Introduction to Higher Airspace Operations

Including Collaboration on Risk-Based Conflict Detection Framework

Jennifer Gentry

March 2021
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

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

- This region is expected to have the most diverse set of operations and highest need for traffic management services
## 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></td>
<td><strong>Space Perspectives</strong></td>
</tr>
<tr>
<td><strong>Business Jet</strong></td>
<td>- Platform: Suborbital space tourism via balloon with manned capsule</td>
</tr>
<tr>
<td>- Platform: Supersonic transport (12-18 pax) Mach 1.4 – 1.6</td>
<td></td>
</tr>
</tbody>
</table>

*2017 GANIS Panel

**Aerion stated cruise altitude is FL400

(© 2021 THE MITRE CORPORATION. ALL RIGHTS RESERVED.)
Performance Categories and Initial Geographic Segregation (Near-Term)

- **Long Endurance Unmanned Balloons**: Likely to be concentrated over developing countries near populated regions.
- **Long Endurance Unmanned Airships & Aircraft**: Likely to be concentrated over developing countries near populated regions.
- **Military (U-2 & Global Hawk)**: Likely to be concentrated over water to minimize travel time between continents and environmental impact.
- **Amateur Rockets**
- **Air Launched Objects**
- **Spacecraft Launch and Recovery**
- **Unmanned Sounding Balloons (e.g., weather balloons)**
- **Manned Balloons**

**SPEED**

- Slower
- Faster
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**: Must meet minimum Class A CNS Requirements in order to reach Class E above FL600
  - Class 3 Amateur Rocket
  - UFB Super Pressure
  - UFB Zero Pressure
  - UFB Sounding

- **Part 400**: No Equipage Currently Required
  - Horizontal Takeoff
  - Vertical Takeoff to Orbit
  - Winged-Reentry
  - Vertical Takeoff and Landing
  - DeOrbit/Decay

- **Part 91**: Balloon with Parachute and Passenger Capsule
  - 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

Commercial Space

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

On Ground Airborne

Flights in domestic airspace rarely exceed 7 hours

Commercial Space operations quickly transit Higher Airspace

Most anticipated operations will last multiple months

Year prior to launch Launch/Departure Year after launch
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 - Head of Communications - L3Harris Inc
- Peter Oden - Director, AF-24/ATM Program - 71d Fires, Inc
- Mike Zelinksi - Director, Unmanned and Emerging Air Traffic Technologies - L3Harris
- Andre Faith - Agile Places Lead - AAM Acceleration & Space
- Dr. Steve Avery - Head Sciences, National Airspace System Program
- Paul Tyler - Air Safety Inspector, Civil Aviation Safety Authority Australia
- Lyle Turner - Head of Aircraft Exchange - L3Harris
- Dan Faugh - Head of System Engineering - L3Harris
- Joe Mowery - Principal Systems Analyst - The MITRE Corporation
- John Clyne - Principal Systems Engineer - The MITRE Corporation

Abstract:
Conflict detection between avionics looking to operate in the climatization pass lower airspace could result in a conflict and lead to a risk of failure for operational safety. The implementation of new concepts is not yet designed to solve this. This paper aims to explore a solution that considers the vulnerabilities and risk of operation in these new concepts and the need for adaptive risk-based conflict detection. The goal is to reduce the risk of failure and improve the overall safety of the system.

Work in Progress

Safety Work

- Operators have SMS in place

NASA/FAA Simulations

- Summer 2020: Real-time simulations with multiple operators and craft types

TCLa (Draft)

- Spring 2021 - TCL1: Realtime is CMA safe and efficient in a low risk environment limited to slow moving unmanned vehicles, at altitude
- Can CMA make use of standard class A airspace

Spring 2022 - TCL2
- Is CMA safe & efficient in a medium risk environment
- Are transition through class A safe and efficient
- Can manned aviation / traditional ATM coexist with CMA

Spring 2023 - TCL3
- Can future transports rely on CMA

Source: World ATM Congress 2020 Panel
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
- **Dr. Steve Barry** – Risk Intelligence Lead, Airservices Australia
- **Paul Taylor** - Air Safety Inspector, Civil Aviation Safety Authority Australia
- **Leonard Bouygues** – Head of Aviation Strategy, Loon
- **Zohaib Mian** – Head of Systems Engineering, Loon
- **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

Source: Industry CONOPs "CTMS" Drone Enable 3
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

- 1\textsuperscript{st} Party Harm: Resulting damage to flight crew or airframes directly involved in the collision
- 2\textsuperscript{nd} Party Harm: Harm to participants or cargo onboard a vehicle directly involved in the collision
- 3\textsuperscript{rd} Party Harm\(^1\)
  - 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 1\textsuperscript{st} and 2\textsuperscript{nd} party harm will dominate
- If conflict is between two unmanned vehicles 3\textsuperscript{rd} party harm will likely dominate

\(^1\) 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
NOTICE

This work was produced for the U.S. Government under Contract DTFAWA-10-C-00080 and is subject to Federal Aviation Administration Acquisition Management System Clause 3.5-13, Rights In Data-General, Alt. III and Alt. IV (Oct. 1996).

The contents of this document reflect the views of the author and The MITRE Corporation and do not necessarily reflect the views of the Federal Aviation Administration (FAA) or the Department of Transportation (DOT). Neither the FAA nor the DOT makes any warranty or guarantee, expressed or implied, concerning the content or accuracy of these views.

For further information, please contact The MITRE Corporation, Contracts Management Office, 7515 Colshire Drive, McLean, VA 22102-7539, (703) 983-6000.

© 2021 The MITRE Corporation. All Rights Reserved.

Approved for Public Release; Distribution Unlimited. Public Release Case Number 21-0484
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.

---

**Limited Tactical Control**: Operations in this region rarely go beyond 100,000 ft.

**High Collision Risk**: Operations in this region reach 330,000 ft and higher.

© 2021 THE MITRE CORPORATION. ALL RIGHTS RESERVED.
No upper boundaries have been legally defined for sovereign, controlled or navigable airspace, either at a national or international level.