Mudd III Documentation

E80 Rocket Research Group

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INTRODUCTION

After analyzing the results of Mudd II's vibration data from ROCStock in June, it was decided that the carbon-fiber and Kevlar composite tubes were too "quiet." In other words, some of the data were so small in amplitude that it was difficult to determine in the field whether the sensor had measured any signal. This was deemed in adequate for the course rockets and it was soon determined that another material with a lower stiffness was required for the tubes and fins in order to measure a higher-amplitude signal. Polycarbonate (PC) tubes and fins were chosen for not only its lower stiffness but also for its high fracture toughness. Due to the fact that most of the rocket's stresses come from vibration and impacts, high fracture toughness is necessary for the longevity of the rocket bodies whereas tensile strength and properties of that nature are not so important. For reference, Table 1 delineates some of the properties of PC.

Table 1 - Physical Properties of Polycarbonate

Density	1200 kg/m^3
Young's Modulus	2 GPa
Compressive Strength	80 MPa
Fracture Toughness	2.1 MPa√m
Specific Heat Capacity	1.2 kJ/kg·K

An added advantage of using PC tubes is that their transparency would allow for better control of adjustments and modifications inside the airframes. There is a slighter chance that one will make a mistake adjusting something inside the airframe if one can see inside.

As the budget received for the funding of the spring 2008 course is small, a scaled-down version of the ideal course will be realized. This will consist of a total of 7 fully-operational polycarbonate rockets. Within these 7 rockets, there will be three different diameter airframes to choose from. Five rockets will be in operation at any given time; two of the rockets will be reserve rockets in case one becomes unusable or otherwise compromised.

GENERAL DESIGN OF MUDD III

In order to cut down on material cost and for better manageability, the Mudd III rockets were constrained to 4 feet in length. It was also required that the vibration sensor data were larger in amplitude, so PC was selected as the primary material. The pedagogical goals of the course also called for some variation in the rockets so that not every team had an identical one. The only practical way to vary the rocket was to change its diameter. Two rockets will be 38 mm ID, three will have 54 mm ID and the last two will have 75 mm ID. The design was constrained to these three standard sizes as many readily available rocket components from most vendors conform to these and in order to minimize spending, the rockets must contain the least number of custom parts possible. The rockets will also all be composed of two sections; the booster section will contain all avionics, except for the pitot tube system in the nosecone, and the forward section will include the recovery system.

As previously learned from the Mudd II design, minimum diameter rockets outfitted with many sensors can become impractical in terms of wiring. Much of the surface of Mudd II was not aerodynamically smooth due to the surface-mounted wires. The Mudd III rockets depart from this design and accommodate wiring in a cavity in between the airframe and the motor mount. This is possible because the smallest rocket accommodates a 29 mm motor mount, and the two larger ones accommodate a 38 mm motor mount. Wires are routed to the cavity and up the airframe via pre-drilled holes near the dynamic strain gauges. Once all the sensors are adhered to the PC airframe, a 0.005 inch thick layer of PC film will be bonded to the airframe using polycarbonate cement, thereby protecting the sensors and keeping the surface smooth. This eliminates the unforeseen problem caused by surface mounting with the Mudd II, making the surface of the Mudd III rockets more aerodynamic by design.

The Mudd III fins will all be made out of 3/16” or 1/8” thick polycarbonate sheets depending on the diameter of the rocket. The means of mounting the fins on the booster section of the rocket will be the two-point mount-though method. Since the fins will be mounted at two points, they will be stiffer and more difficult to break. This method involves surface mounting the fins to the motor mount, placing the motor mount in place and routing the fins through pre-cut slots on the rocket airframe. Once the motor mount and fins are in place, the fins are bonded to the edges of the pre-cut slots on the airframe. For added security for both the fins and the wires in the cavity between the airframe and the motor mount, the cavity is to be filled with expanding foam to immobilize wire and to stick to fins. Like the airframe tubes, the fins will be outfitted with vibration sensors, which will be protected by a layer of PC film.

The avionics section encompasses both the proximal airframe tube and the avionics bed, which is where the electronics boards are mounted. The avionics sub-structure contains all of the mechanical and structural elements of the avionics section. Its function is to support the mounted electronics under high-acceleration and to provide straightforward, quick access to all modifiable parts.

The advantage of using polycarbonate for the avionics section of the rocket is two-fold. The dielectric nature of PC allows for uninhibited transmission of radio waves, which is necessary for onboard video transmission. It was found that a non-conductive avionics sub-structure is necessary from modifying and testing the Mudd II rocket. In addition, the transparency of the PC tubes allows for easy observation and modification of components inside the tubes. The increased ease of "field workability" was demonstrated with Mudd II at LDRS 26 as avionics prep-time was reduced by half.

The electronics in the Mudd III rockets each consist of the following: An RDAS Tiny, a Signal Conditioning Board (SCB), an Inertial Measurement Unit (IMU), a Video Camera and Transmitter (VCT), and a 9-volt 1200mAh lithium battery.

The RDAS serves as the main computer for Mudd III rockets. It provides general flight controls such as parachute ejection. In addition, it logs static pressure (altitude), axial acceleration, and records dynamic strain data from the SCB. The SCB is a low-current RDAS daughter board. It contains unity gain operational amplifiers as well as a precision voltage reference. The SCB is specifically designed to accept signals from piezo-electric dynamic strain gauges and convert them to a scale that is usable for the RDAS.

The IMU is a completely isolated system. It houses a 600MHz Analog Devices Blackfin processor along with on-board data storage. The IMU's sensors include two dual-axis accelerometers along with two dual-axis rate gyros. To get four axes total (three-axis plus one redundant) one of the accelerometers and one of the rate gyros is on a daughter-board mounted perpendicular to the main IMU board. The data stored on-chip will be accessed later via USB and LabView interface and will be processed to provide a special representation of the rocket's flight.

The VCT system in the Mudd III rockets will consist of a Charged Coupled Device (CCD) camera along with a 200mW 2.5GHz transmitter. This system was chosen for four primary reasons: At 811 x 508 pixels, the resolution is superior to other cameras of comparable size. The CCD picture element provides superior color and contrast to CMOS designs. At 22mm x 26mm, the camera is smaller than all other CCD-types found (which is important for mounting). With an operating voltage of 5V at 160mA the VCT could share a single 9V battery with the rest of the avionics. The alternate CCD camera (which is also significantly larger) requires 12V for operation, which would have required expensive lithium polymer batteries for operation.

The recovery system for the Mudd III is very similar to that of Mudd II in that it will be electronically deployed. The bulkplate design for positioning the ejection charge and stress relief mechanism (SRM) is also very similar. However, in order to prevent signal interference with the cameras, the bulkplate material will either be Kevlar composite or PC. As the Mudd III rockets are significantly smaller than the Mudd II, only one parachute will be necessary to recover the rocket. The parachute diameters will be 24” for the small rocket, 30” for the medium rocket and 36” for the large rocket. Separation will be achieved either via a black powder ejection charge ignited by an electric match, or via the use of Pyrodex. As Mudd III is a single-deployment rocket, ejection will necessarily take place at apogee. The only way to minimize drift is to use the minimum diameter for the parachute, while conforming to standard sizes. The shock cord on the Mudd III rockets is identical to the Mudd II shock cord. It will also house a small wire tether to electronically connect the avionics in the nosecone to the main avionics section in the booster. The shock cord connects the nosecone and the rest of the rocket via the use of SRMs located on bulkplates both in the parachute section and on the nosecone. In order to prevent severe burn damage to the shock cord, a nomex sleeve will be utilized on the section of the shock cord that is closest to the ejection charge canister on the bulkplate of the parachute section. In order to protect the parachute from the high temperature, cellulose insulation wadding will be packed in between the ejection charge and the parachute.

CURRENT DESIGN PROBLEMS

In order to view specific design details of the current Mudd III rockets, refer to the SolidWorks solid model part and assembly files. If the files are not readily available, contact Graham Orr (gorr@hmc.edu), Noel Godinez (ngodinez@hmc.edu), Alex Lynch (alynch@hmc.edu) or Professor Spjut (erik_spjut@hmc.edu) in order to gain access to them. Team members who have been given access to the Charlie folder may access files at \\Charlie\Research\Eng\E80 Rocket Project.

The design problems explained below have to be resolved before the Mudd III rockets can be manufactured as they are instrumental in the functionality of the course rockets.

AVIONICS WIRING & CONNECTORS

As shown by the Mudd II rocket, using 32 AWG wire with individual crimp connectors was not as practical as predicted. One of the major problems with this approach was that the 32 gauge wire was much too fragile for extensive handling. The wires broke many times in the process of connecting and disconnecting sensors. While it was convenient to have individual access to every sensor in that configuration, the implementation was far too impractical for field use. In addition, the connectors themselves were difficult to install onto crimped wire and led to many broken wires as well. Once many of these setbacks were remedied, the connectors still posed a problem in the field; the connectors progressively became more difficult to use as disconnected ones tended to get clogged with dust and other debris, making them virtually unusable.

In order for the course students to not have this problem, it was determined that individual pins and jumpers located on a bulkhead were a more robust solution for selecting the sensors from which to read. This would also have the added advantage of lower gauge wire, possibly 26 AWG, being hard-wired onto the back of the jumper panel so that it does not need to be handled. The only part that of this bulkhead that will be under heavy use is the front side with all the pins. It has also been decided that, for simplicity, there will be three main connectors that wire the sensors to this bulkhead. One connector will accommodate 12 sensors from the booster section, another will connect 4 sensors from the parachute section and the last will wire the nosecone electronics to the rest of the avionics section.

However, there are several issues with this design that have yet to be fully addressed. First and foremost is placement in the airframe. The most likely location for such a bulkhead would be the forward part of the avionics bay. Though this would be the most accessible part of the rocket for such an application, wiring is still a major issue. Wires will be routed from both sides of the bulkhead to be soldered onto the aft side, so the design of said bulkhead will have to accommodate for that. In addition, the avionics bay has to be completely removable for maintenance and for supplying fresh batteries, meaning that it is essential to design a way in which to disconnect the avionics bay from everything else. The specifics of the jumper configuration have also yet to be determined.

CAMERA & SHROUDING CONCEPT

Currently, certain problems have occurred with the design of the camera and shrouding assembly on the booster section of the rocket. The current design involves the camera being mounted inside the avionics section. The lens of the camera accommodates an assembly that is secured with a set screw that holds the mirror so that alignment is not an issue. However, since this assembly passes through the airframe of the rocket, air can somewhat flow freely into or out of the rocket through the cut made in order to accommodate this assembly. The problem lies in the fact that when the rocket is in flight, low pressure air flows behind the shrouding where the camera lies. As the altitude sensors in the avionics section are barometric, it is possible that the resulting pressure gradient inside the airframe would yield an inaccurate altitude measurement. The inaccuracy that is possible due to this low pressure flow can range from bad altitude readings to premature parachute deployment.

At this point, Professor Spjut had deemed that it is a better option to simply seal the hole. However, as sealing the hole is a major challenge with the current design, it may be worthwhile to pursue an alternative one that does not require an exposed hole behind the shrouding in the first place.

NOSECONE ELECTRONICS AND TETHER

The Mudd III course rockets are required to have a pitot tube in the nosecone in order to record pressure on a data board within the nosecone. The pitot tube is attached to the board via a flexible rubber tube, which is all housed and mounted inside the nosecone. As there need to be wires for power and signal routed from the nosecone data board to the main avionics section in the booster, there will necessarily have to be a wire tether within the shock cord. Logistics regarding the design of the wire tether and shock cord system aside, the nosecone will require a bulkplate and a set of SRMs to retain the tether and to relieve stress on the wires. The current idea for implementing said device is to use a PML Intellicone, which includes an “avionics section” to be installed within the nosecone. The Intellicone’s “avionics section” is a phenolic tube to which electronics can be mounted. This tube is then mounted inside the nosecone, and the nosecone is then sealed off by a bulkhead to which a shock cord can be attached. However, the actual electronics mounting design has yet to be determined. In addition it has not been determined whether the electronics should be permanently embedded in the nosecone and made inaccessible due to efforts made to protect them. A major problem with the Intellicone idea is that PML does not make one that is compatible with the 38 mm Mudd III. It is possible, however, to implement a similar design with a standard 38 mm nosecone.