Astrophysics Balloon Program Update

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Astrophysics Division, Science Mission Directorate

Astrophysics Advisory Committee
March 15, 2021

Outline

Program Overview

Recent COVID-19 impacts

Providing flight opportunities to science

Responding to the December 2020 APAC Recommendations

> 16) The APAC requests updates on advances in aerostat technologies and other long-duration balloon projects that might enable general guest-observer science using large aperture telescopes with arcsecond pointing precisions across the electromagnetic spectrum.
>
> 17) The APAC recommends that the Astrophysics Division consider adding a formal process for proposing piggyback payloads, potentially across disciplines.

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Balloon Program Overview

Mission Model
8-12 Launched
3+ campaigns
300+ ugrad/grad students participate
40+ Research Institutions


Super-Pressure Balloon

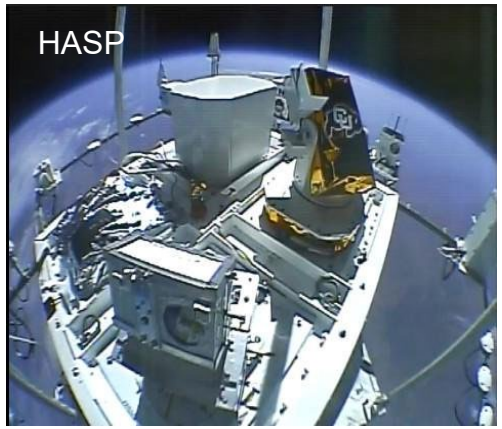
Strategic Objective:

Enable discovery through conduct of frequent scientific balloon flight opportunities for NASA scientific, technology development, and educational investigations.

Balloons provide low-cost, quick response, near space access for:

- Conducting cutting-edge research.
- Developing technologies to enable future spacecraft science missions.
- Advancing lighter-than-air platform technologies.
- Providing Calibration and Validation of on-orbit instrumentation.
- Enabling Hands-on Training of the next generation of scientists and engineers.

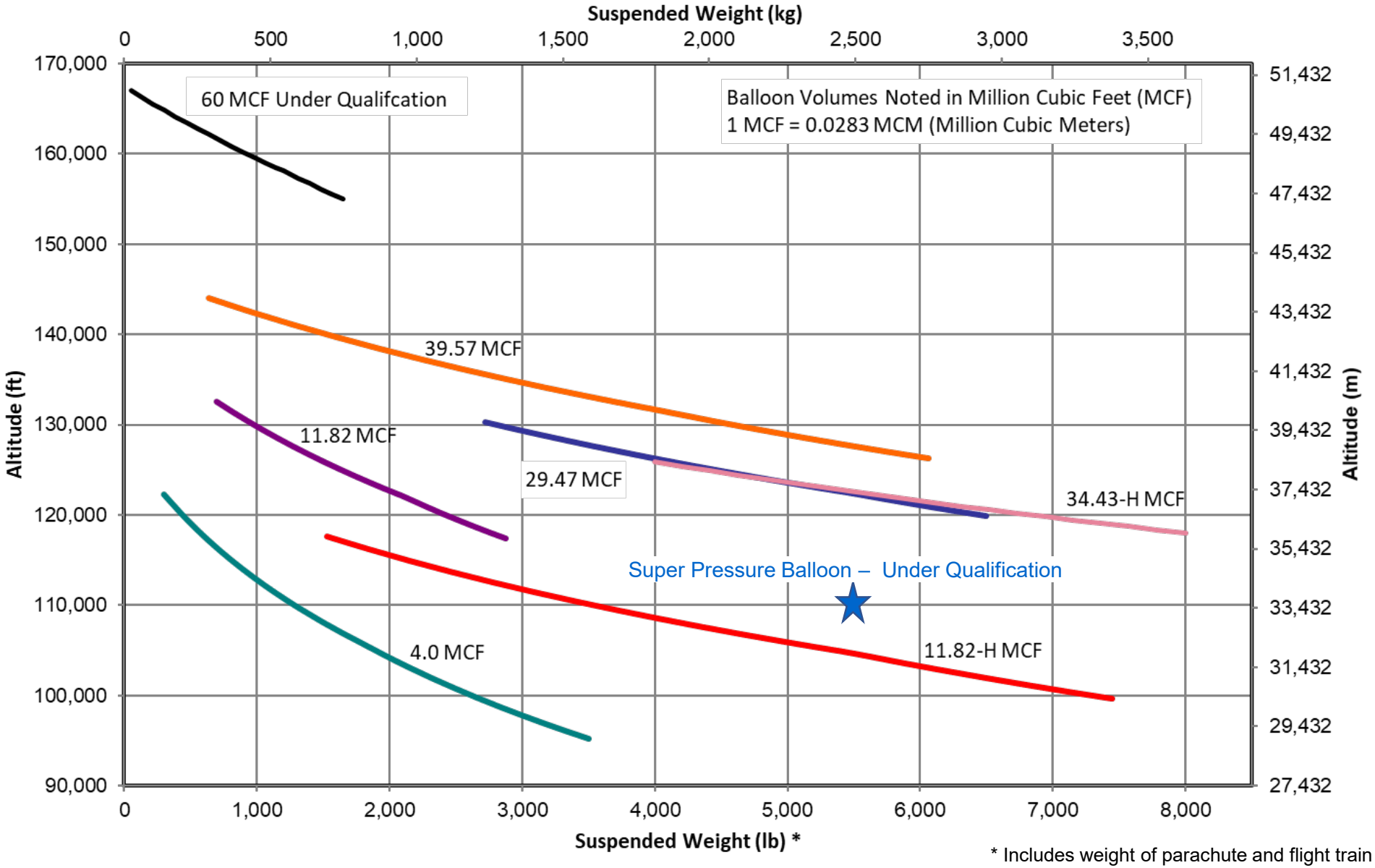

STO-2


HASP


X-Calibur/WASP

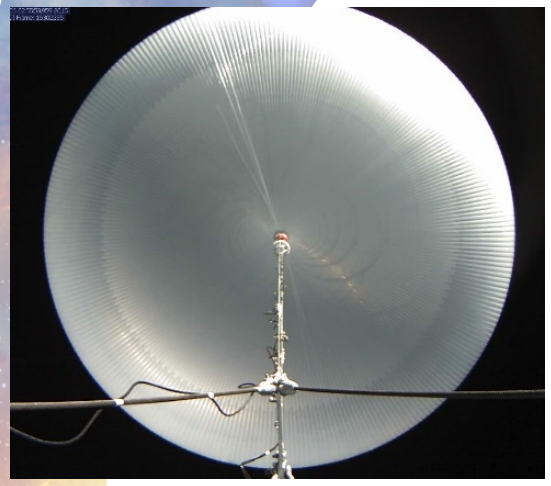

COSI

NASA Zero-Pressure Standard Balloons



* Includes weight of parachute and flight train

Balloon Types

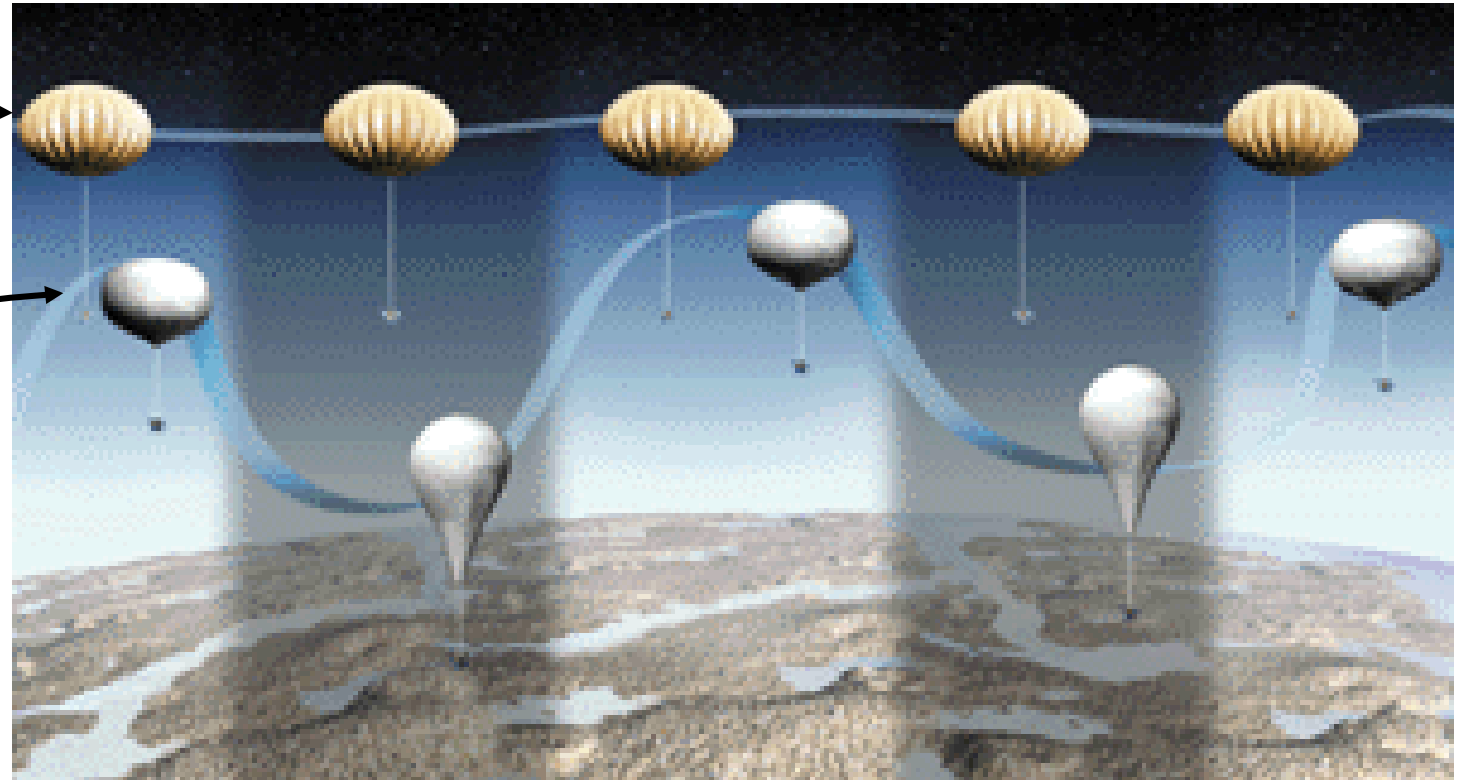


Super-pressure balloon (SPB)

Zero-pressure balloon (ZPB)

Super Pressure Balloon maintains nearly constant volume – ***under development***

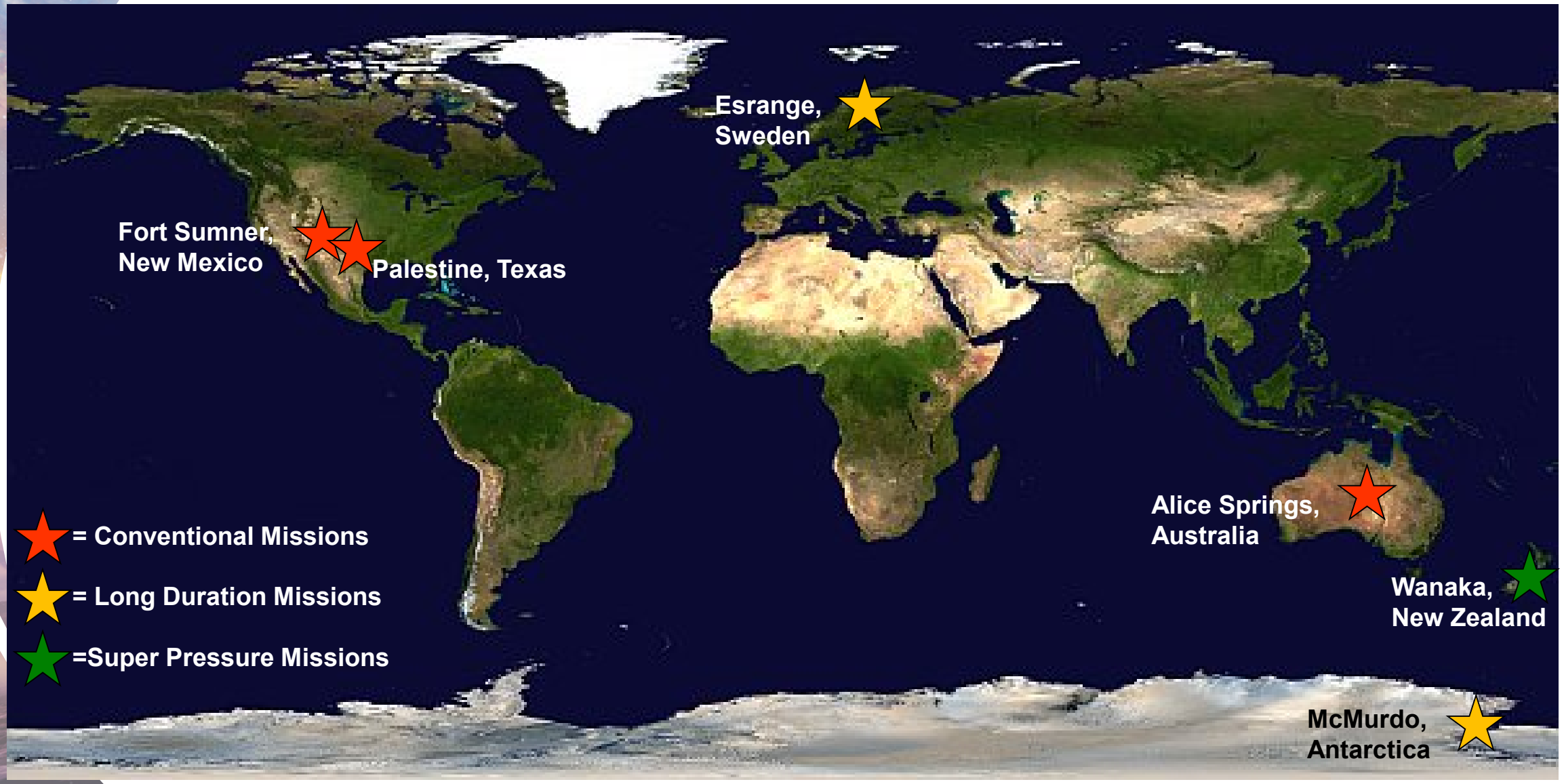
- Allows Ultra Long Duration Balloon (ULDB) Flights
- Provides stable altitude Long Duration Balloon (LDB) flights at mid-latitudes



Zero-Pressure (ZP) Balloon changes volume due to radiative input

- Used for Conventional Flights and Polar LDB Flights

NASA Launch Locations



NASA Support Systems

Balloon Type	Zero Pressure (ZP)	ZP	Super Pressure (SP)
Mission Type	**Conventional**	**LDB**	**ULDB (In development)**
Duration	2 hours to 3 days	4-6 days for Sweden 7-15 for Antarctica up to 55+ days	Up to 100 days 2016 Mid-Latitude Flight = 46 Days
Science Payload Weight	Up to 2,948 kg (Up to 6,500 lbs)	Up to 2,948 kg (Up to 6,500 lbs)	18.8 MCF* – 907 kg (2,000 lbs) science allocation
Typical Float Altitude	29.2 to 38.7 km (96 to 127 kft)	36.5 to 38.7 km (120 to 127 kft)	18.8 MCF – up to 34 km (˜110 kft)
Support Package	**Consolidated Instrumentation Package (CIP)** • Line of Sight (LOS) • Up to 12 Mbps direct return	**Support Instrumentation Package (SIP)** • Line of Sight (LOS) - Up to 12 Mbps direct return • Over The Horizon (OTH) • 6 kbps / 92 kbps TDRSS Downlink** • 80 kbps Iridium option***	
	Small Launch Package (hand-launch class balloons) • Stand alone package for small payload support • LOS and OTH TM & Command (Iridium) 255 byte/min packets • Up to 12 Mbps LOS option • System without batteries ~20 lbs (9 kg) * MCF – Million Cubic Feet **300kbps/1Mbps in development ***Iridium – limited support		

Wanaka, New Zealand

Southern Hemisphere Long Duration Balloon (LDB)/ Ultra Long Duration Balloon (ULDB) Campaign

- Established in 2015
- Flight durations 10 to 60 days+
- Launch Operations on Wanaka Airport
- Safety: Active Risk Assessment Required for Mission
- Limited Payload Dimensions due to Leased Hangar – Working to Build Larger Building To Accommodate Larger Payloads

McMurdo, Antarctica

Southern Hemisphere Polar Long Duration Balloon (LDB) Campaign (annual)

- Established in 1989
- Collaboration with National Science Foundation (NSF)
- 2-3 missions supported each campaign
- Flight durations from 7 to 55+ days
- Launch operations at LDB Site on Ross Ice Shelf outside of McMurdo Station
- Recovery coordinated with NSF
  Winter-over of instrument possible

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Balloon Campaign COVID Impacts

Wanaka, NZ, 2020

-02/21/20 COSI science team deployment.

-03/14/20 BPO decision to cancel the Wanaka 2020 Campaign and redeploy teams.

Palestine, TX, 2020

-04/08/20 BPO decision to move the payload (PIPER) from Palestine to the Ft. Sumner Campaign.

Fort Sumner, NM, 2020

-For all but one payload (PIPER), the PI have withdrawn from Ft Sumner campaign.

-07/09/20 BPO decision to cancel the Ft. Sumner campaign (Nevada as the payload recovery side for Ft. Sumner balloon launches was at the peak of their COVID outbreak).

McMurdo, Antarctica, 2020

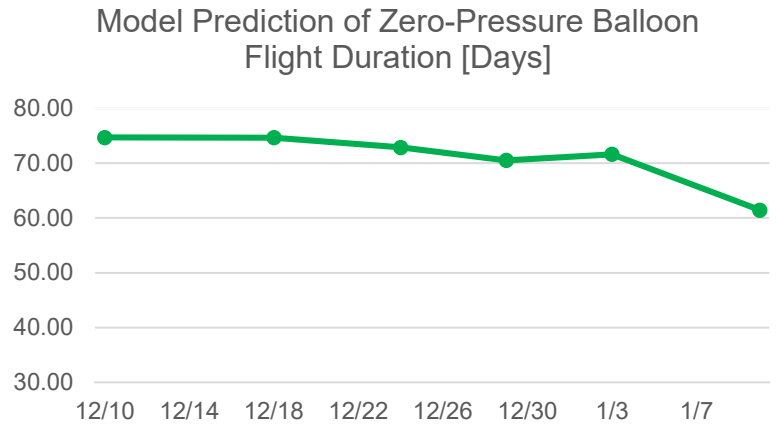
-06/21/20 NSF informed NASA that due to COVID-19 NSF can not support a 20/21 LDB Antarctica campaign.

Wanaka, NZ, 2021

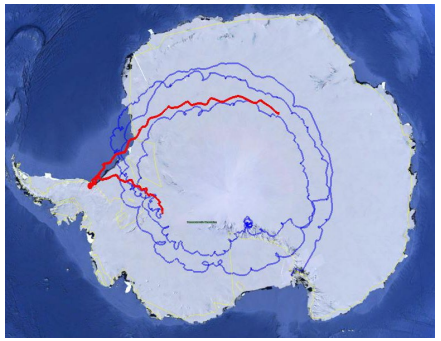
-02/01/21 BPO decision to cancel the Wanaka 2021 Campaign due to NZ travel restrictions.

GUSTO Suborbital Explorer

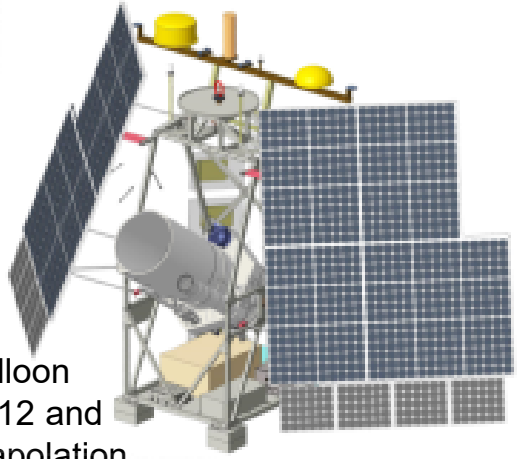
- GUSTO, led by PI Chris Walker (University of Arizona), is an Astrophysics Explorer Mission of Opportunity balloon investigation, scheduled for launch from McMurdo, Antarctica in December 2021, on a 75-day mission.
- Plan was to super-pressure balloon (SPB)
  - Qualify the SPB with test launches from Wanaka, NZ in March 2020 and 2021.
  - Launch GUSTO on SPB make the mission more resilient day/night cycles late in the season.
- Due to COVID, the two qualification flights were canceled, so SPB has not been qualified.
- NASA has decided to fly GUSTO from McMurdo in 2021 on a zero-pressure balloon (ZPB).
- The ZPB offers:
  - Higher lift capacity,
  - Higher flight altitude (39 km vs 33.5 km),
  - Less stringent surface weather conditions for launch operations than SPB, and
  - More launch opportunities.
- GUSTO mission needs to be completed before balloon experiences day/night cycles.
- National Science Foundation (NSF) announced that the 2021/2022 Antarctic field program will again be maintenance-only due to COVID restrictions
  - NASA is determining the impact on GUSTO.



Model Predictions of Expected Flight Duration based on 47 past Antarctica launches. If launched early in the season (nominally opens Dec 1, 3-4 weeks) GUSTO will reach 75-day baseline at >90% and 30-days threshold duration at 99%.



SuperTIGER zero-pressure balloon trajectory in blue (launched 12/8/12 and terminated 55 days later) and extrapolation flight up to 75 days duration in red.



GUSTO Payload

FY20 Balloon Program Manifest

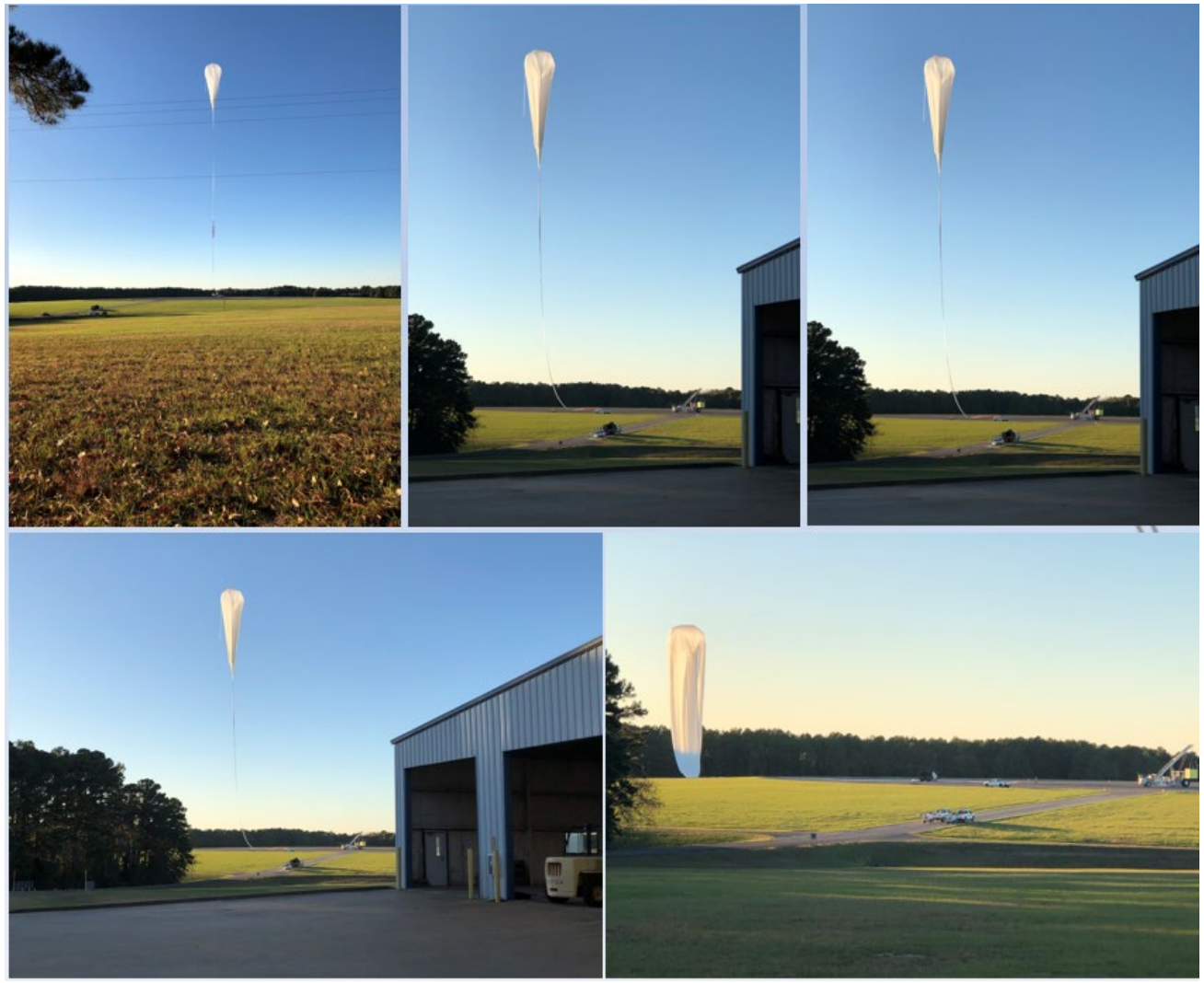
Mission	Discipline	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Fort Sumner, New Mexico	***Fall '19***												
Toon/JPL-Remote/Bailey/VATech/GLO	Upper Atmosphere	*Success*											
Kogut/GSFC/PIPER	IR-Submillimeter	*Success*											
Young/SwRI/THAI-SPICE (Hand Launch)	UV/Visible	*Success*											
Tang/JPL/RECKTANGLE (Hand Launch)	IR-Submillimeter	*Success*											
Livesey/JPL/SWITCH (Hand Launch)	IIP/Upper Atmosphere	*Successful Ground Test*											
McMurdo, Antarctica	***Winter '19***												
Rauch/WUSTL/SuperTIGER	Cosmic Ray/Particle			*Success*									
Devlin/UPENN/BLASTPOL	IR-Submillimeter				*Science Anomaly*								
Salter/CSBF/TRAVALB	Test Flight		*Abort*		*Success*								
Wanaka, New Zealand	***Spring '20***	***Campaign cancelled by BPO after initiated due to COVID-19.***											
SPB Test/Boggs/UCSD/COSI	Test Flight/COSI (PB)												
Palestine, Texas	***Summer '20***	***Campaign cancelled by BPO due to COVID-19.***											
Kogut/GSFC/BOBCAT	IR-Submillimeter												
Kogut/GSFC/PIPER	IR-Submillimeter												
Fort Sumner, New Mexico	***Fall '20***	***Campaign cancelled by BPO due to COVID-19.***											
Kogut/GSFC/BOBCAT	IR-Submillimeter												
Field/CSBF/LDB Test Flight	Test Flight												
Young/SwRI/THAI-SPICE	UV/Visible												
Walker/Large Balloon Reflector	IR-Submillimeter												
Guzik/LSU/HASP	Student Flight Project												
Kogut/GSFC/PIPER	IR-Submillimeter												
Toon/JPL-Remote/Bailey/VATech/GLO	Upper Atmosphere												

Crew Chief Training Exercises

Crew Chief Training (CCT) Exercises are essentially full launch operations without release of the payload from the launch vehicle. (captive balloon)

Multi Purpose:

- Training of new launch personnel
- Qualification of new crew chiefs
- Investigative



From Nov 2020 – Feb 2021 2 complete exercises plus 1 inflation only.

Crew Chief Training Exercises

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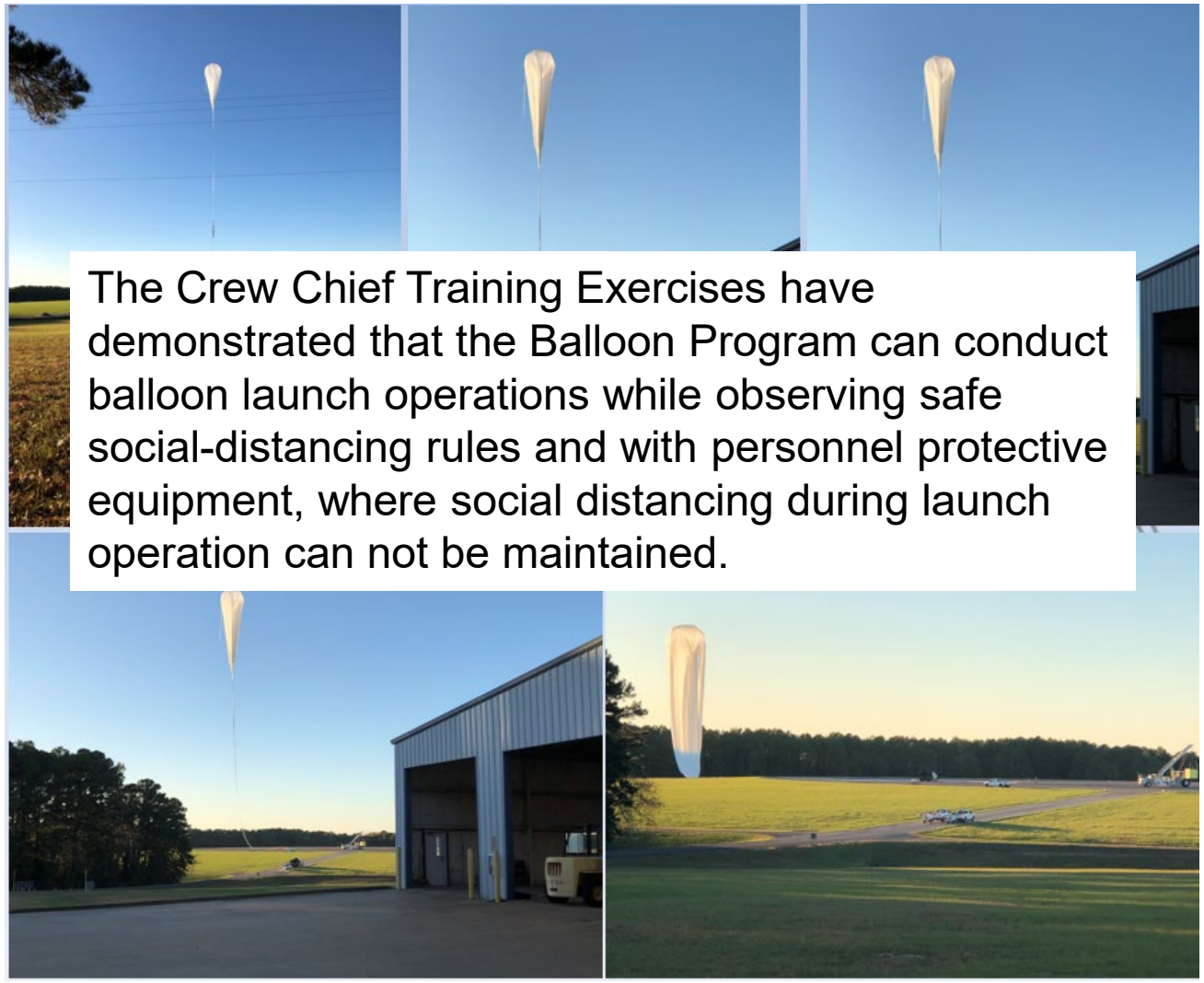

The Crew Chief Training Exercises have demonstrated that the Balloon Program can conduct balloon launch operations while observing safe social-distancing rules and with personnel protective equipment, where social distancing during launch operation can not be maintained.

From Nov 2020 – Feb 2021 2 complete exercises plus 1 inflation only.

FY21 Balloon Program Manifest

Mission	Discipline	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
McMurdo Station, Antarctica	***Winter '20***	***Campaign cancelled by NSF due to COVID-19.***											
Roth / BPO / 60 MCF Test Flight	Test Flight			*Delayed by NSF due to COVID-19*									
Salter / CSBF / TRAVAL-B / Millan / DC / BARREL	Test Flight / BARREL (PB)			*Delayed by NSF due to COVID-19*									
Jones / PU / SPIDER	UV / Visible			*Delayed by NSF due to COVID-19*									
Salter / CSBF / TRAVALA	Test Flight				*Delayed by NSF due to COVID-19*								
Wanaka, New Zealand	***Spring '21***	***Campaign cancelled by BPO due to COVID-19. To be rescheduled for FY22.***											
Hall / BPO / SPB Test / Boggs / UCSD / COSI	Test Flight / COSI (PB)						*Delayed by BPO due to COVID-19*						
Fort Sumner, New Mexico	***Spring '21***												
Chartier / JHU APL / BBC	Heliophysics (H/L)												
Kogut / GSFC / BOBCAT-21A/B	IR-Submillimeter			*Delayed by PI due to COVID-19*									
Kogut / GSFC / PIPER-21A	IR-Submillimeter												
Mullenax / CSBF / CSBF Test Flight	Test Flight												
Salter/ CSBF / Test Flight / Jackson / UCSD / ASHI	Test Flight / ASHI (PB)												
Esrange, Sweden – Alternate to Wanaka	***Summer '21***	***Campaign cancelled by BPO due to COVID-19.***											
Hall / BPO / SPB Test SN 07 / Sample / MSU / BOOMS	Test Flight / BOOMS (PB)								*Delayed by BPO due to COVID-19*				
Roth / BPO / 60 MCF Test	Test Flight								*Delayed by BPO due to COVID-19*				
Palestine, Texas	***Summer '21***	***Flights moved to spring Fort Sumner Campaign.***											
Fort Sumner, New Mexico	***Fall '21***												
Salter / CSBF / CSBF Test Flight	Test Flight												
Guzik / LSU / HASP	Education Outreach												
Stachnik / JPL / JPL-SLS	Upper Atmosphere												
Kogut / GSFC / BOBCAT-21C/D	IR-Submillimeter												
Martin / CalTech / FIREBall-2	UV / Visible												
Chakrabarti / UMASS / PICTURE-C	UV/Visible												
Toon / JPL / JPL-Remote	Upper Atmosphere												
Nowicki / LANL / LANL Test Flight	Gamma-Ray (H/L)												
Kogut / GSFC / PIPER-21B	IR-Submillimeter												
Boering / UCB / MATTADOR TF	Upper Atmosphere												
Young / SwRI / THAI-SPICE	UV / Visible												
Tang / JPL / WHATSUP	Solar System (H/L)												

Rescheduled Flight Opportunities 1/3

FY20 COVID-19 Flight Delays Summary

Primary Mission	Discipline	Campaign Status
Fort Sumner, New Mexico	***Fall '19***	
Toon/JPL-Remote/Bailey/VATech/GLO	Upper Atmosphere	Flown
Kogut/GSFC/PIPER	IR-Submillimeter	Flown
Young/SwRI/THAI-SPICE (Hand Launch)	UV/Visible	Flown
Tang/JPL/RECKTANGLE (Hand Launch)	IR-Submillimeter	Flown
Livesey/JPL/SWITCH (Hand Launch)	IIP/Upper Atmosphere	Flown
McMurdo, Antarctica	***Winter '19***	
Rauch/WUSTL/SuperTIGER	Cosmic Ray/Particle	Flown
Devlin/UPENN/BLASTPOL	IR-Submillimeter	Flown
Salter/CSBF/TRAVALB	Test Flight	Flown
Wanaka, New Zealand	***Spring '20***	
SPB Test/Boggs/UCSD/COSI	Test Flight/COSI (PB)	Not Manifested
Salter/CSBF/TRAVALA	Test Flight	Not Manifested
Palestine, Texas	***Summer '20***	
Kogut/GSFC/BOBCAT	IR-Submillimeter	FY21 Fall FTS
Kogut/GSFC/PIPER	IR-Submillimeter	FY21 Fall FTS
Fort Sumner, New Mexico	***Fall '20***	
Kogut/GSFC/BOBCAT-II/III	IR-Submillimeter	FY21 Fall FTS
Salter/CSBF/CSBF Test Flight-I/II	Test Flight	FY21 Spg/Fl FTS
Martin/CalTech/FIREBall-2	UV/Visible	FY21 Fall FTS
Bailey/VATech/GLO	Upper Atmosphere	FY21 Fall FTS
Bloser/LANL/LTT (Hand Launch)	Gamma Ray	FY21 Fall FTS
Chakrabarti/UMASS/PICTURE-C	UV/Visible	FY21 Fall FTS
Kogut/GSFC/PIPER	IR-Submillimeter	FY21 Fall FTS
Young/SwRI/THAI-SPICE	UV/Visible	FY21 Fall FTS
Tang/JPL/WHATSUP (Hand Launch)	Planetary Sciences	FY21 Fall FTS

Piggybacks	Discipline	Campaign Status
McMurdo, Antarctica	***Winter '19***	
Meshik/WUSTL/BAS	Upper Atmosphere	Flown
Smith/NASA ARC/E-MIST	Space Biology	Flown
Fritts/GATS/PMC Turbo	Upper Atmosphere	Flown
Wanaka, New Zealand	***Spring '20***	
Boggs/UCSD/COSI	Gamma Ray	Not Manifested
Fort Sumner, New Mexico	***Fall '20***	
Miller/JHU APL/BAGEL	Gamma Ray	Not Manifested
Zhou/UCLA/BALBOA	Solar and Heliophysics	FY21 Spring FTS
Sample/MSU/BOOMS	Solar and Heliophysics	FY21 Spring FTS
Agee-DeHart/Idoodlelearning.com/CIS	Student Outreach	FY21 Fall FTS
Chakrabarti/UMASS/CoMIC	Ultraviolet and Visible	FY21 Fall FTS
Mendoza-Bárcenas/IPN/EMIDSS	Upper Atmosphere	FY21 Fall FTS
Yoder/WFF/EV13TF	Tech Demo	Not Manifested
Chartier/JHU APL/HFRX	Geospace	Not Manifested
Komjathy/NASA JPL/INMEX	Geophysics - Infrasound	Not Manifested
Esper/NASA GSFC/MAPPER	Planetary	FY21 Fall FTS
Deland/SSAI/MASTAR	Upper Atmosphere	FY21 Fall FTS
Banfield/CU/MSA	Solar System	Not Manifested
Yoder/WFF/SPARROW	Tech Demo	FY21 PSN
Roth/WFF/WALRUSS	Tech Demo	FY21 Fall FTS

Not Manifested = No rescheduled launch opportunity requested by PI

Rescheduled Flight Opportunities 2/3

FY21 COVID-19 Flight Delays Summary

Goddard Space Flight Center — Wallops Flight Facility

Primary Missions	Discipline	Campaign Status
McMurdo Station, Antarctica	***Winter '20***	
Roth / BPO / 60 MCF Test Flight	Test Flight	FY22 ANT LDB
Salter / CSBF / TRAVAL-B / Millan / DC / BARREL	Test Flight / BARREL (PB)	FY22 ANT LDB
Jones / PU / SPIDER	UV / Visible	FY23 ANT LDB
Salter / CSBF / TRAVALA	Test Flight	FY22 ANT LDB
Wanaka, New Zealand	***Spring '21***	
Hall / BPO / SPB Test / Boggs / UCSD / COSI	Test Flight / COSI (PB)	FY22 NZ LDB
Fort Sumner, New Mexico	***Spring '21***	
Chartier / JH APL / BBC	Heliophysics (H/L)	As Scheduled
Kogut / GSFC / BOBCAT-21A/B	IR-Submillimeter	FY21 Fall FTS
Kogut / GSFC / PIPER-21A	IR-Submillimeter	FY21 Fall FTS
Salter / CSBF / CSBF Test Flight	Test Flight	As Scheduled
Esrange, Sweden – Alternate to Wanaka	***Summer '21***	
Hall / BPO / SPB Test SN 07 / Sample / MSU / BOOMS	Test Flight / BOOMS (PB)	FY22 NZ LDB
Roth / BPO / 60 MCF Test	Test Flight	FY22 ANT LDB
Palestine, Texas	***Summer '21***	
Mullenax / CSBF / CSBF Test Flight	Test Flight	As Scheduled
Salter/ CSBF / Test Flight / Jackson / UCSD / ASHI	Test Flight / ASHI (PB)	As Scheduled
Fort Sumner, New Mexico	***Fall '21***	
Salter / CSBF / CSBF Test Flight	Test Flight	As Scheduled
Guzik / LSU / HASP	Education Outreach	As Scheduled
Stachnik / JPL / JPL-SLS	Upper Atmosphere	As Scheduled
Kogut / GSFC / BOBCAT-21C/D	IR-Submillimeter	As Scheduled
Martin / CalTech / FIREBall-2	UV / Visible	As Scheduled
Chakrabarti / UMASS / PICTURE-C	UV/Visible	As Scheduled
Toon / JPL / JPL-Remote	Upper Atmosphere	As Scheduled
Nowicki / LANL / LANL Test Flight	Gamma-Ray (H/L)	As Scheduled
Kogut / GSFC / PIPER-21B	IR-Submillimeter	As Scheduled
Boering / UCB / MATTADOR TF	Upper Atmosphere	As Scheduled
Young / SwRI / THAI-SPICE	UV / Visible	As Scheduled
Tang / JPL / WHATSUP	Solar System (H/L)	As Scheduled

Rescheduled Flight Opportunities 3/3

FY21 COVID-19 Flight Delays Summary - Piggybacks

Goddard Space Flight Center — Wallops Flight Facility

Piggyback Mission	Discipline	Campaign Status
McMurdo, Antarctica	***Winter '20***	
Bowman/SNL/AIUS	Geophysics	Not Manifested
Buckley/WUSTL/APTLite +	Cosmic Ray, Particle	Not Manifested
Millan/DC/BARREL	Cosmic Ray, Particle	FY 22 ANT LDB
Meshik/WUSTL/BAS-M	Upper Atmosphere	Not Manifested
Smith/NASA ARC/E-MIST	Space Biology	FY 22 ANT LDB
Chartier/JHU APL/HFRX	Geospace	FY 22 ANT LDB
Wanaka, New Zealand	***Spring '21***	
Boggs/UCSD/COSI	Gamma Ray	Not Manifested
Fort Sumner, New Mexico	***Spring '21***	
Miller/JHU APL/BAGEL	Gamma Ray	Not Manifested
Zhou/UCLA/BALBOA	Solar and Heliophysics	As Scheduled
Sample/MSU/BOOMS	Cosmic Ray, Particle	As Scheduled
Mendoza-Bárcenas/IPN/EMIDSS	Upper Atmosphere	As Scheduled
Yoder/WFF/EV13TF	Tech Demo	Not Manifested
Komjathy/NASA JPL/INMEX	Geophysics - Infrasound	Not Manifested
Banfield/CU/MSA	Solar System	Not Manifested

Piggyback Mission	Discipline	Campaign Status
Esrange, Sweden – Alternate to Wanaka	***Summer '21***	
Fritts/GATS/PMC Turbo	Upper Atmosphere	Not Manifested
Palestine, Texas	***Summer '21***	
Jackson/UCSD/ASHI	Solar and Heliophysics	As Scheduled
McEnery/NASA GSFC/ComPair	Gamma-Ray	Not Manifested
Hart/UA/IRCSP	Upper Atmosphere	As Scheduled
Yoder/WFF/SPARROW	Tech Demo	As Scheduled
Ft. Sumner, New Mexico	***Fall '21***	
Agee-DeHart/Idoodlelearning.com/CIS	Student Outreach	As Scheduled
Chakrabarti/UMASS/CoMIC	Ultraviolet and Visible	As Scheduled
Bailey/VATech/GLO	Upper Atmosphere	As Scheduled
Bowman/SNL/InfraLite	Geophysics	As Scheduled
Deland/SSAI/MASTAR	Upper Atmosphere	As Scheduled
Esper/NASA GSFC/NetSI	Planetary	As Scheduled
Veach/SwRI/PLEIADES	Upper Atmosphere	As Scheduled
Roth/WFF/WALRUSS	Tech Demo	As Scheduled

Not Manifested = No rescheduled launch opportunity requested by PI

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Guest-Observer Science

Recommendation 16:

The APAC requests updates on advances in aerostat technologies and other long-duration balloon projects that might enable general guest-observer science using large aperture telescopes with arcsecond pointing precisions across the electromagnetic spectrum.

Response:

Guest-observer science can be supported by LDB (ZPB) or ULDB (SPB) payloads, spending sufficient time aloft to complete the primary and guest observer (GO) science. A funded investigations that have electromagnetic detectors and arcsecond pointing is:

- ASTHROS, which has prevision host a small GO detector (IR);

Providing GO investigation opportunities on a balloon payload is at discretion of the PI. These GO could follow after the completion of the primary science mission. The selection of the GO science is be left to the PI. Funding for such GO investigations could be part of the original PI proposal or a separate APRA proposal.

Piggyback Payloads

Recommendation 17:

The APAC recommends that the Astrophysics Division consider adding a formal process for proposing piggyback payloads, potentially across disciplines.

- Piggyback payloads are typically small, innovative instruments (average 12 kg).
- They do not require all of the support a full scientific instrument payload may need.
- They can be added to an existing flight with little added weight or power requirements.

Response:

Presently, piggyback are accommodated (~15/year) either by primary science missions or BPO test balloon flights, by submitting a Balloon Flight Support Application[1)] to BPO/CSBF.

In Astrophysics, piggyback payloads can already be proposed through the ROSES APRA element either as a standalone detector development/science investigation or as part of technology maturation for full mission (suborbital or orbital). Similarly, HPD and ESD allows piggyback investigations.

1) https://www.csbf.nasa.gov/docs.html

Piggybacks for SMD investigations

Piggybacks	Discipline
McMurdo, Antarctica	***Winter '19***
Meshik/WUSTL/BAS	Upper Atmosphere
Smith/NASA ARC/E-MIST	Space Biology
Fritts/GATS/PMC Turbo	Upper Atmosphere
Wanaka, New Zealand	***Spring '20***
Boggs/UCSD/COSI	Gamma Ray
Fort Sumner, New Mexico	***Fall '20***
Miller/JHU APL/BAGEL	Gamma Ray
Zhou/UCLA/BALBOA	Solar and Heliophysics
Sample/MSU/BOOMS	Cosmic Ray, Particle
Agee-DeHart/Idoodlelearning.com/CIS	Student Outreach
Chakrabarti/UMASS/CoMIC	Ultraviolet and Visible
Mendoza-Bárcenas/IPN/EMIDSS	Upper Atmosphere
Yoder/WFF/EV13TF	Tech Demo
Chartier/JHU APL/HFRX	Geospace
Komjathy/NASA JPL/INMEX	Geophysics - Infrasound
Esper/NASA GSFC/MAPPER	Planetary
Deland/SSAI/MASTAR	Upper Atmosphere
Banfield/CU/MSA	Solar System
Yoder/WFF/SPARROW	Tech Demo
Roth/WFF/WALRUSS	Tech Demo

Piggyback Mission	Discipline
McMurdo, Antarctica	***Winter '20***
Bowman/SNL/AIUS	Geophysics
Buckley/WUSTL/APTLite +	Cosmic Ray, Particle
Millan/DC/BARREL	Cosmic Ray, Particle
Meshik/WUSTL/BAS-M	Upper Atmosphere
Smith/NASA ARC/E-MIST	Space Biology
Chartier/JHU APL/HFRX	Geospace
Wanaka, New Zealand	***Spring '21***
Boggs/UCSD/COSI	Gamma Ray
Fort Sumner, New Mexico	***Spring '21***
Miller/JHU APL/BAGEL	Gamma Ray
Zhou/UCLA/BALBOA	Solar and Heliophysics
Sample/MSU/BOOMS	Cosmic Ray, Particle
Mendoza-Bárcenas/IPN/EMIDSS	Upper Atmosphere
Yoder/WFF/EV13TF	Tech Demo
Komjathy/NASA JPL/INMEX	Geophysics - Infrasound
Banfield/CU/MSA	Solar System

Piggyback Mission	Discipline
Esrange, Sweden – Alternate to Wanaka	***Summer '21***
Fritts/GATS/PMC Turbo	Upper Atmosphere
Palestine, Texas	***Summer '21***
Jackson/UCSD/ASHI	Solar and Heliophysics
McEnery/NASA GSFC/ComPair	Gamma-Ray
Hart/UA/IRCSP	Upper Atmosphere
Yoder/WFF/SPARROW	Tech Demo
Ft. Sumner, New Mexico	***Fall '21***
Agee-DeHart/Idoodlelearning.com/CIS	Student Outreach
Chakrabarti/UMASS/CoMIC	Ultraviolet and Visible
Bailey/VATech/GLO	Upper Atmosphere
Bowman/SNL/InfraLite	Geophysics
Deland/SSAI/MASTAR	Upper Atmosphere
Esper/NASA GSFC/NetSI	Planetary
Veach/SwRI/PLEIADES	Upper Atmosphere
Roth/WFF/WALRUSS	Tech Demo

Piggyback related to SMD funded investigation

Piggybacks are an important part of the BPO's launch opportunities and provide a low-threshold access to the program, particularly for university-funded investigations. Another class has SMD mission related technology development/science investigations.

The ROSES balloon section could be more explicit about piggyback opportunities.

Backup

Other Balloon Program Technologies

Wallops Arc Second Pointer

High Data Rate Data Link

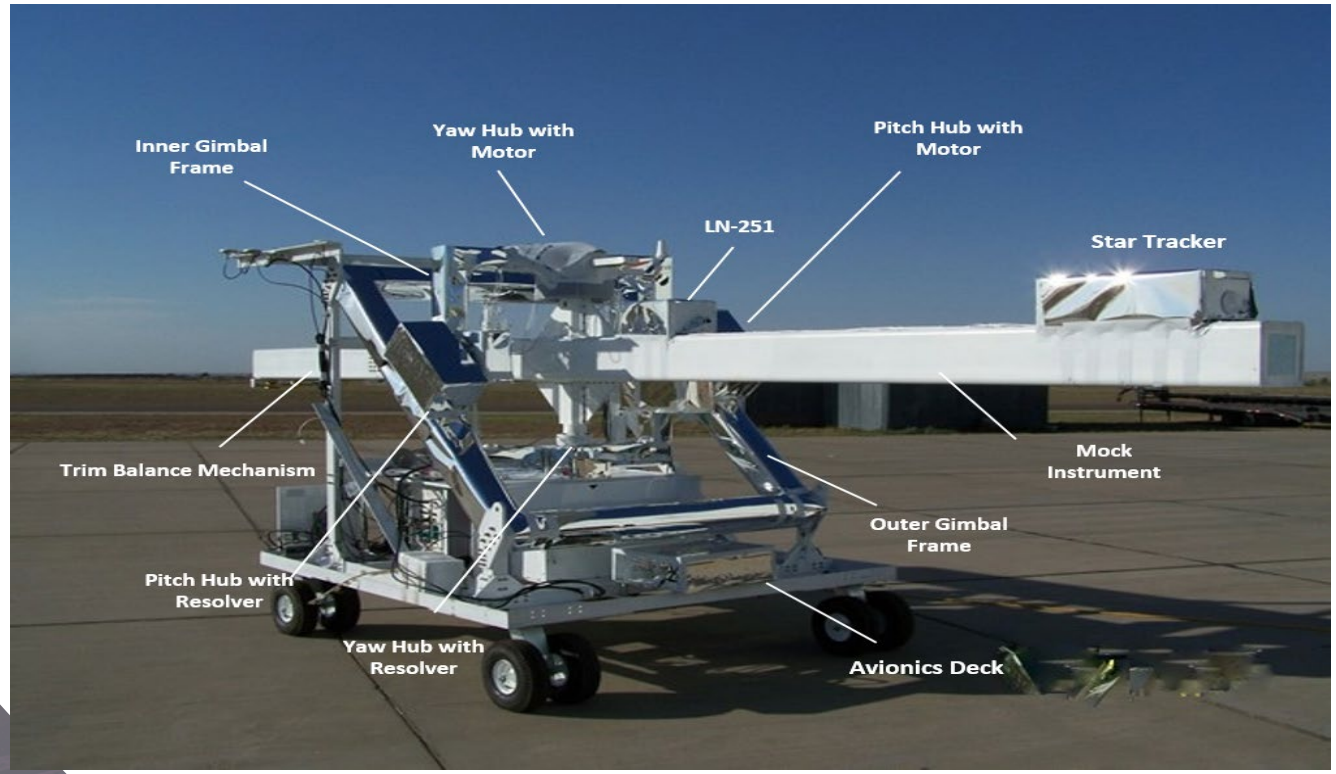
Wallop Arc Second Pointer (WASP)

Performance Stats

Time of Float Before First Pointing Mode: ~3 hour
Pointing Accuracy: Sub-arc-second
Target Lock Time: > 6 hours
Slew Rate:
- Target to Target Maneuvers: 0.1-0.2 °/sec. Rate limit is configurable
- Target Tracking of Non-Inertial Targets:100°/hour

Payload Stats

WASP Components Weight: 385lb
WASP Outer Gimbal Frame (If Required): 214lb
WASP Gondola Weight: 641lb
Light Weight WASP Gondola: *Under Development* ~47 % Mass reduction
Elevation Range: ~65°
Star Tracker:
- Field Of View: 5.0 x 3.7°
- Sun Occultation of 40° with ability to sense
  - > 5 stars in the daytime
  - > 7 stars at night



Telemetry Stats

Line of Sight (LOS):
- Low Rate science interface: 255 byte packet/30 seconds
- Science Stack Packet (1/30 seconds

Tracking and Data Relay Satellite System (TDRSS):
- Backup method: High Rate port (6kbps to 75kbps)
- Low Rate science interface (255 byte packet/30 seconds)
- Science Stack Packet (1/30 seconds)

Iridium:
- Short Burst Data (SBD)
  - Low Rate science interface (255 byte packet/1-15mintues)
  - Science Stack Packet (1/1-15 minutes)
- Pilot: Bi-directional Ethernet data (up to 75kbps)

Ethernet-via-Telemetry (EVTM) :
- Must allow for variable rates from 100kbps up to 9.9Mbps
  - LOS (up to 9.9Mbps)
  - TDRSS (100kbps to ~820kbps)
    - Rates dependent on link obtained through space network

Command Uplink:
- Standard CSBF 2-byte and extended command formats
  - LOS
  - Iridium SBD – available throughout flight
  - TDRSS – available on an as needed basis
- Iridium Pilot – Bi-directional Ethernet

Science Stack:
- (32) Analog inputs (0-5V) 12-bit resolution
- (16) Digital inputs (0,5V)
- (28) Open collector outputs

** WASP is fully configurable to meet a variety of science requirements.

Higher Data Rate Telemetry

Quasonix Ethernet Enabled EVTM transmitter

- Network Jack interface
- Data over Multicast (UPD) packets
- LDB flights require Managed network switch with separate addressing for TDRSS and LOS Data
- LOS data rate up to 12mb
- TDRSS data rate up to 1mb
- Still undergoing testing

This technology is currently under development and is not fully flight-qualified for Science.

Aerostat Technologies

- Raven Aerostar Thunderhead System
- Tethered Aerostats summary by P. Gorham

Thunderhead

Commercially available launch system small scale super-pressure balloons

- 14 – 28 km super-pressure balloons with altitude control for navigation.
- provided power (average per day ~100W).
- ~55 kg science payload.
- high-speed line-of-sight data down link, low-speed Iridium over-the-horizon Telemetry.

Balloon Roadmap PAG on tethered aerostats

Tethered aerostats were identified for two applications of interest: both are most appropriate to polar missions/deployments

1. A high-altitude platform supporting a large telescope that could remain in the polar tropopause at about 8 km altitude would have ambient 220K optics, exceptional transmission, and diffraction-limited seeing in the near IR
   - Bely et al. "POST: Polar Stratospheric Telescope", Space Sci. Rev., 1995
2. A moderate-to-high altitude (3-8km) polar platform with a ice-sheet-viewing radio antenna array could improve ultra-high energy neutrino sensitivity by 1-2 orders of magnitude over existing missions such as ANITA & PUEO
   - D. Besson et al., "Tethered balloons for radio detection of ultra high energy cosmic neutrinos in Antarctica," Nucl. Inst. Meth. 662, S50, 2012.

Polar Stratospheric Telescope (1995)

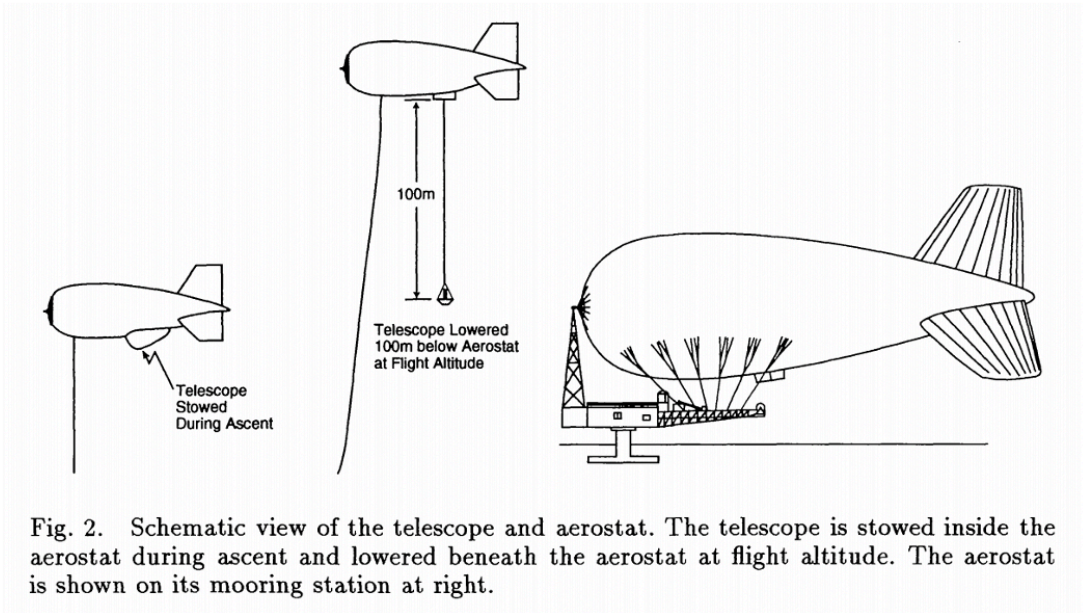
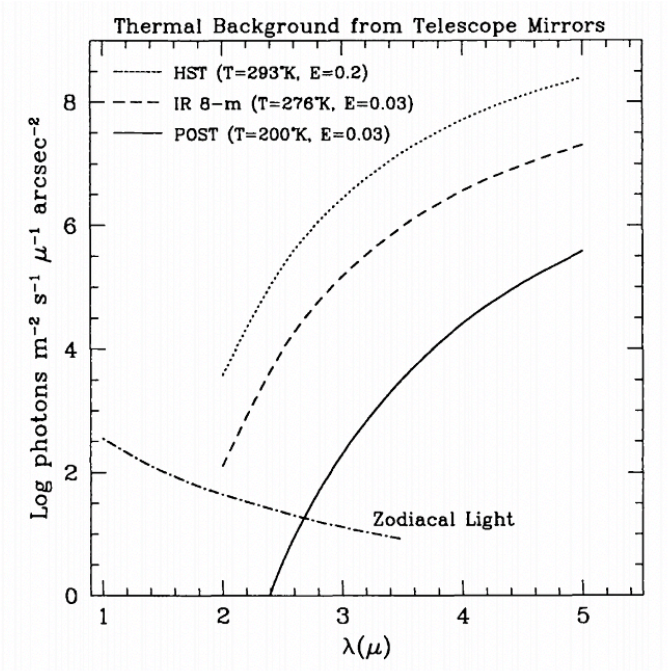
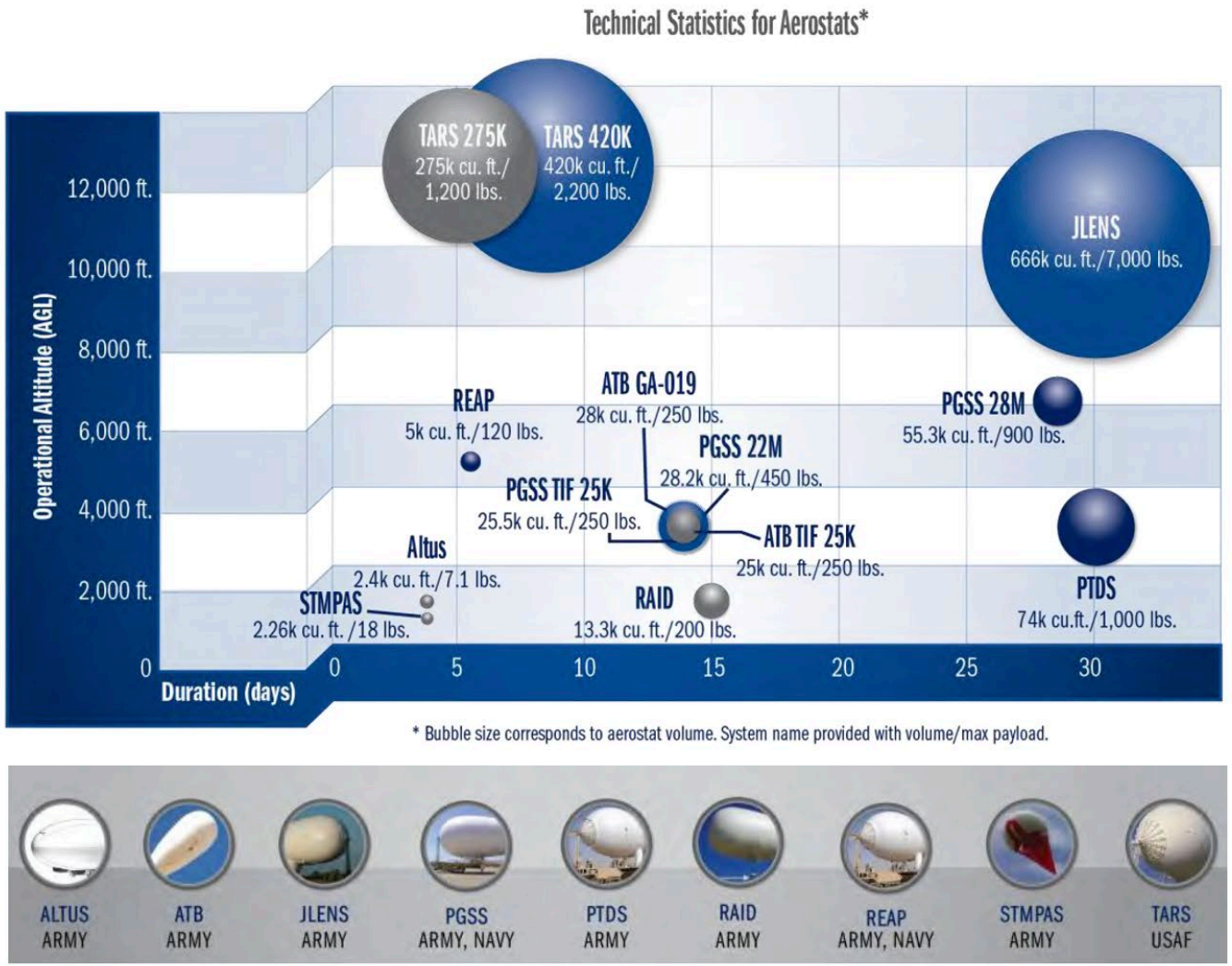


Fig. 2. Schematic view of the telescope and aerostat. The telescope is stowed inside the aerostat during ascent and lowered beneath the aerostat at flight altitude. The aerostat is shown on its mooring station at right.



- Bely et al. Space Sci. Rev., 1995, diffraction-limited 6m sparse aperture, 1300 kg payload. **Could be possible currently with high-end military systems.**
- Requires pointing control to about 10 milliarcseconds, with a disturbance environment that is relatively benign but likely harder than in low-earth orbit

Tethered US Military Aerostats



- Procurement costs for the high-end systems (eg. TARS & JLENS) are of order $20M
- These systems are (currently) not commercially available, but represent the capabilities possible within the field
- Would likely require establishing NASA agreement with vendor to allow non-military use

Tethered Aerostats summary by P. Gorham

High-end Example: USAF Tethered Aerostat Radar System (TARS)

Table 19: TARS Technical Specifications

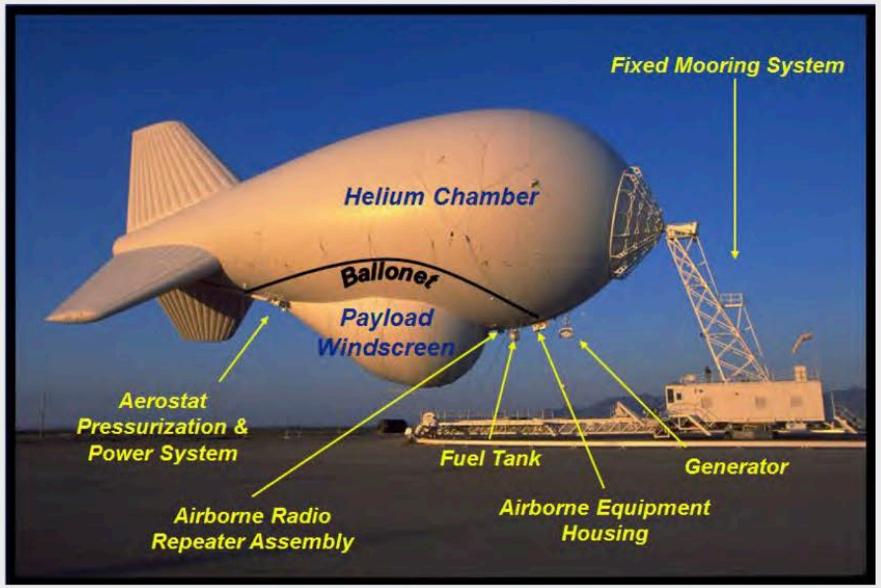


Figure 26: TARS Subsystem Components[32]

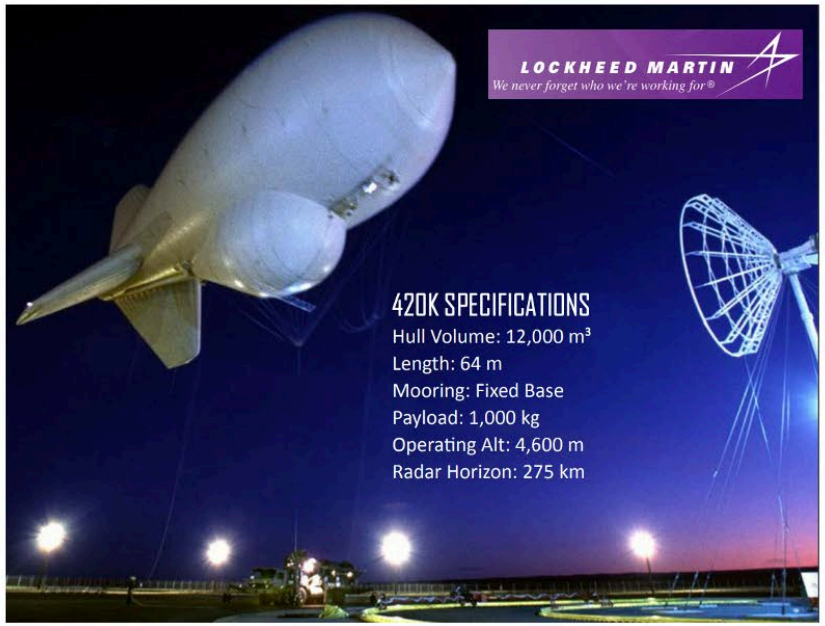
	275K Aerostat	420K Aerostat
Manufacturer:	ILC Dover	TCOM, L.P.
Length:	186 ft.	208.5 ft.
Diameter:	62.5 ft.	69.5 ft.
Volume:	275,000 cu. ft.	420,000 cu. ft.
Max Payload:	1,200 lbs.	2,200 lbs.
Payload Type:	L-88A Radar	L-88(V)3 Radar

Duration: 5–7 days

Flight Ceiling: 25,000 ft., typical = 12,000 ft. MSL

Crew: minimum 6 for winch truck system or minimum 5 for fixed mooring system

- US Air Force radar platform developed primarily for narcotics traffic interdiction in border areas
- 2200 lbs (1000kg) to typically 12-15,000 ft (4.57km)
- Fuel for 6 days, crew of ~6 for operations
- Lockheed Martin shows this as an available product but is unresponsive to queries (applications are all strategic)



Commercial tethered aerostat offerings

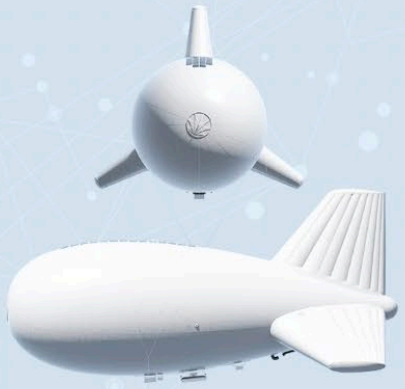
- TARS & JLENS vendors would not quote their systems directly (but public records of procurements indicate $10-20M costs)
  - → There are no current US-based commercial offerings of the largest, high-end aerostats, for payloads of 500 kg or more, altitudes to 5 km
- For smaller systems, <1 km altitude, 50 kg, there are several US commercial vendors, but the PAG did not identify any science customers for small payloads at relatively low altitude
- One international vendor, ATLAS-LTA has impressive capabilities, provided feasibility and ROM costs for South Pole deployment
  - ATLAS-LTA "based" in Israel, with associations and possibly facilities in Russia

ATLAS Lighter-Than-Air

Tethered High Altitude Platform (THAP)

THAP Technical data

Altitude range, m	5 000 - 11 000
Max wind at working altitude, m/sec	50
Max payload weight, kg	300
Max payload power, kW	3
Mission endurance, days	50-100
Volume range, cub.m	7 000 – 12 000



The Tethered Aerostats' Properties by Size/Volume

Parameter/Class	Low Volume TA	Medium volume TA	Large Volume TA
Volume, m³	100 – 1 000	1 000 – 4 000	4 000 – 20 000
Length, m	12 – 27	27 - 40	40 - 73
Operational altitude, m	up to 1 000	up to 3 000	up to 5 000
Flight endurance, days	up to 15	up to 30	up to 45
Payload, kg	up to 100	up to 500	up to 3 000
Max. operational wind speed, m/s	25	35	45
Power supply, kW	up to 3	up to 25	up to 50

- Two classes of offering:

1. Tethered high-altitude platform
   - 300 kg to 11km, 50-100 day dwell time between service
   - **Quoted ROM for South Pole: $5M**
2. Lower-altitude tethered aerostats
   - Medium volume: 500 kg to 3km, 30 day service period, **ROM costs $4.5M**
   - Large volume: 3000 kg to 5 km, 50 day service cycle, **ROM costs up to $18M**

- Since these are almost always custom one-offs, builds could be optimized for a NASA science application

Tethered Aerostats summary by P. Gorham

Acronym List

APAC	Astrophysics Advisory Committee
APRA	Astrophysics Research and Analysis
BPO	Balloon Program Office at WFF
CSBF	Columbia Scientific Balloon Facility in Palestine, TX
ESD	Earth Science Division
GSFC	Goddard Space Flight Center
HPD	Heliophysics Division
LDB	Long-Duration Balloon
MCF	Million Cubic Foot
MCM	McMurdo Station, Antarctica
ROSES	Research Opportunities in Space and Earth Science
SMD	Science Mission Directorate
SPB	Super-Pressure Balloon
ULDB	Ultra Long-Duration Balloon
WFF	Wallops Flight Facility
ZPB	Zero-Pressure Balloon