Enabling Airspace Integration for High Density On-Demand Mobility Operations

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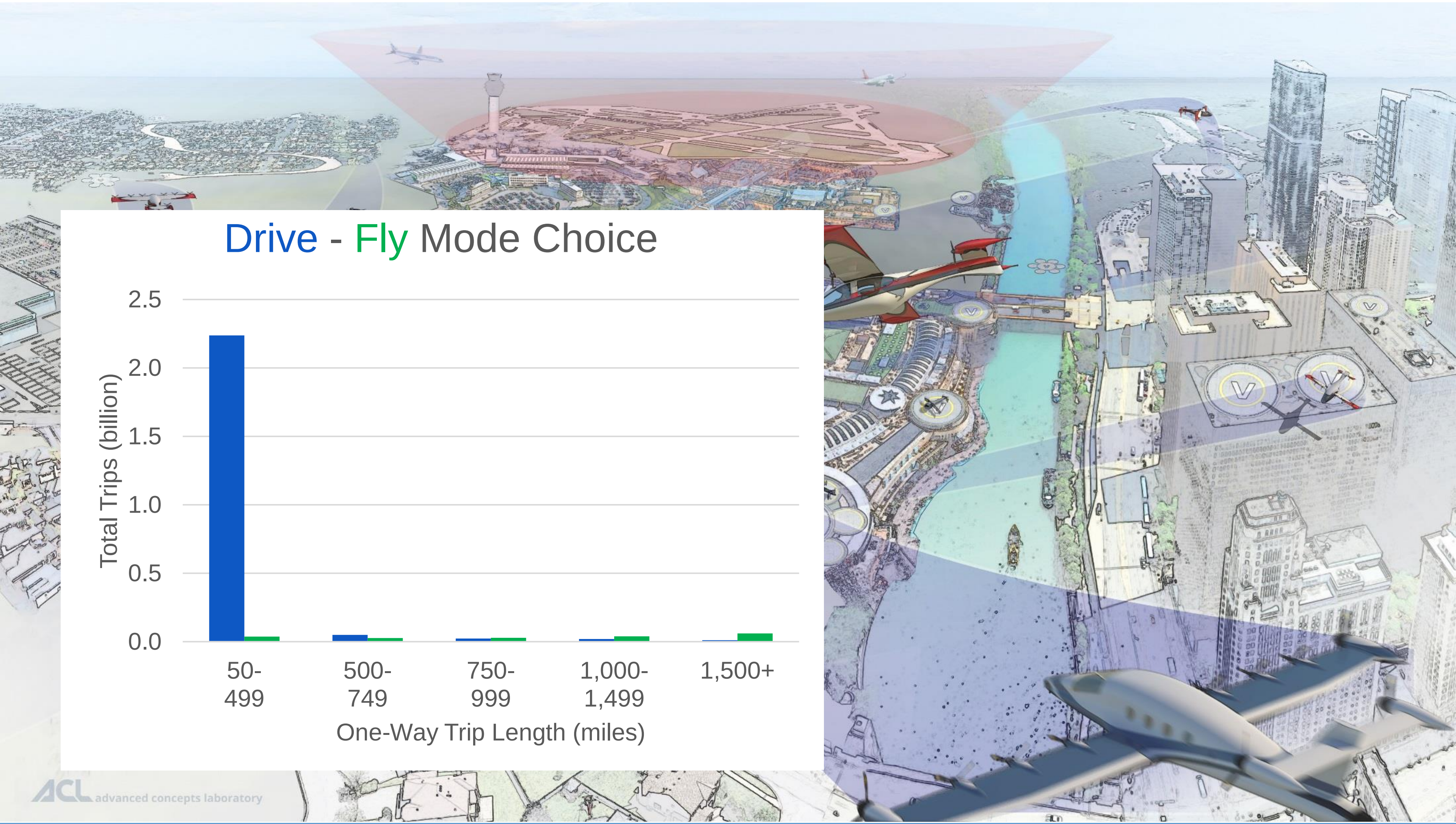
Outline

- Barriers
  - The airspace integration problem
- Opportunities
  - Integrating new airspace users
  - Review of selected capabilities
- Research approach

An incremental approach to airspace integration can achieve high-density on-demand mobility

On-demand mobility



Data source: BTS, “Long Distance Transportation Patterns: Mode Choice”, 2006

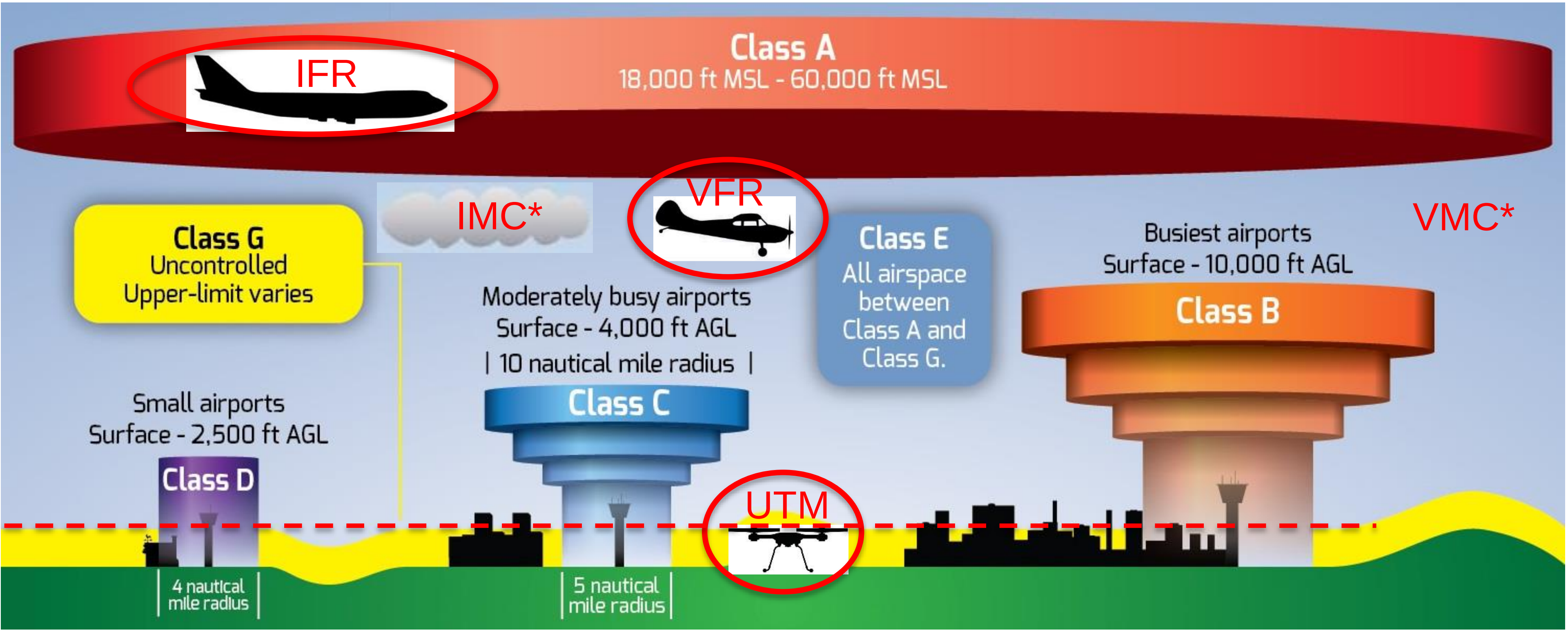
Airspace Integration Definition

Operating safely and efficiently
in a given volume without unreasonably burdening
existing airspace users or air traffic control

Airspace Integration Options

IFR (Instrument Flight Rules): under the supervision of air traffic control (ATC)
VFR (Visual Flight Rules): used largely by general aviation, not commercial operators
UTM (UAS Traffic Management): parallel ATC system for small, low altitude UAS

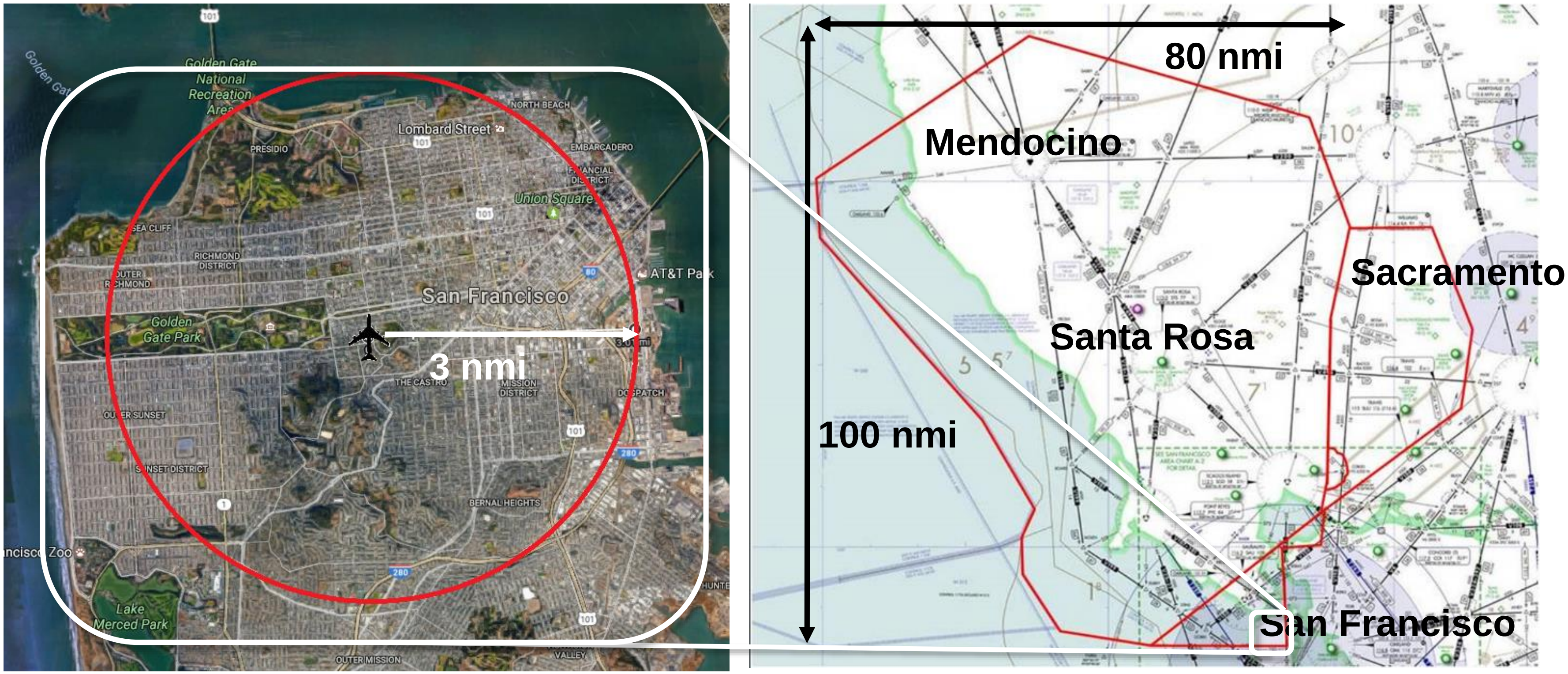
Simplified National Airspace System (NAS)



*VMC/IMC = Visual/Instrument Meteorological Conditions

The IFR Airspace Integration Problem

- High–density reference mission in a single metropolitan area (30x40 nmi)
  - 1200 aircraft, 150,000 passengers per day, more operations than the entire NAS
  - Approximately one on-demand mobility aircraft per square mile



On-demand mobility density is *~400 times* higher than the allowable IFR density

Airspace Integration for New Users

Airspace Integration Principles

1. Does not require additional air traffic control (ATC) infrastructure
2. Does not impose additional workload on human controllers (i.e. ATC)
3. Does not restrict operations of traditional airspace users
4. Will meet appropriate safety thresholds and requirements
5. Will prioritize operational scalability to reach high aircraft densities
6. Allows flexibility where possible and imposes structure where necessary

Airspace Integration Approaches

Start where you are with what you have…

Approach	Advantages	Disadvantages	Prognosis for urban mob.
IFR	Air traffic services allow operation anywhere, anytime	Not scalable	Operationally incompatible, automated technologies and services may extend to urban mobility
VFR	Maximum autonomy from ATC for manned aircraft	Must provide own ATC services, no IMC ops, not scalable	Allows autonomy from ATC, but safety, scalability, and efficiency are too low
UTM	ATC ecosystem for small UAS provides all relevant services	Quality and availability of services for small UAS require extensions for manned aviation	Supplies most services necessary for high density urban mobility, but tech. and procedures still in research phase

How to get to High Density on-demand mobility

…make something of it and never be satisfied

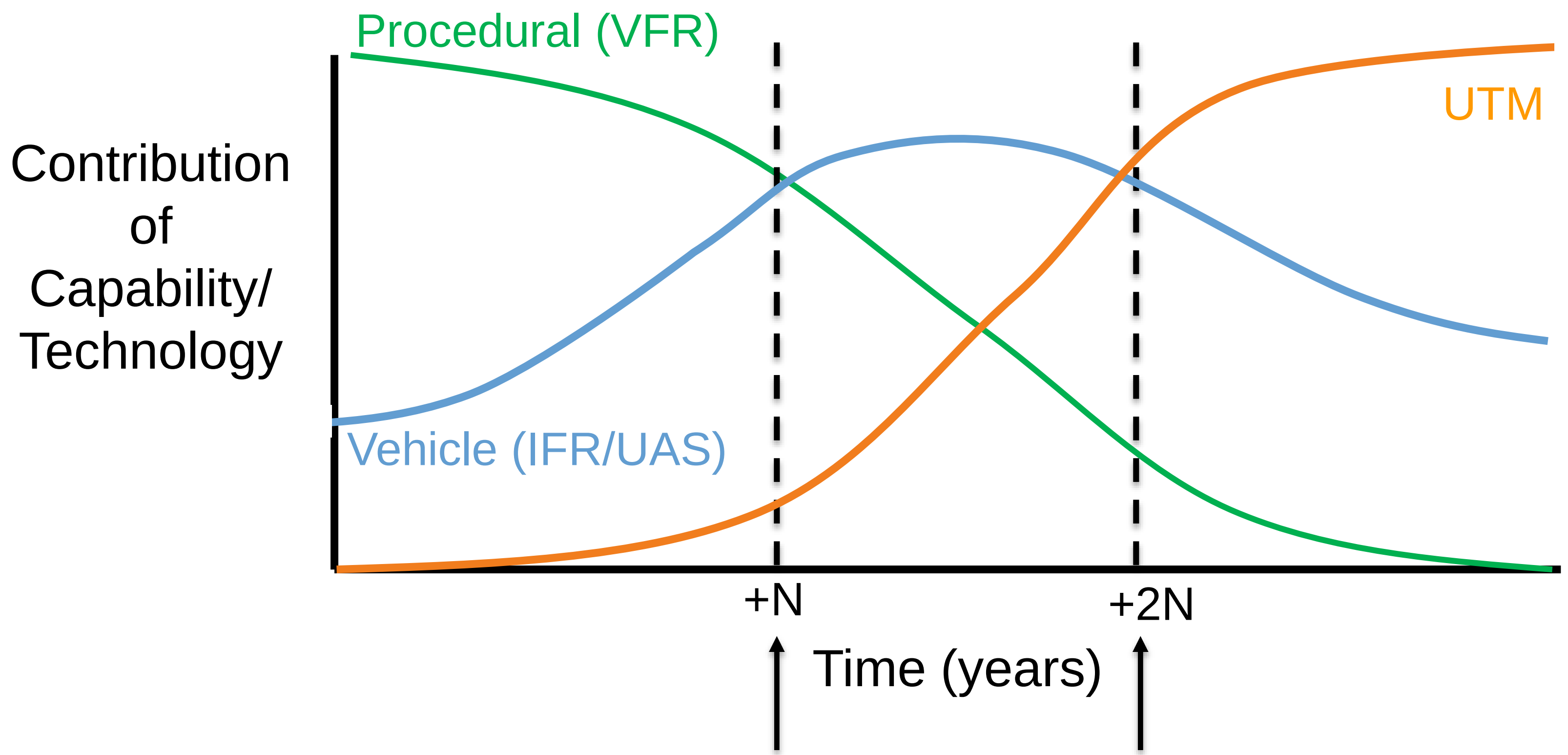
1. Start by operating VFR according to today's rules

2. Incrementally develop and certify aircraft-centric technologies to relieve operational constraints

3. Adopt UTM services as replacements for aircraft-centric technologies and VFR requirements

Approaches to Developing Capabilities

Low Density	Medium Density	High Density
VFR-dominated operations, new procedures	Advanced VFR with adapted UAS, IFR technologies	Autonomous ops. with UTM services



- See and avoid unsafe
- Sequencing and spacing inefficient
- IMC constraints

- Aircraft tech. too costly,
- Centralized coordination may be more efficient
- Pilot needs to be remote

Capabilities Required for Airspace Integration

- Communications
- Navigation
- Surveillance
- Weather/Met. Data
- Security
- Airspace routes
- Airspace constructs
- Airspace classes
- Geofencing
- Take-off and landing areas

- Demand-capacity balancing
- Separation
  - aircraft, obstacles, terrain
- Scheduling, sequencing and spacing
  - to take-off and landing areas, corridors, ops. areas
- Trajectory planning
- Wake avoidance
- All-weather and night-time operations
- Contingency management
- Community impact (noise)

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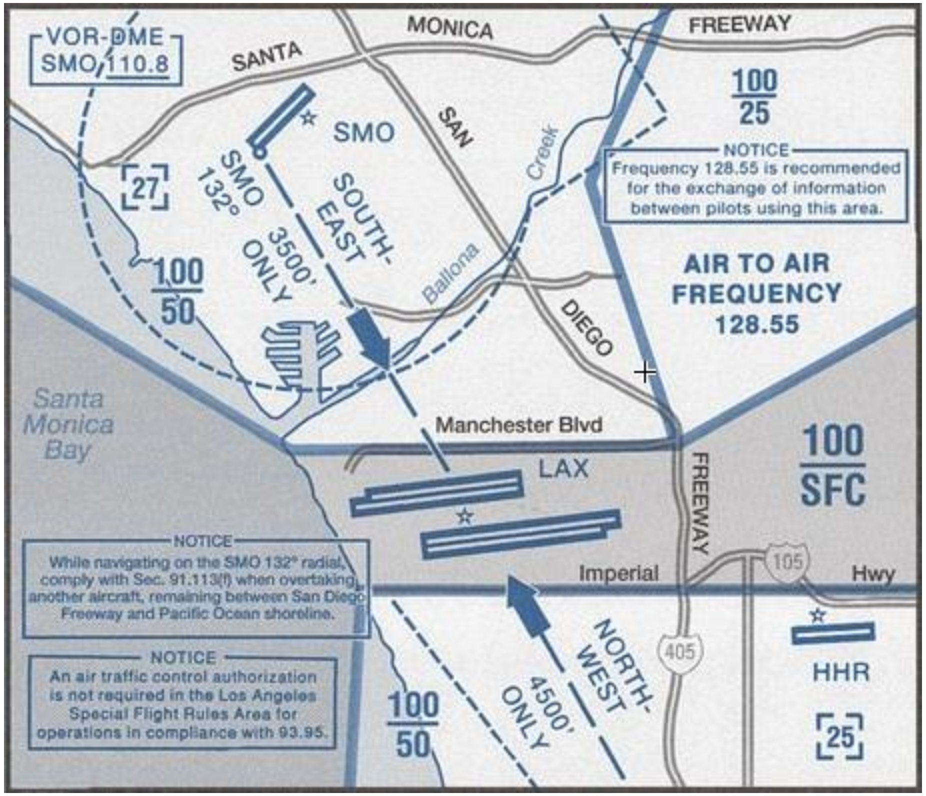
Airspace Constructs (AC)

- Today, AC consist of procedures and rules that enhance safety or efficiency
  - Los Angeles special flight rules area (SFRA)
  - Mode-C veil, with ADS-B (i.e. satellite-based surveillance)
- For on-demand mobility, airspace constructs will compensate for technological limitations
- UTM will provide more efficient airspace access than AC
  - May allow dynamic ACs

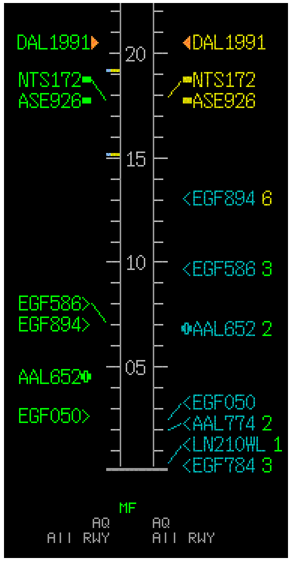


UTM would relieve the need to impose airspace constructs

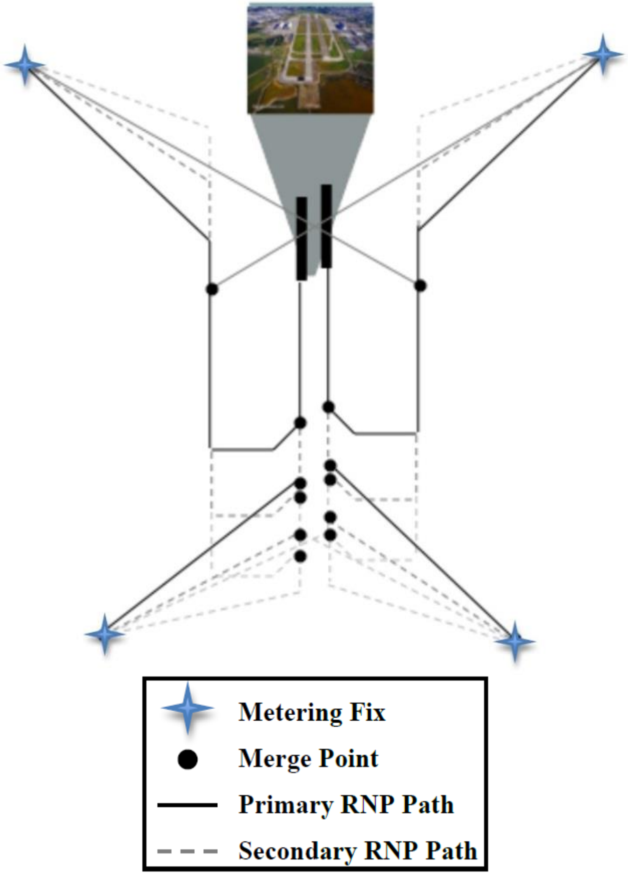
Sequencing, Scheduling, Spacing (SSS)

- Today, SSS is used to regulate the flow of traffic into constrained airspace
  - Airport (terminal) areas
    - VFR aircraft follow procedures and use vision
    - IFR aircraft sequenced far from the airport and merged by humans using advisory tools
  - Weather-impacted enroute sectors
- On-demand mobility will require an automated or distributed SSS capability for VTOLs
- UTM surveillance and trajectory prediction capabilities will directly support SSS functions

Traffic Management Advisor



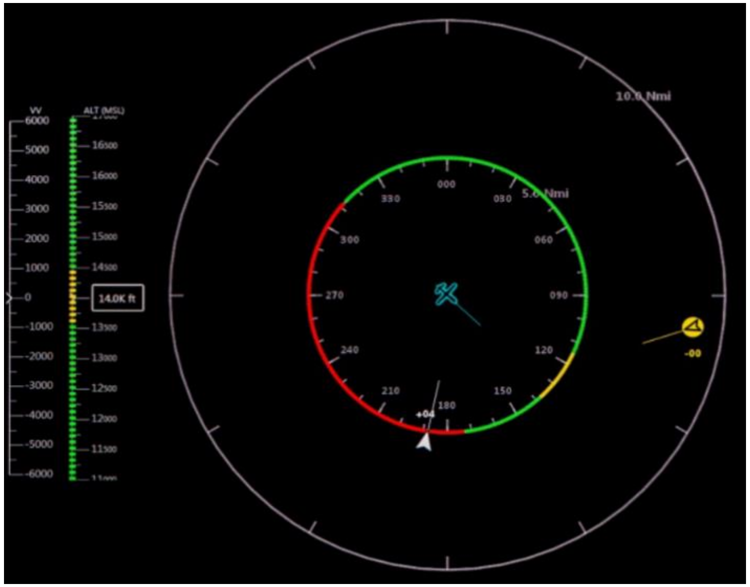
Typical arrival pattern today



UTM does not require SSS, but the services it provides could be extended to this capability

Separation Services

- Today, different aircraft types separate differently
  - VFR aircraft separate visually
  - IFR aircraft separated by ATC, but require visual and electronic collision avoidance
  - Right-of-way rules for aircraft classes
- On-demand mobility aircraft will assume responsibility for separation to avoid IFR capacity limitations
  - UAS detect-and-avoid (DAA) systems
  - Vehicle-to-vehicle (V2V) technologies
- UTM will provide surveillance and separation services, but tailored for small UAS

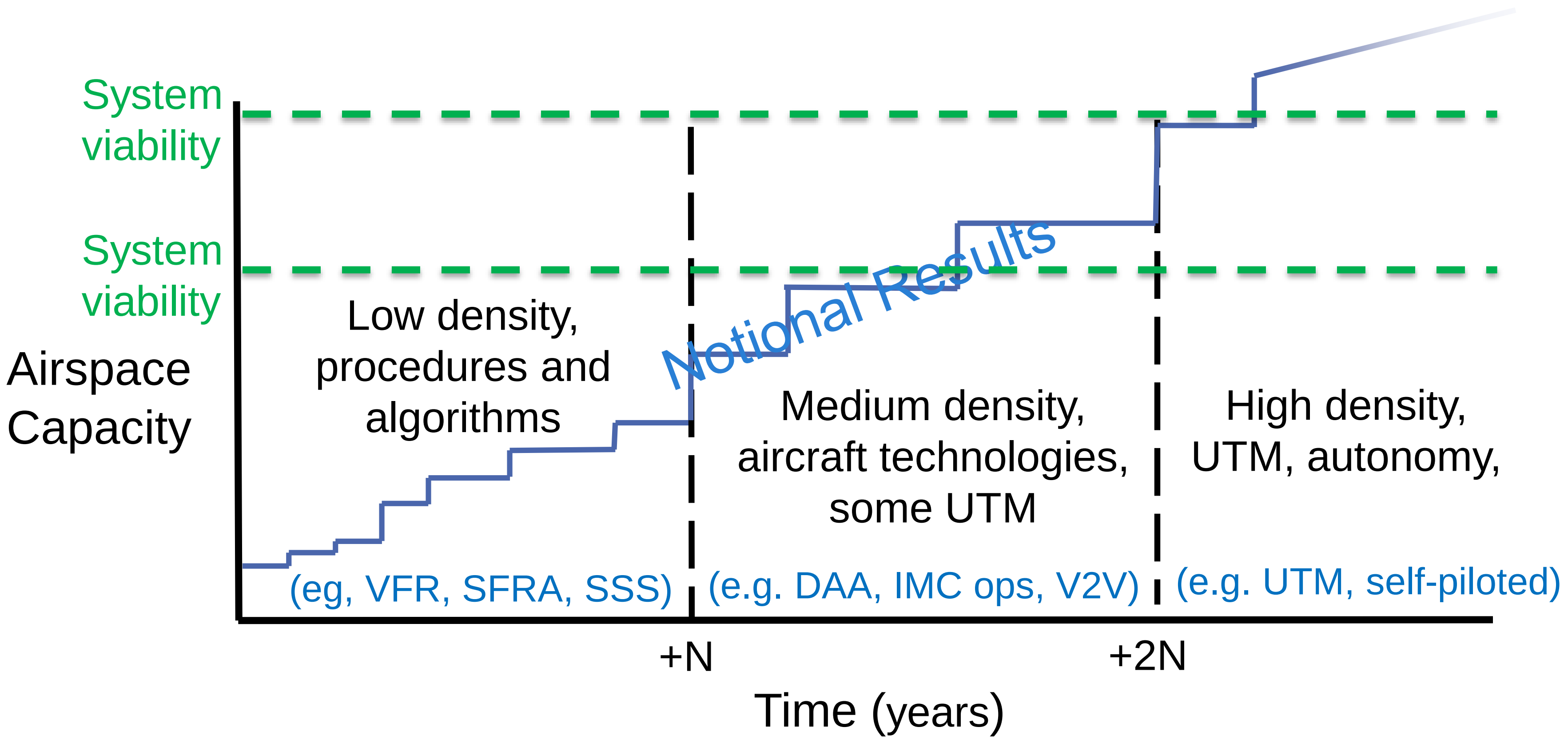


UTM provides separation services, need to reduce risk to apply them to human-carrying aircraft

Research Approach for Airspace Integration

Airspace Capacity Enablers

What capabilities will increase the capacity of the airspace?



Deliver validated data on the cumulative benefits and costs of these capabilities

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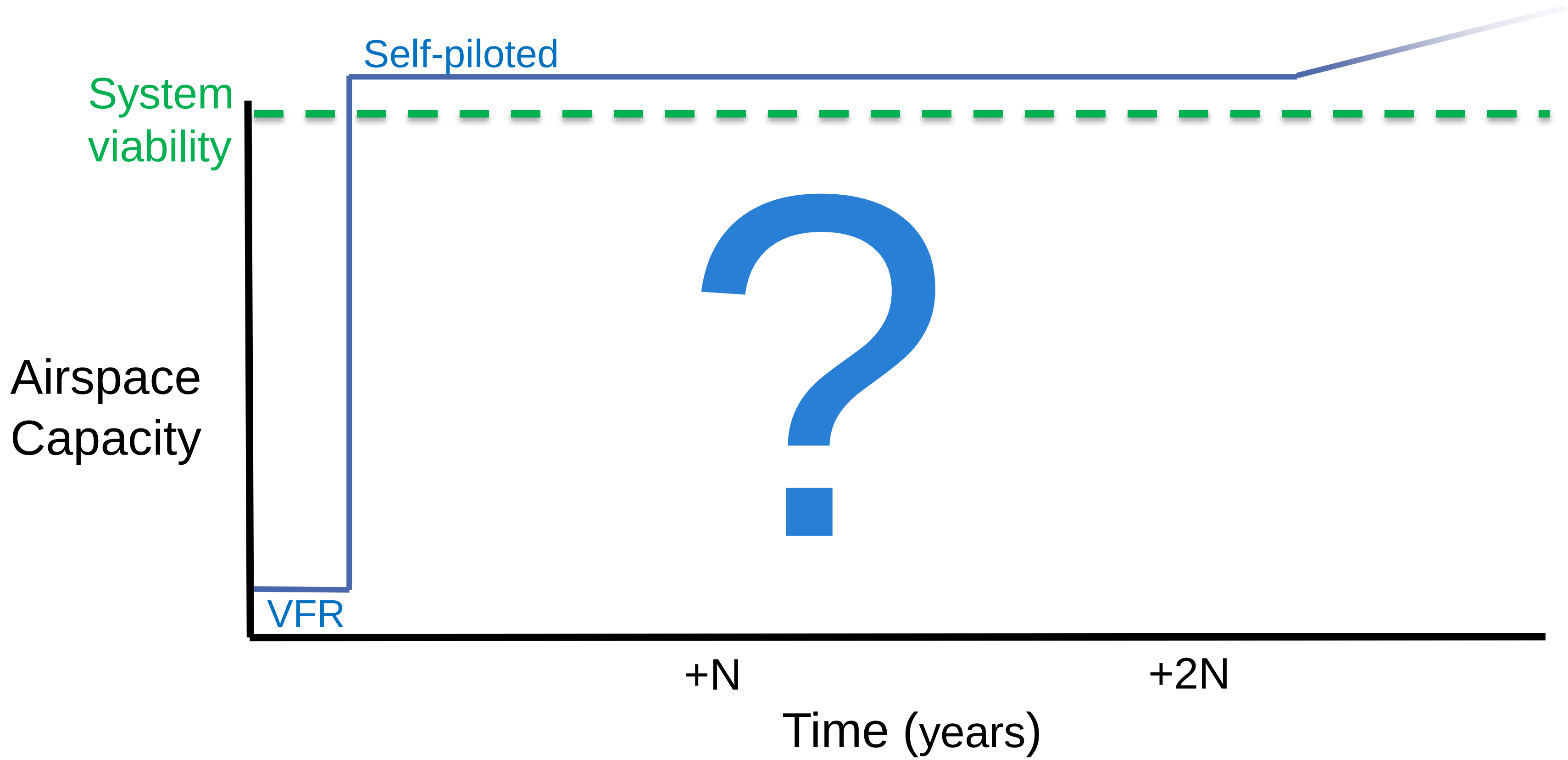

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Next Steps

1. Organize a community of interest for airspace integration
2. Develop a roadmap of airspace integration solutions by density level
3. Develop required airspace services, whether aircraft-centric or in UTM
4. Create analysis, modeling, simulation, flight test infrastructure
5. Verify scalability of airspace solutions through simulations
6. Validate deployability of solutions through flight tests

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Backup

UTM Architecture

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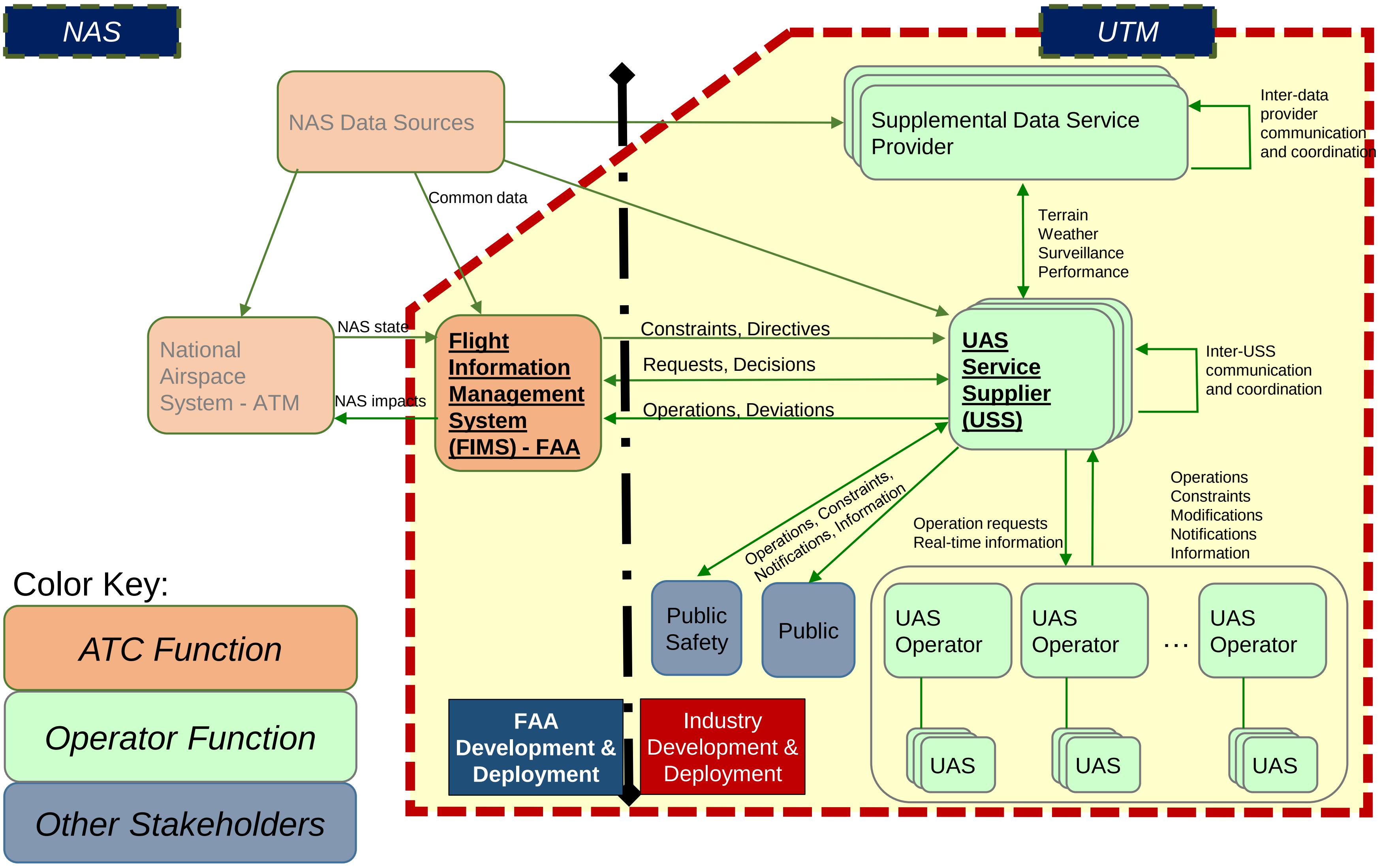
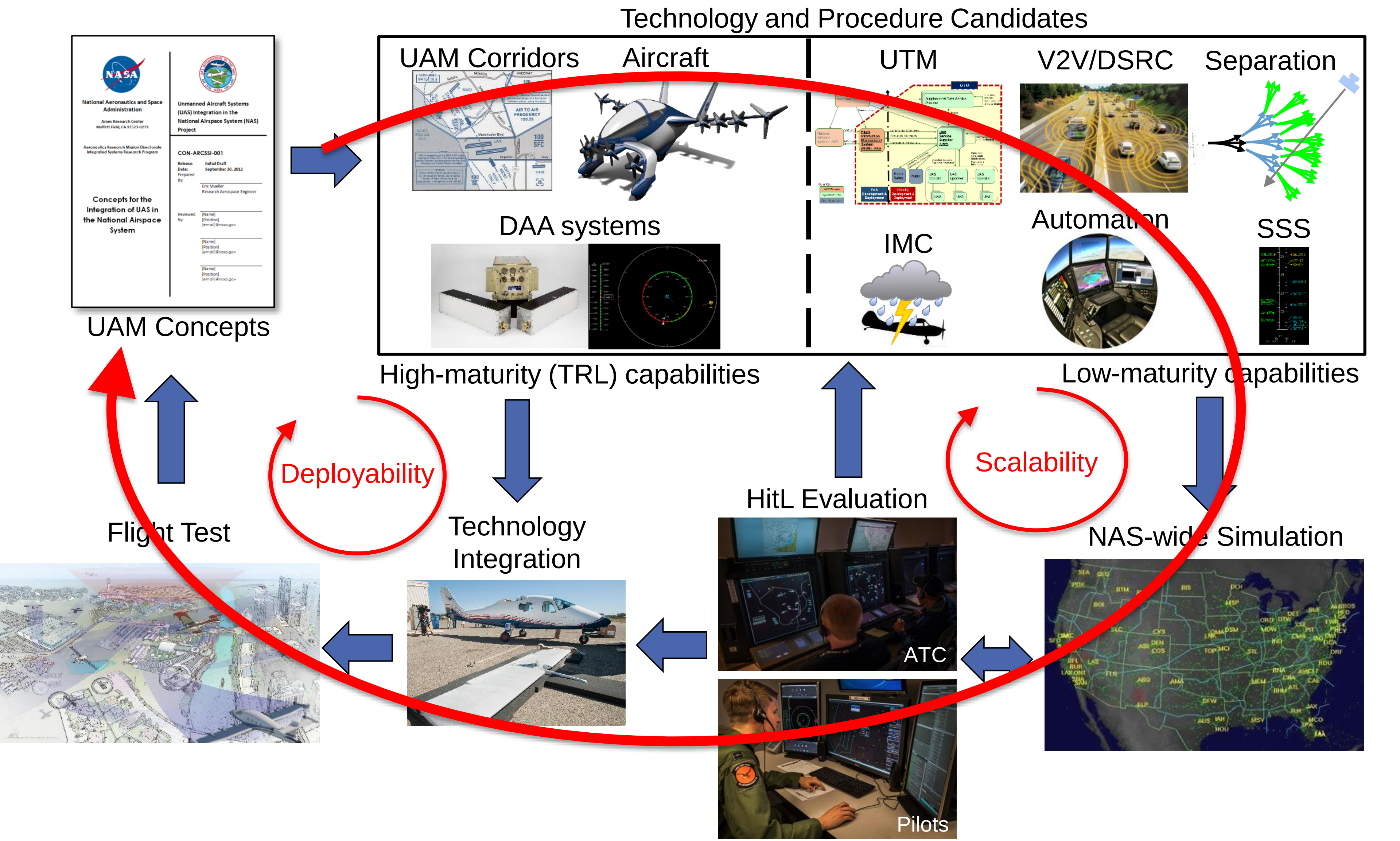


Airspace Integration Research Approach



Airspace Integration R&D Goals

•Provide concepts, technologies and procedures that enable orders of magnitude increases in the capacity of the airspace for novel vehicle types and operations through cooperative airspace traffic management that does not require additional ATM infrastructure

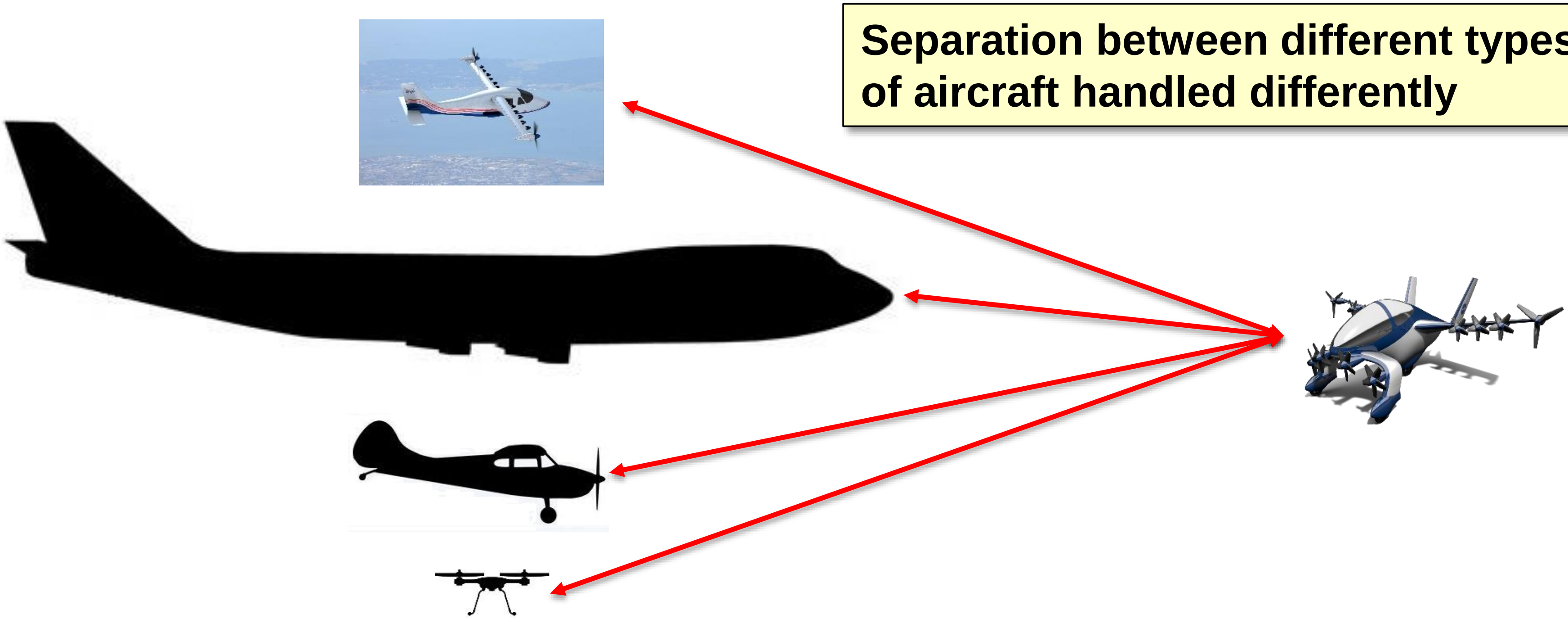
- Flight test demonstration of integrated system *deployability* at successively higher traffic densities
- Simulation demonstration of concept *scalability* with novel capabilities at successively higher densities

Mapping Approaches to Capabilities

Barrier	Procedural	Vehicle	UTM
Information gathering and exchange	Charted routes, GPS & radio beacons, pilot SAA & ADS-B, FIS, VHF	V2V state & intent exchange, 802.11p, aGPS + WAAS, DAA, VDL, cell net.	UTM-aggregated data, V2V backup, limited DAA, aGPS + GBAS, cell net., sat. comm.
Airspace design	UAM corridors in terminal airspace, public helipads	High density corridors enroute, reserved airspace, municipality TOLAs	No UAM structure, some traditional users excluded, neighborhood TOLAs
Airspace Services	Pilot SAA, traditional flight planning	DAA for separation & SSS, AR wake avoidance	UTM-provided services & traj. planning, backup DAA
Resilience, scalability	NOTAMs, scripted contingency ops, daytime only, VMC	V2V-coordinated contingency ops, IMC, night-time	FIMS, dynamic contingency ops, all weather, all times

UAM Separation Services

Separation between different types of aircraft handled differently



Aircraft pairs	Low Density	Medium Density	High Density
UAM-UAM	SAA, AC, ADS-B	DAA, V2V, AC	UTM, V2V, DAA
UAM-IFR	Segregation, SAA, ADS-B	DAA, ADS-B	UTM, DAA
UAM-VFR	SAA, ADS-B	DAA, ADS-B	UTM, DAA
UAM-sUAS	Segregation	V2V, DAA	UTM, V2V, DAA

UTM Architecture and Services

Flexibility where possible, structure where necessary