NASA & NSF

FY20 Balloon Implementation and Management Plan (BIMP)

For Antarctic Long Duration Balloon Flights

To Be Conducted Between October 2019 and February 2020

This implementation plan supports the agreement between the National Aeronautics and Space Administration Science Mission Directorate and the National Science Foundation Office of Polar Programs concerning Cooperation on Matters Related to Balloon Flight Operations in Antarctica. In accordance with that agreement, the Office of Polar Programs and the Balloon Program Office of the Goddard Space Flight Center Wallops Flight Facility are responsible for implementing this plan.

Effective Date
October 2019

820/Balloon Program Office

Goddard Space Flight Center
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National Aeronautics and Space Administration

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NOMENCLATURE

APTLite	Advanced Particle-astrophysics Telescope Lite
ASC	Antarctic Support Contractor (NSF Contractor)
ATP	Approval to Proceed
BARREL	Balloon Array for Relativistic Electron Losses
BAS	Balloon Air Sampling
BIMP	Balloon Implementation and Management Plan
BLAST	Balloon-borne Large Aperture Submillimeter Telescope
BLASTPol	BLAST Polarization
BPO	Balloon Program Office (NASA)
CMB	Cosmic Microwave Background
Co-I	Co Investigator
COMSUR	Commercial Surface (transport) COMAIR Commercial Air (transport)
CSBF	Columbia Scientific Balloon Facility (NASA contractor)
DC	Direct Current
EBEX	E and B Experiment
E-MIST	Exposing Microorganisms in the Stratosphere
eV	Electron Volts
FAR	Federal Acquisition Regulations
FM	Frequency Modulation
FOV	Field of View
FRR	Flight Readiness Review
FY	Fiscal Year (starting October 1)
GAPR	Gondola Automatic Parachute Release
GPS	Global Positioning System
GSFC	Goddard Space Flight Center
GUSTO	Galactic/Extragalactic ULDB Spectroscopic Terahertz
hrs.	Hours
HQ	Headquarters
HWP	Half Wave Plate
IAA	Interagency Agreement
IP	Internet Protocol
IRT	Incidence Response Team
Kbps	Kilo Bits Per Second
Kft	Kilo-Feet
Kg	Kilograms
KHz	Kilo Hertz
km	Kilometer
LDB	Long Duration Balloon
L-DEEP	Long Duration energetic Electron Precipitation Study
LOS	Line of Sight
M	Meter
MCF	Million Cubic Foot
MCM	McMurdo
MHz	Mega Hertz
MIP	Micro Instrument Package
MOA	Memorandum of Agreement
MOC	Mission Operation Center

MPCP	Mishap Preparedness and Contingency Plan
MRR	Mission Readiness Review
MRSO	Mission Range Safety Officer
NASA	National Aeronautics and Space Administration
NOTAM	Notice to Airmen
NSF	National Science Foundation
OA	Orbital ATK
OCC	Operations Control Center
OPP	Office of Polar Programs
OTH	Over the Horizon
PI	Principle Investigator
PIC	Project Initiation Conference
PLR	NSF Office of Polar Programs
PMC	Polar Mesospheric Cloud
PMC turbo	Imaging Gravity Wave, Instability, and Turbulence Dynamics in Polar Mesosphere Clouds Viewed from the Stratosphere
PV	Photovoltaic
ROCC	Remote Operations Control Center
SAPR	Semi-Automatic Parachute Release
SCD	Silicon Charge Detector
SFC	Science Flight Computer
SFR	Star Formation Rate
SIFT	SPB Instrumentation Flight Package
SIP	Support Instrument Package (NASA/CSBF)
SIP	Support Information Package (NSF/ASC)
SITREP	Situation Report
SMD	Science Mission Directorate (NASA)
SPB	Super Pressure Balloon
SSSC	Sun-Solar System Connection
Super-TIGER II	Super Trans-Iron Galactic Element Recorder
TDRSS	Tracking Data Relay Satellite System (NASA)
TRAVALB	Trajectory Validation for GUSTO Pathfinder
TVAC	Thermal Vacuum (test verification & validation)
ULDB	Ultra Long Duration Balloon
USAP	United States Antarctic Program
US	United States
WAIS	West Antarctic Ice Sheet (NSF Remote Site)
WFF	Wallops Flight Facility (NASA GSFC)
WASP	Wallops Arc Second Pointer

1 INTRODUCTION

This document describes the general implementation plans for support of the two main payloads, two hand-launched payload and several piggybacks. Main payloads are Super Trans- Iron Galactic Element Recorder (Super TIGER-II) instrument and Balloon-born Large Aperture Submillimeter Telescope (BLAST)[1]. The two hand-launched balloons are Trajectory Validation for GUSTO Pathfinder-1 and -2 (TRAVALB-1 and TRAVALB-2) [2]which will be launched as long duration missions from the Long Duration Balloon (LDB) Remote Launch Site, located near the Williams Field ski way at McMurdo Station, Antarctica. Super TIGER-II will include four piggybacks: Imaging Gravity Wave, Instability, and Turbulence Dynamics in Polar Mesosphere Clouds Viewed from the Stratosphere (PMC Turbo), Exposing Microorganisms in the Stratosphere (E-Mist), Balloon Air Sampling (BAS), and Advanced Particle-astrophysics Telescope Lite (APTLite)[3]. Launch is expected to occur during the period December 1, 2019 to January 10, 2020. Launch may occur as late as January 15 with National Science Foundation (NSF) concurrence.

All instruments completed pre-shipment integration and testing with Columbia Scientific Balloon Facility (CSBF) support systems (Appendix H). Final "flight ready" assembly of all payloads will be completed at the Antarctica LDB Remote Launch Site.

Super TIGER-II, BLAST, and TRAVALB-1 and TRAVALB-2 will utilize flight-qualified support systems and a plan of operations based on more than 29 years of joint NSF and National Aeronautics and Space Administration (NASA) experience conducting scientific balloon operations in Antarctica. CSBF will be monitoring stratospheric float winds and be prepared to take advantage of an earlier launch should suitable conditions manifest. Primary payload Principle Investigators (PI) retain exclusive authority for declaring flight readiness regardless of readiness of piggyback payloads, in order to maximize primary payload objectives.

Planning is underway to conduct launch of Super TIGER-II at the earliest possible in the campaign season and to fly multiple circumnavigations (circuits) around the South Pole at an altitude of ~130,000 feet or 40 kilometer (km). Super TIGER-II is willing to forego same season recovery at end of flight in order to maximize, to the extent possible, its flight duration. All payloads are planned to be recovered from the Antarctic continent. Approval for multiple circumnavigations will be in accordance with the following section 2.7 (and Appendix H), and with the understanding that same-season post flight recovery becomes less likely.

2 ROLES AND RESPONSIBILITIES

The NASA Balloon Program Office (BPO), of the Science Mission Directorate (SMD)/Astrophysics and Wallops Flight Facility (WFF), and the NSF Office of Polar Programs (OPP) will jointly resolve any conflicts or issues that may arise between their respective organizations. For purposes of this plan, science users are considered as part of the NASA organization. Each agency will keep the other informed as to any issues involving conduct of personnel, logistics issues that may impact the overall conduct of the campaign, safety related issues, and/or issues impacting cost and schedule. The articles contained herein under section 2.0 expound upon specific roles and responsibilities relevant to this Fiscal Year (FY) 2020 plan.

[1] See Appendix A for further information on BLAST.
[2] See Appendix G for further information on TRAVALB.
[3] See Appendices B, C, D, & F for further information on the Super TIGER-II, PMC Turbo, E-MIST, BAS, and APTlite instruments, respectively.

2.1 Support Requirements and Agency Responsibilities

This implementation plan will be conducted in accordance with the support requirements and agency responsibilities as specified in the Interagency Agreement (IAA) between the NASA Science Mission Directorate Astrophysics Division and the NFS Antarctic Sciences concerning cooperation on matters related to balloon flight operations in Antarctica, effective October 1, 2019 through September 30, 2020, which includes the “Attachment for Inter-Agency Agreement (IAA) between the NASA and the NSF in support of NASA Balloon Flight Operations in Antarctica”.

2.2 Approval & Management of Incremental Costs

NASA requests NSF support with transportation of materials and personnel to and from the continental United States and New Zealand within the framework of NSF’s United States Antarctic Program logistics system. NSF will provide NASA with an estimate of the incremental costs to support the LDB projects for FY20. This estimate will be provided by September 30, 2019 and will include an itemized listing of estimated costs. NASA will review estimated incremental costs and will either accept them or modify its requirements. Acceptance of the cost estimate will be confirmed at the time this BIMP is signed. NASA will obligate funding, under an advance payment arrangement and in accordance with applicable Federal Acquisition Regulations (FAR) requirements, to the established NASA/NSF purchase order. NSF, will in a timely manner, obligate these funds to their contract service providers who support LDB activities. NSF will make payments to these service providers upon receipt of invoices and validation of actual costs and will notify NASA of the progress in funding liquidations. At the conclusion of this annual balloon campaign, NSF will provide NASA with a breakdown of all costs incurred, including aircraft sorties conducted in support of NASA payload recoveries. (Summary estimates for incremental costs are shown in Appendix I, which also supports a statement of work for the NASA purchase order).

2.2.1 Cost Controls

These missions are to be conducted in accordance with nominal, established NASA and NSF baseline levels of science support. Requirements that exceed baseline levels of support must be approved by the parties to this plan (see section 5 below). NSF and its contractor, Leidos led team called Antarctic Support Contract (ASC), and NASA/CSBF have established levels of nominal support that both agencies have traditionally offered to their science customers and that will be used by the respective program offices to make final determination as to what is considered baseline level of support. Exceptions and special support requirements required by the NASA Balloon Program will be specifically called out in this plan. Changes to support requirements after the signing of this BIMP will be adjudicated by the parties.

2.2.2 CSBF Commercial Airline Ticketing

Due to tailoring required to respond to its mission operations tempo and programmatic requirements, NASA BPO and CSBF (Event 145) personnel travelling from the United States to New Zealand and return, will travel on commercial airline tickets purchased by NASA and CSBF. CSBF will coordinate with the NSF/OPP prime support contractor as to travel dates in order to insure compliance with NSF/OPP planning. NSF/OPP will not assess reimbursement for commercial airline ticket costs by NASA for these personnel. All other LDB Campaign participant tickets will be procured by NSF/OPP and included in NSF’s reimbursable cost estimate.

2.3 Managers

NASA/CSBF will appoint a Campaign Manager. The Campaign Manager will be responsible for filing all necessary Class I Notice to Airman (NOTAM) with the appropriate agencies and/or flight service stations in regard to each balloon flight. The Campaign Manager will be responsible for planning and implementation of the campaign in accordance with NASA scientific balloon flight support requirements and framework of NSF's United States Antarctic Program requirements. The Campaign Manager will be the field manager responsible for all flight systems, launch support systems, notification to the NSF's ASC of needed roadblocks to support launches, flight related ground support systems, and balloon flight command and control. The Campaign Manager serves as the NASA single point of contact for coordination with the ASC LDB Camp Manager of all balloon related matters, including logistics of personnel on the ice, and daily scheduling of aircraft support. He also serves as the NASA Incident Commander in the case of a mishap, or incident related to NASA balloon operations.

NASA will also provide a Mission Manager from the NASA BPO, as required by NASA's flight and safety assurance plans. The Mission Manager will also serve as the Mission Range Safety Officer (MRSO). The Campaign Manager will coordinate required Tabletop and Off-Nominal Simulation exercises with McMurdo emergency responders to ensure awareness of the approved Mishap Preparedness and Contingency Plan (MPCP). The NASA Mission Manager also serves as the Incidence Response Team (IRT) Lead.

2.4 LDB Camp Manager

NSF/ASC will appoint a LDB Camp Manager who will work with the NASA/CSBF Campaign Manager, as needed, for planning, review, and implementation of the FY20 LDB Campaign. The LDB Camp Manager will be the principle point of contact for NASA, CSBF, and Balloon Science Users for NSF provided materials and services, including coordination and establishment of resources to support balloon launches. The LDB Camp Manager will be the field manager responsible for all NSF/ASC provided support and services.

2.5 Launch Priority

NASA will be responsible for assessment of readiness of the science instruments, payload support systems, flight systems, and associated ground support systems. Normally, the first launch opportunity would be given to the payload that first declares flight-readiness and successfully completes a formal Flight Readiness Review (FRR) conducted by the CSBF. The FRR covers all instruments to be flown on the payload and all of the CSBF flight and ground support systems. After completion of the FRR, including closeout of any action items, payloads must remain intact and be ready for launch at the next available opportunity. With the exception of minor maintenance or final steps that in practice can only be accomplished immediately prior to launch, no additional flight preparation should be undertaken between the FRR and launch.

In addition, an Approval to Proceed (ATP) must be given by the Directorate/Goddard Space Flight Center (GSFC)/WFF/Code 800 prior to launch. Any dismantling or alteration of the payload or any flight subsystem will incur the risk of voiding both the NASA ATP and CSBF Flight Readiness status.

The NASA Balloon Program is responsible for maximizing the scientific return from the suite of missions supported in a campaign. The NASA Balloon Program may adjust launch priorities within the bounds of pre-established individual mission requirements in order to meet this responsibility. Facilities and logistics management will be coordinated by the CSBF Campaign Manager to best accommodate this priority.

Nominal opening of the launch window is around December 1-5 of each year for the McMurdo latitude, based upon establishment of summer season stratospheric anti-cyclone winds. Launch is contingent upon establishment of the anti-cyclone and plans are to take advantage of a possible launch opportunity on or before December 1 if opportunity allows.

2.6 Aircraft Access for Recovery

While LDB missions in Antarctica are attractive because of the convenient and predictable nature of the circumpolar anti-cyclone, a variety of mechanical, environmental and programmatic factors define the point of flight termination. Antarctica is very limited and spatially distant staging facilities means that all but ideally terminated missions risk payloads landing in remote parts of the continent. Aircraft thus become the primary asset to effect payload recovery. Recovery by traverse is also possible, depending on the potential for payloads to land on or near a major traverse route at or about the time a traverse tractor train will be passing. Land traverse recovery may also be contingent upon any given science instrument’s ability to withstand the vibration and shock that is common to land traverse vehicles.

NSF has in its planning, allocated aircraft hours for LDB recoveries. NSF will provide to NASA its plan for aircraft hours for this campaign support, prior to establishment of funding. These are scheduled within time blocks in January and early February when most LDB missions have already been terminated or are about to be terminated. Many other aircraft support requirements are present in these time blocks as well, but the overall needs are balanced with available flight resources in real-time.

NSF will give landed LDB payloads priority for recovery using the Basler aircraft, in exchange for increased funding in the amount agreed to by NASA-NSF. NSF will coordinate with aircraft operations personnel and NASA with CSBF personnel regarding the aircraft operations plans agreed to under the BIMP and ASC planning, prior to Antarctica aircraft operations support for NASA scientific ballooning. When termination is imminent or complete, NASA/CSBF and NSF will coordinate to schedule recovery by the most desirable aircraft, with priority toward the Basler, to fit within other critical United States Antarctic Program (USAP) air asset requirements while minimizing delay to payload recovery.

USAP’s variety of aircraft resources redeploy from Antarctica at different times in February. Typically, helicopter operations cease about the second week of February, LC-130’s depart the continent by February 20th, and Basler and Twin Otter airframes traditionally go off contract by the third week of February. With advance notice, NASA can negotiate with NSF to extend these end dates somewhat to accommodate LDB mission success targets. At the end of season operations, and in conjunction with NSF providing the final costing of support for NASA, for future planning purposes NSF will provide an accounting of sorties flown (Aircraft type/flight hours) in support of NASA Ballooning.

2.7 Multiple Circumnavigations

NASA recognizes that Antarctica is the highest priority campaign for NASA's scientific ballooning community and that it provides the lowest cost access to space for high priority science investigations requiring long duration flights. Since 2002, the NASA science community has designed their missions to take advantage of longer duration flights, with nearly 70% of payloads requiring multiple circumnavigations. As such, it is intended that flights requiring multiple circumnavigations be identified and agreed to prior to implementation of the Antarctic launch campaign. For planning purposes, the nominal flight duration to complete a single trajectory about the South Pole is approximately 14 days.

Allowing any flight to continue for more than a single circumnavigation incurs higher risk for a trajectory that may be untenable for planning successful recovery within the baseline budget and within the same season. Baseline resources include recovery within the geographic region of McMurdo, South Pole Station and/or West Antarctic Ice Sheet, NSF Remote Site, (WAIS) Field Camp as has been typical for most recoveries by Twin Otter, Basler or helicopter. Overland traverse assets may also be considered as viable resources to effect recovery. Flights that must be brought down in any area that is greater than 500 miles distant from these principle-staging locations are subject to being considered as above baseline support for these type missions.

Due to the high environmental sensitivity associated with Antarctica's coastline, NASA/CSBF will not risk any payload or operation whereby there is significant probability that the payload or balloon would come down over water or on the coastline. Consideration will also be made for risks that can impact same-season recovery of the payload and balloon. NASA BPO retains decision authority for committing to multiple circumnavigations, after consultation with the NSF, SMD and CSBF Management. Altitude/Minimum Duration/Desired Duration for each primary mission is as follows: Super TIGER-II (>115 kft/8 days/60 days); BLAST (>105 kft/12 days/28 days) and in flight on January 2.

2.8 Flight Termination

Prior to termination of any balloon flight over Antarctica, the CSBF Campaign Manager will coordinate recovery landing sites with NSF/ASC. CSBF will ensure that NSF/OPP and NASA/BPO are informed of plans for termination. The NASA Mission Manager will ensure that the appropriate NSF representatives are contacted in the event of an unplanned termination or mission anomaly.

Normal end-of-flight termination will be initiated by over-the-horizon (OTH) command with parachute separation accomplished by the CSBF Gondola Automatic Parachute Release (GAPR) system and/or the Semi-Automatic-Parachute-Release (SAPR) system. Due to potential damage to payloads and/or accessibility for recovery, NSF may be requested to provide input/guidance on particular impact locations in order to mitigate risks of bringing the flight systems down onto difficult or inaccessible terrain such as crevasse fields.

2.9 Recovery

Recovery of payloads and balloons will be coordinated by the CSBF Campaign Manager, the ASC Camp Manager, and NSF. NSF/OPP will arrange for assets needed for air or surface recovery. Because each payload has specific recovery requirements and prioritized elements for recovery, science payload specialists will make up part of the recovery team. The goal is to recover 100% of the payloads in the same season. Recovered items will be returned to the LDB Remote Launch Site where the science recovery specialists and/or CSBF will pack them for return to the U.S. NSF/OPP will assess retrograde of smaller size containers by air back to the U.S. on a case-by-case space-available basis. Final coordination of this will be made between the CSBF Campaign Manager, the ASC Camp Manager and NSF/OPP. No consideration will be given to returning the LDB Sea Containers by air at the close of this season.

The highest priority is for full recovery before closeout of the FY20 Antarctic campaign of CSBF flight support systems needed to support future LDB missions and for any onboard science data needed to complete science analyses. Recovery of all other hardware is highly desired before close out of the FY20 Antarctic campaign; however, full recovery of the remainder of the payload hardware and balloon may be completed the following season if assets are not available to make complete recovery this season.

Balloon recovery may be attempted with assistance from NSF/OPP and ASC. The CSBF Campaign Manager has made contingency plans for balloon recovery based on having vehicular support to/from the impact location, as well as adequate remote operations support to insure safe recovery operations. Under no circumstances will a recovery be attempted that involves putting personnel or critical assets at risk.

In all cases, CSBF will record the impact location for each payload and balloon. In the situation where loss of telemetry may occur while still in flight (i.e. pathfinders), the last known position will be reported to NASA and NSF. If no visual verification or telemetry reported position after impact is received, CSBF will annotate projected payload and balloon impact positions based upon predicted descent trajectory and will note such positions as “estimated.”

3 REPORTING

During the campaign, subsequent to personnel arrival and opening of the launch site, NASA/CSBF will provide regular Situation Reports (SITREPS) for distribution within NASA and NSF. NASA/CSBF will provide real-time display of the balloon’s 3- dimensional GPS position and a summary flight status on the INTERNET at the following URL: http://www.csbf.nasa.gov.

4 KEY MILESTONE PROJECTED SCHEDULE

See project documentation for payload-specific detailed schedule.

11/06/19	CSBF personnel begin arrival in McMurdo
11/20/19	Arrival of NASA Mission Manager(s)
11/20/19	Arrival of main contingent of CSBF support personnel
11/23/19	Estimated facilities readiness date (handover date)
12/01/19	Nominal launch window “open” date
12/01/19	Expected “flight ready” date TRAVALB-1
12/10/19	Expected “flight ready” date Super TIGER
12/15/19	Expected “flight ready” date TRAVALB-2
12/24/19	Expected “flight ready” date BLAST
01/10/20	Target launch window closing
02/05/20	Final closeout and departure

5 AMENDMENTS

Changes to this Implementation Plan will occur with exchange of email confirmation between the signatories of this plan. NASA BPO will manage configuration control of this document and will ensure review/approval by the NSF OPP. Signatories are responsible to ensure copies of emails confirming changes are distributed to all key personnel listed in this plan.

APPENDIX
Appendix A - Balloon-Borne Large Aperture Submillimeter Telescope

Balloon-borne Large Aperture Submillimeter Telescope
(BLAST)

BLAST Investigators

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Phil Mauskopf; Arizona State University
Elio Angile; University of Pennsylvania

BLAST Campaign Science Objectives

The objectives of the BLAST Polarization (BLASTPol) instrument are to measure the polarization of dust in compact star-forming regions to determine the role of magnetic fields in star formation. It will also measure the high-frequency polarization of galactic dust in an attempt to determine foreground levels for future Cosmic Microwave Background (CMB) missions.

BLAST Instruments

After decades of research, the physical processes regulating star formation remain poorly understood. Large-scale observations of star forming regions provide counts of the number of dense clouds, each of which will eventually evolve into tens to thousands of stars. However, when simple models of gravitational collapse are applied to the clouds they yield a Galactic star-formation rate (SFR) which is many times what is actually observed. Some process or combination of processes must be slowing the collapse of the clouds. Two important factors are turbulence, which provides kinetic energy against gravitational collapse, and Galactic magnetic fields, which are captured and squeezed by the collapsing cloud, providing a mechanism for mechanical support.

The Balloon-borne Large Aperture Submillimeter Telescope - BLAST, has a comprehensive program in place to make impressive headway in these areas, which fit very well within the SMD 2010 Science Plan's Cosmic Origins program. The Balloon-borne Large Aperture Telescope, BLAST, was originally designed to conduct confusion limited and wide-area extragalactic and Galactic surveys at submillimeter wavelengths from a LDB platform. These wavelengths are impossible or very difficult to observe from even the best ground-based telescope sites. After a series of successful flights (Ft. Sumner 2003, Sweden 2005, and Antarctica 2006) resulting in over 25 publications, BLAST was converted to BLASTPol. The combination of a polarizing grid in front of each of the 266 feed horns at 250, 350 and 500 microns, with a stepped half wave plate (HWP), provided a quick and inexpensive way to make initial measurements of polarized dust emission in star-forming regions. By mapping polarization from dust grains aligned with respect to their local magnetic field, the field orientation (projected on the sky) can be traced.

BLASTPol is the first instrument to combine the sensitivity and mapping speed necessary to map magnetic fields across entire clouds with the resolution to trace fields down into dense substructures, including cores and _laments. A natural follow-up to Herschel/SPIRE, BLASTPol provides the critical link between the Planck all-sky polarization maps with 50 resolution and ALMA's ultra-high angular resolution over a narrow (20”) field of view. Together, these complementary instruments will probe the inner workings of star formation with unprecedented resolution, sensitivity and scope. NASA has identified measuring the polarization of the CMB as a probe of Cosmic Inflation as a high-priority goal.

Several missions are now under consideration (PIXIE and LiteBIRD). These missions will be facing a serious challenge, with signal levels measured in tens of nanokelvins. They will require unprecedented control and rejection of systematic effects and foregrounds. Polarized emission from Galactic dust will be one of the most significant sources of foreground contamination and could ultimately limit their sensitivity. It is crucial that experiments like BLASTPol characterize the dust as fully as possible to inform the design of these missions.

One of the goals of BLASTPol is to take scientific ballooning into a new phase. We plan on making 25% of the flight (~150 hours) available for “shared risk" observing to the community. By operating in an observatory mode, similar to a satellite mission, BLASTPol will serve as a model for future Ultra-Long Duration Balloon payloads with a wide variety of scientific objectives. BLASTPol's goals are consistent with NASA strategic goals. By studying the formation of solar systems in our Galaxy we will advance scientific knowledge of the origin and history of the Solar System. Measurements of polarized dust as a foreground for current and future CMB experiments will have a significant impact on the effort to discover the origin, structure, and destiny of the Universe.

BLAST Flight Requirements

Unique Launch Site Requirements (for science needs)
The BLAST payload was fully integrated, tested and disassembled at the CSBF in Palestine, TX. There are no special shipping requirements for payload but large volume of LHe is required and shipping coordination is ongoing. Upon arrival to McMurdo Station, a BLAST team member will unpack the payload, mount it all to the gondola and mate the power connections. After that, payload will be pre-chilled and fill in with LHe. We need to do pre-flight tests that will require the use of a non-magnetic platform. We may also need to do range tests with an optical source located outside the highbay.

Flight Requirements
The flight requirements are summarized by table below. Power is to be provided by the CSBF balloon systems.

Our goal for our flight is to achieve 24+ days at float. We do not want to launch before December 15th. Can accept a flight as short as 10 days as long as it includes all of January 2nd. We require a float altitude above 105 kft but would like to fly as high as possible. For telemetry, high bandwidth data and video Line of Sight (LOS). Require Iridium dial up and Tracking Data Relay Satellite System (TDRSS) Omni. Request Iridium Pilot. We may ask for TDRSS high gain to be turned off most of the time.

Float Requirements		
Criteria	**Minimum**	**Desired**
Float Altitude	105,000 ft	126,000 ft
Time at Float Altitude	8 days or one circumnavigation whichever is less.	24 days
Altitude Stability	1000 ft	500 ft

Unique Recovery Requirements (for science needs)
Highest Priority – Hard drives.
Second – Electronics unbolted from gondola.
Third – Cryogenic receiver, primary mirror, pointing motors.
Fourth – Gondola frame.

Appendix B - Super Trans-Iron Galactic Element Recorder

Super Trans-Iron Galactic Element Recorder
(Super TIGER-II)

Super TIGER-II Investigators

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Martin Israel – *Washington University*
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Richard Mewaldt – *Caltech*
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Mark Wiedenbeck – *Caltech*
Jake Waddington – *University of Minnesota*

Mission Summary

The Super TIGER (Super Trans-Iron Galactic Element Recorder) long-duration balloon- borne instrument is being prepared for its third Antarctic flight in December 2019. The primary goals of Super TIGER-II (ST-II) are to perform new tests of the origins of galactic cosmic rays. In particular, we will test the model of origin of galactic cosmic rays in OB associations at higher charges than has previously been possible. To do this we will measure the elemental composition of cosmic rays for atomic number (Z) over the range of 26 £ Z £ 40 with improved statistics over that obtained by ST-I, and expand our measurements in the 40 £ Z £ 56 charge range. This will enable us to test the fractionation of refractory and volatile elements, and determine their mass dependence up to Z=56. Extending our measurements up to Z=56 enables us to begin to sample the charge range where r-process production resulting from binary neutron star mergers may become important. In addition, we can test whether nuclei in the Z=50's charge range are produced, injected, and accelerated by the same mechanisms as those in the Z £ 40 range.

Second, we will be able to test for possible r-process enrichment in the galactic cosmic rays. The nucleosynthesis of elements with Z³36 is almost entirely a mixture of two neutron- capture processes – the slow s-process, which occurs in evolved massive stars, and the rapid r-process, which occurs in supernova explosions and very likely in mergers of compact binaries (binary neutron stars and black holes). Some isotopes are made exclusively in one or the other of these processes, while others are made from both. Cosmic-ray isotopic composition for Z<28 and elemental composition for 28 £ Z £ 34 both point to a source enriched in material coming from evolution of massive stars compared with SS composition, indicating origin in OB associations – a mixture of ~80% SS and 20% MSP. That 20% component differs from the SS component primarily by an enhanced contribution from the s- process. Since OB associations are the site of most core-collapse supernovae, one may expect the cosmic rays to show an enrichment of r-process material. In addition, recent models of the merger of binary compact objects make various predictions about r-process production. The elemental composition to be determined with the combination of ST-I and ST-II data will enable us to look for r-process enrichment and to begin testing models of compact star mergers for nuclei with Z £ 56.

A secondary objective is to measure the energy spectra of elements with 10 £ Z £ 30. Heinz & Sunyaev (A&A 390, 751, 2002) have suggested that relativistic jets observed in micro-quasars like GRS 1915+105 and GRO J1655-40 might produce narrow features in some cosmic ray spectra. Such features may be observable in heavy, relatively abundant cosmic rays like 14Si and 26Fe as narrow peaks in the spectra if such micro-quasars have been active relatively recently (i.e. the last few million years) and are nearby.

Campaign Objectives

To achieve this measurement, our goal is to fly ST-II for 30+ days over Antarctica. Since we are flying near solar minimum, this flight duration will enable us to at least double the numbers of events detected in the first flight. This should enable us to better resolve individual element peaks in the Z>40 range, thus allowing us to extend our measurements up to Z=56. This will give us a considerably larger lever arm in testing the injection and acceleration of cosmic ray nuclei.

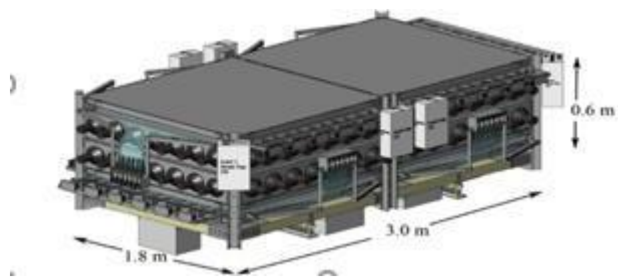


Figure1
Drawing of one of the two modules that compose ST-II

Instrument Description

The Super TIGER-II instrument is essentially the same as Super TIGER-I, with the exceptions that the high voltage power supplies were redesigned for better reliability and the S-counters were modified to provide more room for thermal expansion and contraction due to changing temperatures during transport and flight. The instrument consists of two nearly identical modules. Figure 1 shows a drawing of one of the modules with dimensions and Figure 2 shows an expanded view of the detectors that comprise the instrument.

Each module is composed of three plastic scintillator dE/dx counters, a Cherenkov counter with an acrylic radiator (refractive index, n=1.49), a Cherenkov counter using an aerogel radiator (n=1.04 or 1.025), and a hodoscope composed of scintillating optical fibers. We measure charge and velocity with combinations of S and C1, or C1 and C0, or S and C0. The S1 and S2 scintillators that make the primary measurements of differential energy loss, dE/dx, are located just above the top hodoscope (H1) and just below the lower Cherenkov (C1) respectively. The third scintillation counter (S3) is located below the bottom hodoscope (H2), mainly to identify nuclei that have fragmented in the instrument, and is also a backup measurement in case S2 should fail. Placing H2 between S2 and S3 decouples the two scintillators by preventing most δ-rays produced in S2 from reaching S3. However, we have found that we can obtain essentially as

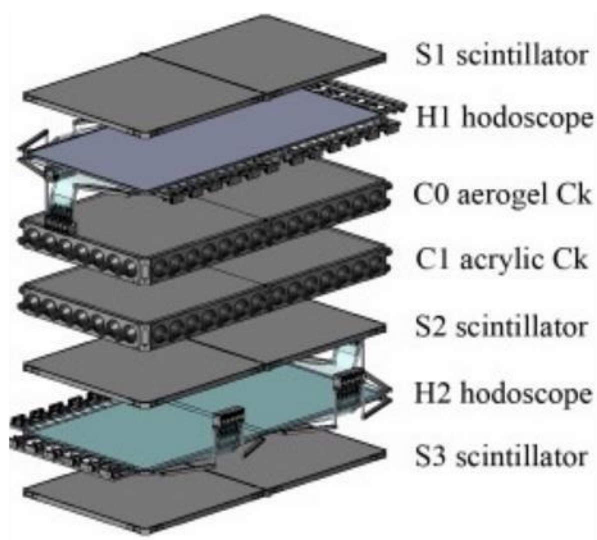


Figure 2
Expanded view of detector stack

good resolution for nuclei with energy below the C0 threshold by ignoring S3 entirely, by simply demanding consistency of S1 and S2 signals.

The use of Cherenkov radiators with different indices of refraction (n=1.043 or 1.025 for C0, and n=1.49 for C1) enables us to use differing techniques to accurately measure charge in complementary energy ranges. For events below the threshold energy of C0 (~3 GeV/nuc), charge is measured by the [dE/dx vs. Cherenkov] technique using the S1 and S2 counters to determine dE/dx with velocity corrections from C1.

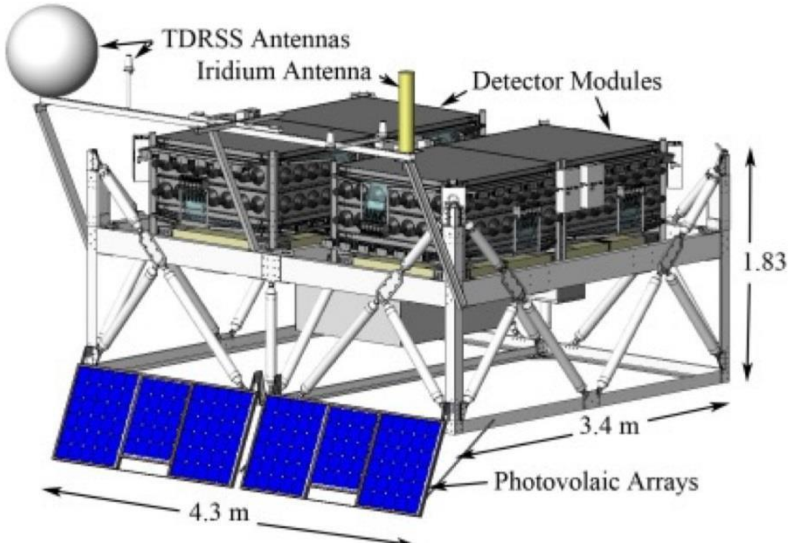


Figure 3
Drawing of full instrument with dimensions

The use of organic scintillators means that the technique is actually [dL/dx vs. Cherenkov] where L is the light produced by particle energy loss (dE/dx) in the scintillator material. Although dE/dx µ Z2, L exhibits saturation effects at high specific dE/dx and the scintillator response becomes more complicated. Figure 3 is a drawing of the complete instrument giving overall dimensions. The instrument is sized to provide us with the maximum detector area consistent with the launch envelope of the Boss launch vehicle. Figure 4 shows the instrument mounted in the gondola during the compatibility test at CSBF. The instrument has been designed so that it can be mechanically disassembled in the field and recovered with any available aircraft in Antarctica including the Basler and the Twin Otter. For more details on the instrument see W.R. Binns et al. (2014) ApJ, 788:18.

Figure 4
Super TIGER-II
shown during compatibility test at CSBF

Flight Requirements

Our goal for our flight is to achieve 30+ days at float. We would like to be launched as soon as possible after the high-altitude vortex sets up and plan to declare flight-ready by December 1st. We require a peak altitude of ≥ 125kft. (In short, we would like to fly as high as possible for as long as possible). For telemetry, we want to have a downlink of high-rate TDRSS (~90 kbs) for the full flight (excluding outages when the TDRSS satellites are not visible) and Iridium OpenPort telemetry. Additionally, we want LOS telemetry during the line-of-sight time following launch, and would like LOS if we come within range on successive rotations around the continent. The first two science objectives can be met using telemetered data only, provided we get reasonably high-rate for most of the flight with a small fraction of telemetry outages. The secondary objective requires recovery of the on-board data disks.

Float Requirements		
Criteria	**Minimum**	**Desired**
Float Altitude	115 kft	128 kft
Time at Float Altitude	8 days or one circumnavigation whichever is less.	60 days
Altitude Stability	N/A	6 kft km

Recovery Requirements

We strongly prefer to recover the instrument the same season that we fly. However, if it is a choice between additional time at float and recovery this season, we will chose additional time at float. The instrument is designed to be disassembled and handled in the field as was successfully done with ST-I. The recovery of ST-I was accomplished with a single Basler flight plus Twin Otter flights to take people to the landing site. This is our preferred method of recovery. However, it can be recovered with multiple Twin Otter flights. This requires more on-ice disassembly time since we have to break the instrument down to fit the plane. In addition, the fiber hodoscope has to be destroyed to fit into the Twin Otter and it requires significant effort to rebuild the hodoscope for later flights. Our plan is to send four members of our science team to the recovery site to disassemble and recover the instrument. We anticipate needing ~4 days of on-ground recovery time, depending upon recovery conditions. If a data recovery is all that can be accomplished this season, there are two flight CPUs and a small pressure vessel (roughly a cylinder 1 foot in diameter with height 6 inches) that houses the disks. They should be easy to access and remove from the instrument.

Appendix C - Polar Mesospheric Cloud Turbulence Experiment (Piggyback)

Polar Mesospheric Cloud Turbulence Experiment (Piggyback)
(PMC Turbo)

Imaging Gravity Wave, Instability, and Turbulence Dynamics in Polar Mesosphere Clouds Viewed from the Stratosphere

(Note: PMC Turbo was configured as a Northern Hemisphere primary mission and was flown on a NASA LDB from Sweden to Canada in July 2018. *The following information focuses upon that Northern Hemisphere mission with additional information as related to the upcoming FY20 Antarctic LDB Mission of Opportunity aboard the Super TIGER payload. – NASA BPO.)*

PMC Turbo Investigators

Dave Fritts – *Global Atmospheric Technologies and Sciences (GATS), PI*
Amber Miller – *University of Southern California*
Glenn Jones – *Columbia University*
Michele Limon – *University of Pennsylvania*
Bjorn Kjellstrand – *Columbia University*
Biff Williams – *Global Atmospheric Technologies and Sciences (GATS)*
Ling Wang – – *obal Atmospheric Technologies and Sciences (GATS)*
Jason Reimuller - *Integrated Spaceflight Systems*
Shaul Hanany – *University of Minnesota*
Christopher Geach – *University of Minnesota*
Bernd Kaifler – *German Aerospace Center*

PMC Turbo Mission Summary

This NASA/H-TiDES PMC Turbo flight was an alternative to the LDB measurements initially proposed to occur via a primary flight from McMurdo at ~38 km for one or two circuits around Antarctica during the 2017-2018 austral summer season (anticipating a 14-20 day flight at a latitude near 78^{o}S). The PMC Turbo flight, in contrast, flew for ~5.5 days in July 2018 at a much lower northern latitude having weaker PMCs.

In order to further test the camera system design and software for harsher S. Hemisphere conditions, and hopefully also collect an independent data set with which to compare our current PMC Turbo observations, we also sought to have one camera added as a "piggyback" experiment with a host that will fly from McMurdo in austral summer 2019-2020. The Super TIGER PI, Bob Binns, was receptive, and we assisted their team in adding one PMC Turbo camera as part of their payload during integration and testing at CSBF in Palestine, TX, in July 2017. For their support, we are very grateful, as our analysis methods would then be fully optimized when our new PMC Turbo data is recovered.

PMC Turbo Campaign Science Objectives

Turbulence, and its influences in geophysical systems, remains one of the "Grand Challenges" in physics and in understanding our environment. Turbulence, and the processes that drive it, play significant roles in stratified fluids such as Earth's atmosphere, oceans, and lakes, and similar fluids exhibiting high Reynolds number dynamics on other planets and in stellar interiors. It also impacts our everyday lives in many ways.

Despite ~80 years of theoretical, experimental, and observational attention, there remain many aspects of turbulence dynamics and effects that have yet to be diagnosed and understood. Understanding the sources, evolutions, and effects of turbulent flows has proven challenging, in part because of the difficulty in visualizing such flows in geophysical systems. Numerical modeling is making major strides, and has revealed many important aspects of these flows. But modeling cannot address the many decades of spatial scales required to describe typical multi-scale flows. Hence, observations that provide a view into these dynamics spanning a broad range of spatial scales and the durations of many such events would provide key insights of value to many research areas. Such a "window" on geophysical turbulence and its sources is provided by a layer of polar mesospheric clouds (PMCs) that occur at an altitude of ~82 km due to a unique combination of dynamics and microphysics in polar summer. The PMC brightness is confined to a shallow depth, i.e., often ~100 m and as thin as a few 10's of m when the environment is dynamically active. Importantly, this thin PMC layer provides sensitivity to the smallest energetic scales in the turbulence inertial range at these altitudes, i.e., ~10-20 m. Four images of turbulence structures seen in the PMC layer by star cameras aboard the EBEX experiment that flew in austral summer 2012-2013 season are shown in Figure 1.

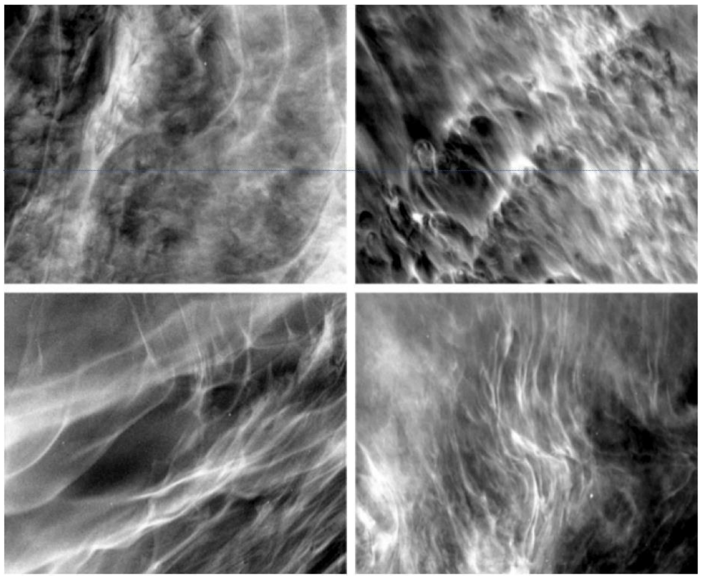


Figure 1
Example EBEX PMC images

Because EBEX did not have a stabilized Field Of View (FOV), it provided only very occasional images of the same dynamics at different times, hence no ability to follow the evolution of the dynamical fields in time.

The PMC Turbo experiment (flown from Sweden in July 2018) improved on the serendipitous EBEX star camera PMC imaging in several ways. To provide continuous viewing of the dynamical fields that allowed us to quantify their morphologies from the dynamics initiating turbulence to the turbulence decay at very small scales (typically 10's of minutes for an individual event), PMC Turbo will use a stabilized viewing platform. A CSBF rotator maintained the PMC Turbo FOV in the anti-sun position to within 0.5°. Two instrument upgrades made PMC Turbo observations unique and especially valuable. The first was the use of seven imaging systems to create a montage of PMC images extending spatial resolution from >100 km to ~10 m – spanning four decades of spatial scales (see Figure 2), with a minimum pixel size of ~3 m. The second was a Rayleigh lidar enabling measurements of temperatures below the PMC layer and profiling of the PMC layer in order to track vertical motions.

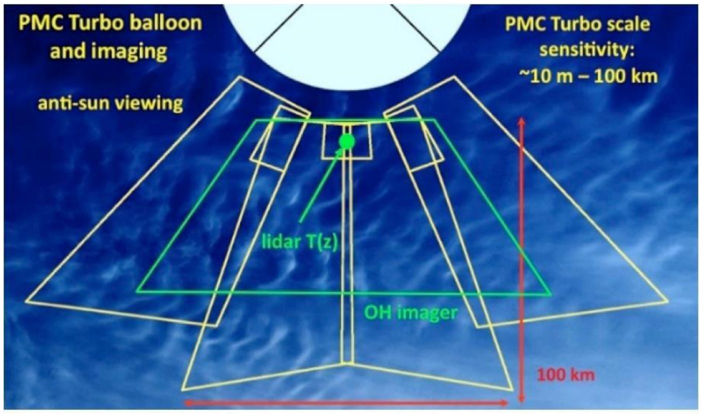


Figure 2
PMC Turbo merged FOVs for the seven imagers (yellow), the OH imager (green), and the Rayleigh lidar (green).

Our analyses of these data to date, together with numerical modeling of multi-scale dynamics to aid our interpretations, are enabling major contributions in defining the pathways to, and the dynamics and consequences of, turbulence in the atmosphere and many other geophysical flows.

Our analyses of these data to date, together with numerical modeling of multi-scale dynamics to aid our interpretations, are enabling major contributions in defining the pathways to, and the dynamics and consequences of, turbulence in the atmosphere and many other geophysical flows.

PMC Turbo Instruments

The primary PMC Turbo instruments included seven imaging systems, four having wide FOVs and three having narrow FOVs. Each included a shutterless Allied Vision 16-Mpixel camera, four 32-TB disk drives, a computer control system, and a software control system that enabled the camera to operate autonomously or synchronized with all the others, and perform command uploads and data downloads as required. Each imaging system was enclosed in a separate pressure vessel for maximum system redundancy (see Figure 3), was powered by a redundant and remotely controllable power system, and used a redundant Ethernet communications system.

The primary secondary instrument included a Rayleigh lidar contributed by the German Aerospace Center (DLR) that was housed in a separate pressure vessel and provided temperature profiles from ~25-80 km and PMC backscatter profiles extending over the PMC layer in the high-resolution portion of the full imaged FOV.

PMC Turbo Flight Requirements

Launch requirements at Esrange included power, standard communications, N_2 for purging the pressure vessels, and testing of the lidar, which was not eye-safe.

Figure 3
PMC Turbo imaging system components

Launching from Esrange and landing in Canada imposed a shorter flight duration than we had anticipated over Antarctica. Together with a single PMC Turbo imager flying with Super TIGER around the Antarctic in austral summer 2019-2020, however, we believe that the combined shorter flight from Esrange in 2018 and a longer flight over brighter and more continuous PMCs over Antarctica in austral 2019-2020 will allow us to address our broader science goals with high confidence. The table below lists our minimum and desired float requirements for the anticipated 2019-2020 piggyback flight.

Float Requirements		
Criteria	**Minimum**	**Desired**
Float Altitude	35 km	38 km
Time at Float Altitude	~7-10 days (one circuit)	2 or 3 Antarctic circuits days
Altitude Stability	3 km	2 km

PMC Turbo Antarctic Recovery Requirements

There are no specific requirements for the Antarctic PMC Turbo Mission of Opportunity flight aboard the Super TIGER-II payload. We would fly only a single, static camera in its own pressure vessel that imposes no special needs for launch or recovery.

Appendix D – Exposing Microorganisms In the Stratosphere (Piggyback)

Exposing Microorganisms In the Stratosphere (Piggyback)
(E-MIST)

E-MIST Team

David J. Smith – *NASA Ames Research Center, PI*
J. Galazka – *NASA Ames Research Center*
S. Waters – *NASA Ames Research Center*
C. Urbaniak – *Jet Propulsion Laboratory*
Venkateswaran – *Jet Propulsion Laboratory*
James – *NASA Kennedy Space Center*
Lane – *NASA Kennedy Space Center*
P. Thakrar – *NASA Kennedy Space Center*
R. Moeller – *DLR*
T. Berger – *DLR*

E-MIST Mission Summary

The pristine Mars environment remains vulnerable to biological contamination and the likelihood of false positives associated with life detection missions (robotic or human) increases without a deeper understanding of which terrestrial microorganisms are most capable of survival, persistence, or growth once delivered to the Red Planet. Earth's polar stratosphere (from about 20-35 km above sea level) mimics the surface pressure on Mars, with cold and dry extremes, elevated levels of ionizing and non-ionizing radiation, and also the presence of oxidizing chemical species. We do not know how combined extremes in the Martian environment impact the survival and response of terrestrial microbes because we do not have the luxury of sample return and no single Earth laboratory chamber can simultaneously produce the full suite of Mars surface parameters. However, microorganisms sent to the Earth's polar stratosphere (which naturally provides a similar combination of extreme Mars-like conditions) can be analyzed using the most sensitive molecular biology tools available.

Exposing Microorganisms in the Stratosphere (E-MIST) is NASA balloon payload that was built to enable such experiments. It is an autonomous hardware system that mounts to the exterior of scientific balloon gondolas, with four independent sample holders for exposing pre-loaded microbiological samples to the stratosphere, which can then be returned to the ground for analysis. Using this payload, our project will evaluate the survival and response of microbial species to Mars-like conditions in the stratosphere over Antarctica on long duration balloon flights. In 2019-2020, E-MIST will fly a piggyback payload onboard the Super TIGER-II LDB mission launching from Antarctica. On this mission, will send NASA-relevant, dormant microbial strains of Bacillus pumilus SAFR032 to the polar stratosphere. The microbe strains are in stasis and securely attached to the payload – nothing is actively growing or capable of dispersing, and the specimens present no hazard to the environment. Everything flown on the E-MIST payload and exposed to the polar stratosphere will return to the USA.

Our project is supported by the NASA Planetary Protection Office and NASA Space Biology. Our Antarctica piggyback flight will contribute significantly new scientific knowledge to by generating publicly-archived datasets and research publications describing the inactivation of enduring spacecraft-associated microbe strains in a robust Mars analog environment.

E-MIST Campaign Objectives

In general, microbe samples from the E-MIST flight experiments will be assayed with state-of-the-art molecular technologies to determine (1) percent surviving microbes (compared to starting quantities); (2) which genes are activated or suppressed (relative to ground controls) due to stress; and (3) the extent of any genetic mutations after exposure to the harsh environment (again compared to ground controls). Our team will employ a variety of traditional and state-of-the-art molecular methods to assess the overall survival and response of the bacteria, while collecting pertinent environmental data and establishing correlations with bacterial physiology. In addition, the "-omics" datasets will be publicly archived, potentially feeding functional genomics studies that will explore the molecular basis of polyextremophile resistance.

E-MIST Instrument

The E-MIST payload is described in previous scientific publications in the journals Gravitational and Space Research and Astrobiology. Four independently rotating skewers fitted with an adjustable aluminum sample base plate allow an exposure time series. Each sample plate holds 10 separate aluminum coupons with microbe samples attached. The plates are enclosed within Nomex-lined cylinders to prevent sunlight from entering during ascent/descent, and when the skewers rotate to a closed position. Each skewer is motor-controlled (SPG30E-300K, Cytron) by a 4-channel motor driver (FD04A, Cytron) held together by an aluminum and polycarbonate frame. Multiple instruments are inside the payload housing, including a GPS unit (SPK-GPS-GS4O7A, S.P.K. Electronics Co.), a radiometer with UV sensors (PMA2100, PMA2107, and PMA2180, Solar Light), and an active dosimeter (M42) from DLR collaborators. Instrument temperatures can be regulated inside the payload with heating pads (5V, Wire Kinetics). The avionics system (chipKIT Max32, Digilent) uses a serial peripheral interface connection to communicate with a micro-SD card (BOB-00544, micro-SD Transflash Breakout, SparkFun) and a micro DB-9 port (1200-1183-MIL, Digi-Key). A GoPro camera is controlled by the avionics and records imagery throughout the flight. Other major hardware components include an altimeter (MS5607, Parallax), 8.5 W heaters (Omegalux Kapton Insulated Flexible Heater, Omega), and multiple resistance temperature detectors (SA1-RTD-B, Omega).

E-MIST Launch Site Ground Support Requirements

Unique Launch Site Requirements (for science needs)

The E-MIST payload was fully assembled at the CSBF in Palestine, TX, alongside the Super TIGER-II LDB integration in July 2019. Microbe samples were pre-loaded with no special shipping requirements. Upon arrival to McMurdo Station, a Super TIGER-II team member will unpack the E-MIST payload, mount it to the gondola, screw on the camera mount, and mate the power connection. On the day of the launch, a Super TIGER-II team member will remove the protective tape covering the UV sensors on the front face of the payload. Next, the payload will be powered on using the master key. The E-MIST payload is ready to launch at that point. Everything else is fully automated.

Flight Requirements

The flight requirements are summarized by table below. Power is to be provided by the CSBF balloon system.

Float Requirements		
Criteria	**Minimum**	**Desired**
Float Altitude	100 kft	120 kft
Time at Float Altitude	8 days or one circumnavigation whichever is less.	28 days
Altitude Stability	10,000 ft	5,000 ft

Unique Recovery Requirements (for science needs)

Upon landing, if the E-MIST payload is accessible, we request two operations: (1) turn power switch to off position and (2) dismount E-MIST payload from gondola (bolts at four brackets) and return to McMurdo. If the payload cannot be transported back to McMurdo on first recovery attempt, then please just perform the power-off operation. Our instruments and samples will be stable indefinitely if the payload needs to remain on ice, while we would truly appreciate an early recovery/return so we can analyze our samples ASAP back in the USA, it is not science critical. All requested operations (described above) have been provided to the Super TIGER-II LDB team in a Standard Operating Procedure reviewed in October 2019.

Super TIGER-II
Integration and Testing
CSBF, Palestine, TX, summer 2018

E-MIST
At float shortly after launch
Fort Sumner, NM, October 2015

Biological Import

NOTE

The P.I. has submitted for approval by NSF the introduction of these dormant microbial strains into Antarctica and will accordingly handle per NSF approved guidance/procedures; the status of which will be reviewed during the pre-deployment Mission Readiness Review (MRR). – NASA BPO

Appendix E – Balloon Air Sampling (Piggyback)

Balloon Air Sampling (Piggyback)
(BAS)

BAS Investigators

Alex Meshik – *Washington University*
Olga Pravdivtseva – *Washington University*
Brian Rauch – *Washington University*

Mission Summary

BAS is intended to collect air at different altitudes over Antarctica. We will analyze noble gas isotopes in these collected samples using high precision mass spectrometry at Washington University. The primary scientific goal of BAS is a better understanding of the evolution of volatiles in terrestrial atmosphere, more specifically, to shed light on the "missing xenon paradox", a ~20-fold Xe depletion relative to other noble gases. Two potential solutions for Xe paradox were proposed. (1) Xe, the heaviest and the least mobile noble gas could be buried in sediments [1,[4] 2], glacier ices [3, 4], silica [5], clathrates [6] or in the Earth's mantle and/or the core [7-9]. (2) Alternatively, due to the lowest ionization potentials among the noble gases, Xe, if ionized by UV in the upper atmosphere, may selectively escape from the Earth [10, 11]. Presently this escape mechanism may operate only near the poles where solar UV forms ozone holes and the ionized species could escape along the magnetic field lines. However, there is no experimental evidence that support either of these two potential explanations of the Xe atmospheric depletion. The BAS experiment is intended to set the limit on the Xe escape in the only place where it could still occur today – in the stratosphere above the poles.

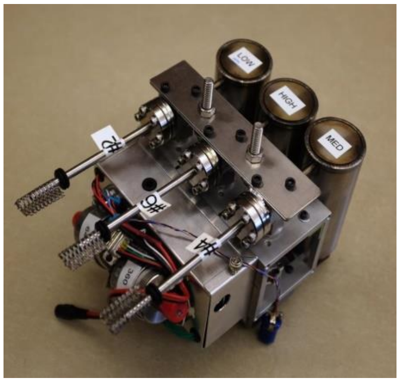
Campaign Objectives

We designed, built and, during the 2018-2019 Antarctic expedition, successfully tested a compact device that automatically captures outside air at different altitudes. The device operates in viscous regime to avoid isotopic and elemental fractionation at sampling. It will fly again on the high-altitude balloon during the 2019-2020 campaign, and the archive of sampled air will be analyzed using high precision isotope mass spectrometry [12].

[4] [1] Podesek F. A., Bernatowicz T., Kramer F. E. (1981) GCA, 45, 2401–15. [2] Bernatowicz T., et al. (1984). JGR 89 B6, 4597–611. [3] Wacker J. F. & Anders E. (1984) GC, 62, 2335–45. [4] Bernatowicz T., Kennedy B. M. and Podesek F. A. (1985) GCA 49, 2561–4. [5] Matsuda J. and Matsubara K. (1989) GRL 16, 81–4. [6] Sill G. T., Wilkening L. (1978) Icarus, 33, 13–22. [7] Stavrou etal., (2018) PRL, 120, 096001. [8] Howie R. T. et al (2016) Nature (Sci. Rep. No.6), 34896. [9] Sanloup Ch., et al. (2005) Science 310, 1174–7. [11] Hebrard E. and Marty B. (2014) EPSL, 385, 40–48. Zahnle,K. J.; Gacesa, M.; Catling, D. C (2018) AGU, Fall Meeting 2018, Abstr #P44B-01. [12] Meshik, A. and Pravdivtseva, O. (2016) 47th LPSC, Abstr # 1681.

Instrument Description

BAS : weight ~ 15 lbs, size < 1' x 1' x 1'
Power: < 1W during balloon ascent (to run processor and pressure sensors).
< 30W during air sampling (4 minutes for each sample).
no power is needed for the rest of the flight.
BAS is electromagnetically and radioactively passive.
BAS does not require telemetry and is self-contained.



"naked" BAS

BAS in the box

BAS mounted on the frame

Flight Requirements

All BAS electronics were modified and calibrated for stable and reliable operation at low temperature and pressure, no cooling or heating is required. During the balloon ascent BAS will automatically draw three air samples at outside pressure of 360, 52 and 12 Torr. A fourth, reference air sample will be taken on the ground shortly after the launch. The only flight requirement is (24 ± 5) VDC capable of providing power specified in the Instrument Description.

Recovery Requirements

The BAS instrument must be recovered for the air samples to be analyzed in the lab, so we would prefer for BAS to be retrieved the same season that Super TIGER-II flies if possible. However, the BAS samples will not be negatively impacted if they are recovered the following season.

Appendix F – Advanced Particle-astrophysics Telescope (Piggyback)

Advanced Particle-astrophysics Telescope (Piggyback)
(APTLite)

APTLite Investigators

James Buckley - *Washington University*
W. Robert Binns - *Washington University*
Brian Rauch - *Washington University*
Martin Israel - *Washington University*
Zachary Hughes - *Washington University*
John Mitchell - *Goddard Space Flight Center*
Georgia De Nolfo - *Goddard Space Flight Center*
Michael Cherry - *Louisiana State University*
Garry Varner - *University of Hawaii*
Stefan Funk - *Erlangen Center for Astroparticle Physics*
Adrian Zink - *Erlangen Center for Astroparticle Physics*

Mission Summary

The Advanced Particle-astrophysics Telescope (APT) is a concept for a future gamma ray and cosmic-ray satellite experiment that would answer key questions in particle astrophysics like the nature of dark matter, the origin of the heavy elements, and the nature of gravitational-wave sources. Like Super TIGER (Super Trans-Iron Galactic Element Recorder), the instrument is aimed at measuring the composition of very rare ultra-heavy cosmic rays. It will also measure the very high-energy abundances of lighter cosmic ray primaries and secondaries to provide a test of models for the propagation of cosmic rays through the galaxy. The key new detector technology is a CsI calorimeter read-out with crossed wavelength-shifting scintillating fibers. APTLite is a small demonstrator for the key APT technology, the imaging calorimeter. The APTLite instrument consisting of a single CsI detector element instrumented with 64 WLS fibers, photodetectors and waveform digitizing electronics covering both the x and y-coordinates of the detector. APTLite will derive its trigger from the Super TIGER-II (ST-2) instrument and will be used as part of a combined data-analysis to identify coincident cosmic-ray events. These events will be used to calibrate the detector response to cosmic rays, and to demonstrate the viability of the technical approach for suborbital flight. APTLite is being prepared for a piggyback flight on the Super TlGER-2 instrument currently being readied for its second Antarctic flight in December 2019.

Campaign Objectives

This mission is closely tied to the ST-2 mission and science goals. Our primary objective is to take data on relatively abundant Iron-group cosmic rays to determine the sensitivity of our new CsI detector and associated readout electronics. This demonstration could pave the way to a new type of measurement of elemental cosmic-ray abundances and high-energy gamma rays and would advance the technical readiness of the approach for a future proposal for a future space-based experiment. The goals of this project closely support ST-2 project, paving the way for future enhancements to the instrument. For the current balloon campaign, the ST-2 collaboration is readying the instrument for ta 30+ day flight over Antarctica.

The APTLite campaign objectives are best understood in the context for the full APT mission. The full APT instrument would consist of 20 layers of scintillating-fiber tracker (SOFT), interleaved with 20 layers of imaging-CsI detectors. As a space-based instrument, the very large detector area (3m x 3m) and up-down symmetry (combined with a high, Lagrange orbit) would provide the instrument with the enormous area and solid angle needed to achieve an order-of-magnitude improvement over existing missions. To make this possible, a new low-cost technological approach based on scintillating fibers is being developed. Using long fibers for the tracker and calorimeter, allows one to read out the detector on the edges using a minimum number of readout channels. Moreover, the relatively simple detector structure consisting of laminated layers of plastic fibers, and passive CsI tiles provides a credible method to produce a very large volume instrument without a corresponding increase in the mission cost compared to present experiments. For example, the proposed APT mission would require about 400,000 channels of readout electronics – about half the channel count of the Fermi Gamma-Ray Space Telescope (Fermi). The instrument would detect gamma rays at energies from 60 MeV- 1 TeV through electron-positron pair production, and at 600 keV tp 30 MeV through multiple Compton scattering. Higher energy gamma rays would produce electron-positron pairs in the CsI layer; by tracking these in the SOFT detector and measuring the signals in the CsI detector from the ensuing electromagnetic cascade, one can determine the direction and energy of each detected gamma ray. At lower energies (around 1 MeV) the gamma rays would interact primarily through Compton scattering; the CsI elements would determine the position and energy deposition of each in a series of Compton scatters, ultimately allowing one to reconstruct the energy and direction of each detected gamma-ray. Using these two techniques together would provide angular and energy reconstruction of gamma rays over an enormous range of energies, from 600 keV to 1 TeV, with an unprecedented geometry factor of up to 30 m2 str.

The same detector construction would provide sensitivity to very rare cosmic-ray events (ultra-heavy cosmic rays or very high-energy light cosmic rays). The multiple CsI layers would measure the ionization energy loss per unit length (dE/dx) and total energy deposition (E) for heavy cosmic rays. Since the ionization loss is proportional to the atomic number squared, this ``multiple dE/dx by total E'' method provides a measure of elemental charge and energy. The APT mission, with a 5-year lifetime, would provide a fully active detector that could provide the statistics needed to answer key questions in cosmic-ray science. In particular, the abundances of ultra-heavy cosmic rays could provide the key discrimination between neutron-star merger synthesis, and r-process supernovae synthesis of the heavy elements. This supports the Super TIGER-II scientific program, and connects closely to the MeV gamma-ray objectives of the APT mission, namely to efficiently and precisely localize n-star merger events for multi-messenger studies.

With the addition of passive radiator material (e.g., mylar foam) between the APT detector layers, the CsI detectors could be used to detect the X-ray transition radiation from very high energy (>10 TeV) light cosmic-ray elements. This capability, if demonstrated, would allow measurements of the Boron-to-Carbon (B/C) ratio up to very high energies, providing a key measurement needed to understand cosmic-ray propagation to the highest energies. Such an understanding is critical to interpret the positron-fraction measurements of experiments like HEAT, Fermi, Pamela and AMS. As such, this cosmic-ray study complements one of the primary objectives of the gamma-ray mission; to use indirect measurements (positrons or gamma rays) to detect or rule-out WIMP dark matter.

Instrument Description

The APTLite instrument is pictured below in Figure 1. The instrument package is roughly 20 inches square and is mounted to the ST-2 truss, below the instrument as indicated. The package consists of the CsI detector, readout electronics, and interfaces to the ST-2 instrument. The detector consists of a 150mm x 150mm x 5mm polished CsI:Na tile bonded to crossed planes of 2mm square (half green/half red) wavelength shifting fibers. The blue scintillation light emitted by the CsI:Na is partially transmitted to the

WLS fibers. In the green layer, blue light is absorbed and green light is isotropically re-emitted with about 4% being piped down to the end of the fiber. Some of the green light that is not totally internally reflected escapes into the red layer where it is absorbed and isotropically re-emitted in the red waveband. Another 4% of this light is piped to the end of the fiber, improving light collection efficiency. Only blue light emitted within a cone is refracted into the WLS fiber. This provides some inefficiency in light collection, but allows one to use the signals in the fiber to centroid the interaction point. Summing all of the light collected in the fibers (and a diffuse white light integrating box) provides the best measurement of the total energy deposition.

An array of Hamamatsu 3mm square SiPM photo detectors on carrier boards read-out the 2mm fibers (the 2mm fibers are formatted onto a staggered array of 3mm SiPMs to provide full coverage of the close-packed 2mm fiber plane). These SiPMs derive their bias voltage (about 40 VDC) from custom high-voltage DAC electronics controlled by an SPI link to the PC-104 flight computer. The signals from the SiPMs go through custom preamplifiers, to the analog to digital converter (ADC) boards. These ADC boards make use of a key technology being developed for APT; analog pipeline (or switched capacitor array ASICs). These ASICs (part of the TARGET series) have been developed over a number of years by collaborator Garry Varner. The custom boards (and firmware) were developed by our collaborators at ECAP (Funk and Zink). While somewhat faster than the ultimate flight electronics, these provide 1Gsps, 10 bit digitization for each of the 64 x and 64 y fiber channels. With a memory depth of 16 microseconds, these provide enough waveform data to: (1) characterize the rapid (10 nsec) pulses from direct interactions in the plastic fibers, (2) measure the relatively slow (400 nsec time-constant) signals from the CsI:Na crystal and (3) to measure the tail of the CsI:Na pulses to avoid saturation of signals from ultra-heavy cosmic rays. Demonstrating this detector and readout chain for heavy cosmic rays, on a balloon flight instrument, constitutes our major objective.

The instrument interfaces to the ST-2 trigger to form joint coincident triggers between ST-2 and APTLite. Data acquisition is accomplished with the PC-104 computer, with most of the data stored on hard disks requiring recovery. The command link and quick-look data will require only very limited bandwidth on a slow Ethernet channel. Power is derived from the ST-2 instrument. Since the development of APTLite is being carried out at Washington University by the ST engineers, integration is straightforward.

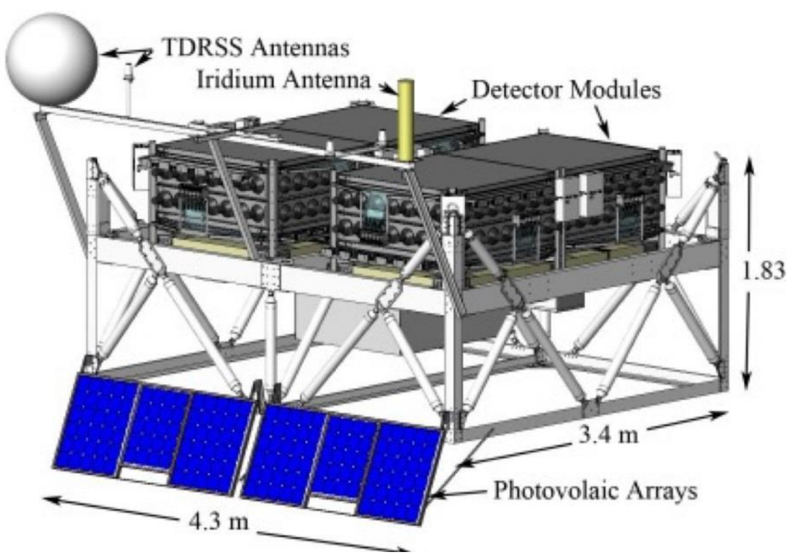


Figure 1
Super TIGER-2 Instrument showing main detector components and dimensions.

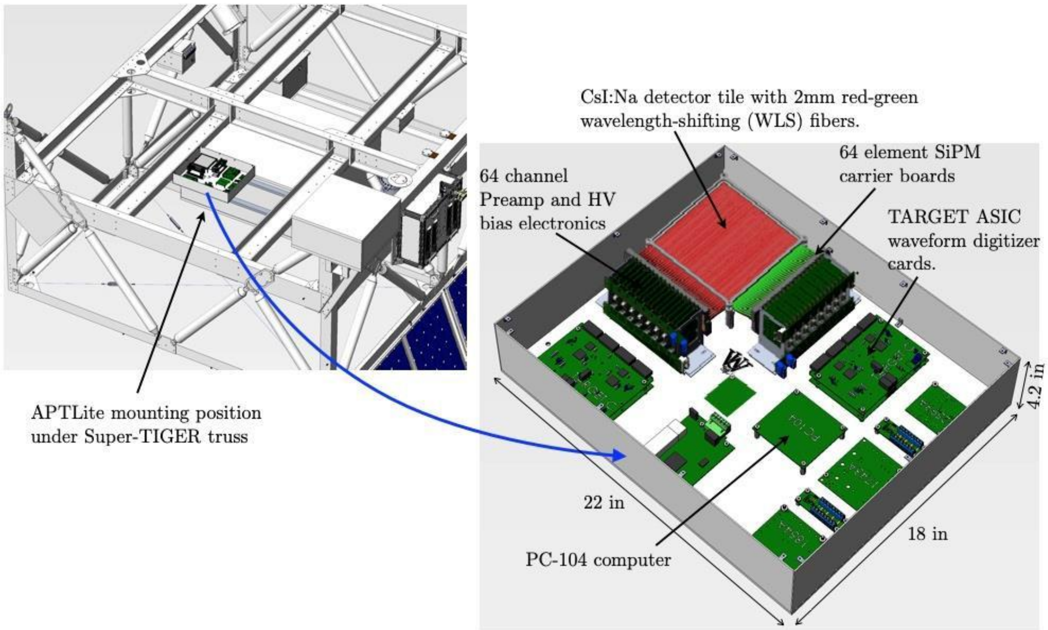


Figure 2
APTLite Instrument and electronics

Flight Requirements

The APTLite flight goals are closely tied to ST-2, which is aiming to achieve 30+ days at float. We would like to be launched as soon as possible after the high-altitude vortex sets up and plan to declare flight-ready by December 1st. We require a peak altitude of ≥ 125kft. (In short, we would like to fly as high as possible for as long as possible.) APTLite will use a small fraction of the ST-2 Iridium Open Port bandwidth for instrument commanding and to telemeter data to monitor instrument performance, but the data volumes will need to be recovered for scientific analysis. The APTLite power relay control will be through ST-2 based on LOS, TDRSS or Iridium commanding.

Float Requirements		
Criteria	**Minimum**	**Desired**
Float Altitude	115 kft	128 kft
Time at Float Altitude	8 days or one circumnavigation whichever is less.	60 days
Altitude Stability	N/A	6 kft km

Recovery Requirements

We prefer to recover APTLite the same season that we fly, and it would be prioritized if only a limited recovery is possible. Data recovery is the highest priority, but the APTLite detector is accessible on the ST-2 gondola and can easily be returned intact for re-use in accelerator beam tests. APTLite does not require any special handling, and its recovery procedure will be included in the ST-2 plan.

Appendix G – Trajectory Valuation for GUSTO Pathfinder -1 and -2

Trajectory Valuation for GUSTO Pathfinder-1 and -2
(TRAVALB)

TRAVALB-1 and -2 Investigators

R. Salter; CSBF – PM
Piggy-back PI - R. Millan; Dartmouth

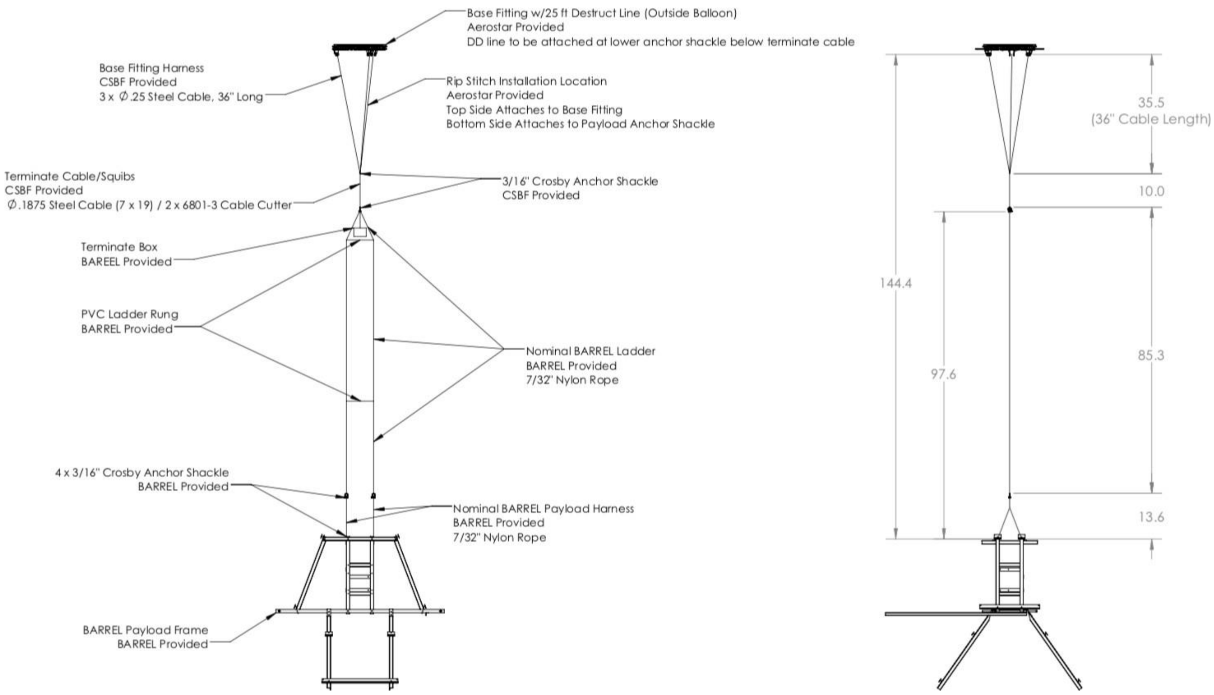
TRAVALB-1 and -2 Mission Summary

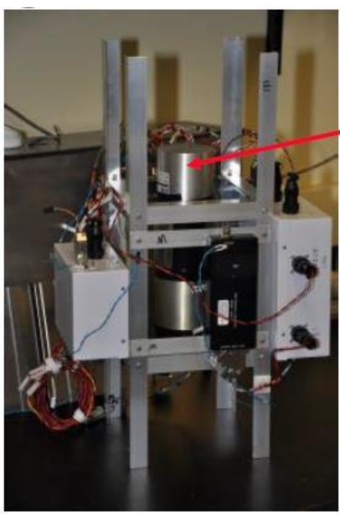
The TRAVALB-1 and -2 Mission acts as a trajectory validation for the Dec 2021 GUSTO SPB Explorers Mission. Mission objectives are to launch at a similar date as the proposed GUSTO Mission, deploy and float at the NASA 18MCF SPB Float altitude (~110Kft) and circumnavigate the continent for > 100 days. BARREL payload has been identified as a Science Mission of opportunity for the mission, and will provide termination and operational support to the mission.

TRAVALB-1 and -2 Campaign Science Objectives

Personnel and equipment will arrive roughly Nov 20th to support the mission. Minimal support from CSBF is expected, and payload integration will occur on the mezzanine in a shared space with the BLAST experiment. Payload and balloon are expected to be fully flight ready on Dec 1. Termination of the flight will hopefully occur at launch + 100 days (or greater). Recovery of the payload is desired if on-continent, but not required, nor should it be planned to occur.

TRAVALB-1 and -2 Instrument

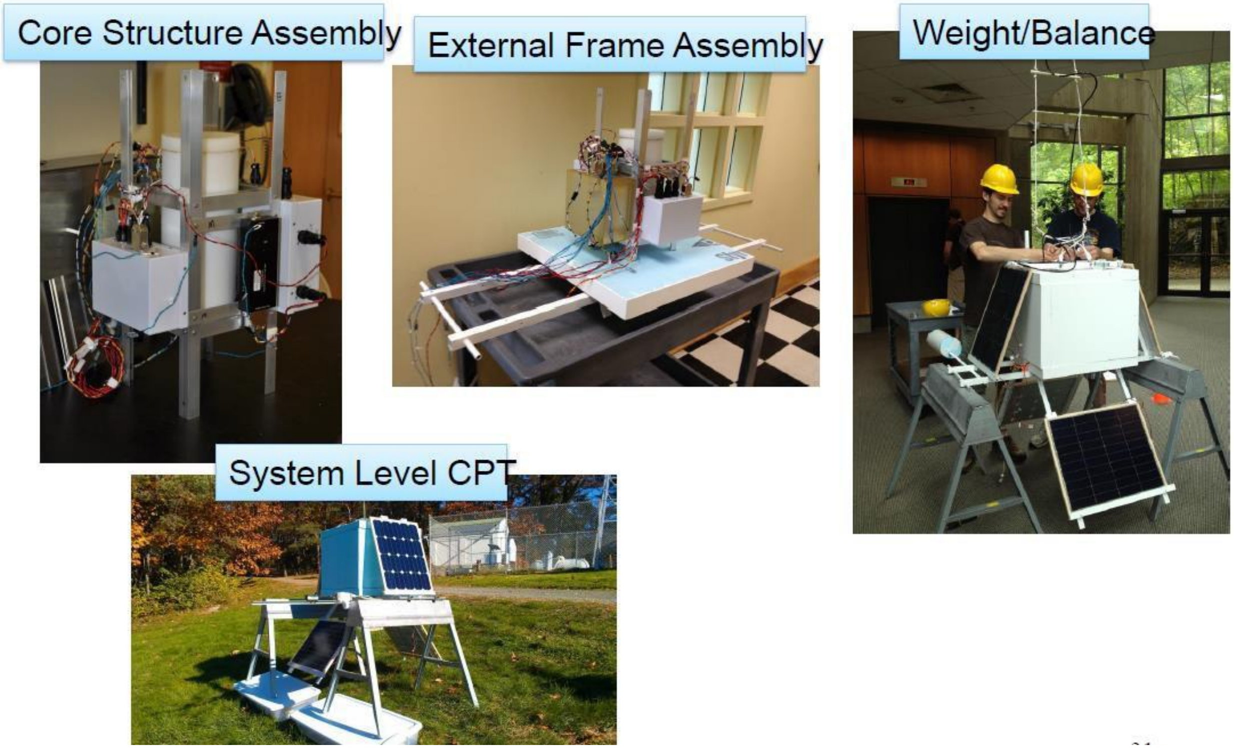




Science
NaI x-ray spectrometer

Supporting Subsystems
Real-time data acquisition system
GPS time and position
Trimble Lassen SQ
Telemetry
Iridium A3LA-X
Terminate
CSBF MIP Heritage
ATC Transponder
PING S/ADS-B Transponder
Tertiary independant tracking
CSBF Iridium Balloon Tracker

Payload
Suspended mass:~ 70 lbs
Power: ~20W (includes 12W heaters, 2W transponder)
Float altitude ~33 km (110,000 ft)



Secondary Mission allows the piggy-back payload (BARREL) to further the goals and support the CubeSat "REAL" mission. The REAL mission goal is to improve our understanding of the physical mechanisms responsible for scattering radiation belt electrons into the atmosphere. BARREL will support this goal and augment the REAL mission by:
Connecting different types of energetic electron precipitation with properties of plasma waves measured by equatorial spacecraft (Val Allen Probes and Arase):
Characterizing when and where different types of electron precipitation occur over a longer time interval and as a different phase for the solar cycle than was previously possible with BARREL (precursor NASA mission).

TRAVALB-1 AND -2 FLIGHT REQUIREMENTS

Unique Launch Site Requirements (for science needs)
The TRAVALB-1 and -2 payload was fully integrated, tested and disassembled at the CSBF in Palestine, TX. There are no special shipping requirements. Upon arrival to McMurdo Station, a TRAVALB/CSBF team members will unpack the payload, mount it all to the gondola and mate the power connections.

Flight Requirements
The flight requirements are summarized by table below. Power is to be provided by the CSBF balloon systems. Successful inflation and launch of the .6MCF SPB Balloon. Desired is full flight, at 110Kft for greater than 100 days, with OTH tracking via iridium (Dual independent systems).

Float Requirements		
Criteria	**Minimum**	**Desired**
Float Altitude	No minimum	110 Kft
Time at Float Altitude	No minimum	100 days
Altitude Stability	Any	Mimic SPB

Unique Recovery Requirements (for science needs)
Desired recovery as possible, but should not be planned to occur. Recovery of the payload/balloon is not required.

Appendix H – Columbia Scientific Balloon Facility Flight Support Systems

Flight Systems – Mechanical

All flights will include standard flight-proven LDB telemetry, command, and control systems. Balloon and parachute sizes are listed below. Standard NASA and CSBF LDB Operation Procedures will be used on each mission.

Super-Tiger Balloon:
Volume: 1.12 million cubic meters (39.57 million cubic feet)
Gore Length: 202 meters (663 feet)
Inflated height: 120.7 meters (396 feet)
Inflated diameter: 140 meters (460 feet)
Mass: 1838 kilograms (4,052 pounds)
RF visibility: No radar yarn built into balloons

Super-Tiger Flight Train (parachute and cable ladder):
Parachute type: Flat circular
Diameter: 39.6 meters (130 feet)
Overall length: 59.4 meters (195 feet)
Parachute mass: 204 kilograms (450 pounds)
Cable ladder/chute cut mass: 68 kilograms (150 pounds)
Cable ladder/chute cut length: 27.4 meters (90 feet)

TRAVALB-1 and -2 Balloons:
Volume: 0.017 million cubic meters (0.6 million cubic feet)
Gore Length: 49 meters (163 feet)
Inflated height: 22 meters (72.4 feet)
Inflated diameter: 38 meters (124.9 feet)
Mass: 117.5 kilograms (259 pounds)
RF visibility: No radar yarn built into balloons

TRAVALB-1 and -2 Flight Trains (parachute and cable ladder):
Parachute type: None
Cable ladder/chute cut mass: ~ 1.8 kilograms
Cable ladder/chute cut length: 1.27 meters (50 inches)

BLAST Balloon:
Volume: 975 thousand cubic meters (34.43 million cubic feet)
Gore Length: 192.6 meters (632 feet)
Inflated height: 117.9 meters (377 feet)
Inflated diameter: 133.8 meters (439 feet)
Mass: 2311.5 kilograms (5,096 pounds)
RF visibility: No radar yarn built into balloons

BLAST Flight Train (parachute and cable ladder):
Parachute type: Flat circular
Diameter: 48.46 meters (159 feet)
Overall length: 73 meters (240 feet)
Parachute mass: 294.8 kilograms (650 pounds)
Cable ladder/chute cut mass: 90.7 kilograms (200 pounds)
Cable ladder/chute cut length: 27.4 meters (90 feet)

Flight Systems – Visual Indicators
Each flight will be configured with parachutes having high-visibility alternating orange and white colored panels.

Flight Systems – Electronic (Telemetry)
Each flight telemetry system is contained within a Support Instrumentation Package (SIP), which includes communication and navigation systems for flight control. Telemetry downlink (return data) and uplink (forward commands) can be accomplished either via direct transmission within line-of-sight (LOS) or via satellite relay on a global basis. The LOS capability is limited to a maximum of 483 kilometers (300 nautical miles) radius from the tracking site. All flights are powered by a photovoltaic (PV) array powering a rechargeable battery system, which is backed up by primary (lithium) batteries for flight-critical systems.

The SIP communication systems include LOS command uplink and LOS telemetry downlink, Tracking Data Relay Satellite System (TDRSS) global uplink and downlink, and Iridium global uplink and downlink. Any command to the flight system can be sent and executed on the balloon payload via any of the above listed systems; therefore, each system provides backup to the other systems listed. Frequencies are listed in Section E.5.

The SIP navigation systems each include independent Global Positioning System (GPS) receivers that provide continuous position and altitude data. Altitude determination is backed up by use of pressure sensor data.

Flight Systems – Electronic (Flight Control)
The flight control systems provide altitude control and flight termination capability. Balloon altitude control is provided by the SIP through manual and automatic ballast control functions. Automatic control features can be turned on or off via any of the command systems and manual commands can override the automatic features at any time.

Flight termination is executed by one of two electronic systems. These two systems are independent and redundant. Each system incorporates an LOS command receiver. In addition, each system is linked to the SIP using optically isolated serial communications links. This link provides routing of commands that are received by the SIP and provides for return telemetry of various termination system parameters. Therefore, each termination system can be commanded and monitored via any of the SIP global communications systems and/or (LOS) command systems. Power for each termination system is provided via primary (lithium) batteries with a capacity sized for twice the needed power capacity.

The termination system will incorporate a "burst switch", which activates the flight termination function in case of failure of the balloon envelope. The burst switch device detects loss of lift of the balloon, and is incorporated to insure clean separation of the parachute and payload from the balloon should the balloon envelope experience failure. Failures of this nature rarely happen after reaching initial float altitude. On the unlikely occasion that it might occur, this type of failure would be expected to take place during ascent shortly after launch.

The termination system will incorporate a minimum altitude cut-down capability that automatically terminates the flight in case the balloon descends below approximately 20 kilometers (65,000 feet) in altitude. This is a safety device that keeps the balloon from loitering in commercial airspace in the event that the balloon envelope should develop a slow leak that may go undetected by the burst switch.

Each flight (Except for TRAVALB-1 and -2) incorporates a Gondola Automatic Parachute Release (GAPR) system and a Semi-Automatic Parachute Release (SAPR) system to provide parachute separation upon ground impact. The GAPR system is armed prior to flight termination and provides for autonomous, automatic parachute separation. The SAPR system is armed after termination during the descent through a series of commands from either the ground station (OCC or ROCC) or the telemetry station in a chase aircraft.

Flight Systems – Radio Frequencies
The following frequencies are used aboard the balloon's SIP and flight control systems.

SIP LOS Downlink (Data Return) – 1 MHz bandwidth channels will be used within the 1444.5 MHz to 1524.5 MHz, 1735 to 1850 MHz, and 2300 to 2400 MHz bands. Coordination of frequencies is made via SPAWAR. They are turned off while the balloon is beyond LOS of the launch and recovery sites. These frequencies can also be controlled by the airborne telemetry station in the chase aircraft.

SIP LOS Uplink (Command Forward) - Aboard the SIP, chase aircraft, and the terminate flight control system, LOS commands operate on 429.5 MHz/FM/5 KHz.

TDRSS - TDRSS is NASA's Tracking Data Relay Satellite System, which is incorporated on the SIP. TDRSS provides global coverage with the balloon via geo- stationary satellites. TDRSS transceivers operate on 2287.5 MHz

Iridium - Iridium is a low-earth-orbit satellite network, which provides global coverage with the balloon flight systems. Iridium transceivers aboard the balloon operate on an international allocation at 1625.0 MHz spread spectrum for data return. Balloon transceivers receive on 1616.0 MHz to accommodate command forwarding. Iridium provides a telemetry and command link between the CSBF ground stations and the balloon and is used on the SIP-configured missions.

Command and Control Ground Stations
The primary command and control ground station will be the Operations Control Center (OCC) located at the CSBF in Palestine, Texas, U.S.A. A secondary command and control center is the Remote Operations Control Center (ROCC) located at the launch site near McMurdo.

The OCC will be manned continuously throughout the flight to monitor balloon performance and to assure proper operation of the balloon systems. The OCC has Iridium and TDRSS terminals for command transmissions and data reception.

The ROCC is the primary control center during the launch and LOS phase of the flight. The ROCC has LOS data return and command forwarding systems. Communications between the OCC and ROCC is accomplished via commercial telephone, Iridium telephone, and the Internet.

Flight Termination and Payload Recovery
Details of the flight termination and payload recovery will be coordinated with the proper authorities as outlined in section 2.8 of this plan.

Appendix I – National Science Foundation Statement of Work and Incremental Cost Estimates

Statement of Work
Service provided by the National Science Foundation (NSF) includes logistical support (air transportation for cargo and personnel, personnel in-transit accommodations), cryogenic materials including hardware and gas, project and consumable materials, and payload field recovery operations not covered under the baseline IAA to support NASA- sponsored scientific payloads flown from Antarctica. Seasonal campaign support is on or about the period of October 17 through April 8 each year, which includes start of shipping until return of retrograde shipments.

Property Furnished by NASA
Not Applicable.

Work Performance
Not Applicable – this is for purchase of personnel airfare, cargo transportation, and consumable materials.

Why this Servicing Agency
The National Science Foundation administers the United States Antarctic Program in accordance with Presidential Memorandum 6646 on behalf of the United States Government. Access to the Antarctic Continent for U.S. Government entities only occurs through the NSF.

Budget
Following are NSF estimates for NASA reimbursement for FY 2020 Antarctica LDB Campaign Support.

LDB 2019-20 Estimated Total	$771,488
Aircraft Support	$649,786
FY119 Credit	-$140,004
LDB 2019-20 Subtotal	$1,281,270
NSF Admin Fee	$94,812
2019-20TOTAL ESTIMATE	**$1,376,082**

NSF Estimated FY20 Antarctic Balloon Campaign Incremental Costs

Appendix J – Procedures for Determining Multiple Circumpolar Missions

Multiple Circum-polar Missions will only be considered based upon science need or extenuating circumstances for sake of safety or recovery of flight systems. ***Only the NASA BPO can authorize multiple circumnavigations, with NSF concurrence, and after consultation with NSF, NASA SMD and CSBF management.*** Approval will only be made just prior to each west-trajectory balloon flight going over the Trans Antarctic Mountains.

Risk Statement - Allowing any flight to continue for more than a single circumnavigation incurs higher risk for a trajectory that may be untenable for planning successful recovery within the nominal baseline operating budget and schedule and for possible mitigation of environmental impact. Baseline resources include recovery within the geographic region of McMurdo, South Pole Station and WAIS Camp, which have been typical for most recoveries as affected by Twin Otter, Basler, helicopter or overland traverse. Flights that must be brought down in any area that is greater than 500 miles distant from these three main staging locations are subject to being considered as above baseline support for these type missions. In addition, due to the high environmental sensitivity associated with Antarctica's coastline, NASA/CSBF will not risk any payload or operation whereby there is significant probability that the payload or balloon would come down over water or on the coastline.

Preplanning Flight Termination – For all missions prior to flight termination, the CSBF Campaign Manager will coordinate with NSF/ASC as to recoverable landing sites prior to effecting end-of-flight termination procedures. CSBF will ensure that NSF/OPP and NASA/BPO are informed of plans for termination. End-of-flight termination may be initiated by over-the-horizon (OTH) command or line-of-sight (LOS) command, depending upon particular circumstances for each flight and to best insure safe impact and recovery. Parachute release after ground impact will be accomplished via CSBF Gondola Automatic Parachute Release (GAPR) system and/or the Semi-Automatic-Parachute-Release (SAPR) system. Although recovery of the balloon may be problematic, balloon recovery will be one of the factors considered in deciding when and where to perform end-of-flight termination.

Procedures

NASA Antarctic long duration balloon missions typically travel on an east-to-west trajectory on or about 78 degrees south latitude. (See figure 1, historical composite of trajectories and figure 2, historical composite of recovery sites.) Duration for each polar circuit is variable but nominally is planned for about 14 days.

Table 1 provides a summary of the activity, roles and responsibilities associated with the decision process for each NASA balloon mission as to whether it is allowed to continue for another circuit about the continent or to be ended. 'T' in Table 1 represents time (plus or minus a few hours) any given flight is predicted to cross the Trans Antarctic Mountains after having made each complete circuit about the continent. All unit times are given in hours. The timeline may be modified in real-time as required by NSF and CSBF personnel who are on site in order to account for changing circumstances/issues and programmatic/mission priorities. Departures from the below listed timeline will be explained by the CSBF Campaign Manager to the BPO and will include the revised estimate.

Table F1. – Multiple Circumpolar Trajectory Decision Process

TIME (Nominal)	CONDITION	ACTION
T - 48	CSBF to have completed health and welfare assessment of balloon flight support systems and instrument status from Science team. CSBF assess flight performance/trajectory and probability of sustained winds to carry mission back around to include best estimate duration and balloon position as it comes back around. It is recognized that polar stratospheric wind data is only available real-time, that forecast models are not accurate, and that CSBF meteorological estimates are a best estimate assessment of satellite derived wind data, institutional experience and dead reckoning. CSBF will confirm science desire to continue mission.	CSBF Report to BPO its findings and recommendation as to Go/No-Go for continuing. (Earlier notification than T-48 may be required based on availability of NSF assets and other extenuating circumstances.) If available, NSF may place air assets on schedule, as may be requested/required for support of flight termination. NASA HQ and NASA BPO confer to determine NASA's position on either terminating the flight or to request NSF concurrence for another circuit about the continent. NASA HQ and NASA BPO have sole responsibility for determining NASA's position as to continuance of mission. For flights having a trajectory that is predicted to fly north of McMurdo as it comes back around, although not a hard and fast requirement for termination, particular consideration will be given to terminating the flight at the earliest and safest point in time in order to mitigate risk of payload loss or incursion into sensitive coastline areas. CSBF trajectory forecasts will be considered in this decision. This will be especially true for such occurrences later in the season, e.g., on or after the end of December.

T-48 to T-24	NASA BPO to confer with NSF MCM Representative as to NASA's desire to continue or end any mission. NSF provides assessment as to availability of aircraft and recovery resources for immediate and extended "end of mission" options, which would include a qualitative assessment by NSF, along with identification of any known issues.	NSF provides NASA concurrence or in lieu of that, rationale for NSF's position that end-of- mission flight termination should commence as soon as possible. If for no other consideration than risk of not being able to perform recovery in the same season, NASA will provide written confirmation to NSF that it understands such risks include increased potential loss of data and equipment, if the payload cannot be recovered the same season as a result of allowing the flight to continue for another circuit about the continent.
T–24 to T-0	CSBF continues to monitor systems health, flight performance and trajectory. Based on NASA & NSF concurrence for termination or continuance, planning and/or monitoring is put into action.	If it has been decided to end the flight as opposed to allowing it to continue for another circuit around, working with NSF/ASC, CSBF will execute plans for termination and recovery of the flight at the earliest time possible in order to achieve the highest probability of recovery of the payload and balloon. NSF will provide guidance in the planning process to account for avoidance of payload/balloon impact onto environmentally sensitive areas and availability of aircraft and recovery assets as may be required.
		If it has been decided to allow the mission to continue, CSBF will continue to monitor systems health, flight performance and trajectory and be prepared as best as possible, to react to any change in status that would warrant a change of plans; thus, change of priority to that of earliest possible termination of flight in order to best achieve recovery of the payload and balloon.

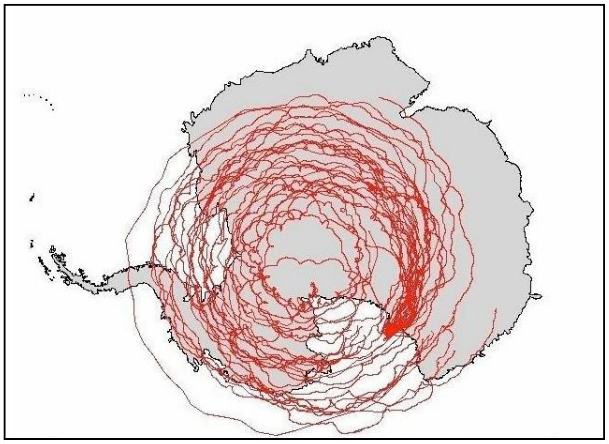


Figure 1. Trajectories of LDB Missions Launched from Williams Field (1990-2006).

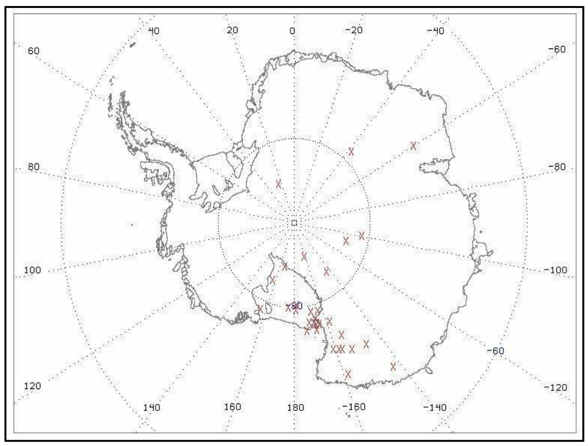


Figure 2. LDB Mission Payload Landing.