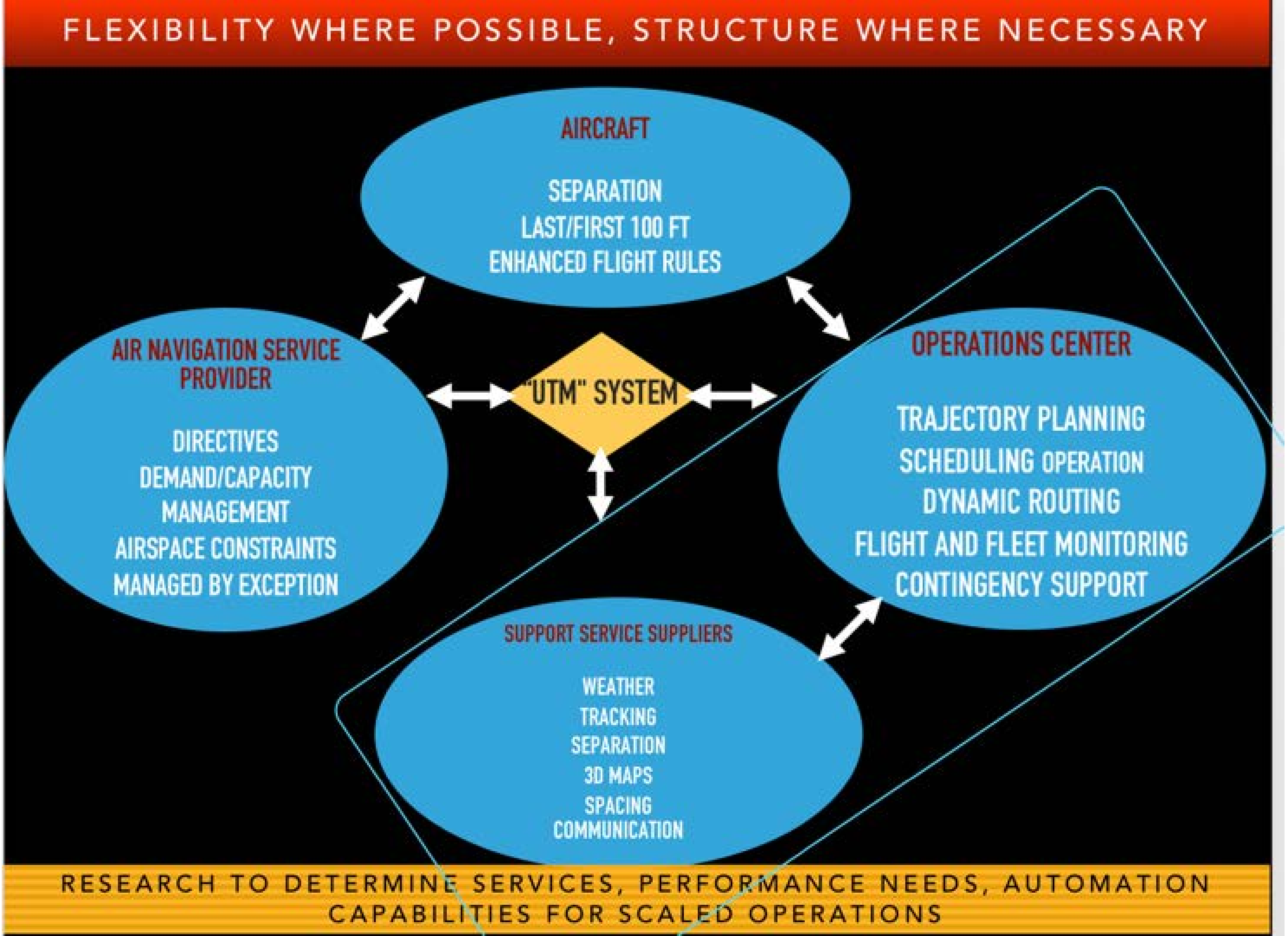
Increasingly autonomous – focused on access, safety and scalability

URBAN AIR MOBILITY: SMALL DRONES TO LARGER PASSENGER CARRYING VTOLS



Emerging and Heritage Users




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

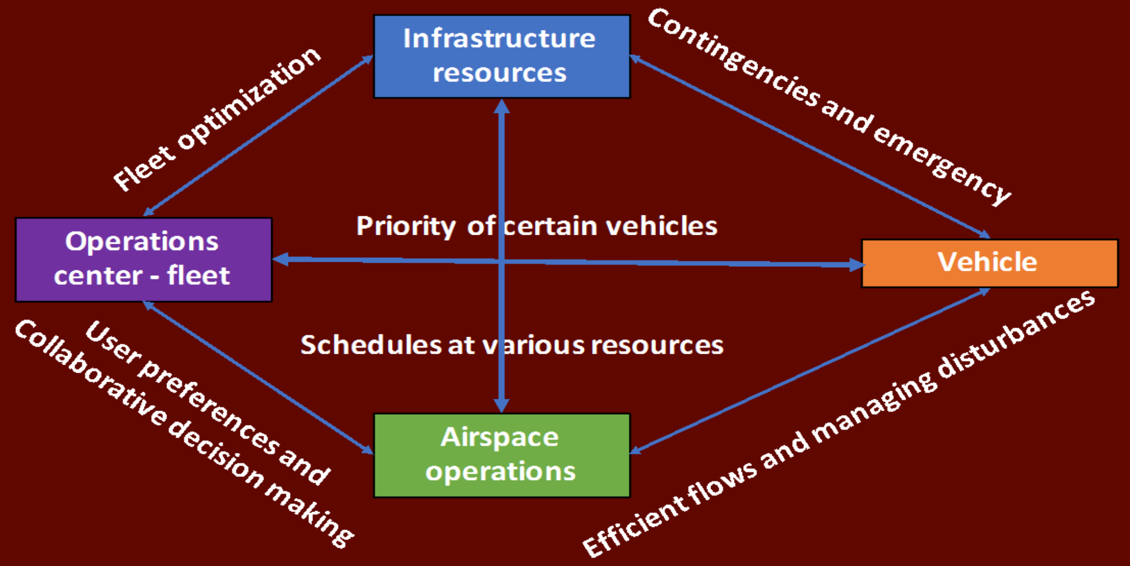
CONNECTIVITY IS KEY

- Availability – real-time and prediction

…

- Demand
- Network

…



- Airworthiness
- Health and status
- Performance

…

- Performance and risk-based
- Scheduling, spacing, separation
- Wx 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

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

Space Traffic Management

High Altitude UTM (upper E)

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

Urban Air Mobility

Low-altitude small UAS

Increasingly Autonomous and Connected Operations

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

Airspace User

Airspace User

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

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

FAA Systems

User or third party services
- Flow management
- Sequencing, and spacing
- User participation strategic Separation (e.g., oceanic)

Automation addresses off-nominal and contingencies

Airspace User

New Airspace User

Airspace User

Airspace User

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

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

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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

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BACK UP

Scalable, Safe, and Efficient Autonomous Operations

Goal: Enable autonomous operations in the national airspace system

- **Motivation:**
  - Smaller and medium size autonomous cargo delivery market is emerging
  - Use of upper and lower airspace is increasing where there are no services
  - Pilot shortage is looming – Regular transport category for short/long haul flights
  - Future urban air mobility operations business case depends on autonomous operation

- **Enable autonomous freighter operations** by integrated air/ground/cloud capabilities
  - Rationale: Regardless of level of autonomy, integration is key - SWA
  - Initial operational evaluation (TRL 4)
  - Demonstration leading up to daily use operations (TRL 6+)

- **Autonomous urban air mobility vehicle operations** – cargo and/or passengers through integrated air/ground/cloud capabilities under nominal and off-nominal condition

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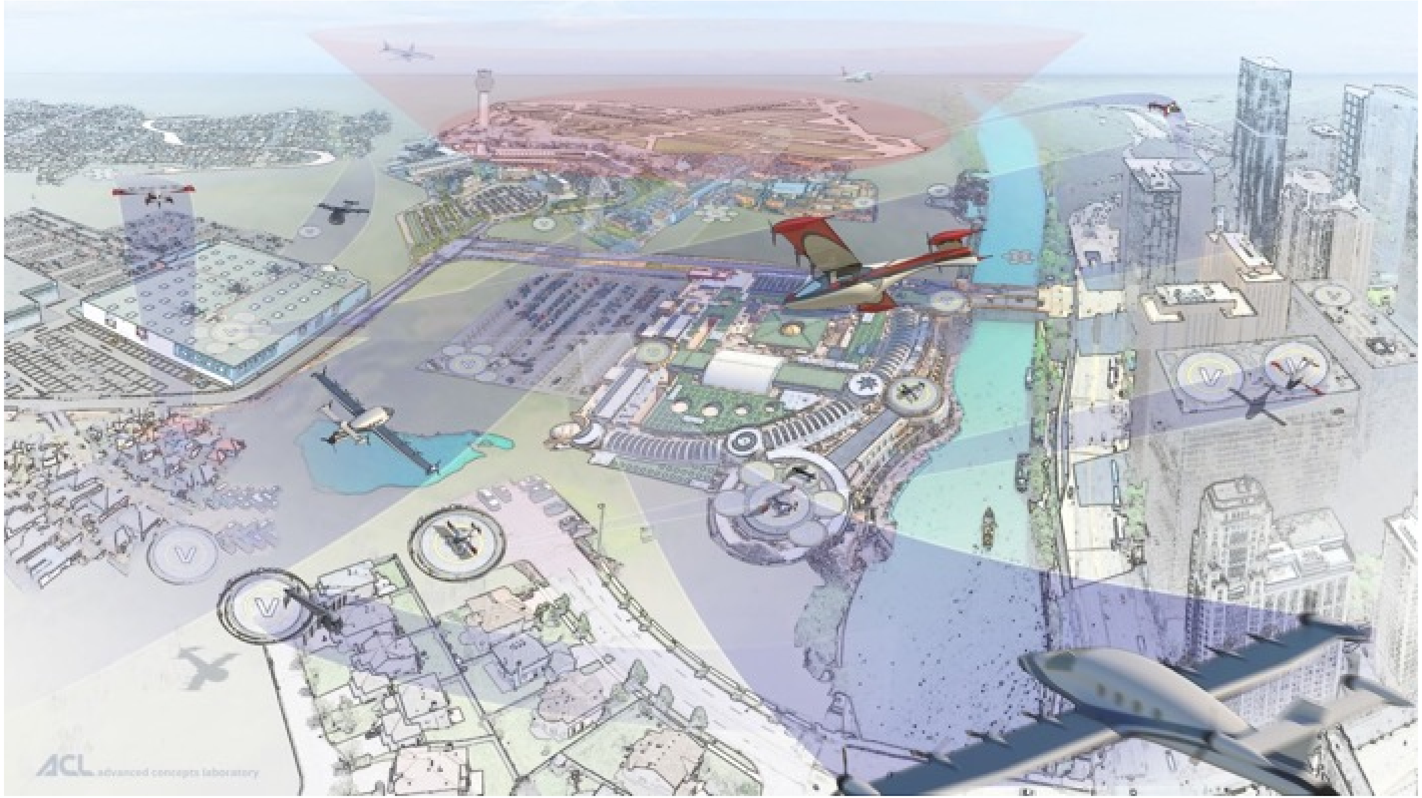
SMALL UNMANNED AIRCRAFT SYSTEMS

VERTICAL TAKE OFF AND LANDING



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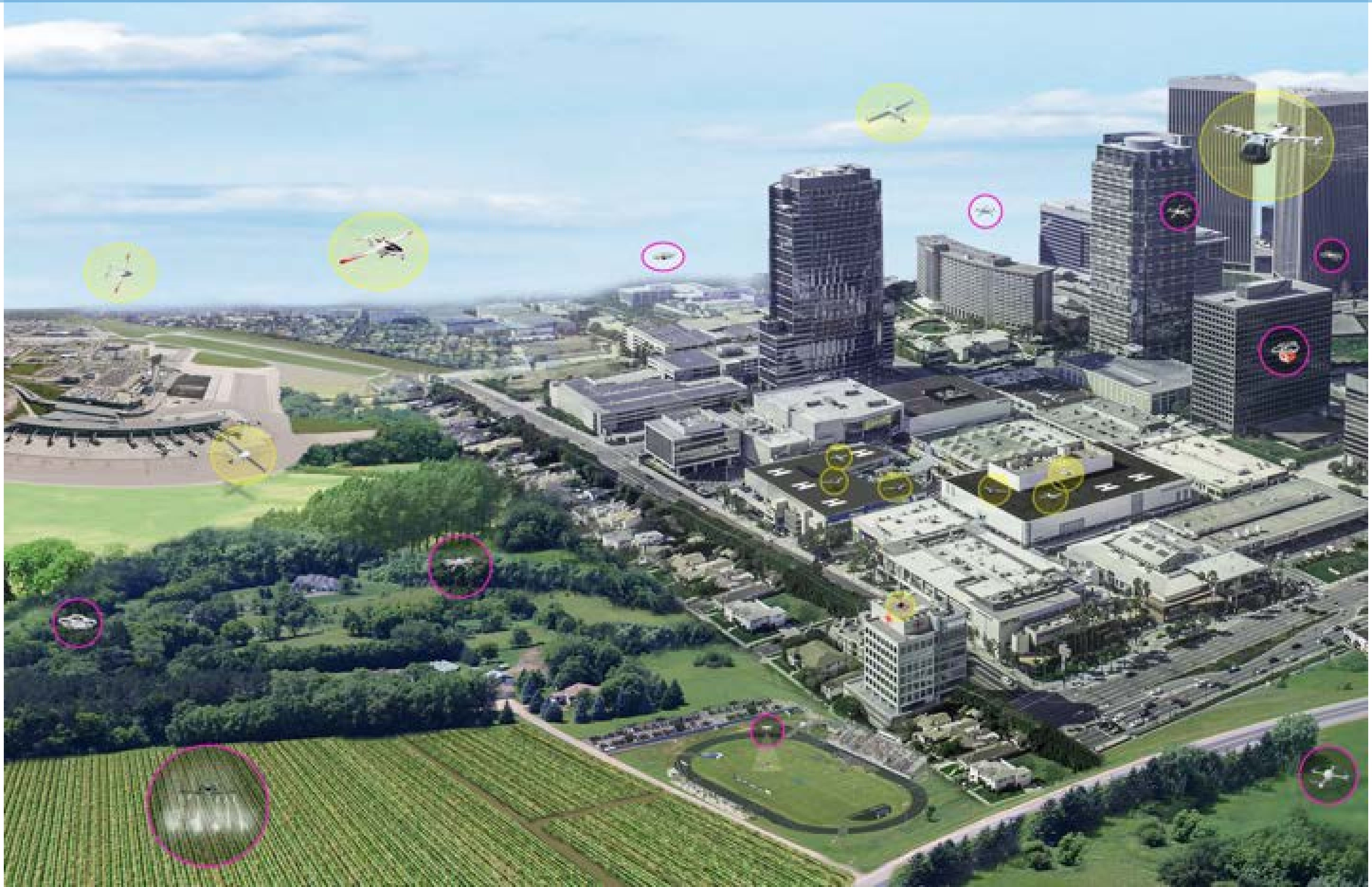

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