The Colorado Space Grant Consortium, The University of Colorado at Boulder Department of Aerospace Engineering Sciences, and the Edge of Space Sciences present

BalloonSat Missions to the Edge of Space

Request for Proposal
#RFP 1400S18

Spring 2018 Announcement

1.0 Overview and Mission Statement

Commented [TS1]: Like the cover page, nice and simple, easy to read and a good graphic

Commented [TS2]: Overall a good proposal. Make sure that you think carefully that your experiment is fair in all aspects. Clear up the ambiguity of the crystal configuration in section 1. Mention more about the LEGO figurines so that somebody who does not know about it can understand what you want to do.
1.1 Mission Statement

The Delta Time (DT) Mission is a high altitude BalloonSat consisting of timekeeping devices to be built by team *Time Stoppers* for the ASEN 1400 course. In all space missions, precise, well timed maneuvers are of the utmost importance. Each procedure must be executed according to a strict schedule. Therefore, accurate timekeeping devices are necessary for all spacecraft. At 30,000 meters above sea level, DT’s mission is to observe the effects of the near space environment on the timekeeping capabilities of crystal oscillators. DT will also examine ways to counteract any time measurement defects throughout the mission, after launch in Windsor, Colorado (1,462 meters above sea level).

1.2 Purpose and Hypothesis

Project DT is attempting to calculate the accuracy of time calculation to better the timekeeping mechanisms for all future spacecraft, both large and small. The DT Project was inspired by atomic clocks’ ability to adjust the frequency at which crystals inside of them oscillate to avoid a loss of time accuracy as temperature changes; however, atomic clocks are expensive, especially for the average group of students. As the space industry grows in the public and private sectors, cutting costs anywhere possible will allow resources to be allocated to other systems, allowing for further spacecraft advancement. If team *Time Stoppers* discovers that insulation for crystal oscillators can serve as an alternative solution to atomic clocks, all spacecraft will benefit in both technical and monetary ways. Project DT aims to explore solutions for efficient time keeping while keeping costs low. Upon further research, Project DT determined that an experiment could be executed to prove that different crystals oscillate at varying frequencies, just as the crystals in some extremely accurate atomic clocks do. Originally, team *Time Stoppers* was planning on measuring time dilation through these crystal’s oscillation frequencies. However, upon further research and calculations\(^1\) regarding how much time dilation would be seen travelling to an altitude to 30km and a minimum external temperature of -80°C no more of a difference than 7,200 picoseconds, or 5 millionths of one second could be seen. Team *Time Stoppers* read multiple papers\(^2\) on this exact effect of temperature on crystal oscillation rates that aided in solidifying the change in mission plan from time dilation to solely crystal oscillation. Because of this minute difference in time, Project DT was altered to only measure the difference in crystal oscillation. The mission will further prove the source of time measurement inaccuracies during space travel at extreme temperatures and altitudes. The BalloonSat will contain two sets of three crystals that vibrate at frequencies of 4MHz, 10MHz, and 12MHz. One set of crystals will be heated and insulated. The other set will be exposed to the outside air in a compartment. Team *Time Stoppers* hypothesize that the 12Hz crystal that is isolated and insulated will return more accurate times compared to the set of control crystals that will be maintained on the ground.

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2.0 Technical Overview

The BalloonSat will be designed to test the effects of the harsh environment of space on crystal oscillators, as well as ways to best mitigate these effects. Each component will be placed in the BalloonSat to effectively balance the weight and for the heater to effectively keep the components warm. The box will be designed such that its rigid structure will keep the internal components secure and to ensure that accurate data will be gathered. Above all else, team Time Stoppers will work safely and improve each other's skills by challenging each other.

2.1 Structure and Design

Team Time Stoppers will assemble an octagonal foam core box with a total internal volume of 30,177.67 cm³. Said octagonal prism will house all sensors and components, including two Arduinos. A small section of the box will be insulated and exposed to the extreme temperatures outside, while the larger main compartment of the BalloonSat will be heated. Included in each Arduino Uno is a 16MHz crystal that serves as the built-in time keeping device. The main, heated section of the BalloonSat will contain the two Arduinos, one of which will be used to record data from both sets of crystals. The exposed section of the structure will house a set of three crystals, that will serve as a comparison to the three crystals in the heated portion of the box as well as the set of three control crystals on the ground. The experiment will revolve around the measurement of oscillation rates of crystals in the near space environment. Passing a low current through the crystals will cause them to oscillate at a specific frequency. The crystal oscillator will distort an electrical field around it once voltage is applied to an electrode on the crystal. After the electric field is removed, the quartz crystal will begin to oscillate at a specific frequency. This frequency will change depending on multiple variables such as temperature of...
environment, and strength of electric field which is produced around the crystal. The crystal oscillation circuit will take this final frequency and produce a measurable electrical pulse. The Arduino will be programmed to calculate a frequency based upon the number of pulses over a set period of time. This calculation shall be performed for each crystal every ten seconds. These frequency calculations will provide a set of data that will show any changes in the oscillation frequency and when those changes occurred during flight. The Time Stoppers will compare the frequencies determined inside the BalloonSat to the frequencies found by GroundOps. Upon proposal granting, team Time Stoppers is requesting extra payload allowance due to the added mass from creating the thermal wall as well as the addition of personal mementos in the box.  

2.2 Software and Command & Data Handling

DT will be collecting and storing data in an SD card connected to an Arduino. The data that team Time Stoppers will be recording is the rate at which crystals of different frequency ratings vibrate when exposed to lower temperatures. The amount of times the three crystals of different frequency ratings oscillate throughout the duration of the flight will be recorded through the Arduino for later retrieval and analysis of time accuracy in the conditions of space.

2.3 Special Features

The unique hardware that the team will need to incorporate into the design include the crystal components from the SparkFun website. The crystals are the bulk of the experiment. There will be three sets of three crystals of frequencies: 4 MHz, 10 MHz, and 12 MHz. One set will be inside the heated section of the BalloonSat for the onboard heated test. Another other set (inside the BalloonSat) will be in the unheated section of the structure, which will be exposed to space conditions. The final set will remain on the ground as a control. The mission requires a third Arduino Uno that will keep track of the time and record data using the three ground crystals. There will be nine crystals total.

2.4 Functional Block Diagram

The following Functional Block Diagram outlines each of the five DT sub-systems and their inner workings. Sensors and cameras are shown in a lavender, while the Arduino Unos and Secure Digital (SD) cards are red. The special feature crystals are shown in green, LEDs to indicate power are yellow, and power supplies are shown in blue. Lastly, the heating element is shown in an orange color. While not in the exact arrangement to be used on the BalloonSat, this diagram aims to ease understanding of the sub-systems interactions with one another to accomplish the overall mission goal.

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2.5 Testing

During the flight, the BalloonSat will experience a variety of forces that could damage the vessel as well as varying extreme temperatures during ascension and descent. To ensure the integrity of the BalloonSat as well as its contents, a variety of tests must be performed to prove resilience and reliability of the structure, taking careful note of each tests’ effects on the structure and the contents of the vessel, and improve upon any failures that may be discovered by March 23, 2018.

2.5.1 Whip Test

The whip test will be a clear and reliable method for analyzing the integrity of the BalloonSat under high g-forces. Following the balloon burst during the flight, the BalloonSat will experience high-acceleration as it plummets towards the earth, where any sudden movement will generate extreme forces on the structure, and if unchecked the integrity of Mission DT would be compromised. The whip test consists of tying the BalloonSat to a rope and spinning it at high speeds, and due to centripetal force, the BalloonSat will experience high g-forces. This
test will be conducted in a secluded area to prevent damage to the BalloonSat and its surroundings.

2.5.2 Drop Test

During the final phase of the BalloonSat descent, the vessel will reach the ground at approximately 50 km per hour, with the assumption of a proper parachute deployment. To ensure the integrity of the vessel as well as the success of mission DT, team Time Stoppers must create a structure that must be able to survive this violent and sudden stop without significant damage to vessel or its components. To ensure success, drop tests will occur multiple times each from varying heights to prove the durability of the payload. Said drop tests will take place off of the Integrated Teaching and Learning Laboratory bridge to reach as close to 50 km per hour as possible. Should any design flaws be revealed, team Time Stoppers will identify and rectify these issues by the set team deadline.

2.5.3 Stair Test

Though the Drop Test will display the survivability of the BalloonSat at high impact, the structure will experience continuous and random forces throughout the flight such as air currents, and being drug post landing. The stair test aims to ensure that the vessel will be capable of withstanding these chaotic movements. By releasing the BalloonSat down a flight of stairs, team Time Stoppers will simulate the blows that the structure could endure during flight and landing in order to discover any weak points in the structure or design that need to be strengthened.

2.5.4 Freeze Test

During the Freeze Test, the BalloonSat will be fully assembled and sealed as if it were to be launched. the BalloonSat system will then be placed inside a cooler with dry-ice for four hours. During this time, DT will measure the internal temperature and humidity of the BalloonSat to ensure that all systems will be working during the entire launch period. Should any sensors or electronics fail during the course of the four hour trial, DT will redesign the the BalloonSat container to incorporate better sealing and heat regulation.

2.5.5 Camera Test

Team Time Stoppers will make sure the GoPro is capable of working in near space conditions, including extremely low temperatures and humidity accumulation. By including the GoPro in the dry ice test the team will be assured that the GoPro is fit to capture footage throughout the duration of the flight. The team will also confirm that the GoPro specific SD Card is emptied and properly re-installed prior to flight.

2.5.6 Sensor Test

DT will test all sensors individually prior to placement inside the BalloonSat to ensure that every sensor is working properly and without errors. Each sensor test will vary based on the purpose of each specific sensor. Sensors to be tested include: Accelerometer, Humidity Sensor, Pressure Sensor, and Internal and External Temperature Sensors. All sensors will be set to default settings to measure the differences between ground and air. The crystal oscillators will need to be tested with an oscilloscope to determine the baseline frequency at which the crystals will oscillate at.

2.6 Safety
In order to ensure the safety of all members, team *Time Stoppers* will adhere to basic guidelines while building and testing the BalloonSat. When using tools or soldering there will always be at least two team members present. The first will operate the tools while the second monitors and guards against any possible injury. During our Whip Test, Drop Test, and Stair Test, all non-essential members of the team shall retreat to a safe distance while observing. All team members that will be handling dry ice during the Freeze Test will be required to wear gloves to prevent ice burns.

### 2.7 Data Retrieval

Team *Time Stoppers* will have a total of four Secure Digital (SD) cards, each recording a different set of data. One 2 gigabyte SD card recording the oscillation of the 4MHz, 10MHz, and 12MHz control crystals on the ground. This data will also serve as the team’s control variable. The other three SD cards will be placed on the payload including: one 32 Gb SD card recording GoPro footage, one 2 gigabyte SD card recording data from the all aforementioned sensors including the oscillation of another set of three crystals, 4MHz, 10MHz, and 12MHz that will be placed near the heating system within the payload. The final 2 gigabyte SD card will be recording the oscillation of a third set of crystals with the same frequencies of which the temperature will not be controlled. Once this data is collected team *Time Stoppers* will analyze said data using various programs such as MATLAB and Excel to ultimately determine the rate of change of oscillation due to in flight temperature changes.

### 3.0 Management and Cost Overview

#### 3.1 Project Schedule

<table>
<thead>
<tr>
<th>Date</th>
<th>Completed Task</th>
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</thead>
<tbody>
<tr>
<td>10 February 2018</td>
<td>RFP completed for final review</td>
</tr>
<tr>
<td>11 February 2018</td>
<td>RFP submitted</td>
</tr>
<tr>
<td>15 February 2018</td>
<td>All additional parts ordered</td>
</tr>
<tr>
<td>28 February 2018</td>
<td>All parts and supplies acquired</td>
</tr>
<tr>
<td>6 March 2018</td>
<td>Preliminary Design Review (PDR)</td>
</tr>
<tr>
<td>8 March 2018</td>
<td>Individual subsystem testing complete</td>
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<tr>
<td>15 March 2018</td>
<td>Box and all subsystems assembled</td>
</tr>
<tr>
<td>16 March 2018</td>
<td>Full product testing begins</td>
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<tr>
<td>23 March 2018</td>
<td>All testing complete and identified malfunctions addressed</td>
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<tr>
<td>26 - 30 March 2018</td>
<td>Spring Break</td>
</tr>
<tr>
<td>3 April 2018</td>
<td>Launch Readiness Review (LRR)</td>
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3.2 Weekly Schedule

Team **Time Stoppers** will meet from 3:00pm - 5:00pm on Wednesday and Friday. Meeting times have also been arranged for 3:00pm - 6:00pm on Thursdays in addition to times on the weekends as needed. Each team member has agreed to block off two hours each weekend as a minimum. The DT Mission is aiming to spread all work out throughout the semester to meet the aforementioned deadlines as well as minimize stress.

### 3.3 Team Member Profiles

**Addison Woodard - Team Lead** | Freshman pursuing a degree in Aerospace Engineering | Strength: Leadership | Weakness: AutoCAD

**Hannah Owens - Team Liaison** | Freshman pursuing a degree in Aerospace Engineering | Strength: Programming | Weakness: AutoCAD

**Thomas Anderson - Design Lead** | Freshman pursuing a degree in Aerospace Engineering | Strength: AutoCad | Weakness: Manufacturing

**Ajayveer Dhindsa - Programming Lead** | Freshman pursuing a degree in Aerospace Engineering | Strength: Programming | Weakness: AutoCAD

**Michael McCuen - Materials Lead** | Freshman pursuing a degree in Aerospace Engineering | Strength: AutoCAD | Weakness: Manufacturing

**Tristan Steinman - Budget Head** | Sophomore pursuing a degree in Civil Engineering | Strength: Manufacturing | Weakness: AutoCAD

**John Hugo - Videographer/Photographer** | Freshman pursuing a degree in Aerospace Engineering | Strength: Programming | Weakness: Manufacturing
3.4 Team Roles Based on Strengths and Weaknesses

**Programming**
Lead: Ajayveer Dhindsa
Lead: John Hugo
*Entire team expected to gain extensive programming experience

**Manufacturing**
Lead: Tristan Steinman
Lead: Hannah Owens
Michael McCuen
John Hugo
Thomas Anderson

**AutoCAD**
Lead: Thomas Anderson
Lead: Michael McCuen
Addison Woodward
Hannah Owens
Ajayveer Dhindsa
Tristan Steinman

**Testing - Sensors**
Lead: Hannah Owens
Tristan Steinman
Ajayveer Dhindsa
John Hugo

**Testing - Box Integrity**
Lead: Michael McCuen
Thomas Anderson
Addison Woodward

**Media and Graphic Design**
Lead: John Hugo
Laser cutting and box details

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### 3.5 Itemized Budget for Mission DT

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<th>Item</th>
<th>Quantity</th>
<th>Weight</th>
<th>Unit Cost (USD)</th>
<th>Source</th>
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<td>70g</td>
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<td>GoPro Session 4</td>
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<td>Arduino Uno + Shield</td>
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<td>30g</td>
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<td>Heating System</td>
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<th><strong>Weight</strong></th>
<th><strong>Cost Per Unit</strong></th>
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