



SpacePart 2006
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Beihang University of Beijing
P.R. China

Recent Developments in Scientific Research Ballooning

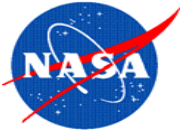
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Mission of the NASA Balloon Program

The Balloon Program Seeks to be a Springboard for Space Science by Providing Low-Cost Access to Space at Altitudes up to 160,000 ft for:

- **Focused Science Investigations** that can be Done Above ~ 99.5% of the Atmosphere
- **Observatory-class Payloads** With Advanced Technologies and Large Aperture/Mass
- **Technology Development and Flight Validation** for Future Space Missions
- **Cutting Edge Science in 10 - 20 Day Missions, with Plans for 60 - 100 Days Flights** as Low-Cost Alternative to orbital missions
- **Hands-on Training of Students and Young Scientists**
 - Average ~ 20 Missions/Year
 - Involves ~ 40 University and Center groups,
 - ~ 200 Scientists and Engineers,
 - ~ 25 Graduate Students, ~ 50 Undergraduate Students
- **Substantial Foreign Involvement** at ~25% of NASA Science level



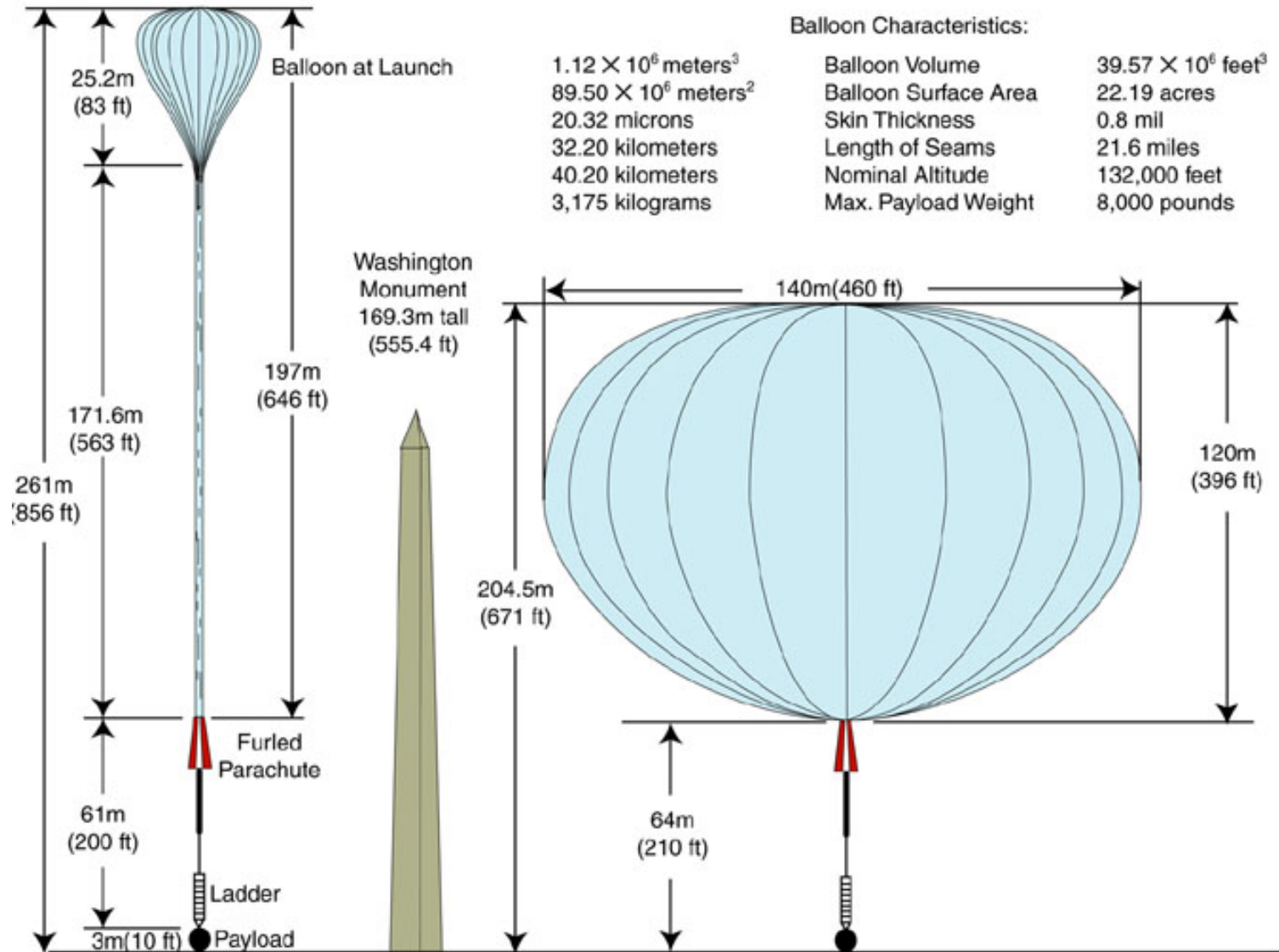
Scope of Balloon Missions

	Conventional	LDB	ULDB*
Flight Opportunities	~ 20 per year	2-4 per year	1 per year
Balloon Type	Zero Pressure (ZP)	ZP	Super Pressure (SP)
Duration	2 hours to 3 days	Up to 41+ days Typical 7-15 days	Up to 100 days
Science Payload Weight	Up to 2,630 kg (Up to 5,800 lb)	1,723 to 2,630 kg (3,800 to 5,800 lb)	1000 kg (2,400 lb)
Typical Float Altitude	29.2 to 38.7 km (96 to 127 kft)	36.5 to 38.7 km (120 to 130 kft)	Up to 33.5 km+ (Up to 110 kft)
Balloon Support Package	CIP •Line of Sight •300 kbps direct return	SIP •Over the Horizon •6-8 kbps TDRSS down	CDM •Over the Horizon •100 kbps TDRSS down
Launch Locations	Fort Sumner, NM; Palestine, Texas; Lynn Lake, Canada; Alice Springs, Australia	Antarctica; Kiruna, Sweden; Alice Springs, Australia; Fairbanks, Alaska	

• Current development project
+ Demonstration Mission

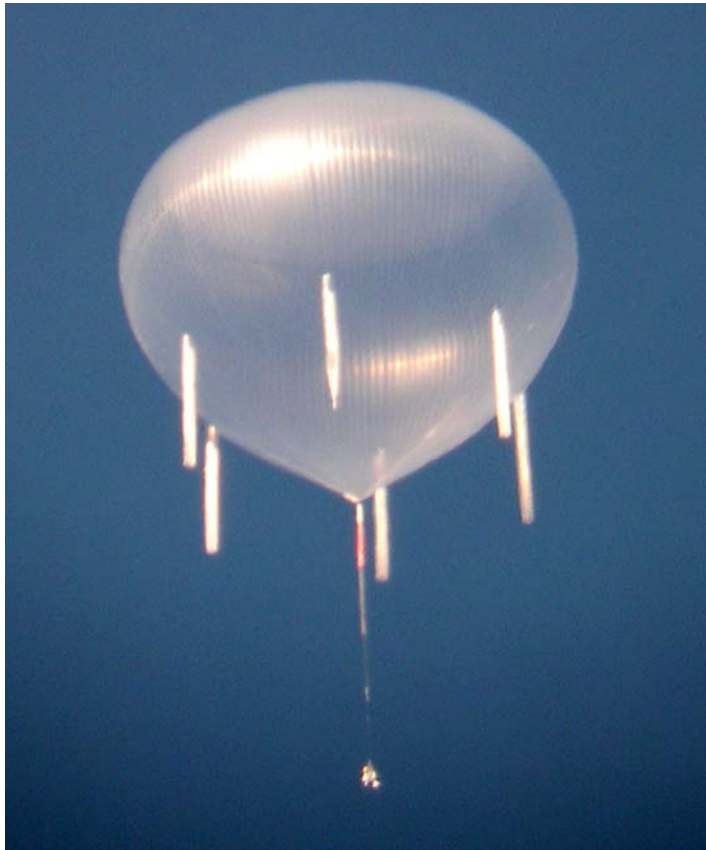


Balloons: How Big?





Photographs of a Vented Zero-Pressure and a Sealed Super-Pressure Balloon at Float Altitude



40 MCF (1.12 mcm) Conventional / LDB balloon at Float



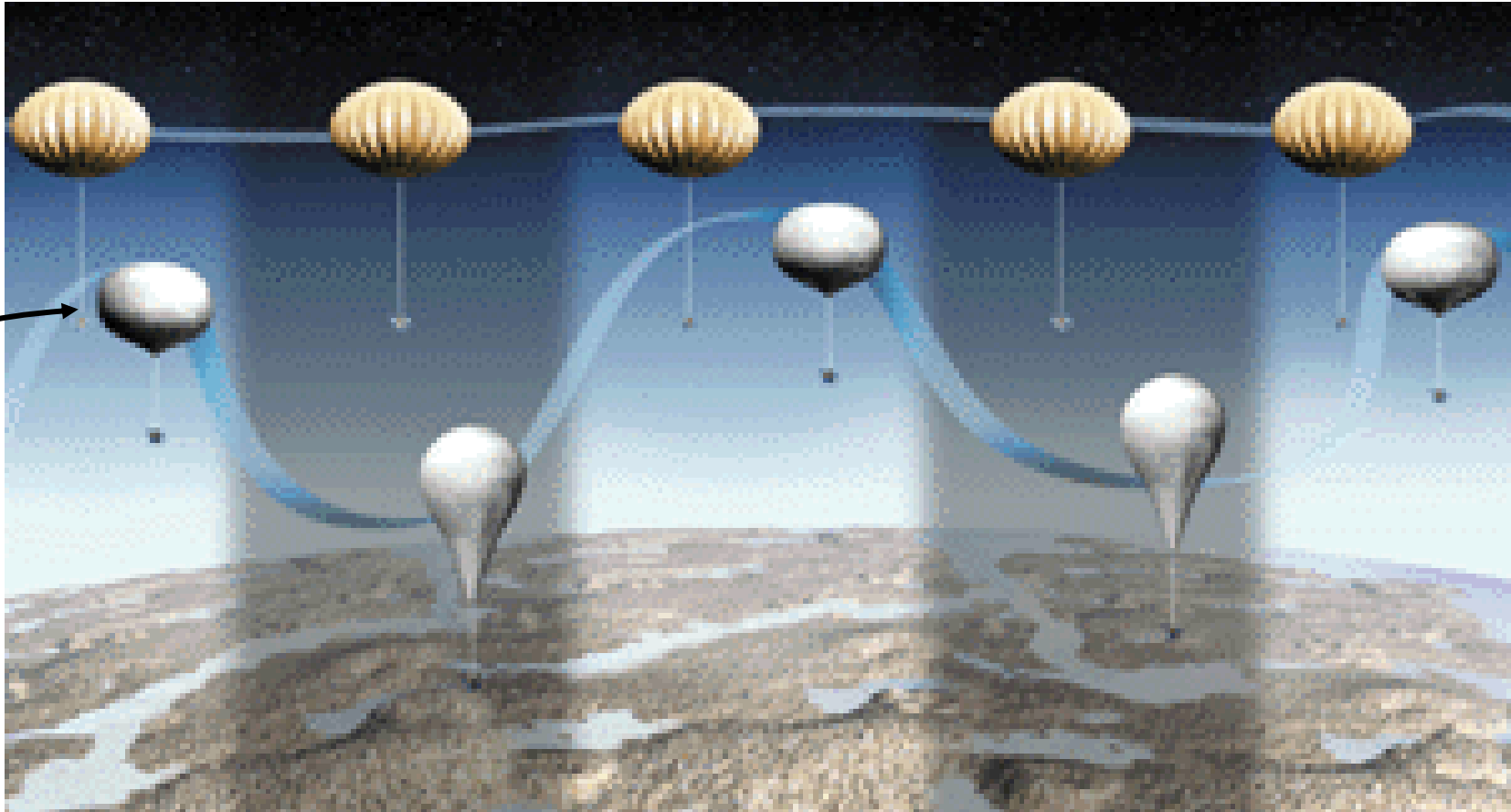
6 MCF (0.17 mcm) Super-Pressure Balloon at Float



Performance of Zero-Pressure and Super-Pressure Balloons

Super-Pressure : Ultra Long Duration Balloon (ULDB)

This new "Pumpkin" balloon is the first new balloon since 1950!

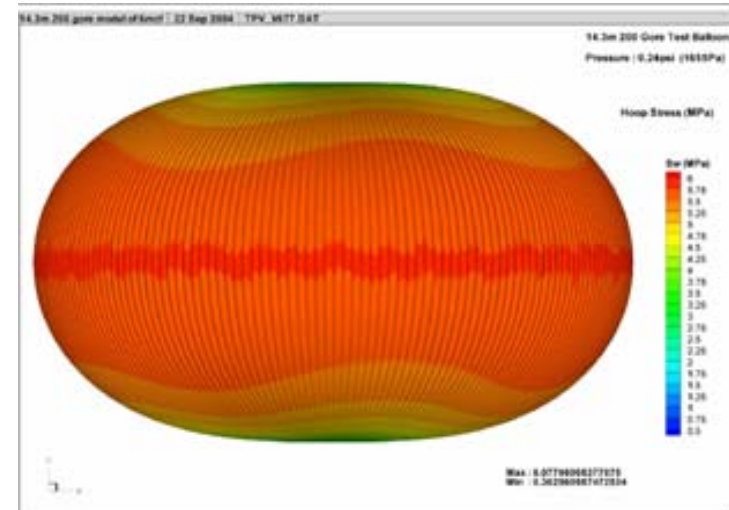


Zero-Pressure Balloon (Conventional and Polar LDB Flights)



Super-Pressure Balloons

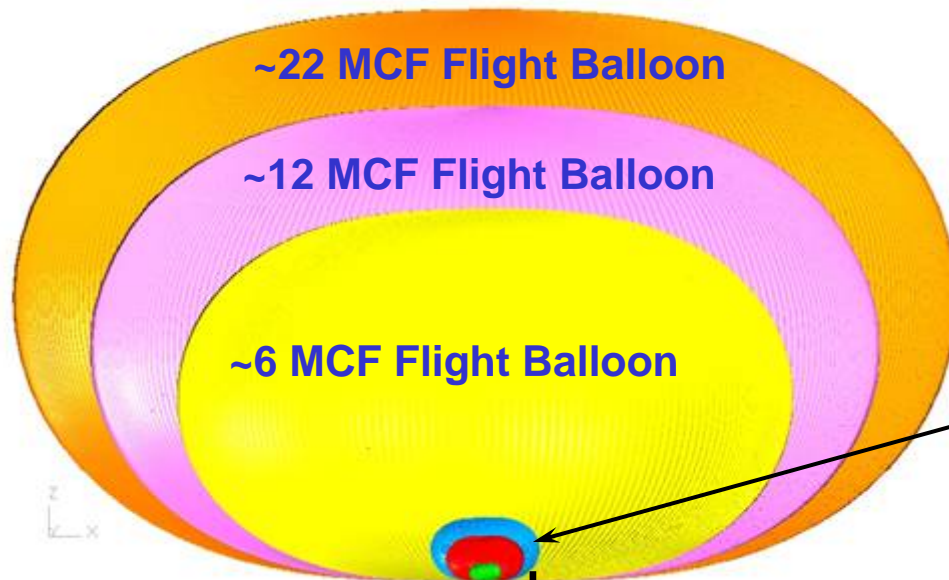
- The Balloon Program Office is currently developing a **Super Pressure Pumpkin Balloon for Ultra Long Duration (ULDB) Flight**
- **Demonstration Requirements**
 - 1-ton instrument to 110 kft
 - 100-day flight goal
 - 60-day minimum
 - Little or no day/night altitude variation
- **Have made great progress in validating an analytical design tool that has accurately predicted scaled model balloon deployment and performance**
- Advances in **Materials Research** at NASA Wallops Flight Facility using Biaxial Cylinder Tests **have clarified critical ULDB material properties**





Development Path of ULDB Balloons

- ULDB Scaled Models are compared to the ULDB Flight Balloons



~ 6 ft Tall Person

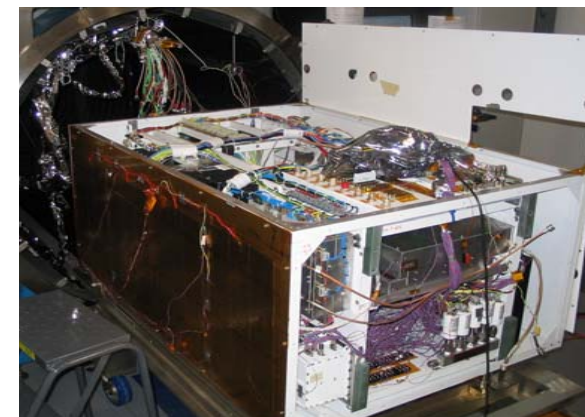
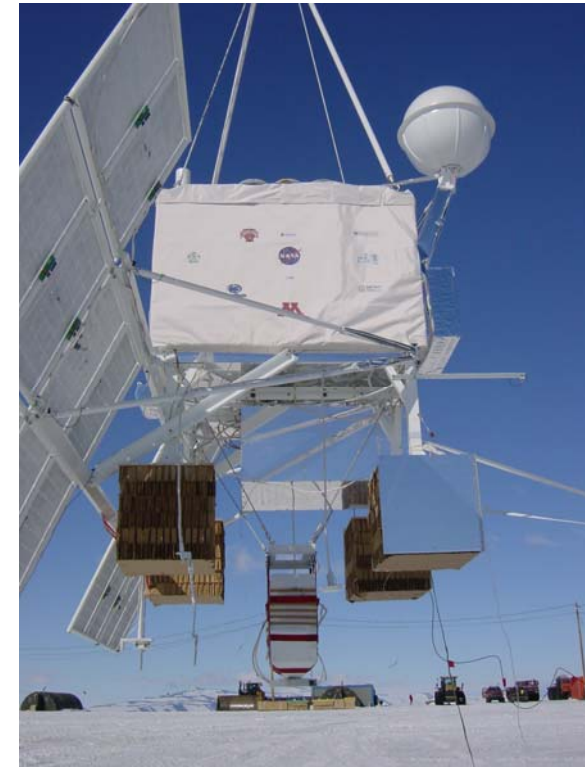
14.3 m Diameter
200 Gore Test
Balloon

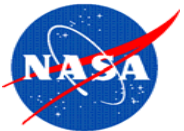




Command Data Module (CDM) ULDB Support System

- **Redundant Data System**
 - Redundant flight computers and on-board hard drives for data storage.
 - Ethernet connection between flight and science computer
- **Redundant Global Communications**
 - Backup Command Decode Deck (BUCD)
 - Used for emergency commanding if flight computers are lost
 - Communications through **TDRSS (100 kb/sec)**, Primary Iridium, Over the Horizon Iridium, TDRSS Line of Sight (LOS), L-Band LOS, and Argos uGPSi
- **Ample Power for Instruments**
 - Produces 900 W of power
 - 10 solar panel – 6 prime, 4 backup
 - Rotator used to align solar panels to the Sun
 - 4 lithium-ion batteries.

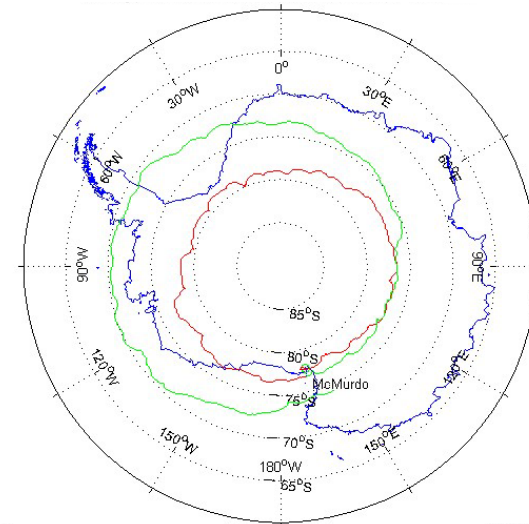
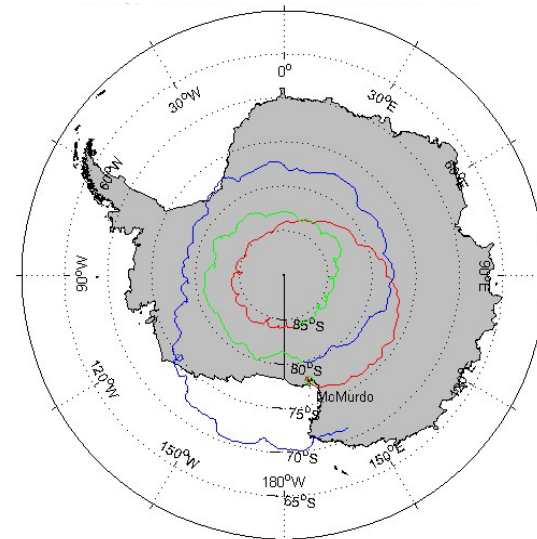
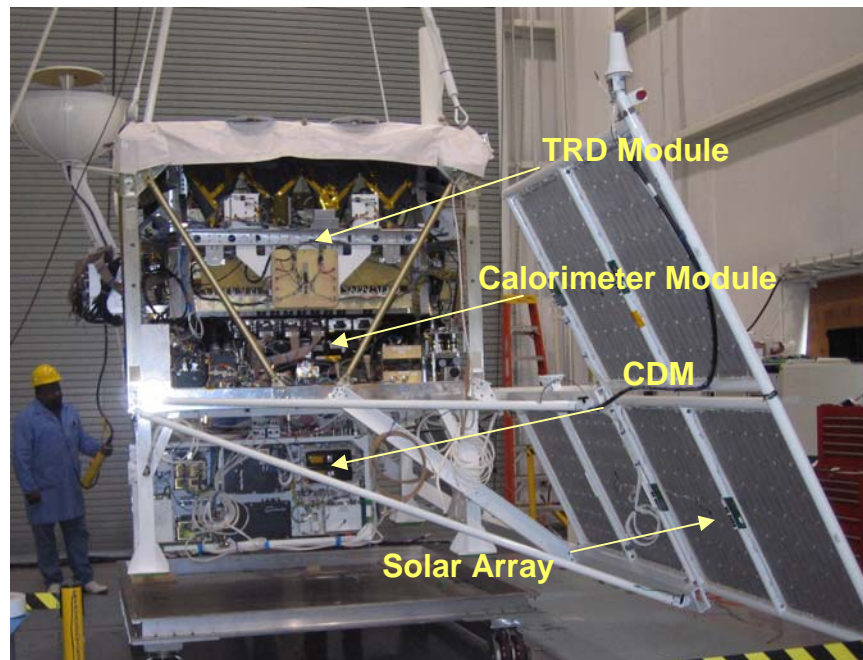




Cosmic Ray Energetics and Mass (CREAM)

Ultra Long Duration Balloon Demonstration Payload

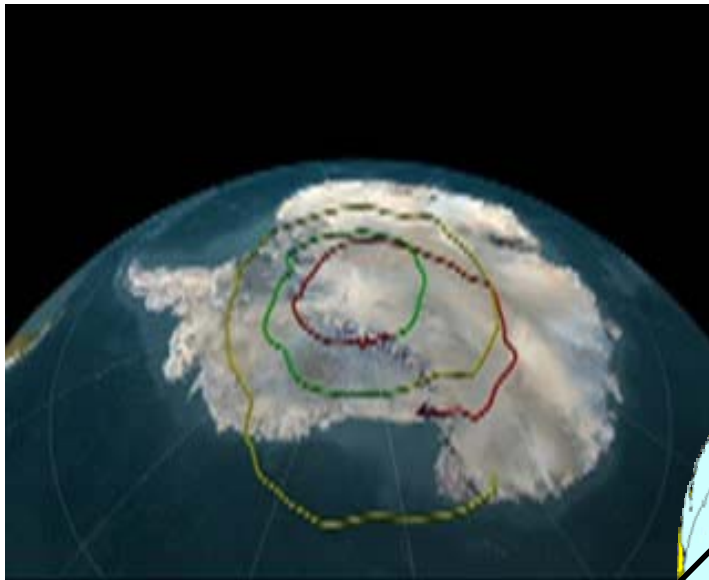
- Direct measurements of individual p - Fe spectra over >2 orders of magnitude leading up to the “Knee”
- CREAM is ~1/4 scale version of the ACCESS Mission prioritized in 2001 NAS/NRC Decadal Study
- The CREAM ULDB Demonstration instrument has been proven with two LDB flights
 - **1st flight:** 41 days, 21 hr, 31 min in three rounds of the South Pole between 12/16/04 and 1/27/05
 - **2nd flight:** 28 days, 9 hr and 52 min in two rounds of the South Pole between 12/16/05 and 1/13/06



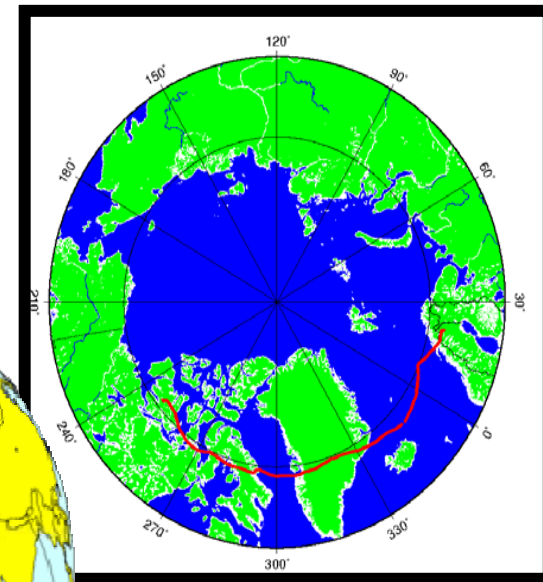


Northern Hemisphere Capability

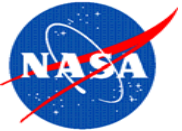
CREAM 41.9 day 3-circumpolar flight in Antarctica 12/16/04 - 1/27/05



BLAST 4.2 day Sweden to Canada flight 6/12/05 - 6/20/05
(Expect to average 5 - 7 Days)



With international over-flight approval 21+ day flights around North Pole would be possible



ULDB Flight Test Summer 2006

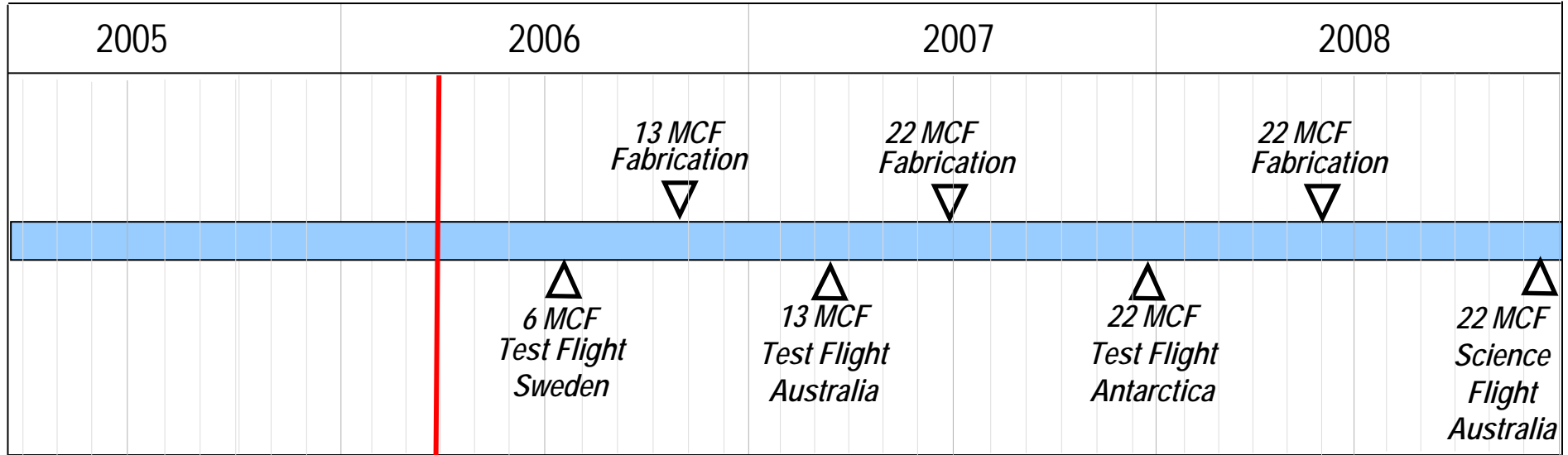
- The 6 MCF Ultra Long Duration Balloon (ULDB) test flight is on schedule for Summer 2006 from Sweden
- The pumpkin-shaped superpressure balloon will be tested for 5 - 7 days between Sweden and Canada
- The flight test will further demonstrate vehicle deployment and stability, as well as validation of design and performance models
- Numerous scaled model balloons ranging from 4 to 14 meters in diameter have been fabricated and tested in preparation for this flight test





ULDB Demonstration Schedule

Calendar Years





Develop Higher Altitude Super Pressure Balloon

- Higher-Altitude (125 kft) Super Pressure Balloon needed for gamma-ray and hard X-ray investigations in the “Beyond Einstein” program

- ULDB Demonstration Flight requirement is 1-ton science instrument to >110 kft

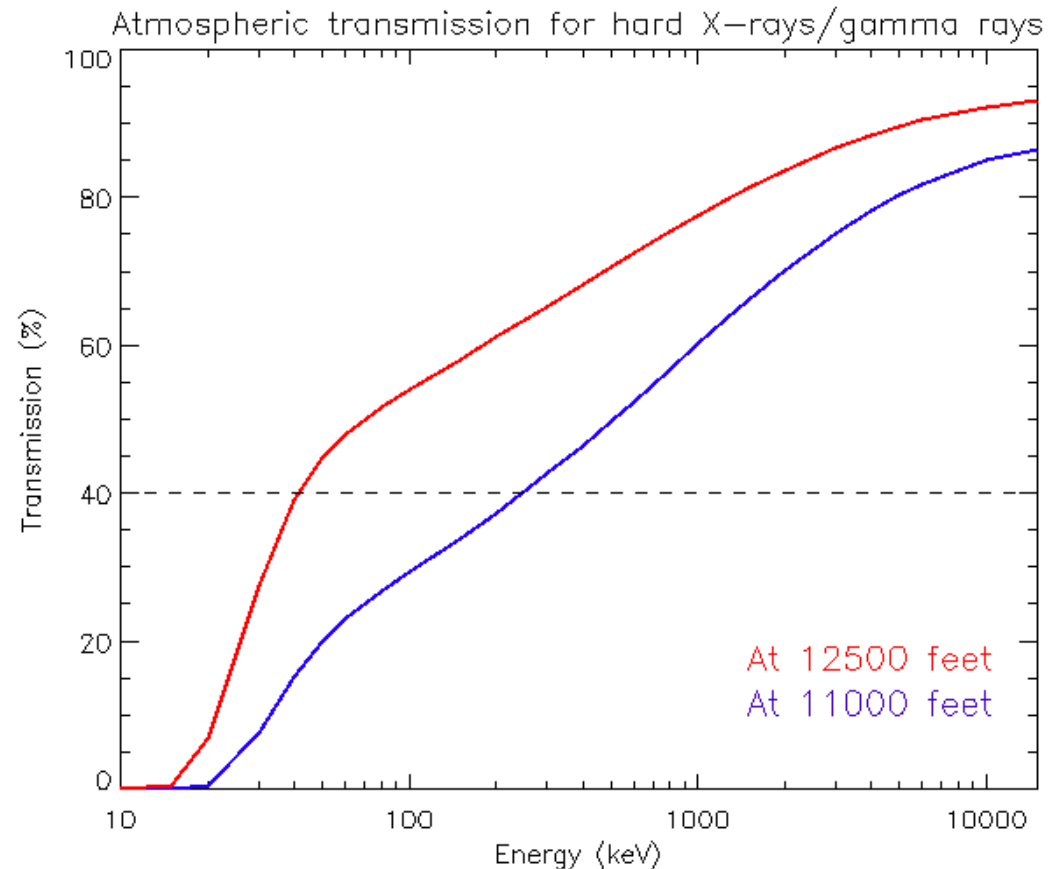
- Beyond Einstein Need:

- 1-ton science instrument at mid-latitude with low cosmic-ray background for ≥ 10 days at full altitude, 125 kft)

- This will require:

- ~ 50% increase in balloon volume, or more!

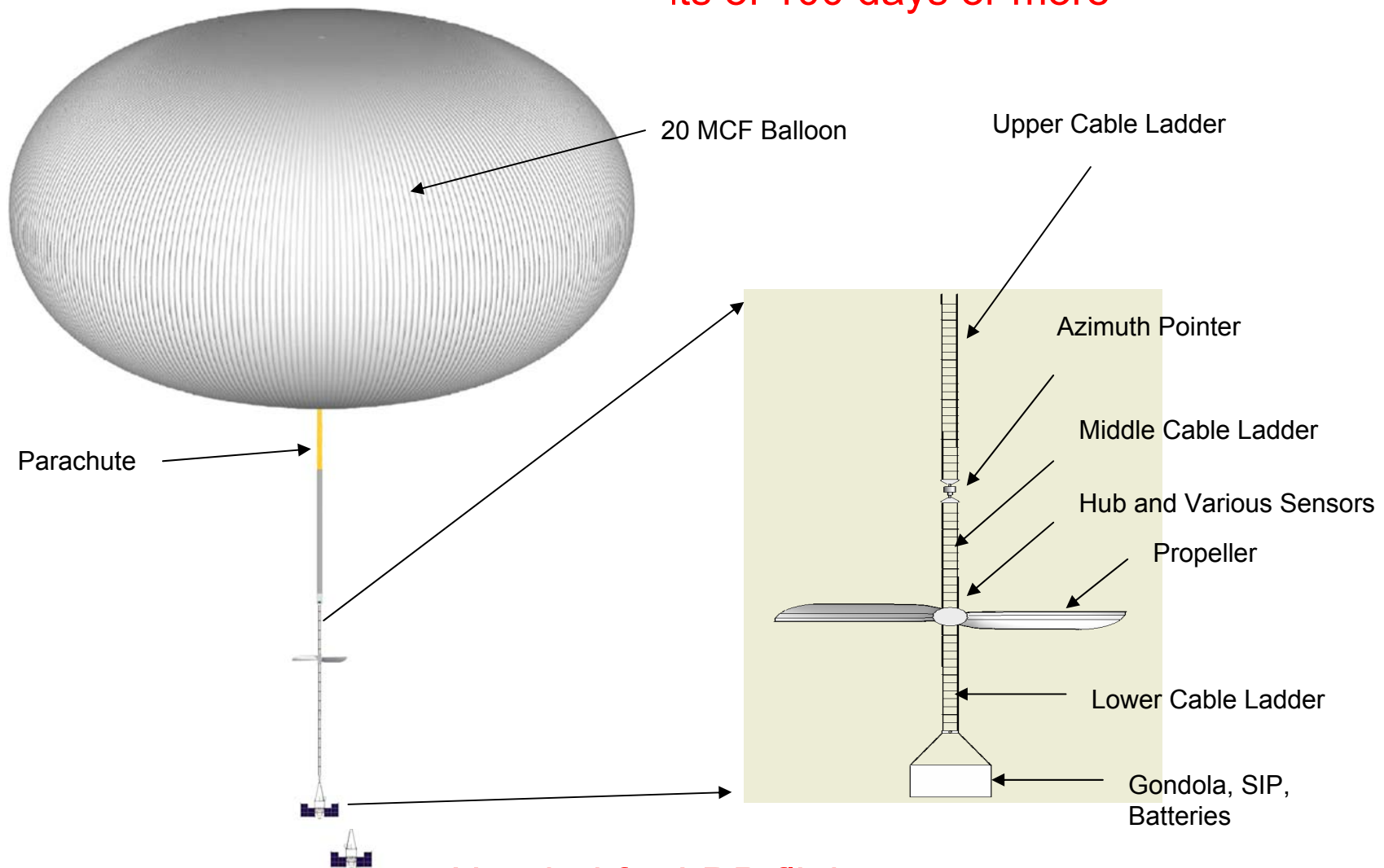
- Lighter-weight support instrumentation





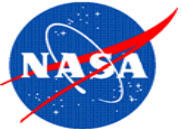
Trajectory Modification Capability Concept

Needed for LDB flights of 100 days or more



Needed for LDB flights

- Keep Antarctic trajectory over the continent even after two circuits
- Ensure that mid-latitude flights do not fly over densely populated areas

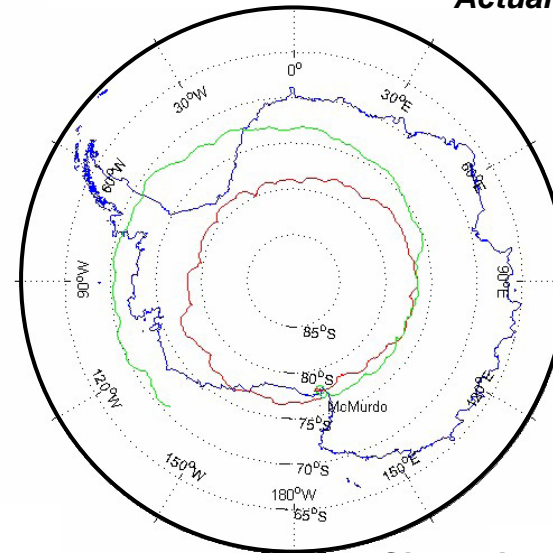


Trajectory Control System (TCS) Concept Study

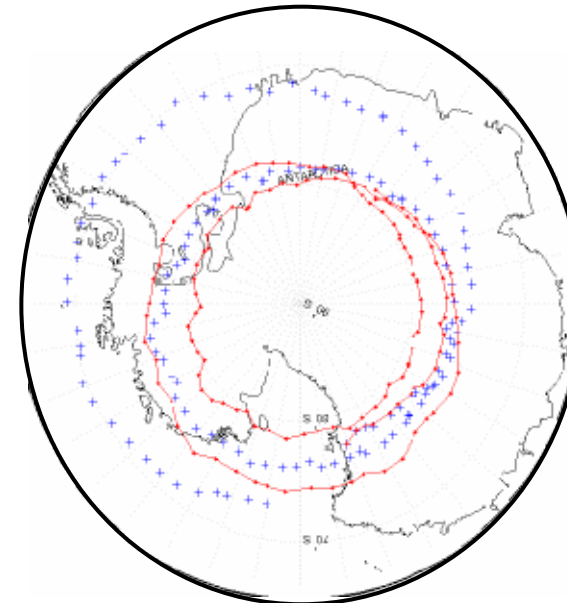
“What if” study on effects of TCS on CREAM II Flight

- Wallops has been studying the design of a propeller driven TCS system with at least 1 m/s control authority
- GSFC looked at the effect of a minimal trajectory control system (TCS) with 0.5 meter/sec control authority on the trajectory of the actual 2006 Cream II balloon flight
- Simulation results are very promising. The balloon trajectory control simulation tool showed CREAM-II would have stayed over the continent and made at least 3 very tight orbits
 - Actual trajectory of Cream II in blue ‘+’.
 - The red solid line represents a TCS with 0.5 m/s control authority

Actual Flight Track



Simulation TCS Flight Track





Concluding Remarks

- Within budget constraints, **all Balloon Program activities respond to recommendations of the Scientific Ballooning Planning Team**
- The Scientific Ballooning Planning Team was chartered in mid-2004
 - To identify scientific objectives for which ballooning has the greatest potential to contribute significantly
 - To show connections of those objectives to National Academy of Science reports, NASA strategic objectives, and/or other planning documents
- The final report **“NASA Stratospheric Balloons: Pioneers of Space Exploration and Research”** currently under Internal Review
 - Is intended to provide input to the discipline subcommittees of the NASA Advisory Council Science Committee
 - Specifies ballooning requirements for optimal and minimal programs
 - Recommends a program that fits into current funding, and identify the limits of such a program
- **Identifies high priority augmentations and their science impacts**
 - Increased number of flights in both Antarctica and in the Arctic
 - Higher altitude ULDB capability
 - Capability for modest balloon trajectory modification

ACRONYMS

ACE	Advanced Composition Explorer
ACT	Advanced Compton Telescope
ANITA	Antarctic Impulsive Transient Antenna
ATIC	Advanced Thin Ionization Calorimeter
BESS	Balloon Borne Experiment with Superconducting Spectrometer
BLAST	Balloon-borne Large Aperture Sub-millimeter Telescope
BOOMERANG	Balloon-borne Observations Of Millimetric Extragalactic Radiation And Geophysics
BPO	Balloon Program Office
CMB	Cosmic Microwave Background
CDM	Command Data Module
CREAM	Cosmic Ray Energetics And Mass
EBEX	E/B Mode Experiment
ELV	Expendable Launch Vehicle
GSFC	Goddard Space Flight Center
HEFT	High Energy Focusing Telescope
InFOCuS	International Focusing Optics Collaboration for uCrab Sensitivity
HERO	High-Energy Replicated Optics
LDB	Long Duration Balloon
LXeGRIT	A Liquid Xenon Gamma-Ray Imaging Telescope
MCF	Million Cubic Feet
NCT	Nuclear Compton Telescope
NSBF	National Scientific Balloon Facility
NSF	National Science Foundation
PAPPA	Primordial Anisotropy Polarization Pathfinder
PI	Principal Investigator
PSL	Physical Science Laboratory – New Mexico State University
SEUS	Structure and Evolutions of the Universe Subcommittee
TIGER	Trans Iron Galactic Element Recorder
TIGRE	Tracking and Imaging Gamma Ray Experiment
TCS	Trajectory Control System
TRACER	Transition Radiation Array for Cosmic Energetic Radiation
ULDB	Ultra-Long Duration Balloon
WMAP	Wilkinson Microwave Anisotropy Probe