THE C.N.E.S. STRATOSPHERIC BALLOON ACTIVITIES

CAPABILITIES, MISSION AND OPERATION

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CENTRE NATIONAL D'ÉTUDES SPATIALES

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

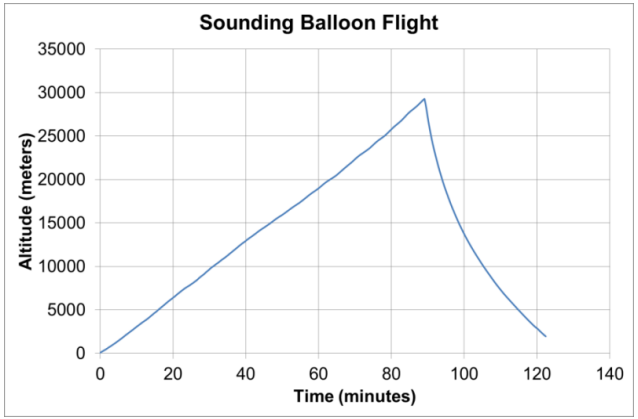
The Balloon Missions

- 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

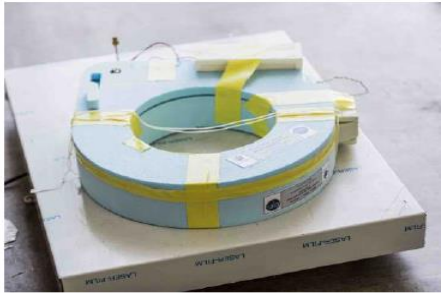
- Material: latex
- Volume : increases during its ascent until its explosion
- Flight level: 30 km to 35 km
- Gondola mass: < 3.0 kg
- Flight duration: 1h30 to 1h45 for ascent
- Telemetry
  - GPS position & PTU transmitted in real time
  - Scientific measurements logged on-board
- Gondola recovery: Yes

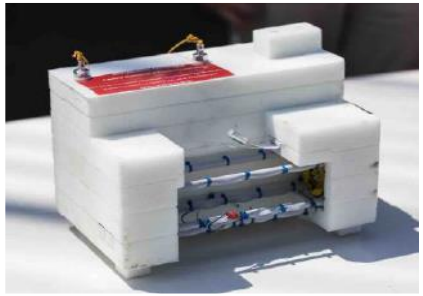
Note: the evolution of the technologies, with in particular the miniaturization, enables to develop powerful instruments with a mass lower than 3.0 kg



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 (CO_2 & 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 CO_2, CH_4 and H_2O
- 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 µm and 50 µm
  - Main typology of the particle: liquid, semi-transparent as mineral/dust, strongly absorbent as carbonaceous and/or porous particles



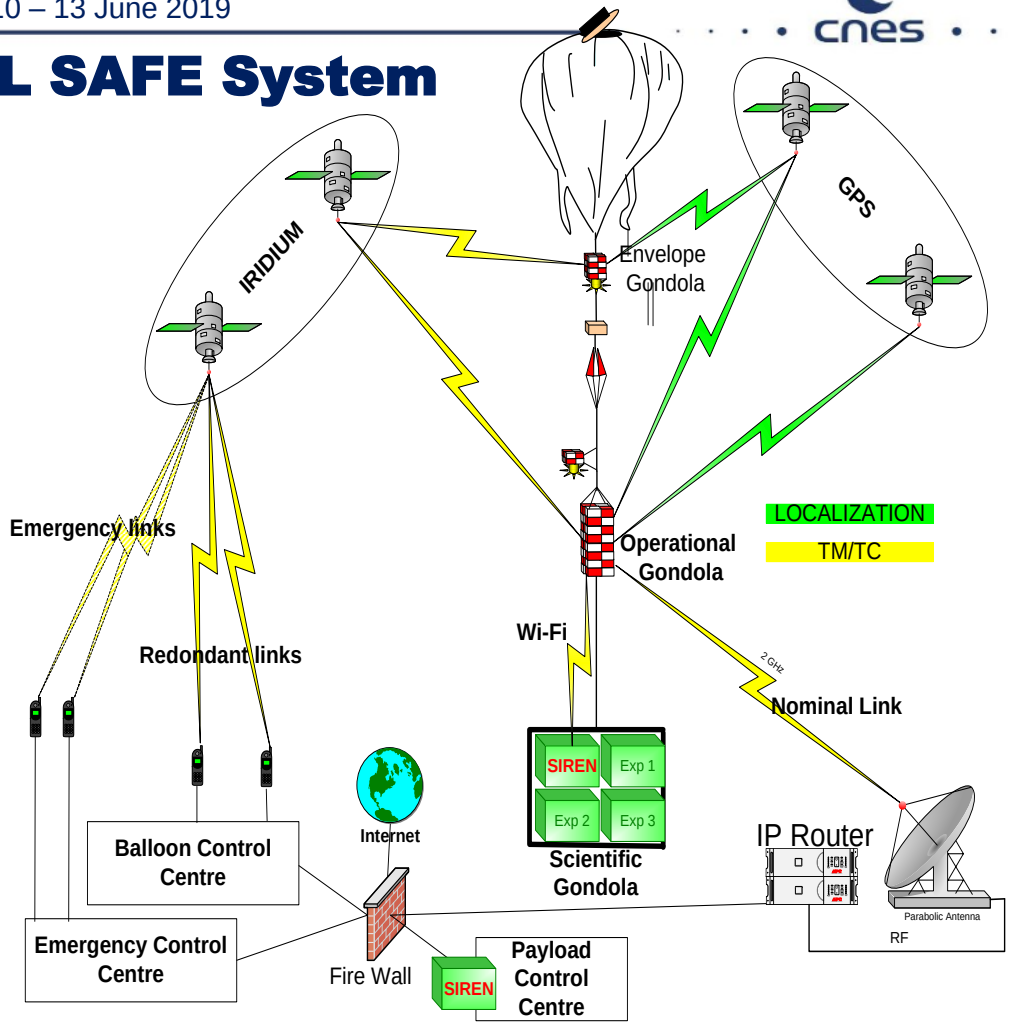


Zero Pressure Balloon - General

- Material: Polyethylene 12 µm to 25 µm
- Volume : 5,000 m^3 to 800,000 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

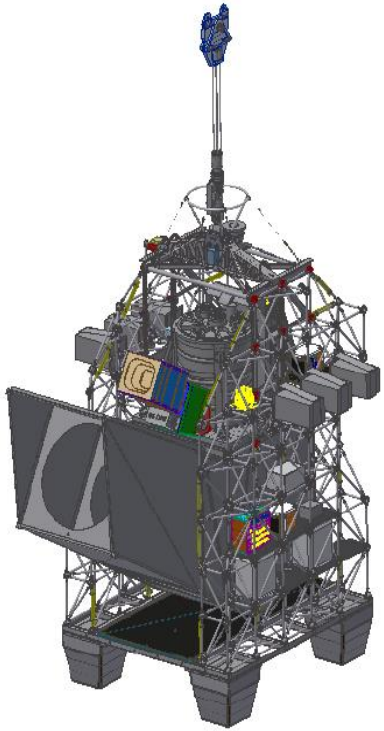
Zero Pressure Balloon – A FAIL SAFE System

- Redundancy of TT&C links
  - A dedicated 2 GHz RF Link (TM 1.5 Mb/s)
  - A worldwide satellite communication link (Iridium)
- Redundancy of OBC, GPS receiver & flight termination sub-system
- Two Fail Safe sub-systems for the valve and ballast tank control
- Redundant ground segment for balloon flight monitoring
- Wi-Fi IP link between Operational Gondola and Payload Gondola
- Payload board to ground communication via 2 GHz RF Link



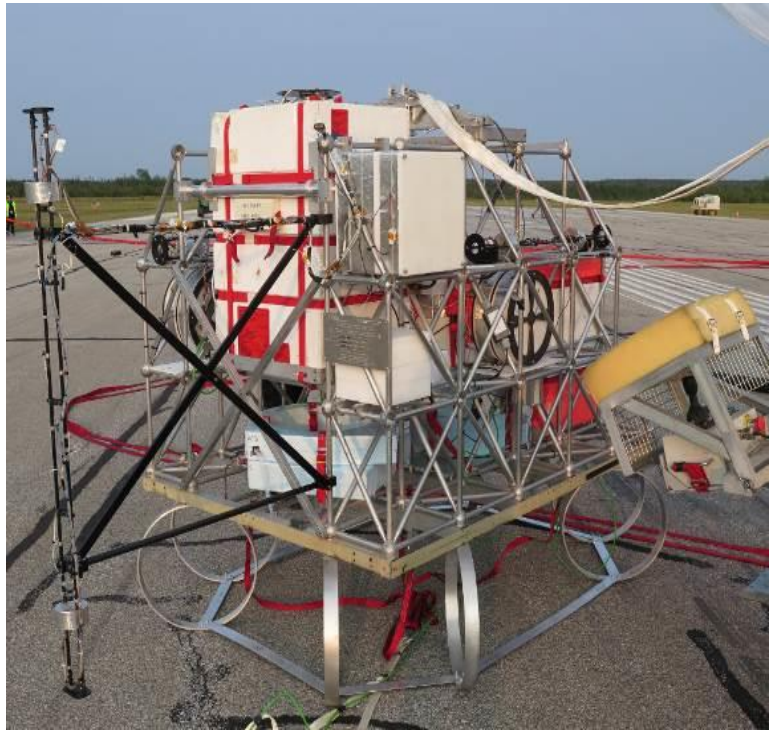
Zero Pressure Balloon – On-board services

- 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 ~ 1 arcmin.
- Fine 2-axis pointing: stability < 1 arsec.



Atmospheric Science gondola : Greenhouse Gas gondola

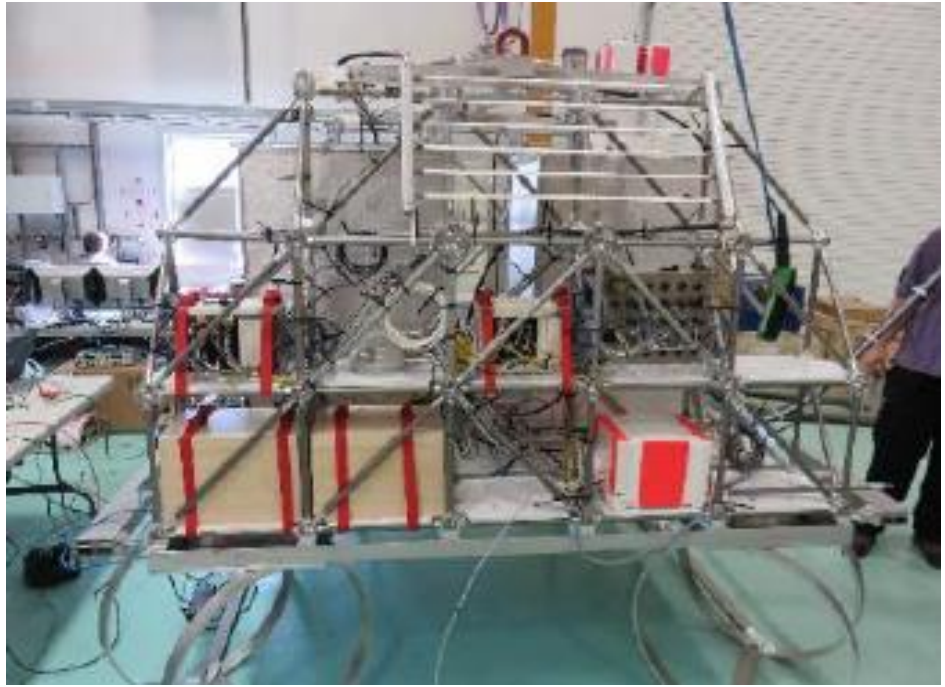
- Its 5th flight during the Timmins 2018 campaign
- CH_4, CO_2 and H_2O concentrations measurements with 9 instruments
  - 4 AirCore: CH_4 & CO_2
  - 3 x Pico-SDLAs: CH_4, CO_2 and H_2O
  - 1 Pico-SDLA-bi-gas (lightweight model developed for Strateole-2 project): CO_2 & H_2O
  - 1 AMULSE: CH_4 & CO_2
- 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 1st flight during the Timmin 2018 campaign
- High resolution spectrophotometry in the middle infrared
- Concentration measurements of chemical trace elements of the atmosphere HCl, HO_x HON_3, N_2O, 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 kg < mass < 40 kg
  - 500 m^3 < volume < 1150 m^3
- Internal over pressure: ΔP up to 20 hPa
- Flight duration: 3 months
  - ΔP↗ with sun & with φ_{IR}↗
  - ΔP↘ during night & with φ_{IR}↘ (cold clouds)
  - $\Delta P > 0$ & $\Delta P < \Delta P_{BURST}$
  - 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)

https://www.hemera-h2020.eu/#
https://www.hemera-h2020.eu/hemera-events/summer-school-2019/

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