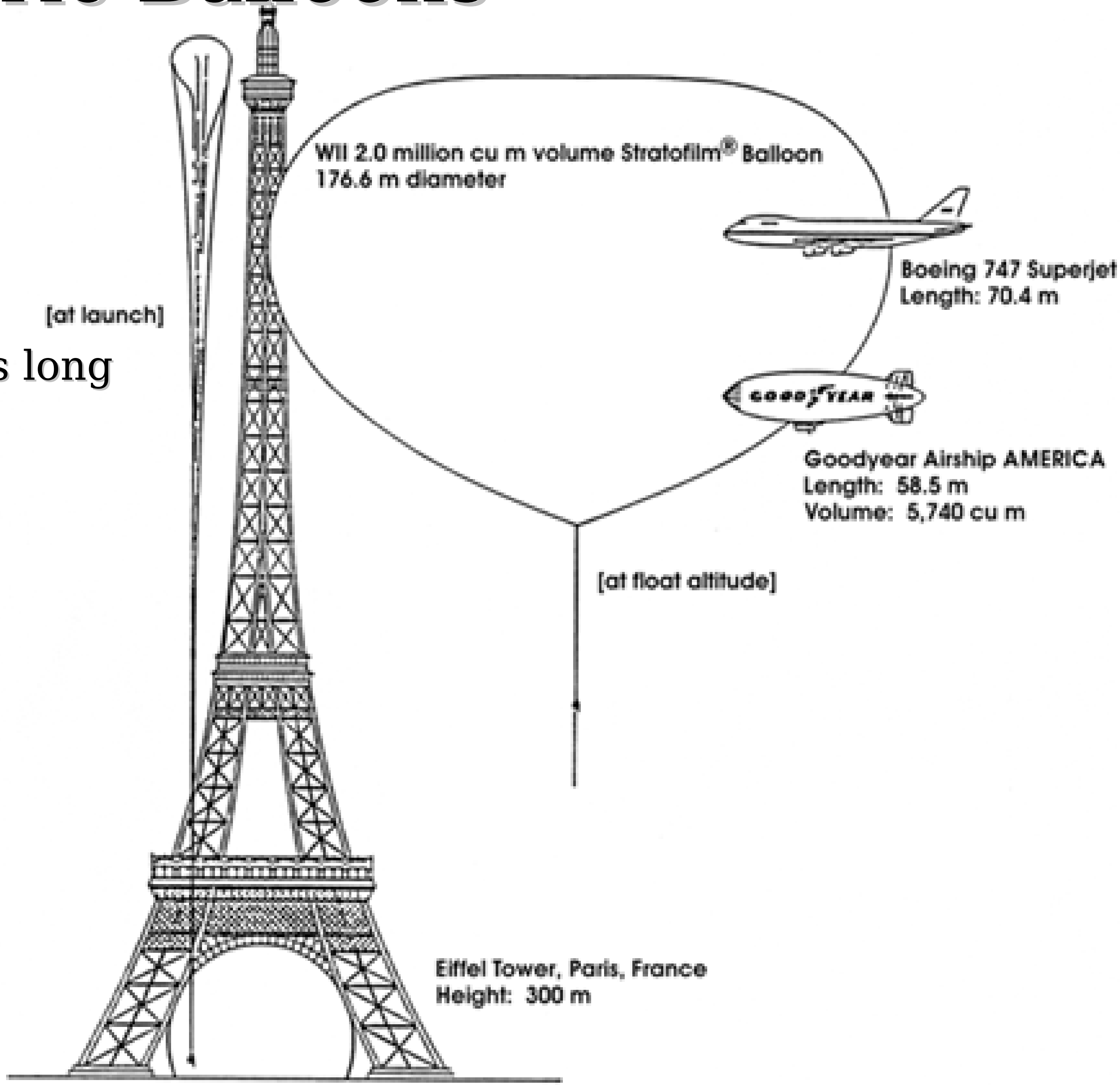
Stratospheric Balloons

35km altitude

1500kg payloads

Flights up to 30 days long

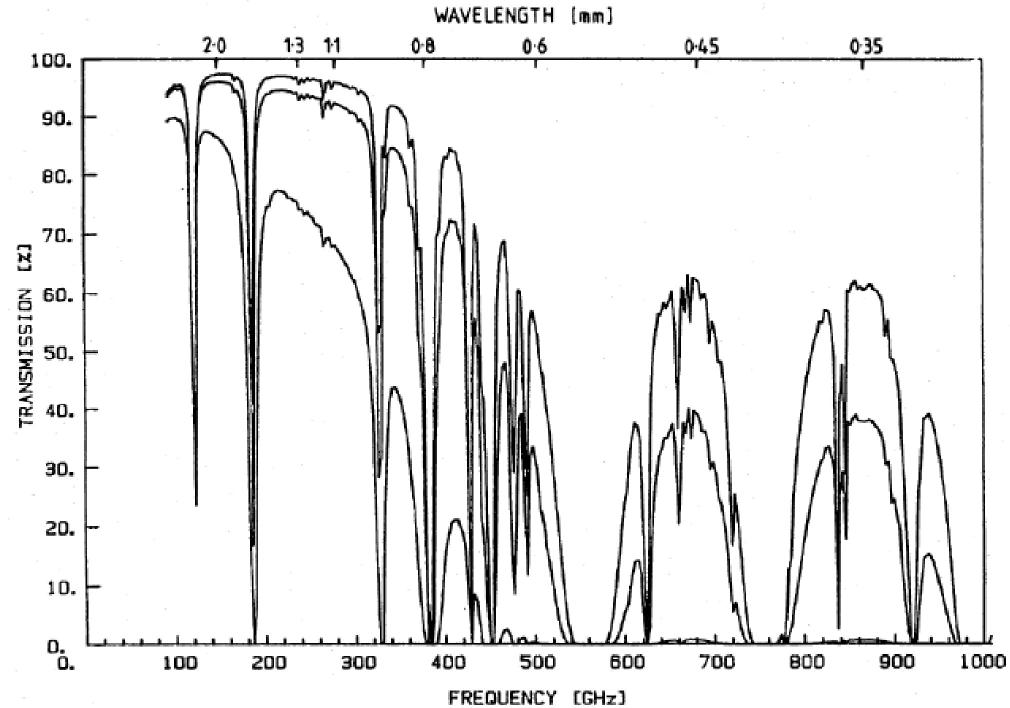


	Space	Balloon	Ground
Cost	>10-100x	1.5x	1x
Max Size	~8m	~2.8m	>100m
Integration Time	Years	Weeks	Indefinite
Chance to fix/ refly	~0	70% (in 1-2 years)	100% (quickly)
Platform Reliability	90%	85%	~100%
Atmosphere	None	~None	Can add noise
FunFactor	0.24	2.28	1.00

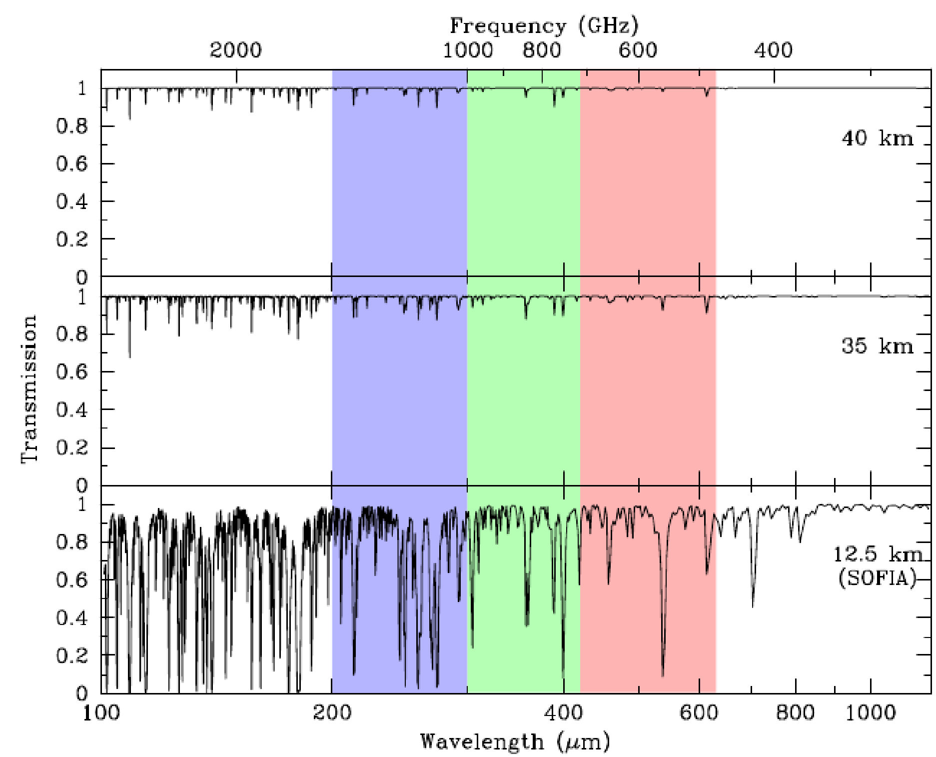
For mm (cmb) Balloons are useful for large angular scales, and short wavelengths (hence Spider and EBEX).

Rule of Thumb: at 150GHz, on small scales, a season on the ground ~ 1 LDB flight.

From the ground, Noise from the atmosphere dominates quickly above 250 GHz, especially for large angular scales.



From the balloon, atmosphere remains mostly harmless through the sub-mm (BLAST is not atmospheric noise dominated).

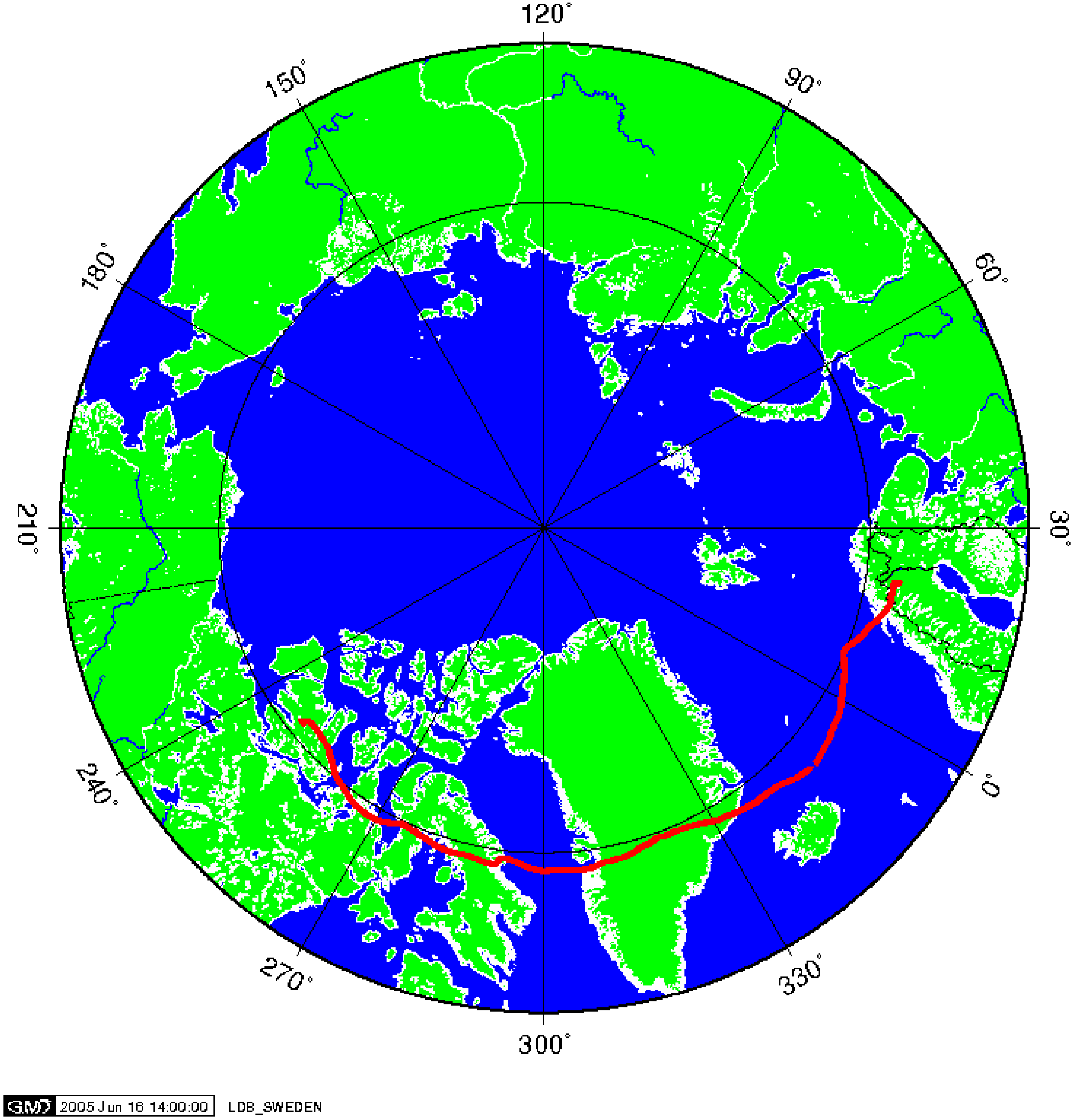


Launch Opportunities

Palestine, Tx	<12h	June to August	Night or Day
Ft. Sumner, NM	<30h	Sept/Oct	Day & Night
Alice Springs, AU	<4days	March	Day & Night
Kiruna, Sweden	4-10 days	June	Day & dusk
McMurdo, Ant	10-40 days	December	Day

BLAST Kiruna Flight

4.5 days

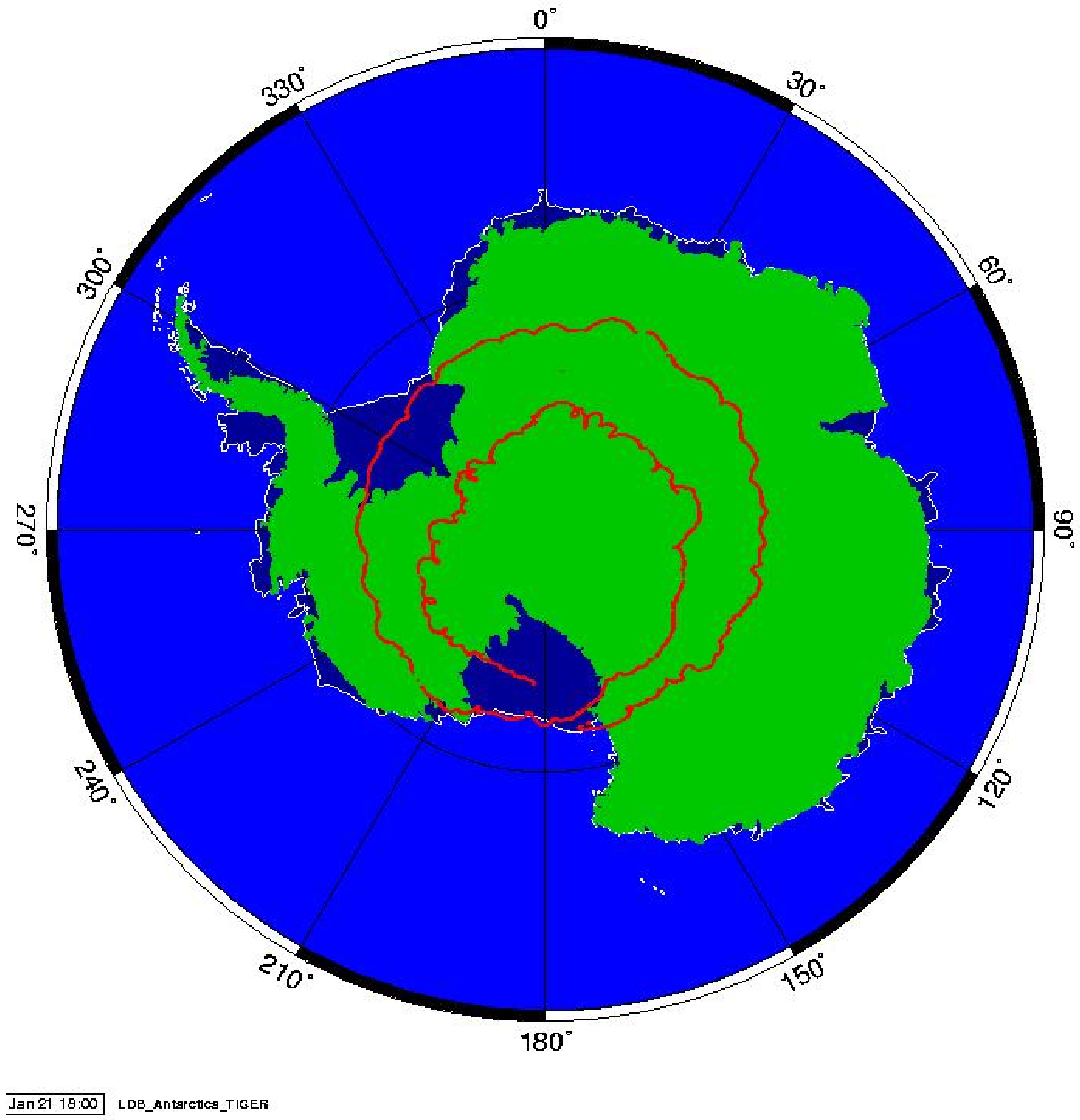


Antarctic flights

Continuous solar illumination
Minimizes diurnal variations

Flights over 30 days possible
(15 days 1 orbit typical)

Launch window: Dec 10 – Jan 10



Communication (eg, BLAST06)

Downlink *"The downlink will be flaky"*

In Line of Sight:

1 Mb/s biphase digital

(occasional glitches for most of the time)

2 Colour Video transmitters

(like marginal broadcast TV)

Over the Horizon:

6 kb/s serial with TDRSS satellite

20s frames means considerable latency

frames can go missing

no data if satellite out of view (~20% for BLAST06)

Data comes to Palestine TX, not the launch location

(so you need internet distribution).

255 bytes per 3 minutes over Iridium phone

We sometimes actually got these.

Avoid requiring good Downlink for success

Store all data on board!

Communication (eg, BLAST06)

Uplink *"The uplink will fail"*
Command packets are sent to CSBF computers, which send them to the payload.

In Line of Sight:

>1 command/s, low latency possible.
(though we did overheat a transmitter doing this)

Over the Horizon:

Low latency (couple second) commanding through TDRSS for ~10min every hour (scheduled windows) when satellite in view. (~80%).

High latency (6 minute to several hour) through irridium.

Low latency irridium was being tested.

Automate everything that you can.
Avoid long commands.
Error check your commands!

Environmental Considerations: Near Vacuum

Cooling:

Forced air and convective cooling don't work!
So, you must use conduction or radiation.

Hard Disks:

Hard disks use aerodynamics to position the read head
so, they don't work at float: need 1 atm pressure
pressure vessel.

Cryogenics:

Liquid cryogens boil at lower temperature at float:
absolute pressure regulators on the cryogen tanks
or
controlled pumpdown

Batteries:

Liquid Batteries: (eg Lead Acid batteries) will boil.

Environmental Considerations: Cosmic Rays

Cosmic ray rate is ~100 greater for polar flights than on the ground.

Detectors:

Bolometric detectors see cosmic rays! Spider webs were invented to reduce CR cross section. Solid absorbers may be a problem.

Electronics:

Electronics (esp RAM) are sensitive to cosmic rays.

- PCs crash every couple of days.
- KVH digital gyros crash about once a week.
- DSPs may see random bit changes.

Use watchdogs on all electronics with a CPU/RAM.
Code should have idiot checks for impossible things.
Consider preemptive reboots.

Environmental Considerations:

Ascent:
During ascent, you will travel through very cold (-50C) air.

The payload will be moving quickly – so forced air cooling.

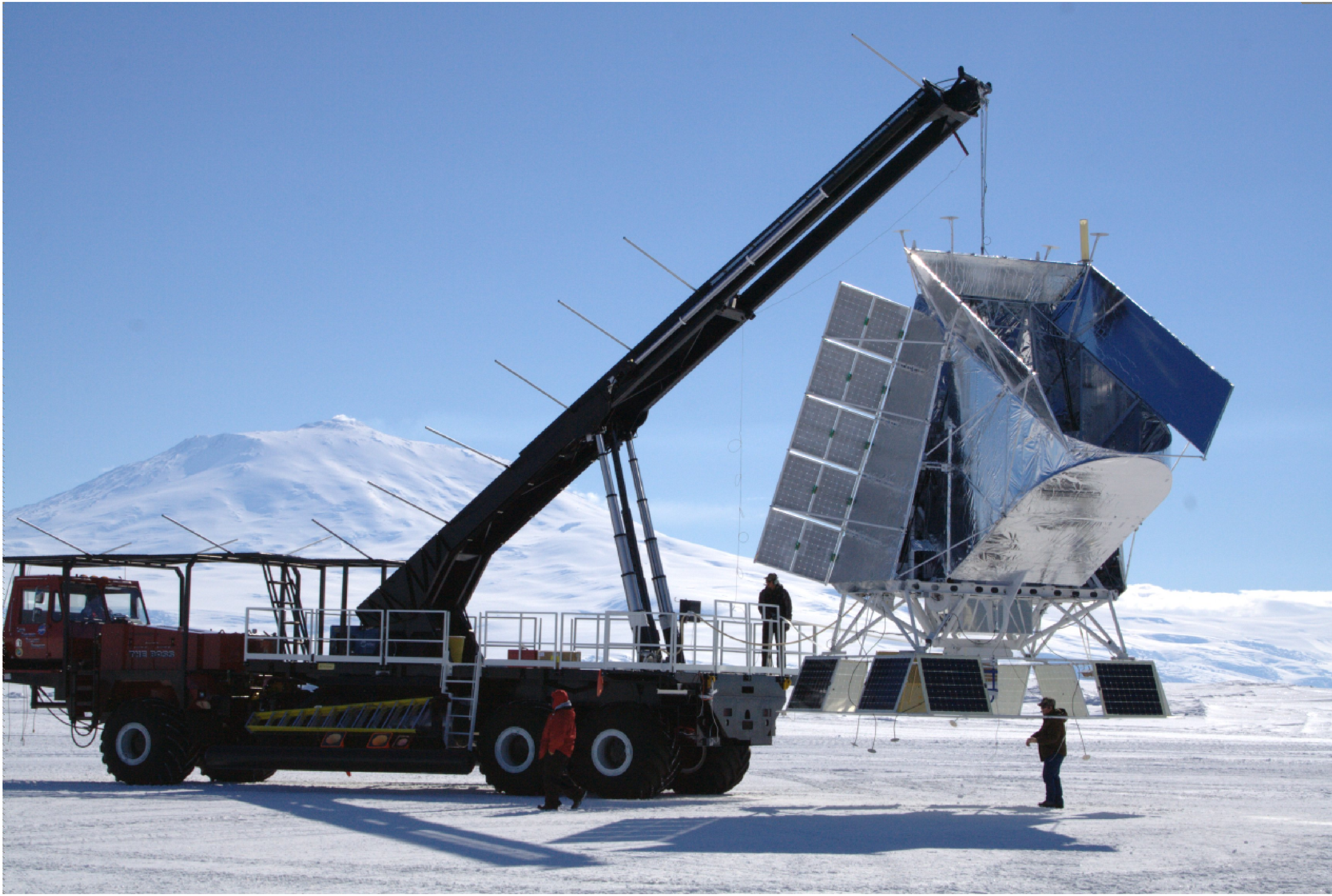
It will take hours to come back into thermal equilibrium.

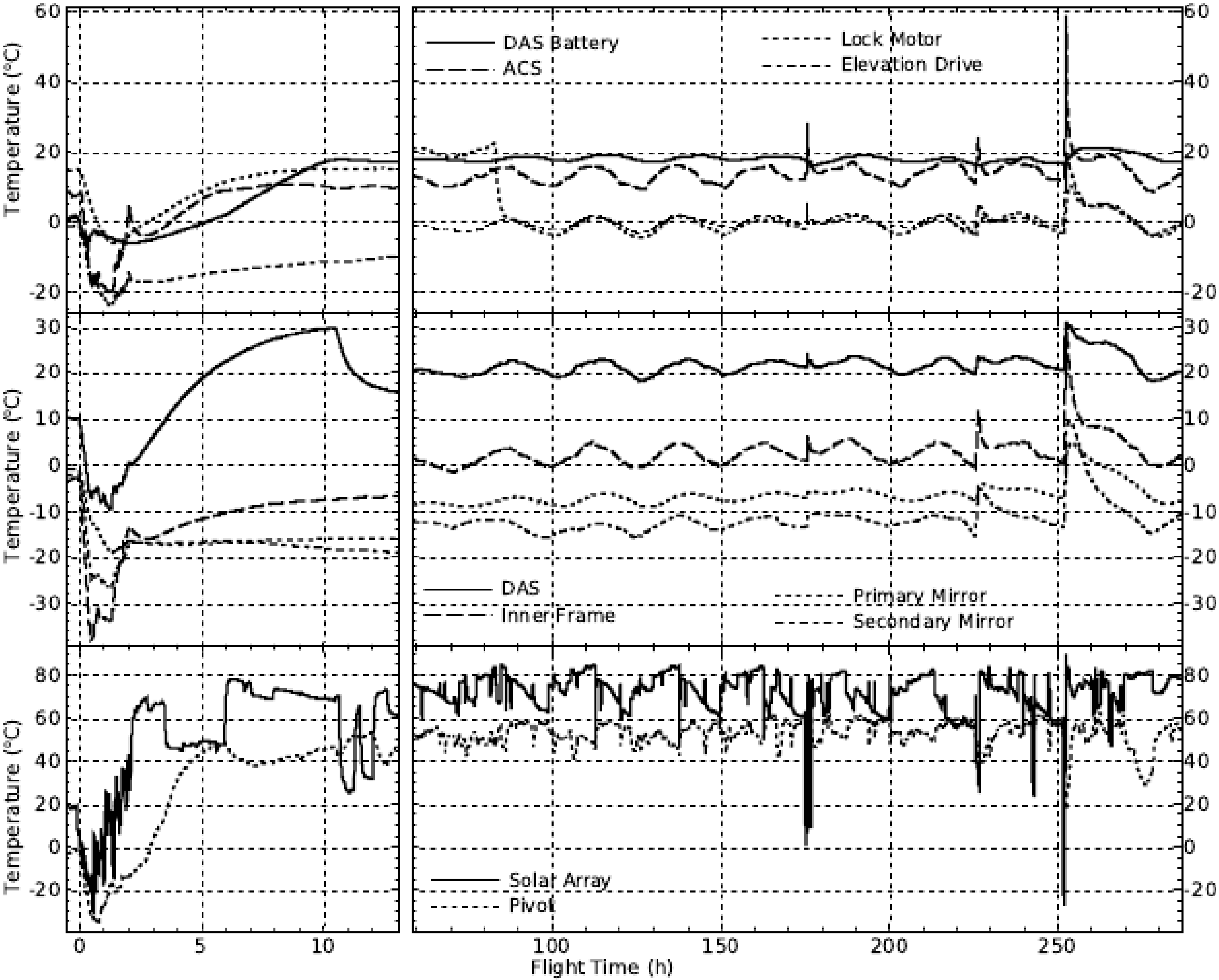
-Consider effect on your optics.
-Insulate electronics (but consider operation in vacuum)

The Sun:
Bare aluminum, at float, in the sun: 140C

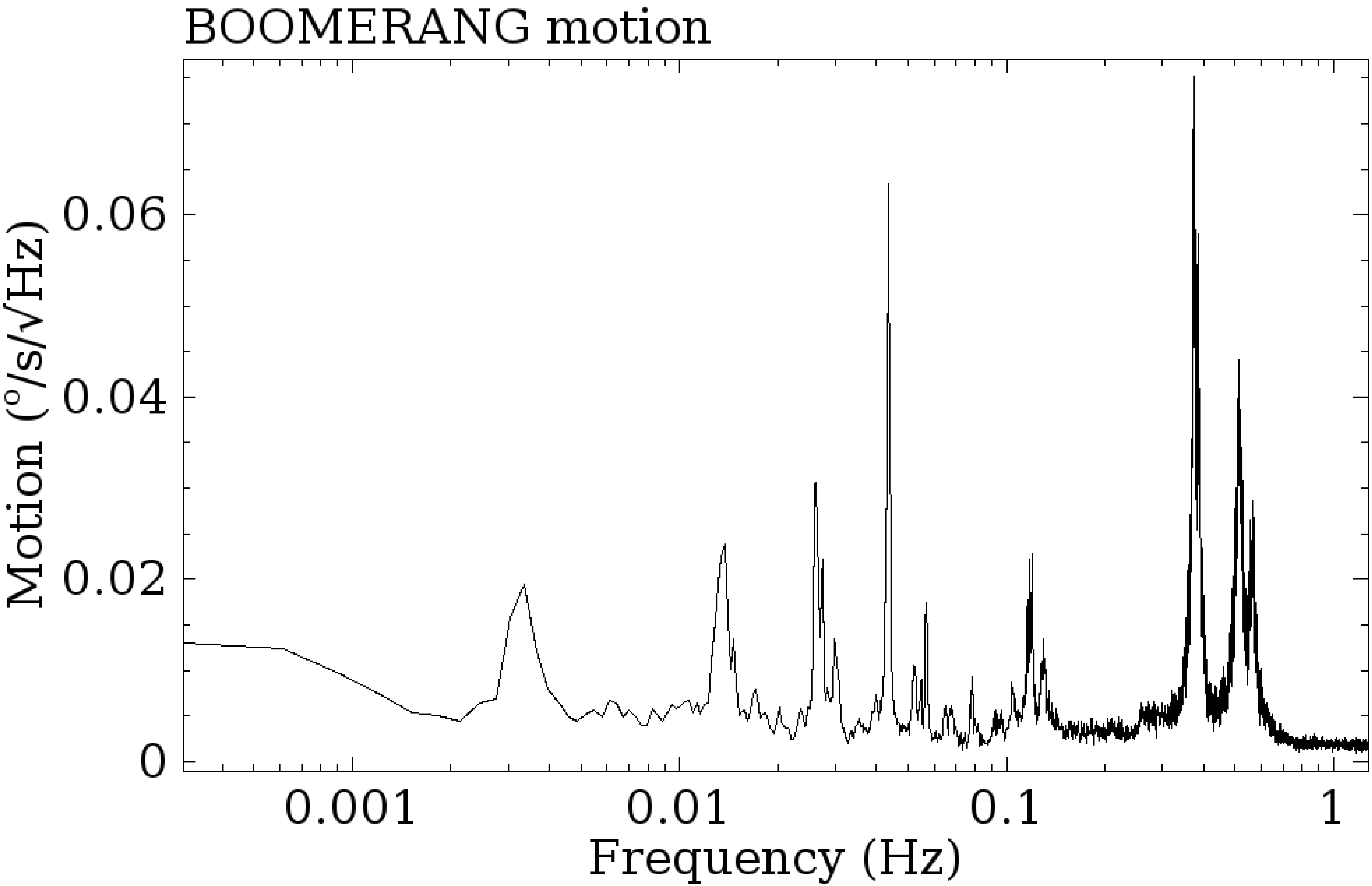
Anything sun facing needs to have a low Visible Absorptivity to IR emissivity ratio: eg, Alluminized Mylar or White Paint.

Sun = Power!




DAS Battery
ACS
Lock Motor
Elevation Drive
DAS
Inner Frame
Primary Mirror
Secondary Mirror
Solar Array
Pivot
Temperature (°C)
Flight Time (h)

Environmental Considerations:



Environmental Considerations: Environmental Testing

If it hasn't been tested it doesn't work!

Electronics and actuators should all be tested in a thermal vac chamber including pressure vessels!
CSBF has one in Palestine.

Verify minimum operating temperature
- test to -50 or failure

Verify vacuum (3mb) operation
- determine equilibrium component heating with 300k ambient temperature

Electronics may overheat, and may not work to their component min temperature.

Actuators often have trouble cold!

Pointing: Where am I looking?

Absolute Sensors:

Magnetometers:	1 degree	100%	fast
Differential GPS	0.25 degree	70%	10 Hz
Sun Sensors	0.25 degree	facing sun	fast
Video star camera	<pixel scale	dark only	10 Hz
Integrating Star Camera	<px scale	day/night	<1 Hz
Tilt sensor	worse than 6'	100%	fast
Encoders	worse than 6'	100%	fast

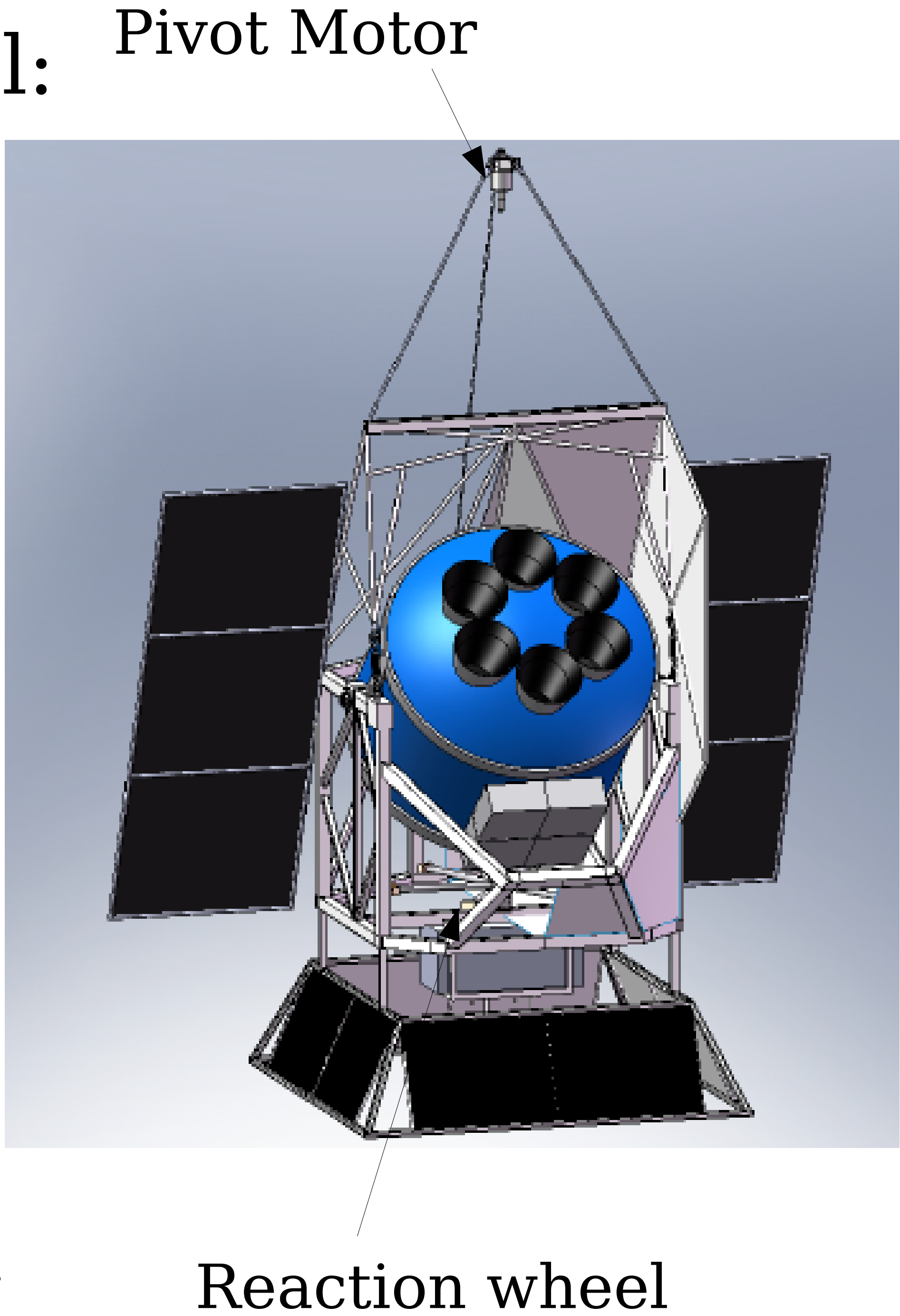
Pointing: Azimuth Control:
2 motor solution

Pivot Motor: twists up the flight train, which applies torque to the balloon.

- -Excellent angular momentum dump
- -Slow, with resonance at 10's of seconds period.

Reaction Wheel Motor: Dumps angular momentum to reaction wheel.

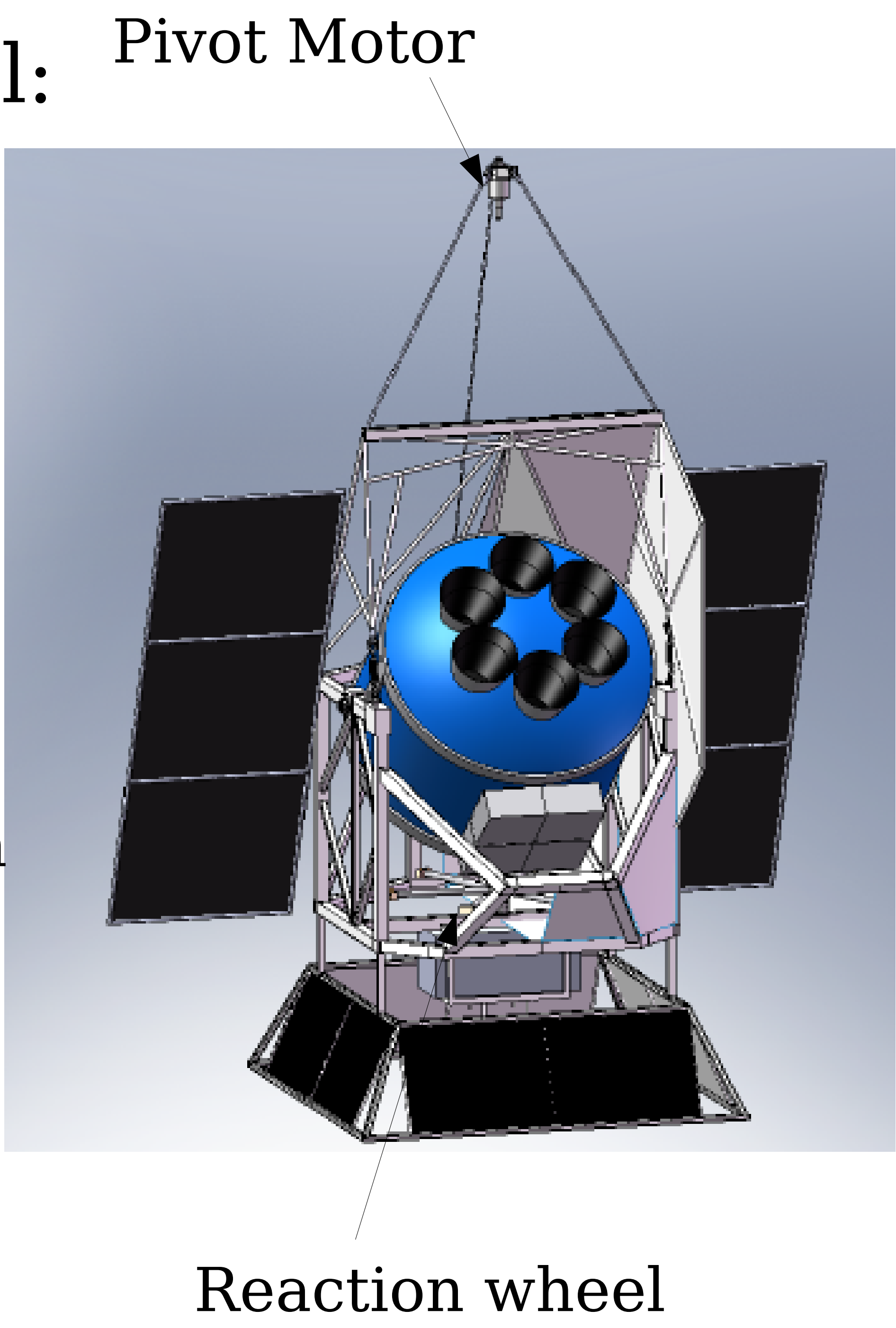
- -Instant response
- -Must be large enough to not saturate before Pivot can respond.



Pointing: Azimuth Control:
Example torque algorithm

Reaction Wheel Motor:
Torque proportional to angular velocity error.

Pivot Motor:
Torque proportional to reaction wheel angular velocity.



Power:

Daytime Flights:

Solar Arrays + NiMH batteries

(eg Cobasys 9500: 85Ah, 12-14.5V, 18.2 kg)

Warning: NiMH batteries are temperature sensitive, and are prone to thermal runaway! But Lithiums are much worse!

Old Supplier (MEER) is ~gone.

Nighttime Flights:

CSBF provides non-rechargeable batteries for flight. They are ~250 Wh/kg.

Battery performance is thermally sensitive: 20C is target.

Mass break-even for Day/Night flights is >4 days.

Some Thoughts

The cost of failure is very high.
(you can't just fix it)

Assume everything will be less reliable at float.
(if it fails on the ground, it will fail at float)

If it hasn't been tested, it doesn't work.

Avoid complexity.
Extra complexity makes for richer and more interesting failure modes.

Increased reliability is better than redundancy.

Include a rich low level command set to handle failures.

Automatically handle 1st order failures.

Every moment at float is precious: and you will be very tired!