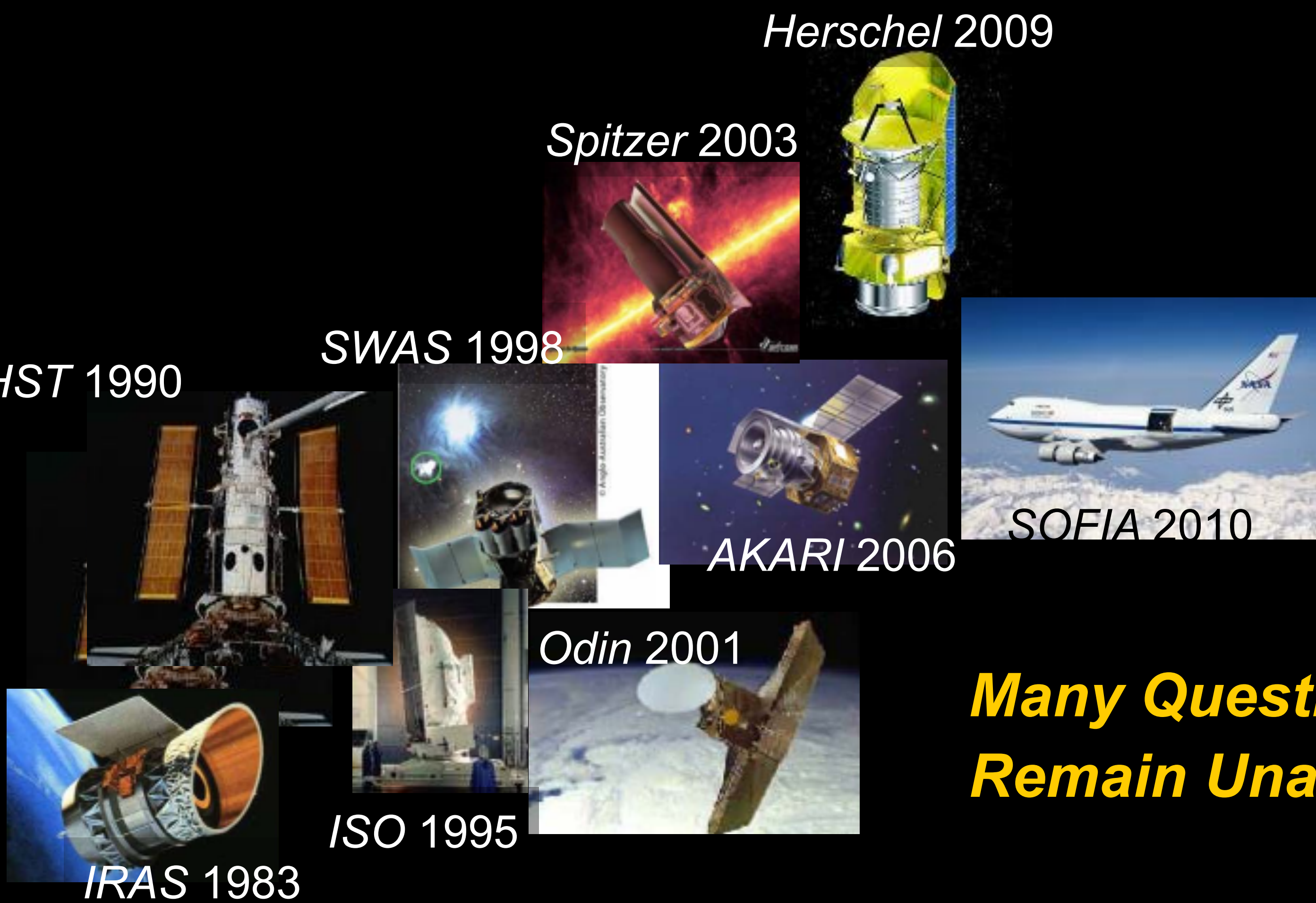
Far-IR Astronomy from *Near Space*

We live in a Galaxy comprised of stars, planets, and people.

Where did it all come from?

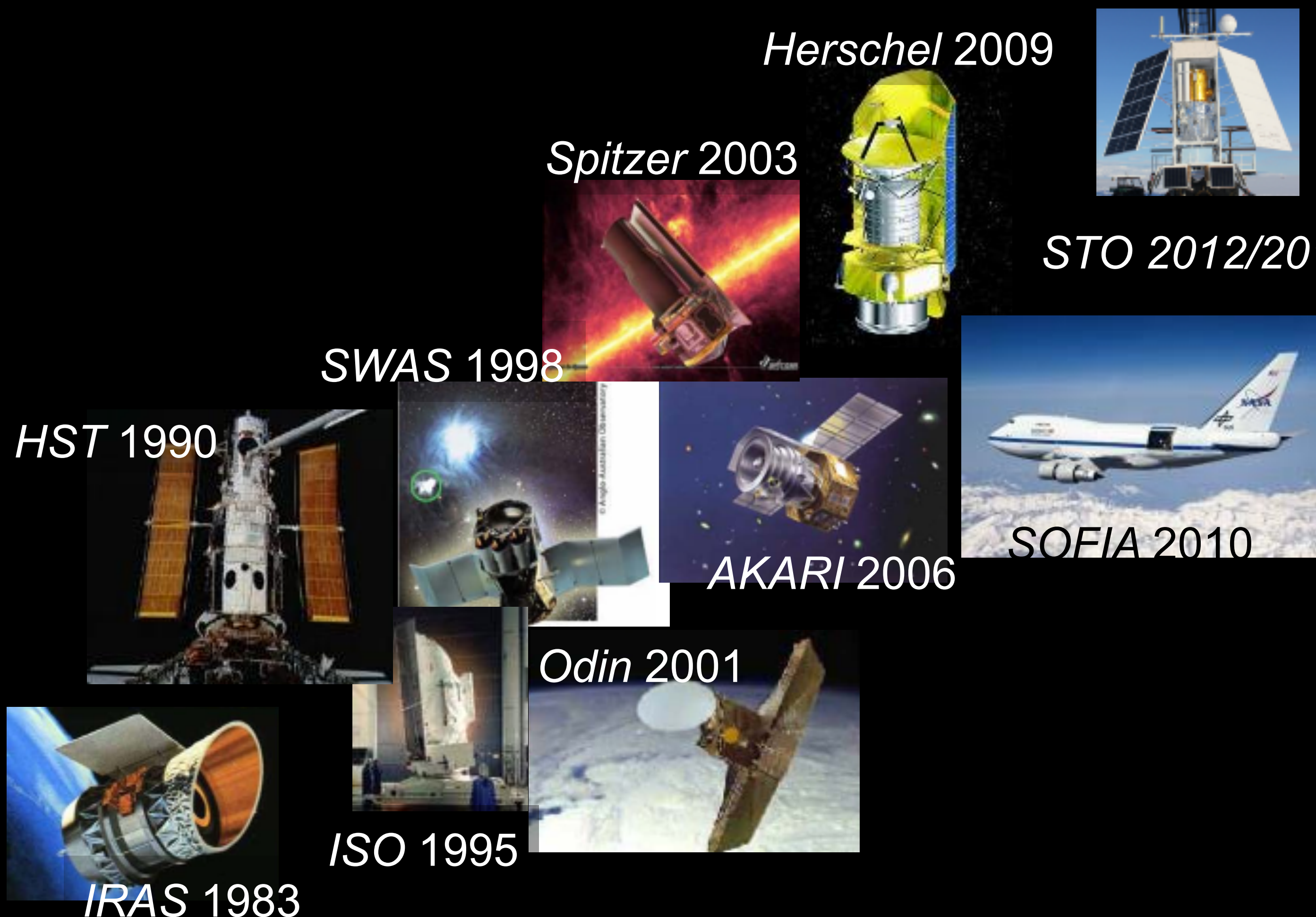
C. K. Walker

IR/THz Missions



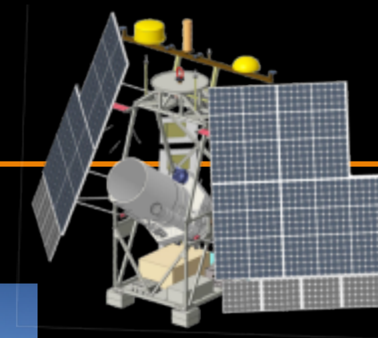
Many Questions Remain Unanswered

IR/THz Missions



IR/THz Missions

GUSTO **is** ***the Next Step!***



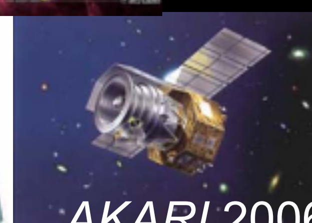
GUSTO 2020

STO 2012/2016

Herschel 2009

Spitzer 2003

SOFIA 2010



AKARI 2006

SWAS 1998

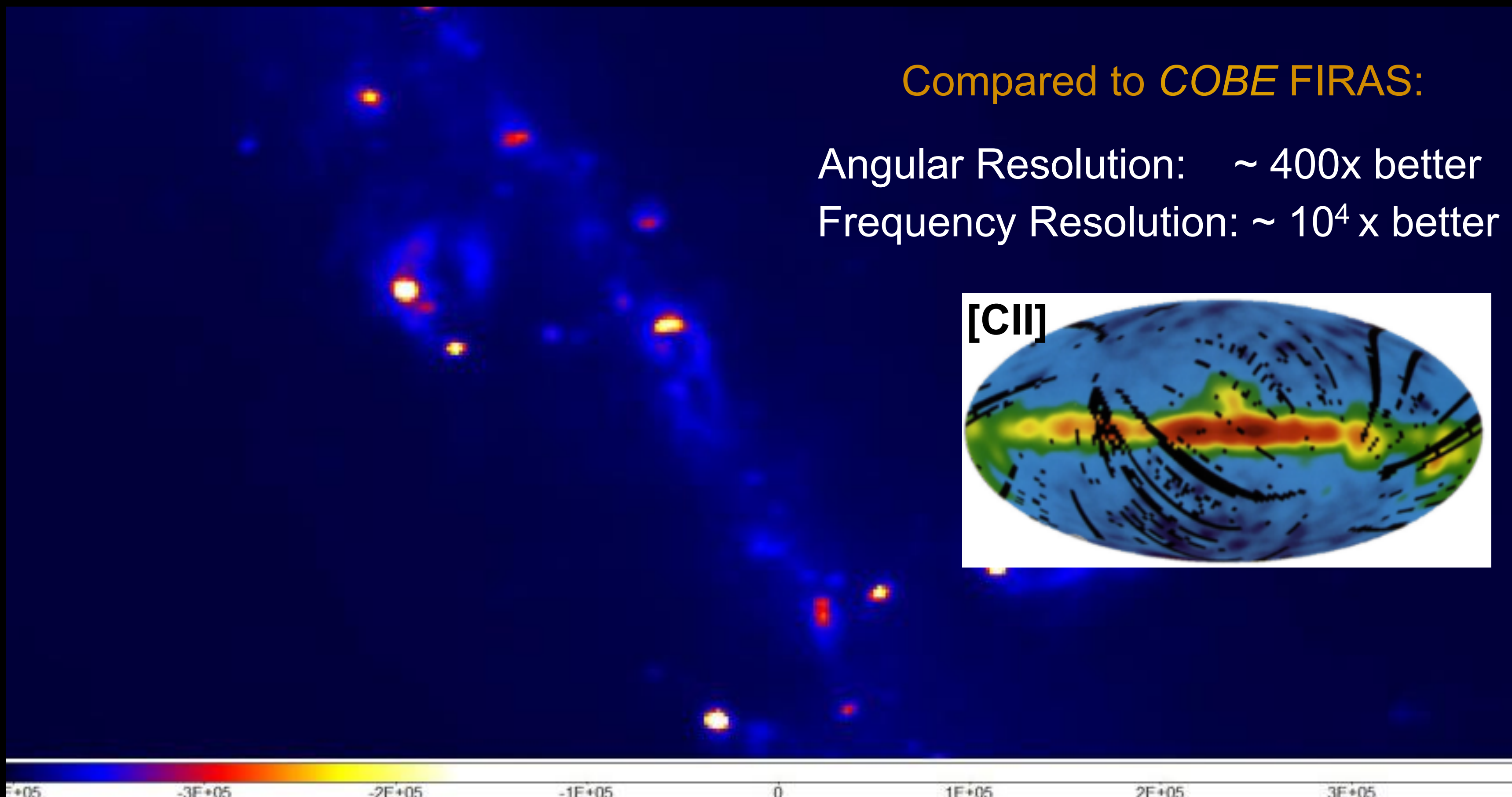
HST 1990

ISO 1995

Odin 2001

IRAS 1983

GUSTO Vastly Improves Available Angular & Spectral Resolution



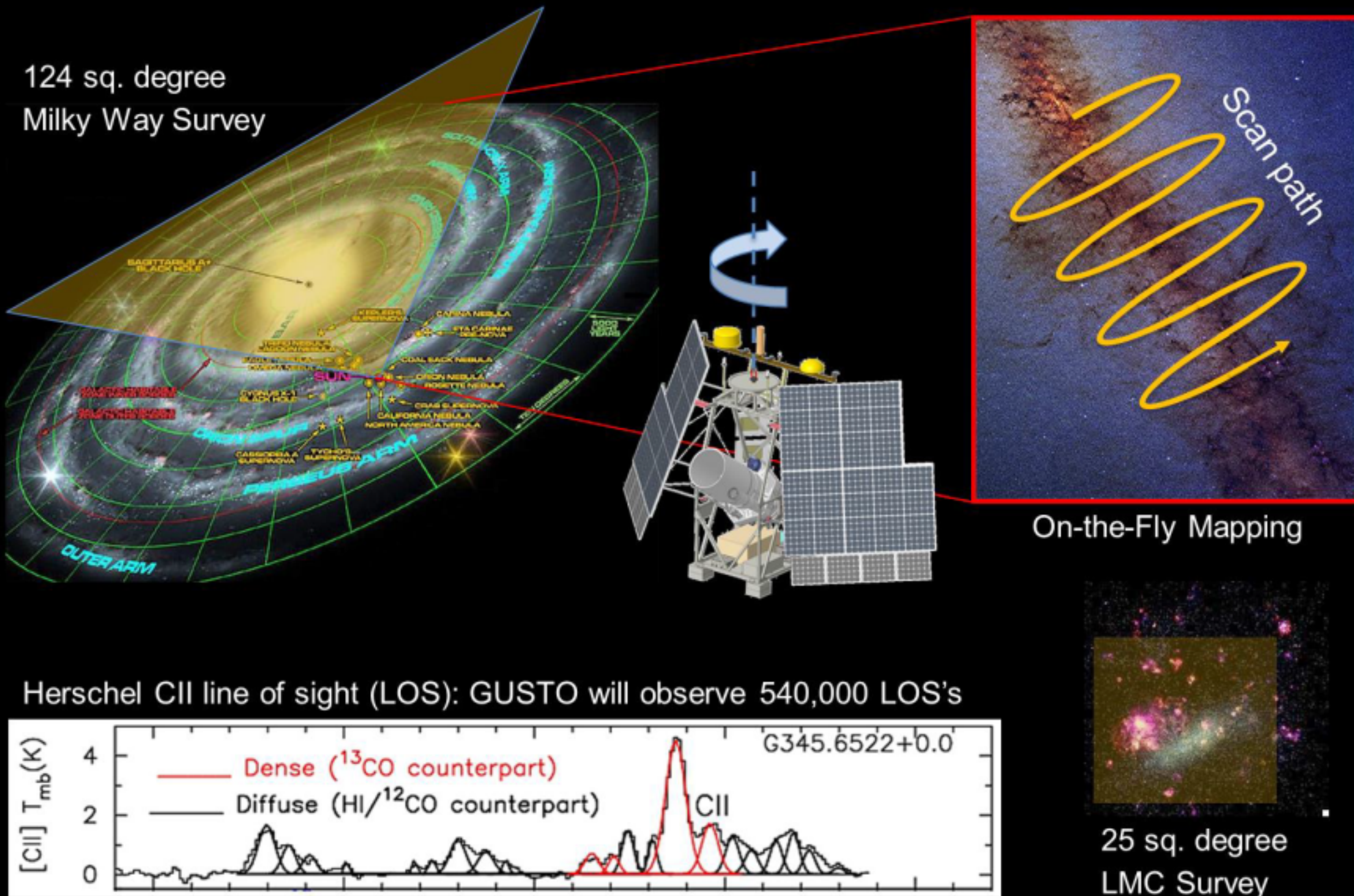
Compared to *COBE* FIRAS:

Angular Resolution: ~ 400x better

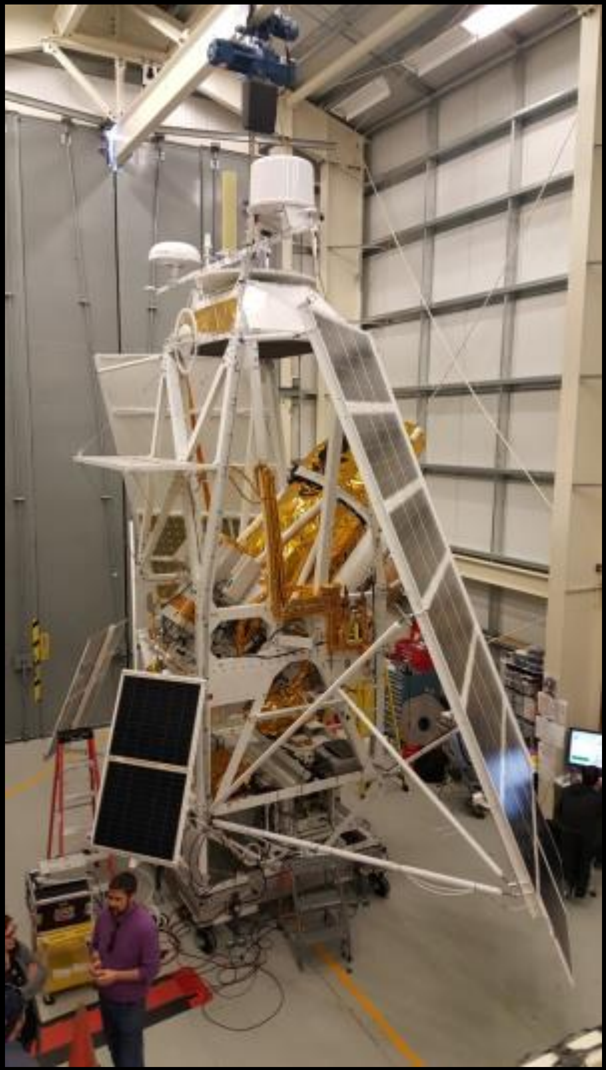
Frequency Resolution: ~ 10^4 x better

Galactic Plane Region Near **l** = 340 IRAS 60 μm: 2’ Resolution

GUSTO Observational Objectives: [CII], [OI], & [NII] Surveys of MW and LMC

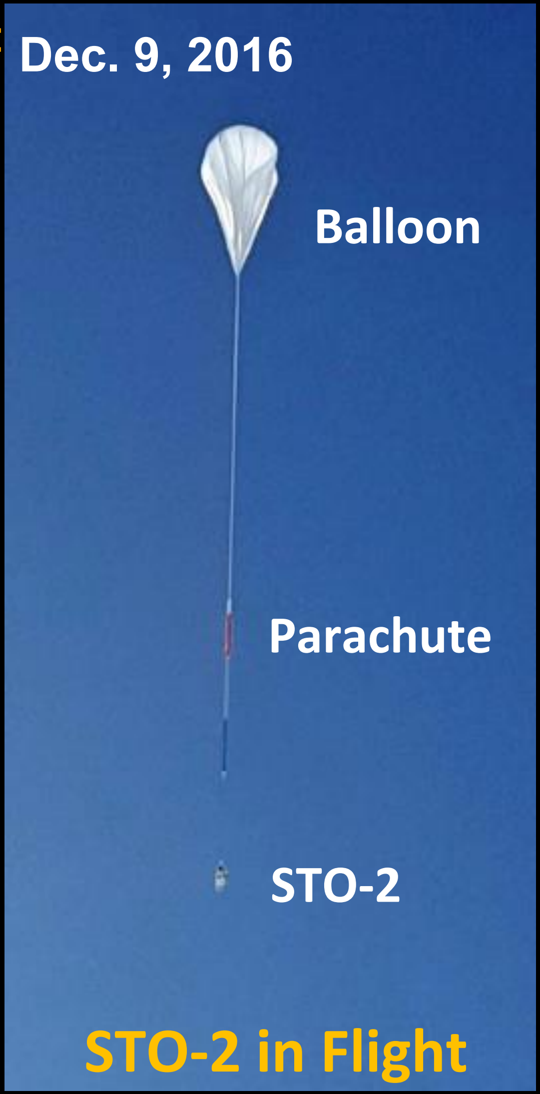


Stratospheric Terahertz Observatory (STO): ***Pathfinder*** for *GUSTO*



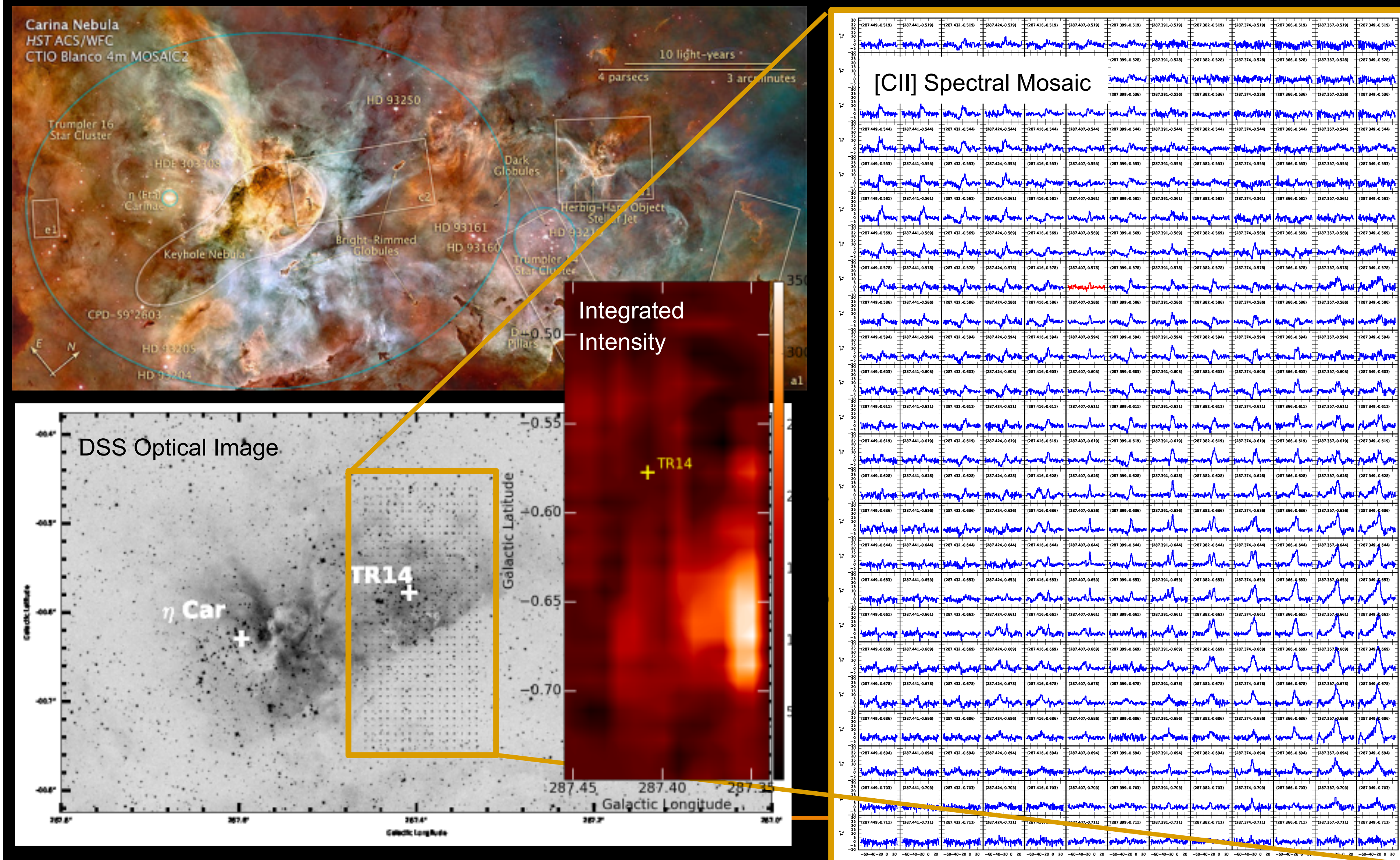
STO provides GUSTO experience:

- Teaming arrangements
- Gondola and instrument architecture
- Observing profile and mission plan
- Data product management



STO-2 Launch 12/9/16

STO-2 [CII] On-the-Fly Map of Carina Nebula
(Site Visit)

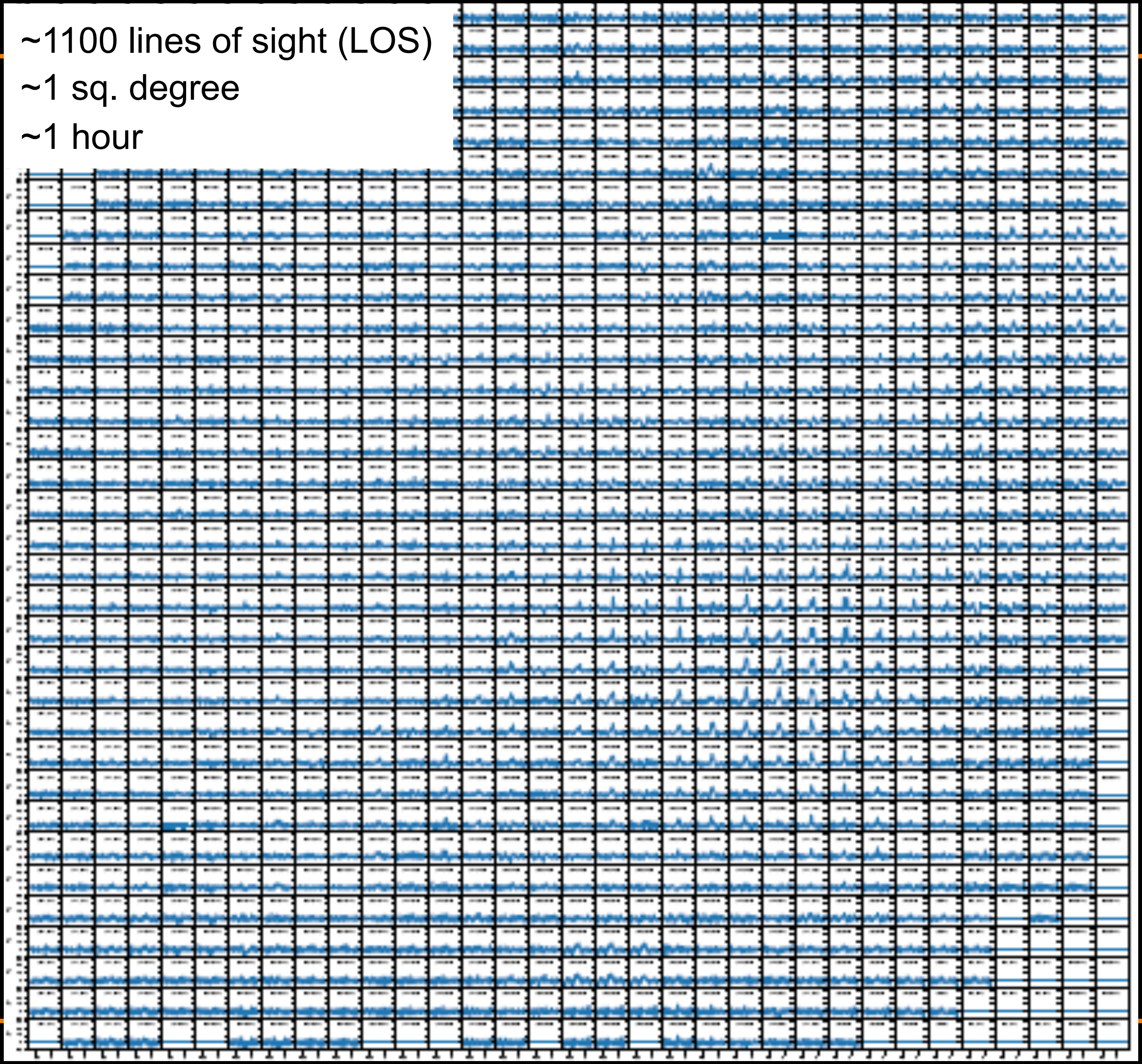


STO-2 [CII] On-the-Fly Map of Carina Nebula

~1100 lines of sight (LOS)

~1 sq. degree

~1 hour



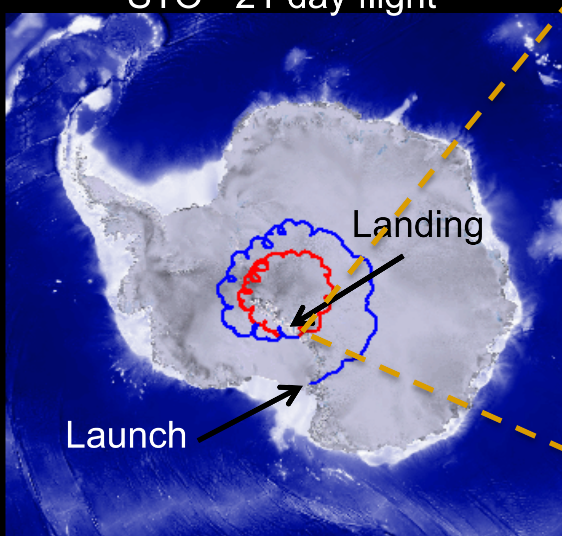
Coming Down….Payload on the Parachute

NASA's New ULDB: A "Satellite on a String"

- The ULDB enables orbital-quality observations at a fraction of the cost.
- High constant altitude, long-duration flights of 100 days or more, large payload capacity, and likely payload recovery establish a **new paradigm** for low-cost, high value scientific observations.

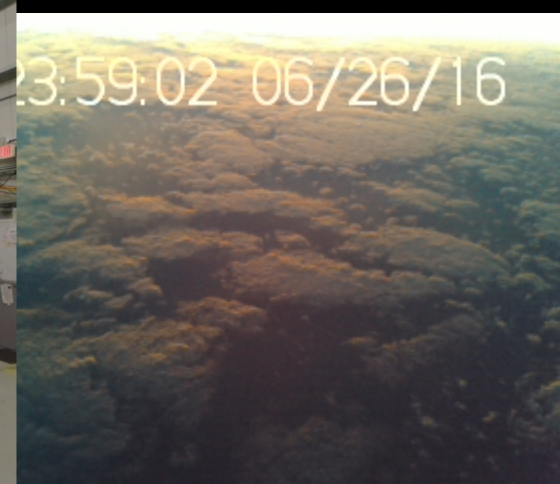
SPB Test Flight, Kiruna, Sweden

STO ~21 day flight

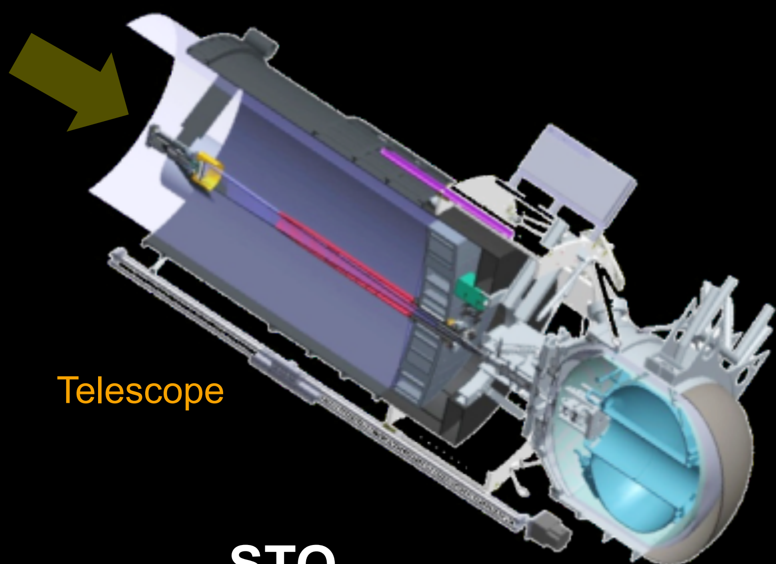


S

SPB View of Earth



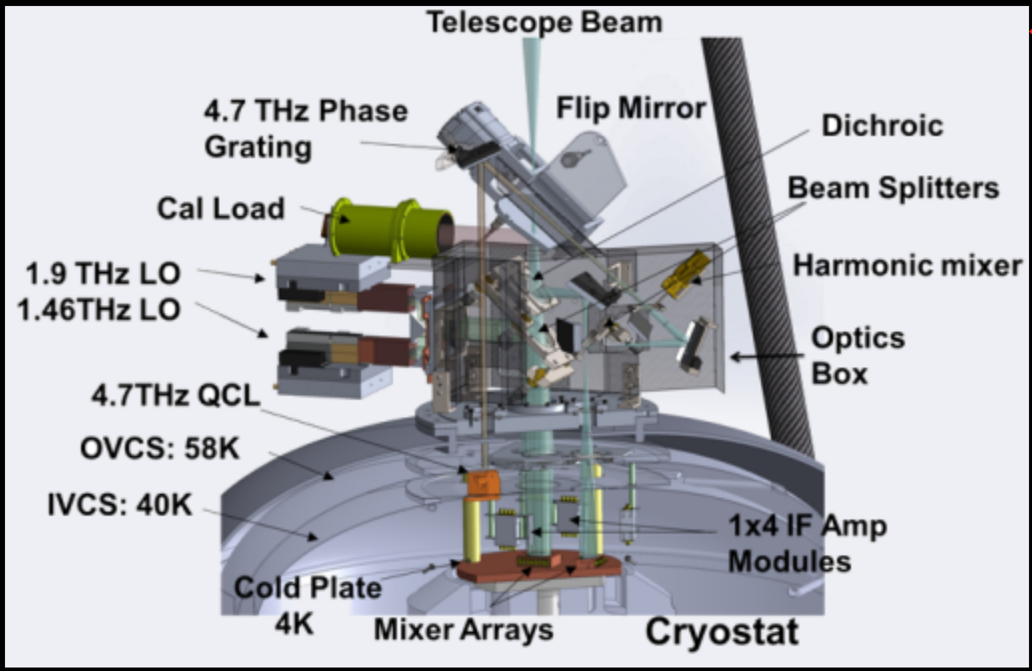
Implementation: Advancing from STO to GUSTO

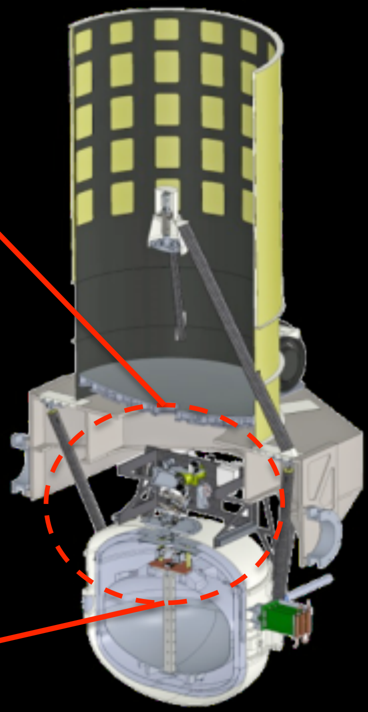


GUSTO will be a mapping machine

- Optimized, light-weight, low-CTE, terahertz telescope
- 4 x Larger focal plane receiver arrays; adding [OI] capability
- Mapping-optimized observing profile and mission plan
- Optimized for ULDB: 5 x Longer Flight

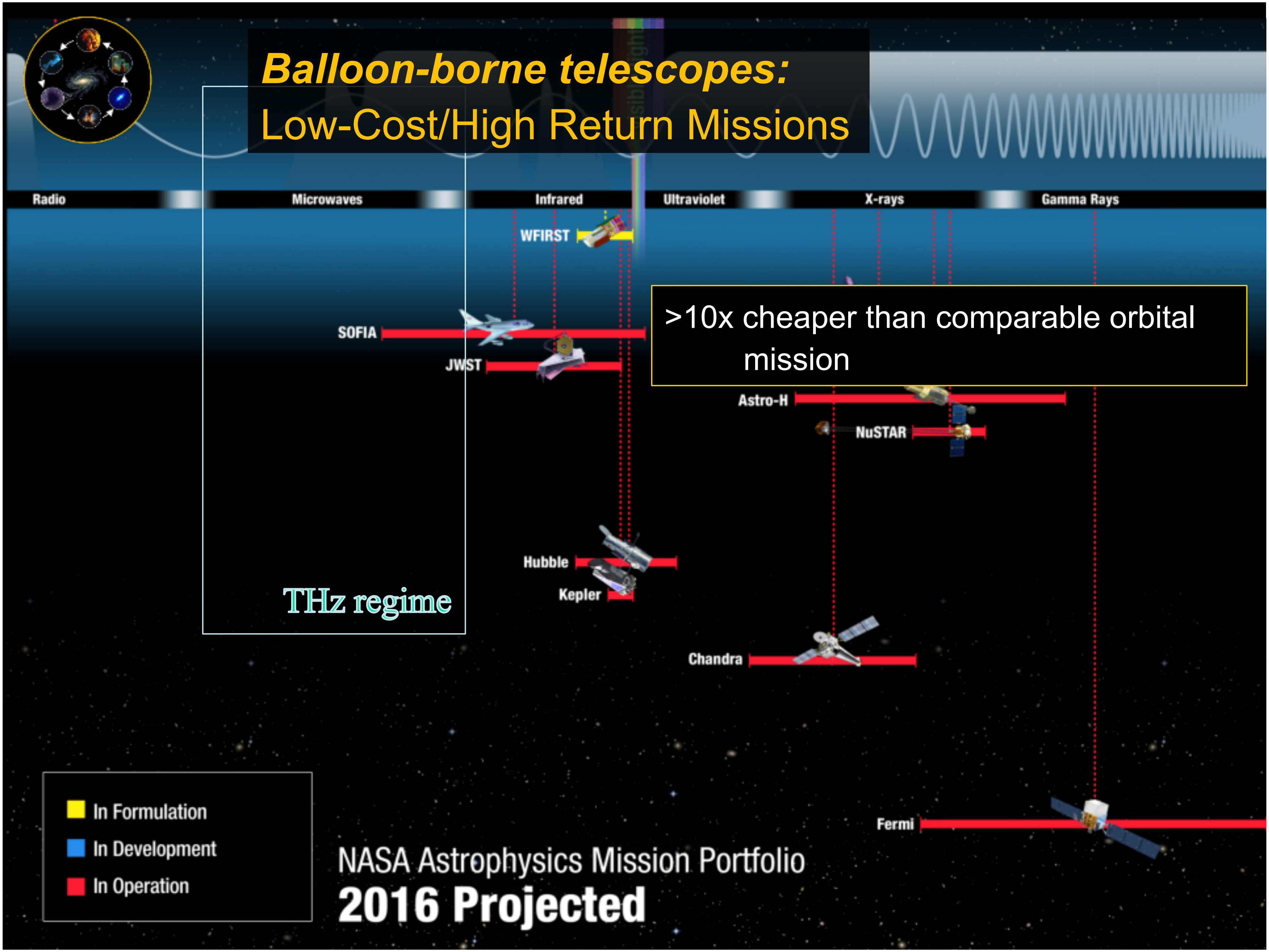
Implementation: Advancing from STO to GUSTO



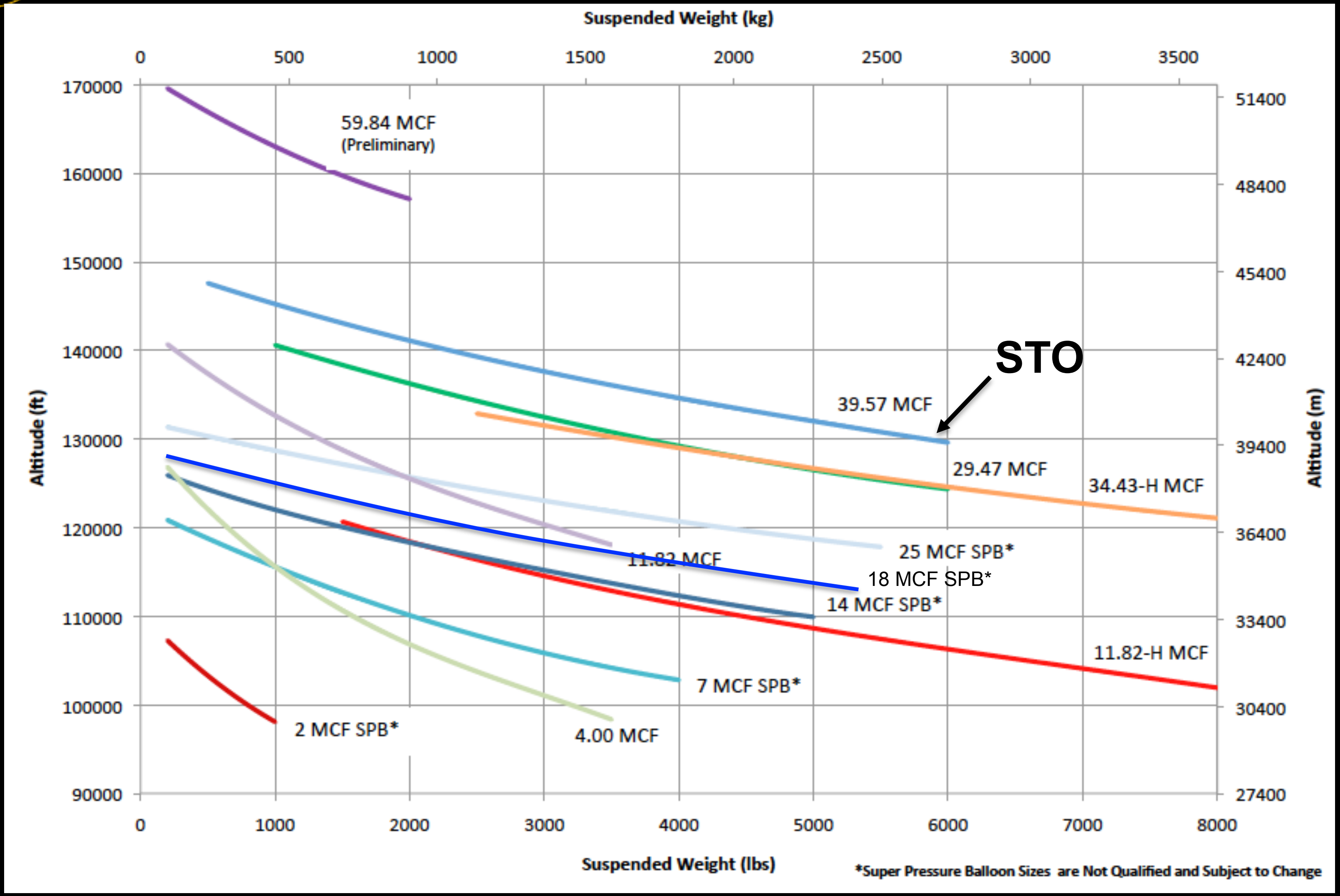


GUSTO **will be a mapping machine**

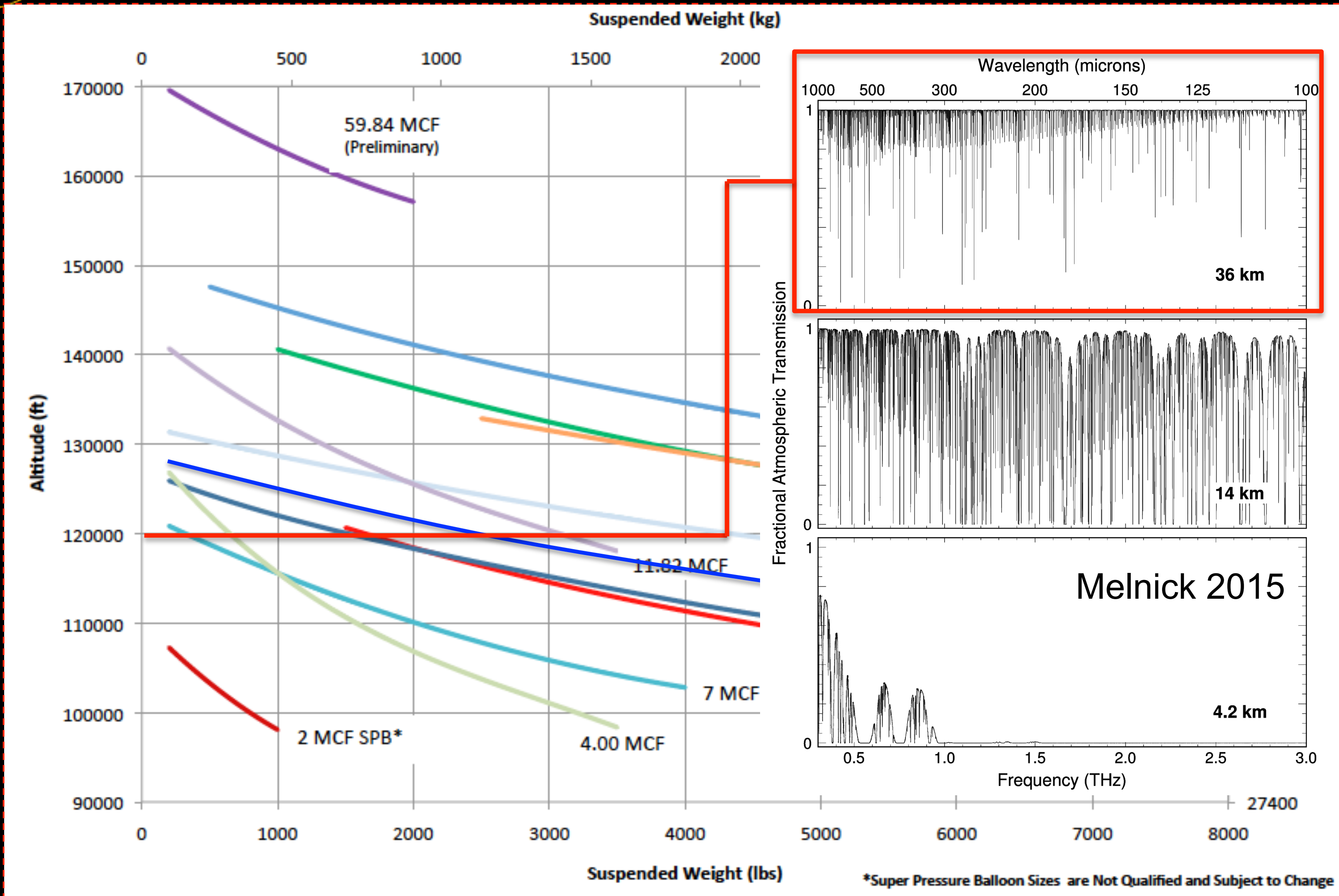
- Optimized, light-weight, low-CTE telescope, THz telescope
- 4 x Larger focal plane receiver arrays; adding [OI] capability
- Mapping-optimized observing profile and mission plan
- Optimized for ULDB: 5 x Longer Flight


Balloon-borne telescopes:
Low-Cost/High Return Missions
Radio
Microwaves
Infrared
Ultraviolet
X-rays
Gamma Rays
WFIRST
>10x cheaper than comparable orbital mission
SOFIA
JWST
Astro-H
NuSTAR
Hubble
Kepler
THz regime
Chandra
Fermi
In Formulation
In Development
In Operation
NASA Astrophysics Mission Portfolio
2016 Projected

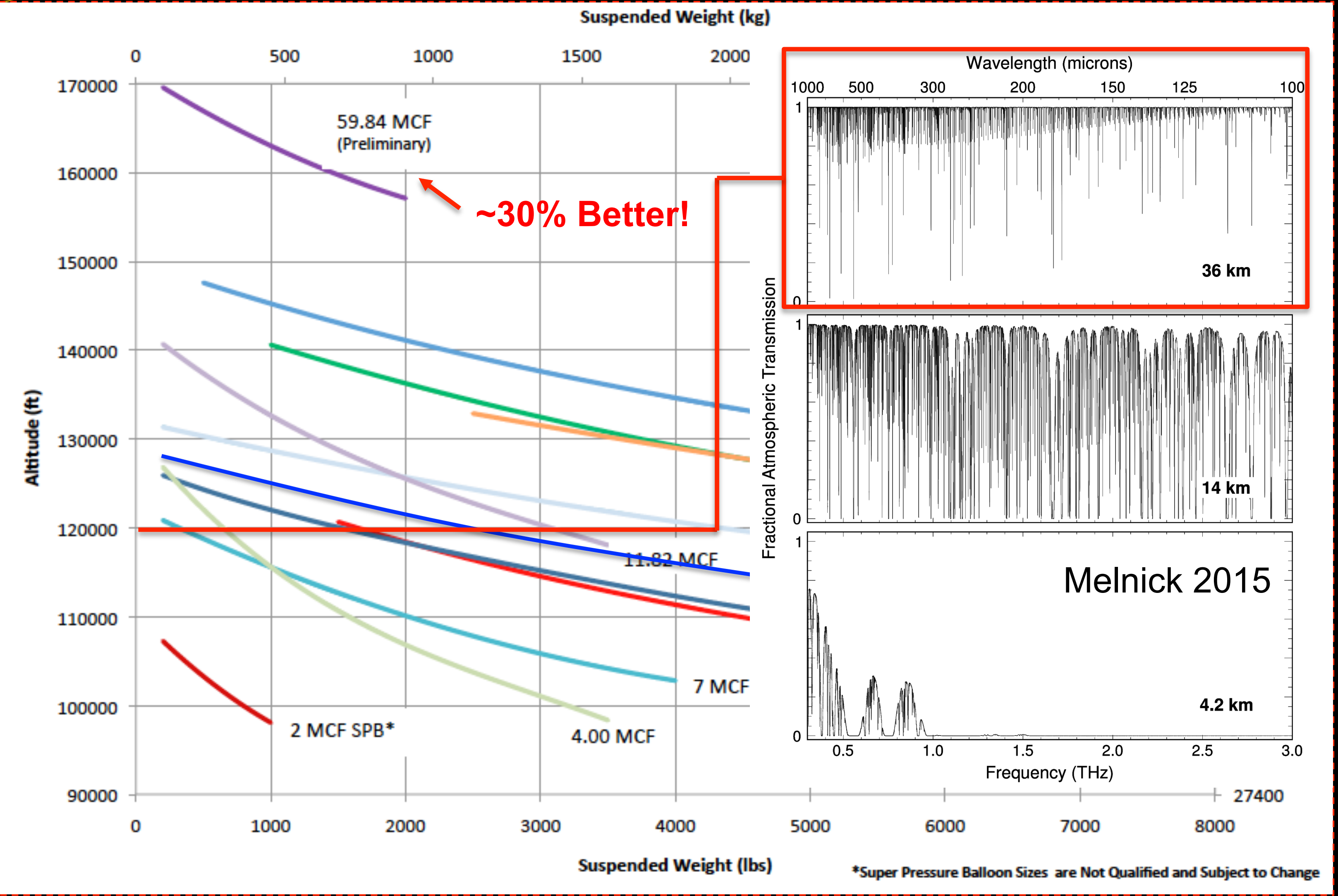
NASA Qualified Balloons



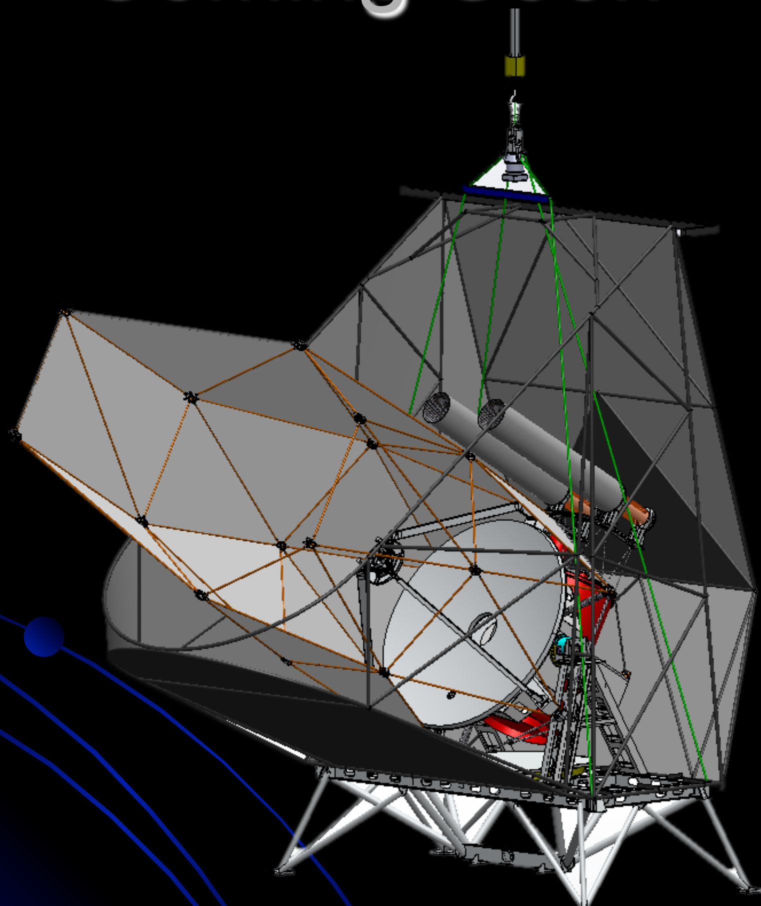
NASA Qualified Balloons



NASA Qualified Balloons



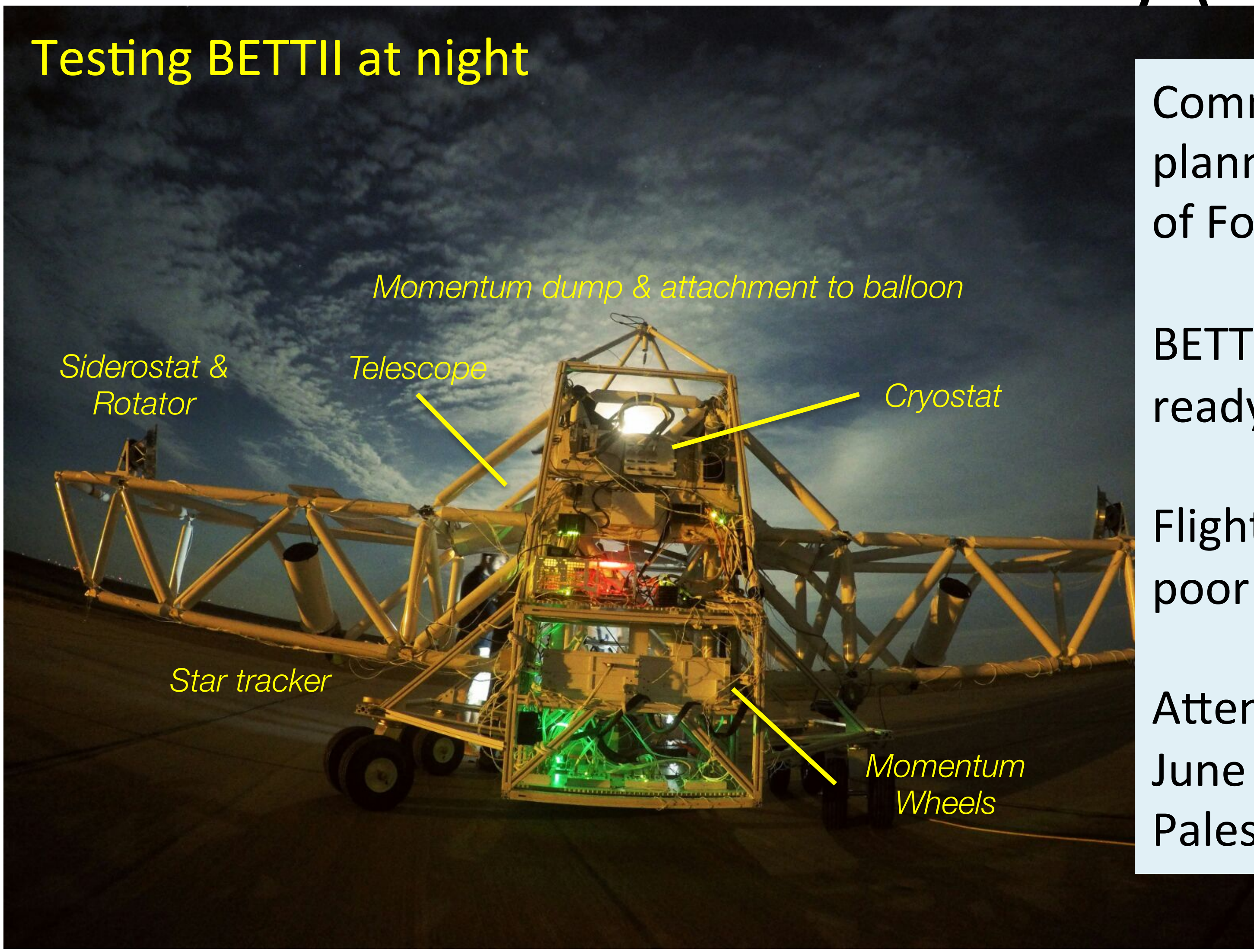
Coming Soon – BLAST-TNG



- 2.5 meter Carbon Fiber Mirror
- 1600+ dual polarization pixels with MKID detectors
- 250, 350, and 500 μm arrays
- 22 arcsec resolution at 250 μm
- 28 day flight!
- 16 times the mapping speed

- First flight December 2017 with Shared Risk Observing

The Balloon Experimental Twin Telescope for Infrared Interferometry (BETTII)



Commissioning flight planned for 2016 out of Fort Sumner, NM.

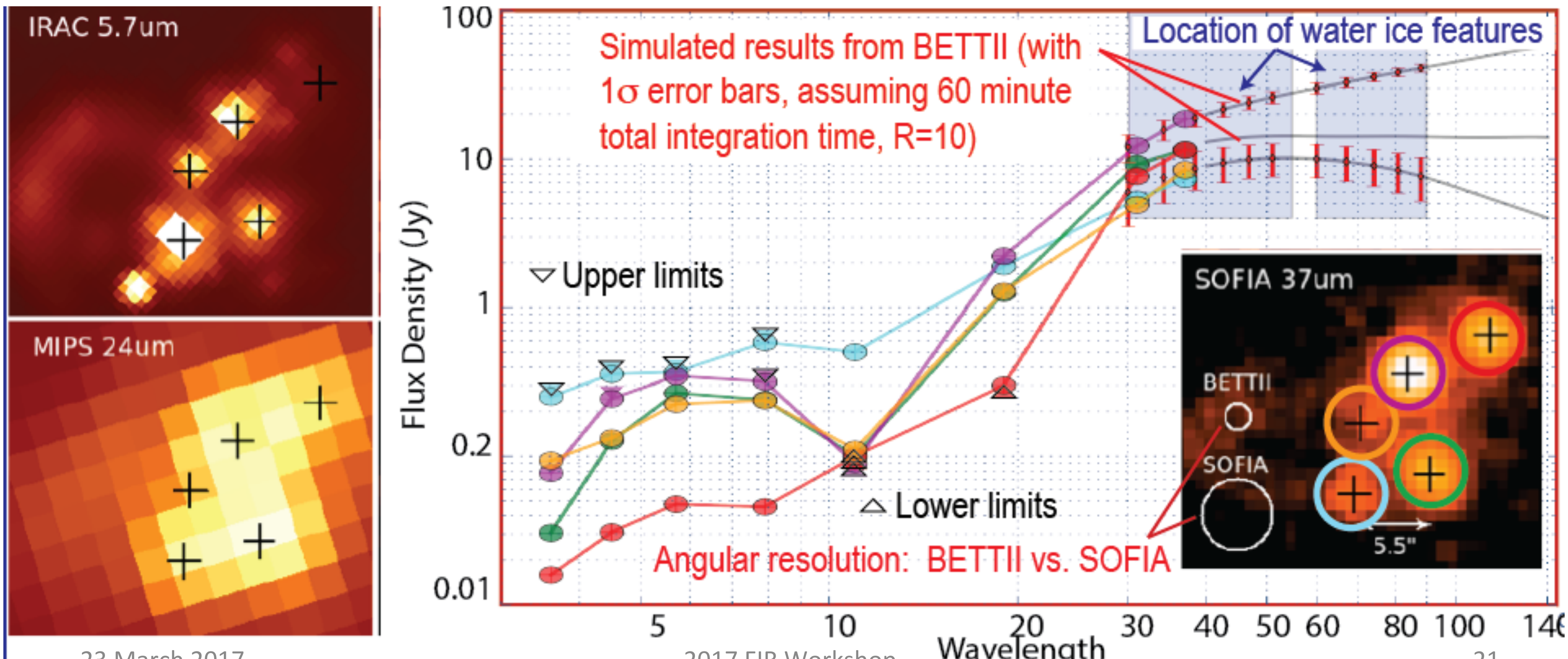
BETTII declared flight-ready, successful FRR.

Flight scrubbed due to poor weather.

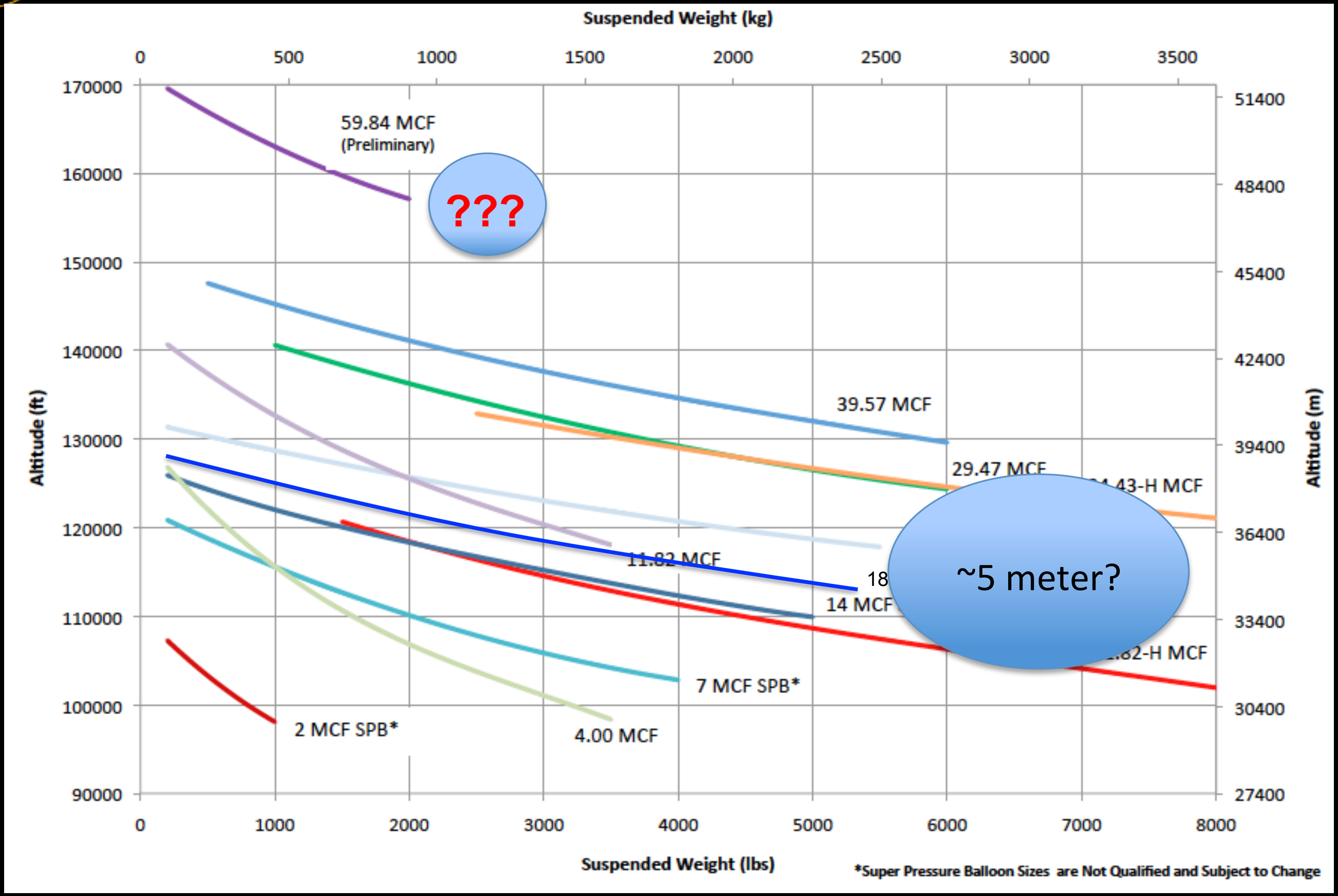
Attempting again in June 2017 out of Palestine.

Science Goals

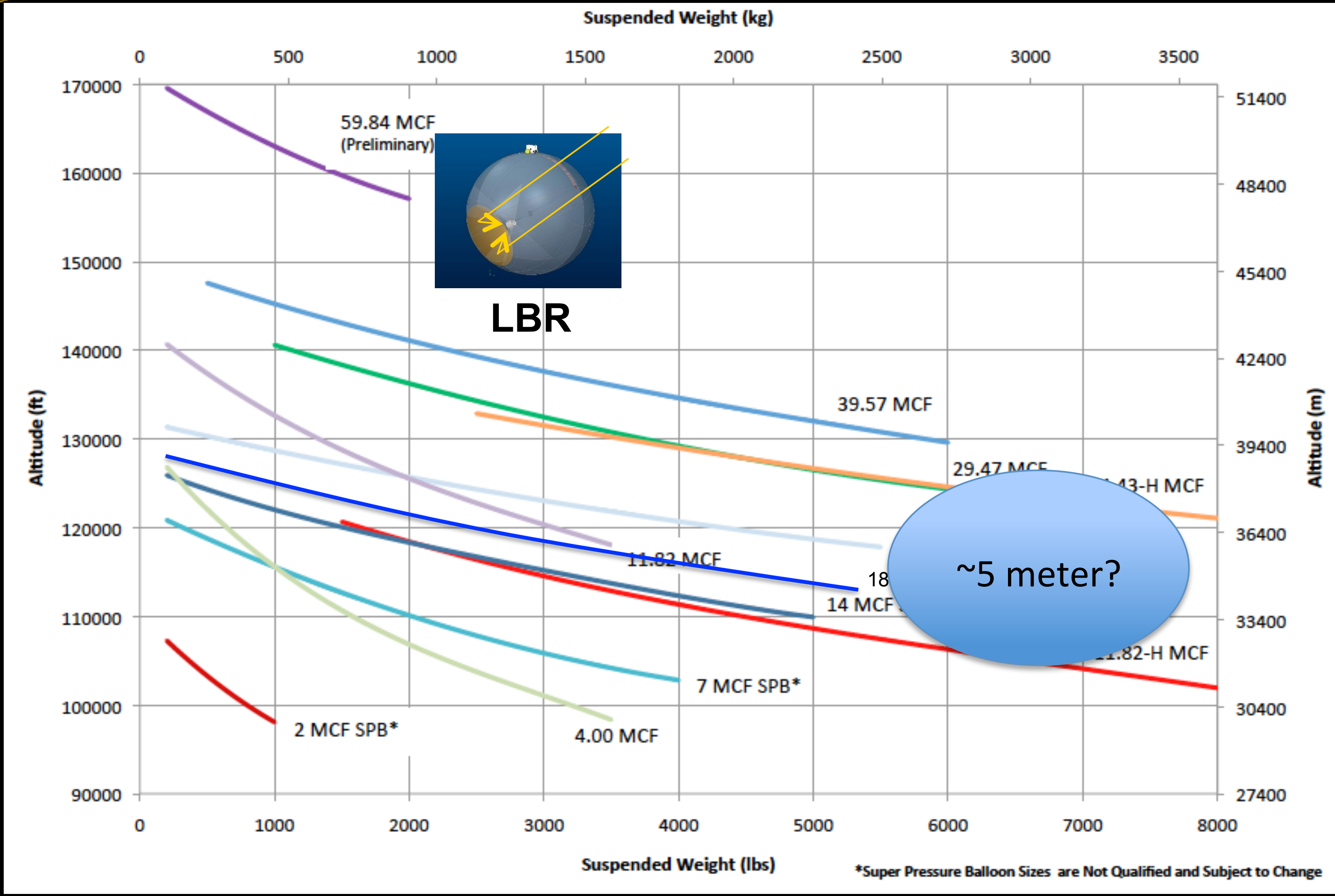
- Bright targets suffering from confusion…
  - AGN
  - Star formation – the high spatial resolution of BETTII, with low-res spectroscopy, breaks model degeneracies...



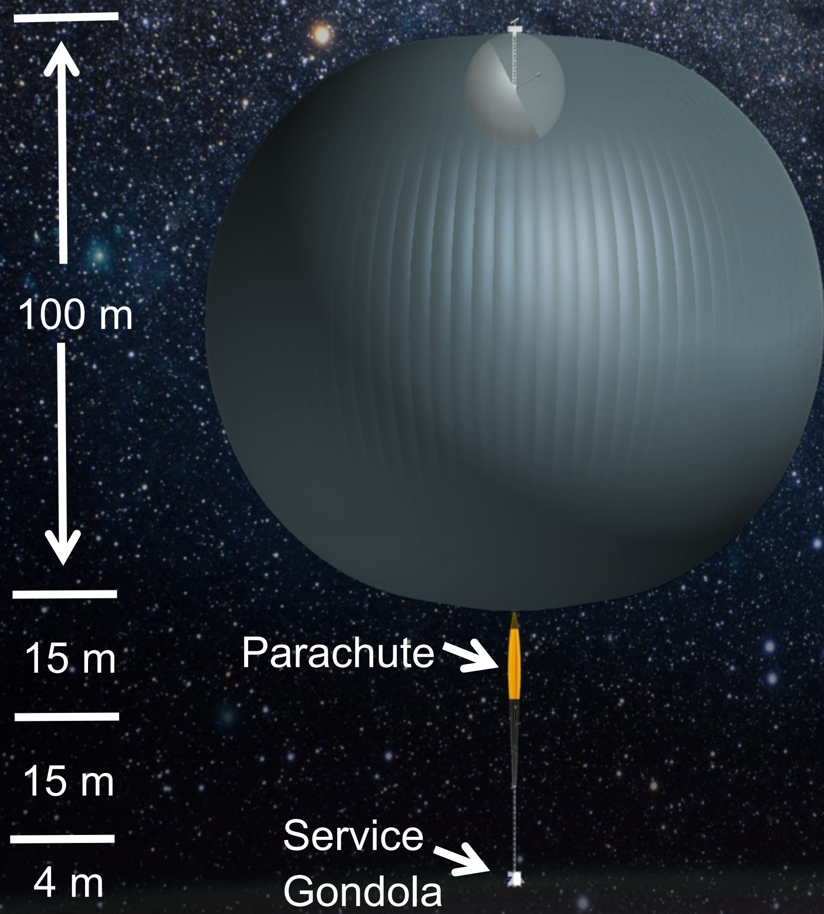
Prospects for Larger Apertures

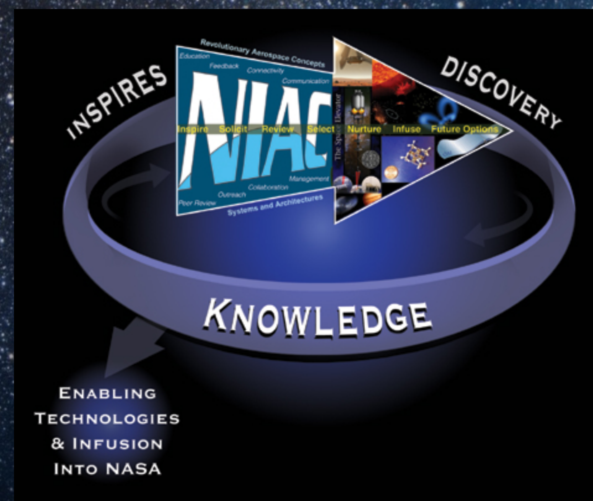


Prospects for Larger Apertures



10 meter Large Balloon Reflector

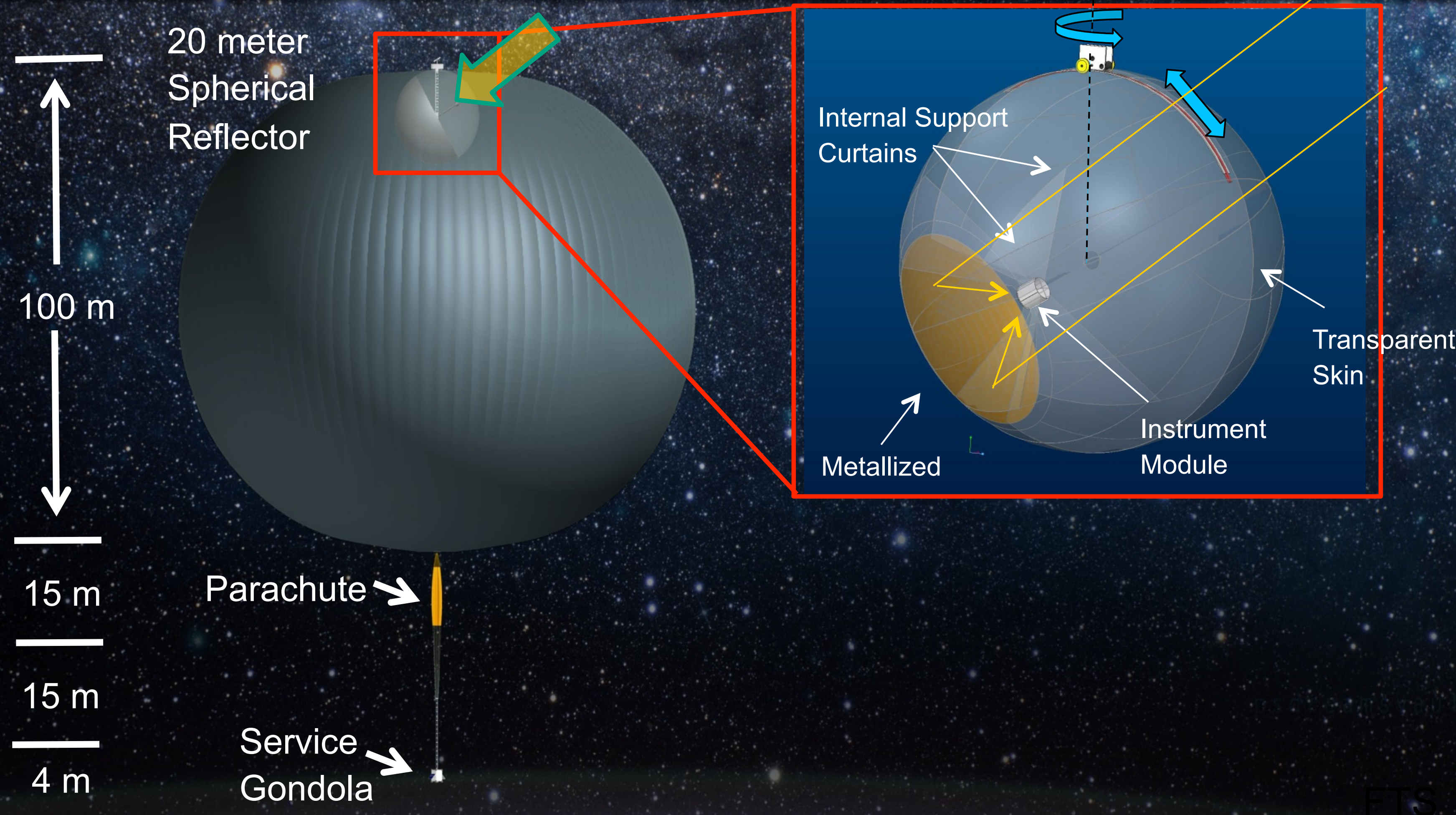




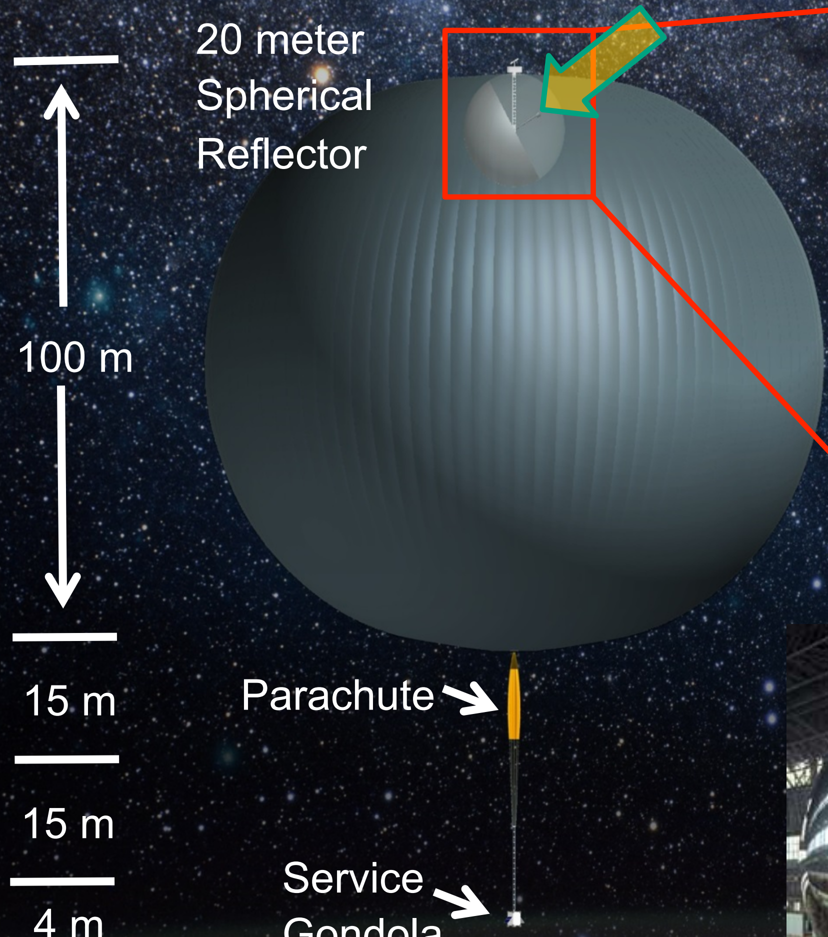
LBR Selected for Phase I Study: 2013

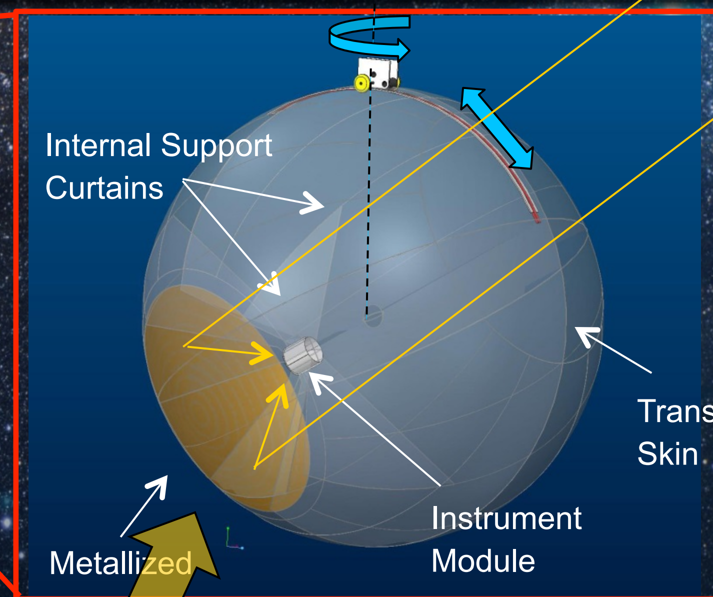
Float altitude >135,000 ft

Large Balloon Reflector (LBR)*



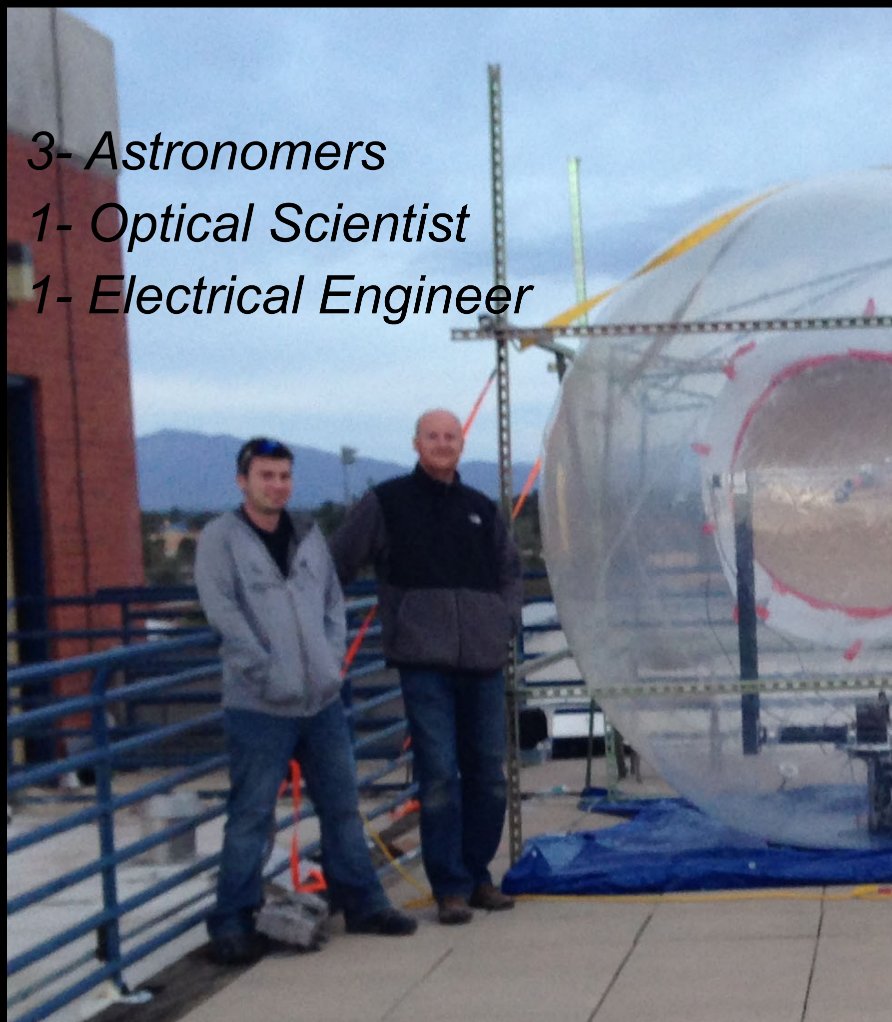
Large Balloon Reflector (LBR)*

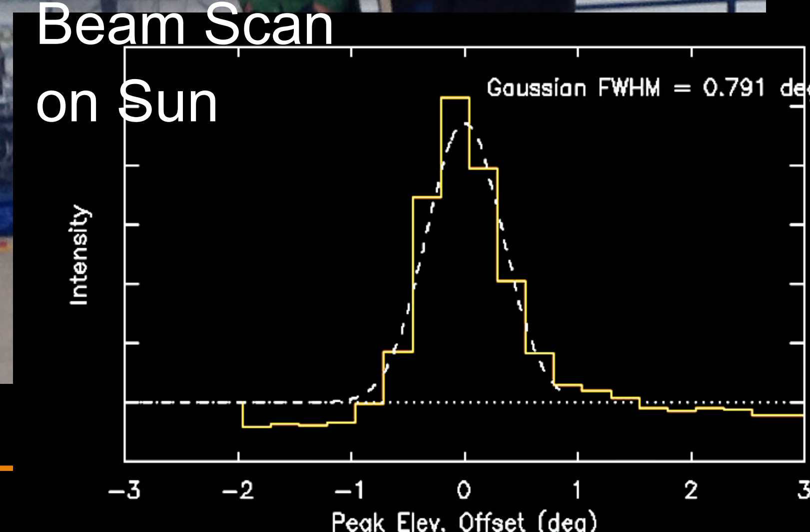




Echo I, PAGEOS Satellites
30.5 m sphere
L band
ca. 1960

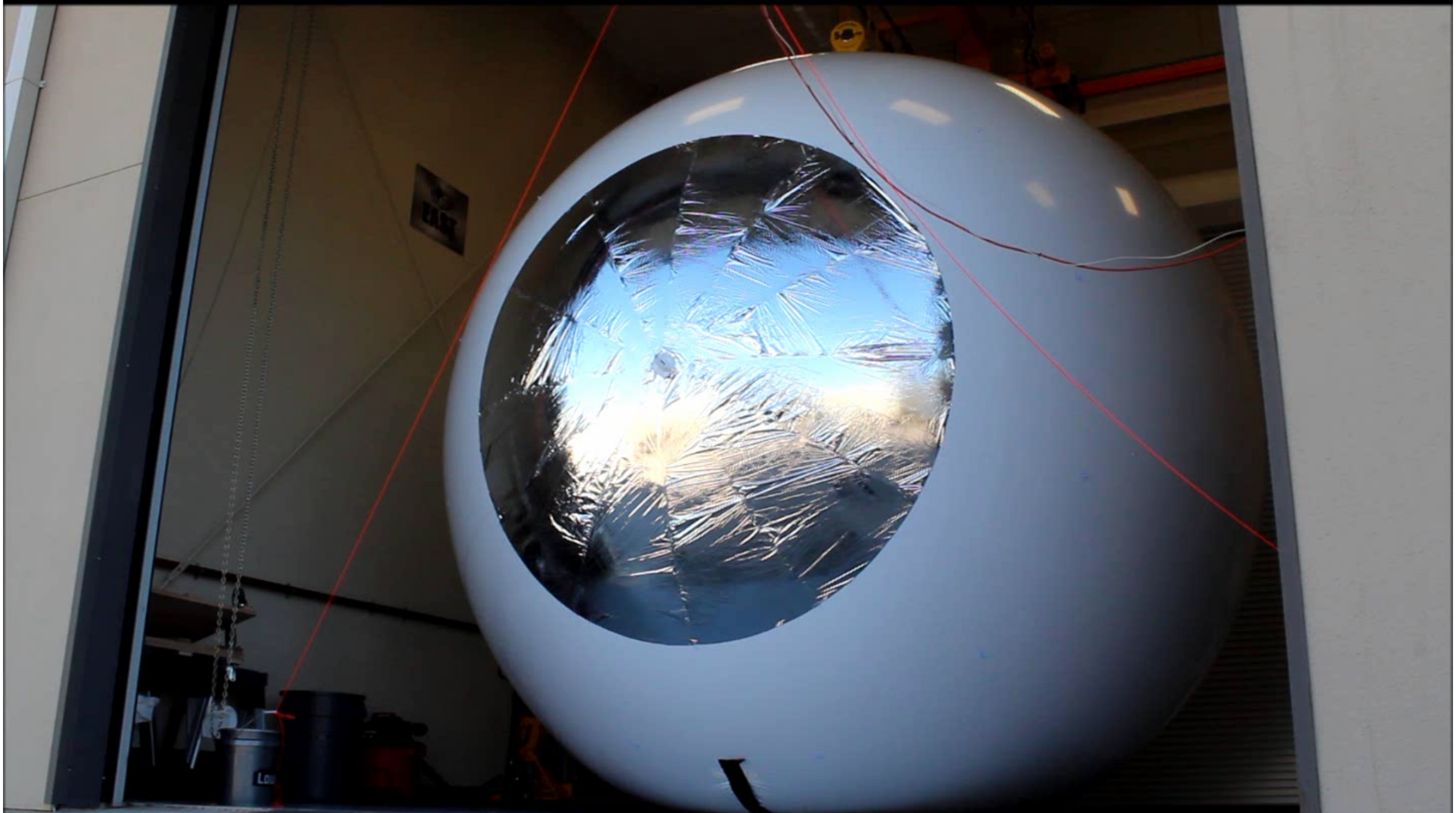
LBR NIAC Phase 1



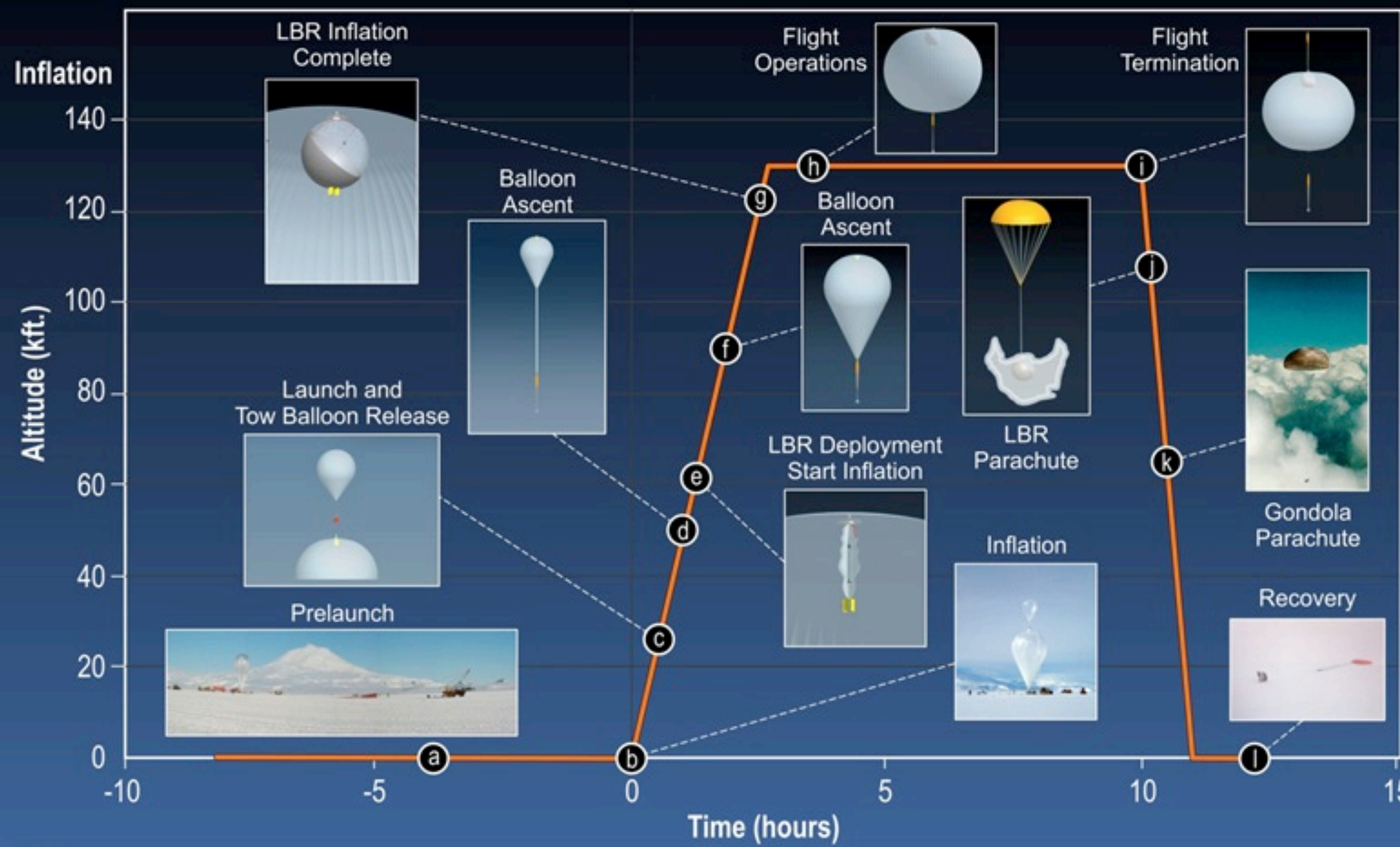


Will propose for suborbital/orbital versions in 2016.

Steerable 5 meter Prototype at SwRI

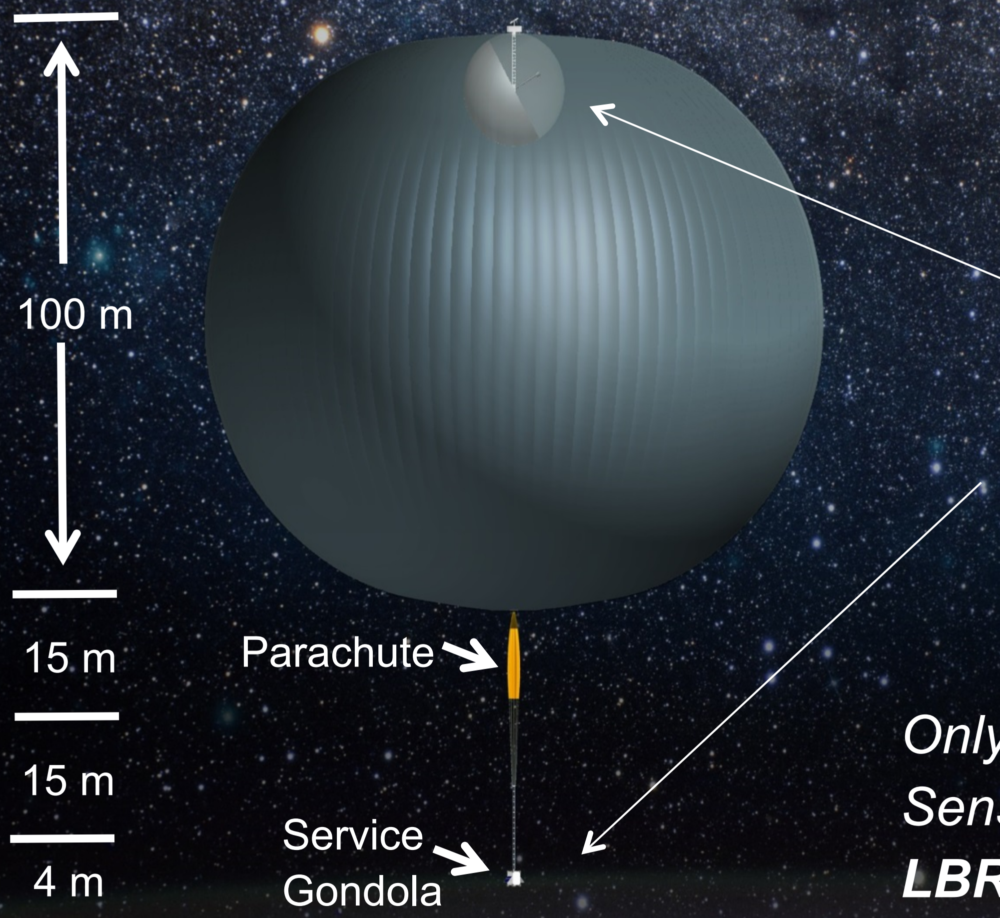


LBR Test Flight Profile



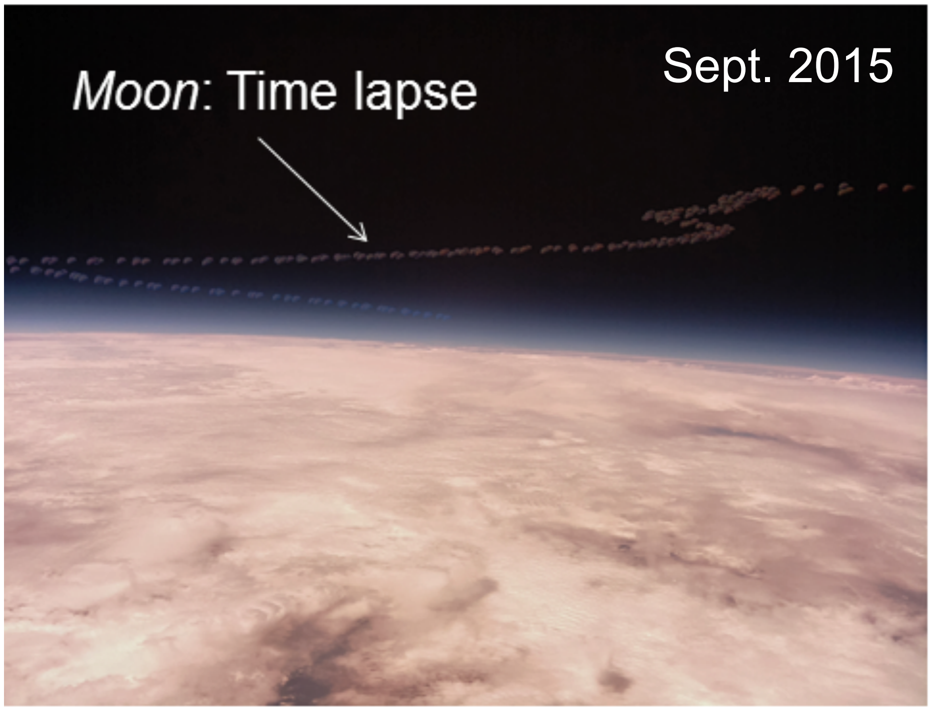
Which LBR Location is Better for Pointing Stability?

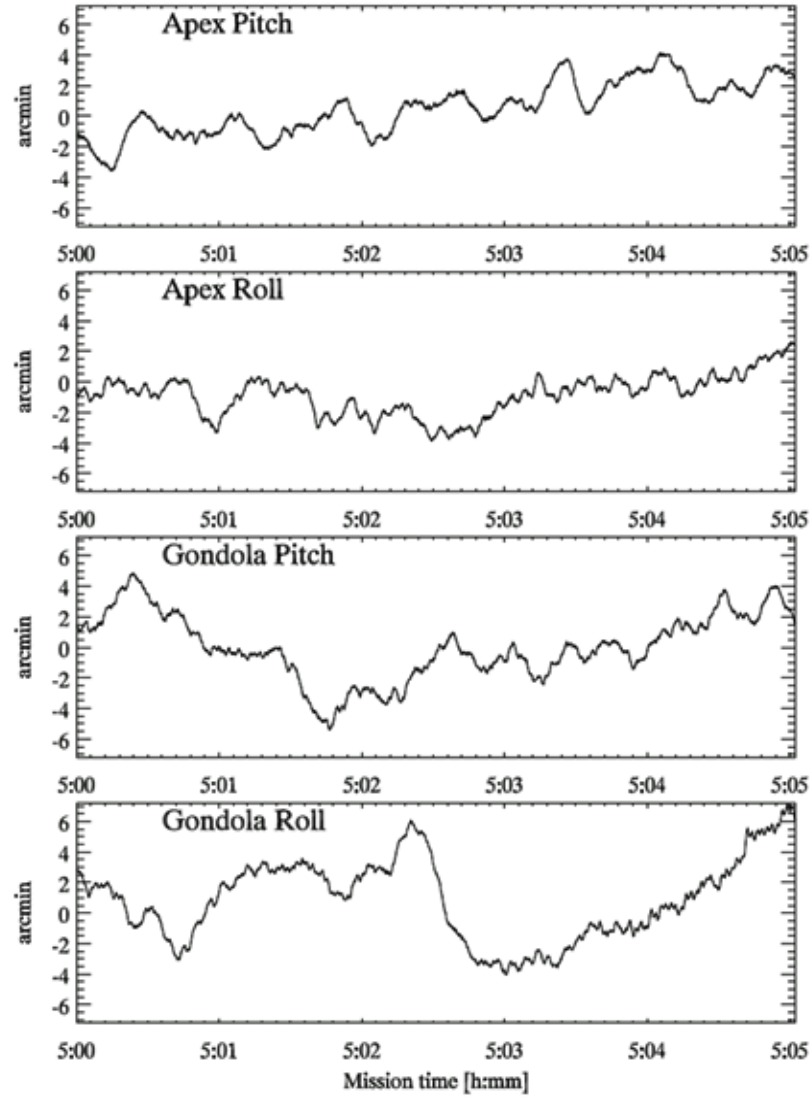
- *Sets upper limit to telescope size*



Apex
or
Gondola ?

Only one way to know for sure…
Sensor package test flight:
LBRSP





<u>LBR Sensor Package Data</u>. *Above:* Time lapse image of the Moon. *Left:* Sample accelerometer data. The frequency and amplitude of jitter at the **<u>Apex is seen to be much more benign than at the gondola.</u>**

FIR/THz Astronomy from Balloons

Ever Increasing Apertures will drive a new era of suborbital science:

- ***ISM Studies***
- ***Galaxy Evolution***
- ***Cosmology***
- ***Planetary***

The Future is Now!