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Stratospheric Balloons – Low-cost platforms for science and technology development

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ABSTRACT

Stratospheric balloons are useful platforms for various research and technology needs. In particular, they can be used for proof of concept demonstrations in preparation of new space and Earth observation missions. A typical balloon flight duration varies from a few hours to several weeks, depending on the balloon type, the choice of season, launch site and flight trajectory. Payloads can be flown at altitudes of 15-40 km. Compared to satellites, stratospheric balloons can be operated at relatively low cost and with shorter lead times from the experiment idea to the flight.

Recently, a new balloon infrastructure project called HEMERA has been selected by the European Commission within its programme Horizon 2020. One of the objectives of HEMERA is to enlarge the user community within research and technology related to stratospheric balloons and to coordinate activities within the field. The project is coordinated by the French space agency CNES and involves 13 partners from various European entities as well as the Canadian Space Agency, CSA. The project was kicked-off in late January 2018 and will be executed during 2018-2021.

Six balloon flights with a target payload mass of 150 kg are foreseen within HEMERA offering free of charge balloon flights to users and scientists from various science fields and/or for technology tests. In addition, several sounding balloon flights are foreseen for smaller payloads of up to 3 kg. The launch sites will be Esrange in Sweden, Timmins in Canada, and Aire sur l 'Adour in France. Two Calls for Proposals are planned in the HEMERA project. The selected experiments will fly on balloons during 2019-2021.

Keywords: Balloon, Stratosphere, Test platform, HEMERA

1. INTRODUCTION

Stratospheric balloons give access to near space between 15 km and 40 km and thus provide a complimentary vehicle to aircraft, unmanned aerial vehicles, rockets and satellites. Balloons offer a less expensive way of observing earth or the universe from above most of the atmosphere than satellites. They provide a slow and stable moving platform which is advantageous for Lagrangian type of atmospheric studies or medium to long term observations of astronomical objects. Balloon flights can be achieved within shorter time-frames than satellites and use the most recent technologies. In addition, most balloon systems and payloads are recovered and can be upgraded to fly again. For all this reasons balloons are an excellent test facility for new space technologies.

Up to beginning of this year, only a few national programs for balloon-borne activities and corresponding facilities existed in the European Union (CNES for France, SNSA for Sweden, ASI for Italy). They were funded by the national agencies and as such were open only to a limited number of scientists and countries (mainly France, Sweden, Italy and Canada). In the past, the scientific community occasionally led joint European scientific projects, as well as balloon activities with the support of ESA for satellite mission validation. However, due to the absence of a joint European balloon program, there was only limited cooperation among technical and research teams on joint development projects or common balloon-related activities.

The HEMERA project aims to improve from this situation (https://www.hemera-h2020.eu/). It intends to build up a European Infrastructure for scientific ballooning and will coordinate, support and enlarge the community in Europe, Canada and associated countries at flight operator, scientific and industrial levels. HEMERA is funded by the Horizon 2020 framework program of the European Union. Partners are space agencies and space access providers, scientific bodies (research centers and universities) and industry.

HEMERA has three major elements: provision of Trans-National Access (TNA) to balloon flights, networking to strengthen and enlarge the user community and joint research (JRA) to improve ballooning technology and scientific instrumentation.

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Table 1. Participants in the HEMERA project

Participant	**Organization name**	**Country**
1	Centre National d'Etudes Spatiales (CNES, coordinator)	France
2	Swedish National Space Agency	Sweden
3	Agenzia Spaziale Italiana (ASI)	Italy
4	Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR)	Germany
5	Canadian Space Agency (CSA)	Canada
6	SSC	Sweden
7	Andoya Space Center	Norway
8	Airstar Aerospace	France
9	Centre National de la Recherche Scientifique (CNRS)	France
10	Karlsruher Institut für Technologie (KIT)	Germany
11	Cranfield University	United Kingdom
12	Istituto Nazionale di Astrofisica (INAF)	Italy
13	Heidelberg University	Germany

HEMERA will coordinate European activities in the field of ballooning in order to provide better and coordinated balloon access to the troposphere and stratosphere for scientific and technological research, attract new users to enlarge the community accessing the balloon infrastructure and foster scientific and technical collaboration and enlarge the fields of science and technology research conducted with balloons. It intends to improve the balloon service offered to scientific and technical users through innovative developments and it will promote standardization, synergy, complementarities and industrialization through joint developments.

2. TRANS NATIONAL ACCESS (TNA)

From the user perspective, HEMERA will essentially provide two services: it offers a possibility to fly small to medium payloads at no cost on CNES or SSC gondolas under Zero Pressure Balloons (ZPB) and sounding balloons (SB). In addition to the flight itself, travels and subsistence for experimenters are funded by HEMERA. The cost for the development and construction of the payload is not included, though. Instruments have to be provided by the scientific organization or the company that wants to use this service.

The second service will be virtual access: the data acquired during those flights will be collected and made publicly accessible on a dedicated web portal, as well as a set of past balloon flight data. This service will be provided by CNRS and INAF.

Access to the balloon flights will be organized through a proposal process with an independent review panel [1]. The proposals shall allow the review panel to judge scientific or technological quality, feasibility, maturity and novelty in science or technology. The proposal process will be executed for the HEMERA consortium by the Swedish National Space Agency (Rymdstyrelsen). More information about the proposal process and relevant documents (e.g. proposal template) can be found at https://www.rymdstyrelsen.se/forskning/utlysningar/aktiva-utlysningar/hemera-call-for-proposals.

Table 2. Timeline of TNA possibilities during the HEMERA infrastructure project

Timeline	**Activity**
July 2018	1. Call for Proposals
15. October 2018	Submission of Proposals (1. Call)
January 2019	Selection of Payloads (1. Call)
Summer 2019	1. Flight possibility with SSC from Esrange
August/Sept. 2019	1. Flight possibility with CNES from Timmins
December 2019	2. Call for Proposals
From Jan. 2020	2. Flight possibility with SSC from Esrange
February 2020	Submission of Proposals (2. Call)
May 2020	Selection of Payloads (2. Call)
August 2020	2. Flight possibility with CNES
From Jan. 2021	3. Flight possibility with SSC
Summer 2021	3. Flight possibility with CNES

In total six flights with ZPBs for up to 150 kg payload will be performed within the HEMERA project: three flights will be performed by SSC from Esrange near Kiruna, Sweden and three flights will be performed by CNES: one from Esrange, one from Timmins, in Canada, the launch place for the third flight is still open. In addition, 20 flights with SBs for up to 3 kg payload will be performed by CNES from Aire sur l'Adour.

Gondolas as platforms to accommodate the payloads will be provided by CNES/SSC. Several instruments will fly on one gondola. Light instruments are preferred to allow more users to fly. All instruments/gondolas will be recovered. Flight levels of up to 38 km and down to 15 km can in principle be accessed. The exact level will depend on total mass of payload and gondola and on meteorological conditions. CNES will fly from Esrange and Timmins in summer only, SSC will provide service from Esrange only but all year round. Service from Aire-sur-l'Adour in France will be offered by CNES all year round but only for SB.

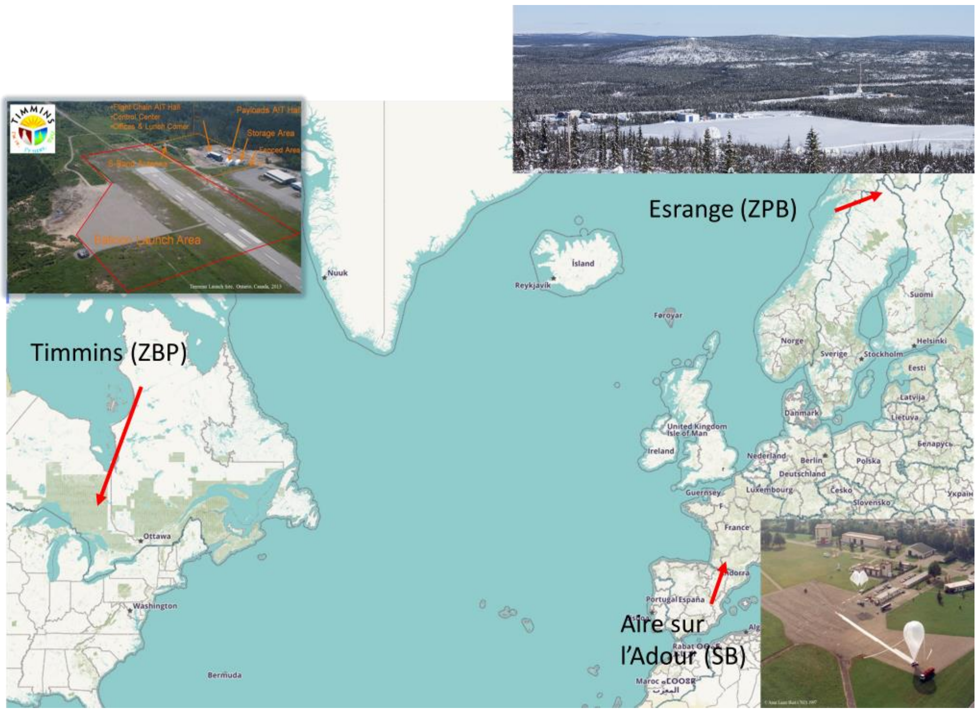

Figure 1. Launch sites for ZPB and SB flights

Wind directions in Esrange and Timmins are in early summer to the west and in winter to the east. In the so-called turn around periods in spring and late summer/autumn wind speeds are very low and long flights can be accomplished. This is the favourite time for HEMERA flights. Esrange offers three large buildings for balloon and payload preparation, laboratories, and a clean room. The balloon pad has a size of 450x500m (see fig. 2). The impact area for free falling objects has a size of 5600 km². Timmins is equipped with a building for balloon preparation and a hangar for payload integration.

In the HEMERA "flight ticket", the following services are included: general management and planning of HEMERA flight, provision of launch vehicle and subsystems necessary for a flight mission with recovery, assembly of selected experiments into the payload gondola, pre-flight testing of the payload gondola (TM & TC), provision of laboratory facilities at the Esrange/Kiruna or Timmins launch site, daytime or night-time launch, operations, piloting and recovery of the gondola payload, data transmission with provisions of real time data from payload and disassembly of the experiments from the payload gondola. Optional services during campaign or flight are the provision of meteorological data, and in particular of meteorological soundings. The figures and tables on the next pages provide essential information about the technical boundary conditions of the HEMERA flights. Exhaustive information can be found in the User Manual for ZPB Infrastructure Access [2].

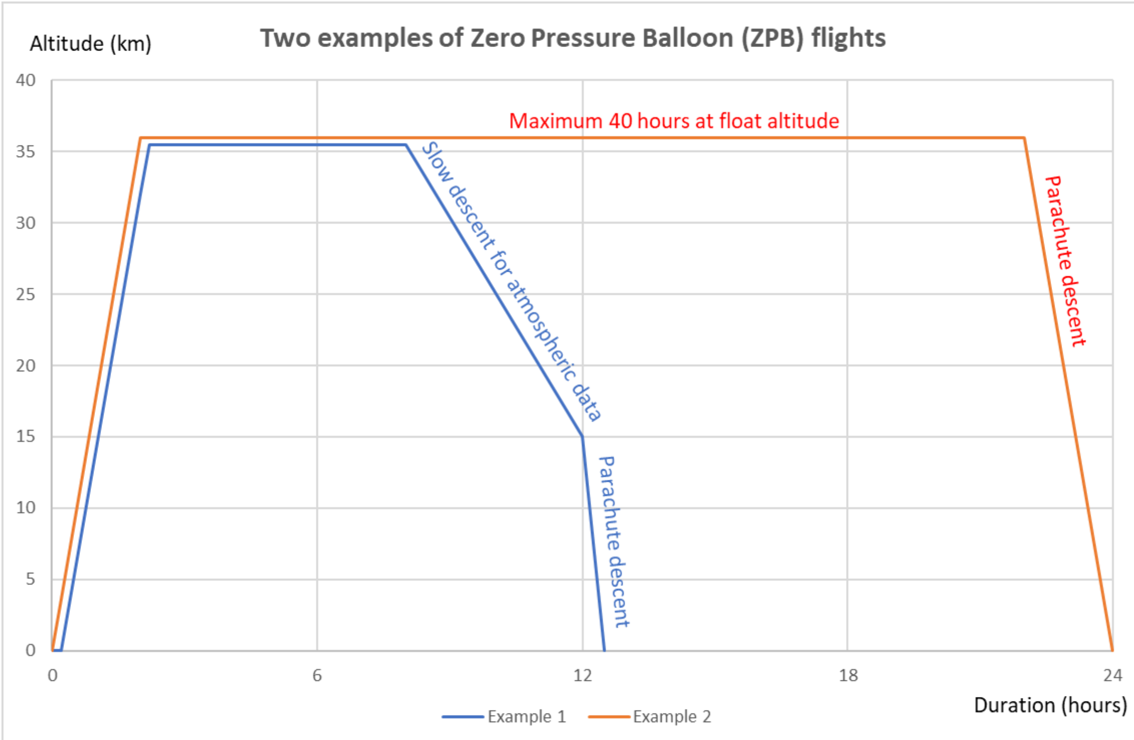

Figure 2. Examples for chronologies of typical stratospheric Zero Pressure Balloon flights

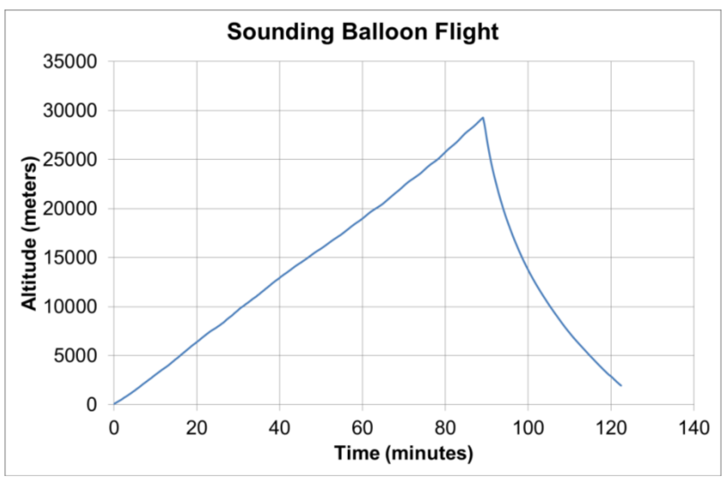

Figure 3. Chronology of a typical sounding balloon flight; Maximum achievable flight levels are approximately ~35 km (6 hPa) with a 2000 g balloon and 38 km (4.5 hPa) with a 3000 g balloon.

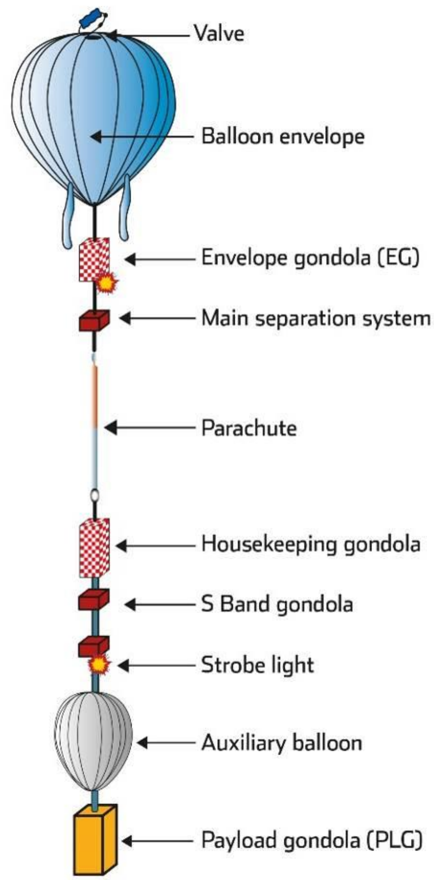

Figure 4: Typical flight configuration for a CNES Zero Pressure Balloon flight. The vertical extension of the whole flight train including balloon envelope is approximately 200 m. The SSC configuration is very similar, but needs no auxiliary balloon.

Figure 5. Launch methods - Left panel: Launch with auxiliary balloon (CNES) – Right panel: Launch with Hercules vehicle (SSC)

Table 3. Characteristics of HEMERA Zero Pressure Balloon flights

	CNES	**SSC**
Zero Pressure Balloons flight characteristics:	Balloon volumes: 150,000 m^3 Flight levels: ~15 km (120 hPa) up to ~33 km (7 hPa) Combined payload gondolas: 250 up to 450 kg Flight profiles: constant ceiling / slow descent Flight durations: up to 38 hours Ascent speed: 5 m/s Slow descent speed: 1 to 5 m/s Landing velocity: 5 to 7 m/s (shock absorbers)	Balloon volumes: 150,000 m^3 Flight levels: ~15 km (120 hPa) up to ~35 km (5,6 hPa) Payload gondola up to 250-450kg (150 kg of experiments included) Flight profiles: constant ceiling / slow descent Flight durations: up to 48 hours during turn around period (spring & autumn – otherwise 4-5 hours) Ascent speed: 4-5 m/s Slow descent speed: 1 to 5 m/s Landing velocity: 5 to 7 m/s (shock absorbers)
Payload requirements for ZPB:	Typically, 150 kg of payload mass per flight Nominally 5 experiments per flight Minimum of 5 kg per experiment Volume constraints in link with gondola sizes	Typically, 150 kg of payload mass per flight Nominally 5 experiments per flight Reserved volume for each Experiment: L x W x H: 500 x 500 x 800 mm^3-
Available gondola (L x l x h)	BANA: 2 m x 0.8 m x 1 m HELIOS: 2.06 m x 1.43 m x 1.44 m CARMENCITA: 2.45 m x 1.85 m x 2,20 m	New gondola under construction: Octagon 1800 x 1800 mm^2 x adjustable height
On-board communication device:	TC max rate: 70 kbit/s TM max rate: 1500 kbit/s 4 asynchronous links: RS232, RS422 or RS485 6 to 10 Ethernet links in UDP or TCP 12 STOR links	2 Mbps duplex nominal, decreasing with range. 10 Ethernet 10/100 Base 2 asynchronous duplex RS-232/422 channels.
On-board optional services	Secured Li-Ion power source: ~- 28 V (up to 1000 W) High performance pointing information (stellar sensor): < 1 arcsec, Pointing rotator: azimuth control < 1 arcmin, axis and elevation control, door opening, actuators, … Thermal monitoring, Date and GPS location, On-board cameras, On-board accelerometers	Relays for external use - on/off, upon request Accelerometer upon request

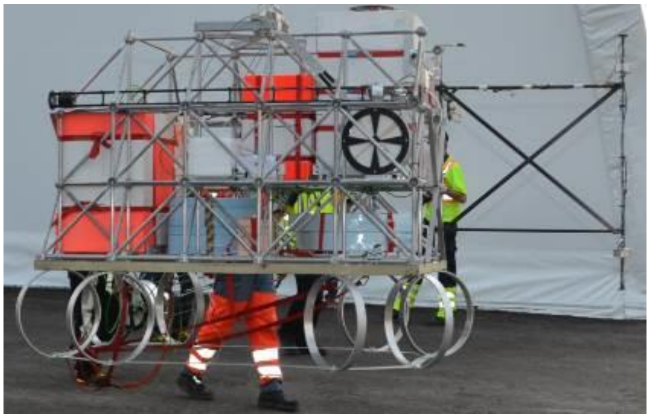

Figure 6: CNES HELIOS gondola.

3. JOINT RESEARCH (JRA)

In parallel to the TNA activities, JRA shall prepare improved services for the future. Activities encompass the development of a light weight flight train, of a telemetry system for the users based on satellite communication and of larger balloon envelopes. In addition, the launch methodologies will be simplified.

The light weight flight train will offer simpler and cheaper flight opportunities for lighter payloads. It will be developed through adaptation of the existing flight train for superpressure balloons. It will be optimal for payload gondola masses between 20 kg and 150 kg and for balloon volumes of 5 000 m^3, 12 000 m^3 and 35 000 m^3. It shall support flight duration from hours to one week. Control of balloon and payload will be primarily accomplished with satellite communication (Iridium).

On the scientific side the definition and development of a set of lightweight innovative instruments (SLII) to provide key atmospheric data for users of the Trans National Access is a key activity. SLII shall provide essential climate variables like pressure, temperature, wind, concentrations of ozone, water-vapor, methane, carbon dioxide, aerosols complemented by altitude and Gamma-ray atmospheric background information. Instruments will be calibrated/validated in atmospheric chambers so they can serve as reference instruments. Visualization and interpretation software will be provided for SLII instruments and for atmospheric data generated by balloons in general. A complementary scientific activity is the search for synergy options and common tools for the infrared hyperspectral imaging technique at European level as preparatory work for future balloon and satellite missions.

4. CONCLUSION

HEMERA is an effort to set up a European infrastructure for stratospheric balloons. It shall provide a long term perspective for science and technology development relying on this platform. In short term perspective, HEMERA will provide trans-national access to European users from science and industry and will thus extend the existing national user communities. In long term perspective, HEMERA will perform groundwork to extend the opportunities stratospheric ballooning can offer and to achieve better cost effectiveness.

REFERENCES

[1] HEMERA Call for Proposals 2018, https://www.rymdstyrelsen.se/forskning/utlysningar/aktiva-utlysningar/hemera-call-for-proposals

[2] HEMERA User Manual for ZPB Infrastructure Access, https://www.rymdstyrelsen.se/forskning/utlysningar/aktiva-utlysningar/hemera-call-for-proposals