CSDC-5 CDR Feedback

October 9th, 2019

Mission Overview

- "Gold Anodized" is not really gold
- Minimum pass time has no real meaning, will have very short pass times
- What is the angle to get a comm link with the ground station?
- The previous board we had died during radiation testing – we thought due to single event upset
    - Latch up can also kill an OBC from radiation – this is more likely than a single event upset
    - Make sure we know what happened, so we don't buy one that does the same again
- **"Heat pipes, really?!" That's a difficult solution, may not need that**
- Payload system counts as built, not buy

Payload

- **Earth is at infinite focus ->** There's no need for a focus motor or other mechanism for focus
- There's a difference between focus and alignment
    - **Alignment will be the issue – This depends on how the lens and sensor are connected and secured to the bus**
    - Will be the driving factor in the payload's performance
- Pixel dimensions – can't have rectangular pixels?
- **If ground blur is less than ½ a pixel, It's irrelevant**
- Not certain that CMOS is better than CCD – but still should work
- **Off-the-shelf DSLR lens**
    - Plastic is an issue
    - Rubber ring – and all rubber, plastic- will need to be removed
    - Potted with something not space qualified -> will outgas and deposit on lens and/or sensor – bad!
    - Focus motor has lubricants likely
    - Should remove all moving parts, focus by putting spacers in – basically make it a fixed focus at infinity
    - Will be tricky to get the lens to work
- Check how big the pixels are
    - Looked up: 3.8 microns pixel size
    - Therefore 11.26 m on the ground
- HUGE image sensor will need significant compression
- Bicubic compression is generally better but slower – but 1 image should be ok – there are some very good algorithms out there
- Put lens in a vacuum chamber to see the change in optics – can you still use it? How is the alignment? Could be messed up, need to confirm for use in a vacuum
- **How is the lens/sensor etc attached to the structure?** "Not as simple as you think it is"
- **How long will it take to calculate exposure time, ISO?**

    - Very, very important – can be km's away by the time it's calculated
    - Control sequence diagram has a lot of errors that need to be fixed
- How is the downlink budget calculate during orbit? ARO specs such as downlink budget is specified in rules – you don't need to uplink this info to choose image compression method…
- Is there any windowing for image compression?
    - Sceptical that we will be able to compress enough to downlink in the time allowed
- **BE VERY CAREFUL about moving parts and materials in payload design**
- **Optics should be designed or modelled in MATLAB**
    - Estimate what the lens has inside in a simulation
    - Get the sensor/lens aligned properly in sim
    - Then change medium to vacuum and see how it changes
- **"TEC is a power hungry and thermal nightmare on cubesats"**
- **Where the discussion on heat pipes?**
    - Filled with ammonium are much more expensive that plain copper
    - Copper tape is cheap and effective
    - Aluminum structure may even be enough to conduct heat away
    - Need to do a detailed thermal analysis in order to determine what solution is needed

Structure

- First rendering slide – must better diagram than the first image showed in payload and earlier
- In drawing the lens include rubber ring – be careful!!!
- "Insane" number of elements in structure model
- Why non-linear model?
    - Can't do a vibration analysis with non-linear
    - Could get away with 2D elements, but this is good
- Why 7075-T6? Reacts poorly with anodizing acids – usually -T73 is used – There is a specific type of aluminum that isn't allowed… double check this
- What are the boundary conditions?
- Are the loads applied simultaneously in G study? One at a time = good
- **Ridiculously low stress result** – The simulation doesn't include mass of components, which is a problem
    - The analysis of the structure alone doesn't matter that much – with components is what you need to ensure works
- **Should test a less constrained model**
- **Deflection should be greater** – possibly used the wrong density?
- Why not beam and plate elements? Too few elements in through thickness
- **Model with 10,000 nodes using beam and 2D elements will just as accurately model the structure**
    - This way it will be much faster to run, so you can re-run and trouble shoot much more
    - Ask yourself if the deflection results actually makes sense (the one in the slides doesn't)
- Numerical modes analysis: good. 150Hz is good, **but NO MASS included – need to redo with load**

- Which load step? (Slide Launch Vibration 1/3)
- **Boundary conditions are too optimistic**
- Represent deployable springs as springs, not forces
- 2mm pin ball radius – good, impressive!
- Don't treat bolt holes as bonded – represent them as bolts – even bolts with washers will potentially chatter – use a beam or other stiffing joint or joint elements
- Launch vibration is actually quasi-static
- 0% margin is too optimistic
    - Use 5% if you're pretty confident
    - **Should be 20% due to the estimation of components used**
        - Good to use comparable systems when you haven't finalized design yet
        - Should indicate which elements are estimates in the table

Thermal

- Primary/secondary systems are not sinks
- Margins – allowable
- Image sensor – to keep in focus need to have a better (smaller) range of temperatures
    - Same for batteries
    - Need a new list of target temperatures for components (data sheet range is not necessarily what you actually want)
- Sun sensors need work – thermal analysis margins
- **Not comprehensive power budget – No OBC, solar cells, PCB's – NEED TO CONSIDER**
- **Batteries are particularly important – consider the thermal issues carefully**
- In 400 km orbit there will be days of constant sunlight – be careful estimating the hot case
- Heat will radiate – very little will translate into bus
- Need a weighted average for thermal analysis
- **Missing a # of components that generate heat – need to include a lot more**
- What is the attitude? Where is the camera pointing? **Telescope will alternate looking at space and earth – very bad for camera sensor and lens**
    - Heating and cooling repeatedly could break lens, kill or seriously damage sensor
- Build model around optics and batteries – these are the two biggest problems
    - Are there thermal gradients?
    - CTE misshape? (?)
- Why are cells deployed after de-tumbling? When panels/antennas deploy the sat will start tumbling again
    - **Deploy immediately, possibly, but pros and cons to both…**
- **Put a panel on the sides that don't have cells – will** mitigate thermal issues and limit stray light that could affect images

Power

- There are discrepancies between the CAD and power diagram
- Different voltages from cells on each panel
- How does EPS combine with the arrays? 4s2p helps, but there will still be a voltage difference

- Look at the EPS datasheet to see if it's okay with those voltage differences
- Power generation slide: "This is the slide that had me worried"
  - Power is not W*h – that's energy
  - May get ~15 W in orbit in sunlight, for ~ 1 h = 15W*h of energy in the best case
- ISS orbit is not always in these conditions – there may be more or less light
- **Redetermine power estimates – taking into account temperatures and sensor datasheet**
- **DOD 78% is completely unreasonable and irrelevant**
  - Use power simulations to find a DOD – as shallow as possible to maximize lifespan
- **Regulations! Safety is a big deal with battery packs**
  - There is a test plan set by nasa that needs to be followed
  - Cells will need to sourced from the same lot – need documentation to prove this
    - Tier 1 supplier only will do this (pansonic, LG, Samsung) but will be difficult to get because they don't like selling them like this
- How are the batteries connected? Don't solder directly to cells
  - Use a spot welder – find one in Kingston, probably too expensive to buy for just this
- **NEED DIAGRAM FOR DISTRIBUTION OF POWER IN SYSTEM**
  - Critical top-level system diagram
  - Great to hand out to new members, use as guideline while building
- Power budget: "A couple of scary things here"
  - TEC – no way
  - Orientation sensor – call this attitude sensor of magnetometer/gyro
- **Power in mech heat sinks??? Doesn't make sense**
- 97W to reaction wheels? Can't pull 100W from these batteries
- Enormous motors, antennas
- **Producing 24 W out of 18 cells? Completely wrong**
- Sun-synchronous orbit -> Not accurate to say the cells are always in the sun
- Orbit length – ISS is much shorter than sun-synchronous – need two estimates
- Power is reduced by amount of time in the dark
- POWER NEEDS WORK
- **Having each operational mode – very good! Only team so far to do that**
- Keep solar panels out of budget
  - Simulate each state step by step and determine how much power is generated, and if there is enough
- Account for seasons
- **Values don't add up at the moment**

ADCS

- **10% required accuracy -> needs to be considered in the range of uncertainty in power generation estimates**
- Choose one of 0 to 6.5 degrees accuracy
- FoV / 4 = accuracy on fine pointing

- Gravity gradient is irrelevant – balances throughout orbit, very small for a small satellite
- Drag coefficient is irrelevant – too small
- ADCS needs to include magnetorquers
- Position simulation
- **Sun sensors: get aluminum or glass with slit**
    - **Internal reflection is a big problem, will produce conflicting results**
- Need to know where you are to use magnetometers
    - Keep track of time and orbit position?
- Calibrating sun sensors: noise if in sun, get variable light levels -> Difficult to calibrate
- **Truth table: accuracy is optimistic**
    - Especially gyroscope – it needs initial value – how do you get that? Uncertainty depends on the uncertainty in the initial value
    - Take picture – map to a known landmark -> Figure out attitude knowing the time and position – but this is complicated to do
- Gyro being better than every other combination except all combined – doesn't make sense
- Magnetometer: field varies a lot, 1 degree is very hard to get – won't in a cubesat
- **Reaction wheels: Shaft is a rotor – where are the motors? These motors have internal pcb's w tracks, but no inertia**
    - Need to add inertia somehow
    - The manufacturer minimizes inertia by design – but we want to maximize
    - May have more momentum transfer than torque
- Stepper motors jitter = problem
- **Need a rotor: to design and build ourselves will be very hard and very likely fail**
    - **Statically and dynamically need to balance – otherwise sat will shake constantly**
    - Will need to buy

COMMS

- "You better know…" is the ground station antenna vertical, horizontal or left polarized/right polarized (or something like that…)
    - Ionsphere will cause random rotation of polarization – circular on ground can be linear at the satellite
- Update table with loss of polarization – 3 dB okay
- Length of antennas will matter (?)
- What's the elevation angle? Required 10 degrees
- Estimates are conservative in table – good
- **Recover sensitivity – always written for chips on earth, at 290 K consistently**
    - **Never like that in space… Consider signal to noise ratio**
    - #s in downlink table are not correct
    - UHF might be better than what we have down
    - Sky is cold in radio band - about 60-70k of galactic noise
    - At the horizon, or in urban areas, ~1000k of noise
    - Rain etc. is negligible at this frequency
- **Antenna: Why 4 wires? If 2 (1 long, 1 short) works, do that**

- **Really big image, 90s downlink with only a few minutes contact per day… will the compression ratio be good enough??**
- Are images also sent to control station? Yes – good
- Make an ARO link budget
- Need only to match initial link value (63.8 kB) to original image size (16 MB), in about 2.5 min = ~1min for processing

OBC

- **Overview: A very small fraction of what the OBC actually does**
  - Run OS
  - Upload software
  - Control payload
  - Run ADCS System
  - Talk to ARO
  - Process images
  - Etc.
- **NEED A BLOCK DIAGRAM OF OBC**
  - The rest will follow
- Not comparator – exclusive OR
  - Need to decide ASAP between multi/single string system
- What kind of bus?
- What actual data is being compared?
- **Need something reliable to bit-shift – maybe a RAD tolerant CPLD**
- **How is the OBC talking to other systems?**
- Outputs need to be combined somehow (multi-string architecture slide)
- A lot of work still to do… need more people
- **Need USB to interface with camera** – computer systems MCU need help
  - Define protocol between busses
  - Need to know how everything interfaces
- Why is the ADCS on a separate computer? Does that computer have the same health checks?
- **How do you know when to point for ADCS and payload? RTC?**
  - **Currently don't have a way to do that**
- ACDC computer must be ready ALL the time
- ARO must be able to control when and where the photo is taken

AI&T

- **Need tests to test individual components** – not the whole satellite – it won't be done in December to do that when you should be testing (lol)
- Typo in dates in AI&T payload
- Need different processor – an architecture and os that matches sensor and microcontroller
- **Tests are not well defined or clear**
- **DATES ARE NO GOOD**
  - **Timelines are not integrated with each other**

    - Ie. Putting it in a vacuum chamber first is not a good idea – test it normally first
- **Need a gantt chart of critical path for testing**
    - Use Gantt Project – free, will track all dependencies, keep it up to date
- How will the Helmholtz cage be calibrated? Only will get rough estimate
- How will torques be measured to test magnetometers?
    - Be clear about what "functionality" means in a testing context – be specific
- Probably won't be able to do a desaturation test

Risk

- High vibration: this is a part of the environment, not a risk
- Low-off gassing is not related to high vibration…
- Radiation damage to sensor – also not a risk, it's an environment thing
    - No lens aperture to close
- **A lot of these are DESIGN CHALLENGES, NOT RISKS**
    - Risks are program management related mostly
        - People not available
        - Supplies don't ship in time
    - Technical risks
        - Analysis won't converge
- Reaction wheel failure: good consideration, but mitigation is having 4 wheels, not what was written
- Single Latch-up: Power cycling won't help hardware damage
- Watchdog, what is it? Use an external one
    - Use a window watchdog if possible
- **Worry about hydrogen particles for radiation** – cobalt is ok but won't cover everything needed
- Comb through and take out "just fails"

Anomaly

- Blurred image therefore buy lens: Doesn't do anything. It's a design challenge, not an anomaly
    - That's not mitigating – it's preventing

CONOPS

- **Make sure every possible state or situation is on diagram**
- Can't calculate desaturation events on the ground, ACDS should do that automatically
- Greedy algorithm – good
    - Take sun angle into account
    - Remember ARO must be able to request photo in real time
- **Consider ARO habits and preferences**
- Need to tell ARO if they get bumped – probably by email

Program Management

- **Need critical path gantt chart**

- **Solar deploy, antenna deploy were not in CDR – should have been**
- Build a prototype at least once to find problems before the real thing is built
- Make a realistic schedule – then tell the customer when you'll be ready (good luck telling larry that…)
- Technology risks – yep, all valid

Outreach

- **Start keeping track of how many people attend each outreach event**

Summary

- **Would debate that the thermal models presented are NOT compliant**
- **"3.9 km including margins" INCORRECT**
- Shouldn't be any surprises on these summary slides – but there is
- Step 1 of OBC
    - Specify
    - Design
    - Build
    - Include the things that seem obvious on the diagram