U-space CONOPS and research dissemination conference

1 October 2019

THIRD SESSION PRESENTATIONS
DROC2OM

DROC2OM
Troels Bundgaard Sørensen
Aalborg University
Drone Command & Control

- 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.

Capabilities
- detect&avoid
- tracking
- identification
- Telemetry and FPV
- Command & Control
  - navigation commands
  - telemetry data
  - configuration info

U-Space Traffic Management
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**
Stay in touch with us – We will be around for a while 😊

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

This project has received funding from the SESAR Joint Undertaking under the European Union’s Horizon 2020 research and innovation programme under grant agreement No 763601

Brussels, 1 October 2019
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
DESCRIPTION OF THE GEOSAFE PROJECT

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.
Systems tested

- DJI - Phantom 4
- DJI - Mavic Air
- DJI – Inspire 2
- DJI - Matrice 100
- DJI - Matrice 600 / S900
- INTEL - Aero
- INTEL - Falcon 8
- YUNEEC - H520 Pro
- THALES
- AEROMAPPER - Avem
- PARROT - Bebop 2
- PARROT - Disco
- SENSEFLY - Ebee
- DELAIRTECH - DT18
- ATECHSYS - HE 190
- Pixhawk
- ATECHSYS X10
- DJI – Inspire 2
- DJI - Matrice 600 / S900
- INTEL - Aero
- INTEL - Falcon 8
- YUNEEC - H520 Pro
- THALES
U1- Pre tactical geofencing

Alert/blocking during flight

~ 75% of tested solutions are almost compliant with U1

Preactical geofencing technology is ready and mainly deployed

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

Restricted area information

09/2018 07/2019
Tactical geofencing technology 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

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.

Restricted area updating during the flight.
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
GEOSAFE

GEOFENCING

FOR SAFE AUTONOMOUS FLIGHT IN EUROPE
PODIUM – Pushing the U-space envelope!
Initial Insights!

Anastasiia SOBCHENKO
SESAR U-space projects Workshop
1 October 2019
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

Operational Feasibility/Acceptability of the UTM system

- 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.....
What needs more thought!? 

- 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!
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
405 followers
1w • Edited

To do is to bel 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 gateway ...see more
USIS
Aline Labreuil, UX Lead, HF expert
Thales Group
Project presentation

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

U2-Flight Planning Management
U2-Tracking/Conformance Monitoring
U2-Tactical geofencing

U2-ATC interface

Brussels, 1 October 2019
Project outcomes summary

35 flights (sept.19), 31 (unique) user interviews, >10 user tests, >30 HMI's 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
Stay in touch with us

Yohann Proust, Project Manager

Yohann.proust.e@thalesdigital.io
U-space CONOPS and research dissemination conference

1 October 2019

TERRA
Victor Gordo
Ineco
<table>
<thead>
<tr>
<th>General requirements</th>
<th>U-Space</th>
<th>Agriculture</th>
<th>Delivery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operational scenario</td>
<td>Rural VLOS/BVLOS RPAS</td>
<td>Fixed route (but not always) Segregated (Geo-cage) Near drones, but spatial segregation</td>
<td>Urban BVLOS RPAS/Autonomous Flexible route Non segregated Simultaneous drones</td>
</tr>
<tr>
<td></td>
<td>CORUS – Type Y</td>
<td></td>
<td>CORUS – Type Z</td>
</tr>
<tr>
<td>Navigation</td>
<td>CNS-NAV</td>
<td>Horizontal precision: 3 - 5 m Vertical precision: 5 - 10 m</td>
<td>Horizontal precision: 0.1-1m Vertical precision: 1 m</td>
</tr>
<tr>
<td>Separations</td>
<td>CNS-NAV Tracking</td>
<td>• Towards terrain: 300 m horizontal and 50 m vertical (100 m vertically with respect to mountains)</td>
<td>• 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)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• 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.</td>
<td>In other case, e.g. drone landing directly on clients’ houses, tactical conflict management would be required. (Strategic Mitigation Low)</td>
</tr>
</tbody>
</table>
## A/G Communication

<table>
<thead>
<tr>
<th></th>
<th>3G / 4G</th>
<th>5G</th>
<th>LoRA</th>
<th>L-DACS</th>
<th>EAN</th>
<th>V2X</th>
<th>WiMAX / Aero MACS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Continuity of Service</strong></td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Medium/Good</td>
<td>Good</td>
<td>Medium</td>
</tr>
<tr>
<td><strong>Availability</strong></td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Medium/Good</td>
<td>Medium/Poor</td>
<td>Good</td>
</tr>
<tr>
<td><strong>Integrity</strong></td>
<td>Good/Medium</td>
<td>Good/Medium</td>
<td>Good</td>
<td>Good</td>
<td>Medium/Good</td>
<td>Poor</td>
<td>Good</td>
</tr>
<tr>
<td><strong>Update rate</strong></td>
<td>Good</td>
<td>Good</td>
<td>Medium/Poor</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td><strong>Data delivery time/Latency</strong></td>
<td>Medium (3G)/Good (4G)</td>
<td>Good</td>
<td>Medium/Good</td>
<td>Good</td>
<td>Medium/Good</td>
<td>Medium</td>
<td>Good</td>
</tr>
<tr>
<td><strong>Bandwidth</strong></td>
<td>Medium (3G)/Good (4G)</td>
<td>Very Good</td>
<td>Poor</td>
<td>Good</td>
<td>Good</td>
<td>Poor</td>
<td>Good</td>
</tr>
<tr>
<td><strong>Data Transfer Security</strong></td>
<td>Medium</td>
<td>Good</td>
<td>Good/Medium</td>
<td>Good</td>
<td>Medium/Good</td>
<td>Poor</td>
<td>Good</td>
</tr>
<tr>
<td><strong>Coverage/Deployment</strong></td>
<td>Good (3G)</td>
<td>Medium/Poor</td>
<td>Medium/Good</td>
<td>Poor</td>
<td>Good</td>
<td>Poor</td>
<td>Medium</td>
</tr>
</tbody>
</table>
TERRA – A/G Communication technologies applicability

Agriculture – Type X/Y

- Continuity of service
- Coverage / Deployment
- Availability
- Data security
- Integrity
- Bandwidth
- Update rate
- Latency

Technologies:
- LTE
- 5G
- LoRA
- L-DACS
- EAN
- V2X
- WIMAX
- Agriculture

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TERRA – A/G Communication technologies applicability

Infrastructure Inspection – Type Y

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

Indicators:
- Continuity of service
- Availability
- Integrity
- Update rate
- Latency
- Bandwidth
- Data security
- Coverage / Deployment

Brussels, 1 October 2019
<table>
<thead>
<tr>
<th></th>
<th>GPS SPS</th>
<th>GPS SPS+RAIM</th>
<th>EGNOS v2</th>
<th>NAVAIDS</th>
<th>Galileo (+GPS)</th>
<th>TOA</th>
<th>AOA</th>
<th>EGNOS v3</th>
<th>AGNSS</th>
<th>RTK</th>
<th>PPP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Accuracy</strong></td>
<td>Medium/Good</td>
<td>Good</td>
<td>Very Good</td>
<td>Poor</td>
<td>Good</td>
<td>Medium/Good</td>
<td>Medium</td>
<td>Very Good</td>
<td>Very Good</td>
<td>Extremely Good</td>
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<tr>
<td><strong>Integrity</strong></td>
<td>Poor</td>
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<td>Good</td>
<td>Good</td>
<td>Poor</td>
<td>Good</td>
<td>Poor/ Medium</td>
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<td>Poor</td>
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<td></td>
</tr>
</tbody>
</table>
TERRA – Navigation technologies applicability

Agriculture – Type X/Y

Accuracy

Coverage/Deployment

Integrity

Continuity of service

Availability

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TERRA – Navigation technologies applicability

Infrastructure Inspection – Type Y

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

Accuracy

Coverage/Deployment

Integrity

Continuity of service

Availability
TERRA – Trials GPS mask angle

Horizontal difference vs mask angle

Vertical difference vs mask angle
## TERRA Analysis result – Surveillance

### Surveillance

<table>
<thead>
<tr>
<th></th>
<th>Drone Radar</th>
<th>Direction Finder /RF</th>
<th>EO/IR Acoustic</th>
<th>ADS-B</th>
<th>5G Tracking</th>
<th>Telemetry reporting (3G/4G)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Accuracy</strong></td>
<td>Medium</td>
<td>Poor</td>
<td>Medium</td>
<td>Good</td>
<td>Medium</td>
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</tr>
<tr>
<td><strong>Update rate</strong></td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Very Good</td>
<td>Good</td>
</tr>
<tr>
<td><strong>Independency from the navigation source</strong></td>
<td>Very Good</td>
<td>Very Good</td>
<td>Very Good</td>
<td>Poor</td>
<td>Good</td>
<td>Poor</td>
</tr>
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<td>Good</td>
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</tr>
<tr>
<td><strong>False plots/tracks</strong></td>
<td>Good</td>
<td>Medium</td>
<td>Medium/Good</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td><strong>Data delivery time/latency</strong></td>
<td>Very Good</td>
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<td>Good</td>
</tr>
</tbody>
</table>
TERRA – Surveillance technologies applicability

Agriculture – Type X/Y

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

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

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Brussels, 1 October 2019

TERRA – Surveillance technologies applicability

Urban Delivery – Type Z

- Drone RADAR
- Direction Finder & RF
- 5G tracking
- Telemetry detection
- EO/IR & Acoustic
- Delivery
- Telemetry reporting
- 3G/4G
- ADS-B
- ADS-B Sat
- Integrity
- Continuity of service
- Coverage/Deployment
- Update rate
- Latency
- False plots/tracks
- Independency from Nav
- Availability
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

• **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.
Stay in touch with us

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
U-space CONOPS and research dissemination conference

1 October 2019

CLASS
CLEAR AIR SITUATION FOR UAS

Alexandre Piot
Airbus Defence and Space
CLASS – The Situation
Project presentation

Drone Identifier and Tracker
Ultra Narrow Band technology

Data Fusion
Fuse Cooperative and Non-Cooperative tracks

Tactical Deconfliction
Real Time Monitoring

Situational Awareness and Alerts
Real Time Monitoring

Gamekeeper 16U
Take on drone spotting: Stare not scan

Drone
ENAC’s technology

Brussels, 1 October 2019
Y Airspace
Statically Managed

- Basic Performance
- Information
- Conformance
- Could be off-line

Z Airspace
Dynamically Managed

- Higher Performance
- Decision
- Enables Tactical Deconfliction
- Real-time management
- On-line
- Alerts
- Update trajectory
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Thank you for your attention