# U-space Information Management, solving big challenges in small packets

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In recent years the benefit of utilizing unmanned aerial vehicles (UAVs) – commonly referred to as "drones" – for civil applications has become more and more apparent. Agricultural land surveying, cinematography, public safety and security or urban package delivery are just a few examples of business opportunities for the use of drones. However, the introduction of these new actors in the airspace will require some sort of mechanism to allow access to many stakeholders in a controlled manner. The European Union´s answer to this issue is **U-space: A Pan-European system of systems** which provides a large set of services to drone operators and stakeholders in drone operations, with the aim of unleashing the market potential of drone operations whilst ensuring safe and secure integration into the current airspace system. The Horizon 2020 project IMPETUS aims to investigate and test information management solutions between the diverse set of envisioned U-space services and stakeholders.

## Fidelity is the key issue in U-space information management

IMPETUS has identified the information needs of drone users by reviewing the entire drone operational lifecycle, starting with mission and individual flight planning, continuing via traffic planning, mission and flight execution, and ending with the end customer who receives the services. A key takeaway of this review was that many of the 'apparently' big **differences between ATM and U-Space are related to "scale"**. Drone services will manage information that will be significantly more detailed, diverse and dynamic. Safety critical information, for instance, will be needed at a much higher fidelity than in today's solutions, such as geospatial information to ensure clearance from terrain and obstacles, local weather information to calculate drone trajectory uncertainties and more precise navigation on a local scale that will only be reached through non-conventional navigation sources (such as signals of opportunity and vision-based navigation).

## Distributed data management

Services of this level of fidelity will require the movement and provision of massive amounts of data to a wide array of users spread out over a large geographical area. Considering these points, we have found that an information management architecture in the cloud and **based on the microservice paradigm** would likely be the best solution for drones. This paradigm is a design concept for organizing an application more efficiently. Legacy monolithic applications (meaning centralized, uniformly packaged and single-language-based programs), quickly reach overwhelming complexity as they grow to meet increasing consumer demand. These types of program architectures are common in the aeronautical world, especially in current air traffic management (ATM) solutions. Microservice-based applications avoid the issues of monolithic programs, as the entire application is split into lightweight self-contained microservices with a clearly defined functionality, typically associated to a business capability, and with interactions between microservices which are managed through a predefined Orchestration Logic. This logic implies the existence of some transversal services such as a **discovery service** that can ask for the existence and location of a service that has been previously registered in the ecosystem.

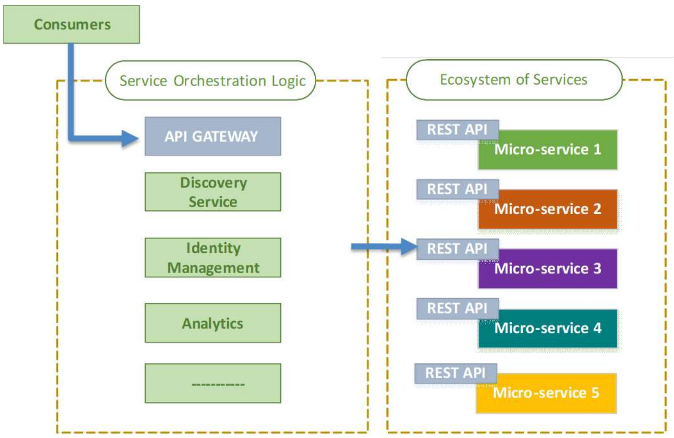


**Figure 1: High-level scheme of microservice-based architecture with orchestration logic.**



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The ability for microservices to be independently deployed has key benefits such as the rapid updates making continuous deployment of the microservice possible, the possibility of using diverse technologies to better address the specific requirements of each microservice or the flexibility required for agile increments of the U-space capacity, which is a good advantage taking into account that U-space is a complex system of systems that will rapidly growth in line with new business needs and evolving regulation. To validate the technical and economic feasibility of this solution, IMPETUS focused on specific research areas:

- Management of **failure modes**, which could affect safety-critical services and thus, safe drone operation.
- **Flexibility** of the solution to assign computing resources as needed optimising the cost implications to the final U-space users.
- **Scalability** taking into account the expected growth of drone operations.
- **Commercial feasibility** of a U-space microservice architecture, with special focus on the business model and how to proportionally bill the services provided.

## Showcase experiments

IMPETUS has replicated and tested the microservice-based architecture in four experiments that developed the following U-space services and also some of the dependencies between them: Tactical Deconfliction and Capacity Management services; Monitoring and Traffic Information services; Drone-specific weather service; Mission and Flight Planning Management services. Some of the results of the previously described research areas are summarized in the following paragraphs.

### Failure mode mechanisms in Tactical Deconfliction and Capacity Management services.

This experiment explored how a drone deconfliction service can interact with other services in the system to maximize the airspace capacity for drones based on dynamic volumes to ensure separation. The size of the volumes was determined by a dynamic weighting scheme which took a large variety of metrics into consideration (such as speed, operating environment, mission type, mission priority, endurance, wind and data quality). Such dynamicity would greatly improve airspace utilization, however at the price of higher complexity in air traffic management solutions. In such a dynamic and complex environment, it becomes essential to design the services in such a manner that **modes of failure are largely deterministic**, so that appropriate mitigations can therefore be built in. Several failure conditions were tested in this experiment, including the case in which a dependent service or data provider fails. Though the Discovery service, one of the core services of this architecture, we designed a categorization system of data providers. Each provider in the system was listed with an alternative provider. Thus, the system was able to successfully switch provider if a lower priority service we were dependent upon fails, e.g. weather data provision. Whenever this process fails, the system was able to increase drone separation to the maximum acceptable level while the service recovered. As the last resource, whenever the group of dependent services attributed as critical for drone operations fails, the system stopped accepting any new vehicles by rejecting their take-off request, sending a “temporarily unavailable” error code.

In conclusion, the micro-service architecture was capable of absorbing failures and incorporating countermeasures able to react in real-time and deterministically. The tests demonstrated that such a feat is not only technologically possible, but also a viable option when realized in coordination and conjunction between services. This approach is an enabler of high-density operations requiring agile responses and adaptability to changes in number of clients.

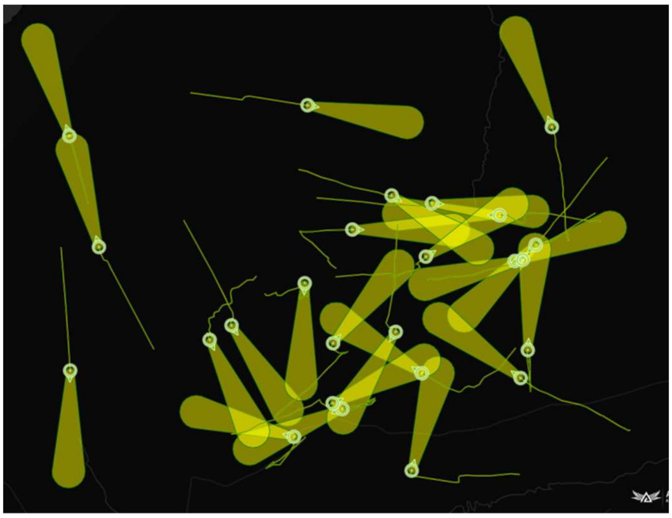

Figure 2: Snapshot of a tactical deconfliction simulation execution with random traffic data. In repeated tests, mission efficiency did not drop below 72% (averaging a drop to 78%), yielding a maximum route deviation average of 22%.



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## Flexibility of Monitoring and Traffic Information services in case of sudden increases in demand

In this experiment, the microservice architecture was subjected to a "stress-test" to analyse how the system can be easily scaled to meet consumer demands. Specifically, drone Monitoring and drone Traffic Information services were simulated and injected with ever increasing amounts of traffic data, to see how the architecture is able to cope with the load. We measured system performance in terms of message latencies, system scalability and maximum workload.

For instance, we found that message filtering greatly reduces the amount of latency in message processing. In the experiment, the data flowing into the monitoring service was filtered to just information about position, battery status and altitude. This technique greatly improved the service's performance (in some cases, latency was reduced by a factor of 40).

Concerning scalability, results showed that the microservice architecture is easily capable of growing to absorb increases in demand without conditioning the performance of the whole architecture. Whenever demand exceeded system capacity, an **additional microservice is instantiated to reduce the load**. In this exercise the overcharge was reduced from 120% to 26% and as a result, message processing delays were reduced to the ones expected in nominal operation. Similarly, when load decreases, microservices are decommissioned to optimize the use of computing resources.

This exercise showed that a microservice architecture is well equipped to deal with peak growths in the number of messages or rises in demand through utilization of a set of mechanisms to detect, mitigate and stabilize its performance; Thus able to absorb all workload increases with no substantial impact on performance. However, in order to provide full redundancy, **duplicity in critical and safety-relevant services shall be provided** regardless of the actual load situation.

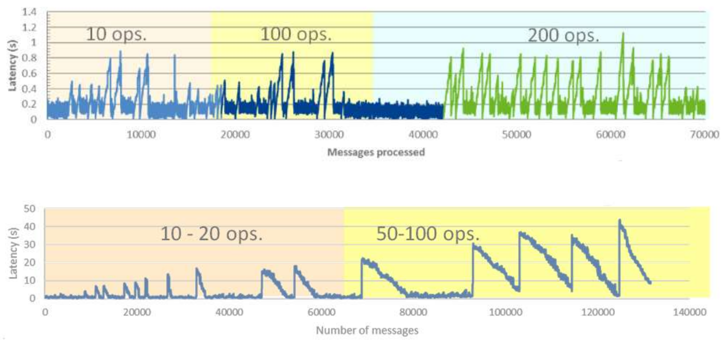


**Figure 2: Results of latency tests on the number of messages processed as drone operations were increased. Sudden increases in messages accumulated delays which were absorbed when the architecture balanced the load between several micro-services instances. Moreover, the use of message filtering techniques (top image) greatly reduces message latency compared to non-filtered messages (bottom image).**

## Scalability of hyper localized weather services for drones

IMPETUS tested a state-of-the-art, hyper localized weather service for drone operations. This service was used to provide probabilistic weather predictions for areas with size of only a few square kilometres and applied to a planned drone trajectory. Results were compared to calculations using current meso-scale weather observations, and showed that higher fidelity probabilistic weather predictions resulted in better informed decisions, overall less uncertainty in drone trajectories.

The weather service's architecture was also built on the microservice concept, which was tested for scalability. Thus, this exercise performed several load tests to see how the micro weather service solution front end behaves under an increasing load of requests. In these tests the evolution of RAM and CPU values were analysed as the total number of users of the service was incrementally increased from 1 to 1000. The microservice architecture was well able to cope with the increasing load, as results showed that RAM, and CPU values were well below the expected maximum usage, and theoretically capable of scaling up to 2000 clients per server before reaching system limits.

In conclusion, the load was linear as expected from the first client. It is also relevant to mention that **no more than 5% of the server was used for the processes associated to the microservice implementation** such as the API Gateway and the interactions with the core weather modules. These modules had to be managing



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the data regardless of client activity, keeping the weather information of every cell updated just in case any client agent start reading from them.

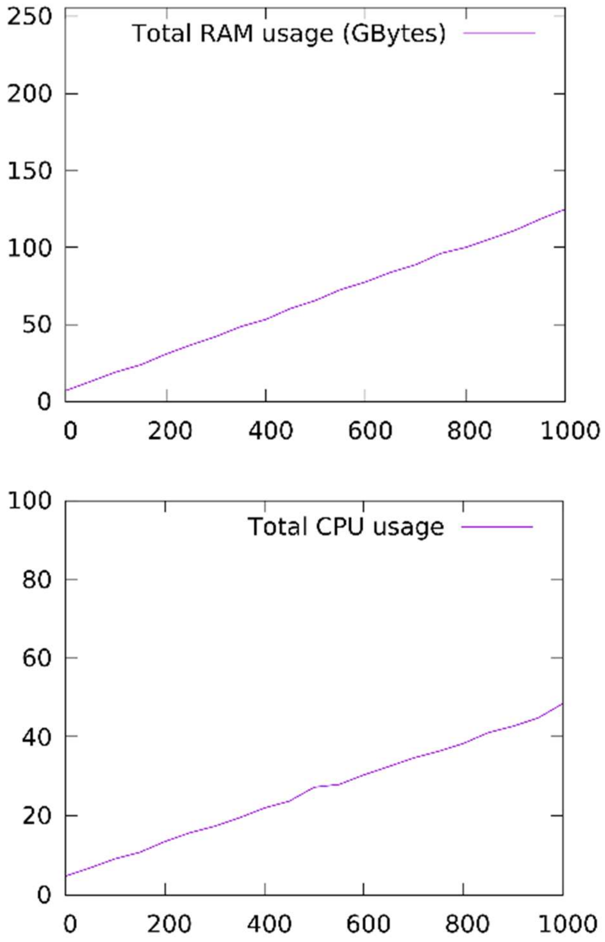


**Figure 3: Both RAM (top image) and CPU usage (bottom image) increased linearly with increasing amounts of users (x-axis). Values peaked well below the maximum expected load. Specifically, RAM usage peaked at 48.77% and CPU load on the server reached 48.24% at 1000 clients.**

## Commercial feasibility to proportionally bill the Mission and Flight Plan Management services

For the flight planning service, which is in charge of approving the submitted drone flight plans, we were able to identify the most resource demanding user requests and analyse the consumption of resources. This could allow designing the future business model of U-space, as user service requests could be precisely (and potentially individually) billed based on the cloud computational resources that they consumed.

As an example, we assessed the cost of providing a Flight Plan Management service under conservative, expected and optimistic projections of the predicted future drone traffic load under the consideration of a punctual pay-per-use billing model. The implementation costs were accurately estimated using the pricing models of commercial cloud computing platforms. Adding the infrastructure costs which are part of a standard micro-service architecture such as the API Gateway and the Discovery service to the base flight planning service costs resulted in an overall cost estimation of less than a quarter of a cent (€) per transaction in all projections.

This exercise showed that, through the microservice approach, it is possible to have a straightforward calculation of the implementation costs and therefore have an **initial estimation on how to bill the different service transactions**.


**Figure 4: Overview of results on the number of transactions per month estimated for conservative, expected and optimistic numbers of drone operations for 2035 and associated transaction costs per flight plan request. It becomes apparent that the costs per transaction reduce dramatically as the number of drones in operation increases.**

## Recommendations for the U-space architecture

The outcomes from IMPETUS experiments focusing on the use of a microservice-based architecture have proven that this framework is suitable for U-space, as long as the following recommendations are considered:

- In the context of building scalable, distributed aviation systems, particularly on cloud technology, it becomes essential to provide deterministic failover during fault conditions.
- Information update rates should be increased depending on the proximity of drone operations. For instance, emergency levels could be defined with specific information update rates – the higher the level, the higher the update rate.
- Interfaces for U-space service interactions should be standardized to allow for the necessary service interconnectivity, the targeting of messages of interest and avoiding bottlenecks in data entry.



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- It is relevant to implement message filtering services in parallel, to avoid sequential processing of messages and improve performance.
- The architecture shall be configured so that the maximum workload admitted by each microservice is 80% of its capacity, in order to deploy additional microservices in-time when the demand increases.
- Critical services shall, at the very least, be deployed duplicated and backup services shall be made available if the 80% demand threshold is reached.
- The cloud or service provider can manage the virtual machines necessary to implement the service requests, which can be billed according to a measure of the computing resources required to satisfy them.

## The next steps

The IMPETUS project has gathered tangible results and experiences on the implementation of drone-related services via the microservice paradigm. For a more complete overview of our assumptions, methods and results, please refer to the impetus website (impetus-research.eu) where we will provide all publicly-available documents free to download at the end of the project – March 2020 -. For more specific questions, feel free to contact us at info@impetus-research.eu or via our LinkedIn group.

## IMPETUS consortium

IMPETUS project has received funding by SESAR. The consortium is leaded by CRIDA and composed of relevant stakeholders providing complementary views on the current and envisioned UTM and ATM systems: ALTITUDE ANGEL, BOEING, C-ASTRAL, INECO, JEPPESEN and TECHNISCHE UNIVERSITAT DARMSTADT.



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