University of Colorado Department of Aerospace Engineering Sciences
ASEN 4018

Project Definition Document (PDD)

ASTROBI ACOUSTIC SENSOR

I^2CE - Ice Impact Characterization around Enceladus

Approvals

	Name	Affiliation	Approved	Date
Customer	Erik Buehler	ASTROBi		
Course Coordinator	Chris Muldrow	CU/AES		

1.1. Project Customers

ASTROBi
Name: Erik Buehler
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1.2. Team Members

Braden Kopec Braden.Kopec@colorado.edu **Project Manager**	Kate Boykin Kabo6094@colorado.edu **Systems Engineer**
Lila Monprode Limo4659@colorado.edu **Manufacturing Lead**	Ryan Bennett Rybe3618@colorado.edu **Electrical Lead**
Jack Huston Jahu1440@colorado.edu **Software Lead**	Joe Miserlian Jomi4816@colorado.edu **Mechanical Lead**
Skylar Clark Skcl3151@colorado.edu **Thermal Lead**	Ben Esser Bees2022@colorado.edu **Vibration Lead & CFO**
Reid Schneckenburger Resc8797@colorado.edu **Simulation Lead**	

2. Problem or Need

Enceladus, a moon of Saturn, has geothermal activity that causes ice geysers to erupt from its southern pole. Scientists and solar system researchers believe that there may be organic life on Enceladus given the conditions that allow the presence of a liquid water ocean under the icy crust of the moon. ASTROBi is sending a satellite to orbit Enceladus, collect samples, and characterize the composition of the ice geysers. The primary goal of the project is to investigate and design an acoustic sensor to measure the energy and frequency of impact of these ice particles. This sensor will be used to verify that the satellite is flying through the geysers. In tandem with other sensors on the satellite, it will also be used to prove that any material collected is from the geysers and not external phenomena such as outgassing or contamination from Earth. This project is a proof of concept, or feasibility analysis, of this type of system. If successful it will prove that a microphone or similar type of transducer can measure extremely small impact vibrations and count particle density in space.

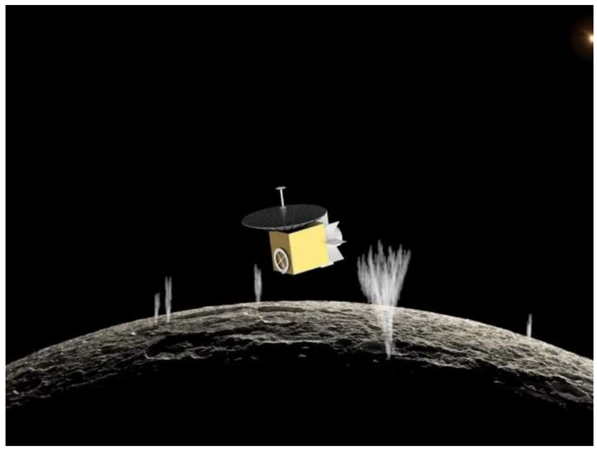

Figure 1: Artist's depiction of a satellite flying through ice geysers

3. Previous Work

This project is not a continuation of a previous project, however it builds upon the infrastructure being provided by the satellite bus, such as power, as the sensor will not need a dedicated EPS subsystem (for the flight model). Furthermore, there has been no work performed by the sponsoring customer, ASTROBi on the acoustic sensor itself, however it will be integrated into the satellite system upon completion of the sensor manufacturing process. There is a RadMet vacuum chamber being used in collaboration with ASTROBi, which will be used in the final testing procedures. Thus, we will be basing our final design on the feedthroughs and connections to the vacuum chamber.

The concept of this project is similar to work done by a previous CU Aerospace Senior Project team during the academic year 2017-2018. Project Dust BUSTER was sponsored by Professor Zoltan Sternovsky and Xu Wang, who requested a sensor to collect and analyze micron-sized dust particles ejected from the surface of a moon or satellite body. The sensor utilized voltage data from the passing particles to characterize mass, velocity, and charge. However, this type of sensor requires that the particles being measured have some existing charge. For project IICE, we will be referencing work used by project Dust BUSTER but will not likely be using their work as the basis for our design and functionalities as there are enough fundamental differences that the designs will not be comparable. The technical knowledge that is contained within the Dust BUSTER documents will aid us as we continue to research, simulate, and manufacture the acoustic sensor needed for project IICE.

The testing methods employed for Dust BUSTER are like those that will be used for project IICE. Dust BUSTER's sensor was tested in a vacuum chamber using a dust dropper to release the dust. The dust then fell through the chamber into the sensor. This has some similarities and some differences to IICE's planned testing method. Project IICE will be housed in a vacuum chamber, but instead of dropping the particles they will be accelerated and shot at the sensor from the side. The testing method for Dust BUSTER can be seen in Figure 2.

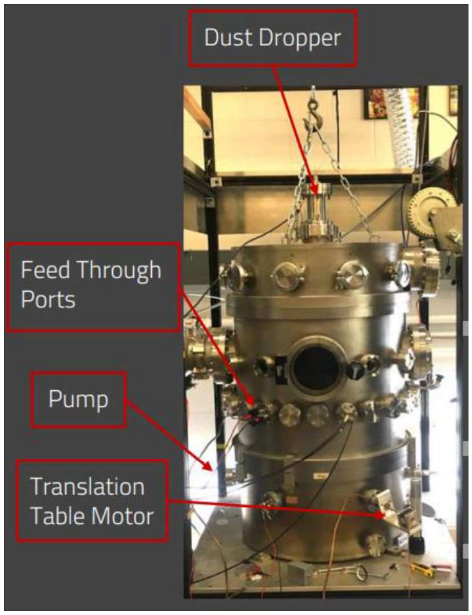

Figure 2: Dust BUSTER's test apparatus

4. Specific Objectives

Level 1 Objective: At minimum, our team will create a sensor that picks up vibrations from ice particle impacts and can characterize the density (number of particles per m^3) of the ice plume at a given time. Our sensor will pick up the energy from impacting ice, convert it into a signal that will be amplified and recorded by a computer. This signal will then be analyzed to determine the acoustic loudness of the impacts throughout the flight, which can be related to the plume density and particle impact frequency.

To create a successful sensor, a simulated model will be created to represent the dynamics of the sensor and assist in the design. Once the sensor is created, it will be tested in a vacuum chamber and have charged particles shot at the surface at the speeds the satellite will expect to impact at. To test the sensor in the vacuum chamber, it needs to fit in the chamber and minimize the noise floor from external vibrations from the vacuum pump, nearby roads, and other phenomena. To prepare for this vacuum chamber testing, the sensor can first be tested by dropping small particles, such as flour, from a low height above the sensor to simulate the low energy impacts it will experience from ice particles around Enceladus.

Level 2 Objective: To achieve a higher level of success, the team will design the sensor to determine secondary characteristics of the incoming particles such as individual particle impact, relative velocity, and mass.

5. High Level Functional Requirements

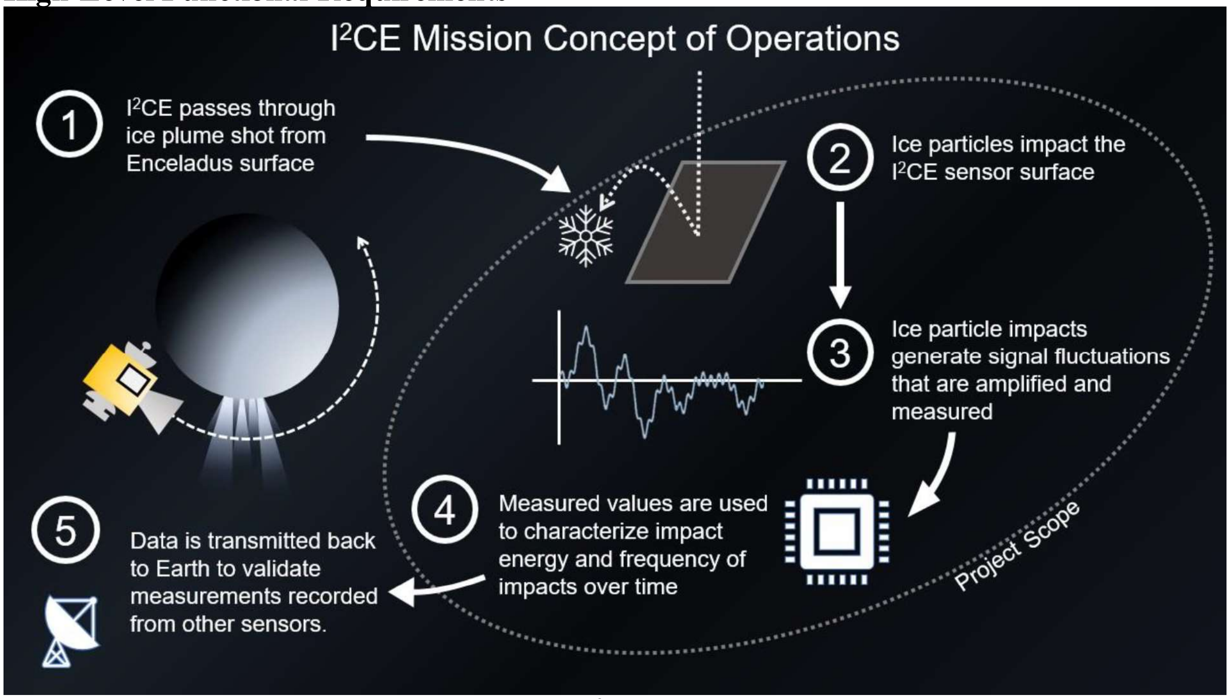

Figure 3: I^{2}CE CONOPS

When referring to "sensor" within the functional requirements below, "sensor" is assumed to be the system as a whole rather than solely the hardware of the sensor transducer itself.
Level 1: Bare minimum
Level 2: Goal Objectives

FR.1 - level 1 level 2	The sensor shall detect magnitude of an incident ice plume over time. The sensor shall relate magnitude to particle size for a given velocity.
FR.2 - level 1	The sensor shall operate in near perfect vacuum conditions.
FR.3 - level 1	The sensor (in vacuum chamber) shall dissipate no more than 1W power.
FR.4 - level 1 level 2	The sensor shall determine the average aggregate impact rate of ice particles. The sensor shall determine individual particle size, mass, and direction.
FR.5 - level 1	The team shall develop a parametric model for predicting the real response of the ice particle impact dynamics on the incident surface.
FR.6 - level 1	The sensor shall fit within the provided vacuum chamber.

6. Critical Project Elements

Critical Element	Constraint Rationale	FR
E1: Vibration Detection	The acoustic sensor must pick up vibrations from extremely low energy impacts and convert them to a signal that can be analyzed.	*FR.1, FR.4, FR.5,*
E2: Noise Mitigation	The particles this sensor will be built to detect are miniscule. The energy that they exert on the sensor plate, even with high velocity, is also miniscule. The sensor will be extremely sensitive, and externally induced noise is going to be very prevalent in our testing environment, so sensor structure and testing environment must reduce external vibrations.	*FR.1, FR.4,*
E3: Vacuum Chamber Testing	Vacuum chamber testing is a high priority deliverable, as such the sensor must operate within chamber constraints.	*FR.2, FR.6*
E4: Simulation	The dynamics simulation must be able to accurately represent the sensor and operating environment to inform hardware design decisions.	*FR.5*

7. Sub-System Breakdown and Interdependencies

This sensor will require software, electrical, mechanical, simulation, vibration mitigation and thermal subsystems.

- **Software:** Local sensor software will be processed by a microprocessor or computer. The processor will receive its data from an ADC connected to the sensor transducer. Once processed, the data will need to be outputted into a human readable format. This will partner with the simulation team in the creation of the sensor model, and manufacturing in the creation of sensor testing.
- **Electrical:** The electrical subsystem is responsible for the transducer, amplifier, ADC, and processor. Electrical will also be responsible for batteries and powering all units, however flight power (out of scope) will be provided with a connection to the main satellite bus. Signals are picked up in the transducer, amplified, converted to digital format, and routed to the processor. Signal processing will be a joint effort between electrical and software.
- **Mechanical:** The mechanical subsystem will be responsible for general hardware design. This includes the sensor plate, the transducer that interfaces with it, and the structure of the sensor that holds all parts together. As a prototype / proof of concept, there will be two housings, one for the hardware that will be inside the vacuum chamber, and the other for the hardware outside of the vacuum chamber. Vibrations from ice impacts on the plate will be read by a transducer, which is converted into a signal that will be sent to the amplifier.
    - **Vibration Mitigation:** Responsible for designing and implementing procedures and hardware to reduce external vibrations to the system, both in vacuum testing and in usage. This will partner heavily with the simulation and mechanical subsystems.
    - **Simulation:** Responsible for the creation of a FEA or similar model to represent the sensor and guide design decisions to be made by the Mechanical team. In specific we will need to know how the sensor will respond to impacts of various sizes and external phenomena. This subsystem will need to work with Vibration Mitigation for error management and modeling.
- **Thermal:** The sensor, transducer, ADC, and amplifier will all be in vacuum, and will need to rely on conduction to a heat sink and a radiator to remove all heat generated. This will interface with the electrical and mechanical subsystems to identify and mitigate points of high energy dissipation.

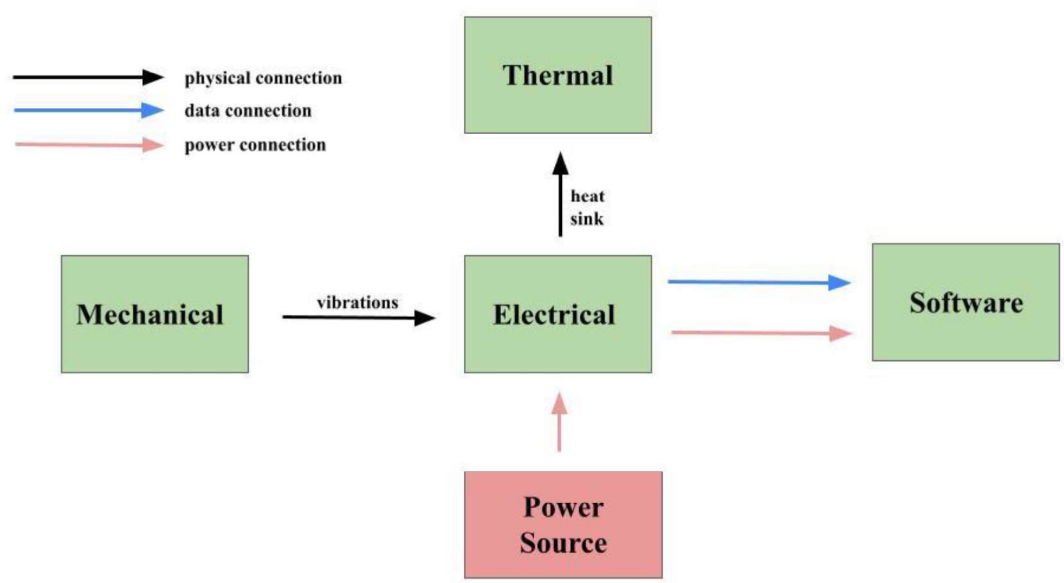

Figure 4: Basic subsystem interface diagram

8. Team Skills and Interests

Team Members	Associated skills/interests	CPEs
Braden Kopec	Skills: Software (MATLAB, C++, C, python), Electrical, Mechanical Design (SolidWorks) Interests: Software, Electrical, Mechanical Design	E1, E2, E3
Kate Boykin	Skills: Manufacturing, high-level system analysis, electrical (soldering) Interests: Manufacturing, electronics, system interdependencies	E1
Lila Monprode	Skills: Manufacturing, Mechanical, Software (MATLAB), soldering Interests: Manufacturing, Mechanical, Thermal	E1, E2
Ryan Bennett	Skills: Software (MATLAB and some C++), CubeSat thermal management, satellite assembly and defect management Interests: Software simulation building, electrical subsystem design, thermal management	E1, E4
Jack Huston	Skills: Software (MATLAB, C++, Python), Mechanical Design (CAD), Electronics (Arduino, Circuits), Propulsion System Dust Mitigation and Filtration Interests: Software, Mechanical Design, Electronics	E1, E2, E3
Joe Miserlian	Skills: Software (MATLAB, C++, Python), Mechanical, Manufacturing Interests: Software, Mechanical, Manufacturing	E1, E2, E3
Skylar Clark	Skills: Software (MATLAB, C, C++, C#, Python), Electrical work with Arduinos, Orbital Simulations (STK, GMAT) Interests: Thermal shielding, simulations, programming	E1, E4
Ben Esser	Skills: Mechanical, Structures, Software (MATLAB), Finance Interests: Vibration mitigation, FEA, and Impact Physics	E1, E2, E3
Reid Schneckenburger	Skills: Software (MATLAB, ANSYS, STK, C++), Electric propulsion testing, Structures Interests: Simulation building, Vibration mechanics, Manufacturing	E4, E2

9. Resources

Describe resources beyond team interest/skills needed to address the critical project elements defined above and identify the source for each. These include specialized equipment, software, facilities, or outside expertise, and any additional financial support needed beyond the $4,000 project funds, along with the source.

Critical Project Elements	Resource/Source
E1: Vibration Detection	Zoltan Sternovsky ASTROBi Plume Sensor FAQ document Dust BUSTER project sponsored by Xu Wang and Zoltan Sternovsky (2017-18)
E2: Noise Mitigation	Francisco Lopez Jimenez Trudy Schwartz
E3: Vacuum Chamber Testing	Testing Facility provided by sponsor (California – more info TBD) ASTROBi Plume Sensor FAQ document RadMet Vacuum Chamber documentation
E4: Simulation	Kurt Maute

10. References

BUSTER, Dust. Dust BUSTER Spring Final Review. 23 Apr. 2018.