

# HAPS-TELEO

## (High-Altitude Pseudo-Satellites for Telecommunication and Complementary Space Applications)

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### Executive Summary

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## 1. Introduction

This document is the Executive Summary of the ESA study “High-Altitude Pseudo-Satellites for Telecommunication and Complementary Space Applications”.

The interest for HAPS is increasing in many areas, from military and security to commercial services. On the Telecom side, HAPS are seen as relays to provide Internet services worldwide, and as a possible complement to satellites. On the Earth Observation side, the near-Space location of the HAPS enables new services or may improve the existing satellite ones. From the satellite or from the HAPS market sides, it is important to understand how both systems can offer complementary services, and what the possible synergies between them are. The main objectives of the study have been to identify the Telecom and Earth Observation services where the HAPS system may bring added values in performance or cost, compared to satellite or terrestrial ones, to highlight gaps in HAPS technologies and to propose a development plan and a roadmap to proceed towards an operational service in the next 5 years.

## 2. Telecom services of interest and scenarios

The following HAPS characteristics have been considered as of interest for Telecom services:

- Larger coverage than terrestrial networks, then less ground infrastructure,
- Rapid deployment, scalable deployment,
- Persistence,
- Flexibility,
- Relatively low cost of reconfiguration and maintenance,
- Very small propagation delay,
- Lower CAPEX than a satellite,
- HAPS based networks possibly cheaper than a terrestrial network with a large number of base stations,
- Environmental benefits for solar-powered long endurance HAPS and enabling the replacement of a large number of current ground towers, masts and associated infrastructure having today severe impacts to the landscape.

Given the above HAPS characteristics and advantages, the following services have been considered as interesting candidates allowing offering differential services for the GEO/LEO market and being even competitive to terrestrial solutions:

- HAPS at geographic points outside satellite coverage,
- Ultra broadband with simple user devices,
- Mobility services,
- Direct 4G/5G and/or Cellular Backhauling 4G / 5G,
- Communication bubble for security or emergency forces over an isolated area or as a backup/redundancy of existing infrastructures.

The number of required HAPS varies a lot for the different services scenarios, from 2 for a security communication bubble, to several 10s or 100s for the broadband or backhauling cases.

The required capacity per HAPS varies as well depending on the scenario, from 1 Gbps to 15 Gbps.

### 3. Earth Observation services of interest and scenarios

In many application domains HAPS may face competition with conventional satellite or airborne technology. Hence, in order to create added values the specific capacities of HAPS need to be exploited; i.e.:

- Near real-time data availability,
- Long endurance missions (weeks to months),
- High flexibility in sensor payloads, from optical, infrared, multispectral to radar and SAR ones,
- Local to regional coverage.

HAPS can be deployed either stand-alone or in combination with spaceborne / airborne missions for creating synergies. For instance in combination with Sentinels 1 & 2 the wide area coverage of the satellites allows synergistic views over regions on land or off-shore in order to select most appropriate locations by stratification where the higher spatial and temporal resolution of HAPS can be most efficiently exploited.

The three following scenarios have been considered as the most interesting:

- disaster management, with an example of industrial disaster,
- maritime Traffic Safety and Security,
- Earth Observation Demonstration Capabilities.

The maritime traffic scenario has been selected for the detailed architecture analysis, as considered as challenging regarding the technical aspects, and also as the one for which customers could be already identified and a business model could be made.

### 4. Telecom systems architectures and performances

The frequencies that will be available for HAPS are still under negotiations at ITU working group level (decision expected at World Radiocommunication Conference 2019 (WRC-19), 28 October to 22 November 2019). For broadband services Ka-band, Q-band and V-band are considered. Only the V-band is now available worldwide, however its use was not emphasized in our study, as it is much less efficient as Ka or Q ones. For the LTE cases the terrestrial frequencies were considered, then S-band and lower ones to enable the use of standard smartphones.

The DVB-S2X and DVB-RCS2 air interfaces were considered for the broadband cases and the LTE for 4G/5G scenarios.

The availability of the service, for the link budget aspects, was taken around 99.7%.

The considered HAPS coverages were several tens of kms, in-line with the capacity defined for the missions of interest.

At ground segment level, the requirement for the user terminal of a steering mechanism, to follow the HAPS trajectory, has been analysed. Providing that even for the “low data rate” solution, several Gbps are required with high availability, a steerable user terminal antenna has been considered as mandatory.

A first overview of broadband Ka/Q-band HAPS payloads has been proposed, from the simplest to the most complex:

- Horns on the user side and steerable array gateway antenna,
- Isoflux antenna with large coverage on the user side and steerable dish gateway antenna,
- Multibeam active antenna on the user side and steerable gateway antenna.

For the LTE payload, the proposed architecture involved a mobile base station node, a mono-beam user antenna, and a steerable gateway antenna.

The required capacities have been reached for the most favorable frequency plans, with several beams for the capacities below 5 Gbps. Highest capacities have been reached with multibeam systems, but remain below the 15 Gbps.

For the LTE scenario, based on the preliminary analysis made in the study, the target capacity seems too high for a single HAPS, but more work is required to be able to conclude.

## 5. Earth Observation system architecture and performances

For a maritime surveillance scenario, an operational system design requires the integration of several a priori independent elements:

- At least one but better more HAPS, depending on the area to be surveyed,
- Surveying vessels hovering in the Area Of Interest,
- Airplanes, Helicopters and UAVs,
- Coastal Radar,
- AIS (coastal and on board of satellites and HAPS),
- EO satellites (i.e. Sentinels + 3<sup>rd</sup> party missions such as SPOT, Pleiades, TerraSAR, PAZ, RADARSAT, CosmoSkyMed, ...),
- Central Command with data analysis facilities (i.e. EO data, HAPS data, SIGINT, ...),
- Communication infrastructure including satellites.

As the overall system is rather complex and would have required a detailed analysis beyond the scope of this study, focus has been made on the HAPS component only.

A layer of 13 HAPS has been sized for the defined mission requirements to detect the boats reaching a surveyed line and to cover a region in the surrounding waters of Tripoli, taking into account the on-board HAPS sensors field of views (optical, AIS, infrared, radar).

In order to reach the Near-Real Time surveillance data release, it is mandatory to have on-board HAPS data processing, for instance by extracting vignettes from the images and sending only the relevant data. The ground segment has to analyse capacities for other multi-source data (e.g. from EO satellites and/or intelligence) to characterise situation and release orders (e.g. to move HAPS to a hot spot).

## 6. Role of HAPS conclusion

In conclusion, we believe that, in order to best match the Telecom needs, the HAPS should focus on

the following challenges:

- the CAPEX and OPEX must be low or an interesting OPEX/lease scenario may be proposed, mainly for the commercial services; the security scenario business model enables however some higher costs;
- the capacity provided per HAPS should be of about 10 Gbps;
- the minimum coverage diameter has to be of about 70 km.

For the Earth Observation services, the maritime surveillance has been considered as a service that could enable some commercial business model. However, the service provisioning model is complex to be set up. More detailed analysis is required together with customers to conclude on how a HAPS service can be introduced best, offering synergies with other components of the system (UAVs, helicopters, ships, ...) and how the overall system cost decreases and the overall system performance increases, respectively.

## 7. HAPS platforms industrial landscape and techno gaps

For what concerns the heritage for unmanned platforms for below 100 kg payloads, the Airbus Zephyr is the worldwide leader in terms of industrial capacity and heritage, with a clear roadmap. The airships, in the lighter than air platform family, have the particularities to enable big payloads. Their development status in Europe is less mature than the solar pseudo-satellites one. The flight tests show that no balloon solution offer the endurance performances and flexibility required for the commercial services defined in our study.

The current HAPS platform technology with flight heritage has some difficulties to fit with the Telecom commercial business models for the following aspects:

- Cost: improvements have to be made to decrease the platform cost,
- Capacity: the requirements are high and the current platforms are too much constrained in available payload mass and power.

The Airbus Zephyr line of products has planned developments to fill this gap.

The current Zephyr platform is compatible with many Earth Observation instruments.

## 8. HAPS payloads industrial landscape and techno gaps

The CotS equipment available in the aeronautical market or for Nanosats is of interest for HAPS.

Terrestrial equipment may be used. However, the stratospheric environment is different from the terrestrial one with respect to much lower temperatures as well as high radiation. But it is clearly not as challenging as for space conditions and rather adaptable for the SEU than for aggregated radiations levels.

Suppliers for military aircraft, already provide a wide range of RF equipment. Most of them may be provided (optional) as hermetically sealed for un-controlled environment and already qualified for altitudes up to 60 000 ft.

The Telecom payload equipment having a low TRL are mainly:

- Multibeam antenna, in Ka or Q/V; fixed antenna are less complex to develop, steerable active ones are much more complex, moreover in the considered frequencies,
- High capacity digital payloads, with RF front end in Ka/Q/V bands,
- High capacity eNodeB payloads, antenna and processing parts.

For the ground segment equipment, synergies are possible with the LEO satellite user terminals or gateways, and HTS satellites Q/V gateways under development.

Existing Ka equipment will have to be modified to meet the HAPS Ka frequencies. For the user terminals the challenge will be to have a low cost Ka-band steerable antenna.

For the Earth Observation payloads used in the maritime surveillance scenario, the optical and infrared ones have high TRLs. The lowest TRLs exist for radar, SAR, and Lidar sensors wrt. size, weight and power consumption especially for night time operations.

Communications payloads are also required to downlink the remote sensing data. Here, Near Real Time availability is often required as a key advantage of HAPS in complementing the satellite service. However, here the communications payloads are less complex than the Telecom ones, and Ka payloads below 1 Gbps capacity have high TRLs.

## 9. Roadmap to go for an operational service

The Telecom requirements for commercial or security scenarios are understood and have been analysed together with two customers: Hispasat and Airbus CIS Secure Communications.

Although there is a clear interest on HAPS services from European organisations such as FRONTEX and EMSA (as shown during the HAPS4ESA workshop in October 2017) Earth Observation services need intensive interactions with maritime surveillance operators to better understand how HAPS can complement existing assets (drones, helicopters, surveillance ships, terrestrial AIS) under operational constraints. The analysis of real Concepts of Operations (ConOps) together with end-users will allow to estimate the transfer of the data to a mission center in Near Real Time and back to operating vessels towards an operational communications performance.

The following Telecom services demo roadmap is proposed:

- Demos with a low capacity broadband payload in Ka:
  - Balloon demo to derisk the payload, mainly for stratospheric environment
  - First HAPS demo: dual link with a DVB-S2 gateway and a DVB-S2 user terminal
  - Second HAPS demo: dual link between a gateway and several users, with a DVB-S2 forward link and a DVB-RCS return link
- Direct 4G/5G service demo:
  - Balloon demo for channel propagation measurements
  - HAPS demo

## 10. Conclusion

The HAPS-TELEO study has shown that the HAPS may complement the traditionally deployed satellite-based networks to improve the services offer, for instance for the broadband ones.

In order to succeed, the HAPS+Satellites systems need further industry actions to show a clear technology roadmap leading to a reduced cost of capacity per Gbps. The TELEO study has identified a number of critical building blocks at HAPS payload and platform levels to achieve this target.

We have started to demonstrate the feasibility of achieving a several Gbps payload on a single HAPS through the combination of the following concepts:

- Innovative payload concepts for a high capacity payload with low mass and low power consumption, including a Q-band gateway HAPS payload,
- Low cost steerable ground user terminal in Ka-band,
- Q-band gateway for HAPS,
- System concept allowing a multibeam payload robust to HAPS dynamics and HAPS handovers.

As expected, it has also been demonstrated that the system capacity is strongly linked to the available bandwidth, even more than power, the ITU requests for HAPS band being higher for region 2 than for regions 1 and 3. Significant effort (lobbying and frequency coordination) has been put in place already, so that the necessary spectrum shall be made available when needed. For the direct 4G/5G business case being of high interest as well, the spectrum availability should be further analyzed but the most probable scenario is that agreements with terrestrial operators will be made, or that these services will be provided by terrestrial operators themselves, using their own spectrum.

For Earth Observation services, passive low mass payloads are feasible today with the first generation of HAPS platforms. To enable surveillance services as studied in TELEO, some more complex instruments need to be developed to overcome constraints of cloud cover / bad weather conditions and night-time operations and multi-payloads capability on a single HAPS is required.

Demonstrations will be required for technology de-risking or precursors to operational service:

- Balloons demos should enable modelling the stratospheric propagation channel and de-risking some new payloads,
- HAPS demos should enable the demonstration of service, and the assessment of the operational availability, with a representative ground segment.



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