



# **THE C.N.E.S. STRATOSPHERIC BALLOON ACTIVITIES CAPABILITIES, MISSION AND OPERATION**

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**ECMWF - Observational campaigns for better  
weather forecasts : 10 – 13 June 2019**



# SUMMARY



- ❖ Overview of CNES balloon activities
- ❖ Sounding Balloon
- ❖ Zero Pressure Balloon
- ❖ Super Pressure Balloon
- ❖ National Program
- ❖ Hemera: European Balloon Research Infrastructure

## **CNES Involvement in Balloon Activities**

### **❖ Programmatic**

- ❖ Participation with scientists to the selection of missions**

### **❖ Design**

- ❖ Balloons, housekeeping gondolas, command-control link and ground segment, launch means**

### **❖ Manufacturing management**

- ❖ Balloons envelopes (Airstar Aerospace), Flight Systems, Ground Segments**

### **❖ Flight Operations**

- ❖ Launch, flight monitoring and control**

### **❖ Development of scientific instruments**

- ❖ Technical support to the Scientific Institutes**

### **❖ Pointing payload gondolas**

- ❖ Design, manufacturing, maintenance and operations are in house activities**

## **The Interests of Balloons**

- ❖ **A quite quick process for developing and operating a balloon experiment (3-5 years against 10-20 years for a satellite project)**
  - ❖ **Platform for science innovation and technology demonstration**
  - ❖ **Reduced development and operational costs**
- ❖ **Possibility to retrieve gondola with instruments, improve and re-use**
- ❖ **Complementarity with satellites : calibration of remote sensing space instruments**
- ❖ **The balloons make measurements higher than the planes and longer than the sounding rockets (up to about 40 km)**
- ❖ **Flexibility and simplicity of launching operations (wide variety of launching sites)**
- ❖ **Few mechanical and implementation constraints : ‘soft’ launching system in regard to rocket launch environment (vibrations and accelerations)**
- ❖ **Access to Near Space**
  - ❖ **Training of young engineers and space researchers**
  - ❖ **Start of ‘space’ activities for new emerging countries**

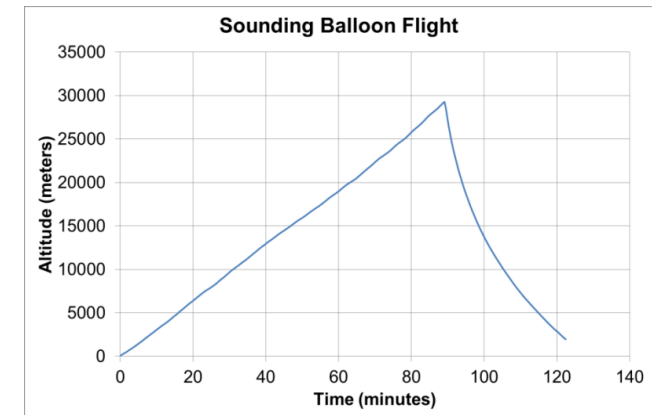
## The Balloon Missions

- ❖ The study of the atmosphere chemistry
  - ❖ The experiments are in situ in the atmosphere (0-40 km)
  - ❖ Remote or in-situ concentrations measurements and air sampling
- ❖ Meteorology dynamics
  - ❖ The balloon, blown by the winds, is an air masses tracer
- ❖ Astronomy
  - ❖ The instruments (telescopes) placed above the dense layers of the atmosphere can measure the least visible radiation from the ground
- ❖ Calibration / validation of satellite instruments and equipment
  - ❖ Calibrations / validations ENVISAT, IASI/METOP, ADM-AEOLUS satellites
  - ❖ Characterization / calibration of solar cells (ESA)
- ❖ Aerostatic crane for the initial free-fall of atmospheric re-entry objects
  - ❖ HUYGENS probe, mockups of shuttles (FALKE and HOPE-X)

## Sounding (Weather) Balloon - General

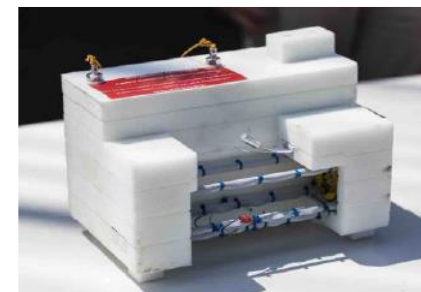
- ❖ Material: latex
- ❖ Volume : increases during its ascent until its explosion
- ❖ Flight level: 30 km to 35 km
- ❖ Gondola mass: < 3.0 kg
- ❖ Flight duration: 1h30 to 1h45 for ascent
- ❖ Telemetry
  - ❖ GPS position & PTU transmitted in real time
  - ❖ Scientific measurements logged on-board
- ❖ Gondola recovery: Yes

**Note:** the evolution of the technologies, with in particular the miniaturization, enables to develop powerful instruments with a mass lower than 3.0 kg



## Sounding (Weather) Balloon - Gondola

- ❖ **AirCore: ('drilling' of the atmosphere)**
  - ❖ Long tube of stainless steel
  - ❖ During ascent, empties its air, and fill itself with during descent
  - ❖ The captured air column is then interpreted in terms of the vertical gas concentration ( $\text{CO}_2$  &  $\text{CH}_4$ ) profile using a Picarro spectrometer
- ❖ **AMULSE (Atmospheric Measurements Ultra Light SpEctrometer)**
  - ❖ Principle: direct absorption laser spectrometry (Wavelength Modulation Spectroscopy)
  - ❖ Accurate (<1%) and fast (<1s) measurements
  - ❖ Concentration of  $\text{CO}_2$ ,  $\text{CH}_4$  and  $\text{H}_2\text{O}$
- ❖ **LOAC: (Light Optical Aerosol Counter)**
  - ❖ Measurements of the light scattered by the aerosols crossing a laser diode beam
  - ❖ Concentrations of non-spherical particles:  $0.2\ \mu\text{m}$  and  $50\ \mu\text{m}$
  - ❖ Main typology of the particle: liquid, semi-transparent as mineral/dust, strongly absorbent as carbonaceous and/or porous particles





## Zero Pressure Balloon - General

- ❖ Material: Polyethylene 12  $\mu\text{m}$  to 25  $\mu\text{m}$
- ❖ Volume : 5,000  $\text{m}^3$  to 800,000  $\text{m}^3$ 
  - ❖ Ø 130 m & Surface (~ 9 rugby fields!)
- ❖ Flight level: 20 km to 40 km
- ❖ Mass budget
  - ❖ Balloon Envelop: 150 kg ÷ 1,700 kg
  - ❖ Scientific gondola: 120 kg ÷ 1,100 kg
  - ❖ At balloon hook: 300 kg ÷ 1,750 kg
- ❖ Flight duration: few hours to few days
  - ❖ Venting ducts at hook
  - ❖ Very sensitive to thermal environment
  - ❖ Natural descent at sunset (ballast required)
- ❖ Gondola recovery: Yes

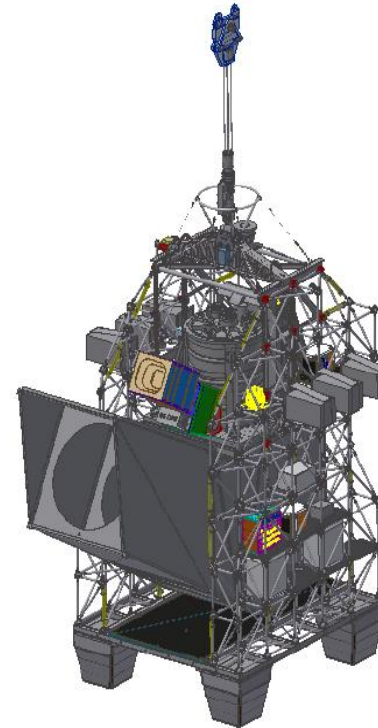






## Zero Pressure Balloon – On-board services

- ❖ Integration / housing into the gondola structure
- ❖ Scientific communication: telemetry (1Mbps) & remote-control (50 kbps)
- ❖ Power distribution: 1000 W
- ❖ Temperature control / regulation
- ❖ Axis control unit: position, speed, ...
- ❖ Daytime stellar sensor: ESTADIUS
- ❖ Inertial measurement unit (OF – IMU90)
- ❖ Azimuth pointing: stability  $\sim 1$  arcmin.
- ❖ Fine 2-axis pointing: stability  $< 1$  arsec.



## Atmospheric Science gondola : Greenhouse Gas gondola

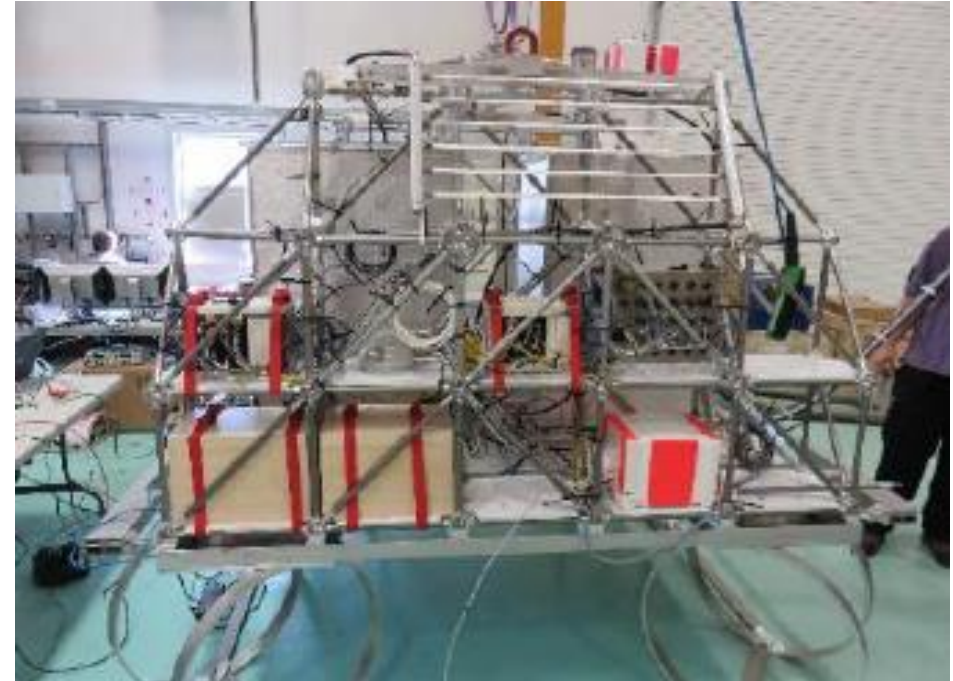
- ❖ Its 5<sup>th</sup> flight during the Timmins 2018 campaign
- ❖ CH<sub>4</sub>, CO<sub>2</sub> and H<sub>2</sub>O concentrations measurements with 9 instruments
  - ❖ 4 AirCore: CH<sub>4</sub> & CO<sub>2</sub>
  - ❖ 3 x Pico-SDLAs: CH<sub>4</sub>, CO<sub>2</sub> and H<sub>2</sub>O
  - ❖ 1 Pico-SDLA-bi-gas (lightweight model developed for Strateole-2 project): CO<sub>2</sub> & H<sub>2</sub>O
  - ❖ 1 AMULSE: CH<sub>4</sub> & CO<sub>2</sub>
- ❖ Slow descent (~ 3 m/s) from 34 km to 12 km
- ❖ Overall mass = 240 kg



## Atmospheric Science gondola : SPECIES Gondola

### SPECtromètre Infrarouge lasEr in-Situ

- ❖ Its 1<sup>st</sup> flight during the Timmin 2018 campaign
- ❖ High resolution spectrophotometry in the middle infrared
- ❖ Concentration measurements of chemical trace elements of the atmosphere HCl, HO<sub>x</sub> HON<sub>3</sub>, N<sub>2</sub>O, etc.
- ❖ Slow descent (~ 3 m/s) from 33 km to 16 km
- ❖ Overall mass = 475 kg





## Super Pressure Balloon - General

- ❖ Materials: multilayers envelope
- ❖ Diameter: 10 m, 11 m, and 13 m
- ❖ Mission flight level: 17 - 20 km
- ❖ Mass under balloon hook: 55 kg
- ❖ Close balloon
  - ❖  $24 \text{ kg} < \text{mass} < 40 \text{ kg}$
  - ❖  $500 \text{ m}^3 < \text{volume} < 1150 \text{ m}^3$
- ❖ Internal over pressure:  $\Delta P$  up to 20 hPa
- ❖ Flight duration: 3 months
  - ❖  $\Delta P \nearrow$  with sun & with  $\varphi_{\text{IR}} \nearrow$
  - ❖  $\Delta P \searrow$  during night & with  $\varphi_{\text{IR}} \searrow$  (cold clouds)
  - ❖  $\Delta P > 0$  &  $\Delta P < \Delta P_{\text{BURST}}$
  - ❖ Gas mass: neither too little nor too much
- ❖ Gondola recovery: no



## **National Program: Balloon Flight Access**

- ❖ **Balloon flights are open to French scientists (free of charge) but also to industry or other entities, on the basis of a participation in operation costs**
- ❖ **Annual flights programming**
  - ❖ **Set up by the Balloons Technical Committee (BTC): CNRS-INSU / CNES entity**
  - ❖ **With representatives of the French TOSCA (atmosphere) and CERES (astrophysics) thematic committees**
- ❖ **The scientific missions are selected by the BTC Steering Committee, following the annual CNES Call for Research Proposals**
- ❖ **The European research infrastructure HEMERA (coordinated by CNES) opens balloon flights at the European level**

## **Hemera: European Balloon Research Infrastructure**

- ❖ **HEMERA is a Research Infrastructure funded by the European Union**
  - ❖ **Providing Trans-National Access to balloon flights**
  - ❖ **Improving ballooning technology and scientific instrumentation**
  - ❖ **Networking to strengthen and enlarge the user community**
- ❖ **13 partners of 6 European countries + Canada**
  - ❖ **Space agencies: SNSB, DLR, ASI, CSA, ASC & CNES**
  - ❖ **Balloon operators: SSC, CNES & Airstar (balloon provider)**
  - ❖ **Scientists: INAF, KIT, Heidelberg U., Cranfield U. and CNRS**
- ❖ **Possibility to fly small to medium payloads at no cost on CNES or SSC gondolas**
- ❖ **Next Call For Proposal in October 2019 for 2 ZPB flights and for 10 SB flights in (2020 / 2021)**



Funded by the Horizon  
2020 framework  
Programme of the  
European Union



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