Outline

• Upper Class E Traffic Management (ETM) in NASA ARMD AOSP ATM-X Project

• ETM Modeling and Simulation Activities Prior to ATM-X Phase 2

• Next steps
AOSP Organizational Chart

Airspace Operations and Safety Program (AOSP)

- Airspace Technology Demonstrations (ATD)
- Air Traffic Management—Exploration (ATM-X)
- System-Wide Safety (SWS)
- UAS Traffic Management (UTM)
NextGen Vision for 2025
Collaborative Service-Based ATM Envisioned in the Future NAS (~2045)
Vision: Accelerate transformation to a digitally-integrated air transportation system that enables access and increases mobility for all users.

Goal: Catalyze the community to provide an all-access, safe, and efficient airspace system through innovative solutions that remove barriers.

ATM-X fully supports Upper Class E Traffic Management (ETM) work.
ETM Modeling and Simulation, prior to ATM-X Phase 2

- ETM Operations Modeling
  - Cooperative operation concepts and scenarios
  - Conflict identification and resolution strategies
- ETM Simulation
  - Flexible engine for Fast-time evaluation of Flight environments (Fe3)
  - High-altitude balloon dynamics
Notional cooperative separation management service processes within Upper Class E Airspace

Flowchart:
- Input
  - Conflict identification
    - Conflict assessment
      - Yes
      - No
    - Yes
  - Take pre-agreed solution
    - Yes
    - No
    - Generate resolution(s)
      - Yes
      - No
      - A solution accepted
        - Yes
        - No
        - Solution deadline expires
          - Yes
          - No
          - Fallback solution
            - Yes
            - No
  - Implement the solution
    - Yes
    - No
    - Conformance
      - Yes
      - No
      - Alert / Take appropriate action
        - Yes
        - No
      - Flight progress
Conflict Resolution Phases: Balloon and Fixed Wing

Minimum safety zone (to fixed-wing)  
e.g. ~5-30 nmi

Minimum safety zone  
(to balloon, if climb rate = 20mpm/1.09 fps)  
Vsep. = 2,000 ft -> ~30 min. -> ~266 – 1,000 nmi  
Vsep. = 1,000 ft -> ~15 min. -> ~133 – 500 nmi

Fixed-wing maneuver only

Both Fixed-wing and balloon can maneuver

Negotiation, Strategic deconfliction, fairness…
**Fe³ Simulation Diagram**

Key characteristics:
- High-fidelity: trajectory (6DOF), CNS, wind, airspace management functions
- Multi-vehicle operations, 2Hz
- Uncertainty study with statistical measurements
- Monte Carlo – capability of running thousands of simulations parallelly
- Real-time factor: ~1,000X to ~100,000X

*Fe³ - Flexible engine for Fast-time evaluation of Flight environments*
**Challenge:** Balloon dynamics are fundamentally different from conventional aviation vehicles (e.g. fixed-wing type)
- Highly dependent on upper-E atmospheric properties
- Highly susceptible to wind
- Vertical control only

**Status**
- Initial 3D model of Balloon developed
- Integrated NRLMSISE-00 (empirical, global reference atmospheric model) implemented initial PI (proportional-integral) controller
- Performed initial tuning of drag coefficient and controller gains based on realistic balloon flight data

Balloon Model with Wind

\[
\begin{align*}
\frac{d}{dt} ((m_b + \eta m_a)v_x) &= \frac{q A_b C_d}{V_{rel}^{(c)}} v_{rx} \\
\frac{d}{dt} ((m_b + \eta m_a)v_y) &= \frac{q A_b C_d}{V_{rel}^{(c)}} v_{ry} \\
\frac{d}{dt} ((m_b + \eta m_a)v_z) &= \frac{q A_b C_d}{V_{rel}^{(c)}} v_{rz} + (m_a - m_b) g \\
\dot{x} &= v_x; \quad \dot{y} = v_y; \quad \dot{z} = v_z \\
V_{rel}^{(c)} &= v_{rx}^2 + v_{ry}^2 + v_{rz}^2 \\
v_{rs} &= v_s - \zeta_s; \quad \ddot{q} = \frac{1}{2} \rho ||V_{rel}^{(c)}||^2
\end{align*}
\]
NASA provides the assessment results and research output such as services architecture and requirements to the community and the FAA for ETM ConOps Maturation.

NASA models performances and services with the community input (e.g., negotiation process), builds scenarios informed by the FAA and the community to reflect the needs and constraints, and conduct simulations to assess the efficacy of the services.
Introducing ETM Services Supplier (ESS)

- Sharing of operational intent should enable safe, fair, and efficient use of Upper Class E airspace
  - Operational intent (plan) conflict identification
  - Resolution of the conflict
- ETM Service Supplier, ESS, can facilitate the conflict identification and resolution among participating operators
ETM participants to submit operational intent to ESS
- Operational intent should be standardized
- Single or multiple ESSs could serve the NAS; the latter requires inter-ESS discovery, communications, and synchronization

With the operational intents, ESS in position to identify 4D intersection of operational intent and inform the operators
- It is possible that 4D intersection to not to be identified as a conflict
Three scenarios developed to facilitate discussion and gather the industry input:
- ESS policy on identifying 4D intersection as a conflict
- Operator response to the identified conflict:
  - Agreements
  - Negotiations
  - Rules of the road
- NASA also engaging with the ETM community members in 1:1 setting:
  - Mission needs and constraints
  - Vehicle performance
  - Timeline
Modeling and Simulation Development

Modeling/data collection:
- Vehicle Model
- Communication, navigation, and surveillance
- Wind

Simulations: performance-based minimum separation

Negotiation/coordination models
- Intent sharing: format, rate, accuracy
- Methods (content/format):
  - Rules of road or agreements
  - Manuel/Automated (option sets)
  - Auction
- Communication
  - Response time
  - Latency
  - Accuracy

Multiple Aerial Vehicle Simulations

Scenarios

Analytical studies
Research Questions to be addressed by simulations

1. Timing and spatial boundaries for conflict resolution and negotiation

2. Size or duration of “rolling intent window”

3. CNS requirements
For both pre-departure and in-flight, identify negotiation/coordination model(s) that are safe, efficient, fair, secure, and scalable:

- Intent sharing: content, format, rate, accuracy, and responsibility
- Methods:
  - Rules of road or predefined agreements
  - Manual/Automated (option sets)
  - Auction
- Communication: response time, latency, and accuracy
- Metrics: efficiency and fairness
Modeling and Simulation Timeline

- Analytical studies for defining minimum separation
- Performance-based minimum separation
- In-flight cooperative operations
- Cooperative operations planning
- Interactions with class A traffic in potential Flexible Floor environment

2021

2022