Introduction to Higher Airspace Operations

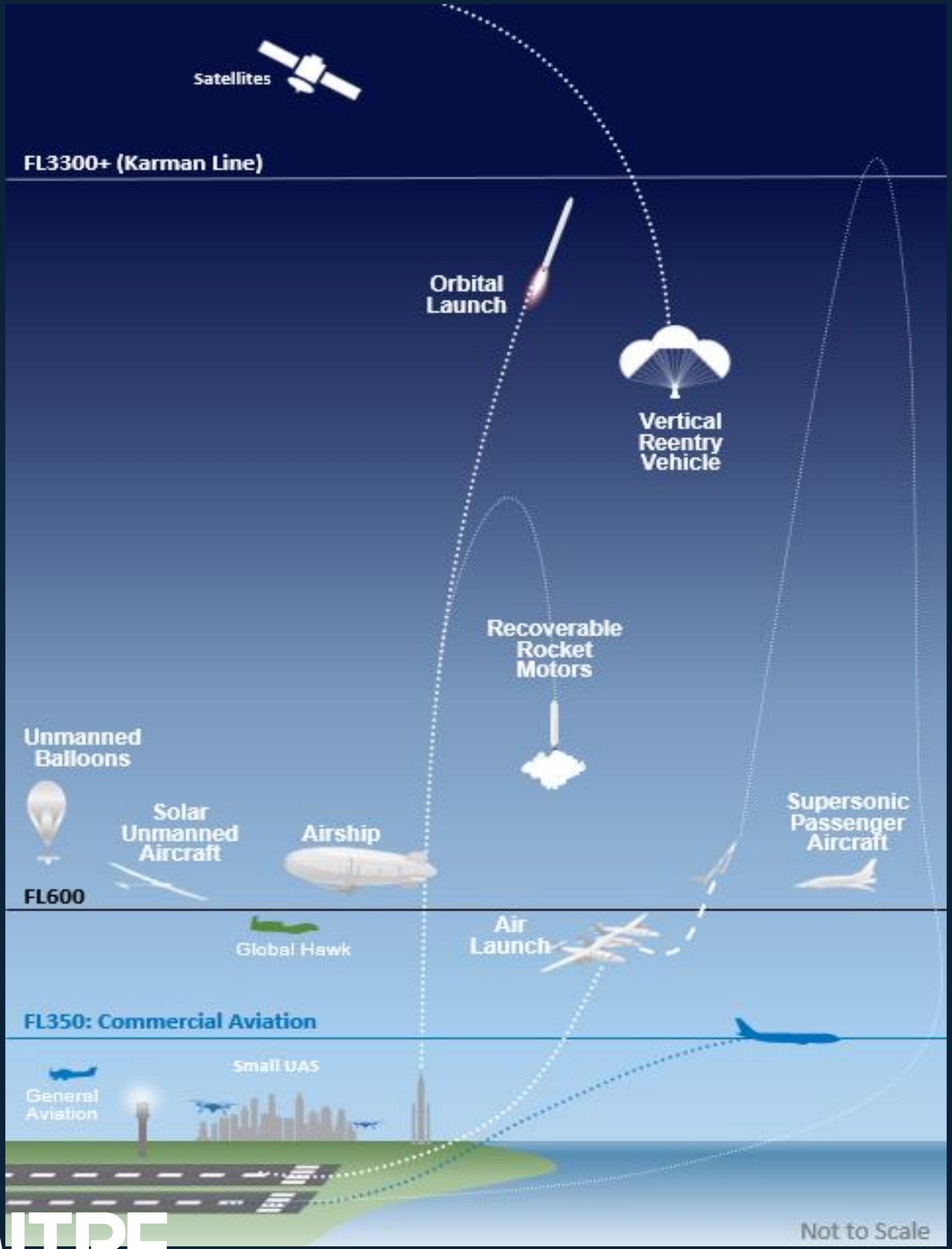
Including Collaboration on Risk-Based Conflict Detection Framework

Jennifer Gentry

March 2021

MITRE | SOLVING PROBLEMS FOR A SAFER WORLD

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

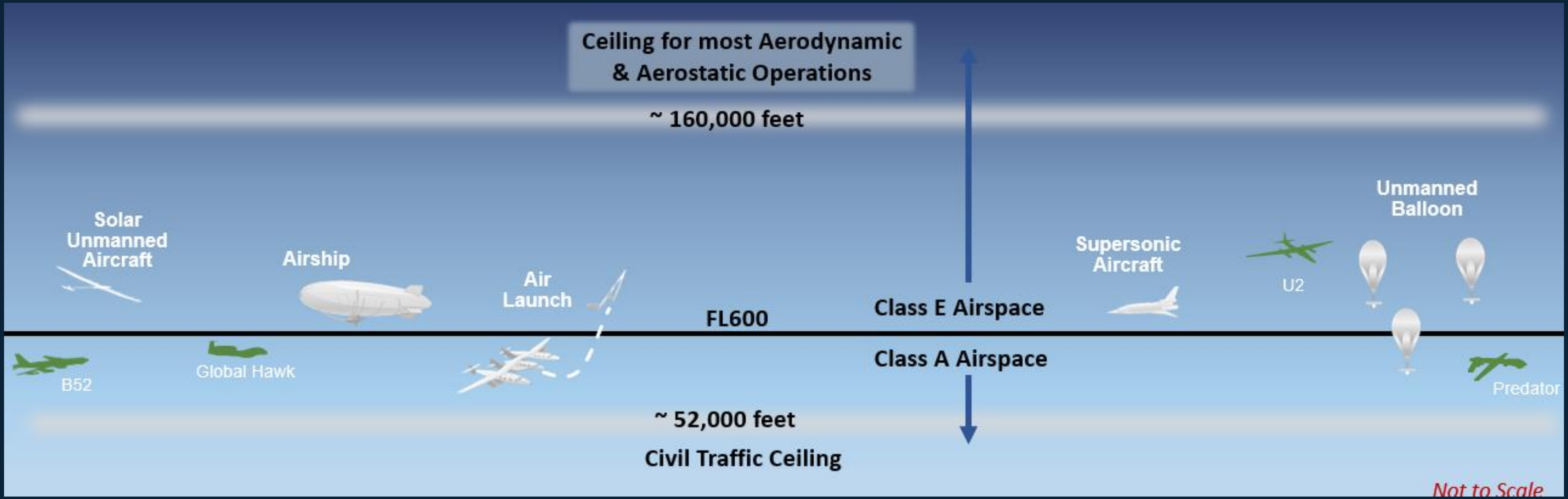


Higher Airspace

- **Globally Focused Platforms are Emerging**
- **They are:**
  - <u>Transporting people and goods faster</u>
    - Supersonic aircraft
    - Commercial space
    - Suborbital space tourism
  - <u>Providing services</u>
    - 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**

MITRE

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)

TRAJECTORY (at Altitude)

Vertical

- -- Unmanned Sounding Balloons (e.g., weather balloons)
- -- Manned Balloons

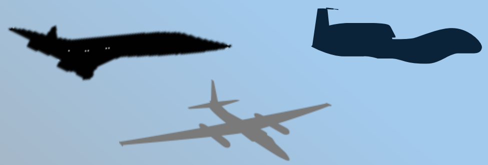
- -- Amateur Rockets
- -- Air Launched Objects
- -- Spacecraft Launch and Recovery

Likely to be concentrated in coastal regions over international waters and from inland spaceports within developed countries

Horizontal

- -- Long Endurance Unmanned Balloons
- -- Long Endurance Unmanned Airships & Aircraft

Likely to be concentrated over developing countries near populated regions



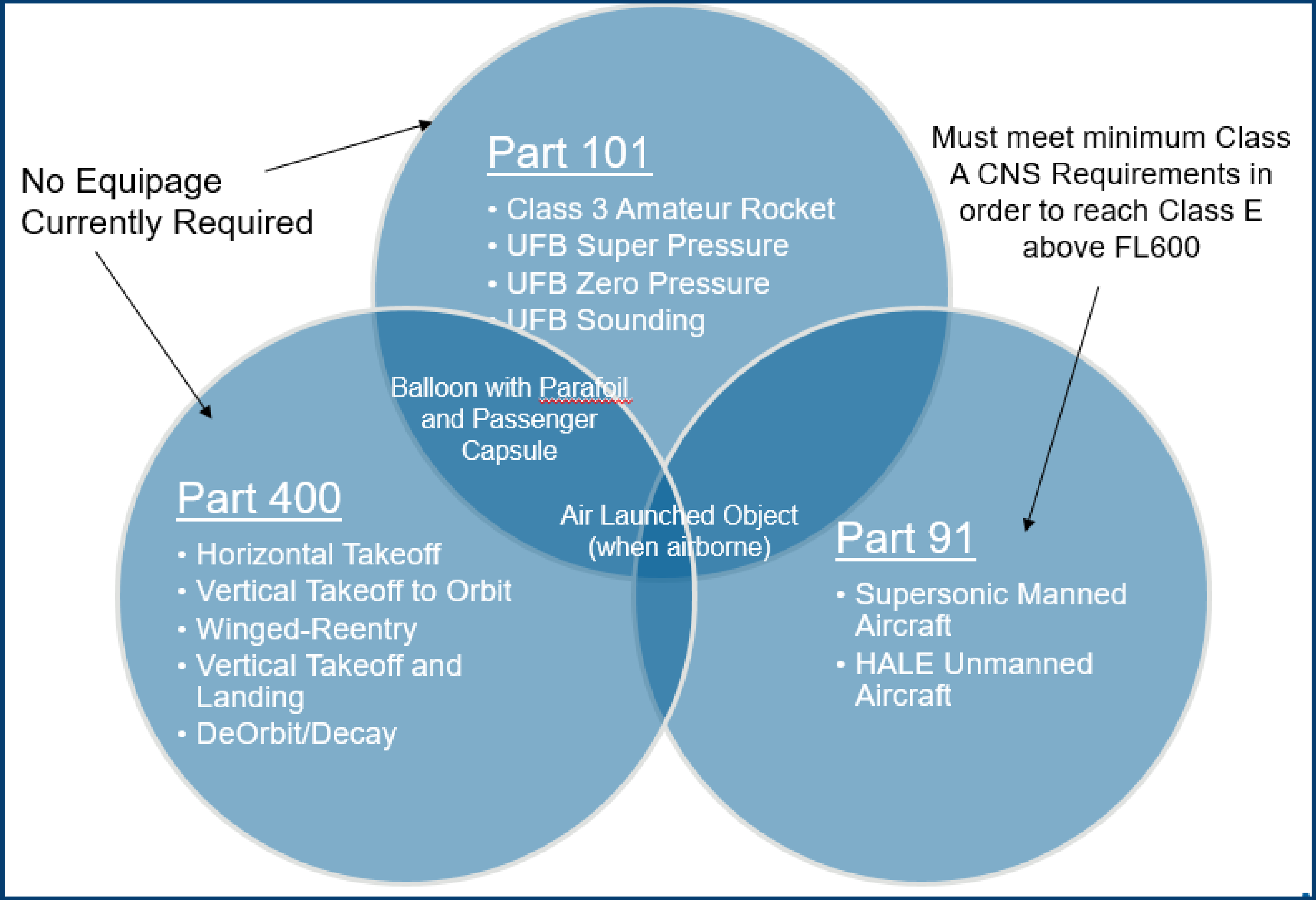
- -- Military (U-2 & Global Hawk)
- -- Supersonic Passenger Transport

Likely to be concentrated over water to minimize travel time between continents and environmental impact

Slower | **Faster**

SPEED

FAA Regulatory Overview for New Entrants

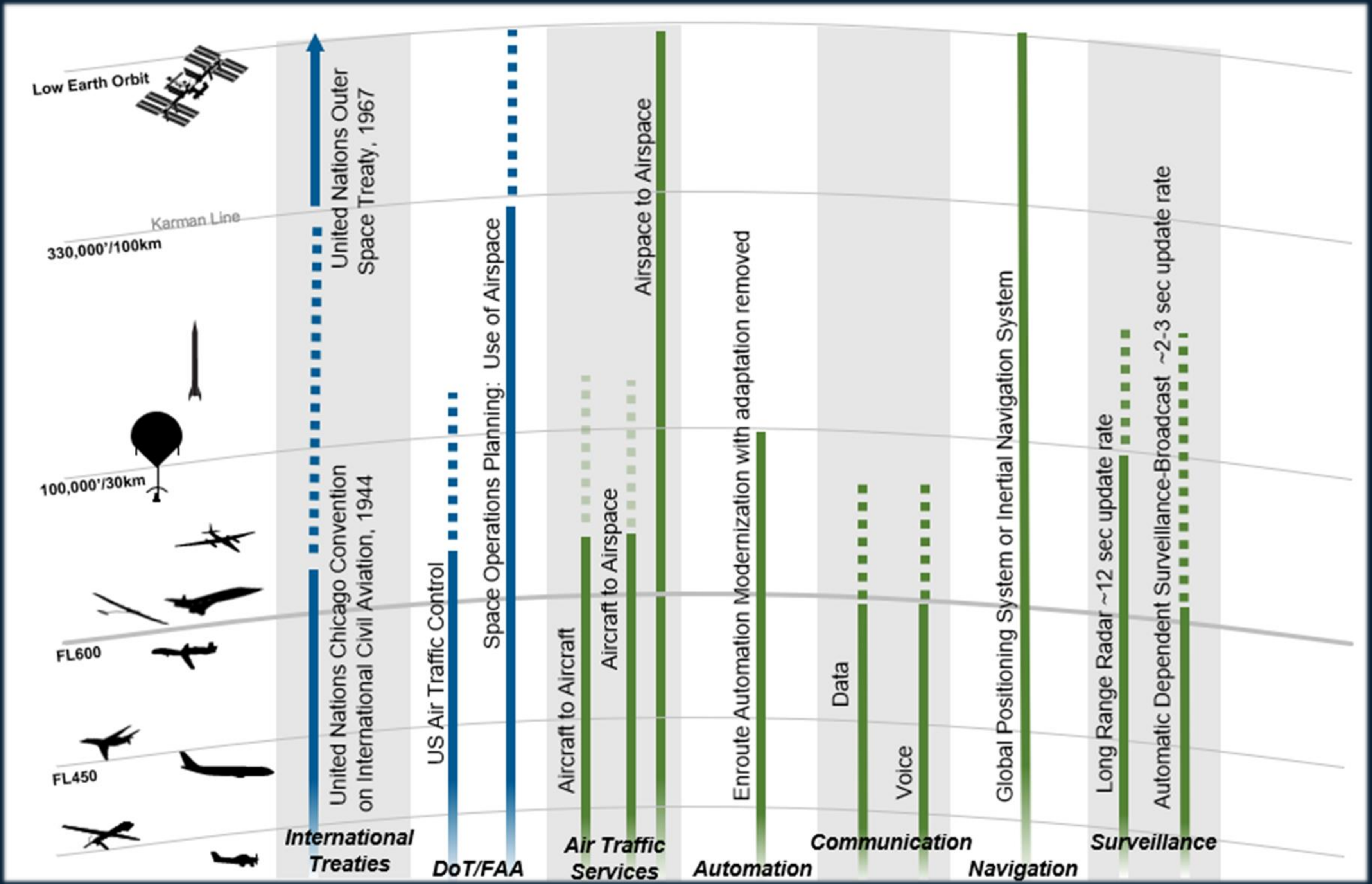


Regulatory classification for new entrants shown on diagram is based on current and/or most likely classification

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

Existing Civil Aviation Authorities & Services*

*High level summary of most applicable services in Higher Airspace



Anticipated Traffic Management Implications

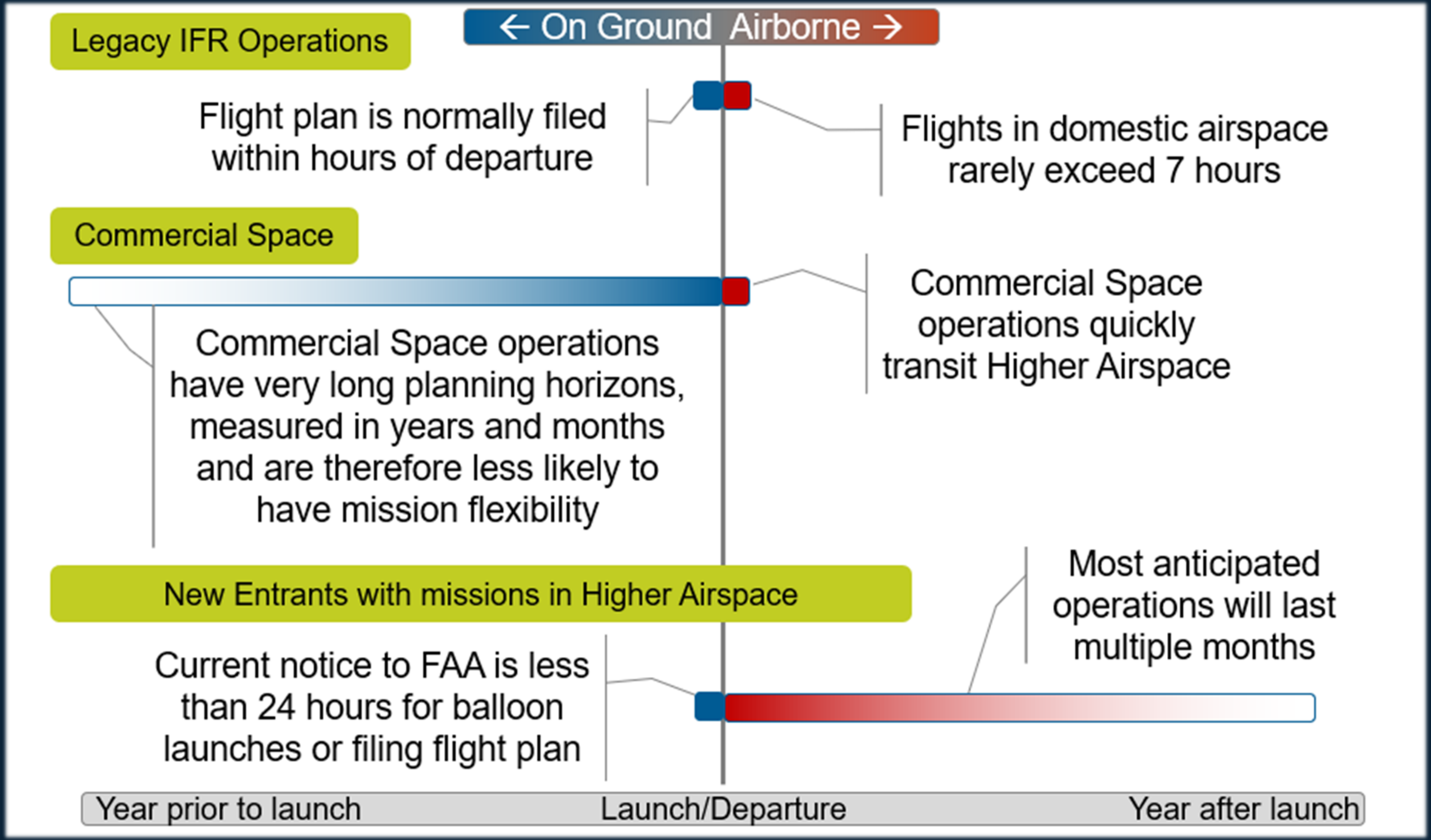
Positives

- 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	Charted TFR	Stationary ALTRV	Restricted Area, with Using Agency Approval	Warning Area, with Using Agency Approval	ATCAA
New Entrants*						
Unmanned Free Balloons	No	No	No	No	No	No
Amateur Rockets	Yes	No	No	No	No	No
Launch and Reentry Vehicles: Orbital & Suborbital	Yes	Yes	Yes	Yes	Yes	Yes
Manned Aircraft	Yes	Yes	Yes	Yes	Yes	Yes
Unmanned Aircraft	Yes	Yes	Yes	Yes	Yes	Yes

*Hybrid operations not included

Yes (green) No (red)

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

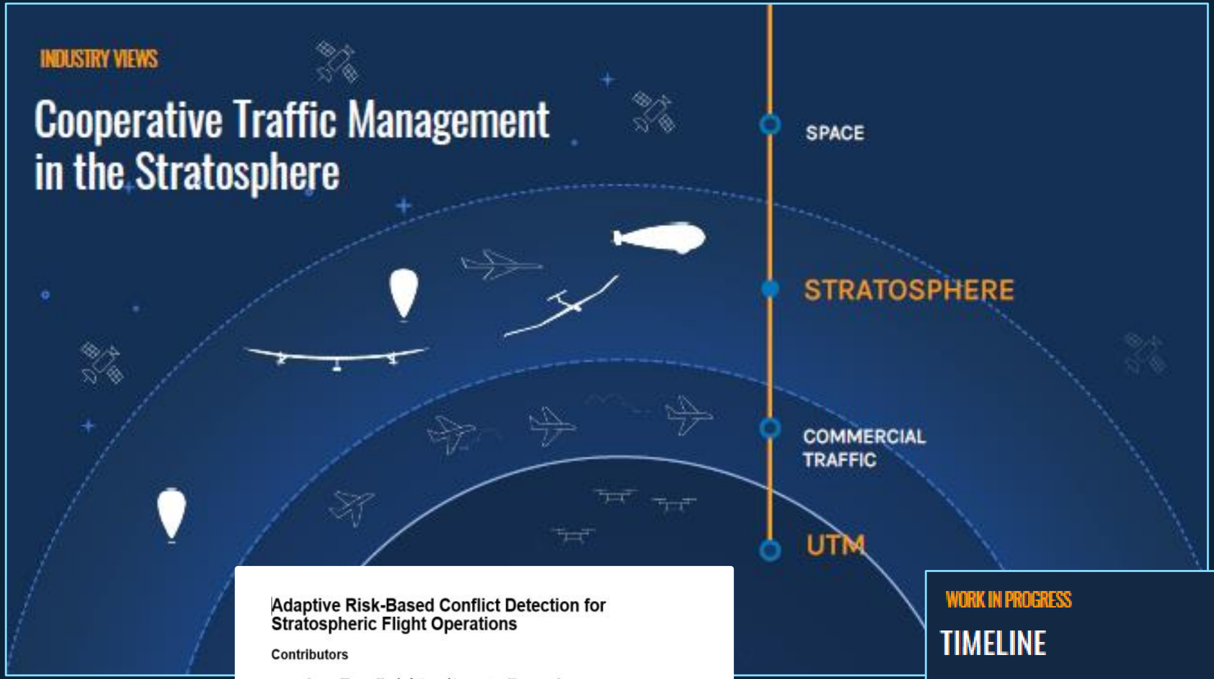
For example, some spacecraft have narrow launch windows, dictated by orbital dynamics, and therefore have minimal launch flexibility. At the other extreme are constellations of airships or balloons which can station-keep for months at a time, preventing other operations from using the airspace.

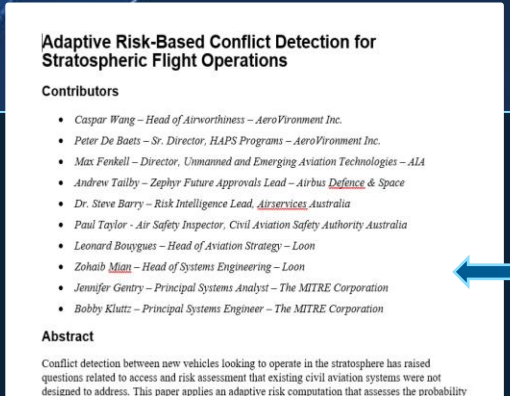
<u>Right-of-Way:</u> In theory, the right-of-way rules found in the 14 Code of Federal Regulations Part 91.113 offer a performance-based approach to determining airspace access priority, as they rely on a vehicle's ability to take evasive action.

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

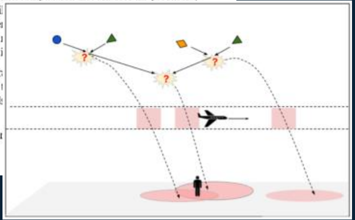
- *Caspar Wang – Head of Airworthiness – AeroVironment Inc.*
- *Peter De Baets – Sr. Director, HAPS Programs – AeroVironment Inc.*
- *Max Fenkell – Director, Unmanned and Emerging Aviation Technologies – AIA*
- *Andrew Tailby – Zephyr Future Approvals Lead – Airbus Defence & Space*
- *Dr. Steve Barry – 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*

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 computation that assesses the probability and severity of undesirable events and the acceptabi level of safety (TLS) uses a flight-centric model (pe passengers (1st and 2nd parties). This approach does many operations are unmanned, and flight duration i

The proposed approach broadens the existing risk fr model with 1st, 2nd, and 3rd party risk. This is suited may linger for months or zip by at supersonic speed unmanned vehicles is 3rd party risk.

If the probability and severity of an undesirable eve 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

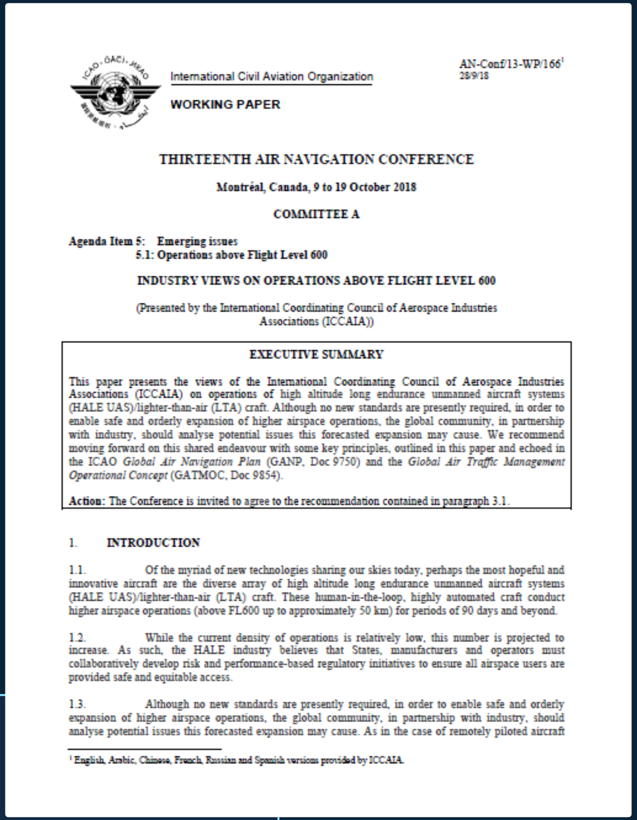
Spring 2021
- Joint operational demonstration

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

WORKING PAPER

AN-Conf/13-WP/166[1]
28/9/18

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.

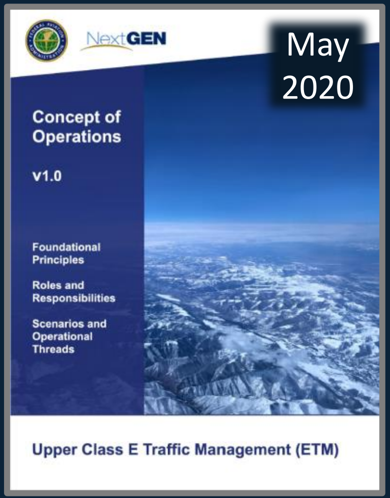
1.2. While the current density of operations is relatively low, this number is projected to increase. As such, the HALE industry believes that States, manufacturers and operators must collaboratively develop risk and performance-based regulatory initiatives to ensure all airspace users are provided safe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

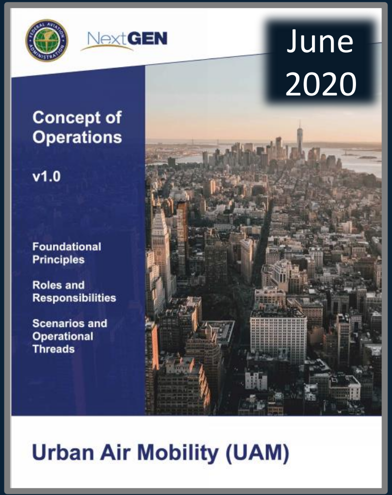
1.3. Although no new standards are presently required, in order to enable safe and orderly expansion of higher airspace operations, the global community, in partnership with industry, should analyse potential issues this forecasted expansion may cause. As in the case of remotely piloted aircraft

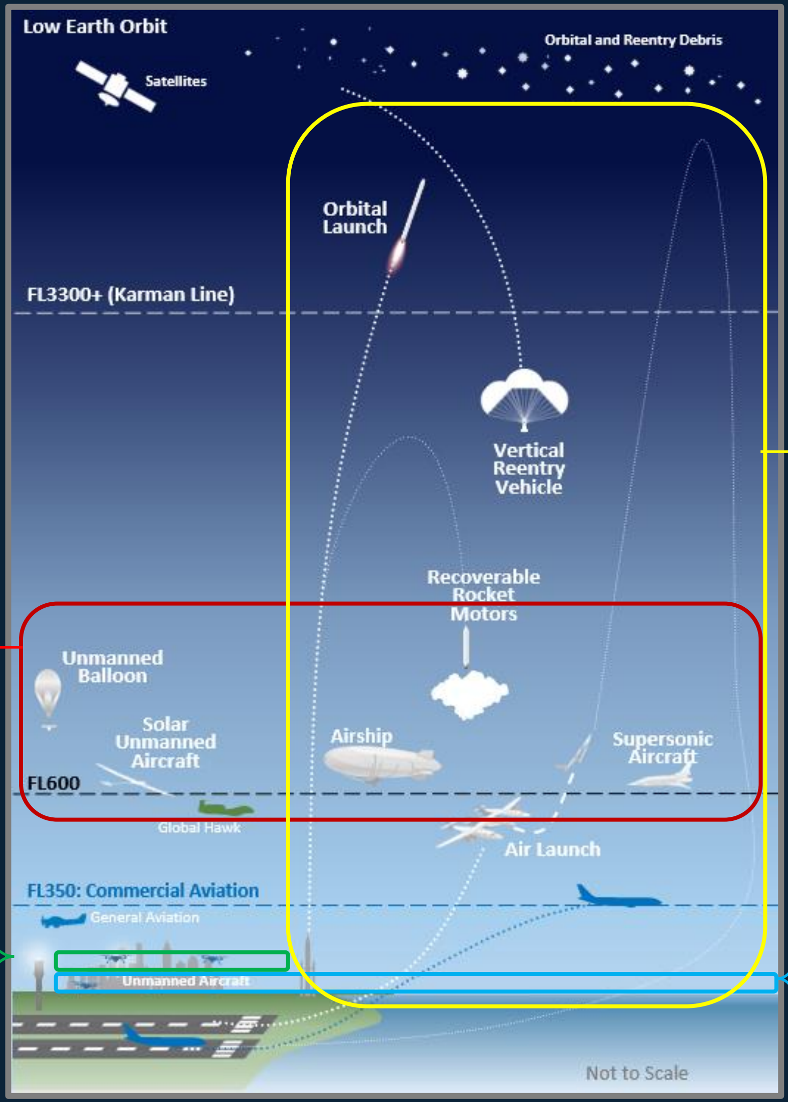
[1] English, Arabic, Chinese, French, Russian and Spanish versions provided by ICCAIA.

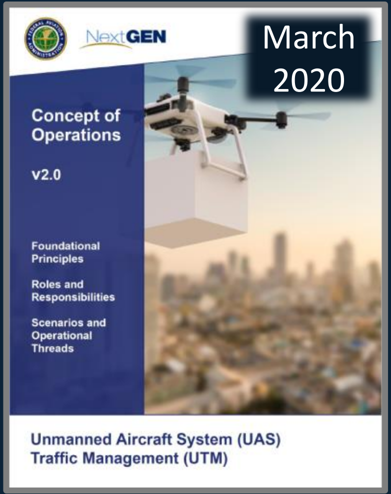
Source: World ATM Congress 2020 Panel

FAA New Entrant ConOps Released in 2020









SESAR 2020 Research Initiative: ECHO

FAA Air Traffic Organization’s Near-Term Initiative

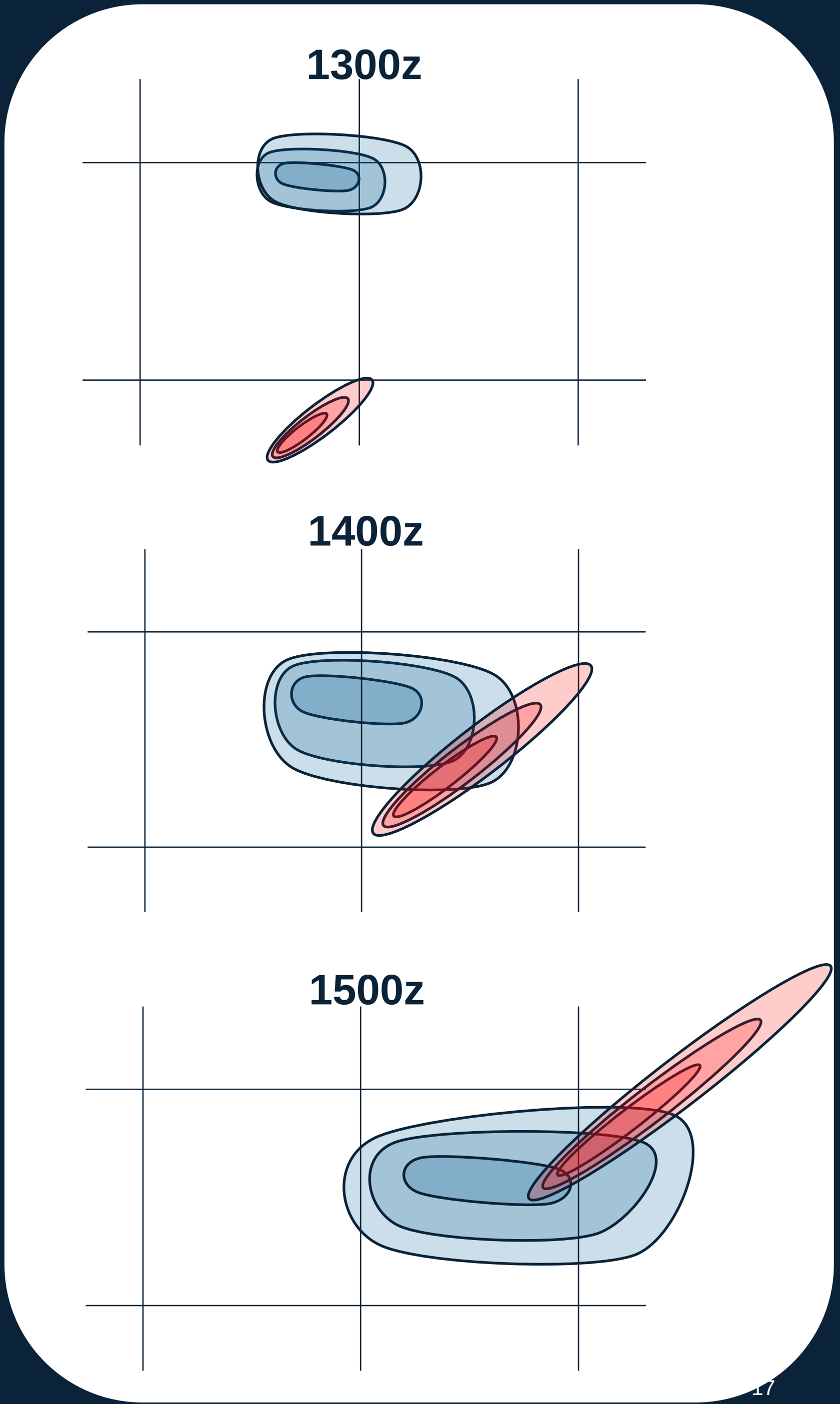
ATO Space Operations is exploring use of existing capabilities that could be used for strategic airspace deconfliction in upper Class E airspace

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**

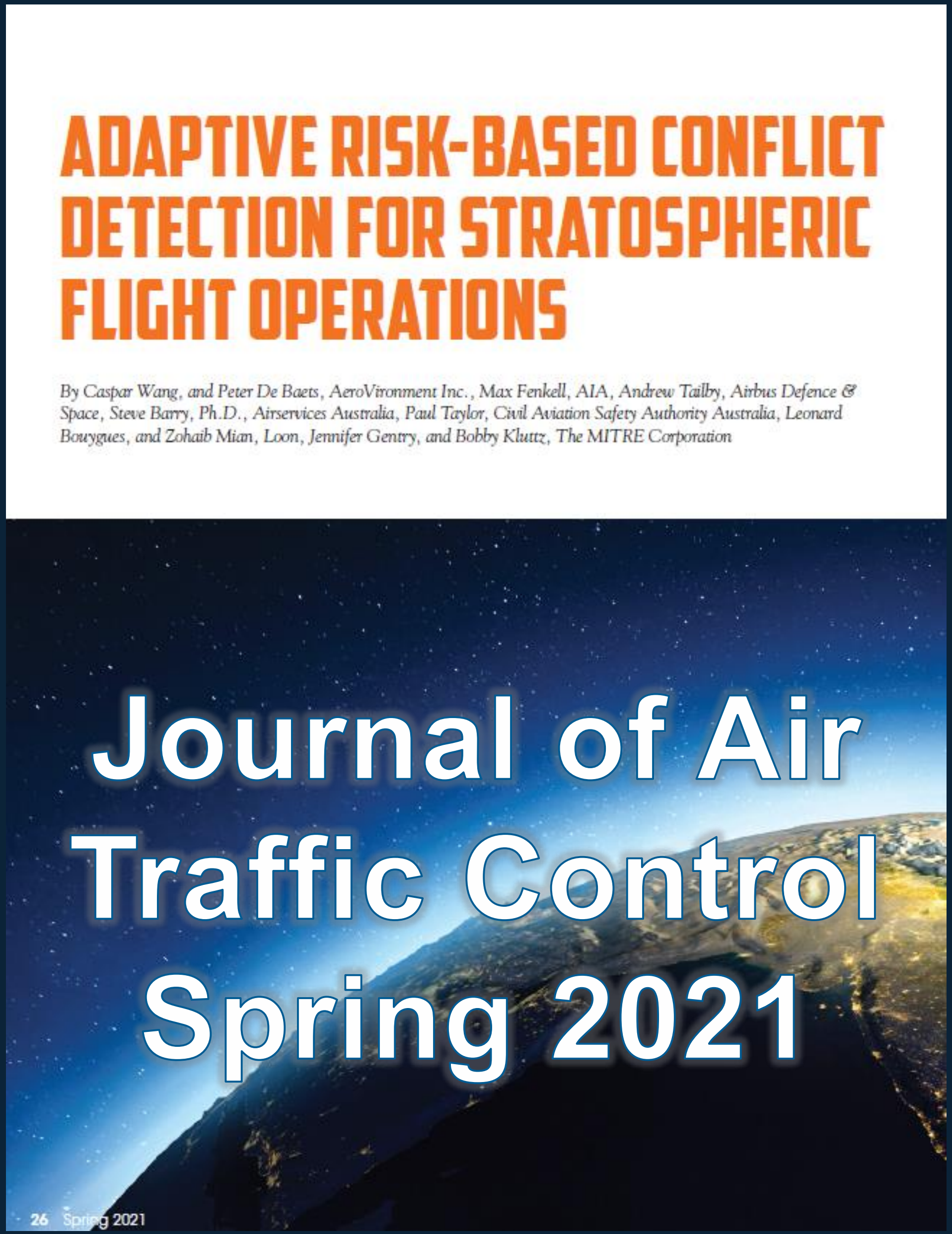
MITRE's Strategic Deconfliction Research

- 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

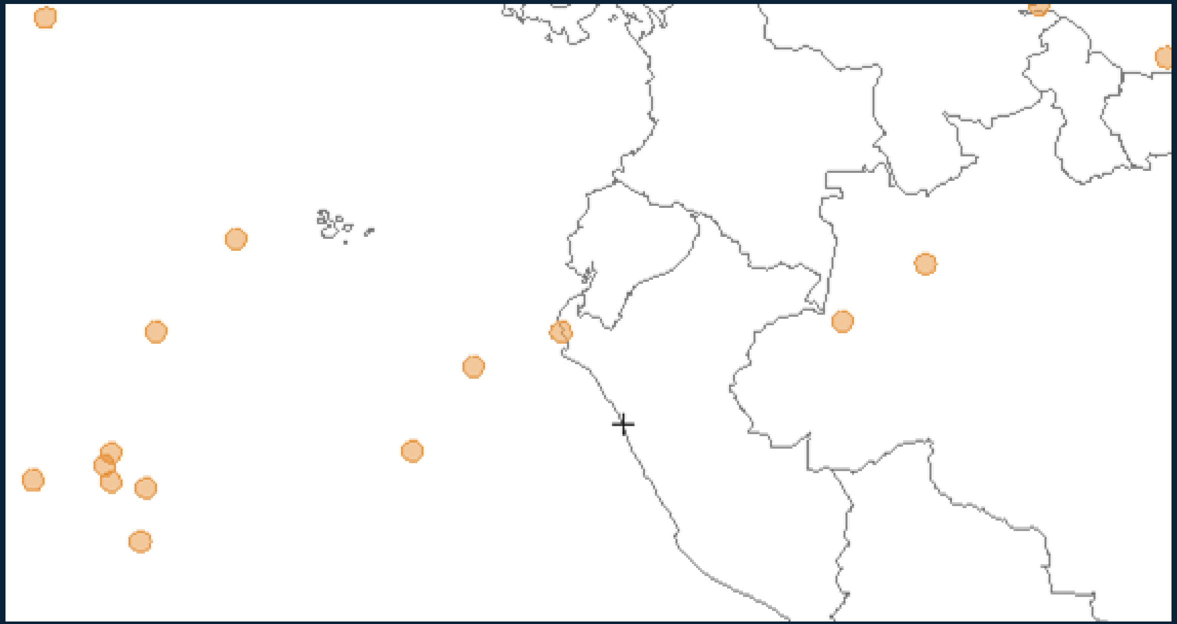
- **Caspar Wang** – Head of Airworthiness, AeroVironment Inc.
- **Peter De Baets** – Sr. Director, HAPS Programs, AeroVironment Inc.
- **Max Fenkell** – Director, Unmanned and Emerging Aviation Technologies, AIA
- **Andrew Tailby** – Zephyr Future Approvals Lead, Airbus Defence & Space
- **Dr. Steve 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

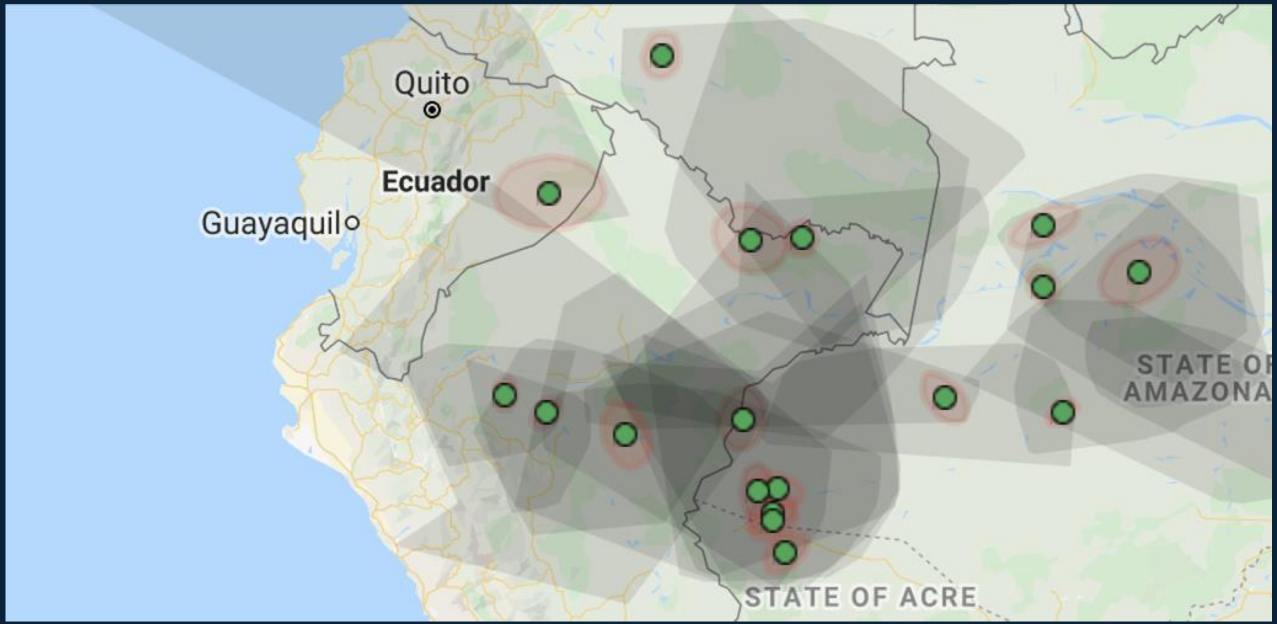


Motivation for Adaptive Risk Based Conflict Detection

- 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

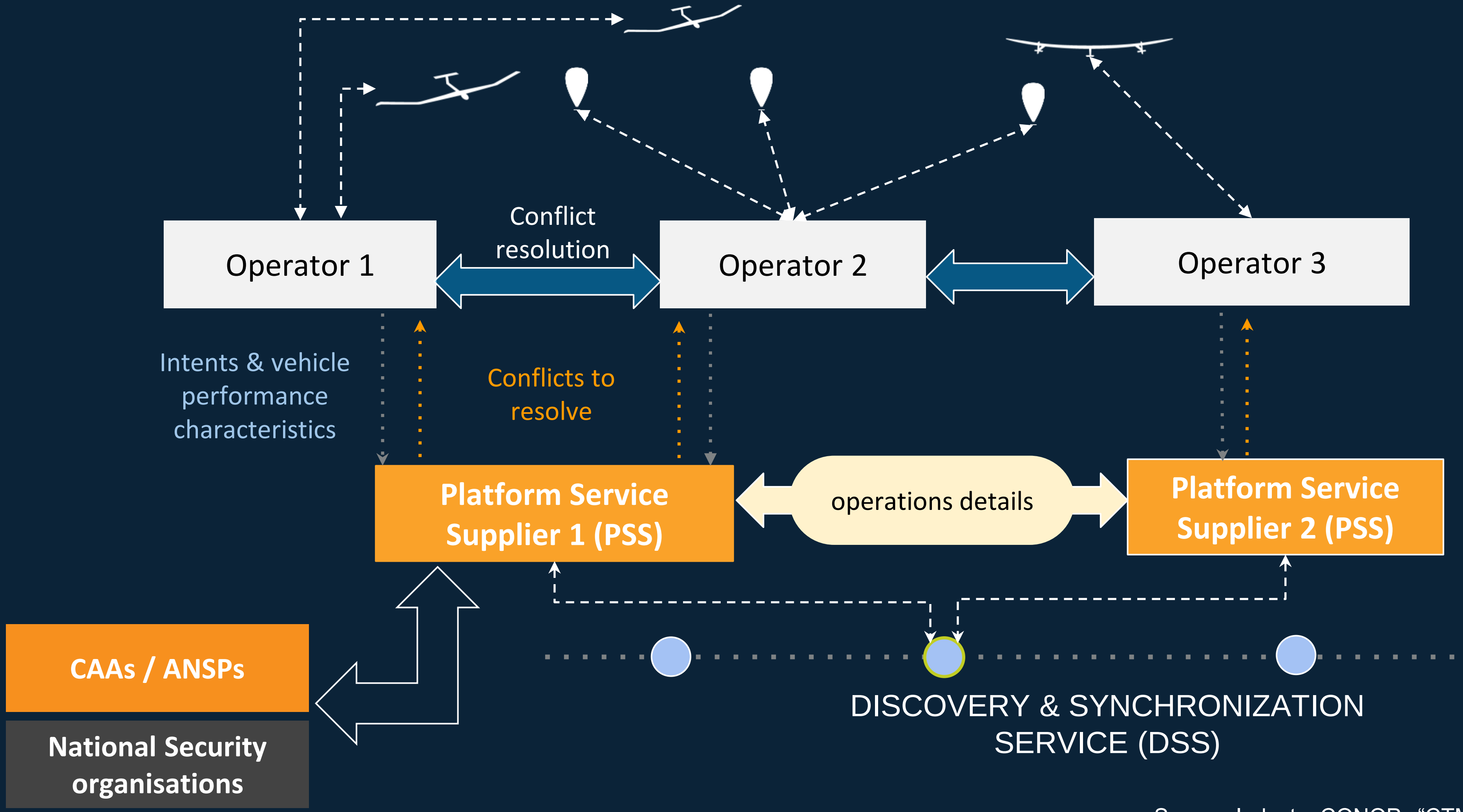




- Missions may last over a year (some loitering/station keeping), others a few minutes
- Wide range of mission objectives, preferences and constraints
- Growing uncertainty of intents in future
- Probabilistic intents – The airspace cannot be structured in corridors
- Frequent airborne replan (can be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

Cooperative Traffic Management in the Stratosphere (CTMS)

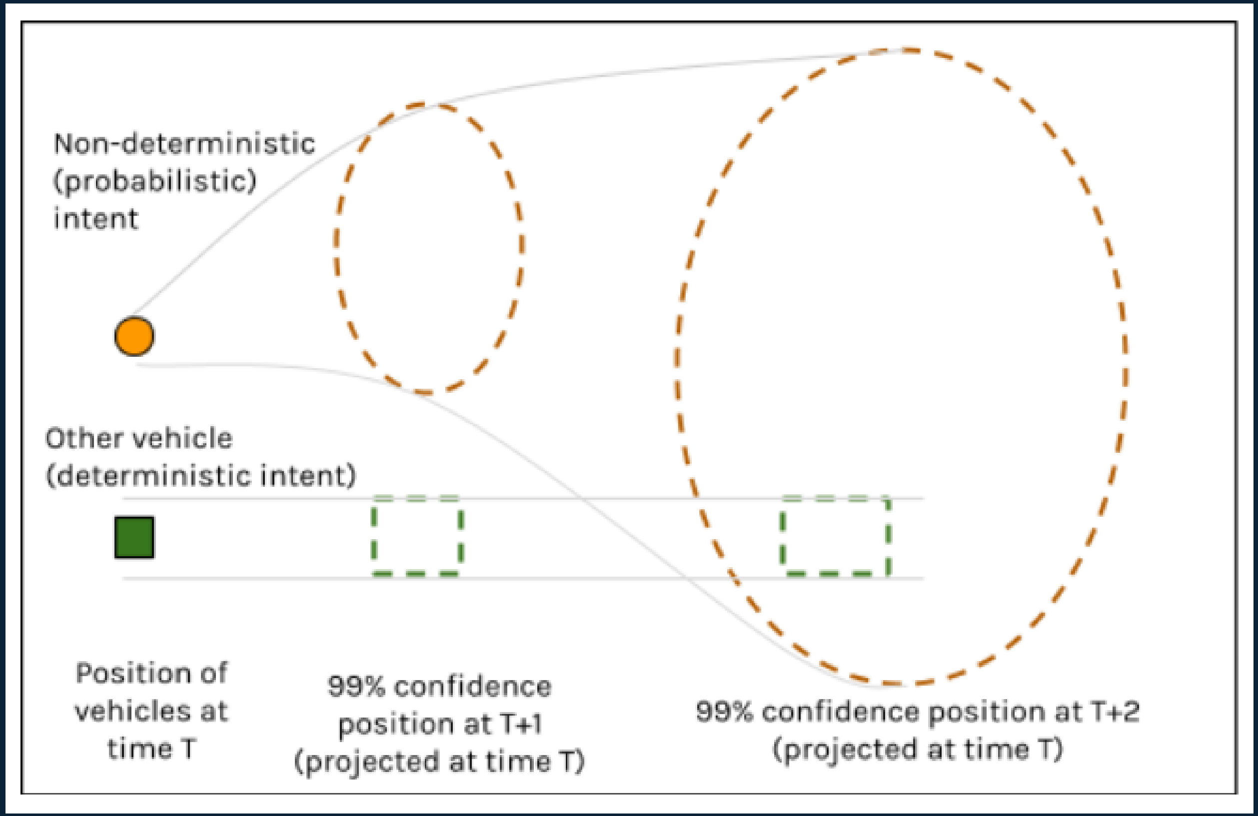
- Necessary to identify which conflicts to resolve/exceed TLS



Source: Industry CONOPs “CTMS” Drone Enable 3

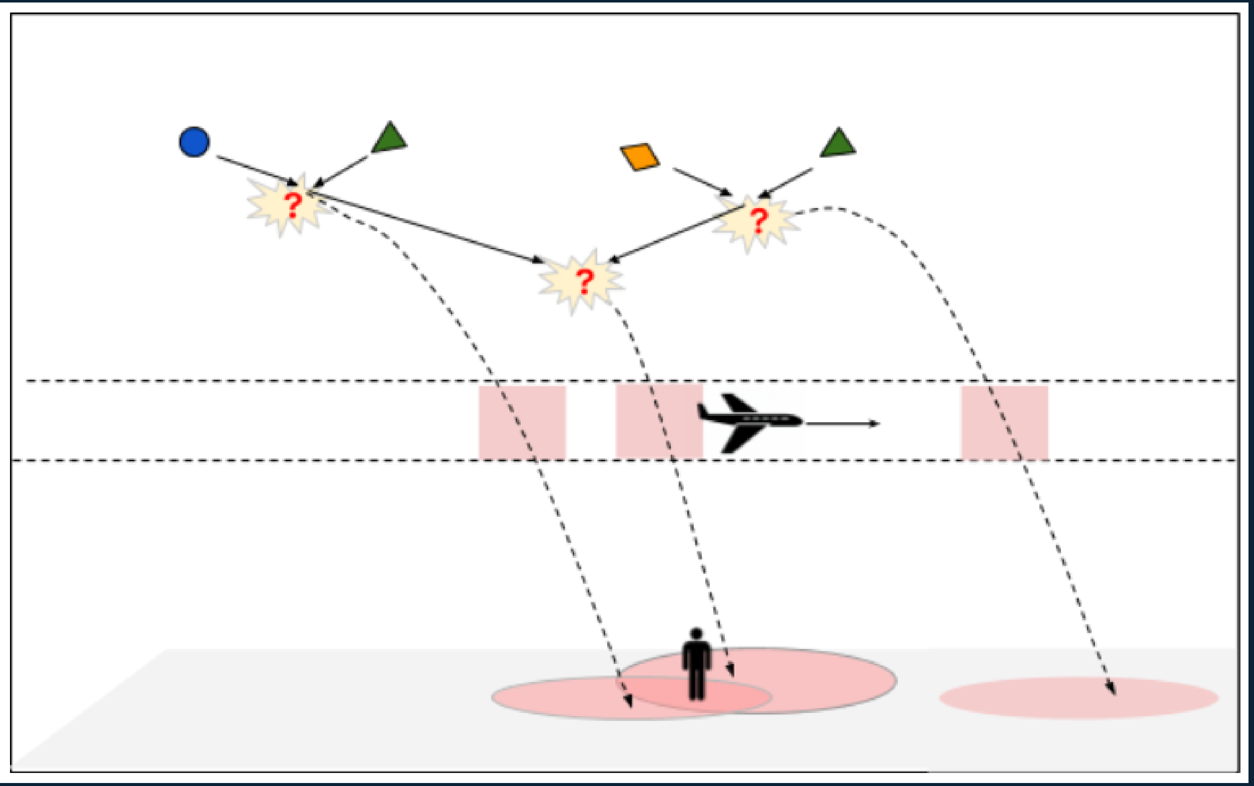
Assessing Probability of Undesirable Events

- 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

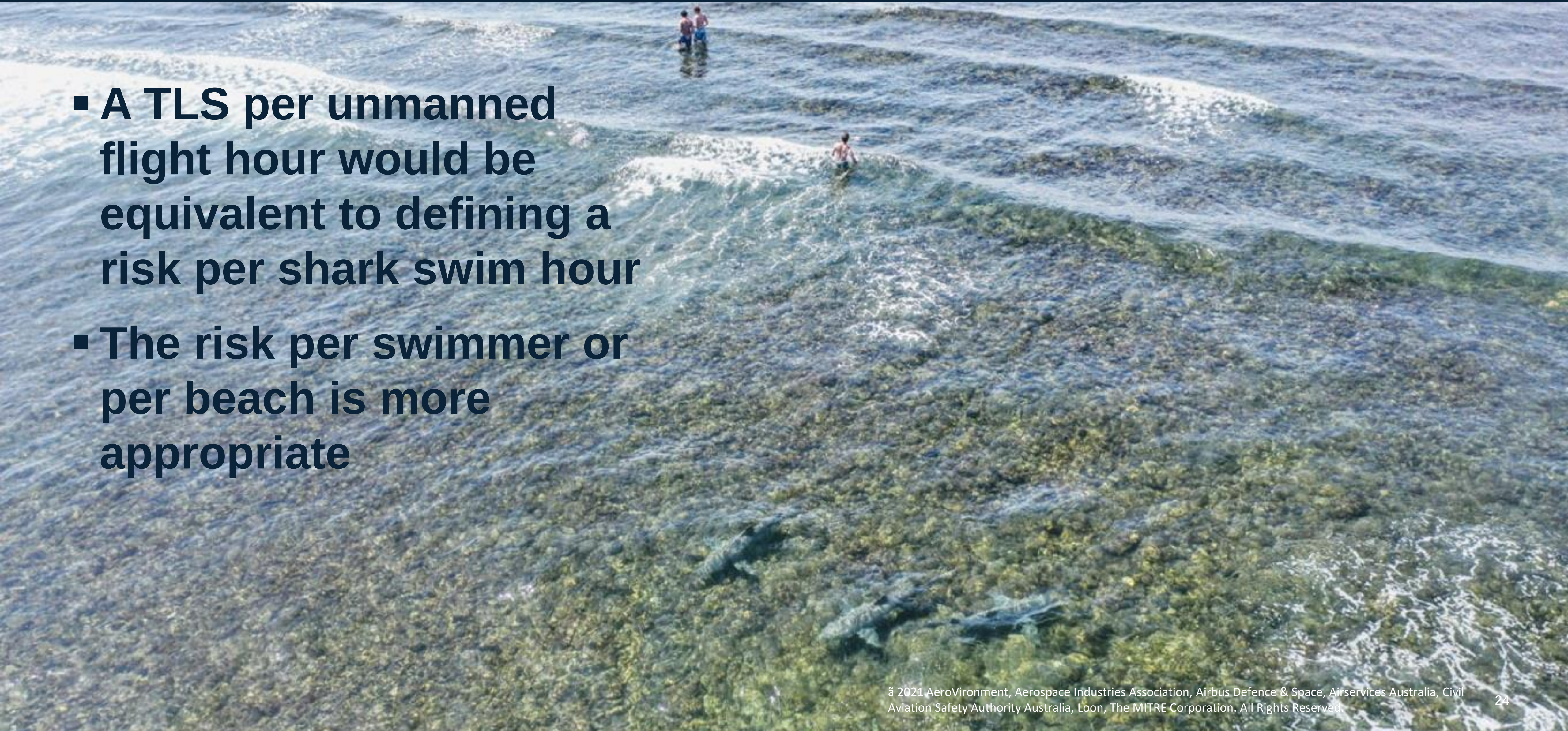
- 1st Party Harm: Resulting damage to flight crew or airframes directly involved in the collision
- 2nd Party Harm: Harm to participants or cargo onboard a vehicle directly involved in the collision
- 3rd Party Harm[1]
  - Fatal injuries to people on the ground
  - Fatal injuries to people in the air
  - Damage to critical infrastructure
- If a manned vehicle is involved in conflict 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

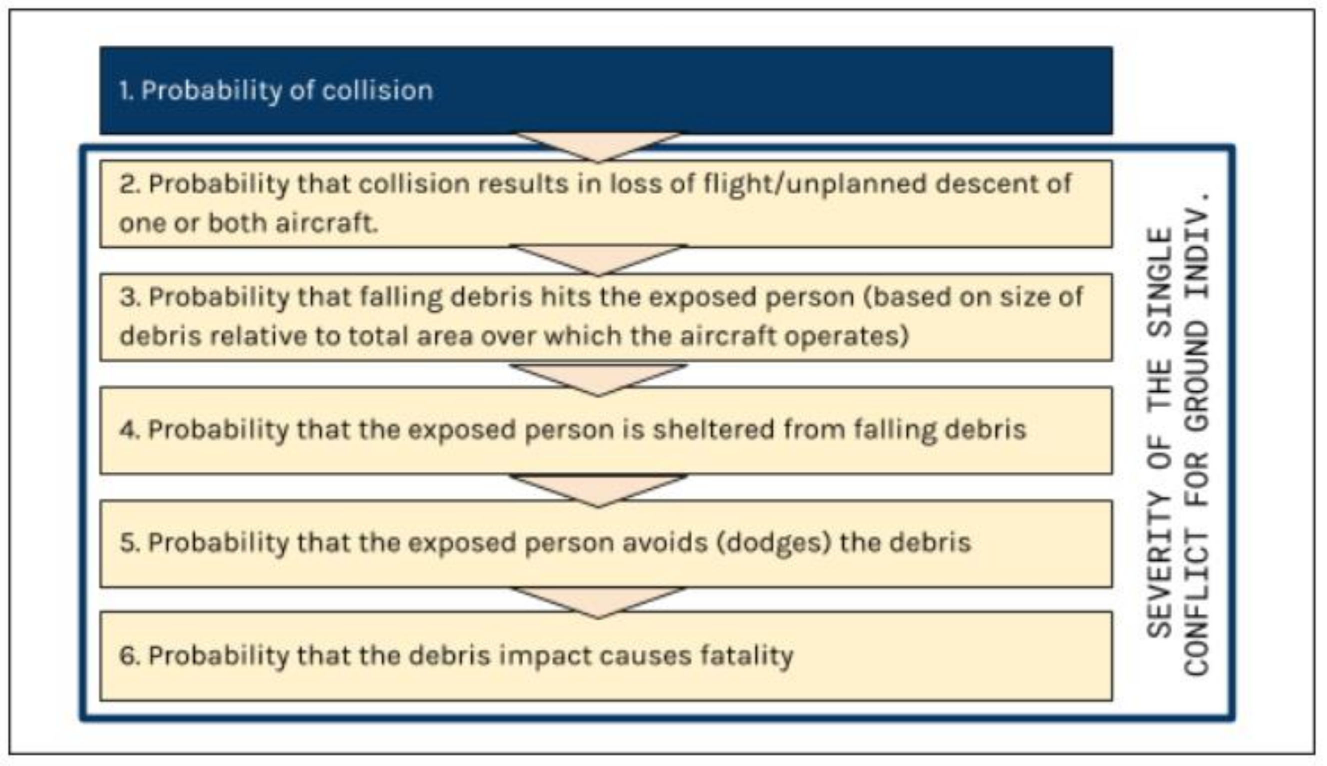
Victim Centric Model

- 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

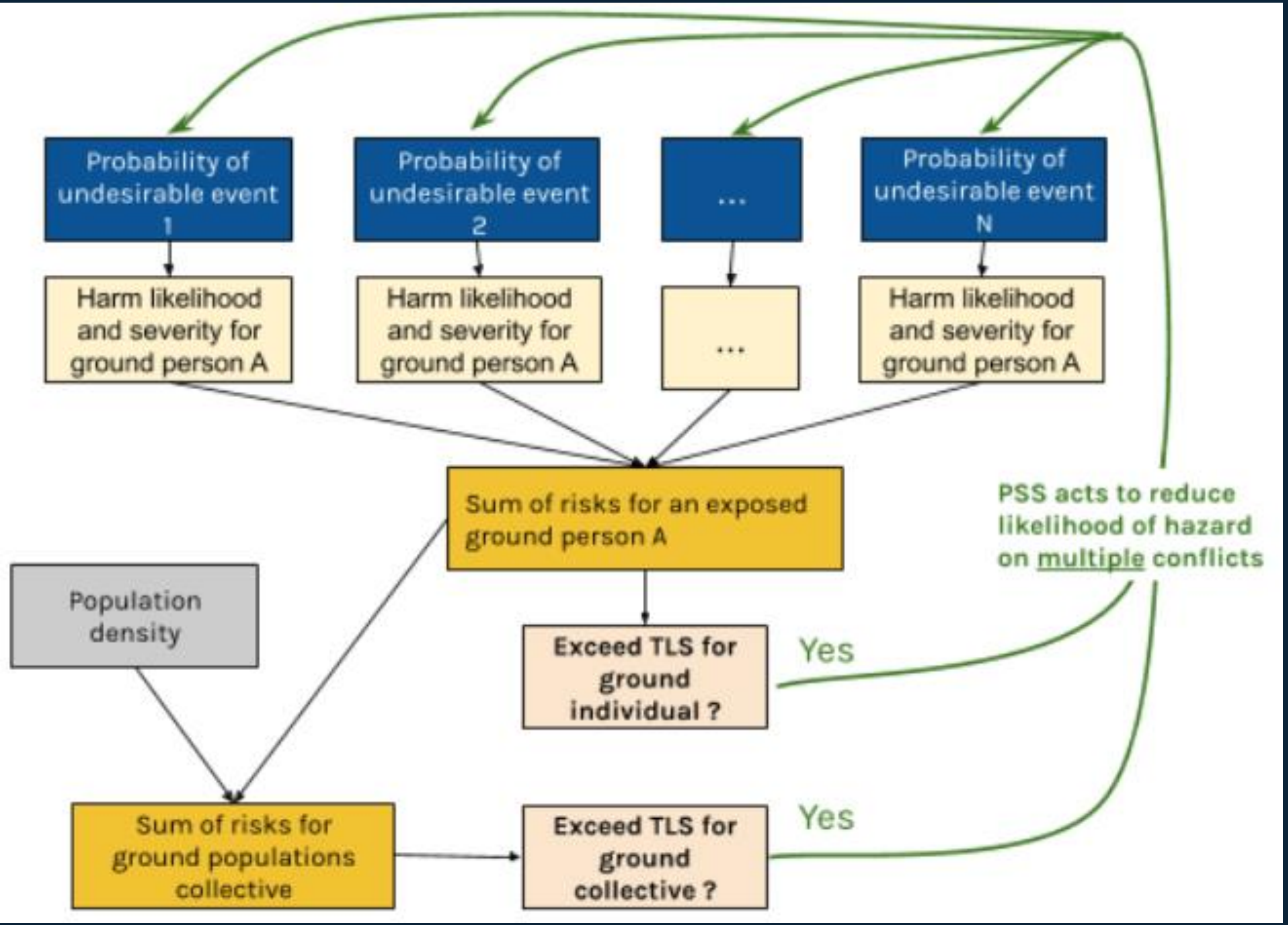
- 3rd party harm is tied to a chain of events:



- 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

Jennifer Gentry

jenniferg@mitre.org

www.linkedin.com/in/jennifer-gentry-6054821

SOLVING PROBLEMS FOR A SAFER WORLD™

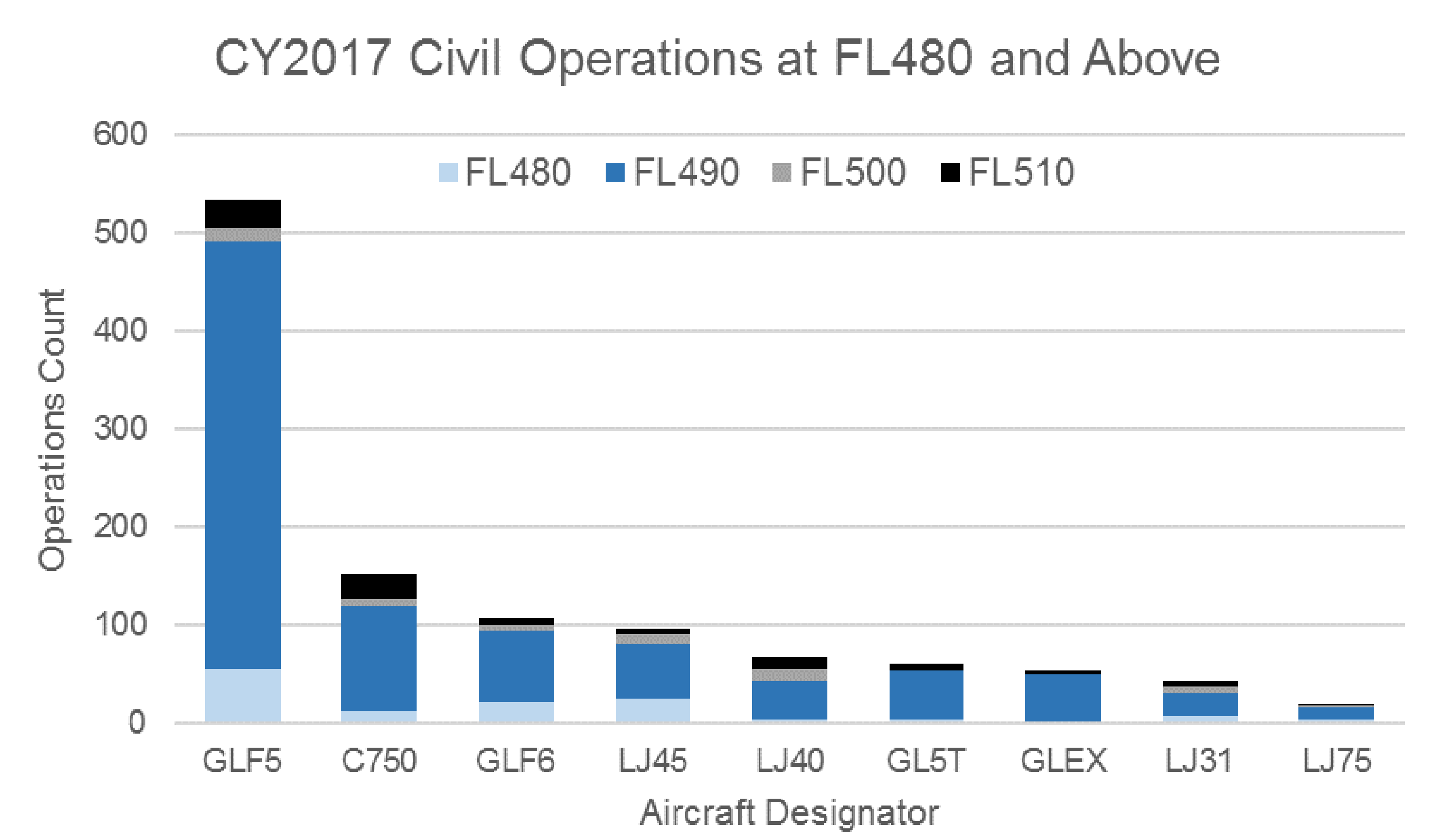
Additional Material

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

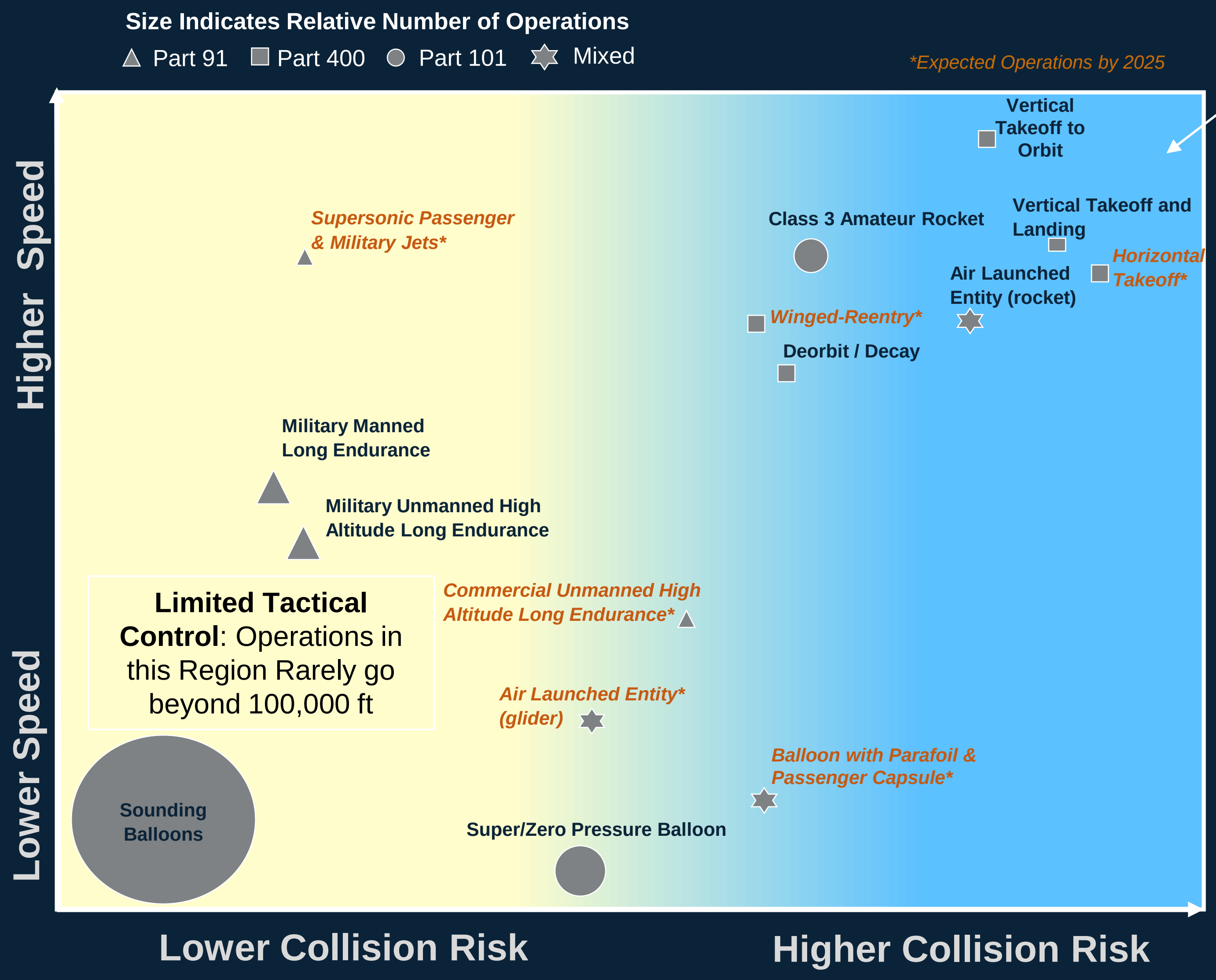
- **Very few civil aircraft routinely fly at FL480 and above**
- **None routinely flew above FL510**



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



Strategic Planning: Operations in this Region Reach 330,000 ft and Higher

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

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

Chart is notional and positions are not exact and variation may exist within any category

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