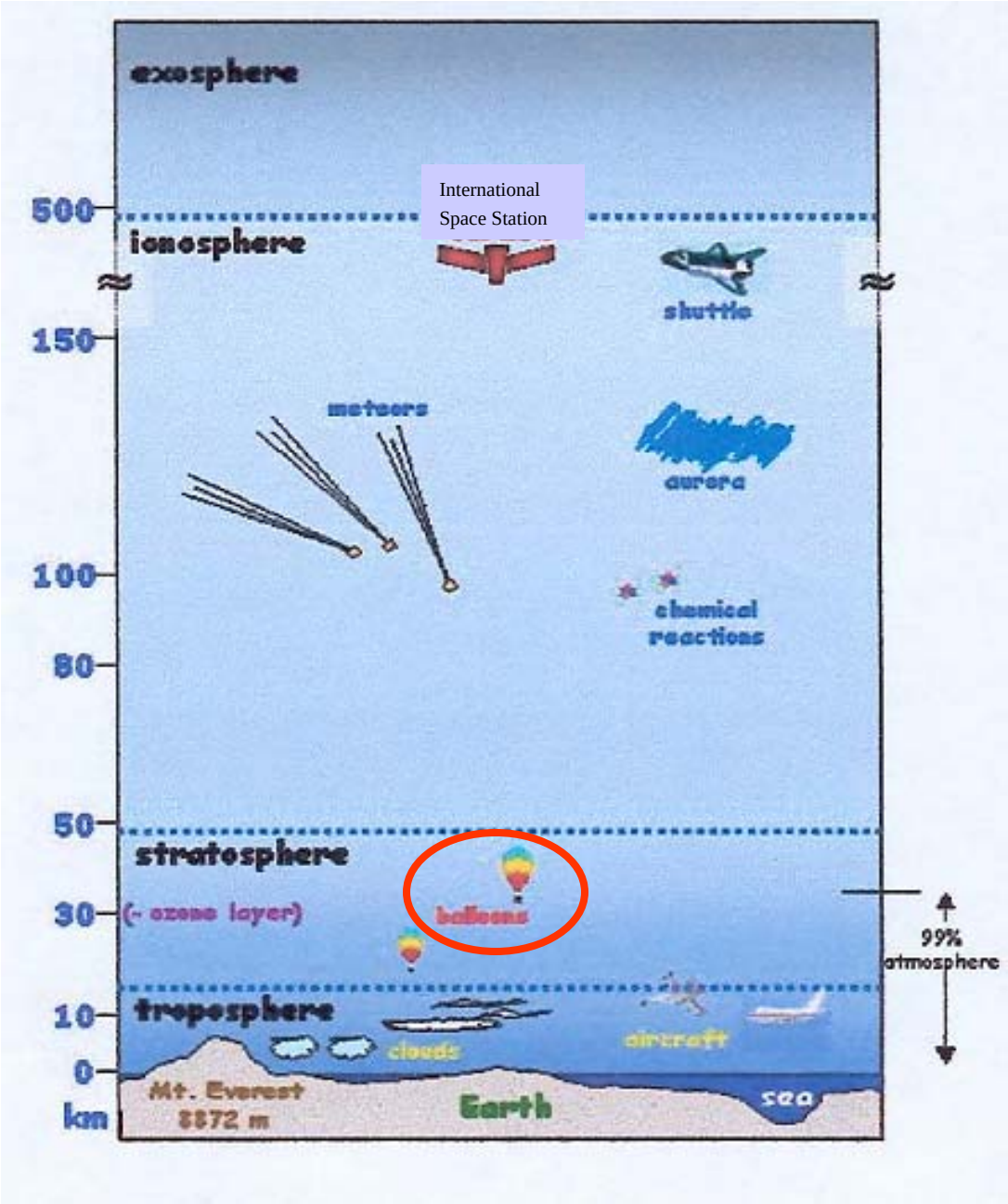
Corso di tecnologie spaziali: i palloni stratosferici

Corso di laurea in Fisica, III anno
Firenze, a.a 2004-2005


exosphere
International
Space Station
500
ionosphere
shuttle
150
meteors
aurora
100
chemical
reactions
80
50
stratosphere
30
(- ozone layer)
balloons
99%
atmosphere
10
troposphere
clouds
aircraft
0
km
Mt. Everest
8872 m
Earth
sea

MEANS OF FLIGHT: main characteristics for the experimentation

STRATOSPHERIC BALLOONS

Payload: total ≤ 3t (detect. ≈ **1t)** at 40 km (≈ 5g/cm3 residual atmosphere)
Data taking: ≤ **1 day** (30 days at the poles)
Launch sites: very few because of winds (speed, direction), populations, airplane routes, manoeuvring area (≈ 1km^3)
Price/event: high (0.5 M$/launch + instrument)

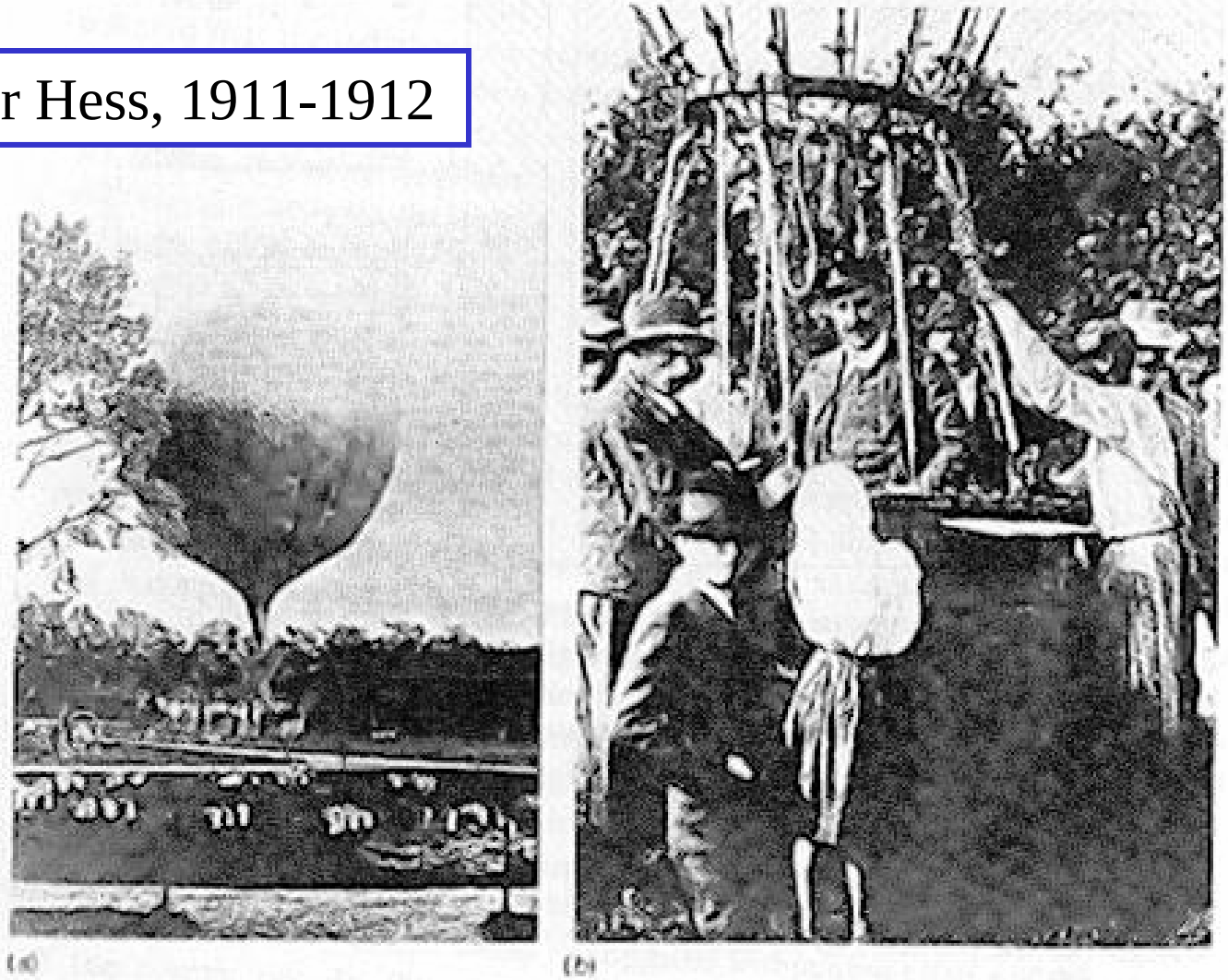
SATELLITES or STATIONS in Low Earth Orbit

Orbit: inclination depends on the launch site (polar is optimal for geomagnetic cut and radiation belt crossing)
Altitude: ≤ 1000 km (radiation belts)
≥ 300 km (atmospheric drag)
'Attitude': not important for CR, but only for γ
Price: 10000/50000 $/kg

INTERPLANETARY PROBES

Useful payload: a few kg → small acceptance
High radiation fluxes: → electron. components and materials

Victor Hess, 1911-1912



(a) (b)

Figure 1.3. The balloon flights of Victor F. Hess. (a) Preparation for one of his flights in the period 1911–12. (b) Hess after one of the successful balloon flights in which the increase in ionisation with altitude through the atmosphere was discovered. (From Y. Sekido and H. Elliot (eds) (1985). *Early history of cosmic ray studies*. Dordrecht: D. Reidel Publishing Company.)

Atmosfera residua
$X(cm)=X_{eq}(g/cm^2)/\rho(g/cm^3)$
0 m slm: 1000 g/cm^2
5000 m slm: 550 g/cm^2
10000 m slm: 300 g/cm^2

I palloni 'aperti':

Volume a 5g/cm^2 (40 km) oltre 1 Mm^3

Materiale molto sottile (20/40μm),

non regge differenze di pressione

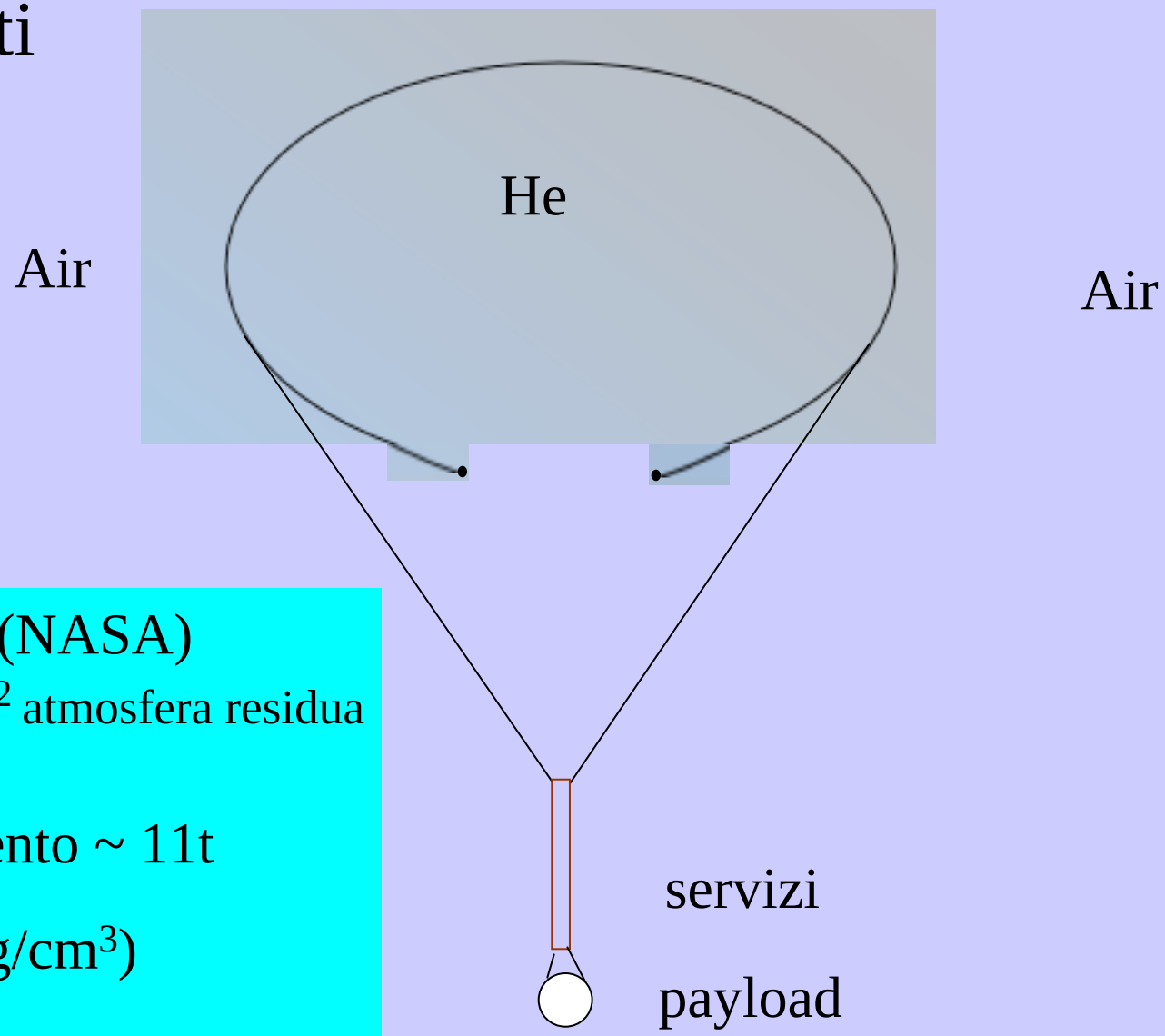
Portata massima circa 3 t

Linea di vista circa 800 km

Durata tipica del volo 20 ore

Il pallone 'casca' per le perdite di elio dovute al ciclo giorno/notte

Palloni aperti

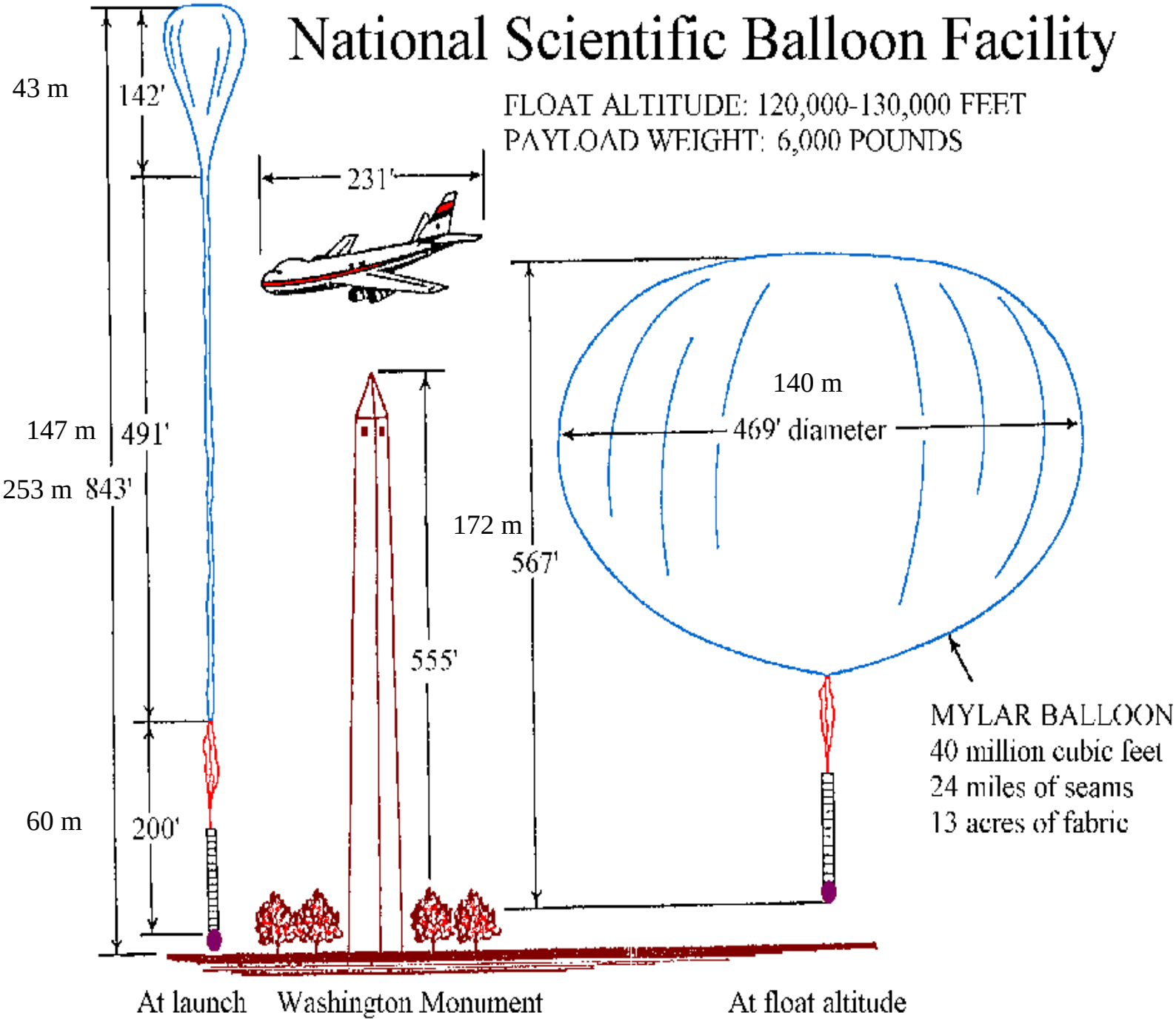


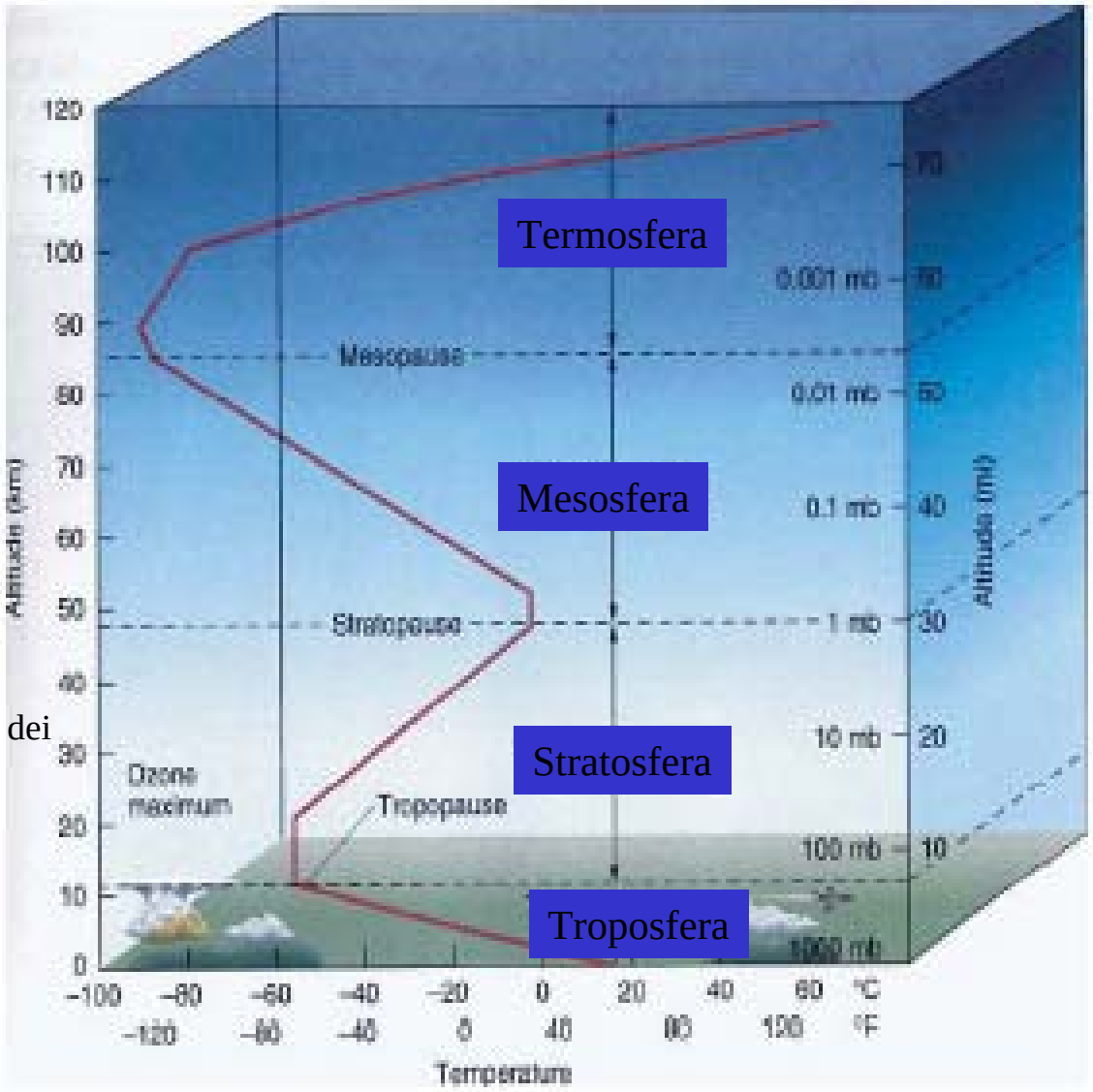
Palloni di classe A (NASA)
2.8 Mm^3 @ 5 g/cm^2 atmosfera residua
R=90 m
Potere di sollevamento ~ 11t

Pallone 4/5 t (ρ=1 g/cm^3)
Servizi 3 t
Payload 3 t @ 38÷40km
(5g/cm^2 atmosfera residua)

National Scientific Balloon Facility

FLOAT ALTITUDE: 120,000-130,000 FEET
PAYLOAD WEIGHT: 6,000 POUNDS





Regione dei palloni

T aumenta per l'assorbimento rapido degli UV di energia più alta

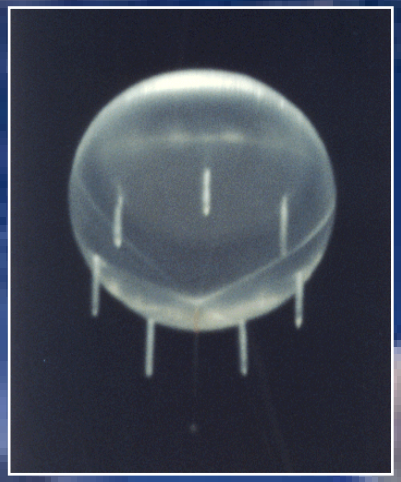
Profilo termico dovuto a O_2 e O_3

T aumenta perché l'Ozono (10 ppm) assorbe gli UV

T diminuisce perche'
ci si allontana dalla terra 'calda'

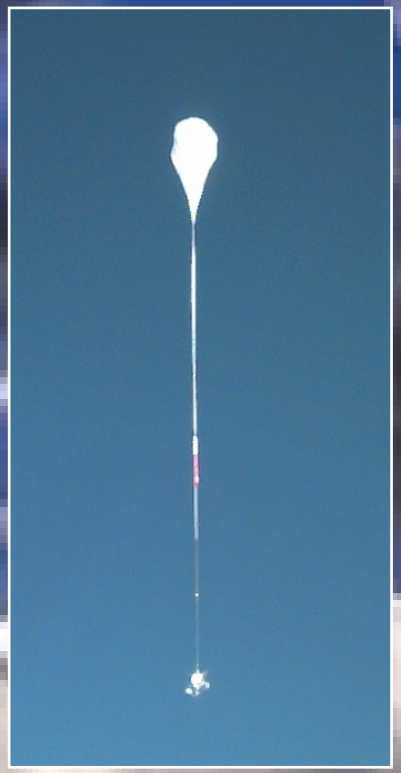
Thermal structure of the atmosphere

- Height~ 40 km
  - → ~5 g/cm^2 residual atmosphere
- Duration of the flight limited by night/day effect
  - → 6-40 hours
- Long duration?

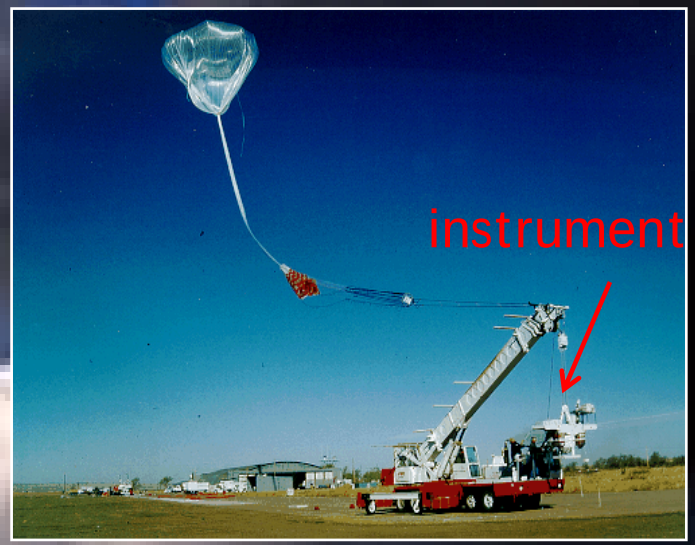


In flight

Raise



Launch



Landing

Le attrezzature per il lancio:

Veicolo per sostenere il ‘carico’

Veicolo per trattenere il pallone durante il riempimento con elio

Uno o piu’ veicoli con le bombole di elio

Palloni sonda per misurare i venti in quota prima del lancio

(Turn-around)

Base di lancio con ampia area di manovra

Hangar per l’assemblaggio ed il controllo dei carichi

Sala di controllo per gli sperimentatori

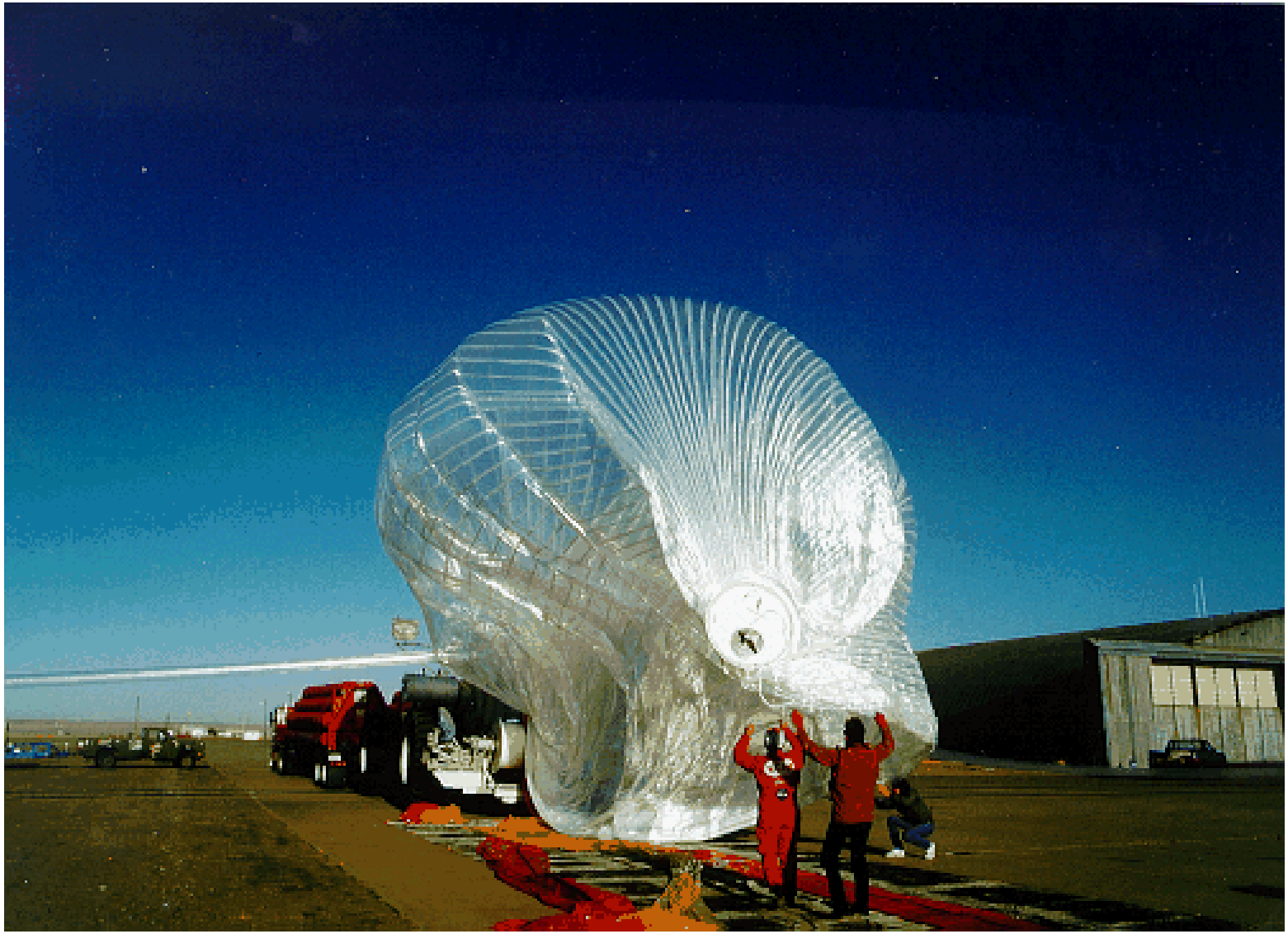
NATIONAL SCIENTIFIC BALLOON FACILITY
Palestine, Texas

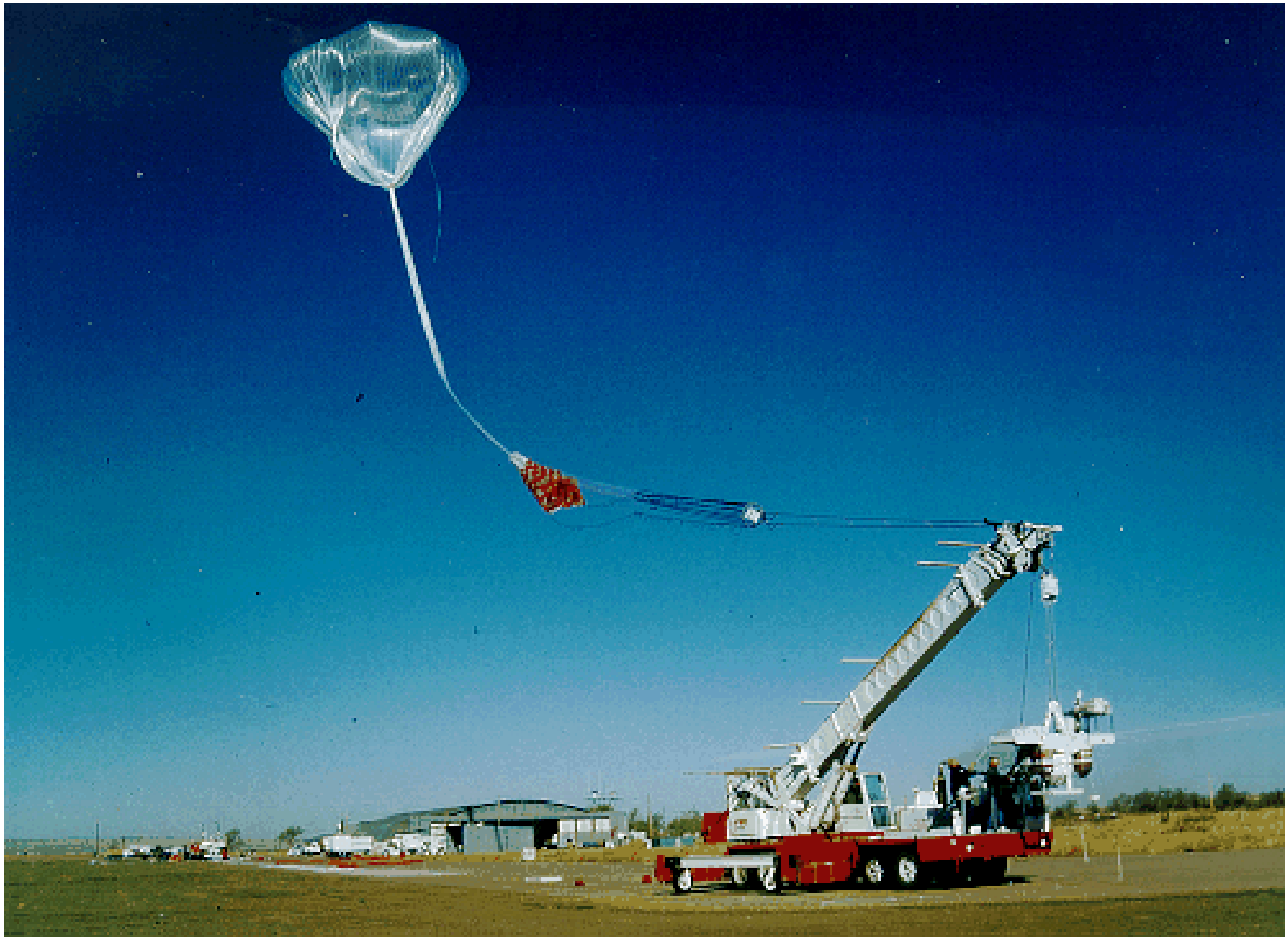
6

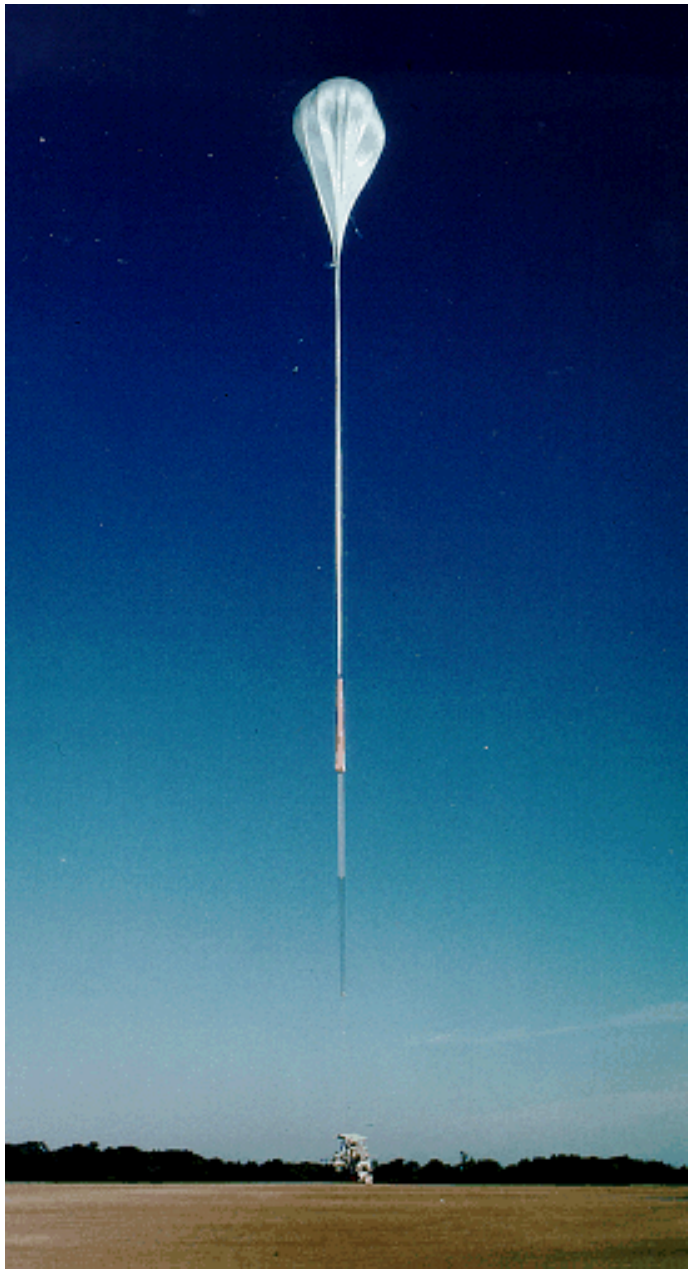
Operazione di lancio con
inizio prima dell’alba per avere
il pallone in quota al sorgere del Sole
E poter sfruttare al massimo la giornata!

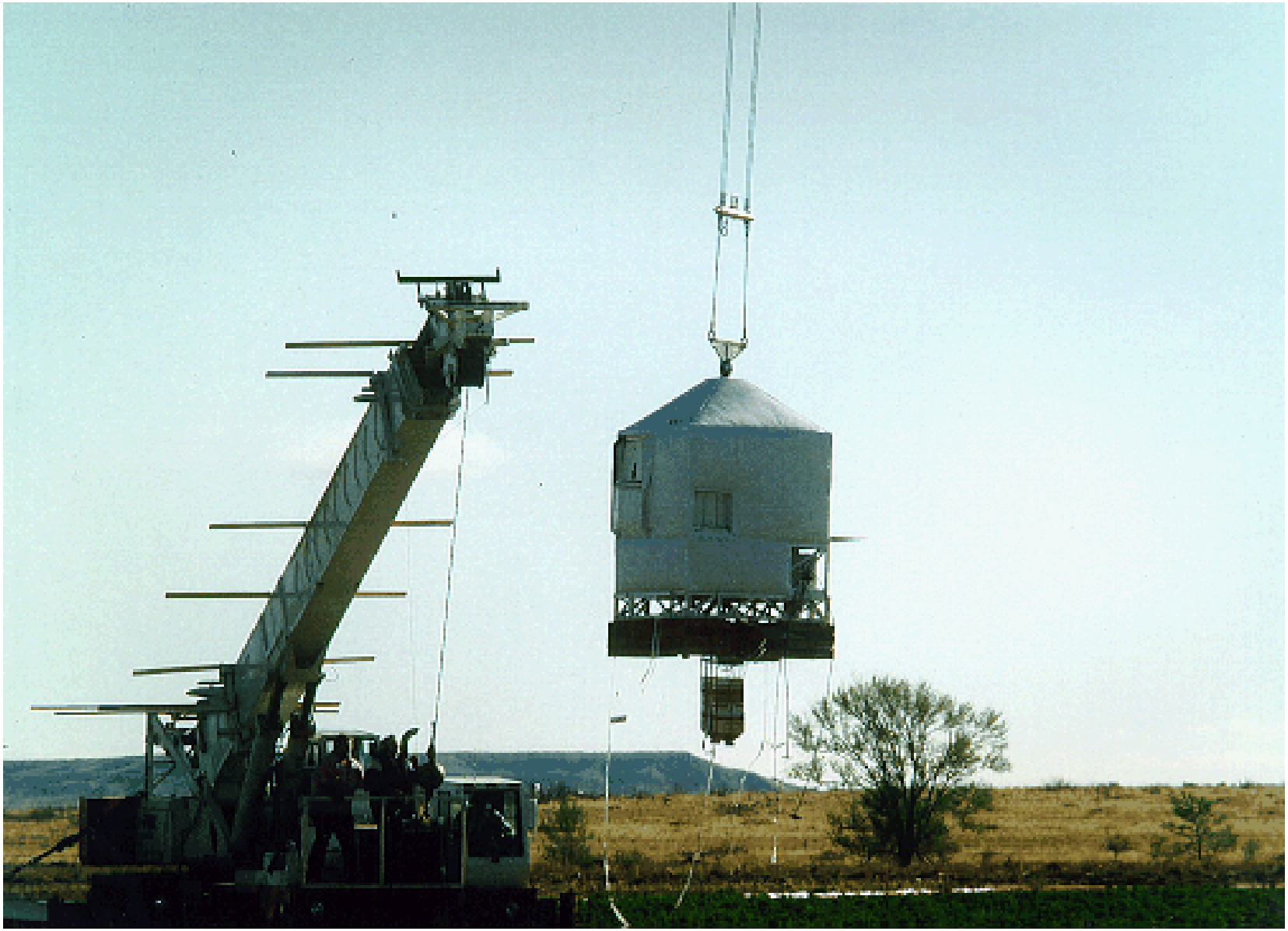
JRH 39143

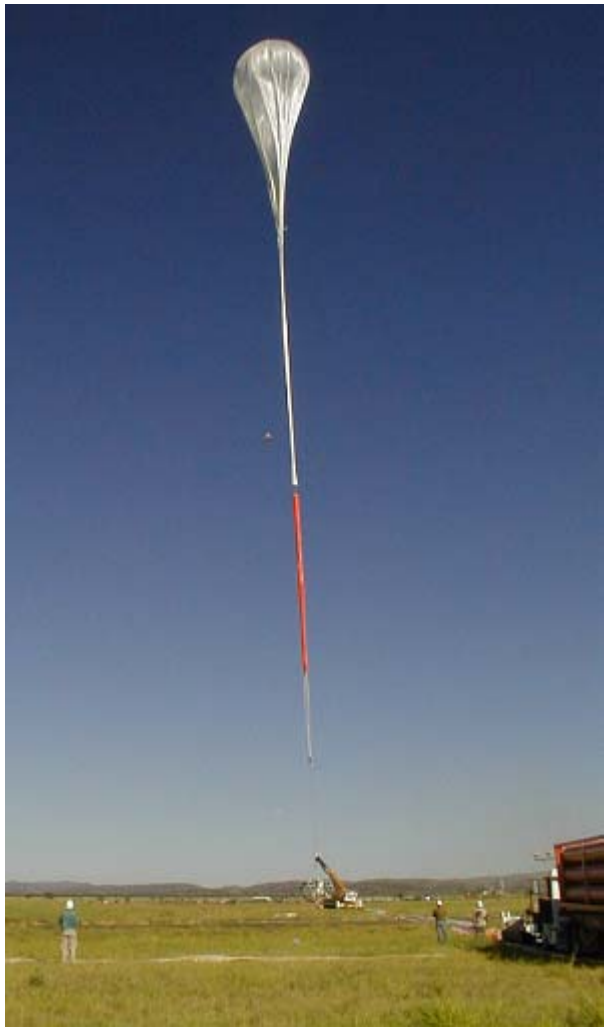
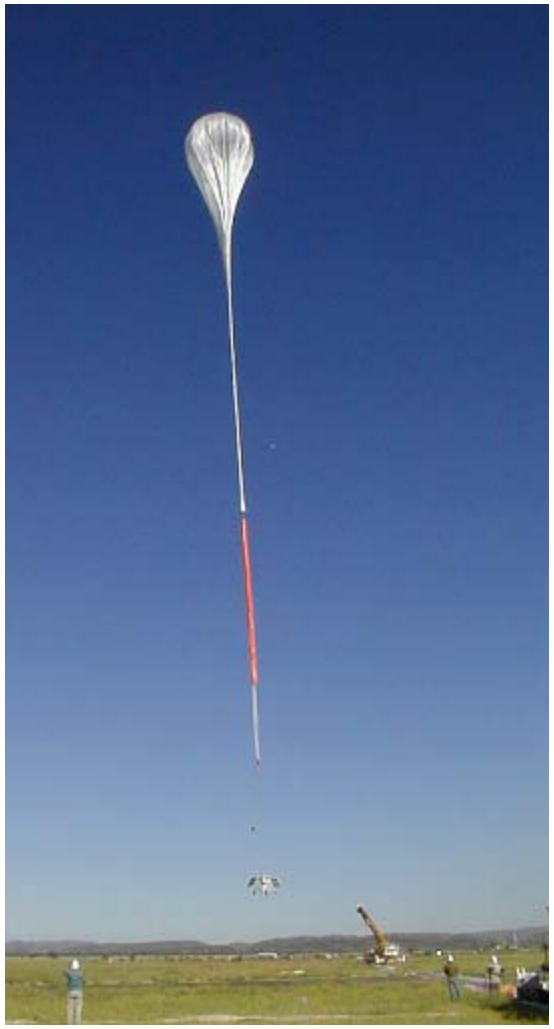
Nightglow in Australia

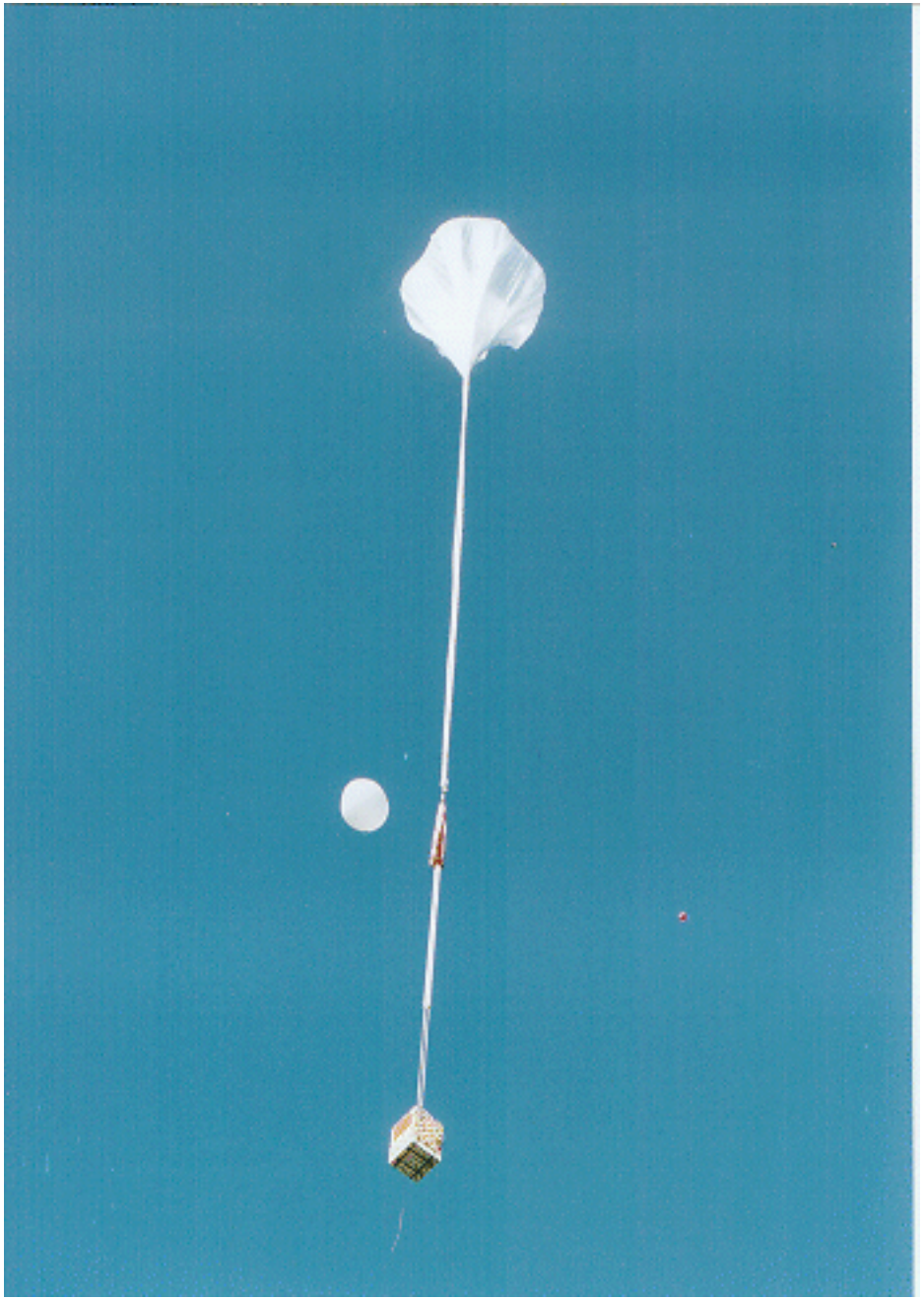




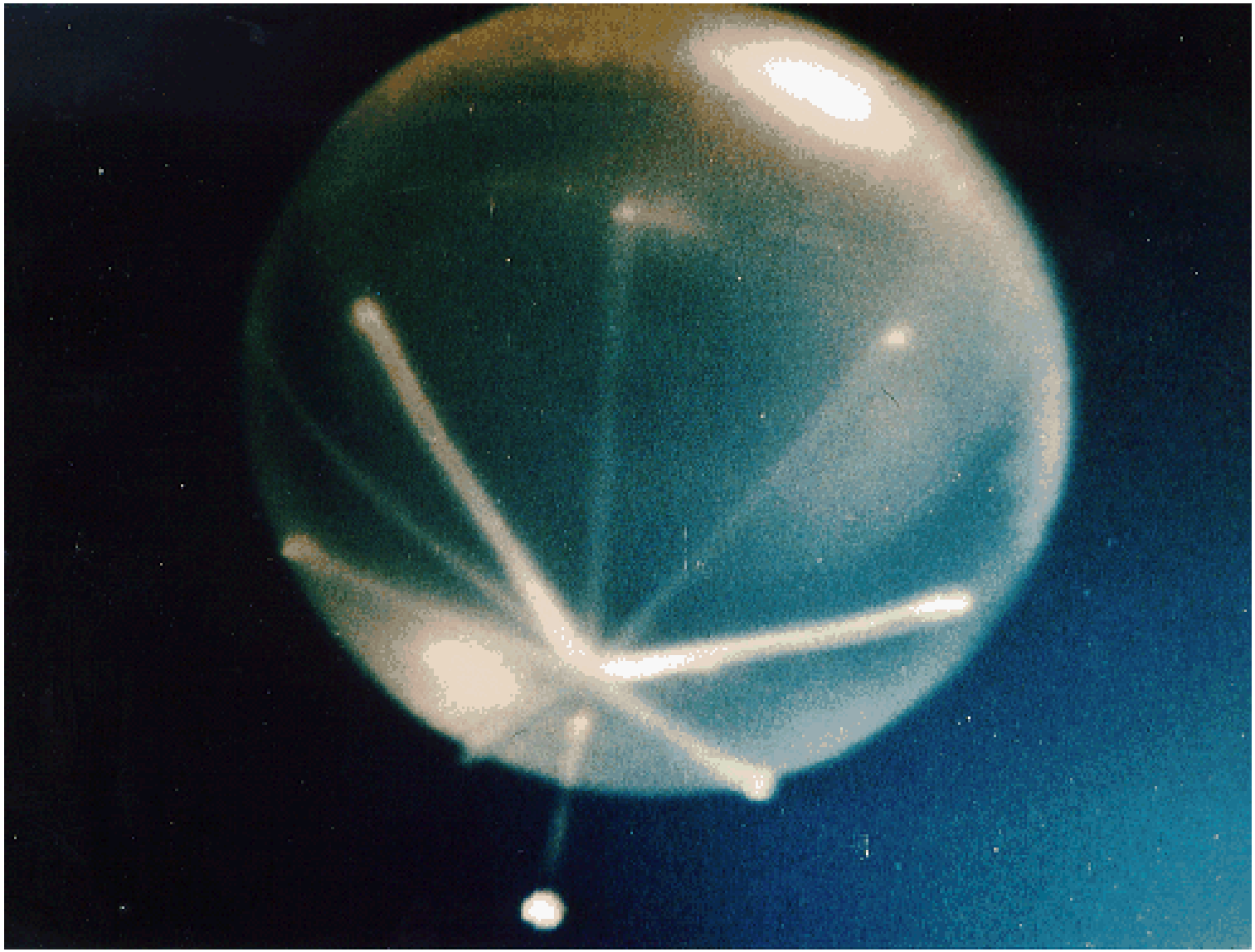






Un pallone in quota

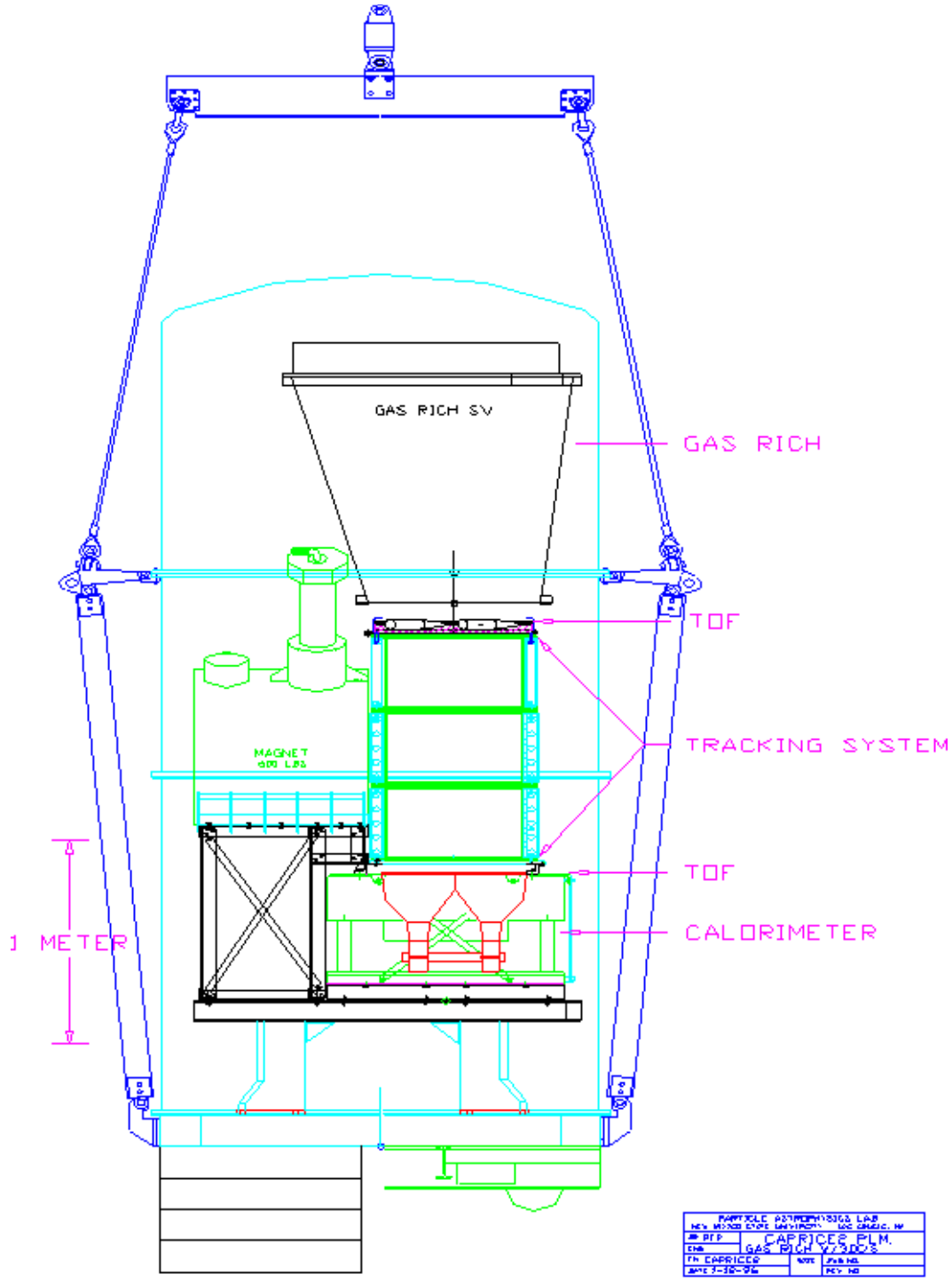


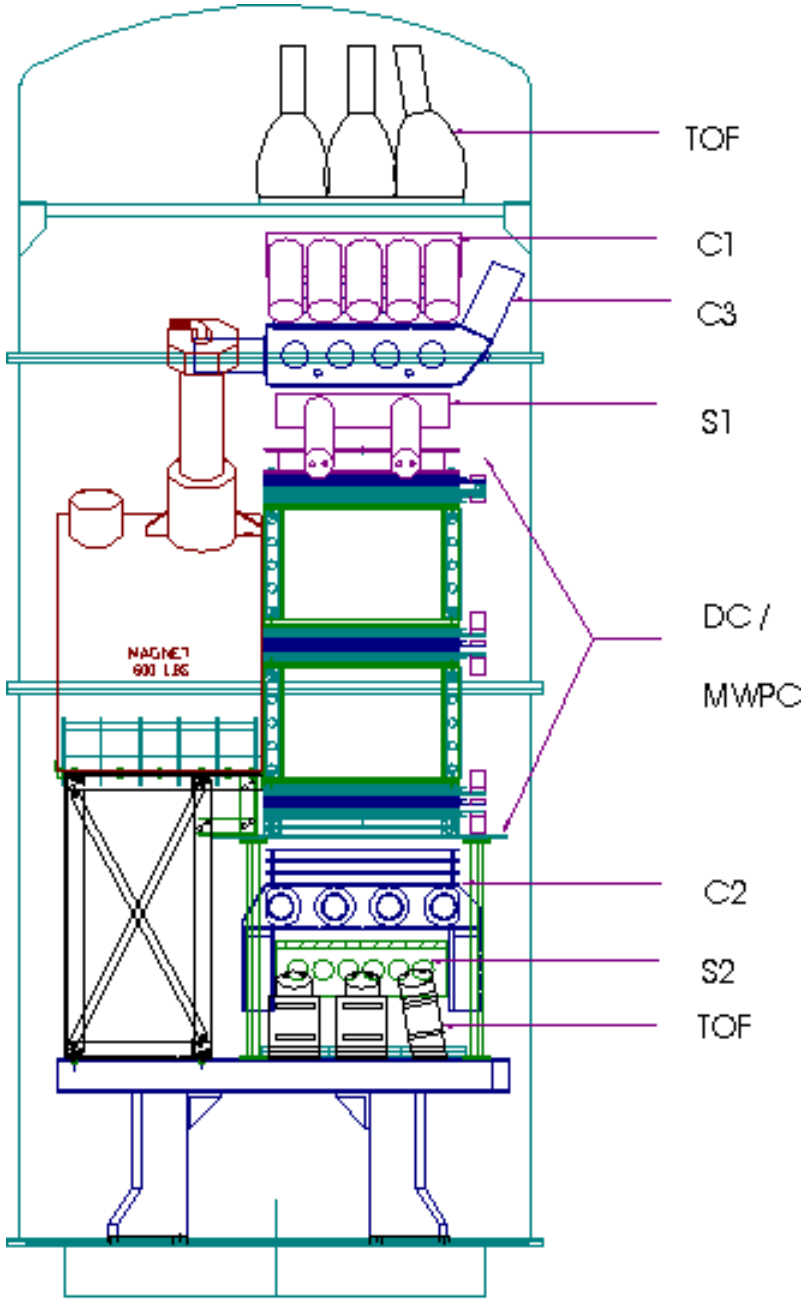
Quando il pallone inzia a perdere quota,
il payload viene sganciato con una carica esplosiva
e viene aperto il paracadute per rallentare la discesa

E’ importante il recupero del payload!!!!

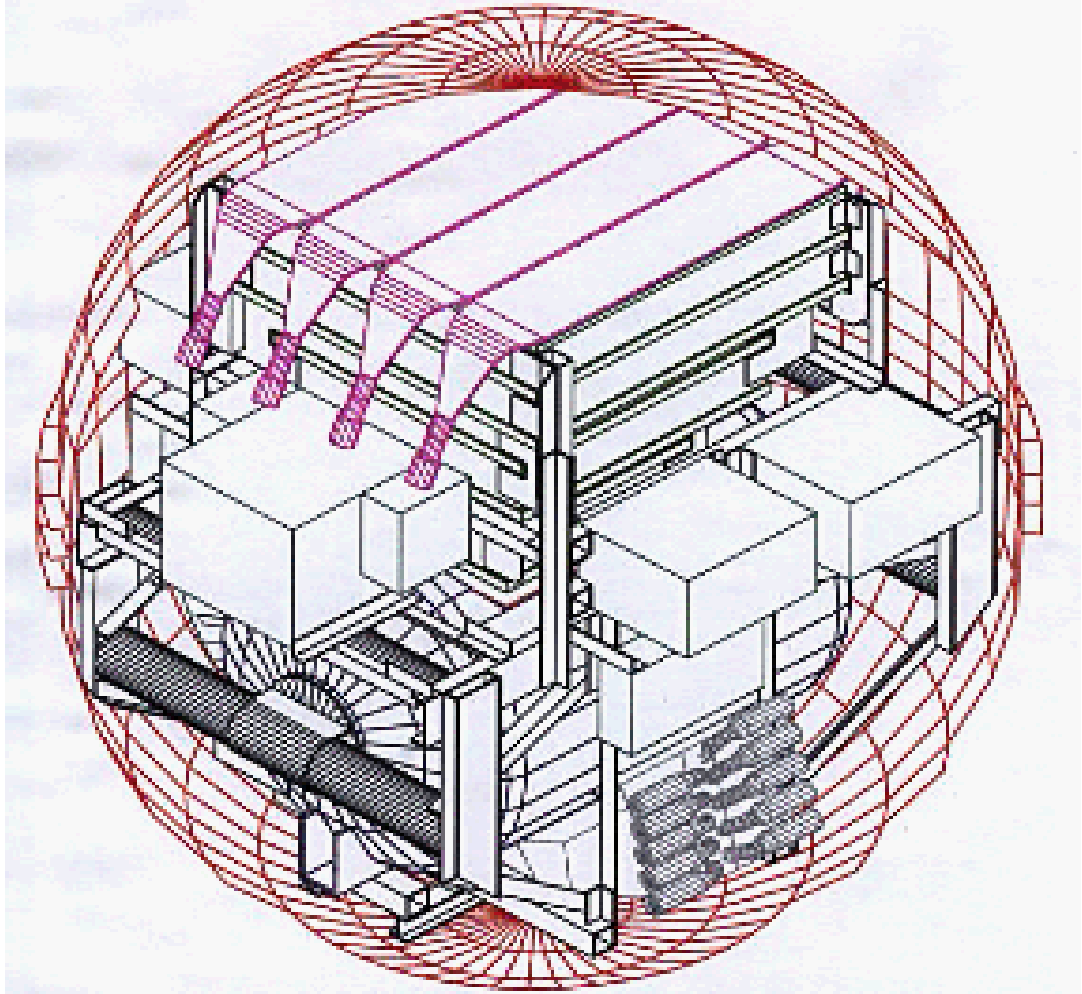
Il payload può atterrare a migliaia di km dal punto di Lancio (fortissimi venti in quota anche nelle condizioni migliori!)

Vari tipi di ‘carico’

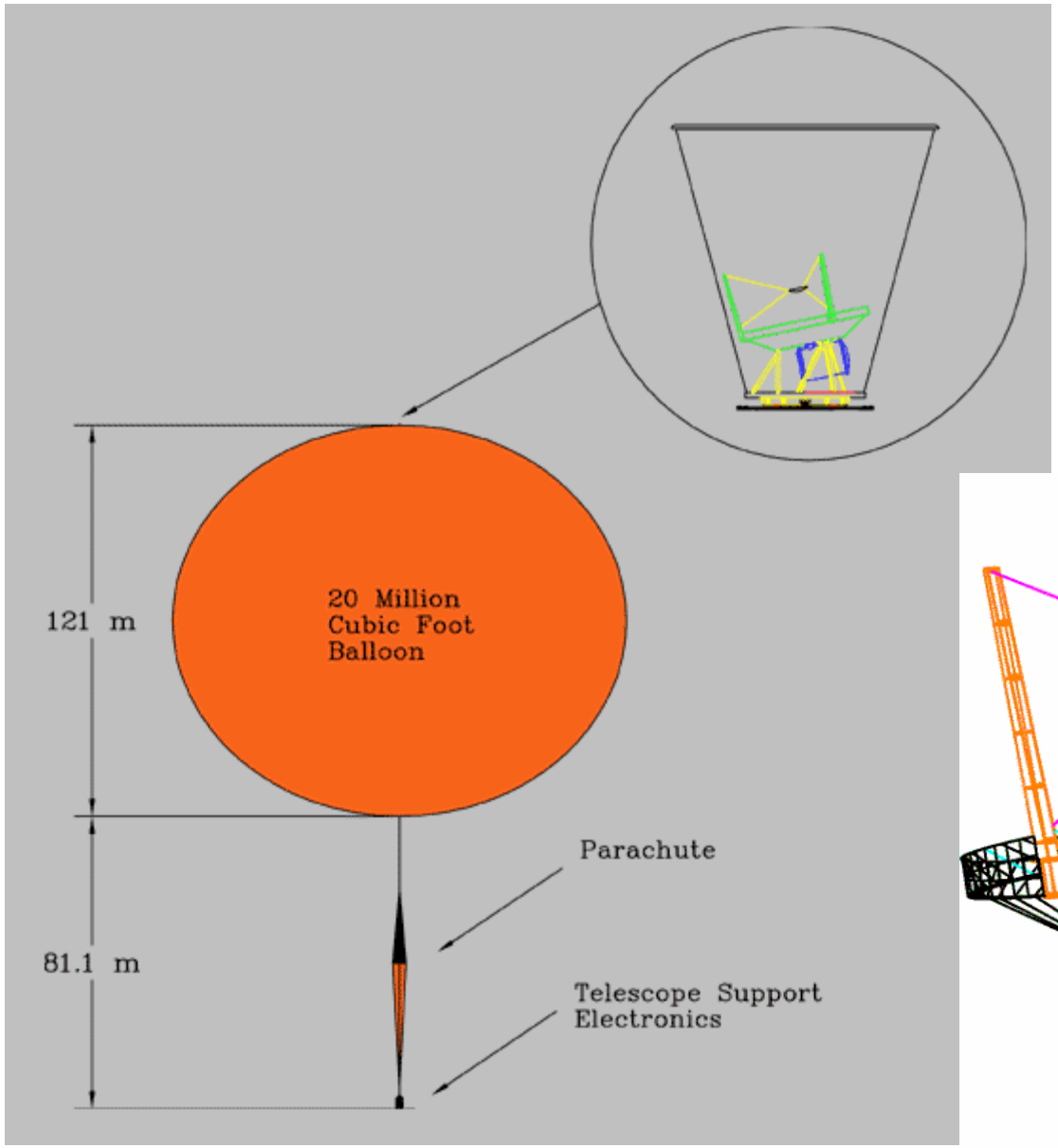

GAS RICH SV
GAS RICH
TOF
TRACKING SYSTEM
MAGNET
TOF
CALORIMETER
1 METER
CAPRICEE PLM.
GAS RICH V/3DC'S

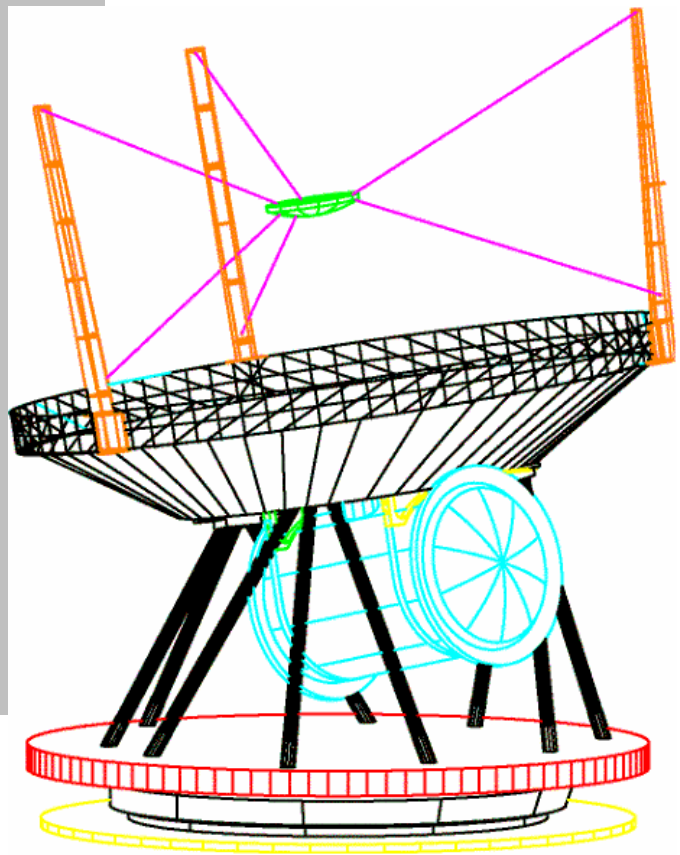

TOF
C1
C3
S1
DC /
MWPC
C2
S2
TOF

HEAT
(High Energy Anti-Matter Telescope)



Un caso singolare:
il pallone TopHat


121 m
20 Million
Cubic Foot
Balloon
Parachute
81.1 m
Telescope Support
Electronics



Tophat

Come si trasferiscono a terra i dati acquisiti?

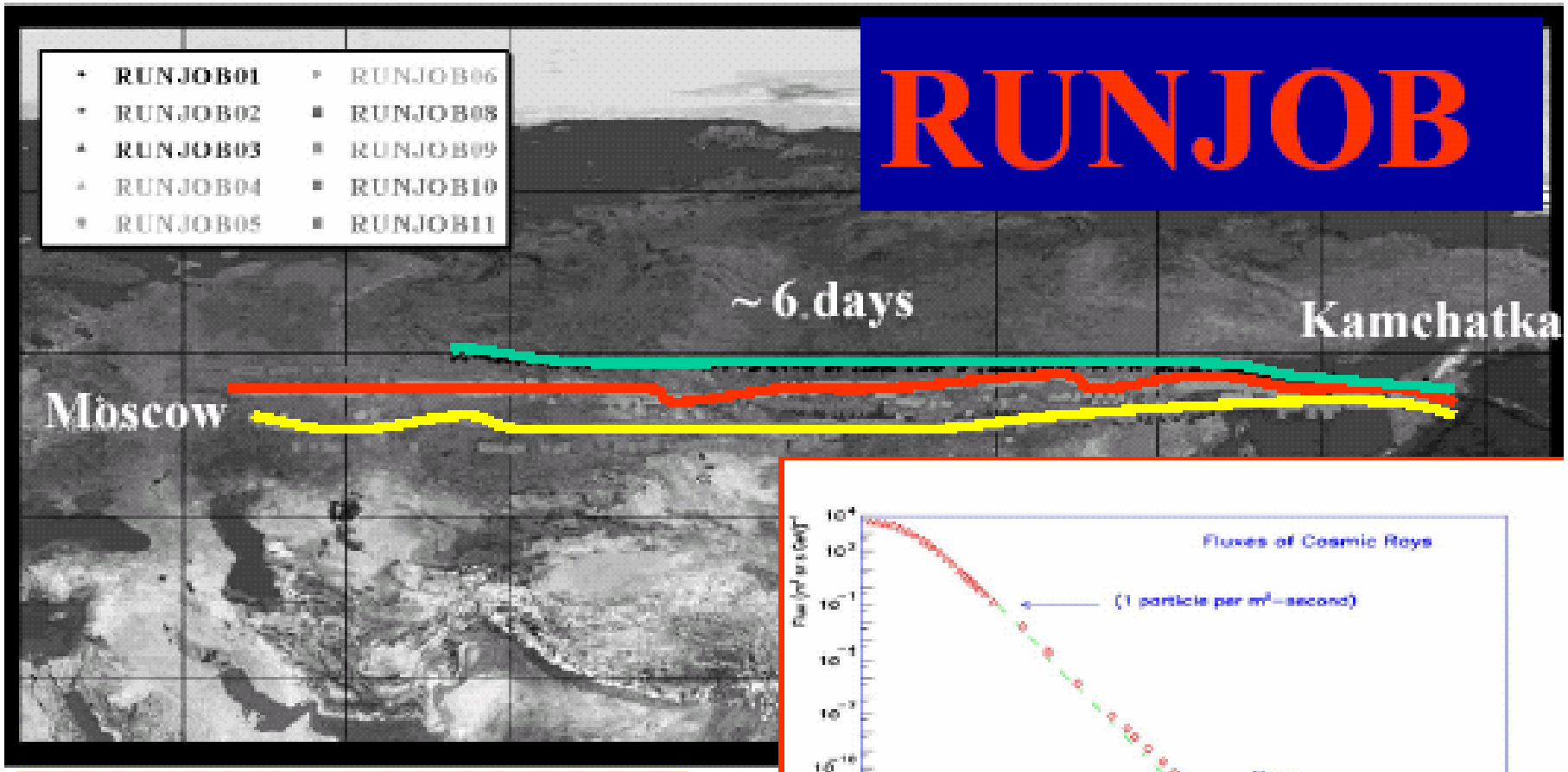
1. Si scrivono i dati su disco/memoria a bordo e si recuperano dopo la caduta
2. Si utilizza un sistema di telemetria ‘custom’ (→ vanno mandati anche comandi!)
   - Aereo che segue il payload (migliaia di km!!!!)
   - Utilizzo di una rete di basi a terra
3. Utilizzo di rete satellitare telefonica (IRIDIUM)

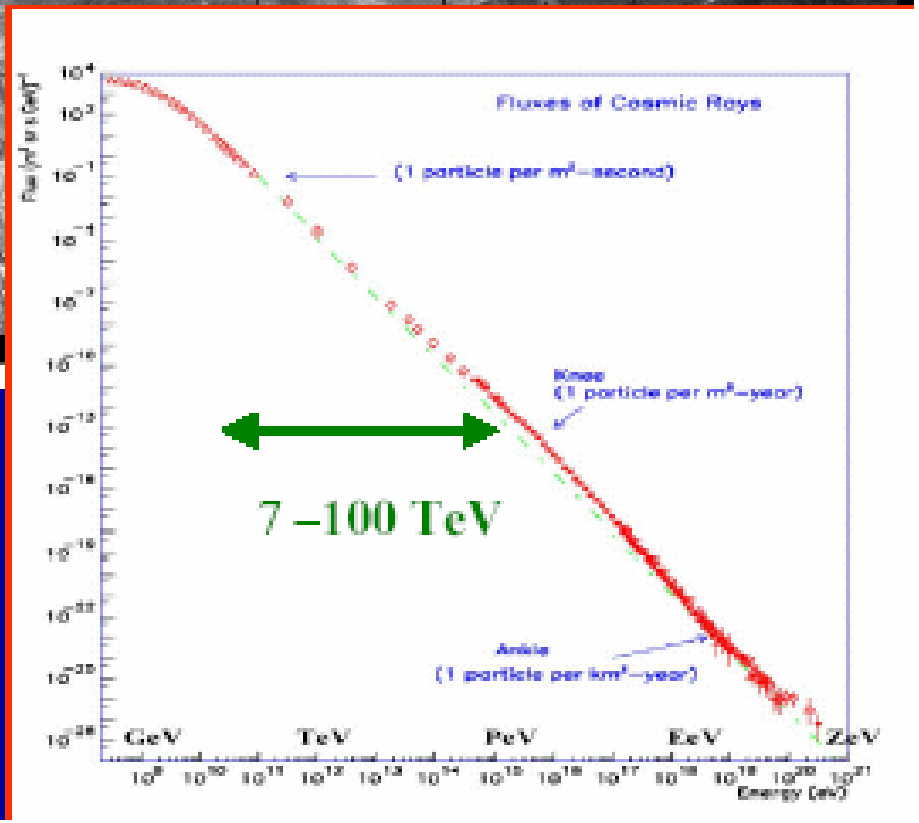
Cosa si usa per alimentare il payload?

Data la durata limitata del volo la soluzione migliore sono le batterie

Esempio:	1 kW, 24 ore → 24 kWora
Batteria ‘commerciale’:	60 Ah, 12 V → 720 Wora
	30 batterie * 10 kg = 300 kg

‘Long Duration Ballooning’ con palloni aperti

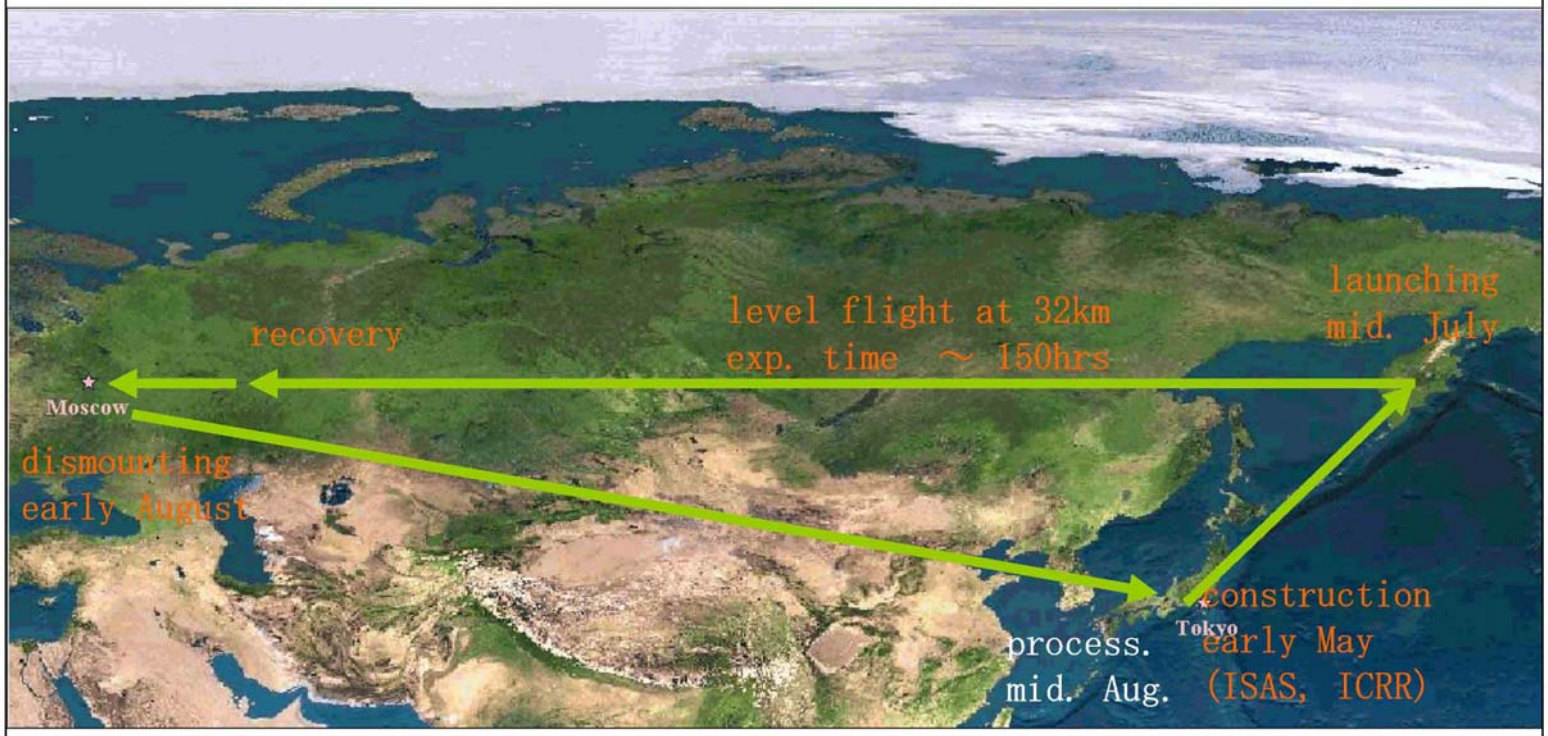


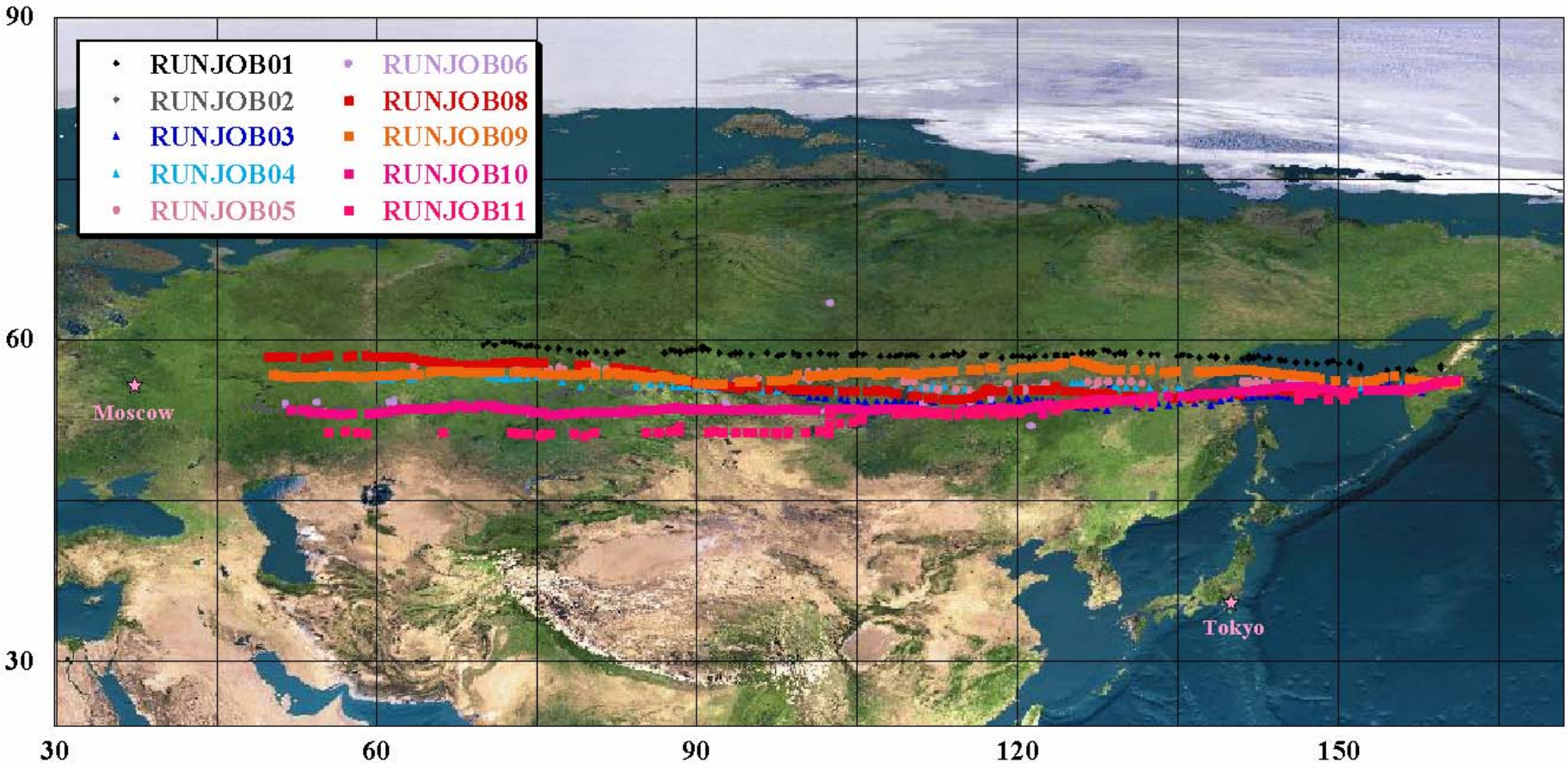


M. Hareyama OG 1.17
S. Kuramata OG 1.1.21
L.G. Sveshnikova OG 1.1.23

CR Composition and Spectra 7- 100 TeV

Performance of RUNJOB experiments

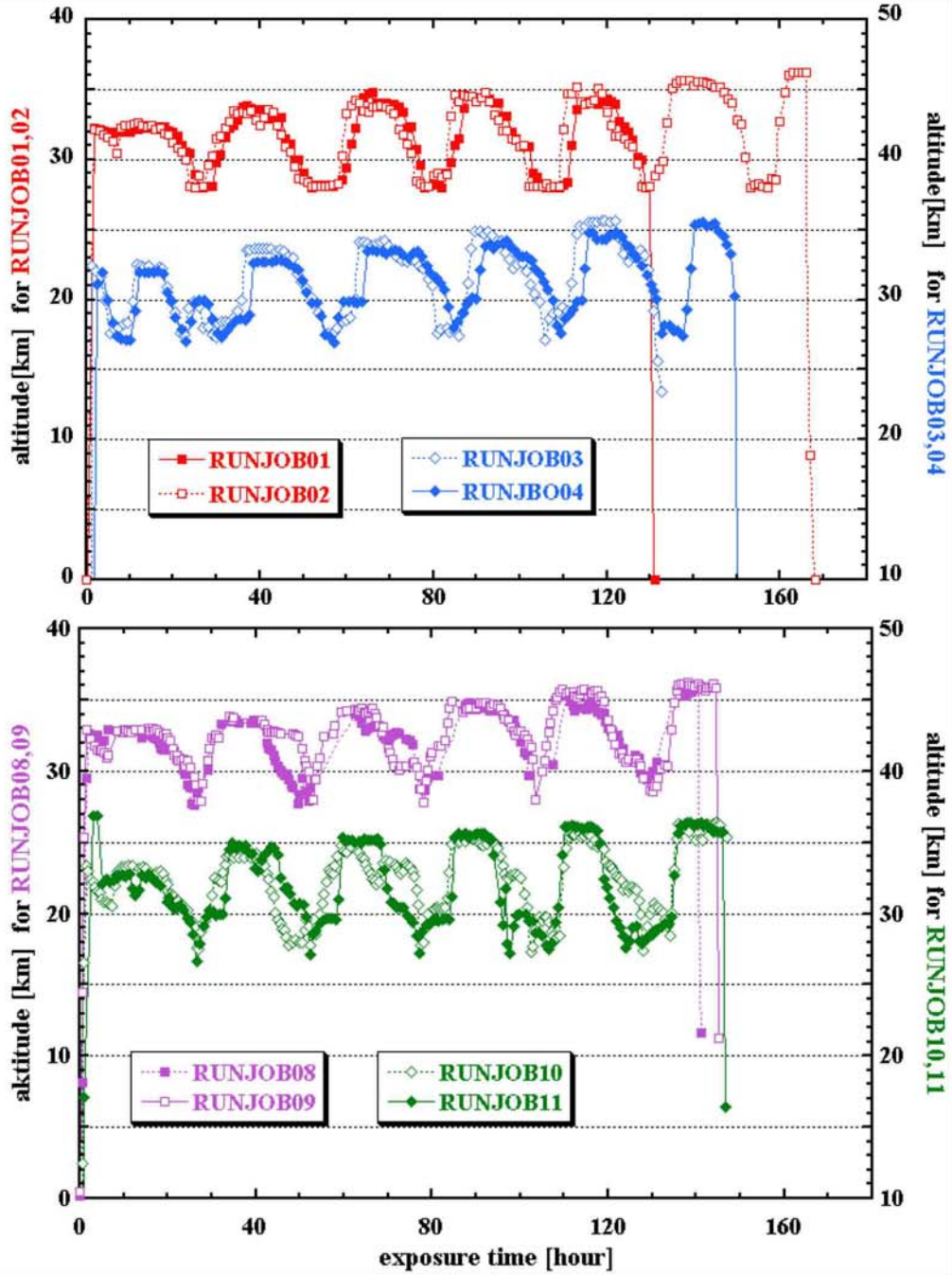



RUNJOB01
RUNJOB02
RUNJOB03
RUNJOB04
RUNJOB05
RUNJOB06
RUNJOB08
RUNJOB09
RUNJOB10
RUNJOB11
Moscow
Tokyo
90
60
30
30
60
90
120
150

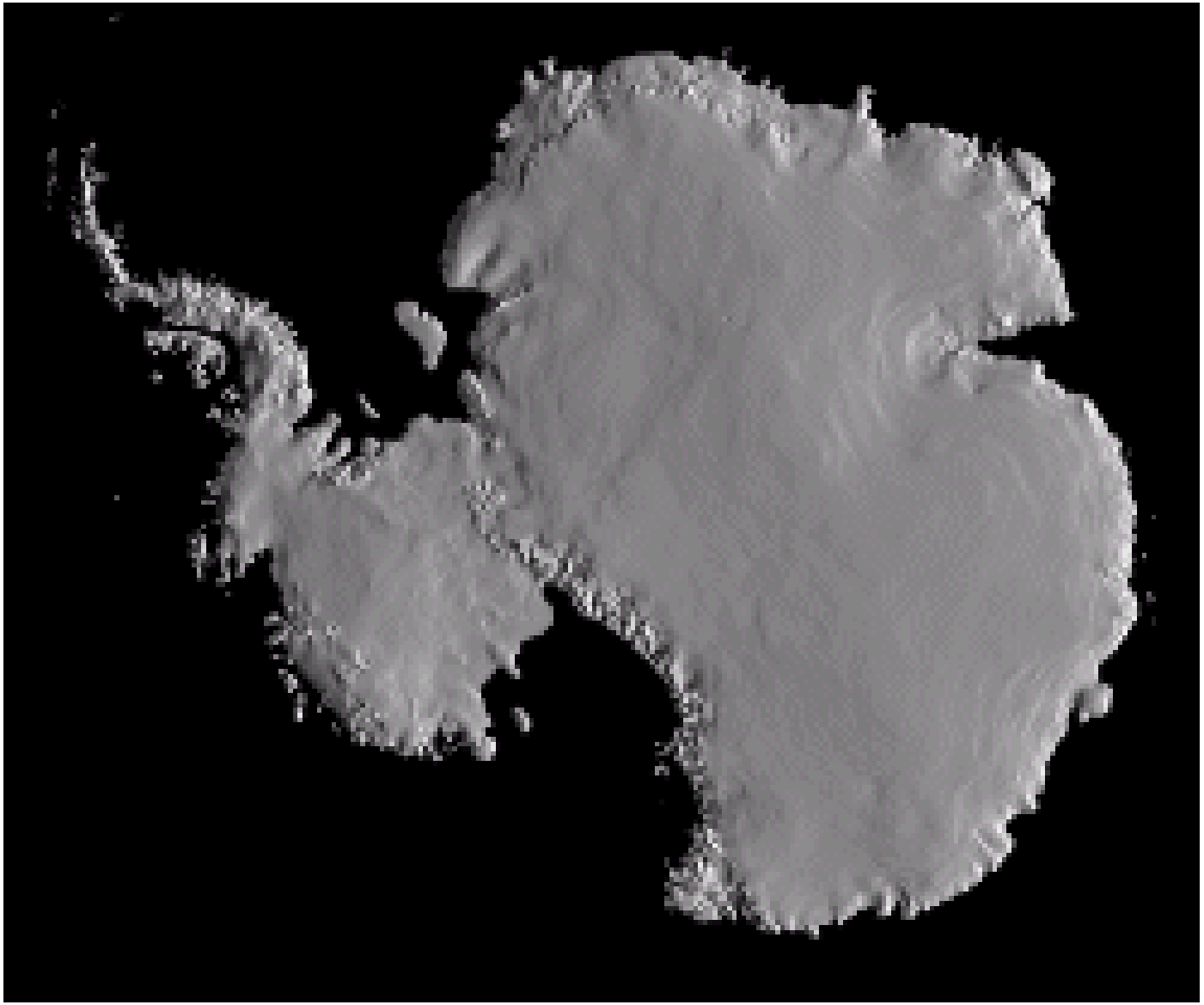
Balloon Altitude

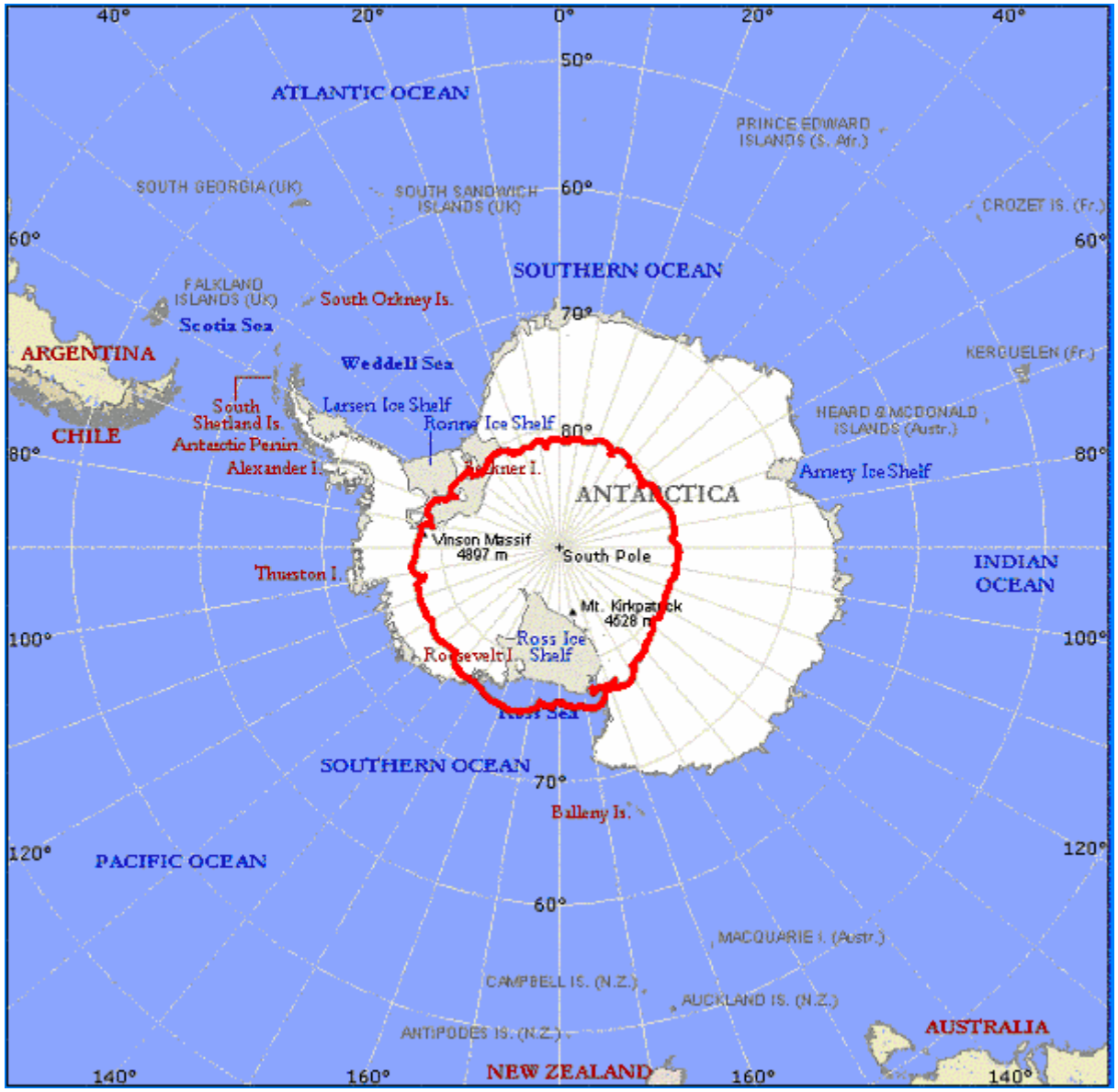
RUNJOB1,2
RUNJOB3,4
RUNJOB8,9
RUNJOB10,11

Average altitude
~ 32km
~ 10g/cm^2



L’Antartide: 24 ore di sole al giorno!!!!!



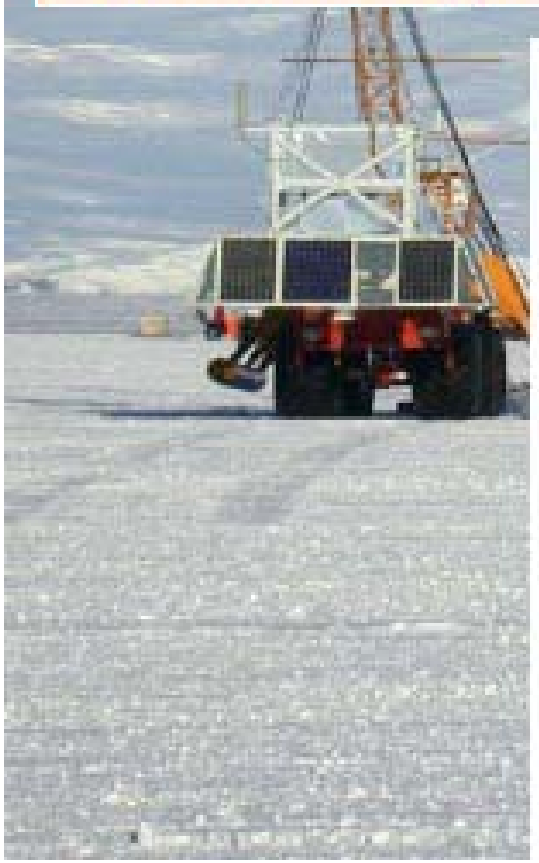

ATLANTIC OCEAN
PRINCE EDWARD ISLANDS (S. Afr.)
SOUTH GEORGIA (UK)
SOUTH SANDWICH ISLANDS (UK)
CROZET IS. (Fr.)
SOUTHERN OCEAN
FALKLAND ISLANDS (UK)
South Orkney Is.
Scotia Sea
ARGENTINA
Weddell Sea
KERGUELEN (Fr.)
South Shetland Is.
Larsen Ice Shelf
Ronne Ice Shelf
HEARD & MCDONALD ISLANDS (Austr.)
CHILE
Antarctic Penin.
Alexander I.
Bunger I.
Amery Ice Shelf
ANTARCTICA
Vinson Massif 4897 m
South Pole
INDIAN OCEAN
Thurston I.
Mt. Kirkpatrick 4528 m
Ross Ice Shelf
Roosevelt I.
Ross Sea
SOUTHERN OCEAN
Balleny Is.
PACIFIC OCEAN
MACQUARIE I. (Austr.)
CAMPBELL IS. (N.Z.)
AUCKLAND IS. (N.Z.)
ANTIPODES IS. (N.Z.)
AUSTRALIA
NEW ZEALAND
40°
20°
0°
20°
40°
50°
60°
70°
80°
100°
120°
140°
160°

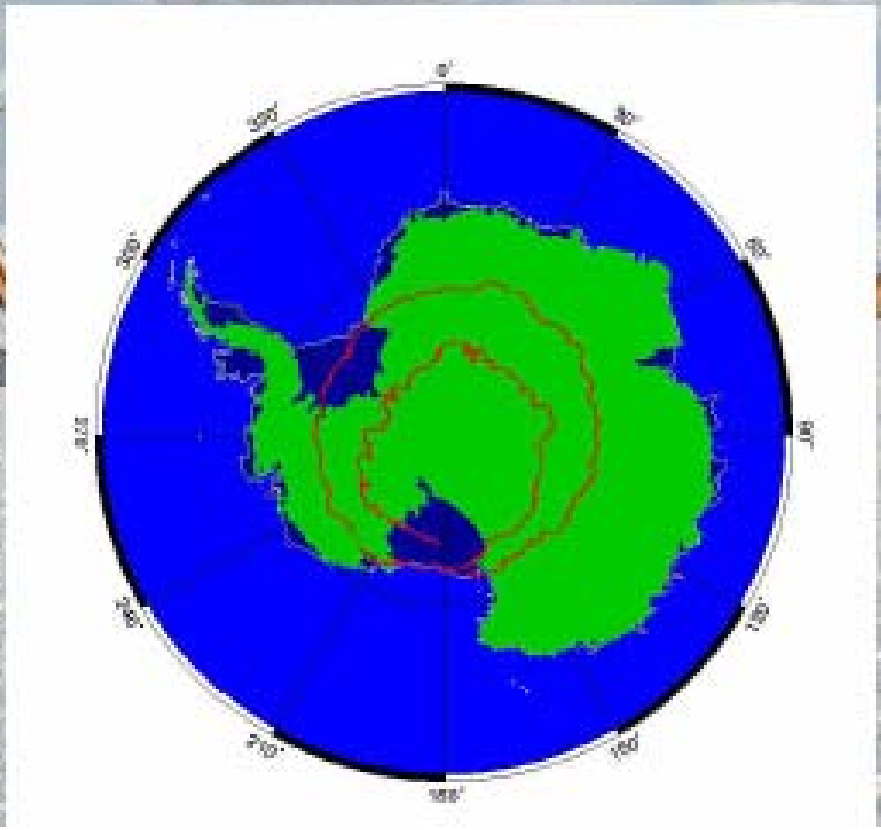
Jason T. Link OG 1.1.7

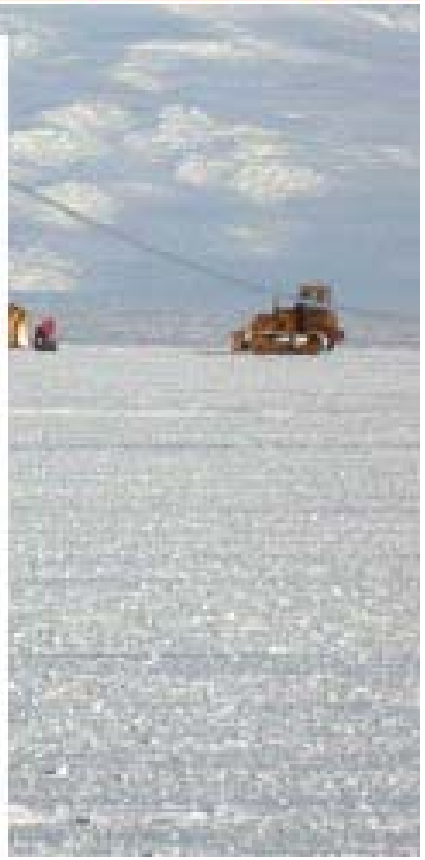
TIGER

Trans iron CR (30 < Z < 40)

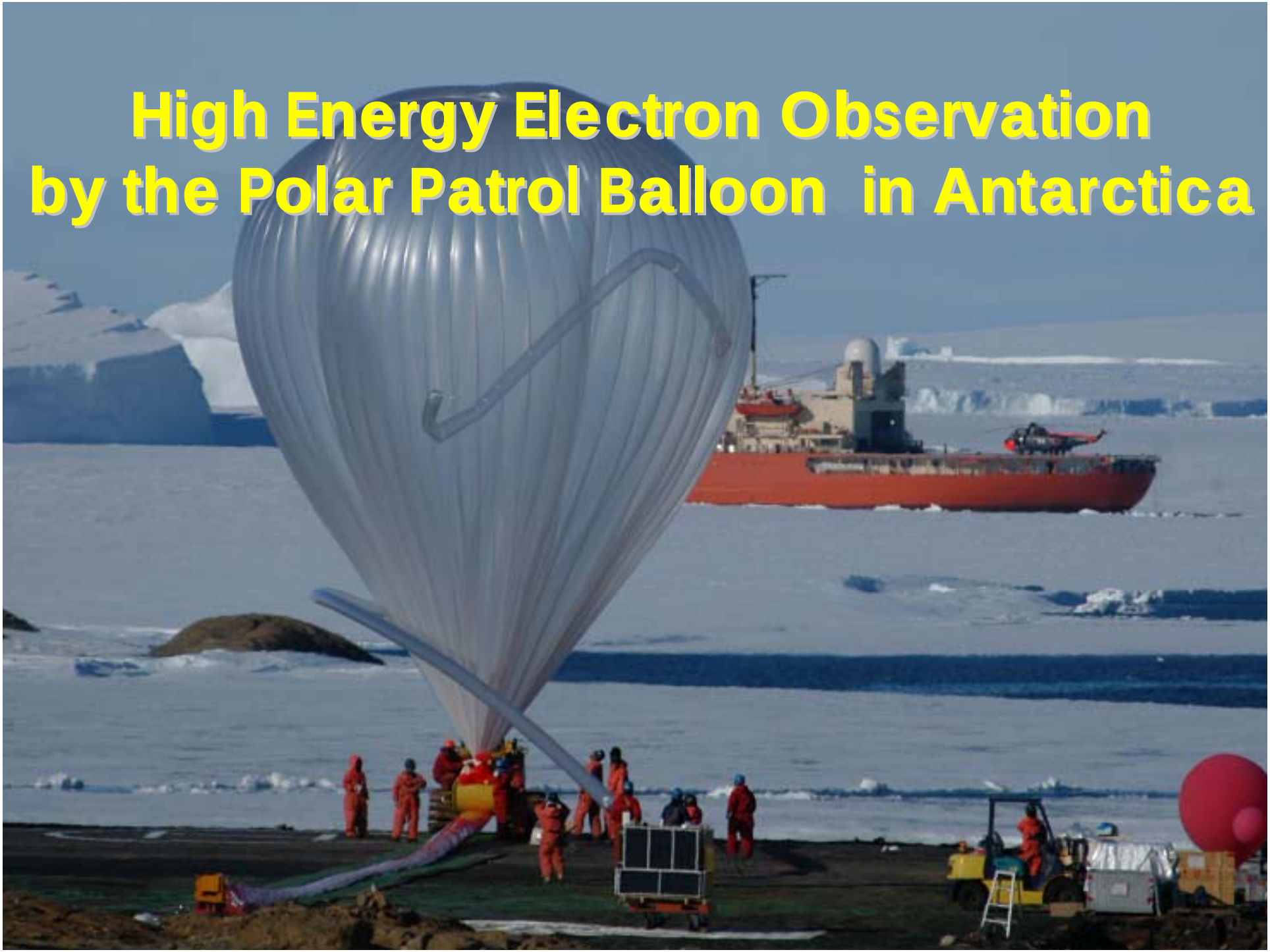
Record long duration antartica flight 31.8 days







High Energy Electron Observation by the Polar Patrol Balloon in Antarctica



Balloon Flight

- Launched at the Syowa Station, Antarctica
- Level Altitude ~34.6 km
- 13 days flight

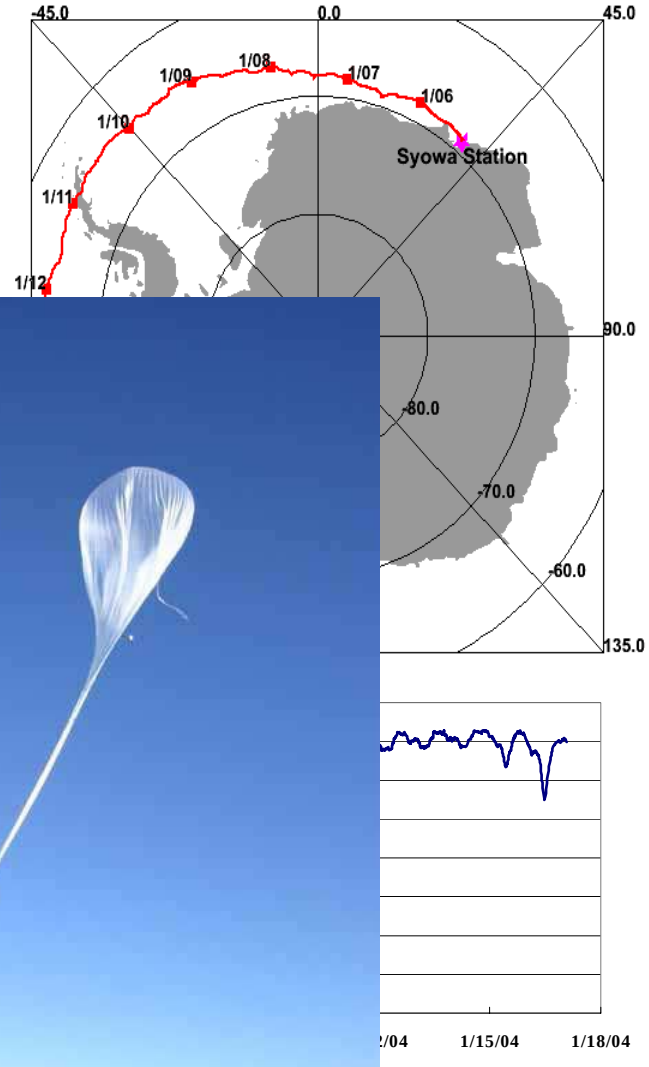
  (Jan. 4, 2004 to Jan. 17)

  HE(>100 GeV)

  5700 events, (0.02 Hz)

  LE(>10GeV)

  22000 events, (3 Hz)



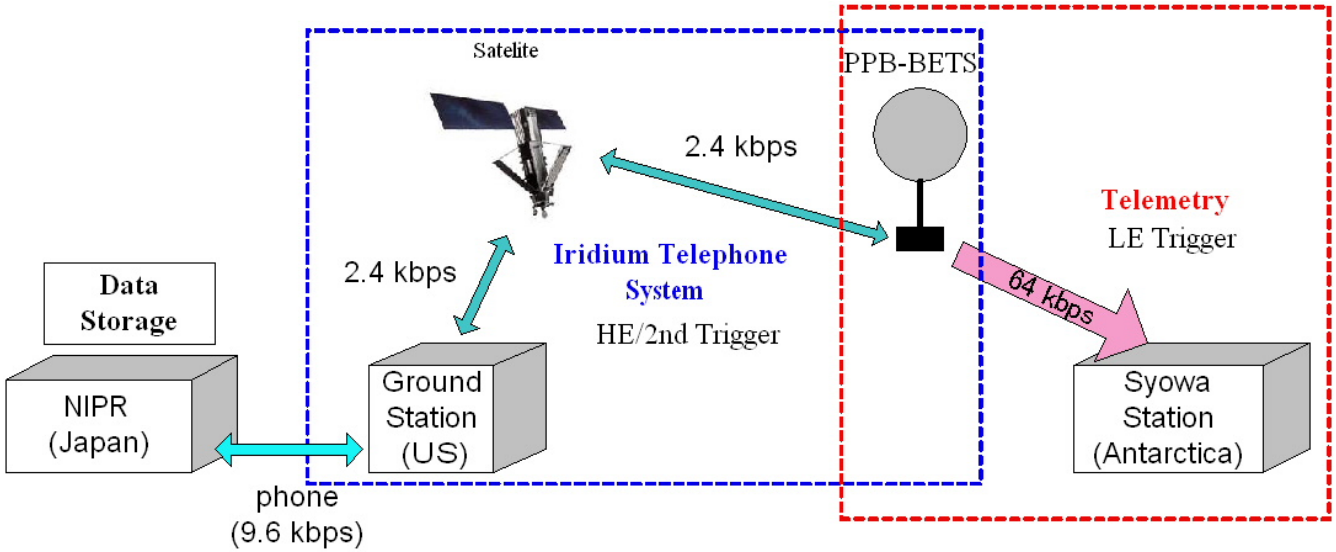
Trigger and Data Transfer System

- Low Energy (LE) Trigger
  - 10 GeV – 100 GeV
  - 10 hours from launching
- High Energy (HE) Trigger
  - 100 GeV – 1 TeV
- 2nd Trigger
  - Software trigger selected from HE

Direct telemetry to Syowa Station

Storage to on-board disk

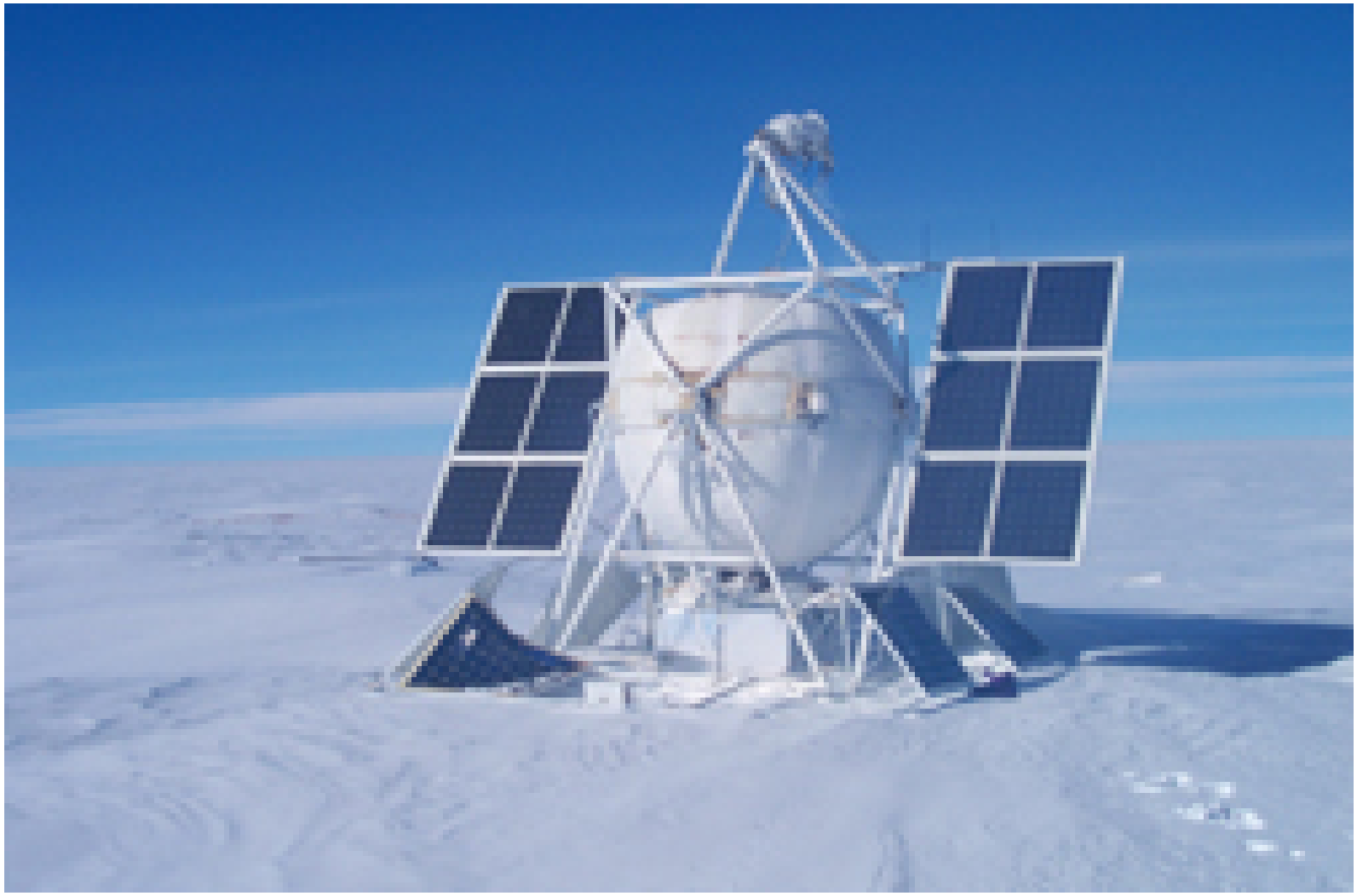
Iridium satellite telephone



la neve, il freddo…

Organizzarsi per l’Antartide..

U. S. AIR FORCE



TIGER

TRACER

Un incidente….

Sviluppo di palloni ‘chiusi’ per Ultra Long Duration Ballooning (ULDB)

ULDB Project

NASA Science Discipline Users

- Atmospheric chemistry
- Atmospheric circulation
- Sub-millimeter & infrared astronomy
- Ultraviolet & optical astronomy (λ>1900 Å)
- High-energy X-ray astrophysics
- Gamma-ray astronomy
- Cosmic ray astrophysics
- Cosmic dust
- Test platforms

ULDB Project

Who Uses Balloons?

- **NASA**
  - Atmospheric
  - Astronomy
  - Astrophysics
- **NOAA**
  - Atmospheric
- **DoD**
  - Surveillance
  - Weapons systems
- **Commercial**
  - Telecommunications
  - Advertising

ULDB Project

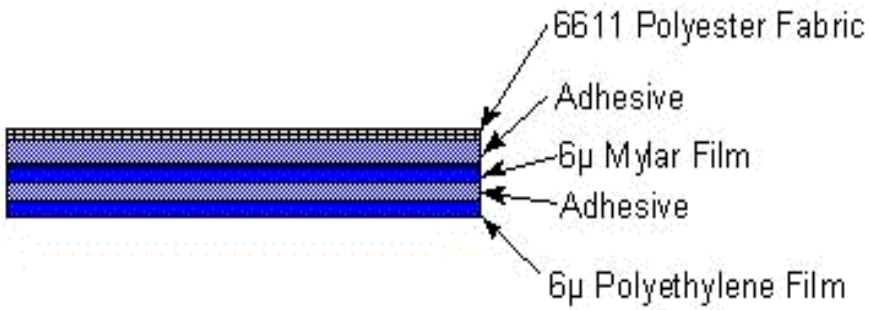
Balloon Design Requirements

- Duration up to 100 days
- Global flight capability
- Total suspended mass of 1600 kg
- Minimum float altitude of 33.5 km

The Balloon is the major technical challenge

Balloon Material

- **Composite material (62 g/m^2 approximately)**
  - Polyester fabric (30 g/m^2)
    - Yarn denier 30g/9000m (warp and fill)
    - Yarn tenacity 6.1g/denier (warp and fill)
    - Yarns per meter 4724/m (warp) and 4252/m (fill)
  - Polyester film (8.8 g/m^2 , 6x10^{-6} m thick)
  - Polyethylene film (5.8 g/m^2 , 6x10^{-6} m thick)
  - Two adhesive layers
- **Strength requirement - 600 N/m**



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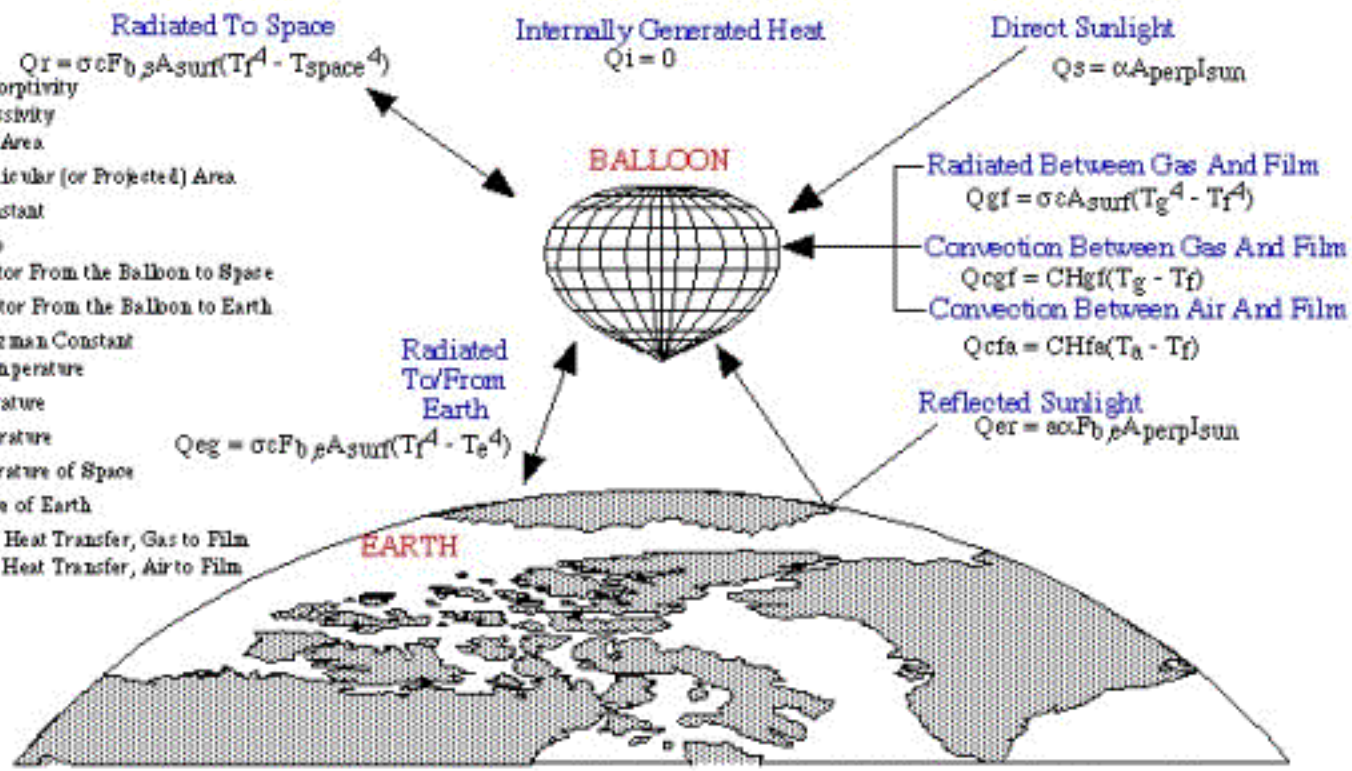
BALLOON IS A THERMAL VEHICLE

ENERGY BALANCE

$$Q_{Sun} + Q_{Reflected\ Sunlight} + Q_{Internal\ Energy} + Q_{Convection\ Gas\ to\ Film} + Q_{Convection\ Air\ to\ Film} = Q_{Radiated\ to\ Earth} + Q_{Radiated\ to\ Space} + Q_{Radiated\ Gas\ to\ Film}$$



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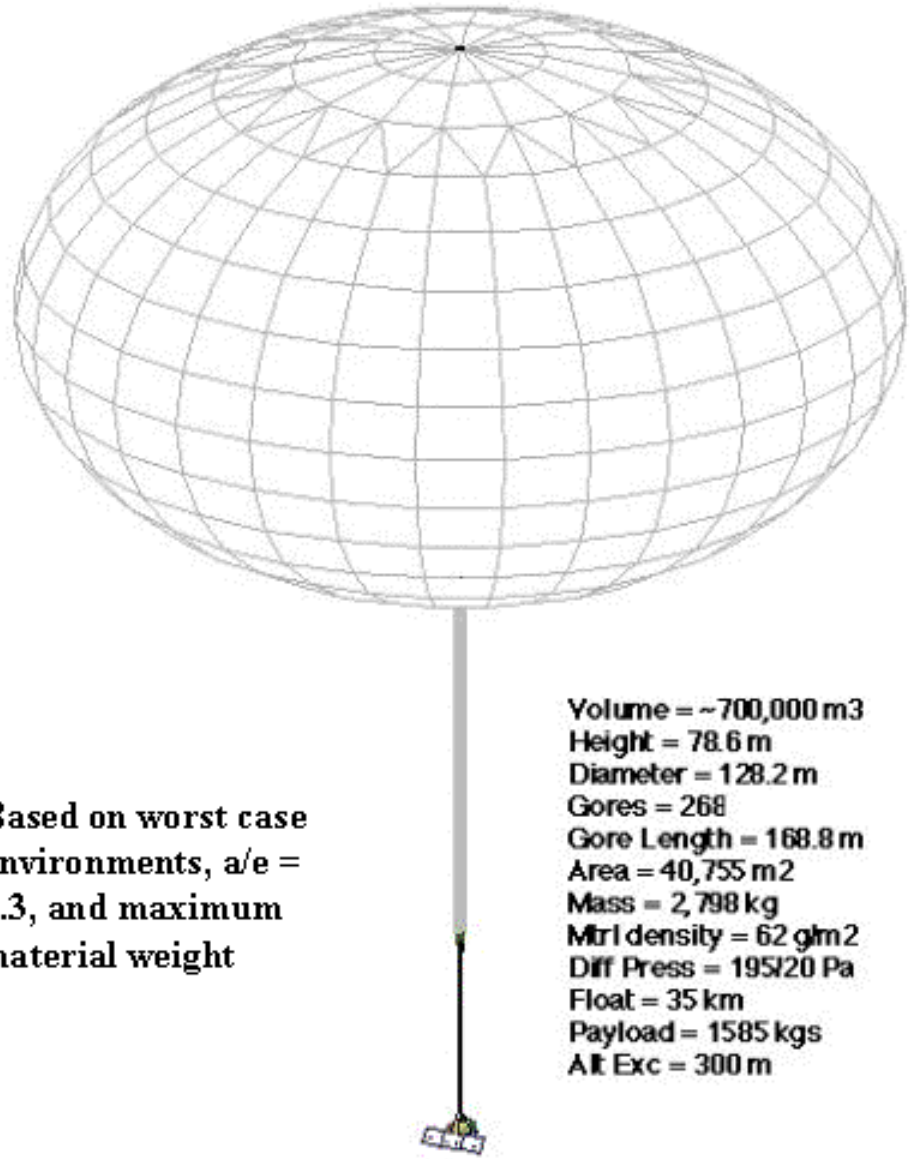
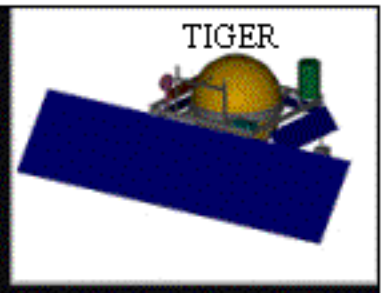


Volume = ~700,000 m3
Height = 78.6 m
Diameter = 128.2 m
Gores = 268
Gore Length = 168.8 m
Area = 40,755 m2
Mass = 2,798 kg
Mtrl density = 62 g/m2
Diff Press = 195/20 Pa
Float = 35 km
Payload = 1585 kgs
Alt Exc = 300 m

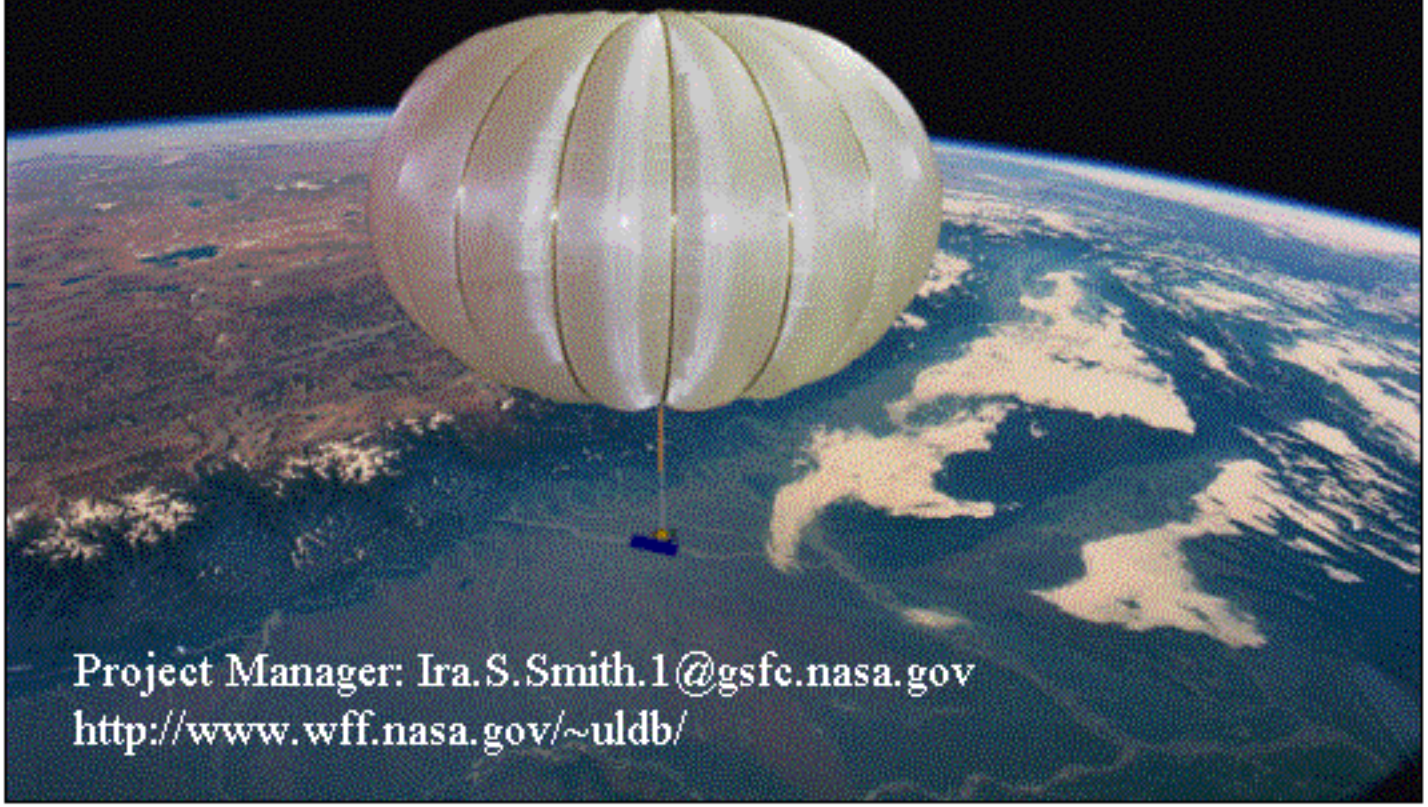
Based on worst case environments, a/e = 0.3, and maximum material weight

ULDB Project

Ultra-Long Duration Balloon Project



Trans-Iron Galactic Element Recorder



Project Manager: Ira.S.Smith.1@gsfc.nasa.gov
http://www.wff.nasa.gov/~uldb/

Fly Where?

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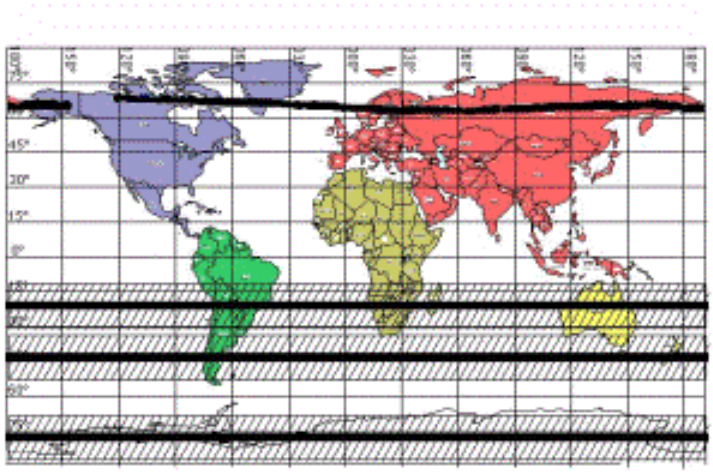

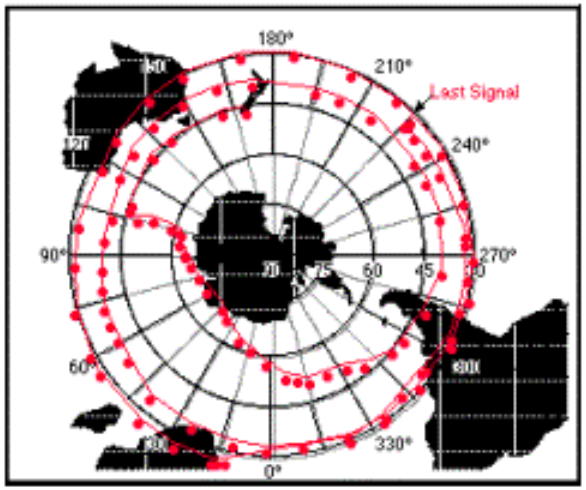

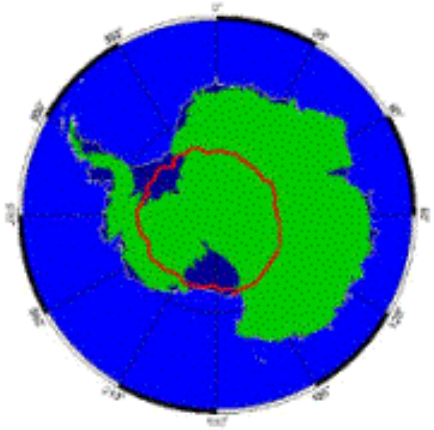

Balloon Payloads: How Large?

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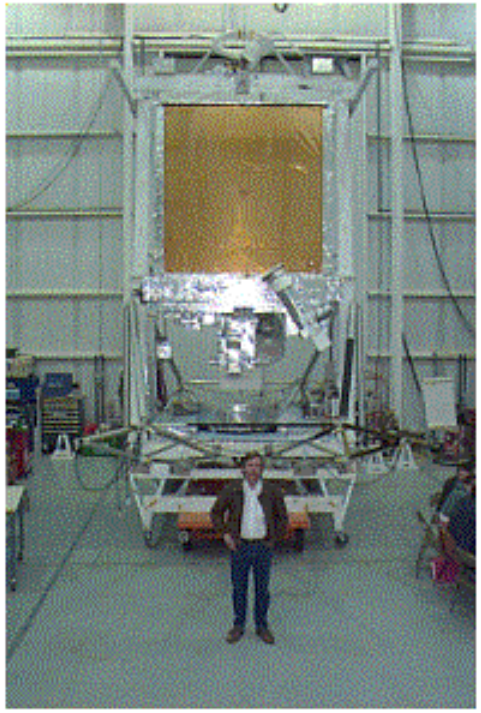
Gamma-ray: HIREGS

Solar Physics: Flare Genesis



Infra-Red: PRONAOS

CMB: Boomerang

Vehicle & Recovery Systems

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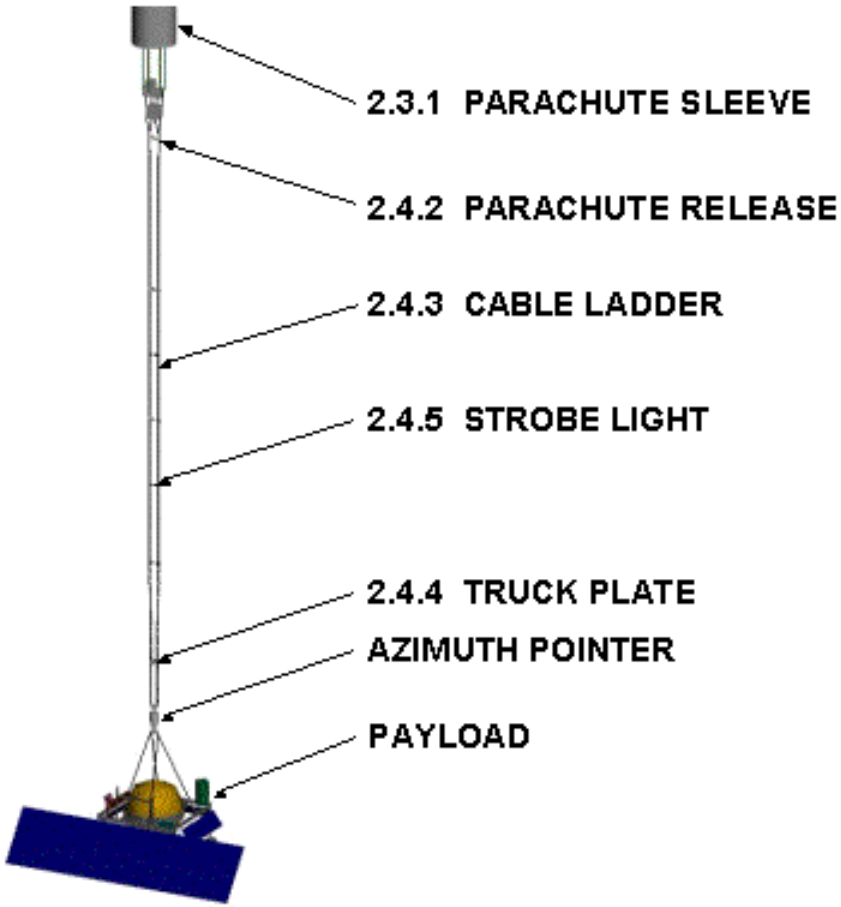

PV Array Structure & Deployment

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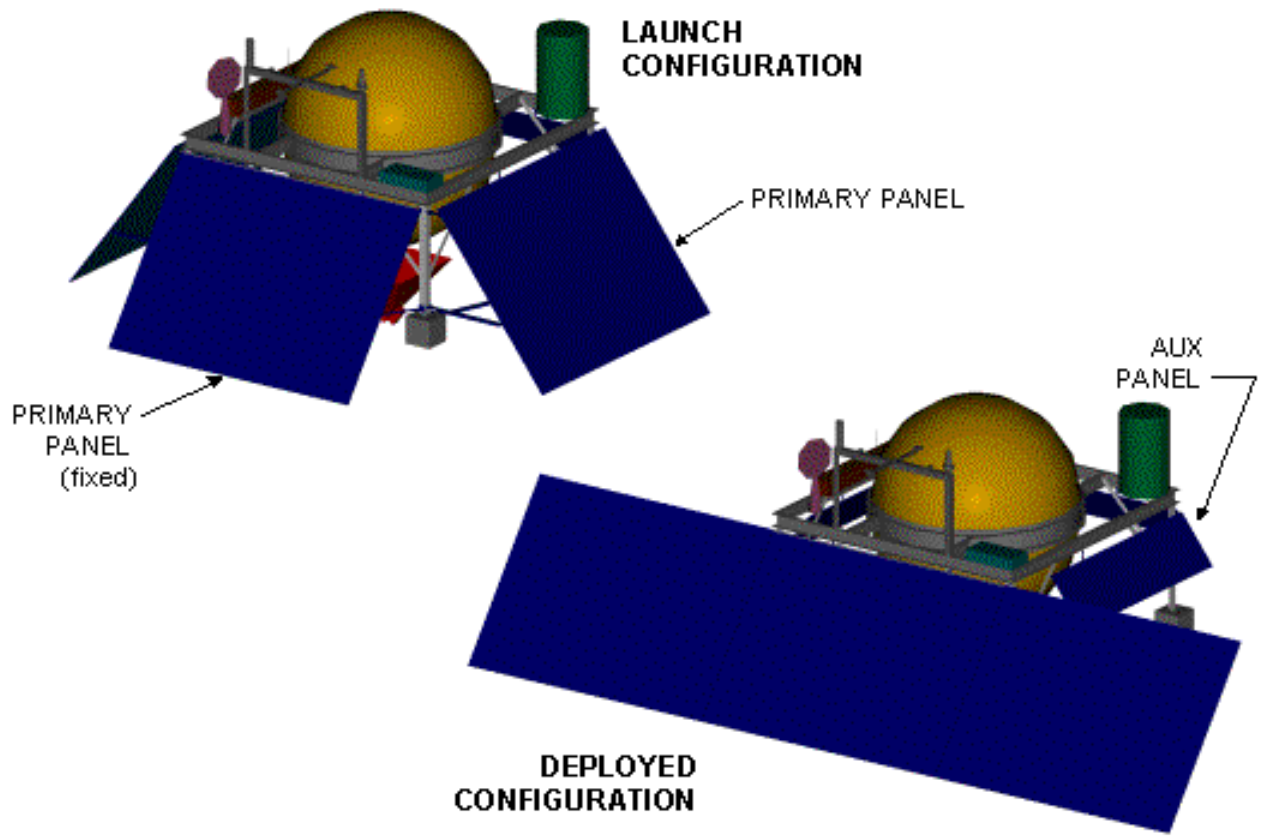
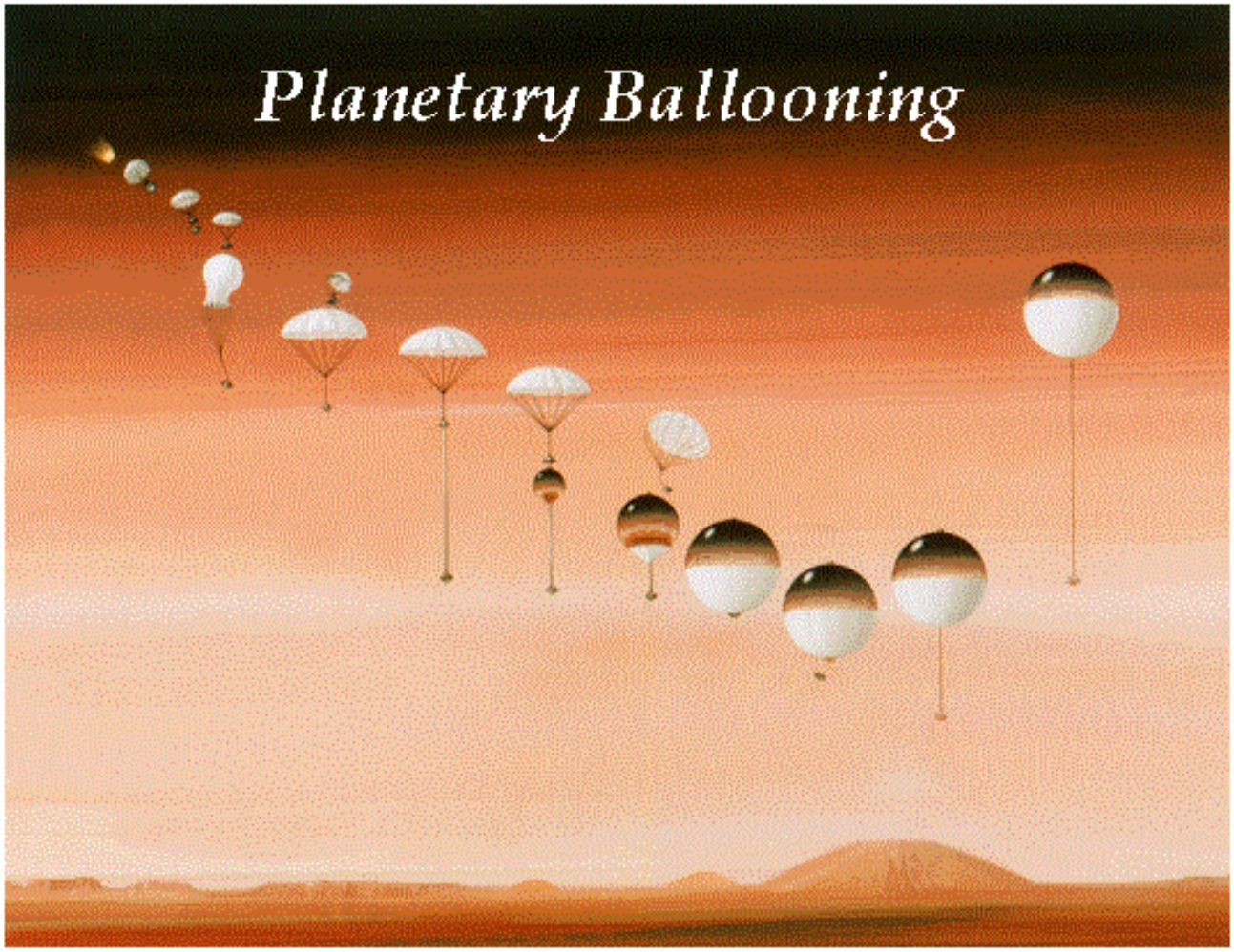


Beyond 2000 Concepts

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