Satellite-Unmanned Aerial Vehicle (UAV) Cooperative Missions: Status and Outlook

ESTEC Contract Nº: 21839/08/F/MOS

Executive Summary

EUROPEAN SPACE AGENCY CONTRACT REPORT:
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EXECUTIVE SUMMARY

This document summarises the work done by the SUAV consortia under the frame of ESA contract number 21839/08/F/MOS, titled "Satellite-UAV Cooperative Missions: Status and Outlook".

The project consortia, which was lead by Indra, was composed by Indra with high experience in satellite communications, ground stations and user terminals and UAV development and MDA with demonstrated experience in satellite, satellite payload and UAV developments.

PROJECT OBJECTIVES

The project was aimed at investigating from a technical and economical perspective the requirements for a satellite-based system to support civil and security Satellite-UAS cooperative missions fully compliant with the current and future ATM regulatory framework. The feasibility and benefit of a dedicated European satellite capability potentially provided by the European Data Relay Satellite system and integrated into European wide-ATM SESAR concept is also addressed in the scope of the project.

CONTEXT

Civil and security Long Endurance UAS have been proposed as main actors to carry out many missions in a near future covering earth observation, security, surveillance of infrastructures, search and rescue, airborne telemetry collection relay, point-to-point cargo delivery, weather data collection, environmental monitoring, pollution detection and other specific scientific and research activities. The design and development of Long Endurance UAV is pushing the demands of the data links. The data links are becoming a competitive value in the UAS because of they impact on its performance e.g. range, endurance, integration into the future European Air Traffic Management and payload feedback capabilities.

The main hurdle that the civil unmanned community is facing is the lack of specific regulatory framework and the airworthiness certification. Unlike the military UAV, most of civil and security UAS applications require flight in non-segregated airspace, which in turn requires specific technology and regulations which are not yet in place. Once these regulations will be in place, a dramatically growth of civil and security UAS is expected in Europe and Canada. It is of paramount importance for the development of the unmanned aviation that UAS can be integrated into the non-segregated airspace and into the Air Traffic Management (ATM) system, in a way that such integration does not introduce any incremental risk to other airspace users. However, there are a large number of important challenges to be overcome before routine operations of UAS in the non-segregated airspace can be a reality, namely:

- Internationally harmonised regulatory and standardisation framework for UAS, which also includes the need for consensus on operational concepts, definitions, and categorization of UAS.
- Airspace and ATM system evolution to cope with the increasing demand of airspace users, among them the Unmanned Aviation community.
- Reliability of UAS and the safety of their operations.
- Effective and affordable collision avoidance system (Sense & Avoid systems) capable of detecting both cooperative (transponder equipped) traffics and non-cooperative (non-transponder equipped) traffics.
- Frequency spectrum allocation and sufficient bandwidth availability for UAS operations.
- Security in UAS operations.
- Insurance liability costs.
- Adequate business cases for UAS operations.
- Social barriers: public apprehension or rejection of UAS and resistance from existing airspace users.

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In the near future, once the regulatory framework is in place and the abovementioned challenges are overcame, the development of a large number of small UAV is envisaged; nevertheless most of these UAV will not be considered as potential users of satellite technologies. Medium-Altitude Long-Endurance (MALE) and High-Altitude Long-Endurance (HALE) are the most promising candidates to take advantage of the satellite technologies. However, Medium Endurance UAVs are also potential candidates to use these technologies for supporting safety of flight communications (Command and Control, Sense and Avoid and ATC relay).

In this context, the inclusion of satellite technologies in the Long Endurance UAVs can provide outstanding benefits to the UAS at a small fraction of system cost:

- Satellite technologies enable missions far beyond line of sight (BLOS) by relying the Command and Control (C2) data link and mission payload data link.
- Satellite technologies enable a smooth and seamless UAS integration into the national non-segregated airspace by relying the ATC communications and the Sense and Avoid (S&A) information to the remote pilot in command.
- Satellite technologies provide high-precision navigation and positioning systems allowing accurate procedures such as Automatic Take-Off and Landing (ATOL).
- Finally, the integration of Satellite and UAS has the potential of unique civil and security Satellite-UAS joint missions, including time-critical and life-critical operations. The synergy between these two systems stem from their complementary characteristics with regards to the capability to provide data to the operators or users. In other words, the disadvantages of one system can be balanced with the other system.

MARKET ANALYSIS AND FORECAST

According to the study of UVS International, the total amount of UAS (it includes all types of UAS) procured and developed by European countries is 27,3%; being France, UK and Germany the first ones (5,98%, 5,44% and 3,84% respectively) in comparison to US with 36,39%, Israel with 7,68%, China with 2,99% and Australia with 1,39%. These numbers show a huge gap between European countries (each one alone) and US, but a competitive ratio when looking at Europe, as a whole, as one single player. This fact pushes the continental efforts in Europe in order to consolidate a solid and independent UAS market.

Regarding the MALE/HALE/HAP UAV, the total of produced and developed MALE/HALE/HAPs is 8,32% of the whole UAS. This is the scenario that forces Europe to use some foreign MALE/HALEs platforms already in the market to be able to enter this sector. This comparison shows that although Europe is a strong player in the total UAS world production, it is behind USA and Middle-East in MALE/HALE/HAPs production (see Figure 1 and Figure 2).

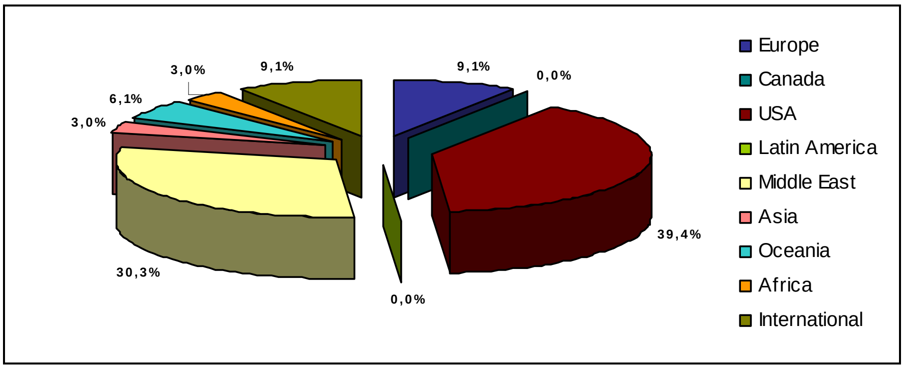

Figure 1: MALEs produced/developed per region

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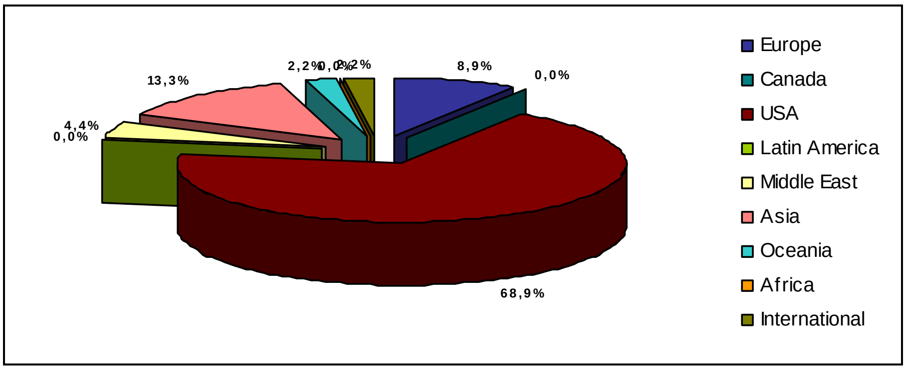

Figure 2: HALE produced/developed per region

Forecast analysis for Europe (Frost and Sullivan, 2008 and Teal Group Corporation, 2008) provide a rough estimate on predicted minimum, maximum and average number of LE UAS procured in Europe year by year during the period 2008-2017. According to these forecasts, about 100 Long Endurance UAV produced and operated in Europe can be expected at the end of the period and more conservatively by 2020 (see Figure 3).

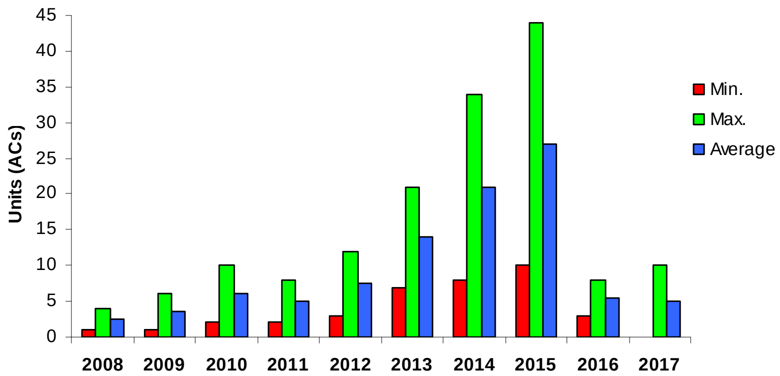

Figure 3: Long endurance (LE) UAS forecast in Europe 2008-2017

SATELLITE-UAS ARCHITECTURE DRIVING REQUIREMENTS

UAV communication data links the key enablers for the satellite-UAS architecture requirements due to the remote nature of the pilot-in-command. Satellite-UAS architectures enabling BLOS operations must support two different types of communications data links, namely safety data link and mission data link. The requirements for these links vary as much as the types of missions and different UAV types.

Safety communication data links is composed by the following data flows:

- The Command and Control link (C2): bidirectional data link dedicated to monitor and control the status of the aerial platform and to allow the supervision of the vehicle by its pilot-in command.
- The ATC relay link: dedicated to provide interaction capabilities between various ATC centres in the ATM system and the pilot-in-command.
- The Sense-and-Avoid link (S&A): dedicated to provide information to the pilot-in-command about surrounding vehicles that may eventually be in conflict with the UAV. The goal is that the pilot-in-command can implement the vigilance and traffic avoidance requirements imposed on him by the

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ICAO rules of the air. The S&A implementation is, at the time being, unclear; nevertheless, it has been identified as one of the main key enablers for the integration of the UAS in the national airspaces.

Mission communication data link is composed by

– The Mission link: bidirectional data link dedicated to transfer all mission data gathered by the payload or payloads on-board the UAV to the Operational Payload Analysis Centre (OPAC) centre, where it can be properly exploited, as well as data link needed to control, monitor and supervise the payload (e.g. camera orientation, etc).

Safety communications performance requirements (latency, availability and integrity) are likely to be similar to those on manned aircrafts (ATC communications). Typically, these communications require a high reliability and a secure data link with low data rate that can be easily accommodated at low frequency bands .e.g. L or S frequency band.

Mission communications performance requirements are less stringent than safety communications since they not carry safety of flight communications, but it usually requires much more bandwidth to transmit the data gathered by the payload, which forces to use higher frequency bands (Ku and Ka frequency band). Efforts to standardize data links have resulted in the use of the Common Data Link (CDL), typically a full-duplex, wideband data link when used by UAS, and usually jam-resistant and secure. CDL is the DoD standard for high capacity data communications of airborne sensor data. UAS mission payloads cover a wide range of applications they require a large variety of data rates.

Satellite-based data links must be integrated into two different environments: the deeply embedded, power, weight and size constrained UAV and the ground station, which is usually operated in an environment without such stringent constraints.

Data link needs also includes security aspects, efficient use of the spectrum, dynamic resource allocation in order to accommodate the communications resources to each flight phase, support of robust waveform (EPM) and support for a large variety of payloads.

SATELLITE-UAS ARCHITECTURES

Based on the Satellite-UAS driving requirements, several architectures were proposed to support the integration of the UAS into the space segment. Figure 4 illustrates the generic overall scenario for the integration the UAS in the space segment in order to take advantage of SatCom and SatNav services and to support cooperative missions.

Several architectures have been proposed, taking into account two time frames: short-time frame architecture and long-time frame architecture.

For the short-time frame architectures, it has demonstrated that current systems providing safety services (Inmarsat and Iridium) do not meet the required service performances (availability, integrity, latency and capacity). Therefore, these individual systems can not be used to support the UAS integration into the non-segregated airspaces. For the short-time frame, this problem can be solved with a hybrid architecture using in parallel Iridium and Inmarsat.

To meet the future long endurance UAV requirements it appears that it is necessary to develop specific satellite payloads UAV oriented supporting safety and mission communications. Three different long-term architectures have been proposed to support the integration of the UAS while meeting the service requirements. The preferred long-term architecture is a good compromise between cost, risk and technical performance. This architecture is based on a full redundant system covering the targeted area. The satellite architecture supporting such services consists of:

– 2 GEO satellites in hot redundancy with reconfigurable and steerable high beam antennas. The steerable beams are used to accommodate UAV traffic density needs.

– Flexible, scalable and full redundant ground segment,

– Full redundant user segment.

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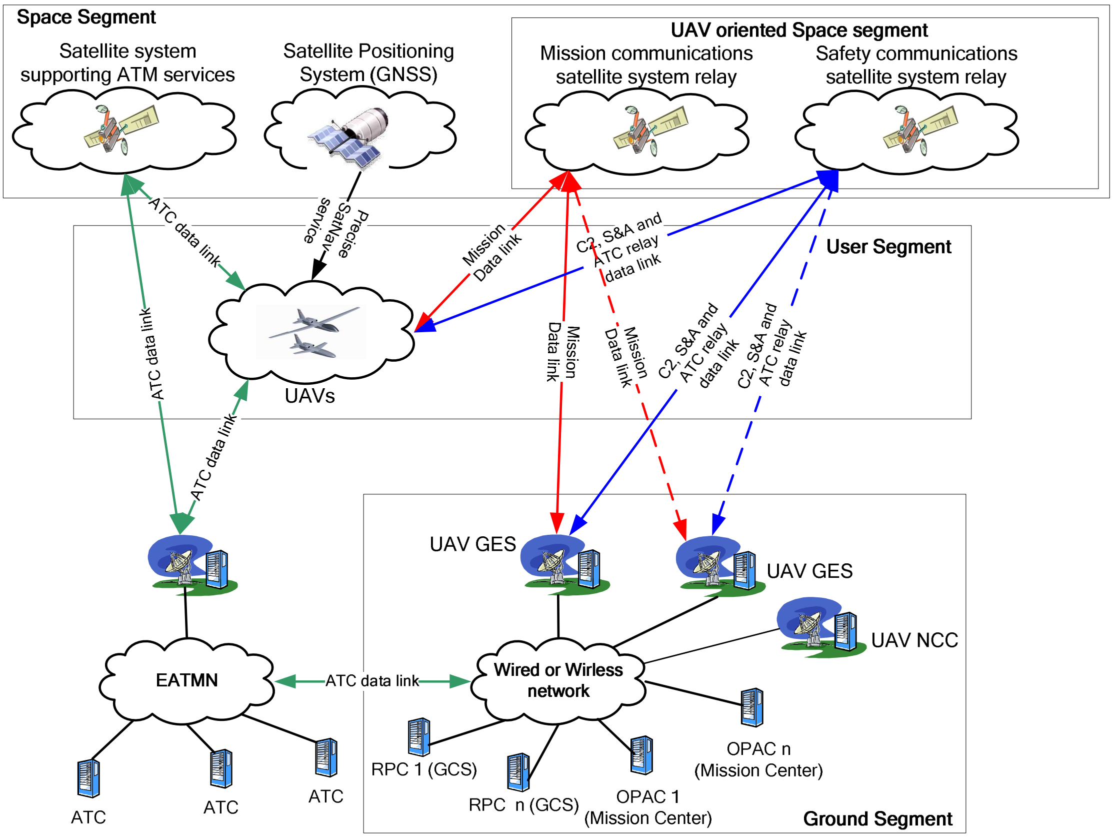

Figure 4: Satellite-UAS architecture

The proposed architecture can be expanded with the addition of HEO constellations providing service to northern latitudes. The option of using a HEO constellation for supporting Satellite-UAS cooperative missions could consider the development of specific payload or just leasing bandwidth to existing or planned Canadian or Russian HEO constellations. Besides, the architecture can also be expanded to a global coverage with the cooperation of non-European partners. In this case, global interoperability has to be guaranteed.

CONCLUSIONS

The analysis of the driving requirements shows that there are some open points:

- In the future, an important growth of civil and security MALE and HALE UAS is expected, as most of the European countries are currently developing UAVs. However, today these UAVs have to operate in a segregated airspace. A regulatory framework enabling the UAV operation in non-segregated airspaces is mandatory. Such integration is still unclear and must be solved as soon as possible.
- Aeronautical community agrees on the fact that in order to ease the UAS integration in the ATM, a “sense and avoid” system emulating the “see and avoid” of manned aircrafts must be implemented. Which technologies to use and how to implement such procedures are questions still unsolved.
- There is a need for an open standard for the Command and Control data link in order to avoid proprietary solutions and market fragmentation.

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– It is rather difficult to estimate the bandwidth requirements for mission communications as there are a large dispersion of payload types and mission types.

The proposed long-term architecture is fully compliant with the Satellite-UAS driving requirements and can cope with the safety and mission communications data links.

The future European Data Relay Satellite (EDRS) system has been identified as one of the main future satellite systems supporting satellite-UAS cooperative missions.

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