Detecting Subsurface Water from Orbit, Design and Verification of a Space-Based Sensing Platform

Sydney Steele, Adriana Formby-Fernandez, Thomas Rodriguez, Daynah Rodriguez, Sophie Neumaier, William MacKunis Ph.D. (Faculty)
Embry-Riddle Aeronautical University, Daytona Beach, FL

Abstract

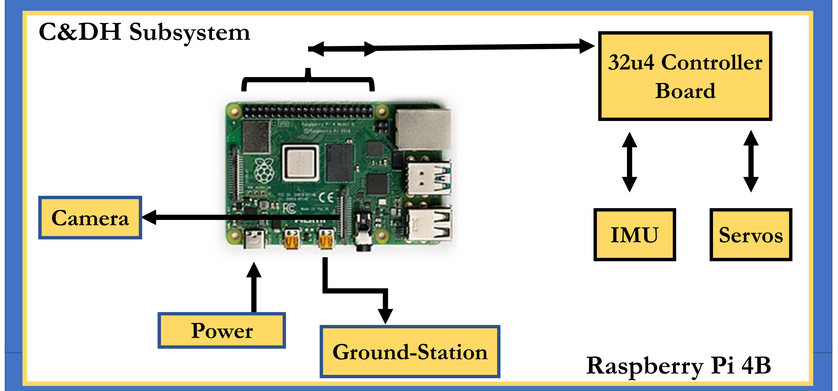
Direct detection of water on planets beyond Earth has always been a primary goal for space exploration. Our project "Boreas" focuses on the integration of a student-designed S-Band Radar-based water detection system, which is capable of ice penetration. For improved reliability, the system is equipped with an automatic attitude determination and control subsystem. The Boreas project aims to design, test, and fabricate a small-scale radar capable of seeing through substantial layers of ice or other material covering a given body of water. Our orbiting radar will be able to orient itself to the planet during flyby and maintain nadir orientation as the sensing subsystem takes in subsurface data. This design was inspired by Jupiter's moon Europa, which is known to harbor subsurface high-salinity oceans and further motivated by the recent exciting discovery of liquid water on Mars. The opportunities for application of the Boreas orbiter are numerous.

Design Objectives

i. Verify functionality of Radar chirp penetration through ice-sheet or similar material
ii. Maintain Nadir pointing & autonomous correction for orbit perturbations through ADCS subsystem
iii. Successfully decode map of material and water depth from radar return signal through original data processing software strategy
iv. Ensure safety of vital components through a radiation hardened orbiter structure design

Subsystems

- **Command & Data Handling**
  - ➢ Raspberry Pi 4B: High Level
    - Image processing (Filtering, Centroiding)
    - Radar data processing
    - Sensor Fusion
    - Controller board Master
    - Ground-Station Communication
  - ➢ A-Star 32u4 Controller Board: Low-Level
    - Servo Motors Control
    - Sensor integration (Radar, IMU)



- **Attitude Determination & Control (ADCS)**
  - ➢ IMU: Inertial Measurement Unit
    - Using the accelerometer, team plotted the roll and pitch in a processing data environment
    - Allows for real time orientation tracking.
    - Accelerometer/Gyro/Magnetometer
  - ➢ Raspberry Pi Camera
    - Motion detection with color tracking
    - Allows for detection of thermal hot spots along surface if used with infrared camera to detect

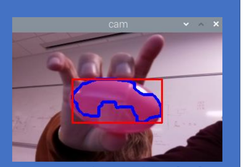
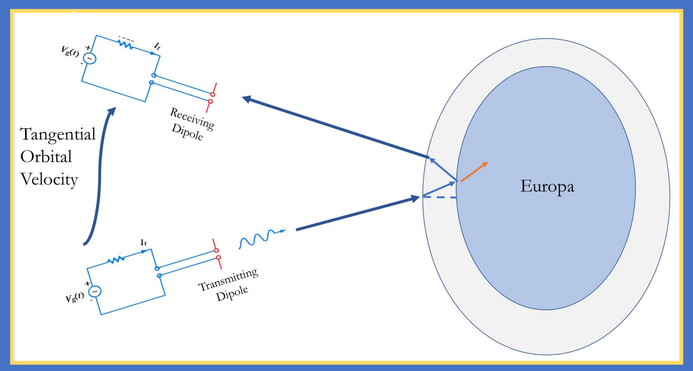


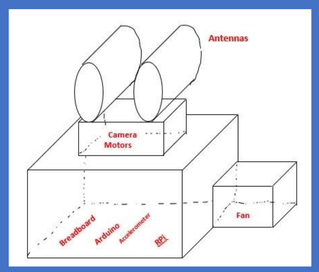
Image tracking – Proof of concept

Water Detection



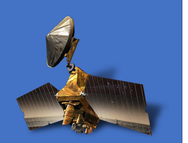
Transmission and Reception of Sounding Radar Chirp

➢ Antenna Design
- Transmit 9 [MHz] sounding radar chirps into ice
- Receiving dipole will detect changes in amplitude (dependent on material type)



Radar Integration Strategy

Applications



➢ Europa Clipper Mission (NASA)
- Similar suite of instruments on Clipper orbiter to detect liquid water under thick ice surface during flyby

➢ Mars Reconnaissance Orbiter (MRO)
- Similar suite of instruments on MRO that detected water on Mars in 2015

➢ Glaciology on Earth
- Detection of possible holes under ice in polar regions can lead to potential forecasting of large-scale glacier breakoff