**FP6-IST-2003-506745 CAPANINA**

**Deliverable Number D03**

# *List of aspects to be experimentally validated*

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| **Author(s):** | Marco Bobbio Pallavicini, Paolo Concari |
| **Participant(s) (partner short names):** | CGS |
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## Abstract:

Deliverable D03 is an output document from the initial activities of Workpackage 4.1, 'System Testbed', started on February the 1st.
It is a preliminary list of the aspects within the CAPANINA study that could potentially be tested and validated through the trial and measurement campaigns foreseen within the project.
The document was completed after taking as inputs, the initial definition of the project goals stated in the technical annex to the contract, the results of the activities during the Kick Off meeting, preliminary exchange of information and ideas with project partners and deliverable document D01 from Workpackage WP1.1.
The goal of the document is to provide an initial guideline evidencing what could be the most significant issues to be experimentally validated in order to demonstrate feasibility and effectiveness of Broadband communications from aerial platforms.
The document shall possibly be updated if and when further issues come to light in the early phase of the project.

Keyword list:
"Tethered Platform", Stratospheric, Balloon, Broadband, Trials, Aerostat,

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# EXECUTIVE SUMMARY

Envisaged broadband services dictate a series of requirements on the architecture of the whole system, including ground and aerial nodes. This report identifies areas where experimental validation will be potentially beneficial.

Aspects identified to be experimentally validated for mm-wave systems include:
- Feasibility and functioning of low power on-board antenna for BFWA.
- Steerable antennas.
- Technical issues for onboard equipment.
- Cellular architecture of service coverage on ground.
- Fade mitigation techniques.
- Internetworking capability, high data rate point-to-point link, broadcasting of high quality video, direct connectivity user-user,
- Propagation channel measurement.
- Fully integrated connection through Stratospheric node.

Aspects identified to be experimentally validated for optical systems include:
- Feasibility of free-space optical high-rate backhaul downlink.
- Propagation channel measurements.
- Effectiveness of acquisition.
- Tracking and steering systems and technical issues for onboard equipment subject to stratospheric environment.

Additionally, integration of different devices within payload bay will be experimentally validated.

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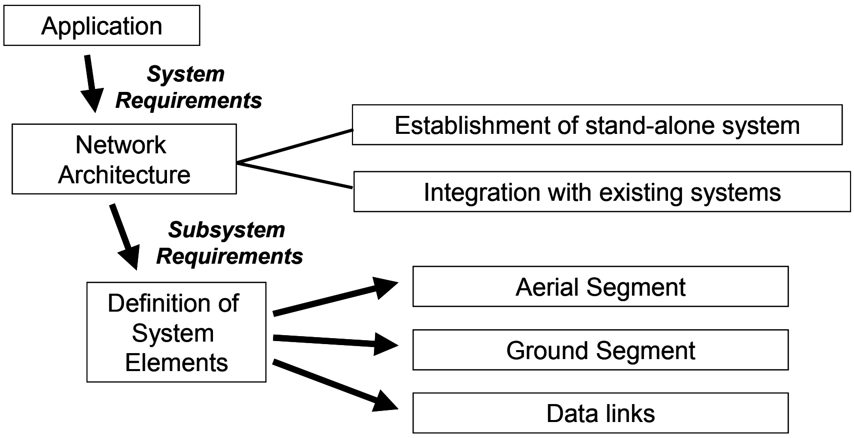
# LIST OF ACRONYMS

| | |
|---|---|
| ATM | Asynchronous Transfer Mode |
| BFWA | Broadband Fixed Wireless Access |
| FEC | Forward Error Correction |
| HAP | High Altitude Platform |
| IP | Internet Access |
| IPL | InterPlatform Link |
| PL | Payload |
| RF | Radio Frequency |
| Tx | Transmission |

# 1. Introduction

The FP6 CAPANINA project is specifically about communications from aerial platforms delivering broadband to a community of users, where 'Broadband' is taken to mean data rates above 256 kbit/s. CAPANINA aims to show how burst data rates of up to 120 Mbit/s can be delivered to fixed or moving users anywhere within the coverage area on ground guaranteed by the aerial node.
The reference points for aerial nodes are high altitude platforms (operated in the lower stratosphere). Test campaign will performed with the aid of stratospheric balloons (17-22km altitude) and of low altitude tethered balloons (300m altitude). Such an approach will ease trial and measurement operations, and will allow at the same time to help further validation of potential use of low altitude aerial platforms.

In parallel with analyses of feasibility and economic competitiveness of establishing a new stratospheric segment for placing Broadband Communication nodes, several aspects have to be pointed out during the study in connection with technical feasibility and costs for a short/medium term development of such an infrastructure.
System development goes through different definition levels, as shown in the following simplified figure.




The process for on-course validation of complex developing system is shall follow the guidelines below.

Envisaged broadband services possibly provided through the aerial system dictate a series of requirements on the architecture of the whole system, including ground and aerial nodes. Associated with the architecture, a lower limit is established for the performance metrics of availability, supported data rates and data processing/routing, with all the constraints arising from the goal of integration with existing communication systems.
Such aspects are studied via analysis and simulations, based on existing systems and models of the new technologies.

The defined architecture sets the lower limit on performance metrics for single elements (aerial nodes, ground nodes, data links within the propagation channel), drawing the baseline for technical/cost trade-off analyses of the involved technologies and subsystems.
Definition and development of elements necessary to build up the system shall be supported by prototyping and experimental validation. Those validations are the goal of the trial and measurement campaign within the project. After having assessed via a suitable test campaign the modelled performance of the system elements, a solid implementation of the whole system architecture and functioning would be possible.

The aim of the following paragraphs is to select those aspects arising from the system study that are significantly critical to require an experimental validation at this stage. This should be done by focusing on the critical targets while avoiding repetitions and dispersion of resources.

Main reference for the following list is document CAP-D01-WP11-BT-PUB-01.

# 2. Validation of mm-wave systems

### *2.1 Feasibility and functioning of low power, low weight, low cost on-board antenna for BFWA*

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|---|---|
| **Description** | Develop and test breadboard (reduced or in its entirety) of the studied antennas, representative of performance, weight and power figures. |
| **Operational issues** | Antennas will be assessed while verifying communication links during preliminary partial tests (in laboratory or through low altitude aerial support experiments). |
| **Main results** | Performance assessment of antennas and compatibility with the aerial platform and cost figures. |
| **Candidate systems for testbed implementation** | Laboratory<br>Tethered balloon |

### *2.2 Steerable antennas*

| | |
|---|---|
| **Description** | Demonstration of different systems developed for mechanical, electronic, and mechatronic beam steering. |
| **Operational issues** | Easy-to-display aerial supports (e.g., low altitude tethered balloons) would allow trials on steerable on-board antenna systems, in order to verify the ability of maintaining directional links through real-time interaction with information acquired about the platform attitude (program track), or via integrated auto-tracking capability of the antennas themselves. |
| **Main results** | Demonstration of technical feasibility of low cost, low power consumption, low weight automatic tracking and pointing system for onboard antenna aimed at maintaining the datalink.<br>Test results could also potentially be applied to Interplatform Links (IPL). |
| **Candidate systems for testbed implementation** | Laboratory<br>Tethered balloon |

### *2.3 Technical issues for onboard equipment subject to stratospheric environment*

| | |
|---|---|
| **Description** | Demonstration of the robustness and of proper functioning of the overall communication subsystem (e.g., RF, baseband equipment) at high altitude environmental conditions (low temperature, low pressure, high radiation, monatomic oxygen, ozone). Demonstration of capability of sustaining environmental transitories during climb and descent to designated altitude (outgassing, temperature gradient, icing). |
| **Operational issues** | Proper functioning of the aerial equipment will be tested by experiencing the real environment during climbing and stationing at designated altitude. Significant parameters will be monitored during flight mission if necessary. |
| **Main results** | Proper design of the onboard equipment for stratospheric operations. |
| **Candidate systems for testbed implementation** | Laboratory<br>Stratospheric balloon |

## 2.4 Cellular architecture of service coverage on ground

| | |
|---|---|
| **Description** | Deliver cellular architecture coverage on ground by forming multiple beams. |
| **Operational issues** | Multibeam PL antenna should be operated onboard the platform, while user terminals on ground can access the system from different cells. |
| **Main results** | Ground area coverage of the service and effectiveness of the cellular architecture,<br>Interference figures,<br>Accessibility of the user terminals, |
| **Candidate systems for testbed implementation** | Tethered balloon |

## 2.5 Fade mitigation techniques

| | |
|---|---|
| **Description** | Demonstration of different methods for automatic fading protection.<br>Receivers are implemented with received-power monitoring system, integrated with adaptive control mechanism to command real-time counteractions.<br>*Adaptive power control*: the system maintains Tx power to the minimum level necessary to provide desired margin; when fading is detected, request for increase in power is forwarded to Tx node (dynamic system).<br>*Adaptive FEC* (Forward Error Correction): the system enables the FEC code rate to be modified.<br>*Adaptive Modulation*: the system allows modulation type to be changed in order to offer increased resilience to fading.<br>*Adaptive rate*: the system would allow the data rate (hence the bandwidth) to be reduced for the came carrier power. |
| **Operational issues** | The demonstration of such methods would require co-operation of the modems at both sides of the connection.<br>Some examples of the methods could be demonstrated on a point-to-point connection under conditions of real fading (rain, fog) with a fully implemented automatic system.<br>Alternatively the sole adaptive system effectiveness could be demonstrated, by manually giving the activation command through a parallel channel (e.g. fibre optic for the tethered balloon).<br>In case of unavailability of affordable systems for testbed implementation, a simulation approach could be adopted. |
| **Main results** | Demonstration of effectiveness of developed methods and systems for protection against fading.<br>Evaluation of the impact of fading control on the applications. |
| **Candidate systems for testbed implementation** | Tethered balloon |

## 2.6 Internetworking capability

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|---|---|
| **Description** | Verify up to application layer the capability of internetworking (interface between different protocol solutions, encapsulation of IP datagrams within ATM cells, secure connections). |
| **Operational issues** | Internetworking capabilities will be validated mostly by network emulation. Possibly testing of different options through real communication chain could be performed. |
| **Main results** | (See description) |
| **Candidate systems for testbed implementation** | Tethered balloon (TBC)<br>Stratospheric balloon (TBC) |

## 2.7 High data rate point-to-point link

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|---|---|
| **Description** | Verify the modelled high data rate link using the available onboard and ground antennas through a simple point-to-point communication at predefined frequency and modulation format(s). Verify the link budget.<br>Ground Station - HAP, uplink and downlink.<br>User Terminal – HAP, uplink and downlink. |
| **Operational issues** | Data link should be assessed in conditions representative of design, which means significant stability figures for the aerial platform, displacement angles between terminals according to system definition, proper power feeds. |
| **Main results** | Assessment of the performance of the antennas (ground and onboard).<br>Robustness of the link in presence of aerial platform movement. |
| **Candidate system for testing** | Tethered balloon<br>Stratospheric balloon |

## 2.8 Broadcasting of high quality video

| | |
|---|---|
| **Description** | Delivery of BFWA through the aerial node at bursts rates of up to 120Mbit/s (video terminal providing high quality content directly to the HAP via uplink and broadcasted to ground users). |
| **Operational issues** | One or more user terminals within the coverage area on ground receiving broadcasted video. Data could be either sent from the Hub to Hap and real-time broadcasted, or previously uploaded on the HAP and simply broadcasted. |
| **Main results** | Ground area coverage of the service.<br>Accessibility of the user terminal. |
| **Candidate systems for testbed implementation** | Tethered balloon<br>Stratospheric balloon |

## 2.9 Direct connectivity user-user

| | |
|---|---|
| **Description** | Verify the possibility of data exchange between two user terminals without passing through the Hub. |
| **Operational issues** | Communication test through HAP, between two user terminals within the coverage area on the ground. |
| **Main results** | User to user connectivity. |
| **Candidate systems for testbed implementation** | Tethered balloon |

## 2.10 Propagation channel measurement

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|---|---|
| **Description** | Significant reference conditions of the propagation channel could be measured in order to validate some aspects of the models developed for channel simulation. |
| **Operational issues** | Propagation measurement through multi-element array for simultaneous data capture, verification of effects of calculated propagation impairments.<br>Those measurements could be done for significant reference conditions, and results compared with developed models. |
| **Main results** | Validation of some aspects of the propagation channel models |
| **Candidate systems for testbed implementation** | Tethered balloon<br>Stratospheric balloon (TBC) |

## *2.11 Demonstration case-study: fully integrated connection through Stratospheric node*

| | |
|---|---|
| **Description** | Demonstration of simplified service involving Hub, HAP and user terminal(s). |
| **Operational issues** | The simplest implementation for trial (likely to be followed for trial-2) is a single beam transparent transponder. PL would be a Ka band transponder connected to a single antenna and feed structure via suitable filters. |
| **Main results** | Full validation of a real broadband connection through stratospheric platform under design conditions. |
| **Candidate systems for testbed implementation** | Stratospheric balloon |

# 3. Validation of optical laser communication systems

## 3.1 Feasibility of free-space optical high-rate backhaul downlink

| | |
|---|---|
| **Description** | Verify modelled link (high data rate) using developed onboard and ground systems through a simple point-to-point downlink communication at predefined frequency and modulation format. Verify the link budget. |
| **Operational issues** | Data link will be assessed at lower altitude at first, in order to validate communication terminals and modulation techniques, free from significant channel dispersion problems and from challenging pointing issues (big divergence transmitter onboard). |
| **Main results** | Assessment of functionality of terminals (ground and onboard), and of modulation techniques.<br>Robustness of the link in presence of aerial platform movement. |
| **Candidate systems for testbed implementation** | Tethered balloon |

## 3.2 Propagation channel measurements

| | |
|---|---|
| **Description** | Assess channel viability (atmospheric impact) for downlink from HAP at designated operating altitude. Verify the amount of attenuation, divergence and distortion of the optical beam due to atmospheric turbulence and due to density and humidity gradients. |
| **Operational issues** | Assess the data link and measure beam attenuation, dispersion and distortion on ground for downlink from designated altitude. |
| **Main results** | Viability of atmospheric channel for long distance free-space optical data links. |
| **Candidate systems for testbed implementation** | Tethered balloon<br>Stratospheric balloon |

## 3.3 Effectiveness of acquisition, tracking and steering systems

| | |
|---|---|
| **Description** | Demonstrate the ability of developed systems to perform the proper tracking and steering of terminals in order to maintain the optical data communication link. |
| **Operational issues** | Onboard transmitter and ground receiver (telescope) will keep themselves in view by acquiring each other's relative positions, using precise tracking information and consequent pointing. The optical system is possibly integrated by RF-GPS data link in order to simplify pointing. After an initial check, the acquisition, tracking and steering system will be assessed during the stratospheric communication/channel verification test campaign. |
| **Main results** | Feasibility of cost effective solutions for acquisition, tracking and steering systems for optical communication systems (particular attention is paid to the aerial onboard device).<br>Mutual tracking capabilities between two aerial terminals could also be demonstrated, for verifying possible implementation of Interplatform links (IPL). |
| **Candidate systems for testbed implementation** | Tethered balloon<br>Stratospheric balloon |

### *3.4 Technical issues for onboard equipment subject to stratospheric environment*

| | |
|---|---|
| **Description** | Demonstration of the robustness and of proper functioning of the overall optical communication subsystem at high altitude environmental conditions (low temperature, low pressure, high radiation, monatomic oxygen, ozone). Demonstration of capability of sustaining environmental transitories during climb and descent to designated altitude (outgassing, temperature gradient, icing). |
| **Operational issues** | Proper functioning of the aerial equipment will be tested by experiencing the real environment during climbing and stationing at designated altitude. Significant parameters will be monitored during flight mission if necessary. |
| **Main results** | Feasibility of cost-effective low weight, low power optical communication terminal, suitable for onboard stratospheric operations. |
| **Candidate systems for testbed implementation** | Laboratory<br>Stratospheric balloon |

# 4. System integration of the aerial node

## *4.1 Technical issues for integration of different devices within payload bay on a stratospheric platform*

| | |
|---|---|
| **Description** | Demonstration of the system engineering and integration issues for developing a multi-payload bay for high altitude use. Integration of the functioning payloads with the proper electrical and data connections. Thermal and pressure considerations, safe recovery system. |
| **Operational issues** | After possible partial integration tests performed in laboratory, a stratospheric flight mission will demonstrate design and integration of the fully equipped multi-payload bay through operation at design conditions and subsequent recovery of the platform on ground. |
| **Main results** | Proper design of the fully integrated aerial node for stratospheric operations. |
| **Candidate systems for testbed implementation** | Laboratory<br>Stratospheric balloon |