CubeSat for Rwandan Agricultural Monitoring (C-RAM) Mission Design Documentation

Team Artimis

2024 Rwanda Space Impact Day

Students Outreach Program

TRL SPACE

RSA
Rwanda Space Agency

1. Introduction

This document will be used to document the process and content of your CubeSat Mission Design. Please fill in the required information in the sections below and feel free to add additional details as necessary to support your mission.

2. Instructions

1. Please provide the necessary information regarding your CubeSat mission design.
2. Follow the guidelines outlined in the Challenge Guidelines Document.
3. Use the information below to prepare your pitch presentation using the supplied template.

3. Team Details

Name of the School:

Carnegie Mellon University - Africa

Name of your team

Artimis

Supervisor Name

Team Members:

1. **Team Lead**: Mohamed Alpha
2. **Mission Planner**: John Kakai
3. **Systems Engineer**: Mohamed Alpha
4. **Payload Specialist**: Mukama Francois
5. **Business Specialist**: Eudoxie Umwari

4. Mission Details

Chosen Problem:

(State the problem and briefly describe the theme/problem you have chosen. 300 words maximum)

Rwandan agriculture faces challenges such as limited access to information, inefficient irrigation practices, and crop losses due to pests and diseases. These factors contribute to low productivity and hinder economic growth in the agricultural sector, which is a significant contributor to Rwanda's GDP.[1]

MISSION OBJECTIVE

(Briefly describe what your CubeSat Mission aims to achieve. 300 words maximum)

To enhance agricultural productivity in Rwanda by providing farmers with timely and accurate data on crop health, soil conditions, and localized weather patterns.

CUBESAT DESIGN

(Describe your CubeSat design, detailing the payload and how the payload will collect the data and other subsystems that the satellite will require for your mission to be successful. Use drawings and/or pictures for illustrations if necessary. Refer to the CubeSat Mission Challenge Guidelines for clarity. 500 words maximum)

CubeSat for Rwandan Agricultural Monitoring (C-RAM)

CubeSat Design:

C-RAM will be a 2U CubeSat (100 x 100 x 200 mm) utilizing a modular design for efficient component integration. This modularity allows for easier assembly, testing, and potential future upgrades.

Payload:

The primary payload consists of:

1. **Hyperspectral Imager:** This is the core of C-RAM. It will capture images in hundreds of narrow spectral bands, enabling detailed analysis of:
   a) **Crop health:** Identifying stress, disease, and nutrient deficiencies.
   b) **Soil composition:** Mapping soil types and moisture levels.
2. **Multispectral Imager:** Provides complementary data to the hyperspectral imager with a wider field of view, aiding in:
   a) **Vegetation indices:** Calculating indicators like NDVI for overall crop health assessment.
   b) **Land cover classification:** Mapping different crop types and land use patterns.

Data Collection

1. **Orbit:** C-RAM will be deployed in a Sun-synchronous orbit at an altitude of approximately 550 km. This orbit provides consistent illumination conditions for imaging and ensures regular coverage of Rwanda.
2. **Revisit Time:** The orbit will be designed for a revisit time of under 3 days, allowing for frequent monitoring of agricultural areas and capturing rapid changes in crop conditions.
3. **Data Acquisition:** The hyperspectral and multispectral imagers will capture images of farmland. Onboard processing will extract key information like vegetation indices and crop health indicators.
4. **Data Transmission:** Processed data will be transmitted to ground stations in Rwanda via S-band communication for analysis and dissemination to end-users.

Subsystems

1. **Onboard Computer (OBC):** The brain of C-RAM, responsible for:
   a) **Data Handling:** Managing data acquisition, processing, storage, and downlinking.
   b) **Attitude Determination and Control System (ADCS):** Maintaining the CubeSat's orientation for accurate imaging and pointing towards ground stations.
   c) **Command and Data Handling (C&DH):** Receiving commands from the ground station and managing communication.
   d) **Power System:** Generating power from solar panels, storing it in batteries, and regulating power distribution to all subsystems.
2. **Communication System:** An S-band transceiver and antenna will handle communication with ground stations for command uplink and data downlink.
3. **Structure and Thermal System:** The CubeSat structure will provide mechanical support and protection for all components. The thermal system will regulate temperature to ensure optimal operating conditions.

Success Factors

The success of C-RAM relies on the seamless integration and operation of all subsystems. The hyperspectral and multispectral imagers will provide valuable data for agricultural monitoring. The OBC, communication system, and ADCS will ensure reliable data collection, processing, and transmission. The power system will provide the necessary energy, and the structure and thermal system will protect the CubeSat in the harsh space environment.

SELECTED ORBIT AND REASONS

(Referring to the provided document (CubeSat Mission Challenge Guidelines) select which Orbit you need to put your satellite mission)

C-RAM's mission to provide timely and accurate agricultural data for Rwandan farmers necessitates a specific orbit to optimize data collection and ensure mission success. A **Sun-synchronous orbit (SSO)** at an altitude of approximately 550 km has been chosen for the following reasons:

1. Consistent Illumination:

- SSOs are designed so that the satellite passes over any given point on Earth's surface at the same local solar time each day. This ensures consistent lighting conditions for image acquisition, crucial for accurate analysis of crop health and other parameters.
- Consistent illumination minimizes shadows and variations in spectral reflectance due to changing sun angles, improving the quality and reliability of the data.

2. Global Coverage with Focus on Rwanda:

- While SSOs provide global coverage, the inclination can be tailored to prioritize specific regions. C-RAM's orbit will be optimized to maximize coverage of Rwanda while still allowing for observations of surrounding areas for regional context and potential future expansion.

3. Frequent Revisit Time:

- The chosen altitude of approximately 550 km allows for a revisit time of under 3 days over Rwanda. This frequent monitoring is essential for capturing rapid changes in crop conditions, such as the onset of disease or water stress, enabling timely interventions by farmers.

4. Suitable for Agricultural Monitoring:

- SSOs are widely used for Earth observation missions, including agricultural monitoring, due to their consistent illumination and global coverage. The combination of hyperspectral and multispectral data acquired in this orbit is ideal for assessing crop health, soil conditions, and land use patterns.

5. Reduced Atmospheric Interference:

- The 550 km altitude strikes a balance between minimizing atmospheric drag and ensuring sufficient spatial resolution for the imaging instruments. This altitude reduces atmospheric scattering and absorption, which can distort spectral data.

6. Cost-Effectiveness:

- SSOs are well-established and commonly used for small satellite missions, offering a cost-effective solution for deploying C-RAM. Launch opportunities to SSOs are readily available from various launch providers.

In summary, the Sun-synchronous orbit provides the ideal combination of consistent illumination, frequent revisit times, and suitable coverage for C-RAM's agricultural monitoring mission in Rwanda. This orbit will enable the acquisition of high-quality data to support informed decision-making by farmers and contribute to improved agricultural productivity.

COLLECTED DATA:

C-RAM's payload is designed to acquire specific data crucial for improving agricultural practices in Rwanda. Here's a breakdown of the data types the satellite will collect:

1. Hyperspectral Data:

a) **High-resolution spectral signatures:** The hyperspectral imager will capture detailed spectral information across hundreds of narrow bands for each pixel in the image. This allows for precise identification of:

   I. **Crop species:** Distinguishing different crops and varieties.

   II. **Crop health:** Detecting stress due to water deficiency, nutrient deficiencies, disease, or pest infestations.

   III. **Soil properties:** Analyzing soil composition, organic matter content, and moisture levels.

2. Multispectral Data:

a) **Vegetation indices:** The multispectral imager will capture data in specific wavelengths to calculate vegetation indices like:

   I. **Normalized Difference Vegetation Index (NDVI):** A widely used indicator of plant health and greenness.

   II. **Enhanced Vegetation Index (EVI):** Improved sensitivity to variations in canopy density and biomass.

b) **Land cover classification:** Broader land cover information, including:

   I. **Crop type mapping:** Identifying the distribution of different crops across the landscape.

   II. **Land use changes:** Monitoring deforestation, urbanization, and other land use patterns.

Data Fusion and Derived Products

Combining the hyperspectral and multispectral data will allow for the generation of valuable derived products, such as:

a) **Precision agriculture maps:** Creating detailed maps showing variations in crop health, soil conditions, and water stress within fields.

b) **Crop yield forecasts:** Estimating potential crop yields based on the observed conditions and historical data.

c) **Irrigation recommendations:** Providing farmers with specific guidance on when and how much to irrigate their crops.

d) **Fertilizer recommendations:** Optimizing fertilizer application based on soil nutrient levels and crop needs.

e) **Pest and disease alerts:** Early detection of potential outbreaks to enable timely interventions.

Data Accessibility

The data collected by C-RAM will be processed onboard and transmitted to ground stations in Rwanda. This data will then be made accessible to farmers and other stakeholders through various platforms, such as:

a) **Mobile applications:** Providing farmers with easy access to information on their smartphones.

b) **Web portals:** Offering interactive maps and data visualization tools for researchers and policymakers.

c) **Agricultural extension services:** Integrating satellite data into existing agricultural advisory services.

Add a picture of the Satellite drawn by the students:
(Attach to this document a picture of the CubeSat you have designed.)