1.) Satellite 1: Eagle-1

Morehead State University and Kentucky Space

1.1 Overview

A new satellite standard was proposed in 2009 by Professor Robert Twiggs (Morehead State University) for a satellite even smaller than the CubeSat called PocketQub™. This Fempto-class satellite is a 5 cm cube and can fit in a pocket. The PocketQub™ leverages the CubeSat standard and also leverages the revolution in the miniaturization of electronics. PocketQub™s will ultimately have a wide range of applications including:

- Network Nodes
- Sensor Systems
- Satellite Constellations
- Inexpensive, Redundant, Spatially Organized

The Eagle-1 spacecraft is designed to provide a component testbed for various spacecraft technologies, primarily among them being a de-orbit system that also increases the spacecraft radar cross section. To support this goal, the Eagle-1 spacecraft contains a number of components, such as a commercially available unrestricted 8 bit microcontroller and basic electronic components. Eagle-1 uses the bus, power systems and radio that equals one PocketQub Unit (PQU). The de-orbit system developed at Morehead State uses 0.5 PQU in stowed configuration and expands using a PCB and copper substrate-based structure that both produces a gravity gradient inducing a de-orbit maneuver and increases the radar cross-section making the cube more easily detected by space surveillance radar.

Commercially available components for PocketQub™s include power generation and handling system, communication system, and payload interface. The Morehead State University PocketQub™ mission is designed to perform femtosat de-orbit measurements. Its intent is to measure the effectiveness of the de-orbit system after a baseline orbit is established and the de-orbit system is engaged. The satellite design is shown in Figures 1 below.

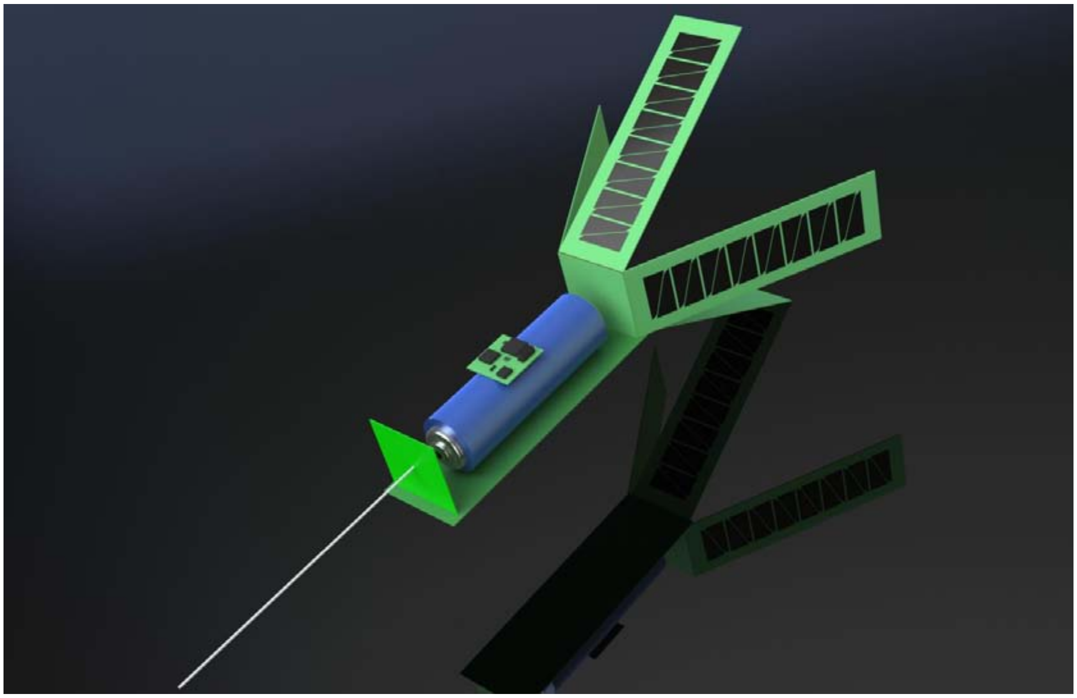

Figure 1.0 CAD Model of Eagle-1—On-orbit configuration with solar panels deployed

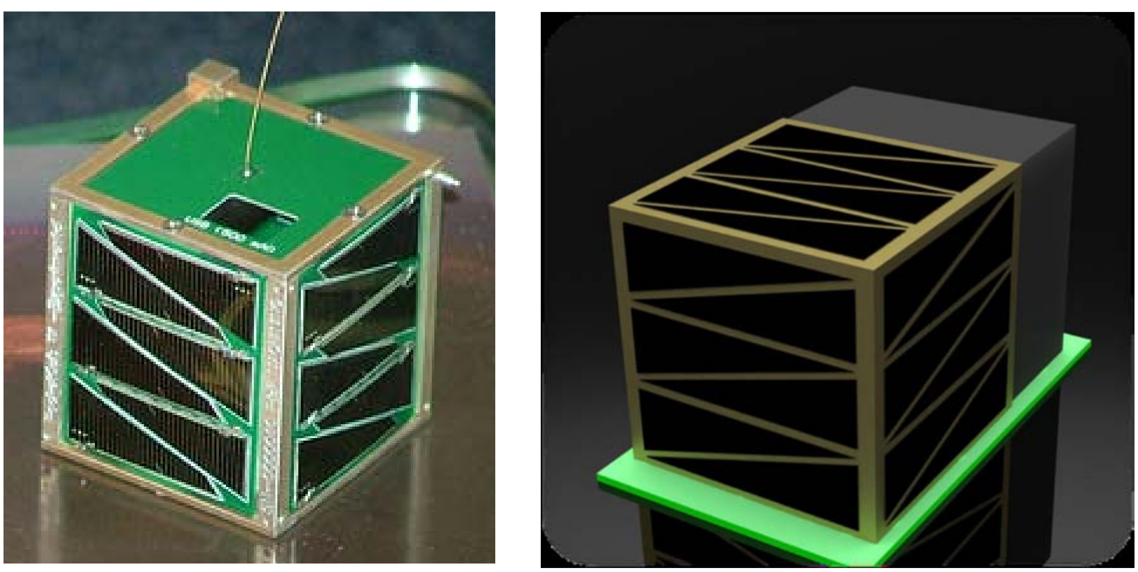

Figure 4.0 Photograph of Prototype PocketQub™ (L) and CAD model of PocketQub with De-Orbit mechanism (R)

Because of the extreme constraints on space and mass in the PockeQub standard, only the most basic subsystems are included. These are: a power system (EPS), a communications system utlizing a GMSK transceiver and whip antenna, and de-orbit system. The satellite structure is composed of 1.6mm FR4 PCB mounted to an anodized aluminum frame. Solar Cells cover the PCB on all sides. A whip antenna is mounted to the +Z face of the Qub. Basic specifications for each subsystem are provided below. This first iteration of the Kentucky Space-Morehead State University developed Pocket-Qub is a basic system that generates and stores power, and beacons constantly communicating with the MSU Earth station which will measure flight dynamical data to evaluate the effectiveness of the de-orbit system. The de-orbit system will be initiated within 72 hours of the satellites ejection from UNISat and will, it is expected, beacon for 2 months and de-orbit with in 10 years.

1.2 Command and Data Handling

The C&DH system Eagle-1 is designed to check overall health, interpret ground station commands, service the payload, and store data for later retrieval. A standard Inter-IC ("I2C") communication bus is utilized to connect several analog-to-digital converters (ADCs) to the C&DH processor.

The C&DH processor is a commercially available micro-controller, model PIC18LF6720 from Microchip Corporation running at 4MHz. This processor contains 128kB of Flash memory for software storage and non-volatile data storage. Eagle-1 uses 7 MAX1039 analog-to-digital converters from Maxim Integrated Products to acquire most of the health data. It also collects battery information via two DS2761 Integrated Circuits (ICs), also from Maxim. Health and payload data are stored on two AT24C1024 serial EEPROM FLASH memory devices. Each holds 128kB of non-volatile data.'

1.3 Communications Subsystem

The Communication subsystem consists of a deployable di-pole antenna or monopole antenna. A low power radio transceiver operating in the HAM 440 MHz band is the main communications channel. The transceiver can be disabled by ground station command uplink, if required. Basic Specifications are given below:

• GMSK Transceiver:
o TX, RX: 400 – 470 MHz
o 12 dBm to 30 dBm
o AX.25, 9600-38400 baud

1.4 Electrical Power Subsystem

With the limited volume, mass, and surface area available on a PocketQub, any EPS system can only provid power for an extremely limited time (weeks to months). Eagle-1 utilizes a basic MPPT Power Board. EPS scpecifations are shown below:

EPS:

o System: 3.3V, 1 Amp
o Solar Input: 25.0V, 1 Amp
o USB Charger at 500 mA

The USB power and debugging interface is a standard mini USB connector capable of supporting up to 500 mA of current. The USB interface consists of a CP2102 USB/UART bridge that interfaces to the satellite bus for debugging.

Power is stored in a Lithium-Ion batterty, secifications provided below:

o Li-Ion Battery, 750 mAh
o I2C Health and Status Information

The power generation system consists of commercially-available SpectroLab solar cells that are 27% efficient. Specifications for the solar panels (of which there are 4) are below:

Solar Panel:
o Voc: 15V
o Vmp: 13V
o 6 TASC Cells

1.5 Structure and Mechanisms
The structure of Ealgle-1 is constructed of aircraft grade 6061-T6 aluminum and weighs approximately 50 grams. The structure supports the antenna and solar panels externally. Internally, circuit boards are mounted to internal mounting hard-points. The structure is hard-anodized. The total mass including the de-orbit system is under 200 grams.

1.6 Software
Software for the processors on Eagle-1 is written in C, leveraging hand written code from students. The C&DH software coordinates all operations of the spacecraft, as the C&DH software is central to all other systems of the spacecraft. The C&DH software deals with the collection of housekeeping and payload data. The Communication system software controls the transceivers international AX.25 standard data packet operations. The payload software communicates with the payload deployment system, processes payload data and communicates with the C&DH system.

1.7 Payload
The payload is a deployable de-orbit system with a dual purpose of increasing the spacecraft's RF cross section. The de-orbit system consists of a deployable set of 8 PCB panels with copper faces that are approximately 4 cm x 4 cm. They provide a total area of 0.0128 m^2. The de-orbit maneuver created by this system employs the strategies of increasing the satellite system's total surface area and creating a gravity gradient orientation.

Flight data will be produced from data collected as various Earth stations track the spacecraft RF beacon. Keplerian elements will be generated from mathematical analysis of the trajectory data. Flight dynamics are inferred from the Keplerian elements allowing numerical modeling of the orbital mechanics of the satellite. As the orbital mechanics change over the satellite's short lifetime, the decay properties will be measured and compared to theoretical models. This experiment will evaluate the effectiveness of the de-orbit system and provide relevant data regarding the orbital decay effects (atmosphere profile, satellite ballistic coefficient effects, gravitational gradient effects, and gravitational affects of Earth asymmetries). The results of this experiment will be published in the open literature.