 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
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

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**GUSTO Gondola Stats**

<table>
<thead>
<tr>
<th>Dimensions (W x D x H)</th>
<th>24.5 x 15.5 x 21.5 ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observatory CBE mass</td>
<td>1459 kg</td>
</tr>
<tr>
<td>Average power usage</td>
<td>1000 W</td>
</tr>
<tr>
<td>Average power generation</td>
<td>1700 W</td>
</tr>
</tbody>
</table>

**GUSTO is the pathfinder for future bold balloon programs**
1) Address every identified weakness
2) Maintain science goals from Step I Proposal
3) Recosting exercise should be done early
4) Keep reserve at $\geq 30\%$
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!
Lessons Learned: PI Perspective

Phase A

CSR
Site Visit

Phase B

“Not in Kansas Anymore”
Project Timeline


Yellow Brick Road

- Launch
- Science

Start 6/15/15

Phase A 6/15/15 - 3/31/17

Phase B 4/1/17 - 1/3/19

Phase B 10/1/17 - 1/3/19

Phase C 1/4/19 - 2/10/21

Phase D 2/11/21 - 2/31/21

Phase E 5/7/22 - Finish 9/30/22

Payload PDR 9/25/18

SRR/MDR 5/9/18

PDR 11/13/18

KDP-C 3/12/19

CDR 10/21/19

Payload Pre-Environmental & PSR 12/15/20

KDP-E 10/1/21

Gondola Ready for Payload Integration 1/19/21

Launch 12/15/21


Gondola/Payload Integration Complete Review 5/6/21

BPO-FRR 12/1/21

PFAR 7/1/22

Project Flight Readiness Review 12/3/21

Pre-ship Review/BPO Mission Readiness Review/Operational Readiness Review/Mission Readiness Review 7/16/21

BPO-CERR 1 (As Necessary) 2/4/22

BPO-CERR 2 (As Necessary) 3/4/22
Phase B → Phase C/D

- I&T
- CDR
- KDPC
- MMRs
- SRR
- SMA
- Project Plan

Cost Cap
Reserves

- Phase B
- Phase C/D

ARBS
CDR
KDPC
PDR
MMRs
SRR
SMA

Haunted Forest

I'd turn back if I were you

Witch's Castle

1 mile
Help achieve Mission Success
### Crystal Ball: Risk Management

#### Likelihood of Occurrence

<table>
<thead>
<tr>
<th>5 - Very High</th>
<th>4 - High</th>
<th>3 - Moderate</th>
<th>2 - Low</th>
<th>1 - Very Low</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>= GUSTO-R-028</td>
<td></td>
<td>= GUSTO-R-004</td>
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<td>= GUSTO-R-008</td>
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<td>= GUSTO-R-006</td>
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<td>= GUSTO-R-024</td>
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<td>= GUSTO-R-061</td>
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<td></td>
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<td>= GUSTO-R-027</td>
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</tr>
</tbody>
</table>

#### Consequence of Occurrence

<table>
<thead>
<tr>
<th>1 - Very Low</th>
<th>2 - Low</th>
<th>3 - Moderate</th>
<th>4 - High</th>
<th>5 - Very High</th>
</tr>
</thead>
</table>

#### Top Ten

<table>
<thead>
<tr>
<th>Code</th>
<th>Motion</th>
<th>Title</th>
<th>Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>010</td>
<td>=</td>
<td>Band 3 Mixer Performance</td>
<td>Mitigate</td>
</tr>
<tr>
<td>025</td>
<td>=</td>
<td>IF standing waves in spectra</td>
<td>Mitigate</td>
</tr>
<tr>
<td>028</td>
<td>=</td>
<td>Super Pressure Balloon Lifetime</td>
<td>Watch</td>
</tr>
<tr>
<td>045</td>
<td>=</td>
<td>Late Start of I&amp;T in Antarctica</td>
<td>Watch</td>
</tr>
<tr>
<td>024</td>
<td>=</td>
<td>Band 1 &amp; 2 Oscillator DC Power Consumption</td>
<td>Watch</td>
</tr>
<tr>
<td>027</td>
<td>=</td>
<td>Low Mass Margin</td>
<td>Mitigate</td>
</tr>
<tr>
<td>008</td>
<td>=</td>
<td>Band 3 QCL LO meeting all requirements on schedule</td>
<td>Watch</td>
</tr>
<tr>
<td>006</td>
<td>=</td>
<td>Cooling System Degradation/Failure</td>
<td>Mitigate</td>
</tr>
<tr>
<td>Current Rank</td>
<td>ID</td>
<td>Title</td>
<td>Risk (If...Then Statement)</td>
</tr>
<tr>
<td>-------------</td>
<td>-----</td>
<td>----------------------------</td>
<td>------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>1</td>
<td>010</td>
<td>Band 3 Mixer Performance</td>
<td>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.</td>
</tr>
<tr>
<td>2</td>
<td>025</td>
<td>IF standing waves in spectra</td>
<td>If the payload design provides for inadequate stability of the spectroscopic baselines, then the payload will not meet measurement requirements.</td>
</tr>
<tr>
<td>3</td>
<td>028</td>
<td>Super Pressure Balloon Lifetime</td>
<td>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.</td>
</tr>
<tr>
<td>4</td>
<td>045</td>
<td>Late Start of I&amp;T in Antarctica</td>
<td>If the Antarctic Campaign starts late (after November 1st) then the GUSTO launch readiness will be delayed.</td>
</tr>
<tr>
<td>5</td>
<td>024</td>
<td>Band 1 &amp; 2 Oscillator DC Power Consumption</td>
<td>If the Band 1 &amp; 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.</td>
</tr>
<tr>
<td>6</td>
<td>027</td>
<td>Low Mass Margin</td>
<td>If the Observatory mass allocation is exceeded, then flight duration may be shortened.</td>
</tr>
</tbody>
</table>

**General Notes:**
- For risk #010 Band 3 Mixer, ASU peer review shows work plan to mitigation. UA and ASU to have dual developments to test this risk.
- For risk #025 IF standing waves in spectra, the updated approach is to keep the risk status as "Watch".
- For risk #028 Super Pressure Balloon Lifetime, the mitigation deadline has been extended.
- For risk #045 Late Start of I&T in Antarctica, the risk status remains "Watch".
- For risk #024 Band 1 & 2 Oscillator DC Power Consumption, the thermal analysis of updated LO mounts surpasses requirements.
- For risk #027 Low Mass Margin, MEL scrub to be conducted.

**Mitigation Status Updates:**
- 9/12/19 (PNB): Unallocated Observatory Mass Margin has decreased to ~ 2%. The total mass margin is now back to ~ 2%. This has to do with added more allocated margin, which has decreased substantially the unallocated mass margin. Continuing 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.
- 11/7/2019 (MIR) Currently watch, but Pietro took action to consider if there are any mitigation steps to include.
Success is a Team Effort

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

Knowledge
Leadership
Passion
Grit

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