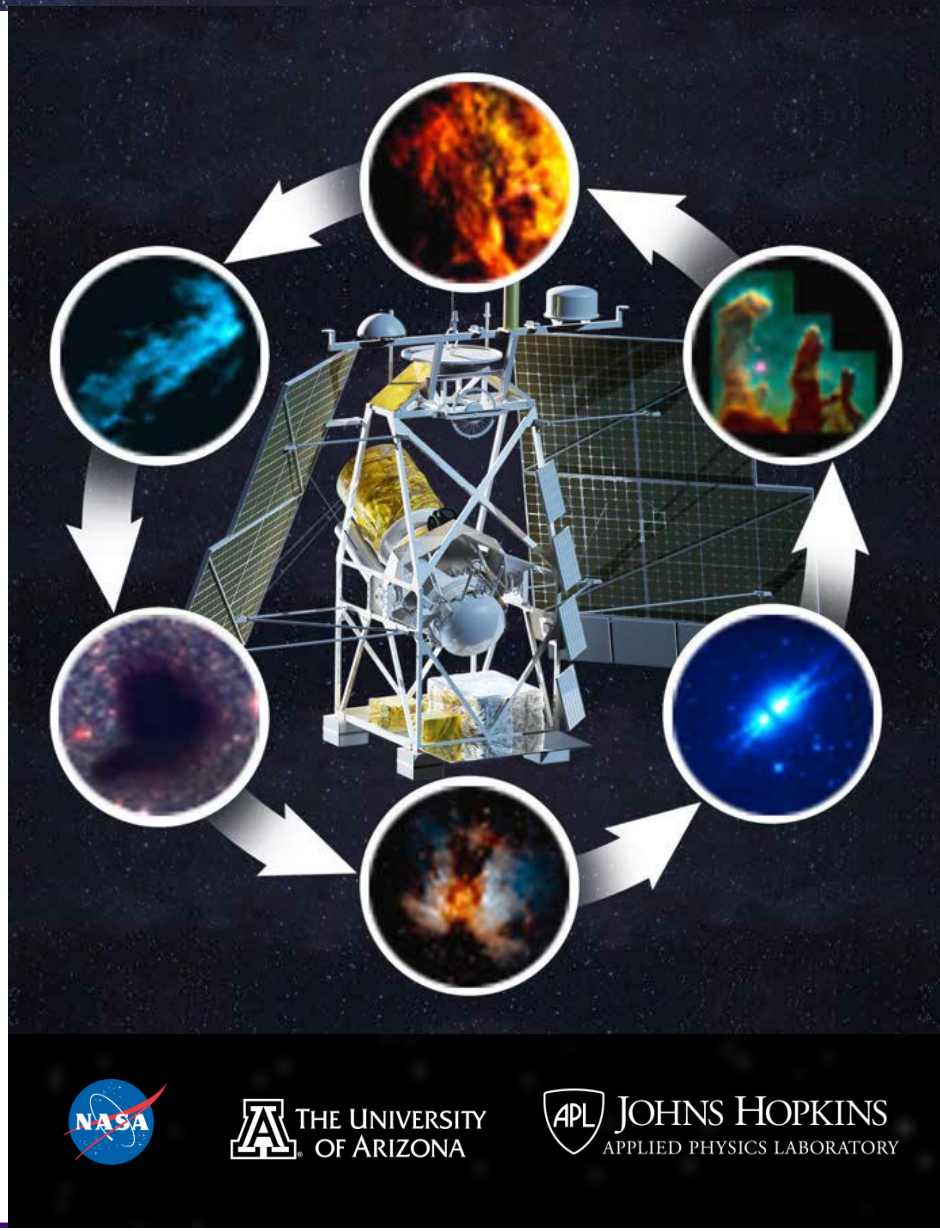
Galactic/Extragalactic ULDB Spectroscopic-Stratospheric Terahertz Observatory (GUSTO)

Project Overview

Principle Investigator	Dr. Christopher Walker
Deputy PI	Dr. Craig Kulesa
Project Manager	Matthew Reinhart
Deputy Project Manager	Richard Fitzgerald
Payload Manager	Hop Bailey
Deputy Payload Manager	David Dolana



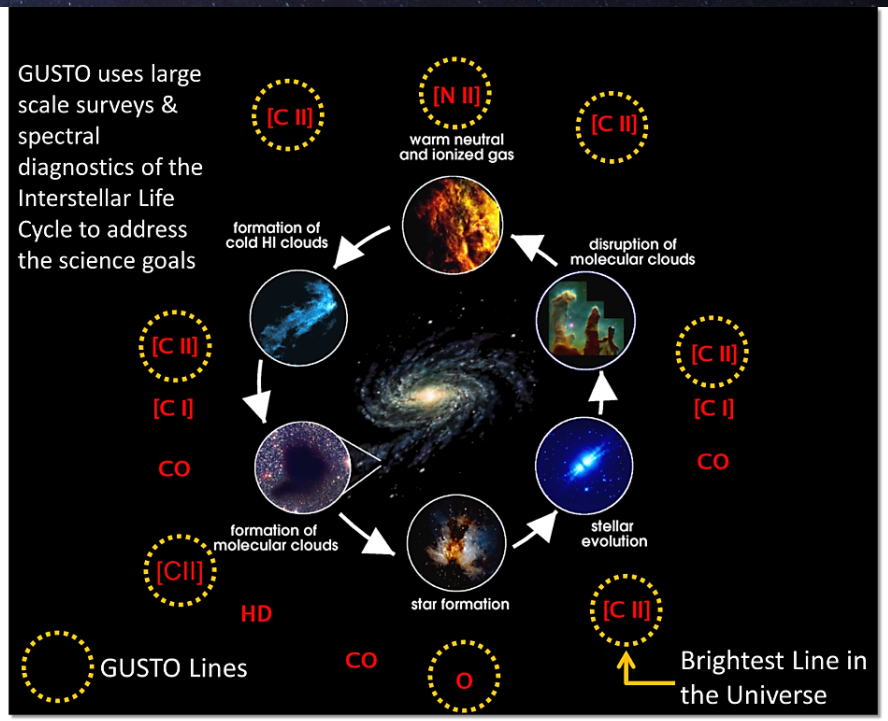
Science Objectives: [CII], [OI], & [NII] Surveys of MW and LMC

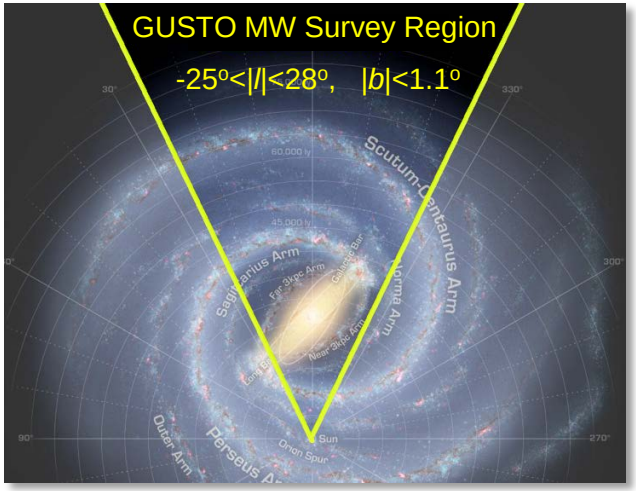
GUSTO will serve as Rosetta Stone for a comprehensive understanding of the inner workings of the Milky Way and Large Magellanic Cloud by surveying them in 3 important far-infrared (THz) interstellar lines

Science Goals:

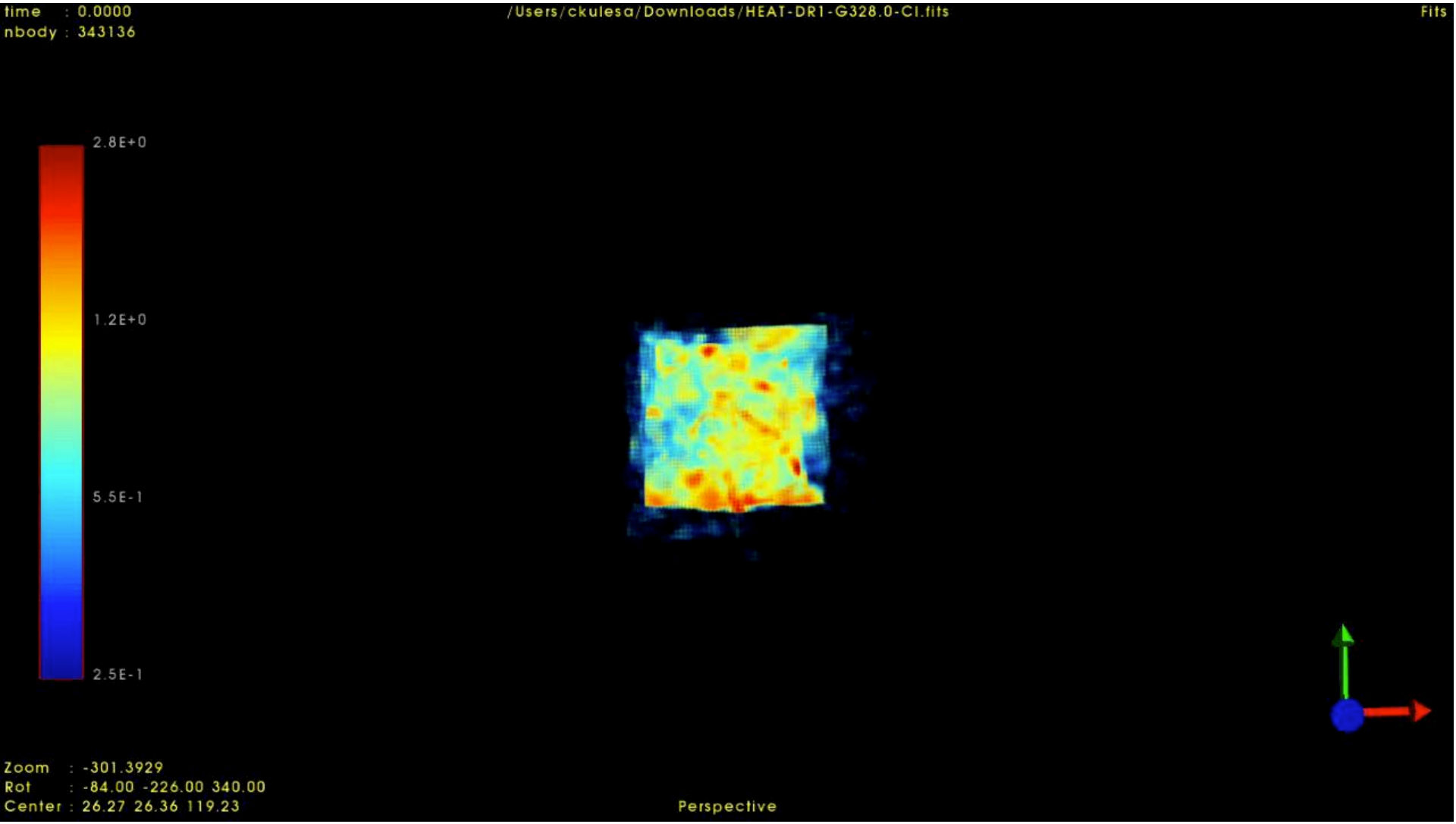
1. Determine the constituents and life cycle of interstellar gas in the Milky Way (MW).
2. Witness the formation and destruction of star-forming clouds
3. Understand the dynamics and gas flow to and in the Galactic Center
4. Understand the interplay between star formation, stellar winds and radiation, and the structure of the interstellar medium (ISM) in the Large Magellanic Cloud (LMC)
5. Construct Milky Way and LMC templates for comparison to distant galaxies

GUSTO provides a cost-effective approach to probe the full life-cycle of star formation and stellar evolution.



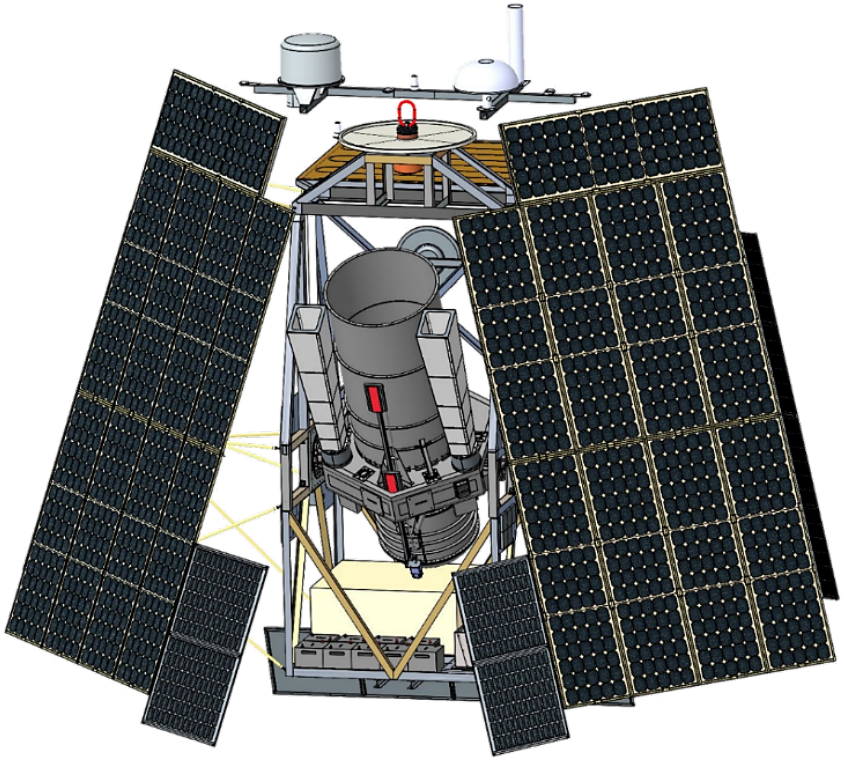


Spectral Resolution is Key to Disentangling Complex Lines of Sight



Mission Overview

- NASA's First Balloon Class D Explorer Mission
  - Designated as a Category 3, Class D Mission
  - First Balloon Explorer Mission of Opportunity selected for Phases B-F.
- Project Management
  - UA: PI, Payload
  - APL: PjM, MSE, Gondola, MOPS
  - NASA BPO: Balloon hardware, launch services
- Mission Profile
  - **First full balloon science** mission that will :
    - Use the NASA developed Super Pressure Balloon system
    - Fly for 75 days or more at 110 kft (33.5 km) altitude
  - Launch from Antarctica in December 2021
  - Mapping mission:
    Slow scans across Milky Way and Large Magellanic Cloud
  - ~100% duty cycle science observations
- Science Payload:
  - 0.9-m F/10 Cassegrain telescope optimized for THz frequencies
  - 3x8 pixel array of cryogenically cooled heterodyne detectors
  - 150 liter LHe cryostat maintains detectors at 4K for 100+ days
- Gondola (Observing Platform):
  - 2.5 axis stabilized gravity gradient attitude control system
  - Power system with solar arrays and Li-Ion rechargeable batteries
  - Liquid cooling system to support payload heat dissipation requirements
  - Telecomm & balloon control via NASA provided SIP electronics



GUSTO Gondola Stats	
Dimensions (W x D x H)	24.5 x 15.5 x 21.5 ft
Observatory CBE mass	1459 kg
Average power usage	1000 W
Average power generation	1700 W

GUSTO is the pathfinder for future bold balloon programs

Lessons Learned: PI Perspective

Phase A

1) Address every identified weakness
2) Maintain science goals from Step I Proposal
3) Recosting exercise should be done early
4) Keep reserve at ≥ 30%
5) Identify back-up suppliers for key components and name them as such in the CSR
6) Develop a complete list of descopes
7) Develop a complete Master Schedule
8) Gain familiarity with the SMA process
9) Heritage is essential to reducing perceived risk
10) Be prepared to do it all again!

Phone Call

CSR

Site Visit

Wait

Phone Call

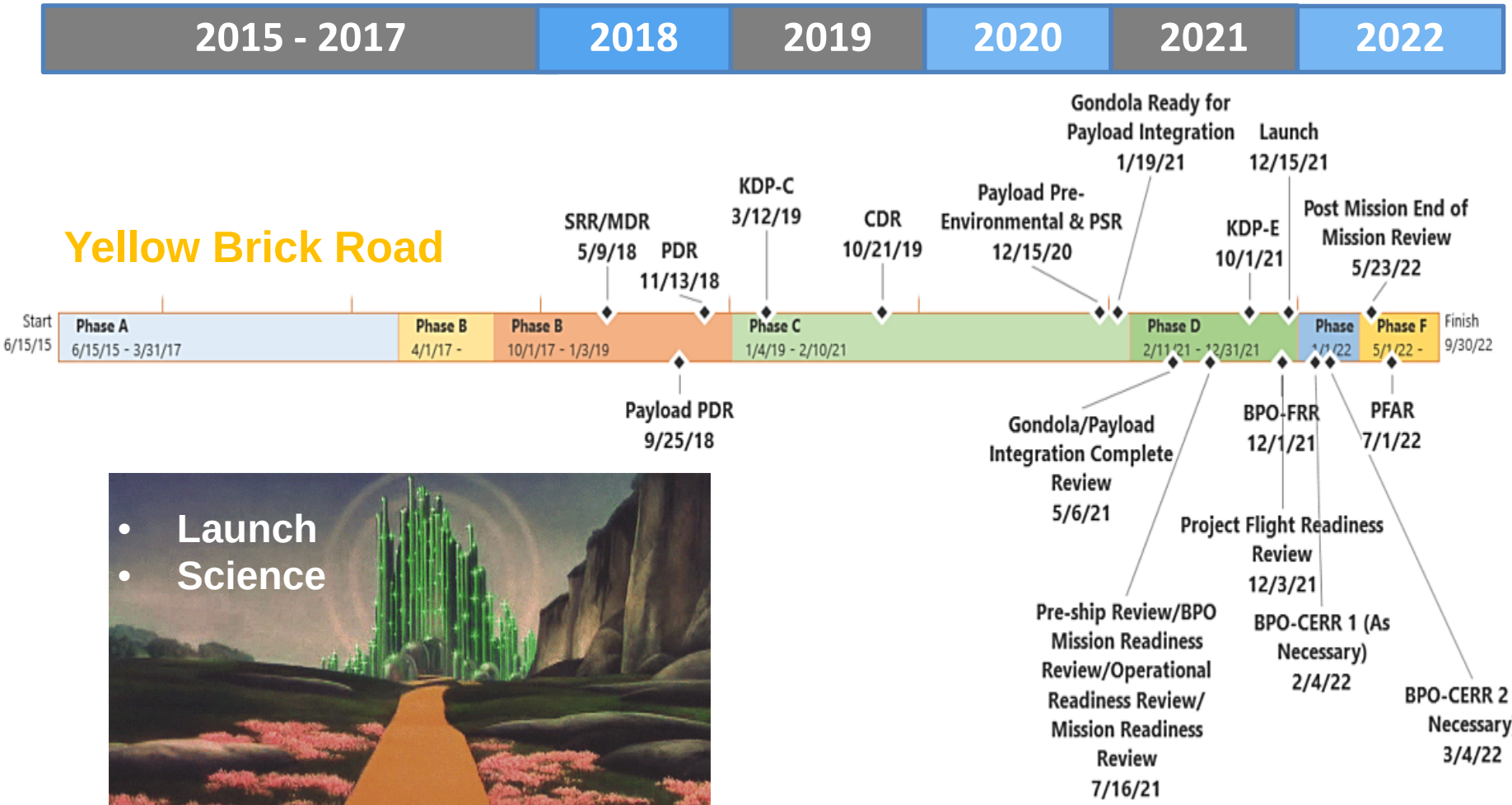
Lessons Learned: PI Perspective

Phase A

Phase B

"Not in Kansas Anymore"

Project Timeline



Phase B → Phase C/D

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Crystal Ball: Risk Management

Likelihood of Occurrence	1 - Very Low	2 - Low	3 - Moderate	4 - High	5 - Very High
5- Very High					
4- High					
3- Moderate		= GUSTO-R-028			
2- Low			= GUSTO-R-008 = GUSTO-R-024 = GUSTO-R-027	= GUSTO-R-010 = GUSTO-R-025	
1- Very Low				= GUSTO-R-004 = GUSTO-R-006 = GUSTO-R-061	= GUSTO-R-045

Consequence of Occurrence

Top Ten	Code	Motion	Title	Approach
1	010	=	Band 3 Mixer Performance	Mitigate
2	025	=	IF standing waves in spectra	Mitigate
3	028	=	Super Pressure Balloon Lifetime	Watch
4	045	=	Late Start of I&T in Antarctica	Watch
5	024	=	Band 1 & 2 Oscillator DC Power Consumption	Watch
6	027	=	Low Mass Margin	Mitigate
7	008	=	Band 3 QCL LO meeting all requirements on schedule	Watch
8	006	=	Cooling System Degradation/Failure	Mitigate

Crystal Ball: Risk Management

Current Rank	ID	Title	Risk (If...Then Statement)	Likelihood	Consequence	Category	Approach	Mitigation Status Updates
1	010	Band 3 Mixer Performance	If Band 3 receiver performance (sensitivity and/or stability) is lower than expected, then mission mapping speed will be reduced and one or more baseline L1 science requirements may not be met.	2-Low	4-High	Technical	Mitigate	1/13/2020 CAK: Screening of alternative devices on the same chip is returning workable performance. 4 mixers have been screened to be acceptable with mean noise temperature of 680K DSB. It is anticipated that we may regain the full complement of B3 mixers at the next report on 1/15. 12/9/2019 CAK: Overvoltage event has damaged the screened B3 mixers. There are redundant devices on the HEB chips and SRON has been instructed to wire-bond to the next devices for optical alignment and performance testing. Schedule delay is ~2 weeks but in principle no technical risk change. Changed mitigation deadline to end of Jan 2020. 11/6/2019 CAK: 8 flight devices have been screened to meet the 700K noise requirement (average is 670K). May consider changing the risk to indicate Band 3 "receiver" performance to cast the net a bit wider. 10/1/2019 CAK: Band 3 mixer screening is proceeding and the best 6 devices meet flight requirements with a mean lens-coupled Tmix of 665 K DSB. Maintain risk at present level. 9/12/2019 CAK: SRON is now screening HEBs that meet Band 3 performance requirements. This has some schedule penalty but should reduce schedule risk later on.
2	025	IF standing waves in spectra	If the payload design provides for inadequate stability of the spectroscopic baselines, then the payload will not meet measurement requirements.	2-Low	4-High	Schedule	Mitigate	1/13/2020 CAK: Integrated testing of prototypes has not yet reached the series of standing-wave evaluations. UA continues to work toward test completion. Delayed end date of mitigations 1 month. 12/9/2019 CAK: Cryostat test setup completed. Mixer tests to be performed at UA with prototype electronics starting this month. Need updates from ASU on their mitigation. 9/12/2019 CAK: End-to-end testing of Mixer Bias Board, LO controller, and PID control of mixers to be started this month. Standing waves to be evaluated at this time. 8/12/2019 CAK: ASU peer review shows work plan to mitigation. UA and ASU to have dual developments to test this risk. Science team advised on risk and science data team identifying how much residual standing wave structure can be fixed in software and meet L1 requirements.
3	028	Super Pressure Balloon Lifetime	If the Super Pressure Balloon (SPB) does not demonstrate a 75 day mission duration, then GUSTO may not achieve all of its baseline Level 1 science requirements.	3-Moderate	2-Low	Technical	Watch	12/9/2019 and 1/13/2020 CAK: No changes. 11/6/2019 CAK: Changed "if...then" statement to better capture intent and update to 75 days mission duration. No changes. 9/12/19, 8/12/19 and 6/6/2019 CAK: No updates, continue to watch. 3/27/2019 CAK: No updates. CSBF's test flight program schedule for SPB continues to be in flux. 2/21/2019: Risk Board: No update. 01/28/2019: Risk Board: Approach updated to "Watch". Mission duration shortened by 25%. Monitor super pressure balloon development for next steps. 01/28/2019 (PNB): Since mitigations are complete suggest changing Approach to "Watch".
4	045	Late Start of I&T in Antarctica	If the Antarctic Campaign starts late (after November 1st) then the GUSTO launch readiness will be delayed.	1-Very Low	5-Very High	Schedule	Watch	01/13/20 (PNB): No change. Continue watching. 12/10/19 (MJR): Reassessed scoring to focus on 1-year launch (with greater consequence and lower likelihood) 12/10/19 (PNB): No change in mitigation status this month. 11/7/2019 (MJR) Currently watch, but Pietro took action to consider if there are any mitigation steps to include.
5	024	Band 1 & 2 Oscillator DC Power Consumption	If the Band 1 & 2 local oscillators have higher than anticipated DC power dissipation, the LO thermal plate will run hotter, which could decrease the longevity of the LO amps and multipliers.	2-Low	3-Moderate	Technical	Watch	1/13/19 and 12/9/2019 CAK: Thermal analysis of updated LO mounts surpasses requirements (CDR slides). VDI is completing build of first flight pixels and testing is in progress. 8/12/2019 CAK: Updates to manufacturable LO mounts will trigger another thermal analysis. Update expected for UA STOP review. 6/6/2019 CAK: Cooling loop (pump) RFA closed and internal review of Observatory thermal system performed with good closure on thermal loop.
6	027	Low Mass Margin	If the Observatory mass allocation is exceeded, then flight duration may be shortened.	2-Low	3-Moderate	Technical	Mitigate	01/14/2020 (DFK): No update. Continue to monitor. Mass margin continues to be low. MEL scrub to be conducted this month. 12/10/19 (PNB): No update. Mass margin still low. 11/6/19 (PNB): Initial power analysis indicates that it is possible to remove a battery without incurring in power issues at end of mission. post MCDR SRB has doubts, additional battery discharge data and analysis will be needed. 10/2/19 (PNB): Mass margin remains low. 9/4/19 (PNB): Unallocated Observatory Mass Margin has decreased to ~ 2%. The total mass margin is now back to 9.2%. This has to do with added more allocated margin to systems which has decreased substantially the unallocated mass margin. Contiuing to work on reducing mass wherever possible. The ExPO with concurrence from the GUSTO project has directed the SPB team to revisit the analysis of what is the minimum amount of ballast needed for a 75 days mission out of Antarctica

Liens & Threats

Success is a Team Effort

Knowledge
Leadership
Passion
Grit

Explorer Program Office
- Your extended project Family
- Advocates within the NASA system
- Deep knowledge of how to run a mission
- Access to unique resources
- Always ready to help

SMA
- Helps keep bad things from happening
- When they do, provides a path forward

Project Management
- Keeps project on schedule and cost
- Risk Management

Science Team
- Sets Science Objectives & Requirements
- Keeps “eyes on the prize”

Instrument Team
- Turns ppts into reality
- Works to achieve the requirements necessary for mission success

Light at End of the Tunnel

Phase E/F