Long duration balloon flights from Esrange Space Center carrying instruments for Astrophysics and Cosmic Ray

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1. Abstract

Esrange Space Center located in northern Sweden has during 45 years been a leading launch site for both sounding rockets and stratospheric balloons. We have a unique combination of maintaining both stratospheric balloons and sounding rockets launch operations. Most balloon flights are normally handled inside Scandinavia but since 2005 semi-circular flights are performed with recovery in northern Canada. The Swedish and Russian Governments have signed an agreement for peaceful exploration of space on 9 March 2010, which will permit circumpolar balloon flights. Within this agreement we are able to offer the science community long duration balloon flights in the Northern Hemisphere with durations for several weeks.

The balloon operations at Esrange Space Center are yearly expanding. Both NASA and CNES have long term plans for balloon flights from northern Sweden. We have also received requests from Japanese Universities and JAXA for future balloon missions. To handle balloon campaigns with large numbers of payloads or build up for two different campaigns a new big assembly hall was ready for use in April 2011.

In total 10 payloads have been flying for 4 to 5 days from Esrange westwards with landing in northern Canada since 2005. The SUNRISE balloon borne solar telescope is one example which made in June 2009 a more than 4 days semi-circular balloon flight from Esrange. The Sunrise project is a collaborative project between the Max Planck Institute for Solar System Research in Katlenburg-Lindau and partners in Germany, Spain and the USA.

The first circumpolar flight will take place in the second half of June 2012 with the PoGOLite balloon borne telescope studying the polarisation of gamma-rays from pulsars and will be recovered in Scandinavia after 12-15 days. The PoGoLite project is a collaborative project between Swedish, French, Japanese and US scientific teams.

2. Introduction

The Esrange facility was established by ESRO, the European Space Research Organisation in 1966. At the start the facility was using sounding rockets and ground-based scientific equipment to conduct research mainly in the field of aurora research and atmospheric physics. The location north of the Arctic Circle (68° N, 21° E) combined with a favourable sub-arctic climate made the site excellent for sounding rocket launchings into the aurora. The first sounding rocket was launched from Esrange in November 1966.

In 1973 the first stratospheric balloon launches were conducted from Esrange and around 20 flights are being made yearly. Most of these flights are aimed at atmospheric and astronomical research, but over the years a number of technical flights have been made from Esrange.

The use of stratospheric balloons for scientific applications as a supplement to satellites and ground based instruments has increased and the balloon is a stable platform that can hold a payload in the higher atmosphere for several days. We are able to launch extremely large balloons carrying payloads up to two tons. Many scientists, like astronomers studying weak signals from deep space, need a long measuring time for their experiment onboard. The stratospheric wind conditions will determine both the duration and the direction of the balloon. Stratospheric balloons are launched all year round but we take advantage of specific seasonal conditions like the dominating flight directions eastwards during the winter and westwards during early summer. Semicircular balloon flights have been made at Esrange Space Center since 2005 and now we are planning for circumpolar balloon flights.

3. Infrastructure

The infrastructure at Esrange Space Center for balloon launchings are up-to-date and consists of three payload assembly halls, one assembly hall for flight train preparation and a very large launch area for both auxiliary and dynamic launch techniques (250 000m^2). A dedicated balloon launch vehicle for handling large balloon and heavy payloads is available.

Fig. 1. Ready for balloon release

3.1 Payload assembly halls

Three payload preparation assembly halls are available at Esrange Space Center.

3.1.1 The Chapel:
The Chapel has a floor space of 80 m^2 with two offices available. The hoist capacity is 1000 kg with an available height of 5.2 m. The Chapel is well equipped with outlets for 230V power and Internet.

3.1.2 The Cathedral:
The Cathedral has a floor space of 293 m^2 with four offices and a kitchen available. The hoist capacity is 3200 kg with an available height of 7 m. The Cathedral is well equipped with outlets both for 110V and 230V power and Internet.

3.1.3 The Dome:
The Dome has a floor space of 795 m^2 with four offices, labs, workshop, conference room and a kitchen available. The hoist capacity is 4000 kg with an available height of 10 m. The Dome is well equipped with outlets both for 110V and 230V power and Internet.

3.1.4 The Basilica:
The Basilica is dedicated for flight train and balloon system preparations with a floor space of 323 m^2 and two offices, meteorological room and an operation room available. The hoist capacity is 1000 kg with an available height of 3.35 m. The Basilica is well equipped with outlets both for 230V power and Internet.

3.2 Balloon launch vehicle

The balloon launch vehicle has a weight of 50 tonnes and a length of 17 m. It can carry a maximum load of 4 tonnes and has a crane height of 12 m.

Fig. 2. The balloon launch vehicle

4. Telemetry and command

4.1 EBASS

The ESRANGE Balloon Service System EBASS is mainly used during line of sight balloon flights for housekeeping, piloting, navigation and flight termination. Limited serial data links are also provided for the user. The EBASS system is working in the UHF frequency band with an operational time of 60 hours. The EBASS can handle suspended loads up to 1 ton and the system mass is 17 kg for the light version and 30 kg for the heavy version.

3.3.2 E-Link

The E-Link is a high speed transparent Ethernet telemetry system for communication with the balloon experiment. The standardised interface helps the user to simplify the telemetry and telecommand with the airborne equipment. The system is built in separate units providing integration in the experiment gondola or in the flight train. E-Link provides a 2 Mbps data link with full duplex and consists of airborne units and mobile ground stations.

The E-Link system is designed for line of sight operation and is working with spread spectrum modulation in the S-band with a battery operational time of > 20 hours. The maximum range at LOS is 500 km with the balloon at 30 km altitude. The user interface is Ethernet 10/100 Base-T with full duplex. The E-Link system mass is 20 kg.
The E-Link is successfully used for critical calibration and fine tuning of the scientific telescope on the balloon gondola for missions like the PoGoLite and Sunrise during the first part of a long duration flight (LOS).
SSC is working on a new version of the E-Link with a data capacity of > 20 Mbps

3.3.3 TM/TC beyond line of sight

When the balloon is out of LOS (>500 km) all telemetry and telecommand between the balloon payload and Esrange will be performed by satellite communication. The Iridium satellite network provides nominally 10 – 100 kbps data bitrate. SSC is investigating the possibility to increase the bitrate to 100 – 500 kbps.

5. Launch Window/Trajectories

5.1 Winter period

Balloon launchings during the winter period are mainly for atmospheric research where many of the balloons are launched into the polar vortex but some are also in the field of astronomical research. The predominating stratospheric winds are rather strong from W to NW which gives 2-5 hours of ceiling time and with recovery of the payloads either in Finland or Russia. Balloon launchings in the winter period are usually carried out in cooperation with CNES, France. One example of a project during the winter period was the ARCHEOPS project with recovery near the Ural Mountains in Russia.

5.2 Summer period

During the summer period from mid-May to mid-July the stratospheric winds are very stable from the east, which makes that period very suitable for medium to long duration balloon (LDB) flights. These LDB flights are very suitable for astronomical and cosmic ray payloads where a long measuring time is needed. During this period the latitude excursions are not expected to exceed +/-3°. The payloads are equipped with redundant flight proven systems for line-of-sight and beyond-the-horizon telemetry and commanding. Total flight duration would be in the order of 5-7 days. This new capability is a joint effort between the SSC, Esrange and the National Aeronautics and Space Administration (NASA). The inauguration flight which was named BLAST was performed on 11 June 2005. In total ten payloads has been flying for 4 – 5 days from Esrange westwards with landing and recovery in northern Canada since 2005.

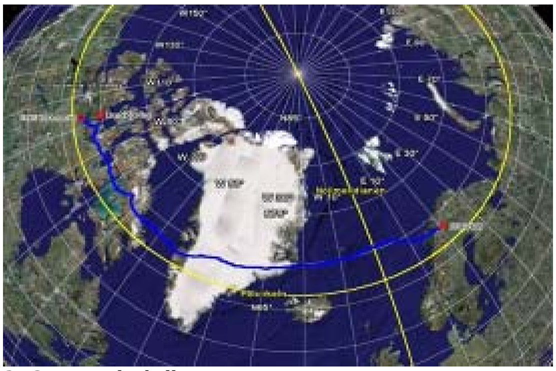

Fig. 3. Semicircular balloon trajectory

5.3 Turn around periods

During the turn-around periods in late April and early May and second half of August the stratospheric winds are very low and irregular which means that the payloads can be in the line-of-sight up to 2-3 days. These wind conditions are ideal keeping the balloon near Esrange providing scientific measurements continuously for days or handling complicated and dangerous technical drop test from high altitude with safe landing inside Esrange rocket recovery area. In May 2011 we performed two successful drop tests of heavy rocket formed bodies called D-SEND-1. The drop tests from high altitude gave JAXA valuable data for designing future supersonic commercial aircrafts. Next step for JAXA is to perform drop tests of a scale model of a supersonic test plane at Esrange in 2014.

5.4 Circumpolar trajectories

The Swedish and Russian Governments have signed an agreement for peaceful exploration of space on 9 March 2010, which will permit circumpolar balloon flights. Within this agreement we are able to offer the science community long duration balloon flights in the northern hemisphere with durations for several weeks. The maiden circumpolar flight within this agreement will be in late June 2012 when flying the PoGoLite gamma ray instrument with an 1,12 Mm^3 balloon. The recovery is planned in Scandinavia 12 – 15 days after a completed circumpolar flight.

Fig. 4. Circumpolar balloon trajectory

6. LDB flights

6.1 Sunrise

The Sunrise solar telescope is studying the complex processes on the surface of the sun and is a collaborative project between the Max Planck Institute for solar system research in Katlenburg-Lindau and partners in Germany, Spain and the USA. A semicircular flight was made in 2009 and the telescope was pointed directly to the sun taking images. In order to track the sun during flight, the gondola was equipped with a pointing system that enables the gondola to rotate horizontally. The E-Link telemetry system was used during the initial part of the flight when calibrating the scientific payload system. Landing and recovery was performed in northern Canada.

Fig. 5. Sunrise solar telescope

6.2 PoGoLite

PoGoLite will be the first circumpolar balloon flight within the Swedish – Russian agreement with a planned launch in June – July. A 1,12 Mm^3 balloon will carry the 2000 kg gondola to 38 kilometres altitude on a 12 – 15 days circumpolar flight with landing and recovery in Scandinavia. The PoGoLite balloon borne telescope is studying the polarisation of gamma-rays from pulsars in the 25 – 80 keV energy range and is a collaborative project between Swedish, French, Japanese and US scientific teams. The PoGOLite payload consists of a Polarimeter Telescope Assembly, a Data Acquisition System, and a precision pointing gondola. The telescope contains an array of phoswich detectors made from plastic scintillators, surrounded on the side and bottom by anti-coincidence counters made from BGO crystals. Polarized gamma rays are expected from a wide variety of sources including rotation-powered pulsars, accreting black holes and neutron stars, and jet-dominated active galaxies. Polarization has never been measured at soft gamma-ray energies where non-thermal processes are likely to produce high degrees of polarization. The polarization is derived from the azimuthal distribution of Compton scattering angles in the sensitive volume of the instrument. The scattering angle will be measured by detecting coincident Compton scattering and photo-absorption sites in an array of 217 phoswich detectors. Polarization measurement requires high purity coincident signal detection. PoGOLite applies a well-type Phoswich Detector technology for this purpose. The technology has proven to be very effective in reducing source-confusion and cosmic-ray-induced backgrounds.

SSC is responsible for the gondola, power system, telecommunications, launch, piloting and flight safety issues. The balloon flight will be headed by SSC in the Operations Control Center at Esrange Space Center. The first part of the balloon flight (LOS) will be extended over the Atlantic Ocean using a mobile E-Link station located at the Alomar facility near Andöya in Norway transferring data to Esrange. When the balloon is beyond the line of sight all commands and data communication will be made over the Iridium satellite system.
PI for the PoGoLite project is Professor Mark Pearce, KTH Sweden.

Fig. 6. The PoGolite gondola

7. Conclusion

Stratospheric balloons have been launched for near 40 years at Esrange Space Center. Fruitful cooperation with CNES France and CSBF USA has successfully gained the development of launching stratospheric balloon at Esrange. SSC is unique having their own professional launch teams for both sounding rockets and stratospheric balloons. SSC is since many years launching complicated scientific and technical payloads during various conditions. The long experience, extensive infrastructure, highly developed technical systems and the qualified staffs allows SSC to look into more qualified balloon operations. The next challenge for SSC will be to perform the first maiden circumpolar balloon flight in late June 2012.