FAMU-FSU College of Engineering

Department of Electrical and Computer Engineering

System-Level Design Review

ECE-ME Senior Design Project

Project title: Cosmic Cube

Team: #4

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Submitted in partial fulfillment of the requirements for

EEL4911C - ECE Senior Design Project I

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Executive Summary

Description

Cosmic radiation is generated by interstellar bodies. For example, one of the many possible ways they occur is when a star undergoes a supernova event. The particles produced travel throughout the universe, largely unimpeded. Because of the extraordinary power of such cosmic events, the resultant particles are highly energetic. When one of these particles hits Earth's atmosphere, a shower of particles is produced that continues to the surface. Some common particles that make it through our atmosphere are: muons, protons, electrons, and neutrons. By understanding when and where these particles come from, it allows for a better comprehension of the forces that shape our universe.

The cosmic particles that are of interest are moving very fast and are invisible to our eyes, therefore complex methods of detection are required to detect them. The purpose of the Cosmic Cube is to detect these particles during a shower caused by a cosmic event. The Cosmic Cube will convert the invisible particles into electrical signals that can be processed, measured, recorded, and compared. The product also will be designed such that it can easily integrate with others so that more instances of a particular type of event can be detected.

Team

This team consists of five engineering students. Two of the students are ME majors and have a background in mechanics and structures. The other three students are ECE majors and have a background in electrical systems and programming. Skills possessed by the team include the following: programming, CAD design, troubleshooting, machine work, and power. The team works well together and is determined to be successful. Advising the team are Ph.Ds.' with backgrounds in advanced physics and electrical engineering.

Target market

Currently, the only instruments capable of detecting cosmic particles are only accessible to professionals, thus leaving out the amateur astronomer. The Cosmic Cube will put cosmic particle astronomy within reach of amateurs as well as link amateurs and professionals together. The goal of the Cosmic Cube is to be so accessible that it can be found on the shelves next to conventional telescopes.

For the amateur user, operation will be optimized for table top use and home computer interfacing. For the more serious enthusiasts, professionals, and academics, the Cosmic Cube will integrate into a much larger cube that is capable of detecting more events as well as direction of trajectory. The Cosmic Cube will integrate into a 27 channel cube. The basic principle, to detect particles, will be preserved except now origin of the particles can be determined.

List of Revisions

Date	Revision	Comments
11/09/2012	1	Original Document
11/13/2012	2	Added Acknowledgements
11/15/2012	3	Added Formatting/Additional Documentation

Table Contents

1 Introduction

1.1 Acknowledgements

The Cosmic Cube team would like to acknowledge Dr. Ray O'Neal and Dr. Michael Frank. Both professors have been an integral part of the designing process and framework of the overall development of the cosmic cube. Dr. O'Neal, with a background in physics and particle astronomy, helped shape the design and functionality of the cube. Dr. Frank, with a background in computer and electrical engineering, provided insight on how to approach the network of circuitry needed for the project.

1.2 Problem Statement

There is a need to detect high-energy cosmic rays because although research has been done regarding the subject, the exact origins of these extremely high-energy particles are not known in all cases.

Detecting these cosmic ray showers on earth and recording the presence, timing, energy levels, and trajectory can help to link the rays to possible events in space that could have produced these showers on earth. There are cosmic ray detectors already in operation yet they are extremely bulky and expensive. This model is designed so that the price per unit will be low, targeting a larger market of buyers, creating a means for the backyard astronomer to have access to this technology. The detector will be compact and visually stimulating to appease buyers yet still operational to maintain detector functionality.

1.3 Operating Environment

The device can be operated both safely and efficiently in an inside or outside environment. Though the majority of the subsystems involved with the cube will be fully operational indoors the GPS unit however will not be able to function unless the user can allow the GPS antenna an unobstructed view of the sky. This can be solved by placing the antenna near a window. The product should be handled with care, since it is somewhat fragile. It is safe to have as a centerpiece in homes or to be taken outside to be exposed to more particles. When placing the cube outside, it should only be exposed to mild weather conditions.

1.4 Intended Use(s) and Intended User(s)

Intended users include researchers, backyard astronomers/general public, and special application groups.

Researchers: Those who want to use the cosmic cube to gather data for studies and projects relating to high-energy cosmic rays. These can be individuals in universities, local high schools, and scientists out in the field.

Backyard Astronomers/General Public: Individuals who don't have funding or work for a major company. These are people who have interest in space maybe as a hobby or career pursuit and want to use the cosmic cube to detect high-energy cosmic ray events in their area.

Special Application Groups: With the added feature of being able to detect gamma rays the portable cosmic cube segment can be used in aiding with the search for nuclear devices and differentiating between materials and locations that have been contaminated by harmful radioactive material.

The Cosmic cube is meant to be an open source project where individuals using the device can develop their own means of translating the data provided by the cube such as event time, particle species, and event trajectory into something more meaningful to them. The user interface will be very simple and rudimentary. Most likely it will consist of a window depicting the raw data and a means to save the data to the local hard drive or external device. A future goal for the project is to allow peer-to-peer style sharing, as opposed to central server based, to share recorded event data. In addition there will be multicolored Light Emission Diodes (LEDs) found on the outside cube to indicate various energy levels of particles that pass through the cosmic cube.

1.5 Assumptions and Limitations

Assumptions

- Of the particles that strike the scintillator, the ones that are of interest in particle astronomy will be in the range of 1-4GeV range.
- However, particles of greater energy may occasionally be encountered.
- A fraction of the energy deposited by the cosmic rays will be absorbed by the scintillator.
- The cube will be subjected to terrestrial radiation as well as cosmic rays.
- A Cosmic particle will strike the scintillator material at least 1 per microsecond possibly more frequent.

Limitations

- The length of a cube segment can be no greater than 30cm on any given side.
- The time resolution of the device will be no slower than 100 nanoseconds.
- A commercially available Cosmic Cube when mass produced should cost approximately $1000.

Funding

Currently, the Cosmic Cube has been given $750.00 from FSU College of Engineering's ECE department. Additionally, Dr. O'Neal will be providing samples of scintillator, lead- free substitute, and photo-detectors. Dr. Frank has also indicated that there may be additional funding if absolutely necessary. The team is currently seeking donations for the other components to put towards the Cosmic Cube prototype.

These lists will be subject to change as the project is further developed.

1.6 Expected End Product and Other Deliverables

The Cosmic Cube will be commercialized but one complete prototype cube, with the following components will be completed by the end of April 2013. This list is subject to change while the project is ongoing.

- User's Manual
- 1 working cube segment complete with
    - Enclosure
    - Scintillator
    - Solid-state Photodiode
    - GPS Module
    - DAC board
    - Wi-Fi Module
    - Power Supply
- Design schematics
- All codes files developed for microcontrollers
- Bill of materials required for manufacturing additional units

2 System Design

2.1 Overview of the System

The following block diagram, shown in Figure 1, gives an overview of the flow of information for the Cosmic Cube.

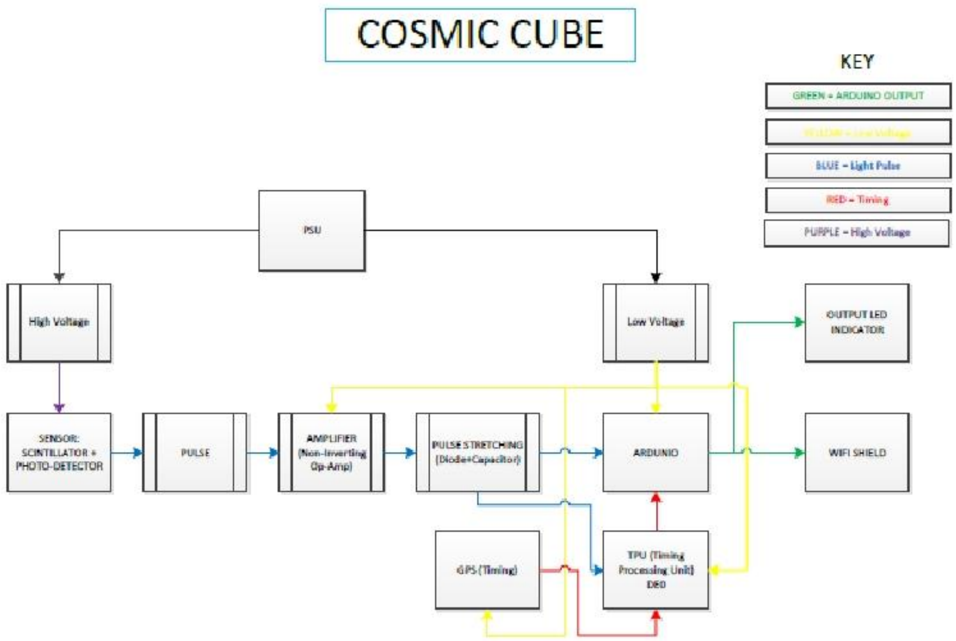


Figure 1 - Block Diagram of Cosmic Cube System

A technical drawing of the cube design can be viewed in **Figure 2** and a model of the structure that will house the individual cubes can be seen in **Figure 3**.

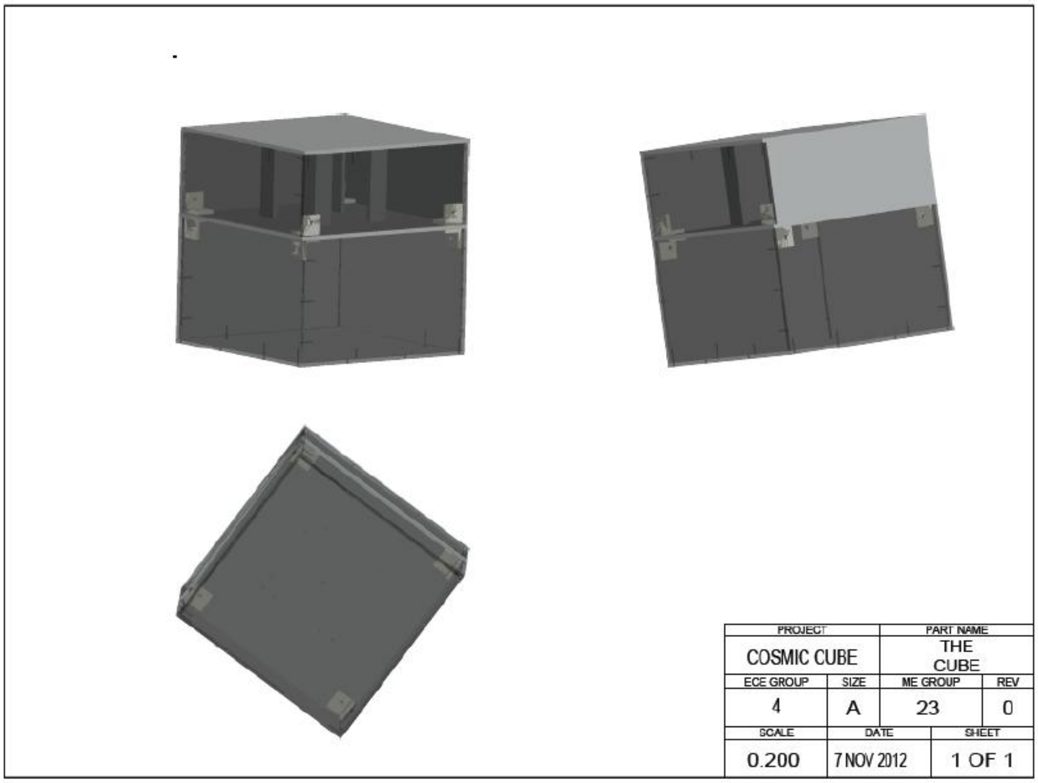


Figure 2 - Cube Design

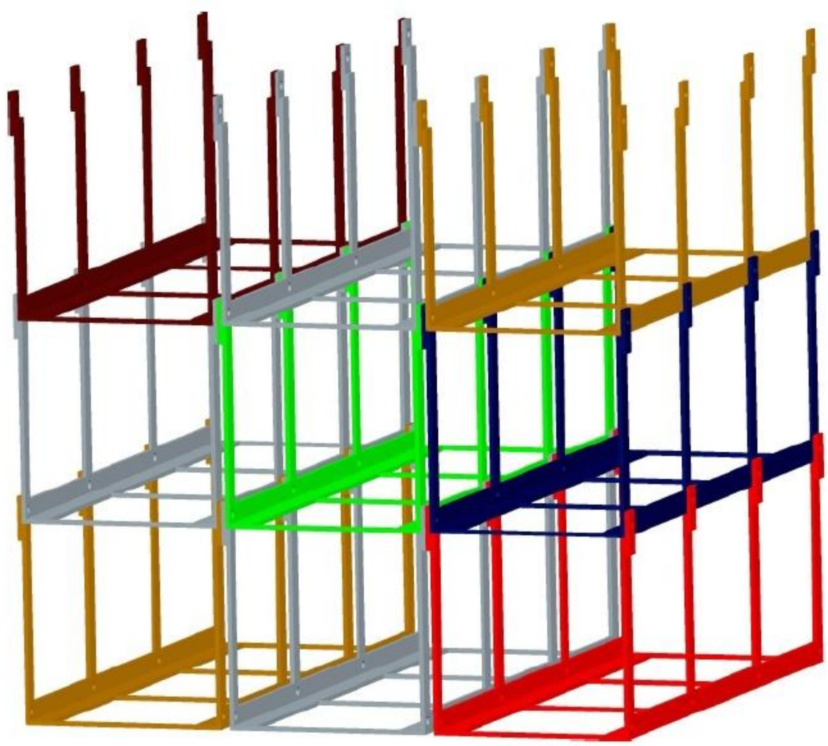


Figure 3 - Cube Connector Structure

2.2 Major Components of the System

The following includes brief descriptions of all the major components; scintillator, photo- detector, microcontroller/CPU, global position system (GPS), Wi-Fi, the structure, light emitting diodes (LED), and the radioactive isotope.

The purpose of the scintillator is to convert high energy particles into photons. When the cosmic radiation strikes the dense material on the top of the scintillator material, a mini shower is created. The mini shower travels through the scintillator, depositing energy along the way. The energy from the particle shower causes the scintillator atoms to bump up to a higher energy level. When the scintillator atoms fall back to their previous state, a photon is released. The amount of photons per amount of energy deposited for the scintillator material can be calibrated using a radioactive isotope of known energy.

The purpose of the photo-detector is to turn the photons from the scintillator into an electrical signal that can be measured and processed by the CPU. The type of photo-detector to be selected will be an MPPC (Multi-pixel photon counter). This is a solid state type of detector that is capable of counting actual photons. A standalone photo-detector has an analog output. To be useful for detecting the number of photons, a digital output would have to be created from the analog signal. An MPPC module would be much more suited to this project due to its digital output.

The microcontroller/CPU will serve as the main hub of the cosmic cube. It will interface directly with the photo-detector, Global Position System (GPS), Wi-Fi, and Personal Computer and possibly a multi-color LED. The microcontroller will receive a pulse or change in voltage values from the photo-detector to signify the detection of photons generated from the cosmic particle striking the scintillation material.

The purpose of the GPS is to provide accurate timing data for events recorded by the Cosmic Cube. The GPS module chosen for the design project will be the Arduino GPS Shield. With an out of the box accuracy of 1 microsecond the Shield will provide enough accuracy for the Timing Processing Unit to then acquire the nanosecond accuracy.

The Wi-Fi communication is used to communicate accumulated data to the user's computer. Since we would like this to be able to operate outside of the building (for high speed electron detection), Wi-Fi communications were chosen as the means to link the user's computer to the data. This will allow the user to be some distance away from the cosmic cube while it operates, as well as potentially allow more than one user to see what the cosmic cube sees.

All of the electronic components of the Cosmic Cube need a housing structure. The cube size is currently an estimation made on a 2.5" diameter circular sensor that is 6" tall, and the scintillator material being 4" on a side. The cube has two compartments, one which holds all of the electronics including the sensor, and other that holds the scintillator. The sensor will slide into a cylinder in the bottom compartment to help block out light, and the lens will be just high enough so that there will not be any unnecessary pressure from the weight of the scintillator on the lens.

To connect the cubes together, the system will have a cubby holes type design, where each cube has a slot it can slide into, and the systems can be expanded upon to add more cubes just by buying more sections and bolting them on.

The sensor (scintillator plus photo-detector) will require calibration. Radioactive isotopes can be used since they emit similar radiation. A gamma source with known electron voltage, such as Co-60 can be acquired for a reasonable cost and without the need for a special license. Since the scintillator material is given with known photons per electron voltage specification and Co-60 sources are reasonably calibrated, the resulting photons produced from a cosmic event can be compared to our calibration for use in determining what was detected. The calibration isotope will be left in place so that the cosmic cube can be periodically checked for proper operation.

Timing Processing Unit (or TPU) is a chip that will serve mainly as counter/timer to track the time of when the particle strikes the scintillator, to the degree of 100 nanoseconds. This is mainly because the current GPS that will be interface will not provide the timing accuracy needed for this project. In addition the TPU will also be responsible for to store of the timing data until called by the main microcontroller.

2.3 Subsystem Requirements

2.3.1 Scintillator

The function of the scintillator is to convert the cosmic radiation into light. As cosmic radiation enters the scintillator material, in the form of a subatomic shower of particles, scintillator atoms are bumped up to a higher energy level. When the scintillator atoms fall back to a lower energy level, they release a photon. These photons are proportional to the amount of energy absorbed by the scintillator of the cosmic event. Lead substitute sheeting will be used to create a mini shower when a cosmic ray hits the scintillator.

The type of scintillator chosen is EJ204, made by Elgen. It emits light in the 408nm range with a yield of 10,400 photons per 1MeV absorbed. The size of the scintillator is to be 10cm on each side. Shielding the scintillator from light will entail painting the scintillator with a material such as Teflon or Tyvek paint and then wrapped in Tyvek material.

2.3.2 Photo-Detector

The purpose of the photo-detector is to convert the photons produced in the scintillator by the cosmic ray shower into an electrical signal that can be measured. An MPPC (Multi Pixel Photon Counter) was chosen due to its specialty in counting individual photons. When a photon strikes a pixel in the MPPC, a pulse is produced. As multiple pixels are struck by multiple photons, the output pulses add together. As more energy is absorbed by the scintillator, the output pulse grows.

The MPPC chosen is the S10362-33-025C, made by Hamamatsu. It is a 14400 pixel MPPC with an active area of 3mm by 3mm. The MPPC requires a voltage of 70v to operate. It will interface with the scintillator through optical grease.

Since the output pulse of the MPPC is very small in amplitude and very short in length, the MPPC will require both an amplifier and a pulse stretcher. The amplifier will consist of simple OP-AMP set to for a gain of 100-1000 depending on the magnitude of the pulse produced by the scintillator and photo-detector combo. The pulse stretching will be done by a diode and capacitor. As the signal change from high to low, the capacitor will charge through the diode. Once the microcontroller has finished with the pulse, the microcontroller will be set to discharge the capacitor. Advanced testing of the scintillator + photo-detector will need to be done before the amplifier and pulse stretcher can be finalized.

2.3.3 Microcontroller/CPU

This microcontroller will be responsible for the interpretation of incoming signals, processing the data, formatting it and transporting the data to any computer. The Arduino interacts with the other components of the system and completes the following tasks:

1. Receives data from Photo-Detector through analog input pin.
2. Retrieve's Cosmic Particles timing data from the Timing Processing Unit (TPU) via Serial Peripheral Interface (SPI) Protocol interaction between the two chips for when the particle struck the scintillator.
3. Transfers all data via Arduino Wi-Fi-Shield to be wirelessly transmitted to the user's Computer.
    a. Time at which Cosmic Particle event occurred
    b. Magnitude of Energy for particle
    c. What Type of Particle
4. Controls Light Emitting Diodes (LEDs) for visual conformation of the type of particle that struck the scintillator material.

2.3.4 Global Position Systems (GPS)

The GPS will be responsible for sending incremental pulses to the TPU at a rate of 1 pulse per second, allowing the TPU to increase timing accuracy by counting the nanoseconds and microseconds between each incremental pulse.

2.3.5 Wi-Fi

The WIFI unit in this project is going to serve primarily as an interface to transport data from the Cosmic Cube's microcontroller to the user's computer.

2.3.6 Structure

The structure is the housing that encloses all of the parts of the Cosmic Cube. It is required to keep the components safe and protected from the environment. The portion of the sub-cube that contains the scintillator must have no light entering that area, while still having removable panels. The electronics being used need to be enclosed as much as possible within the sub-cube.

The sub-cubes must be able to be attached to other cubes or placed in an expandable structure.

2.3.7 Radioactive Isotope

The radioactive isotope will assist in testing and calibration of the Cosmic Cube's sensor (scintillator and photo-detector). Strontium 90 is the isotope that will be used. It is a beta emitter that emits a beta with energy of 546KeV and has a half-life of 28 years. The isotope source will be placed on the scintillator's lead plate and the output pulse will be measured on an oscilloscope.

2.3.8 Power Supply

The PSU (power supply unit) consists of a standard multiple output low voltage power supply and a high voltage variable power supply. The low voltage supply will provide 12DC volts for the Arduino UNO board, 5DC volts for the GPS shield, and 3.3DC volts for the WIFI shield. It will work off of 120VAC.

The high voltage power supply chosen is the A01, made by EMCO. This power supply can supply up to 100VDC at 10mA depending on the input voltage of 0-5VDC. This power supply is solely meant for the photo-detector. A voltage divider along with the 5v low voltage power supply will set the input voltage and thus the output voltage.

2.3.9 Timing Processing Unit (TPU)

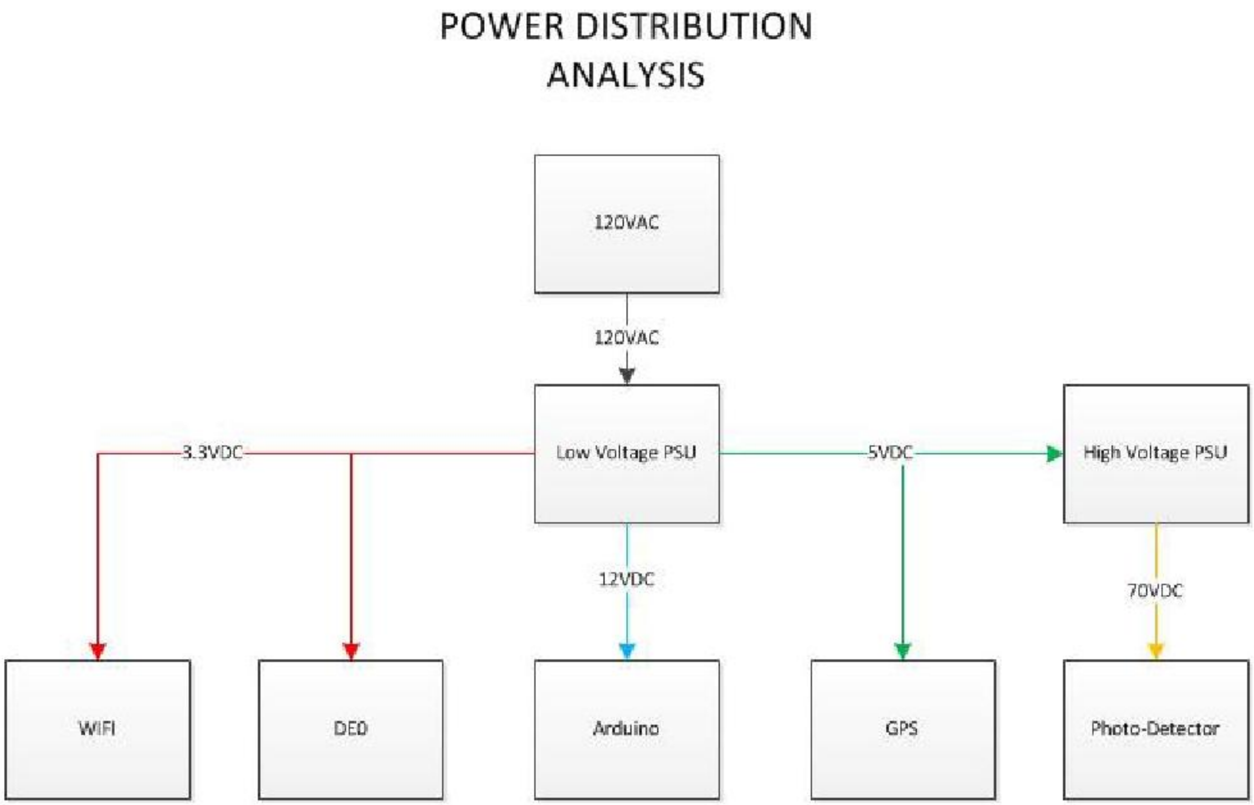
The TPU will be responsible for tracking the time at which cosmic particles strike the scintillator with precision timing. The TPU interacts with the GPS and Microcontroller of the system and will be able complete multiple task. Such task include be able to receive an analog signal from the microcontroller and the Arduino GPS Shield. The TPU will serve also as a timer/counter to count with 100 nanosecond accuracy. Store the time at which it receives an analog signal from the microcontroller to 100 nanosecond accuracy. Output the timing data back to the microcontroller.

2.4 Design Process

The design of the Cube has been completed with decisions made on which products to purchase and implement to complete the overall system. To be completed includes ordering of parts, programming subsystems, construction the cube housing, and assembling the final cube.

3 Design of Major Components/Subsystems

Contained within this section of the document will be the overview of the Cosmic Cube as well as details that specify the characteristics of each part needed before selection. Across each aspect of the components selection process at least 3 parts were compared in order re-verify that are selection for components were correct. The parts that was selected for this project can be found in the excel graph at the end of each section. With the team selection both is **highlighted in yellow**. The majority of the team's decisions for selection of components were based cost as it was very important aspect of this project, because this product is meant to be affordable for the average consumer.



3.1 Scintillator

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The EJ204 material was chosen because it is readily available, relatively easy to machine, and a sufficient amount was provided to us. Although it isn't the perfect choice, given our photo-detector's parameters, it is expected to be adequate.

TYPE	PHOTONS/MeV	WL(nm)	Light Output (%)
EJ204	10400	408	68
***EJ208**	**9200**	**435**	**60**
EJ200	10000	425	64

3.2 Photo-Detector

The purpose of the photo-detector is to convert the photons produced in the scintillator by the cosmic ray shower into an electrical signal that can be measured. An MPPC (Multi Pixel Photon Counter) was chosen due to its specialty in counting individual photons. When a photon strikes a pixel in the MPPC, a pulse is produced. As multiple pixels are struck by multiple photons, the output pulses add together. As more energy is absorbed by the scintillator, the output pulse grows.

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The MPPC chosen is the S10362-33-025C, made by Hamamatsu. It is a 14400 pixel MPPC with an active area of 3mm by 3mm. The MPPC requires a voltage of 70v to operate. It will interface with the scintillator through optical grease. It was chosen based on its large active area, high number of pixels, and it being provided to the group for free.

PART #	AREA (mm^2)	PEAK WL (nm)	PIXELS	COST($) S10362-33-025c
S10362-33-025c	9440	14400	323.00	
S10362-11-100U	1	440	100	144.00
***S10362-11-025U**	**1**	**440**	**1600**	**144.00**

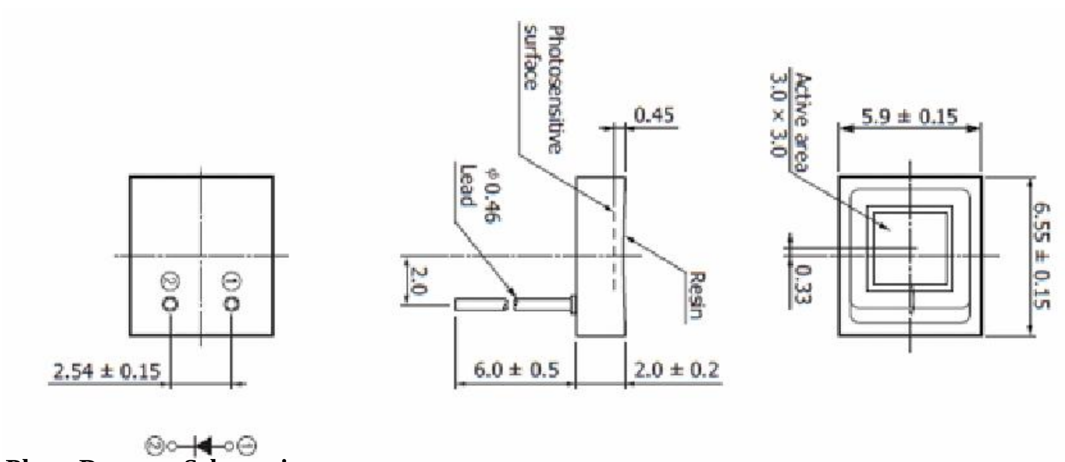


Photo Detector Schematic

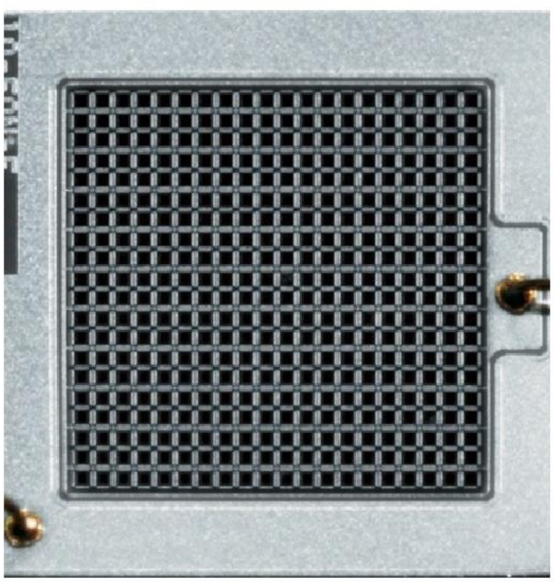
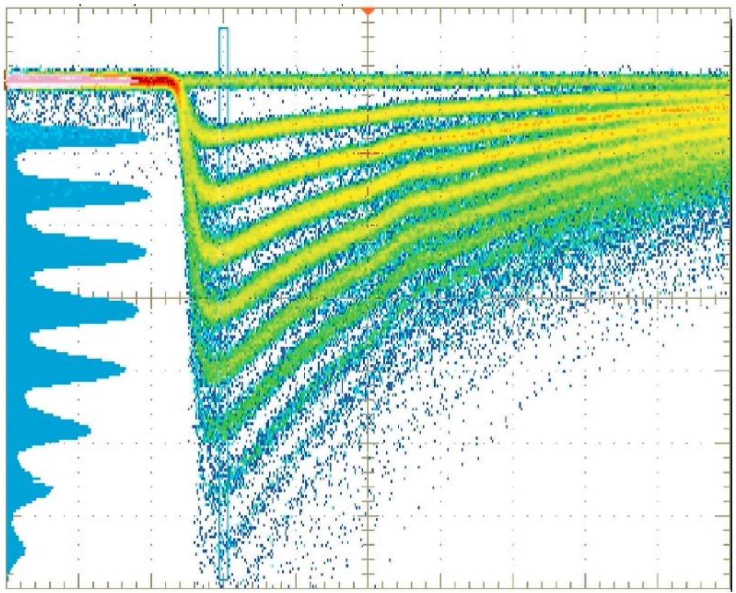


Image of sensor



S10362-11-025U Pulse waveform when using an amplifier (120 times)

3.3 Microcontroller/CPU

The microcontroller selected for use in the cosmic cube project is the Arduino Uno. A schematic of the Arduino Uno can be viewed in Figure 4. The Uno microcontroller is both affordable and can be easily powered via USB or power supply.

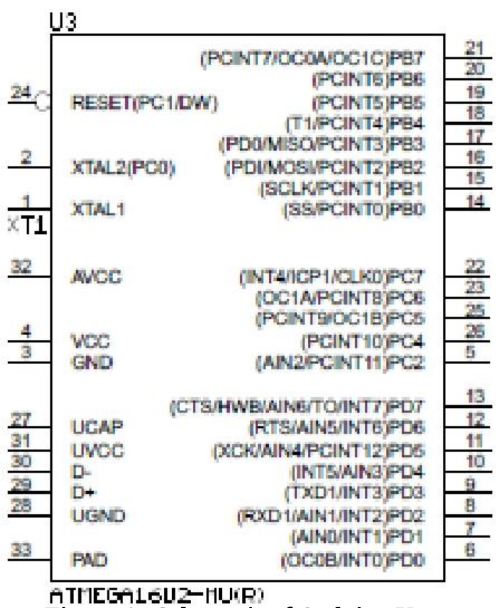


Figure 4 - Schematic of Arduino Uno

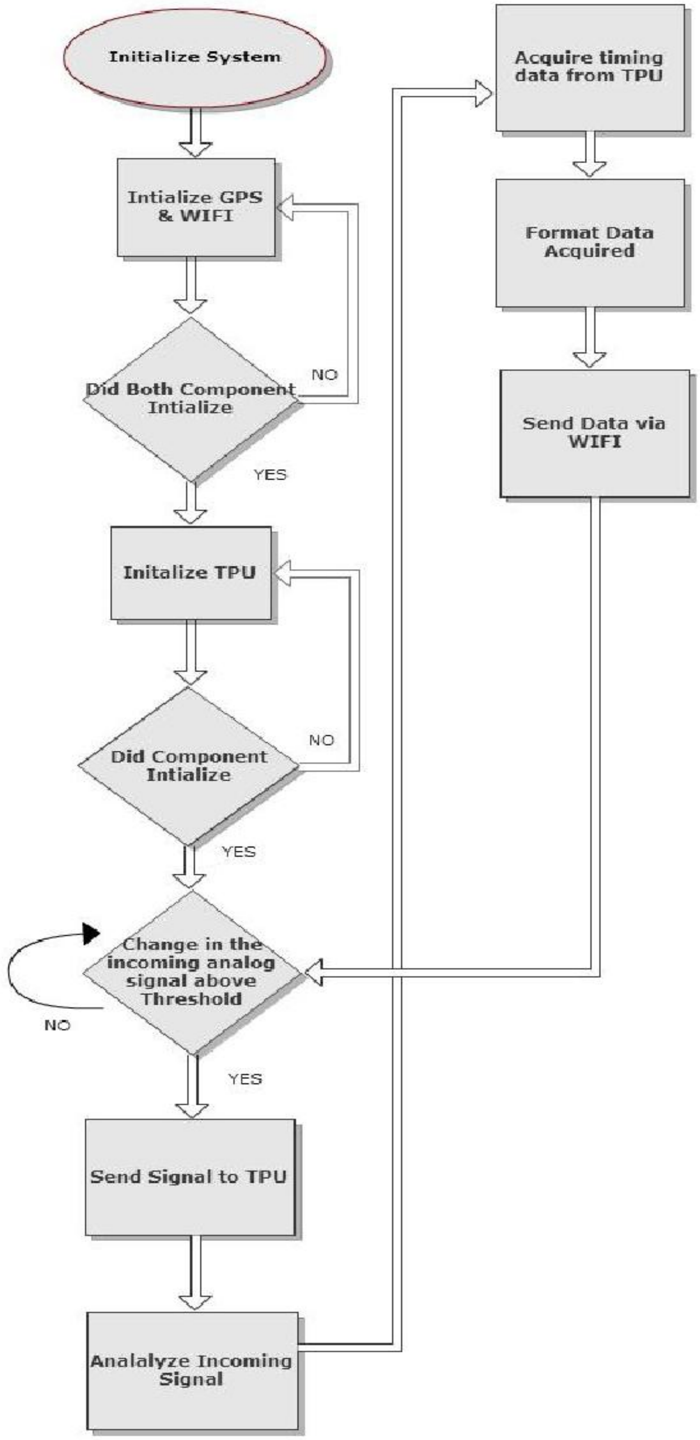
The following table shows the requirement and justification for a possible component selected for use:

Requirements:	**Justification:**
Clock speed under 100 nanoseconds	Multiple cubes collecting data in locations around the world must be able to keep precise timing data for cosmic particles detected.
At least 5 Digital Input/output Pins and 5 Analog Input Pins of Channels	Each Microcontroller will eventually be responsible for controlling multiple sub-cubes to correlate data
Price	This will eventually be a commercial product and needs to be affordable to the mass market
Memory	Enough memory to program multiple libraries, needed for interfacing with multiple components

The microcontroller evaluated for possible selection in this project range on memory size, number of inputs, price, etc. Below is a table that indicates both which three microcontrollers that was compared and the component that was choose. Ultimately, when selecting a microcontroller it came down to price because the main goal of this project is developing an affordable consumer product. The Arduino meets all requirements needed for this project the price is affordable not to hurt the budget of this project. It also has plenty of memory per the price of this chip and it has enough pins to allow control of the system with not only one sub- cube but the possible integration of additional sub-cubes.

Part	Clock Speed (ns)	# of Channels	Memory	Interrupts	Price ($)
Stratix III	2	272 I/O	144KB	Y	2,895.00
***Arduino UNO R3**	**63**	**14-D-I/O; 6 A-I**	**32KB**	**Y-External**	**29.95**
DAQ-2000	25	24-D-I/O; 4 A-I	-	Y	595.00

The risks for the Microcontroller/CPU are listed in Section 6.

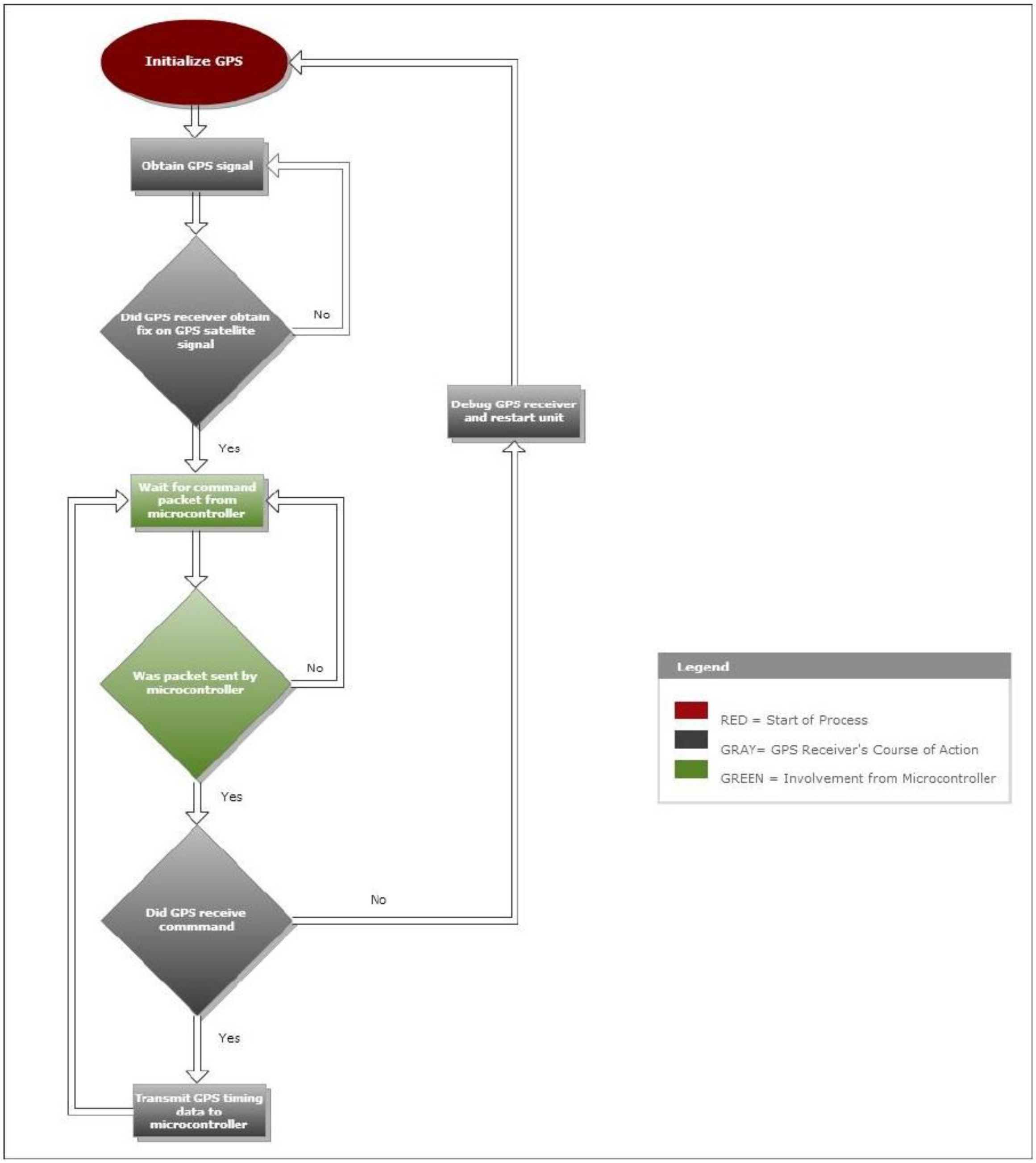

Initialize System
Intialize GPS & WIFI
Did Both Component Intialize
NO
YES
Initalize TPU
Did Component Intialize
NO
YES
Change in the incoming analog signal above Threshold
NO
YES
Send Signal to TPU
Analalyze Incoming Signal
Acquire timing data from TPU
Format Data Acquired
Send Data via WIFI

3.4 Global Position Systems (GPS)

The EM-406 GPS module and stackable headers will be soldered to the GPS shield. Once soldered the GPS shield will then be connected to the Arduino Mega 2560 via the stackable headers. The previous GPS module chosen for the design was the Resolution T GPS Timing module by Trimble. What was attractive about the Resolution T was its high timing accuracy of 15ns which was achieved by generating a PPS signal through the combination of using an on board 12.504 MHz oscillator and an algorithm to remove the error associated with matching the GPS signal with the closest clock edge of the signal generated from the oscillator. Ultimately what caused the Resolution T to be rejected was the ease of implementation of the GPS module with the existing components. The Resolution T had little to know documentation to provide a means to interface the unit with the microcontroller. The device could be purchased with an accompanying interfacing board which provided an AC/DC power supply adapter, USB port for interfacing with other components, and two types of external antennas needed for the GPS unit to be able to pick up signal from the GPS satellites. However, the cost of all these additional components was far too great and would surpass the budget given to the project team. The GPS Shield with GPS module EM-406 became the popular choice because the ease of interfacing it with the microcontroller, the price of the unit which was within our budget, and the many documentation as well as support on how to use and program the unit.

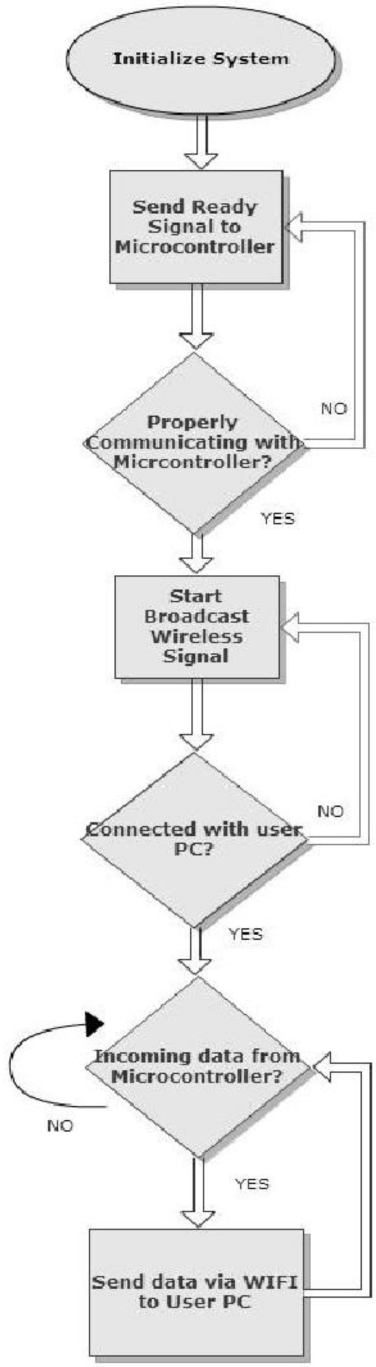
Requirements:	**Justification:**
Timing accuracy to at least 1 second	Needed for TPU to keep increased timing accuracy
Ease of interfacing	Much programming and calibration is needed for the project and if less time is required to program the GPS. More time can be allotted for other parts of the project.

The GPS module will need to be interfaced with the microcontroller and the power supply. The expectations of the power supply interface will be to supply the GPS unit with 5V DC which will be needed to operate the device. This voltage will need to be maintained through either time the GPS unit is to be operational. The expectations of the microcontroller interface are to have the microcontroller be able to receive data from the GPS as well as transmit data to the unit. The data sent to the microcontroller will provide real time tracking of incoming cosmic particles being observed by the cosmic cube. The data being sent to the GPS unit will be commands asking the unit to send particular timing data when needed to the microcontroller. Because the GPS receiver alone can only provide a timing resolution of 1us the timing data obtain from the GPS will be further refined by using the clock cycles provided by the microcontroller. This will allow the timing resolution to be in the nanosecond range of accuracy to GPS time. The GPS receiver can be programmed using C++ coding. Sample code can be found in the Appendix.



3.5 Wi-Fi

The Wi-Fi shield selected for use is the DEV-11287(Arduino WIFI Shield). A schematic for the Wi-Fi shield is shown in Figure 5.



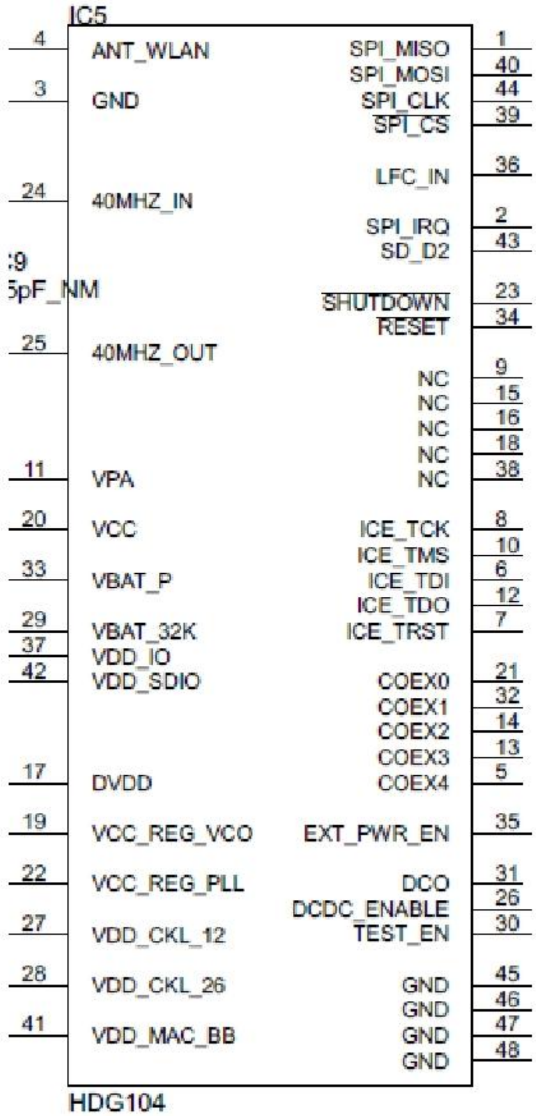


Figure 5 - Schematic of DEV-11287(Arduino WIFI Shield)

The following table shows the requirement and justification for a possible component selected for use:

Requirements:	**Justification:**
Range minimum of 25 ft.	The Cosmic Cube can be used outside within close proximity without needing to relocate the user's computer
Ease of Interface	If less time is required to program and interface, more time can be attributed to other parts of the project
Price	This will eventually be a commercial product and needs to be affordable to the mass market

The next table shows the decision matrix on why the DEV-11287(Arduino WIFI Shield) was chosen as compared to other similar parts.

Part#	Range(ft.)	Data Rate (kbps)	Cost ($)
XB24-Z7WIT-004	400	250	25.95
***DEV-11287(Arduino WIFI Shield)**	**50**	**100**	**84.95**
WRL-08665 (SparkFun)	300	250	22.95

Risks associated with the Wi-Fi are detailed in Section 6.

3.6 Structure

There will be two compartments inside of the sub-cube. The bottom compartment will house the electronics, and the body of the sensor. The top compartment will contain the lens of the sensor, the scintillator, and the deflection material. Aluminum L-brackets will be used to hold the scintillator and deflection material securely in position over the sensor lens. A rubber gasket will be used around the cube edges to ensure that no light enters the top compartment and give false readings. The top compartment will be made of 3/16" Aluminum, and bolted together using #2- 56 bolts that are 5/8" deep. The bottom compartment of the cube will be made of clear 3/16" Plexiglas with the same bolt size as the top compartment. Having the electronics in a clear enclosure will have an appealing look to consumers since they can then see the "brains" of the cube. In the bottom portion of the cube, there will be either a small container holding the sensor in the center, or gasket sealant will be used to hold the sensor in place and block out light.
Shelves, as well as wire holes will be added into the bottom compartment once the amount and size of the electronics are determined. The sub-cube sides are as symmetric as possible to increase the ease of manufacturability and assembly. Since everything will be bolted together, a consumer could make new parts to enhance or alter the cube to better fit their specific needs.

The sub-cubes will attach to each other through a cubby-hole type design. The cubes will individually slide onto a shelf that can hold one row of three cubes. These sections can then be bolted to the side or on top of another section in order to add more cubes. The current design is to allow for a total of 27 sub-cubes in a "cubic" shape; however more sub-structure sections can still be added, but it will not make the cube shape.

The current sub-cube design is 10 inches on a side. The top compartment is 4 inches tall, while the bottom side is 6 inches tall. This can be scaled up if required to make more room for all of the electronics, or if possible scaled down to make the cube and sub-cube as small as possible.

Possible Ray Scatter Materials		
Material	**Density (g/cm^3)**	**Price($/ounce)**
Lead	11.36	$0.06
Silver	10.49	$34.60
Bismuth	9.78	$1.06
*Ecomass Compound	11.0	N/A
Possible Cube Materials (12x12 Plate, 0.25" Thick)		
Material	**Weight/Ft^2 (lbs)**	**Price ($)**
*Plastic Acetal	1.8126	$27.58
*Al 6061	3.528	$28.54
Stainless Steal	10.322	$96.11

3.7 Radioactive Isotope

The radioactive isotope will assist in testing and calibration of the Cosmic Cube's sensor (scintillator + photo-detector). Strontium 90 is the isotope that will be used. It is a beta emitter that emits a beta with energy of 546KeV and has a half-life of 28 years. The isotope source will be placed on the scintillator's lead plate and the output pulse will be measured on an oscilloscope. Strontium 90 was chosen because the beta energy is more likely to be absorbed than a gamma emitter.

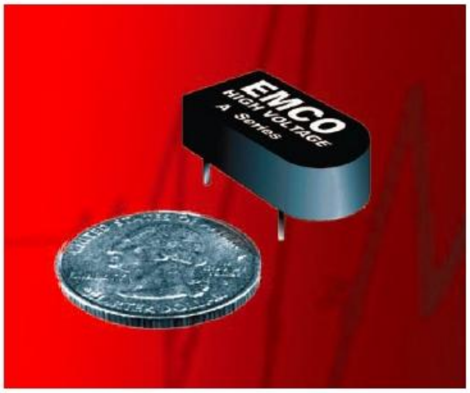
Isotope	Energy(KeV)	Half-Life (years)
***Co-60**	**1173.2, 1332.5**	**5.27**
Cs-137	661	30.1
Eu-152	1408	13.5

3.8 Power Supply

The PSU (power supply unit) consists of a standard multiple output low voltage power supply and a high voltage variable power supply. The low voltage supply will provide 12DC volts for the Arduino UNO board, 5DC volts for the GPS shield, and 3.3DC volts for the WIFI shield. It will work off of 120VAC.

The high voltage power supply chosen is the A01, made by EMCO. This power supply can supply up to 100VDC at 10mA depending on the input voltage of 0-5VDC. This power supply is solely meant for the photo-detector. A voltage divider along with the 5v low voltage power supply will set the input voltage and thus the output voltage.

The low voltage power supply was chosen because it has the proper voltages for all of the main components, minus the photo-detector. The high voltage power supply was chosen based on its output voltage being ideal for the photo-detector as well as its ability to be controlled viasimple means.

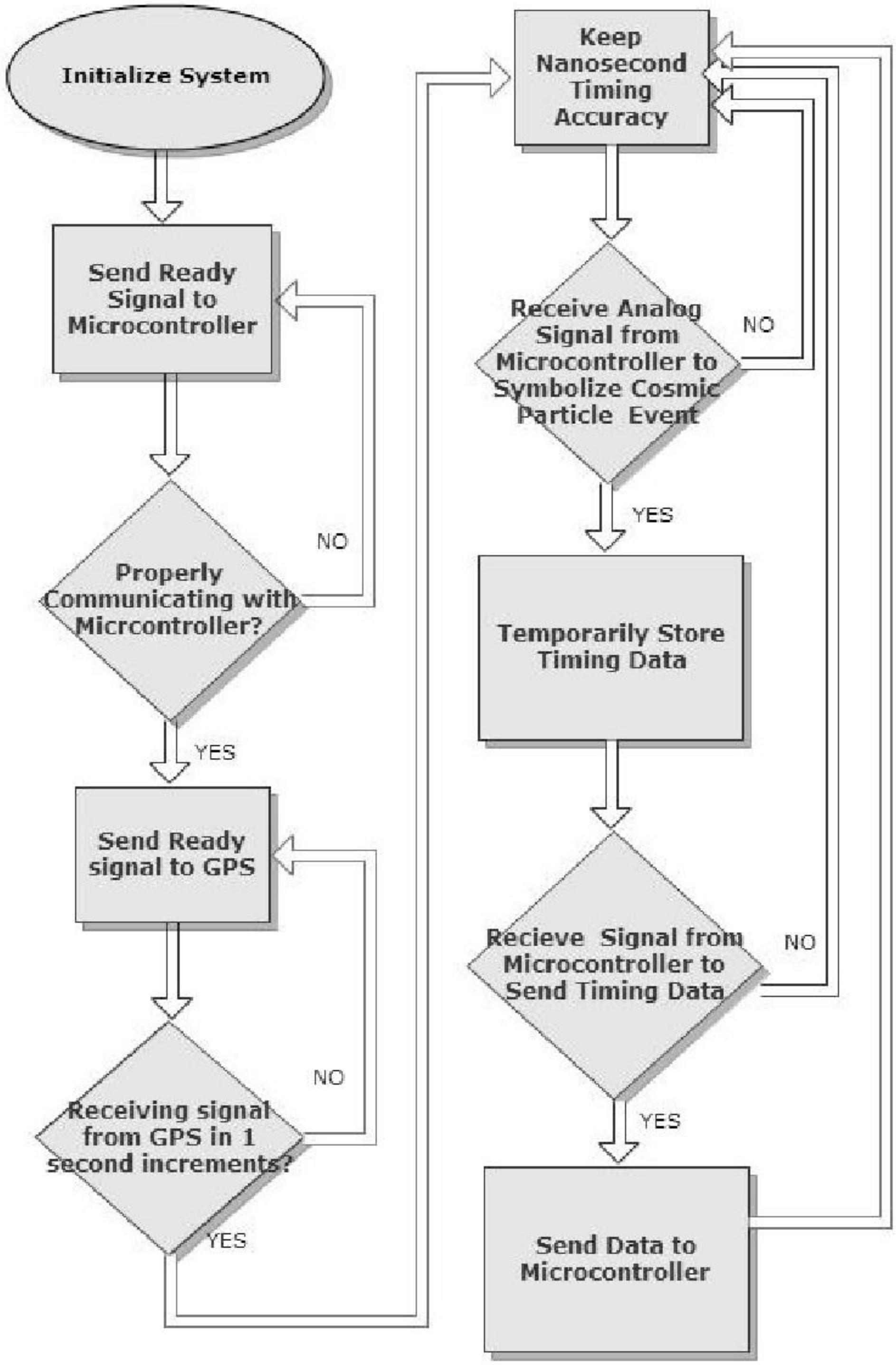


3.9 Timing Processing Unit (TPU)

The TPU was chosen late in the component selection process for the Cosmic Cube project and therefore was not compared with two other possibilities for TPU chips. However, the chip was nevertheless still researched, evaluated and approved by an advisor.

This chip like all components that were selected for this project it had to meet the criterion in order to be selected. The TPU had the following requirements/justification to meet:

Requirements:	**Justification:**
Clock speed under 100 nanoseconds	Multiple cubes collecting data in locations around the world must be able to keep precise timing data for cosmic particles detected.
At least 5 Digital Input/output Pins and 5 Analog Input Pins of Channels	Each Microcontroller will eventually be responsible for controlling multiple sub-cubes to correlate data
Price	This will eventually be a commercial product and needs to be affordable to the mass market
Memory	Enough memory to program multiple libraries, needed for interfacing with multiple components


Initialize System
Send Ready Signal to Microcontroller
Properly Communicating with Micrcontroller?
NO
YES
Send Ready signal to GPS
Receiving signal from GPS in 1 second increments?
NO
YES
Keep Nanosecond Timing Accuracy
Receive Analog Signal from Microcontroller to Symbolize Cosmic Particle Event
NO
YES
Temporarily Store Timing Data
Recieve Signal from Microcontroller to Send Timing Data
NO
YES
Send Data to Microcontroller

4 Schedule

The schedule for the project is located in the Appendix.

5 Budget Estimate

	Total Hours	Hourly Rate	Total
Personnel	(31 weeks)		
Matthew Gibson (EE)	372	$30.00	$11,160.00
Cole David Gray (ME)	372	$30.00	$11,160.00
Crystal Hill (ME)	372	$30.00	$11,160.00
Don Lundi (EE)	372	$30.00	$11,160.00
Kenneth Spradley (EE)	372	$30.00	$11,160.00
		Subtotal:	$11,600.00
		Fringe Benefits (29%)	$16,182.00
		Total Personnel Cost:	**$71,982.00**

Expenses	Cost	Quantity	Total
Scintillator Material (EJ-204)	$500.00	1	$500.00
Photo Detector (S10362-11-025U)	$144.00	1	$144.00
Microcontroller (Arudino Mega 2560 R3)	$58.95	1	$58.95
Wi-Fi Shield (Arduino DEV - 11287)	$84.95	1	$84.95
GPS (Trimble Receiver 52664-45)	$108.72	1	$108.72
Radioactive Isotope (Cobalt 60)	$79.00	1	$79.00
LEDs	$6.58	1	$6.58
Plexiglass (3/16"x12"x48")	$24.99	1	$24.99
Aluminum Plate (3/16"X12"X48)	$47.65	1	$47.65
Lead Plate (1/8"X12"X12")	$47.91	1	$47.91
Angle Aluminum (1/8"X4')	$9.69	1	$9.69
DE0 Nano (Altera)	$86.25	1	$86.25
LED - RGB Diffused Common Cathode			
(COM-09264)	$1.95	5	$9.75
Jumper Wire F/F (PRT-08430) - Pack of 10	$3.95	2	$7.90
		Total Expenses	**$1,254.19**

Overhead Costs	
Total Direct Costs (Personnel+Expenses)	$73,236.19
Overhead Costs (45% of Direct)	$32,956.29
Equipment	0
Total Project Cost	**106,192.48**

6 Overall Risk Assessment

The cosmic cube segments are designed to be operated either indoor or outdoor between temperature ranges of 27-100 degrees Fahrenheit ((-3)-38 degrees Celsius). The segments will be resistant to water. However, they will not be water proof. Therefore the cubes should never be left outdoors if it is raining. The scintillator material incased within the device is very delicate. The segments should remain fairly stable and the user will need to avoid situations where the cube will be excessively shaken as this may lead to the scintillator fracturing or even breaking.

6.1. Technical Risks

Title of Risk	Description	Probability	Consequence	Strategy
Scintillator Polishing Inadequate	Sanding and polishing job is inadequate resulting in photon scattering that prevents the photo-detector from capturing the photons	Low	"Severe" Resulting in photon scattering that prevents the photo-detector form capturing the photons	Re-sand and polish until complete
Dropping the scintillator	Dropping the scintillator will cause it to crack	Medium	"Devastating" Unreliable scintillator for detecting of light energy deposited by particles in scintillator	To prevent this from happening the scintillator is being stored with bubble wrap
Inadequate reflective paint	Paint chosen is not reflective enough to be useful to keep outside light from entering the scintillator thus accidently detected by photo detector	Medium	"Severe" Outside light accidently detected by photo-diode giving false results	To ensure this risk is minimal, the paint chosen will be of a type commonly used by others: Tyvek or Teflon white paint
Contaminated photo-detector	Dust particles and skin cells could cover or contaminate the sensor	Medium	"Moderate" Low amounts of dust will only lower efficiency rather than completely preventing functions	To prevent contamination, the photo-detector will only be removed from its packaging when ready to connect to scintillator
Wrong voltage for phto-detector	The voltage is too low or too high	Low	"Severe" If the voltage is too low the photo-diode will not function. If the voltage is too high, the photo-detector will be damaged	To prevent under and over voltage, a precision power supply will be used

Incorrect Isotope calibration	Isotope is not positioned correctly to allow for maximum exposure of the scintillator	Low	"Moderate" Incorrect Calibration	To ensure the scintillator gets maximum exposure of the isotope, the source itself will be placed directly on the light shielded scintillator
Isotope Radiation Exposure	People exposed while testing and calibrating cosmic cube	Low	Unknown Consequences	To prevent harm to the operator, a low activity source was chosen and won't be accessible to the user once the Cosmic Cube is fully assembled
Low voltage power supply underpowered	-	Low	"Severe" Many of the components won't run correctly	To minimize this risk, a power supply was chosen with more than sufficient power capacity
Low voltage power supply voltage is too high	-	Low	"Moderate" Power supply voltage is too high, it may damage the components	The power supply was chosen such that the output voltages are matched to the components. A voltage meter will also be used to verify voltages before connecting components.
High voltage power supply voltage is too high or too low	-	Moderate	"Moderate" Could break photo-detector	Before connecting the photo-detector, the high voltage power supply voltage will be checked with a voltage meter
Microcontroller Memory Size	Memory size is too small	Moderate	Could take much time to reduce code in order to work properly	By selecting parts that were easily interfacing it allows more efficient use of time and less program

Small bolts insufficient strength	The small bolts are not strong enough to make the structure secure and strong enough to withstand small impacts	Low	"Moderate" Structure could break on impact	Increase Plexiglas width so bigger bolt can be used that has more strength
Plexiglas cracking	The Plexiglas cracks during drilling and tapping process	Moderate	"Moderate" Plexiglas would crack	Increase Plexiglas width, so it is less likely for it to crack because it has more strength
Timing Unsynchronized	The GPS module provides times that are lagging that of the signal received by the GPS satellites	High	"Minor" Nanosecond timing is no longer accurate	Issue can be corrected by editing the coding for the GPS unit.
Unable to interface GPS	Unable to interface with microcontroller	Low	"Minor"	The GPS Shield was chosen because it can be easily integrated with the chosen microcontroller.

6.2 Schedule Risks

6.2.1.1 Schedule Risk 1: <Programming the Wi-Fi>

Description

The Wi-Fi may take some additional programming which could push back the completion of this portion of the project.

Probability: Low
The low probability was decided because research done on the schematics of the Wi-Fi has helped to prove that the chance of additional programming will not be that great.

Consequences: Minor

The consequences of the Wi-Fi not being completed are not that high because it is one of the last components to be completed so it will not butt into time that is allotted for other tasks. Also, this is not a requirement set by the project, but an added feature.

Strategy

The plan to manage this risk is if needed more people will be added to the task of programming the Wi-Fi so that the time taken to complete it is lessened.

6.2.2 Schedule Risk 2: Programming the Microcontroller

Description

The microcontroller may take some additional programming or a setback may be hit while the programming is being completed which could push back the completion date of this portion of the project.

Probability: Low
The low probability was decided because research has been done on the microcontroller.

Consequences: Severe

The consequences of the microcontroller not being programmed on time will hurt the rest of the project because if it is not completed the rest of the components cannot interface.
Strategy

A preliminary plan on how to program the microcontroller is starting to take place and will help to prevent the actual time to program the controller going over schedule.

6.3 Budget Risks

6.3.1 Budget Risk 1: Going over budget on expenses

Description

Purchasing all of the required components for the project has proven to be over the $750 allotment.

Probability: Very High

The parts to be purchased have been compiled and the price is over the budget.

Consequences: Moderate

If more funding is not found, the consequences could be that all of the parts could not be purchased to complete the project.

Strategy
Maximize the budget.

7 Qualifications and Responsibilities of Team Members

7.1 Qualifications of Matthew Gibson

Matt Gibson is a Senior ECE student. He has built electrical projects all his life relating to power and energy. He is able to solder, design circuit boards using CAD, troubleshoot using oscilloscopes and digital multi-meters as well as utilize design software such as AutoCAD. Matt Gibson has held a job at a local utility for nearly 1.5 years working as an Engineering Intern. He has chosen power as a concentration and plans to go into either the utilities or power plants. Matt Gibson has taken charge of the sensor (scintillator and photo-detector), power supply, and radiation source. Matt Gibson also has earned a math minor.

Responsibilities:
Lead Electrical-Computer Engineer (ECE)
Scintillator, Photo-detector, Radioactive Isotope

7.2 Qualifications of Cole Gray

Cole Gray is a senior in Mechanical Engineering with a minor in physics and mathematics, and is in the Dynamics Systems and Controls track. Cole has always tinkered with things, taking them apart to see how they work, and making things from scratch, which requires good problem solving skills. He recently built a 350 cubic inch motor from the bare blocks and converted into a 1984 Toyota Pickup. He is efficient at working in a team and getting his designated parts done on time, while also giving suggestions on how to better the system. Cole is innovative, and can think outside the box when needed when designing a new product. He can solve problems as they arise in a design, as well as foresee possible future problems with current designs. Cole will spend as much time as required to get a job done right, as opposed to rushing to finish on time with an unsafe product.

Responsibilities:
Lead Mechanical Engineer (ME)
Structure

7.3 Qualifications of Crystal Hill

Crystal Hill is a Mechanical Engineering major. Her main duty is to manage the budget for the project. The qualifications that she has for this position include experience working as a bookkeeper for the Pfeiffer Law Group, where she has been employed for the past 1.5 years. Crystal has also successfully completed courses in Materials Science, Mechanics of Materials, and Engineering Design Methods. These courses are relevant to material selection, structural design, as well as advanced techniques in the engineering design process.

Responsibilities:
Financial Advisor
Structure

7.4 Qualifications of Don Lundi

Don Lundi is an Electrical Engineering student at Florida State University. Don has completed related courses dealing in computer architecture, intro into field programmable logic devices, and micro based system design. Don has always shown interest in the field of mathematics at an early age and expanding his educational pursuits into engineering allowed him to apply his love of math into practical facets of his life.

Responsibilities:
Electrical-Computer Engineer (ECE) Assistant
GPS

7.5 Qualifications of Kenneth Spradley

Kenneth Spradley a senior electrical engineering student at Florida A&M University (FAMU) slated to graduate in spring 2013. He will serve as the Cosmic Cube's both Team Lead and Lead Programmer. Kenneth has worked as the lead programmer in the Title III Research at FAMU for Dual Autonomous Land & Air Security and Surveillance. He also interned for Ford in the summer of 2012 where he managed a team of engineers to conduct a Gage Repeatability & Reproducibility on Switch Feel Equipment to confirm the validity if the data received from this extremely sensitive equipment. His extensive studies at the FAMU-FSU College of Engineering include numerous classes that can be applied to the project Digital Logic, Microprocessors, Field Programmable Logic Devices (FPLD) and Digital Communication.

Responsibilities:
Team Leader
Lead Programmer
Microcontroller, Wi-Fi, TPU, Power Supply

8 References

[1] ELGEN-Scintillator specifications
[2] Hamamatsu-Photo-Detectors
[3] http://hardhack.org.au/book/export/html/2 Cosmic Ray Detectors
[4] http://www.arduino.cc/
[5] Burr, K.C.; Gin-Chung Wang; , "Scintillation detection using 3 mm × 3 mm silicon photomultipliers," Nuclear Science Symposium Conference Record, 2007. NSS '07. IEEE , vol.2, no., pp.975-982, Oct. 26 2007-Nov. 3 2007 doi: 10.1109/NSSMIC.2007.4437179
URL: http://ieeexplore.ieee.org.proxy.lib.fsu.edu/stamp/stamp.jsp?tp=&arnumber=4437179&isnumber=4437154
[6] http://www.onlinemetals.com/merchant.cfm?pid=724&step=4&showunits=inches&id=233&top_cat=1http://www.indexmundi.com/commodities/?commodity=lead
[7] http://www.kjmagnetics.com/proddetail.asp?prod=D61AD-P
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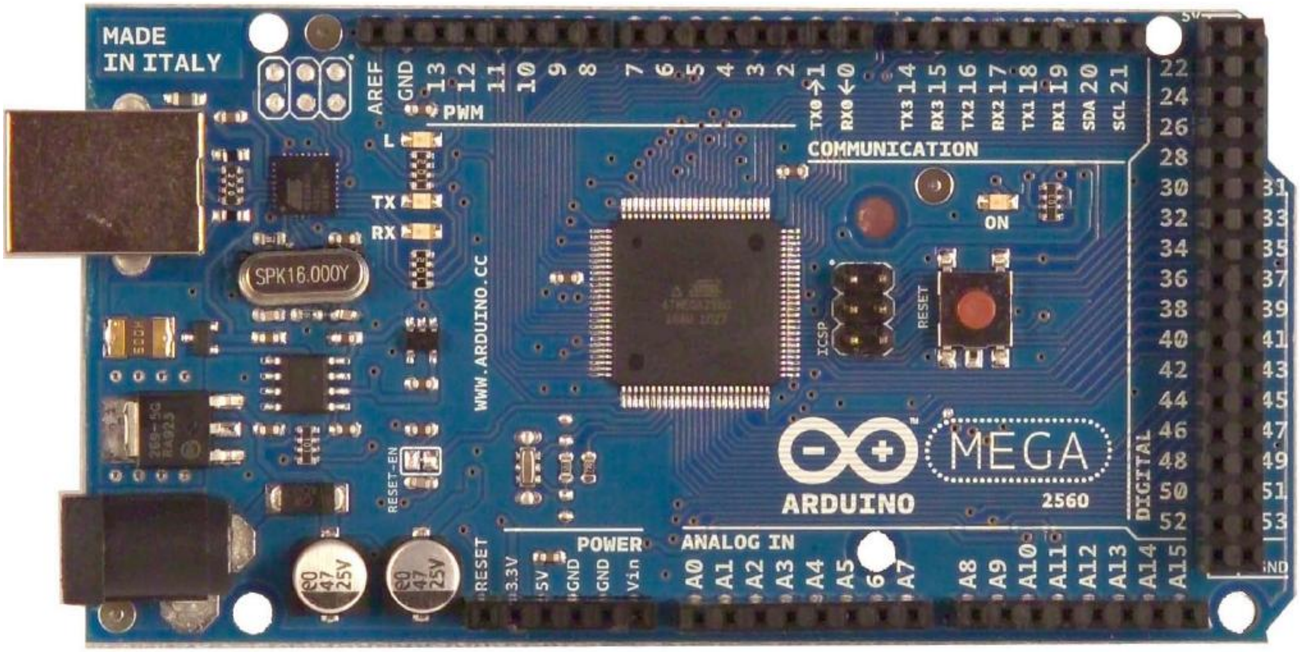
[10] http://trl.trimble.com/docushare/dsweb/Get/Document-550777/
[11] http://trl.trimble.com/docushare/dsweb/Get/Document-221342/ResolutionT_UG_2B_54655-05-ENG.pdf

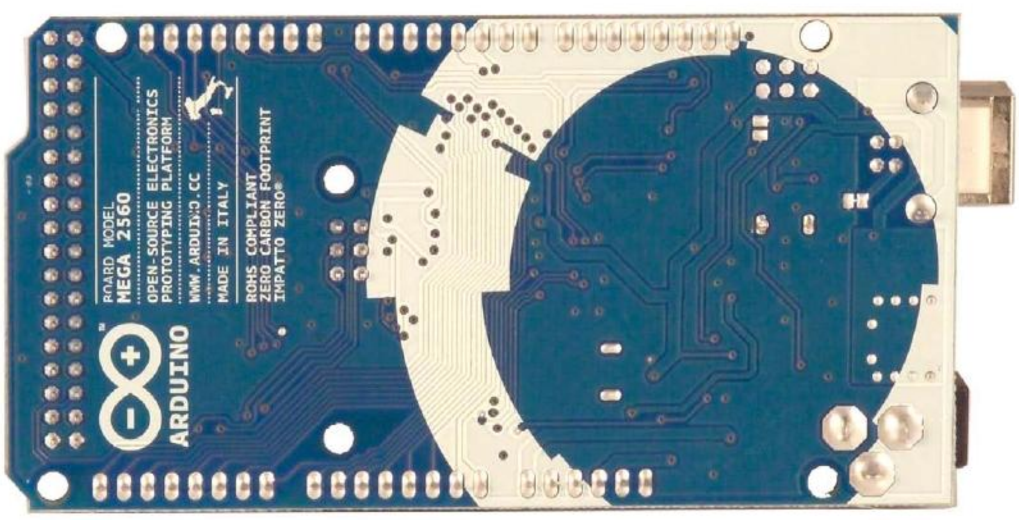
9 Appendices

```
'-----------------------------
'Get and display the data
'-----------------------------
func Dispit()

  dim tstr as string
  dim newtime as string
  dim oldgpstime as string

  FormMenu(0,0,0,"")
  FormButton(Disp_Start,-1,-1,-1,-1,"Abort")

 'First Open the File
  if FileOpen(1,gfname,Open) = 0 then
    msgbox("Unable to open file: "+gfname,0,"Open File")
    FormMenu(0,0,1,"")
    FormButton(Disp_Start,-1,-1,-1,-1,"Start")
    exit()
  endif

'===========================================================
'----- Main Data Display Loop ------------------------------
loop:

  if FormButton(Disp_Start,0) > 0 then
   FileClose(1)
   FormMenu(0,0,1,"")
   FormButton(Disp_Start,-1,-1,-1,-1,"Start")
   exit()
  endif


  if FileEOF(1) = 1 then
    FileClose(1)
    Print "End of Data"
    FormMenu(0,0,1,"")
    FormButton(Disp_Start,-1,-1,-1,-1,"Start")
    exit()
  endif

'----- Read a Line of data from Log File ----------
 procNMEA(FileReadLine(1))

'----- If we get a GGA message lets update the display
 strif NMEAmsg = "GGA" then
    newtime=converttime(GGA_UTCTime,-5))
    FormLabel(Disp_time,-1,-1,-1,-1,newtime)
    Formlabel(Disp_Fix,-1,-1,-1,-1,GGA_FIXtxt)
    Formlabel(Disp_mode,-1,-1,-1,-1,GSA_SATMODE)
    Formlabel(Disp_sats,-1,-1,-1,-1,GSA_SATCOUNT)
    GSV_NOM=0
    GSV_MSG=0

    if GGA_Fix <> 0 then
       Formlabel(Disp_Longitude,-1,-1,-1,-1,GGA_Longitude+GGA_EW)
       Formlabel(Disp_Latitude,-1,-1,-1,-1,GGA_Latitude+GGA_NS)
       Formlabel(Disp_Alt,-1,-1,-1,-1,GGA_AltValue+GGA_AltUnit)
       Formlabel(Disp_Course,-1,-1,-1,-1,RMC_COG)
       Formlabel(Disp_Speed,-1,-1,-1,-1,Format(float(RMC_SOG * 1.1508),".0")+" mph")
     else
       Formlabel(Disp_Longitude,-1,-1,-1,-1,"")
       Formlabel(Disp_Latitude,-1,-1,-1,-1,"")
       Formlabel(Disp_Alt,-1,-1,-1,-1,"")
       Formlabel(Disp_Course,-1,-1,-1,-1,"")
       Formlabel(Disp_Speed,-1,-1,-1,-1,"")
     endif
```

Example GPS Code

Arduino Mega 2560





Overview

The Arduino Mega 2560 is a microcontroller board based on the ATmega2560 (datasheet). It has 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Mega is compatible with most shields designed for the Arduino Duemilanove or Diecimila.

Schematic & Reference Design

EAGLE files: arduino-mega2560-reference-design.zip
Schematic: arduino-mega2560-schematic.pdf

Summary

Microcontroller ATmega2560
Operating Voltage 5V
Input Voltage (recommended) 7-12V
Input Voltage (limits)
Digital I/O Pins
Analog Input Pins
DC Current per I/O Pin DC Current for 3.3V Pin
Flash Memory
SRAM
EEPROM
Clock Speed

Power

6-20V
54 (of which 14 provide PWM output)
16
40 mA 50 mA
256 KB of which 8 KB used by bootloader
8 KB 4 KB
16 MHz
The Arduino Mega can be powered via the USB connection or with an external power supply. The power source is selected automatically.

External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the Gnd and Vin pin headers of the POWER connector.The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts. The Mega2560 differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega8U2 programmed as a USB-to-serial converter.

The power pins are as follows:

- **VIN -** The input voltage to the Arduino board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin.

- **5V -** The regulated power supply used to power the microcontroller and other components on the board. This can come either from VIN via an on-board regulator, or be supplied by USB or another regulated 5V supply.

- **3V3 –** A 3.3 volt supply generated by the on-board regulator. Maximum current draw is 50 mA.

- **GND -** Ground pins.

Memory

The ATmega2560 has 256 KB of flash memory for storing code (of which 8 KB is used for the bootloader), 8 KB of SRAM and 4 KB of EEPROM (which can be read and written with the EEPROM library).

Input and Output

Each of the 54 digital pins on the Mega can be used as an input or output, using pinMode(), digitalWrite(), and digitalRead() functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 kOhms. In addition, some pins have specialized functions:

Serial: 0 (RX) and 1 (TX); Serial 1: 19 (RX) and 18 (TX); Serial 2: 17 (RX) and 16 (TX); Serial 3: 15 (RX) and 14 (TX). Used to receive (RX) and transmit (TX) TTL serial data. Pins 0 and 1 are also connected to the corresponding pins of the ATmega8U2 USB-to-TTL Serial chip.

External Interrupts: 2 (interrupt 0), 3 (interrupt 1), 18 (interrupt 5), 19 (interrupt 4), 20 (interrupt 3), and 21 (interrupt 2). These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value. See the attachInterrupt() function for details.

PWM: 0 to 13. Provide 8-bit PWM output with the analogWrite() function.

SPI: 50 (MISO), 51 (MOSI), 52 (SCK), 53 (SS). These pins support SPI communication using the SPI library. The SPI pins are also broken out on the ICSP header, which is physically compatible with the Uno, Duemilanove and Diecimila.

LED: 13. There is a built-in LED connected to digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off.

I^2C: 20 (SDA) and 21 (SCL). Support I^2C (TWI) communication using the Wire library (documentation on the Wiring website). Note that these pins are not in the same location as the

I2C pins on the Duemilanove or Diecimila. The Mega2560 has 16 analog inputs, each of which provides 10 bits of resolution (i.e. 1024 different values). By default they measure from ground to 5 volts, though is it possible to change the upper end of their range using the AREF pin and analogReference() function.

There are a couple of other pins on the board:

AREF. Reference voltage for the analog inputs. Used with analogReference().

Reset. Bring this line LOW to reset the microcontroller. It is typically used to add a reset button to shields which block the one on the board.

Communication

The Arduino Mega2560 has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega2560 provides four hardware UARTs for TTL (5V) serial communication. An ATmega8U2 on the board channels one of these over USB and provides a virtual com port to software on the computer (Windows machines will need a .inf file, but OSX and Linux machines will recognize the board as a COM port automatically. The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the board. The RX and
TX LEDs on the board will flash when data is being transmitted via the ATmega8U2 chip and USB connection to the computer (but not for serial communication on pins 0 and 1).

A SoftwareSerial library allows for serial communication on any of the Mega2560's digital pins.

The ATmega2560 also supports I2C (TWI) and SPI communication. The Arduino software includes a Wire library to simplify use of the I2C bus; see the documentation on the Wiring website for details. For SPI communication, use the SPI library.

Programming

The Arduino Mega can be programmed with the Arduino software (download). For details, see the reference and tutorials.

The ATmega2560 on the Arduino Mega comes preburned with a bootloader that allows you to upload new code to it without the use of an external hardware programmer. It communicates using the original STK500 protocol (reference, C header files).

You can also bypass the bootloader and program the microcontroller through the ICSP (In-Circuit Serial Programming) header; see these instructions for details.

The ATmega8U2 firmware source code is available in the Arduino repository. The ATmega8U2 is loaded with a DFU bootloader, which can be activated by connecting the solder jumper on the back of the board (near the map of Italy) and then resetting the 8U2. You can then use Atmel's FLIP software (Windows) or the DFU programmer (Mac OS X and Linux) to load a new firmware. Or you can use the ISP header with an external programmer (overwriting the DFU bootloader). See this user-contributed tutorial for more information.

Automatic (Software) Reset

Rather than requiring a physical press of the reset button before an upload, the Arduino Mega2560 is designed in a way that allows it to be reset by software running on a connected computer. One of the hardware flow control lines (DTR) of the ATmega8U2 is connected to the reset line of the ATmega2560 via a 100 nanofarad capacitor. When this line is asserted (taken low), the reset line drops long enough to reset the chip. The Arduino software uses this capability to allow you to upload code by simply pressing the upload button in the Arduino environment. This means that the bootloader can have a shorter timeout, as the lowering of DTR can be well-coordinated with the start of the upload.

This setup has other implications. When the Mega2560 is connected to either a computer running Mac OS X or Linux, it resets each time a connection is made to it from software (via USB). For the following half-second or so, the bootloader is running on the Mega2560. While it is programmed to ignore malformed data (i.e. anything besides an upload of new code), it will intercept the first few bytes of data sent to the board after a connection is opened. If a sketch running on the board receives one-time configuration or other data when it first starts, make sure that the software with which it communicates waits a second after opening the connection and before sending this data.

The Mega2560 contains a trace that can be cut to disable the auto-reset. The pads on either side of the trace can be soldered together to re-enable it. It's labeled "RESET-EN". You may also be able to disable the auto-reset by connecting a 110 ohm resistor from 5V to the reset line; see this forum thread for details.

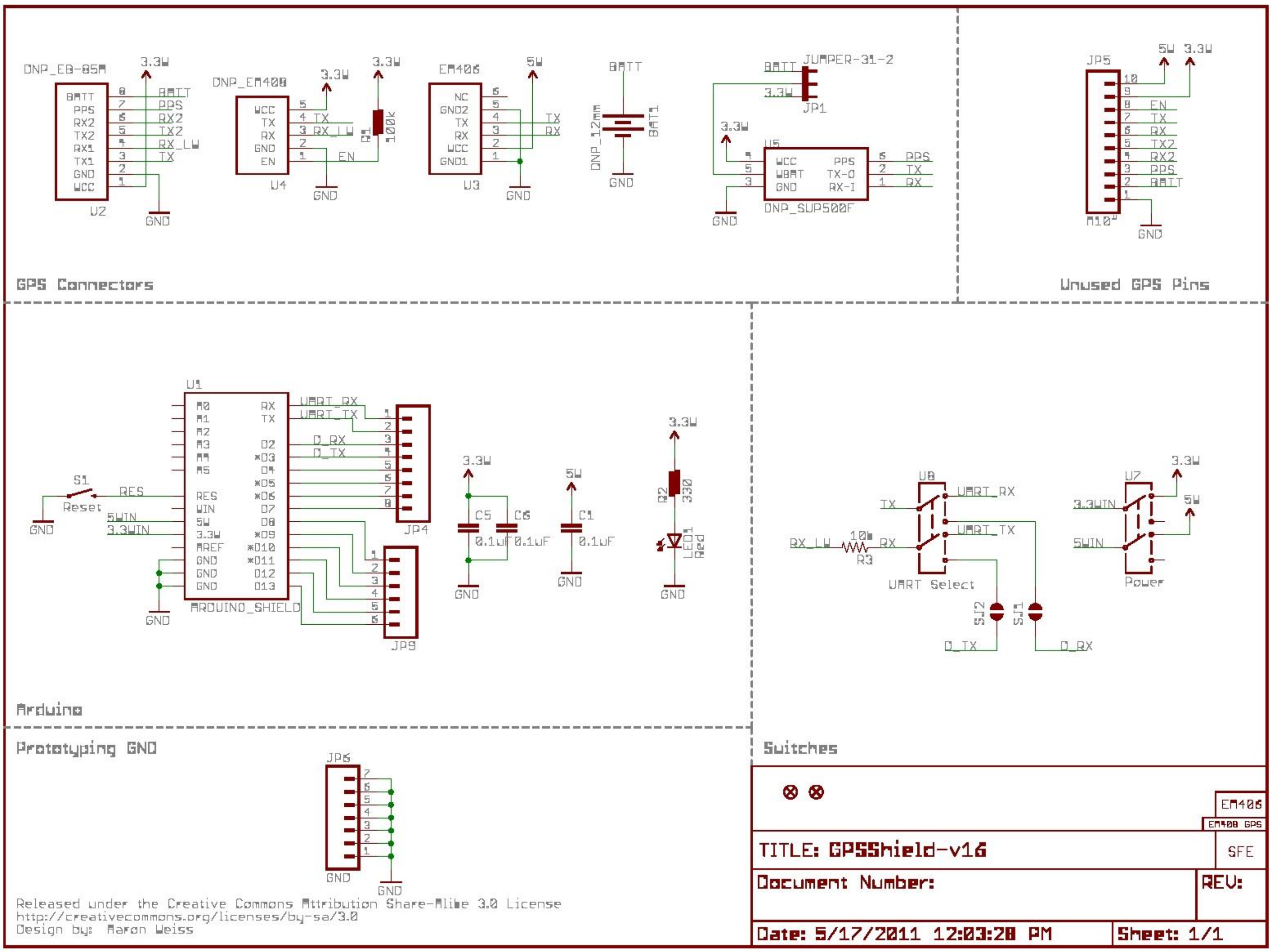
USB Overcurrent Protection

The Arduino Mega2560 has a resettable polyfuse that protects your computer's USB ports from shorts and overcurrent. Although most computers provide their own internal protection, the fuse provides an extra layer of protection. If more than 500 mA is applied to the USB port, the fuse will automatically break the connection until the short or overload is removed.

Physical Characteristics and Shield Compatibility

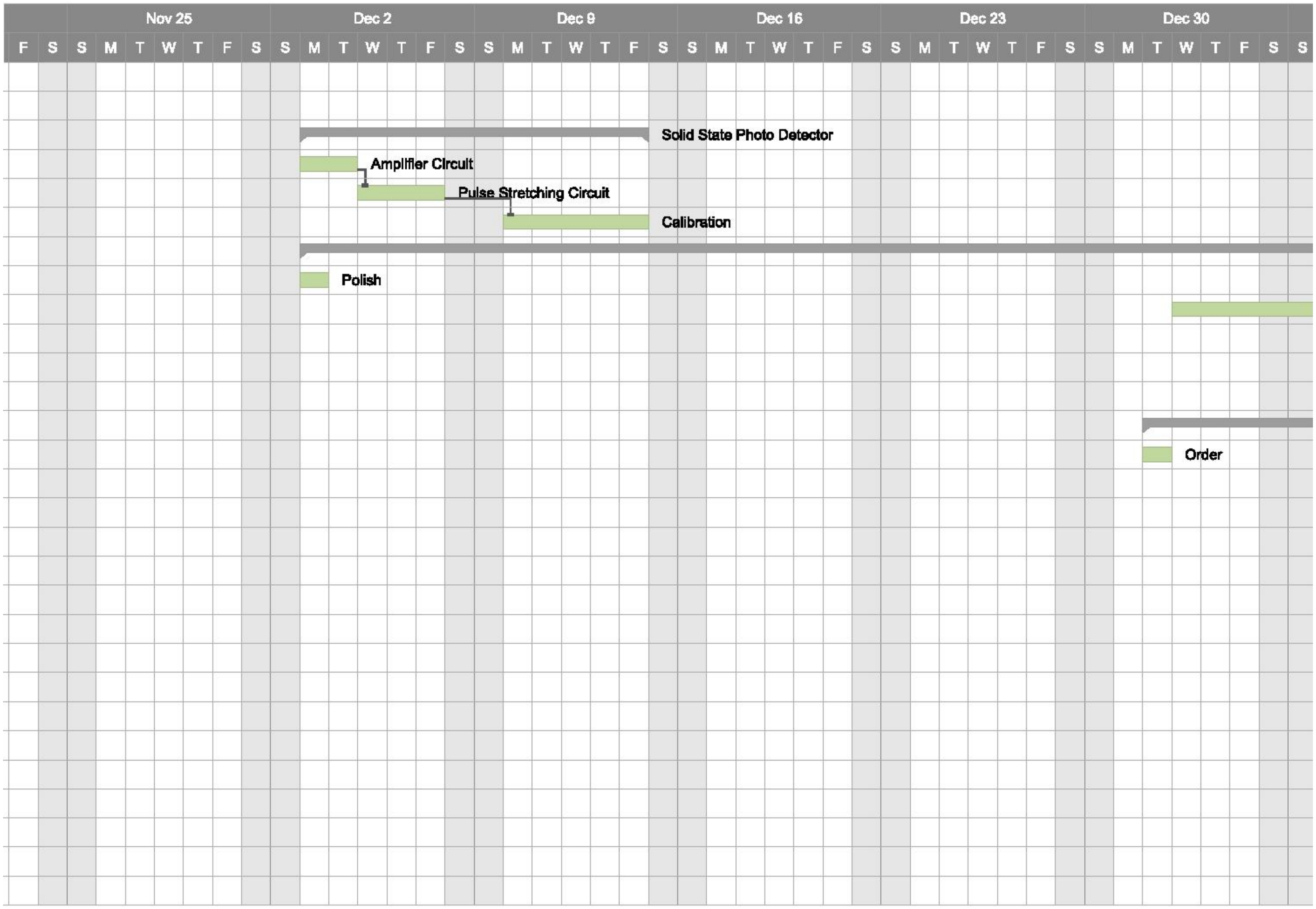
The maximum length and width of the Mega2560 PCB are 4 and 2.1 inches respectively, with the USB connector and power jack extending beyond the former dimension. Three screw holes allow the board to be attached to a surface or case.
Note that the distance between digital pins 7 and 8 is 160 mil (0.16") not an even multiple of the 100 mil spacing of the other pins.

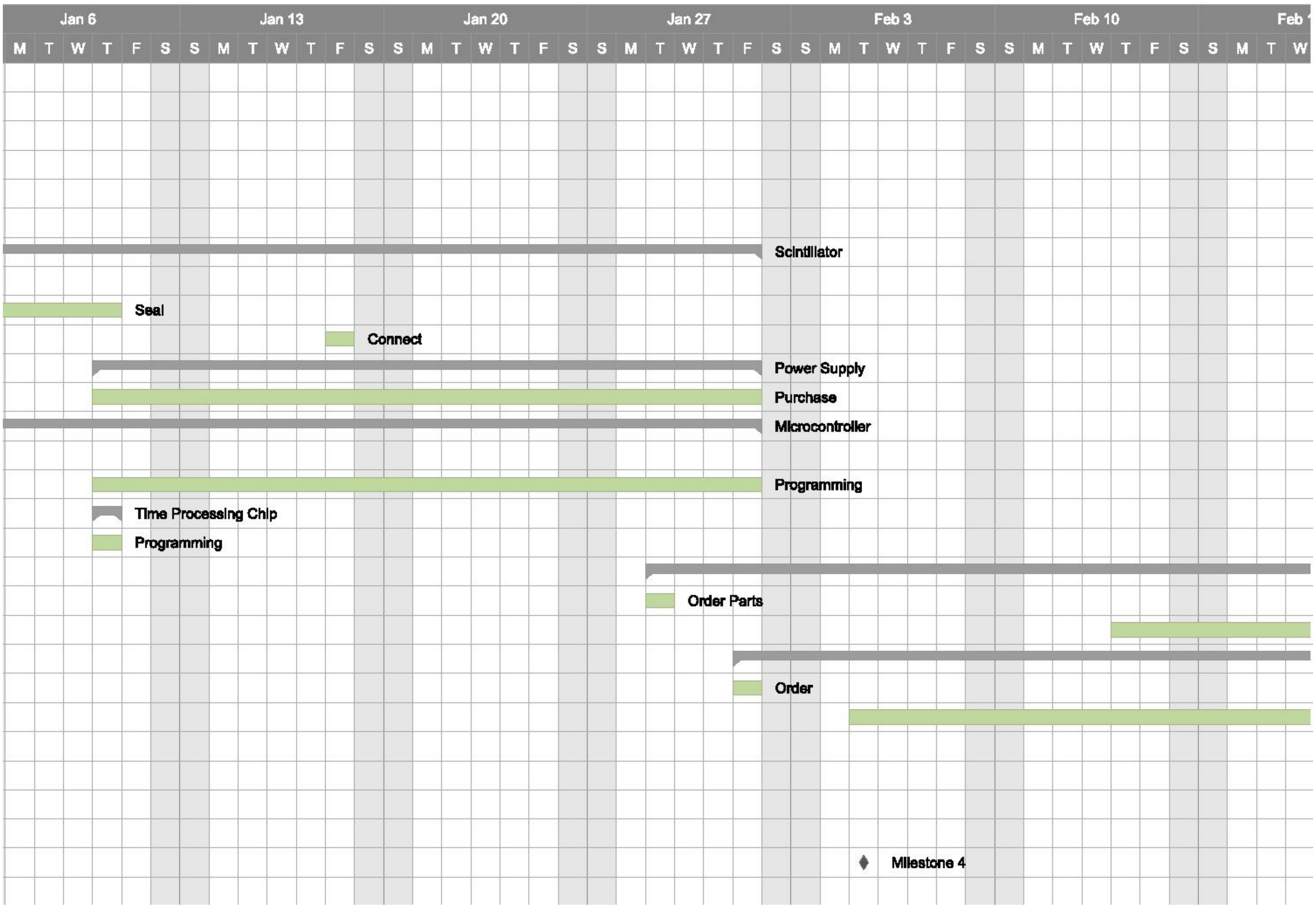
The Mega2560 is designed to be compatible with most shields designed for the Uno, Diecimila or Duemilanove. Digital pins 0 to 13 (and the adjacent AREF and GND pins), analog inputs 0 to 5, the power header, and ICSP header are all in equivalent locations. Further the main UART (serial port) is located on the same pins (0 and 1), as are external interrupts 0 and 1 (pins 2 and 3 respectively). SPI is available through the ICSP header on the Mega2560 and Duemilanove / Diecimila.
Please note that I^2C is not located on the same pins on the Mega (20 and 21) as the Duemilanove / Diecimila (analog inputs 4 and 5).

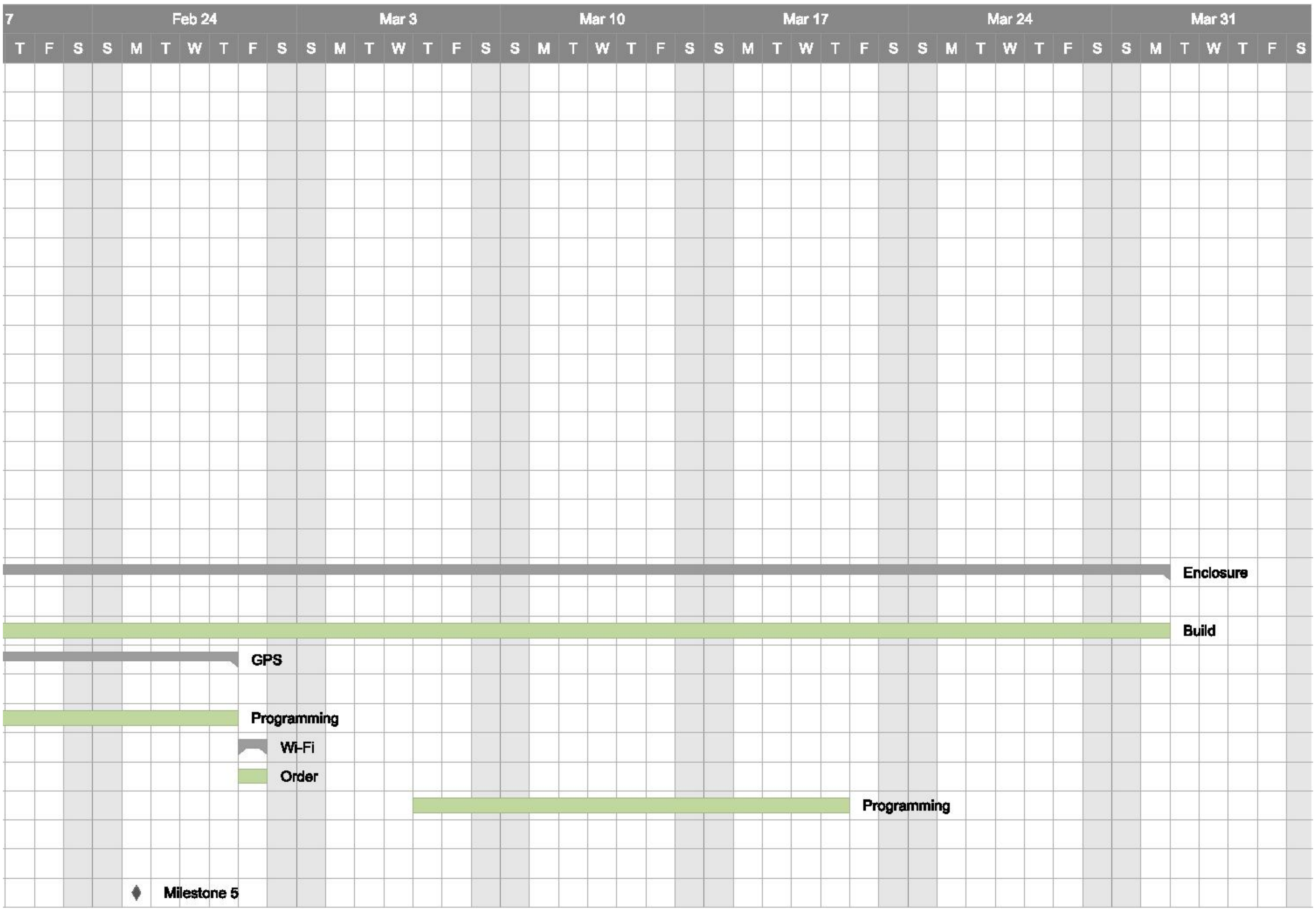

GPS Connectors
Unused GPS Pins
Arduino
Switches
Prototyping GND
UART Select
Power
Released under the Creative Commons Attribution Share-Alike 3.0 License
http://creativecommons.org/licenses/by-sa/3.0
Design by: Aaron Weiss
TITLE: GPSShield-v16
Document Number:
REV:
Date: 5/17/2011 12:03:28 PM
Sheet: 1/1

Cosmic Cube Schedule

Task Name	Start Date	End Date	Oct 28 – Nov 18
Isotope	11/01/12	11/09/12	Isotope
Choose Isotope	11/01/12	11/09/12	Choose Isotope
Solid State Photo Detector	12/03/12	12/14/12	
Amplifier Circuit	12/03/12	12/04/12	
Pulse Stretching Circuit	12/05/12	12/07/12	
Calibration	12/10/12	12/14/12	
Scintillator	12/03/12	02/01/13	
Polish	12/03/12	12/03/12	
Seal	01/02/13	01/10/13	
Connect	01/18/13	01/18/13	
Power Supply	01/10/13	02/01/13	
Purchase	01/10/13	02/01/13	
Microcontroller	01/01/13	02/01/13	
Order	01/01/13	01/01/13	
Programming	01/10/13	02/01/13	
Time Processing Chip	01/10/13	01/10/13	
Programming	01/10/13	01/10/13	
Enclosure	01/29/13	04/01/13	
Order Parts	01/29/13	01/29/13	
Build	02/14/13	04/01/13	
GPS	02/01/13	02/28/13	
Order	02/01/13	02/01/13	
Programming	02/05/13	02/28/13	
Wi-Fi	03/01/13	03/01/13	
Order	03/01/13	03/01/13	
Programming	03/07/13	03/21/13	
Milestone 3	11/15/12	11/15/12	Milestone 3
Milestone 4	02/05/13	02/05/13	
Milestone 5	02/25/13	02/25/13	


Nov 25
Dec 2
Dec 9
Dec 16
Dec 23
Dec 30
F S S M T W T F S S M T W T F S S M T W T F S S M T W T F S S M T W T F S S M T W T F S S
Solid State Photo Detector
Amplifier Circuit
Pulse Stretching Circuit
Calibration
Polish
Order


Jan 6
Jan 13
Jan 20
Jan 27
Feb 3
Feb 10
Scintillator
Seal
Connect
Power Supply
Purchase
Microcontroller
Programming
Time Processing Chip
Programming
Order Parts
Order
Milestone 4



Feb 24
Mar 3
Mar 10
Mar 17
Mar 24
Mar 31
Enclosure
Build
GPS
Programming
Wi-Fi
Order
Programming
Milestone 5

Task Name	Start Date	End Date
Milestone 6	04/03/13	04/03/13
Milestone 7	04/08/13	04/08/13