Introduction to Higher Airspace Operations

Including Collaboration on Risk-Based Conflict Detection Framework

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Higher Airspace

- Globally Focused Platforms are Emerging
- They are:
  - Transporting people and goods faster
    - Supersonic aircraft
    - Commercial space
    - Suborbital space tourism
  - Providing services
    - Highly automated constellations on station for months
- This region will be home to extreme diversity
- However, most operations will be cooperative and known to air traffic control
Higher Airspace *(There is no official definition or name for this region)*

**Higher Airspace Begins**

Where civil manned operations end

- Based on 2017 data, these operations currently top out at 51,000 feet

*Implication:* U.S. higher airspace operations occur in Classes A and E

- **This region is expected to have the most diverse set of operations and highest need for traffic management services**

**Higher Airspace Ends**

Where atmospheric density can no longer sustain lift through aerodynamics or buoyancy

*Implication:* This region is considered “airspace,” and sovereign to the underlying territory within FAA’s jurisdiction
Higher Airspace Environment

<table>
<thead>
<tr>
<th>Operation Type</th>
<th>Speed</th>
<th>Duration</th>
<th>Cruise Altitude (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unmanned Balloons (Super &amp; Zero Pressure)</td>
<td>Low</td>
<td>Hours - Months</td>
<td>50,000 to 75,000</td>
</tr>
<tr>
<td>Manned Balloons (Space Tourism)</td>
<td>Low</td>
<td>Hours</td>
<td>100,000</td>
</tr>
<tr>
<td>Long Endurance Unmanned Aircraft</td>
<td>Low</td>
<td>Days - Months</td>
<td>60,000 to 85,000</td>
</tr>
<tr>
<td>Supersonic Transport Aircraft (Manned)</td>
<td>Very High</td>
<td>Hours</td>
<td>50,000 to 70,000</td>
</tr>
<tr>
<td>Unmanned Airships</td>
<td>Low</td>
<td>Days</td>
<td>55,000 to 70,000</td>
</tr>
</tbody>
</table>

- Long duration operations (typically months) are highly sensitive to weight and tend to rely on solar power
- The thinner the atmosphere, the more difficult it becomes for operations that rely on lift to maneuver
- Super and hypersonic aircraft have narrow viable speed ranges (also known as the “coffin corner”) and large turning radii
- Operations that rely on buoyancy have limited control and maneuverability at all altitudes, including higher airspace, unless an engine is present (e.g., airships)
# Commercial Vehicles Planning to Operate in Higher Airspace (Horizontal Trajectories)

<table>
<thead>
<tr>
<th>Aircraft</th>
<th>Lighter-than-Air</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Airbus – Zephyr</strong>*</td>
<td><strong>Loon</strong>*</td>
</tr>
<tr>
<td>• Platform: High altitude long endurance solar UAS</td>
<td>• Status: Winding down operations (as of 04/2021)</td>
</tr>
<tr>
<td><strong>Aerovironment - Hawk</strong></td>
<td>• Platform: Super pressure balloons</td>
</tr>
<tr>
<td>• Platform: High altitude long endurance solar UAS</td>
<td><strong>Thales – Stratobus</strong>*</td>
</tr>
<tr>
<td><strong>Boeing/Aurora – Odysseus</strong></td>
<td>• Platform: Solar airship</td>
</tr>
<tr>
<td>• Platform: High altitude long endurance solar UAS</td>
<td><strong>Worldview – Stratollite</strong>*</td>
</tr>
<tr>
<td><strong>Boom - Overture</strong>*</td>
<td>• Platform: Hybrid balloon with steerable parafoil for payload recovery</td>
</tr>
<tr>
<td>• Status: XB-1 2019 demonstrator (fastest civil aircraft)</td>
<td><strong>Sceye</strong></td>
</tr>
<tr>
<td>• Platform: Supersonic transport (50-75 pax) Mach 2.2</td>
<td>• Platform: High altitude airship</td>
</tr>
<tr>
<td><strong>Spike &amp; Aerion</strong>** Business Jet</td>
<td><strong>Space Perspectives</strong></td>
</tr>
<tr>
<td>• Platform: Supersonic transport (12-18 pax) Mach 1.4 – 1.6</td>
<td>• Platform: Suborbital space tourism via balloon with manned capsule</td>
</tr>
</tbody>
</table>

*2017 GANIS Panel  
**Aerion stated cruise altitude is FL400
Performance Categories and Initial Geographic Segregation (Near-Term)

- **Unmanned Sounding Balloons** (e.g., weather balloons)
- **Manned Balloons**
- **Long Endurance Unmanned Balloons**
- **Long Endurance Unmanned Airships & Aircraft**
- **Amateur Rockets**
- **Air Launched Objects**
- **Spacecraft Launch and Recovery**
- **Military** (U-2 & Global Hawk)
- **Supersonic Passenger Transport**

**Speed**

- **Slower**
  - Likely to be concentrated over developing countries near populated regions
- **Faster**
  - Likely to be concentrated in coastal regions over international waters and from inland spaceports within developed countries
  - Likely to be concentrated over water to minimize travel time between continents and environmental impact
FAA Regulatory Overview for New Entrants

New entrants operating in higher airspace are primarily regulated by three different Parts in Title 14 CFR, each with significantly different equipage and operating requirements.

- **Part 101**: No Equipage Currently Required
  - Class 3 Amateur Rocket
  - UFB Super Pressure
  - UFB Zero Pressure
  - UFB Sounding
  - Must meet minimum Class A CNS Requirements in order to reach Class E above FL600

- **Part 400**: Balloon with Parachute and Passenger Capsule
  - Horizontal Takeoff
  - Vertical Takeoff to Orbit
  - Winged-Reentry
  - Vertical Takeoff and Landing
  - DeOrbit/Decay

- **Part 91**: Air-Launched Object (when airborne)
  - Supersonic Manned Aircraft
  - HALE Unmanned Aircraft

Regulatory classification for new entrants shown on diagram is based on current and/or most likely classification.
Existing Civil Aviation Authorities & Services*

*High level summary of most applicable services in Higher Airspace
**Anticipated Traffic Management Implications**

**Positives**

- The lack of convective weather and jet stream increase operational predictability
- The preponderance of unmanned operations would likely result in less severe collision outcomes
- Technologically advanced operators are likely to be able to coordinate well with other operators

**Negatives:**

- Weight-sensitive vehicles, with limited onboard equipment and power, creates ATM integration challenges
- Handling off-nominal situations with unmanned operations may be more complex
- New airspace needs associated with constellations of loitering vehicles will challenge established norms
- The inability to rely on tactical or last-resort collision avoidance will require deconfliction in advance (strategic planning)
- Single-use and novel vehicles challenge standard safety practices associated with airworthiness and equipment certification that historically have enabled integration
Key Challenge: Syncing Up Timelines when Planning Airspace Use

- Legacy IFR Operations: Flight plan is normally filed within hours of departure.
- Flights in domestic airspace rarely exceed 7 hours.
- Commercial Space Operations: Commercial Space operations have very long planning horizons, measured in years and months and are therefore less likely to have mission flexibility.
- New Entrants with missions in Higher Airspace: Current notice to FAA is less than 24 hours for balloon launches or filing flight plan.
- Most anticipated operations will last multiple months.

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Current Airspace Options and Priority System

First-Come-First-Served: This is not practical for upper airspace due to the variety of mission types

For example, some spacecraft have narrow launch windows, dictated by orbital dynamics, and therefore have minimal launch flexibility. At the other extreme are constellations of airships or balloons which can station-keep for months at a time, preventing other operations from using the airspace.

Right-of-Way: In theory, the right-of-way rules found in the 14 Code of Federal Regulations Part 91.113 offer a performance-based approach to determining airspace access priority, as they rely on a vehicle’s ability to take evasive action.

Is it fair/equitable to ask more maneuverable operations to do all the accommodating?
Industry, ANSP & Research Efforts
Recent Industry Activities & Timeline

Cooperative Traffic Management in the Stratosphere

Adaptive Risk-Based Conflict Detection for Stratospheric Flight Operations

Contributors:
- Cooper Wang - Director of Innovations - Lennox Aerospace
- Steve Knepper - Director, DARPA Program - Lennex Aerospace
- Mike Kedia - Director, Unmanned and Emerging Aviation Technologies - L2
- Andrea Tally - Deputy Program Lead - Ascend Aeronautics
- Dr. Steve Shry - Principal Investigator, Stratospheric Aviation
- Paul Tyler - Air Safety Inspector, Civil Aviation Safety Authority

Abstract:
Conflict detection between air vehicles taking off or landing at the stratospheric level can lead to increased safety and risk management. This paper proposes the development of algorithms and systems that can identify potential conflicts and provide guidance to avoid them. The system is designed to work with unmanned aerial vehicles (UAVs) and other stratospheric aircraft. The proposed approach involves the use of risk-based conflict detection and avoidance algorithms that can be integrated into the flight management system of each aircraft. This technique aims to reduce the risk of mid-air collisions and enhance the overall safety of stratospheric operations.

Work in Progress

Safety Work

Fall 2020
- While paper on "risk/performance" tradeoff for CTMB

NASA/FAA Simulations

Summer 2020
- First time simulations with multiple operators and craft types

TCLs (Draft)

Spring 2021
- TCL 1
  - Test UAS safe and efficient in a low risk environment
  - Can UAS be made to use older class A airspace

Spring 2021
- TCL 2
  - Test UAS safe and efficient in a medium risk environment
  - Are transition through class A safe and efficient
  - Can manned aviation / traditional ATM coexist with CTMS

Spring 2023
- TCL 3
  - Can future transports rely on CTMS
FAA New Entrant ConOps Released in 2020
European Higher Airspace

ECHO is a two-year project that will deliver a comprehensive demand analysis and the concept of operations for higher airspace to allow safe, efficient and scalable operations.
FAA Air Traffic Organization’s Near-Term Initiative

Goal: Improve Safety Assurance in Upper Class E

- Upper Class E Airspace allows for VFR & IFR flights
- For IFR flights, existing separation standards do not cover interactions between expected vehicles types (e.g., supersonic to UAS)
- Need more comprehensive approach that can accommodate diverse vehicle performance

ATO Space Operations is exploring use of existing capabilities that could be used for strategic airspace deconfliction in upper Class E airspace
MITRE’s Strategic Deconﬂiction Research

- Use contours to characterize predictions about future positions
- Operators periodically update service suppliers with contours for current and future time periods
- Contours provide basis for calculating probability of undesirable events
- Conflict is probability of undesirable event greater than a threshold; threshold operationalizes Target Levels of Safety (TLS)
- Overlapping contours do not necessarily imply a conflict that must be resolved immediately
The Team

- **Caspar Wang** – Head of Airworthiness, AeroVironment Inc.
- **Peter De Baets** – Sr. Director, HAPS Programs, AeroVironment Inc.
- **Max Fenkell** – Director, Unmanned and Emerging Aviation Technologies, AIA
- **Andrew Tailby** – Zephyr Future Approvals Lead, Airbus Defence & Space
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- **Jennifer Gentry** – Principal Systems Analyst, The MITRE Corporation
- **Bobby Kluttz** – Principal Systems Engineer, The MITRE Corporation
Motivation for Adaptive Risk Based Conflict Detection

- Traditional aviation uses a flight-centric model (per flight hour) to measure harm to crew and passengers (1st and 2nd parties)
- Traditional model does not extend well to higher airspace operations:
  - Many operations are unmanned - 3rd party risk will likely be primary focus
  - Flight duration is not indicative of risk
- Operations may have non-deterministic trajectories – not practical to “block” entire airspace
- Propose an adaptive risk computation that assesses the probability and severity of undesirable events
  - If likelihood of harm resulting from an undesirable event exceeds the target level of safety (TLS) for any party, deconfliction is necessary
Proposed Solution Must Accommodate Many Non-Traditional Flight Characteristics

- Missions may last over a year (some loitering/station keeping), others a few minutes
- Wide range of mission objectives, preferences and constraints
- Growing uncertainty of intents in future
- Probabilistic intents – The airspace cannot be structured in corridors
- Frequent airborne replan (can be every minute)
Cooperative Traffic Management in the Stratosphere (CTMS)

- Necessary to identify which conflicts to resolve/exceed TLS
Assessing Probability of Undesirable Events

- In the stratosphere many trajectories will be non-deterministic
- Operators will share intents with different levels of confidence
- Overlap of intents provides basis for calculating undesirable events
- Overlapping intents does not necessary imply TLS will be exceeded
Categories of Harm

- **1st Party Harm**: Resulting damage to flight crew or airframes directly involved in the collision
- **2nd Party Harm**: Harm to participants or cargo onboard a vehicle directly involved in the collision
- **3rd Party Harm**
  - Fatal injuries to people on the ground
  - Fatal injuries to people in the air
  - Damage to critical infrastructure
- If a manned vehicle is involved in conflict, 1st and 2nd party harm will dominate
- If conflict is between two unmanned vehicles, 3rd party harm will likely dominate

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1 According to JARUS guidelines on SORA 2.0
Victim Centric Model

- A TLS per unmanned flight hour would be equivalent to defining a risk per shark swim hour
- The risk per swimmer or per beach is more appropriate
3rd Party Harm

- 3rd party harm is tied to a chain of events:

- Population density and air traffic density are inputs to calculation
- Probability of the undesirable event (e.g. collision) is the controllable component of the likelihood of harm
Aggregating 3rd Party Risk

- Risks across multiple potential conflicts are aggregated to determine total risk to a 3rd party
- If TLS is exceeded operators are alerted and reduce the likelihood of undesirable events for one or more potential conflicts
Further Research Needs

- Detailed timeline to resolve conflicts
- Should all vehicles have the same right to a portion of 3rd party risk
- Should risk be allocated by operator
- Appropriate way to express risk for each category of harm: individual vs. collective
- Definition of the region and time period over which the risk needs to be assessed
- Appropriate TLS thresholds
Additional Material
What’s Already Up There?

2016: 15,631,000 flights were handled by FAA

Less than 1,200 domestic flights at FL480 and above in 2017

▪ Very few civil aircraft routinely fly at FL480 and above
▪ None routinely flew above FL510

Filters Applied:

– Removed records with military aircraft, military airports and missing data (airport or aircraft)
– Excluded records with the same departure and arrival airport

Source: MITRE Threaded Track
New Entrant Performance Categorization

- **Lower Collision Risk**: Implies controlled trajectory for collision avoidance or low collision severity outcome.
- **Higher Collision Risk**: Implies low to no real-time control over trajectory for collision avoidance or high collision severity outcome.

- **High Collision Risk**: Operations in this Region Reach 330,000 ft and Higher

- **Low Collision Risk**: Expected Operations by 2025

- **Limited Tactical Control**: Operations in this Region Rarely go beyond 100,000 ft

- **Strategic Planning**: Expected Operations by 2025

- **Chart is notional and positions are not exact and variation may exist within any category**
No upper boundaries have been legally defined for sovereign, controlled or navigable airspace, either at a national or international level.