Enabling Airspace Integration for High Density On-Demand Mobility Operations

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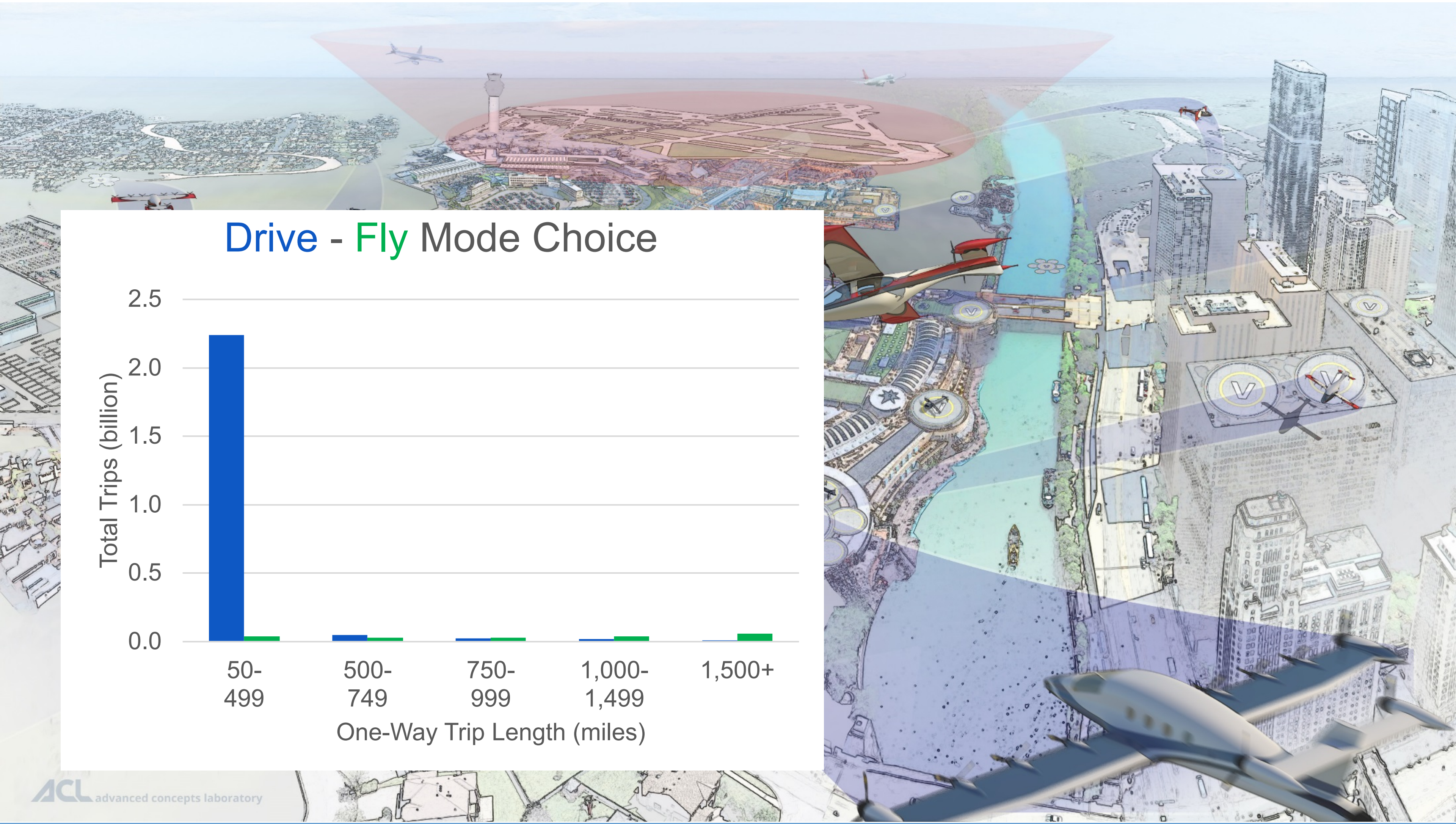
Outline

- 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

ODM Terminology

- On-demand mobility (ODM) is a form of *transportation* in which travelers select the origin, destination, and timing of travel
  - Implies that trips are not aggregated with (m)any other travelers
- Term has come to imply that trips are taken in aircraft
  - Cars provide effective on-demand ground transportation today
  - Some instead use terms ‘on-demand air mobility’ or ‘on-demand air transportation’ or ‘air mobility on demand’
- Why implement ODM?
  - The ‘thin tail’ of the demand distribution represents a huge number of trips but can only be practically/affordably serviced by aircraft that operate on-demand
  - Satisfy latent (unmet) travel demand
  - Better satisfy existing travel demand satisfied by other modes
- What about aircraft size and range?
  - Typically ‘personal’ and commuter aircraft (<~10 pax)
  - No strict range limits; most likely shorter-range trips (largely for cost reasons)

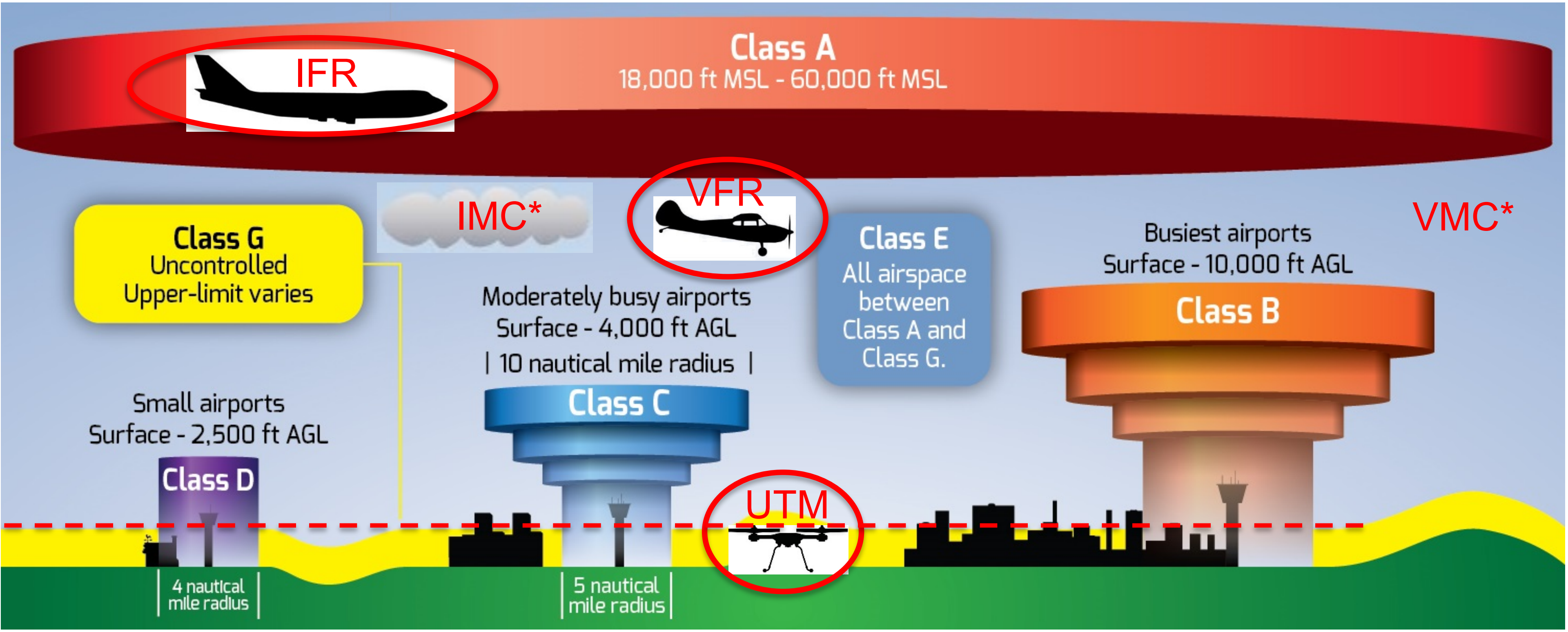
Airspace Integration Definition

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

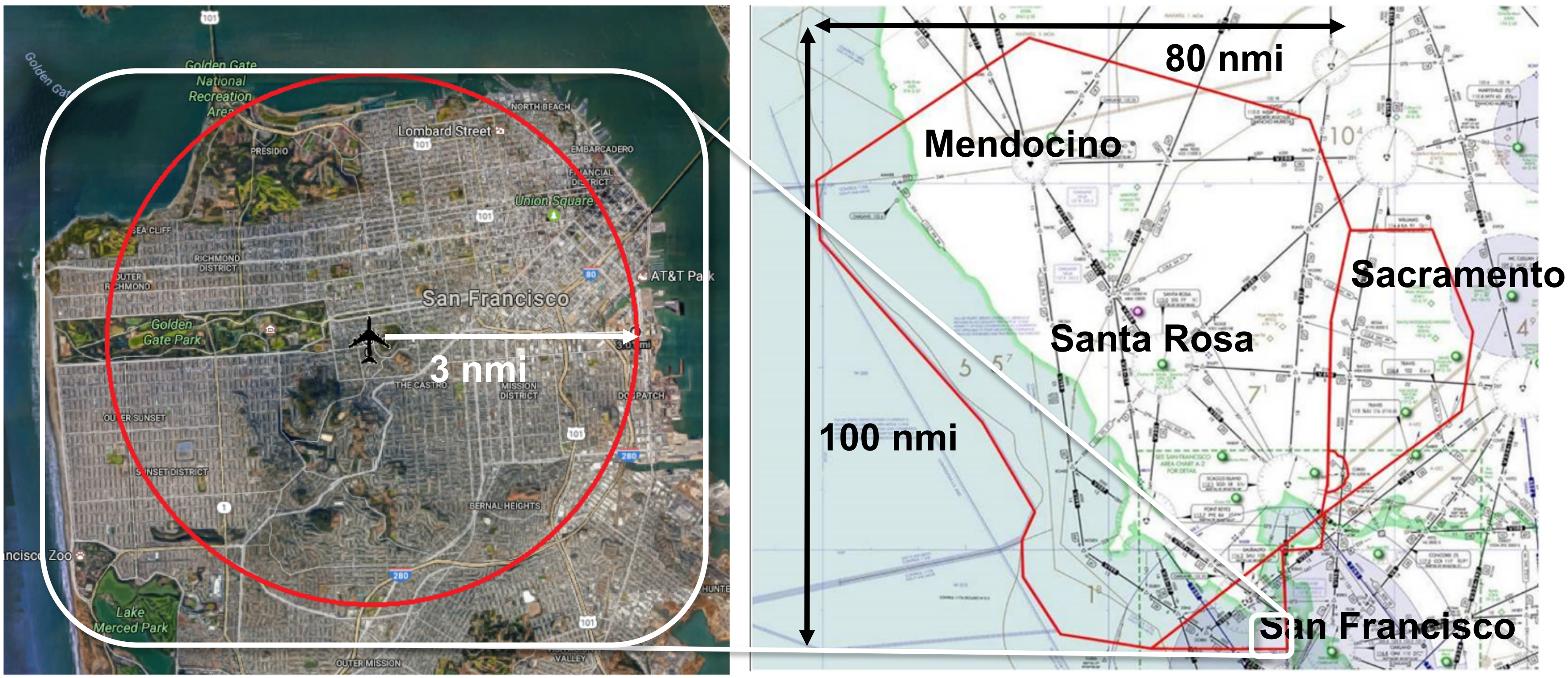
Simplified National Airspace System (NAS)



*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 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

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

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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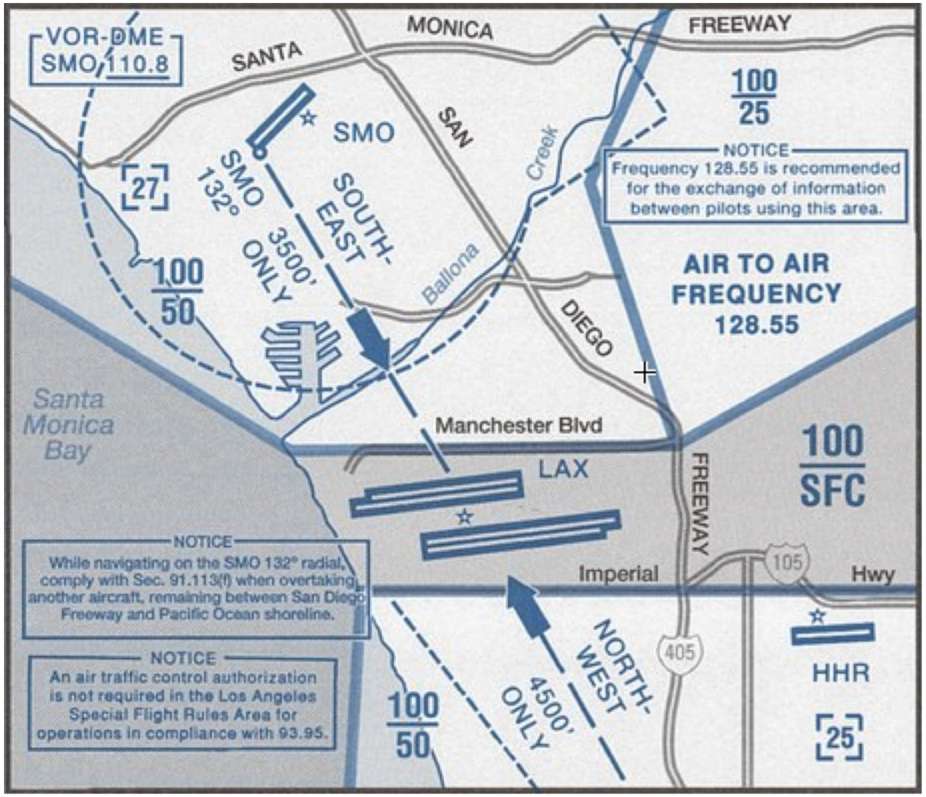
Airspace Constructs (AC)

- 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

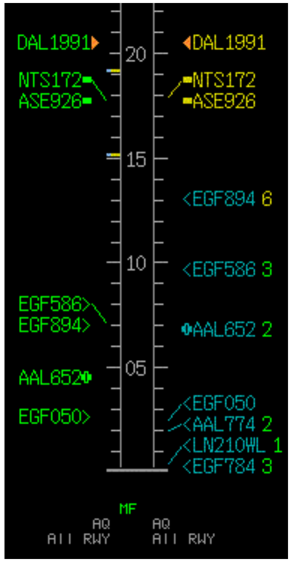


UTM would relieve the need to impose airspace constructs

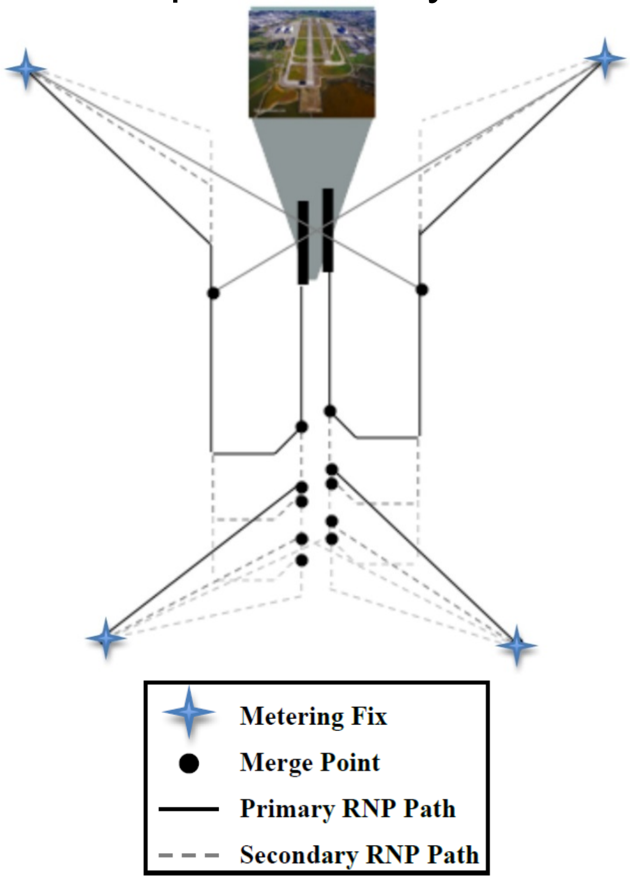
Sequencing, Scheduling, Spacing (SSS)

- 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



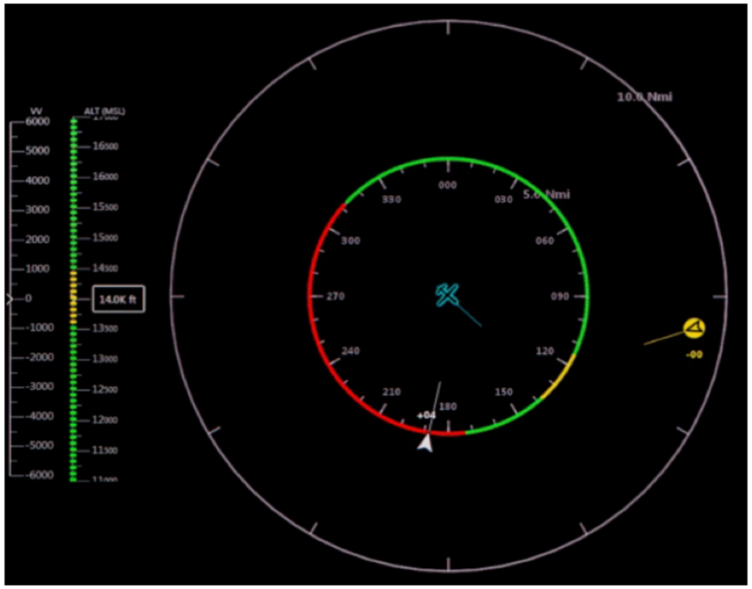
Typical arrival pattern today



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