# Definition of a HAPS system in support of air quality and greenhouse green gas services

HAPSVIEW
For Air Quality

ESA's Living Planet Symposium, 23 – 27 June, Bonn

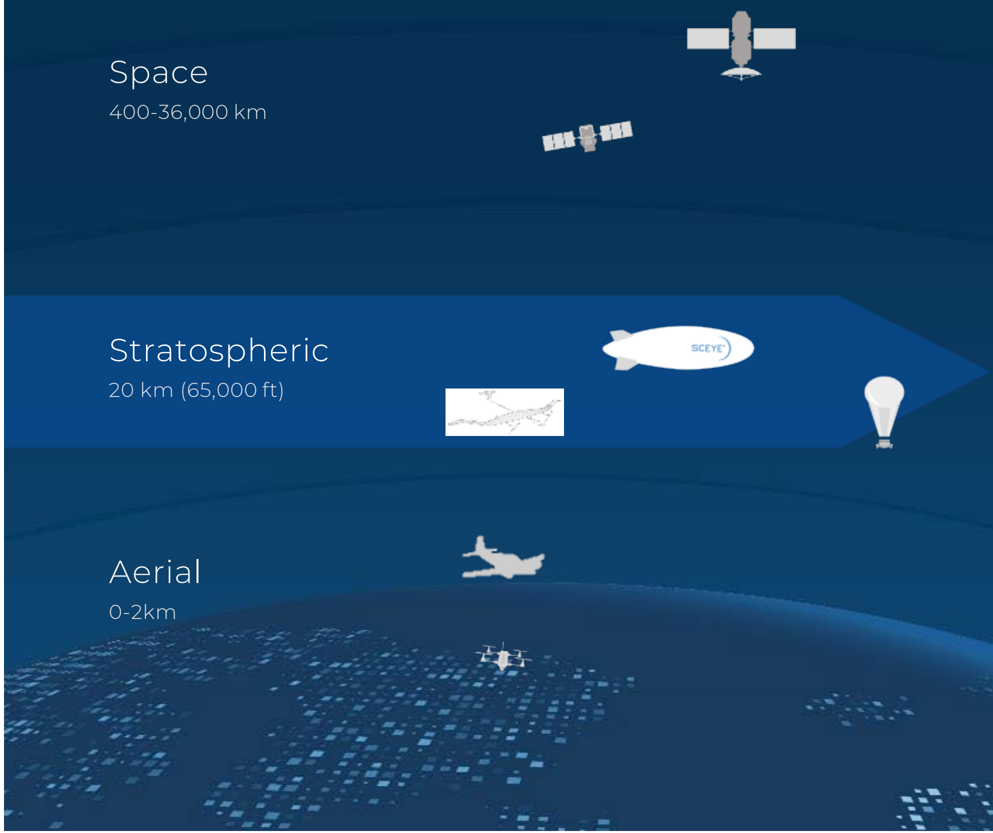
KNMI ABB SCEYE gmv INNOVATING SOLUTIONS

# HAPSVIEW’s objectives

**HAPSVIEW was an ESA activity to identify how HAPS can provide data to operational air quality or GHG services, such as air quality modelling or greenhouse gas emission inventories.**

- The identification of the air quality and GHG modelling user requirements for high-resolution atmospheric composition data to be provided by HAPS.
- The demonstration of the impact a HAPS system can have on improving the status of air quality or GHG modelling in synergy with satellite data
- Definition of the mission requirements for use cases, including the technical platform and the instrument requirements, preliminary system concepts, air space regulations, geophysical data products and synergies with existing and planned satellite missions.

# Sweet-spot altitude




Stratosphere is the best of both worlds

- ✓ Near – enough to see in high definition, live feeds
- ✓ Heavy lift – LTA : multi-instrument (100's kg)
- ✓ Power – solar closed-loop (LTA : 1-10kW)
- ✓ **Station – characterize vast areas**
- ✓ Endurance – LTA : 200+ days
- ✓ Range – 27,000 sq mi coverage
- ✓ Direct connection – 2G/3G/4G/5G & IoT/RPA

# Comparing HAPS

## FIXED WING

"Solar-powered airplanes have very little thrust and therefore fly slowly. They suffer greatly when trying to fly both high and slowly. That problem is increased by their inability to turn sharply to be station-keeping."

**– Can't lift nor power payload**

## AIRSHIP

"Airships will dominate this [HAPS] market because heavier-than-air options will not produce enough excess electric power to both fly and supply all payloads."

**– Enough space and lift**

## BALLOON

"Balloons are the original persistent aerial platforms [...] But they float with the wind and so cannot provide persistent service to fixed locations on the ground unless replaced frequently."

**– Too random to be controlled**

Quotes from "Global Stratospheric UAV Payloads" by Market Forecast and Market Forecast to 2025" By Ed Herlik, May 2017.

# Fixed wing

**Small payloads – 2-10kg**

**Custom payloads – SWAP reduction**

**Power – 100W supply**

**Source – solar → limited surface area for capture and small battery bank**

**Endurance – weeks+ (26 day record)**

**Speed – 55-110kmh (15-30 m/s)**

**Station → wide radius circles (10km) – few degrees of bank, increasing energy required for higher bank angles**

**Range – regional → mid-range missions**

**+/- 40º latitudes – growing over time to +/- 80º**

***Applications | single mission focus***

# Balloons

**Small payloads – 10-20kg**

**Power – 100W supply**

**COTS equipment – adaptation for stratosphere**

**Source – solar → limited capture and small battery bank**

**Endurance – weeks → months**

**Drift → unpowered, very wide radius circles, random paths (150km+)**

**Range – intercontinental → long-range missions**

**+/- 70º latitudes – growing over time to +/- 90º**

***Applications | single mission focus***

# Airships

**Large payloads – 100 → 500kg +**

**Power – 10’s kW supply**

**COTS equipment – minimum adaptation**

**Source – very large solar capture → large battery banks**

**Endurance – 200+ days : months → years**

**Persistent → station keeping on spot**

**Highly maneuverable → fly and course : track, ’mow’**

**Speed – 0-100kmh sprint (0-28m/s)**

**Tight turning radius → low speed, stationary turn**

**Range – intercontinental → long range missions**

**+/- 40º latitudes – growing over time to +/- 70º**

**Application | multi-role : *work-horse of the sky***

# User requirements

European Air Quality Normative Framework and Future Outlook

- Analysis performed in preparation of the future Copernicus generation (NEXTSPACE)
- Consolidation of end user needs of space-based observations
- Policy aspects include regulations related to actions on emission reductions related to air quality, substances depleting the ozone layer and climate change policies
- Policy aspects related to CO2 emissions from Agriculture, Forestry and other land use (AFOLU)
- Energy policies on sustainable energy production and safe and secure energy supply (e.g. monitoring of methane leaks)
- Specific policies related to air quality in the framework of the EU Clean Air Policy:
    - Ambient air quality directives
    - National emissions ceiling directive
    - Control on the sources of air pollution incl transport, industry, domestic combustion etc

# User requirements

## User communities

**Two key stakeholders involved in the study**

- The province of South Holland / Municipality of Rotterdam
- Ministry of Environment and Spatial Planning (Regional government of Andalusia) / Seville Town Hall

**Wider user community involved indirectly in the study**

- EU institutions
- International and European research community incl. CAMS
- National institutions
- National research communities w.r.t. Air Quality
- Public companies
- Private companies
- Other

# Use cases – gathered candidates

## Potential HAPS applications along observable atmospheric components:

| Paris Agreement Monitoring Mission | Nitrogen Cycle Mission | Urban Smog Mission | Metropolitan Surface AQ Mission | Industrial Hazard Monitoring Mission |
|---|---|---|---|---|
| $CO_2$ | $NO_2$ | $NO_2$ | $NO_2$ | Volatile Organic Compounds (VOC) |
| $NO_2$ | $NH_3$ | CO | Ozone | |
| | | HCHO | PM | |

# Selected Use Cases

**In order to get feasible mission requirements, only two use cases were selected:**

## Use Case #1: "Paris Agreement Monitoring Mission"

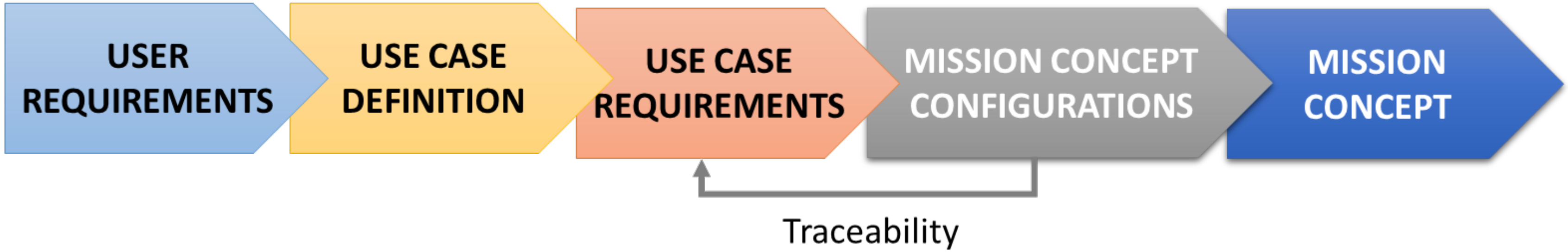
- Priority-A components: $CO_2$, $NO_2$
- Priority-B components: HCHO, $CH_4$, CO, Aerosols

## Use Case #2: "Metropolitan surface AQ Mission"

- Priority-A components: $NO_2$, $O_3$, PM
- Priority-B components: $CO_2$, $CH_4$, CO, HCHO

# From Use Case to Mission Concept

## Traceability from Use Case to Mission Concepts:




## From this traceability analysis with Use Case requirements several conclusions can be drawn:

- Multi-payload mission propose better compliances
- Duplication of system allows a better coverage (spatial and temporal) of the area of interest
- To get complete compliance with use case requirements, new technology shall be developed (lidar for instance)
- Hybrid approach seems more promising than pure LTA or HTA

# Consortium approach for mission selection

**Consortium though was to propose several concept that can cover several application inspired from the Use Case but also a development plan in the dissemination of HAPS throughout Europe for air quality and green house gases monitoring.**

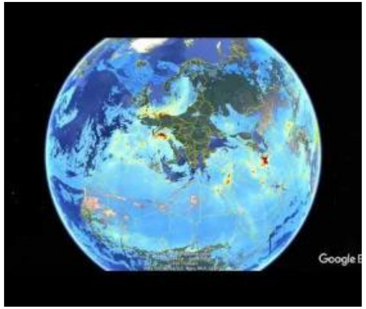
| | |
|---|---|
| Ready to Fly Mission Configuration | High TRL based concept<br>Rely on existing technology<br>Limited compliance with Use Case |
| User-Driven Mission Configuration | Mid TRL based concept<br>Technology to mature<br>Better compliance with Use Case |
| Forward-Looking Mission Configuration | Low TRL based concept<br>New technology and science to develop<br>High Level of compliance with Use Case |
| Event tracking Mission Configuration | More private oriented mission<br>Focus on event detection such as gas leaks<br>Aim to help ground system targeting the area of interest |

# Ready to Fly Mission Configuration

## Platform

**ADS Zephyr**

## Instrumentation



- **TNO spectrolite**
- **Commercial Hyperspectral camera**

## Programmatic

- **TRL: 5-6**
- **Timeframe: 2-3 years**
- **Best suited for a short-term demo**

## Species of interest

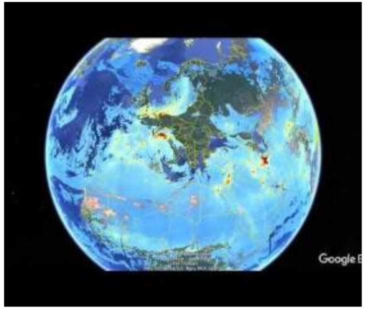
- **$NO_2$,**
- **HCHO,**
- **AOD**

# User-Driven Mission Configuration

## Platform

**LTA platform**

## Instrumentation



- **Spectrolite**
- **SWIR dispersive spectrometer**
- **Commercial Hyperspectral camera**

## Programmatic

- **TRL: 3-4**
- **Timeframe: 3-5 years**
- **Best suited for a mid-term mission**

## Species of interest

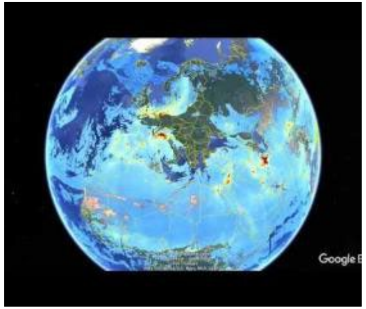
- **$NO_2$,**
- **HCHO,**
- **AOD,**
- **$CO_2$,**
- **$CH_4$,**
- **CO,**
- **Aerosol**

# Forward-Looking Mission Configuration

## Platform

**LTA and HTA platforms**

## Instrumentation



- **Spectrolite**
- **SWIR dispersive spectrometer**
- **Commercial Hyperspectral camera**
- **LIDAR system**

## Programmatic

- **TRL: 2-3**
- **Timeframe: > 5 years**
- **Best suited for a long-term mission**

## Species of interest

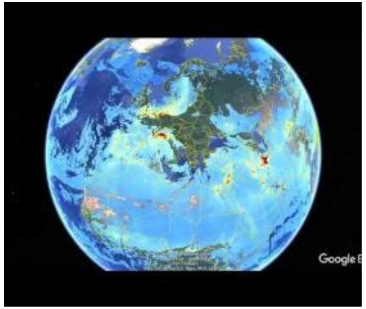
- **$NO_2$,**
- **HCHO,**
- **AOD,**
- **$CO_2$,**
- **$CH_4$,**
- **CO,**
- **Aerosol**
- **Particulate matter**

# Event tracking Mission Configuration

## Platform

**LTA or HTA**

## Instrumentation



- **Gas correlator**
- **Imaging dispersive system**
- **Imaging FTS**

## Programmatic

- **TRL: 4-5**
- **Timeframe: 3-5 years**
- **Best suited for a mid-term mission**

## Species of interest

- **$CH_4$**
- **$NO_2$**
- **$CO_2$**

# Mission Requirement Document
# Criteria for definition

**Two criteria were followed for the definition of the mission objective, the selection of required geophysical products, and selection of HAPS system**

**User needs.** Defined on the results of consultations with **Rotterdam/South-Holland** and **Seville/Andalusia** local and regional authorities.

**Maturity.** Feasibility has been assessed by obtaining the user requirements using the status of the science and state-of-the-art technologies. **Both user uptake and SRL/TRL (science and technology readiness level) are taken into consideration.**

# Mission Requirement Document
# Paving the way to a demonstration

From the previously analyzed configurations **the most suited for a short-term demonstration was the ready to fly configuration.**

The MRD followed a **simplified combined mission concept of the Paris Agreement Monitoring HAPS mission** and **the Metropolitan Surface Air Quality mission.**

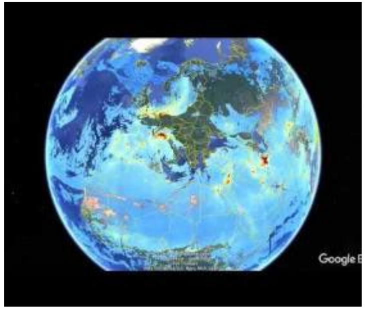
While the Metropolitan Surface AQ mission primarily focusses on the understanding of ozone pollution and the chemical and physical processes affecting ozone concentrations, the Paris Agreement Monitoring HAPS mission focusses on CO2 and NO2, primarily on the detection and quantification of the emissions in the metropolitan areas.

# Mission Requirement Document
# Proposed demonstration concept

## Platform

**Sceye 2**

## Instrumentation



- **TNO spectrolite**
- **Commercial Hyperspectral camera**

## Programmatic

- **TRL: 5-6**
- **Timeframe: 2-3 years**

## Species of interest

- **$NO_2$,**
- **$O_2$-$O_2$ band,**
- **AOD,**
- **ALH**

# Thank you

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