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Wireless Power Transfer for Lunar Microsensors

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Wireless Power Transfer

- Transmission of electrical energy without the physical link of wires
- Three primary methods: [1]
  - Inductive Coupling Power Transmission
    - Very short range / high efficiency
  - Microwave Power Transmission
    - Short to long range / medium efficiency
  - Laser Power Transmission
    - Long range / low efficiency

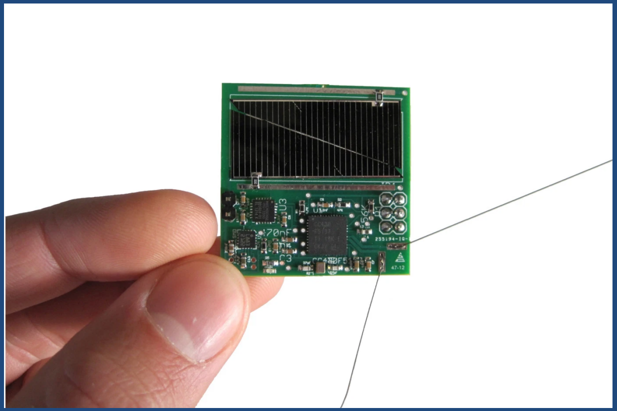
Why The Moon

- Renewed interest in lunar exploration
  - NASA's Artemis program forecasts manned lunar surface mission by 2024
  - Additionally the program will incorporate Lunar Cubesats and other types of automated exploration, experimentation, mining systems [2]
  - No FCC regulation of transmission, open to more extensive development

Intended Microsensor Devices

General Engineering Principle: Start small then scale up

- Our target parameters for power delivery are based on the smallest successfully deployed nanosatellite to date – the Sprite ChipSat [3]
- 5 gram, 3.5 x 3.5 cm PCB, powered by solar cell that delivers up to 60 mA at 2.2 V [4]

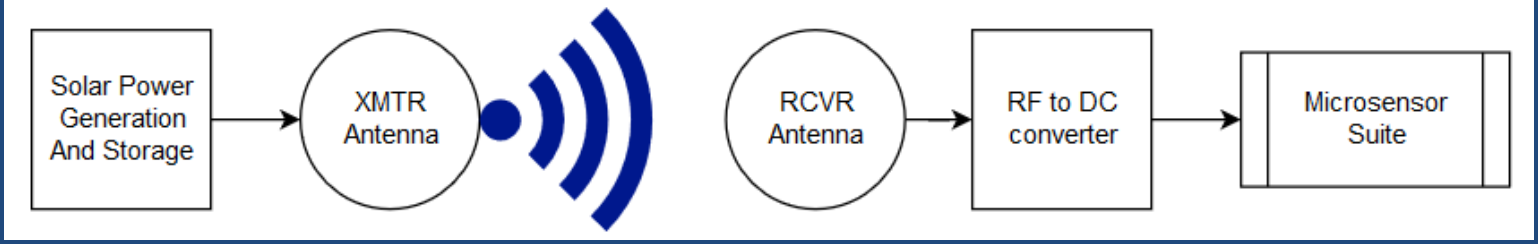


- Note: these nanosats are not included in the scope of this project beyond determining dimension and power delivery parameters

Project Parameters

- Microwave wireless power transfer system
- Primarily for operation on the lunar surface
  – Address specific challenges of a lunar environment
- Provide alternative method of powering chipsat type devices

Design



- Solar power generation and storage will be off-the-shelf (OTS) components, determined after primary testing and performance analysis is completed

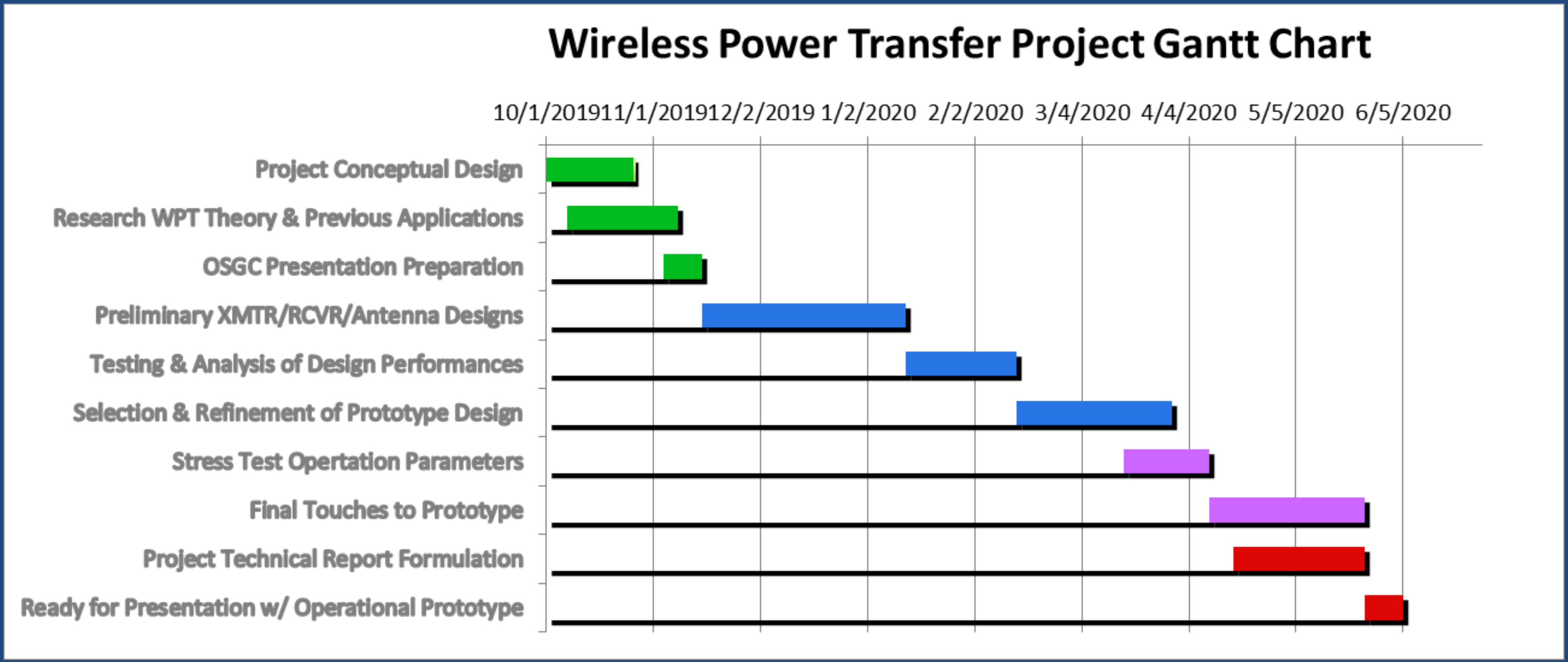
Component Organization

- Power Supply & XMTR
  - Battery component modular for optional inclusion
  - All final build XMTR circuitry to be enclosed in compact, lightweight, sealable, 3D printed container
- RCVR & DC Converter
  - Small enough to integrate with nanosat devices
  - Final build will also include a 3D printed container for the nanosat element as an optional component for additional environmental protection

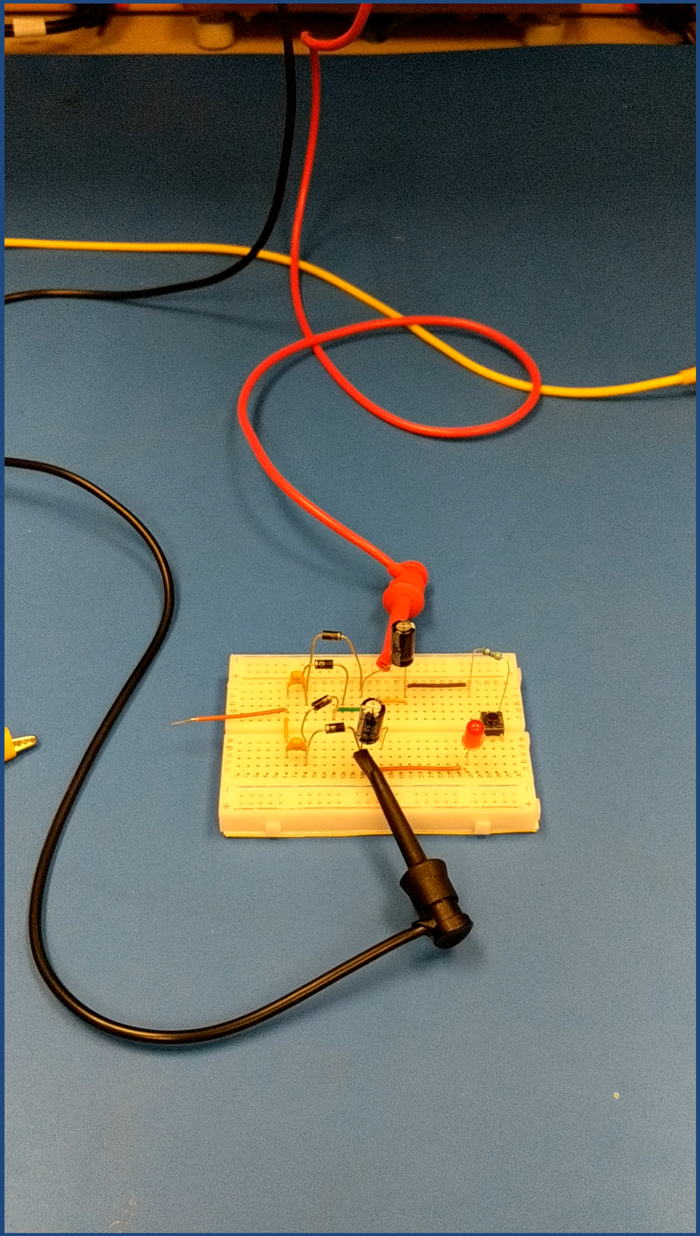
Project Outline

- Phase 1: Research and Conceptual Design
- Phase 2: Preliminary Design Builds, Testing, and Performance Analysis
- Phase 3: Stress Testing and Refinement of Final System

Timeline

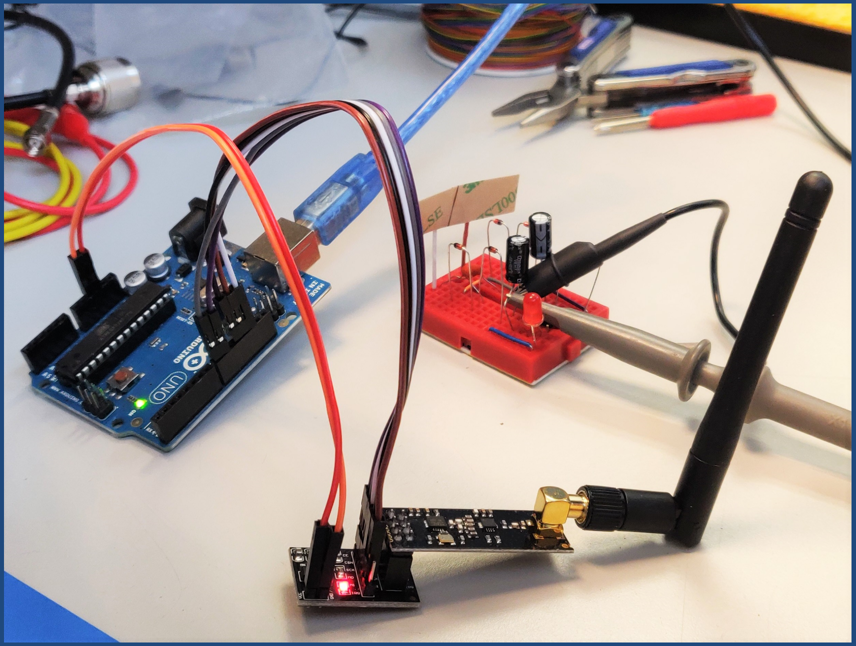

Wireless Power Transfer Project Gantt Chart
10/1/2019
11/1/2019
12/2/2019
1/2/2020
2/2/2020
3/4/2020
4/4/2020
5/5/2020
6/5/2020
Project Conceptual Design
Research WPT Theory & Previous Applications
OSGC Presentation Preparation
Preliminary XMTR/RCVR/Antenna Designs
Testing & Analysis of Design Performances
Selection & Refinement of Prototype Design
Stress Test Opertation Parameters
Final Touches to Prototype
Project Technical Report Formulation
Ready for Presentation w/ Operational Prototype

Energy from Ambient RF Demo



Phase 2 Plan

- Transitioning into Phase 2 this week
- Begin with OTS Arduino components for first transmitter element
  - 2.4 GHz
  - Paired with a simple rectenna circuit



Phase 2 Next Steps

- Design and build at least 3 additional XMTR / RCVR pairs to operate at/above/below WiFi frequency range (~3 GHz & 900 MHz)
- Mix of OTS and specially designed components

Testing

- Each system will be tested to determine power transfer efficiency at various ranges
- Best performing system will be selected, then tested further with:
  - Signal amplification
  - Omnidirectional vs array of directional antennas
  - Software control techniques to boost signal power

Power Supply

- Once selected system operating parameters are set, power supply requirements will be matched to OTS solar panel and battery
  - Goal is continuous power for entire lunar rotation
  - Lunar day is between 29 & 30 earth days [5]
    - Battery capacity for 15-day lunar dark side transition
    - Recharge during lunar daylight transition

Stress Test

- 5 – 10 battery charge/discharge cycles to ensure proper switching between solar panel and battery
- 24-hour full system test monitoring power delivery to nanosat load element positioned at maximum operating range

Lunar Environment

- Temperature on the lunar surface varies from +120 C to as low as -250 C [6]
- These extreme temp ranges will be taken into consideration during circuit design and OTS component selection
- Currently investigating options to test the final system under these conditions during the stress test window

Moon Dust

- Unique environmental hazard
  - Particles are primarily silicon – highly abrasive
  - Particles routinely levitate several centimeters off the surface due to electrostatic charging from solar wind
  - Strong adherence to surfaces [7]
- Enclosure cases to protect XMTR (and optionally RCVR) circuitry
- Solar Panel efficiency losses must be factored in

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Questions?

References

- [1] A Brief Overview of Wireless Power Transfer Techniques, https://www.researchgate.net/publication/295616542_A_Brief_Overview_of_Wireless_Power_Transfer_Techniques
- [2] NASA's Exploration Campaign, https://www.nasa.gov/feature/nasas-exploration-campaign-back-to-the-moon-and-on-to-mars
- [3] KickSat Nanosatellite Mission, https://directory.eoportal.org/web/eoportal/satellite-missions/k/kicksat
- [4] KickSat-2 project launches 105 cracker-sized satellites, https://techcrunch.com/2019/06/04/kicksat-2-project-launches-105-cracker-sized-satellites/
- [5] The Length of the Lunar Cycle, https://individual.utoronto.ca/kalendis/lunar/index.htm
- [6] LRO: Temperature Variation on the Moon, https://lunar.gsfc.nasa.gov/images/lithos/LROlitho7temperaturevariation27May2014.pdf
- [7] Design of Equipment for Lunar Dust Removal, https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19920010136.pdf