Complete Detailed Design: Phase-End Summary

This document should continue to document your journey through MSD, so include work-in-progress as well as latest results – this document can be edited live online. Any time you post a snapshot of a document for a phase review, be sure you have a live document to back it up. **Your file repository should still contain original editable files, not just .pdf files**.

Use the Phase 4 folder to store information supporting this document. Some templates are available in this folder for your use.

Remove all template text from this page prior to your final Detailed Design Review.

Individual and Team Vision for Complete Detailed Design Phase [Tanner]

- What did your team plan to do during this phase?
- What did your team actually accomplish during this phase?
- Since this phase will require students to do more independent work, your team should also capture a summary of key tasks completed, and who was responsible.

Feasibility: Analysis, Simulations

Goals

- Justify that the design decisions you are making will result in an acceptable solution.

Instructions

1. Complete various analysis and simulation exercises as required by your project
2. Identify a system "transfer function" based inputs, outputs, and key design parameters. This can be done via theoretical analysis or empirical prototyping. It's often helpful to work with multiple members to make sure each subsystem is accurate.
3. Using all of your analyses and models, determine values of all <u>quantitative</u> design parameters. These could be specific values and/or acceptable ranges.
4. Confirm that the selected concepts and design plans will be able to achieve the desired performance of your system. Also anticipate any potential failure modes associated with your chosen concepts.

Required Artifacts

- Document listing your quantitative Design Parameters, including quantitative targets and acceptable tolerances.
- Evidence of your feasibility work, including writeups of any theoretical analysis, and/or photos and videos of your simulations
- Summarize what you learned for each feasibility activity, and what decisions were made as a result.
- A summary table that compares your ERs to what your design is anticipated to deliver, based on your feasibility work, e.g., expected performance vs requirements.

Feasibility: Prototyping

Goals

- Quickly test the feasibility of competing options that would be time consuming to simulate
- Quickly evaluate a key but uncertain component or subsystem of your design before making design decisions dependent on that component or subsystem
- Begin or continue fabricating or implementing critical elements of your final product or process

Instructions

1. Identify the functions that are uncertain, which can best be addressed by prototyping
2. Make use of MSD surplus, rapid prototyping, foam core, breadboard, cardboard, wireframe, etc.
3. Consider investing more time and budget into higher-fidelity prototypes
4. Consider purchasing high-risk components

Required Artifacts

- In this document, include
    - what you wanted to learn
    - the limitations of the prototype
    - summarize what you learned
    - explain the decision made as a result
- Photos can be embedded in this document. Videos can be posted in EduSourced.

Drawing, Schematics, Diagrams

Goals

- Update any changes required since the Preliminary Detailed Design Review.
- Complete the remaining detailed design of your system.

Instructions

1. Document all CAD files in Edusourced
2. Document all Schematics & PCB design files (if applicable) in Edusourced
3. Document Software architecture in Edusourced
4. Adhere to all required design standards.

Note: Make sure file repositories survive MSD (no Google Drive files, outside servers which may expire in time)

Required Artifacts

- Complete hierarchy of design files, from system level down to components. This may include (but is not limited to):
    - CAD models/sketches

- Software design, including specific coding requirements
- Electrical diagrams (timing diagrams, schematics, etc)
- Note that your file archive needs to include actual design files, in addition to manufacturing files (e.g., CAD solid model files, plus manufacturing files like drawing files and/or STL files)
- Note that your file archive needs to include actual design files, in addition to manufacturing files (e.g., CAD solid model files, plus manufacturing files like drawing files and/or STL files)
- List of relevant standards, and how your team is satisfying them

- <u>Complete</u> parts list

Bill of Material (BOM) [Drew]

Goals

- Confirm that all expenses and contingencies are accounted for and afforded by the project financial allocation, a financial feasibility analysis.
- Long Lead Items ordered or ready to order

Instructions

1. Using the Sample BOM.xlsx, fill out your team's bill of materials and add it here.
2. Be sure to include all components that will be purchased, or the material for those that will be fabricated. Estimate 3d prints at $0.03/gram.
3. Include items that have been donated, along with anticipated cost if the client were to purchase these in the future
4. Consider the cost of anticipated potential failure modes
5. Include *estimates* for unknowns, such as open design items and shipping costs
6. Identify long-lead time items, and their order dates

Required Artifacts

- Updated BOM available in EduSourced, with a snapshot/summary in this document.
- Brief summary of the team's budget status: what assumptions have you made, are you projected to be within budget or not, are there any cost risks, etc?
- If necessary, a budget increase request

Test Plans

Vibe Analysis Test using Ansys (ER 4):

Subsystem/ Function/ Feature Name:	Vibe Analysis
Date of Test:	
Performed By:	Eva Czukkermann
Tested By:	Eva Czukkermann
Concluded Condition of meeting Engineering Specification:	

I. TESTING SPECIFICATION

Specification Number	Importance	Source	Function	Specification (Metric)	Unit of Measure	Marginal Value	Ideal Value	Comments/Status
S4	3		System	IAW MIL-STD-810H Figure 514.8D-6 and Figure 514.8D-9	N/A	Yes	Yes	

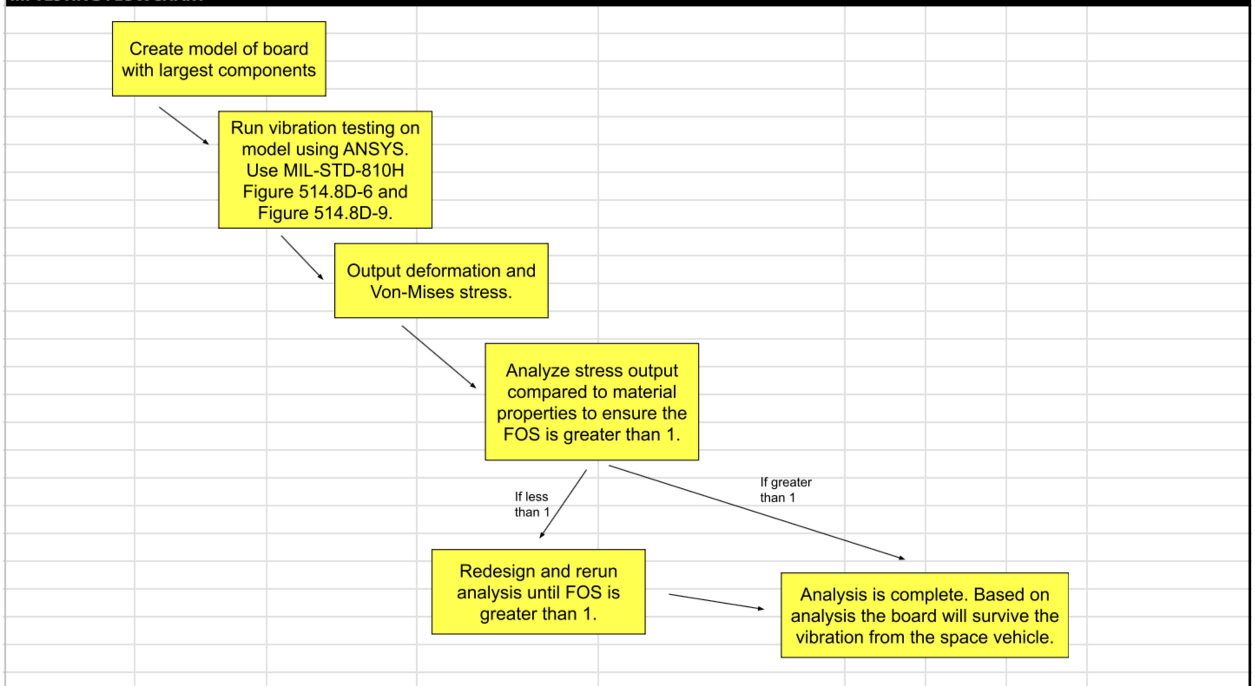
II. EQUIPMENT REQURIED

Specification Number	Equipment or Instrumentation required
S4	Ansys, CAD

III. DATA COLLECTION STRATEGY

Specification Number	Data acquisition strategy
S4	The goal of this test is to ensure the board can survive the frequencies/vibrations it will experience while assembled in a space vehicle.

III. TESTING FLOWCHART



MIL-STD-810H Figure 514.8D-6 and Figure 514.8D-9 reference Table 514.8D-IV for levels (W_1, W_2, f_0, f_1). See the figures and table below:

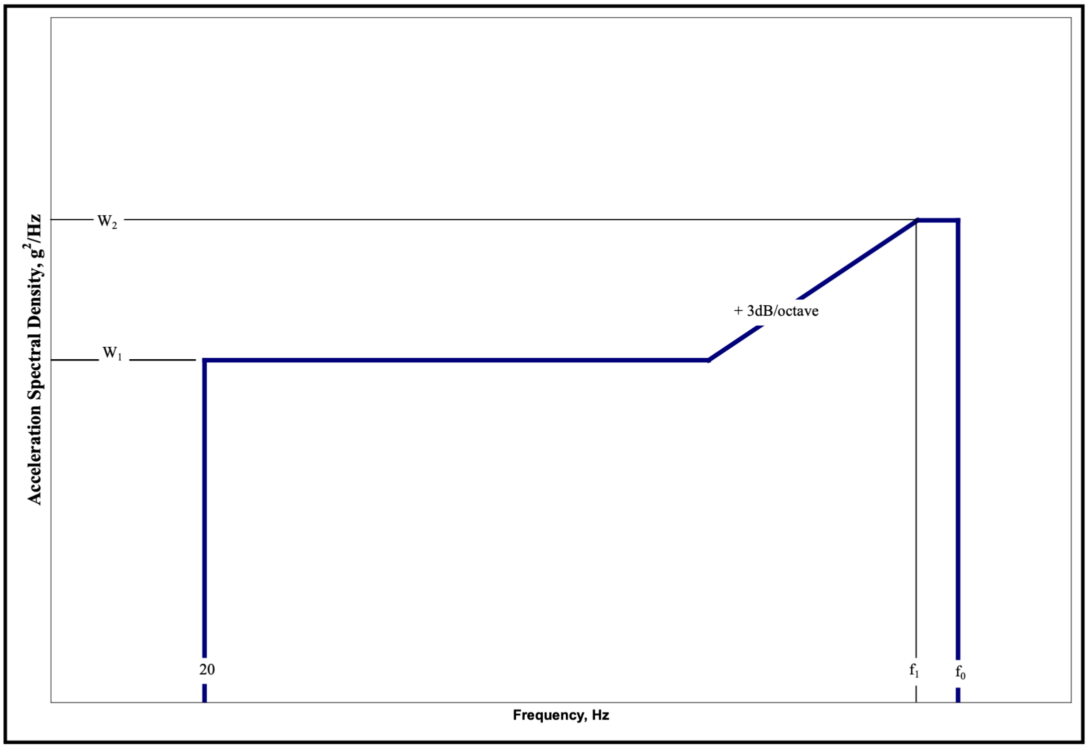


Figure 514.8D-6. Category 15 - Jet aircraft store vibration response.

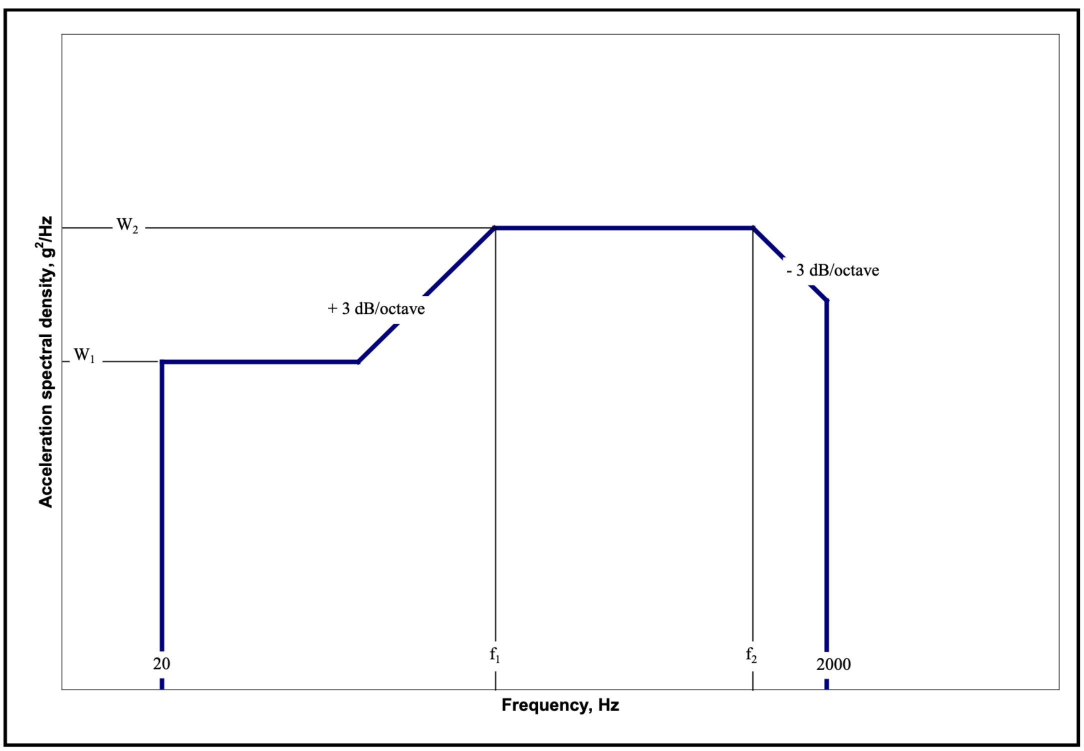


Figure 514.8D-9. Category 16 - Jet aircraft store equipment vibration exposure.

Table 514.8D-IV. Category 15 - Jet aircraft external store vibration exposure.

$$W_1 = 5 \times 10^{-3} \times K \times A_1 \times B_1 \times C_1 \times D_1 \times E_1 \; ; \quad (g^2/Hz) \quad \underline{1/}$$

$$W_2 = H \times (q/\rho)^2 \times K \times A_2 \times B_2 \times C_2 \times D_2 \times E_2 : \quad (g^2/Hz) \quad \underline{1/}$$

$$M \le 0.90, \; K = 1.0; \quad 0.90 \le M \le 1.0, \; K = -4.8 \times M + 5.32; \quad M \ge 1.0, \; K = 0.52 \quad \underline{2/}$$

$$f_1 = 10^5 C(t/R^2), \; (Hz) \; \underline{3/}, \underline{4/}, \underline{5/}; \quad f_2 = f_1 + 1000, \; (Hz) \; \underline{3/}:$$

$$f_0 = f_1 + 100, \; (Hz) \; \underline{6/}, \underline{7/}$$

Configuration	Factors		Configuration	Factors	
Aerodynamically clean	A_1	A_2		B_1	B_2
Single store	1	1	Powered missile, aft half	1	4
Side by side stores	1	2	Other stores, aft half	1	2
Behind other store(s)	2	4	All stores, forward half	1	1
Aerodynamically dirty 8/	C_1	C_2		D_1	D_2
Single and side by side	2	4	Field assembled sheet metal		
Behind other store(s)	1	2	fin / tail cone unit	8	16
Other stores	1	1	Powered missile	1	1
	E_1	E_2	Other stores	4	4
Jelly filled firebombs	1/2	1/4			
Other stores	1	1			

M – Mach number.
H – Constant = 5.59 (metric units) ($= 5 \times 10^{-5}$ English units).
C – Constant $= 2.54 \times 10^2$ (metric units) (= 1.0 English units).
q – Flight dynamic pressure (see Table 514.8D-V) – kN/m^2 (lb/ft^2).
ρ – Store weight density (weight/volume) - kg/m^3 (lb/ft^3).
Limit values of ρ to $641 \le \rho \le 2403$ kg/m^3 ($40 \le \rho \le 150$ lb/ft^3).
t – Average thickness of structural (load carrying) skin - m (in).
R – Store characteristic (structural) radius m (in) (Average over store length).
= Store radius for circular cross sections.
= Half or major and minor diameters for elliptical cross section.
= Half or longest inscribed chord for irregular cross sections.

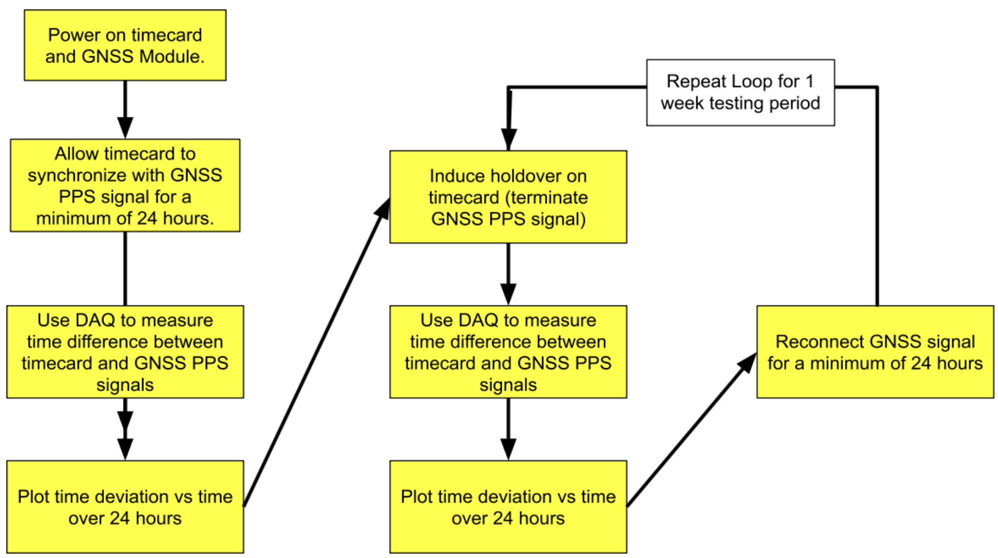
1/ – When store parameters fall outside limits given, consult references.
2/ – Mach number correction (see Annex B).
3/ – Limit f_1 to $100 \le f_1 \le 2000$ Hz
4/ – Free fall stores with tail fins, $f_1 = 125$ Hz
5/ – Limit length ratio to: $0.0010 \le C(t/R^2) \le 0.020$
6/ – $f_o = 500$ Hz for cross sections not circular or elliptical
7/ – If $f_0 \ge 1200$ Hz, then use $f_0 = 2000$ Hz
8/ – Configurations with separated aerodynamic flow within the first ¼ of the store length. Blunt noses, optical flats, sharp corners, and open cavities are some potential sources of separation. Any nose other than smooth, rounded, and gently tapered is suspect. Aerodynamics engineers should make this judgment.

Representative parameter values

Store type	Max q		ρ		f_1	f_2
	kN/m^2	(lb/ft^2)	kg/m^3	(lb/ft^3)	Hz	Hz
Missile, air to ground	76.61	(1600)	1602	(100)	500	1500
Missile, air to air	76.61	(1600)	1602	(100)	500	1500
Instrument pod	86.19	(1800)	801	(50)	500	1500
Dispenser (reusable)	57.46	(1200)	801	(50)	200	1200
Demolition bomb	57.46	(1200)	1922	(120)	125	1100
Fire bomb	57.46	(1200)	641	(40)	100	1100

See [this document] for an explanation of why these figures and the table are used. They will be used to perform a structural analysis to ensure the time card can withstand the vibrations it will experience.

Holdover Accuracy Verification (ER 9):

Subsystem/ Function/ Feature Name:			Holdover Accuracy					
Date of Test:								
Performed By:								
Tested By:								
Concluded Condition of meeting Engineering Specification:								
I. TESTING SPECIFICATION								
Specification Number	Importance	Source	Function	Specification (Metric)	Unit of Measure	Marginal Value	Ideal Value	Comments/Status
S9	1	ITU-T G.8273	Timing	Timekeeping drift *shall* not exceed 30 nanoseconds.	Nanoseconds per Earth day	1	30	
II. EQUIPMENT REQURIED								
Specification Number	Equipment or Instrumentation required							
S9	Oscilloscope, GNSS Module							
III. DATA COLLECTION STRATEGY								
Specification Number	Data acquisition strategy							
S9								

This test allows us to verify the metrics of ER9: “Timekeeping drift shall not excede 30ns per day”. This test is performed by monitoring the time error of the timecard while doing the following: synch the timecard to GPS for a day, cut off gps communications for a day, resync for a day, and repeat as needed (we chose one week total for this test). The metric obtained from this test is the maximum time error of the timecard during any given time of this experiment except for the initial synchronization.

Functionality of Historical Data (precursor to ER 9):

Subsystem/ Function/ Feature Name:	Functionality of Historical Data
Date of Test:	
Performed By:	
Tested By:	
Concluded Condition of meeting Engineering Specification:	

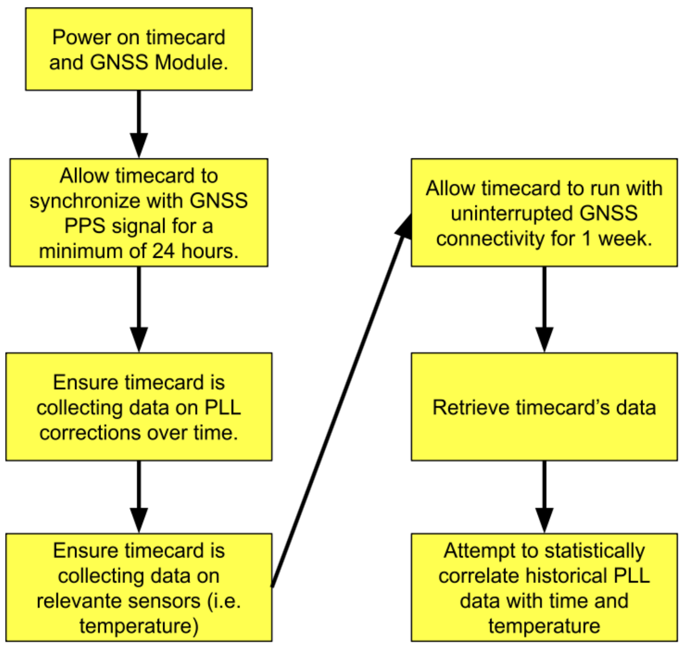
I. TESTING SPECIFICATION

Specification Number	Importance	Source	Function	Specification (Metric)	Unit of Measure	Marginal Value	Ideal Value	Comments/Status
Precursor to S9	3		Timing Corrections		N/A	Yes	Yes	

II. EQUIPMENT REQURIED

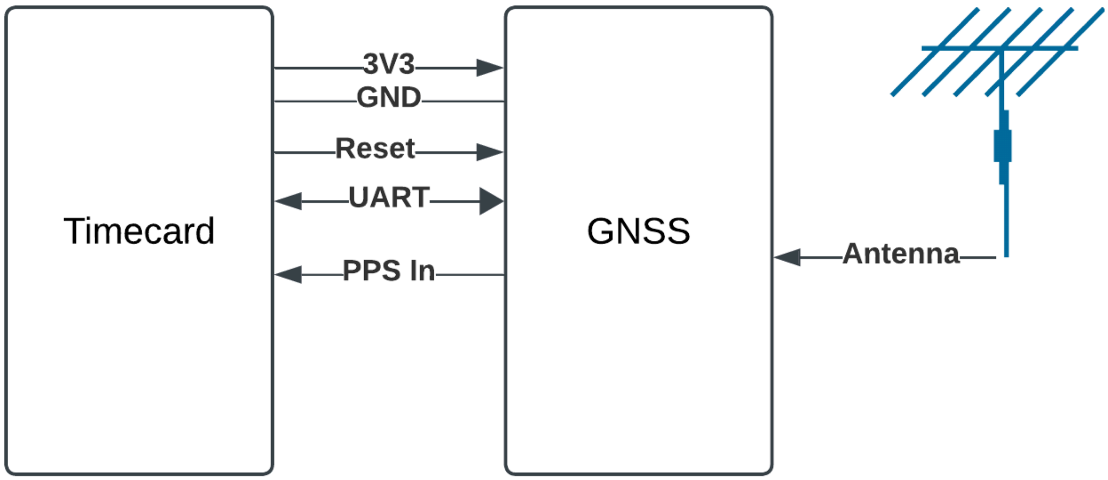
Specification Number	Equipment or Instrumentation required
Precursor to S9	Computer, GNSS Module, temperature DAQ

III. DATA COLLECTION STRATEGY

Specification Number	Data acquisition strategy
S9	

While designing our system, we must be able to statistically correlate frequency errors of the clock to both time and temperature. This test serves as a way to obtain the data to perform this statistical correlation. The timecard runs for a long time (1 week is chosen) while already locked to GPS and constantly in communication with GPS, and data is collected on the frequency adjustments that are needed for this clock over time, along with temperature data.

GNSS and Clock Drift Test:



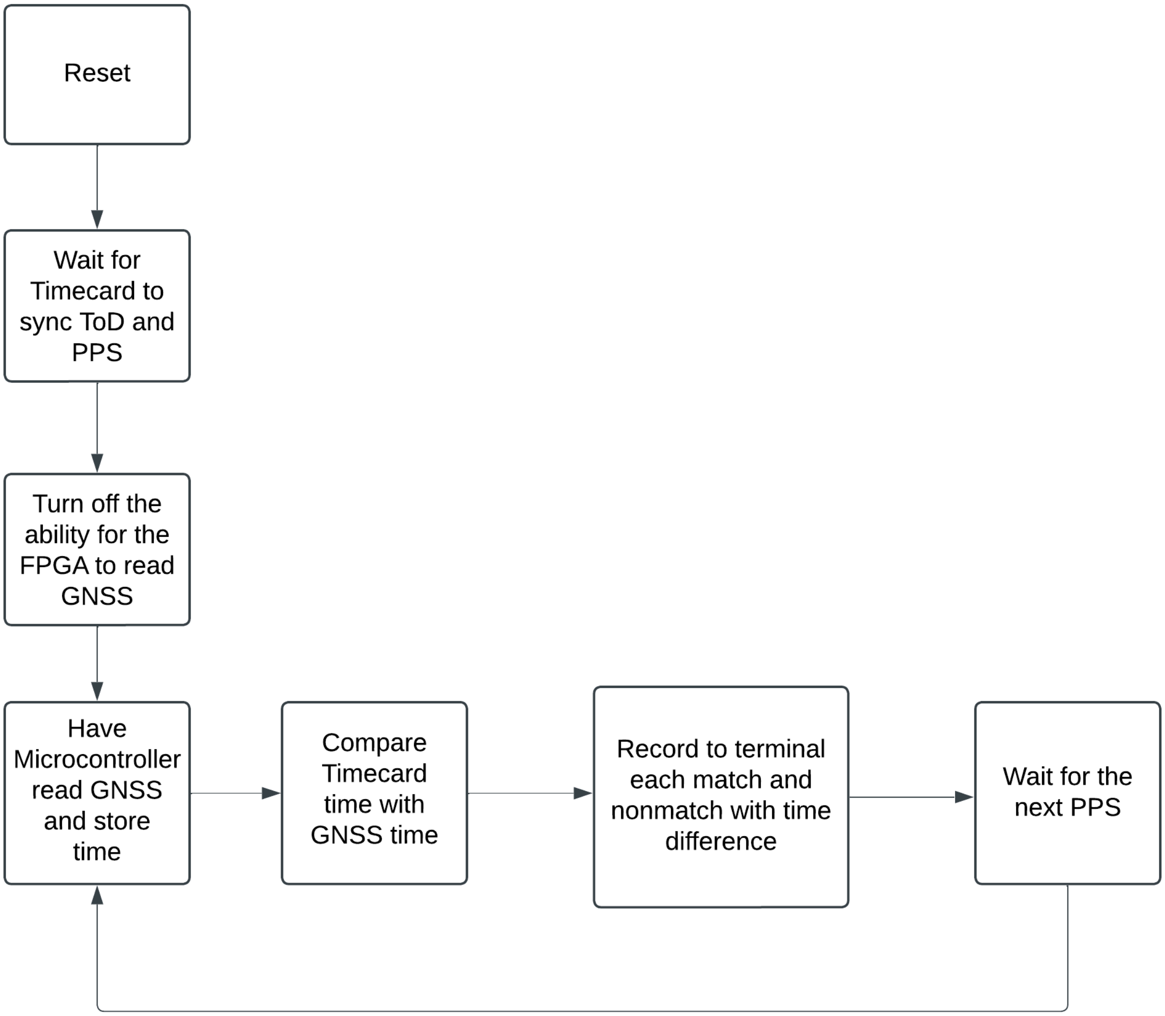
The timecard is designed to interface with a GNSS module using the ToD (Time of Day) Slave IP block from the Open Compute Time Card Project. By integrating a GNSS receiver and antenna, the system can receive signals from Galileo.

A program can be implemented on the microcontroller to read and compare the ToD values from the GNSS module and the timecard. These comparisons can be output to the terminal and logged into an error file for later analysis. This functionality allows for real-time monitoring of synchronization accuracy between the GNSS and the timecard.

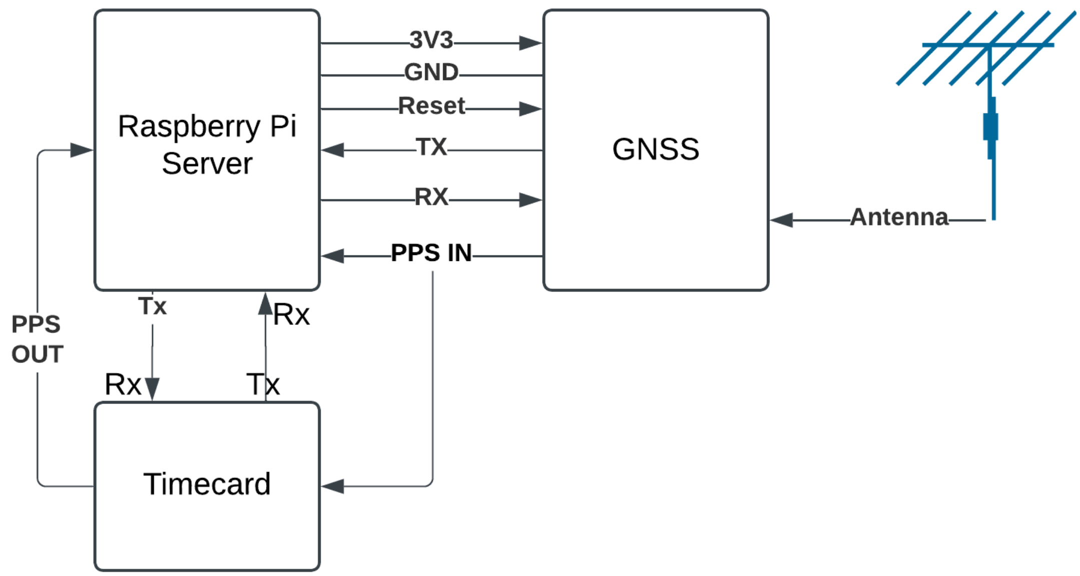
System Details:

- **Power Supply:** The GNSS module is powered directly via the SoC GPIO.
- **Data Communication:** Data from the GNSS is transmitted to the timecard over UART.
- **Signal Configuration:** The ToD Slave block is configured to use the Galileo signal provided by the GNSS.

The program is designed to operate autonomously over extended periods, provided the system remains undisturbed. This capability facilitates testing of the system’s long-term performance, particularly under conditions without an active GNSS connection. Such testing will provide valuable insights into system behavior and stability over time.


Reset
Wait for Timecard to sync ToD and PPS
Turn off the ability for the FPGA to read GNSS
Have Microcontroller read GNSS and store time
Compare Timecard time with GNSS time
Record to terminal each match and nonmatch with time difference
Wait for the next PPS

GNSS Test Plan



Goal of test:

The objective of this test is to have the raspberry pi gather data from the GNSS and relay it back to the timecard. The initial version will be sending the data over UART but will be set up for CAN when the interface is ready.
The GNSS is powered with 3v3 from the Raspberry.
The GNSS sends and receives data from UART.
The GNSS provides a PPS signal that will be taken in as the PPS IN signal. This will be used by the DPLL on the time card to synchronize.
The Raspberry Pi will send a signal to the GNSS telling it what frequency to read off of. In our case if we want to read from Galileo we will use the frequency 1575.42 MHz.
The GNSS will send data to the Raspberry Pi over UART. The GNSS data will be in a NMEA format, parsing for the GPRMC or the Recommended Minimum Navigation Data, and the GPZDA the Time and Day. The data can then either be relayed or processed to a preferred data type to be received by the Timecard.
The data collected from the GNSS is then relayed to the Timecard to set the reference time.

The purpose of this test is to configure a Raspberry Pi to collect data from a GNSS module and relay it to the timecard. In its initial implementation, the data transfer will occur over UART, with provisions for transitioning to CAN once the interface becomes available.

System Overview:

- **Power Supply:** The GNSS module is powered by a 3.3V supply from the Raspberry Pi.
- **Communication:** The GNSS communicates bidirectionally with the Raspberry Pi via UART.

- **PPS Signal:** The GNSS provides a PPS (Pulse Per Second) signal, which serves as the PPS IN signal for the timecard. This is utilized by the DPLL on the timecard for synchronization.
- **Sync Time**: Have a server that can pull the time from Galileo.

Operation Details:

1. **Frequency Selection:**
   The Raspberry Pi sends a command to the GNSS module specifying the desired frequency for operation. For instance, to receive data from the Galileo system, the frequency 1575.42 MHz will be configured.
2. **Data Collection:**
   - The GNSS transmits data to the Raspberry Pi in NMEA format over UART.
   - Relevant NMEA messages include:
     - **GPRMC:** Recommended Minimum Navigation Data.
     - **GPZDA:** Time and Date.
   - The Raspberry Pi parses these messages to extract essential data.
3. **Data Processing and Relay:**
   The extracted data is either relayed as-is or processed into a preferred format before being sent to the timecard. The timecard uses this information to establish the reference time.

Goals:

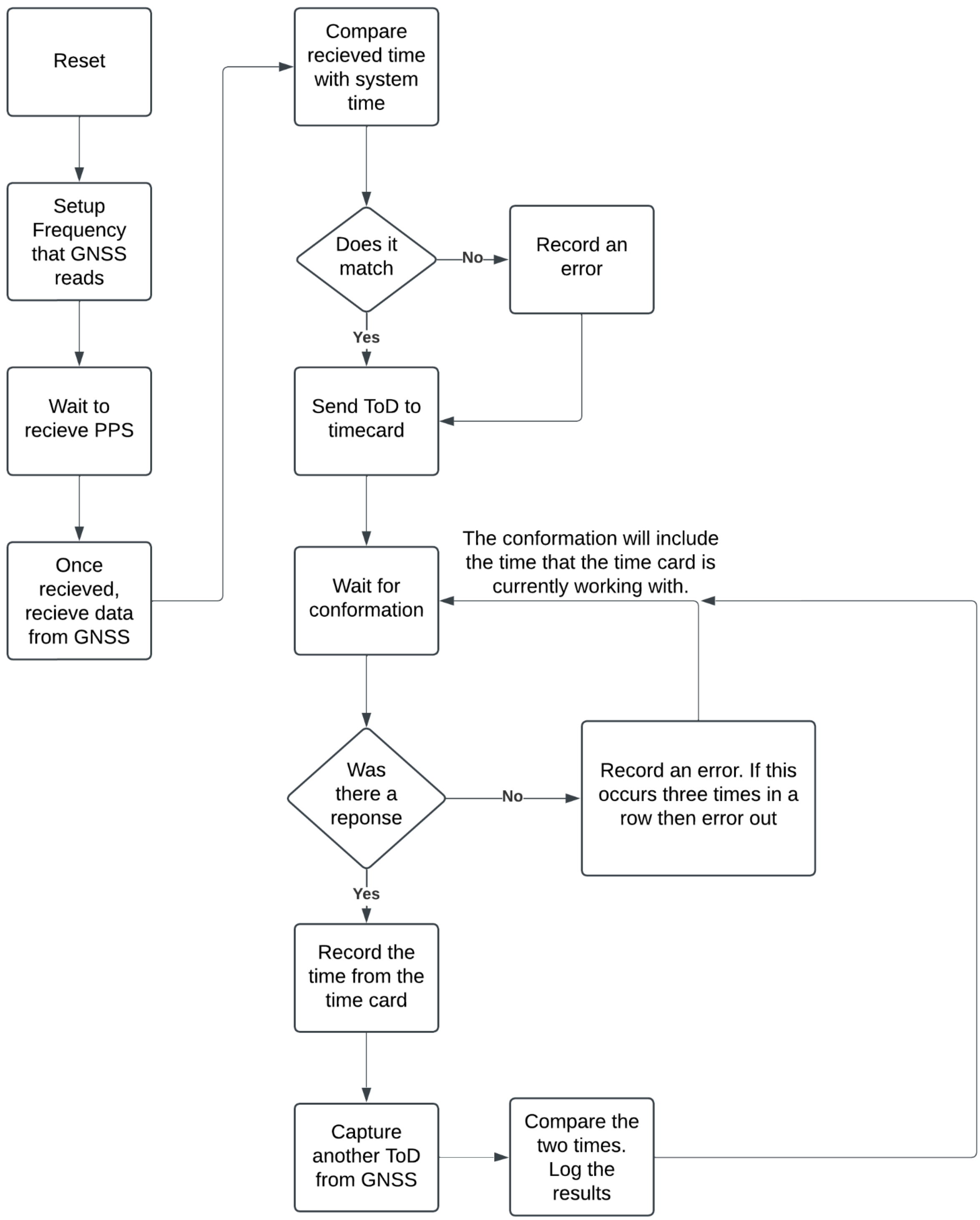
- Successfully gather and relay GNSS data to the timecard.
- Configure the system for seamless transition to CAN communication.
- Ensure accurate synchronization with the PPS signal.

From looking up examples online of people doing similar thing I have found this github repo:
https://github.com/jacobjhansen/RTCM-Pi
I can use this as an example for extracting data from the NMEA messages and relay them to the timecard. Work smarter not harder.
The reason why we are using a raspberry pi as our server is because we could just set up the interface for GNSS with the timecard but IT isn't allowing us all to remote into the computer that we have our Vivado environment setup on. The raspberry pi offers a mobile way of developing a test setup.

Required Materials:

- Raspberry Pi
- Sparkfun GNSS Receiver Breakout Board - Possible Long Lead Item (Already has been ordered)
- GNSS Antenna - Possible Long Lead Item (Already has been ordered)

Outline of Server's Operation:



Goals.

- To create a set of plans that will demonstrate objectively the degree to which the Engineering Requirements will be satisfied by the either component, subsystem, or system tests.

Instructions

1. Complete test plans specifying the data to be collected, instrumentation to be used, testing procedures and personnel who will conduct the tests.
2. Tests to assess accuracy of feasibility models: Make plans and execute these tests throughout the second half of MSD I (these should be nearly complete or complete by the Detailed Design Review)
3. Tests to verify that your final subsystems work: Make plans and execute these tests once you start your final prototyping, prior to system integration
4. Tests to verify that your final system satisfies the ERs your team and client agreed to: Generally, you will execute these tests once you start your final system integration
5. Note that tests to verify that you've met a system constraint or delivered a required feature may be fairly trivial. You don't need a detailed test plan to demonstrate that your prototype budget was <$500 or that your full system weighs less than 20 lb, for example. Discuss with your guide if you're not sure how much detail to include.
6. If your team's testing will involve human subjects, you must review the RIT Human Subjects Research Office "Protecting Human Subjects" page found here: https://www.rit.edu/research/hsro/ for details on securing approval for work with human subjects
7. Look at industry test standards (e.g., ASTM). The RIT library maintains an infoguide with links to standards databases found here: https://infoguides.rit.edu/standards , many of which provide industry-standard test procedures for a variety of components and systems. Cite these if used

Required Artifacts

- Test Plans (use the “Requirements and Testing.xlsx” template), available in EduSourced. Include an updated version of the document in this phase folder, labeled by phase to distinguish it.
- In this document, include a table that summarizes the degree to which ERs are addressed by your test plans.
- If applicable, an Institute Review Board or Institute Biosafety Committee submission (allow **at least** 30 days for this to be reviewed - more time is idea, since the IRB or IBC outcome may be a request for you to modify your proposed test protocol)

System Design and Flowcharts/System Block Diagram

- Update from preliminary detailed design as required
- Expected Performance vs. Requirements based on Detailed Design

Risk Assessment [Drew]

Goals

- To re-evaluate your identified risks or add newly identified risks

Instructions

1. Updated assessment from Preliminary Detailed Design. Have you driven the likelihood and/or severity down as you worked through the details of your design?
2. When a team chooses to take a technical risk in order to potentially create a more valuable outcome to the client, tie your risk management to your project plan: build and test early to allow time for a pivot
3. Teams should regularly update their risk register to identify new issues and close issues that have been addressed: when making major design decisions, when concluding building, testing, or analysis, throughout the project
4. Include *all* risks/harms you have anticipated, even those that you will transfer to the client and not address during the scope of MSD.

Required Artifacts

- Risk register that is updated regularly, available in EduSourced with associated Risk Burndown chart by phase
- Summarize highest priority risks in this document: *what* are they, and *who* is doing *what* to mitigate them?

Open Items

Use this space to call out unresolved items and provide your plans for resolution. Include aspects of your project that are not complete per the phase description.

Project Management [Eva & Tanner]

Update the Task-based Project Management list using Trello. Each card should include:

- Description of Task to be completed by next group meeting by individual team members
- Task Owner identified
- Date Task issued
- At minimum there should be 3 column from L to R:
    - Planned Tasks
    - Tasks in Process
    - Completed Tasks

The Trello board should be linked to this document along with a snapshot
Mid-Phase Sprint/Scrum Review with Guide based on Trello board
Sprint-end Retrospective - Answer the following questions:

- What went well?
- What could be improved?
- What do we commit to improving in the next Sprint?

Capture progress within the phase by showing planned tasks vs in process vs completed tasks. The Trello board should be linked to this document with a snapshot of the board.

- What went well?
    - We continued to make progress with the materials that we have. We ordered our most expensive component - the CSAC SC45.
- What could be improved?
    - Not all team members have defined tasks to work on during each meeting. We also don't stick to the tasks we listed out in our Trello board tasks.
- What do we commit to improving in the next Sprint?
    - We commit to staying more organized with taskings and ensure we know our short term and long term goals.

Link to Trello Board

Design Review Materials [Eva]

Be sure to update the following in your Phase 4 folder:

- Pre-read
- Presentation and/or handouts
- Notes from review, including action Items
- Supporting documentation for your client.

Share this page and relevant supporting documents with your client in preparation for the review. This will ensure that they know what you will be presenting and how to view all your work. Draft work you've been keeping in a Google drive should be copied to this phase folder in EduSourced as a snapshot in time of your progress.

Pre-read: Summary Report and Presentation

- Agenda
    - Discuss progress made in the Detailed Design Phase
- Presenters
    - Eva Czukkermann, Ian Dolfi, Nsadhu Muyinda, Drew Schacke, Luke Schrom, Tanner Smith

Notes from Review with Action Items: Design Review Notes

Supporting Documentation:

Presentation

System Block Diagram

Trello Board

Risk Assessment

Gantt Chart

Requirements and Testing

Bill of Materials

Vibe Figure Explanation

Goals for next phase

As a team, where do you want to be at your next review? Visualize for the customer what the end state for the next phase will be.   What are your goals for the next phase?
This is particularly important as your team prepares to leave for break, and well-thought-out plans will help you hit the ground running at the start of MSD II.

Individual phase plans (what did I plan to do, what did I actually do, what did I learn, what do I plan to do next, and what blockers might I have) are due to myCourses.

Required ArtifactsRequired Artifacts

- Include a list of planned tasks, by team member, for the upcoming phase. *A snapshot of your overall project plan (Gantt chart) should be linked in this document, and must be included in your EduSourced Phase folder*
- Phase-end Retrospective - Answer the following questions:
    - What went well?
    - What could be improved?
    - What do we commit to improving in the next Phase?

Plans to do work during break often fall through. You have a break for a reason – use it!