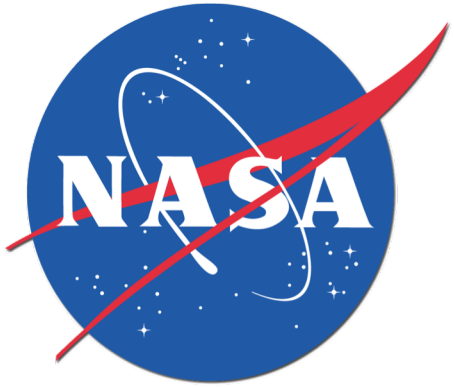
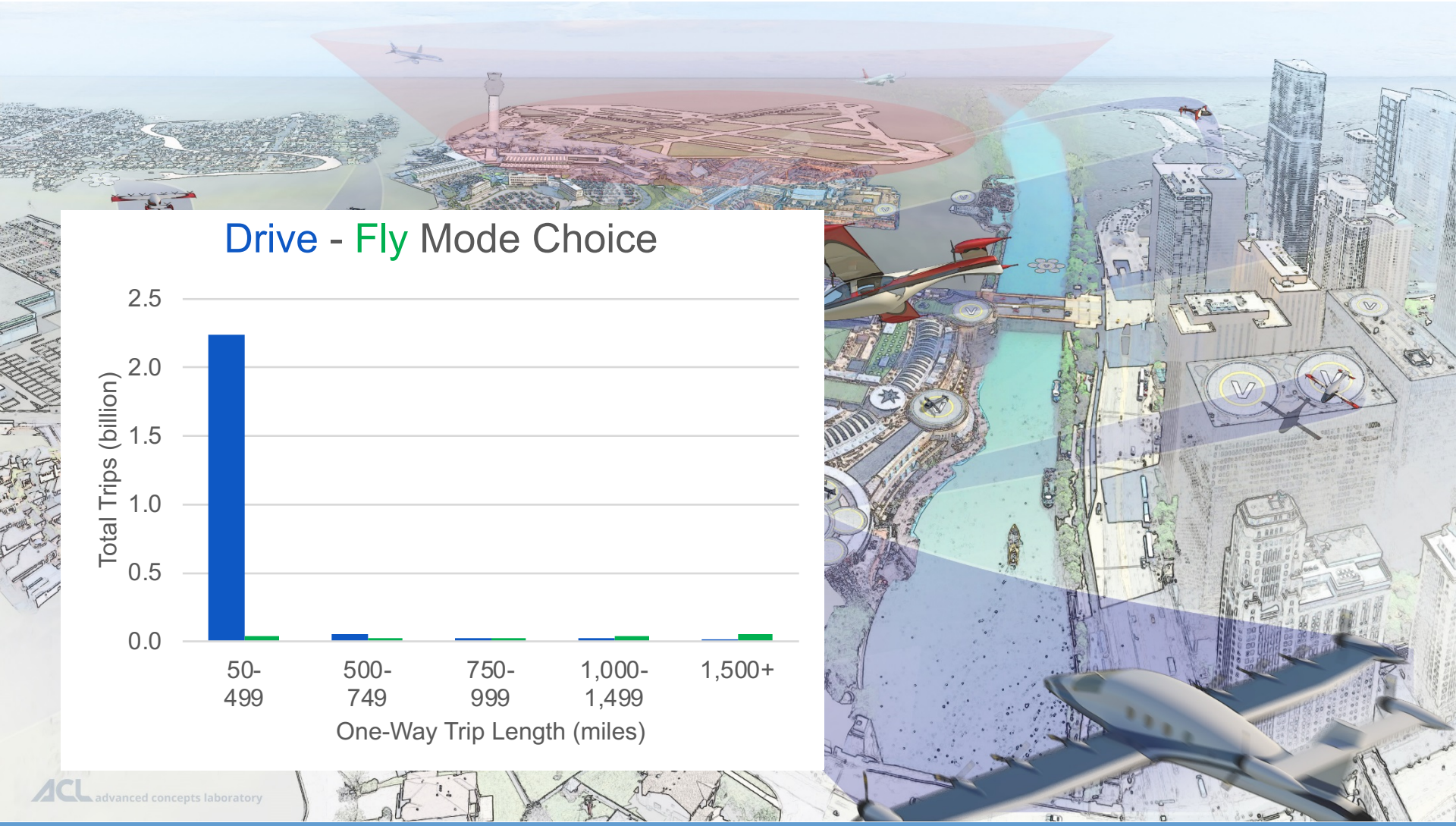
Enabling Airspace Integration for High Density Urban Air Mobility Operations

Eric Mueller

1/10/2018



Urban Air Mobility



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

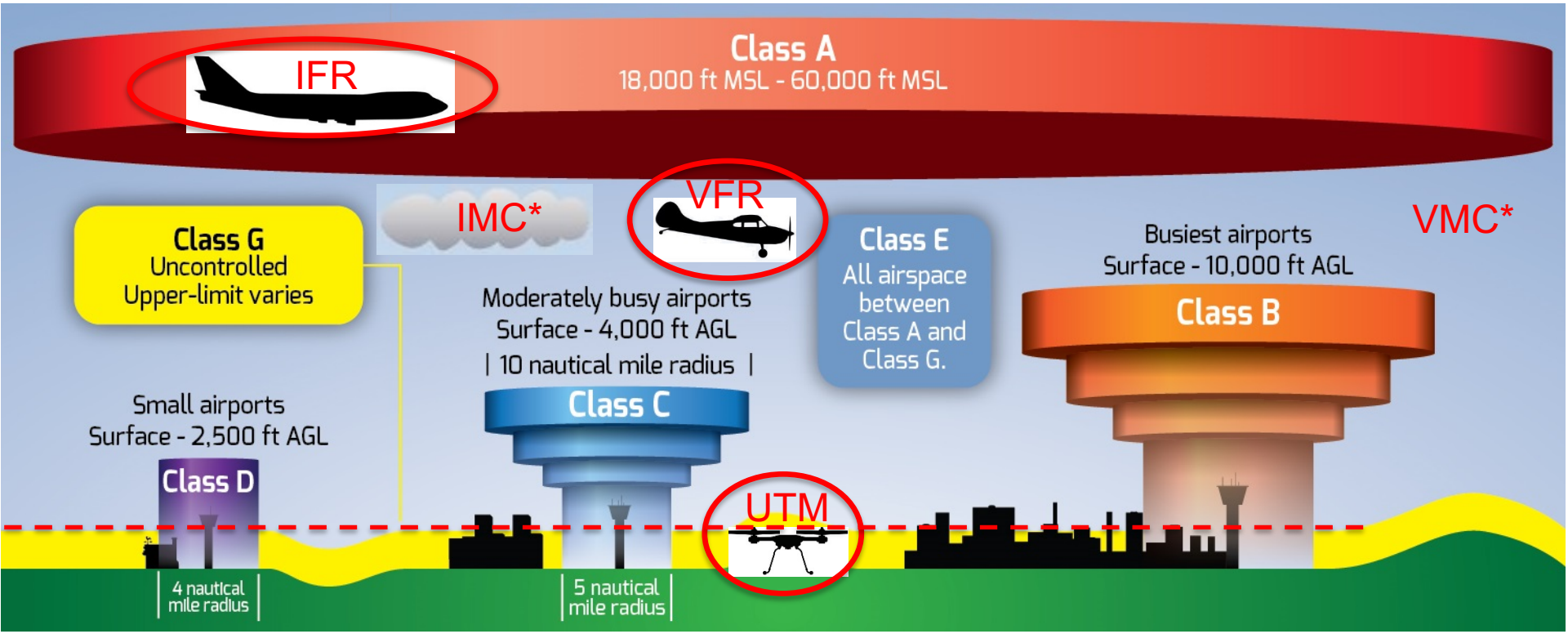
Airspace Integration Definition

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)

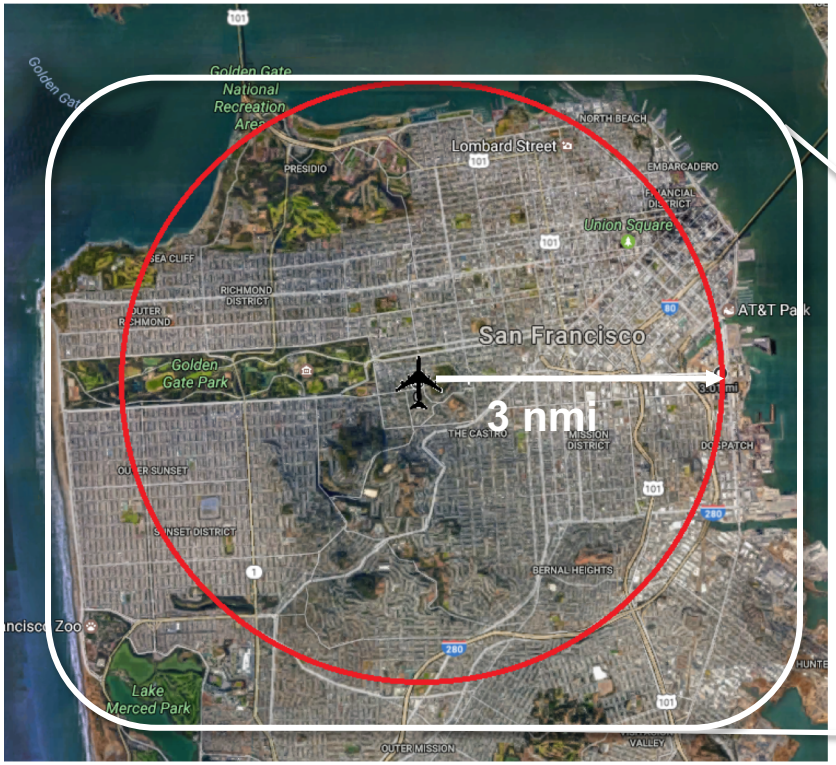


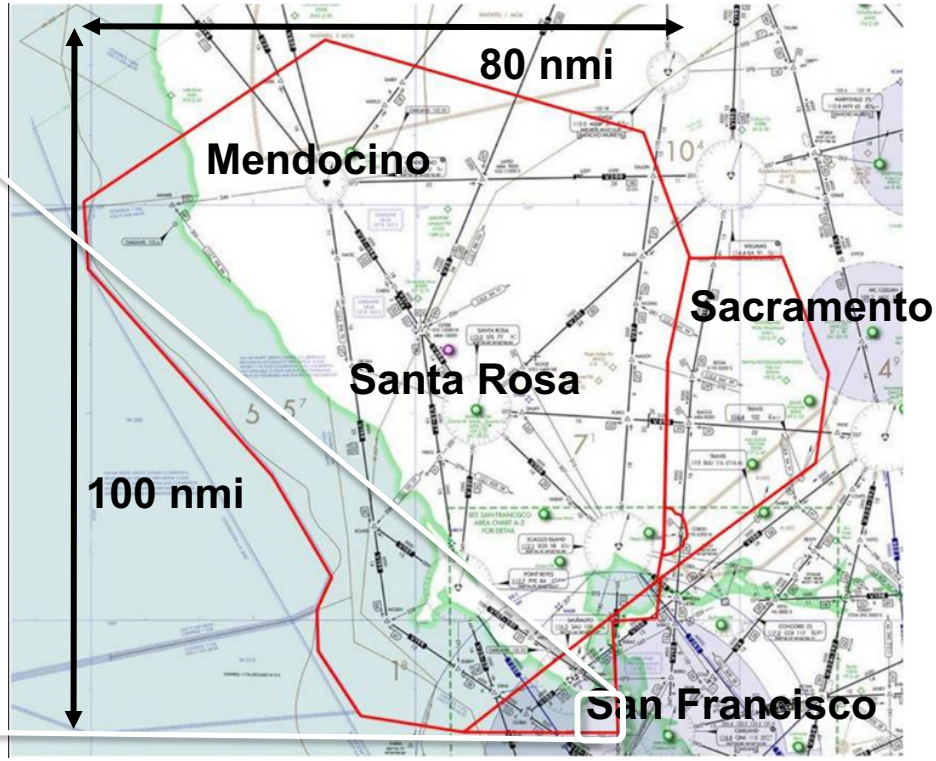
*VMC/IMC = Visual/Instrument Meteorological Conditions

Image courtesy of Flight Test STEM

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 urban air mobility aircraft per square mile





Urban air mobility density is ~*400 times* higher than the allowable IFR density

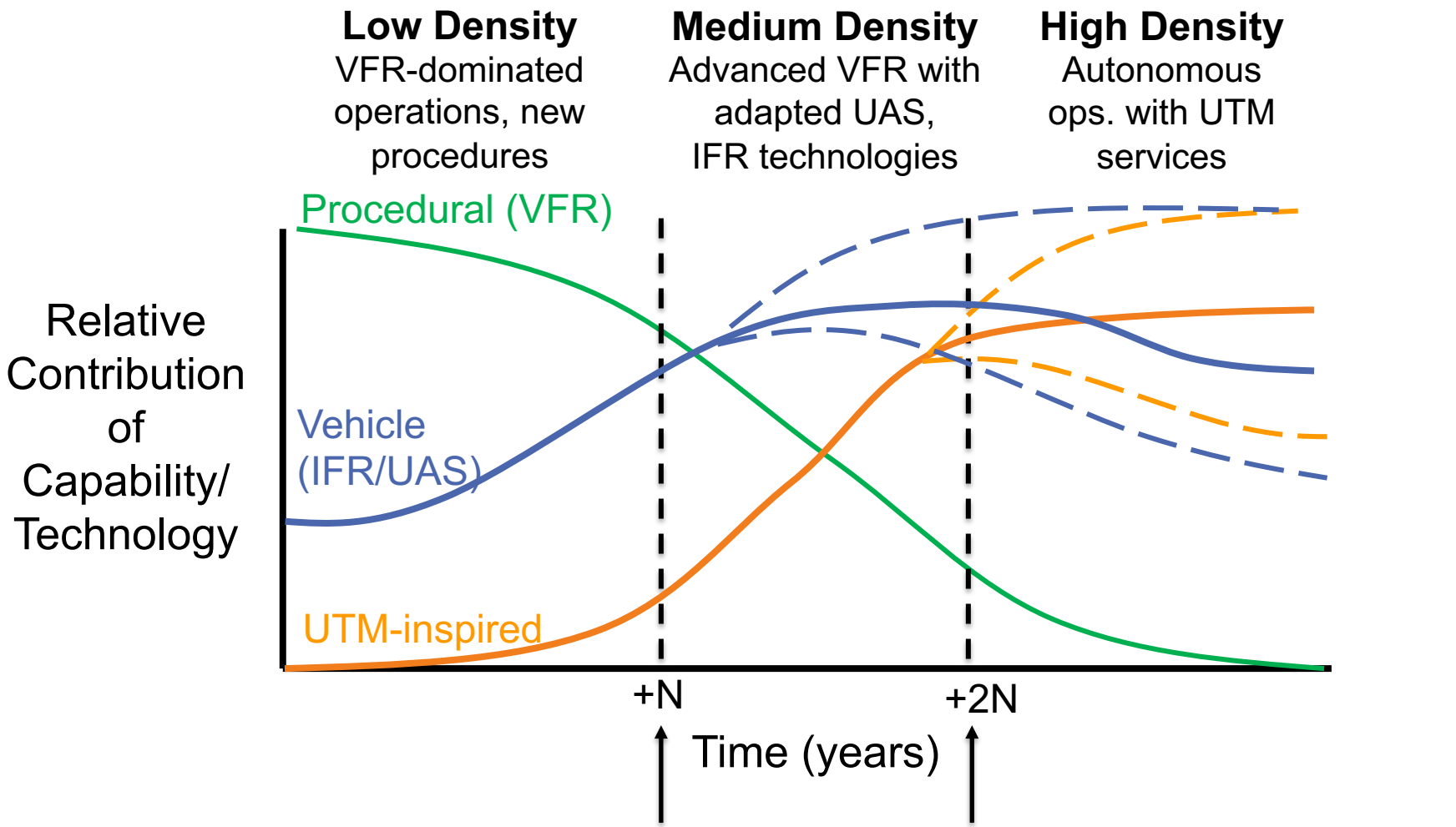
How to get to High Density Urban Air Mobility

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

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

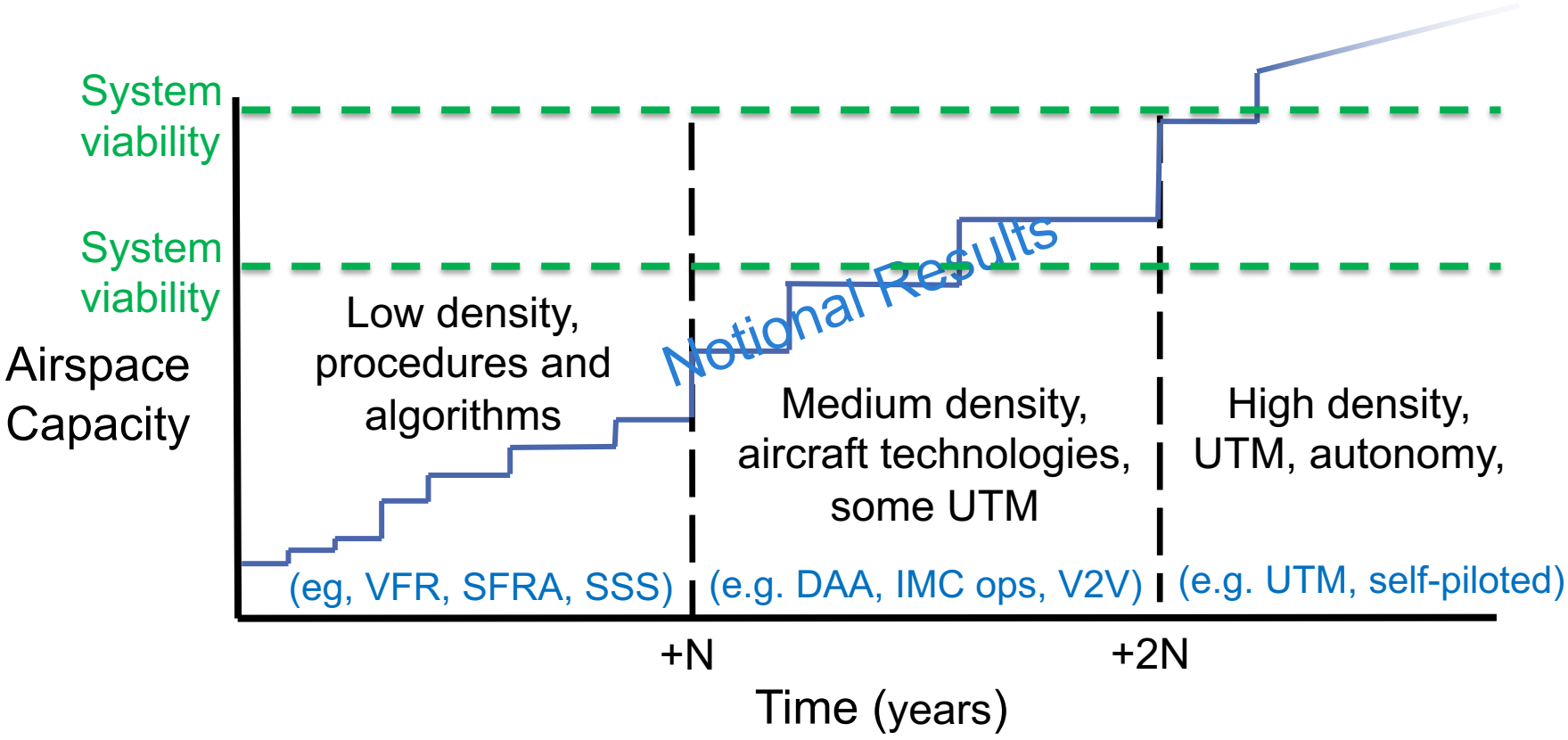
3. Adopt UTM services as replacements for aircraft-centric technologies and VFR requirements (as appropriate and available)

Approaches to Developing Capabilities



Airspace Capacity Enablers

What capabilities will increase the capacity of the airspace?



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

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

An incremental approach to airspace integration can achieve high-density urban air mobility

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Backup

Airspace Capacity Enablers

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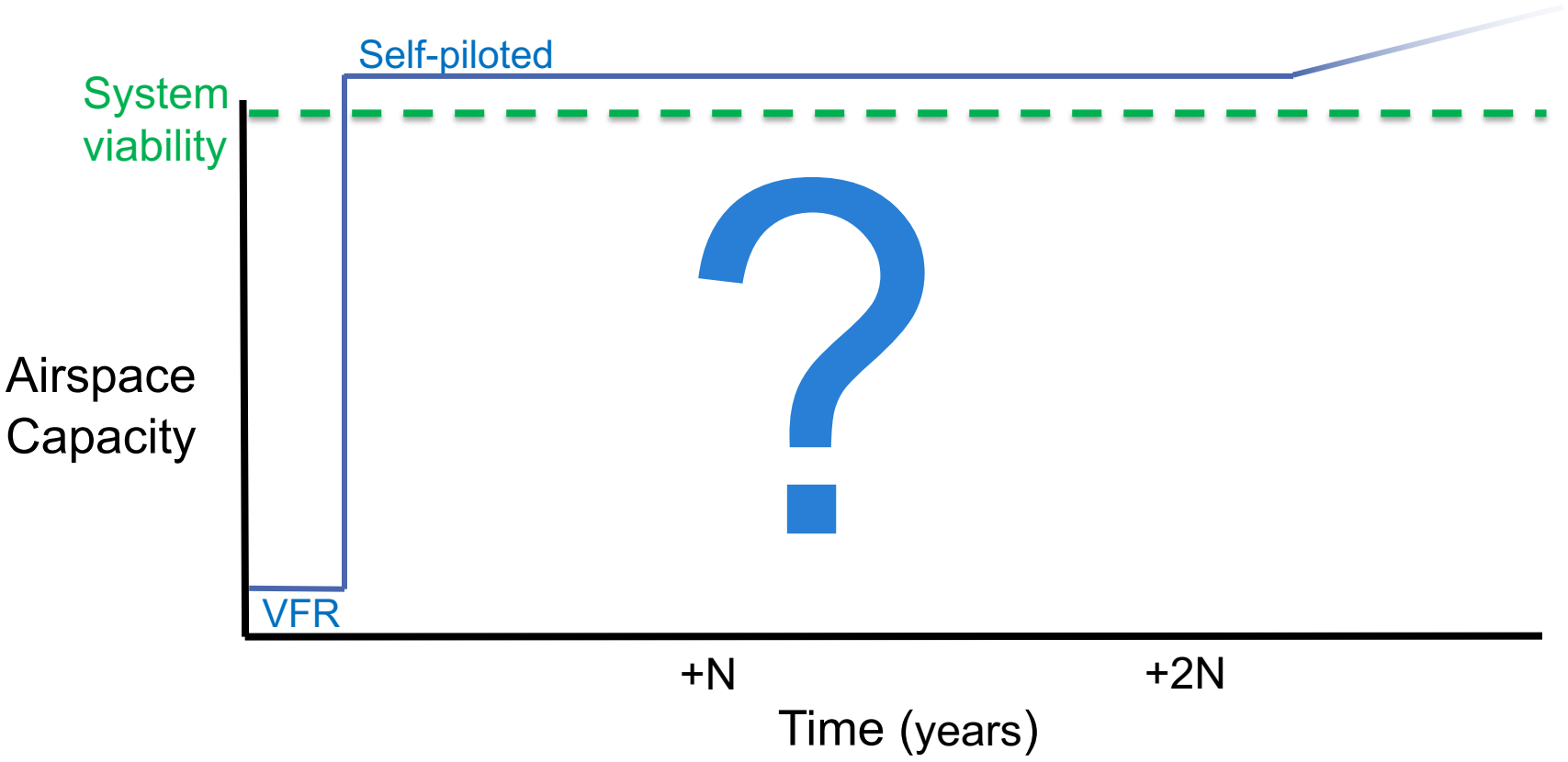

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Airspace Integration Principles

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

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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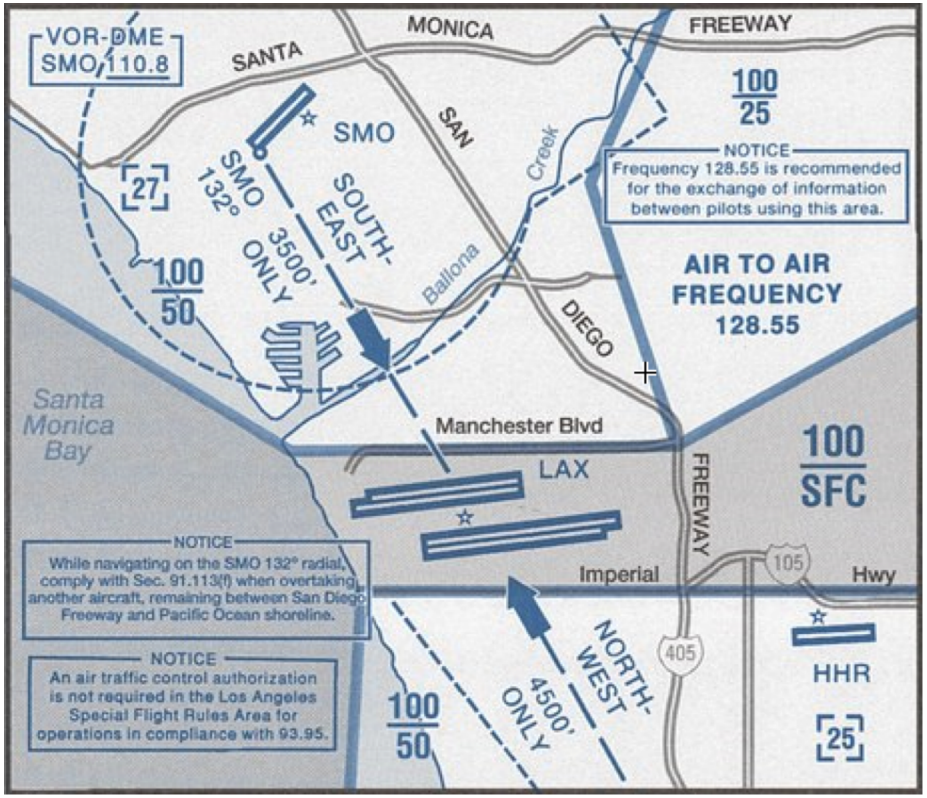
Airspace Constructs (AC)

- 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 urban air mobility, airspace constructs will compensate for technological limitations
- UTM will provide more efficient airspace access than AC
  - May allow dynamic ACs

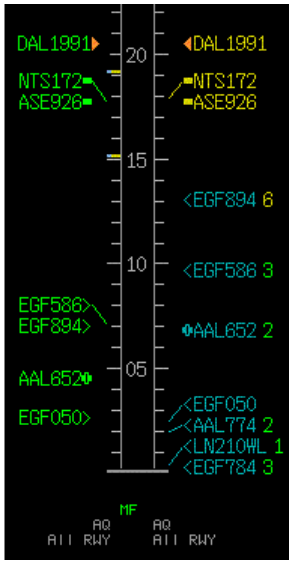


UTM would relieve the need to impose airspace constructs

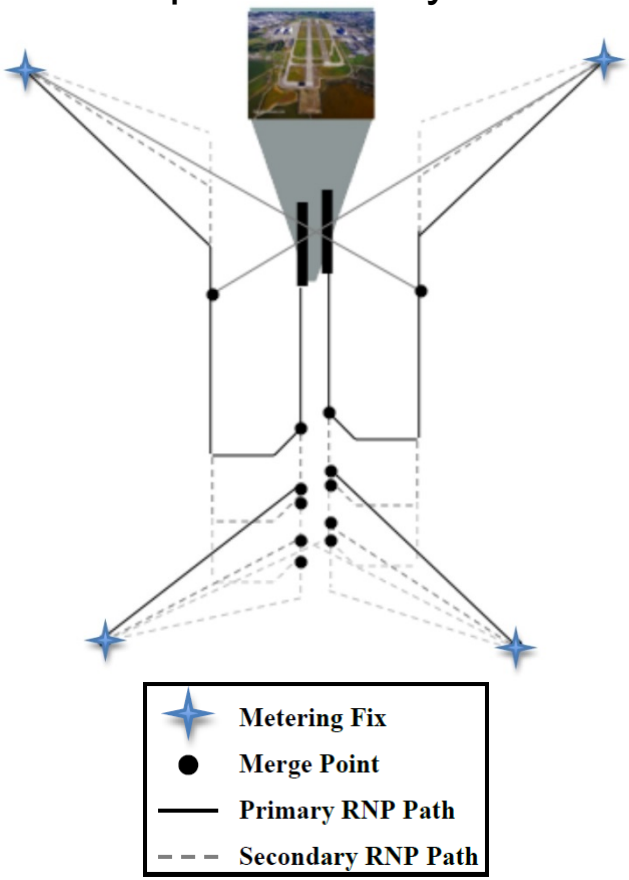
Sequencing, Scheduling, Spacing (SSS)

- 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
- Urban air 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



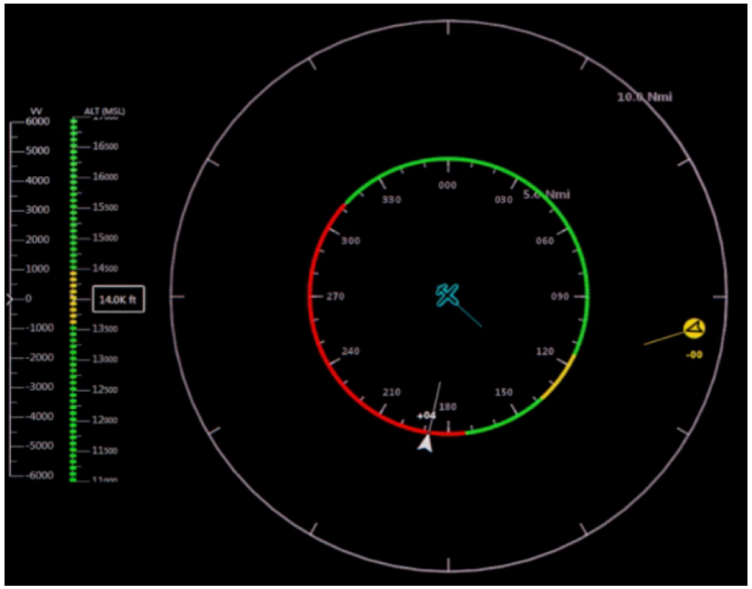
Typical arrival pattern today



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

Separation Services

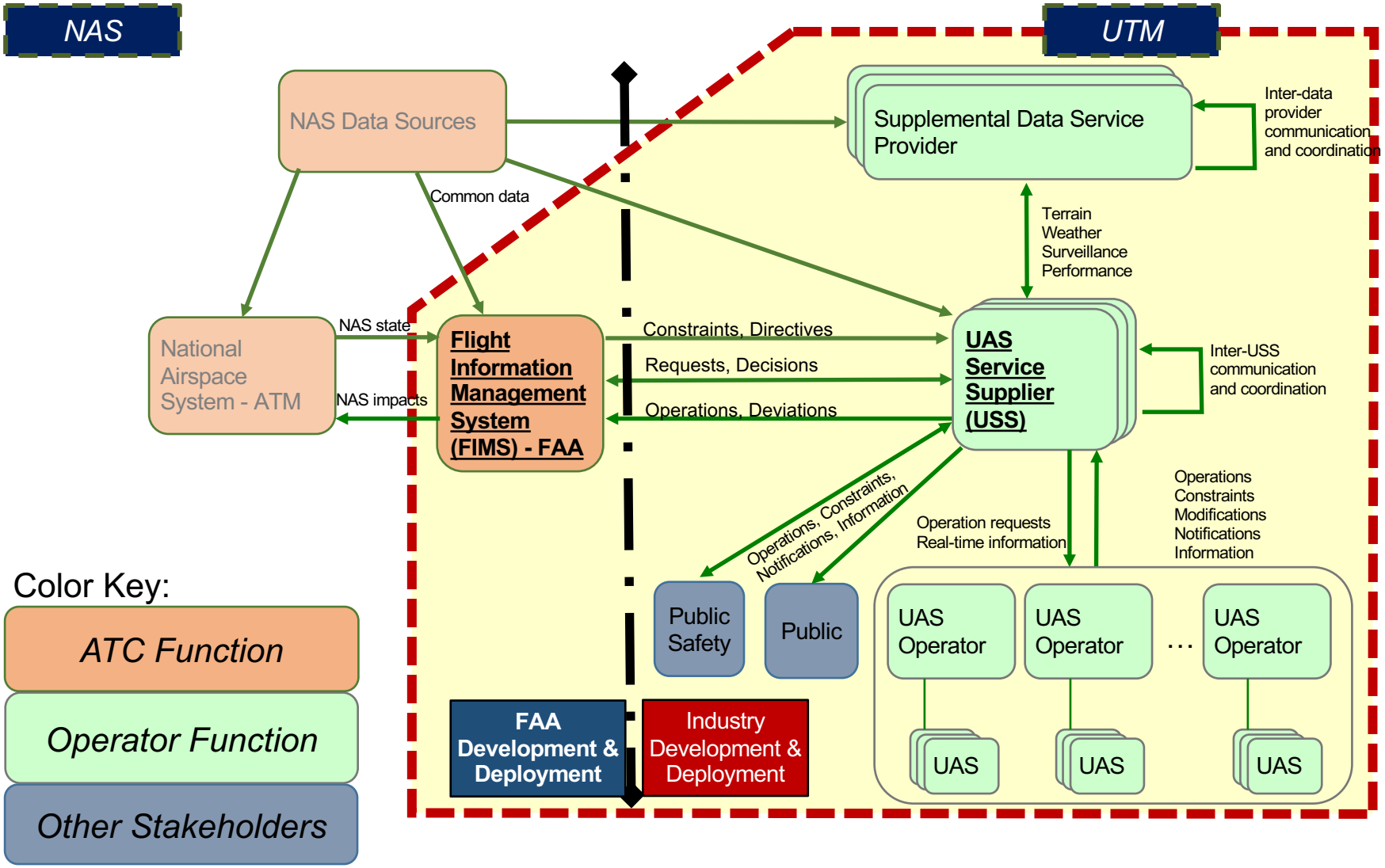
- Today, different aircraft types separate differently
  - VFR aircraft separate visually
  - IFR aircraft separated by ATC, but require visual and electronic collision avoidance
  - Right-of-way rules for aircraft classes
- Urban air mobility aircraft will assume responsibility for separation to avoid 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



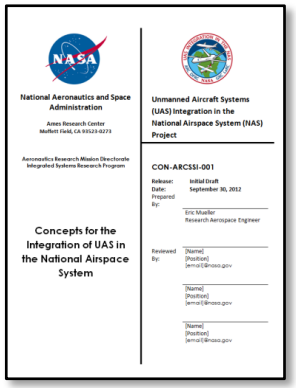
UTM provides separation services, need to reduce risk to apply them to human-carrying aircraft

UTM Operations

UTM Architecture



Airspace Integration Research Approach



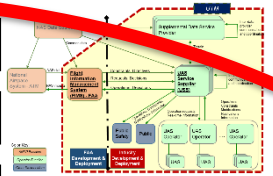
UAM Concepts

Technology and Procedure Candidates

UAM Corridors

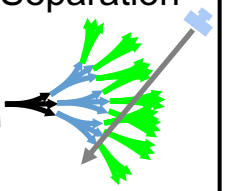
Aircraft

UTM

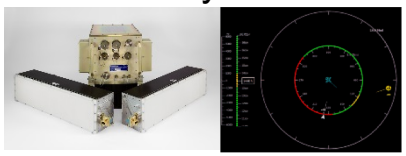


V2V/DSRC

Separation



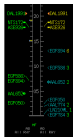
DAA systems



IMC

Automation

SSS



High-maturity (TRL) capabilities

Low-maturity capabilities

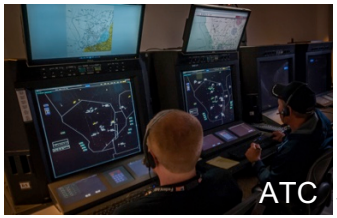
Deployability

Scalability

Flight Test

Technology Integration

HitL Evaluation



NAS-wide Simulation

Airspace Integration R&D Goals

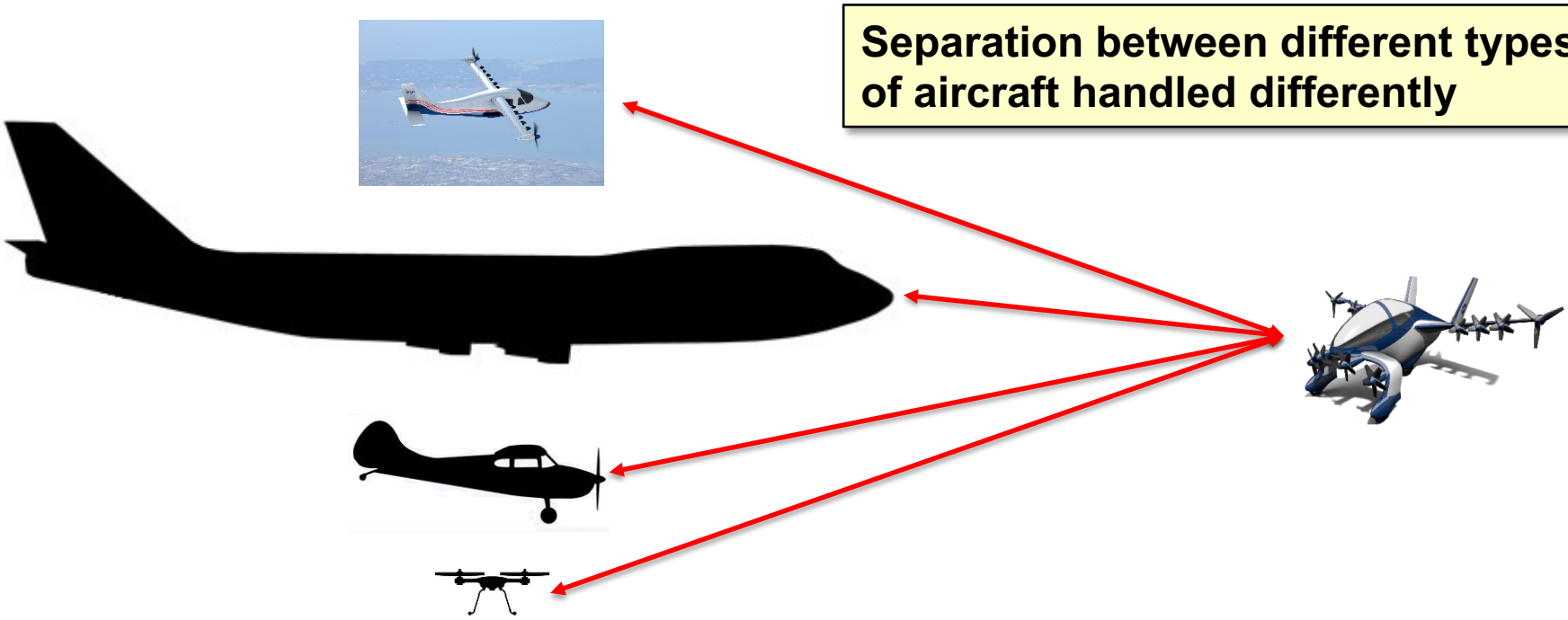
•Provide concepts, technologies and procedures that enable orders of magnitude increases in the capacity of the airspace for novel vehicle types and operations through cooperative airspace traffic management that does not require additional ATM infrastructure

- 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



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