



2019
World ATM Congress

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Stand 849

U-space Concept of Operation



- 9 member consortium
- 21 member advisory board
- 200+ U-space Community Network
- 8 *sibling* projects
- 8 demonstration projects
- 100+ organisations involved

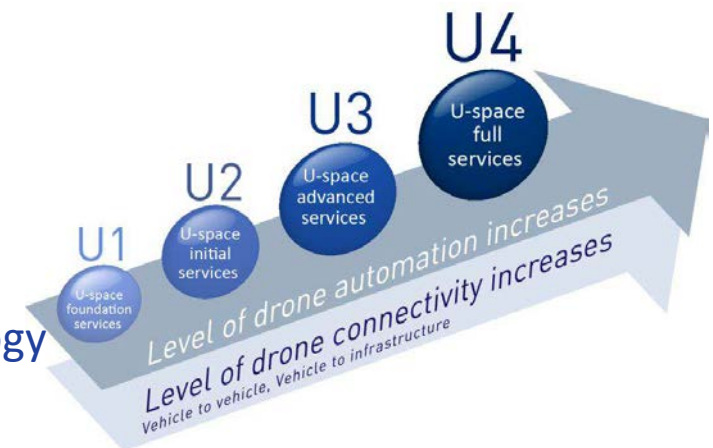


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CORUS scope

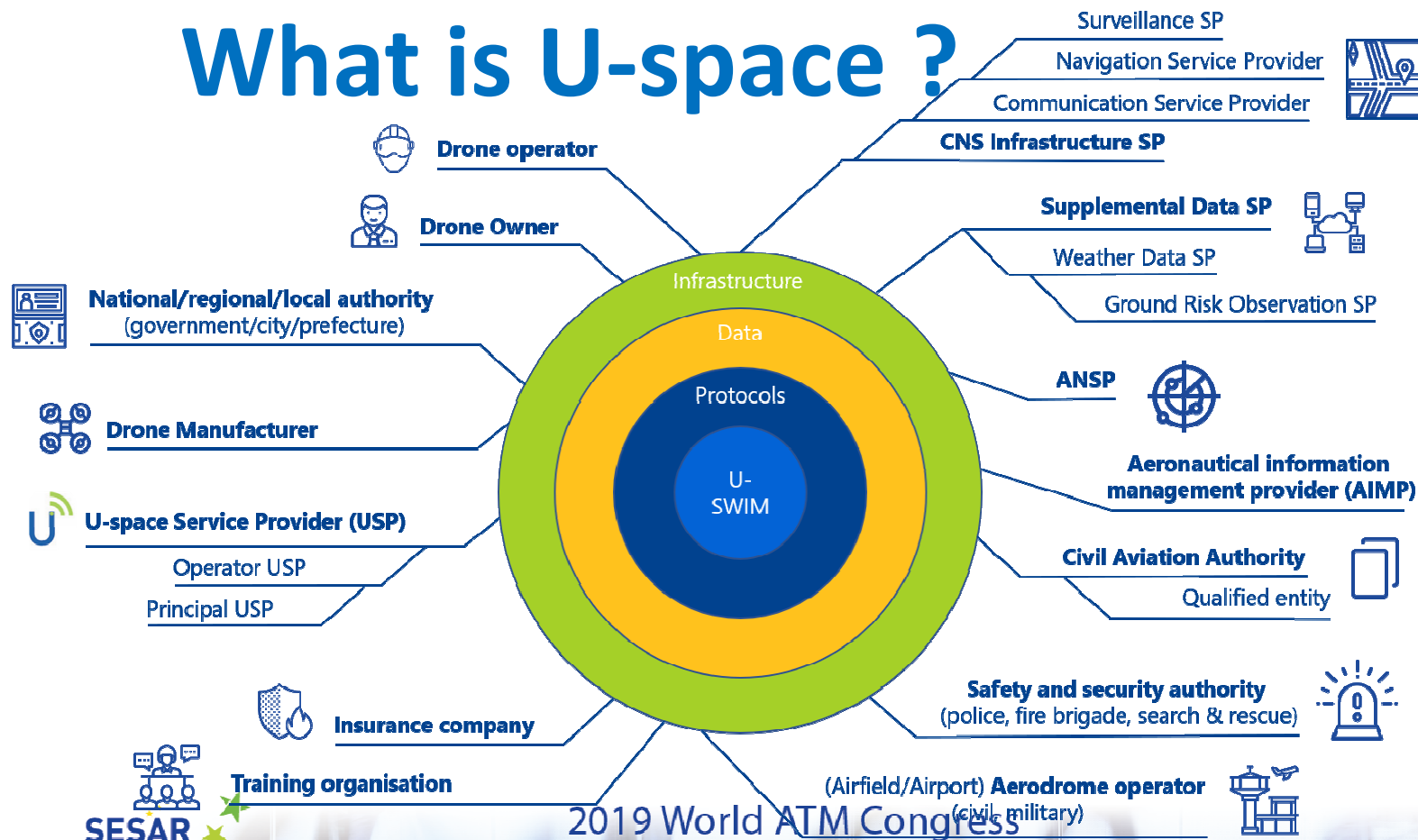
- CORUS is initially concerned by VLL
 - = below VFR
 - U-space can be thought of as serving small drones
- CORUS inherits the definition of U-space in services and levels
 - From Blueprint and Roadmap
- CORUS initially describes a way of working in the reasonable cases
 - then works towards the more difficult situations
- CORUS makes very few assumptions about technology
- CORUS defines an architecture top-down
 - The sibling projects explore the same architecture bottom-up



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What is U-space ?



U-space
is a set of
services

Principles:
Safety first
Open market
Social
acceptance
Equitable
access
ECAC wide



EASA operation categories

Open, Specific & Certified

- Open:
 - Little training of pilot
 - Limitations on aircraft
 - Limitations on where the flight can take place



- Specific
 - Risk assessment & Mitigation required per flight
 - Or trusted operator with good record
 - Trained Pilot

- Certified
 - As manned operations
 - Certificate of air worthiness for aircraft
 - Certified pilot
 - Operator's certificate

CORUS subdivision of VLL into Volumes

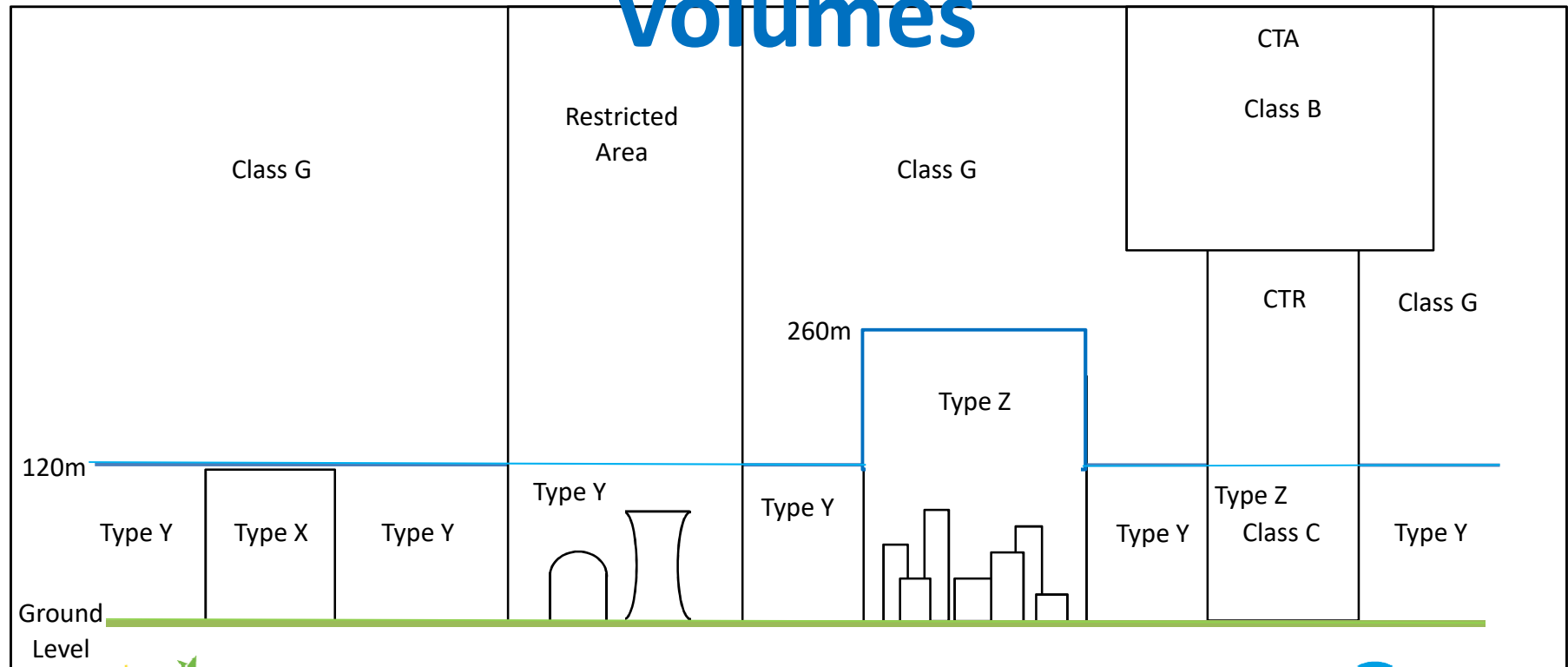
- X: No conflict resolution or separation service is offered
- Y: Pre-flight conflict resolution is offered only
- Z: Pre-flight conflict resolution and in-flight separation are offered
- Access to X is easy
 - No operation plan needed
- All responsibility for separation is with the remote pilot
- Facilitates VLOS and Open class operations
- BVLOS or Autonomous ops need significant risk mitigation
- Y and Z airspace offer pre-flight conflict resolution
- Access to Y or Z is based on acceptance of an Operation Plan.
 - Y & Z can be used to implement No Drone Zones
 - Either can have specific requirements for flight (equipment, training, ...)
- Y & Z offer Traffic Information
 - Needs surveillance and tracking
- Z offers in-flight conflict resolution
 - Either by U-space service
 - Or by ATS in controlled airspace
- Y facilitates BVLOS
- Z enables higher densities



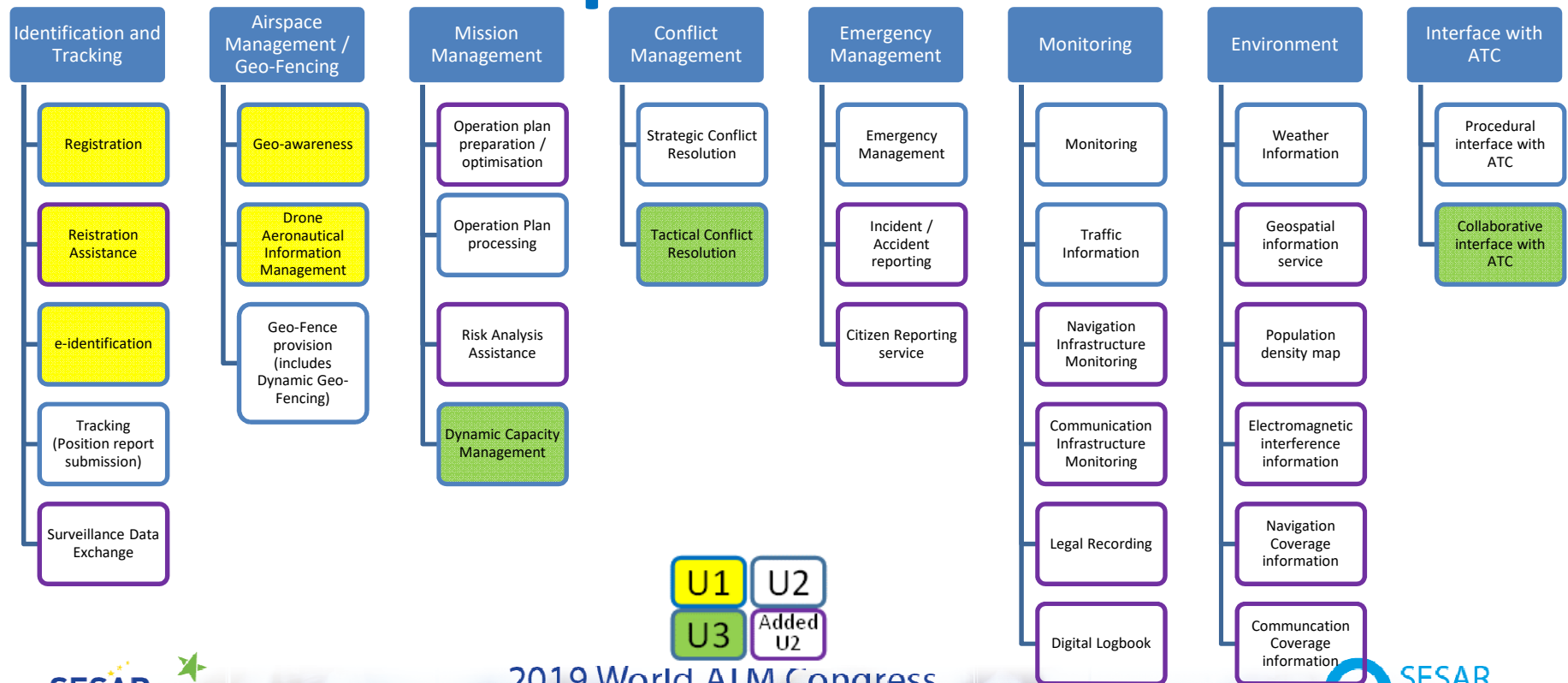
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CORUS subdivision of VLL into Volumes



U-space services



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Operation Planning & Tracking *in Y & Z volumes*

- Drone ops plan differs from ICAO 4444 plan
- But covers the same information
 - Who
 - flies What
 - Where
 - and When
 - + supplementary info
- Uncertainties need to be explicit
 - “Take off between 14:00 and 14:45”
 - *This is a new industry and we lack experience*
- Plans are used for pre-flight conflict detection
 - Probability of conflict needs to be considered
 - *The conflict detection should be useful*
- Tracking will mostly use dependent surveillance.
 - The drone pilot/operator will be responsible for ensuring position reports are sent
 - Reports may be derived from E-Identification
- Many surveillance sources will not be certified
 - Track data of limited value
 - Warnings can be given
 - Pilot or Detect-and-Avoid must remain involved
- Type Z volumes may require certified surveillance sources
- Tracking drones helps protect manned aviation who may enter VLL
 - Even imprecise tracks are better than none...

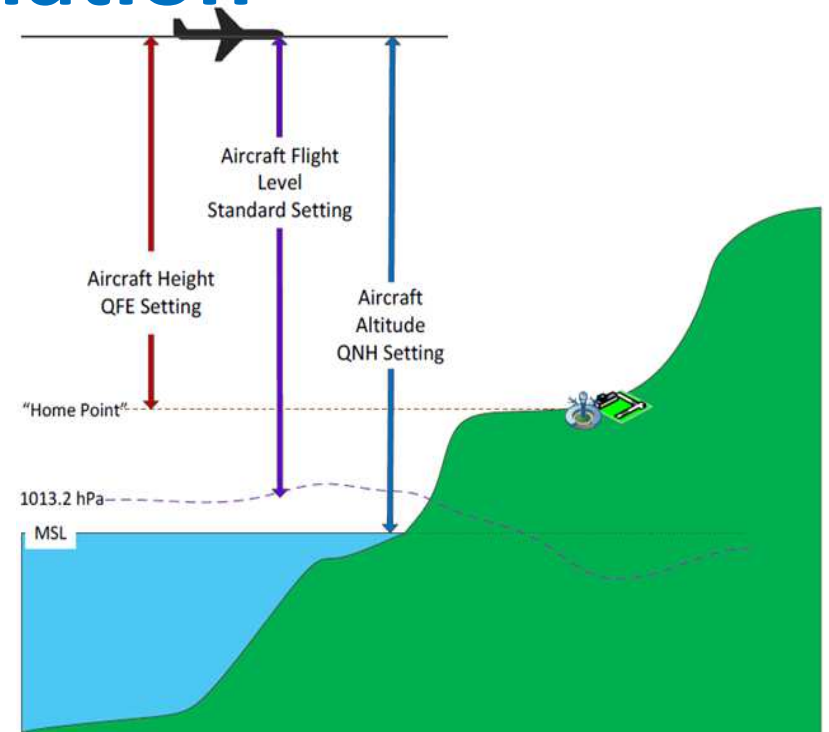


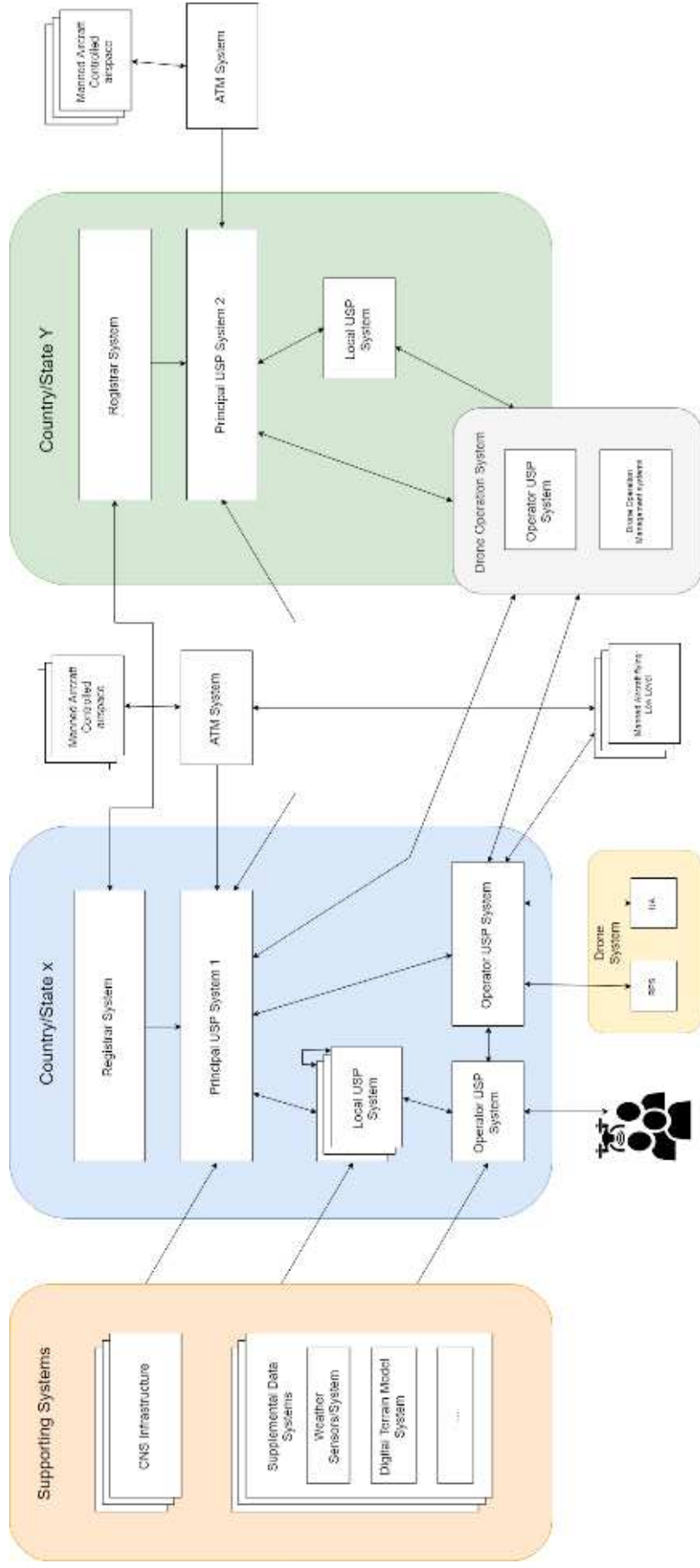
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U4 – full integration of drones with manned aviation

- The ConOps mostly discusses
 - Segregation
 - Accomodation
- U4 is Integration requires some cooperation with manned aviation:
 - How to measure and express height
 - What does North mean
 - Universal use of compatible Electronic Conspicuousness
 - Evolution of the rules of the air
 - Some integration of U-space into ATM
 - Some new tasks for manned pilots
 - Lots of training is needed
 - Especially for drone operators





Thanks!

- Questions?
- Contact:
corus.info@eurocontrol.int



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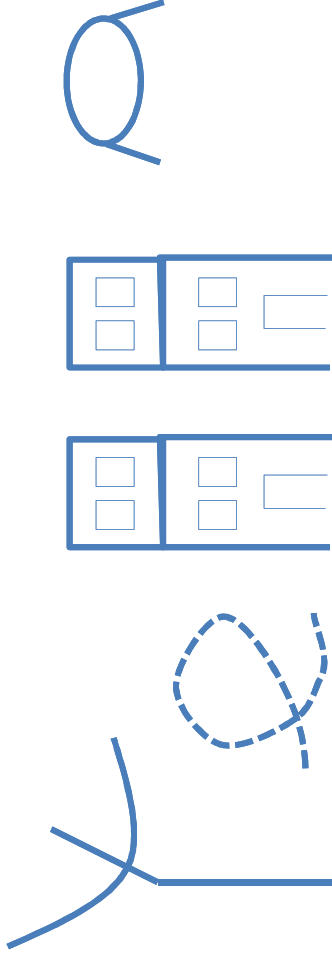
Technological European Research for RPAS in ATM (TERRA)

Victor Gordo (INECO)



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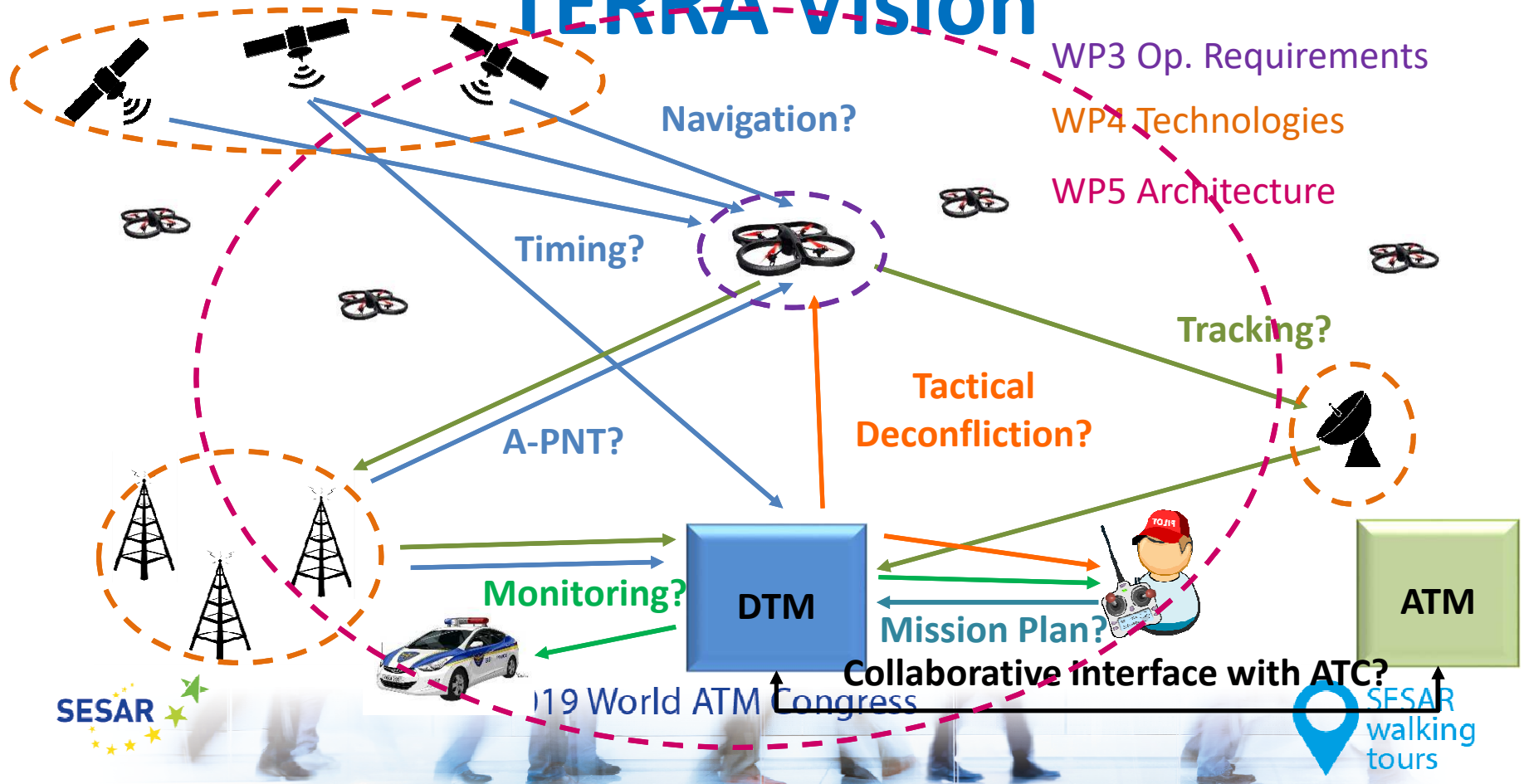
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TERRA Vision



Operational Needs

Requirements	U-Space	Agriculture	Delivery
Operational scenario		Rural VLOS/BVLOS Fixed route (but not always) Geo-cage - Near drones, but spatial segregation	Urban BVLOS Flexible route Non segregated - Simultaneous drones
Send Mission/Flight Plan	Flight Plan Management	Drone operator would ask for alPoorance to fly in a certain piece of airspace (flight plan 15 minutes in advance).	Operator will fill in a flight plan indicating origin and destination, and desired time slot. Include also: Identifier, Capabilities, etc.
Obtain flight plan validation	Strategic deconfliction	Once confirmed by the system, this area will be geo-caged for this operator	DTM will manage the route through an optimization plan (shortest path, other drone trajectories, drone/pilot capabilities, restrictions...)
Navigation	CNS-NAV	Horizontal precision: 3 - 5 m Vertical precision: 5 - 10 m GPS/EGNOS, and contingency means	Horizontal precision: 0.1-1m Vertical precision: 1 m Combination of sensors: GNSS MC/MF + LTE + IRS,
Separations	CNS-NAV Tracking	- Towards terrain: 300 m horizontal and 50 m vertical (100 m vertically with respect to mountains) - Towards other drones: in case of conflict, the drone pilot or DAA systems will have to solve them.	- Towards other drones: flight levels and landing areas could be defined, to reduce the risk of conflicts between drones (equipped with DAA). In other case, e.g. drone landing directly on clients' houses, tactical conflict management would be required. (Strategic Mitigation Poor)



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Technologies Analysis

Navigation										
	GPS SPS	GPS SPS+RAIM	EGNOS v2	NAVAIDS	TOA	AOA	RSSI	AGNSS	RTK	PPP
Accuracy	Medium/Good	Good	Very Good	Poor	Extremely Good	Medium/Good	Medium	Very Good	Extremely Good	Extremely Good
Integrity	Poor	Good	Good	Good	Good	Poor/Medium	Medium	Good	Poor	Poor
Availability	Good	Good	Medium/Good	Medium	Good	Good	Medium	Good	Medium	Good
Continuity of Service	Good	Good	Medium/Good	Good	Very Good	Good	Medium	Good	Medium	Good
Coverage/Deployment	Medium/Good	Medium/Good	Medium/Good	Poor	Medium/Good	Poor	Poor	Medium/Good	Poor	Good



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Technologies Analysis

A/G Communication						
	5G LTE	LoRA	L-DACS	EAN	V2X	WiMAX /Aero MACS
Continuity of Service	Good	Good	Good	Medium/Good	Good	Medium
Availability	Medium	Good	Good	Medium/Good	Medium/Poor	Good
Integrity	Good/Medium	Good	Good	Medium/Good	Poor	Good
Update rate	Good	Medium/Poor	Good	Good	Good	Good
Data delivery time/Latency	Good	Medium/Good	Good	Medium/Good	Medium	Good
Bandwidth	Good	Poor	Good	Good	Poor	Good
Data Transfer Security	Medium	Good/Medium	Good	Medium/Good	Poor	Good
Coverage/Deployment	Medium/Poor	Medium/Good	Poor	Good	Poor	Medium



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Technologies Analysis

Surveillance						
	Drone Radar	Direction Finder /RF	EO/IR Acoustic	ADS-B	5G Tracking	Telemetry reporting (3G/4G)
Accuracy	Medium	Poor	Medium	Good	Medium	Good
Update rate	Good	Good	Good	Good (ground) / Medium (Satellite)	Very Good	Good
Independency from the navigation source	Very Good	Very Good	Very Good	Poor	Good	Poor
Integrity	Good	Good	Good	Good	Good	Good
False plots/tracks	Good	Medium	Medium/Good	Good	Good	Good
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Coverage/Deployment	Poor	Poor	Poor	Poor (ground) / Medium (Satellite)	Poor	Good

Machine Learning (ML)

To aid both monitoring of nominal VLL UAS operations, as well as early detection of off-nominal (trajectory deviation) condition

Conflict prediction modelling

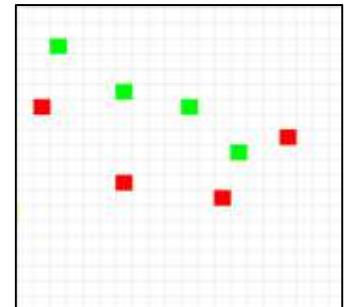
using neural network modelling explore whether ML could be used to predict in advance whether a drone traffic pattern would result in conflict

Rule-based reinforcement learning

using reinforcement learning explore whether a set of safety 'rules-of-the-road' be identified to reduce collision risk in samples of VLL drone traffic

Results

- **Conflict prediction modelling** - ANN modelling provided encouraging first evidence that ML methods can be very useful in helping predict conflicts in the urban scenario
- **Rule-based reinforcement learning** - The problem of frequent follow-on conflicts with other traffic could be mitigated even under higher traffic densities.



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Topic 02: Drone Information management



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DREAMS: DRone European AIM Study



contribute to the definition of **Drone Information Management**



fill the gap between the existing information used by traditional manned aviation and the needs of U-Space concept



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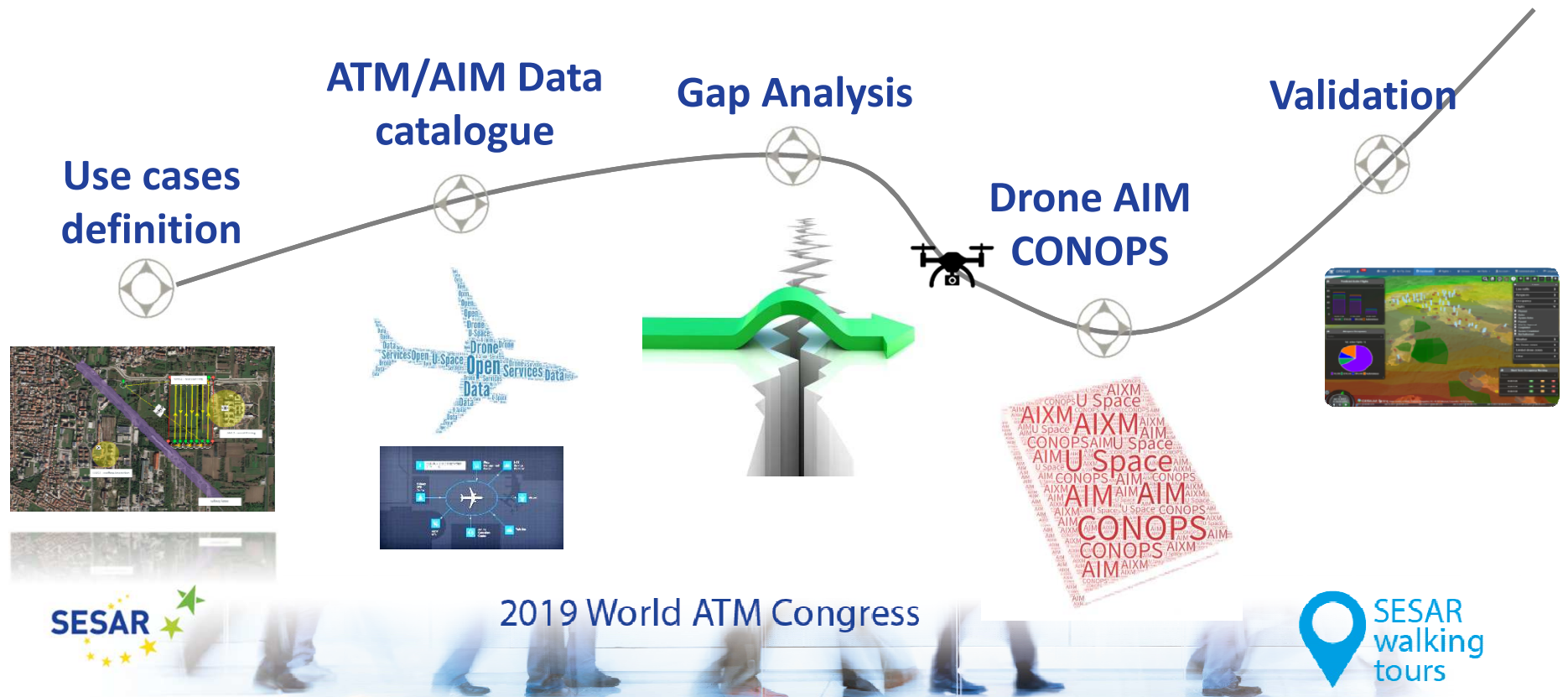




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Path to Drone AIM



Gap Analysis outcome

Seven key information categories:

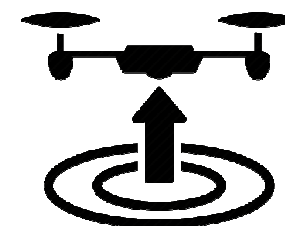
1. Meteorological
2. Environment
3. Flow management
4. Flight
5. Communication&Navigation
6. Surveillance
7. Drone



Future unmanned flights need **additional information and data** to fullfill the operational needs



Example: **Take-off and Landing area, Protection area for Airport without ATZ**





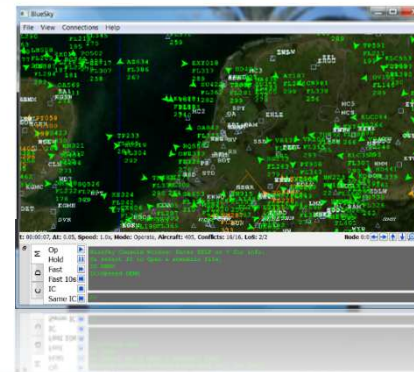
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Validation activities



- Update and integration of IDS (**DREAMS**) and TU Delft (**BluSky**) simulation platforms
- Validation scenarios implementing new features and services analyzed in the project



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U-space – IMPETUS presentation



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Drone Information Management Showcase Services in U-space

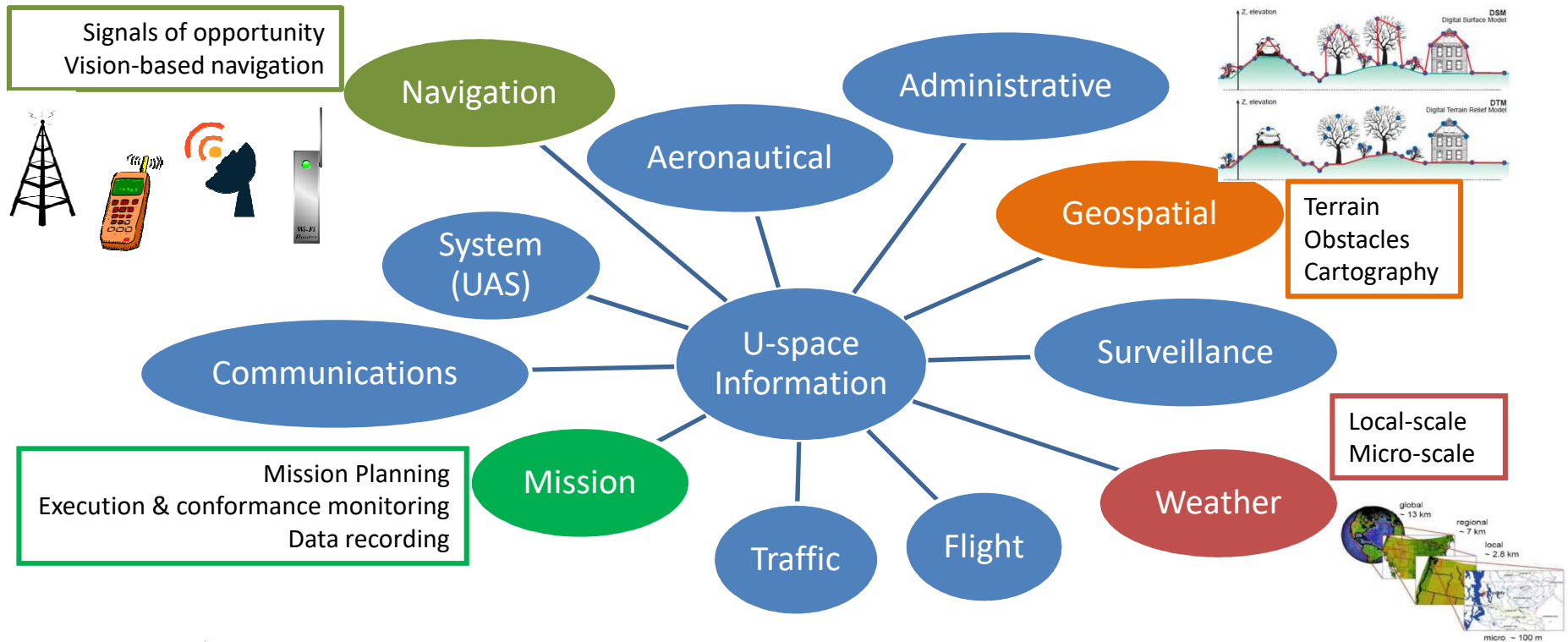
Marta Sánchez Cidoncha
CRIDA



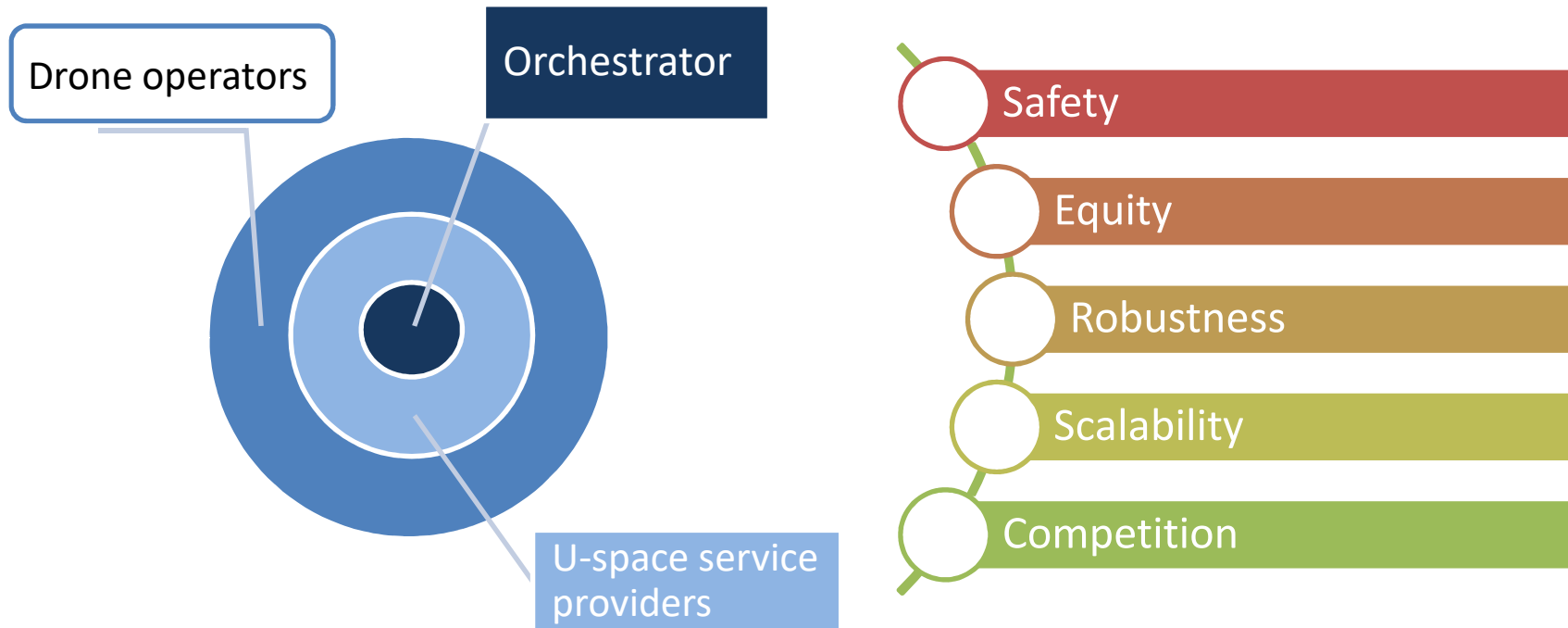
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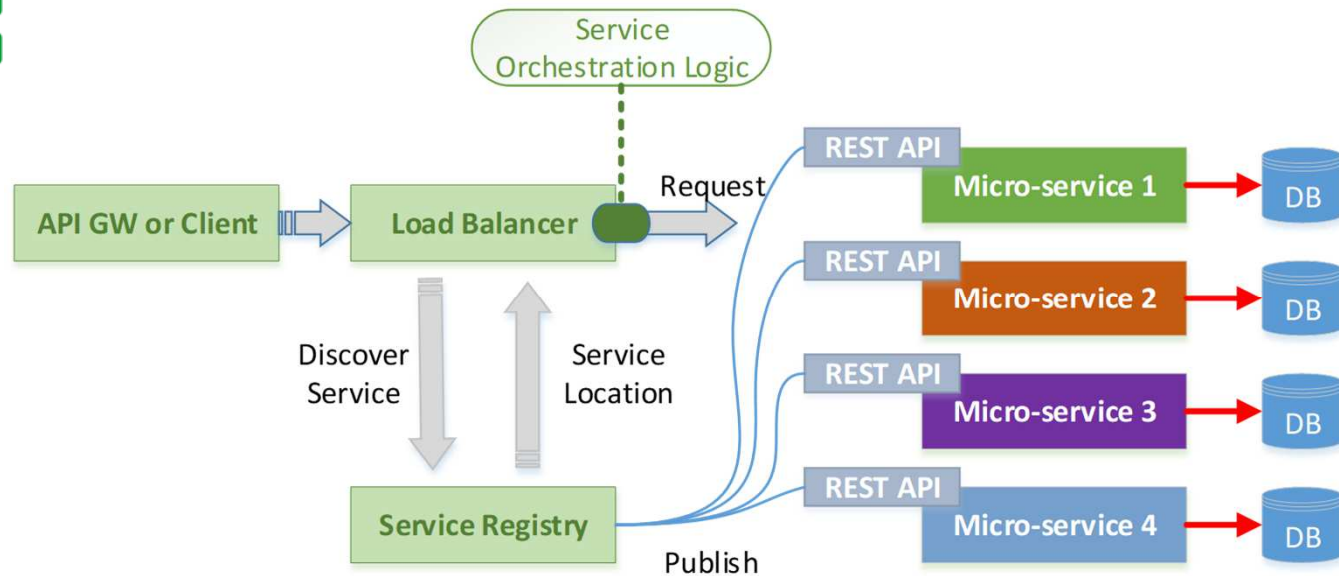
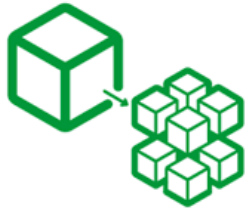
Information needs of future drone operations



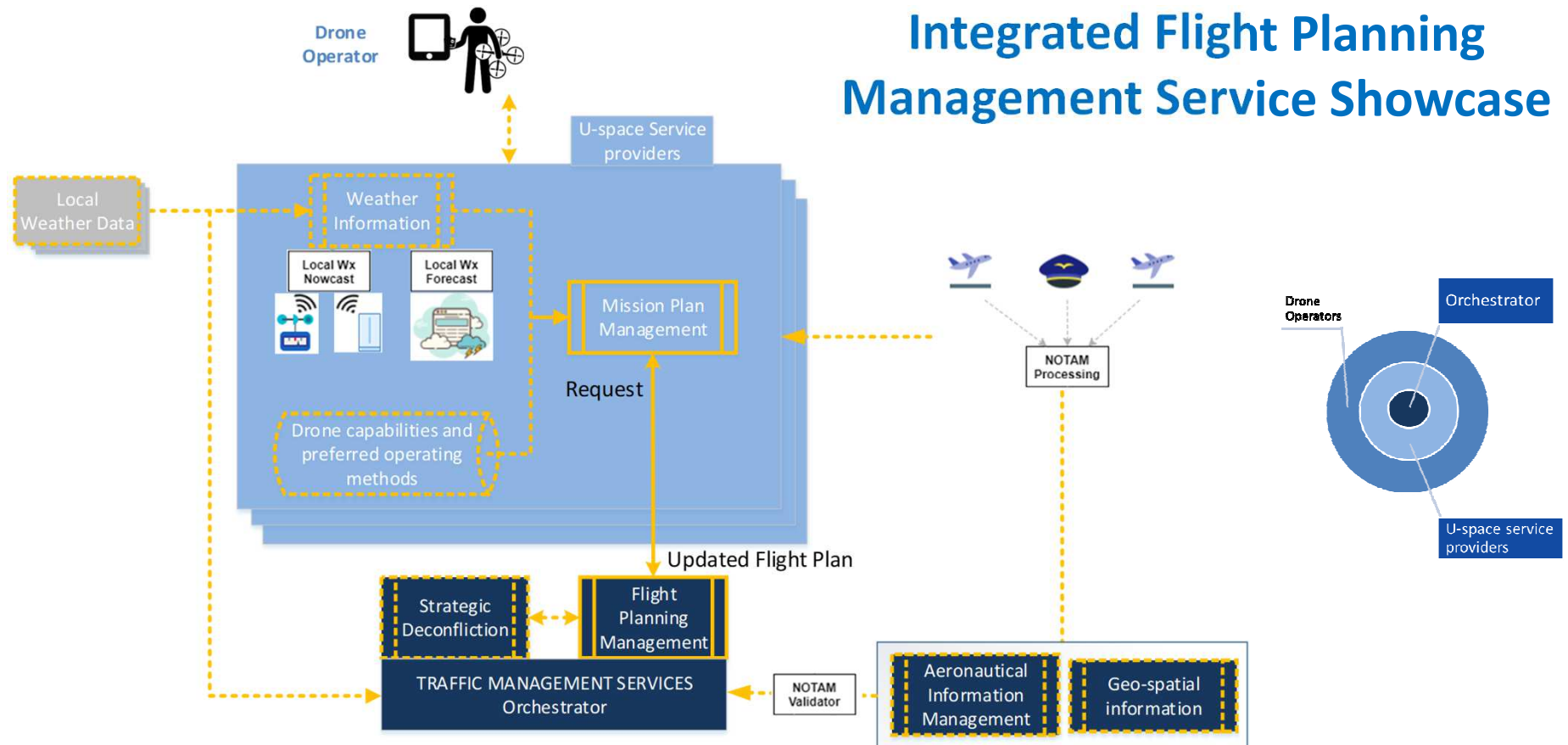
The architectural solution - a federated scheme



The architectural solution – micro-service paradigm



Integrated Flight Planning Management Service Showcase



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Take-away Messages

Architectural Solution

- **Federated** scheme plus **micro-services** paradigm
- Supports **U-space objectives** of safety, equity, scalability and flexibility

Business Aspects

- Intrinsic to drone operations
- Some flight executions are **mission-driven**

Demonstrations

- Scheduled this year
- Will provide **evidence of performance** and technical refinement



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impetus-research.eu



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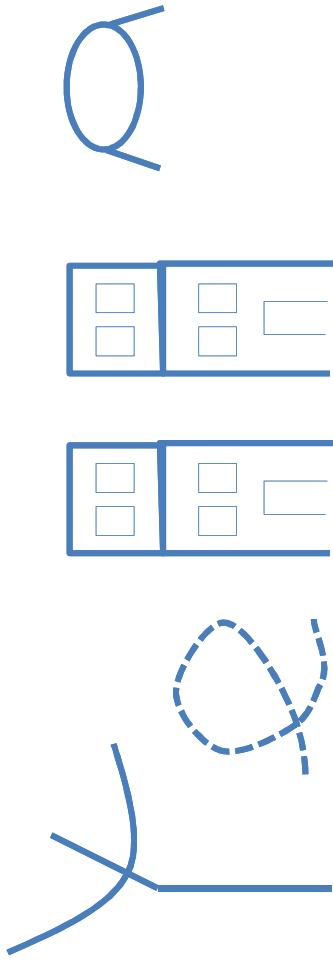
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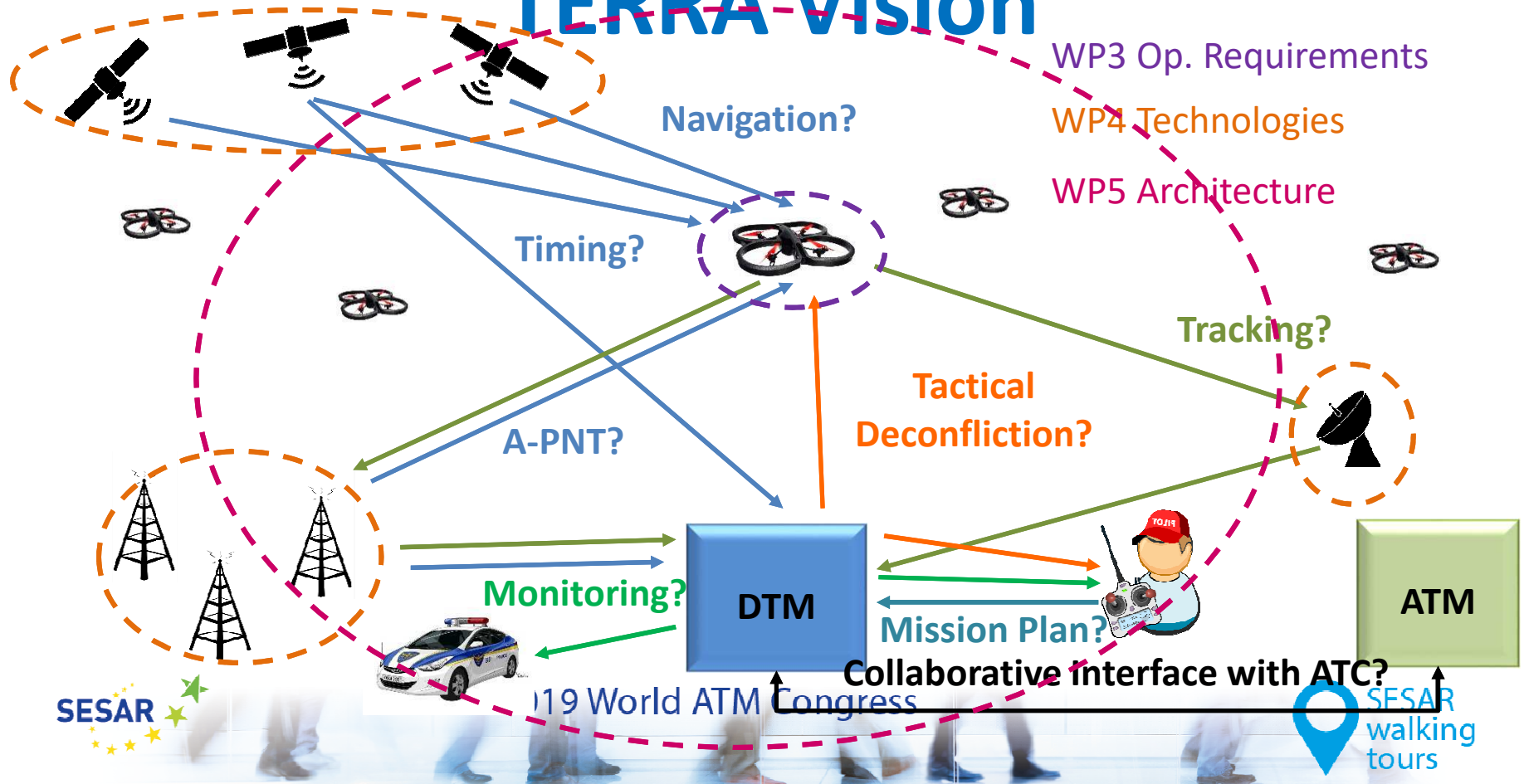
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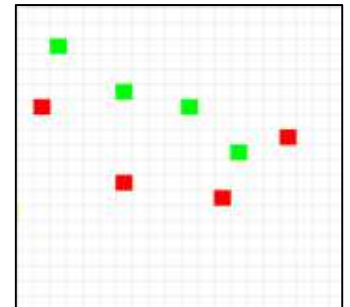
Rule-based reinforcement learning

using reinforcement learning explore whether a set of safety 'rules-of-the-road' be identified to reduce collision risk in samples of VLL drone traffic

Experiment design

Analysis used a 3x2x2 experimental design and varied the following factors:

- **Aircraft count** (4 vs 8 vs 16)— the total number of birthed aircraft;
- **Look-ahead time** (Poor vs Good)— Snapshot time, in number of steps before conflict;
- **Traffic structure** (Poor vs Good)— Randomized vs semi-structured traffic patterns.



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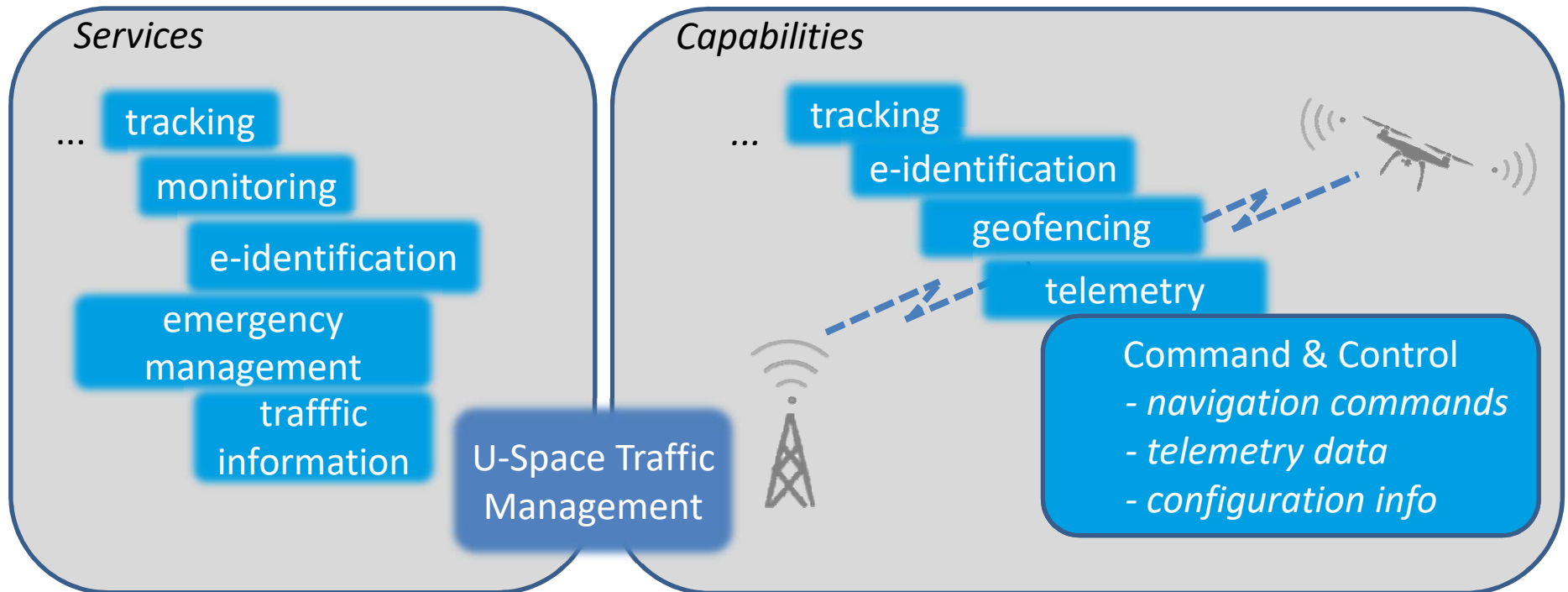
  **Drone Critical Communication** 



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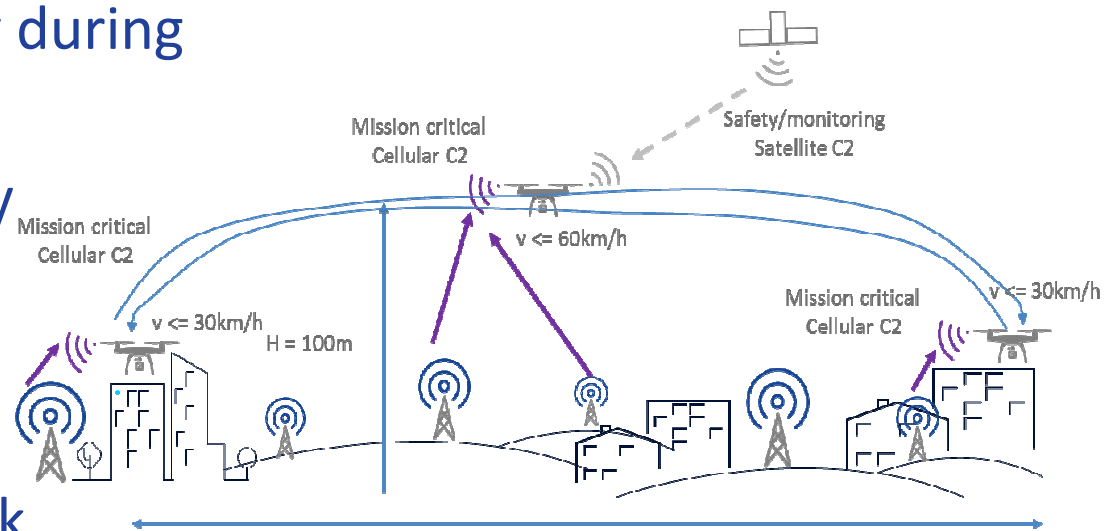
Drone Command & Control



Hybrid Cellular-Satellite DataLink

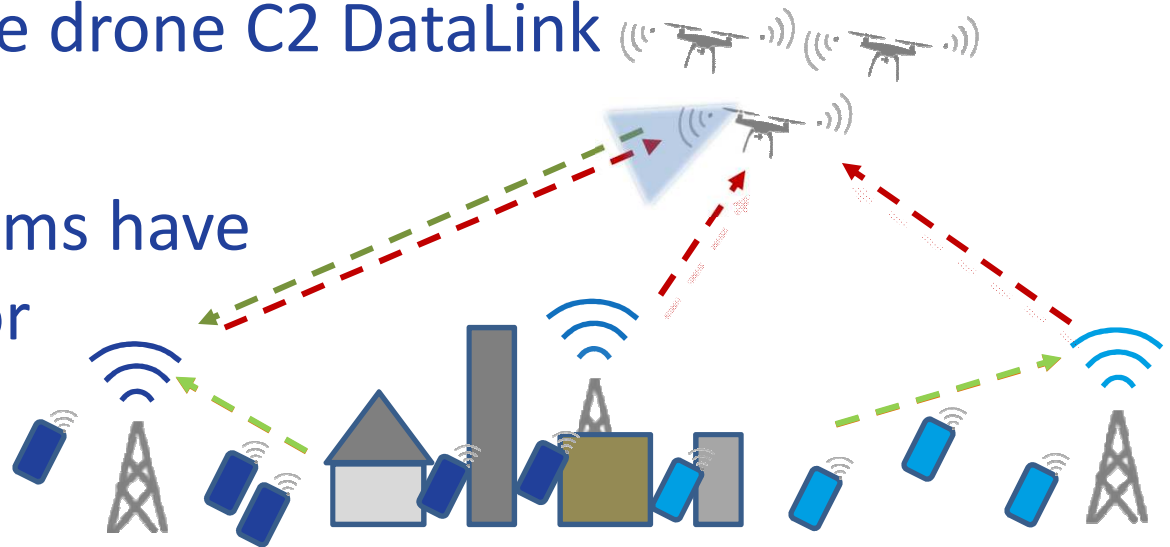
- Urban Fast-delivery Service by Drone

- Cellular connectivity during critical flight phases
- Satellite connectivity as a backup and for deserted areas (en-route)
- Adaptive C2 DataLink



C2 via Existing Cellular Networks

- Radio “visibility” is significant, causing interference issues for both the drone C2 DataLink and cellular users
- Effective mechanisms have been identified for interference mitigation



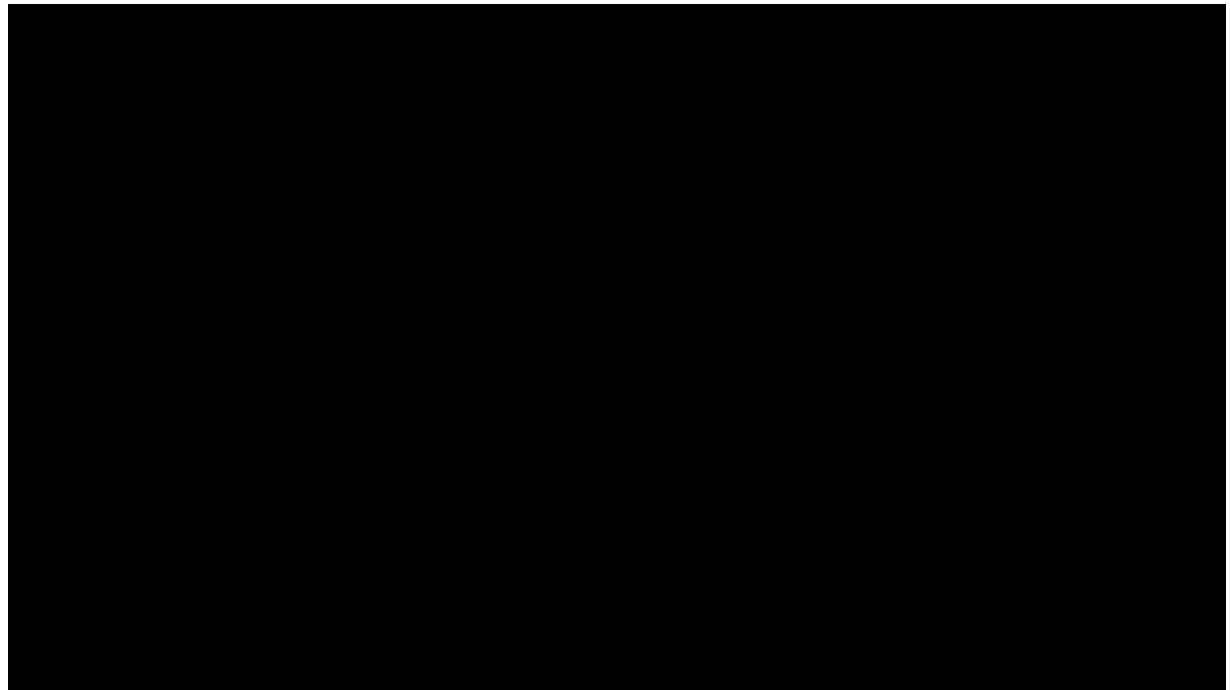
C2 Reliability in Existing Networks



Sending and
receiving command
and control data
packets



99.9% of all packets
delivered within 50
milliseconds!



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Conclusion

- The cellular network infrastructure provides an existing and almost ubiquitously available communication channel for reliable command and control of drones, sharing spectrum and infrastructure but also cost with terrestrial services
- Promising low-complexity solutions have been identified to integrate drone C2 DataLink communication in cellular networks
- When combined with multi-link automatic switching, C2 DataLink reliability and availability can be ensured in almost all environment types, particularly using satellite links for deserted areas and to allow U-Space users transitioning to the ATM



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DroC²om



NOKIA Bell Labs

atesio



AALBORG UNIVERSITY
DENMARK

THANK YOU VERY MUCH FOR YOUR ATTENTION



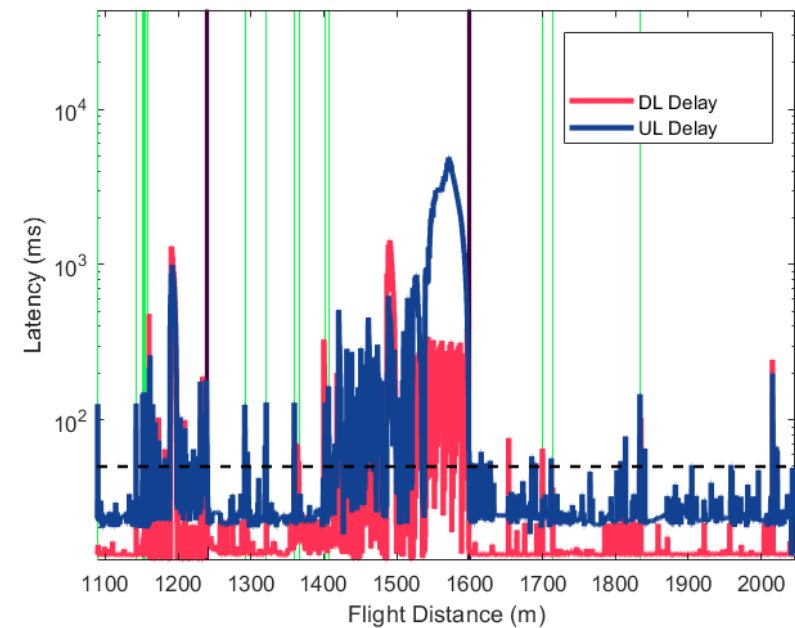
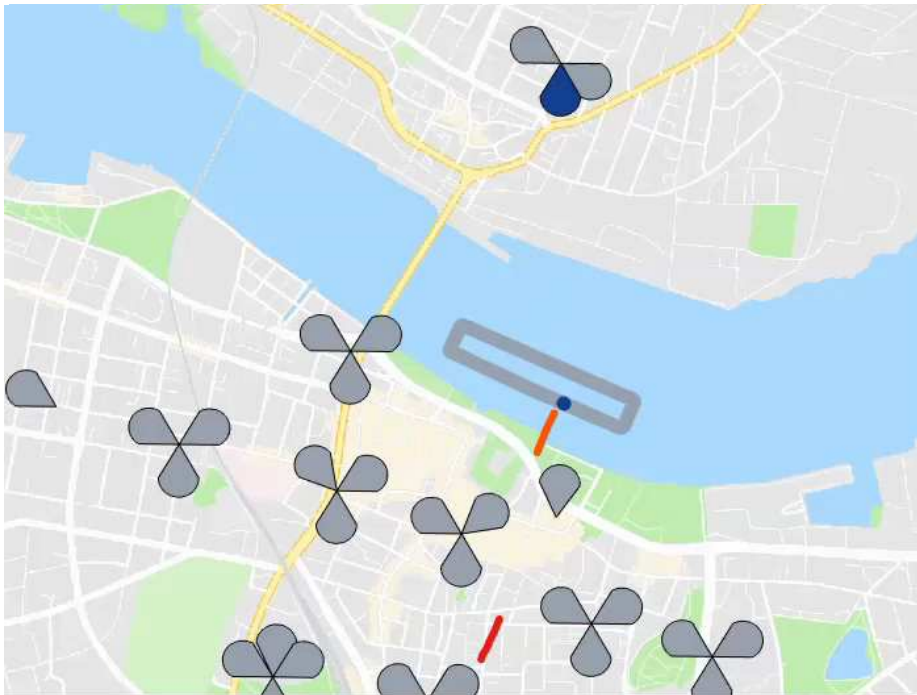
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under grant agreement No 763601



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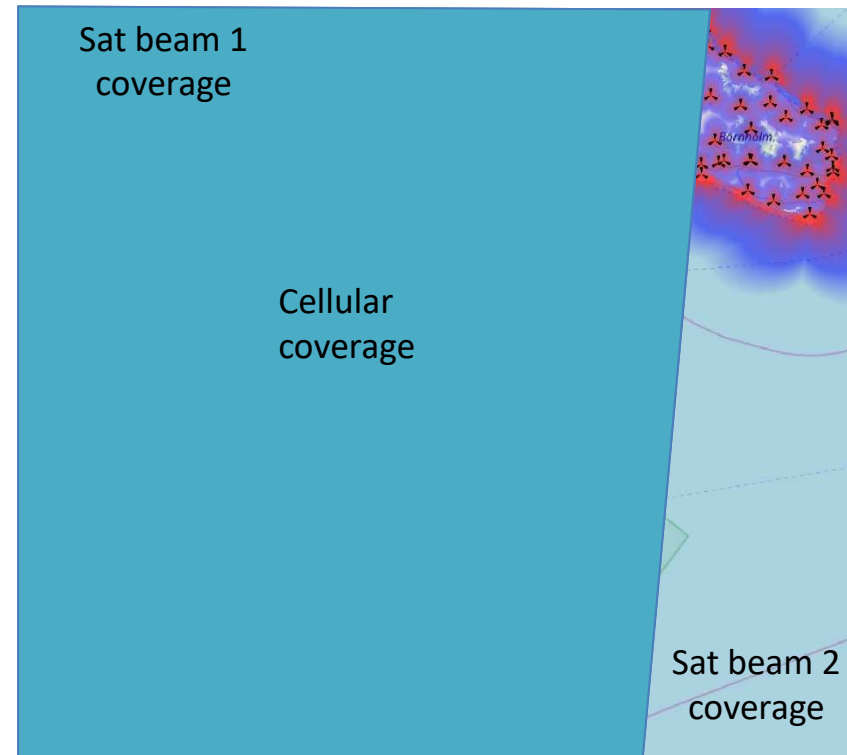


C2 Reliability in Live Networks



Scenario-based evaluation

- Rügen/Bornholm
 - 237 sites with 711 LTE 800 MHz cells
 - 2 geosynchronous sat-beams
 - Use cases for combined Hybrid C2 datalink





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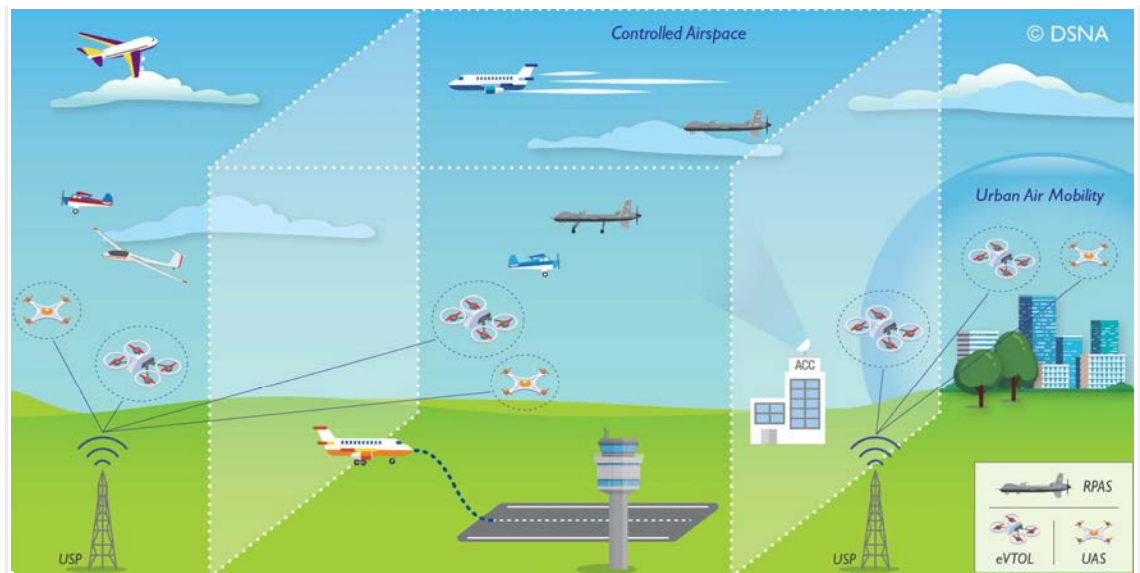
U-SPACE TOGETHER

Fast-tracking drone integration
in a safe sky

MARTIN Antoine
AVENEAU Christian



**SAFE, FAIR AND
EFFICIENT U-SPACE
FOR BOTH
MANNED AND UNMANNED
AVIATION**



EFFICIENT DRONE OPERATIONS IN A SAFE SKY?

Strengthened safety

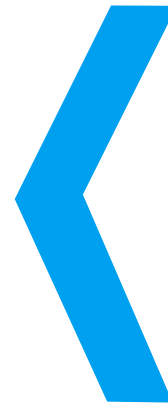
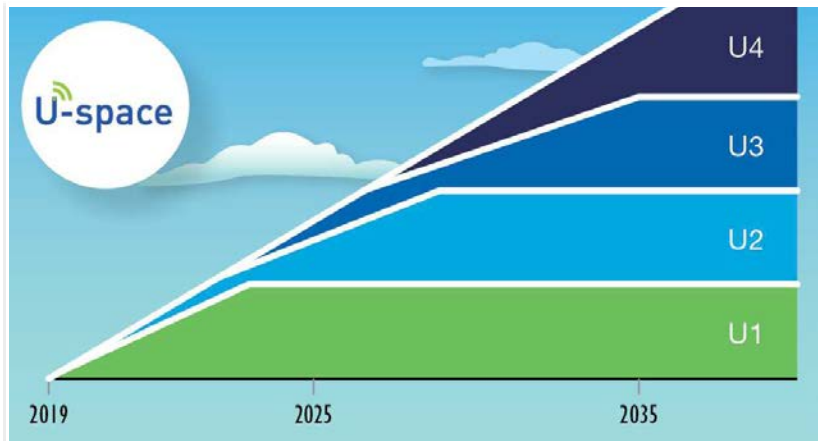
Open airspace according to:

- UAS airworthiness
- Risk assessment
- Social acceptance





U-SPACE: TOWARDS IMPLEMENTATION



- ⊙ **U1 Basic services**
(e-registration, e-identification)
- ⊙ **U2 Initial services**
(flight planning, authorization and tracking)
- ⊙ **U3 Advanced services**
(dynamic airspace management)
- ⊙ **U4 Full services**
(digital, automatized and interconnected operations)



Concept of Operations for
euRoPean Unmanned Systems

U-SPACE: CORUS

A project led by EUROCONTROL with
9 partners

- ◉ Designing an UTM system to manage drones in European very low level (VLL) airspace
- ◉ Safe interaction with other airspace users, fostering drones economic development and enlarging the drone operations, being acceptable by the society



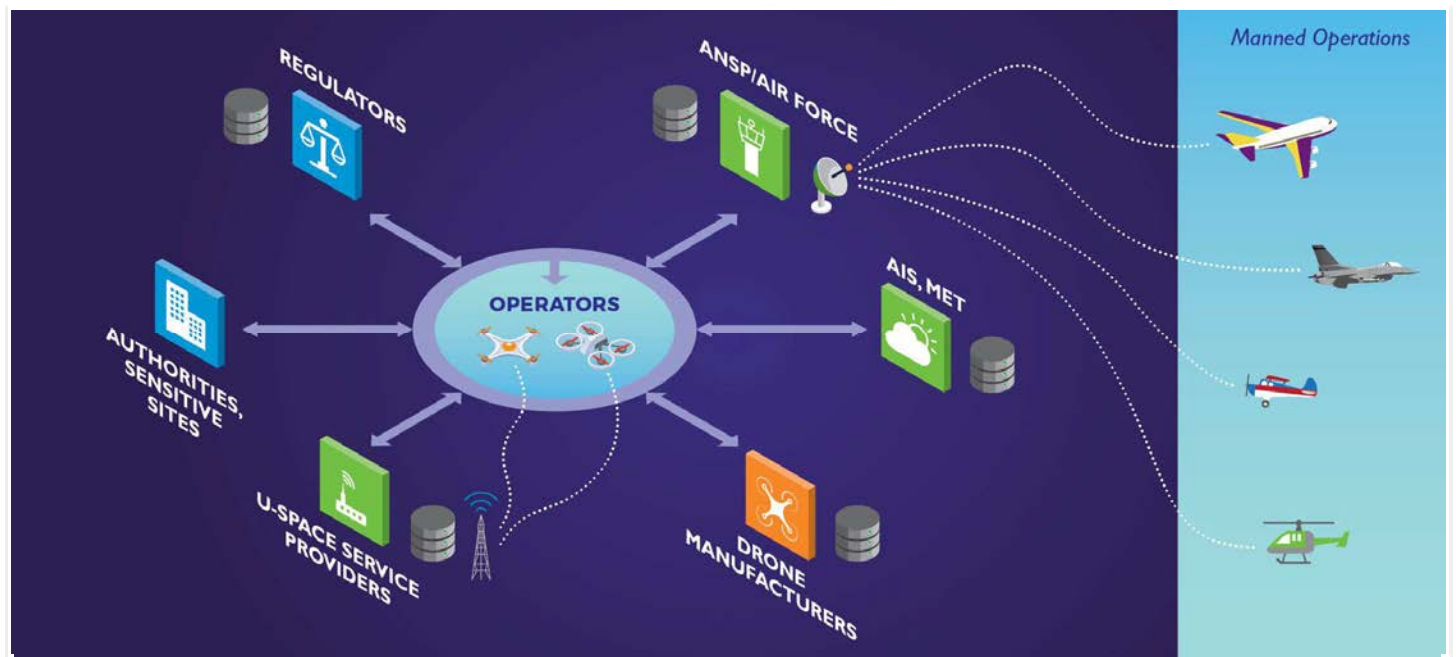
SESAR 2020 Project



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DSNA'S VISION

An « Open
customer-
centric »
approach



DSNA ACTIVITIES

Project led by Thales, 7 partners

- ◉ UTM services with automated assistance to operators: Hungary and France
- ◉ Regulations and ATC
- ◉ Evidence that U1 and U2 services can support all B-VLOS operations

USIS U-Space Initial Services

U1	E-identification	★ ★
	Pre-tactical geofencing	★ ★
U2	Tracking	★ ★
	Flight planning management	★ ★ ★
	Weather information	★ ★
	Drone aeronautical information management	★ ★
	Procedural interface with ATC	★ ★
	Emergency management	★ ★
	Strategic deconfliction	★ ★
U3	Monitoring	★ ★
	Collaborative interface with ATC	★ ★

SESAR 2020 Project



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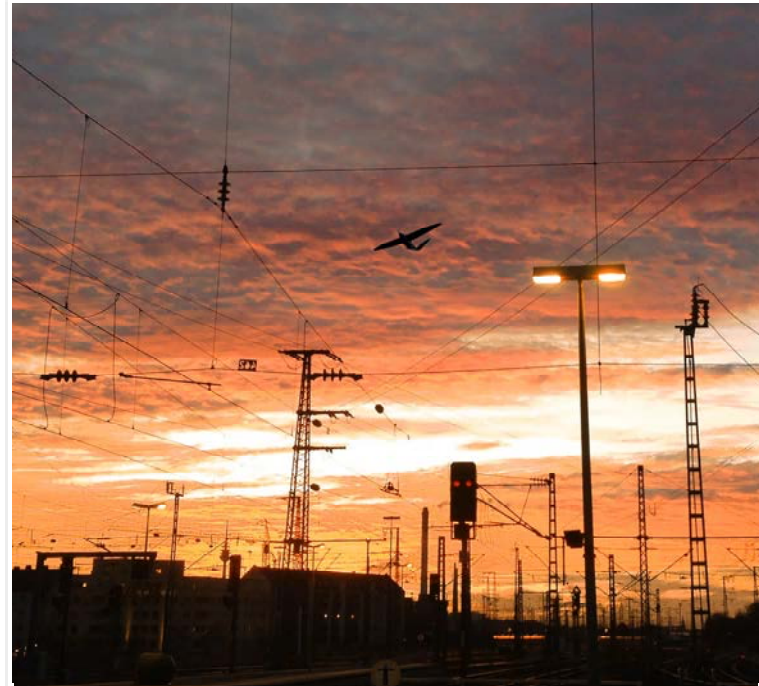
DSNA ACTIVITIES

Project led by EUROCONTROL

4 complementary Very Large-Scale Demonstrations in controlled & uncontrolled airspace

- ⦿ In urban and rural areas
- ⦿ In the vicinity of airports
- ⦿ In mixed environments with manned aviation

Proving Operation of Drones with Initial UTM Management



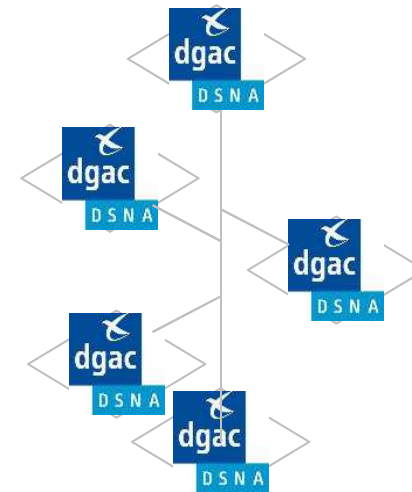
SESAR 2020 Project



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DSNA ACTIVITIES

Call for U-space Partnerships



- ◉ Open and iterative selection process towards U-space commissioning
- ◉ U-space services, drone-based services, other services & their business models

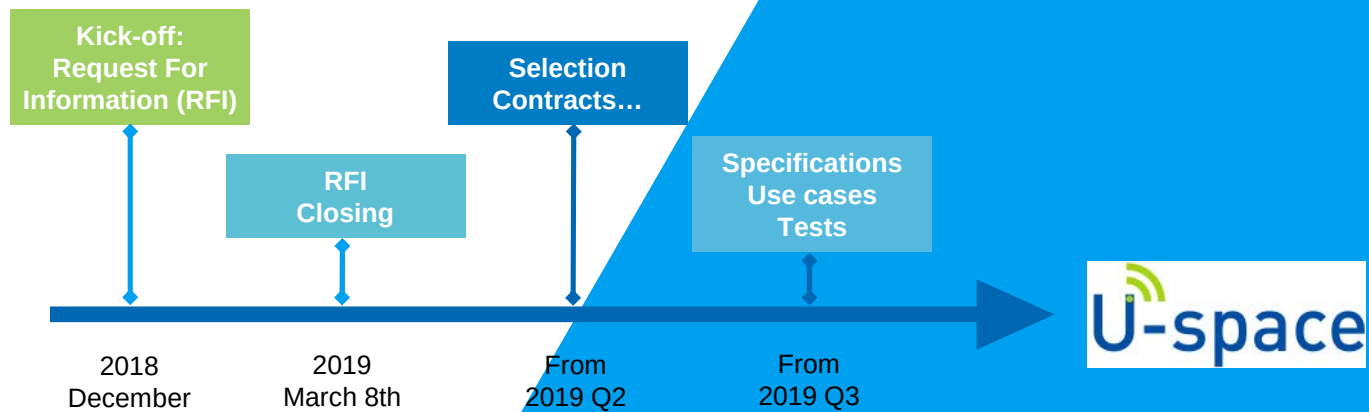
- ◉ Pre-implementation within French operational test sites
- ◉ SWIM-UTM supported



DSNA ACTIVITIES

Call for U-space Partnerships

Roadmap





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