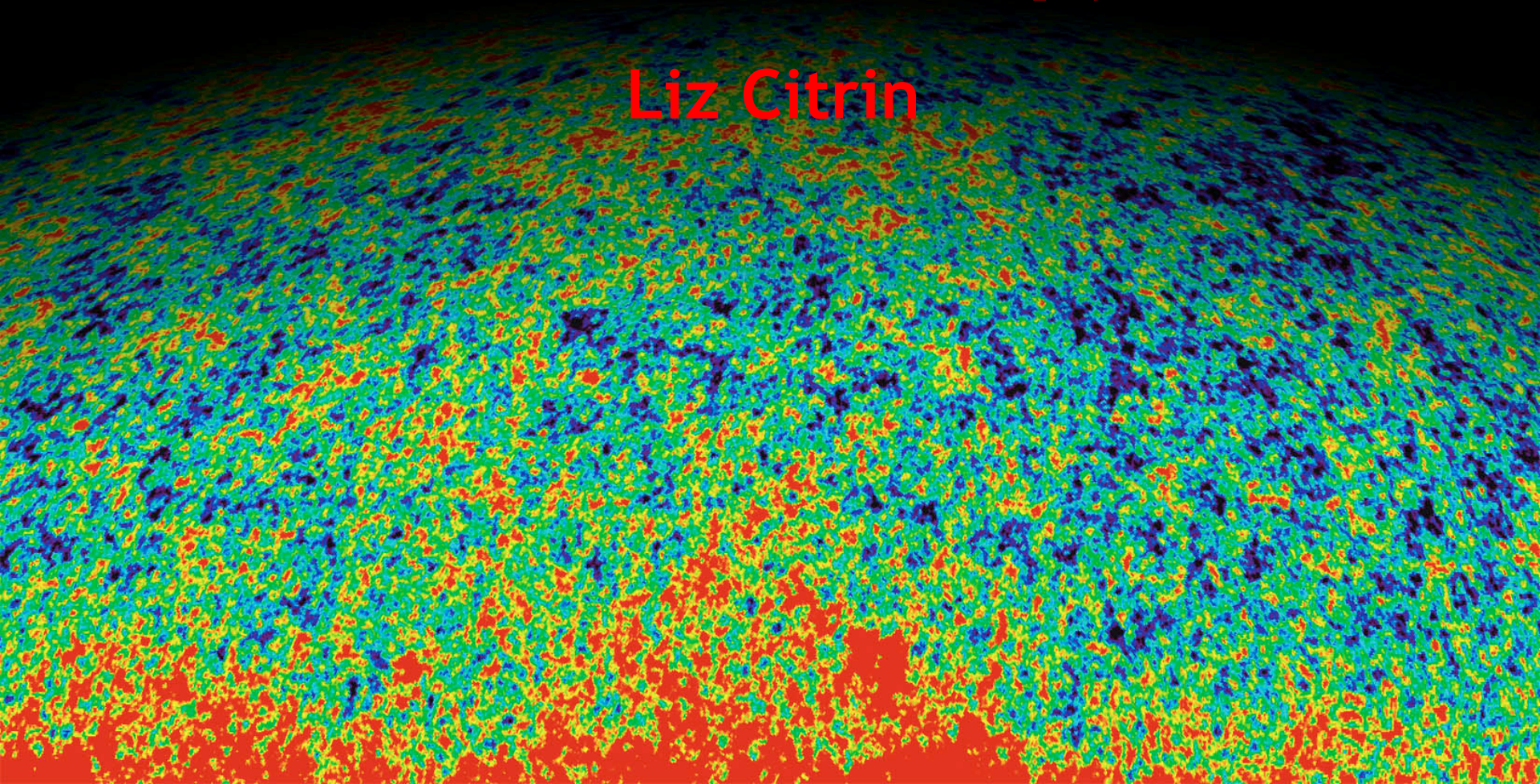




WMAP The Wilkinson Microwave Anisotropy Probe

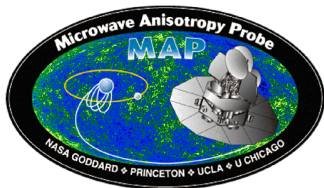
Liz Citrin





MAP was launched to answer fundamental cosmological questions:

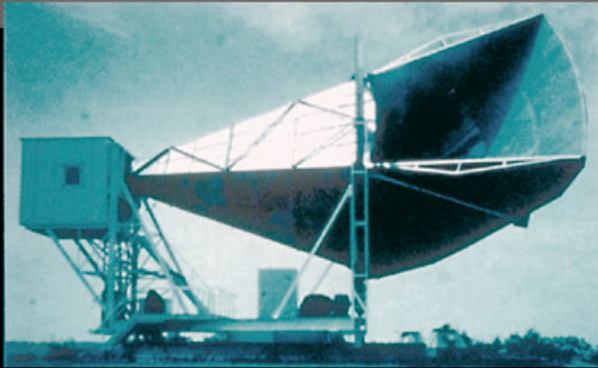
- Will the universe expand forever, or will it collapse?
- Is the universe dominated by exotic dark matter?
- What is the shape of the universe?
- How and when did the first galaxies form?
- Is the expansion of the universe accelerating rather than decelerating?



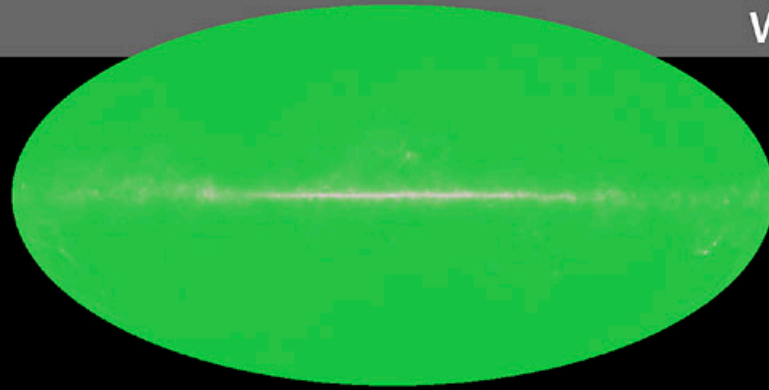
WMAP results:

- The WMAP team has reported the first direct detection of pre-stellar helium, providing an important test of the big bang prediction.
- WMAP now places 50% tighter limits on the standard model of cosmology than our previous 5-year WMAP results.
- WMAP has detected a key signature of inflation.
- WMAP strongly constrains dark energy and geometry of the universe.
- WMAP places new constraints on the number of neutrino-like species in the early universe.
- WMAP has detected, with very high significance, temperature shifts induced by hot gas in galaxy clusters.
- WMAP has produced a visual demonstration of the polarization pattern around hot and cold spots.

1965

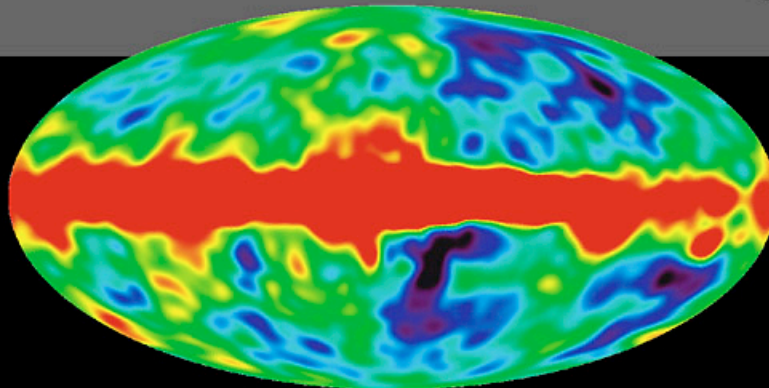
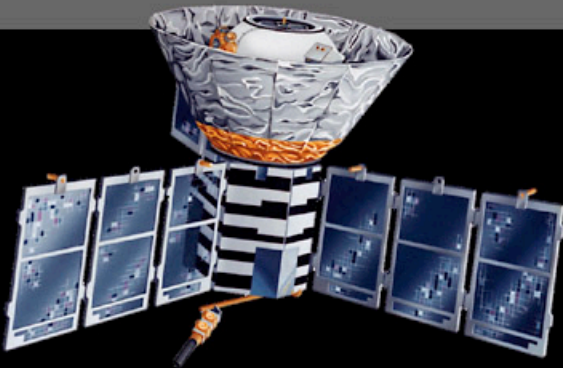


Penzias and
Wilson



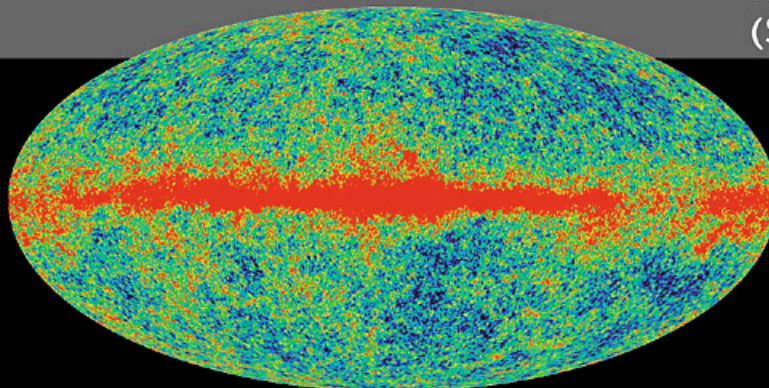
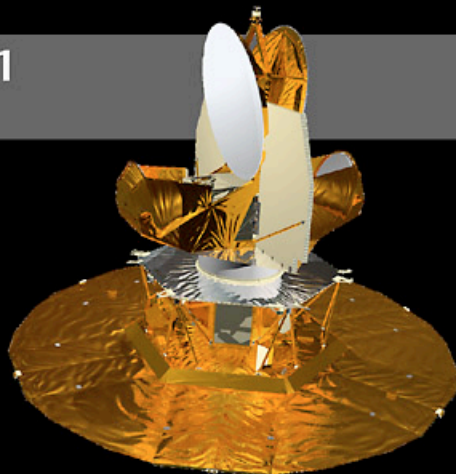
1992

COBE



2001


MAP
(Simulated)

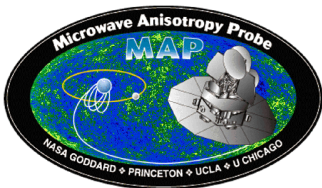




The MIDEX-Class Explorers

Motivated by the expressed desires of the scientific community

- INCREASED RESEARCH OPPORTUNITIES
 - BROADENED OPPORTUNITY FOR PI MISSIONS
 - CLOSER TO GRAD STUDENT AND POST-DOC CYCLE TIMES
- 
- MORE FREQUENT LAUNCHES
 - REDUCED COST PER MISSION
 - SHORTER MISSION DEVELOPMENT TIME



MAP: One of the First MIDEX Missions

Midex Guiding Principles (2/95)

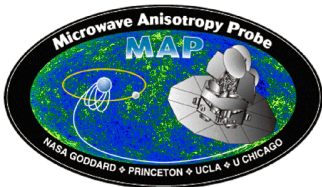
- One boundaryless team
- Emphasize trust, individual and team responsibility
- Apply common sense to all processes and activities
- Flat, streamline project organization; no watchers, just doers
- Small focused subteams with full team validation
- Consolidated & streamlined reporting
- Maximize team efficiency, sharing and reuse of resources
- Drive for lowest mission cost regardless of who pays
- Systems engineering must be present everywhere



WMAP Principal Investigator

Chuck Bennett

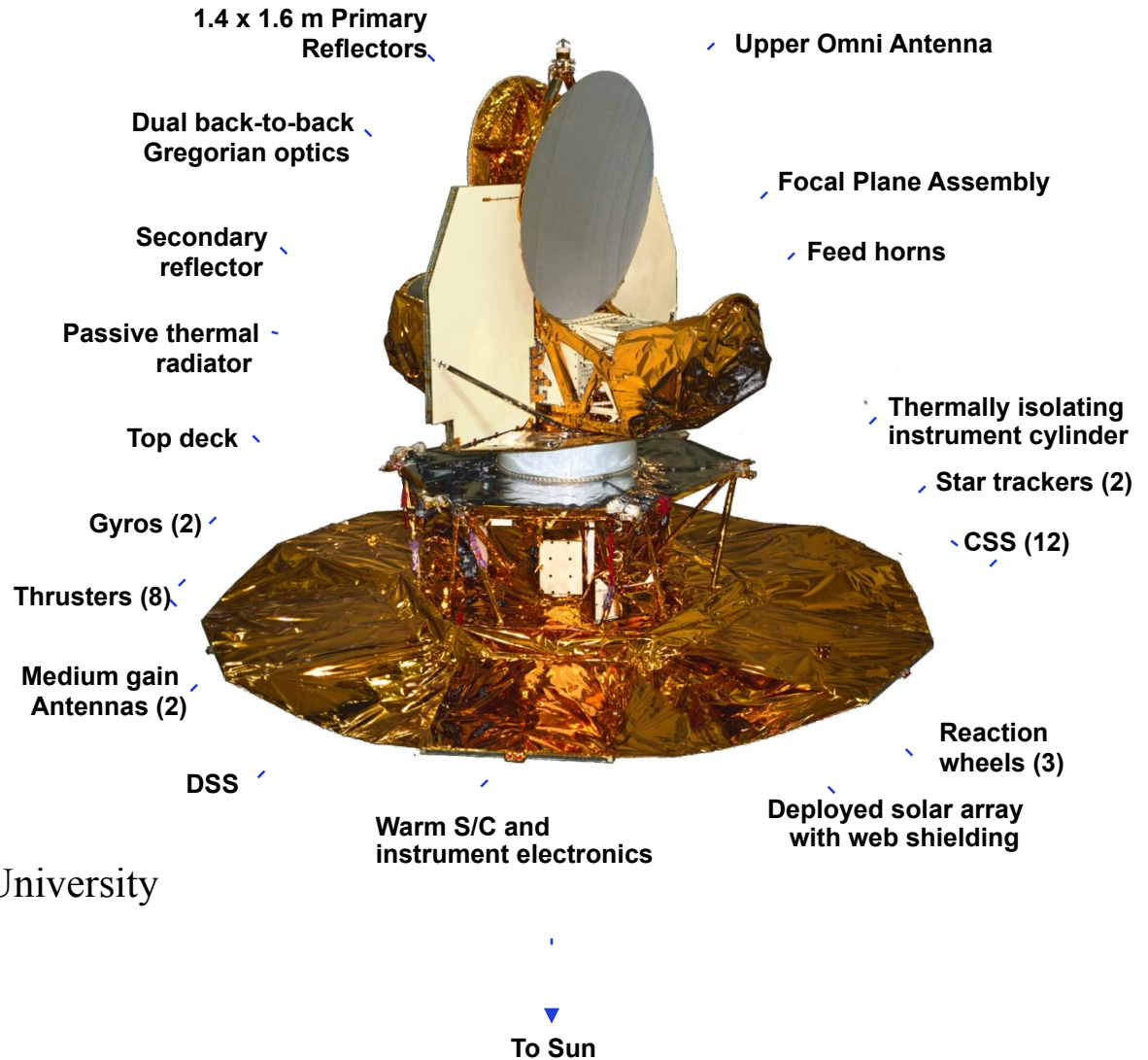




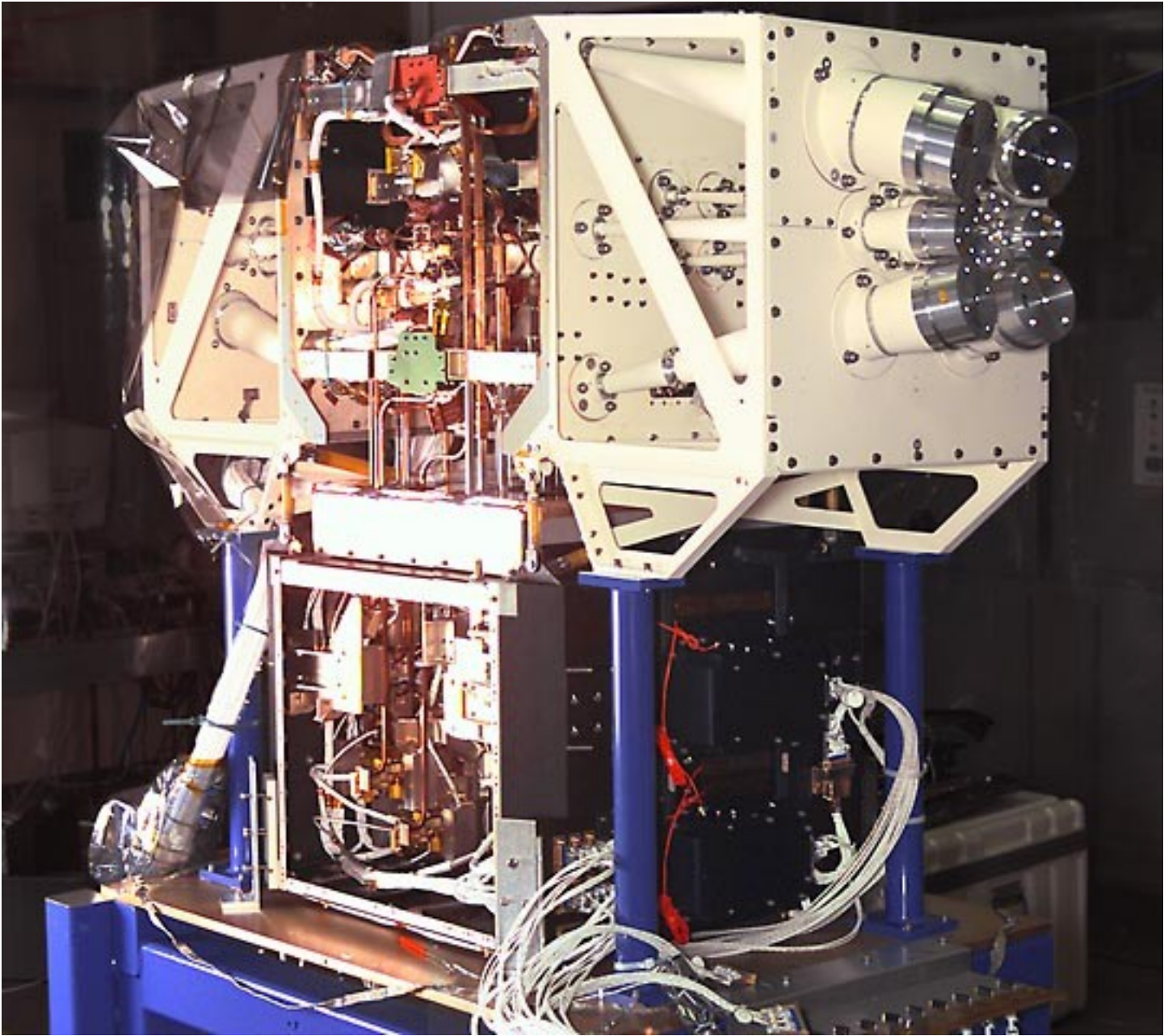
The Mission

Microwave Anisotropy Probe

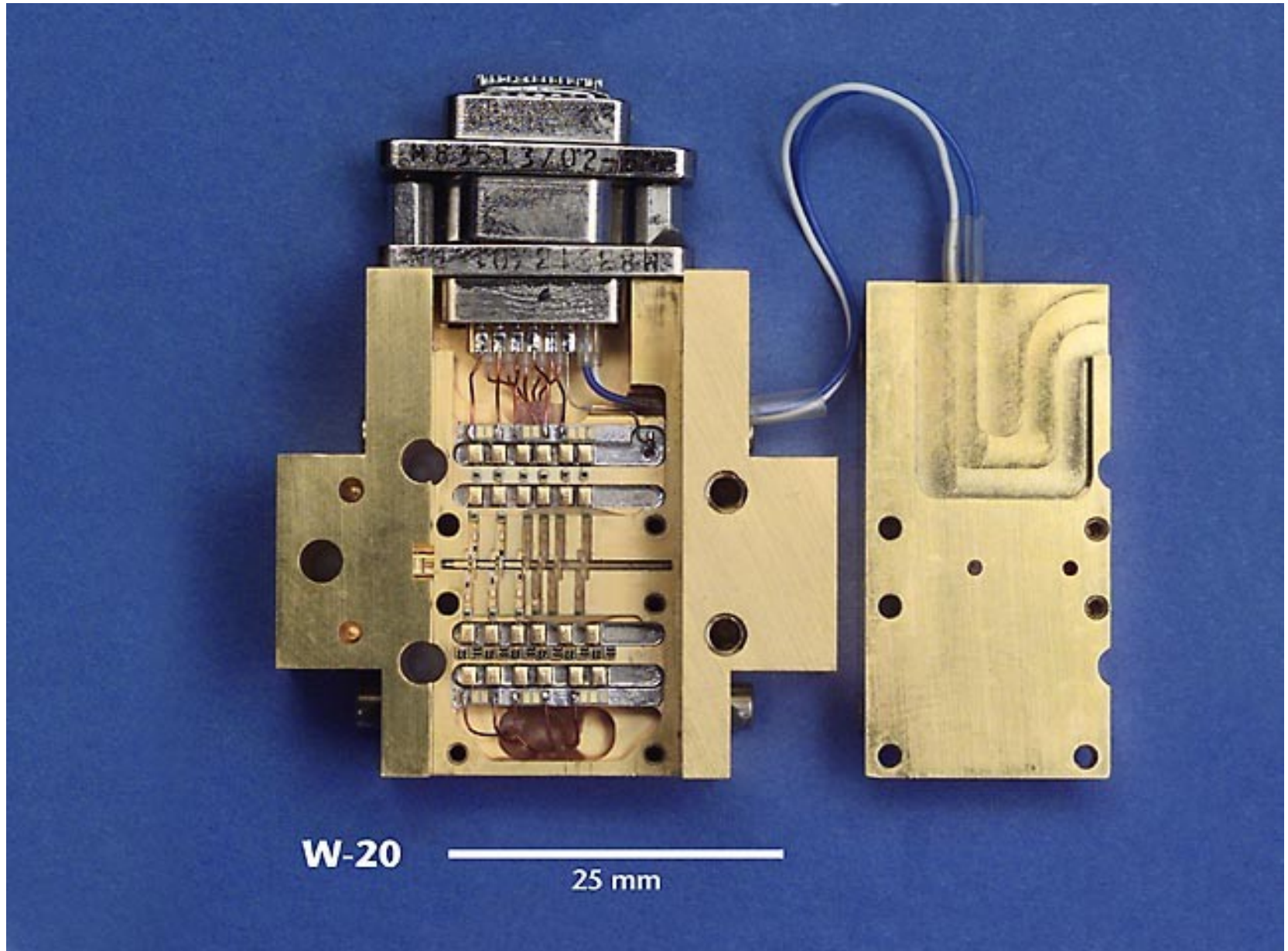
- Map the Cosmic Microwave Background Radiation
- Follow on to COBE with 50 times the resolution
- Medium Size Explorer, MIDEX
- Operate at L2, Store and forward data every day
- 3 Axis, Scan Sky at 1 revolution every 2 minutes
- 835 Kg, 3.6 meters tall, 5.1 across
- 400 Watt load, 72 Kg Fuel

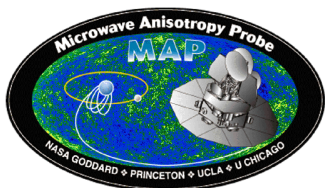


• A partnership between Princeton University and Goddard Space Flight Center

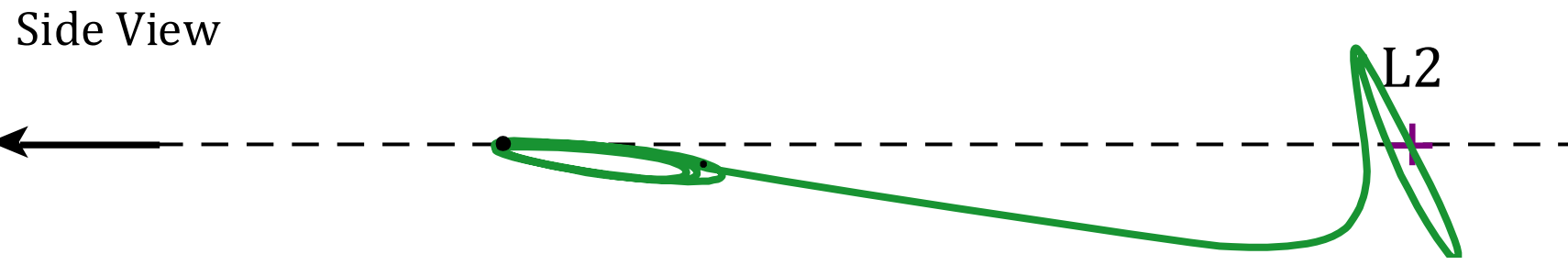
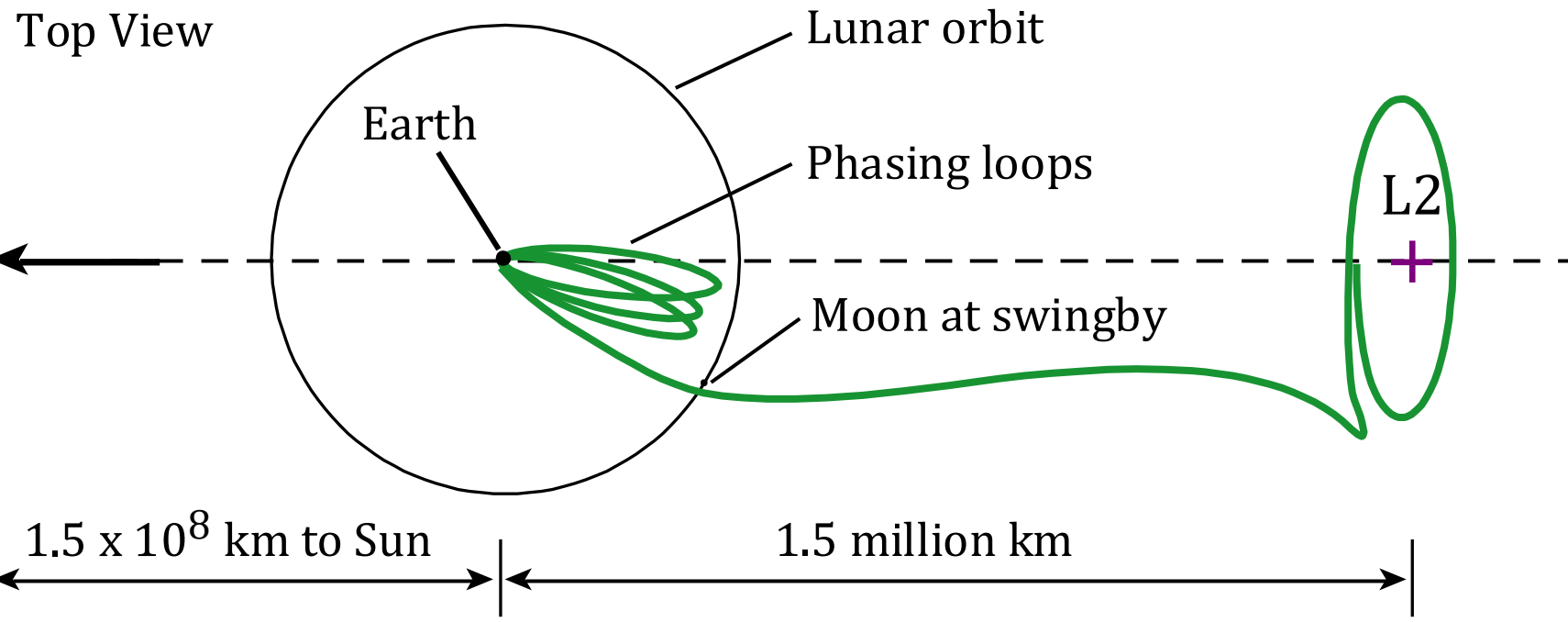


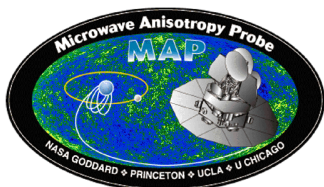
STATE-OF-THE-ART HEMT AMPLIFIERS



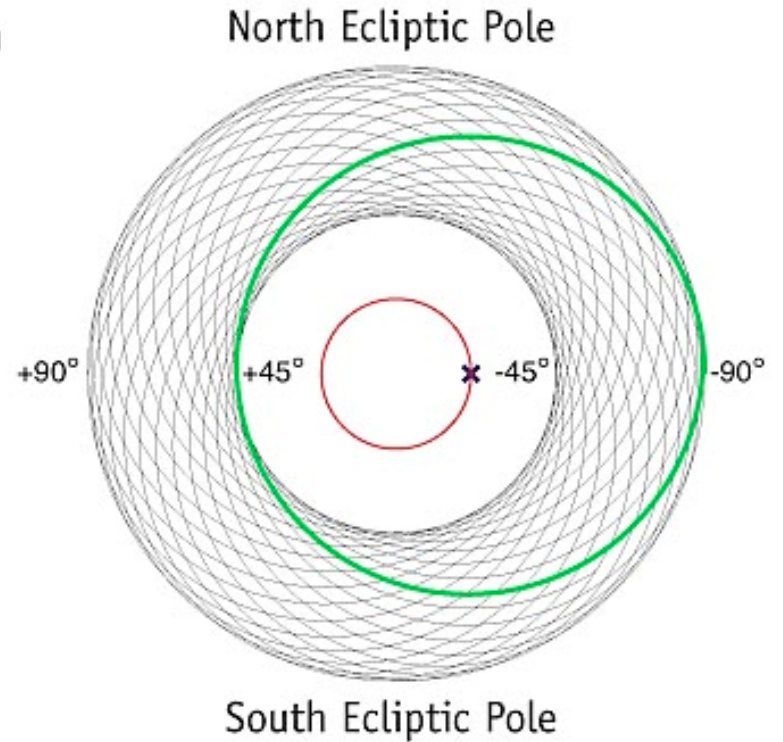
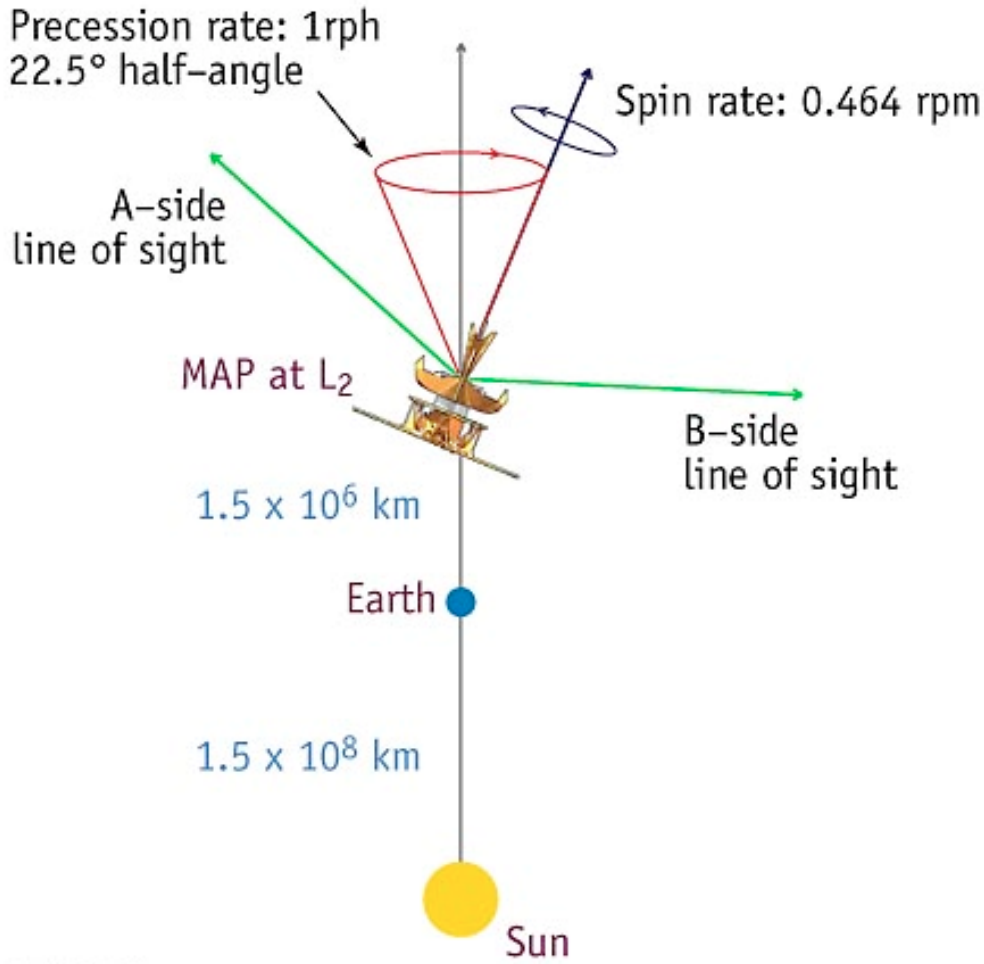


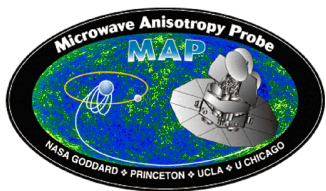
MAP Trajectory to L2



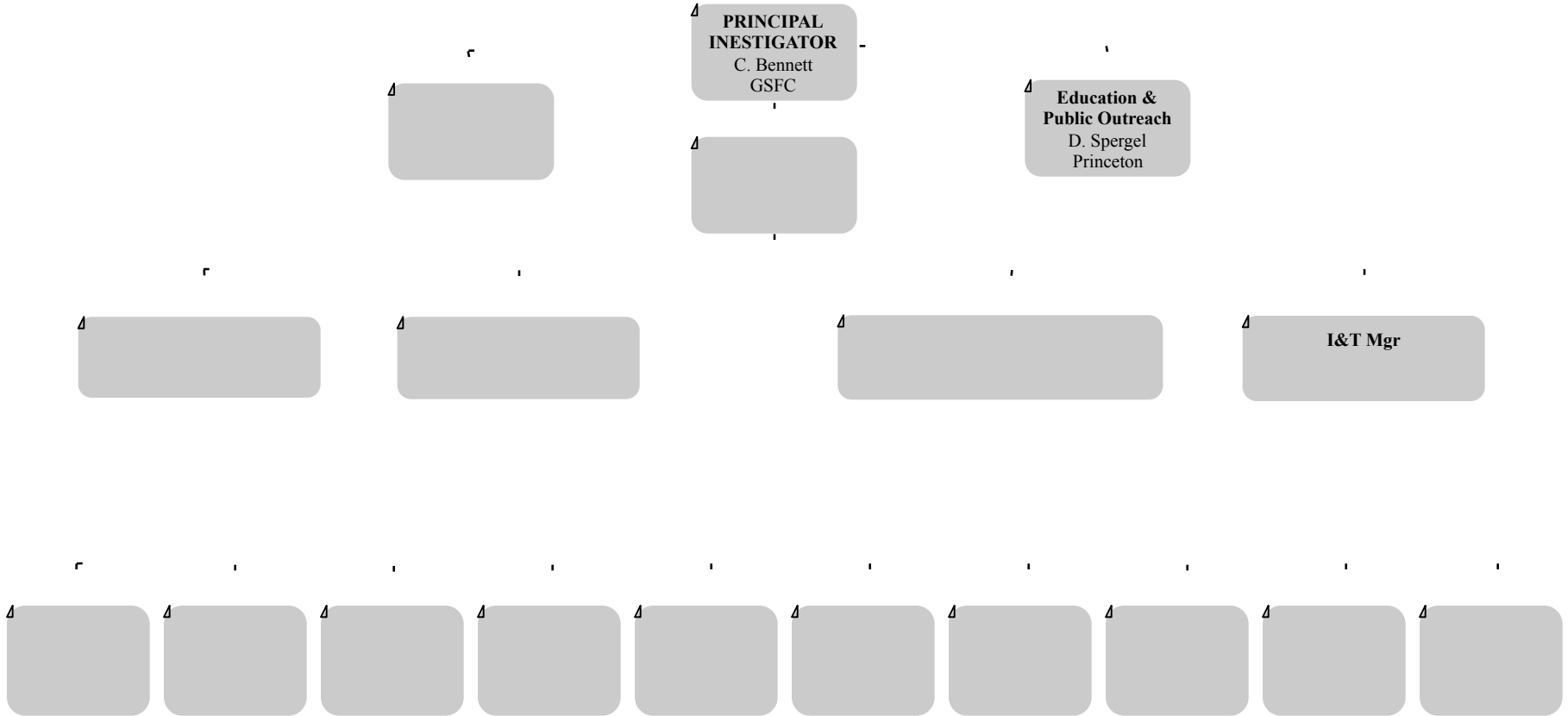


MAP Sky Scan





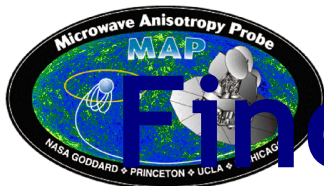
The MAP Organization





MAP: The Good

- Small co-located team
 - Great communications
 - Real team focus – team understood the mission, the end goal
- Clean and clear organization
 - Roles and responsibilities well-understood by all team members
- Good systems engineering
 - Thoughtful consideration of what's important
 - Thorough reliability program, appropriate for single string mission
 - Selected redundancy added after CDR based on reliability analyses
- Willingness and ability to challenge established ways of doing business
 - Same ground system & staff for development and I&T
 - All flight software consolidated in one organization
- Peer level reviews
 - Thorough peer-reviewed design
- Significant test time at all levels



Finding the Weak Links

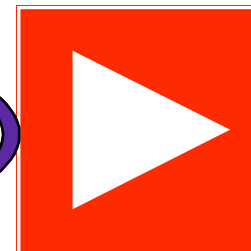
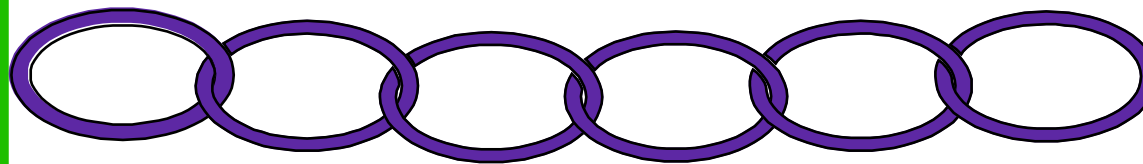
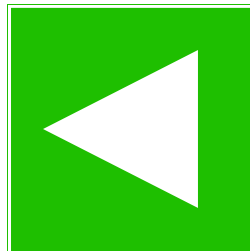
MAP Reliability Program

Forces That Threaten Links

Murphy's Law:
Anything that can go wrong, will

Mission Success

Design



Moving Surfaces	Software and Operations	Parts Application	Understanding of Environment	Workmanship	Random Failure
-----------------	-------------------------	-------------------	------------------------------	-------------	----------------

Design Margin, Redundancy	Integrated Software and Operational Plan	Parts Stress Analysis to PPL21	Analysis with Single Common Environmental Spec	Inspection to NHB5300 or Equivalent, Material and Process Control	Good Parts, Simplicity, Robust Design with Graceful Degradation, Redundancy
Peer Review	Peer Review	Peer Review	Peer Review		

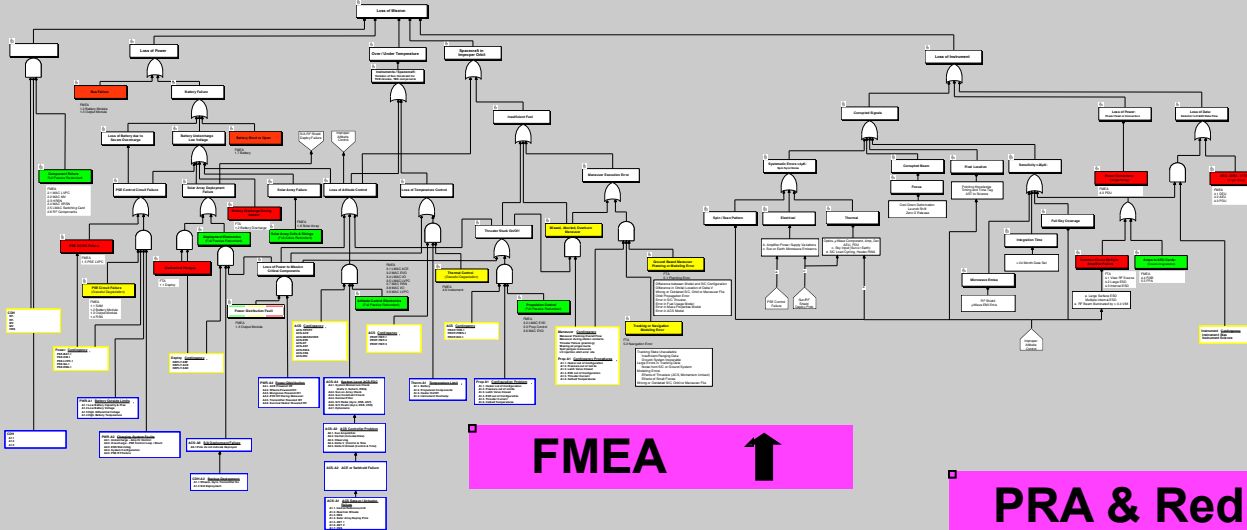
Mitigators

Test	Test	Test	Test	Test	Test
------	------	------	------	------	------

**Where is the weakest link?
What will cause a link to break?
Will the "System" hold with a broken link?**

Reliability Analysis

Mission Fault Tree

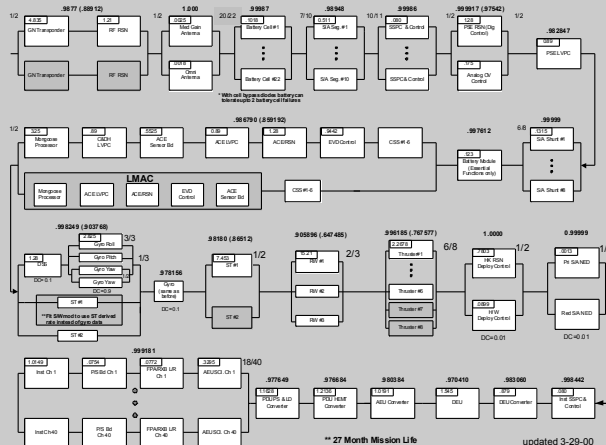


FMEA



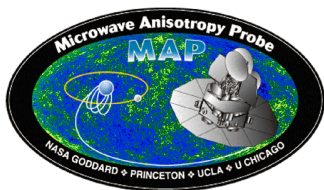
PRA & Redundancy Study

Reliability Block Diagram



Reliability Improvement	Location	Performance	Future Descope (Mass, Pwr)	System Reliability Improvement	Mass	Power	Cost	Schedule	Comments	
1 Flight Software to allow 2 out of 3 Wheels	Mongoose ACS Software	Minimum Science, Reduced Control & Acquisition	N/A	70%	0	0	Med	Low	SW change can be delayed until failure	
2 More Thrusters, Flight Software to allow Thruster Backup	Same bracket as Radials	Minimum Science, Additional Fuel Usage	No	30%	1.2	4 Watts Heater	Low	Low		
3 2nd Star Tracker & XRSN	XRSN in MAC, Xpndt beside existing on bottom deck	100%	Yes	11%	6.5	6 Watts 0 Heater	Med	Low		
4 2nd Star Tracker	Under Top Deck near PSE	100%	Yes	13%	7	8-12 Watts	Med	Low		
5 2 More Thrusters, Flight Software to allow Thruster Backup	Same bracket as Radials	Minimum Function, Minimum Science	Yes	14%	6.5	0 Watts	Med	Low		
6 Flight SW to allow Star Tracker to backup Gyros	Mongoose ACS Software	No Backup for Acquisition, 100% Mission	N/A	9%	0	0	Low	Low		
Subtotal				249%*	21.2	22 Watts				
Reliability improvement of selected options				249%*						
7 2nd AEU & PDU 2020 Configuration, DEU Single String	Bottom Deck, PDU Under Top Deck w/4th Wheel	Loss of 1/2 of Instrument	No	7%	10.3	8.5 Watts	Med	High	3 mos for windings, No Actels	
8 4th Wheel	Bottom Deck equally spaced, or on Bottom Deck TBD	100%	Yes	13%	4th wheel w/ SW, 52% 4th wheel inc SW (2 of 4), 51% w/o SW (3 of 4)	17	10-15 Watts Heater	Med	Med	Large Mechanical System Impact
9 PSE Linear Regulators and Assurance Output Modules Remain on	2nd side of existing boards	100%	No	2%	0.2	0 watts	Med	Med	Long Lead Parts	
10 DEU with 2020 split	Loss of 1/2 of Instrument	No	No	11%			High	High	Parts Availability, Actels	
Subtotal				106% of 78%*	27.5	23				
Reliability improvement potential of all options				38%*						

* The percentage improvement is not a summation of the individual option improvement percentages.



MAP: The Not-so-Good

- Small team
 - Very thin in some critical areas (CM, Scheduling)
- Some systems engineering misses
 - Spacecraft charging mitigation requirements
- Unexpected challenges encountered in unfamiliar engineering territory
 - Trajectory analysis/maneuver planning/rehearsals for lunar swingby
 - Quiet power bus requirements – no heater cycling
- System-level reviews
 - A mixed bag

