EML 4552C: Senior Design

Team 18: CanSat Competition

Design for Manufacturing-Reliability-Cost

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Prototype design and components to be manufactured:

When deciding upon the various manufacturing methods for use in the CanSat, a few guidelines helped narrow the possibilities. Competition rules mandated that a mass of no more than 700 grams was used and no more than $1000 be spent, meaning that the use of most metals would not allow the weight to be kept at a minimum and that expensive materials may also be out of the question. Also, since we are using electronics that must communicate wirelessly, metals again were taken off the available resources list. This showed that a main use of plastics, due to their light weight, inexpensiveness, and relatively easy to manipulate, would be the best decision. The used designs were mostly based off of parts that would be easily acquirable and that needed the least amount of modification while a small number of parts would need to be custom made.

Dealing with plastics, it was clear that the best way to manufacture a detailed prototype would be to 3-D print it. It is a somewhat expensive means of acquiring a part, but for a one off, it is the right decision. Other parts that needed to be created or modified were the Aero-Braking arms, structural supports, and the payload envelope. The arms and supports are wooden and needed to be slightly modified from a rod stock. Using wood, minimal weight would be able to be achieved while simultaneously keeping the strength necessary to hold up to applied forces. These modified parts would be done in house using simple machine shop tools.

Other parts necessary were acquired by purchasing existing items. McMaster Carr was the main supplier of parts due to their relatively low cost, range of selection, and timely delivery. Parts acquired through the company include the container, payload envelope, wooden rod stock, torsion springs, adhesive and the aero-braking material, Tyvek. During prototyping, multiple materials were purchased in order to choose the perfect one for the application. Tyvek was chosen versus Nylon due to its major advantage in weight, ease of implementation and replacement, and abundant amount of material for the same price of Nylon. The Tyvek is also strong and tear resistant, but also by layering it will become even stronger.

Needed Product Specifications:

The CanSat must weigh 700g with a tolerance of 10g.

The CanSat must fit within the rocket's payload section that is 130mm in diameter and 250mm in length.

The CanSat must not have any sharp edges protruding beyond the container.

The container must not free fall.

The CanSat must fall at 20m/s with a tolerance of 1m/s when falling from 670m to 400m.

The payload must separate from the container at 400m.

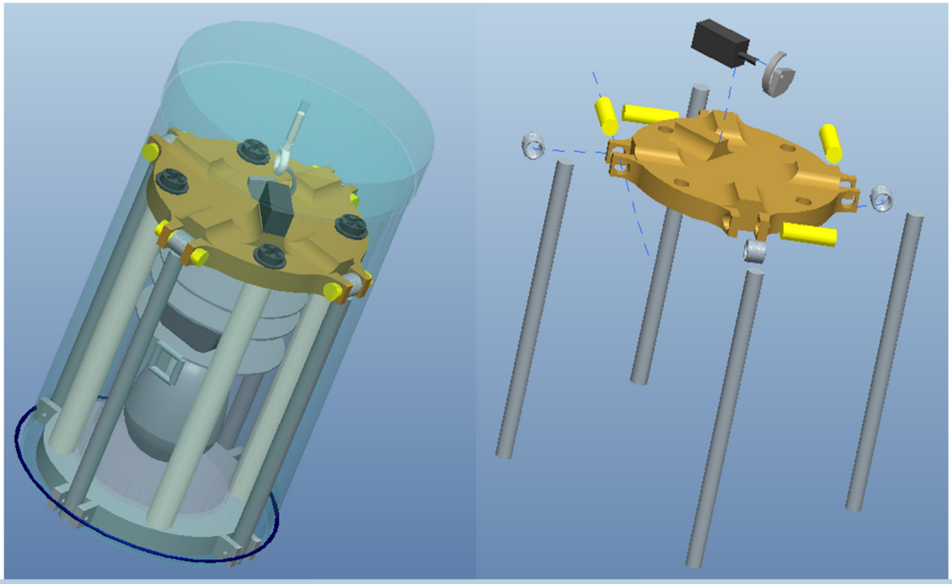
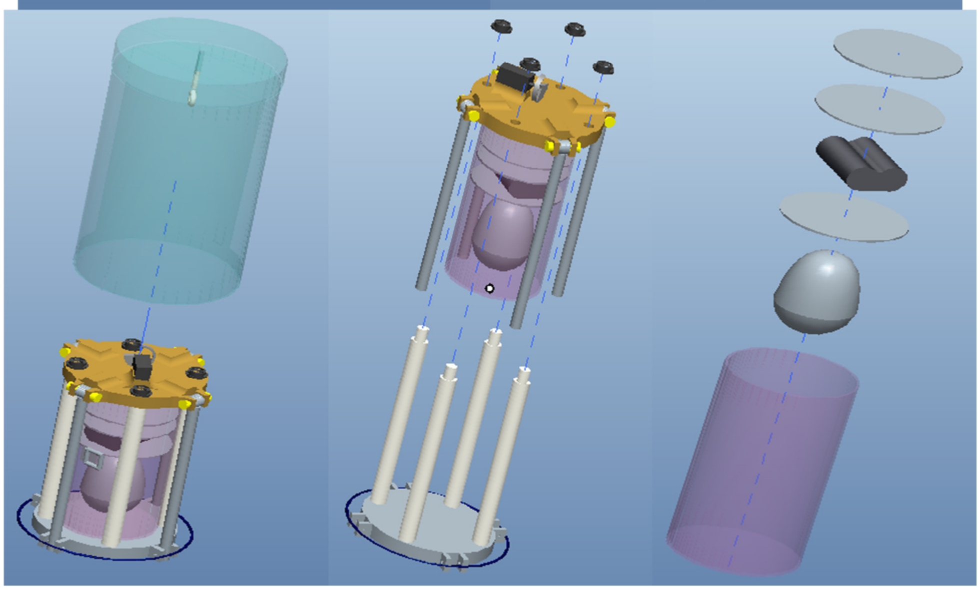
The payload must use an aero braking structure to limit its velocity to below 20m/s, it cannot be a parachute or streamer.

The payload will house the electronics and must protect a raw egg placed inside.

All components of the CanSat must be capable of surviving a 30 g shock.

The CanSat must be bright orange.

Upon receiving all the components and starting the prototype build, some parts need to again be modified in order to properly fit together with one another. This includes reaming out the structure support holes in the aero top and bottom pieces in order to get proper fitment. Also, the torsion springs do not have a consistent center hole diameter. So the part that needed to be made to go through, may have to be sanded in order to get the correct performance characteristics from the springs. Some other parts may need the same form of modification during assembly, but will be addressed when minor testing can be done.

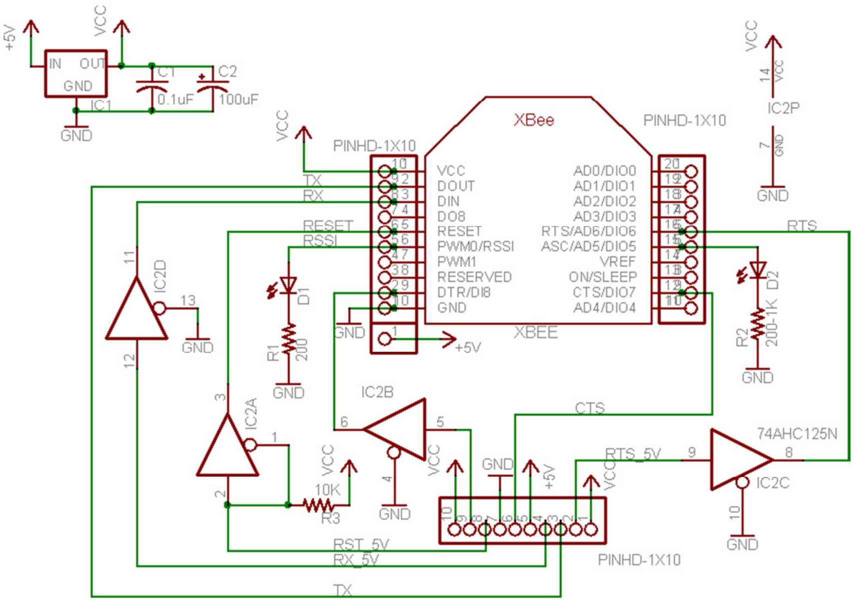



An “out-sourcing” approach was used for all circuitry except for the battery holder and the wire bundles that serve as interconnects to each component platform. The manufacturing process selected for these components was to purchase separate “pre-fabricated” printed circuit boards (PCBs) for each sensor. Each of these PCBs has the circuitry routed from the pins of the sensor to each supporting electronic component and then through-hole solder pads located at the edge of each sensor PCB

The Sensor Subsystem consists of a GPS module, a Pressure/Temperature sensor, Accelerometer, and Voltmeter. Each sensor has been placed on a printed circuit board (PCB) with the proper circuitry routed and supporting electronic components placed by a third party manufacturer. In order for the circuits to fit the relatively small special constraints all electronic components of the Sensory Subsystem are surface mount devices (SMDs). The schematic for the devices is shown.

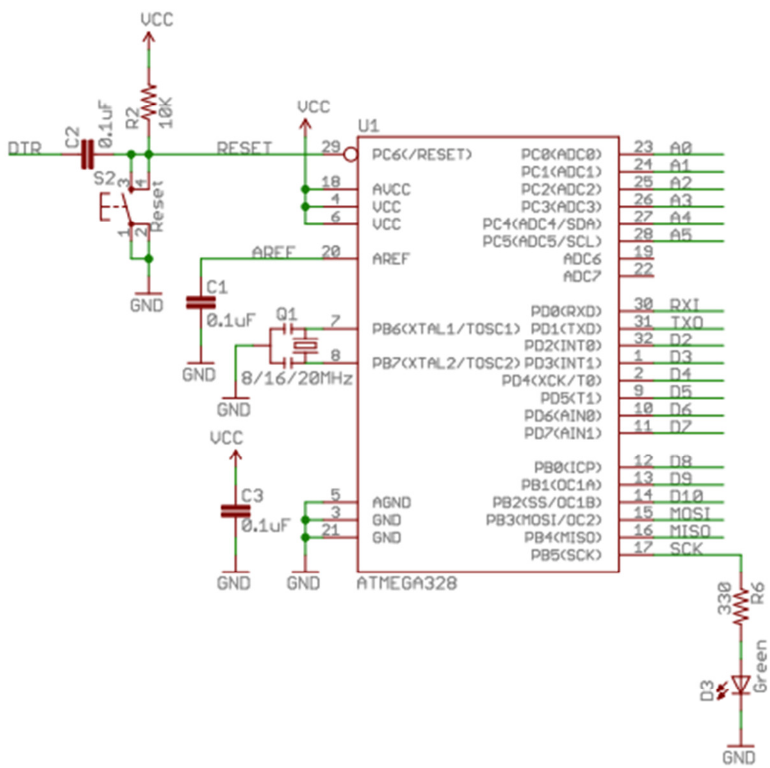
The XBee Pro Series 1 transceiver module handles the RF Communications. The module is procured as a prefabricated device on a PCB. The XBee must have support circuitry in order to operate properly and to interface with the microcontroller. The support circuitry is shown in the following:

schematic.



The Xbee is then wired to the microcontroller via the Rx and Tx pins of the adapter.

The microcontroller is the Arduino Pro Mini, 16 MHz Atmel 328 (“The ProMini”) and was ordered from Sparkfun Electronics. The Pro Mini is an 18x33 [mm] prefabricated PCB with SMDs and circuit routing to through-hole solder pads. It is based on the Atmel Atmega 328. The schematic for the Ardiuno Pro Mini is shown.



In brief, the wiring of the Sensory subsystem to the Pro Mini is as follows. The column on the left indicates the pin reference of the sensor and the column on the right is the pin reference on the microcontroller

XBEE (Adapter) Reference	Arduino Pro Mini Reference (Pin #)
Rx	TXO (31)
Tx	RXI (30)
Vin	Vcc (4)
Gnd	GND (3)

GPS Module Reference	Arduino Pro Mini Reference (Pin #)
Rx	D2 (32)
Tx	D3 (33)
Vin	Vcc (4)
Gnd	GND (3)

BMP-085 Reference	Arduino Pro Mini Reference (Pin #)
SCL	A5 (28)
SDA	A4 (27)
Vin	Vcc (4)
Gnd	GND (3)

ADXL 326 Reference	Arduino Pro Mini Reference (Pin #)
X	A0 (23)
Y	A1 (24)
Z	A2 (25)
Gnd	GND (3)
Vin	Vcc (4)

The battery supply voltage is connected through a SPST switch to the raw input of the Pro Mini (Pin 2). The ground of the electrical power system is connected to all common ground through the microcontroller ground (Pin3).

Design for Reliability:

Base on failure mode and effect analysis the four main points of mechanical failure can occur at the parachute, separation mechanism, aero-brake , and sensor protection. Based on FMEA standards, the severity of failure can be rated between 1-6, with 1 having "No relevant effect on reliability or safety" and 6 having "catastrophic (product becomes inoperative) failure". The main mission of the cansat is to safely deliver a payload from an aerial vehicle. A trade off to ensuring that the payload is intact is that the structure of the cansat can only be used for one descent without replace of structural support components. To ensure reliable performance of the cansat, special attention has been given to the deployment mechanisms. By ensuring proper performance during the descent, structural damage to the cansat will be limited resulting in reuse of the certain components of the cansat if desired. Furthermore the mounting locations of the electronic components were chosen to add extra protection from impact of the landing.

During the first phase of descent, the parachute will be connected to the payload via a swivel connector. This connector will prevent the parachute chords from tangling from any cross-winds. A severity rating of 5 is given to the parachute based on the fact that it's failure could affect the performance of the separation mechanism and cause the cansat to free fall to the ground. The separation mechanism was also selected for repeatable performance. If the separation fails but the parachute works, minimal damage will be done because the parachute will significantly decrease the descent velocity. The motor was selected based on the torque required to overcome the mass requirement of 700g of the cansat. We achieved a higher factor of safety for the separation ring by using aluminum as the material of choice for its superior mechanical properties compared to a plastic alternative comparable size. The severity of the motor failing is relatively low.

Phase two braking mechanism incorporates torsion springs to force the aero structure to deploy. The torsion springs need to be strong enough to quickly bring the aero brake rods to the ideal level to achieve the desired amount of drag to bring the cansat to the required descent velocity. By using larger torsion springs achieve the quick deployment time for a reliable aero braking structure. If it fails to deploy, the damage will be irreparable.

The mission to protect the sensor or the egg is dependent on the placement of the polystyrene beads. The detection of any irregular placement of the beads can be caught prior to operation and thus has a low chance of failure.

Electronic components can be tested for reliability and repeatability of results. Further testing can be done to determine potential failure modes and long term survivability.

Design for Economics:

One of the best ways to make a cost effective prototype is to use items that already exist rather than make every piece individually. For this reason, rather than making the payload envelope and container from a mold or cutting it out using a CNC mill, already made plastic jars that are approximately the correct size were modified. The jars are very inexpensive and require few tools to modify, $4 to $10. Since the product does not need to be extremely strong, wood or plastic rods can be used as the structural supports. These rod are very inexpensive, strong, are easy to work with and do not damage the tools as much as metal. Also, metals could interfere with the radio signals of the CanSat. Even though it is not as inexpensive as using mill to make the parts, it is very time effective to have some parts like, the aero-braking top and bottom, rapid prototyped with 3D printing. This allowed us to make these pieces without the chance for human error in making the product and reduce the necessary production time. The cost of this can be fairly high though depending on the material, about $1 to $20 per cm^3. A high quality parachute was purchased for around $5. The egg protection is very inexpensive, only around $10 for 100 liters. The polystyrene beads can be difficult to work with however because they can be spilt. The final product will use saran wrap to try to prevent this occurrence. The fabric for the aero-braking structure will be tyvec fabric, it is tear resistant, easy to work with and very inexpensive, $ 6.07 per m^2. Assembly should be fairly simple, most of the parts are glued together and a few pieces are screwed on.

Electronic components were selected such that the overall cost of procurement and implementation were kept to a minimum. Also, a key factor in each electronic component selection was the availability and ease of procurement. To maintain this low cost and ease of availability, the components were acquired from reputable sources such as Adafruit™ Industries, Sparkfun™ Electronics, and Digikey™ Corporation. This allowed us to avoid the cost of designing and printing a custom circuit board. The total cost of the electronics, communications and electrical system is under $250. However, this does not include some of the accessories used to program and interface with the electronics. Other tools like breadboards, soldering iron, wire stripper, pliers and screw-drivers are necessary to put together the prototype and fabricate the final design. The software was designed from freely available software platforms (Tcl, Python, Arduino) and runs in open source programs so no software had to be purchased. The only input costs for the software is the laptop computer used to implement the programming.

Electronic Component Cost			
Component	Quantity	Unit Price	Total Cost
Xbee Series 1 Pro	2	$32.00	$64
Antennae	2	$5.16	$10.32
BMP085 Barometric Pressure Sensor	1	$20.00	$20
ADXL345 Accelerometer	1	$20.00	$20
Adafruit Ultimate GPS	1	$40.00	$40
Arduino Pro Mini	1	$10.00	$10
Battery	1	$12.00	$12
Motor	1	$16.00	$16
Wires, solder, pins, screws	1	$8.00	$8
PCB perfboard, Misc	1	$15.00	$15
Torsion Springs	2	$7.44	$14.88
Slot Pins	1	$5.29	$5.29
Nylon Eyebolt	1	$5.67	$5.67
Semi-Clear Plastic Bottle	1	$5.95	$5.95
Semi-Clear Plastic Bottle	1	$13.87	$13.87
Tyvec Fabric	15	$1.13	$16.95
Plastic Rod	2	$1.60	$3.20
Glue	1	$35.77	$35.77
Primer	1	$5.70	$5.70
Fluorescent Paint	1	$5.70	$5.70
Printed Parts	79.67 cm^3	$2.00	$318.68
Assembly	2 hours	$20.00	$40.00
Total			$686.68