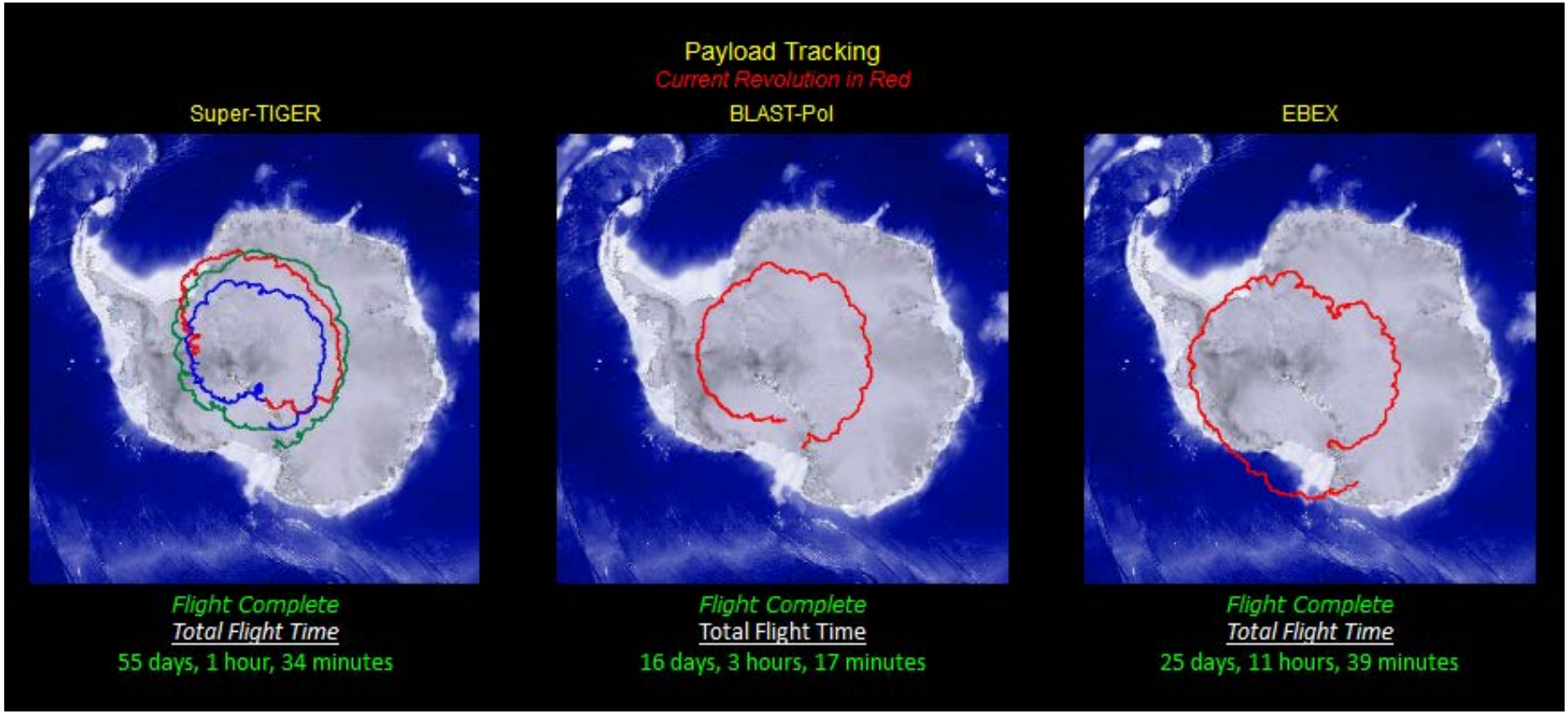
Astrophysics Subcommittee Meeting

April 16, 2013

"Report on the Balloon Program"



W. Vernon Jones
Senior Scientist for Suborbital Research

FY-13 Antarctic Campaign: 2012-13 Season

Three balloon payloads launched in Dec. 2012 collectively flew 96 days!

Super-TIGER (PI: Binns/Washington U. St Louis): Dec 8 launch, **55-day flight**.

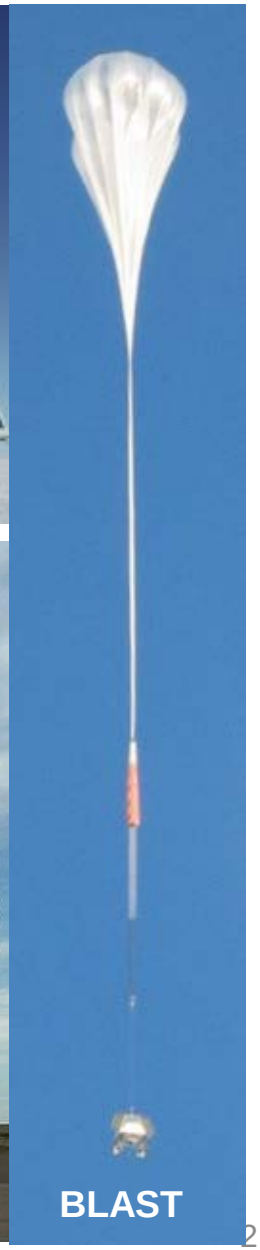
Studying the origin of cosmic rays via heavy elemental abundance measurements.

BLAST-pol (PI: Devlin/U. Penn): Dec 25, **16-day flight.**

Mapping of polarized dust emission along the Galactic Plane; influence of magnetic fields on star formation.

EBEX (PI: Hanany/Minnesota): Dec 28. **25-day flight.**

E- and B-mode Explorer; CMB polarization as a probe of cosmic inflation and gravitational lensing.

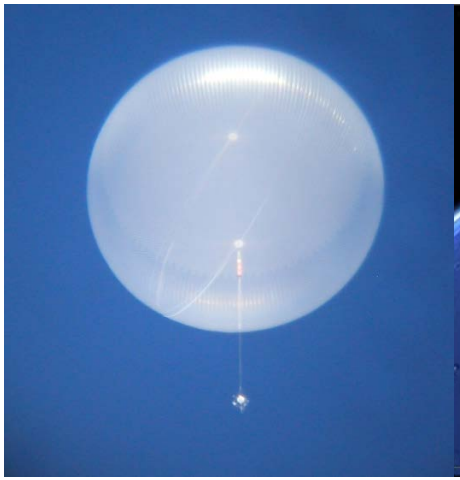


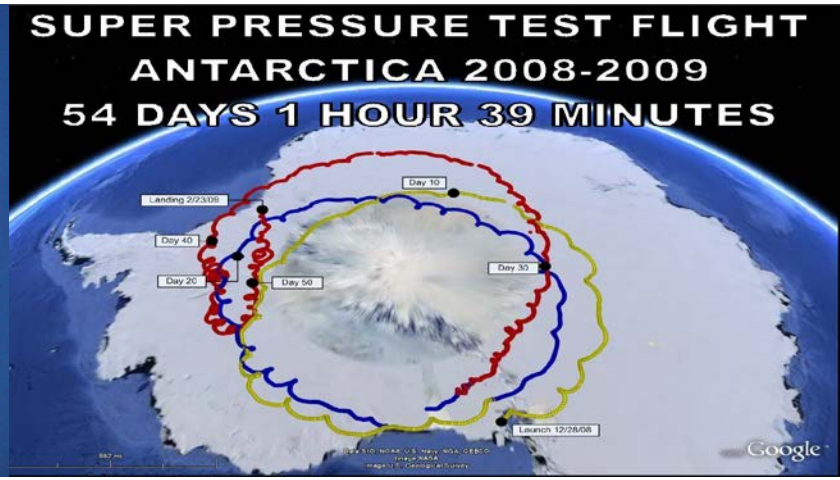
SuperTIGER Exceeded 2008-09 SPB Flight Record

- **2008-09 SPB Test**
  54 days of flight:

✓ Balloon remained pressurized- no apparent gas loss.

✓ It could have flown indefinitely.

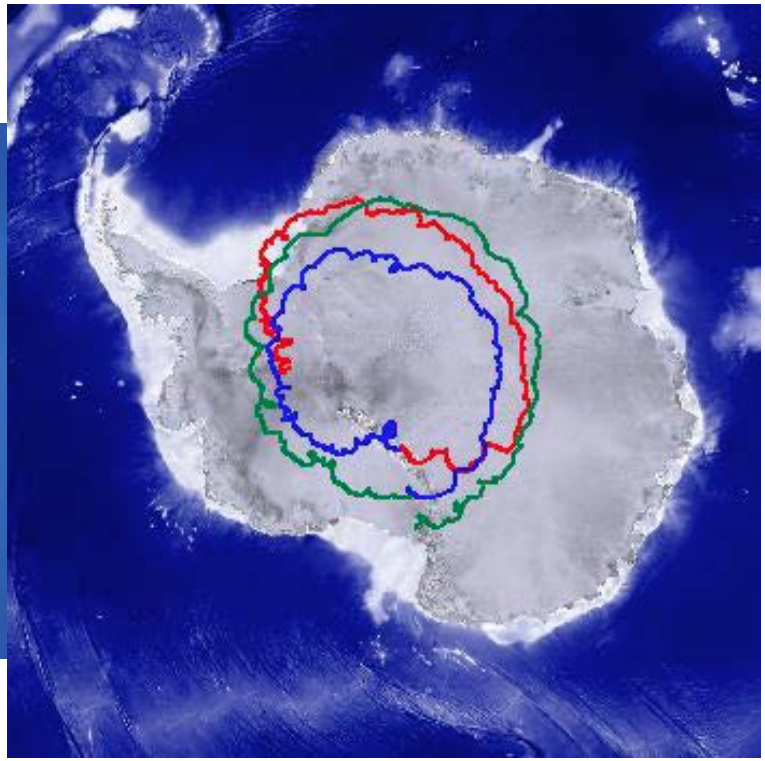




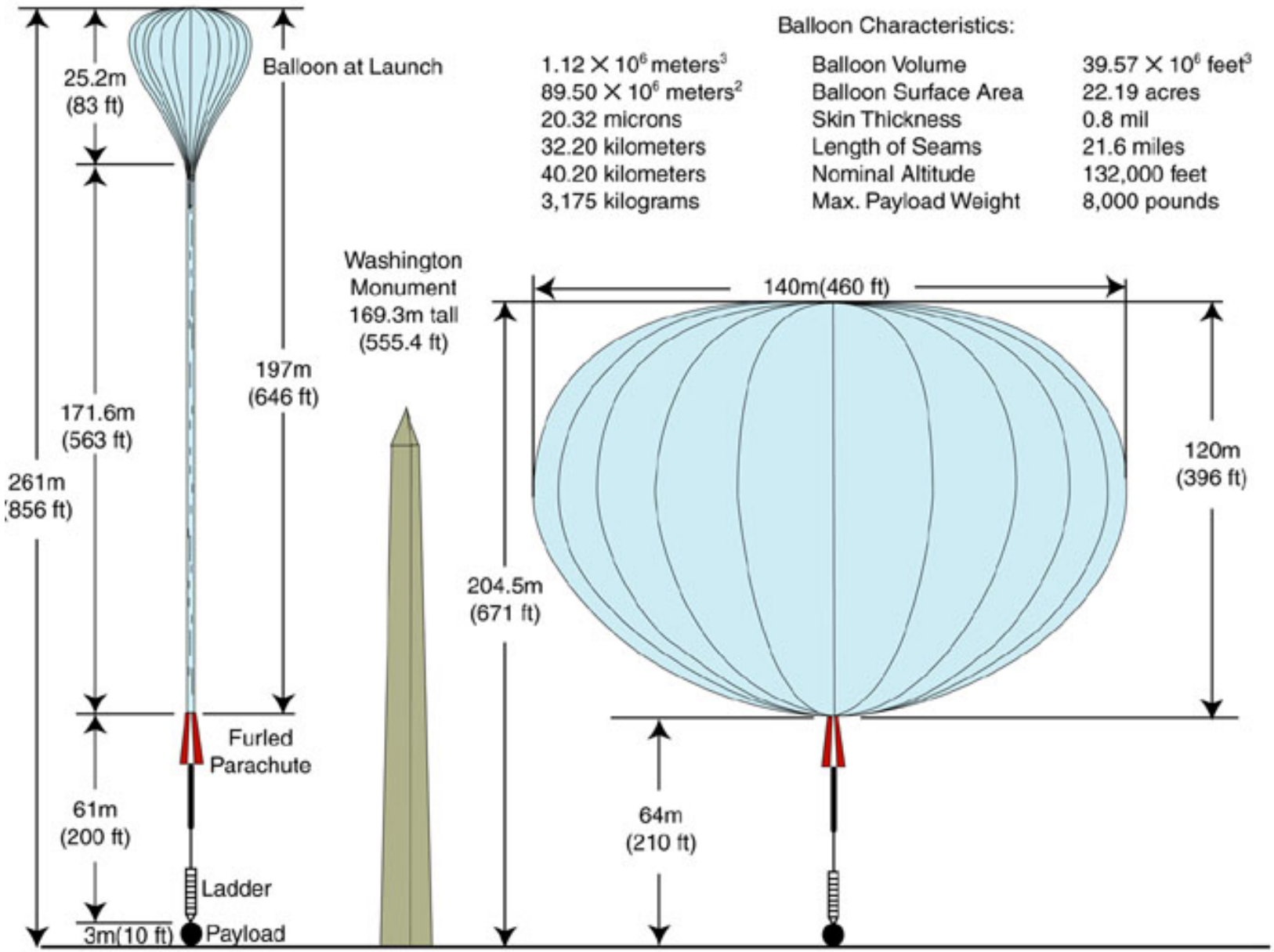
- **2012-13 SuperTIGER**
  55 days of flight:

✓ Vented Zero-Pressure balloon in equilibrium with the atmosphere.

✓ The altitude changed with air temperature/pressure.

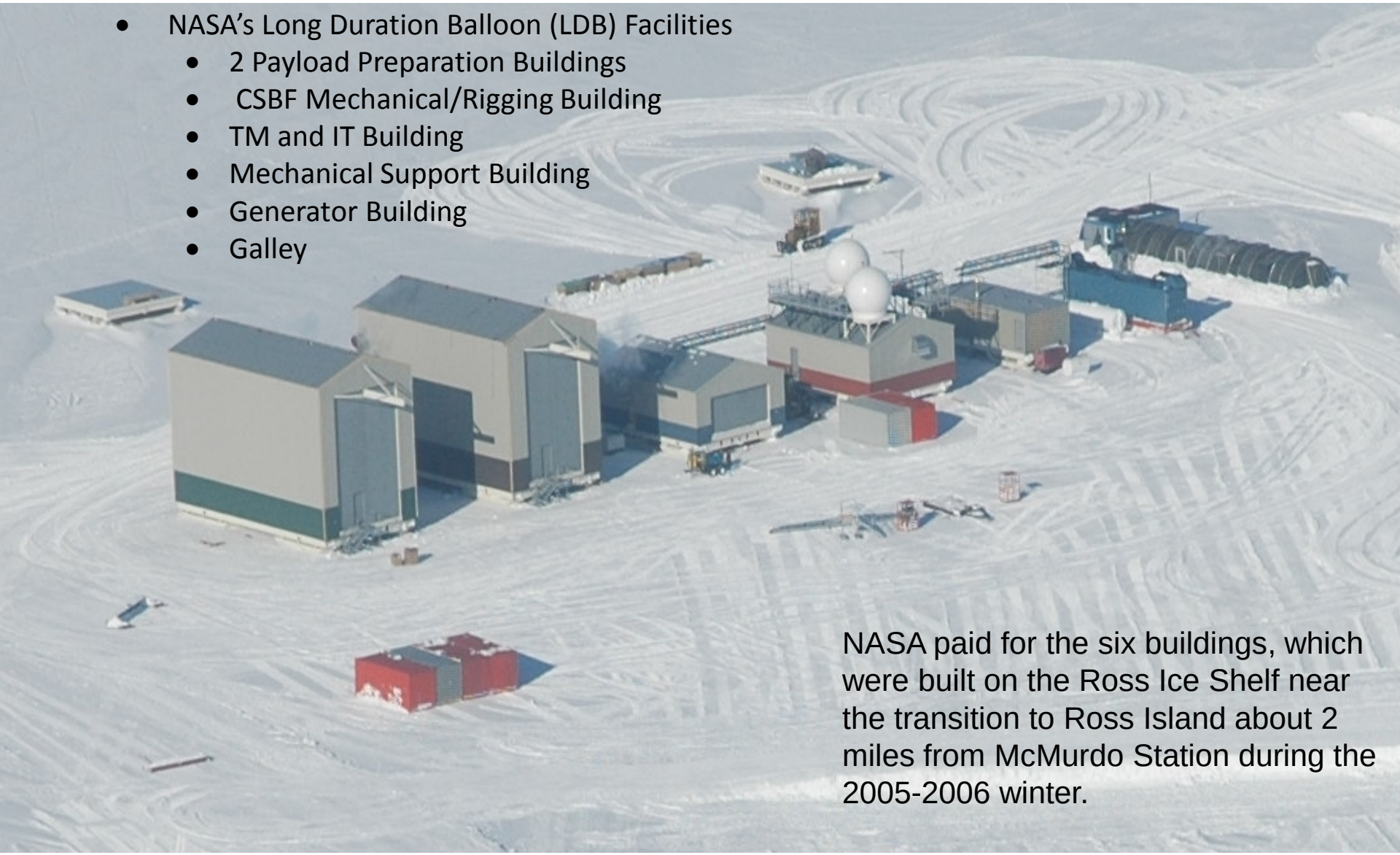


Scientific Research Balloons: How Big?



NASA LDB Launch Site, McMurdo

- NASA's Long Duration Balloon (LDB) Facilities
  - 2 Payload Preparation Buildings
  - CSBF Mechanical/Rigging Building
  - TM and IT Building
  - Mechanical Support Building
  - Generator Building
  - Galley



NASA paid for the six buildings, which were built on the Ross Ice Shelf near the transition to Ross Island about 2 miles from McMurdo Station during the 2005-2006 winter.

FY 2013 Balloon Flight Schedule

Status as of: 04/08/13

Principal Investigator (PI) / Institution / Instrument	Discipline	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Fort Sumner, New Mexico	**Fall 12**												
Grindlay / HU / ProtoEXIST P2 (CO)	Gamma Ray/X-Ray	♦	**SUCCESS**										
Antarctica	**Winter 12**												
Binns / WU / SuperTIGER	Particle Astrophysics			♦	**SUCCESS - RECORD!**								
Hanany / UM / EBEX	IR-Submillimeter			♦	**SUCCESS**								
Devlin / UP / BLAST	IR-Submillimeter			♦	**SUCCESS**								
Kiruna, Sweden	**Summer 13**												
Fairbrother / GSFC / 18 MCF SPB	Test Flight								◊				
Knoelker / NCAR / SUNRISE II	Solar and Heliospheric Physics									◊			
Fort Sumner, New Mexico	**Fall 13**												
Ball / CSBF / LDSD Launch Method Test	Reimbursable/Test Flight											◊◊◊	
Kogut / GSFC / BOBCAT	IR-Submillimeter											◊	
Guzik / LSU / HASP [MoO - Maraia Capsule]	Student Flight Project											◊	
Bale / UCB / GRIPS	Solar and Heliospheric Physics												◊
Krawczynski / WU / X-Caliber	Gamma Ray/X-Ray												◊
Gaskin / MSFC / HEROES	HOPE/Gamma Ray/X-Ray												◊
Kopp / LASP / HYSICS (Stuchlik / GSFC / WASP)	Special Projects												◊
Cheng / APL / BRRISON	Planetary												◊

14 Missions: 2 Foreign & 1 Domestic Flight Campaigns.

1	Ft. Sumner	(Fall 12)	Conventional
3	Antarctica	(Austral Summer 12-13)	LDB
2	Sweden	(Summer 13)	LDB & SPB
	Test		
8	Ft. Sumner	(Summer-Fall 13)	Conventional

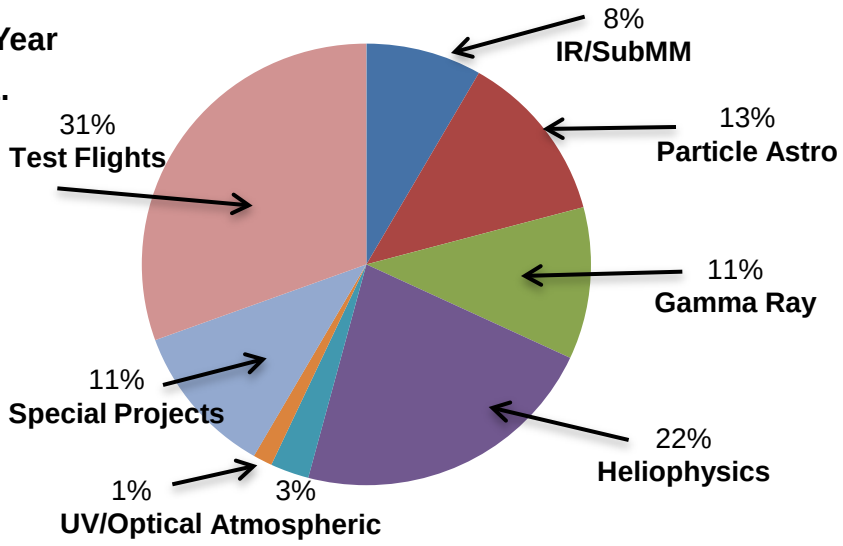
Notes: CO – Carry Over from FY12 Fall Fort Sumner Campaign.

Discipline Flight Rates

Discipline	FY 08	FY 09	FY 10	FY 11	FY 12	FY 13
IR/Sub-mm Astrophysics	0	1	1	2	2	3
Particle Astrophysics	3	3	1	1	1	1
Gamma Ray/X-Ray Astrophysics	0	1	3	3	1	3
Heliophysics, Geospace	1	3	4	5	3	2
Upper Atmos. Research	0	0	0	1	1	1
UV Optical	0	1	0	0	0	0
Special Projects	1	1	0	4	2	2
Test Flight	9	3	2	4	4	2
Year Total	14	13	11	20	14	14

DECADAL AVERAGE: 15 Flights per Year

& PERCENTAGES VALID THRU FY-11.



Antarctica: Center Piece of NASA Ballooning

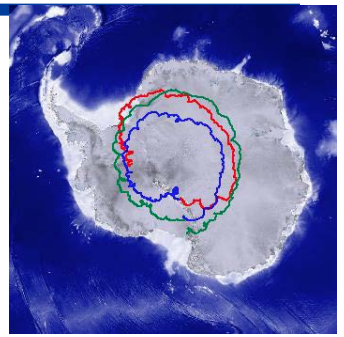
- NASA-NSF/OPP Long-Duration Ballooning (LDB) provides:
  - NASA's lowest cost access to space (>= stratosphere).
  - Spacecraft-scale payloads (1000 - 2000 kg science instruments).
  - Recoverable/Re-usable payloads increase exposure at low cost.

- The Balloon Program has focused on expanding the highly successful LDB flights **OVER / AROUND** Antarctica.
  - Flight durations of up to 4-8 weeks.

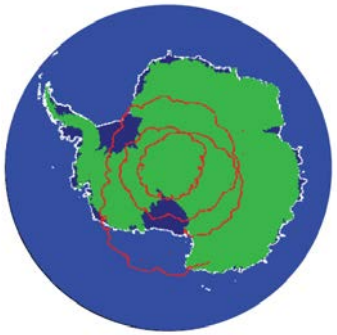
Flight support to 3 payload flights every year.

- Frontier Astrophysics on Super-Pressure Balloons (SPB) will justify Ultra-Long Duration Balloon (ULDB) flights **FROM** Antarctica In the coming decade.
  - ULDB flights from Antarctica would yield long exposures:
  - 60 days now; 100 days soon.

- NASA is working with NSF/OPP to enable **flights to leave Antarctica for possible recovery** in South America, New Zealand, Australia, etc.
  - The initial ULDB capability **does not include recovery of payloads.**



55-day SperTIGER Flight Dec - Feb 2013



42-day CREAM flight Dec - Jan 2004-05

54-day SPB flight Dec - Feb 2008-09

History of Antarctic LDB Flights

❖ 44 Antarctic LDB Flights Since 1991

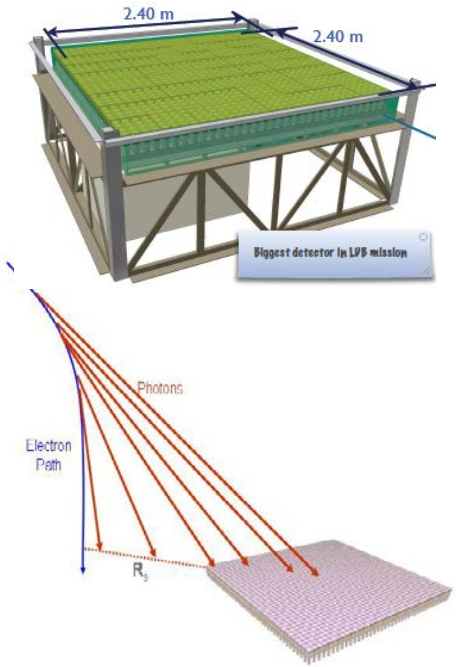
- 31 single circumpolar flights with durations of 8 - 25 days.
- 6 double circumpolar flights with durations of 20 - 32 days.
- 5 triple circumpolar flights with durations of 35 – 55 days.
- 2 super-pressure balloon (SPB) test flights: 54 days; 22 days.

❖ Recent History and Near-Term Plan

- FY 2012 Campaign (2011-2012 Season).
  - Cosmic Ray Electron Synchrotron Telescope (CREST).
  - Stratospheric Terahertz Observatory (STO).
- **FY 2013 Campaign (2012-2013 Season).**
  - **Balloon Large Aperture Sub-millimeter Telescope (BLAST).**
  - **E and B EXperiment (EBEX).**
  - **Super-Trans Iron Galactic Element Recorder (SuperTIGER).**
- FY 2014 Campaign Candidates (2013-2014 Season).
  - Antarctic Impulsive Transient Antenna (ANITA).
  - Boron And Carbon Cosmic-rays in Upper Stratosphere (BACCUS).
  - A Large Angular Scale Millimeter-wave Polarimeter (SPIDER).
- FY 2015 Campaign Candidates (2014-2015 Season).
  - Super-Pressure Balloon Test.
  - Gamma Ray Imaging Spectrometer (GRIPS).

FY-12 Antarctic Campaign: 2011-12 Season

CREST (Cosmic Ray Electron Synchrotron Telescope) PI: Musser/U. Indiana; 10.6 days



- Observes characteristic linear trail of synchrotron photons generated as an ultra high energy electron passes through the Earth's magnetic field.
- Detector is 2 x 2 m^2 array of 1600 1" diameter BF_2 crystals.

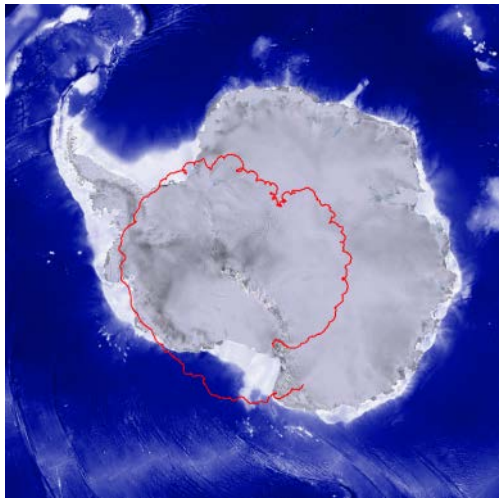
STO (Stratospheric Terahertz Observatory) PI: Chris Walker/U. Arizona); 13.4 days

- Utilizes the Flare Genesis platform for THz surveys to probe the life cycle of the Interstellar Medium.
- C+, N+ galactic plane survey using a 0.8 m telescope with two cryogenic 4-pixel THz arrays.

GUSSTO Explorer MO based on **STO** was not down-selected.

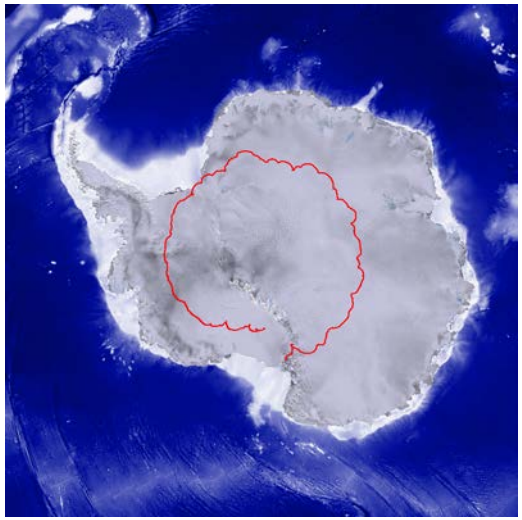
FY-13 Antarctic Campaign: 2012-13 Season

- **EBEX** (E and B EXperiment) PI: Hanany/ U. Minnesota: 25-1/2 days.
  - 8,000 lbs / 34-H (34 MCF Heavy) balloon.
    - Largest payload ever launched by CSBF.
  - Thermal issue with azimuth controller made it difficult to point.
  - Observation scheme was changed.
  - Payload partially recovered, including stored data, but not the receiver & gondola frame.
  - Second flight proposed for Dec-2016.



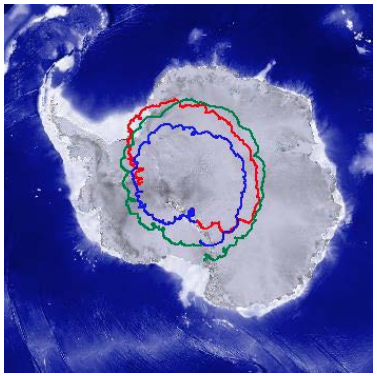
FY-13 Antarctic Campaign: 2012-13 Season

- **BLASTPol** / (Balloon Large Aperture Space Telescope) PI: Devlin/U. Pennsylvania; 16+ Days.
  - 5,882 lb / 39 MCF balloon.
  - Cryogens depleted.
  - Solid state data recorder failures during flight.
  - Operations/science success.
  - Full recovery of payload.



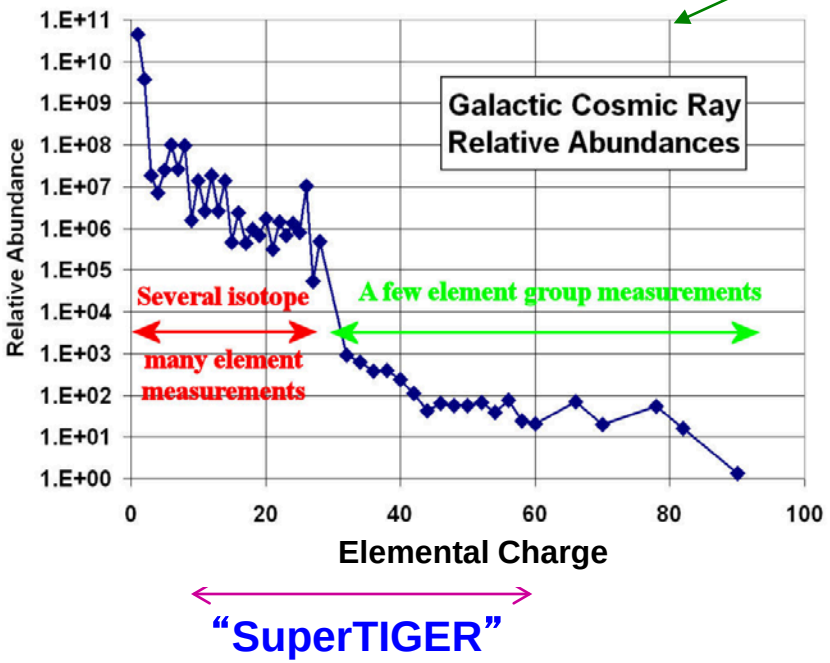
FY-13 Antarctic Campaign: 2012-13 Season

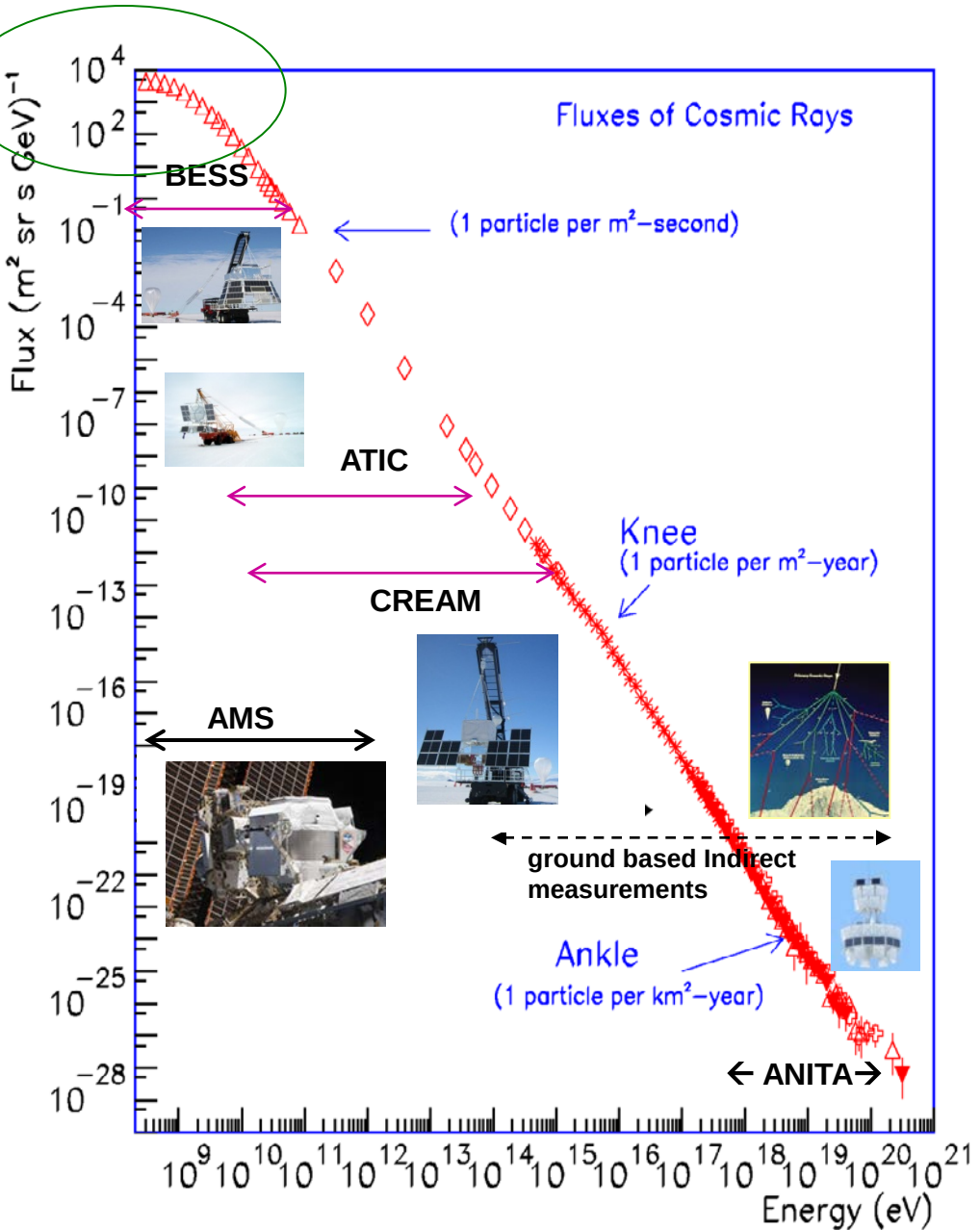
- **Super-TIGER** / (Super-Trans Iron Galactic Element Recorder) PI: Binns/Washington U., St. Louis; **55+ days**.
  - **Longest NASA Antarctic flight ever.**
  - 6,000 lb / 39 MCF balloon.
  - Operations & science success.
  - Solid state data recorders (identical with those on BLASTPol) failed during flight.
  - All high priority data down though TDRSS.
  - Payload not recovered this season.
- Proposed to:
  - Analyze data;
  - Recover payload;
  - Prepare for Dec-2016 reflight.



SuperTIGER Launch 12/8/12

Cosmic Rays Cover Enormous Range of Flux and Energies



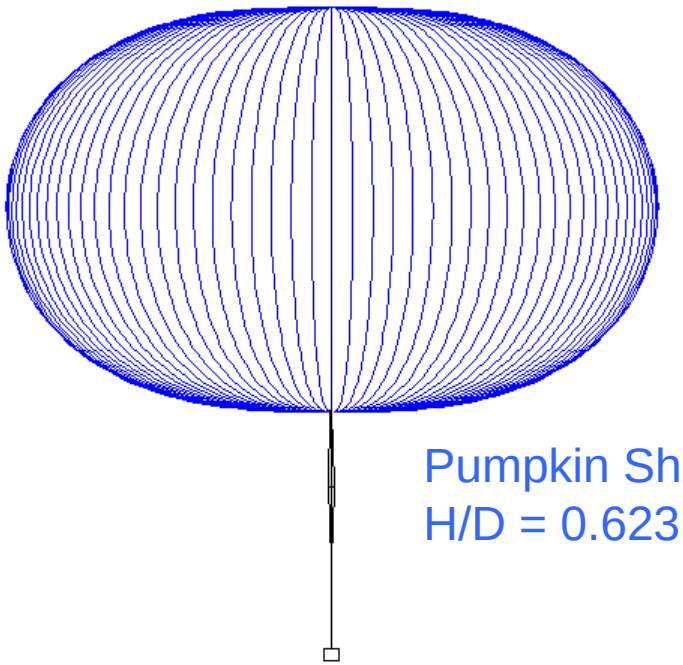


- Relative abundances range over 11 orders of magnitude
- Detailed composition limited to less than ~ 10 GeV/nucleon

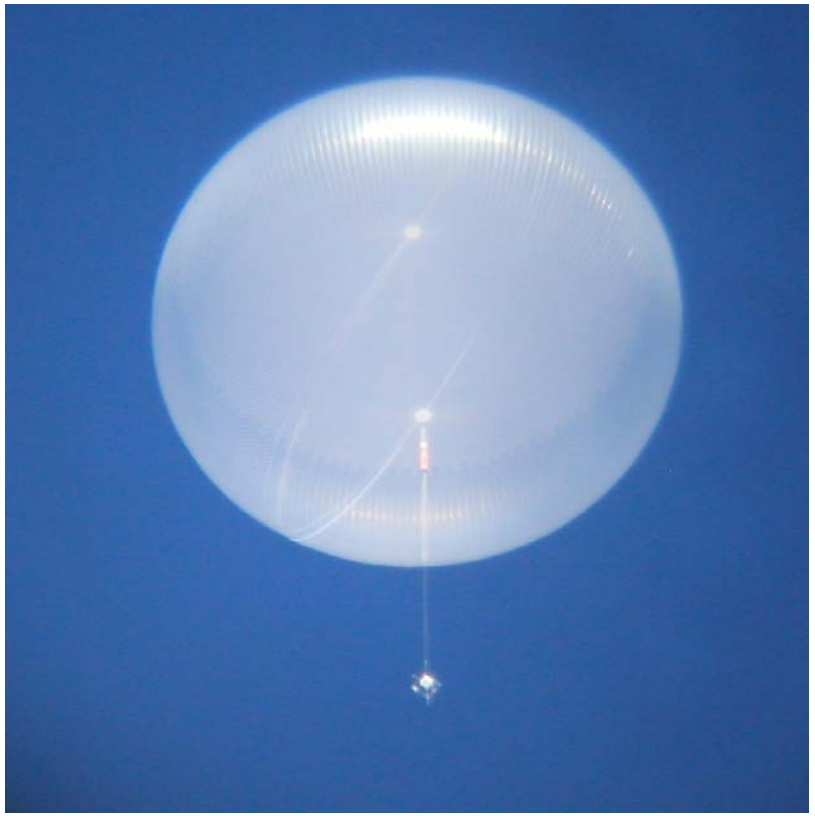
Evolution to Super Pressure Ballooning

- Long Duration Balloon (LDB) flights employing conventional, zero-pressure balloons have a proven history of scientific discovery, with many cited achievements.
  - Most high priority projects are proposing multiple LDB missions.
- Super-pressure balloons are major technological advance.
  - They offer an order of magnitude increase in flight capability.
  - They enable Ultra Long Duration Balloon (ULDB) flights (60-100 days).
  - They open areas of exploration closed to zero-pressure balloons, e.g., LDB flights in non-polar-regions.
- Costs to convert most LDB payloads for ULDB flights are modest.
  - LDB and ULDB together form a science opportunity continuum.
  - They offer significant science at fraction of the cost of a space mission.
  - ULDB missions may be acceptable alternative to some Small Explorer (SMEX) missions..
- Is there a "sweet spot" in the LDB – ULDB – SMEX continuum?
  - Balloon payloads have been solicited as Missions of Opportunity in Explorer AO's.
  - Two balloon missions (ANITA, GUSSTO) selected for Phase A studies.

Super Pressure Balloon (SPB)
" First New Balloon Design in more than 60 Years "



Pumpkin Shape
H/D = 0.623



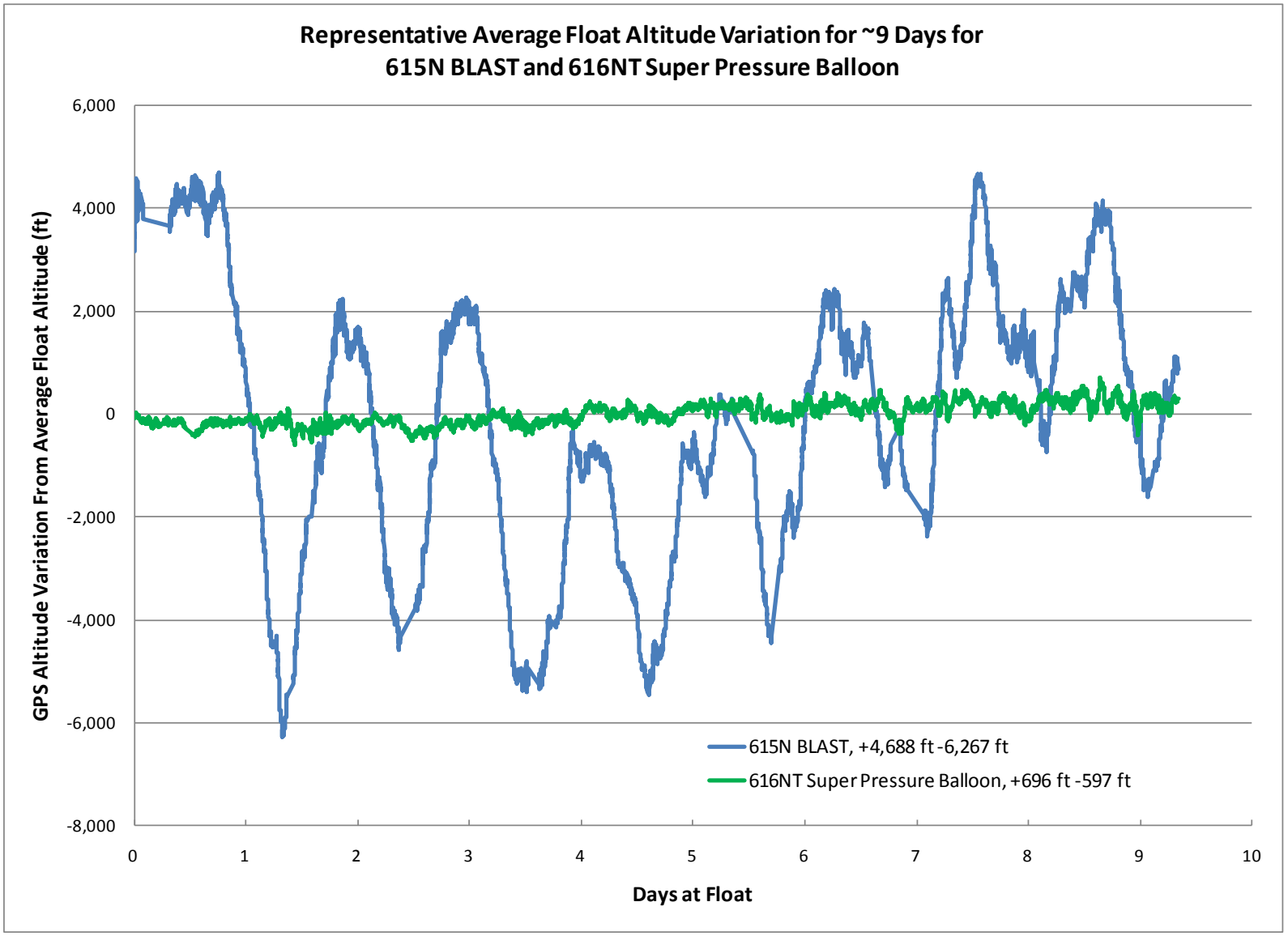
Photograph of 7 MCF SPB at float
Altitude: ~33.87 km (~111,100 ft)

Schematic / Statistics

- Volume = 420,150 m^3 (14.837 MCF)
- Diameter = 105.832 m
- Height = 65.946 m
- Number of gores = 230
- Gore length stressed = 139.023 m
- Gore width stressed = 1.471 m
- Film thickness 38 microns (1.5 mil)

- 54-day test flight 12/28/08 – 2/20/09
- 22-day flight of 14.8 MCF with 4000 lb payload during January 2011

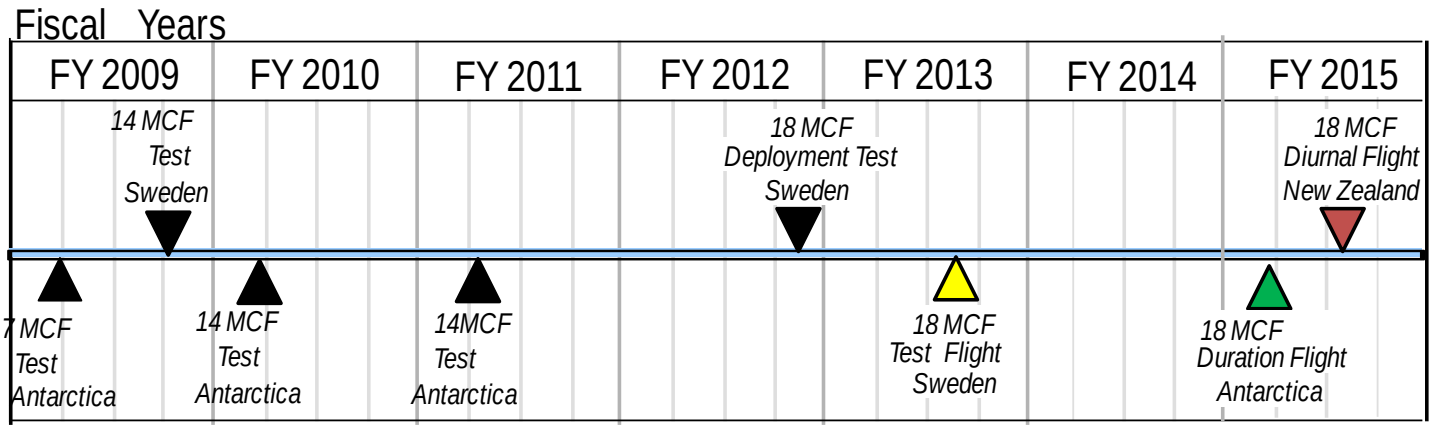
Zero- and Super-Pressure Balloon Altitude Comparison



14.9 MCF Super Pressure Balloon Test Flight

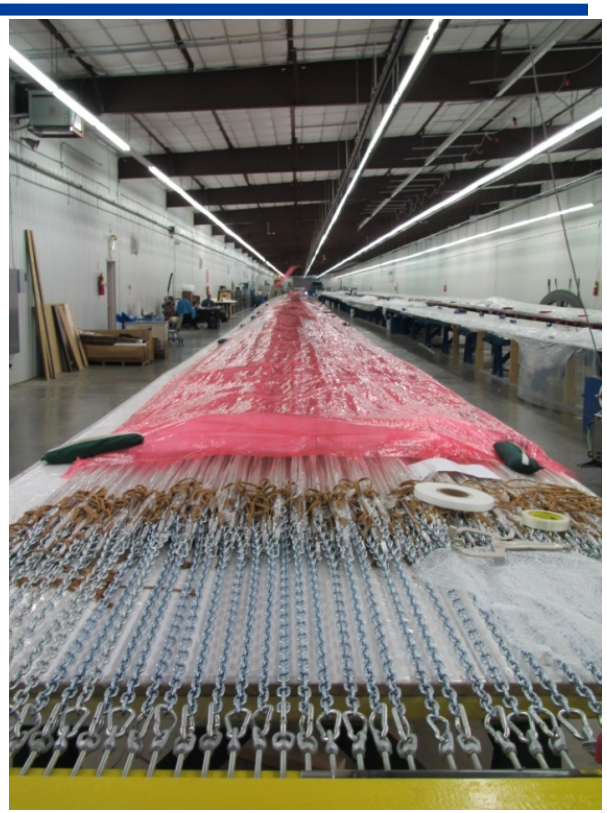
Super Pressure "Stair Step" Development Path

Volume	Flight Number	Launch Date	Suspended Weight	Altitude	Duration	Location
~201,000 m^3 (~7 MCF)	591 NT	Dec 28, 2008	680 kg (1,500 lbs)	33.5 km (110,000 ft)	54 days	Antarctica
~420,000 m^3 (~14.9 MCF)	616 NT	Jan 9, 2011	1,814 kg (4,000 lbs)	33.5 km (110,000 ft)	22 days	Antarctica
~532,200 m^3 (~18.8 MCF)	631NT	Aug 14, 2012	2,270 kg (5,000 lbs)	33.5 km (110,000 ft)	6.5 hours	Sweden
~532,200 m^3 (~18.8 MCF)		May/June 2013	2,270 kg (5,000 lbs)	33.5 km (110,000 ft)	4-7 days	Sweden
~532,200 m^3 (~18.8 MCF)		Dec 2014	2,495 kg (5,500 lbs)	33.5 km (110,000 ft)	Duration	Antarctica
~532,200 m^3 (~18.8 MCF)		March/April 2015	2,495 kg (5,500 lbs)	33.5 km (110,000 ft)	Duration	NZ
~736,200 m^3 (~26 MCF)		TBD	1,814 kg (4,000 lbs)	35.7 km (117,000 ft)		TBD



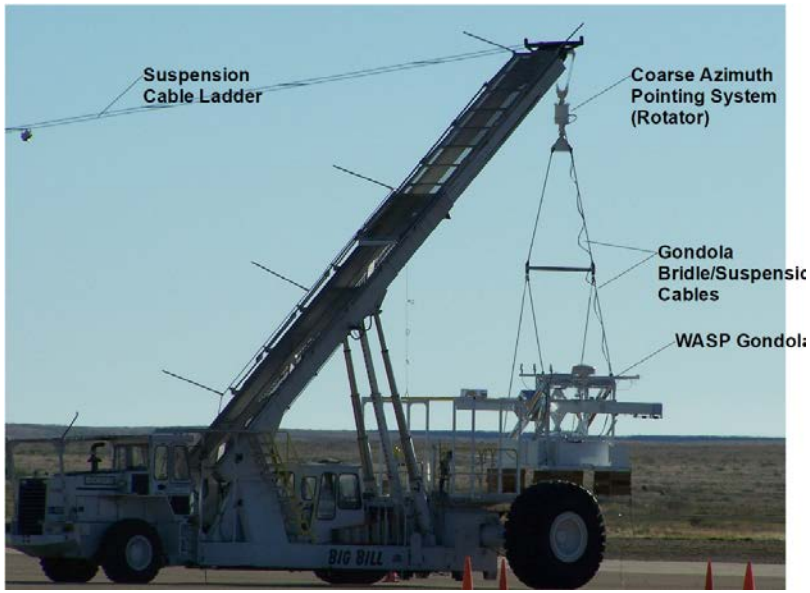
18.8 MCF SPB By the Numbers

- **Inflated volume ~ 18.8 million cubic feet**
- Number of Gores = 280
- Length of Each Gore ~ 492 feet
- Inflated Diameter ~ 376 feet
- Inflated Height ~ 233 feet
- Fitting diameter ~ 4.8 feet
- Shell film thickness ~ 1.5 mil (0.0015 in = 38 micron)
- Final Weight of Balloon ~ 5,114 pounds
- Number of Gore Width Measurements = 6,440 (23 per gore)
- Amount of Load Tape Tendon in Balloon **~ 137,760 ft (26 miles)**
- Amount of film visually inspected, re-rolled and dispensed for this balloon **> 1.3 million square feet - over 30 acres of film!**
- **Minimum amount of walking just to seal balloon = 55 miles**
- Balloon shipping box ~16 ft x ~6 ft x ~5.3 ft
- Gross Weight of Balloon in Box ~ 8,832 pounds



Wallops Arc Second Pointer (WASP) Project

- A WASP test flight was conducted from Ft. Sumner, N.M. on October 7, 2011. The flight duration was ~ 5 hours.
- The project team exercised the proto-type WASP system for ~ 2 hr at float altitude of 102,000 ft (32 Km).
  - Demonstrated sub-arc second pointing stability with the mock telescope in a typical flight environment.
  - Inertial target offsets were issued from the ground to demonstrate science operations mode and target acquisition dynamics.
  - System was able to maintain arc-second pointing stability during discrete ground-commanded gondola azimuth adjustments.
- The Solar HYSICS payload will be flown on the WASP in FY13 Fall Fort Sumner campaign.

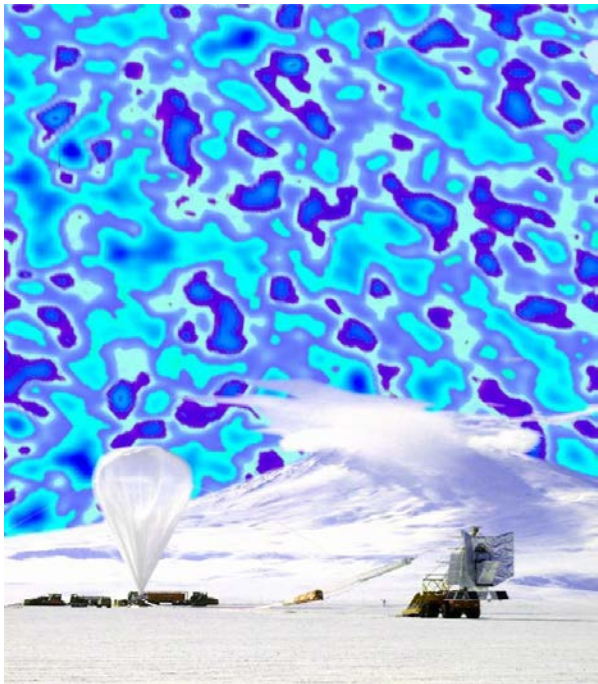


Highlights of Science Results from Antarctic Ballooning

- 2006 Balzan Prize for Astronomy and Astrophysics was awarded to:
  - Paolo de Bernardis, Fisica Spazielw Universita' degli Studi di Roma La Sapienza
  - Andrew Lange Physics Department, California Institute of Technology

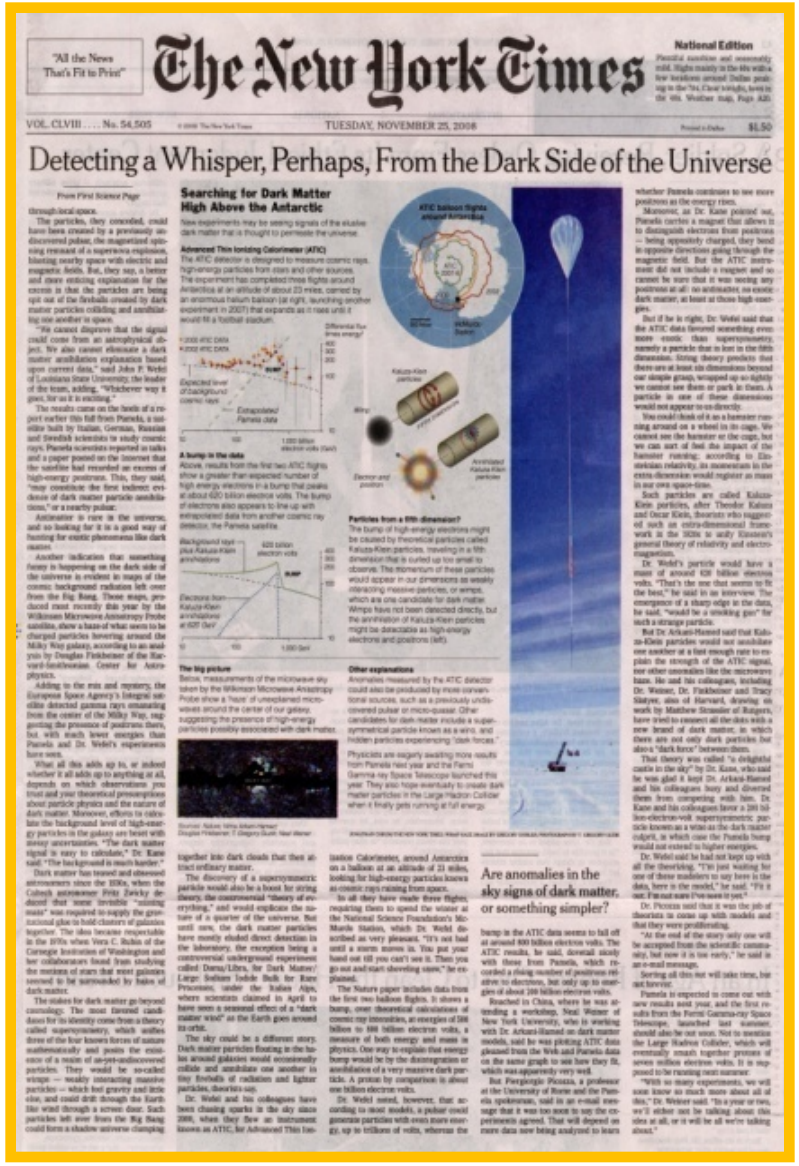
"For their contributions to cosmology, in particular the Boomerang Antarctic balloon experiment."

- The Balzan Prize is "One of the highest awards for science, culture and humanitarian achievement, ranking close to the Nobel Prize"
  - Awarded only occasionally for Observational Astronomy and Astrophysics
    - Reinhard Genzel (2003)
    - Fred Hoyle and Martin Schwarzchild (1994)
    - Martin Rees (1989)
    - Jan Oort (1984)



ATIC discovers mysterious surplus of high energy electrons

Chang et al., Nature, **456**, 362-365 (2008)



"All the News That's Fit to Print"

The New York Times

National Edition

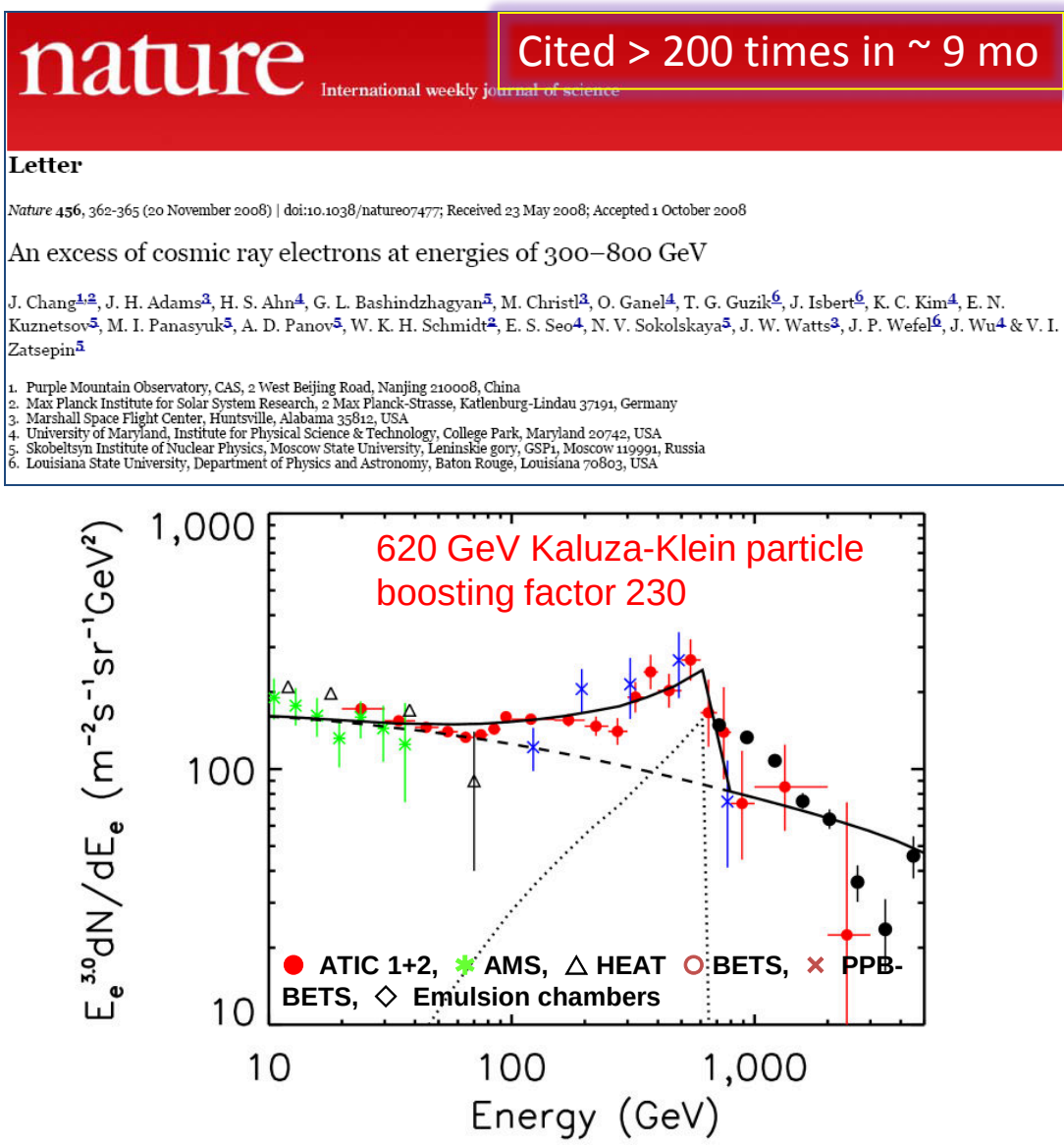
VOL. CLVIII . . . No. 54,505 TUESDAY, NOVEMBER 25, 2008 $1.50

Detecting a Whisper, Perhaps, From the Dark Side of the Universe

From First Science Page

Searching for Dark Matter High Above the Antarctic

Are anomalies in the sky signs of dark matter, or something simpler?



nature

International weekly journal of science

Cited > 200 times in ~ 9 mo

Letter

Nature **456**, 362-365 (20 November 2008) | doi:10.1038/nature07477; Received 23 May 2008; Accepted 1 October 2008

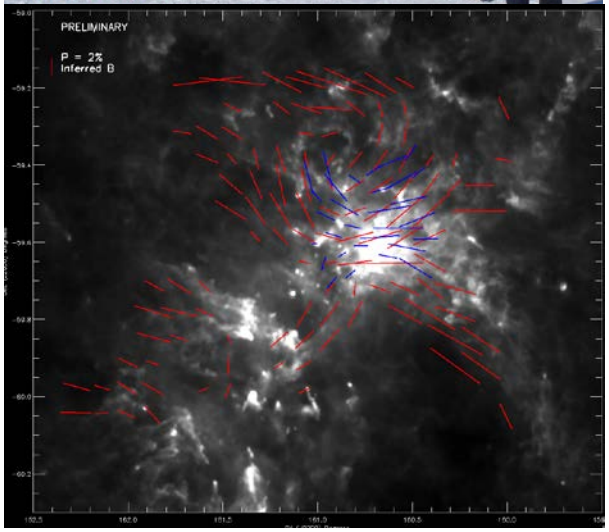
An excess of cosmic ray electrons at energies of 300–800 GeV

J. Chang[1,2], J. H. Adams[3], H. S. Ahn[4], G. L. Bashindzhagyan[5], M. Christl[3], O. Ganel[4], T. G. Guzik[6], J. Isbert[6], K. C. Kim[4], E. N. Kuznetsov[5], M. I. Panasyuk[5], A. D. Panov[5], W. K. H. Schmidt[2], E. S. Seo[4], N. V. Sokolskaya[5], J. W. Watts[3], J. P. Wefel[6], J. Wu[4] & V. I. Zatsepin[5]

1. Purple Mountain Observatory, CAS, 2 West Beijing Road, Nanjing 210008, China
2. Max Planck Institute for Solar System Research, 2 Max Planck-Strasse, Katlenburg-Lindau 37191, Germany
3. Marshall Space Flight Center, Huntsville, Alabama 35812, USA
4. University of Maryland, Institute for Physical Science & Technology, College Park, Maryland 20742, USA
5. Skobeltsyn Institute of Nuclear Physics, Moscow State University, Leninskie gory, GSP1, Moscow 119991, Russia
6. Louisiana State University, Department of Physics and Astronomy, Baton Rouge, Louisiana 70803, USA

BLAST / BLAST POL

- BLAST has been flown three times in Antarctica.
- The second Antarctic flight in FY 2011 (Dec 2010) was featured in Sky and Telescope.
  - Three papers from that flight are in final stage of preparation.
- The FY-13 flight observed 6 nearby star-forming regions:
  - Maps were larger than in FY11
  - And, they have better resolution.
- Preliminary FY13 BLASTPol Map of the Magnetic Field Direction in the Carina Nebula:
  - Red: BLASTPol 2012
  - Blue: SPARO (Li et al., 2006)



Antarctic Transient Impulsive Antenna (ANITA)

Science and Technology Recognition

- Askaryan effect (SLAC 2007)
  - Coherent Cherenkov emission from cascades in ice
- Enables utilization of entire Antarctic ice sheet as a potential detector → ANITA

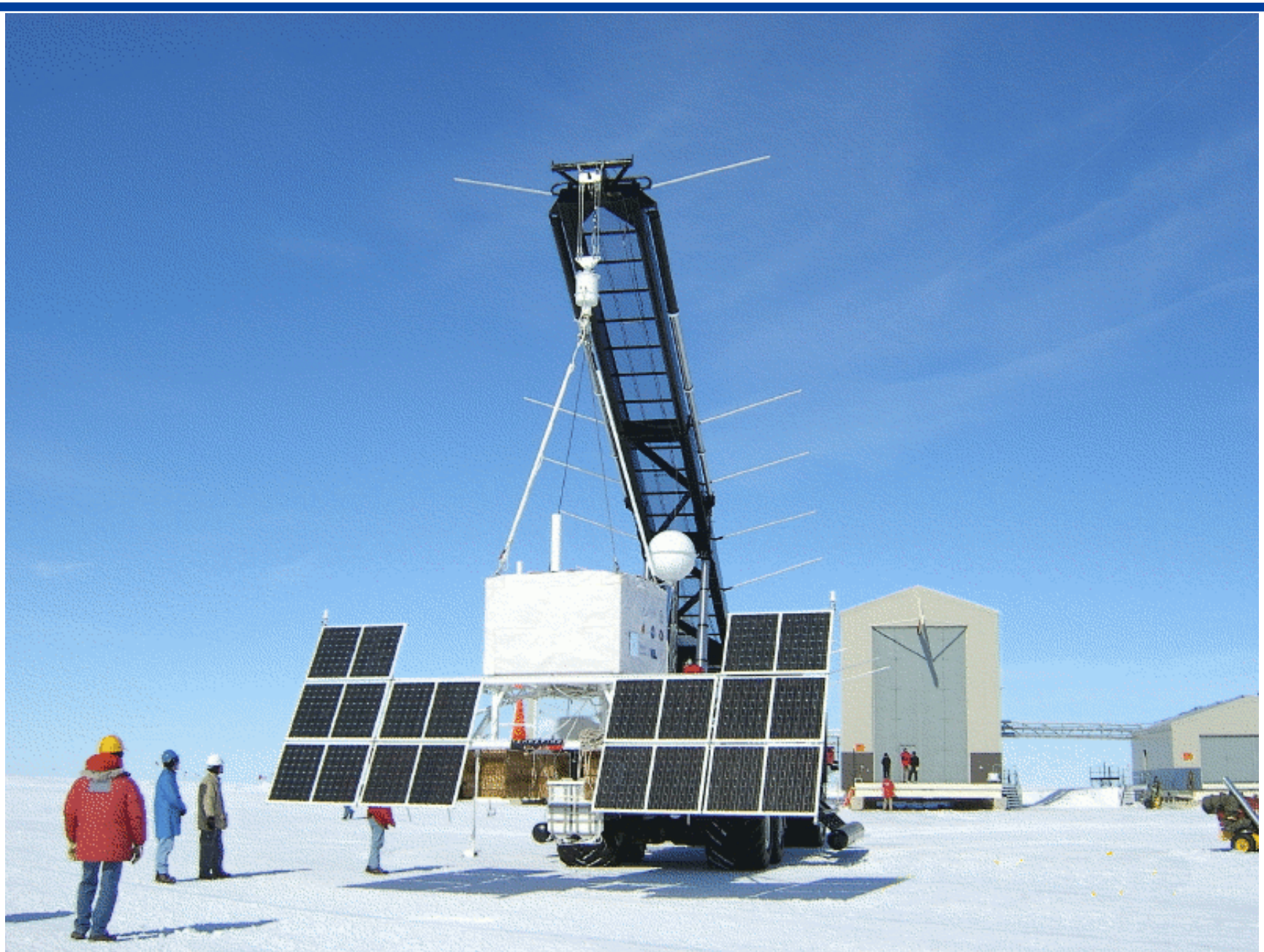
- Geo-synchrotron emission.
  - Curvature radiation from UHECR air showers in Antarctic geomagnetic field (strongest, most vertical on Earth!).
- ANITA sees these radio impulses in reflection off Antarctic surface.
  - Has energized a whole new effort in this field.

Programmatic Issues

- Some balloon trajectory modification is needed to take full advantage of super-pressure balloons (SPB) for ULDB flights in non-polar regions.
  - Payload recovery cannot be assured without some level of trajectory control.
- NASA has identified a potential launch site at Wanaka, New Zealand to accommodate non-Polar LDB / ULDB missions.
  - There is potential risk of losing the payload in the Southern Ocean, since recovery is not initially required.
- SPB/ULDB is quasi-level of effort, in that its development is within the same budget as balloon operations for science missions.
  - Given its priority, should it be accelerated by stopping something else?
- The balloon program throughput is highly dependent on payload funding, but there is no increase in ROSES/APRA for more payloads.
  - Explorer MOs offer balloon mission opportunities, but none selected to date.
  - Very recently GUSSTO and earlier ANITA successfully completed Phase A studies, but neither was selected.
- What is appropriate cost box for ULDB payloads, APRA vs. Explorer, especially when you consider "non-recovery" initially.

THANK YOU !

Key Events in a Balloon Launch Sequence



BACK UP

SuperTIGER Press Links

1. http://newsfeed.time.com/2013/02/05/nasa-super-tiger-balloon-breaks-two-records-soaring-over-antarctica/
2. http://www.space.com/19407-antarctica-balloon-longest-flight-record.html
3. http://www.reuters.com/article/2013/02/04/nasa-balloon-record-idUSnPnDC54056+160+PRN20130204
4. http://guardianlv.com/2013/02/nasas-super-tiger-experiment-measures-cosmic-rays-breaks-records/
5. http://news.wustl.edu/news/Pages/24740.aspx
6. http://news.wustl.edu/news/Pages/24693.aspx
7. http://news.wustl.edu/news/Pages/24652.aspx
8. https://news.wustl.edu/news/Pages/24828.aspx
9. https://news.wustl.edu/news/Pages/24783.aspx
10. http://blogs.riverfronttimes.com/dailyrft/2013/01/super-tiger-balloon-antarctica-wash-u.php
11. http://sites.wff.nasa.gov/code820/news/story77.html
12. http://phys.org/news/2013-01-super-tiger-shatters-scientific-balloon-antarctica.html
13. http://phys.org/news/2013-02-super-tiger-lying-southern-hemisphere-winter.html
14. http://www.treehugger.com/clean-technology/super-tiger-balloon-breaks-record-longest-flight-collects-cool-data.html
15. http://www.donegaldaily.com/2013/01/20/donegal-scientist-conquers-antarctica-with-amazing-balloon-record

Acknowledgements

- Executive oversight of the NASA Balloon Program is provided by the Astrophysics Division, Science Mission Directorate, NASA Headquarters
- Implementation of the Balloon Program is delegated to the Goddard Space Flight Center Wallops Flight Facility (WFF) at Wallops Island, Virginia http://www.wff.nasa.gov/balloons
- Balloon flights are conducted by the Columbia Scientific Balloon Facility (CSBF) in Palestine, Texas http://www.csbf.nasa.gov/
- The CSBF is managed by the Physical Science Laboratory, New Mexico State University, under contract with WFF
- The balloons are manufactured by Raven Industries, Aerostar Division in Sulfur Springs, Texas
- The Antarctic LDB program would not be possible without the crucial contribution of the U.S. National Science Foundation Office of Polar Programs and the Antarctic Support Contractor