Preliminary Design Review

Mars Hard Lander Electrical System

WATTS UP

Meet the Team

- **Project**: Mars Hard Lander Electrical System
- **Sponsor:** Steve Matousek - JPL
- **Team members**:

    Abdulrahman Almutairi - PCB Designer & Software Manager

    Ahmad Sai - System Architect & Test Engineer

    Anthony Hamamji - Team Lead, Power Manager, & Analog Circuits Designer

    Bilim Sydykov- RF Designer, Communication logistics Manager, & PCB Assembly

    Conner Neuhart - Software Director & Finance Logistics Manager

    Nasser AlMuaili - Mechanical Designer & Hardware Manager

Product Objectives

- **Design and build an electrical system for a Mars Hard Lander:**
  - Collect localized environmental data at Mars hard lander site.
  - Transmit collected data through the Mars Relay Network.
  - Implement Error-Correcting Code protocols to ensure data remains consistent and uncorrupted.
  - Store data onboard until the communication window is open.
  - Support modular payload interfaces that enable scientific exploration of Mars.

- **Vision:**
  - Low Cost
  - Reliable
  - Environment Resilient
  - Modular

Product Requirements

Marketing Requirements

- **Can survive High Impact Landing**
- **Can operate with continuous power**
- **Withstand Martian weather conditions**
  - Extreme Low temperatures
  - Dust accumulation
- **Ability to communicate with Mars Relay Network**
- **Powered by Solar and Batteries**
- **Onboard storage to store collected data**
- **Sensor measurements:**
  - Pressure - Acceleration - Altitude - Voltage Monitoring -Magnetometer
- **Modular Payload Support**
  - Ability to support additional payloads

Engineering Requirements

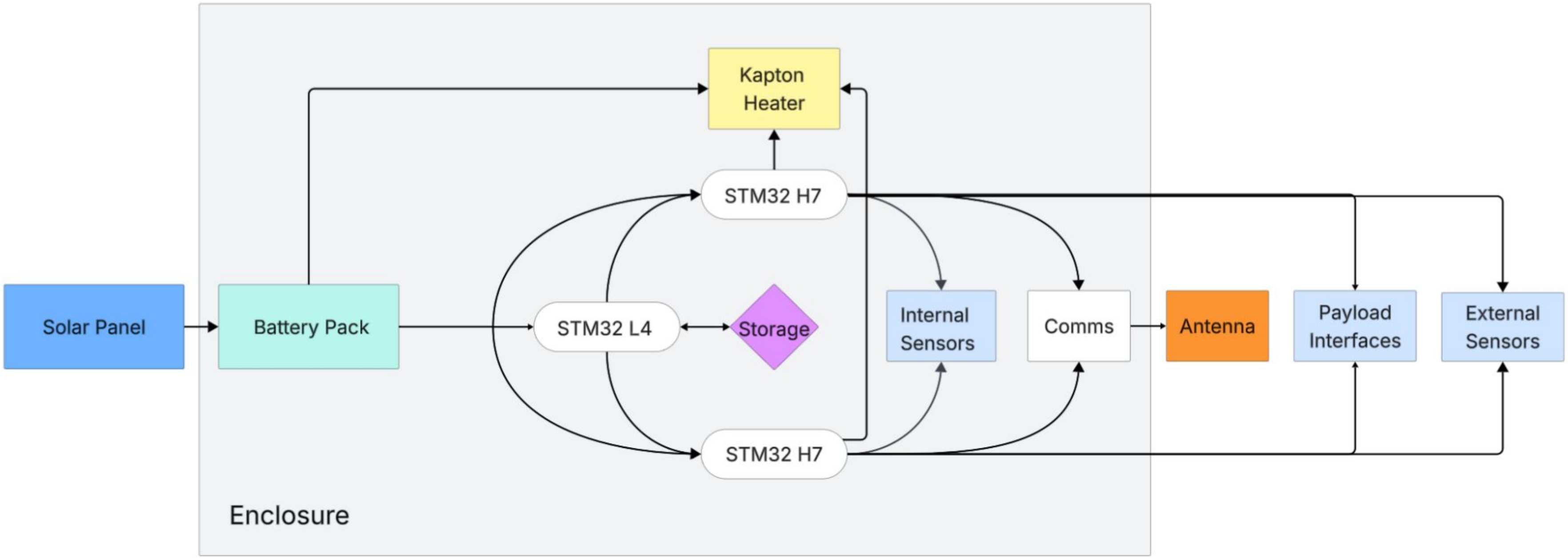
- **Power & Energy (Generation - Storage - Budget):**
  - Batteries shall supply all subsystems for ≥ 2 sols (≅ 48.9 hr) without sunlight.
  - Remain operational for ≥ 2 Martian years (≅ 3.7 Earth years).
- **Structural/ Mechanical Survivability (Shock & Impact):**
  - Withstand impact of at least 200 g.
- **Environmental Survivability - Thermal, Ingress/Dust:**
  - Operate nominally between -10 °C and 0 °C
  - Maintain ingress protection of ≥ IP54 against dust.
- **Payload modular interface:**
  - Include 4 modular payload ports.
- **Transmit/Store Data:**
  - Transmit 1-month worth of data within a 10-minute window.
  - Locally store ≥ 1 month of sensor data
  - Take sensor data every 5 minutes.
- **Sensors:**
  - Measure pressure: 0 - 1500 Pa.
  - The accelerometer capture up to 3000 g.
  - Magnetometer detect up to ± 2000 nT.

Use Cases

- The lander autonomously collects environmental data and transmits it through the Mars relay network.
- Future mission teams integrate a new payload using the provided electrical and mechanical interfaces.
- Engineers reprogram the lander firmware post-deployment to change operating modes or update data protocols.
- The lander enters and maintains a low-power survival state to preserve functionality through extended Martian nights and dust events.

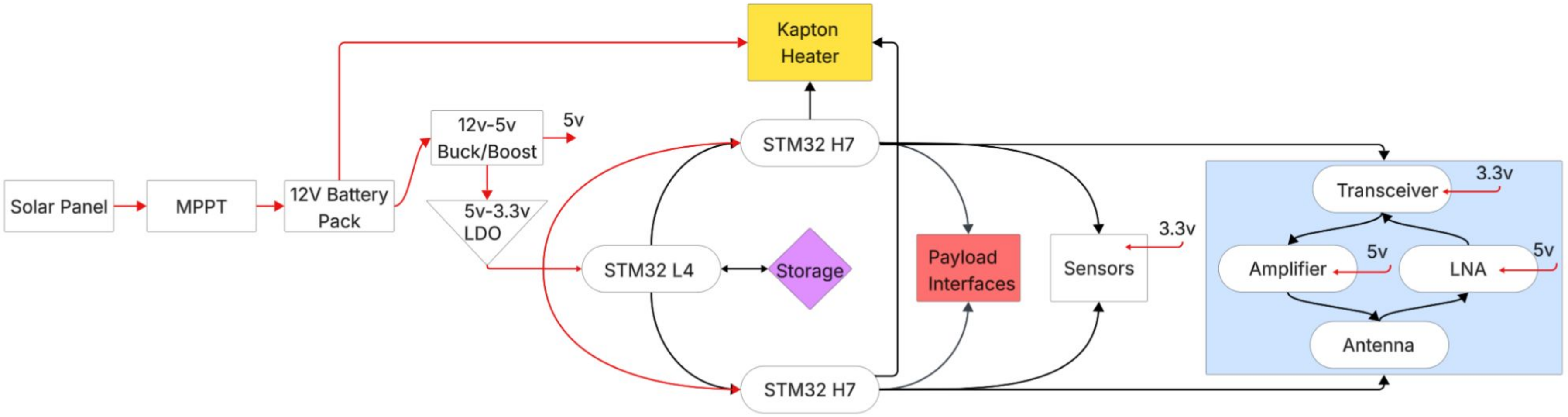
Product Block Diagrams

Functional Block Diagram

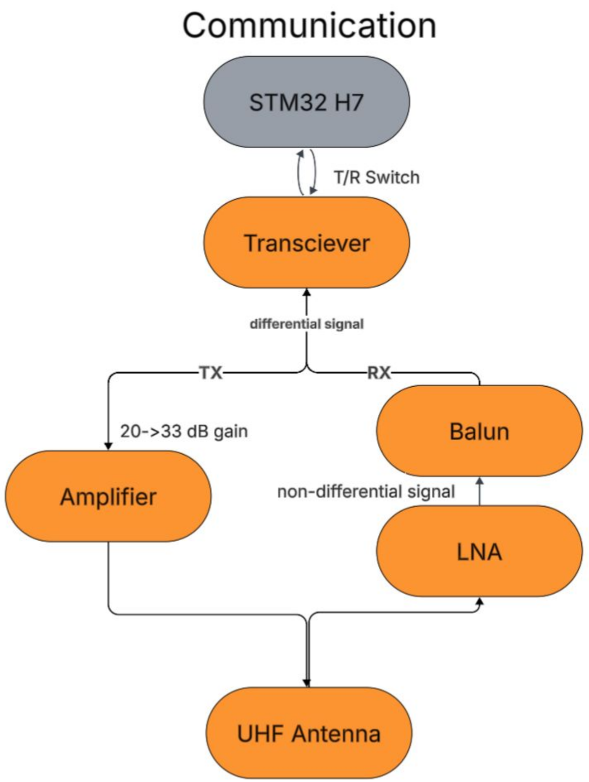


Hardware

Functional Decomposition Level 1

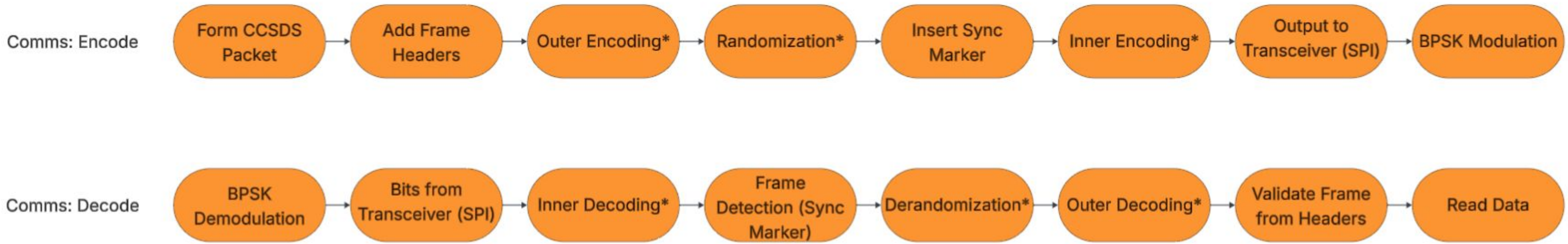


Radio Hardware Diagram



Software

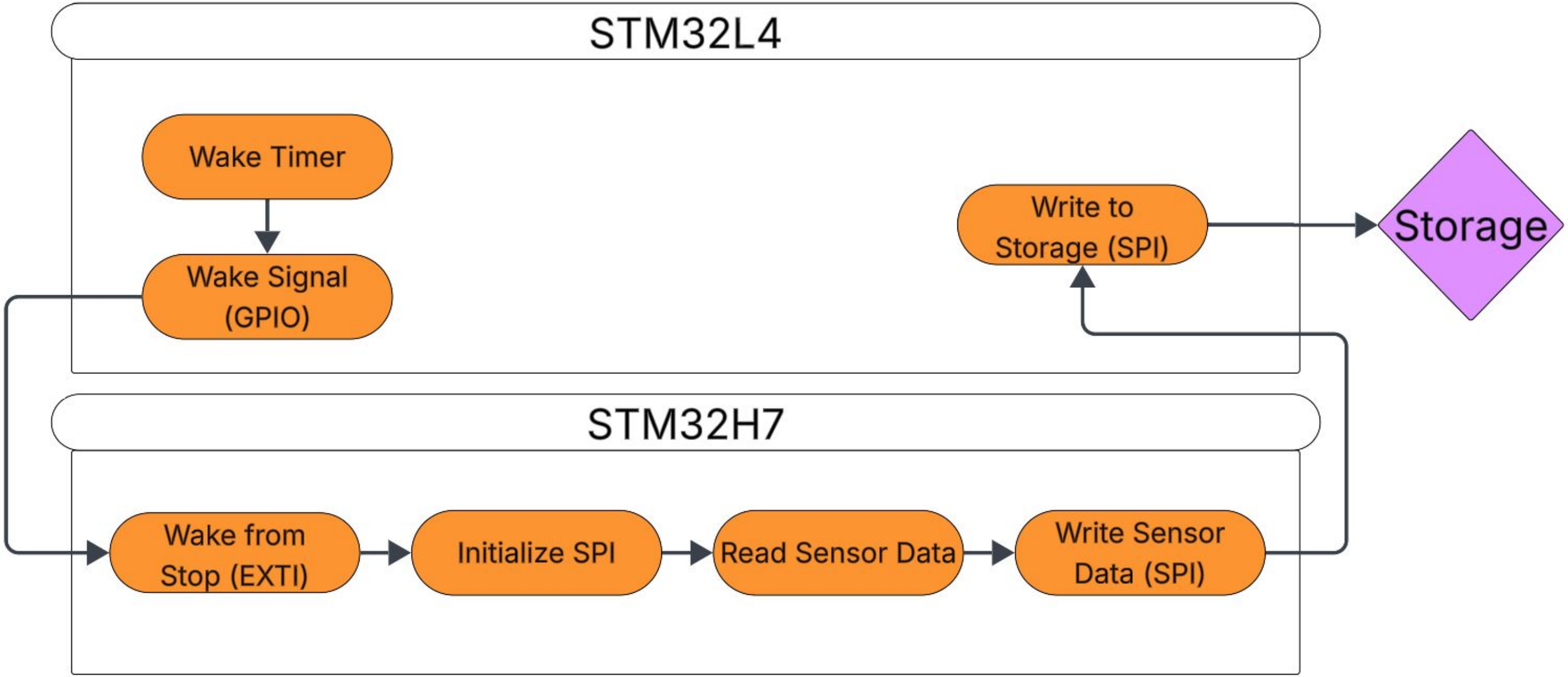
Radio Software Diagram



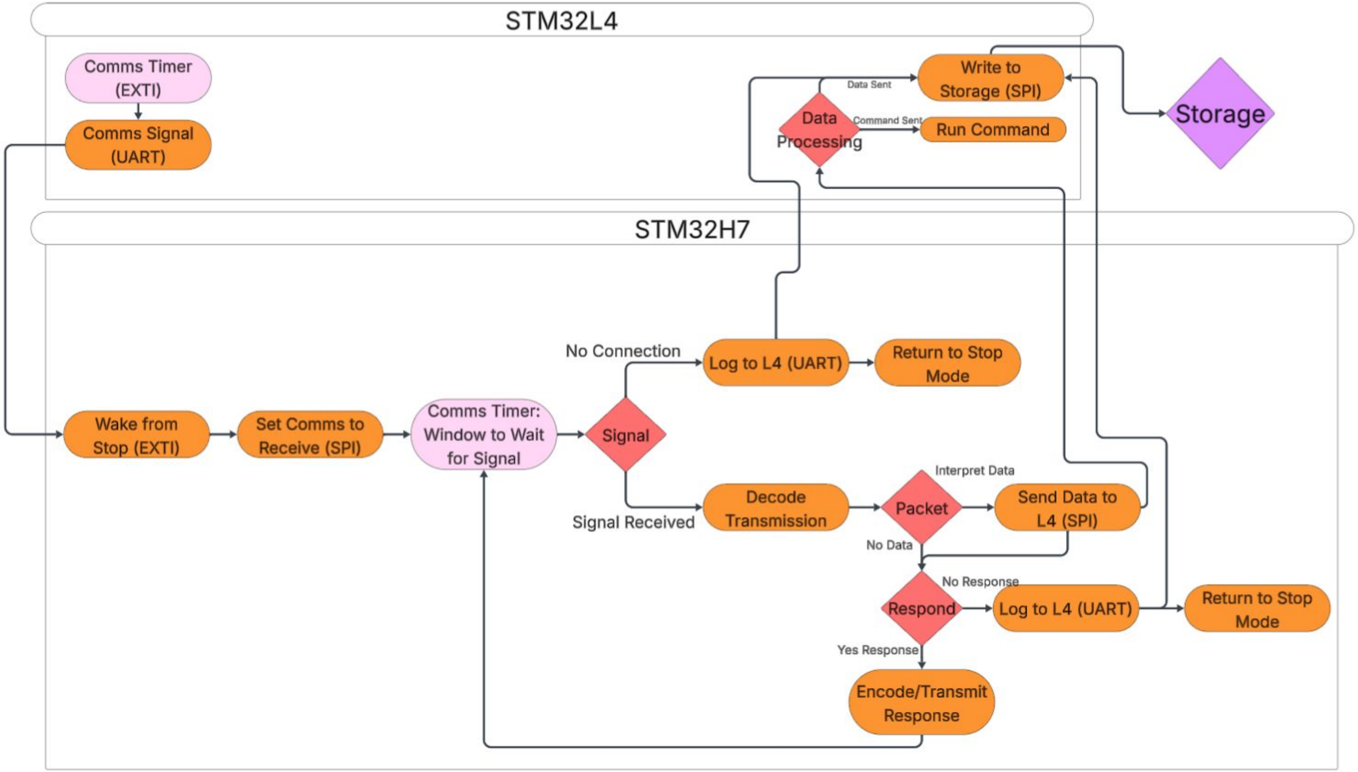
Note:

- Asterisks denote steps that depend on link configuraiton
- In our configuration, Inner encoding is Convolutional, and outer encoding is Reed-Solomon

Software: Sensor Data Collection



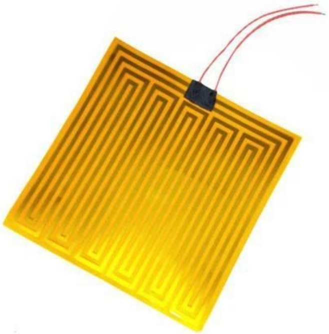
Software: Comms Management

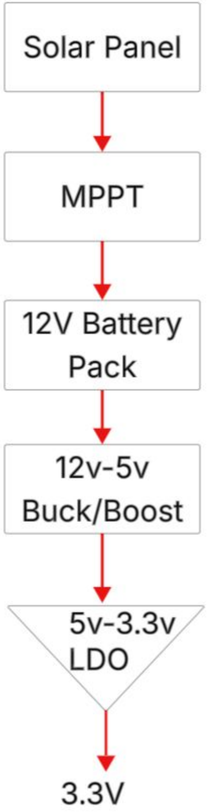


Product Design

Power Design

- **Battery Technology:**
  - EVE 18650
  - 3S3P pack: 11.1v nominal, 10.5 Ah, 116 Wh
  - Polyimide heaters for temperature control
- **Solar Panel:**
  - 200W
  - 12v

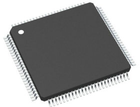




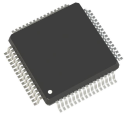
Technology Selection

- **Power:**
  - EVE 18650
  - 3S Battery Protection Board
  - 200W, 12V Solar panel
  - ZK-SJ20 Buck MPPT

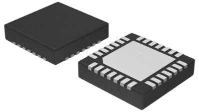
- **Processors and Memory:**
  - STM32H735VHT6
  - STM32L496RGT6
  - EMM128-TY29-5B101 (Flash Memory)



H7



L4

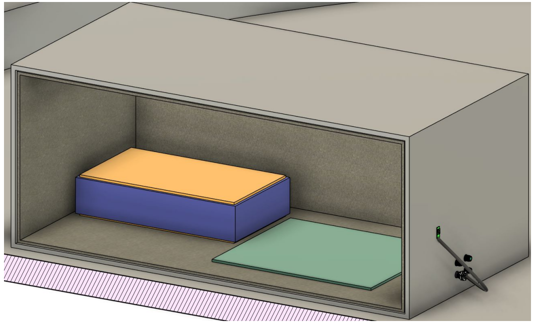


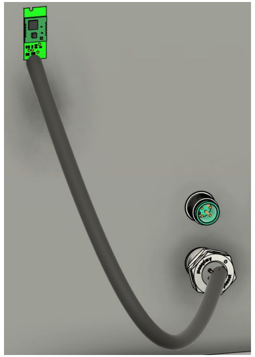
- **Radio:**
  - AX5043 (Transceiver)
  - QPL9547TR7 Low Noise Amplifier (Receive)
  - BT33L Amplifier (Transmit)

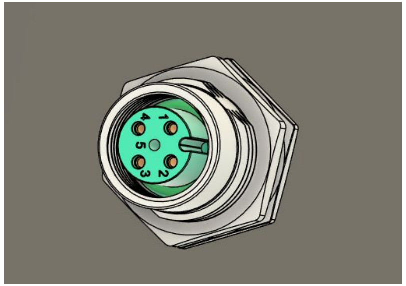
- **Sensors (In-system):**
  - BME280 (Temp,Humidity,Pressure)
  - IAM-20380HT (Gyro)
  - MLX90395 (Magnetometer)
  - 540A (Analog Accelerometer)
  - 1918 (Light Sensor)

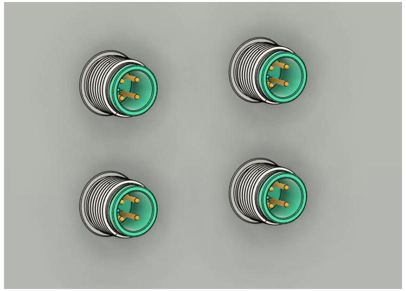
Enclosure breakdown

- Brown layer is the insulation foam, this can handle temps of -201C to 104C
- Orange layer is the heaters
- Grey is the outer layer is the enclosure itself
- The blue box is the battery compartment
- Connectors mounted to the side of the enclosure to keep the dust of mars from getting into the enclosure while still allowing for external payloads
- The dark green represents the PCB
- The bright green represents a potential payload
- The black tube represents a sealed bundle of wires









Payloads

Design can support 4 payloads:

- **2 x Payload Type 1:**
  - V_{MAX}= 3.3v, I_{MAX}= 0.1A
  - Runtime: 10 mins
  - I^2C
- **Payload Type 2:**
  - V_{MAX}= 5v, I_{MAX}= 0.25A
  - Runtime: 10 mins
  - I^2C
- **Payload Type 3:**
  - V_{MAX}= 12v, I_{MAX}= 0.5A
  - Runtime: 10 mins
  - I^2C

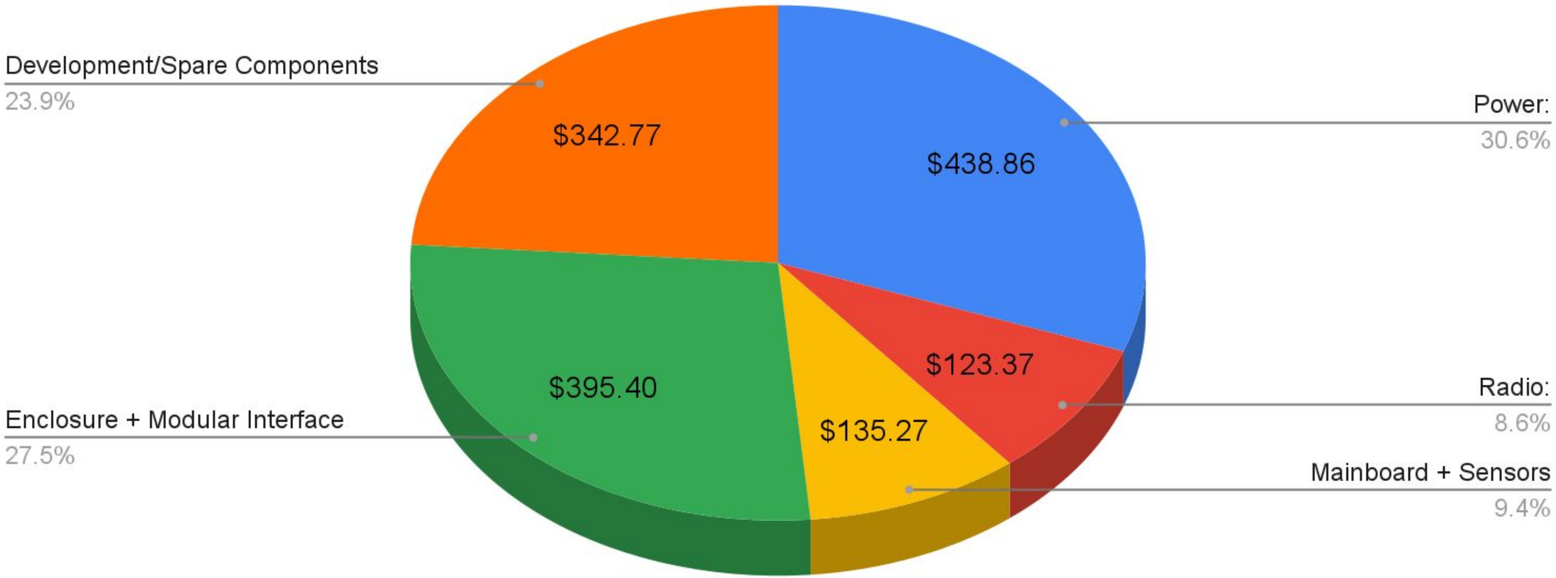
Possible Payload:

- **SPS30 Optical Dust sensor:**
  - I^2C / UART
  - Operating voltage: 5 V
  - Current Draw: 55- 60 mA
  - Has a 5-pin female VH connector

Budgets

Cost Estimates

$1,435.67



Cost Budgets

Power Budget

Without Payload

- Expected Energy usage:
  - 15.5 Wh/day
- Runtime of Battery with 80% of charge:
  - 6 days
- 6 days = 5.84 Sols

With Payloads

- Expected Energy usage:
  - 16.9 Wh/day
- Runtime of Battery with 80% of charge:
  - 5.53 days
- 5.53 days = 5.38 Sols

Phase 1 - Design Approach

Design Approach:

- **Split Phase 1 into five parallel tasks:**
  - STM32H7 first prototype (Abdulrahman/Ahmad/Bilim)
  - Dev-board firmware bring-up (Ahmad/Conner)
  - Antenna design & early testing (Conner/Bilim/Anthony)
  - Battery design & testing (Anthony)
  - Sensor data collection setup (Nasser)
- **Integrate into one working prototype (antenna + battery + uC + sensors)**

Phase 1 - Test Plans

- **Antenna**
  - Check BPSK modulation/demodulation
  - Test CCSDS packet encoding/decoding
  - Measure power draw
- **Battery**
  - Check voltage accuracy
  - Check charging
  - Test heater / temperature behavior
- **Microcontroller**
  - Determine basic functionality of MCU
  - Test sensor collection and payload
  - Test wake-from-sleep reads

Schedule

- Technology Selection - 10/10
- 1st Part Order - 10/21
- Preliminary Design Review (PDR) - 10/30
- Mini Expo Poster - 11/14
- Battery Pack / Power Management - 11/20
- Proof of Concept Demos - 11/21
- ECEE Mini Expo 1 - 12/4
- Phase 1 Write-Up - 12/4
- Antenna Circuitry - 12/12
- Enclosure Design - 12/20

Phase 2 - Design Approach & Test Plans

- **Electrical:**
  - Design a separate PCB for each processor.
  - Test & validate PCB functionality for each microcontroller.
  - Cold temperature testing for batteries and PCBs (Dry Ice)
- **Antenna:**
  - Develop PCB design for communication .
  - Assemble TX & RX channels for clean data transfer, including UHF antenna.
  - Verify CCSDS packet full encode and decode
  - Assemble testing substation for data transmission testing.
  - Debug possible data transmission errors.
- **Mechanical:**
  - Testing out ways to reinforce the PCB to withstand the high impact.
  - Vacuum & Temperature test the components and enclosure
- **Software:**
  - Verify software implementation of ECC memory
  - Control H7 MCUs' power state using L4 MCU wake-up signals and UART

Phase 3 - Design Approach & Test Plans

- **Electrical:**
  - Full microcontroller integration of the STM32H7 with the STM32L4.
  - Integrate all sensors and antenna circuitry to the final PCB design.
- **Antenna:**
  - Test data transmission environment between substation and communication boards.
  - Check transmitted data for clean output based on the readings we get on Earth.
- **Software:**
  - Finalized Embedded code for L4 MCU to manage H7 MCUs

Risks

Risk Assessment

Development Risk	Impact on Development	Risk Mitigation	Failure Response
PCB Complexity	High	• Design/Test in Stages • Simplify uC Design	• Reduce Number of Microcontrollers
Software Integration of Microcontrollers	High	• Test Communication Between uCs • Test Wake/Sleep modes	• Reduce Number of uCs
Radio Integration	High	• Test Antenna Independent from mainboard	• Replace parts (alternative models)

Risk Assessment

EXPO Deployment Risk	Impact on Deployment	Risk Mitigation	Failure Response
Radio Demo	High	• Use Alternate legal band (LoRa)	• Pre recorded successful transmission
Board Boot	High	• Keep backup firmware	• Use spare board / dev board
Battery Safety	High	• Extra Battery Pack	• Use power supply

Risk Assessment

Mars Deployment Risk	Impact on Deployment	Risk Mitigation	Failure Response
Battery Overheating	High	• Design/Test in Stages • Simplify uC Design	• Reduce Number of Microcontrollers
Microcontroller software integrity	High	• Radiation shielding • ECC to reduce likelihood of errors	• Use Redundant uC to remote code upload and attempt repair
Solar Panel Failure/ Performance Decline	High	• Support vibrator payload	• None

Questions?

Supporting Slides:

Hook & Elevator Pitch

Hook:

Traditional soft-landing architectures limit scalability due to mass, cost, and mechanical complexity. A hard-landed platform removes the need for deceleration hardware, enabling a simpler, lighter, and more repeatable architecture for deploying distributed sensor nodes across Mars.

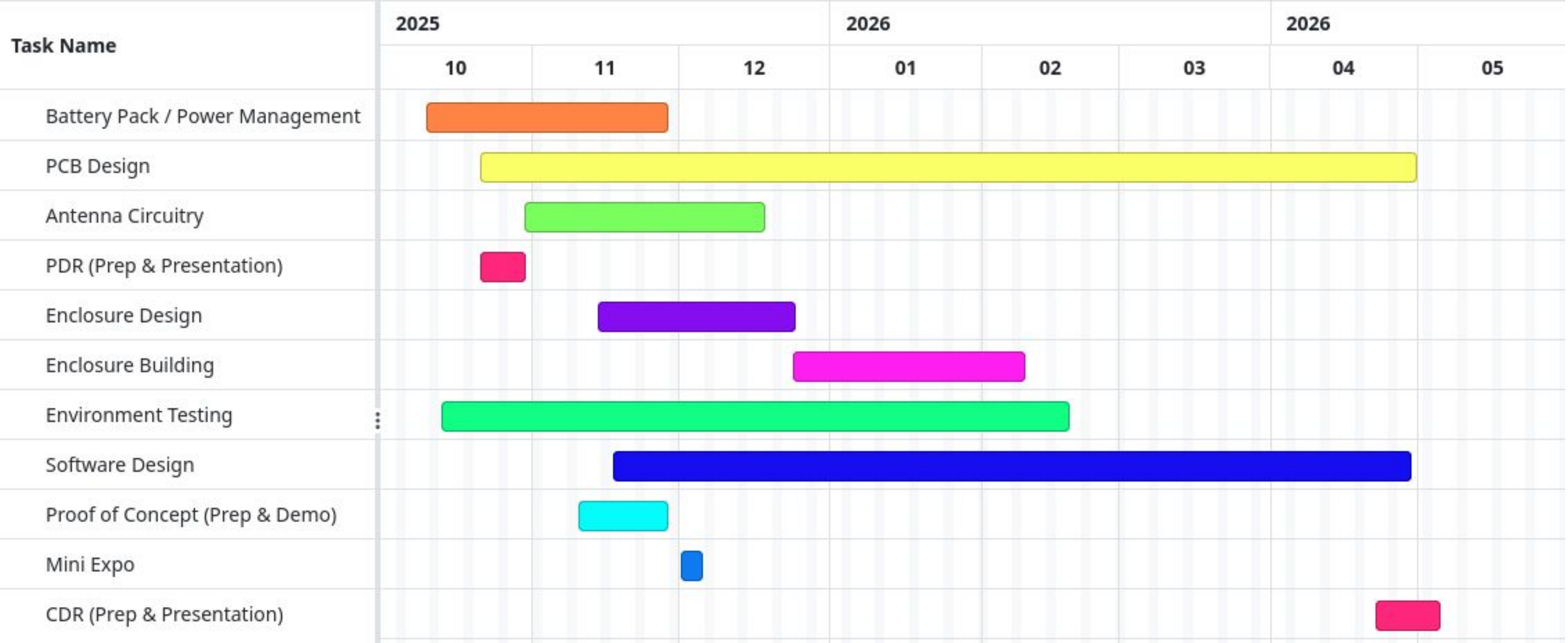
Elevator Pitch:

We are developing a low-cost, high-impact-survivable Mars hard lander that operates as a fixed environmental sensor node. After impact, it powers up autonomously, collects localized environmental data, stores it redundantly, and transmits it to the Mars relay network on a scheduled basis. Because it removes the complexity and cost of soft-landing hardware, this architecture is inherently scalable, repeatable, and deployable as a distributed sensor network for long-duration Martian science.

Design Constraints

- Must integrate with Mars Relay Network for reliable communications.
- Maximum size of 1 m × 1 m footprint to meet strict size limits.
- Engineered for harsh Martian conditions to ensure mission survivability of ~3.7 years.
- Easily reproducible design enabling rapid deployment.
- Cost-optimized architecture for budget-conscious missions.
- Ultra-low-power operation to extend lander lifetime.

Schedule (GANTT Chart)



Engineering Requirements

- **Environment**
  - ✔ Impact: 200-2000g
  - ✔ Thermal: -45C to 55C
  - ✔ Pressure: 6-7 millibars
  - ✔ Radiation: 76-80 mGy/year (earth year)
  - ✔ Dust/Debris: PCB protection down to 0.5 microns
  - ✔ Heating: maintain 5°F/- 15°C ambient temperature
- **Measurement (Collect Data Every Minute)**
  - ✔ Pressure: 0-1500Pa
  - ✔ Acceleration: 0-3000G
  - ✔ Altitude: -8 to 2 km
  - ✔ Voltage: Two sig. fig. accuracy
  - ✔ Magnetism: +- 2000 nT
- **Network**
  - ✔ Send data every 2 hours within 5 minute window
- **Power**
  - ✔ Power solution must last for 2 mars years
  - ✔ Battery Life must last at least 2 Sol day
- **Functionality**
  - ✔ Overall system must survive for at least 2 Mars years
- **Storage**
  - ✔ At least 1GB onboard data storage
  - ✔ At least 10GB onboard program storage
- **Payload Interfaces**
  - ✔ At least 3 payload interfaces

Power Budget Calculations

Component	V_DD (V)	I (A)	P_tot	t_ON (hr)	E_tot (Whrs)					
STM32H7	3.3	0.62	2.046	0.25	0.5115					
STM32L4	3.3	0.15	0.495	24	11.88					
Component	V_DD (V)	I (A)	P_tot (W)	t_ON (hr)	E_tot (Whrs)					
BT33L	5	0.4	2	0.166667	0.333334	Transmit Amp		Battery Capacity	Runtime without payloads	Runtime with payloads
QPL9547	5	0.065	0.325	0.166667	0.054166775	Recieve Amp		116.55	5.999356063	5.530247816
AX5043			0.8	0.333334	0.2666672	Transiever				
Component	V_DD (V)	I (A)	P_tot (W)	t_ON (hr)	E_tot (Whrs)					
220483 Polymide	12	0.208	4.992	0.5	2.496					
Component	V_DD (V)	I (A)	P_tot (W)	t_ON (hr)	E_tot (Whrs)					
Payload 1	3.3	0.1	0.33	0.166667	0.05500011					
Payload 2	3.3	0.1	0.33	0.166667	0.05500011					
Payload 3	5	0.25	1.25	0.166667	0.20833375					
Payload 4	12	0.5	6	0.166667	1.000002					
Total		2.393	18.568		16.86000395	Wh	15.54166798			