Problem Definition: Phase-End Summary

Team Vision for Problem Definition Phase

We were able to accomplish the following during Phase 1:

- Identified basic purposes and use-cases for the timecard and it's future possibilities.
- Preemptively researched existing time cards including those from Meta and Safran. We then compared different characteristics of these to get a better understanding of the characteristics our time card should have.
- Obtained basic information, allowing us to brainstorm possible restrictions and requirements.
- Identified basic engineering requirements and standards and how they correspond to the customer requirements.
- Recognized risks and constraints that need to be considered when in the design phase.

Methods

The problem was initially defined by the description given by the customers of this project (Philip Linden and Ashley Kosak). The specifications were benchmarked against two competitor products. The customer provided videos and documents which was reviewed. Additional research was performed on relevant terms and applications. Lastly, specific details were discussed with the customers in a video call meeting which provided a better understanding of the goal of the project and how to accomplish it.

Problem Statement

The current ready-to-use space-qualified precision timekeeping devices available cost hundreds to millions of dollars.

The goal of this project is to design and build a derivative Time Card that meets the form-factor and environmental constraints of a CubeSat that is a low-cost alternative. It must have comparable performance under $10k.

The functional prototype must meet drift requirements with statistically significant confidence and it must be an open source design. Additionally, the size, weight, and power characteristics must be compatible with 12U cubesat or smaller and operational characteristics compliant with NASA LunaNet Standard. The timekeeping drift must be less than 30 nanoseconds per Earth day. The atomic clock must survive deep space conditions for at least 10 years and be widely interoperable with existing spacecraft systems.

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Source: EduSource Information

Team Values & Interactions

Our top five team values are:

- Timely communication: To operate effectively, we need to ensure we are communicating in a timely manner and not ignoring messages. If this is done, we will fall behind and/or other team members will have to pull extra weight, which is not acceptable.
- Honest feedback: Everyone should be comfortable giving and receiving feedback. It is often hard to know where you need to work, so it is important to have someone point out areas of improvement without hard feelings being had.
- Relatively equal contribution: We are working in a team, we need to ensure we are all pulling our weight and not one person is doing all the work. We also need to ensure we are utilizing our strengths.
- 100% effort on all tasks: If we all put in our maximum effort on all tasks, we can produce quality deliverables without having to be stressed.
- Open minded: Everyone has different ideas, we need to ensure we are considering all ideas before we make decisions.

Should conflict arise, we will list the pros and cons of the situation, discuss them, and come to a final solution together.

We will hold team members accountable by providing honest feedback about the issue at hand. We need to ensure we discuss and understand the different points of view.

We communicate via text and Slack outside of class.

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Use Cases

Scenario: Competition across colleges to sync time and measure distance between satellites using an atomic clock.

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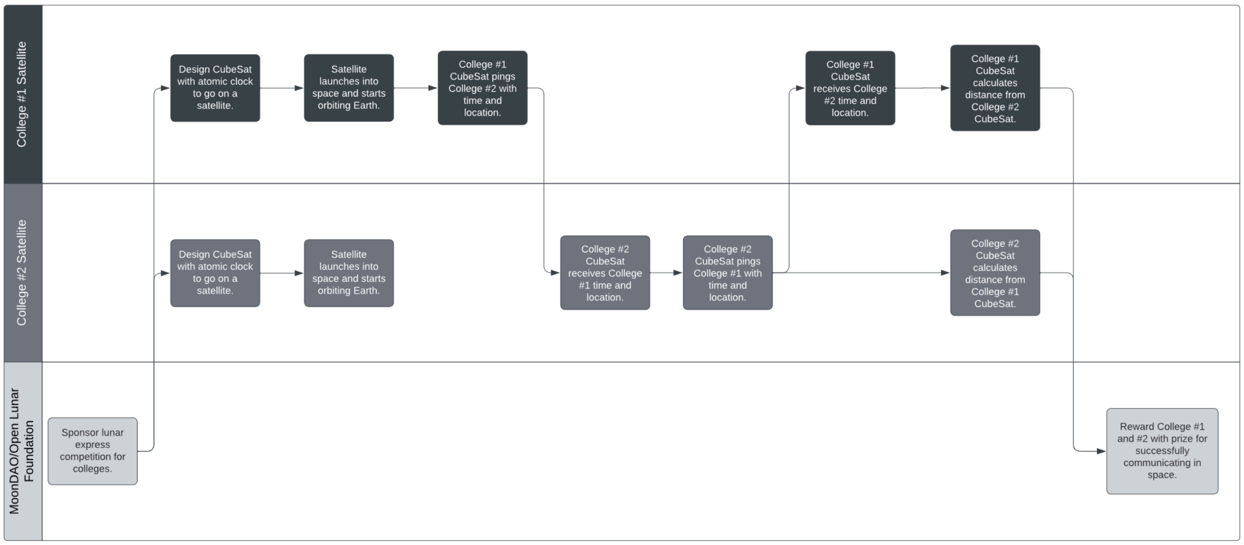
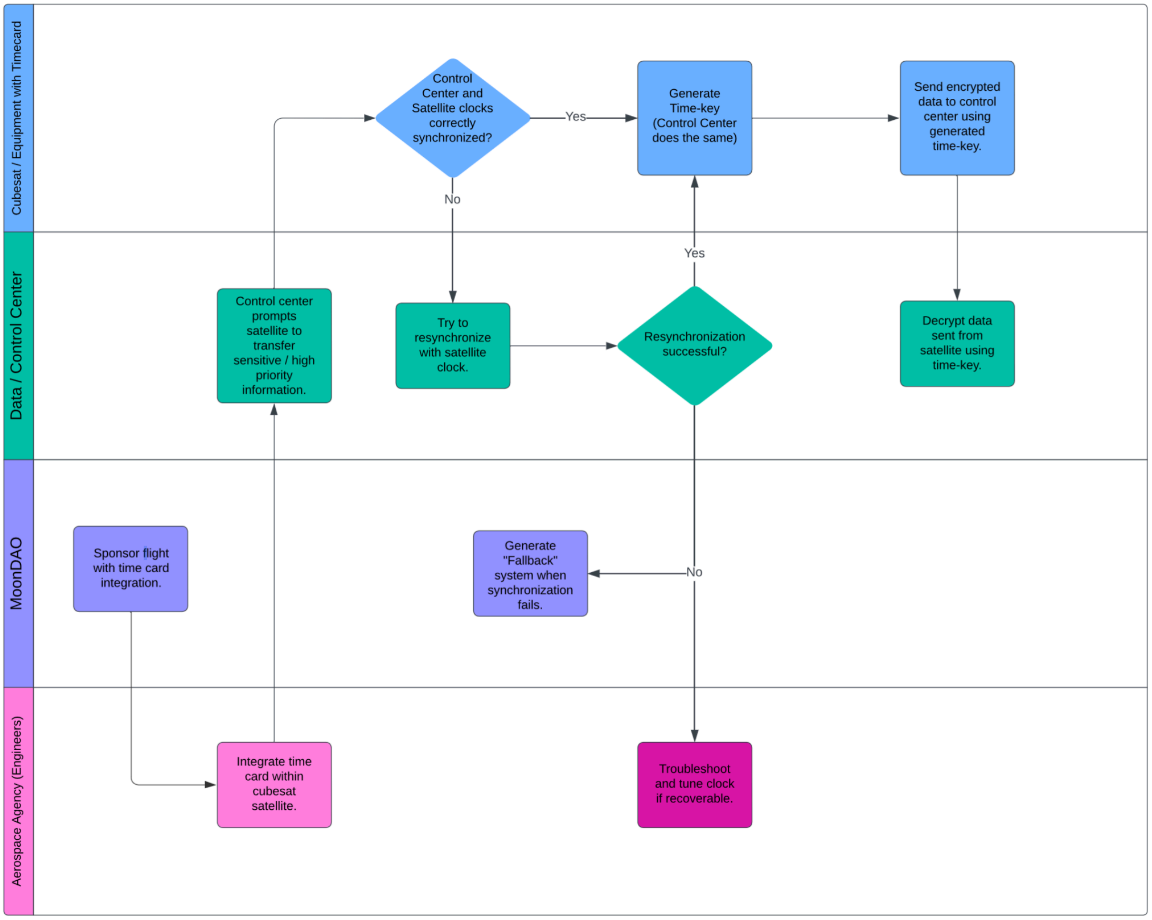


Team: 22257 Space Time Card

<u>Scenario</u>: Atomic clock/time card used for time-based encryption between satellite and ground based communications.



Customer Requirements (Needs)

CR #	Importance	Description
CR1	9	Design and build a functional derivative Time Card containing FPGA (and other processes) as well as other board components.
CR2	3	Compatible with CubeSats and its standards
CR3	3	Operational characteristics are compliant with NASA LunaNet Standard
CR4	1	All components rated to survive deep space conditions (GEO and beyond) for at least 10 years
CR5	1	Widely interoperable with existing spacecraft systems
CR6	1	Minimize size, weight, and power characteristics
CR7	9	Maintains accuracy over time
CR8	3	Communicates with other time networks

For easier viewing, please follow this link.
The customer requirements listed above compile necessary accomplishments further described by the engineering requirements listed below. Importance is ranked from 1-9, 9 being the highest importance. These requirements are mapped to engineering requirements in House of Quality.

Engineering Requirements (Metrics & Specifications)

ER #	Importance	Source	Function	Engr. Requirement (metric)	Unit of Measure	Marginal Value	Ideal Value
S1	3	CR1	Funcional FPGA	Clock frequency for FPGA *shall* be between 10-60 MHz	MHz	5	10-60
S2	3		Processing	Microcontroller/ Processor *shall* support RTOS	N/A	Yes	Yes
S3	1	CR3, CR4	Survives in space according to standards	*Shall* be operable within 0-70C.	degrees C	1	0 - 70
S4	1			*Shall* withstand vibe and shock testing IAW ~~MIL-STD-1540~~ **specify sections/insert doc (waiting for Tiona)**	N/A	Yes	Yes
S5	1			*Shall* withstand SMC-S-016 Figure 6.3.5-1 Minimum random vibration spectrum, unit acceptance test. **need frequency range (waiting for Tiona)**	N/A	Yes	Yes
S6	9	CR2, CR5, CR8	Compatible with existing spacecraft systems	*Shall* meet industry standard communication protocol accoridng to PCIe Base Specification Rev 4 Version .3	N/A	Yes	Yes
S7	3	CR6	Size, Weight and Power Characteristics	*Shall* not exceed 16cm X 8cm X 2cm in outer dimensions.	cm	1	16x8x2
S8	1			*Shall* be 3 kilograms.	Kg	1	3
S9	1			Average power *shall* not exceed 5 Watts.	Watts	1	5
S10	9	CR7	Accurate over time	Timekeeping drift *shall* not exceed 30 nanoseconds.	Nanoseconds per Earth day	1	30
S11	3	CR8	Utilize GNSS communications	*Shall* have minimal error when synchronizing on-board time.	Nanoseconds	15	30
S12	3		Server Communication	*Shall* have minimal error when syncronizing other systems' times.	Nanoseconds	15	30

For easier viewing, please follow this link.
These engineering requirements represent the verifiable characteristics of this system. Importance is ranked from 1-9, 9 being the highest importance. Each engineering requirement is mapped to a customer requirement defined in the last section of this document.

Constraints

- Size, weight, and power characteristics must compatible with 12U CubeSat or smaller.
    - This constraint is measurable and traces back to CR2.
- Timekeeping drift must be less than 30 nanoseconds per earth day.
    - This constraint is measurable and testable and traces back to CR7.
- An FPGA must be included for custom programmable logic synthesis.
    - This constraint is not measurable or testable and can be traced back to CR1.
- An integrated atomic clock must be used for the timekeeping.
    - This constraint is not measurable or testable and can be traced back to CR1 and CR7.
- The project must be completely open-source.
    - This constraint is not measurable or testable and can be traced back to CR1.
- The maximum budget is constrained to $10k with preference placed on keeping costs under $5k.
    - This constrain is not measurable or testable and can be traced back to CR1.

There are no customer requirements that are deemed Out of Scope after discussing with the client.

House of Quality

		ER>>>	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	
CR #	Importance	**Description**	Clock frequency for FPGA shall be between 0.5-1GHz	Microcontroller/ Processor that supports RTOS with flash memory(512KB) and SRAM(128KB)	Operable within 0-70C	Shall withstand vibe and shock testing IAW MIL-STD-1540	Shall withstand SMC-S-016 Figure 6.3.5-1 Minimum random vibration spectrum, unit acceptance test	Shall meet industry standard communication protocol INSERT DOC Has PCIe breakout board that connects to server (Has to meet industry standard communication protocol)	Maximum 16cm X 8cm X 2cm(based on Safran timecard)	Shall be less than 5 kilograms	Max average power	Timekeeping drift	Timekeeping drift	Synch on-board time to within minimal tolerance around UTC	Synch other systems' times to within minimal tolerance around UTC
CR1	9	Design and build a functional derivative Time Card containing FPGA (and other processes) as well as other board components.	x	x											
CR2	9	Compatible with CubeSats and its standards						x	x	x	x	x			
CR3	3	Operational characteristics are compliant with NASA LunaNet Standard			x	x	x								
CR4	1	All components rated to survive deep space conditions (GEO and beyond) for at least 10 years													
CR5	1	Widely interoperable with existing spacecraft systems						x							
CR6	1	Minimize size, weight, and power characteristics							x	x	x	x			
CR7	3	Maintains accuracy over time											x		
CR8	3	Communicates with other time networks												x	x

For easier viewing, please follow this link.
All customer requirements are addressed by an engineering requirement. All engineering requirements and constraints are traceable to customer requirements. This ensures that all constraints and engineering requirements are necessary. From the ER-CR mapping, it can be concluded that the team has captured the essential needs of the customer.

Open Items

As per CubeSat standards, durability of the timecard needs to be further understood with respect to the project and what it entails (durability vs. functionality).

- More research is needed in order to understand alternative devices and how this goal can be verified.

Whether a SOC can be used instead of an FPGA and (or) a microcontroller.

- The advantages and disadvantages of weight, power characteristics, and complexity must be considered for a better option.

GNSS and PCIe break out / dev boards must be

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Design Review Materials

The following was discussed and noted during the design review meeting. Items were corrected according to comments and updated throughout this document.

Meeting Notes:

- Update requirements based on Philip's email and resend/post on EduSourced updated documentation
    - Make sure to send everyone what we updated - specify
- Add other use cases that might impact design
- Need to clean up engineering/customer requirements document
    - All shouldn't be of highest importance
        - Just because it maps to a high customer requirement doesn't mean it needs to be high
    - Need to quantify engineering requirements
    - Need to have a way to verify all requirements
    - Don't list what we're using/what is going to happen - need to state what specifications it will meet
    - Source - which customer requirement?
        - Ensure all customer requirements are covered
        - Don't have extra engineering requirements that don't trace to a CR and aren't needed
    - Constraint limits your options
        - Size, power
        - Kinda gives you the solution already
        - Forces you to throw away possible solutions
        - Can ask why
    - Requirements are attributes customer is looking for you to deliver
    - Engineering requirements will define through numbers what you're going to do it
        - Ex. GNSS receiver is solution not engineering requirements

Linked Documents:

Presentation Slide Deck

Benchmarking

Problem Statement

Risk Management

Requirements and Testing Document

Goals for next phase

Our goals for the next phase include:

- Identify Possible FPGAs, Microcontrollers, CSACs, OCXOs, TCXOs.
  - Possible removal for the need of CSAC?
- Understanding of GNSS receivers and interfacing with previously mentioned atomic clock (Hardware vs software solutions).
- Verify functionality and environmental testing of prototype parts.
- Explore other open source projects. Obtain as a team fundamental operation and basic layout of the card.
- Identify possible hardware and software improvements and implementations (cost, speed, environmental resistance).
- Formal list of planned tasks (per team member) and overall project plan will be updated upon completion.