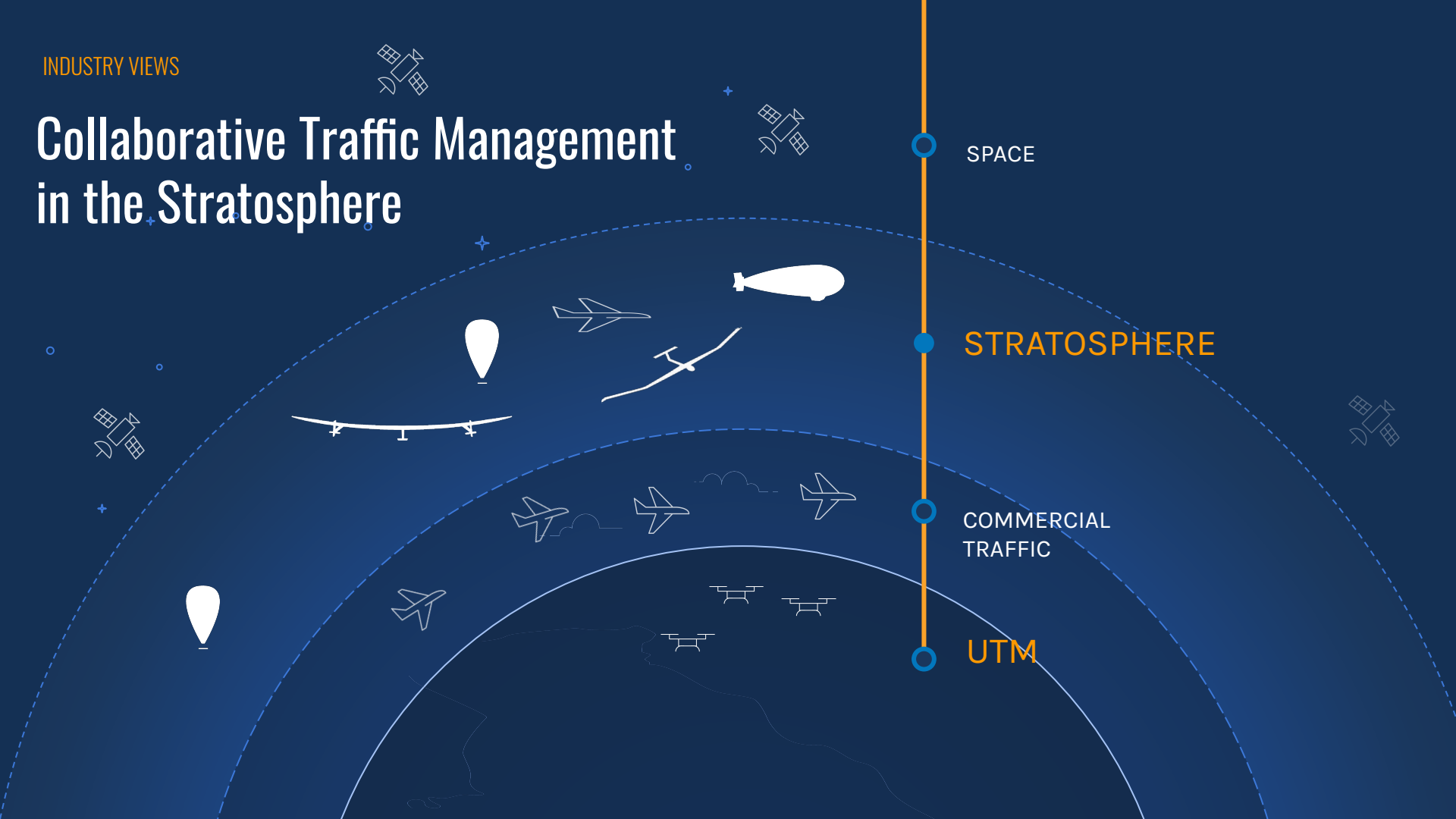
INDUSTRY VIEWS

Collaborative Traffic Management in the Stratosphere



Collaborative Traffic Management in the Stratosphere — A Concept for Partnership in High Altitude Operations

David Hansell
Global Head of Aviation Regulation and Policy
Loon

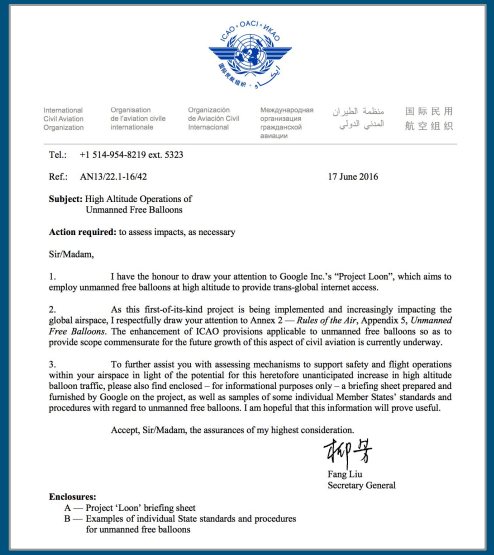
Andy Tailby
Future Approvals Lead, Zephyr Program
Airbus

Léonard Bourgues
Head of Aviation Strategy
Loon

The FAA does not intend to provide traditional separation services in upper E, once vehicles have reached altitude.

Teri L. Bristol
Chief Operating Officer, Air Traffic Organization

Endorsed by ICAO's General Assembly, Loon was recognized to support SDGs 9 & 17 and ICAO NCLB



International Civil Aviation Organization | Organisation de l'aviation civile internationale | Organización de Aviación Civil Internacional | Международная организация гражданской авиации | منظمة الطيران المدني الدولي | 国际民用航空组织

Tel.: +1 514-954-8219 ext. 5323

Ref.: AN13/22.1-16/42 17 June 2016

Subject: High Altitude Operations of Unmanned Free Balloons

Action required: to assess impacts, as necessary

Sir/Madam,

1. I have the honour to draw your attention to Google Inc.'s "Project Loon", which aims to employ unmanned free balloons at high altitude to provide trans-global internet access.

2. As this first-of-its-kind project is being implemented and increasingly impacting the global airspace, I respectfully draw your attention to Annex 2 — *Rules of the Air*, Appendix 5, *Unmanned Free Balloons*. The enhancement of ICAO provisions applicable to unmanned free balloons so as to provide scope commensurate for the future growth of this aspect of civil aviation is currently underway.

3. To further assist you with assessing mechanisms to support safety and flight operations within your airspace in light of the potential for this heretofore unanticipated increase in high altitude balloon traffic, please also find enclosed – for informational purposes only – a briefing sheet prepared and furnished by Google on the project, as well as samples of some individual Member States' standards and procedures with regard to unmanned free balloons. I am hopeful that this information will prove useful.

Accept, Sir/Madam, the assurances of my highest consideration.

Fang Liu
Secretary General

Enclosures:
A — Project 'Loon' briefing sheet
B — Examples of individual State standards and procedures for unmanned free balloons

- Endorsed global technical solutions consistent with SARPs, including Loon LLC
- Recognized that Loon LLC Supports SDGs 9 & 17 and ICAO NCLB
- Recommended that States finalize operational Letters of Agreement with Loon LLC

LEADING INDUSTRY VIEWS

SINCE 2016, THE STRATOSPHERIC COMMUNITY HAS BEEN COLLABORATING ON THE DEVELOPMENT OF COOPERATIVE TRAFFIC MANAGEMENT IN THE STRATOSPHERE (CTMS)

Regulation

Research

Industry Cooperation

ICCAIA

DEFENCE AND SPACE

Zephyr operations in Australia

An insight into stratospheric flying and Cooperative Traffic Management (CTMS)

Andy Tailby
Zephyr Future Approvals Lead

AIRBUS

Way up there >FL600 (ish)

- Review key Zephyr characteristics
  - As they affect air traffic management
- How we operate currently in Australia
  - Getting up and down
  - Extended operations in the stratosphere
- Zephyr–Loon CTM arrangements
  - Industry-led cooperative separation management
- How we can take CTM forward
  - In manageable steps
- Some points to take away / discuss

A new air traffic management paradigm?

Solar-powered High-Altitude Long-Endurance (HALE) don't behave like conventional aircraft

Diverse stratospheric craft have different capabilities and constraints

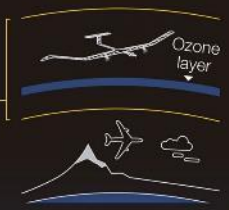
Zephyr

Pioneering the stratosphere

The world's leading solar-electric stratospheric unmanned aerial vehicle

What is it?

Runs on sunshine in the **stratosphere**



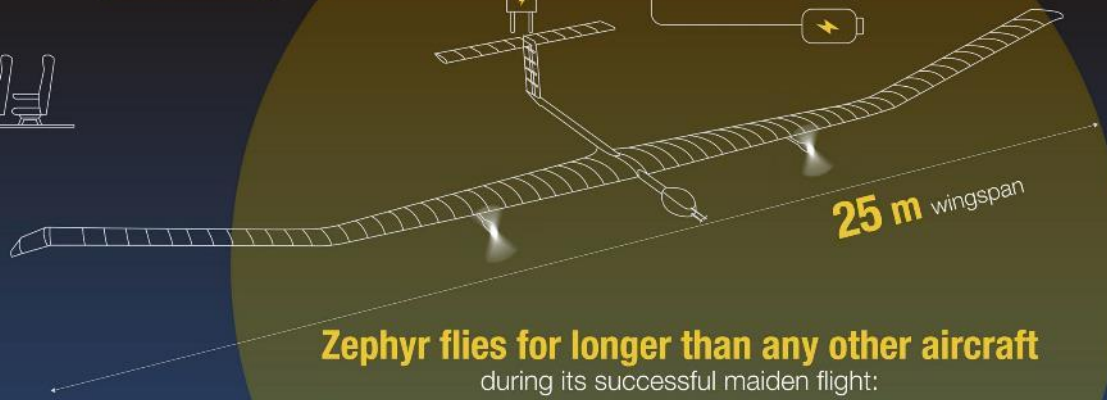
Weighs **75 kg**

Supports up to **5 times** its own weight

Manufactured from fibres no thicker than **a human hair**

Powered by **the sun**

Zephyr uses **solar energy, with secondary batteries** charged in daylight to power overnight flight



Zephyr flies for longer than any other aircraft
during its successful maiden flight:

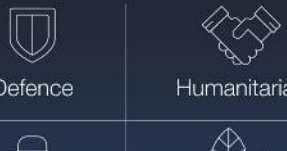
25 days, 23 hours, 57 minutes

What will it do?

Zephyr:

See clearly | Sense efficiently | Connect precisely

Zephyr is able to **revolutionise missions** all over the world:

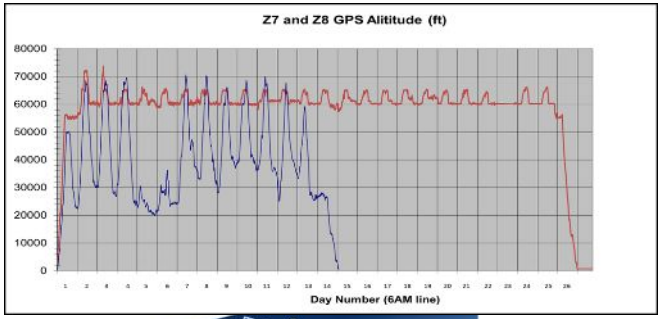


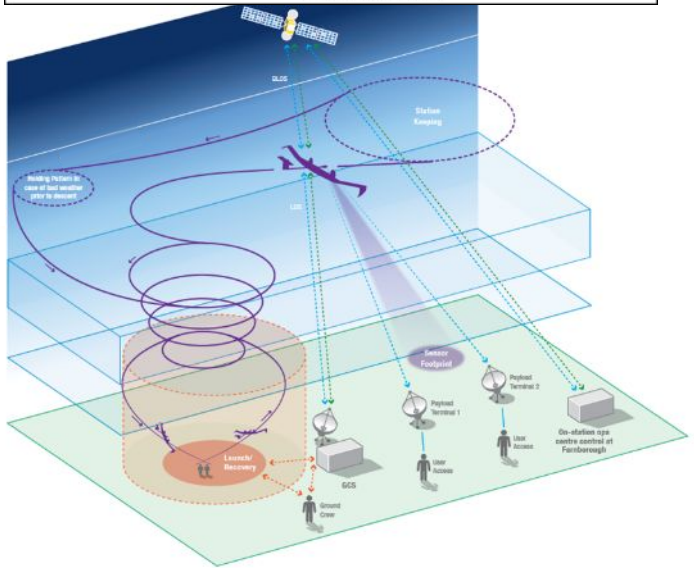
Defence | Humanitarian | Security | Environmental

AIRBUS

Zephyr (solar HALE) operations are characterised by …

- **Daytime climb, night time descent**
  - Level at ‘dawn’ altitude
- **Limited performance** & manoeuvrability
  - Slow (50 KTAS)
  - Low ROC/D (± 150-100 fpm)
- Extremely long (1 year) **endurance** in:
  - Holding areas
  - Mission areas (station keeping)
- **Global** operations
  - A few launch & recovery sites
  - Strategic Operating Centres
- **Waves** of launch and recovery
  - On an opportunity basis (weather)
- **Constellations** of multiple RPA
  - m:n ratio of crews:platforms





Is it a balloon?
Is it a plane?
No, it’s a HAPS

Launch/recovery could be a seasonal phase at a particular location

Occupancy of tropospheric levels a few hours

Not at (busy) airfields

Not integrated with (near to) IFR traffic

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Current Zephyr airspace management

FL900

Class G

FL600

Class A

FL245

Class F

FL180

Class G

SFC

Cooperative Airspace
- Large collaborative operating area
- Unrestricted Zephyr operation DCFL
- In and above Class A airspace
- Infrequent routine reporting to ANSP
- Obligation to ensure separation from Loon

De-confliction Flight Level = FL550

Controlled Airspace
- NOTAM'd Temporary Restricted Areas
- Altitude blocks and segmentation
- ANSP separation provision
- Communication protocol (telephone)

Uncontrolled Airspace
- NOTAM'd Temporary Restricted Areas
- Limited activation times
- Airbus controlling authority
- 'Pass well clear' when practicable
- Regular blind radio calls

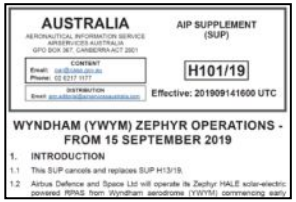

airservices

Airbus Zephyr unmanned aircraft operations in Brisbane FIR

Letter of Agreement

LoA_3489

Version 1


AUSTRALIA

AIP SUPPLEMENT (SUP)

H101/19

Effective: 201909141600 UTC

WYNDHAM (YWYM) ZEPHYR OPERATIONS - FROM 15 SEPTEMBER 2019

1. INTRODUCTION

Energy management

Safe separation

Letter of Agreement with ANSP

>5000 ft margin between DCFL and highest credible ATM traffic

Tactical DCFL reduction as agreed with ANSP

Local stakeholder liaison important

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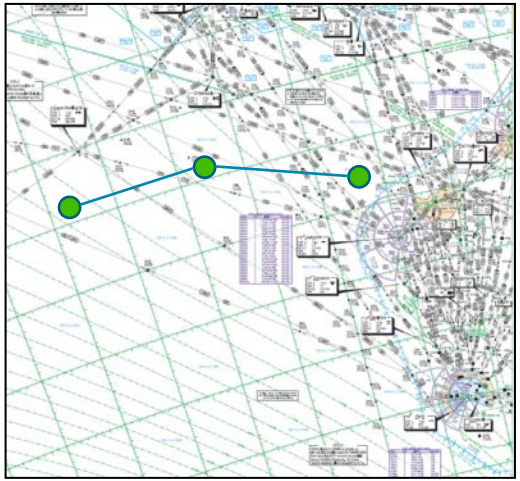
Off-nominal conditions

- Unplanned descent into controlled airspace (any cause)
  - Likely to be predictable well in advance of DCFL passing
  - Coordinate temporary airspace [reservation] volumes below DCFL
  - In many cases, re-climb possible during daylight – TRA ‘stepping stones’
- Lost link flight plan(s) known by ANSP
  - Still above DCFL
- Transponder failure position reports a/r
- In future – inability to achieve navigation or performance necessary for intended CTM separation



Contingencies develop slowly (hours-days)

Assess performance impact

Increase frequency of ANSP communication

Coordinate predicted RPA behaviour and airspace planning

Aviate – Communicate - Navigate

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Today's Loon - Zephyr CTM

CTM protocol

Shared knowledge of:
- Common procedures
- Trajectory prediction capability/uncertainty
- Vehicle manoeuvrability (vertical/horizontal)
- Altitude datum and holding accuracy
- Broad mission intent (operating areas)

Conflict identification

- FIR email alerts to Zephyr
- Call Zephyr control station if:
  - Balloon 50NM from Zephyr operating area
  - Balloon 100NM from Zephyr position

- Check Loon FIR email alerts
- Assess potential conflict using Loon ATM or ADS-B source
- Call Loon MC if potential for conflict exists

Conflict resolution

- Confirm potential conflict (<100NM)
- Agree resolution plan
- Target min separation:10NM and 3000ft
- Recognise mission constraints
- Back up is ROA – Zephyr gives way

- Manoeuvre balloon to implement resolution plan

Monitor and check

- Manoeuvre Zephyr to implement resolution plan

Current *Human-centric, position-based, limited* CTM

Today's tools, only two actors

Conflicts develop (very) slowly

Precautionary separation criteria

Bilateral system – no single-point failure

Record and report for improvement

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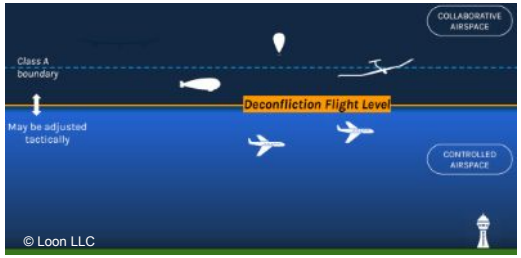
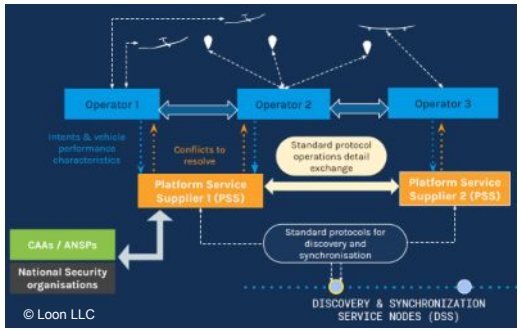
Basic building blocks of CTM

- An agreed **CTM/ATM boundary**
  - De-confliction flight level (DCFL)
- ***CTM protocol*** above DCFL
  - ANSPs and operators
  - Normal ops and off-nominal events
- **ATM accommodation** below DCFL
  - Special-use airspace or procedures
- Discovery and **synchronisation** service
  - Who's out there?
- Platform Service Supplier
  - ***Conflict identification***
- Communications and procedures
  - ***Conflict resolution***





CTM is simple in principle – and in practice (for now …)

Knowledge of own and other vehicles capabilities and constraints

Protocol for ensuring separation and resolving conflict

Communications to coordinate separation

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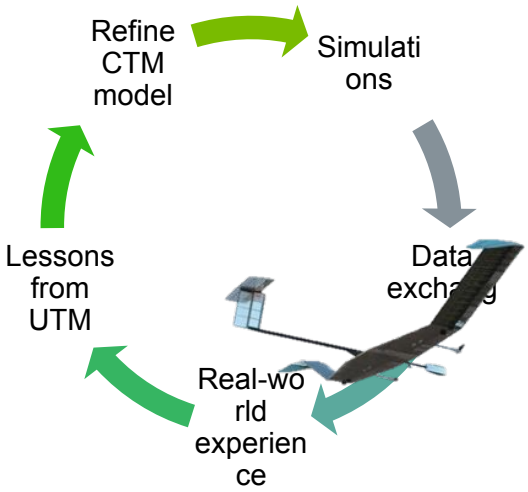
Near-term CTMS next steps

- Establish data exchange protocols
- Risk-based de-confliction approach
  - HAPS vs UFB ≠ HAPS vs SSBJ
- Connect multiple fleet management systems (proto-PSS)
- Automate conflict identification
  - Similar vehicle dynamics to start
- Engage ANSPs, draw on UTM
- Joint long-term simulations
- Later:
  - Automate conflict resolution rules
  - Accommodate diverse vehicle dynamics



Iterate towards *automated 4-D, intent-based, universal* CTM

Opportunity exists NOW to learn from safe real-world experience

Some wider considerations:

Changes to Annex 2?

Non-baro altitude reference?

Risk-based requirements?

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Conclusion

- Practical safe CTM in ‘Higher Airspace’ is happening now
- We are learning together and sharing information with stakeholders
- Strive to harmonise CTM requirements globally, for oceanic and territorial airspace
- The best overall solution may challenge some norms
  - Variable DCFL, altitude reference, collision avoidance criteria …..
- CTMS (and UTM/U-Space) principles could benefit all air traffic management

Any questions?

Zephyr operations in Australia

An insight into stratospheric flying and Cooperative Traffic Management (CTMS)

Andy Tailby
Zephyr Future Approvals Lead

DEFENCE AND SPACE

- Presentation to the ICAO Air Navigation Commission
- 11th May 2020

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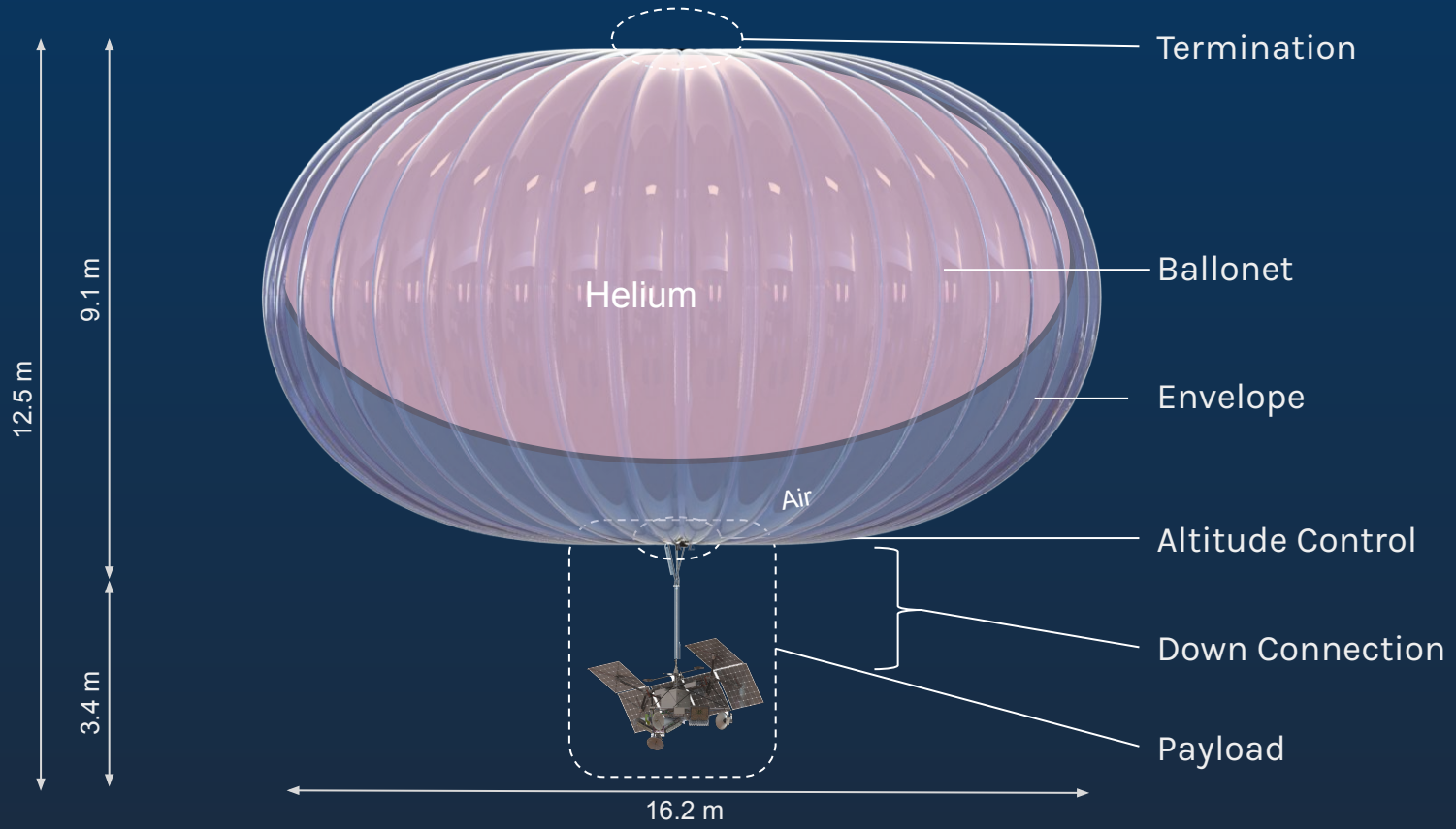
LOON™
Connect People Everywhere

VEHICLE OVERVIEW



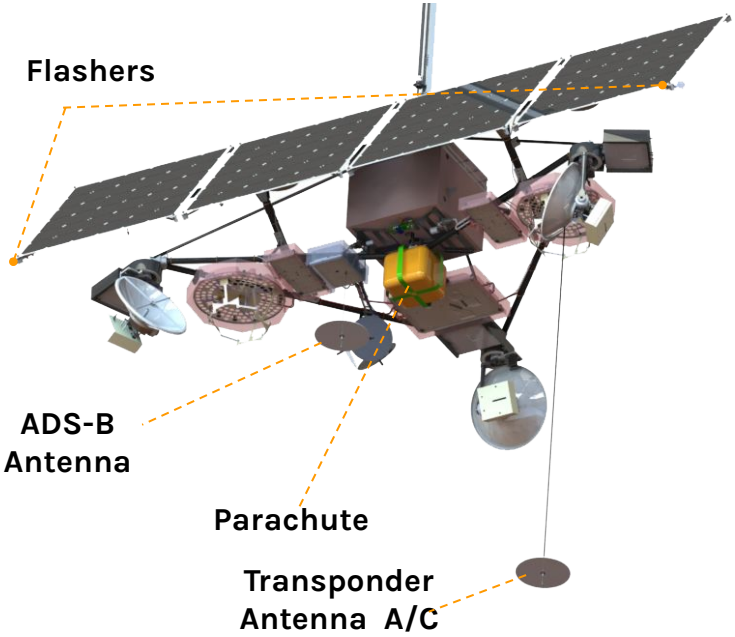
DESIGNED FOR SAFETY, EXCEEDING ICAO, FAA REQUIREMENTS

REDUNDANT POSITION AND TRACKING

- Certified Transponder (ADS-B out with Mode A/C)*
- Redundant sensors: barometric altitude measurement & GPS position.
- Independant & redundant communication (Iridium & Inmarsat)
- Omnidirectional flashers (> 5NM vis.)
- Radar Reflective Materials
- Live tracking website

REDUNDANT FLIGHT TERMINATION

24/7 MISSION CONTROL OPERATION



ICAO- & FAA-COMPLIANT SAFETY MANAGEMENT SYSTEM, CLOSE CAA SAFETY COORDINATION

International Civil Aviation Organization

SASP-WGH/31-WP/04
3/10/2018

WORKING PAPER

SEPARATION AND AIRSPACE SAFETY PANEL (SASP)
31st WORKING GROUP MEETING

***Washington DC, USA*, 29 October to 9 November 2018**

Agenda Item X: Horizontal Separation

Circular and guidance material for high altitude balloon operations
(Presented by Paul Taylor (Australia), Prepared by Dr Steven Barry)

FAA Partnership for safety

Collision Risk Model for Google Loon

airservices

Network Performance & Analysis,
ATM Network Services,
Information Management and Technology,
Airservices Australia

Australian Government
Civil Aviation Safety Authority

Version 2.2

Effective 28 September 2017

Report and Analysis	Dr Steven Barry, Rubai Amin
Authorisation	Dr Steven Barry, Network Performance and Analysis, Airservices: Advisor to ICAO SASP and Member of ICAO SASP Mathematicians Sub Group.
	Dr Steven Barry — Digitally signed by Dr Steven Barry DN: cn=Dr Steven Barry, o=Airservices Australia, ou=Network Performance And Analysis, email=steve.barry@airservicesaustralia.com, c=AU Date: 2017.09.28 12:25:18 +10'00'

Abstract:
This report provides an initial assessment for the collision risk of operations for Google Loon (high altitude balloon operations) in the Australian FIRs down to FL 500, interacting with aircraft above FL 450.

It considers the risk of Google Balloons:

1. descending below FL 500: $R < 2 \times 10^{-5}$ per flight hour
2. descending to FL 450: $R < 10^{-10}$ per flight hour
3. colliding with an aircraft operating above FL 450: $R < 10^{-16}$ per flight hour

TECHNICAL ACHIEVEMENTS

1M+ HOURS OF FLIGHT EXPERIENCE ACROSS THE GLOBE

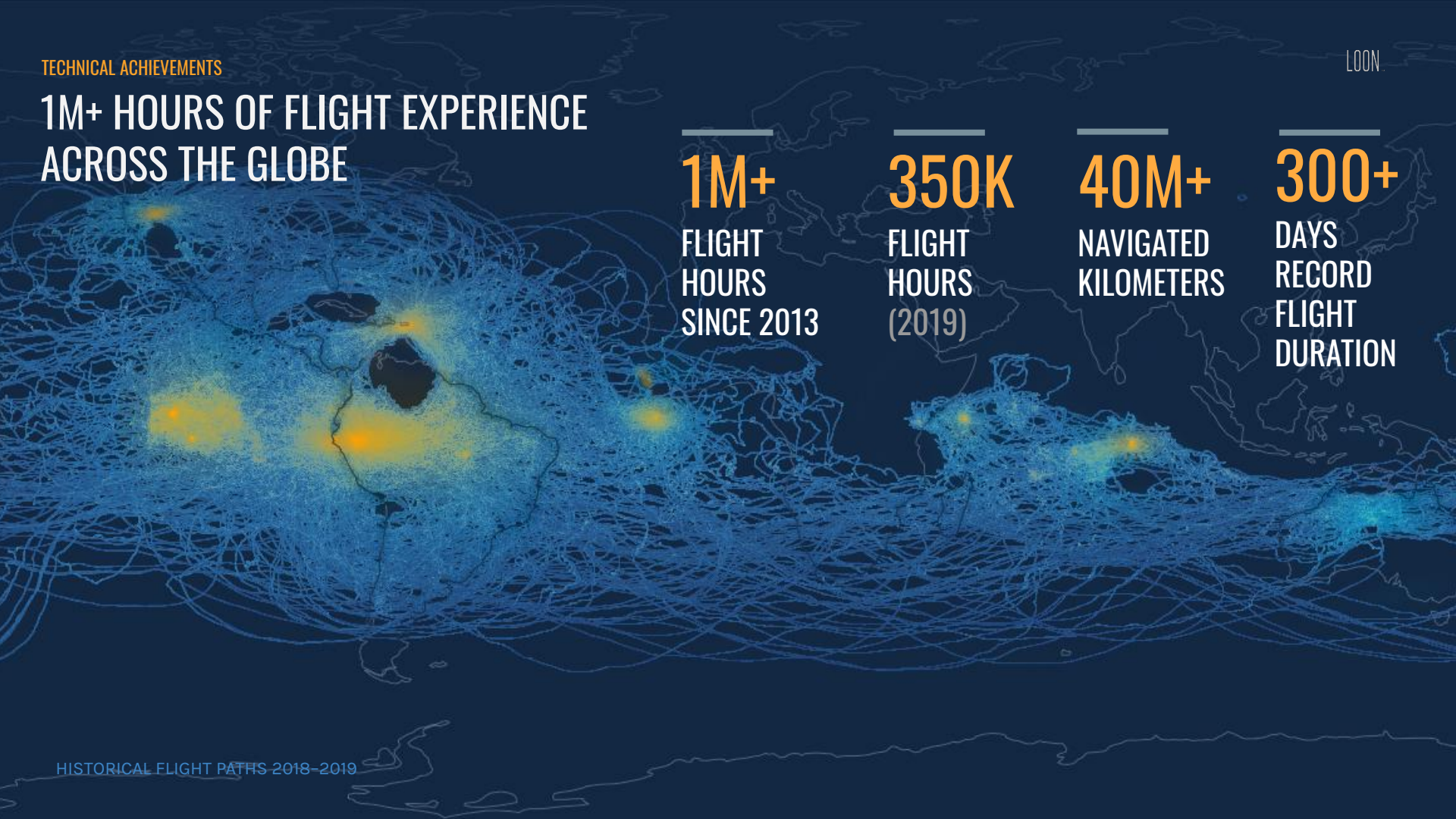
LOON

1M+
FLIGHT HOURS SINCE 2013

350K
FLIGHT HOURS (2019)

40M+
NAVIGATED KILOMETERS

300+
DAYS RECORD FLIGHT DURATION



HISTORICAL FLIGHT PATHS 2018–2019

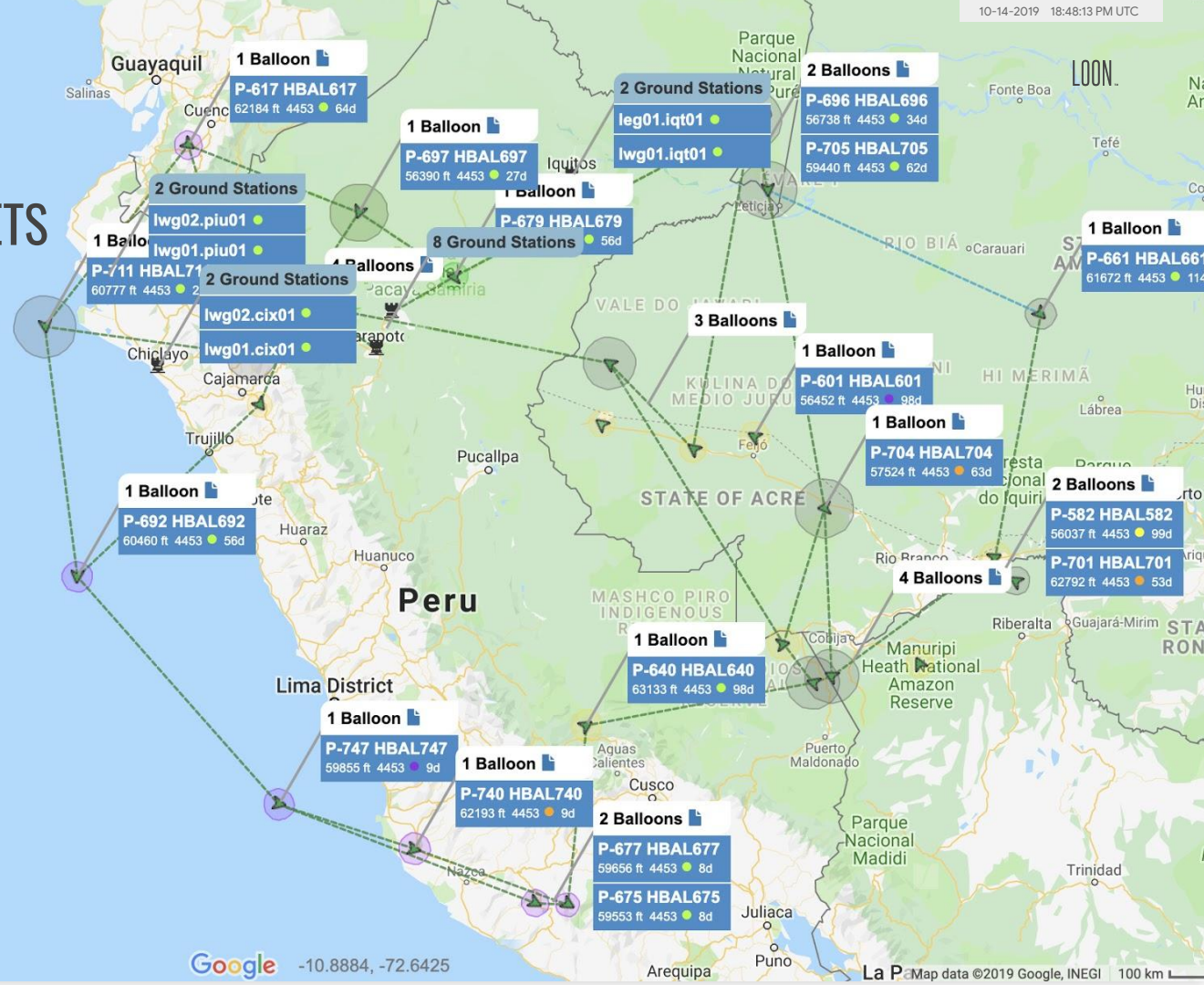
TECHNICAL ACHIEVEMENTS

SAFELY FLOWN AND DECONFLICTED LARGE FLEETS

25+
VEHICLES LOCAL FLEET SIZE

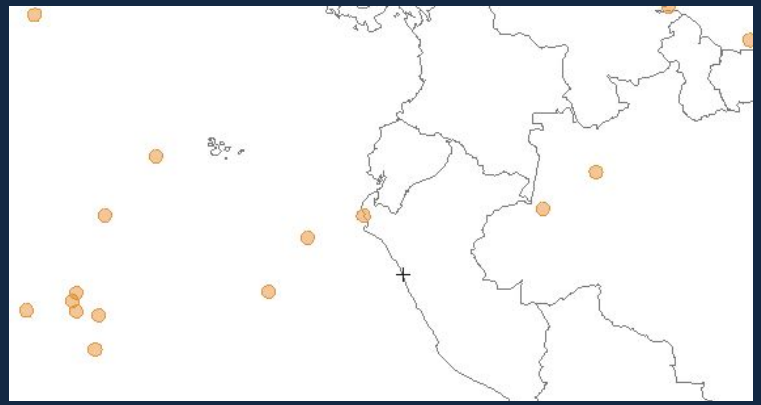
75+
VEHICLE AIRBORNE SIMULTANEOUSLY

BILATERAL DECONFLICTION AGREEMENTS



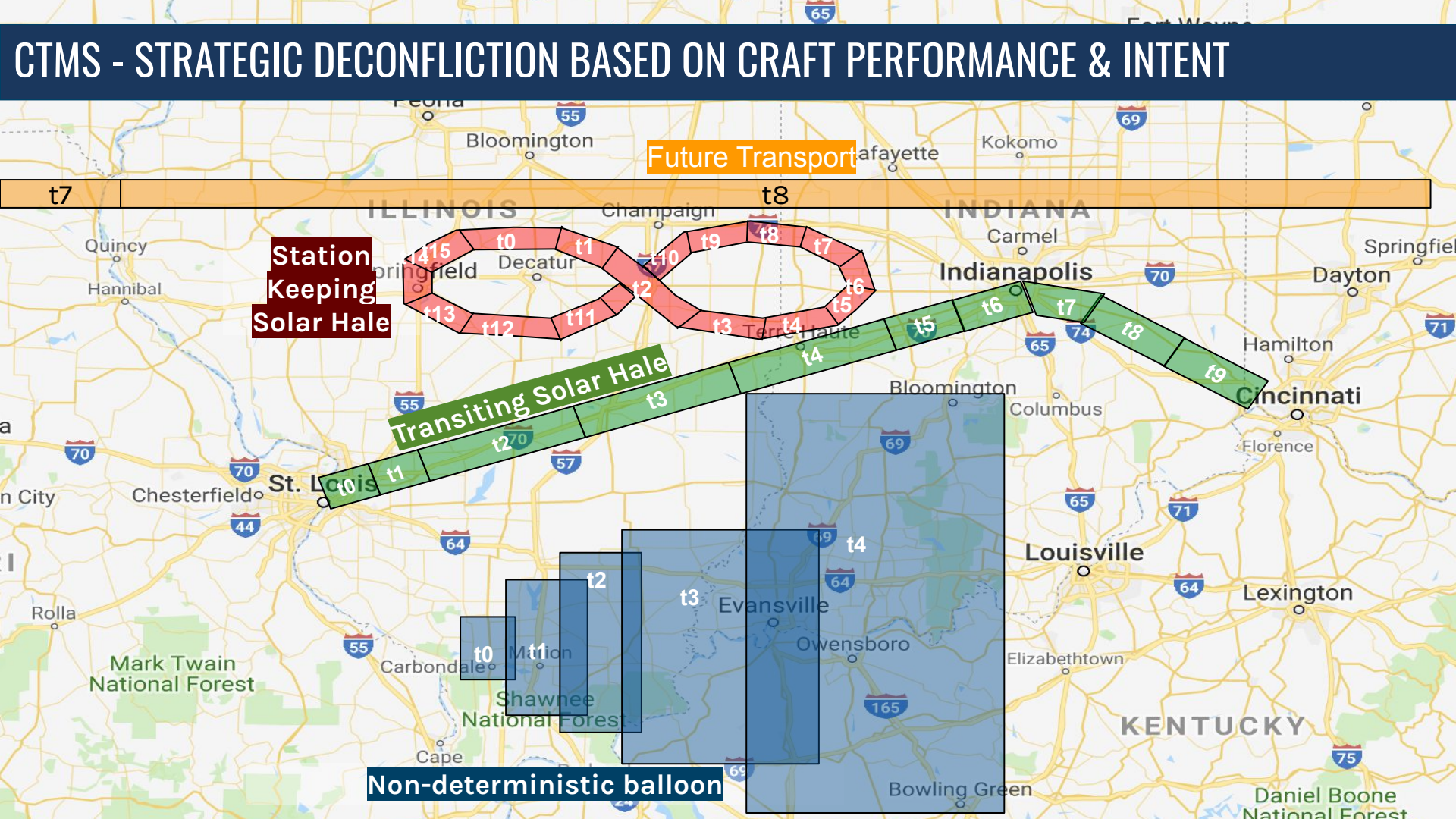
MANAGING A COMPLEX AND DYNAMIC ENVIRONMENT

EXPANDED FROM UTM PRINCIPLES TO MANAGE STRATOSPHERE SPECIFICS



- Federated DSS enables discovery and synchronisation
- Operators exchange 4D intents and **time dependent performance characteristics**.
- Intents may be a rolling window in the near future (few hours). They may be **updated frequently** while airborne (possibly on a minute basis)
- 4D intents may be probabilistic and contain probability information.
- PSSs alert operators at appropriate timing on conflicts that need resolution: based on intents, performance, and risk assessment.
- Operators negotiate conflict resolution based on mission, constraints and performance.
- Deconfliction Flight Level set tactically by ANSPs enables safe collaboration below FL600 (above FL500)

CTMS - STRATEGIC DECONFLICTION BASED ON CRAFT PERFORMANCE & INTENT



CONSTANT REPLAN & UPDATE

CTMS RELIES ON RISK BASED FRAMEWORK FOR IDENTIFYING CONFLICTS & APPROPRIATE TIMEFRAME

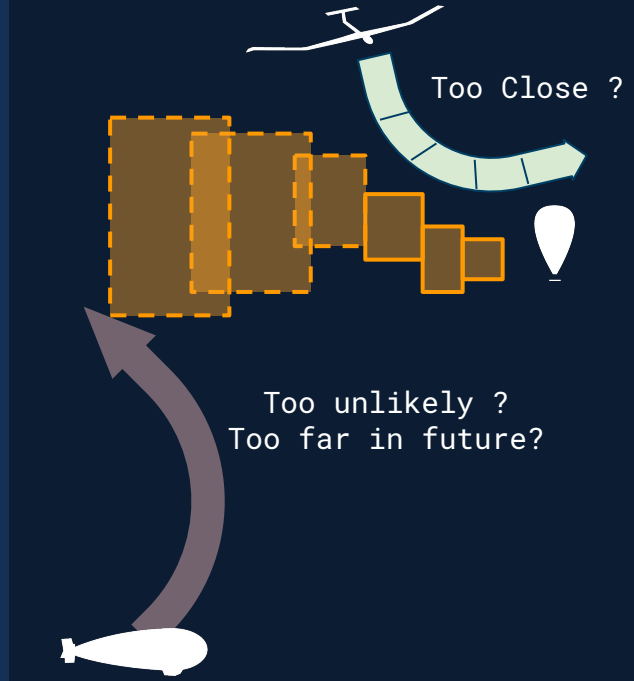
ARE INTENTS TOO CLOSE ?

IS THE CONFLICT WORTH RESOLVING NOW ?

WELL CLEAR TOLERANCE DEPENDENT ON PERFORMANCE OF **BOTH** VEHICLES

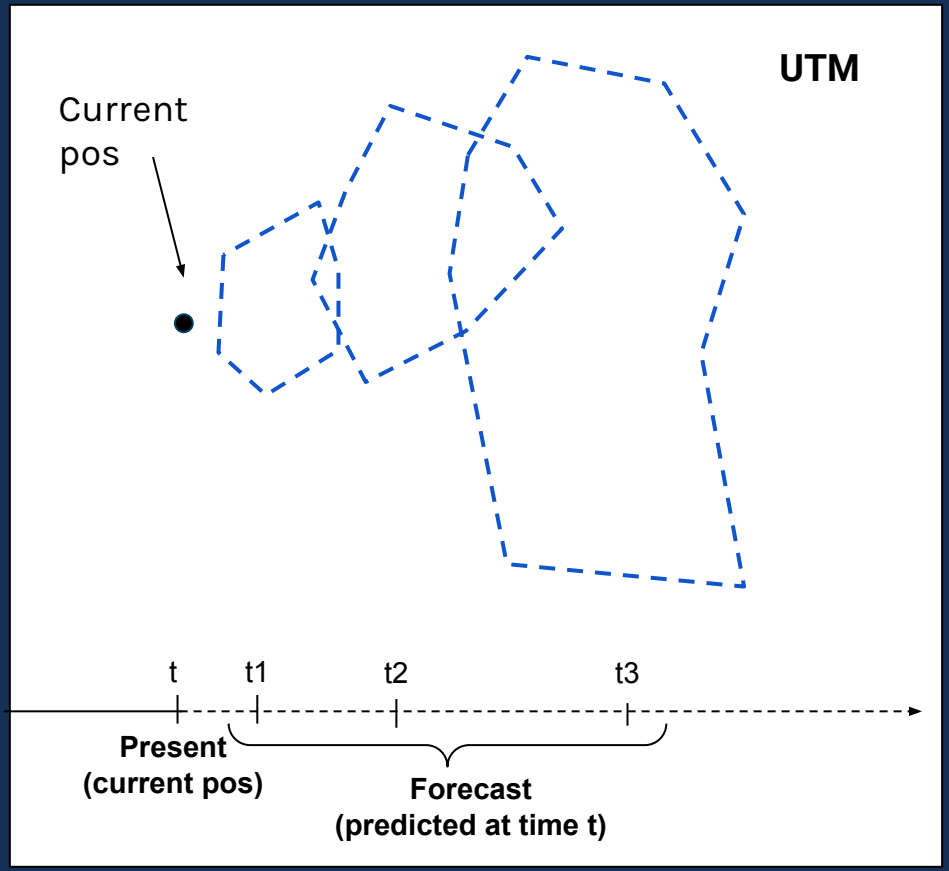
CONFLICT SEVERITY RATING

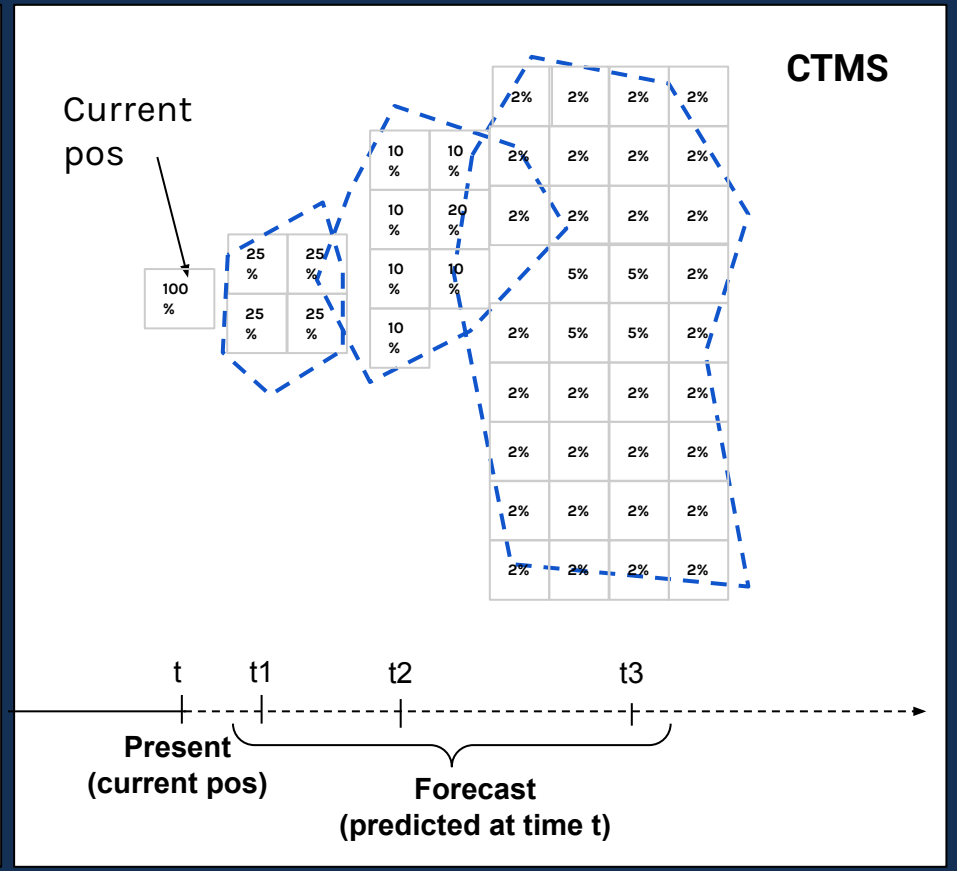
- TIME HORIZON OF CONFLICT
- CONFLICT PROBABILITY
- CONFLICT RESOLUTION TIME & VEHICLES' MANEUVERABILITY
- LOSS OF SEPARATION SEVERITY



NON-LINEAR TRAJECTORIES

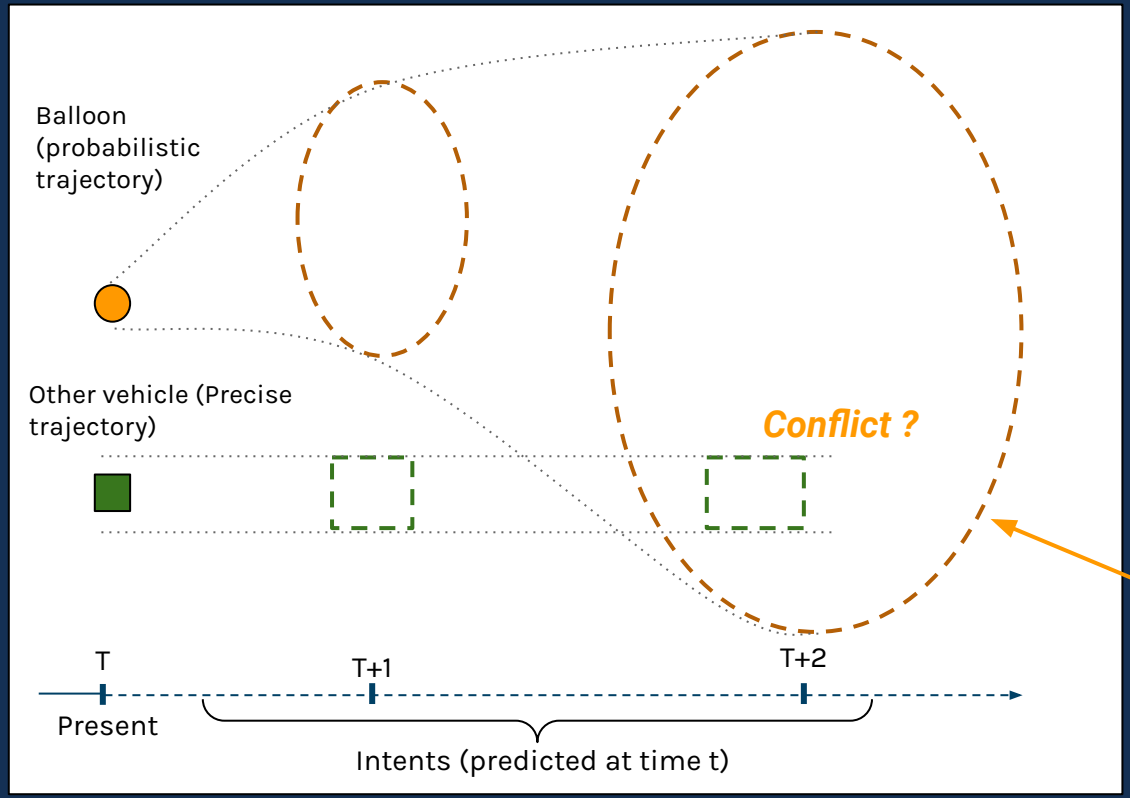
CTMS WILL ADD PROBABILITIES TO INTENTS -

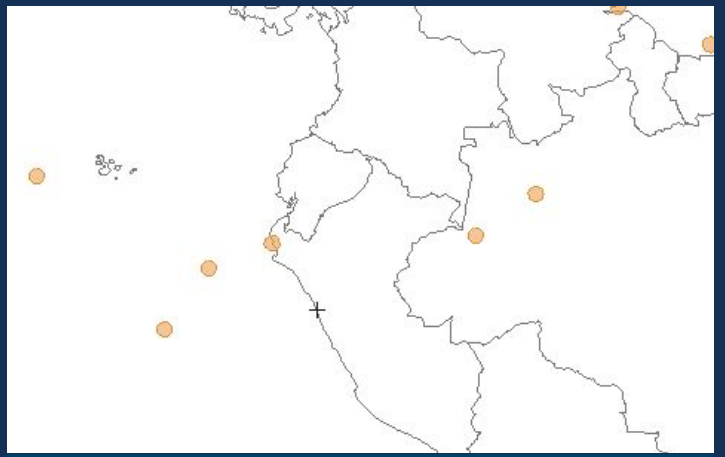




CONSTANT REPLAN & UPDATE

4D INTENT OVERLAP IS NOT SUFFICIENT TO ENSURE EFFICIENT AIRSPACE USAGE



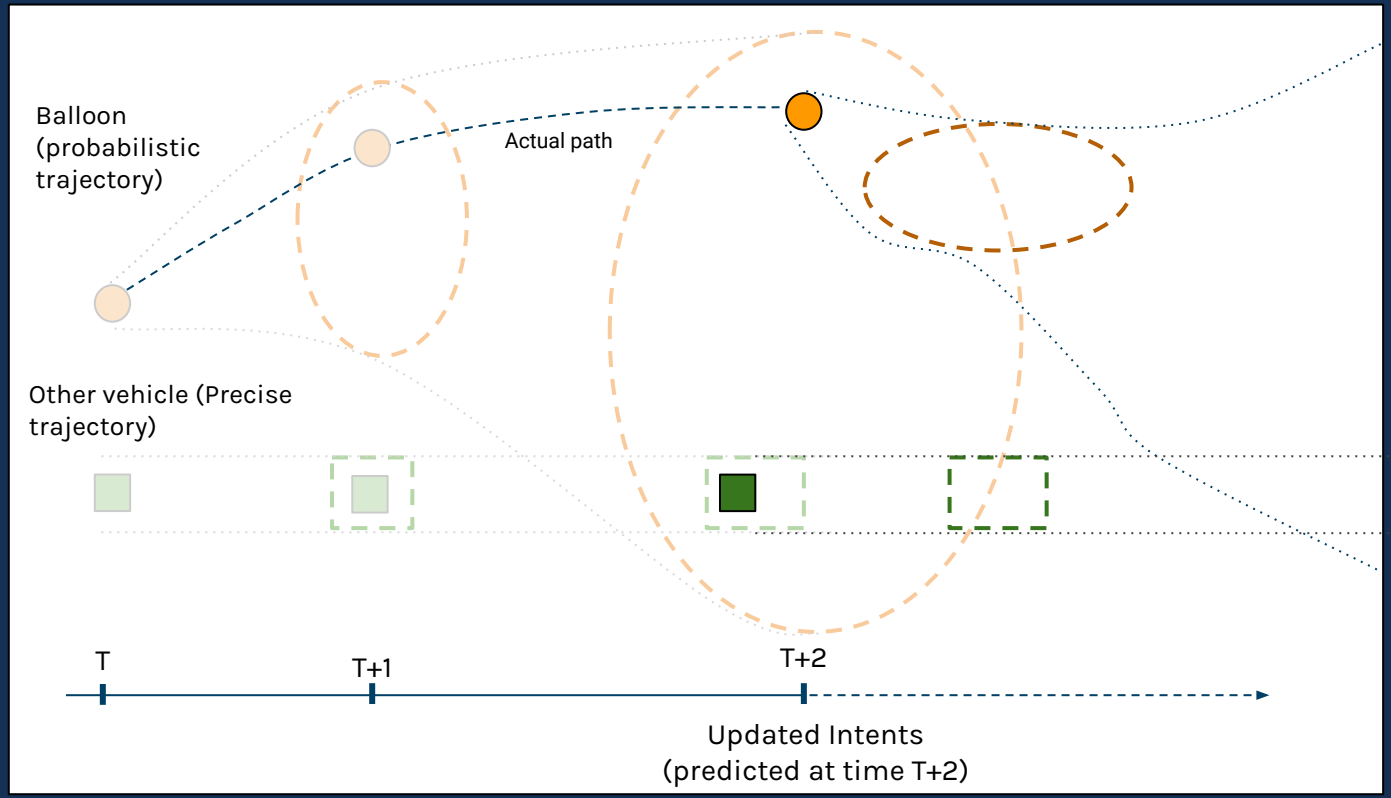


Balloon actual position data

At a 2h Horizon the probabilistic intents can be Thousands of square nautical miles in surface and 10’000ft in altitude

CONSTANT REPLAN & UPDATE

4D INTENT OVERLAP IS NOT SUFFICIENT TO ENSURE EFFICIENT AIRSPACE USAGE

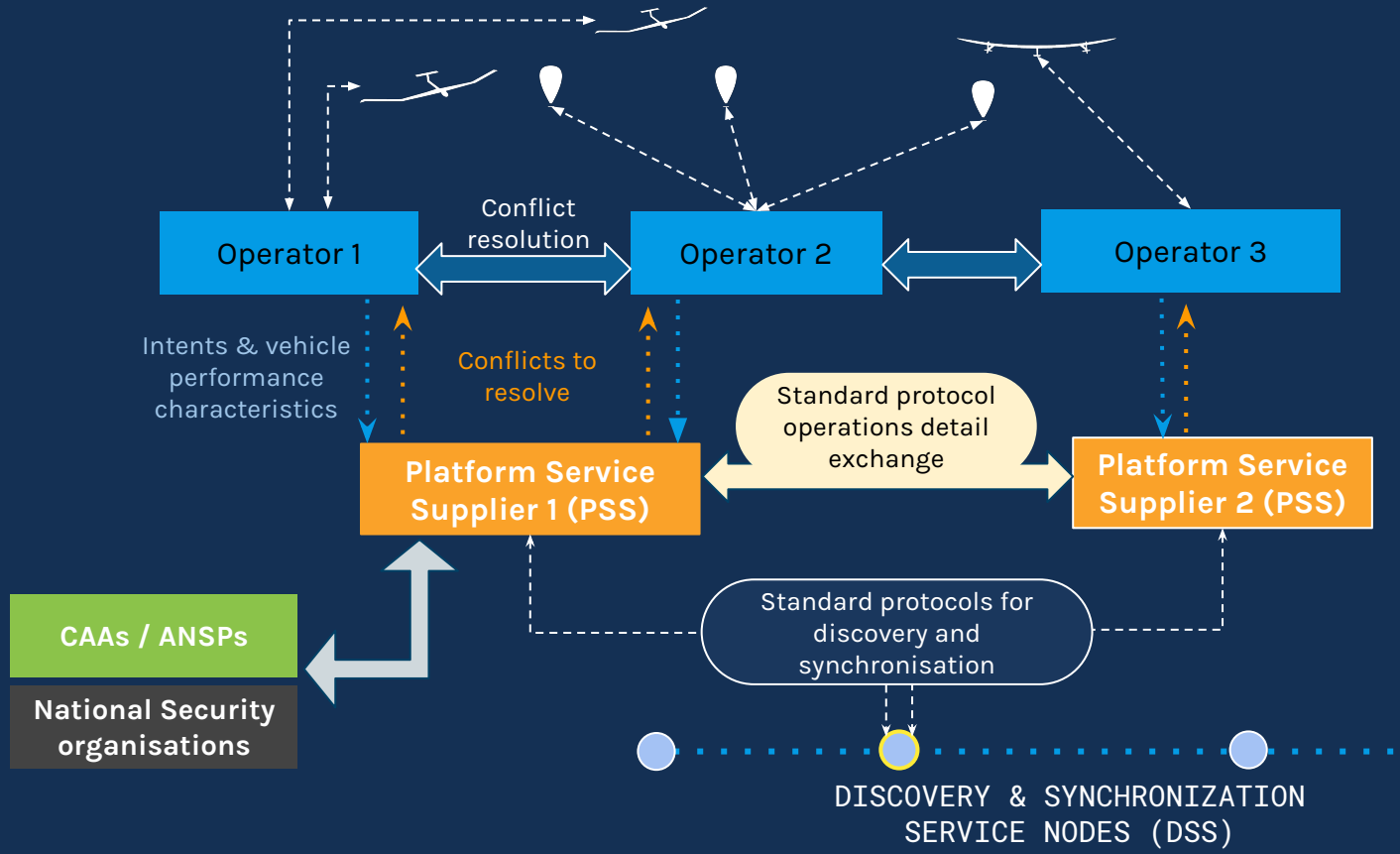


Non-deterministic intents grow in size with future. Example for Loon: at 2h horizon:

- Intent surface area average may average to 1200 NM^2 (equivalent to 19NM radius circle)
- Intent altitude reservation may average 6000 ft

A NEW INDUSTRY

CTMS - HIGH LEVEL ARCHITECTURE



COMMAND & CONTROL
FLEET MGT
CONFLICT RESOLUTION

STRATEGIC CONFLICT IDENTIFICATION & AIRSPACE AWARENESS

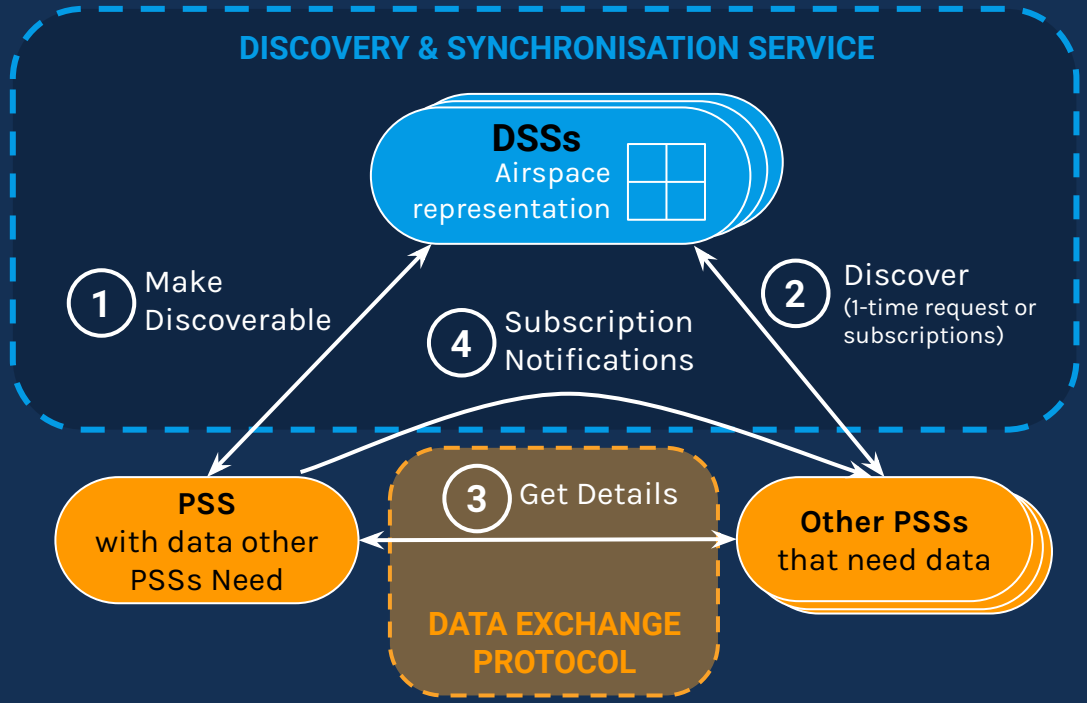
AIRSPACE CONSISTENCY

ALIGNED WITH REMOTE ID - ASTM STD

DSS - DISCOVERY & SYNCHRONISATION SERVICE

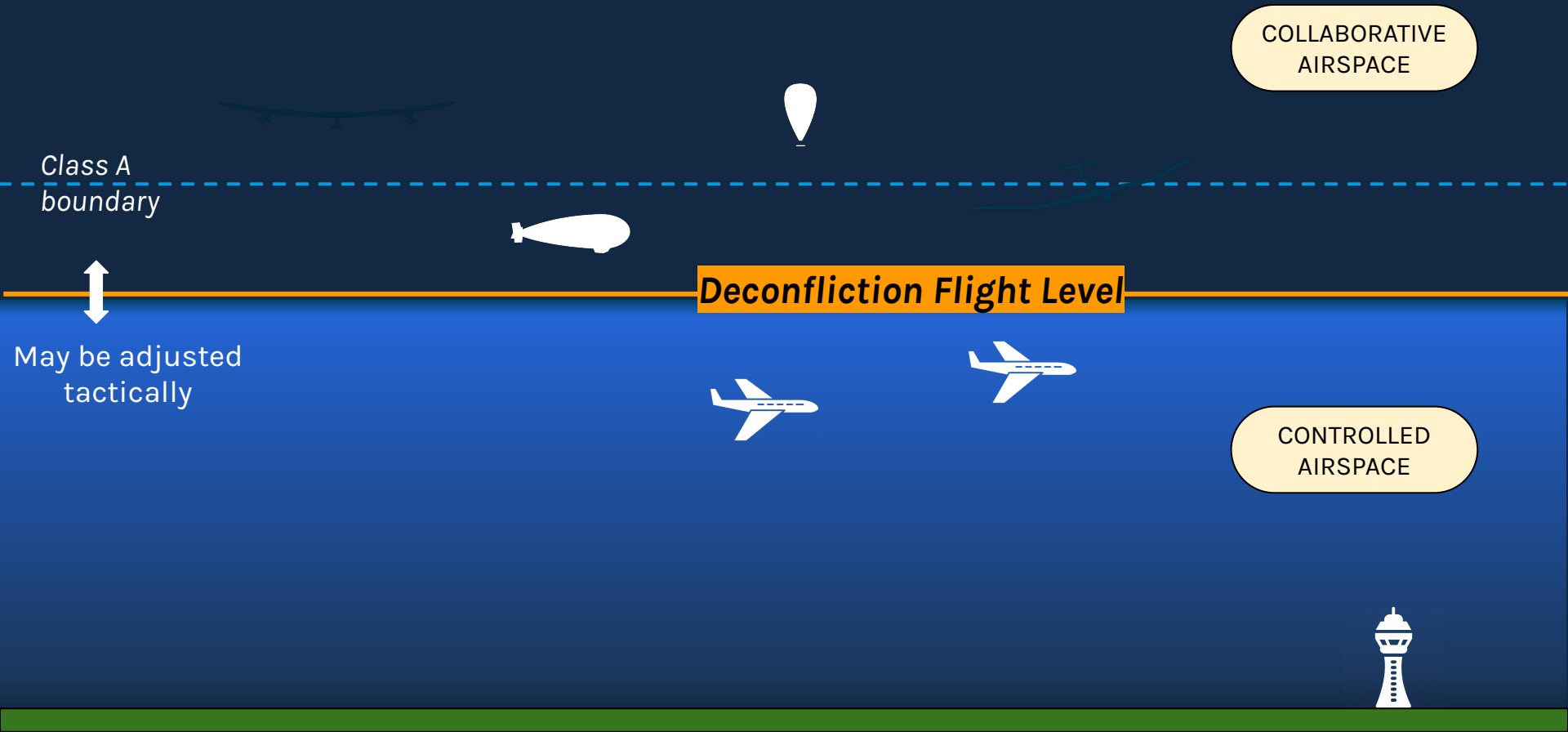
Decentralized (federated) Globally Consistent and Redundant Infrastructure that:

- Informs PSS on which parties need to exchange information
- Ensure consistency/synchronisation in the deconfliction process



Accessing Airspace Below FL600 is critical for HAPS

CTMS - DECONFLICTION FLIGHT LEVEL ADJUSTED TACTICALY BY THE ANSP



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

European Coordination/Pathway

- Stratospheric Community has also been coordinating with the Europe for several years
- US/Europe collaborating on Stratospheric Operational Concepts via mutual institutional arrangements
- European operators and regulators are also working closely with ICAO; including participation in Drone Enable and other key ICAO events
- Chairs of ICAO Panels are informally coordinating on cooperative Traffic Management concepts to ensure harmonization
- COVID dependent; European institutions plan:
  a Stratospheric Market Analysis Workshop tentatively in early 2021 and
  a CONOPS Workshop in Mid 2021

BACKUP