

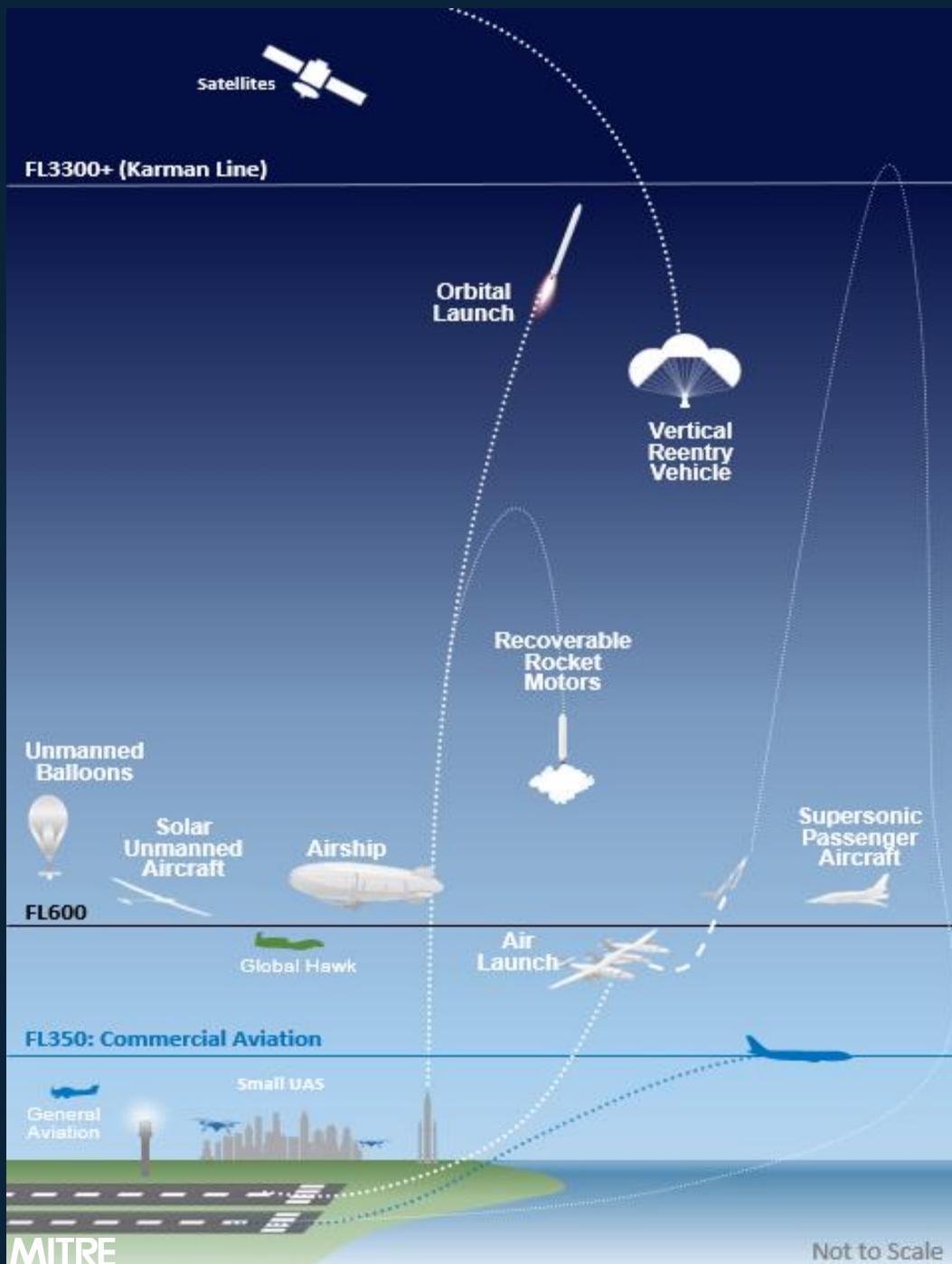
Introduction to Higher Airspace Operations

Including Collaboration on Risk-Based Conflict Detection Framework

Jennifer Gentry

March 2021

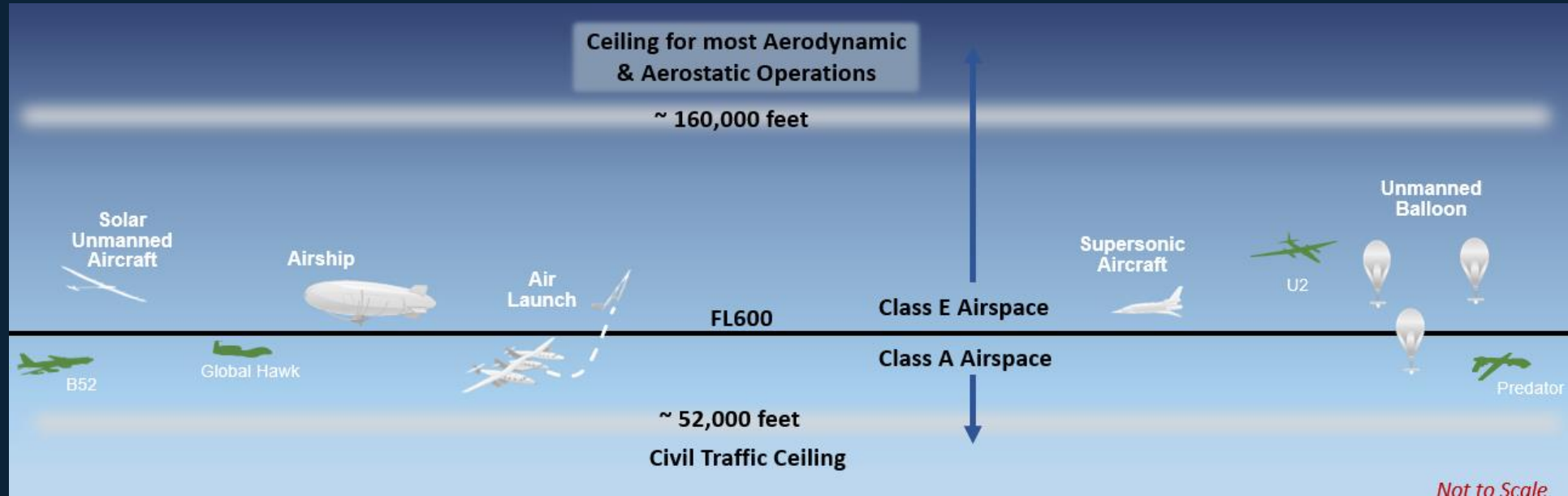
MITRE | **SOLVING PROBLEMS
FOR A SAFER WORLD**



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

Operation Type	Speed	Duration	Cruise Altitude (ft)
Unmanned Balloons (Super & Zero Pressure)	Low	Hours - Months	50,000 to 75,000
Manned Balloons (Space Tourism)	Low	Hours	100,000
Long Endurance Unmanned Aircraft	Low	Days - Months	60,000 to 85,000
Supersonic Transport Aircraft (Manned)	Very High	Hours	50,000 to 70,000
Unmanned Airships	Low	Days	55,000 to 70,000

- 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)

Aircraft

Airbus – Zephyr*

- Platform: High altitude long endurance solar UAS

Aerovironment - Hawk

- Platform: High altitude long endurance solar UAS

Boeing/Aurora – Odysseus

- Platform: High altitude long endurance solar UAS

Boom - Overture*

- Status: XB-1 2019 demonstrator (fastest civil aircraft)
- Platform: Supersonic transport (50-75 pax) Mach 2.2

Spike & Aerion** Business Jet

- Platform: Supersonic transport (12-18 pax) Mach 1.4 – 1.6

*2017 GANIS Panel

**Aerion stated cruise altitude is FL400

Lighter-than-Air

Loon*

- Status: Winding down operations (as of 04/2021)
- Platform: Super pressure balloons

Thales – [Stratobus](#)*

- Platform: Solar airship

Worldview – Stratollite*

- Platform: Hybrid balloon with steerable parafoil for payload recovery

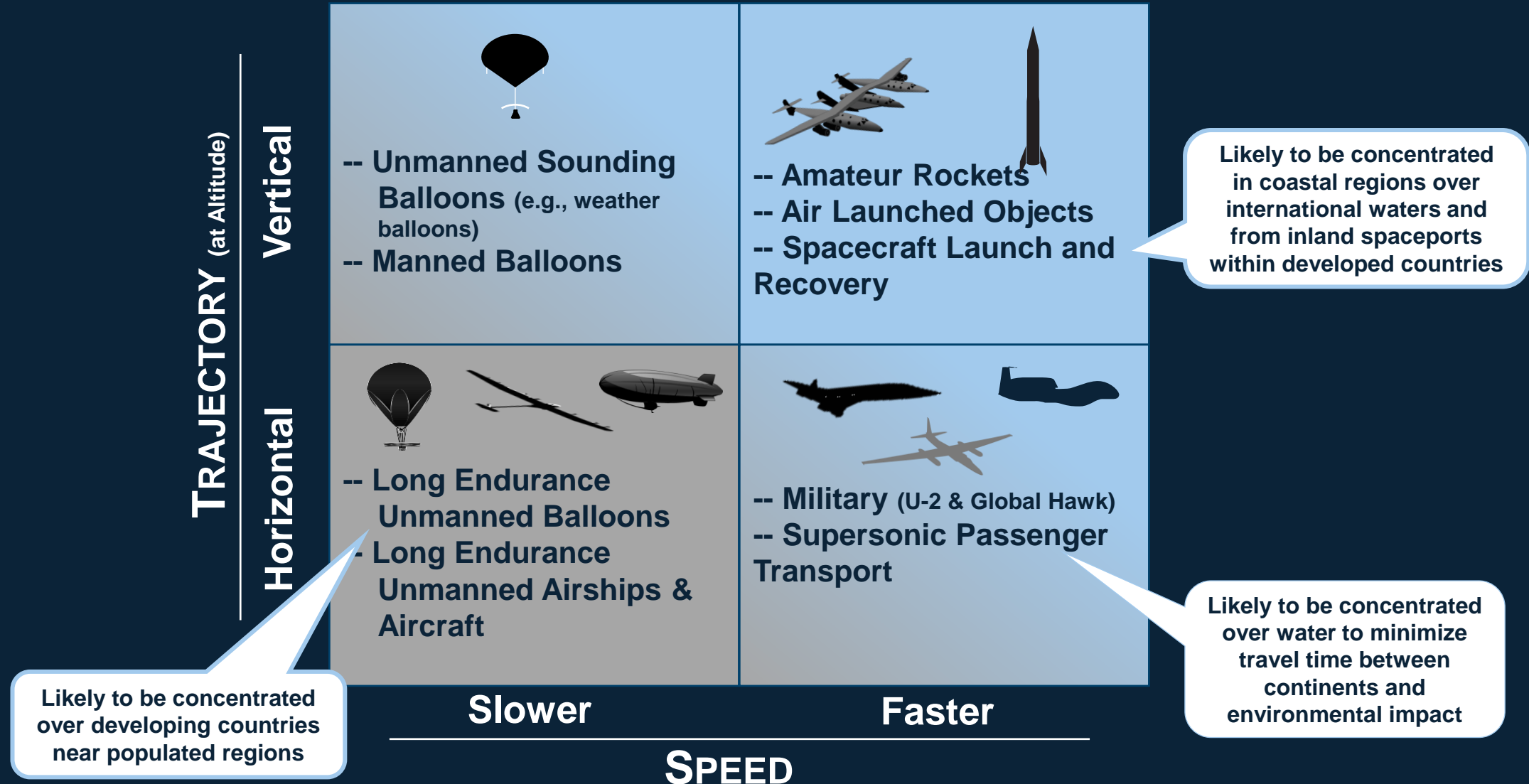
Sceye

- Platform: High altitude airship

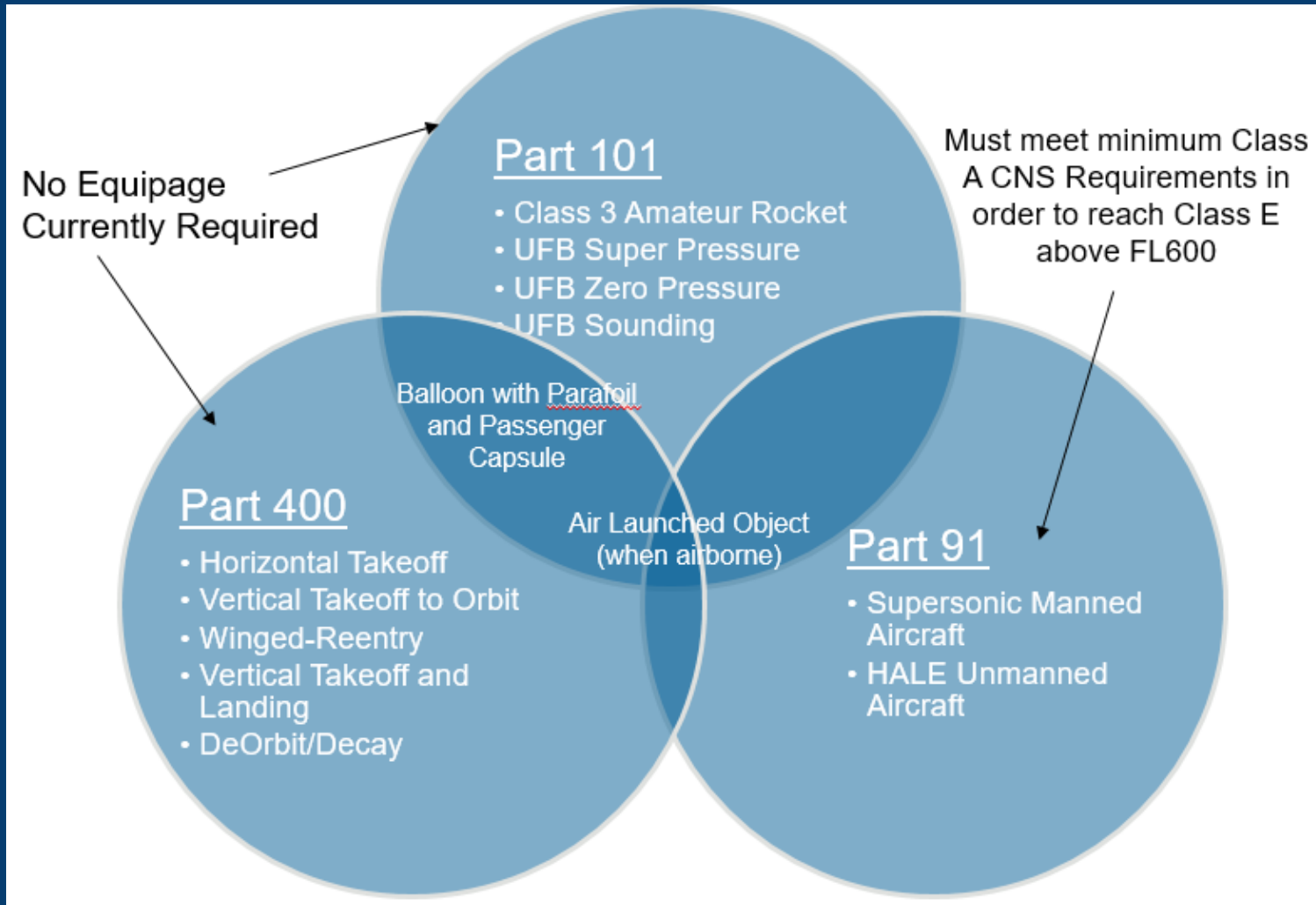
Space Perspectives

- Platform: Suborbital space tourism via balloon with manned capsule

Performance Categories and Initial Geographic Segregation (Near-Term)



FAA Regulatory Overview for New Entrants

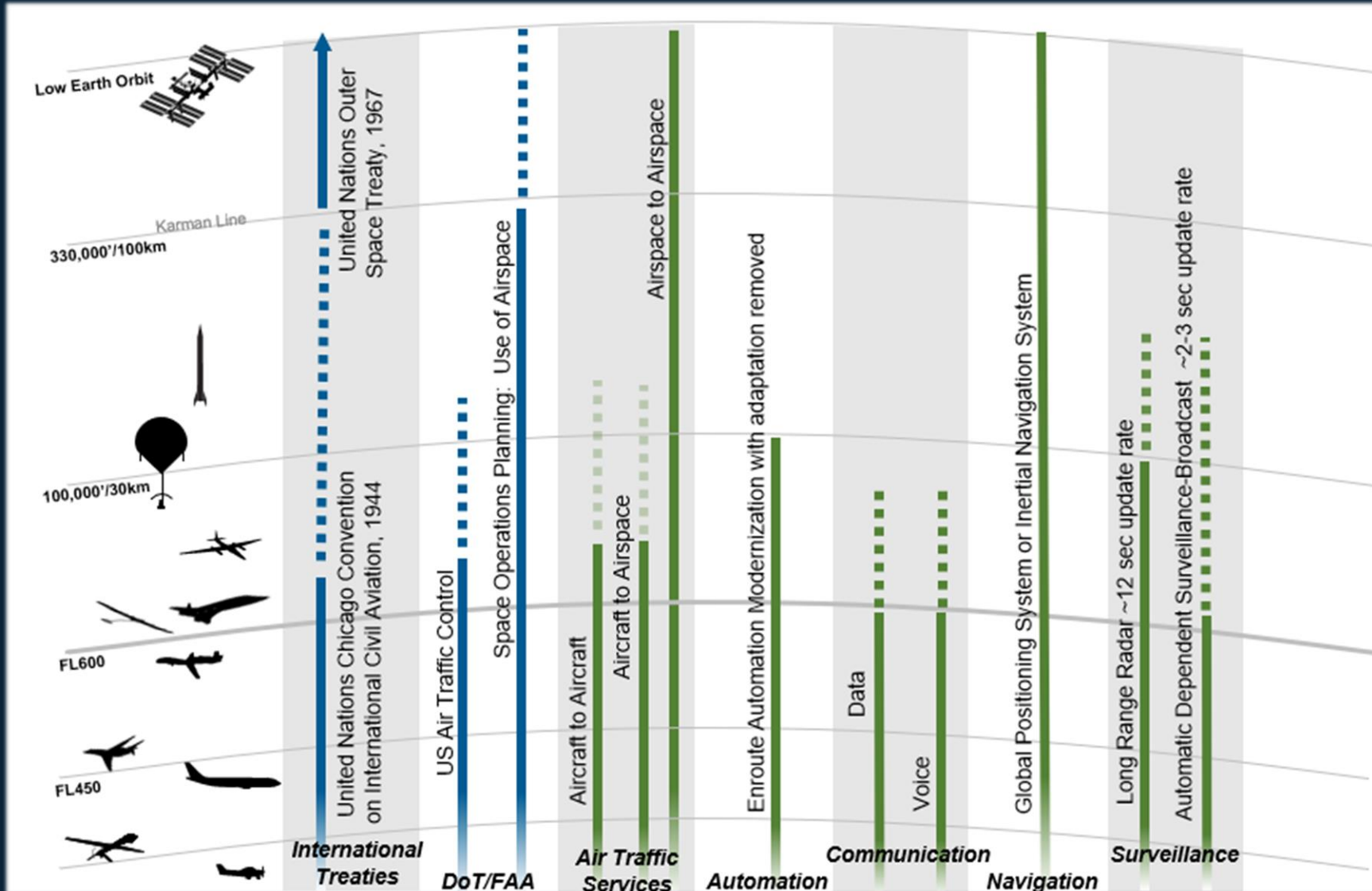


New entrants operating in higher airspace are primarily regulated by three different Parts in Title 14 CFR, each with significantly different equipage and operating requirements

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

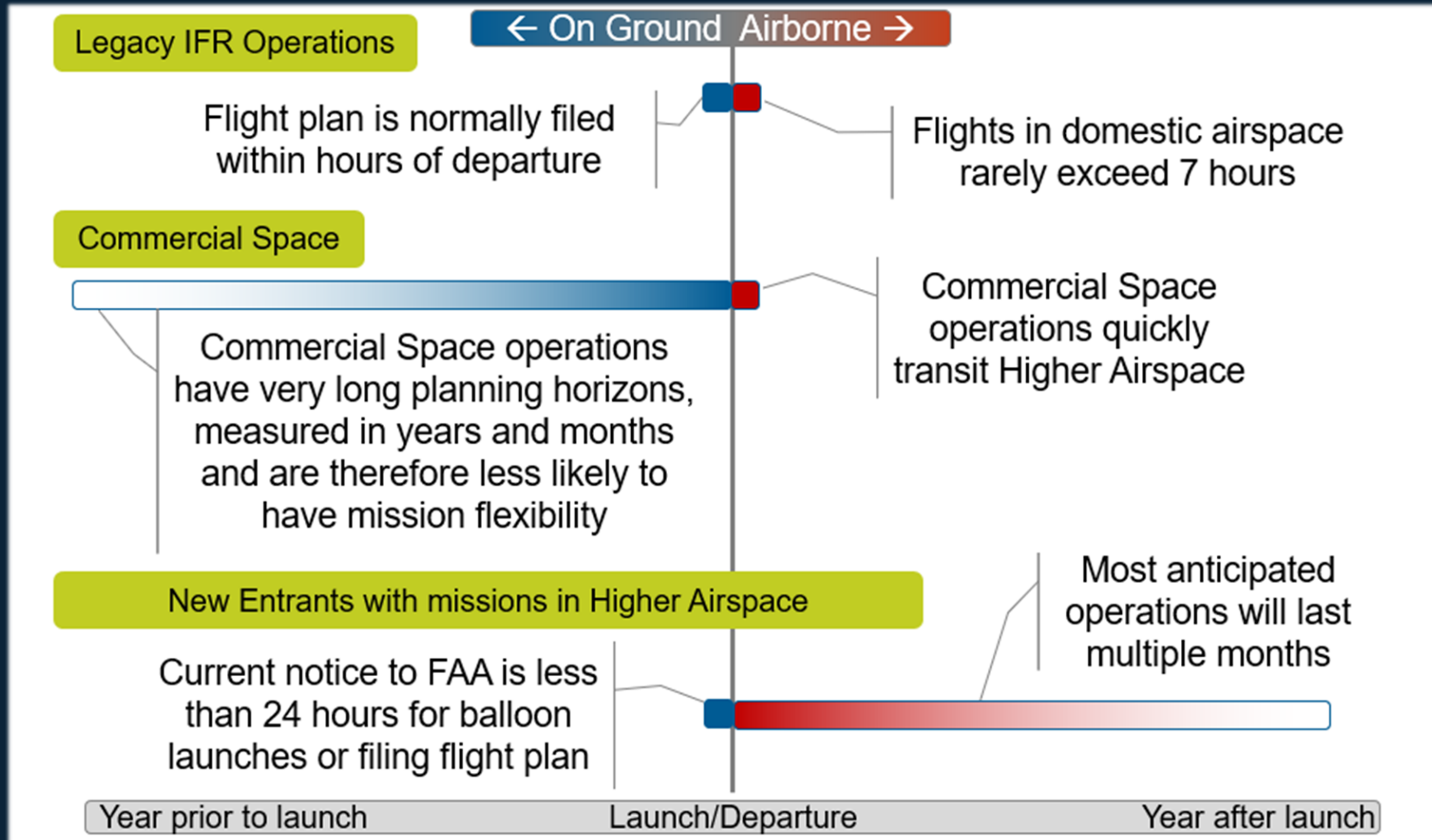
Positives

- 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



Current Airspace Options and Priority System

Airspace Options for Civil Operators	TFR	Chartered TFR	Stationary ALTRV	Restricted Area, with Using Agency Approval	Warning Area, with Using Agency Approval	ATCAA
New Entrants*						
Unmanned Free Balloons	●	●	●	●	●	●
Amateur Rockets	●	●	●	●	●	●
Launch and Reentry Vehicles: Orbital & Suborbital	●	●	●	●	●	●
Manned Aircraft	●	●	●	●	●	●
Unmanned Aircraft	●	●	●	●	●	●

*Hybrid operations not included

● Yes ● No

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

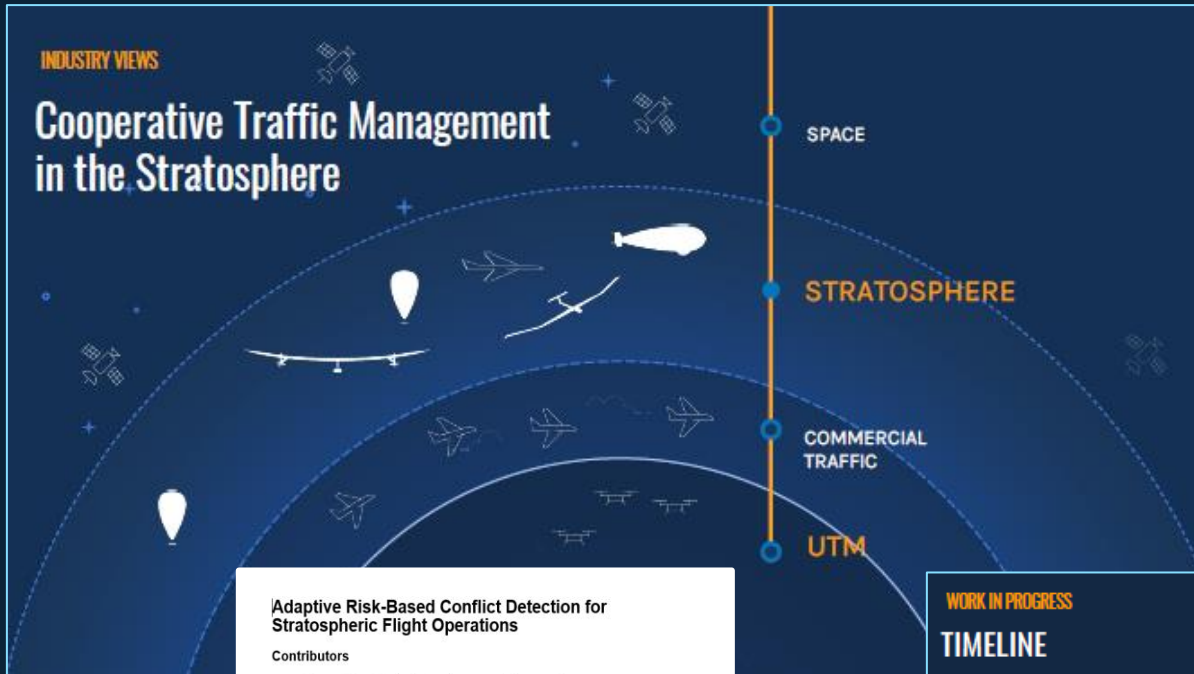
For example, some spacecraft have narrow launch windows, dictated by orbital dynamics, and therefore have minimal launch flexibility. At the other extreme are constellations of airships or balloons which can station-keep for months at a time, preventing other operations from using the airspace.

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



Adaptive Risk-Based Conflict Detection for Stratospheric Flight Operations

Contributors

- Caspar Wang – Head of Airworthiness – AeroVironment Inc.
- Peter De Baets – Sr. Director, HAPS Programs – AeroVironment Inc.
- Max Fenkell – Director, Unmanned and Emerging Aviation Technologies – ALA
- 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 Bouvygues – Head of Aviation Strategy – Loon
- Zohaib Mian – Head of Systems Engineering – Loon
- Jennifer Gentry – Principal Systems Analyst – The MITRE Corporation
- Bobby Klutz – Principal Systems Engineer – The MITRE Corporation

Abstract

Conflict detection between new vehicles looking to operate in the stratosphere has raised questions related to access and risk assessment that existing civil aviation systems were not designed to address. This paper applies an adaptive risk commutation that assesses the probability and severity of undesirable events and the acceptable level of safety (TLS) uses a flight-centric model (per passengers (1st and 2nd parties). This approach does many operations are unmanned, and flight duration in the stratosphere. The proposed approach broadens the existing risk model with 1st, 2nd, and 3rd party risk. This is suited to operations that may linger for months or zip by at supersonic speed; unmanned vehicles is 3rd party risk. If the probability and severity of an undesirable event deconfliction is necessary.

WORK IN PROGRESS

TIMELINE

Safety Work

- Operators have SMS in place
- Fall 2020**
 - White paper on risk/performance based framework for CTMS
- Early 2021**
 - White paper on Human Automation Teaming
- Spring 2021**
 - ICAO Performance based Guidance Material for unmanned free balloons

NASA/FAA Simulations

- Summer 2020**
 - Fast time simulations with multiple operators and craft types
- Fall 2020**
 - Real time simulation including interactions with ANSP
- Early 2021**
 - Draft FAA CONOPs
- Spring 2021**
 - Joint operational demonstration

TCLs (Draft)

- Spring 2021 - TCL1**
 - Is CTMS safe and efficient in a low risk environment limited to slow moving unmanned vehicles, at altitude
 - Can CTMS make use of unused class A airspace
- Spring 2022 - TCL2**
 - Is CTMS safe & efficient in a medium risk environment.
 - Are transition through class A safe and efficient
 - Can manned aviation / traditional ATM coexist with CTMS
- Spring 2023+ - TCL3+**
 - Can future transports rely on CTMS

International Civil Aviation Organization
AN-Conf/13-WP/165'
28/9/18

WORKING PAPER

THIRTEENTH AIR NAVIGATION CONFERENCE
Montréal, Canada, 9 to 19 October 2018

COMMITTEE A

Agenda Item 5: Emerging issues
5.1: Operations above Flight Level 600

INDUSTRY VIEWS ON OPERATIONS ABOVE FLIGHT LEVEL 600
(Presented by the International Coordinating Council of Aerospace Industries Associations (ICCAIA))

EXECUTIVE SUMMARY

This paper presents the views of the International Coordinating Council of Aerospace Industries Associations (ICCAIA) on operations of high altitude long endurance unmanned aircraft systems (HALE UAS)/lighter-than-air (LTA) craft. Although no new standards are presently required, in order to enable safe and orderly expansion of higher airspace operations, the global community, in partnership with industry, should analyse potential issues this forecasted expansion may cause. We recommend moving forward on this shared endeavour with some key principles, outlined in this paper and echoed in the ICAO Global Air Navigation Plan (GANP, Doc 9750) and the Global Air Traffic Management Operational Concept (GATMOC, Doc 9854).

Action: The Conference is invited to agree to the recommendation contained in paragraph 3.1.

1. INTRODUCTION

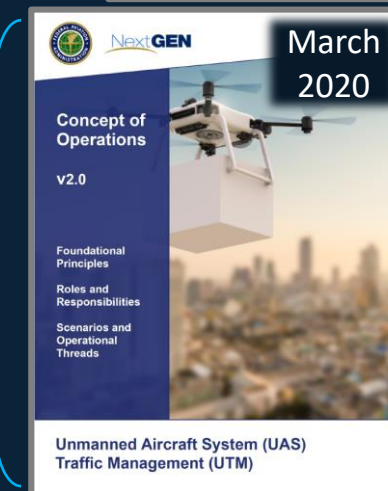
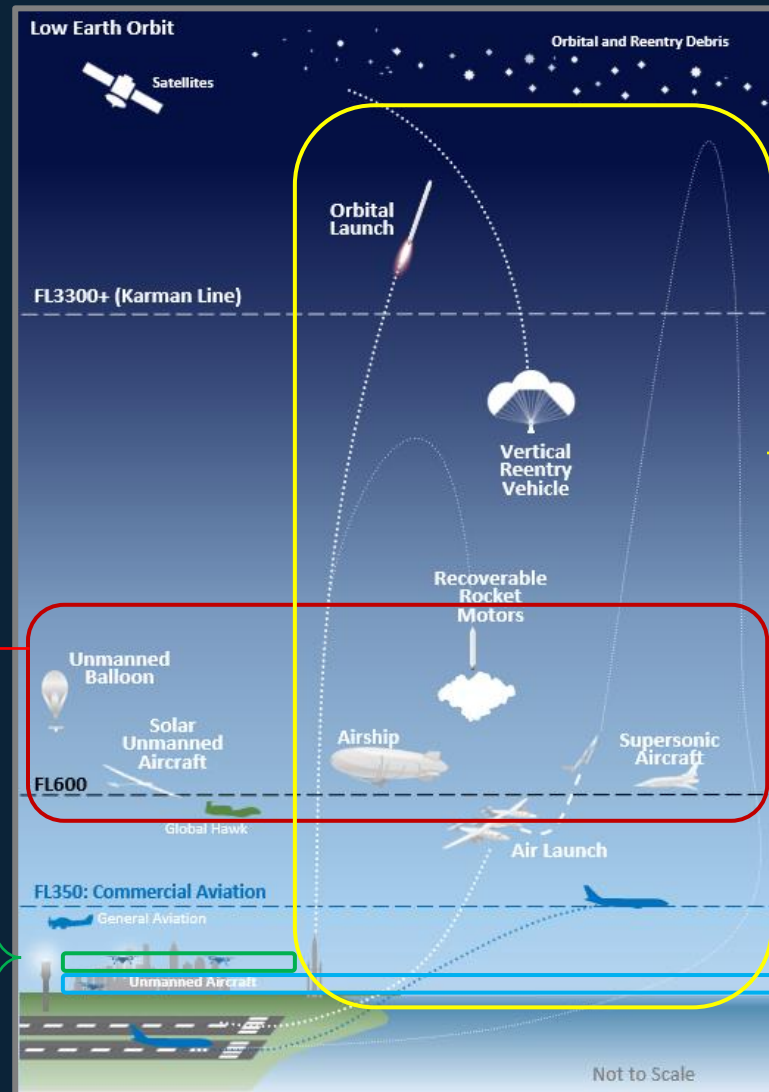
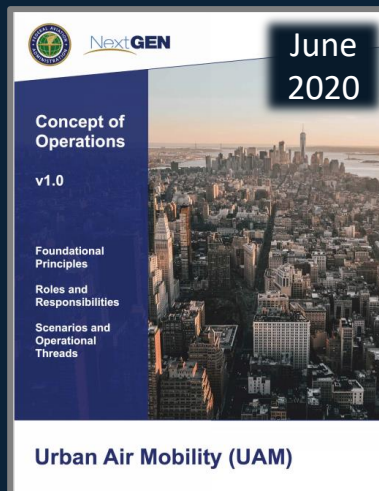
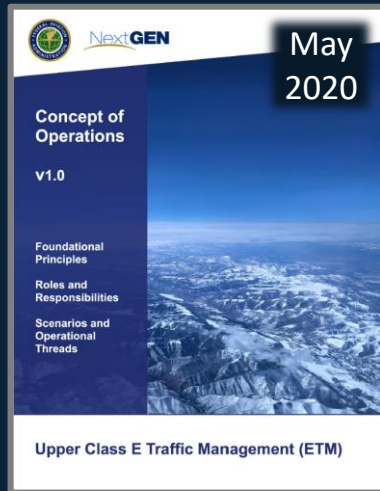
1.1. Of the myriad of new technologies sharing our skies today, perhaps the most hopeful and innovative aircraft are the diverse array of high altitude long endurance unmanned aircraft systems (HALE UAS)/lighter-than-air (LTA) craft. These human-in-the-loop, highly automated craft conduct higher airspace operations (above FL600 up to approximately 50 km) for periods of 90 days and beyond.

1.2. While the current density of operations is relatively low, this number is projected to increase. As such, the HALE industry believes that States, manufacturers and operators must collaboratively develop risk and performance-based regulatory initiatives to ensure all airspace users are provided safe and equitable access.

1.3. Although no new standards are presently required, in order to enable safe and orderly expansion of higher airspace operations, the global community, in partnership with industry, should analyse potential issues this forecasted expansion may cause. As in the case of remotely piloted aircraft

¹ English, Arabic, Chinese, French, Russian and Spanish versions provided by ICCAIA.

FAA New Entrant ConOps Released in 2020



SESAR 2020 Research Initiative: ECHO



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



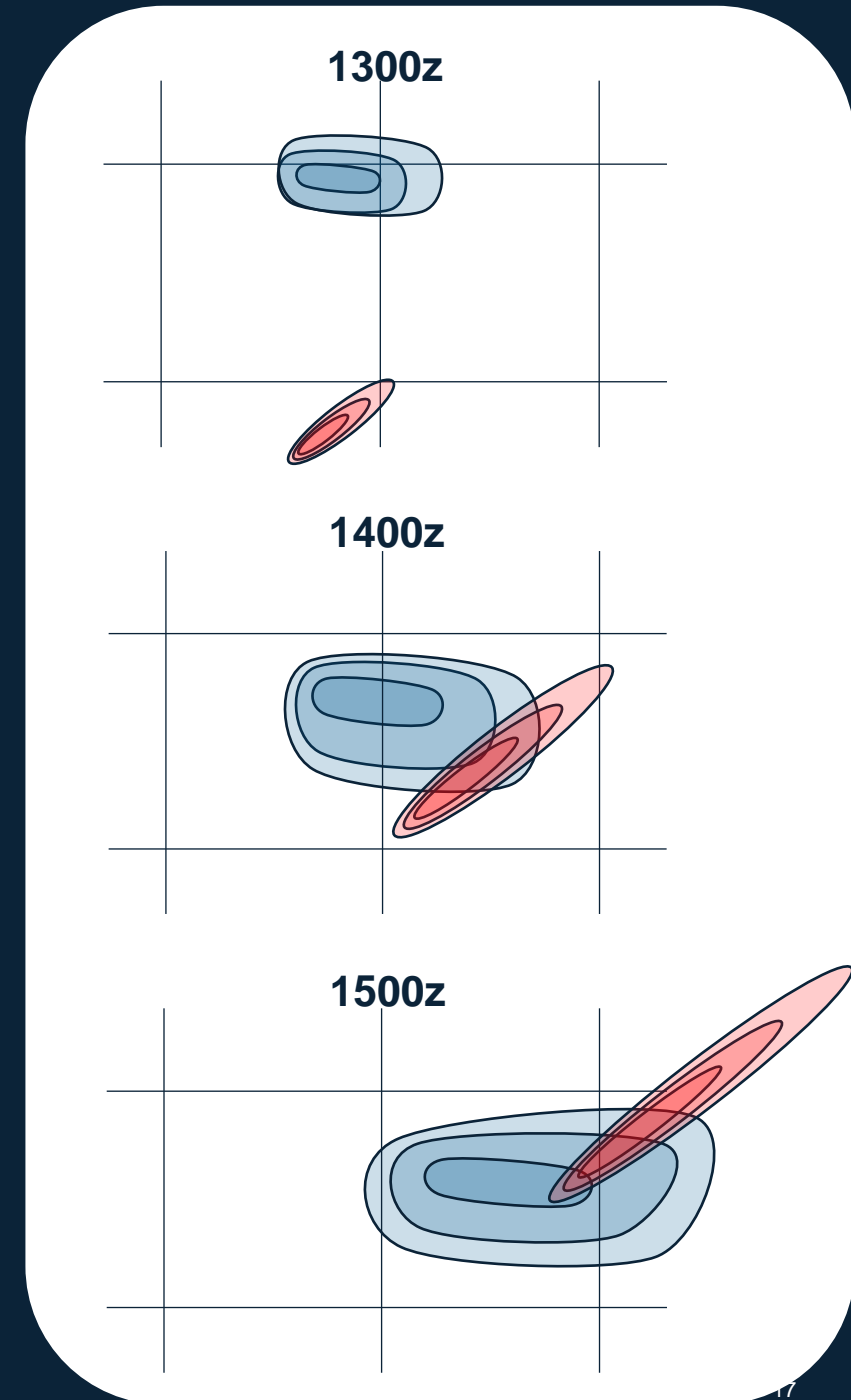
ATO Space Operations is exploring use of existing capabilities that could be used for strategic airspace deconfliction in upper Class E airspace

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

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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- **Bobby Kluttz** – Principal Systems Engineer, The MITRE Corporation

ADAPTIVE RISK-BASED CONFLICT DETECTION FOR STRATOSPHERIC FLIGHT OPERATIONS

By Caspar Wang, and Peter De Baets, AeroVironment Inc., Max Fenkell, AIA, Andrew Tailby, Airbus Defence & Space, Steve Barry, Ph.D., Airservices Australia, Paul Taylor, Civil Aviation Safety Authority Australia, Leonard Bouygues, and Zohaib Mian, Loon, Jennifer Gentry, and Bobby Kluttz, The MITRE Corporation

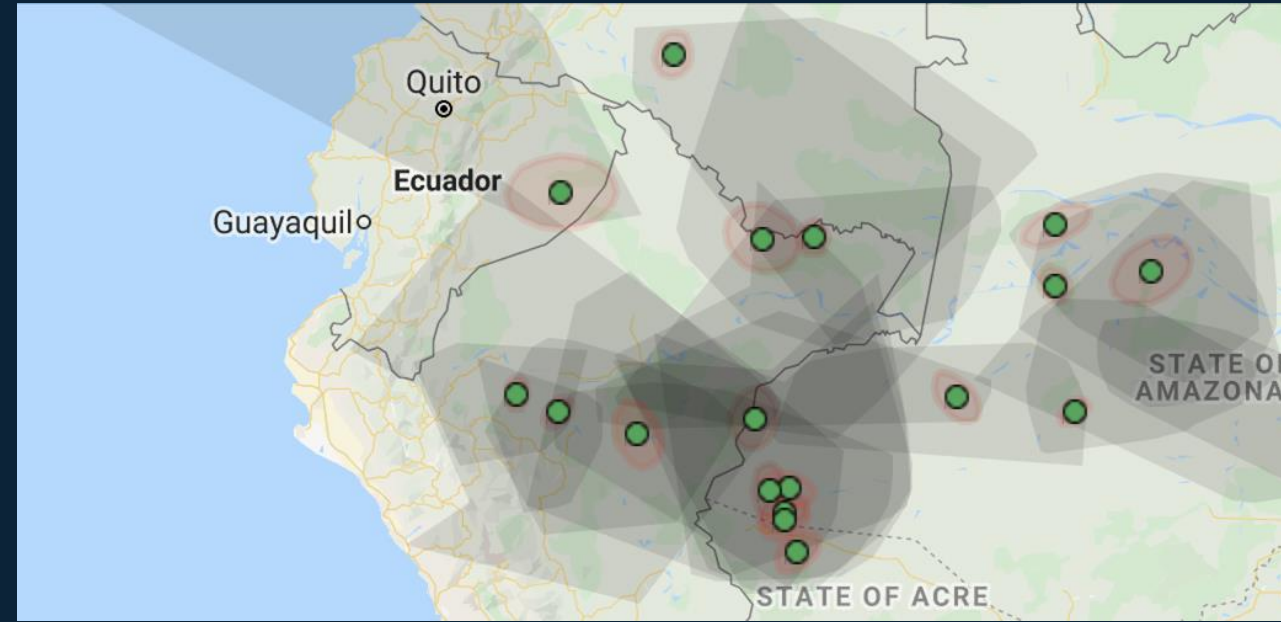
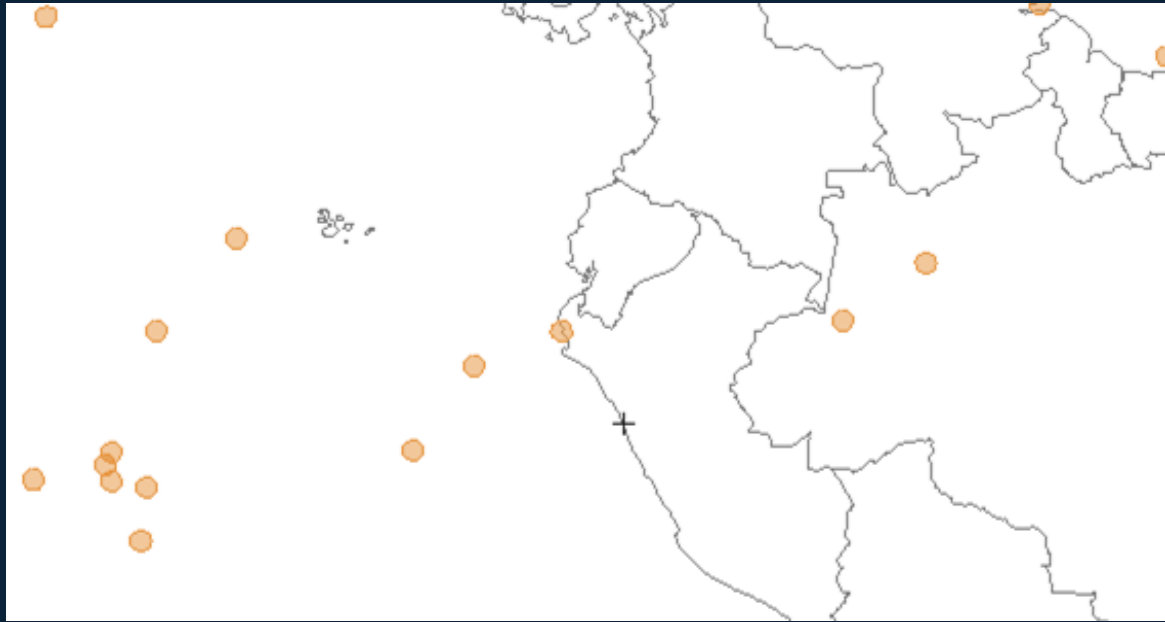
Journal of Air Traffic Control Spring 2021

26 Spring 2021

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

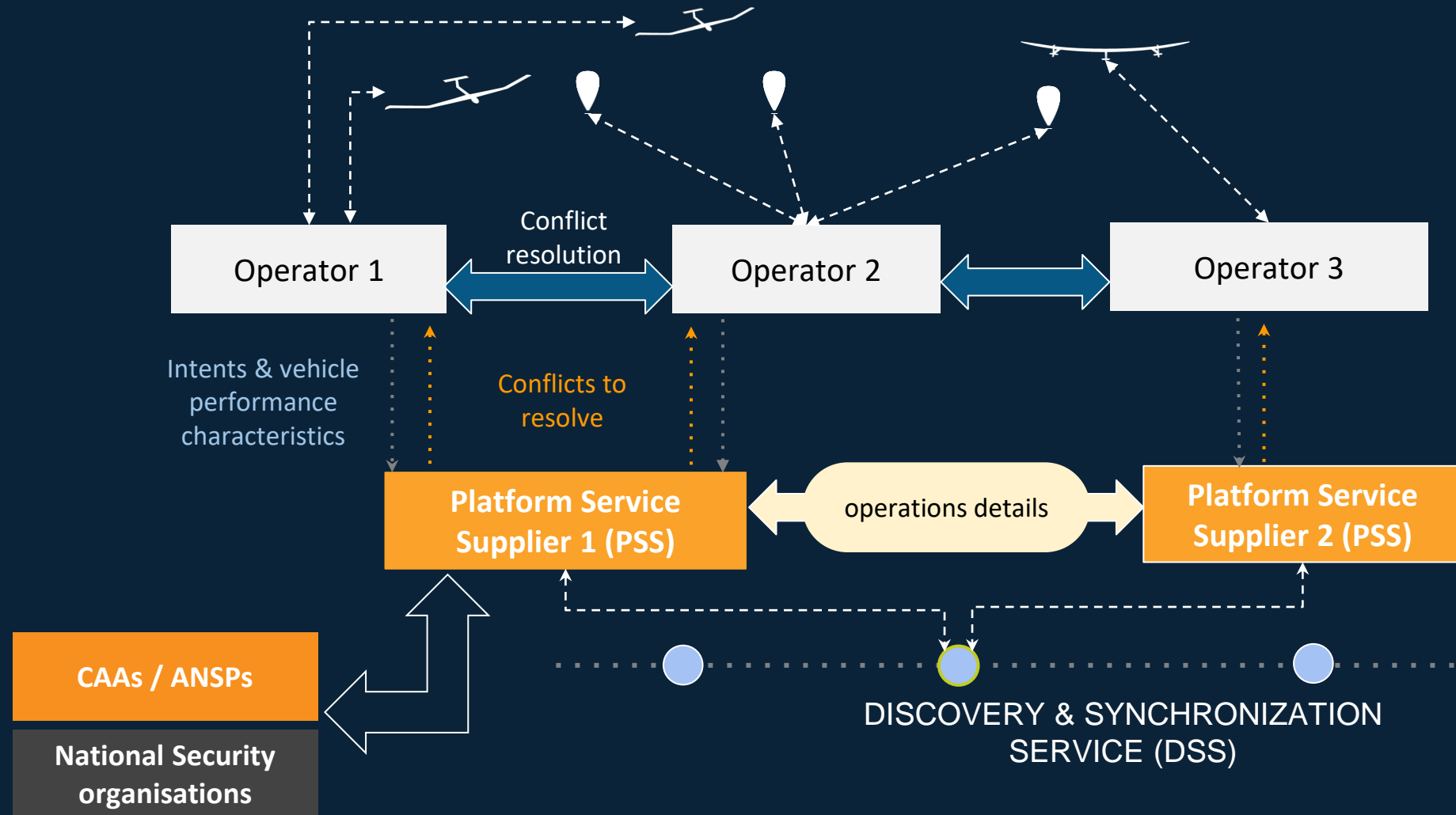
Proposed Solution Must Accommodate Many Non-Traditional Flight Characteristics



- 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)

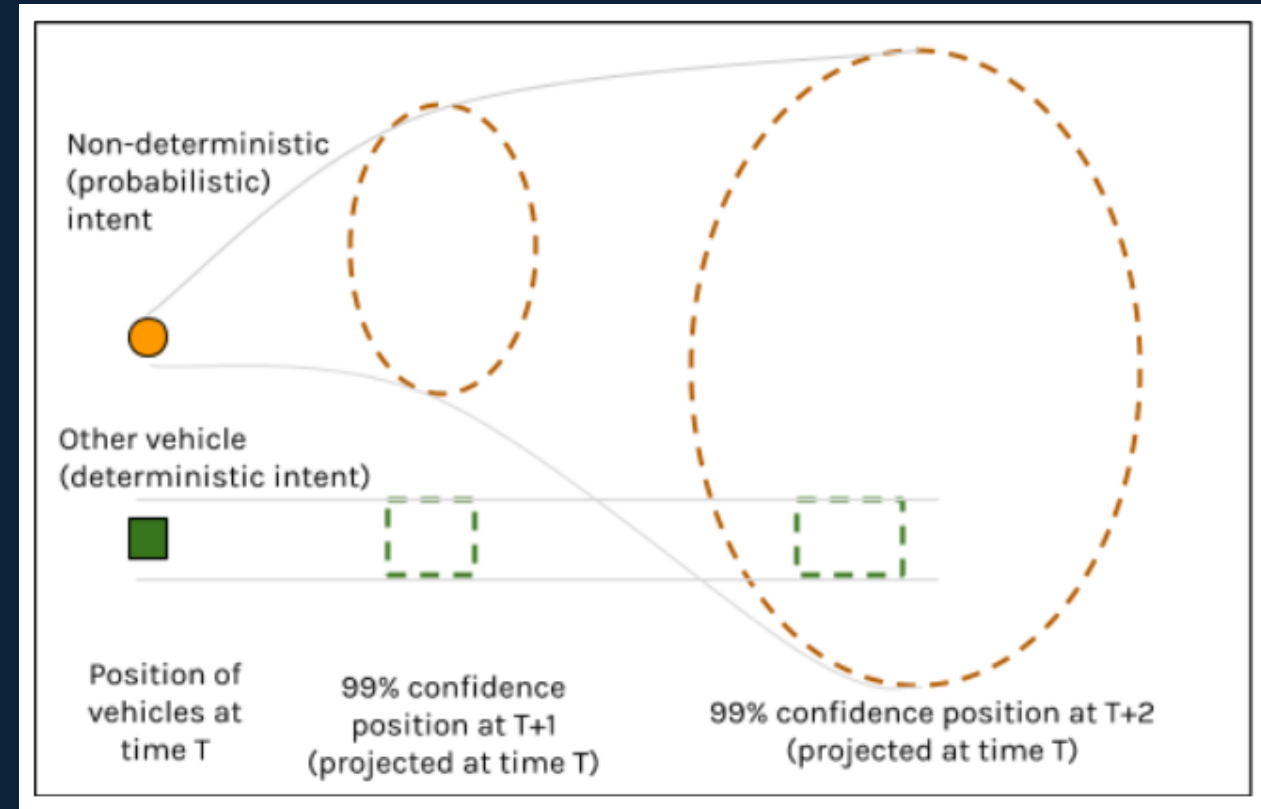
Cooperative Traffic Management in the Stratosphere (CTMS)

- Necessary to identify which conflicts to resolve/exceed TLS



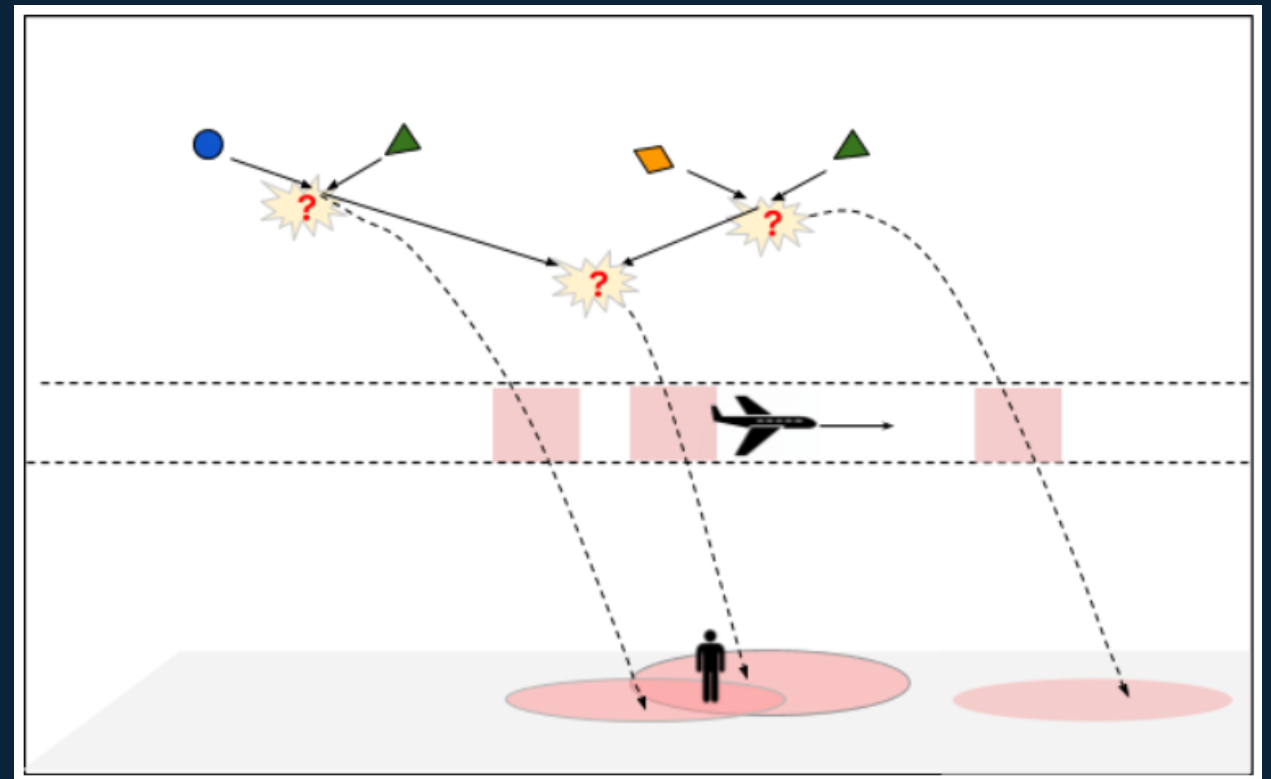
Assessing Probability of Undesirable Events

- 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 Harm¹
 - 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



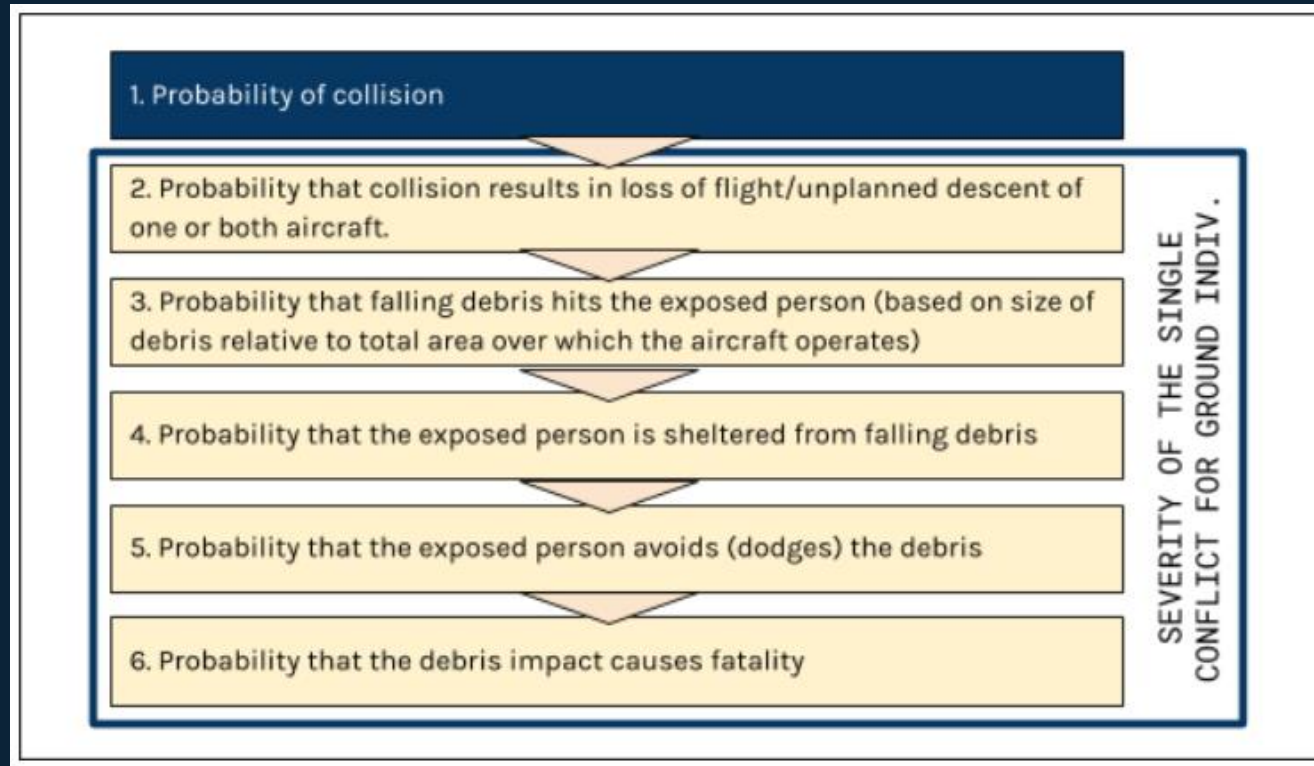
¹ According to JARUS guidelines on SORA 2.0

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

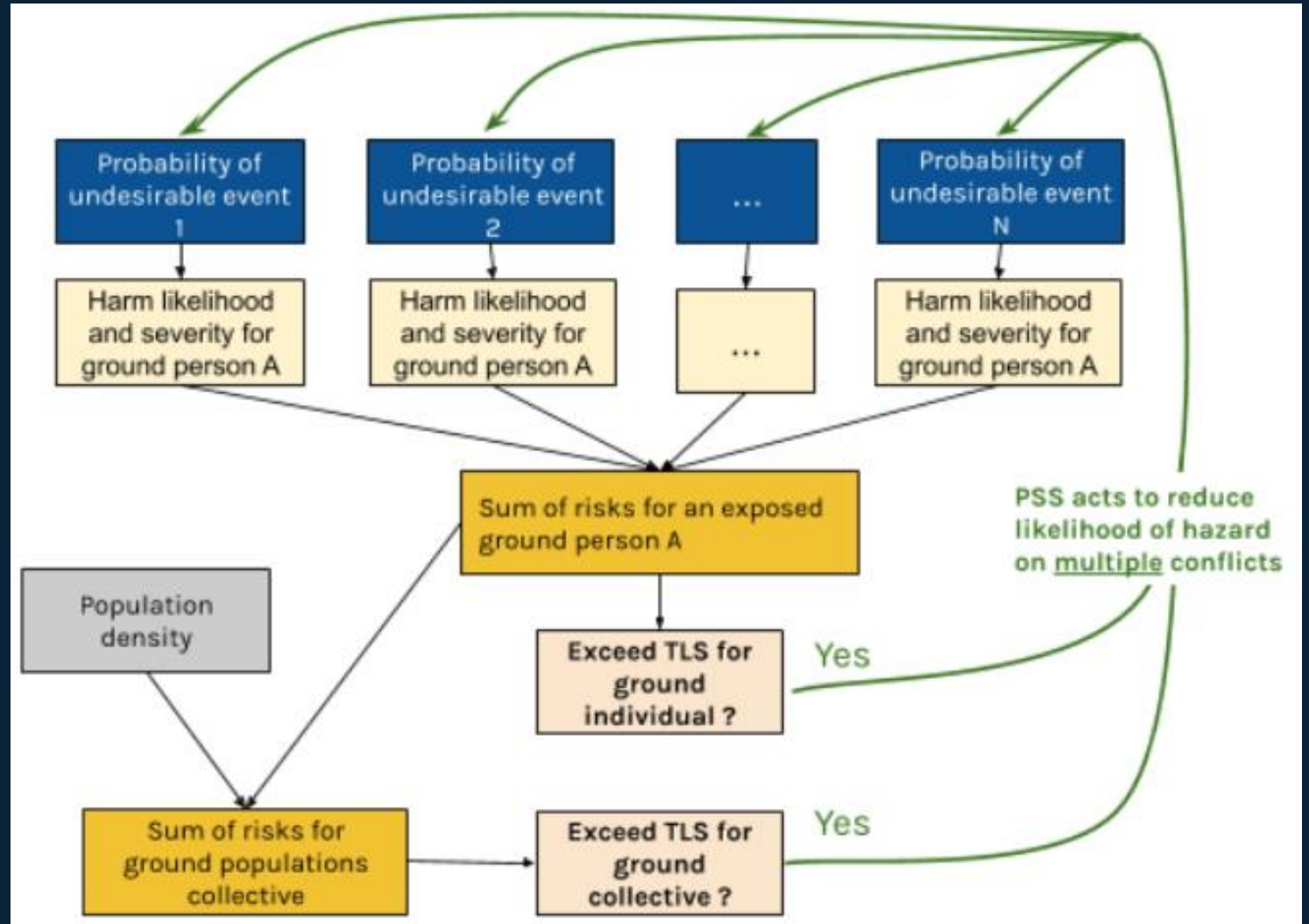
- 3rd party harm is tied to a chain of events:



- 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

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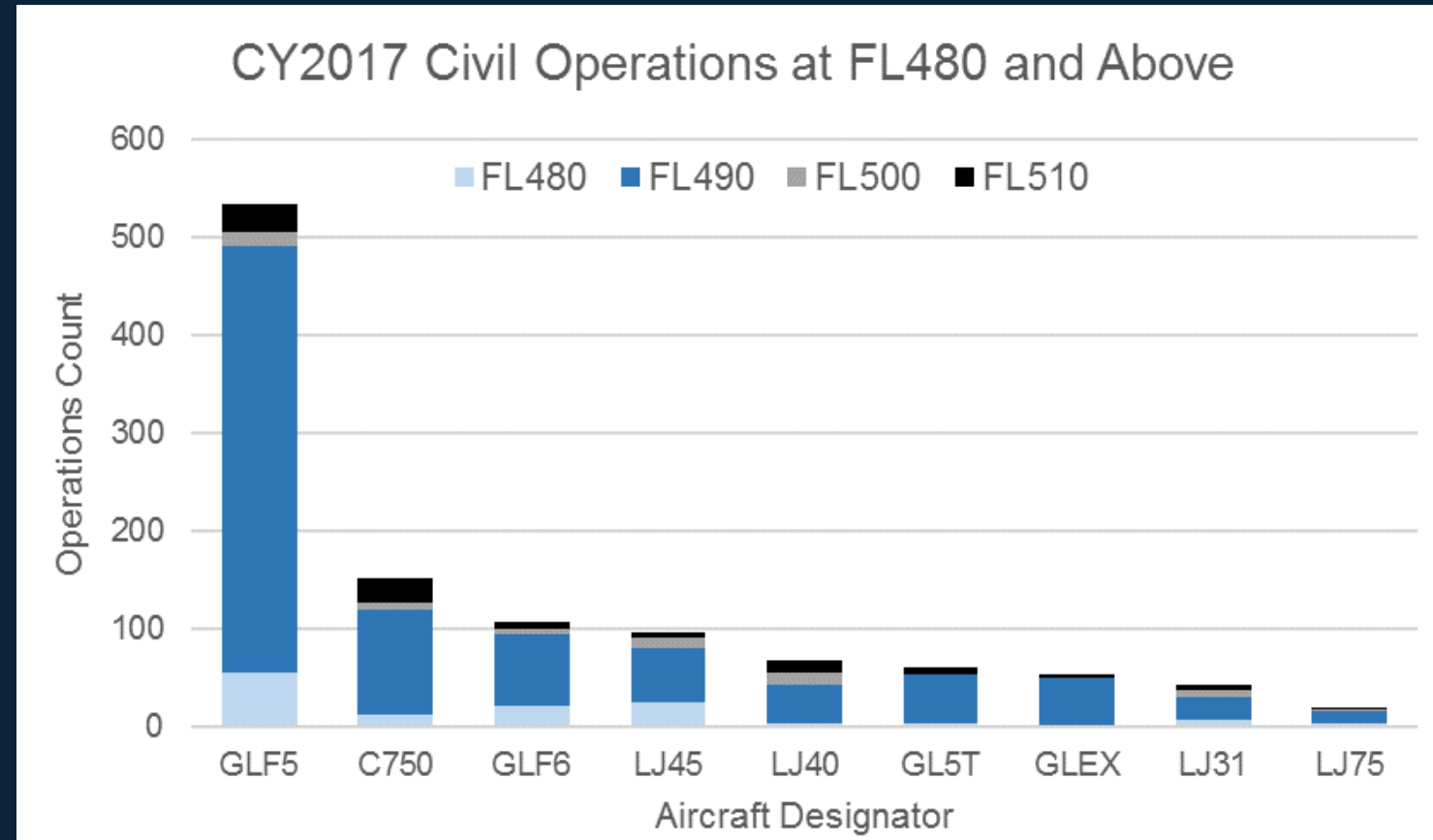
Additional Material

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**

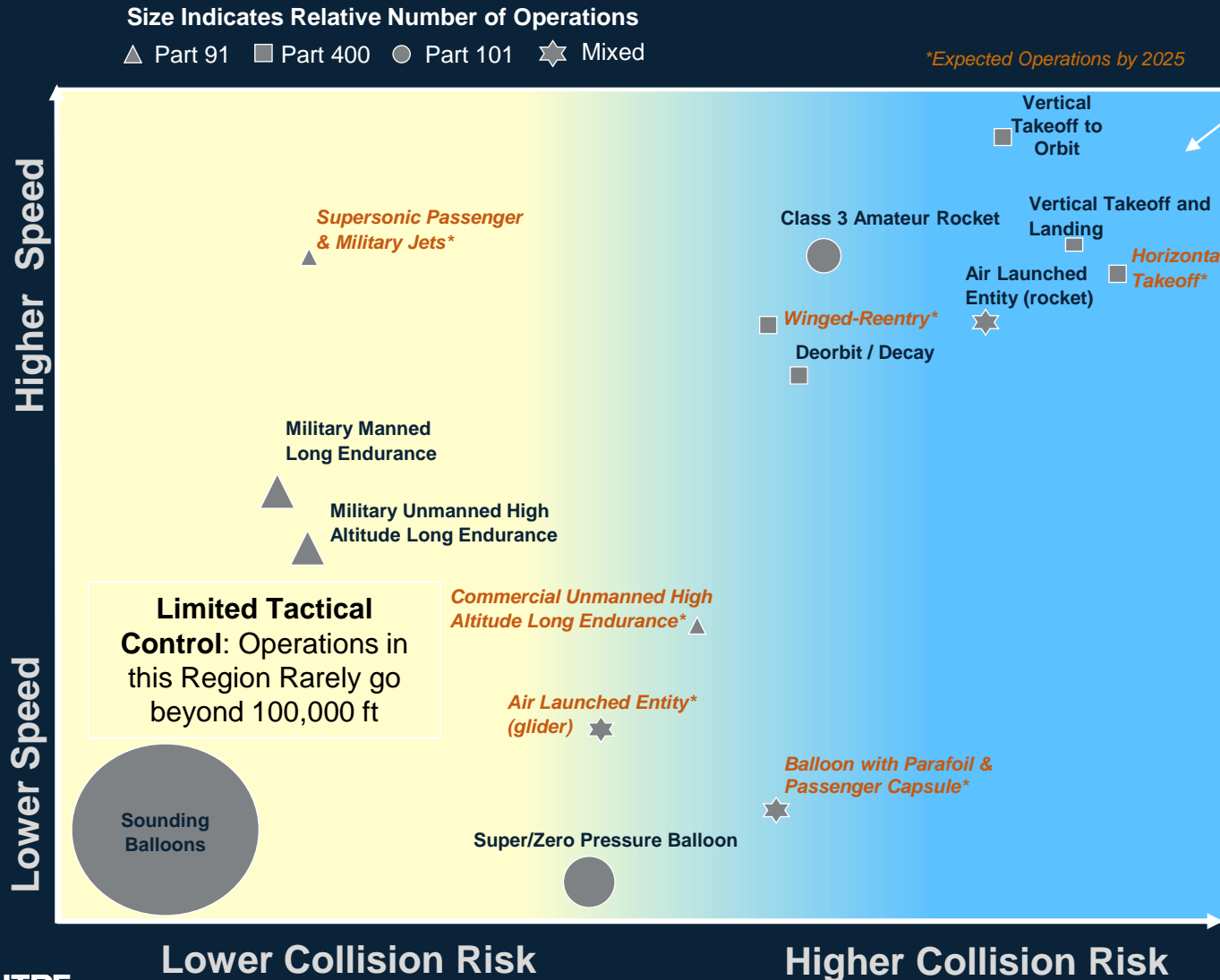


Source: MITRE Threaded Track

- **Filters Applied:**

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

New Entrant Performance Categorization



High Collision Risk: Implies low to no real-time control over trajectory for collision avoidance or high collision severity outcome

Low Collision Risk: Implies controlled trajectory for collision avoidance or low collision severity outcome

Current Environment

Regulatory and Legal Framework Key Findings

No upper boundaries have been legally defined for sovereign, controlled or navigable airspace, either at a national or international level

