UC Irvine Rocket Project 2006-07

Guidance Control And Data Telemetry Video System

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Summary

The UC Irvine Rocket Project (UCIRP) is a collaborative effort among multidisciplinary undergraduate students from the Henry Samueli School of Engineering. This project spans a one academic- year life-cycle with goals that demonstrate the application of engineering concepts and tools in order to produce functional designs in the field of space technology.

The 2005-06 UCIRP Team undertook a monumental project in designing and building a rocket and demonstrated great achievements. UCI Rocket 2005-06 was launched and recovered successfully on Sep 9th 06, and the record of the data of the position, velocity, acceleration, and the attitude of the rocket during flight was analyzed. The new goal of the 2006-07 UCIRP Team is to design, build, and launch a rocket using a commercially available solid state rocket motor with a control system that has the capability of controlling the roll of the rocket. Using our knowledge of control system, we were able to put together an Inertial Measurement Unit to sense the rotational force as well as the rotational force on the rocket and use control law to keep the rocket stable. Whereas, our G-Wiz fligher computer and an experimental Universal Flight Control computer will help us monitor the flight through videos and other datas. Being in a large group of mutildisciplinary engineers, we were able to learn how to communicate with each other and to help each other to learn more about rocketry.

Motivation and Goals

The overall goals for the rocket project this year is to design, build, launch, and recover a rocket capable of delivering a CanSat type payload to an altitude of 12,000 feet Above Ground Level (AGL). The goals of the group are designed to ensure the successful launch of the rocket as well as provide data and information so that the success of the subsystems can be evaluated. The development of a rocket capable of reaching an altitude of 12,000 feet provides an opportunity to deliver a CanSat payload to the appropriate altitude. While many university campuses compete in a CanSat program, few develop the rockets to launch them to the appropriate altitude. The ability to deliver a CanSat payload provides UCI with the means of further testing of a CanSat without the need for outside sources. This provides UCI with a unique opportunity should UCI ever develop a continual CanSat team. Future collaboration between the UCIRP and a CanSat team would be beneficial to the development of undergraduate research on campus. In order to build an appropriate rocket, it must exhibit the ability for it to deploy the recovery system and the CanSat properly which requires an attitude control system.

Most university rockets are built without an attitude control system in an attempt to simplify the overall design. Our attempt to develop an attitude control system will demonstrate the ability to implement a control law and an inertial measurement unit to control the roll angle of the rocket to prevent the parachute cables from tangling during deployment and to ensure the stability of the video. The addition of a data acquisition and video system provides valuable data to assess the success of the rocket as a CanSat deployment rocket.

Furthermore, for our senior design, our goals are from the Guidance Control System and Data Telemetry Video systems to:

- Develop an attitude control system to control the roll angle of the rocket.
- Design and build an onboard data acquisition system capable of recording and transmitting such parameters as altitude, velocity and acceleration for use in post-flight analysis.
- Design and build a redundant video recording system capable of recording and transmitting video to show the deployment of the parachute and the effectiveness of the attitude control system.

Guidance Control System (GCS)

The design of the GCS, which has been recently renamed RCS (roll control system), has gone through several design changes and goal re-evaluations. The UCI Rocket Project is a student run project so the task of coming up with goals and the workings of the system has fallen primary on ourselves, the students. The primary goal of the RCS is to control the roll of the rocket so that is holds stable about the z-axis during flight. The reason for this is because we plan to launch a CanSat from our rocket as a payload it will be carrying. A CanSat is a can sized satellite that can be used to hold electronics to measure certain parameters, such as temperature and pressure. To avoid complications in deploying the CanSat we need the rocket to be as free from any rolling motion as possible. If the rocket were to experience any roll about the z-axis we would risk the CanSat interacting with the airframe in a non ideal way. Another reason why we have chosen to control roll in such a manner is to use the knowledge acquired from roll control and apply it to pitch and yaw control. Roll control was the easiest and safest to undertake, so we are also using this as a stepping stone to more advanced guidance system. It's easiest because we are only worrying about one axis. It is the safest means because worst case scenario is that the RCS cannot control the roll correctly and the rocket has excessive roll which can only further stabilize the rocket rather that affect its trajectory. From this we have set the following requirements:

- Design a lightweight mechanical and electrical system to control rocket roll.
- Design the mechanics and electronics to fit inside a 6 inch diameter rocket body.
- Ensure accuracy of canards to within 1 degree of desired position.

GCS Design Approach

The development of the an electrical system consists of a inertial measurement unit and a microprocessor that will take the data from the measurement sensors and processed to turn the analog voltages into pulse width modulation that will guide the mechanical system to stablize the rocket by using the canards. Inertial Measurement Unit are composed of micromachined inertial sensors such as gyroscopes and accelerometers. For our guidance control system, we will have two dual axis accelerometers and three single axis gyroscopes that will measure the acceleration force due to gravity and the rotational force to determine where the rocket is heading and how its movement is changing in all three directions [4].

Accelerometers are devices that measure linear acceleration that may be static, like the constant force of gravity, or it can be dynamic - caused by moving or vibrating the accelerometers [3]. They can help us understand the rocket's movement to see if it is flying vertically as we wanted or is it going to fall over and so forth. In our control system, we chose Analog Devices ADXL321EB for our accelerometers. These accelerometers are sensors ADXL321 on evaluation boards that consist of polysilicon surface-micromachined structure built on top of a silicon wafer that can measure up to plus or minus 18 g or 18 meter per second square [1]. They are built using differential capacitor technique meaning that acceleration will deflect the beam and unbalances the capacitors that consists of independent fixed plates and plates attached to the moving mass [1]. The changes in the capacitors result in an output square wave whose amplitude is proportional to acceleration in each of the two axis which will goes through demodulation and low pass filter stages to get the signal output in analog [1, 6]. The low pass filter have an ouput capacitor where the user can set a bandwidth. This filtering improves measurement resolution and helps prevent aliasing [1].

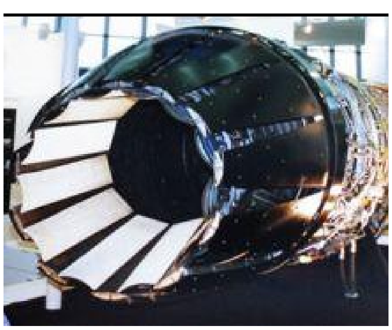
From previous experience, we have received samples of integrated zener diodes from Tyco Electronics and the small size of the diodes make them useless to us because we could not physically solder the device. However, by getting the ADXL321EB we can have the ease of analysis due to the size of one square inch in dimension which is five times bigger the size of the accelerometers without the evaluation boards. The tradeoff is that the output has been converted to analog and then it would need to be converted back into digital again to be process in the microprocessor. The multiple conversion would have a higher error of quantization as these data are process many times. Furthermore, the ADXL321EB have been set to 50 hertz and user can only decrease it by adding extra capacitors. The typical bandwidth for inertial navigation is from zero to one hundred hertz [5]. For a higher the bandwidth, the more noise the data will encountered but they will be more accuracy as the error of converting the signal into the digital domain is inversely proportional to the frequency [6]. The higher bandwidth will also draw more current as it is working faster. Nevertheless, we will leave the bandwidth at 50 hertz because it is within the range since a further decrease in bandwidth will give us less accurate data. At last, these two accelerometers will need to be mounted orthogonal to each other to measure the three axis we need [3].

As for the gyrocopes, they are sensors that measure the rotational force along an axis. Gyroscopes can detect the angular motion of a car and can be used to control the vehicle from spinning out of control [5]. The usage of gyroscopes along with the accelerometers in our system will allow us to control the rocket and keep it on a near straight path. We also decided to use Analog Devices ADXRS401EB for our gyroscopes. ADXRS401EB is an evaluation board of the single axis gyrocope ADXRS401 that implemented a resonator technique rather than the differential capacitors that of the accelerometers. A resonator is where the device resonate at a particular frequency [5]. The ADXRS401EB consists of two vibratory frames that are driven into resonance once there is a rotation about the axis normal to the plane of the chip. The velocity from the resonance will create a Coriolis force, a force along the motion of reference. This force will be detect by capacitors “pick-off” structures along the edges of the frame [2]. The output will go through demodulation and filter stages to produce analog voltages proportional to the angular rate about the axis normal to the chip [2]. Furthermore, the gyrocopes are designed with two identical frames to resist external shock and vibration. There are also charge pumps on the chip to boost the applied voltages because the resonator required 14 to 16 volts to operate and the supplied voltage is usally only 5 volts [2, 5].

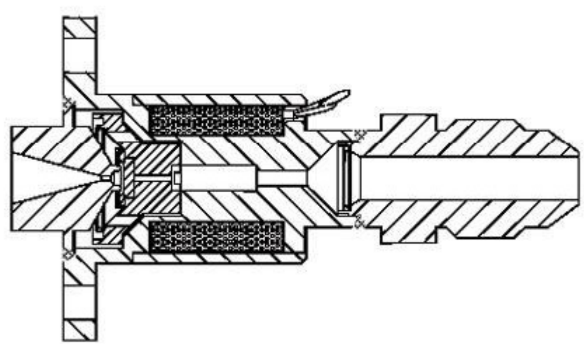
Similar to the accelerometers, we chose the gyrocopes with the evaluation board because its size is bigger than the size of gyroscopes without an evaluation board. However, the ADXRS401EB only has a bandwidth of 20 hertz at the output [2]. Yet the typical bandwidth for the gyrocopes in control system and inertial navigation is only from 0 to 10 hertz so we have decided to add another capacitor at the output with a value of 100nF to reduce our gyrocopes bandwidth to 7 hertz [5]. These gyrocopes will also need to be mounted orthogonal to each other for them measure the rotation in all three axis. Lastly, for our microprocessor of the electrical system, we chose a Microchip PIC16F917 microcontroller, a small central processing unit with also an analog to digital converter that will process our data from the Inertial Measurement Unit with a speed of 8 megahertz and 14 KB of on board memory. We will also have two extend 2 MB of memory to prevent the microcontroller from being running out of memory.

As for the mechanical system, our requirements for this system have led us down several paths before realizing the path we are currently on. From a mechanical standpoint, we have tried to follow several paths of innovation. We first need to become aware what possibilities were our there. There are several mechanical ways to affect the motion of a rocket during flight. The three types that we spent our time learning about were as shown from figure 1 below.

Thrust Vectoring



Cold Gas Thrusters



Canards

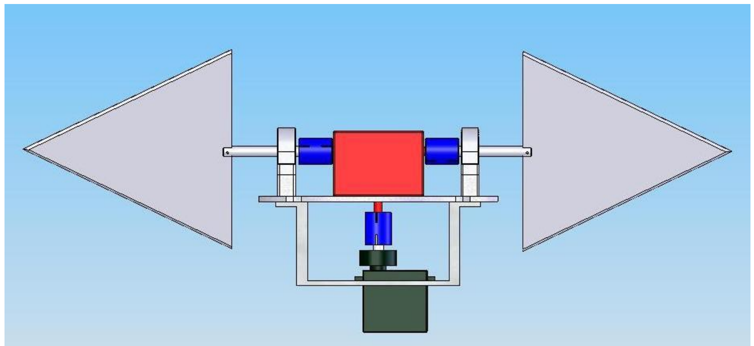


Figure 1. The three different types of mechanical support to control the rocket. Thrust Vectoring and Cold Gas Thruster have a bigger size in comparison with the canards.

The first means of attitude control we looked was thrust vectoring which works by changing the direction of the hot gases coming out of the rocket. However, this means can only affect pitch and yaw, not roll. We then chose to move on to cold gas thrusters which work by means of propelling some gas (most of the time some oxygen containing gas such as CO_2). This is similar to how the NASA Space Shuttles Make minor attitude controls in space. After running through the equations we found that a tank bigger than the rocket itself would be needed to provide enough impulse to rotate the rocket 180° in 1 second as one can see from figure 1 above. It seems that there is a reason we only that cold gas thrusters being mainly used in space where air flow and friction does not play a role. We then decided to go with canards which are essential smaller wings placed up higher on the rocket that can be moved to control the air flow going over the rocket and give us roll control. A little research on the canard we find that the canard is an airframe configuration of a fixed winged aircraft in which they are mounted further ahead of the tail fins. Early canard implementation of the canard is where we get the word “canard” from which is French for duck. It was said that these early plans, with canards, resembled a flying duck according to observers hence the name [7]. The canards are controlled by a servo that is attached by a coupling feeds into a 2:1 gear box that then counter rotates the two canards that then can induce roll in the rocket.

Using a PIC microprocessor we plan to implement the code we will need to use to make use of our inputs and turn them into outputs that the servo can understand and reflect, as well as store data for post flight analysis. The requirements for the control law are as follows:

- Control the angular velocity of the rocket using a PIC micro-controller.
- Ensure rocket canards will return to center in the event of system instability or failure.
- Limit the range of canard motion to +/-10 degrees.

The control will also have these features:

- Angular velocity is controlled using PID control.
- Feedback is achieved through integration of the gyro signal, which will be sampled at 100 Hz
- The digital servo is programmed for a fail-safe position of 0 degrees.
- The digital servo is set for a +/-20 degree range of motion.

A rough diagram of our closed loop control law is shown in figure 2 in the next page. The physical response includes a representation for the rocket and its motion. The IMU then relays all it's acceleration data to the PIC which then integrates to get velocities which is then run through a PID controller for which our K values and stability will be theoretically calculated and fined tuned through testing. The results from the PIC are then sent to the mechanics of the GCS, mainly the servo, which then influences the roll on the rocket and the loop continues to make adjustments.

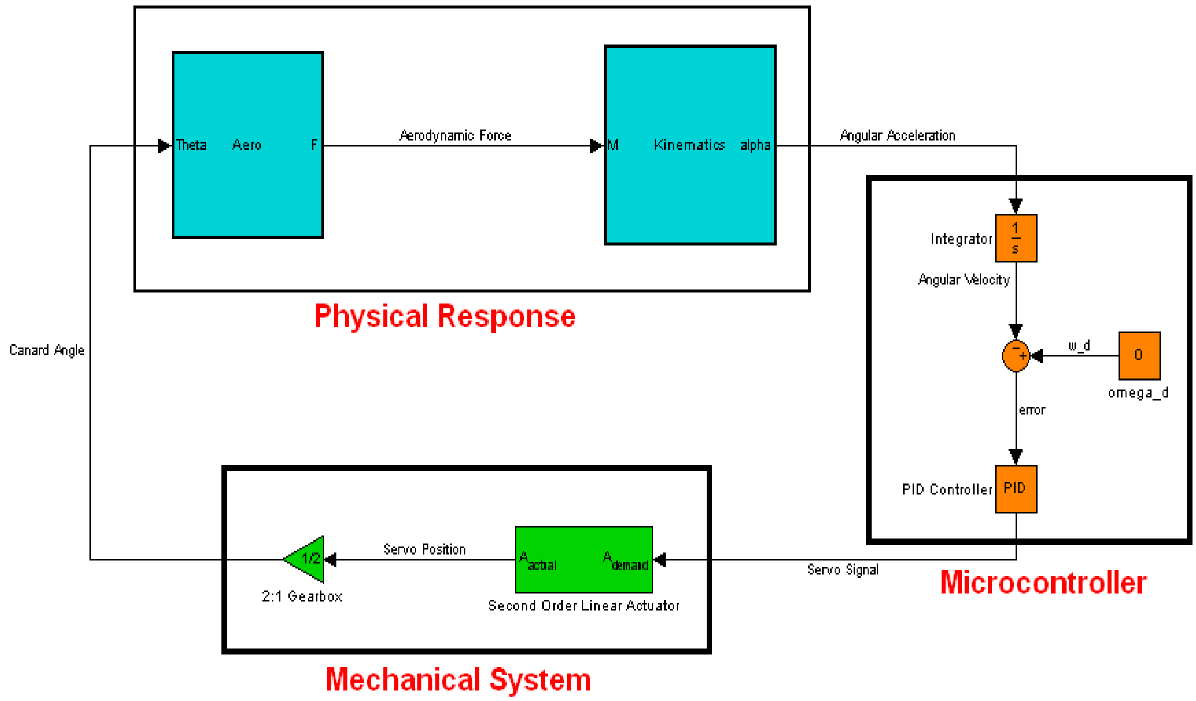


Figure 2. Overall schematic of the guidance control system where it data from the physical response will be process in the microcontroller before sending to the servo to control the rocket.

There were several constraints that we had to consider on the electronics end of the system. As most electronics do, heat is produced from the current running through the copper wire which could potentially affect the rocket itself as well as cause inconsistencies in the readings from the devices. Our inertial measurement unit consists of several gyros and accelerometers. They each require around 5 volts to operate, however, they only use on the order of a few milliamps of current so there is no danger of excessive heating from these devices. The servo however used 5 volts and when stalling can use up to 4200 milliamps when stalling occurs. After some testing of the servo we can see that there is some heating that occurs in the operation of the servo, but it is minimal in how hot it gets and how far it is allow to travel. Any heat dissipated from the servo will not affect the other electronics because the servo is contained within the mechanics of the system which is complete separated from the electronics with even an aluminum plate in between the two parts of the system.

There is also a power constraint which led to the specific power supply we are using. Everything in our electronics operates in the 4.5 – 6 volt range and everything requires a current of a very few milliamps except the servo. This lead us to chose a power supply that could provide that voltage range and the maximum current needed. We searched for several places, mostly online, and found an online provided that could allow us to make customer battery packs for RC electronics (planes, cars, etc). We chose a 5 cell battery pack which gave us 5 times the 1.2 volts for an output of 6 volts. Furthermore, the cells were each rated for 4200 mAh and they were assembled in series. With this battery we could potentially max out the current on the servo the whole flight and still get almost an hour out of the battery.

There also is a size constraint that we needed to meet which was to fit everything inside a 6 in diameter circle. Height of the system as less of a concern, but we are trying to make it as small as possible. We are in constant communication with the sub-team that is making the airframe so that they are aware of how much space is required for the system. The UCI Rocket Project is a 3 quarter project and at this stage we are only in the beginnings of putting the whole system together. The plan, schematics, diagrams and theory have been chosen, and in the next quarter we will finish the assembly and begin rigorous testing of the system to be ready for our launch on June 9th. When it comes to testing, for our guidance control system, we will need to use to turn table to test our gyroscopes as the rotation around the table will give create a force. On the other hand, we will test whole system in the wind tunnel because force from we can see if our system is stable against wind force because that will also make the rocket become less stable.

GSC Budget:

Through various means of funding from the university and the students we have obtained we have been able to fund our project and a parts list for the electronics section can be seen below.

3 ADXRS401EB Gyroscopes	\$50.00 x 3 = \$150
2 ADXL321EB	\$29.95 x 2 = \$59.90
PIC Microcontroller	\$40.00 x 1 = \$40.00
2 two MB Flash Memory	\$2.50 x 1 = \$5.00
Misc (Bread boards, wire, solder, etc)	\$25.00
6V 4200mAh Custom NiMH Battery Pack and charger	\$100.00
Hitec 5955TG Servo	132.24
Hitec HFP-10 Servo Programmer	178.24
TOTAL	690.38

The majority of our parts have been donated to our sub-team through communication with manufacturers and sample parts. The gyros and accelerometers were provided through a sample program with Analog Devices. For the servo and servo programmer, we contacted Hitec and explained to them our project and they were more than happy to donate the two items to us. In return we will be giving them feedback on how well their devices perform. They have not used the devices in applications similar to our own, but are beginning to move in that direction, so any information we can provide them they are more than happy to receive.

GCS Improvement

For the IMU, the major improvement would be obtaining multiaxis accelerometers. So far, three axis accelerometers have been tested but have not been commercialized yet [5]. Once three axis accelerometers are commercialized, we can integrated them into our system without having to mount the accelerometers orthogonally to each other. Although we have the space in the rocket, the connection of the devices to the power supply and the microprocessor can be very disorganized. The same is also true of the gyroscopes. Gyroscopes with dual axis of three axis will help us to worry less about the wiring and more on how to improve the control system. Although we have moved on to use cell battery pack from just regular non-rechargeable batteries of last year design, we can further our voltage regulator by looking more into a combination of active, linear, and switching regulators [9]. Finally, the microprocessing can have better memory on board so that we would not need to extend two more memory modules because then the wiring would also be more complicated. As for the mechanical system, the different configurations in canards can have different effect on the force thus if we change the canards to rectangular form, we can realize a different perspective on control system.

Data Telemetry and Video System (DTVS)

This team will provide altitude determination, tracking of the rocket and data acquisition during flight and recovery. It will also include collecting video footage and data such as acceleration, velocity and altitude will be used for post flight performance analysis of the rocket. Duties include design, development and integration of the onboard flight computer. Operations include device calibration, ground station wireless communication and data transmission, as well as providing power for the Recovery system. This team will be implementing an experimental flight controller, designed by one of our sponsors, Thomas Miller of Black Magic Missile Works

(BMMW). The team will work closely with (BMMW) to develop and test firmware for the onboard flight computer. The requirements for DTVS are:

- Obtain in flight data such as altitude, velocity and acceleration
- Analyze post flight performance of the rocket
- Obtain onboard flight video and verify the operation of the roll control and recovery sub-systems

<u>DTVS Design Approach</u>

PART 1 – G-Wiz DCS Flight Computer

DCS flight computer will serve as the primary computer in the rocket. It will acquire, record and transmit real time data from the rocket. The transmitted data i.e. GPS coordinates will be used to find the rocket after recovery. The computer will be programmed to ignite e-matches at apogee and at critical altitude to perform dual recovery. Moreover, the system will have a failsafe with remote override in case there is a need to execute recovery remotely. Figure 3 and 4 show the computer top and bottom view.

Figure 3 – G-Wiz DCS Flight Computer top view

Figure 4 – G-Wiz DCS Flight Computer bottom view

The specifications for the G Wiz will also have an on board 50g accelerometer, temperature sensor, real time clock to time all flights, 5 High current (20 amp) pyrotechnics outputs, individually programmable, and:

- Events detected, and usable for pyrotechnics trigger or to start a timer:
  - Launch detect (Inertial or break-wire)
  - Burnout (or Nth burnout)
  - Stage Ignition (or Nth ignition)
  - Greater or equal to set altitude, on ascent
  - Apogee
  - Barometric Apogee (for tumbling boosters)
  - Less or equal to set altitude, on descent
  - Landing
  - Timer time-out
  - Analog inputs reaching set values
- Event detected and recorded:
  - Continuity Change

    - Record buffer overflow
    - Pyrotechnic port on / off
- Timers usable with every event
- 12-bit ADC for acceleration, and 7 user analog channels
- Expandable - daughter cards with special features:
    - Barometric altitude card provides a high-quality pressure sensor capable of accurate data over 120k ft.
    - The Barometric Altitude cards can also include a Telemetry transceiver for bi-directional data transfer and a GPS module.
    - A 2 axis card will add a Z & X axis, providing a full 3 axis of acceleration data. This card will use 2 of the on-board analog inputs.
- All analog inputs are filtered
- Analog input sampling and recording up to 1000 samples/second
- Records all data on standard Compact Flash card. Multiple flights on a card
- English or Metric units (Feet/Miles or Meters/Kilometers).
- Fail-safe power switching
- Safety shunt, with off-board option.
- Multiple flight configurations
- 30 Mip 32 bit RISC processor.
- Flash Memory for firmware upgrades
- Unit dimensions: 6.25” x 2” x 1.25” (With daughter card)

PART 2 – Rocket Data Acquisition System (RDAS) and video transmission

RDAS will serve as a back up computer in the rocket. In any event RDAS will ignite backup charges and record data during the flight of the rocket. Moreover, with the use of the expansion board, the flight parameters will be overlaid over the transmitted video, which is broadcasting to the ground station. RDAS is very simple to configure and use. The data will be used to verify other flight computers onboard. Figure 5 shows RDAS (left), expansion overlay board (center), and simple user interface for RDAS programming (right).

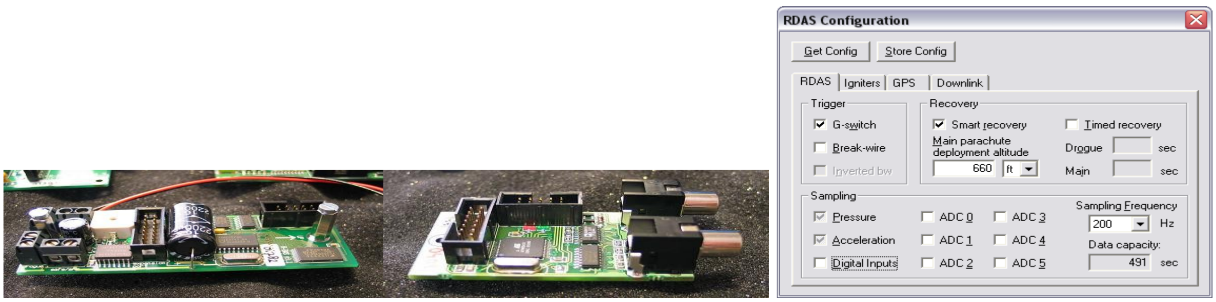


Figure 5 – RDAS, Overlay Board, Configurations Interface

Video Recording and Transmission

In order to verify the operation of other sub-teams, DTVS needs to implement redundant video system. The video feed from the rocket during the flight must be both recorded onboard and transmitted to the ground station. In order implement it, we will be using one digital recording camera to capture high quality video and save it onboard of the rocket with 2 miniature CMOS cameras mounted back to back and transmitted via ATV transmitter that operates at 426 MHz frequency and has a maximum TX power of 1.5W. The transmitter requires FCC license to operate. The CMOS cameras will be transmitting one at a time. At the apogee the cameras' power will be switched by DCS flight computer and the ground station will verify the deployment of the parachute. The antennas that will be used are 7 element circular polarized Yagi antenna for the best RX video distance and quality as shown in Figure 6 and an inverted V-horizontal dipole antenna will be used for the best signal coverage right below the rocket. The antenna was designed and going to be build here in UCI. Figure 7 illustrates the design.

Figure 6– Circular polarized Yagi antenna

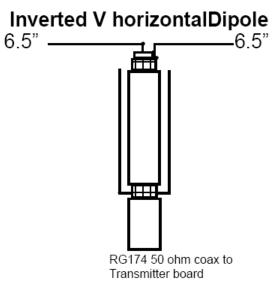


Figure 7 – Inverted V-horizontal dipole antenna

PART 3 – Universal Flight Computer (UFC)

The UFC is a custom flight computer that is being developed by Black Magic Missile Works and UCI Rocket Project team. So far, the full hardware is done and the firmware is being written. When the development and testing is completed, the UFC will be the ultimate flight computer in the armature rocketry. The core of the Controller is an Atmel 32-Bit ARM 7 Micro Controller providing a wide variety of resources and sufficient memory and processing power for most applications (additional I/O resources and processors can be added when needed for more complex applications or for redundancy). Below are the features for the UFC:

- CPU: Atmel AT91SAM7A3, 30 MHz (27 MIPS)

- On-chip Flash: 256 Kbytes (10,000 write cycle, 10-year data retention)
- On-chip SRAM: 32 Kbytes
- User Serial Ports (115.2 Kbps): Three, Port 0 has RTS/CTS and is TTL for the RF Modem, other ports are RS-232 TX/RX only and have drivers for GPS and 3-Axis Sensor
- USB 2.0 Port (12 Mbps): One, 2KByte FIFOs. USB port is the primary ground support link
- TWI (I_2C) Port (400 Kbps): One, externally accessible for I/O expansion
- CAN (Controller Area Network) Ports: Two, used for inter-processor communication
- MCI (Multimedia Card Interface) Port: One, supports plug-in Flash memory for extended data logging, multiple flights
- Analog Channels: Sixteen, 10-bit, 0.1% reference, 0.1% resistors. Eight channels are preset to 4.8V full scale. Two channels are also preset to 4.8V full scale, but also include a +12V source for voltage output pressure sensors. Two channels have a +12V source and differential
- Programmable Gain Amplifier (1, 2, 4, 8, 16, 32, 64, 128, 256, 512, 1024, 2048, 4096 gain) for use with bridge type millivolt pressure sensors. The remaining channels are dedicated to the accelerometer, sensing the excitation voltage (+12V), battery current sensing and battery voltage sensing.
- PWM Channels: Eight, 20-bit with 36 volt, 1,200ma. half-bridge drivers (for future use with up to four Black Magic Missile Works dynamic thrust Hybrid motors or Attitude Control System).
- May also be used as just digital I/O channels, or for driving moderate current loads
- User Defined Digital I/O: Twelve (including eight from PWM channels, additional ports through

- I2C bus)
- Pyrotechnic Igniter Channels: Two, 1 amp current sourced with continuity sensing.
- Accelerometer: ±40g, ±1%
- Barometric Altitude Sensor: 0.15-16.2 psia (15-bit ADC)
- Temperature Sensor: -55ºC to +125ºC
- Board Size: 2.5” x 6.0”
- Board Power: 6-25VDC @ 2.8 Watts max. dissipated (not including external peripherals and pyrotechnic channels), separate power for PWM drivers can be up to 30V
- Operating Temp. Range:-40ºC to +85ºC (critical components)

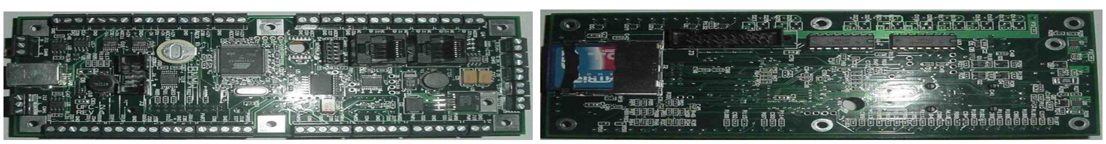
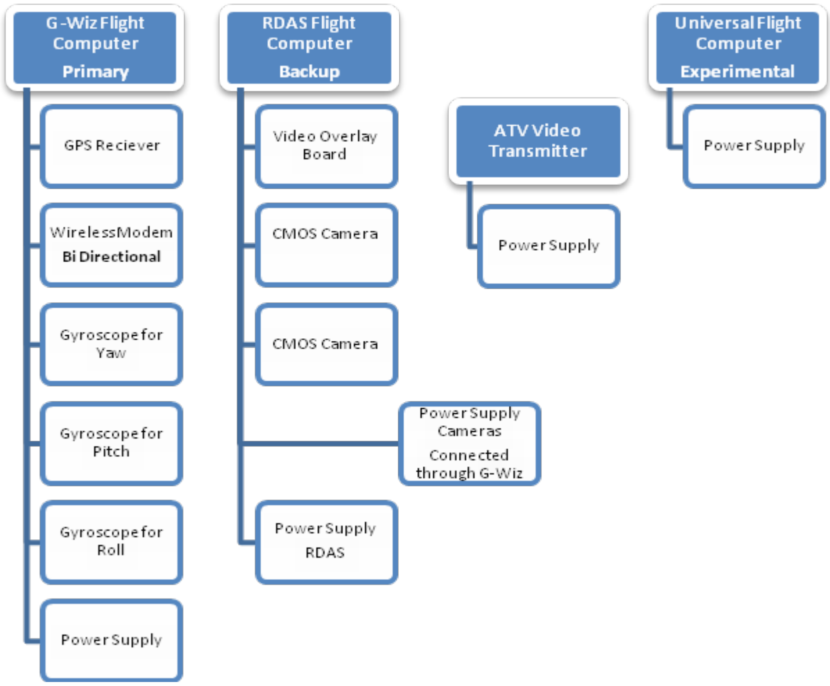


Figure 8 – The left one is of the UFC board views and the right is the Universal Flight Computer.

<u>DTVS Sub-System Block Diagram</u>

The following diagram show where the different parts of the DTVS will help satistfy the requirements of the team goals. As mentioned, the UFC will be an experimental computer from the UCI Rocket team will help in developing the custom flight computer to satisfy the requirement of the UCI Rocket Project in the future years.



DTVS Budget

Similar to GCS, most of DTVS expense comes from fundings of UROP and other donations. The table below shown the cost of DTVS.

Item	**Price**
DCS Flight Computer	$ 1,200.00
RDAS Compact and OSD	$ 300.00
Power Supplies	$ 100.00
Universal Flight Computer	$ -
ATV System	$ 140.00
Antennas for ATV	$ 150.00
Cameras	$ 400.00
Total	**$ 2,290.00**

DTVS Status and Improvement

The current status of DTVS is that we are working on the UFC firmware development for serial drivers, USB drivers, and the coding of altidude algorithm development. The ATV antenna design for inside the rocket which will include inverted V horizontal dipole. We are also working with G-Wiz flight computer to keep improving our design and contact the company that provide us the computers for support. In the next quarter, we will begin testing of flight computers, continue working on UFC software, and mounting the hardware.

Once we have data from the UFC, future improvements of the DTVS system can have the UFC instead of the G-Whiz as its concentration is solely concentrate in rocketry. Other antennas can also help improve our data as some will not be able to get good signals unless it is located at a longer distance from the rocket. Lastly, we can add more cameras to help us record the rockets from multiple directions and parts of the rockets.

Conclusion & Non Technical Issues

In conclusion, UCI rocket project is the student led project. We research, design and build in order to reach our goals and meet our requirements. Moreover, we incorporate different outside resources for help with money and knowledge. We had to learn how to utilize our resources and seek donation from companies. Each week we meet in the general meeting to discuss the progress of the project and then we separate into our subteams to work afterward. The leaders of this project also meet with the mentors every week and the members can also come see the mentors if they have any problems. We also have a design review every quarter where professors and other people from the industry come to give us feedback on our design and approach. Furthermore, we have an advisor at our weekly meetings to help us out further with our design.

This is the second year and the second rocket we are building. On June 9th we will fly the rocket at Dry Lake Lucerne. Secondly, this student run project has been a wonderful learning experience for what actually happens in the real engineering world. We were able to work with engineers from multiple disciplines and collaborate together on a single project as seen from figure 9 in the following page. Early on we had to establish a hierarchy to aid us in working smoothly with each other. There was constant collaboration between members and other sub-teams. The mechanical and the electrical aspects of this project had to constantly communicate with each other to accommodate the needs of all the collective parts. Every single change that a team member made effectively affected not only that particular sub-team but every other sub-team and potentially the whole rocket. This system, and project, required that we use everything we've learned in class over the last 4 years. It even required us to have a basic physical understanding of the rocket as well as an electrical understanding.

Another major value that we have learned from this project is how to adapt to the many changes. For example, we started out wanted to protect the reverse biasing of the IMU sensors with zener diodes so we looked for samples from Tyco Electronics. However, as mention earlier, the sizing were very small so we had to look elsewhere for a simpler diode. As a result, we have obtained some from Marvac Electronics and at the momment, we are looking into shunt voltage regulators instead. The similar situation with filtering the device. At first, we had to review the different filters and then calculate the values of resistors and capacitors for a typical bandwidth. Then only to find out that the pins from the devices can only decrease the bandwidth, not increasing it. Although we also have many changes in the homeworks and other classes projects, the senior design give us a sense of responsibility because most of our labs from the different courses were already performed and we did not need to come up with the design itself. Therefore, students should be flexible, be open minded, and should not be discouraged if something doesn't work out. Instead they should try to look for other ways because then they will be able to learn more things.

We also advise the future senior class is to utilize their time better. Students should be consistent and try not to fall behind because there are deadlines. In addition, professors are willing to help and being in this project will give the students a chance to be closer to the faculties. Some of us do not attend office hours for various reasons and this project is an opportunity to work with them as well as other students. Sometimes it is very hard to work with different people who have different opinions, but students should try to reach a common ground and be professionals with each other.

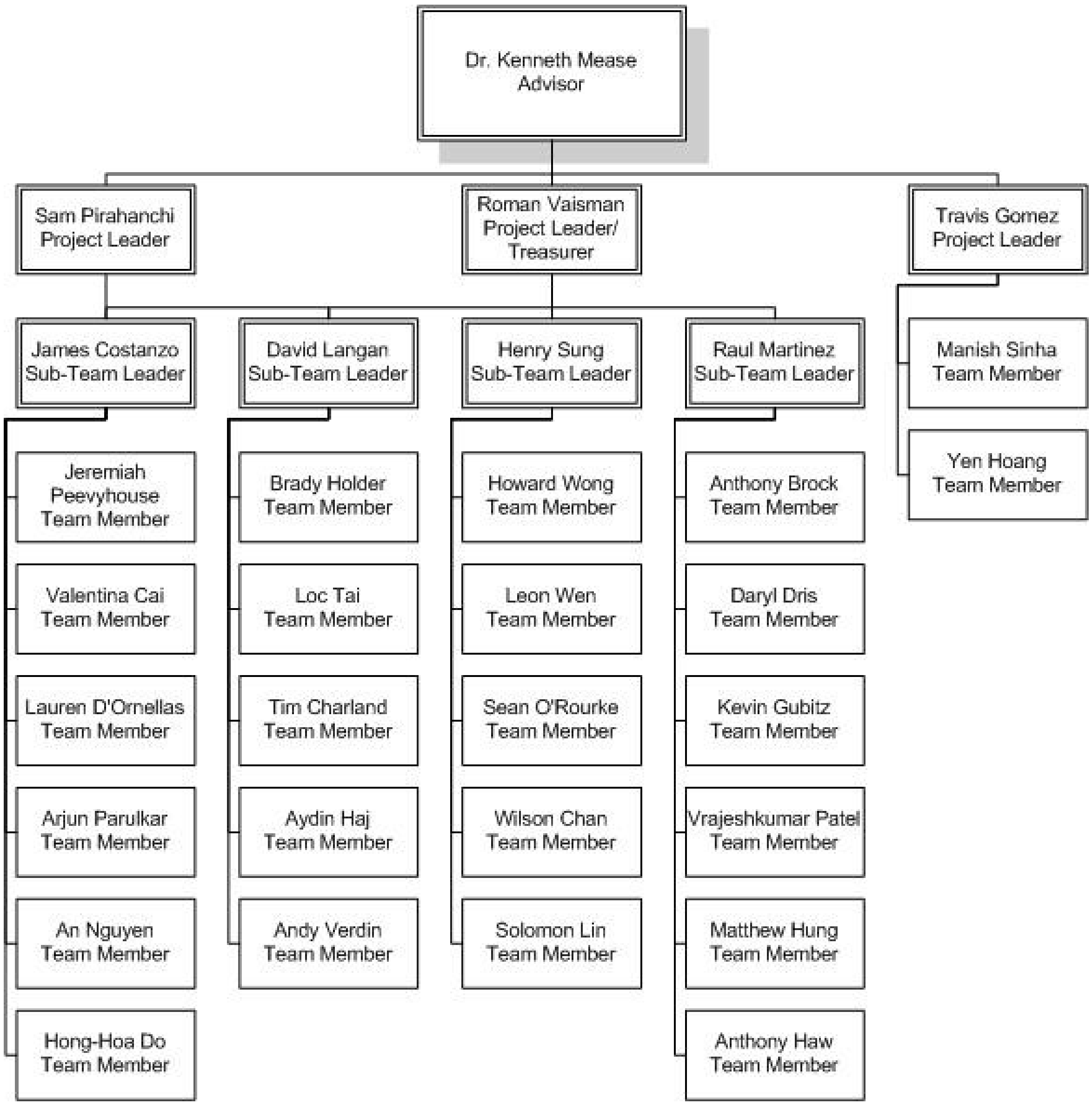


Figure 9. The organization chart of the project for 2006-07. Multiple disciplines of engineers coming together to learn how to work with each other.

References

[1] Analog Devices ADXL321- Small and Thin ±18g Accelerometer. Datasheet, Norwood, MA, 2004.

[2] Analog Devices ADXRS401- ±75°/s Single Chip Yaw Rate Gyro with Signal Conditioning. Datasheet, Norwood, MA, 2004.

[3] http://www.dimensionengineering.com/accelerometers.htm.

[4] http://www.howstuffworks.com/gyroscope3.htm.

[5] Beeby, S., et al., *MEMS Mechanical Sensors.* Artech House, Inc. Norwood, MA., 2004.

[6] "MEMS Accelerometers," InSmart Sensors and MEMS," *Kluwer Academic Publishers*, Norwell, MA., 2004.

[7] http://en.wikipedia.org/wiki/Canard_(aeronautics)

[8] Microchip Technology Inc. PIC16F917/916/914/193- 28/40/44 Pin Flash Based, 8 Bit CMOS Microcontrollers with LCD Driver and nanoWatt Technology. Datasheet, Chandler, AZ, 2005.

[9] http://en.wikipedia.org/wiki/Voltage_regulator

Appendix

- www.analog.com – Analog Devices sell in bulk but they gladly sent us free accelerometers and gyroscopes samples of about 10 each when we said that we were working on a school project
- Hitec – another company that offered us free equipments such as the servo, the only requirement they ask is to provide them feedback on how their equipments perform
- MarVac Electronics – another place to buy equipments, beside online, they have a store in Costa Mesa so if you don't have time to wait for the shipping, you can browse around
- DigiKey-also sell equipments, although it was hard for us to understand the catalog
- UCI Science Library – our university has a lot of reference book from the SCI bar so feel free to look for any programming or other reference books as it helped us to learn more about rocketry