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ESBO DS
Stratospheric Observatory

D5.2 – ESBO *DS* CONCEPTUAL DESIGN REPORT (GROUND SYSTEM)

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Authors	Philipp Maier, Michael Lundin, Christian Lockowandt
Approved by	Christian Lockowandt

TABLE OF CONTENTS

LIST OF ABBREVIATIONS AND DEFINITIONS

Abbreviation	Definition
CNES	Centre National d'Études Spatiales
ESBO	European Stratospheric Balloon Observatory
FIR	Far Infrared
HALOE	Halogen Occultation Experiment
JAXA	Japan Aerospace Exploration Agency
LDB	Long Duration Ballooning
LOS	Line-Of-Sight
NASA	National Aeronautics and Space Administration
NIR	Near Infrared
SPB	Super Pressure Balloon
SSC	Swedish Space Corporation
ULDB	Ultra Long Duration Ballooning
USAP	United States Antarctic Program
UV	Ultraviolet
ZPB	Zero Pressure Balloon

REFERENCE DOCUMENTS

[RD1]	ESBO *DS*. D5.1 Conceptual Design Report – Flight System. Version 1.0 26 June 2020.
[RD2]	ESBO *DS*. D3.2 Concepts Preliminary Technical Specification. Version 1.0 30 April 2019.
[RD3]	ESBO *DS*. D4.1 Design Specification File. Version 1.0 30 April 2019.
[RD4]	NASA. Near Earth Network (NEN) Users' Guide. 453-NENUG, Revision 4. 14.03.2019.

1 INTRODUCTION

This document contains a description of the ground segment required for the operation of the ESBO flight platforms. It thereby distinguishes between ground segment elements that are common to all three envisioned flight systems (see [RD1] for details of the flight systems) and dedicated ground support systems required for the individual flight platforms.

The conceptual design presented in this report is based on the requirements as listed in the ESBO *DS* Preliminary Technical Specification [RD2] and on the design decisions as detailed in the ESBO *DS* Design Justification File [RD3].

This Conceptual Design Report for the ESBO ground segment complements the Conceptual Design Report for the ESBO Flight Platforms [RD1].

2 SCOPE

This report considers ground system elements that are required for both the “technical” operation of the balloon and gondola systems as well as ground elements / ground support equipment that is particular to the scientific payload (and may therefore vary with different instruments being flown). The report describes both groups of ground system elements separately: ground system elements and equipment specific to the scientific payload in chapter 3, ground system elements primarily required for gondola/balloon operations in chapter 4.

Part of the goal of this report and the underlying work is to identify which of the already existing ground infrastructure and systems can be used for ESBO flights and operation and which elements / infrastructure may still need to be developed or built up (in particular for the very large FIR flight system). To this end, particularly chapter 4 starts from the existing infrastructure, analyzing what can be used and what will be required in addition. The elements and equipment that will still need to be developed and/or provided in addition are furthermore summarized in chapter 5. These items constitute an important input to the ESBO development roadmap (Deliverable D7.1).

3 GROUND SYSTEM ELEMENTS SPECIFIC TO FLIGHT PLATFORMS

This chapter lists the ground system elements required by / to support the scientific payload of each specific flight system. In addition, the general specificities of each flight system with regard to its requirements on the ground segment are listed, which will be of importance for the considerations in chapter 4.

3.1 UV FLIGHT PLATFORM

The UV flight platform is the by far smallest and lightest platform among the three flight platforms foreseen. The gondola physical dimensions are well within the range of payloads regularly flown today, so that in this regard it poses little challenges for the ground segment. Several aspects of the scientific payload and wavelength region require particular attention and equipment during ground handling, however.

3.1.1 Scientific payload-specific elements

UV optics, due to the short wavelength under study, are extremely sensitive to contamination (contamination causes straylight and thereby degradation of the image quality and sensitivity). Generally, UV optics should therefore be handled under ISO 6 cleanroom conditions (see ISO 14644-1) or better (time-limited exposures to worse cleanroom conditions may be tolerated if the required surface cleanliness level can still be maintained including these exposures). The main particular items of ground support equipment required for UV payloads are driven by this requirement.

- <u>Cleanroom environment/tent (at least ISO 6) to handle UV optics</u>
  Balloon launch sites, as also described in chapter 4, typically do not provide sufficient-quality cleanroom conditions. Checks and alignment procedures of the optics after transport to the launch site need to be carried out such conditions, however. A cleanroom tent providing at least ISO 6 (commercially available item) is therefore foreseen to provide workspace for checks and alignment of the UV payload compliant with the contamination requirements.
- <u>Dry nitrogen supply to flood telescope and optics to avoid contamination</u>
  In order to avoid contamination by dust, but also by humidity (which, particularly during ascent, could condensate on optical elements), the telescope and all UV optics need to be maintained in a dry nitrogen environment whenever possible. Particularly, the telescope will be slightly overpressured (by approx. 15 mbar) with dry nitrogen before launch to avoid contamination and entry of moisture during ascent. For maintaining this environment, a supply of dry nitrogen gas (standard commercial supply in standard gas containers) will be required.
- <u>UV source for alignment-check after shipment</u>
  At least for the prototype version of the UV flight system, the payload optics were not specifically designed to withstand the random vibrations expected during transport to the launch site. In order to check and potentially adjust the alignment of the UV optics after arrival at the launch site, a UV source will be required.

3.1.2 Non-payload related specificities of flight platform

- Comparatively low gondola mass (approx. 750 kg)
- Well manageable gondola dimensions (approx. 3 x 3 x 3 m^3)

With the rather standard dimensions, handling, transport and recovery of the gondola will not require specialized equipment beyond that available at existing balloon flight sites (see also following chapter).

3.2 NIR FLIGHT PLATFORM

3.2.1 Scientific payload-specific elements

- <u>Liquid nitrogen supply for cryogenics</u>
  The cryogenic system as baselined for the NIR flight platform relies upon liquid nitrogen for cooling. As liquid nitrogen cryostats have a certain boil-off rate even without internal power dissipation, the cryogen needs to be refilled shortly before launch to provide sufficient cooling for a long flight and to avoid unnecessary oversizing of the cryogen tank. To this end, liquid nitrogen needs to be provided at the launch site. Liquid nitrogen is a standard commercial product.

3.2.2 Non-payload related specificities of flight platform

- High gondola mass (approx. 2t)

The NIR flight platform will be heavier and somewhat larger than the UV platform. Nevertheless, it will still be within the mass and size range of commonly flown gondolas. For recovery with a standard helicopter, the gondola will be designed to allow disassembly into components of ca. 1 t mass.

3.3 FIR FLIGHT PLATFORM

With the large dimensions of the FIR flight platform, it exceeds the geometric size and the mass of payloads usually handled at balloon bases at the moment. Provision of additional equipment will therefore be necessary. The scientific payload poses particular challenges in terms of the primary mirror size.

3.3.1 Scientific payload-specific elements

- <u>Liquid helium supply for cryogenics</u>
  The cryogenic system as baselined for the FIR flight platform relies upon liquid helium for cooling. As liquid helium cryostats have a certain boil-off rate even without internal power dissipation, the cryogen needs to be refilled shortly before launch to provide sufficient cooling for a long flight and to avoid unnecessary oversizing of the cryogen tank. To this end, liquid helium needs to be provided at the launch site. Liquid helium is a standard commercial product and has in the past been delivered even to remote launch sites such as McMurdo base in Antarctica.
- <u>Alignment equipment</u>
  Due to its size (5 m diam.), the primary mirror will likely need to be shipped to the launch site separately from the rest of the gondola (the size just about fits into a C-17, which is typically used to bring supplies to e.g. the McMurdo base). As the telescope will then need to be assembled on site, equipment required for alignment will need to be provided on site.

3.3.2 Non-payload related specificities of flight platform

- Very large gondola mass (> 3.6 t)
- Very large gondola (> 5 x 5 x 5 m^3)

As mentioned above, the FIR gondola will likely, due to its geometrical size, need to be shipped to the launch site as subassemblies and then assembled on site. Equipment required for the assembly therefore needs to be available at the site or brought there as well.

The recovery of the gondola and payload poses a similar challenge: commonly used helicopters can only carry payloads of about 1 t. The gondola therefore will need to be disassembled into subassemblies for recovery on site of the landing, which complicates the recovery procedure.

4 EXISTING GROUND SYSTEM INFRASTRUCTURE

The main elements of the infrastructure that is required for preparing, launching, flying and recovering stratospheric balloons can be divided in three parts;

- Fixed or permanent infrastructure that cannot be installed quickly or can be moved easily.
- Mobile infrastructure that can be brought in from other locations or can also be accommodated from local suppliers and removed after a balloon campaign.
- Personnel to operate the infrastructure and execute the balloon campaign.

There is of course not always a clear distinction or definition between the two first different types of infrastructure. The extent of the infrastructure is also dependent on the size/mass of the gondola and balloon. The size of the balloon is also dependent on the float altitude. A higher altitude requires a larger balloon. The overall description below is not making any difference for this, this is discussed in the description for the different launch sites. The sizes can be defined in three different categories related to the three different sizes of telescopes;

- Medium, 0.5 m telescope diameter (UV)
  This size can be handled by the medium to large balloons existing today depending on the required float altitude. The existing infrastructure can also handle these gondolas and balloons.

- Large, 1.5 m telescope diameter (NIR)
  This size can be handled by the largest balloons that exists today depending on the requirements on float altitude. The existing infrastructure can also handle these gondolas and balloons.

- Super large, 5 m telescope diameter (FIR)
  This size cannot be handled by the largest balloons that exist today. Larger balloons able to take heavier loads have to be developed and manufactured. This is most probably feasible as no new design have to be developed. Most of the infrastructure can handle these larger balloons but some infrastructure has to be modified and extended, such as the launch vehicle and launch spool. Also existing buildings including the handling infrastructure (cranes) might need extensions to some extent to accommodate larger and heavier gondolas.

The type of infrastructure is also dependent on the launch technique that is used. As only the dynamic release technique is used for the largest balloons and gondola today only this technique has been considered in this document. The main difference is in the launch vehicle used for holding and releasing the gondola before flight. The description below is focusing on the larger items that could be defined as infrastructure also including vehicles etc. The total amount of required infrastructure is also dependent if more than one flight is foreseen in parallel at the same time or in close proximity in time which would require extra capacity of the same infrastructures.

4.1 FIXED OR PERMANENT INFRASTRUCTURE

- Launch field:
  This is the area used for assembling the total flight train, parachute, balloon, and

gondola before flight. It is then used for filling the balloon and launching the complete vehicle. It has to have a length as long as the complete vehicle (balloon, parachute, and flight train) plus some space for letting the launch vehicle manoeuvring to favourable launch position. For the largest balloons this is approximately 300-400 m. To be able to launch in different wind directions this length should be available in a couple of directions. The surface should be even, level, and smooth. Such surfaces as gravel, hard sand, packed snow/ice, paved, concrete can be used. The surface must be able to handle heavy vehicles. The launch field should be close or next to the preparation, integration, and storage facilities. Such existing infrastructures as airfields could be used as launch fields.

- Preparation, integration and testing facilities:
  The flight equipment must be prepared, integrated, tested and accommodated before flight. The facilities to be used are normal indoor working conditions with standard working infrastructure such as electrical power, lightning, internet connections etc. For the preparation, integration and testing of the gondola extra infrastructure might be required such as some type of lifting (traveling crane) infrastructure inside the facility. It would be used for lifting the gondola during integration and tests. The ceiling height and size of the access doors to the facility has to be able to handle the total size of the gondola.

- Operation facility
  During launch and flight the operational teams will operate and control both the balloon flight system and the gondola via the operational networks and terminals that are connected to the links to the balloon. These links could be either Iridium connections (requiring internet connections) or direct links via line of sight transmitters and receivers. The operational equipment and personnel have to be accommodated in one or more operational facilities equipped with normal working conditions including internet connections. One special required infrastructure is uninterrupted power backup in case of failure in the power system. As the total space required for the operational facility is not too large this facility could also be a mobile infrastructure. The operation teams are normally divided in two teams or functions, one team operating the flight of the balloon, the second team operating the gondola and the systems and instruments onboard the gondola. The teams don't have to be at the same physical location but have a good communication link. The operational team or part of it can also be located remotely compared to the launch site.

- Support facilities for personnel
  In case of a launch facility is used where the personnel is not permanently stationed at the site such facilities as lodging and restaurant have to be available or arranged for.

Figure 1 Gas canisters on trailer at Esrange

4.2 MOBILE INFRASTRUCTURE

- Gas cisterns/trailers with helium
  To fill the balloon with the required helium gas mobile canister or trailer with gas canister has to be available. As the balloon will be placed according to present and predicted wind direction at the launch time the filling point cannot be foreseen in advance. Therefore, the gas supply is preferably mobile. The total capacity of the gas trailer or trailers is dependent on the size of the balloon and if multiple balloons will be launched.

- Launch vehicle/mobile crane
  This is used for holding the gondola during launch preparation and move into position for the release of the gondola and the rest of the flight systems and balloon. This vehicle can be a special designed or modified vehicle that is only used for this purpose. It can also be a mobile crane that is temporarily modified for the purpose. This makes it possible to use locally available infrastructure in case of launch sites that are only used occasionally and difficulties or high costs for transport of dedicated launch vehicle to launch site. The size or capacity of the vehicle is dependent on the size and mass of the gondola that it has to lift and hold. It must also be possible to move the vehicle at the launch moment for an optimal release.

- Launch spool and vehicle
  The launch spool is a dedicated and specialized mobile infrastructure required for the launch. It is used for holding the balloon close to the ground during filling the balloon with gas without damaging the fragile plastic in the balloon envelope. The size and mass of the spool is related to the size and lifting capacity of the balloon. The spool has to be moved/pulled by a standard heavy vehicle during the launch preparation on the launch pad.

- Trailer and vehicle for balloon layout
  The balloon crate with the balloon must be moved during the layout of the balloon on the launch pad. For this a trailer pulled by a vehicle is used. The balloon crate is placed on the trailer and the balloon is unfolded from the crate on to the ground while the vehicle is moving the trailer with the crate. These are standard vehicles that in most cases can be arrange with locally in case of launch sites that are not used regularly.

- Ground station
  For the communication with the gondola/balloon during Line Of Sight, LOS. A ground station with smaller directional antenna, transmitter and receiver is used. This system can be used when the balloon is relatively close to the ground station. The big advantage is the relatively high bandwidth that can be achieved for the communication link. The ground station can be moved to different locations and if more than one ground station is used the range of the high bandwidth link can be extended. The ground station has normally to be placed at the remote site in advance of the balloon launch. This requires stable and predictable flight trajectories to be implemented.

- Lifter
  For lifting heavy items at the launch site. Standard equipment.

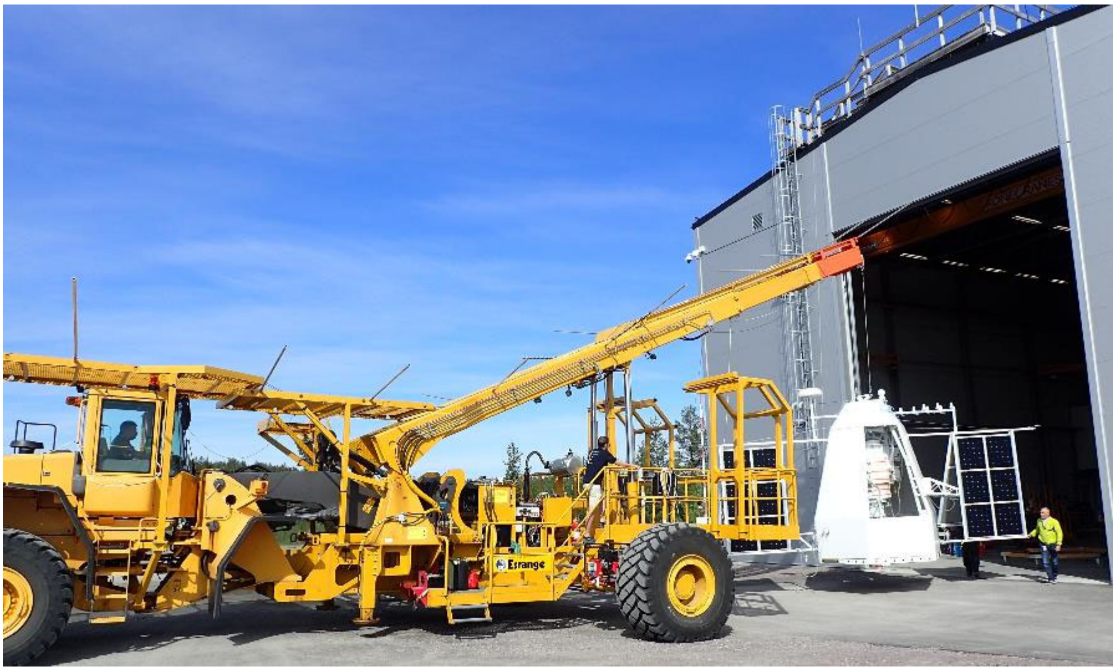

Figure 2 Launch vehicle "Hercules" at Esrange picking up gondola in the Dome integrating facility

4.3 RECOVERY INFRASTRUCTURE

After the flight is terminated and the gondola and all other equipment and systems have landed, everything has to be recovered. There is of course an interest in recovering the gondola and most of the systems for reuse etc. but also the parts that can not be reused such as the balloon envelope has to be recovered from an environmental point of view. The landing site can to some extent be controlled by terminating the flight at a favorable landing site along the balloon flight trajectory. The landing site is normally in a remote area with no infrastructure. The normal procedure for recovery of the systems are to disassemble the systems at the landing site into sizes that can be handled by the first in line recovery vehicle which normally is a helicopter (or small aircraft in Antarctica). Depending of the size of gondola it can also be lifted directly by the helicopter. The equipment is then transported to the closest road or airfield for further transportation with more cost-efficient transportation. This transportation is either back to the launch site or directly to the development/refurbishment site of the gondola and other flight systems. The most critical infrastructure here is the helicopter for the first line of transportation. It is of course preferable with a helicopter that can bring out the complete gondola in one piece, but this would require a large helicopter to a very high cost. A lifting capacity of reasonable easily available helicopter is around 1000 kg. The recovery vehicles are normally provided by external suppliers and not part of the permanent infrastructure.

4.4 PERSONNEL

To perform stratospheric balloon campaigns successfully a trained team of personnel is required. The team handles different tasks and can be divided in the following main functions:

- Launch
- Operation
- Safety
- Gondola
- Recovery

Depending on the overall campaign schedule, launch window, recovery operation, etc. approximately 20-30 persons are required for fulfilling all tasks not including the science tasks but the gondola with its support functions. The total workload can be very high due to long work periods and a limited campaign period and this might require that some personal are redundant which makes it possible for part of the team working in shifts to recover even if the campaign continuous. The operation and safety functions might require redundant "shift" personnel if the flights are longer than one day as the balloon and gondola might need 24/7 operation.

Figure 3 Balloon launch spool at Esrange.

4.5 KIRUNA, SWEDEN

Esrange is a fully equipped base for preparing, launching, flying and recovering stratospheric balloons up to the largest balloons that exist today and their payloads. It is permanently staffed year-round. Different balloon campaigns are performed each year at different time periods of the year. It is run and operated by SSC and used for SSC balloon campaigns. It is also used by other balloon operators worldwide such as NASA, CNES, JAXA etc.

It is used both for flight and recovery in the area of the Scandinavian countries (Sweden, Norway, Finland) and for long duration flights with either western trajectories or eastern trajectories including recovery in the countries covering these flight paths. The flight path over Russia have been used but is difficult and unreliable to establish overflight permissions and landing permissions.

Esrange have all required infrastructures at the base both the permanently installed infrastructure, mobile infrastructure and the required personnel that is permanently stationed at Esrange. Both the mobile infrastructure and the personnel can be moved to other launch sites in case another site will be used.

Since 1974, over 600 scientific balloons have been launched from Esrange, the largest balloon with a volume of 1 120 000 m^3, the heaviest payload being 2000 kg. Four buildings for preparation, assembly, integration and test are located at the north edge of the launch field.

The total launch pad area is 250 000 m^2. The launch field is designed to launch balloons in different directions, divided into six runways with at least 400 m length. The directions are

N, S, NW, NE, E and SE. The surface of the launch pad is gravel with a foundation that can carry heavy vehicles.

There are four balloon/gondola preparation buildings, located at the north end of the balloon pad. They are called “the Dome”, “the Chapel”, “the Cathedral”, and “the Basilica”.

Figure 4 Balloon launch pad at Esrange looking northwest.

The Dome

is the main user building during campaigns and is primarily used for gondola and payload assembly. It has a ground floor area of 19 m by 24 m (450 m^2), allowing for assembly of large payloads inside. The main door is 7 x 10 m, which facilitates payload pick up during the countdown. The hall is equipped with an overhead travelling crane, which has a lifting capability of 4 t lifting to a maximum height of 7 m. Four 500 kg swing arm telfers are mounted on the walls of the main hall. The north part of the building is a two-floor office area. On the ground floor area there is a combined kitchen and office, and a rest room. On the second floor, there are four user offices. All areas are equipped with Internet.

Figure 5 Inside the Dome integration hall at Esrange.

The Cathedral
is mainly used for payload handling and assembly. This is also a building to be utilized by the user during balloon campaigns. The floor area is 375 m^2 out of which 296 m^2 is payload preparation area. The main door of the Cathedral is 6.9 x 4.7 m.

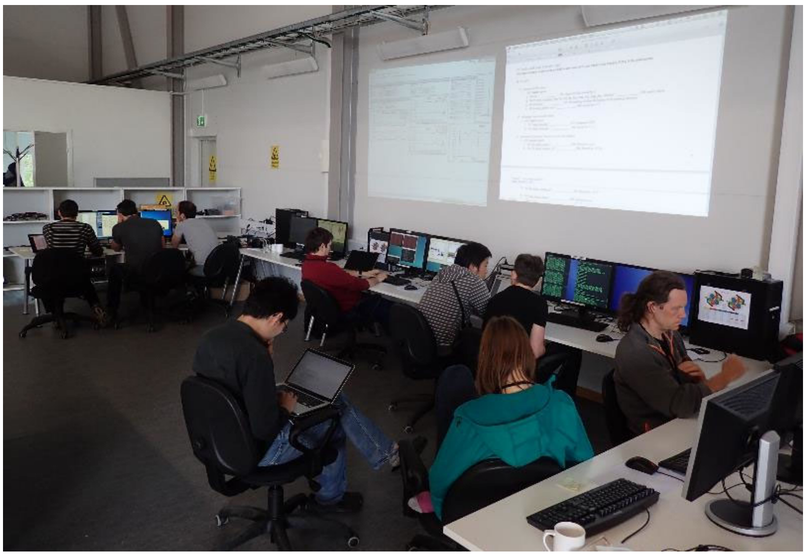

Figure 6 Science operation team setup in the Dome at Esrange.

The Basilica

The Basilica serves as a storage of balloon launch equipment such as 4-weeler, dollies with tools, instruments, filling equipment, outdoor lights, blimp etc. This building is mainly used for preparation of flight train. It is also used for preparations of flying equipment, such as smaller parachutes and ballast machines. The floor area is 323 m^2 of which the assembly hall is 308 m^2. The assembly hall is equipped with a crane, which has a lifting capability of 1 t lifting to a maximum height of 3.3 m.

The southern part of the building is a two-floor area. The Balloon Operation office is situated on the top floor and has Internet access. On the ground floor area there are two user offices also equipped with Internet.

Figure 7 Balloon operation team in the Basilica at Esrange

The Chapel

This building has a floor area of 180 m^2. The building is mainly used by the section Instrumentation for balloon equipment preparation. To support pre-flight operations, a crane of 1000 kg lifting capability runs along the ceiling, also allowing loads to be carried 2 m outside the entrance door. The crane has a max lifting height of 3.35 m.

4.5.1 Conclusion

The medium and large telescopes/gondolas can be handled today at Esrange. The super large telescope/gondola can be handled at Esrange after some minor modifications and expansions have been performed at Esrange such as modifications to launch vehicle, launch spool and integration building.

4.6 TIMMINS, CANADA

Timmins is a base run by CSA and CNES located at the east sector of the Victor M. Power airport, close to the end of the 10-28 runway. The airport is located 10 km north of Timmins city. The first scientific balloon flight campaign was performed in 2014.

The main building of 350 m^2 with a high bay is used for integration of gondolas and flight systems. The operation control room is on the second floor in the same building.

The Payload's Assembly, Integration and Test (AIT) hall is also used for payloads and can host up to 5 payloads which can be prepared simultaneously. It has an area of 300 m^2 and a height of 7.5 meters under crane hook. A third building, similar in construction to the Payload's AIT but somewhat smaller is used as a storage shelter for the heavy launch support equipment.

Figure 8 Timmins/Victor M. Power airport with balloon buildings within the red circle and balloon launch area marked with green circle.

The launch area, it is located in the east end of the runway 10-28 offering a useful area of 400 meters of diameter.

In the operative side the CSA Canadian team is in charge of all safety aspects including communication with Air Traffic Control, cartography, the radio soundings, the data acquisition and delivery to the CNES launch team before the launch decision is made, and the recovery of the balloon and flight trains after landing.

Most of the mobile infrastructure required for the launch and flight of stratospheric balloons, including ground station, have to be brought into Timmins or/and rented from local provider.

As the location of Timmins can result in relative long flights over land, it can be beneficial with more than one ground station.

4.6.1 Conclusion

The medium and large telescopes/gondolas can be handled today at Timmins concerning the fixed infrastructure. The mobile infrastructure has to be brought in or provided from local providers. All trained personnel have to be brought in. The super large telescope/gondola can probably be handled at Timmins after modifications and expansions have been performed at Timmins such as integration buildings.

Figure 9 Balloon buildings at Timmins, © Canadian Space Agency

4.7 WANAKA, NEW ZEALAND

NASA have established a relative new balloon launch base at Wanaka airport on New Zeeland. One of the purposes is to fly SPB from this base and let the balloon circulate the Antarctica over the ocean for long duration flights. A launchpad has been constructed 2016 next to the airport with a nearly 600 m diameter and spokes for different layout direction of the balloon and flight train. This makes it possible to use the balloon launch pad without any longer disturbances in the traffic at the airport.

The airport is only providing very basic infrastructure so most of this have been provided by NASA for the previous balloon missions and have to be provided by any other balloon operator wanting to use the Wanaka airport.

4.7.1 Conclusion

At the moment is probably only possible to launch and fly medium sized telescopes/gondolas from Wanaka. The mobile infrastructure has to be brought in or provided from local providers. All trained personnel have to be brought in. For larger missions it is probably necessary to invest in new and larger integration and preparation facilities.

Figure 10 Wanaka airport and balloon launch pad on New Zeeland

4.8 MCMURDO, ANTARCTICA

The NASA balloon launch facility on Antarctica is situated on the Ross Ice Shelf at the Williams Field close to the McMurdo base. It is only used during a short period during the Antarctic summer in December and January. The nominal launch window for this base is between December 10 and January 10 each year. The start of the launch period is determined by the establishment of the seasonal polar wind circulation pattern that is required to maintain trajectories over the continent for recovery on the continent. The end of the period is determined by the United States Antarctic Program (USAP) requirements to complete seasonal close-out operations before the winter period.

All the infrastructure is semi mobile to protect it from the heavy winters. This have the consequences that the base has to be prepared before each campaign and prepared for the storage after each campaign. The snow is prepared and packed so it can be used as launch field. It is situated on the Ross Ice Shelf.

As the season is short and the base is normally used by NASA during the season some of the infrastructure and personal probably have to be duplicated in case it should be used by other campaigns than NASA depending on the size and complexity of the missions.

Figure 11 The McMurdo balloon base on the Ross ice shelf. The launch pad can be seen at the right as a large circle.

The following buildings are available and used for the balloon activities at the base. Two large and high identical buildings are used for payload/gondola assembly. That can accommodate large gondolas. One lower building that is used as mechanical/rigging workshop for preparation of balloon flight systems. The telemetry building used for communication and operation. There are also buildings for support infrastructures such as heating, electricity, toilets, kitchen etc.

At the end of the available balloon season the buildings are moved onto snow berms and anchored for the winter to avoid getting the building buried in snow.

The recovery is performed with small aircrafts and helicopters and can be very difficult depending on the location, weather conditions and availability of aircraft and helicopters. Sometimes the equipment has to be left until next season specially if the landing is late in the season.

Figure 12 The different buildings used for the balloon campaigns by NASA at McMurdo

Figure 13 Launch vehicle used at McMurdo

Figure 14 Moving one of the integration buildings at McMurdo at the seasonal closure of the base.

McMurdo station also houses a 10 m X-band ground station as part of the NASA Near Earth Network which is regularly used for satellite downlink (particularly for Earth observation satellites) [RD4]. Whether this station can be used for downlink of balloon data still needs to be clarified.

4.8.1 Conclusion

The medium and large telescopes/gondolas can be handled today at McMurdo concerning all infrastructure. All trained personnel have to be brought in. The super large telescope/gondola can probably be handled at McMurdo after modifications and expansions have been performed at McMurdo such as integration buildings, launch vehicle and launch spool. One of the major issues with super large gondolas at Antarctica will be the recovery of the gondola. It is already problematic for the medium and large gondolas. The McMurdo base is a NASA infrastructure and it is unclear to what extent and under which circumstances the infrastructure can be used by another operator or if NASA can provide flight opportunities for a non-NASA gondola.

5 NEEDS FOR DEVELOPMENT AND CREATION

ULDB / SPB Demonstration Needs	
LT-DemN-ULDB-01	Reliable long-term operation Heavy-lift SPBs need to demonstrate reliable long-term operation, i.e. reliably reaching 50+ days of flight with sufficient flight time margin to reach areas with recovery possibilities. The technique has been under development during a long time and is reaching an operational phase but need further testing and demonstration. For full potential it also needs to be tested during different seasons or nigh/day periods. So, it also can be used for longer dark night observations.
LT-Dem-N-ULDB-02	Safe payload landing and recovery A technical and operational solution to safe and reliable recovery of payloads have to be developed as mentioned below. This technique has to work reliable under many different conditions and circumstances. Therefore, is it important to test and demonstrate this under different real field conditions.
ULDB / SPB Development Needs	
LT-DevN-ULDB-01	Safe payload recovery A reliable technical and operational solution to safely and reliably recover payloads of heavy-lift ULDB/SPB flights needs to be developed. In the perspective of a program relying on re-use of equipment and system both for reducing costs but also to improve refights rates of equipment. The development can be divided in three functions, selecting safe landing sites during flight, perform smooth and safe landing for minimum damage to equipment, fast and easy recovery of the equipment from the landing site.
LT-DevN-ULDB-02	European operation of ULDB/SPB flights for heavy payloads A European capability to operate ULDB/SPB flights for heavy payloads needs to be developed. This both includes the required technique and knowledge but also access to suitable launch sites that gives access to suitable flight trajectories. These sites would be situated outside Europe in some cases. A build-up of infrastructure in these places would also be necessary for more sustainable programs. This capability should preferable be performed partly in cooperation with US that have spent

	considerable time and recourses on this capacity to save development time and recourses.
LT-DevN-ULDB-03	Increase of ULDB/SPB payload masses The supported payload mass (suspended mass) of ULDB/SPBs needs to be increased to ~ 3 t for the ESBO FIR flight system. The ULDB/SPBs under development and test doesn't have this load capacity. They have to be increased to carry these increased loads.
LT-DevN-ULDB-04	Increased data links For flights that exceeds a distance of one or a couple of hundred kilometres from the communication ground station the communication have utilised different types of satellite links. These links have been with a relatively low data band width. This can be a major disadvantage when large amount of data from onboard instruments have to be downloaded. This data links has to be improved in future flights. One solution could be to develop systems that can communicate with future satellite constellations for Internet services in case such systems will materialise and be available in the future. Another solution could be to improve the LOS system with pointing antennas for higher band width over longer distances.
LT-DevN-ULDB-05	Increase of existing ZPB payload mass capacity In parallel to the development of SPB the ZPB will still be an attractive option for future missions. The existing ZPB are not dimensioned to carry the larget gondolas that can be foreseen for the future balloon borne telescopes up to 5 m diameter. The existing technique could still be used for increased gondola masses but larger balloons that could also carry hevier loads have to be developed and tested.
Ground Station Needs	
LT-DemN-GS-01	Set-up of an X-band ground station at Halley station Set-up of an X-band ground station for science data downlink at Halley station (or a similar position around halfway along circumpolar trajectory from McMurdo). Suitable ground stations are commercially available e.g. as mobile trailers.[1]

[1] See e.g. Viasat 5.4 Meter Mobile X-band Tracking System, https://www.viasat.com/sites/default/files/media/5_meter_fixed_antenna_010_web.pdf