U-space CONOPS and research dissemination conference

1 October 2019

THIRD SESSION PRESENTATIONS

U-space

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JOINT UNDERTAKING

DROC2OM

DROC2OM
Troels Bundgaard Sørensen
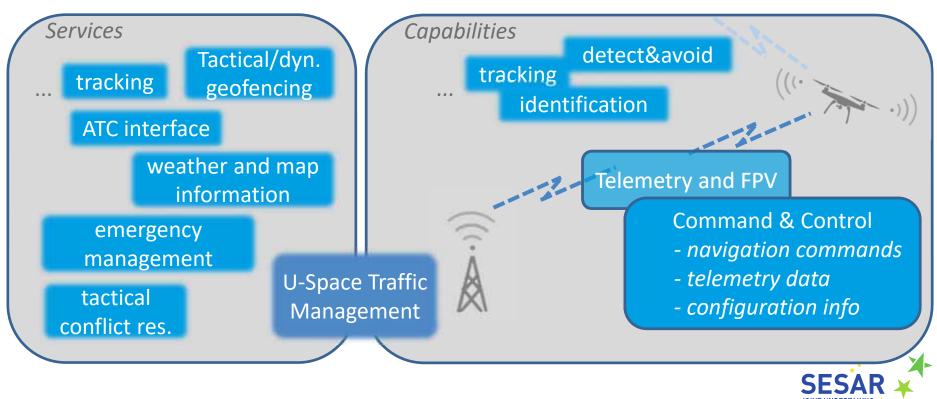Aalborg University

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Drone Command & Control

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- Project focus is on Command and Control (C2) capability, challenging the use of existing cellular and satellite infrastructure for the C2 data link
  - using measurement trials (live flight), integrated cellular-satellite inter-system design and simulation evaluation

Services

... tracking   Tactical/dyn. geofencing

ATC interface

weather and map information

emergency management

tactical conflict res.

U-Space Traffic Management

Capabilities

detect&avoid

... tracking   identification

Telemetry and FPV

Command & Control
- *navigation commands*
- *telemetry data*
- *configuration info*

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Command & Control via existing Cellular Networks

- Radio "visibility" is significant, causing interference issues for both the drone C2 datalink and cellular users
  - there is both a C2 reliability issue (downlink interference), and a performance impact on terrestrial services (uplink interference) to solve
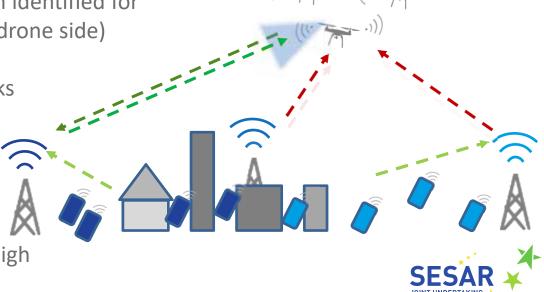
- Effective mechanisms have been identified for interference mitigation (on the drone side)
  - Selecting best of *N* beams
  - Connecting on multiple links
    (https://youtu.be/twsDFQqS7vU)
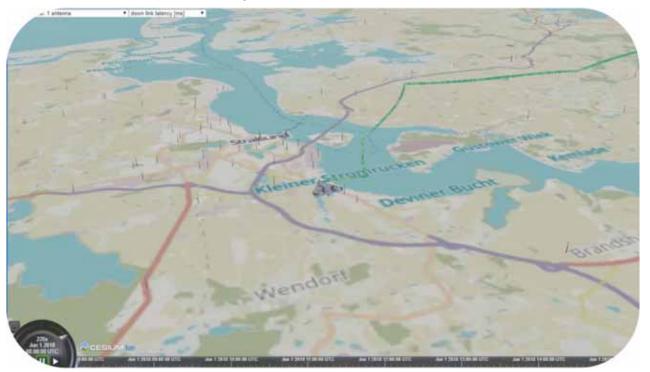
- Low to moderate complexity in implementation
- Will be needed when cellular network load/drone density is high

Demonstration of Project Results

- Demonstration tool at the stand outside, and to become available from project website and/or SJU web pages
    - Demonstrates the C2 *availability* and *service level compliance* over urban, sub-urban and maritime environment for hybrid cellular-satellite C2 link
    - Visualizes the impact of different service constraints and different technical solutions for low latency and reliable C2 datalink

DroC2om Outcome Summary

- *Existing cellular systems can support C2 datalink communications*
  - *C2 on cellular provides an almost ubiquitously available communication channel, sharing spectrum and infrastructure but also cost with terrestrial services*
- *Hybrid cellular-satellite architecture relying on state-of-the-art solutions*
  - *Hybrid architecture combines low latency and coverage of cellular with reliability and scalability of satellite communications, and allows transitioning to the ATM*
- *Low to moderate complexity solutions, including multi-link connectivity and beam switching, for ensuring drone C2 link quality in highly loaded cellular networks*
  - *Can be implemented on the drone side*
- *Impact to EUROCAE standardization and 3GPP specifications on LTE support for aerial vehicles*

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Please visit our website for a list of public deliverables, publications and presentations (downloads available)

http://www.droc2om.eu/

DroC2om is on LinkedIn

DroC2om U-Space Project

atesio

NOKIA Bell Labs

AALBORG UNIVERSITY
DENMARK

ThalesAlenia
Space
a Thales / Leonardo company

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Brussels, 1 October 2019

GEOSAFE

GEOSAFE
Jean-Guy Blete
THALES AVS France

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GEOSAFE PROJECT PRESENTATION

1st of October 2019

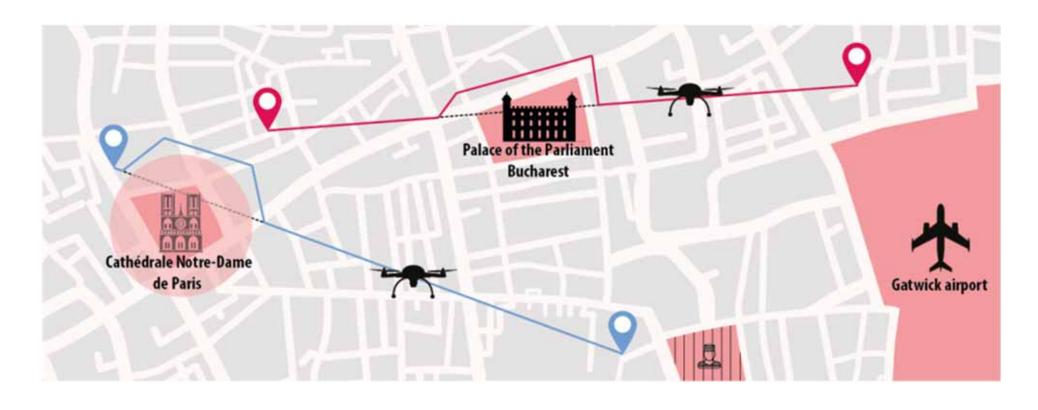# What is Geofencing?

Geofencing service : U-space level

U1 LEVEL
Pre-tactical geofencing

The service provides the operator with geo-information about predefined restricted areas (prisons, airports, etc.) used during the flight preparation

U2 LEVEL
Tactical geofencing

The service brings the possibility to update the operator with geofencing information even during the flight

U3 LEVEL
Dynamic geofencing

The service targets the drone itself and then this service requires data-link connectivity to a geofencing system that allows the data to be updated during the flight

U4 LEVEL
Full services

WHAT ?

To establish state-of-the-art of geofencing solutions regarding U-space regulation
To propose improvements and recommendations for future geofencing system definition.

HOW ?

One-year long flight-test campaign:

- 290 tests (rural and urban environments)
- 16 drones
- 18 mission planners
- with 7 objectives to test

WHY ?

To be able to deploy U-space. U1 and U2 should be validated and a part of U3 too. Project will provide recommendations for standardization

THALES   SPH engineering   MARINE   AEROMAPPER   techsys   AIRMAP

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DJJI - Phantom 4

DJI - Matrice 100

DJI - Mavic Air

DJI - Matrice 600 / S900

DJI – Inspire 2

INTEL - Aero

YUNEEC - H520 Pro

INTEL - Falcon 8

DELAIRTECH - DT18

ATECHSYS - HE 190

AEROMAPPER - Avem

Pixhawk

ATECHSYS X10

PARROT Bebop 2

PARROT - Disco

SENSEFLY - Ebee

THALES

AEROMAPPER

Atechsys

AIRMAP

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U1- Pre tactical geofencing

Alert/blocking during flight

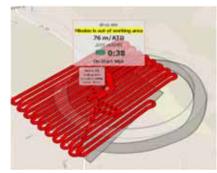**Restricted area information**

09/2018   07/2019
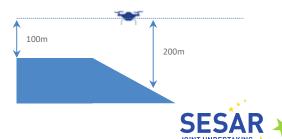
Alert-Blocking during flight preparation

Pretactical geofencing technology is ready and mainly deployed

~ 75 % of tested solutions are almost compliant with U1

- Fixed/temporary restricted area digital database shall be available and provided by official sources
- Standardization of zone definition
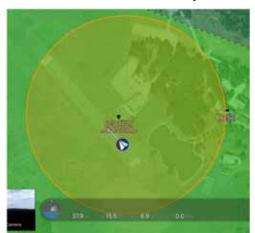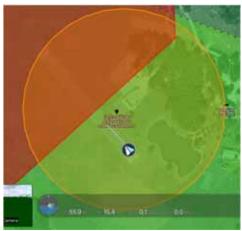- Standardization of altitude / height reference

100m

200m

U2 – Tactical geofencing

Alert/blocking during flight

Tactical geofencing technologie is ready but not deployed yet

1 drone tested is almost compliant with U2

Since not studied by the pilot before the flight, information regarding the tactical geofencing provided during flight should be clear and unambiguous
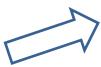
U3 – Dynamic geofencing

Restricted area updating during the flight

Dynamic geofencing technology is mature but not deployed yet

No tested drone are compliant

Dynamic geofencing requires both standard geofencing capabilities and the capacity to maintain a data link between the UAS and the UTM service provider during flights

VLD (Very Large Demonstration)

10th of October 2019
Atechsys, Pourrières, France

Final demonstration will show several drones from different types flying near restricted area in a UTM context

This final demonstration will have several purposes:
- Highlight the results obtained during the test period
- Show the technology readiness level of existing geofencing solution
- Show the link between active geofencing services and UTM services

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GEOSAFE

GEOFENCING
FOR **S**AFE
AUTONOMOUS
FLIGHT IN **E**UROPE

BRETIGNY – enhancing business operations

- 5 scenarios
- 100+ flights
- Reserved Zone
- CTR vicinity
- VLOS, BVLOS

ODENSE – Regular drone usage and interoperability with manned aviation

- 5 scenarios
- 45 flights
- Restricted airspace
- Class G, TIZ, AFIS
- VLOS, BVLOS

Rodez - entering/exiting CTR, ATCO interactions

- 5 scenarios
- 10 flights
- Class D CTR
- BVLOS
- C2 loss….

Marknesse & Eelde – "unexpected" scenarios

- 3 scenarios
- 30 flights
- Class C CTR
- VLOS, BVLOS
- Priority, diversion..
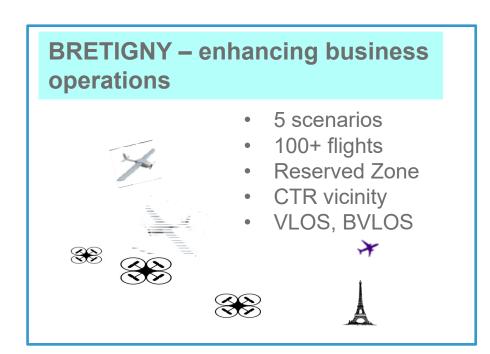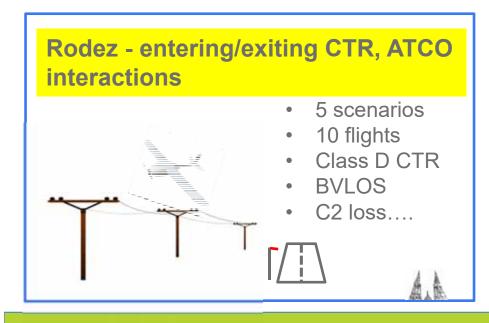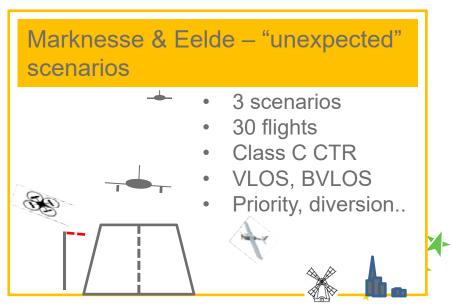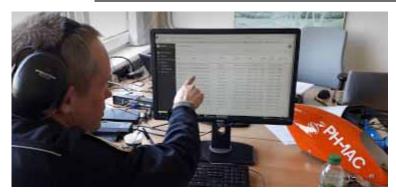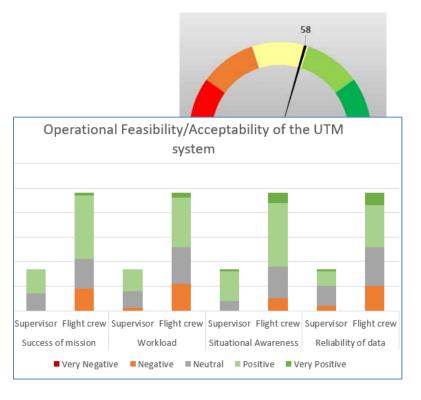
Insights from Demos!

Supervisor/ATCO

Flight crew

58

Operational Feasibility/Acceptability of the UTM system

	Supervisor	Flight crew	Supervisor	Flight crew	Supervisor	Flight crew	Supervisor	Flight crew
	Success of mission		Workload		Situational Awareness		Reliability of data	

■ Very Negative ■ Negative ■ Neutral ■ Positive ■ Very Positive
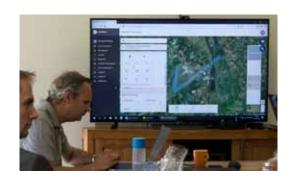
What works well!

- Faster, more efficient flight authorisations, especially where trajectory requires multiple authorisations……..

- Single HMI for flight preparation (avoid multiple systems)

- Increased situational awareness of zones and cooperative traffic

- The technology works, e.g. GSM-based trackers, etc.

- Easy to use…..

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What needs more thought!?

Initial.........

- Access to trustworthy, official and up to date aeronautical national and local legislation for drone operation

- Effective coordination procedures and phraseology.. (intra flight crew and with supervisor/ATCO)
  - Mitigate against mobile phone limitations

- Consistent drone-on-tracker performance/robustness/RF interoperability

- Improve HMI usability and accessibility (in the field!)

- Seeing and avoiding GA without a transponder!

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Dissemination!

U-space? What works well? What can be improved?
Proving Operations of Drones with Initial UTM (PODIUM) Dissemination event

17 October 2019
9:30 - 17:00
EUROCONTROL Brussels HQ
Meeting room PILATUS

U-space PODIUM
495 followers
1w • Edited

To do is to be! EUROCONTROL visited Orange Belgium today to prepare the conclusions, recommendations and dissemination for U-space PODIUM. Orange experts have provided Access Point Name connectivity and secure gatew ...see more

57 · 1 Comment

USIS

USIS
Aline Labreuil, UX Lead, HF expert
Thales Group

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- Test and validation in both experimental and operational conditions of U-space Services U1 and U2
- BVLOS, e-VLOS, VLOS
- Rural to urban environment

HungaroControl   THALES   dgac DSNA   ENAC

DFS Deutsche Flugsicherung   UNIFLY   ALTAMETRIS

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Project presentation

- 90 KM2 (900m height)
- **Specific operations**
- HungaroControl lead
- **EASA Cat regulation (aut/man)**
- Complex scenarios:
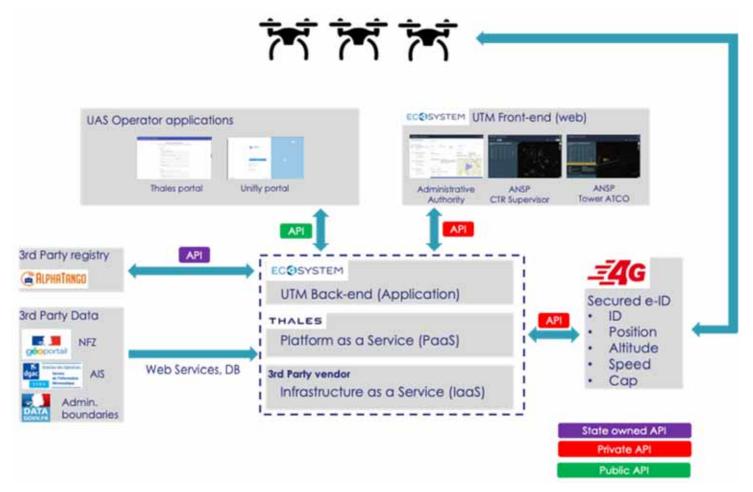 - BVLOS (parcel delivery, surveillance)
  - Cross-boarder operations

- 5 700 KM2
- **Live operations**
- DSNA lead
- **French regulation (man)**
- Multi-stakeholders:
  - ANSP (CTR Sup, ATCOs)
  - Local/administrative authorities

Project presentation

U1-e-Registry   **U2-Flight Planning Management**   **U2-ATC interface**
U1-e-ID   **U2-Tracking/Conformance Monitoring**
U1-Pre-tactical geofencing   U2-Tactical geofencing

Project outcomes summary

- *35 flights (sept.19), 31 (unique) user interviews, >10 user tests, >30 HMIs prototyped*
- *Conclusion*
  - *Services can be quickly deployed in legacy environment (technical, regulatory) even when not limited to ANSP*
  - *The variability from a country to another can be managed via technical solutions without creating fragmentation*
  - *User value creation is more efficient than any regulatory obligation*
- *Point of attention*
  - *Agility over hazardous predictions*
  - *Holistic approach of the users community*

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Yohann Proust, Project Manager

Yohann.proust.e@thalesdigital.io

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TERRA Requirements

General requirements	U-Space	Agriculture	Delivery
Operational scenario		Rural VLOS/BVLOS RPAS Fixed route (but not always) Segregated (Geo-cage) Near drones, but spatial segregation CORUS – Type Y	Urban BVLOS RPAS/Autonomous Flexible route Non segregated Simultaneous drones CORUS – Type Z
Navigation	CNS-NAV	Horizontal precision: **3 - 5 m** Vertical precision: **5 - 10 m**	Horizontal precision: **0.1-1m** Vertical precision: **1 m**
Separations	CNS-NAV Tracking	• Towards terrain: **300 m horizontal and 50 m vertical** (100 m vertically with respect to mountains) • Towards other drones: these separations have to be **managed by the drones**, not by a U-Space service in rural environment. **Likelihood of collision** with other drones is **very limited**; 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). (Strategic Mitigation Medium/High) **In other case**, e.g. drone landing directly on clients' houses, **tactical conflict management** would be required. (Strategic Mitigation Low)

TERRA Analysis result – A/G Communications
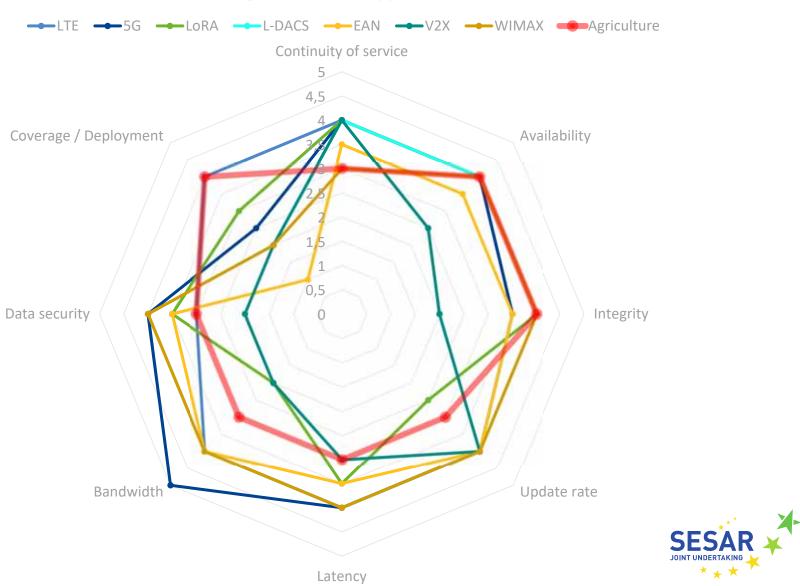
A/G Communication

|	3G / 4G	5G	LoRA	L-DACS	EAN	V2X	WiMAX /Aero MACS
Continuity of Service	Good	Good	Good	Good	Medium/Good	Good	Medium
Availability	Good	Good	Good	Good	Medium/Good	Medium/Poor	Good
Integrity	Good/Medium	Good/Medium	Good	Good	Medium/Good	Poor	Good
Update rate	Good	Good	Medium/Poor	Good	Good	Good	Good
Data delivery time/Latency	Medium (3G)/ Good (4G)	Good	Medium/Good	Good	Medium/Good	Medium	Good
Bandwidth	Medium (3G)/ Good (4G)	Very Good	Poor	Good	Good	Poor	Good
Data Transfer Security	Medium	Good	Good/Medium	Good	Medium/Good	Poor	Good
Coverage/Deployment	Good (3G) Medium (4G)	Medium/Poor	Medium/Good	Poor	Good	Poor	Medium

TERRA – A/G Communication technologies applicability
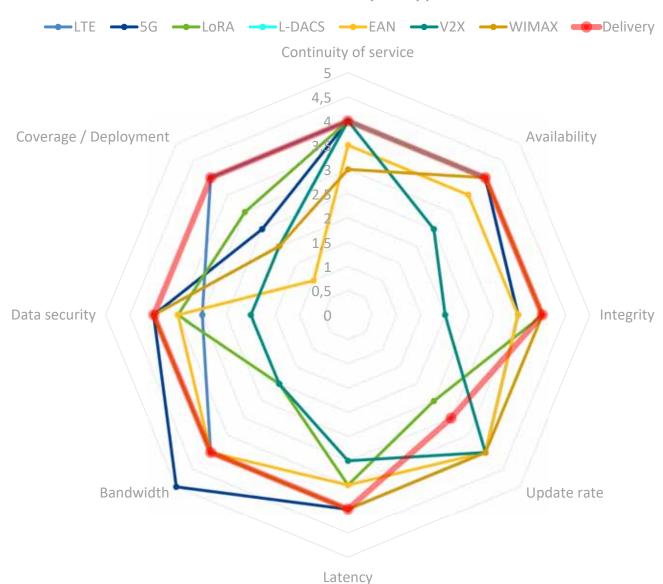
Agriculture – Type X/Y
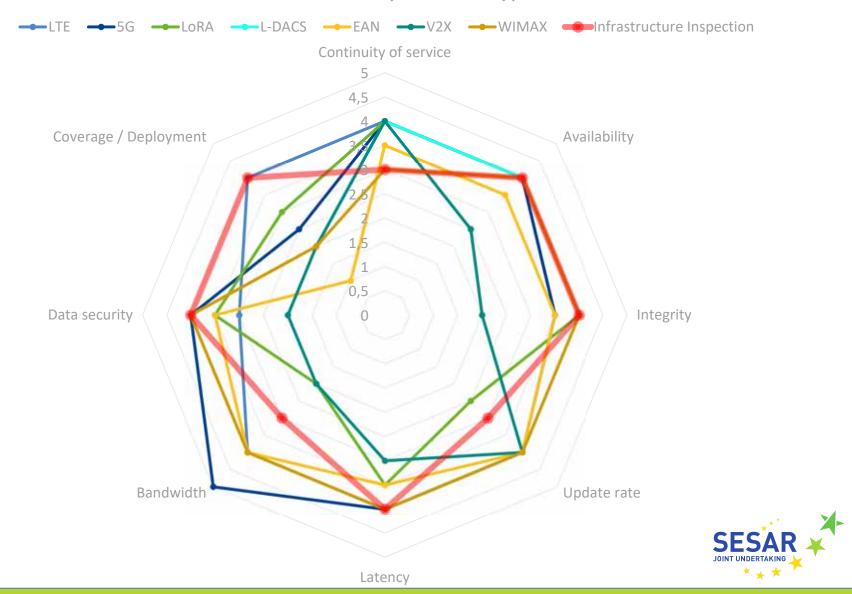
Brussels, 1 October 2019

TERRA – A/G Communication technologies applicability

Urban Delivery – Type Z

TERRA – A/G Communication technologies applicability

Infrastructure Inspection – Type Y

Legend: LTE, 5G, LoRA, L-DACS, EAN, V2X, WIMAX, Infrastructure Inspection

Axes: Continuity of service, Availability, Integrity, Update rate, Latency, Bandwidth, Data security, Coverage / Deployment

Scale: 0, 0,5, 1, 1,5, 2, 2,5, 3, 3,5, 4, 4,5, 5

TERRA Analysis result – Navigation

U-space
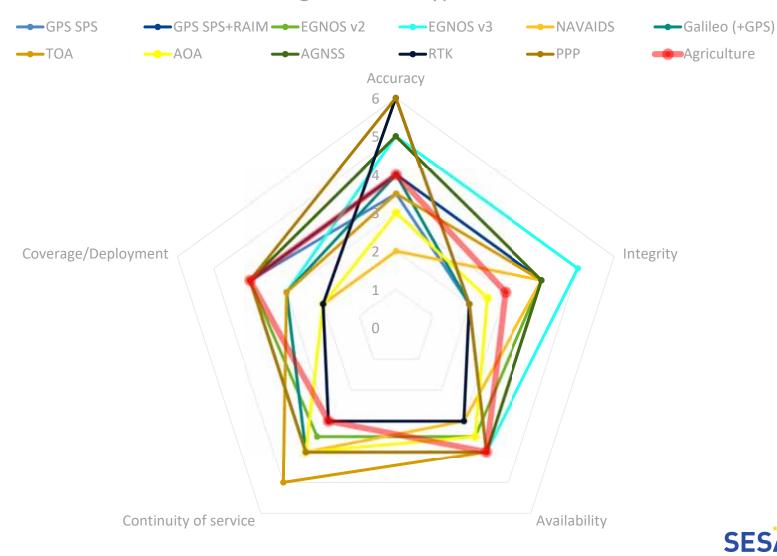
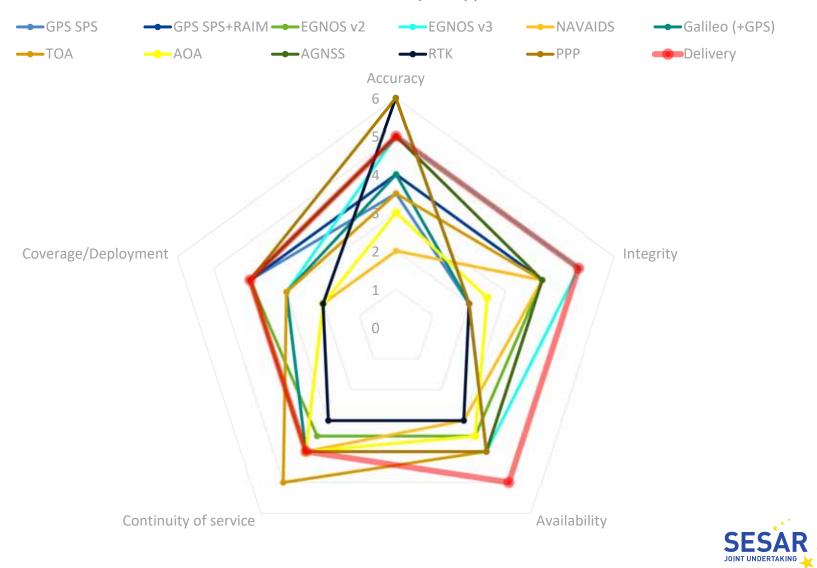| Navigation											
	GPS SPS	GPS SPS+RAIM	EGNOS v2	NAVAIDS	Galileo (+GPS)	TOA	AOA	EGNOS v3	AGNSS	RTK	PPP
Accuracy	Medium/Good	Good	Very Good	Poor	Good	Medium/Good	Medium	Very Good	Very Good	Extremely Good	Extremely Good
Integrity	Poor	Good	Good	Good	Poor	Good	Poor/Medium	Good	Good	Poor	Poor
Availability	Good	Good	Medium/Good	Medium	Good	Medium/Good	Good	Good	Good	Medium	Good
Continuity of Service	Good	Good	Medium/Good	Good	Good	Very Good	Good	Good	Good	Medium	Good
Coverage/ Deployment	Medium/Good	Medium/Good	Medium/Good	Poor	Medium	Medium	Poor	Medium	Medium/Good	Poor	Good

TERRA – Navigation technologies applicability

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Agriculture – Type X/Y

Legend: GPS SPS, GPS SPS+RAIM, EGNOS v2, EGNOS v3, NAVAIDS, Galileo (+GPS), TOA, AOA, AGNSS, RTK, PPP, Agriculture

Axes: Accuracy, Integrity, Availability, Continuity of service, Coverage/Deployment
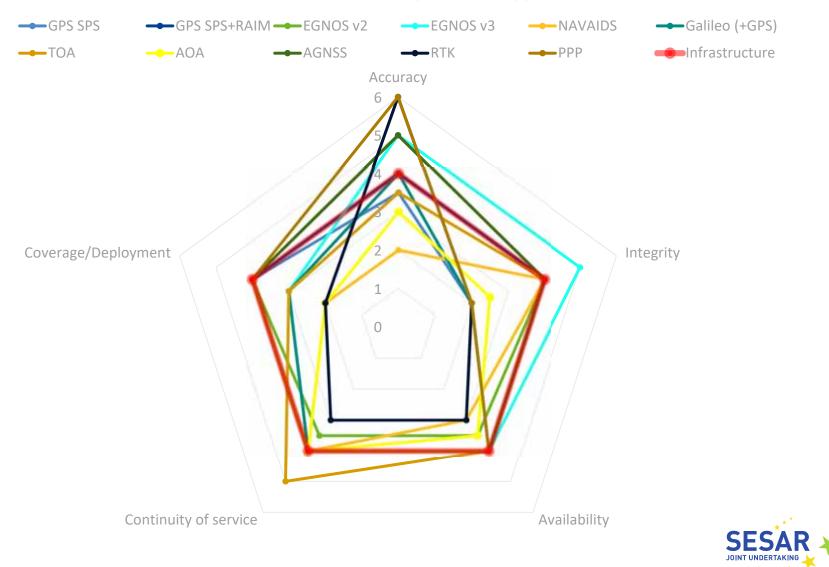
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TERRA – Navigation technologies applicability

Urban Delivery – Type Z
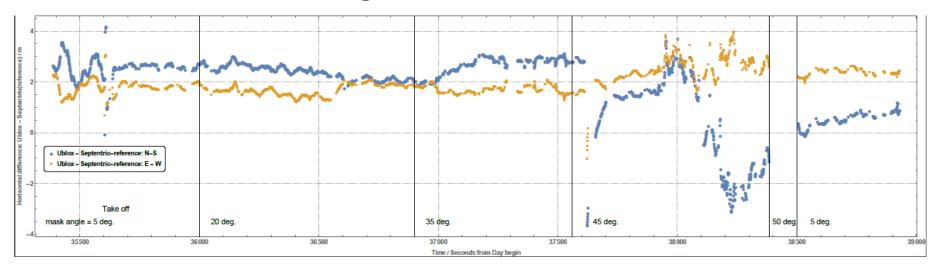
TERRA – Navigation technologies applicability

Infrastructure Insepction – Type Y

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Legend:
- GPS SPS
- GPS SPS+RAIM
- EGNOS v2
- EGNOS v3
- NAVAIDS
- Galileo (+GPS)
- TOA
- AOA
- AGNSS
- RTK
- PPP
- Infrastructure

Axes: Accuracy, Integrity, Availability, Continuity of service, Coverage/Deployment
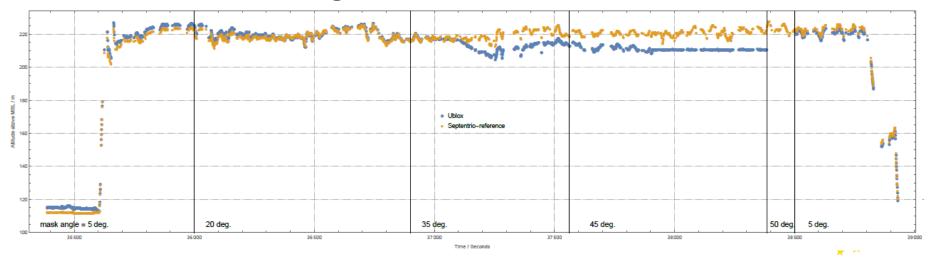
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TERRA – Trials GPS mask angle

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Horizontal difference vs mask angle

Vertical difference vs mask angle
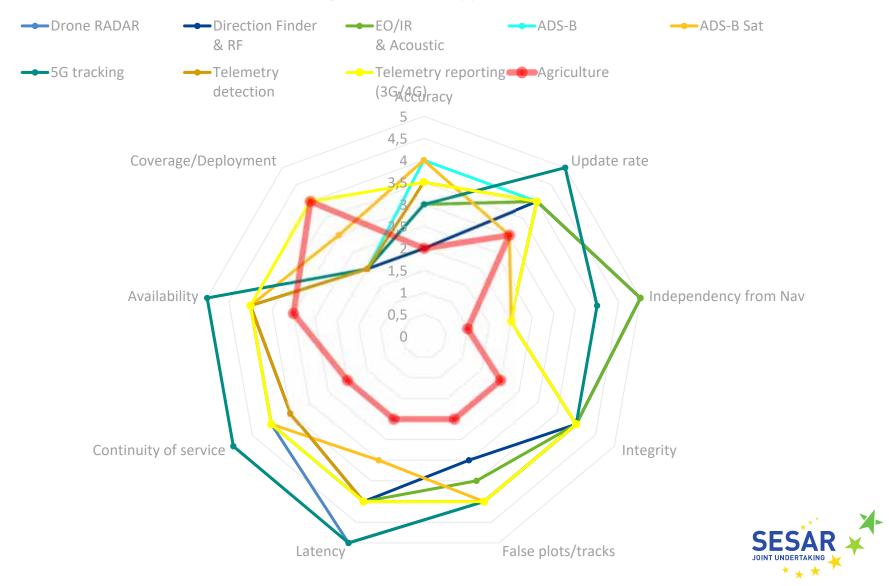
TERRA Analysis result – Surveillance

Surveillance

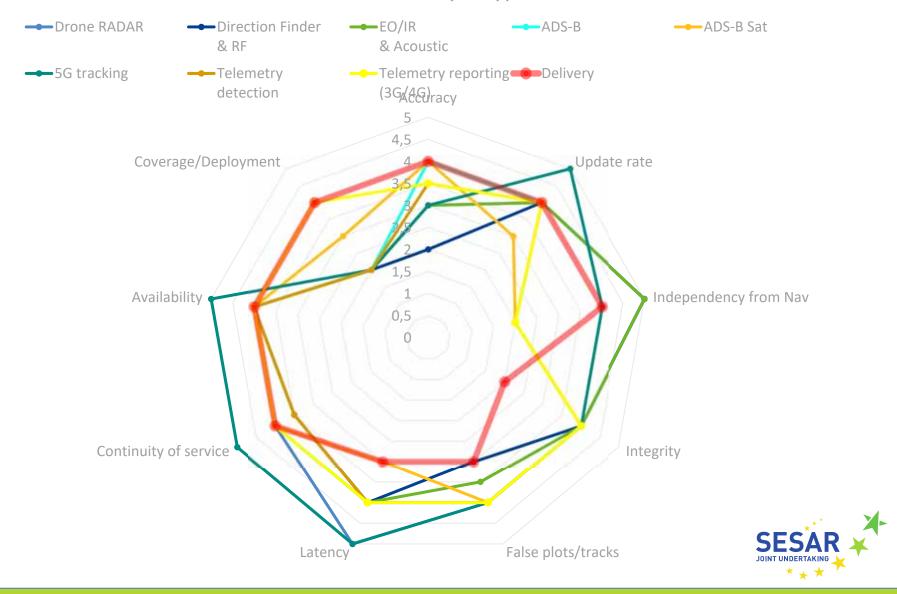|	Drone Radar	Direction Finder /RF	EO/IR Acoustic	ADS-B	5G Tracking	Telemetry reporting (3G/4G)
Accuracy	Medium	Poor	Medium	Good	Medium	Good
Update rate	Good	Good	Good	Good (ground) / Medium (Satellite)	Very Good	Good
Independency from the navigation source	Very Good	Very Good	Very Good	Poor	Good	Poor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

TERRA – Surveillance technologies applicability

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Agriculture – Type X/Y

Legend:
- Drone RADAR
- Direction Finder & RF
- EO/IR & Acoustic
- ADS-B
- ADS-B Sat
- 5G tracking
- Telemetry detection
- Telemetry reporting (3G/4G)
- Agriculture

Axes: Accuracy, Update rate, Independency from Nav, Integrity, False plots/tracks, Latency, Continuity of service, Availability, Coverage/Deployment

Scale: 0, 0,5, 1, 1,5, 2, 2,5, 3, 3,5, 4, 4,5, 5

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TERRA – Surveillance technologies applicability

Urban Delivery – Type Z

Legend:
- Drone RADAR
- Direction Finder & RF
- EO/IR & Acoustic
- ADS-B
- ADS-B Sat
- 5G tracking
- Telemetry detection
- Telemetry reporting (3G/4G)
- Delivery

Axes: Accuracy, Update rate, Independency from Nav, Integrity, False plots/tracks, Latency, Continuity of service, Availability, Coverage/Deployment

Scale: 0, 0,5, 1, 1,5, 2, 2,5, 3, 3,5, 4, 4,5, 5

TERRA – Surveillance technologies applicability

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Infrastructure Inspection – Type Y

- Drone RADAR
- Direction Finder & RF
- EO/IR & Acoustic
- ADS-B
- ADS-B Sat
- 5G tracking
- Telemetry detection
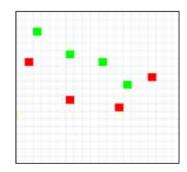- Telemetry reporting (3G/4G)
- Infrastructure

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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.

TERRA outcomes summary

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- *Current CNS technologies allow the deployment of U2 services in simple environments.*
- However, *the existing technologies present some drawbacks, which limit their application for complex scenarios* (e.g. urban canyons) and high drone densities.
    - *Rural environments can be safely flown with current technologies.*
    - *Urban scenarios will require operational restrictions to cope with the provided navigation accuracy and integrity, and also on the limitations of cellular coverage for drone communications.*
- *To allow full U-space deployment, improved technologies are required.*
    - *New technologies like 5G, Galileo, EGNOS v3, etc., could cover the gaps identified in complex environments.*
    - *Additionally, artificial neural networks modelling has shown the potential benefits of ML for use in predicting and classifying drone trajectories in the urban delivery case.*
        - *Accordingly, ANN seem to be a promising solution for conflict detection*
        - *Additionally, problem of frequent follow-on conflicts with other traffic could be mitigated even under higher traffic densities.*

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Stay in touch with us

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TERRA U-space site:
https://www.sesarju.eu/projects/terra

Main contact for project communication: Victor Gordo
vgordo@ineco.com

Final Workshop:

Rome, December 2019

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U-space CONOPS and research dissemination conference

1 October 2019

Alexandre Piot
Airbus Defence and Space

Project outcomes summary

U-space

Y Airspace
Statically Managed

U2 Tracking
- Basic Performance
- **Information**

U2 Monitoring
- Conformance
- Could be off-line

Z Airspace
Dynamically Managed

U3 Tracking
- Higher Performance
- **Decision**
- Enables Tactical Deconfliction

U3 Monitoring
- Real-time management
- On-line
  - Alerts
  - Update trajectory

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Stay in touch with us

U-space

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Thank you for your attention

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