# Satellite-UAV Cooperative Missions: Status and Outlook

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# Executive Summary

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# Contract No. 21829/08/F/MOS

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## *CHANGE RECORDS*

| ISSUE | DATE | § CHANGE RECORDS | AUTHOR |
|---|---|---|---|
| 1.0 | June 3rd 09 | First version | Erwan Le Ho |
| 1.1 | June 29th 09 | §7: trade-off for safety communications updated (§7.3.2)<br>§7: reference to EDRS requirements added (§7.5) | Erwan Le Ho |
| 1.2 | July 15th 09 | Minor modification on table 2 | Erwan Le Ho |

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## 1. CONTEXT

This document is the executive summary of the ESA study "UAV-Satellite cooperative missions", carried out from October 2008 to June 2009. It summarizes, in a self standing manner, main results of the project.
The project consortium, which was lead by Thales Alenia Space, was composed by Thales Aerospace France, Thales Aerospace UK and Thales Alenia Space Italy.

## 2. INTRODUCTION

Up until the 1990s, the majority of UAVs have been small, tactical-based systems, relying heavily on narrowband and wideband LOS data links for transmitting and receiving control and mission data respectively. However, with the introduction of medium and high altitude UAVs, with extreme long range and endurance, there is a growing requirement for BLOS capabilities. As illustrated below, satellites can contribute to:

- Precision navigation through GNSS signals
- UAV Command & Control through secure communication links
- Insertion in general airspace through the relay of ATC communications
- Collision avoidance through the exchange of Sense & Avoid data
- Payload data transfer through broadband links

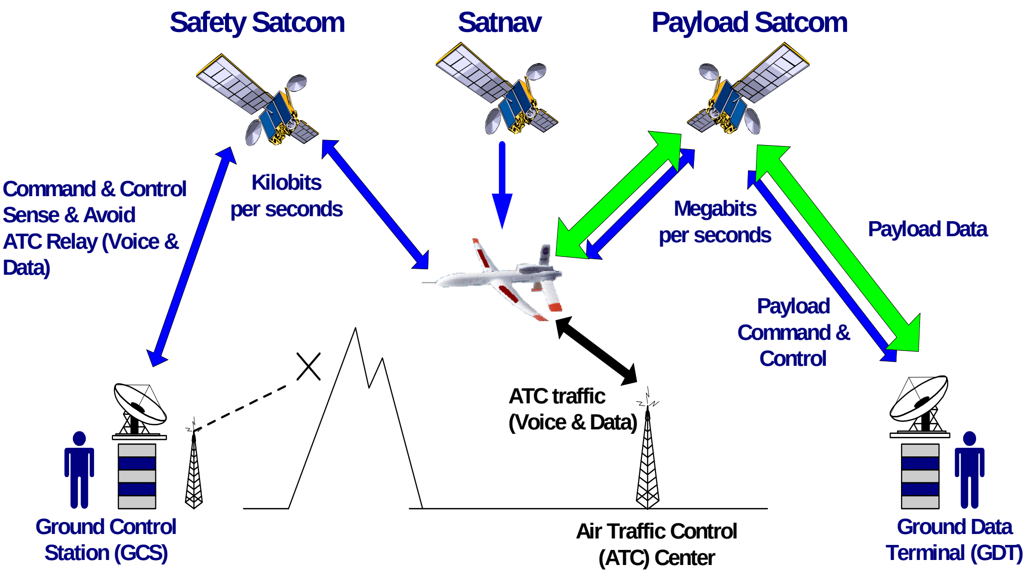


**Figure 1: Satellite's role**

The study aims at determining which satellite-UAV architectures are the most appropriate. It is organized as presented on the following chart:

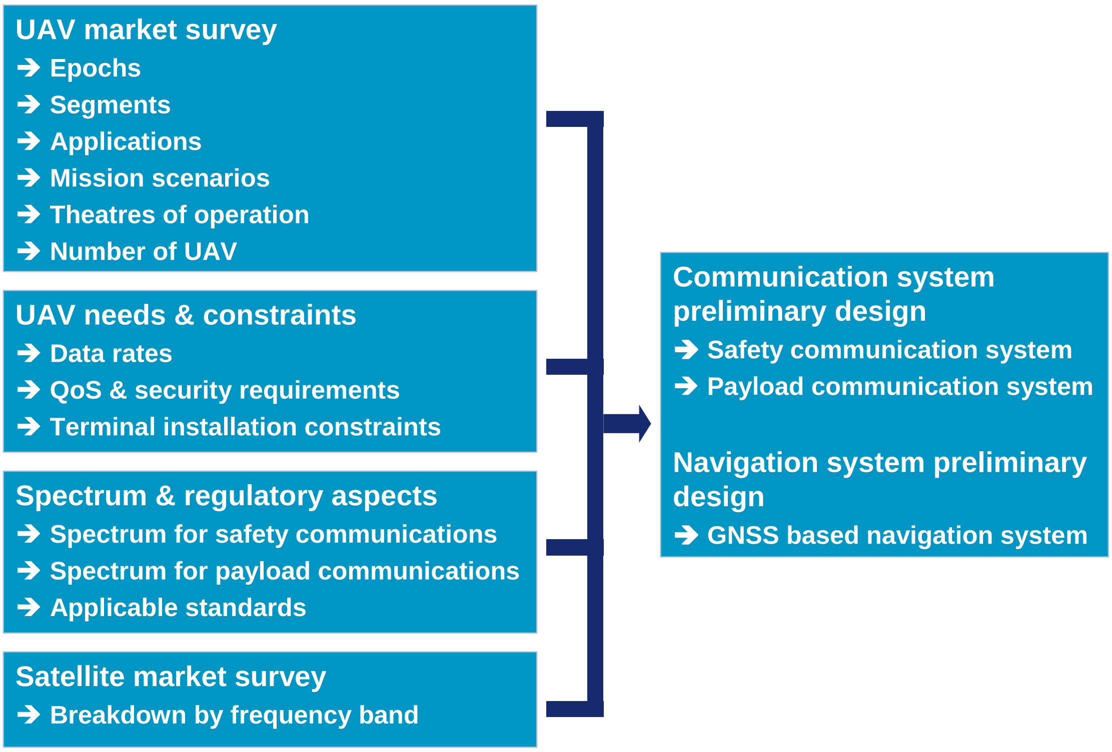


**Figure 2: Methodology of the study**

## 3. UAV MARKET SURVEY

### 3.1 BLOS-capable UAV market environment

As presented on Table 1, throughout this study, three epochs have been considered.

The segmentation that has been incorporated is as follows:

- TUAV: Only the larger UAVs (>400 kg) within this segment will have a BLOS data link requirement.
- MALE: The MALE segment encompasses all systems that have a maximum take-off weight greater than 1,500 kg and an operational endurance greater than 24 hours.
- HALE: The HALE segment encompasses all systems that have a maximum take-off weight greater than 8,000 kg and an operational endurance greater than 24 hours.

Whilst the above segmentation is based on existing military terminology, the three categories will also adequately address future civil applications. For example, TUAV will be used for more localised civil applications, within 300 km of a given location. On the other hand, MALE and HALE UAVs will be used for longer range and over the horizon capabilities given the larger platforms and payload carrying capacity.

| | 2009 Epoch 1 2015 | Epoch 2 2025 | Epoch 3 2035+ |
|---|---|---|---|
| *Quantities, Types, Operators & Manufacturers* | • <1,000 air vehicles (inc US)<br>• MALE, Strike, HALE<br>• <10 nations, Military<br>• <5 manufacturers including US | • >1,000 air vehicles (inc US)<br>• MALE, Strike, HALE, UCAV<br>• <30 nations, Military & Civil<br>• <5 manufacturers including US | • >>1,000 air vehicles (inc US)<br>• MALE, Strike, HALE, UCAV + civil airliners & freighters<br>• >30 nations, Military & Civil<br>• >5 manufacturers including US |
| *Roles, Conops & Applications* | • ISR<br>• Strike<br>• Remotely piloted | • ISR<br>• Boarder/Coastal monitoring<br>• Maritime Reconnaissance<br>• Asset monitoring<br>• Strike & combat<br>• Remotely piloted & limited autonomous flight | • ISR<br>• Boarder/Coastal monitoring<br>• Asset monitoring<br>• Strike & combat<br>• Remotely piloted & limited autonomous flight<br>• Unmanned freight transport<br>• Unmanned civil transport |
| *Constraints* | • Budget – extended deployments<br>• Public perception – mistrust<br>• Safety | • Budget<br>• Hostility/lobbying from manned industry, pilots<br>• Safety | • Budget<br>• Hostility/lobbying from manned industry, pilots<br>• Public perception – mistrust<br>• Safety |
| *Satellite's Role* | • Transmission of sensor data (FMV, SIGINT)<br>• Navigation (FMV, course guidance, onboard telemetry) | • Transmission of sensor data (FMV, SAR radar, SIGINT)<br>• Navigation (course guidance, onboard telemetry)<br>• Command, Control & Communications | • Transmission of sensor data (FMV, SAR radar, SIGINT, hyper-spectral)<br>• Navigation (course guidance, onboard telemetry)<br>• Command, Control & Communications |
| *Air Traffic Control environment* | • Virtually no flying in un-segregated airspace<br>• Research into "sense & avoid" technologies | • Early adoption of results of MIDCAS, ASTRAEA & Eurocontrol initiatives | • SESAR adoption<br>• Regular flight in un-segregated airspace |

**Table 1: Characterisation of the three epochs**

## 3.2 BLOS UAV scenarios

Four scenarios have been defined:

- **Scenario 1 - Civil Area Operations**: envisioned as the normal operating mode for UAVs in civil airspace, especially those applications that are undertaken by government organisations such as Homeland Security and research agencies
- **Scenario 2 - Civil Route Operations**: typically power and pipeline surveillance. The main difference with regards to Scenario 1 is the fact that mission activities are performed whilst the UAV is transiting between waypoints on a pre-planned flight plan.
- **Scenario 3 - Civil Integrated en-route Operations**: typically long haul unmanned freight or passengers transport, would not be possible until Epoch 3.
- **Scenario 4 - Military Area Operations**: typical long range, long endurance UAV operations in military controlled airspace.

## 3.3 Predicted UAV numbers

### *3.3.1 UAVs by segment & domain*

In Epoch 1, MALE platforms will dominate the market with almost zero BLOS-capable TUAVs. This proportion is set to change into Epoch 3.

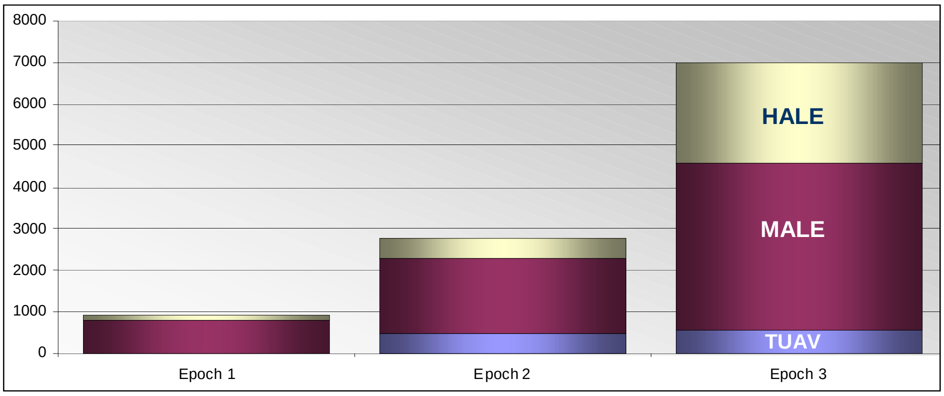


**Figure 3: Global worldwide cumulative UAVs using BLOS by Segment**

In Epoch 1, Military use of UAVs will vastly outnumber Civil uses, but by Epoch 3 (if the regulatory issues are resolved) the situation will be reversed.

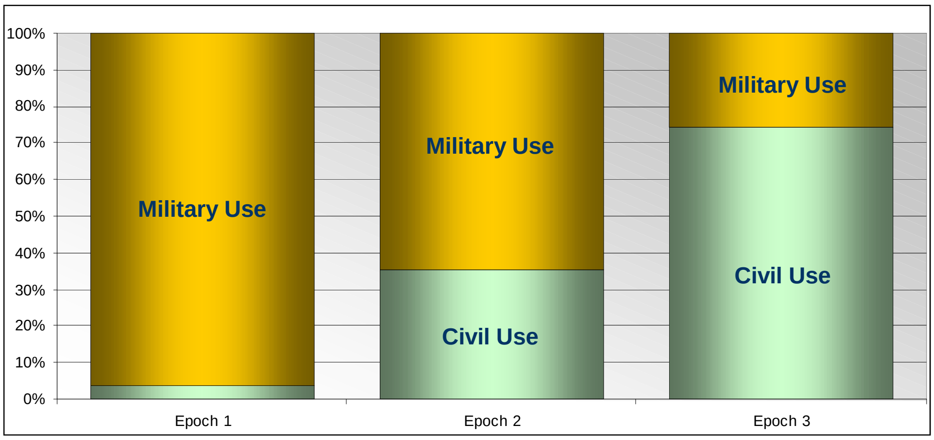


**Figure 4: Global worldwide cumulative UAVs using BLOS by Domain**

### *3.3.2 Canadian and European UAV usage model by scenario*

Based on the market data, the assumption made is that 25% of the total UAVs for each region are operating in a given phase of a scenario.

<u>Scenario 3 specific: Canadian and European international civil usage</u>
To enable further analysis of potential satellite usage of Canadian and European BLOS-capable UAVs outside of the European region, an assumption based on existing air routes has been made.

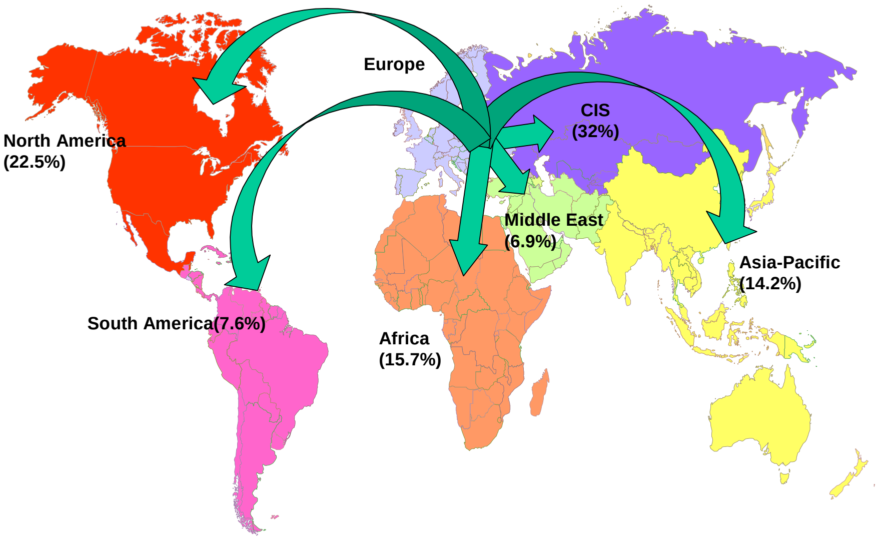


**Figure 5: UAV BLOS routes to/from Europe**

<u>Scenario 4 specific: European and Canadian military usage outside of the region</u>
In order to incorporate the fact that military UAVs are likely to be used outside the region in which they were procured, an assumption has been made on potential areas of tension risk.

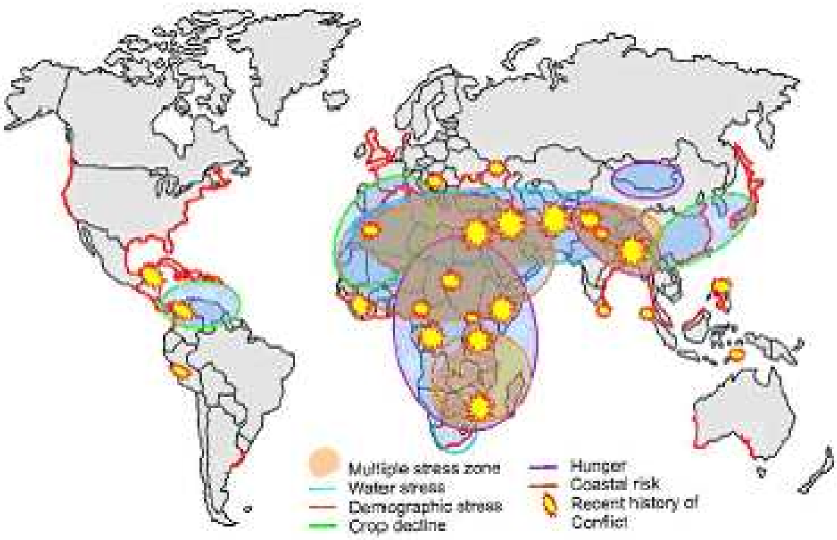


**Figure 6: Map of potential multiple stress zones**

Table 2 details the total number of BLOS-capable UAVs operating <u>over a given region</u> <u>at any given time</u> <u>for Canada and European nations</u> for each of the three epochs.

| | Epoch 1 | | | Epoch 2 | | | Epoch 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | TUAV | MALE | HALE | TUAV | MALE | HALE | TUAV | MALE | HALE |
| US | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 11 | 4 |
| Canada | 0 | 3 | 0 | 4 | 17 | 0 | 4 | 62 | 11 |
| South America | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | 2 |
| Europe | 0 | 26 | 5 | 17 | 76 | 26 | 19 | 187 | 94 |
| Africa | 0 | 4 | 1 | 2 | 8 | 2 | 2 | 17 | 7 |
| Asia Pacific | 0 | 4 | 1 | 2 | 8 | 2 | 2 | 16 | 7 |
| Middle East | 0 | 4 | 1 | 2 | 7 | 2 | 2 | 12 | 6 |
| CIS | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 16 | 5 |
| **Total** | **0** | **41** | **8** | **27** | **116** | **32** | **32** | **325** | **136** |

**Table 2: Canadian and European BLOS-capable UAVs flying simultaneously by region of operation**

# 4. UAV NEEDS & CONSTRAINTS

## 4.1 Communication needs

As illustrated on the following figure, UAV communications encompass:

- ATC communications (voice & data)
- UAV specific safety communications
- Payload communications

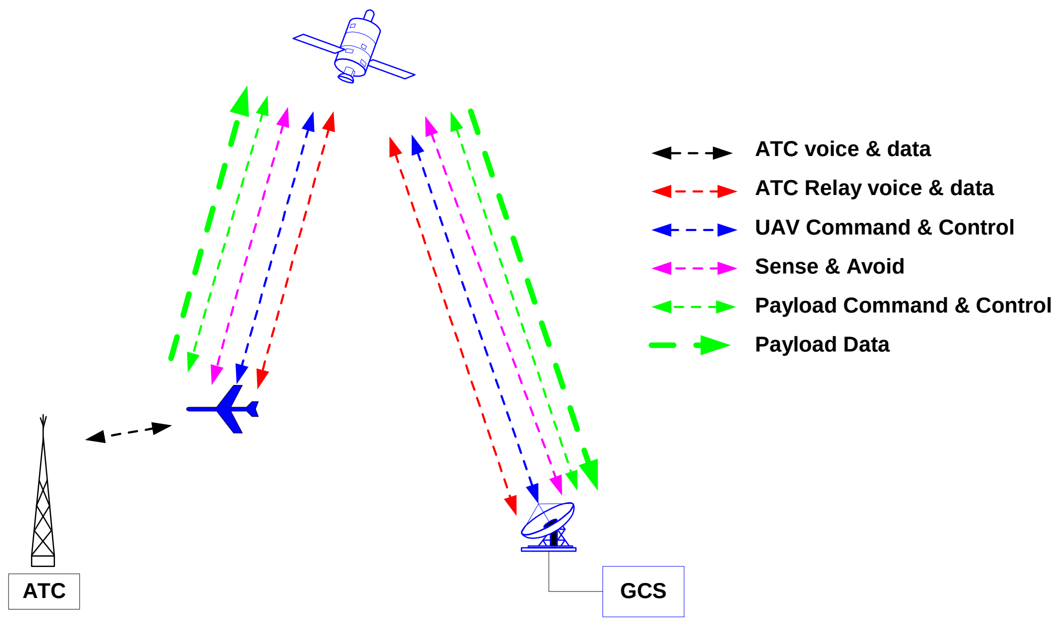


**Figure 7: UAV communications overview**

UAV specific safety communications represent 20-30 kbps in both directions distributed as follows (UAV to GCS: 26 kbps, GCS to UAV: 17 kbps):

- ATC Relay Voice + Data (10 kbps in both directions): COCR (Communications Operating Concept and Requirements for the Future Radio System) defines very high availability requirements (99,99975%)

- UAV Command & Control (6 kbps in both directions): messages definition is mainly based on STANAG 4586
- Sense & Avoid:
  - o UAV to GCS (10 kbps): collected data (e.g. ADS-B) + S&A status
  - o GCS to UAV (1 kbps): S&A configuration

Payload communications include:

- Payload Command communications (around 1 kbps): messages sent by the ground station to the UAV to properly set sensors on board UAV and perform mission applications.
- Payload Control communications (around 1 kbps): messages sent by the UAV to the ground station carrying information about payload status as for example the mode of operation or measured values regarding satellite terminal equipment and sensors parameters.
- Payload Data communications: sensors data (e.g. high-definition imagery, full motion video, …) sent by the UAV to the ground station. Typical UAV payloads are:
  - o EO (Electro-Optical) / IR (Infrared)
  - o Radars : SAR (Synthetic Aperture Radar) , MTI (Moving Target Indicator), ISAR (Inverse SAR)
  - o ESM: Electronic Support Measures
  - o SIGINT: Signals Intelligence
  - o Communication relay

  The average data rate depends on the type of payload being used, the sensor resolution, the structure of the data being transmitted and the mode of operation. Several data reduction processes can be used (video/image compression, data compression, dynamic compression, automatic interest area detection). Average data rates considered in Epoch 3 are depicted on the following figure depending on the family of applications.

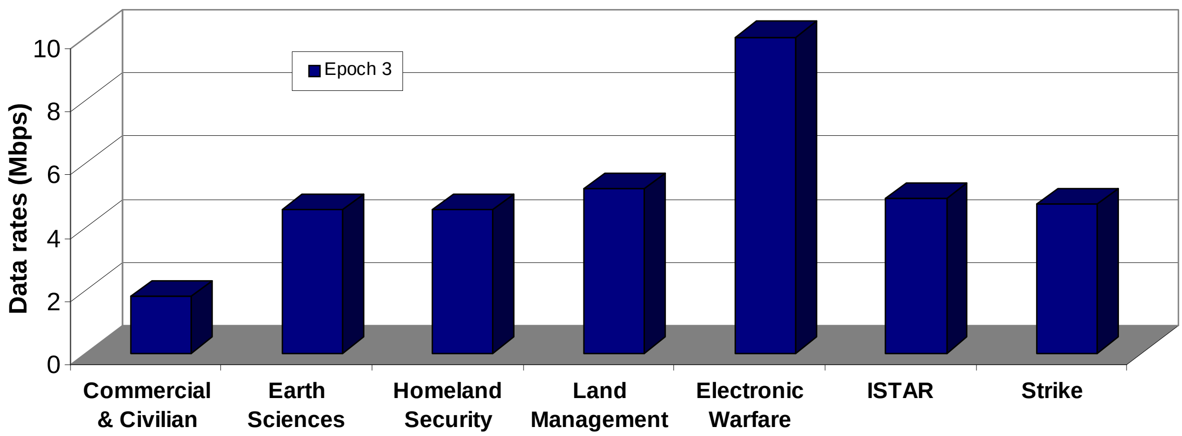


**Figure 8: Average data rates by family of missions**

## 4.2 UAV Terminal

Each UAV segment has limitations in terms of SWAP (Size Weight And Power). Following maximum characteristics are considered:

- Payload communications:
  - TUAV: 45 cm dish antenna, 40 kg for the overall communication system
  - MALE: 90 cm dish antenna, 100 kg for the overall communication system
  - HALE: 130 cm dish antenna, 200 kg for the overall communication system
- Safety communications:
  - 10-20 cm patch antenna, 5 kg for the overall communication system

# 5. SPECTRUM & REGULATORY ASPECTS

## 5.1 Spectrum for safety communications

UAS are aircraft in nature and frequency bands allocated to the Aeronautical Mobile Satellite Service ("AMSS") are of interest for these systems. In addition, Command, Control and Communications ("C3") of UAS relate to "safety of flight" as soon as the Unmanned Aircraft intends to fly in a non-segregated airspace with traditional air traffic. In this case, civil aviations are expected to maintain the safety and regularity of flight of all types of aircraft and require additional UAS features for that purpose, e.g. certification, interoperability and the use of "protected" spectrum. ICAO and other authorities consider that this implies "*that allocations used, in particular, for UAS command and control, ATC relay and sense and avoid in non-segregated airspace are in the AM(R)S, AMS(R)S and/or ARNS".* The following options can be thus envisaged:

- L-band (1.6/1.5 GHz) provides 10 MHz of AMS(R)S in both directions, growing demand for co-frequency MSS raises difficulties in accessing the spectrum despite AMS(R)S priority status, long haul in-orbit experience
- 5GHz band provides >60 MHz of AMS(R)S making an attractive option once sharing with the Microwave Landing System is demonstrated, limited in-orbit experience

UAS flight in segregated airspace, as well as derogatory UAS flight in non-segregated airspace, may rely on generic MSS allocations.

## 5.2 Spectrum for payload communications

Frequency bands allocated to Mobile Satellite Service ("MSS") are convenient to UAS payload communications. For reasons of antenna size, available bandwidth and in-orbit congestion, higher frequencies are likely preferable than lower ones to enable UAS mission data links with "broadband like" data rates. The following MSS frequency range can be thus considered:

- X-band (8/7 GHz) : 125 MHz of MSS allocated, long-haul usage and main focus on NATO applications
- Ku band (14/11 GHz) : some hundreds MHz of MSS uplinks allocated (depending on the geographical area), long haul usage but the band is nearing congestion in practise
- Ka band (30/20 GHz) : 1500 MHz of MSS allocated among which 2/3 have main focus on NATO applications, the band is under expansion
- Q/V band (40-50 GHz) : wide bandwidth with limited experience

## 5.3 Applicable standards

As of today, standards and regulations applicable to UAV safety communications are relatively limited and almost exclusively from the military domain, and more specifically from NATO. It is worth mentioning:

- NATO Standardization Agreement (STANAG) 4586 (standard interfaces of UAV control system for NATO UAV Interoperability): it is aimed at military use but there is no civilian equivalent. As an example, it is used as the core part of the ASTRAEA standardization activities. It mainly specifies the messages to be exchanged between the UAV and the ground segment. The safety communication system (C2, S&A, ATC relay) itself is not specified. GCS to UAV communications are pretty much programme specific.
- USAR (UAV Systems Airworthiness Requirements): originally from France, it has been integrated within NATO standards, as STANAG 4671. it includes some requirements, mainly qualitative, on the communication system.

Standards applicable to UAV payload communications are more numerous. They come from the military environment in the context of NATO, under the STANAG umbrella, and Military Standard (MIL-STD) under the MIL-STD-188 umbrella, related to telecommunications and particularly the MILSATCOM group.

# 6. SATELLITE MARKET SURVEY

An analysis, from a satellite market perspective, on how satellites can support UAS needs have been carried out. Key conclusions are as follows:

- In Epoch 1, Ku-band systems are by far the most prevalent BLOS systems installed on UAVs (e.g. Global Hawk and Predator). They rely on commercial satellites. Not used at the beginning of the period, Ka-band is expected to significantly grow in terms of units along the epoch supported by many Ka-band satellite systems both commercial and military to be launched during the period.
- In Epoch 2, although Ku-band still represents the largest part of the demand associated to payload communications, Ka-band and, to a lower extent, X-band grab an increasing part of this demand. Ku-band demand is expected to be served by both commercial and military capacity due to the deployment of dedicated military Ku-band hosted payloads or satellites. Although Ka-band capacity is still mainly from Ka-band military satellites, Ka-band commercial satellites represent a growing part (25%).
- In Epoch 3, the trend observed in Epoch 2 is assumed to be reinforced, Ka-band and X-band demands overtaking Ku-band demand. Ka-band is enabled on small UAVs by improved links and smaller sized equipments.

# 7. PRELIMINARY COMMUNICATION SYSTEM DESIGN

## 7.1 Introduction

In this study, it is assumed that safety communications and payload communications are based on two different communication systems. This assumption relies on the following statements:

- Safety communications are between the UAV and the GCS while payload communications are between the UAV and the GDT. Both ground entities may not be collocated.
- It is likely that safety communications will have to rely on an AMS(R)S spectrum, which is not sufficient for payload data
- The certification of the communication system(s) will be a complex process and will be different for safety communications and payload communications.

## 7.2 System requirements

System requirements for safety and payload communications are summarized on the following figure. They are derived especially from the UAV market survey, the identification of UAV needs and constraints and the analysis of spectrum and regulatory aspects. On top of these sources, additional requirements are considered regarding design concepts (scalability, modularity, flexibility, interoperability) and management and governance constraints. Finally, risk and cost aspects are as well integrated.

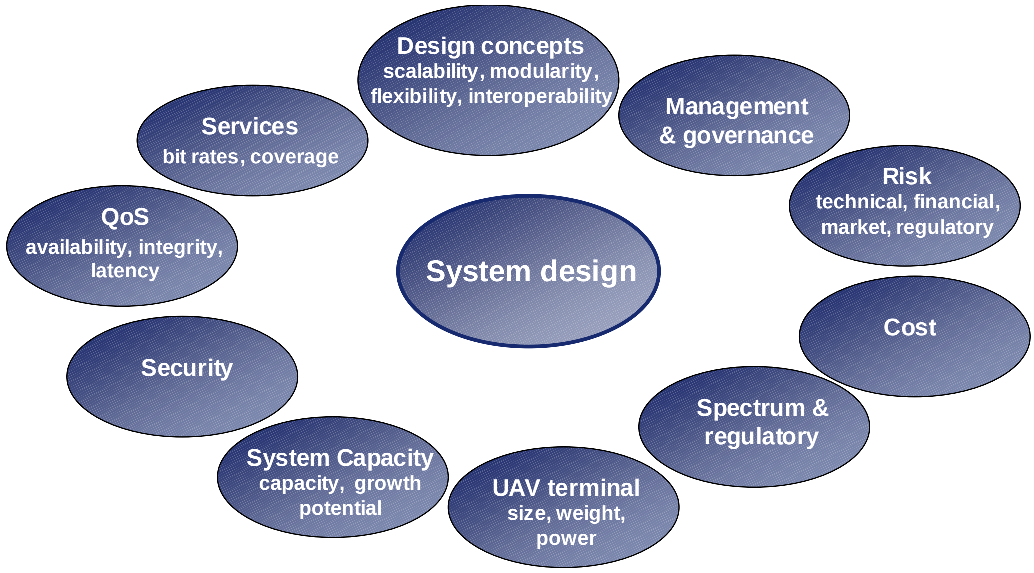


**Figure 9: System requirements for safety communications**

## 7.3 Safety Communications

### *7.3.1 Reference architectures*

Six reference architectures have been considered:
- Architecture based on Artemis for a demo mission
- Architecture based on Inmarsat & MTSAT
- Architecture based on Iridium
- Hybrid architecture (Inmarsat + Iridium) to achieve better availability performances
- Architecture based on IRIS
- Dedicated system at 5GHz

All these solutions offer safety oriented services, especially aeronautical services. They operate, at least partly, on an AMS(R)S band.

The architectures based on Inmarsat and/or Iridium are short term options while the dedicated system at 5GHz is a medium to long term option. Artemis could be envisaged for a demo mission.

### *7.3.1.1 Hybrid architecture*

An architecture based on either Inmarsat or Iridium is likely to not provide sufficient performances in terms of availability. A possible option is then to consider a hybrid architecture combining Inmarsat and Iridium:

- Inmarsat: Swift Broadband with low gain antenna (under study, 25 kbps, aims at being certified as a safety aeronautical service)
- Iridium: Multi-link (N x 2.4 kbps) through ML-PPP protocol

The proposed architecture is presented below. The concept is similar to the one used today between the narrowband link and the wideband link (e.g. Global Hawk). Data are sent on both links in parallel and recombined at application or transport layer

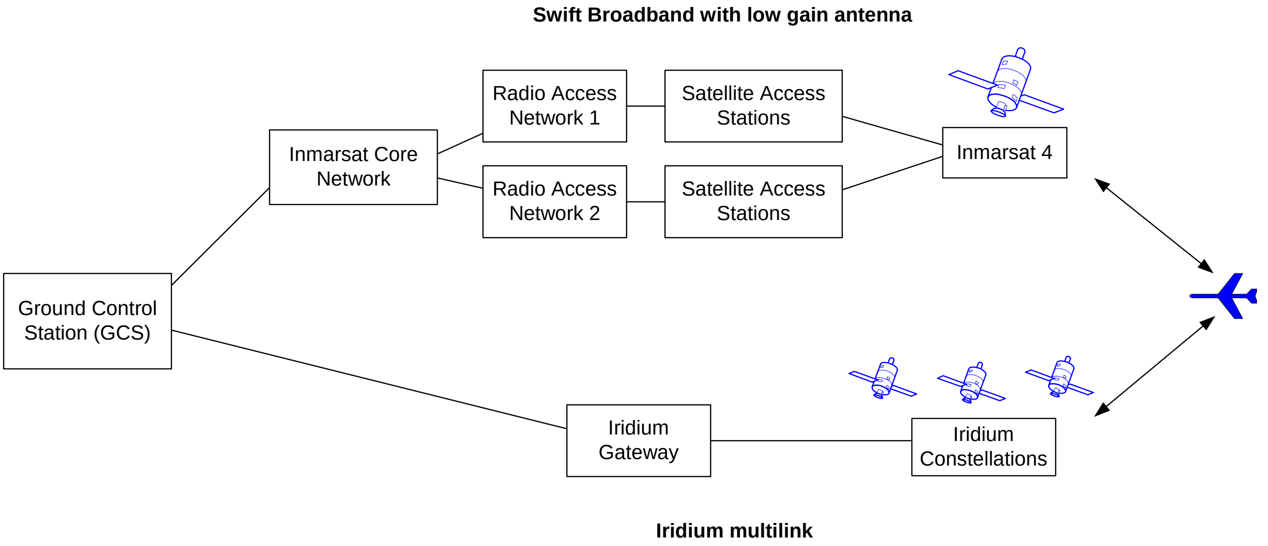


**Figure 10: Inmarsat/Iridium hybrid architecture**

### *7.3.1.2 Architecture based on IRIS*

The IRIS communication system will offer safety aeronautical services, achieving high QoS performances. It could be envisaged then to reuse IRIS for UAV communications. However, IRIS is designed for low data rates services (ATS and AOC) and for a limited capacity. Reusing IRIS would thus require a modification of the system (waveform and possibly satellite payload) to meet UAV needs.

### *7.3.1.3 Dedicated system at 5GHz*

Another option consists in deploying a dedicated solution. It is quite likely that UAS safety communications in non segregated airspace will have to be conveyed using a safety aeronautical spectrum, i.e. an AMS(R)S spectrum, namely the L band or the 5 GHz band. For capacity purposes, only the 5 GHz option is envisaged in this study.

The general architecture is presented on the following figure. The satellite transparently relays user data (S&A, $C^2$ and ATC relay) and network management messages or from the UAV through a 5 GHz link. A full redundancy is considered to achieve high availability performances.

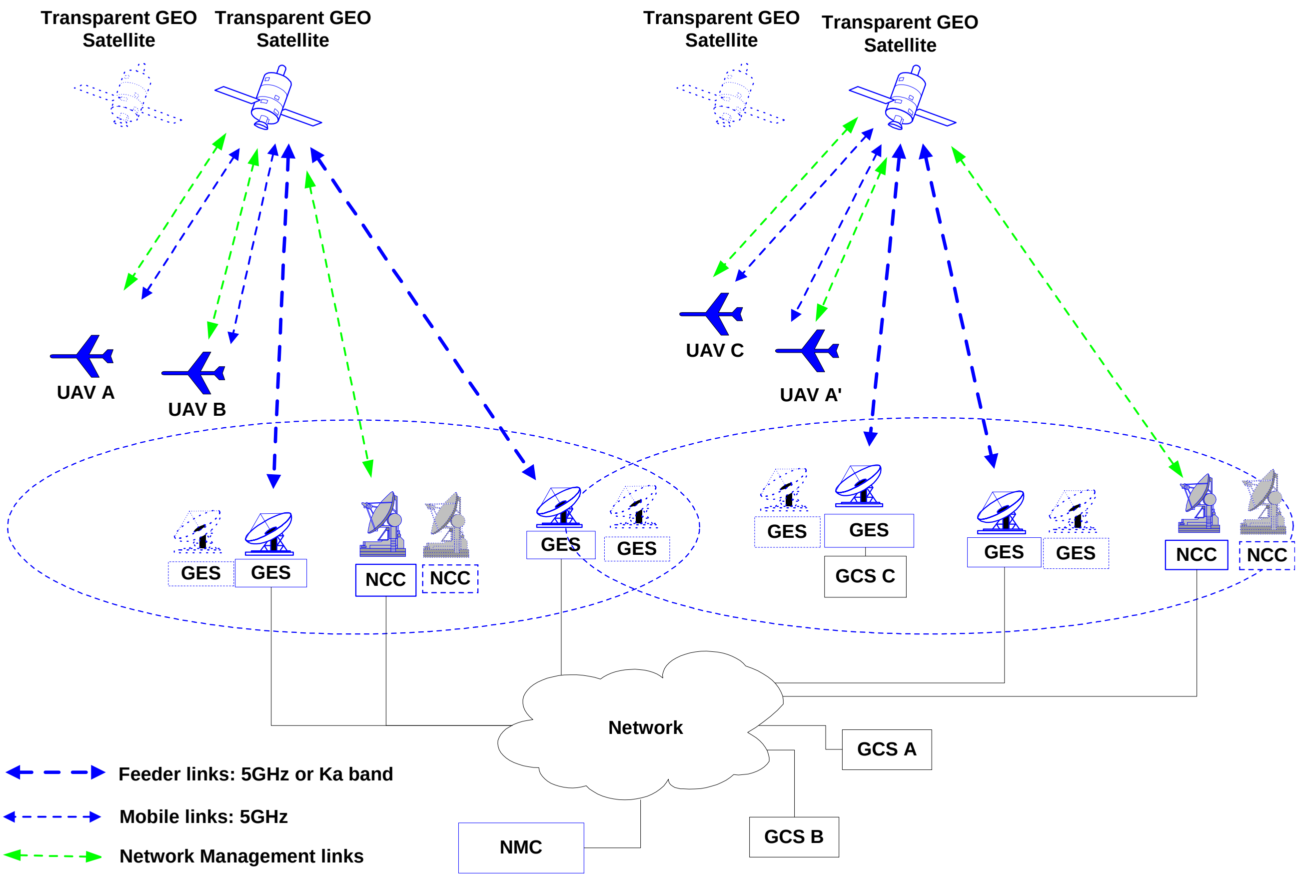


**Figure 11: Dedicated system at 5GHz – general architecture**

## *7.3.2 Trade-off*

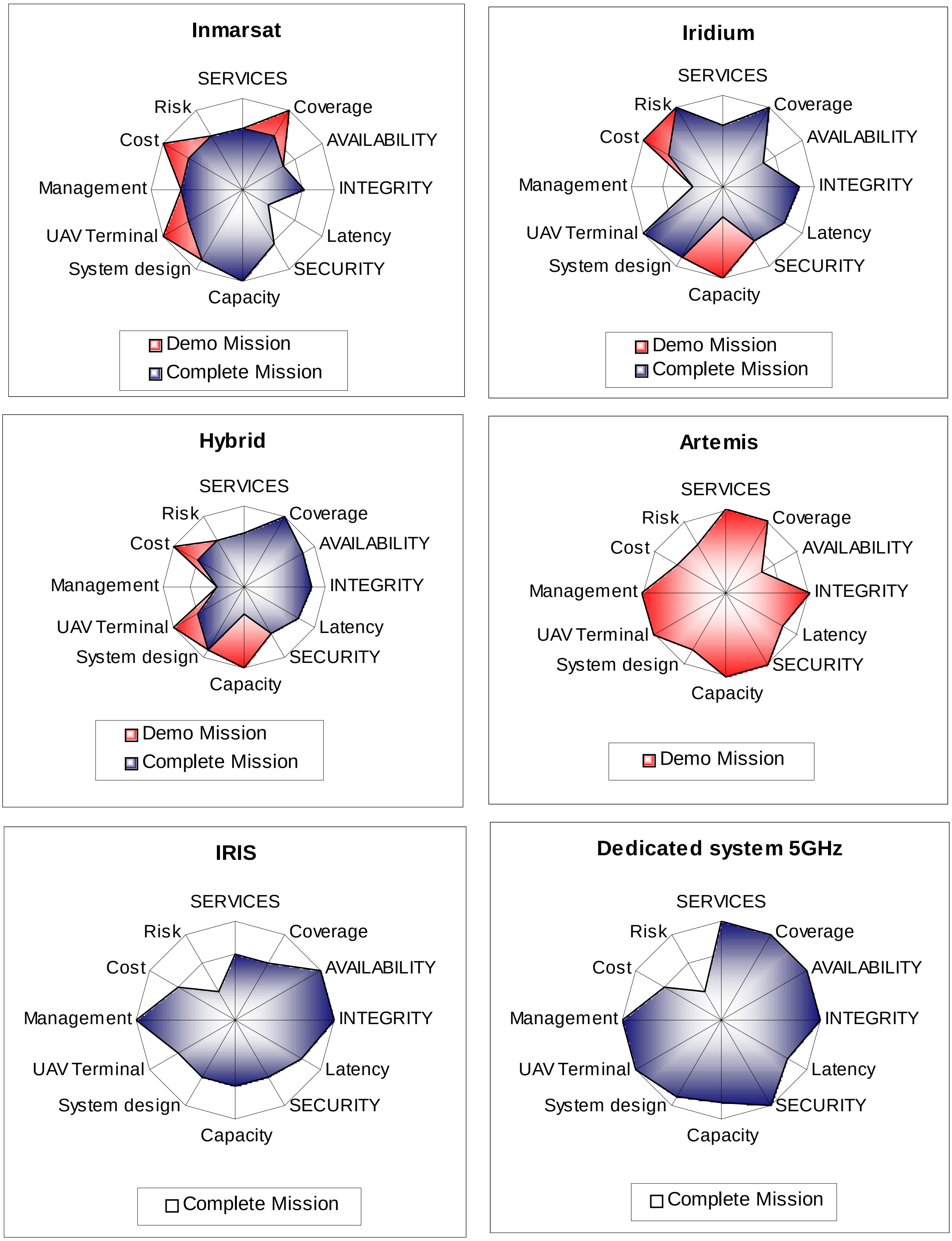


**Figure 12: Synthesis by solution**

This trade-off analysis leads to the following conclusions:

- The architecture based on Artemis and on the hybrid architecture rank first for a demo mission. However, the architecture based on Artemis is not compatible with availability requirements due to the not redundant space segment. As a consequence, an hybrid architecture combining, on one hand, Artemis and, on the other hand, Iridium or Inmarsat has to be considered.
- Despite the higher risk, an architecture based on a dedicated system gets the best score for the complete mission.
- The architecture based on IRIS reaches a good score but such an option would require significant changes on the IRIS nominal architecture, which may be considered unlikely considering the complexity of the program.
- The architecture based on Iridium and the hybrid architecture get good scores for the complete mission. However, the architecture based on Iridium is weak on capacity and availability requirements, which can be considered as mandatory. The hybrid architecture makes it possible to achieve a better availability but is limited in terms of capacity. Moreover, both options rely fully or partly on a non-European system.
- The architecture based on Inmarsat is ranked last mainly because of QoS performances.

As a conclusion, the following roadmap can be derived:

- **Demo mission**: hybrid architecture combining Artemis satellite and Redu control station with Inmarsat or Iridium
- **Short term**: hybrid architecture combining two existing space segments, Inmarsat & Iridium
- **Medium to long term**: dedicated system at 5GHz

## 7.4 Payload communications

### *7.4.1 Reference architecture*

The general architecture is represented on the following figure. The space segment relies on commercial GEO satellites (e.g. Eutelsat Atlantic Bird 2 in Ku-band or Eutelsat Hot Bird 6 in Ka-band and Ku-band).

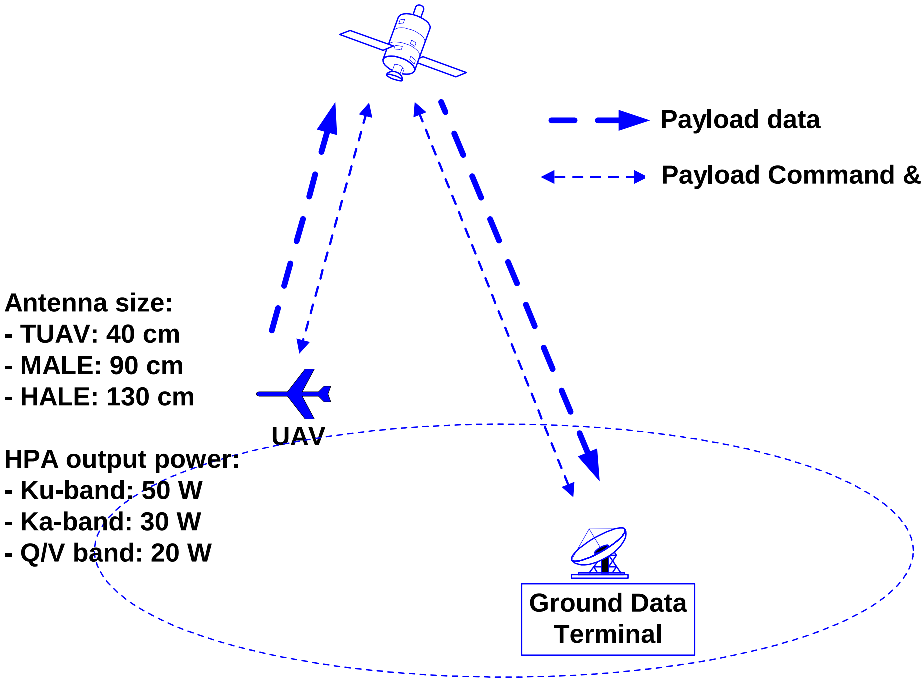


**Figure 13: Reference architecture for payload communications**

The following three frequency bands are considered (X-band not considered due to its exclusive military usage):

- Ku-band: most commonly used on UAV today but high load
- Ka-band: evolution of satellite communications as a consequence of Ku-band congestion, commercial offer will expand
- Q/V band: may be envisaged in the future as an alternative for UAV applications

Following tables report the maximum achievable throughputs depending on the frequency band and on the UAV segment. UAV transmitted powers have been assumed to be equal to 50 W, 30 W and 20 W for respectively Ku-band, Ka-band and Q/V band. These values correspond to current state-of-the-art product characteristics.

| Max achievable throughputs (DVB-S) Max = 13 Mbps | Ku-band | Ka-band | Q/V band |
|---|---|---|---|
| **TUAV** | 2.5 Mbps | 1 Mbps | <1 Mbps |
| **MALE** | 13 Mbps | 5 Mbps | 2.5 Mbps |
| **HALE** | 13 Mbps | 13 Mbps | 5 Mbps |

**Table 3: Maximum achievable throughputs**

Thus, during Epoch 1, the current technology is ready for supporting all expected BLOS UAV segments, i.e. MALE and HALE UAVs. Starting from Epoch 2, a part of TUAV are expected to rely on BLOS capabilities. However, as of today, TUAV performances may not be compatible with all foreseen TUAV applications.

### *7.4.2 Trade-off*

Ku-band and Ka-band commercial satellites associated state of the art satellite terminal COTS can offer sufficient data rates, except for some TUAV applications. Ku-band is the most used option as of today but is threatened by a congestion situation. Ka-band appears thus to be the best mid to long term option, once commercial Ka-band products are widely available. Such a solution could be based on EDRS (European Data Relay Satellite) Ka-band payload.

As a conclusion, the following roadmap can be derived:

- **Demo mission**: use of Artemis satellite and Redu control station
- **Short term**: use of existing constellations, esp. commercial satellites (e.g. Eutelsat in Ku-band)
- **Medium to long term**: use of EDRS (European Data Relay Satellite) Ka-band payload

## 7.5 EDRS requirements

The system analysis carried out for payload communications makes it possible to derive a set of requirements for EDRS, which is currently under definition. These requirements are split into 8 categories:

- Mission
- System
- Airborne segment
- Ground segment
- Space segment
- Payload command link
- Payload control link
- Payload data link

## 7.6 Governance & distribution chain

In addition to UAV users (military or civil), the actors of an European UAV communication system can be listed as follows:

- Communication Service Providers (CSP)
- Satellite Operator (SOP)
- Satellite Owner (SOW)
- Satellite Ground Segment Operator (SGO)

The nature of each actor (military, public or private) is as of today not defined. However, the possible scenarios can be listed. A proposal is presented in the following table.

| | Communication Service Provider | Satellite Ground Segment Operator | Satellite Operator | Satellite Owner | Comments |
|---|---|---|---|---|---|
| **Option #1** | Private | Private | Private | Private | Examples:<br>- Inmarsat Classic Aero (CSP: SITA or ARINC, SGO: gateway operators, SOP & SOW: Inmarsat)<br>- Skynet 5 (CSP, SGO, SOP & SOW: Paradigm) |
| **Option #2** | Public | Private | Private | Private | This model could be used for the architectures based on Inmarsat or Iridium |
| **Option #3** | Public | Public | Private | Private | This model could be used for the architectures based on Inmarsat or Iridium if dedicated gateways are deployed |
| **Option #4** | Public | Public | Public | Public | Example: Galileo (except for CSP, which is not applicable for Galileo) |
| **Option #5** | Private | Private | Private | Public | Example: Skynet 4 |

**Table 4: Possible distribution chains**

## 8. PRELIMINARY NAVIGATION SYSTEM DESIGN

The UAV includes a navigation platform, which is interfaced with the flight management system. This navigation platform, also known as GNSS/INS platform, combines the following functions:

- **Inertial platform** providing acceleration and distance covered (X, Y), Z vertical distance can be provided by Altimetry Radar or Barometric Vertical NAV (Baro VNAV)
- **Gyroscopic platform** providing in real time X, Y, Z attitude
- **GNSS platform** providing X, Y, Z position plus reference time

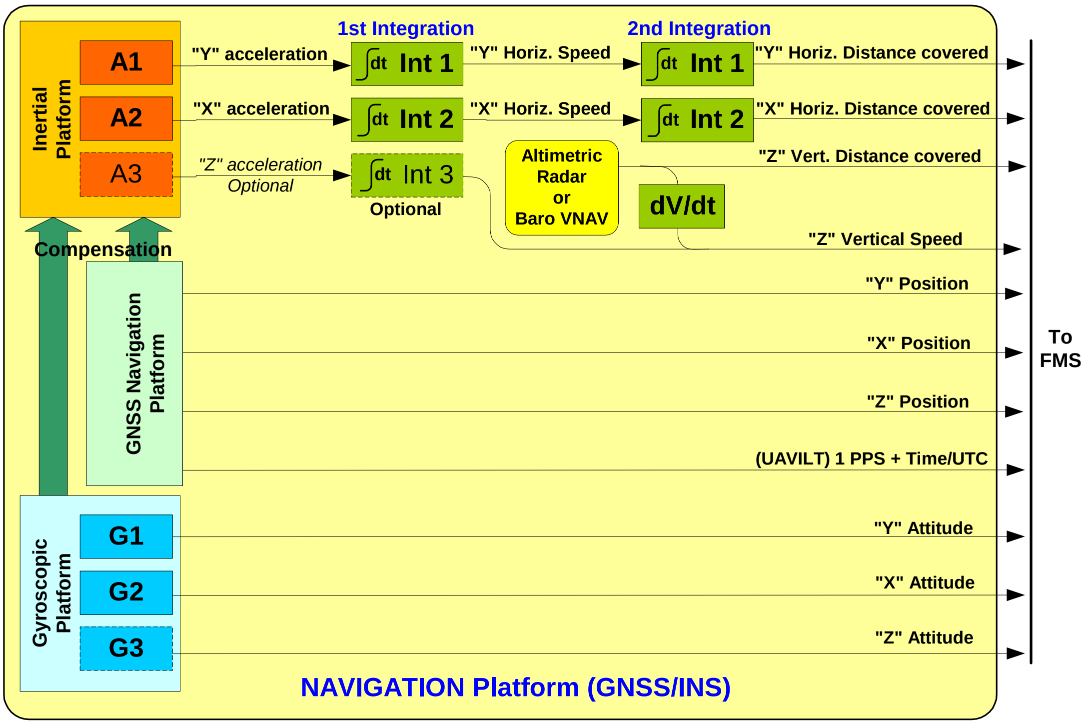


**Figure 14: UAV navigation platform**

GNSS possible configurations depending on the required positioning level are as follows

- Mono-constellation (GPS, GLONASS) mono or dual frequencies
- SBAS: Satellite Augmentation Systems (Wide Area Augmentation): EGNOS, WAAS
- Multi-constellation (GPS, GLONASS, GALILEO)
- GBAS: Ground Based Augmentation Systems (Local Area Augmentation): civil systems or military systems (JPALS: Joint Precision Approach and Landing System)

## 9. CONCLUSION

Satellite communication and navigation systems are an answer to the challenges brought by the expected significant increase in the usage of UAS:

- GNSS signals enable precision navigation, cooperative collision avoidance (ADS-B) and automatic take-off and landing
- The use of today's L-band systems (Inmarsat & Iridium) and COTS through an hybrid architecture is a first step allowing:
    - To provide secure and sustainable communications for C2, S&A and ATC Relay
    - To pave the way to an European dedicated system, e.g. at 5GHz (dedicated satellite or piggy-back)
- Today's broadband satellites (e.g. Eutelsat in Ku-band) can be used to convey high bit rates payload data.
- EDRS, when available, will make it possible to rely on an European system integrating UAV needs in its design and providing a high available capacity.

## 10. FUTURE RELATED ACTIVITIES

The next step is to carry out a demonstration:

- To keep on working out the insertion of UAV within civil airspace, implementing a complete End-to-End scenario (e.g. emergency procedures)
- To test the technical feasibility (e.g. coexistence of the various involved systems, LOS/BLOS handovers, GCS handovers,…)
- To validate performances and position them with regards to requirements (e.g. security and availability aspects)
- To refine the End to End system architecture

## 11. PROJECT CONTACT POINTS

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## 12. LIST OF ACRONYMS

| | |
|---|---|
| ADS-B | *Automatic Dependant Surveillance – Broadcast* |
| AMSRS | *Aeronautical Mobile Satellite (en Route) Service* |
| AMSS | *Aeronautical Mobile Satellite Service* |
| ARNS | *Aeronautical Radio Navigation Service* |
| ASTRAEA | *Autonomous Systems Technology Related Airborne Evaluation & Assessment* |
| ATC | *Air Traffic Control* |
| ATS | *Air Traffic Services* |
| BLOS | *Beyond Line Of Sight* |
| C2 | *Command & Control* |
| C3 | *Command, Control and Communications* |
| COCR | *Communications Operating Concept and Requirements* |
| COTS | *Commercial Of The Shelf* |
| EDRS | *European Data Relay Satellite* |
| EO | *Electro-Optic* |
| ESM | *Electronic Support Measures* |
| FMV | *Full Motion Video* |
| GBAS | *Ground Based Augmentation System* |
| GCS | *Ground Control Station* |
| GDT | *Ground Data Terminal* |
| GES | *Ground Earth Station* |
| GNSS | *Global Navigation Satellite System* |
| GNSS/INS | *Global Navigation Satellite System / Inertial Navigation System* |
| HALE | *High Altitude, Long Endurance* |
| ICAO | *International Civil Aviation Organization* |
| IR | *Infra Red* |
| ISAR | *Inverse SAR* |
| ISTAR | *Intelligence, Surveillance, Target Acquisition and Reconnaissance* |
| ITU | *International Telecommunications Union* |
| JPALS | *Joint Precision Approach and Landing System* |
| LOS | *Line Of Sight* |
| MALE | *Medium Altitude, Long Endurance* |
| MIDCAS | *Mid-air Collision Avoidance System* |
| MIL-STD | *Military Standard* |
| ML-PPP | *Multi-Link Point to Point Protocol* |
| MSS | *Mobile Satellite Services* |
| MTI | *Moving Target Indicator* |
| NATO | *North Atlantic Treaty Organisation* |
| QoS | *Quality of Service* |

| | |
|---|---|
| S&A | *Sense & Avoid* |
| SAR | *Synthetic Aperture Radar* |
| SBAS | *Satellite Based Augmentation System* |
| SBB | *Swift Broadband* |
| SESAR | *Single European Sky ATM Research* |
| SIGINT | *Signals Intelligence* |
| STANAG | *Standardization Agreement* |
| SWAP | *Size Weight And Power* |
| UAV | *Unmanned Aerial Vehicle* |
| UCAV | *Unmanned Combat Air Vehicle* |
| USAR | *UAV System Airworthiness Requirements* |
| WAAS | *Wide Area Augmentation System* |
| WRC | *World Radiocommunications Conference* |

**END OF DOCUMENT**