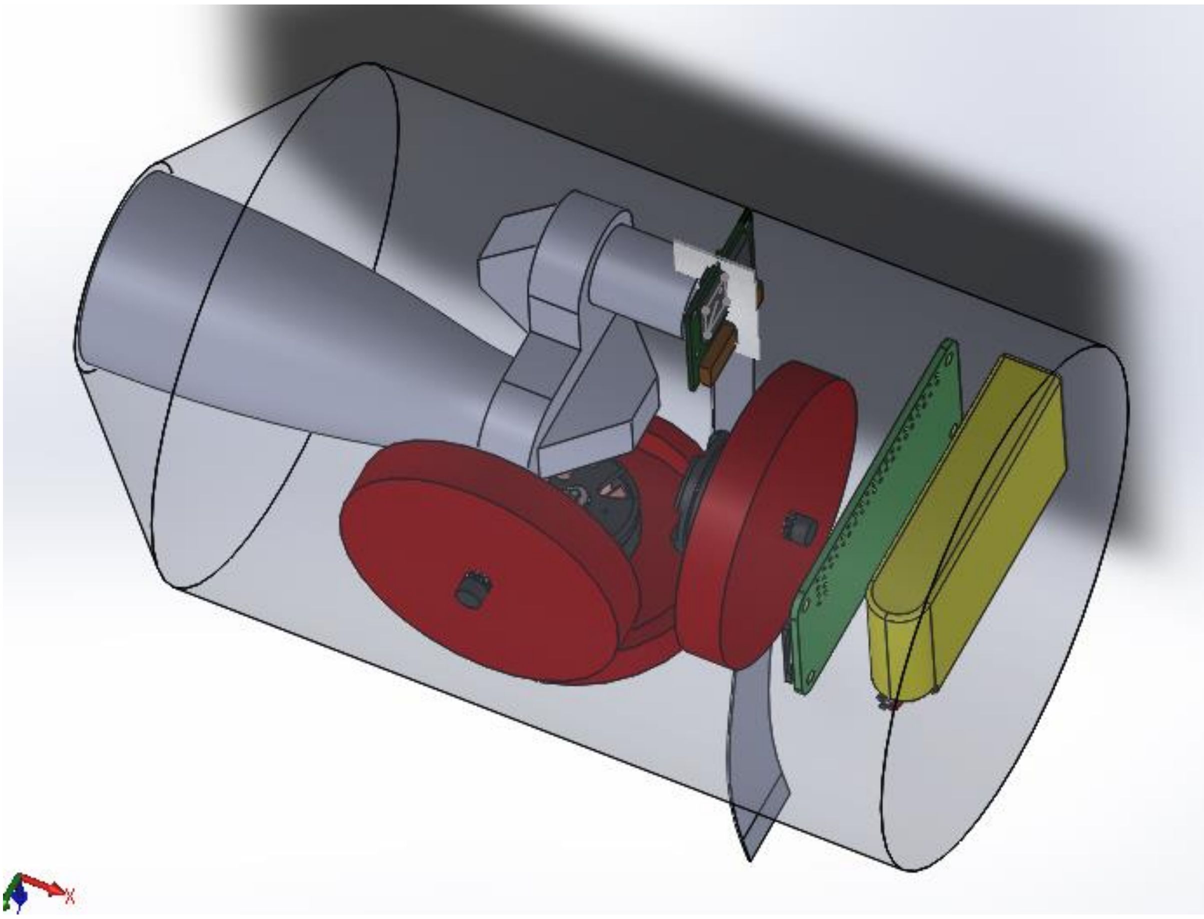
Problem Analysis - 2 March 2018

The John Tebbutt Space Telescope



Problem analysed by Bradley King from spec v0.1 20180115

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Project Goal

The task is to design a proof of concept for the John Tebbutt Space Telescope. The John Tebbutt Space Telescope is required to photograph planets vast distances away, taking instructions from users on earth, where they can determine the habitat of the planets and the suitability of life. To achieve the task, certain objectives will need to be met. To simulate the satellite in space, certain restrictions have been applied.

Requirements

- Semi-autonomous 3D “hands off” control.
- High precision camera / zoom
- Interpreted commands in equational geocentric spherical coordinates.
- Live video feed from base station.
- Mission Critical systems individual power and testing from space rated controller.
- All equipment must fit into a BX3 mailing box.
- 25min demo time.
- Strict size, weight and COG requirements – 750g 145mmx100mm dia cylinder.
- Maximum energy storage in li-po of 4.16W.
- $200 budget
- A range of different sized planet images on a4 paper placed at a distance from the demonstration ground to represent the distances expected in space. (25m)

Scope

The specification (assignment doc v0.1) provides the design and outcome criteria for the John Tebbutt Space Telescope below is the scope for the project.

- Design of a satellite and base station, Satellite to have 3D control.
- The physical construction and build of both ground station and satellite.
- Electronics - design and fabrications.
- Firmware - master control microcontroller and all other sub modules where required.
- Interface software – allowing control of the satellite, debugging and images.
- Orientation Control – design to implementation and programming.
- Plausible design for space - No devices that require gravity or the atmosphere. MCU class must be space rated.

A space rated design is out of scope, ie launch stresses, radiation, material selection.

Imaging and telemetry.

Getting a clear image will be required to allow reading of small text, there will be challenges from vibrations from the reaction wheels, and movement from the control system. Using a 15x zoom lenses over the 25m target range, the camera has a view of 1.5m x 1m, 25 times the size of the A4 paper allowing some inaccuracy in the control system. To allow the control systems larger movement, a highspeed camera to reduce the blur. Post processing can be used to stack multiple images to remove noise from movement and sharpen. The camera system will need to be mounted using a vibration damping material.

Control

The hardest part of the challenge will be control. Tuning the control system to allow clear photos. While maintaining an accuracy of ±2 degrees, the limit to allow an a4 page to be seen in the camera. As the satellite will run up to 25 minutes it is highly likely that the control system will saturate. As the 608zz bearings have ~2.5N.mm of static friction a desaturate command could be designed to slowly reduce the energy stored in the flywheel at every moment the system has stopped moving.

As the “Planets” are on a 4x2m board, Angular velocity isn’t much of a concern, where oscillations will make the image unusable. The control loop can be tuned by modelling in Simulink to make it critically dampened.

Electronics and power

The limited energy available means high efficiency regulators, a low derivate coefficient in the control loop, to reduce excess power being used in control. Using brushless motors with regen to regenerate the energy being used for control. Reducing all offset in COG to stop energy being wasted due to gravity, this effect will be gone in space.

Interface
Having enough control so solve any issue on the day from the base station. The base station can use image stacking to combine multiple images to create a higher resolution

Cost
As the base station is included in the budget it needs to be thoughts of at the same time as the satellite.

Candidate Design.
The design can have 4 different streams worked on in parallel mechanical and power management bus, orientation control system, telemetry and imaging and ground control interface. These can be worked on mostly independently. At the start of the project system boundary API's need to be created to allow each sub system to be designed, built and testing independently. Building a test bed early will be a key for success.

Subsystems

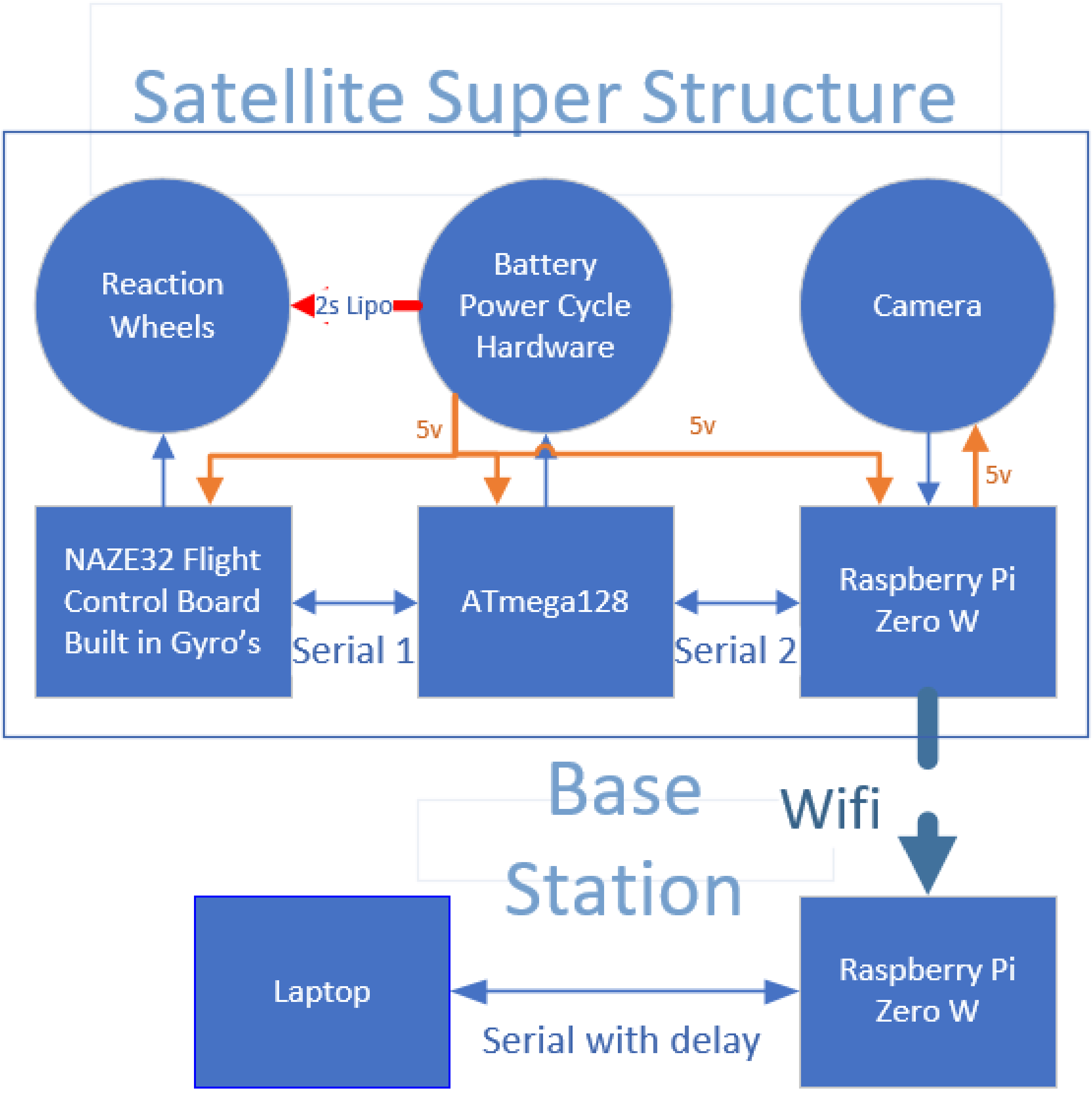
Subsystem	Resources	Duration	Dependencies
Reactance system	Motors and Flywheels	2 weeks	
Telemetry	Raspberry PI's	3weeks	
Imaging	Camera/ Telescope	3weeks	
Mechanical – design and iterations	Solid works	6 weeks	Power Management, Reactance System, Imaging Design
Power Management Design	PCB, ATMEGA128	3 weeks	Mechanical
Control Systems	Simulink	4 weeks	Mechanical System, Reactance system
Satellite Firmware	ATMEL Studio	3 weeks	Power Management Design
Ground control interface	Laptop	4 weeks	Telemetry Link Designed

Milestones

Task	Description	Date
Testing Unit	A 1 axis unit for testing control model. And image stability	March 28th
Pcb Ordered	Pcb ordered, mechanical build started	March 28th
Progress demo 1	Basic Functionality	April 17th
Progress demo 2	Advanced Functionality	May 1st
Progress demo 3	Bonus Functionality	May 15th

Risks

Risk	Mitigation Strategies
Camera not getting a clear image	Post processing software. Vibration Dampening Mounting
Control loop oscillations.	A single axis development platform should be designed early to allow both camera and control loops to be tested early
Running out of power	Early bench testing to confirm expected run time with all components
Catastrophic failure of Reaction wheels from vibrations	Using accelerometers to monitor all vibrations, with safety thresholds set to cut power.
Weight savings impacting structural integrity	Using a FEA program to analyse the designs for weak points before construction.


Satellite Super Structure
Reaction Wheels
2s Lipo
Battery Power Cycle Hardware
Camera
5v
5v
5v
NAZE32 Flight Control Board Built in Gyro's
Serial 1
ATmega128
Serial 2
Raspberry Pi Zero W
Base Station
Wifi
Laptop
Serial with delay
Raspberry Pi Zero W