Joud Bamehriz

ENGINEERING PORTFOLIO

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1 Profile

- **Name:** Joud Bamehriz
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About this portfolio

This portfolio supplements my resume by highlighting selected aerospace engineering projects spanning spacecraft systems, atmospheric modeling, and flight hardware. The projects presented here reflect my experience working across modeling, analysis, and experimental validation in multidisciplinary, industry-sponsored research environments.

Each project includes a concise technical overview, a description of my individual contributions, and key results or outcomes. Where applicable, links to source code, simulations, or experimental documentation are provided. Together, these projects demonstrate my approach to engineering problems: combining physical insight, quantitative analysis, and system-level thinking. I welcome questions or discussion about any of the work presented and can be reached via email.

2 Cryogenic Boil-Off Recondensation System — NASA X-Hab

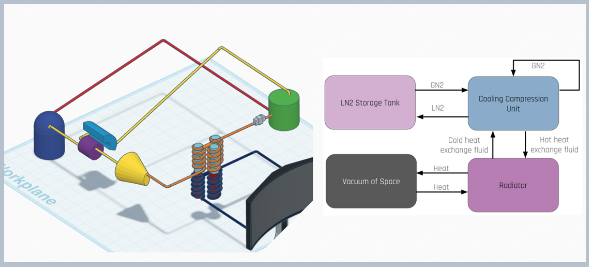
2.1 Project Overview

- **Engineering Problem:** Cryogenic nitrogen storage tanks experience heat ingress that leads to periodic pressure reduction, nitrogen boil-off, and venting to space, increasing consumable mass and limiting mission duration.

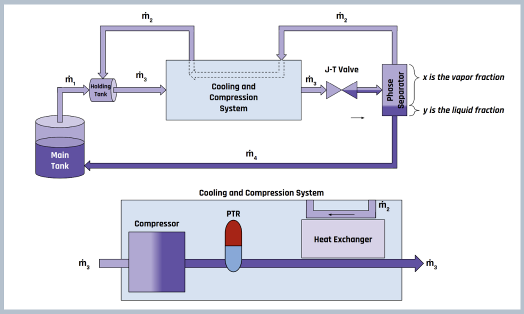
- **System Objective:** Develop a deployable, space-relevant cryogenic system capable of recapturing and recondensing nitrogen boil-off gas (GN_2) to minimize LN_2 losses.

- **Technical Approach:**
  - Utilize low-mass, low-power pulsed-tube cryocoolers to enable GN_2 reliquefaction
  - Integrate a high-emissivity radiator to reject heat directly to the vacuum of space
  - Reduce dependence on mass- and power-intensive cryogenic pumping systems

- **Design Process:** Requirements derived from the NASA X-Hab solicitation and stakeholder feedback, supported by component-level trade studies emphasizing thermal performance, safety, and system integration, shown in Fig.1.



(a) Overall system setup



(b) GN_2 recondensation system configuration

Figure 1: Recondensation system designed to fulfill stakeholder requirements.

- **Experimental/Numerical Validation:**
  - Benchtop radiator testing to validate radiative heat-rejection capability and thermal load capacity
  - Benchtop recondensation testing to verify reliquefaction feasibility and production rate
  - Test configurations designed with strong emphasis on safety and risk mitigation
  - Aspen-based system simulation to model nitrogen boil-off, recondensation processes, and heat rejection performance shown in Fig.2.

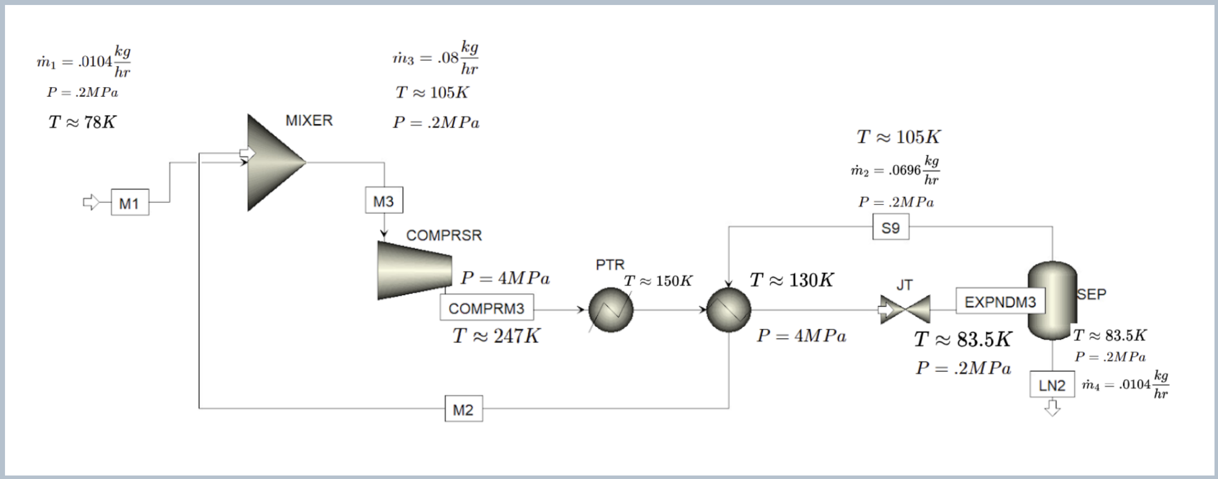


Figure 2: ASPEN simulation of the Cooling & Compression cycle

2.2 My Contributions

- **Role:** Safety Officer and Cooling & Compression Cycle Designer
- Conducted system-level risk analysis and prepared formal risk assessments, including hazard identification, mitigation strategies, and safe test procedures for cryogenic and pressurized systems.
- Selected the thermodynamic cooling and compression cycle and defined key component performance requirements based on mission constraints.
- Developed and executed a system-level ASPEN simulation to analyze thermodynamic performance and calculate liquid nitrogen yield.

2.3 Final Deliverables

A Scaled, space-relevant system architecture supported by numerical models, computer simulations, and experimental results, enabling future transition toward a flight-qualified system. This project is Ongoing; the system is currently progressing through internal and stakeholder design reviews and will transition to testing soon.

3 Detecting the Forbush Decrease - NASA Nationwide Eclipse Ballooning Project

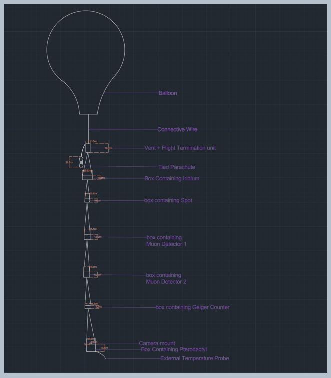
3.1 Project Overview

- **Scientific Problem:** Forbush decreases are transient reductions in galactic cosmic ray intensity caused by interplanetary disturbances such as coronal mass ejections (CME). Despite being well-documented, the atmospheric response of secondary cosmic rays during these events remains incompletely characterized, particularly as a function of altitude.

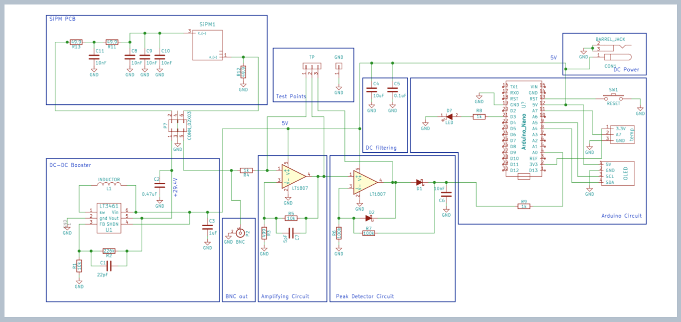
- **System Objective:** Design and execute a high-altitude balloon-based experiment to measure variations in cosmic ray flux across multiple atmospheric layers, enabling direct observation of Forbush decreases and their correlation with solar activity.

- **Technical Approach:**
  - Built, and calibrated a scintillator-based muon detector for atmospheric particle measurements
  - Developed software tools to predict balloon flight trajectories and receive alerts for CME-driven space weather events
  - Deployed a helium-filled weather balloon carrying a multi-instrument payload to sample the upper atmosphere during targeted solar events
  - Measured charged particle flux using a muon detector and Geiger counter across varying environmental parameters (altitude, pressure, and temperature)
  - Compared baseline cosmic ray flux measurements with data collected during CME-induced Forbush decrease events

- **Design Process:** The payload architecture was developed to balance mass, power, and data fidelity constraints associated with high-altitude balloon flights. Instrument placement along the balloon train was optimized for safety, telemetry reliability, and data quality. The final configuration included a flight termination unit (FTU), parachute, tracking and imaging systems, particle detectors, and custom telemetry electronics, as illustrated in the figures below.



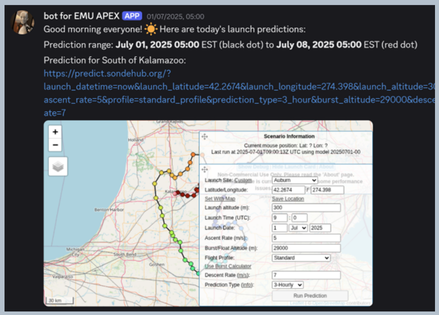
(a) High-altitude balloon payload configuration



(b) Muon detector subsystems circuit diagram

3.2 My Contributions

- **Role:** Flight Director and Software Development Lead
- Built and calibrated the scintillator-based muon detector; identified the need for a Geiger counter to enable coincident detection and designed mechanical enclosures and mounting hardware in CAD to ensure structural integrity and safety.
- Developed software tools to predict balloon flight trajectories and generate solar event alerts to support mission planning; source code available in this GitHub repository.
- Planned and executed high-altitude balloon launches, ensuring compliance with FAA regulations and meeting safety, telemetry, and payload recovery constraints.
- Developed data processing pipelines to analyze cosmic ray count rates and assess potential Forbush decrease signatures.

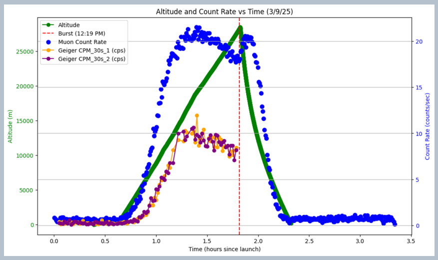


(a) Launch Prediction software results

(b) One example of a lightweight, 3D-printed enclosure designed for external sensor mounting on the payload.

3.3 Results

A balloon-borne experimental platform was successfully designed, integrated, and flown, producing altitude-resolved cosmic ray count rate data from both a scintillator-based muon detector and a Geiger counter. Flight data were processed to generate cosmic ray count rate profiles as a function of altitude and time as shown in the plot below. Due to flight timing, atmospheric conditions, and space weather variability, no statistically significant difference between baseline and CME-associated flights was observed in the measured count rates. These results highlighted the sensitivity of Forbush decrease detection to flight conditions, solar event strength, and environmental noise.



(a) Launch Prediction software results

(b) A shot from one of our flights

4 Improving Chemical Heating in a Martian Upper Atmospheric Model — MGITM

4.1 Project Overview

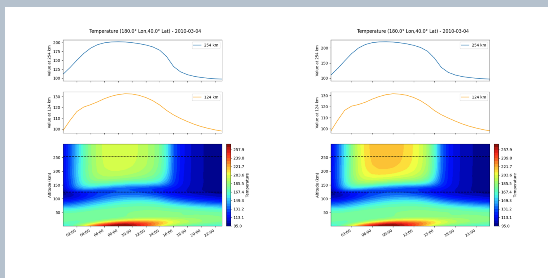
- **Scientific Problem:** Accurate modeling of the Martian upper atmosphere is critical for understanding planetary evolution, energy balance, and interactions with solar radiation. Existing numerical models often rely on simplified assumptions for chemical heating, limiting physical realism in long-term simulations.
- **System Objective:** Improve the physical fidelity of the Mars Global Ionosphere-Thermosphere Model (MGITM) by refining assumptions related to exothermic chemical reactions and chemical heating efficiency in the Martian upper atmosphere.
- **Technical Approach:**
  - Modified MGITM source code to explicitly incorporate exothermic reaction energy contributions into the atmospheric energy balance
  - Updated heating efficiency assumptions based on values reported in atmospheric chemistry literature
  - Implemented changes in a new model branch to enable direct comparison against the baseline configuration, source code can be viewed here GitHub repository
  - Executed global simulations over short-term (3-day) and long-term (27-day) periods to assess impacts on thermospheric structure
- **Design Process:** A controlled branch-to-branch comparison was used to isolate the effects of chemistry and heating updates. Key parameters were modified in the chemistry and thermodynamic modules of MGITM, and simulation outputs were evaluated using altitude-dependent temperature and heating rate profiles to assess physical consistency and model stability.

4.2 My Contributions

- This was an individual project, overseen by a faculty advisor.
- Identified limitations in MGITM's chemical heating formulation and proposed physics-informed improvements.
- Implemented and managed parallel model branches to enable controlled performance comparisons.
- Executed and analyzed global simulations to assess the impact of chemistry updates on temperature structure and heating rates.
- Interpreted results in the context of Martian thermospheric physics and long-term model stability.

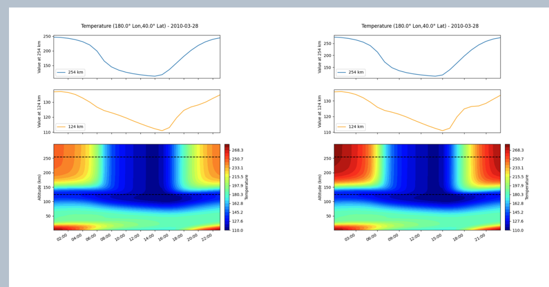
4.3 Results

The updated MGITM configuration produced nonzero chemical heating rates consistent with expected exothermic reaction behavior in the Martian upper atmosphere. Short-term simulations exhibited modest warming relative to the baseline model, while long-term simulations showed stabilized temperature gradients, indicating improved physical realism without runaway heating.



(a) Original Model (b) Updated Model

(a) Model output comparison after 3 days



(a) Original Model (b) Updated Model

(b) Model output comparison after 27 days

Relative to the baseline configuration, temperature estimates improved by approximately 15%, bringing modeled thermospheric temperatures into closer agreement with expected physical behavior. These results demonstrate the sensitivity of upper atmospheric structure to chemical heating assumptions and provide a foundation for future validation against observational datasets such as MAVEN.

This work was presented at multiple scientific conferences, supporting dissemination of the modeling approach and results within the planetary science and space physics communities.

5 In-Situ Resource Utilization (ISRU) Propulsion System Development

5.1 Project Overview

- **Engineering Problem:** Sustained human and robotic exploration of the Moon and Mars requires propulsion systems that reduce dependence on Earth-supplied propellant. Conventional chemical propulsion architectures are mass-limited and logistically constrained when supporting long-duration surface operations and return missions.

- **System Objective:** Design and analyze an electric propulsion system that leverages in-situ resources to produce, condition, and utilize propellants for ascent, descent, or surface mobility applications, enabling scalable and sustainable exploration architectures.

- **Technical Approach:**
  - Evaluate candidate ISRU-derived propellants and oxidizers based on availability, performance, and system complexity
  - Develop a thermodynamic and system-level model of propellant production, storage, and feed to the propulsion system
  - Develop a computational model that helps in assessing the feasibility of different propellants
  - Assess propulsion performance trade-offs including specific impulse, thrust-to-weight ratio, and power requirements

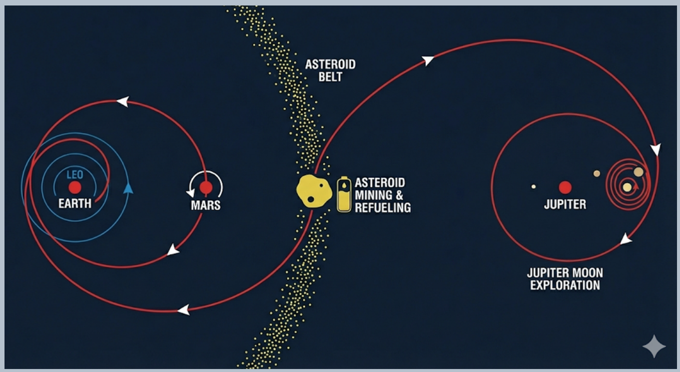


Figure 7: Mission Architecture Visualized

- **Design Process:** System requirements were informed by deep space mission architectures reported in the literature and as shown in Fig7. Trade studies were conducted across propellant combinations, storage conditions, and engine operating regimes to balance performance, scalability, and integration with upstream ISRU processes.

- **Numerical Analysis and Modeling:**
  - Developed thermodynamic models to estimate propellant production rates and storage losses
  - Modeled engine performance using ideal and non-ideal cycle assumptions to bound achievable thrust and efficiency
  - Performed sensitivity analyses to quantify the impact of resource purity, storage temperature, and power availability on propulsion performance

5.2 My Contributions

- **Role:** Propulsion Physics and Systems Analysis Lead
- Developed system-level propulsion models linking ISRU production rates to engine operating conditions and mission-level performance metrics, source code can be found in this GitHub Repository
- Conducted trade studies comparing multiple ISRU-compatible propellant options, identifying key drivers for performance and system mass.
- Integrated propulsion modeling with upstream resource processing assumptions to evaluate end-to-end feasibility.

5.3 Final Deliverables

A physics-based propulsion system model and supporting trade studies demonstrating the feasibility and performance bounds of ISRU-enabled propulsion architectures. This work provides a foundation for future refinement, experimental validation, and mission-specific optimization.

6 Current Projects

6.1 Automated Flight and AI-Based Glider Control

Industry partners: Systems Technology Research, sponsored by DARPA
Our Team's Role: Developing and training machine learning models to identify atmospheric updrafts and environmental features relevant to autonomous soaring flight. The project combines flight data analysis, feature extraction, and supervised learning to enable automated decision-making for sustained, energy-efficient flight. Ongoing efforts focus on improving model robustness, generalization across flight conditions, and integration with flight control logic.

6.2 Smart Space Glove Development

Designing a sensor-integrated glove system intended for use in space or reduced-gravity environments. The project focuses on embedded sensing, signal conditioning, and real-time feedback to monitor hand motion, force application, and operational state. Current work emphasizes system architecture, sensor selection, and embedded control strategies compatible with spaceflight constraints.