Augmented Reality Simulator

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# Challenge Definition

# Project Solution

## Customer Value Proposition

## Changes From Original Proposal

## Key Technical Elements

# Product Performance Evaluation

## Performance Metrics

## Failure Analysis

# Technical Documentation

## Design Constraint Analysis, Phase 1

Augmented reality applications are intended to be worn by their users, so the most important design constraints include packaging, power management, and convenience of the headset. Sensor processing demands present challenges for the microprocessors, but the self-contained nature of the project relaxes requirements on inputs and outputs. The central control unit will perform fewer tasks and thus has limited real-time and power constraints.

### Processing Requirements

The microcontroller component of the headset must handle wireless communication and all sensors, as detailed in Table 1. The most intensive task of the microcontroller will be decoding and filtering the 9-DOF inertial measurement unit (IMU) data measuring the user’s head orientation. This task requires floating point math and must run at a constant rate for best results, imposing hard real-time constraints. String processing will be required on the global positioning system (GPS) data to parse its output into latitude and longitude coordinates.

Table 1: Computational tasks and real-time constraints for headset and central control unit

|  |  |  |  |
| --- | --- | --- | --- |
| Task | Runs on | Data Rate | Jitter Requirement |
| IMU filtering | Microcontroller | 800 Hz | 5 us |
| GPS string parsing | Microcontroller | 20 Hz | None |
| Wireless communication | Microcontroller | 11.5 KB/s | 1 ms |
| Battery monitoring | Microcontroller | 1 Hz | None |
| Graphics rendering | Headset GPU | 30 Hz | 5 ms |
| Simulation logic | CCU | Varies | Varies |

Wireless communication will require parsing packets received, but data reception rates will be limited to 115200 baud by the wireless module [1]. The wireless signal level and battery level will only be checked once per second to save CPU time.

On the dedicated headset motherboard, the only task will be performing graphics rendering. The GPU will receive data over a serial peripheral interface (SPI), which can be processed in parallel with rendering. The central control unit only has to handle wireless communication and simulation logic, so it has few processing constraints. Its usage will depend on the complexity of the active simulation.

### On-Chip Peripheral Requirements

On the headset, the microcontroller must be able to handle each sensor connection as shown in [Appendix] and Table 2. The connection to the external GPU will be handled via SPI, requiring five dedicated pins for clock, data in, data out, data ready, and chip select. An inter-integrated circuit (I2C) bus will be used for both the inertial measurement unit [3] and the battery monitor chip [4]. Two asynchronous serial ports will be used for the GPS [5] and wireless units, each requiring two pins for transmitting and receiving data.

Table 2: Required on-chip microcontroller peripherals for headset

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Device | Peripheral | Special Features | Minimum Speed | Pin Count |
| External GPU | SPI | Master Mode, Chip Select | 800 KHz | 4 |
| GPS | Serial |  | 38.4 Kbaud | 2 |
| Fuel Gauge, IMU | I2C | Open-Drain, Current Sink | 400 KHz | 2 |
| Wireless | Serial | Full Duplex | 115.2 Kbaud | 2 |
| Future Expansion | GPIO | Configurable Data Direction | N/A | 10 |
|  |  |  | **Minimum Pins:** | 20 |

The headset GPU motherboard must have a compatible SPI port to interface with the microcontroller over SPI as described above. It also must support a standard display output such as VGA, composite, or HDMI for rendering to a commercially available screen. A second available standard interface such as USB is also preferred to allow future expansion to input devices worn by the user for more advanced simulations.

The central control unit will require a USB port for a keypad for initial user configuration input. It must have either a serial port capable of 115200 baud or another USB port to connect to the wireless communication device. A standard display output will also be required to provide initial user configuration feedback.

### Off-Chip Peripheral Requirements

To satisfy the project metrics, a GPS unit, IMU sensor, wireless radio, and battery monitor chip must be installed on the headset. The GPS should be able to function in a difficult landscape with minimal loss of accuracy; its position update rate is also important for real-time screen updates. Almost all GPS units interface over a standard UART interface. The IMU determines the orientation of the user’s head using three 3-axis sensors: a gyro, a compass, and an accelerometer. Low noise and good resolution are important for head tracking accuracy, and the IMU must interface over a standard protocol such as SPI or I2C.

Wireless communication keeps the central control unit and the headset connected throughout the simulation. High reliability and low latency are paramount to meet the real-time requirements of the simulation. The wireless device must also transmit at least 6-8 KB per second of data and must be able to report the signal quality and strength. A range of 150 yards line of sight will handle most simulations. Battery monitoring components must provide either an alert pin or preferably an estimate of capacity remaining.

For the central control unit, a wireless communication device compatible with the headset and user input devices must be installed. The user input device must be interfaced over an available motherboard USB port and must have a comparable size to the motherboard. As a regular computer keyboard would be bulky, a simple numeric keypad will be adequate.

### Power Constraints

Power will be limited on the headset, as it will run on a lightweight single lithium ion cell worn by the user. The biggest power consumer will be the graphics processor and display used to render images. The wireless radio and GPS also consume power to send and receive data. By comparison, the current draw of the microcontroller, IMU, and battery monitor is negligible. The headset aims to waste no more than 1 watt as heat to increase battery life. Low-dropout linear regulators are required, since no available switch-mode regulator can efficiently convert a battery voltage as low as 3.7 V to the required 3.3 V as shown in Table 3.

Table 3: Power supply constraints and supply rails in use on Phase 1 headset

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Supply Rail | Voltage | Current Required | Topology | Peripherals Powered |
| Vcore | 3.3 V | 500 mA | Linear | Graphics Processing |
| VMCU | 3.3 V | 350 mA | Linear | Microcontroller, Wireless, GPS |
| VADC | 3.3 V | 30 mA | Linear | IMU |
| VDISPLAY | 5 V | 300 mA | Boost | Display, USB |

Power consumption is not a significant factor on the central control unit motherboard, as it will be powered via an AC transformer. Active cooling is inconvenient to install, so the heat dissipation must be low enough to be adequately managed by passive cooling systems.

### Packaging Constraints

The headset is designed to be portable and worn by the user. Of the peripherals in use, the display, inertial measurement unit, and antennas must be placed on the user’s head. An adjustable mount for the half silvered mirror and reflection shield must be provided to allow users with different head sizes to position the device for optimal viewing conditions. The device should be packaged in one unit without exposed wires, as non-technical users should not be expected to plug in parts. Packaging must be able to withstand the vibration and impacts that are inevitable for wearable electronics, and must be able to tolerate outdoor temperatures.

The central control unit has fewer size restrictions as it will remain stationary throughout gameplay. It must be durable enough to withstand outdoor temperatures. Any packaging materials selected must also be compatible with the antenna to avoid signal reflections that could reduce the range of the headsets. The central control unit should have a simple keypad interface to ensure casual users can simply select a simulation and start immediately.

### Cost Constraints

While cost is a consideration when differentiating between similar parts, cost is not an overriding constraint at this time and is secondary to other design constraints. A soft limit of $250/headset and $100/CCU was used to guide parts selection, as competing products are generally very expensive even in quantity. For example, Google Glass [2], a product with higher quality compact optics, is currently priced at $1500, and several other augmented reality products such as ARQuake [3] and CastAR [4] have not left development.

### Microcontroller Selection

Processing power, particularly with floating point, is the biggest concern for microcontroller selection. Even though graphics are not processed on this device, high-speed IMU filtering leads to better head tracking performance. Current consumption is secondary as other parts will dominate power use. With these constraints set, Table 4 shows the devices which were considered, all of which met the constraints for on-chip peripherals and pin count.

Table 4: Decision matrix for Phase 1 headset microcontrollers

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Part | I/O | RAM | Flash | Clock | DMA | Special Features | Cost |
| STM32F405RGT6 | 51 | 192K | 1M | 168MHz | 16 | Floating Point Unit | $11 |
| PIC32MX695F512H | 53 | 128K | 512K | 80MHz | 8 |  | $10 |
| ATSAM4S16BA-AU | 47 | 128K | 1M | 120MHz | 22 |  | $10 |

The STM32F405 chip was chosen due to the availability of a low cost $15 development board and its very high computational performance, particularly with single cycle floating point operations. This device features extra RAM and processing power for future expansion.

### Motherboard Selection

As the GPU motherboard is the largest power consumer on the headset, low power consumption is mandatory. Small size and light weight is also important for a portable device. Since any dedicated GPU vastly outperforms the microcontroller, relative performance is not a concern. The motherboard should also feature a USB port and SPI interface, as this project aims to re-use the same part on the central control unit to reduce development effort.

Table 5: Decision matrix for Phase 1 motherboards

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Part | Idle Power | RAM | USB | SPI | Clock | Cost (board) |
| Raspberry Pi Model A | 2 W | 256M | 1 | 1 | 700MHz | $25 |
| BeagleBone Black | 2 W | 512M | 1 | 2 | 1GHz | $45 |
| Intel® Atom™ Board | 12 W | 2G | 4 | 1 | 1.8GHz | $150 |

As shown in Table 5, the Raspberry Pi Model A was chosen for its low power consumption, cost, and outstanding community support. Examples exist all over the Internet for handling tasks on the Raspberry Pi, whereas the BeagleBone Black is fairly new and hard to acquire. The added power use of an Intel® Atom™ board and its high cost led to its rejection for Phase 1.

### Sensor Selection

Due to advancements in MEMS technology, most inertial measurement units provide excellent noise performance and accuracy. Power consumption is not an issue as other parts dominate power use. A breakout board must be available since most IMUs come in LGA packages that cannot be soldered by processes easily available to students.

Table 6: Decision matrix for 9-degree of freedom inertial measurement unit (IMU)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Part | Gyro | Accelerometer | Compass | Resolution | Cost (board) |
| STEVAL-MKI108V2 | L3GD20 | LSM303DLHC | LSM303DLHC | 16/12/16 | $27 |
| MPU-9150 | MPU-9150 | MPU-9150 | MPU-9150 | 16/13/16 | $50 |
| SparkFun IMU | ITG3200 | ADXL345 | HMC5883L | 16/13/12 | $50 |

As seen in Table 6, the slightly increased resolution of the MPU-9150 is offset by its cost and lack of documentation, particularly for the use of its powerful internal filtering algorithms. The cheaper SGS Thomson part [5] was chosen instead, as it offered no disadvantages to the expensive SparkFun 9-DOF sensor stick [6].

Past senior design groups experienced problems with low resolution and slow updates from GPS. The real-time constraints of this project call for a fast and high-resolution receiver module. Power consumption is also a concern, as the GPS unit will always be tracking the user.

Table 7: Decision matrix for GPS receiver unit

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Part | Resolution | Update Rate | Accuracy | Antenna | Power Use | Cost |
| Venus638FLPx | ~0.3m | 20Hz | 2m | External | 29 mA | $50 |
| GP-635T | ~1m | 5Hz | 2m | Integrated | 56 mA | $40 |
| Smartphone | ~5m | 1-5Hz | 10m | Integrated | N/A | Varies |

The recently released Venus638FLPx vastly outperforms comparable units [7] due to its excellent resolution and astonishing 20Hz update rate as shown in Table 7. Real-world tests as described in [Appendix] confirmed the superior signal quality of external antennae.

### Wireless Communication Selection

This project requires low latency and acceptable data rates as shown in Table 8. Range tests as described in [Appendix], however, indicate that unrealistically tall antennas are required to obtain the advertised range on many types of RF communications modules.

Table 8: Decision matrix for Phase 1 wireless communication devices

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Part | Data Rate | Range (LOS) | Latency | Cost |
| XBee Pro 900HP | 11.5 KB/s | 300 m | 50ms | $40 |
| nRF24L01+ | 25 KB/s | 100 m | 50ms | $20 |
| Bluetooth and Cell Phone Radio | 100+ KB/s | 2000+ m | 500ms | $30 |

Despite the range and data rate advantages of offloading wireless to a cell phone, the latency in tests was shown to be unacceptable for augmented reality. Cell phone signal reliability also left much to be desired, so the XBee Pro will still be used for its superior range over the nRF24L01+ module [8], whose range does not meet the design metrics.

### Power Supply Selection

## Design Constraint Analysis, Phase 2

### Microcontroller and Sensor Selection

For the Phase 2 headset, the same microcontroller was re-used for processing sensor data from Phase 1. The project code base was designed for this device, so utilizing the same part greatly reduced development time. Likewise, the sensors used in Phase 1 performed excellently at their required tasks, and these devices were re-used for Phase 2. Re-use of proven devices also reduced the cost metric of Phase 2 by utilizing parts already available from Phase 1.

### Motherboard Selection

After the completion of Phase 1, the hidden limitations of the selected Raspberry Pi Model A motherboard were exposed. Although its low power consumption led to long battery life, the graphics processing unit on board was extremely difficult to use. Tasks such as displaying text and loading models from disk took excessive amounts of time, impeding refresh rate metrics.

With the contribution of two Intel® Atom™ Terasic DE2i-150 boards from the Cornell Cup sponsors, the motherboard criteria were revisited. Due to the simplicity of coding graphics on the standard OpenGL framework for the Intel® Atom™ board, the higher power consumption was accepted as a necessary cost for a better Phase 2 implementation. This choice required a power supply redesign.

### Power Supply Selection

## Schematic and Theory of Operation, Phase 1

## Schematic and Theory of Operation, Phase 2

## PCB Layout Design Considerations

Due to the extensive use of surface mount components in this project, a custom-designed printed circuit board (PCB) was chosen as the most reliable method of implementing the schematic design. OSH Park, the manufacturer used by the Purdue Electrical Engineering department to outsource PCB production, quotes the minimum values shown in Table 9 for their standard specification designs. For optimal manufacturing yield and to allow tolerance for best practice, the PCB was designed with wider tracing and spacing and a larger drill size. In addition, acute angles and sharp corners were avoided, as these features can trap etchant during manufacturing and lead to broken traces on the final board.

Table 9: PCB specifications for OSH Park [9], 1 mil = 0.001 inch

|  |  |  |
| --- | --- | --- |
| Metric | Given | Chosen for Manufacturability |
| Trace Thickness | 6 mil | 10 mil |
| Trace Spacing | 6 mil | 8 mil |
| Drill Diameter | 13 mil | 15 mil |
| Drill Tolerance | 5 mil | *N/A* |
| Copper Thickness | 1 | *N/A* |

## Phase 1 PCB – Full System Board

The form factor and connector placement were the most important of the Phase 1 custom PCB requirements. To properly mate with the Raspberry Pi, the outer PCB dimensions and 26-pin I/O header placement had to exactly match the motherboard mechanical specifications [10]. External connectors for USB charging, the battery, and the radio antennas must also face outwards on the border of the PCB to allow connections once inside the final packaging.

The major radio frequency emitters on this board contribute electromagnetic interference (EMI) which could disrupt the inertial measurement unit (IMU). As the global positioning system (GPS) unit has an external antenna [11] which moves its noise emissions far from the PCB, the XBee radio and antenna [1] was placed in the lower left corner far away from the IMU; the noise amplitude decreases with the square of the distance. The external oscillator was also located as close as possible to the microcontroller to limit unintentional EMI emissions.

### Microcontroller

Several of the components of this project, most notably the USB boot loader described in the microcontroller datasheet, depend on a stable clock source. Therefore, an external crystal oscillator in a through-hole package was utilized with the recommended load capacitance of 20pF [12]. As the crystal traces also add impedance, the EAGLE “*run length-freq-ri*” tool was used to match the trace lengths to reduce reflections due to mismatched impedance. The crystal was also placed close to the microcontroller. Similarly, the same method was used to match the USB data trace lengths to less than the stated 0.05 inch tolerance for length mismatch [13].

Part placement near the microcontroller was also a major concern. The circuit board was designed using the EAGLE Layout Editor, which already contained the project schematics, but the built-in auto router produced unsatisfactory results. To make the PCB easier to manually route, pin assignments on the microcontroller were chosen to limit crossing signals, and parts were carefully placed around the microcontroller. After final placement, the most convenient spare I/O pins were brought out to pads, and a spare serial port was connected to a header to enable debugging and future expansion as is best practice.

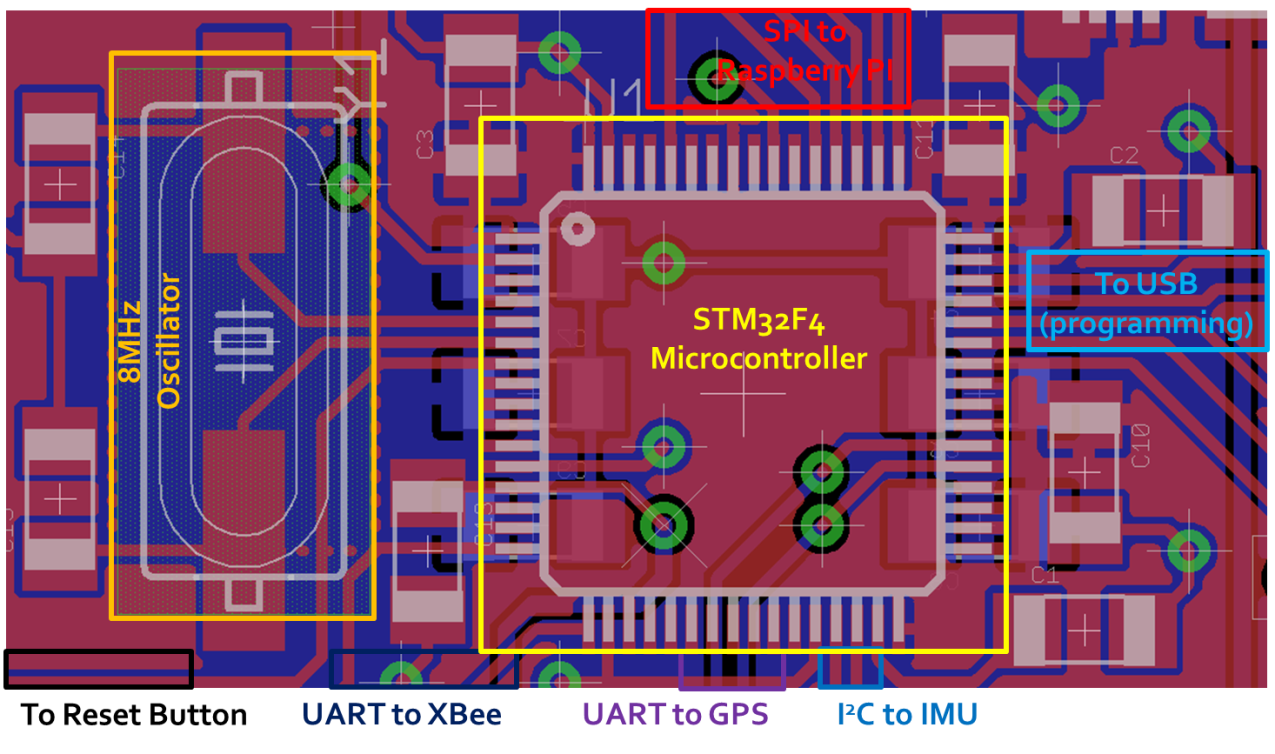


Figure 1: Signal routing near microcontroller showing oscillator circuit and decoupling capacitance

To ensure optimal power supply to the microcontroller, a large power and ground plane along with twelve decoupling capacitors were used. One of these capacitors was placed near each power supply pin as recommended by the manufacturer [14], with the remaining capacitors placed as close as possible to limit the parasitic equivalent series resistance (ESR) between the microcontroller and each capacitor.

### Power Supply

The power supply for this board must deal with a fluctuating load and battery management to maximize the device battery life while reducing the risk of device failure due to overheating. Total current could be up to 2 A during radio transmission events as evidenced by the design constraint analysis, so power supply traces were widened according to the trace heat equations (shown below) recommended by OSH Park to reduce resistive losses [15].

**Example**: is given to be (see Table 9) and of heating was allowed. Therefore, for a power supply trace carrying of current, the calculation of the minimum trace would be (1 mil = 0.001 inch):

Therefore, this trace should be no narrower than 0.031 inches to carry the rated current with less than the specified temperature rise. In practice, traces of twice the minimum width were selected to reduce power loss from trace resistance and increase battery life.

Power and ground planes were emphasized to simplify power routing. The bottom of the board was devoted to a ground plane with few signal traces to reduce the size of noise-inducing ground loops. Power planes also provide heat dissipation paths with low thermal resistance for the regulator circuits, keeping them cool to increase reliability. A sample of one area of the power supply with these practices applied is shown in Figure 2.

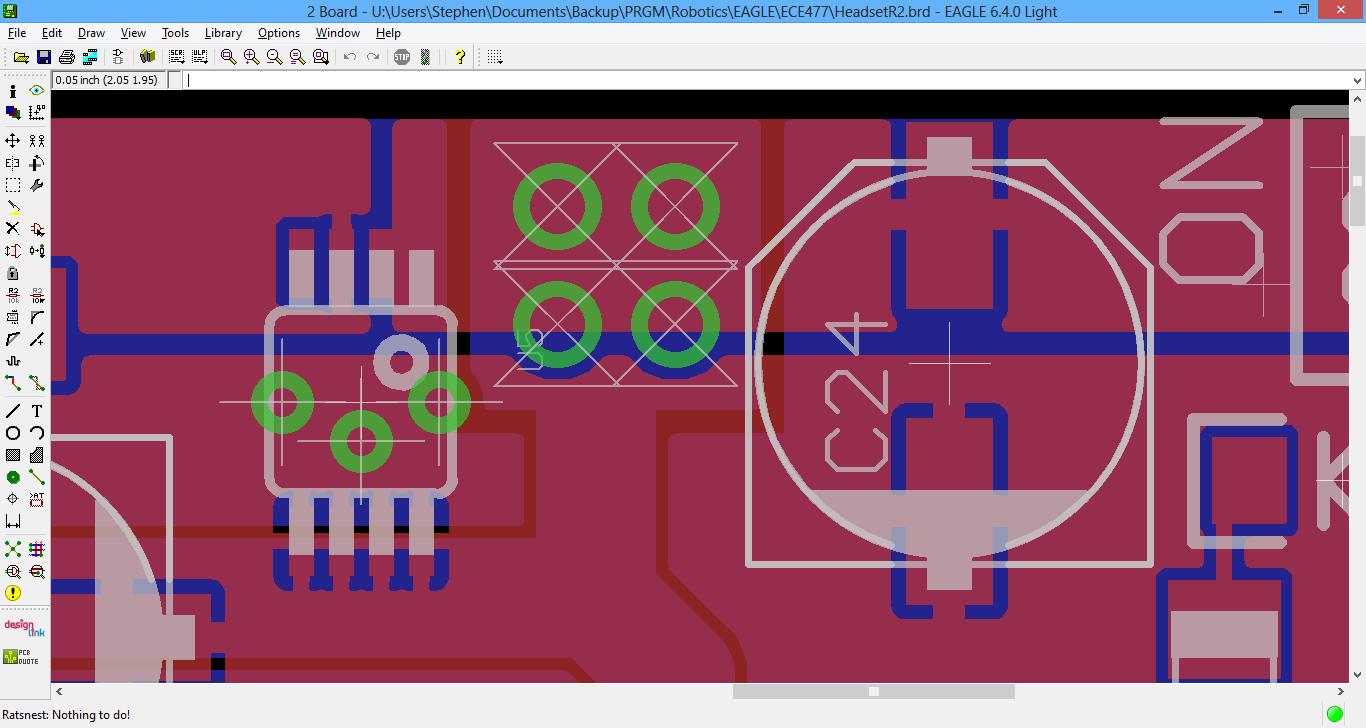


Figure 2: Close-up of power supply showing bulk capacitance and power planes

Capacitors were chosen and placed on the board to handle large surge current demands of the microcontroller and radios while processing or transmitting data. Solid bulk capacitors with low ESR were placed near the power input and after each voltage regulator. Additional ceramic capacitors recommended for stability were also placed close to each low-dropout regulator [16]. The step-up converter used to generate 5V for the display [17] was located far away from the rest of the circuit to reduce its EMI coupling to the sensors.

To reduce noise coupling between the IMU and the digital circuits, a separate low-dropout regulator with outstanding noise rejection was dedicated for the IMU power supply and placed close to it. Although the IMU communicates its results using a digital protocol that is resistant to interference, noise on the power supply can still disrupt the computed orientation [5]. This regulator does not have to power other loads, so switching noise is reduced.

### Fabrication and Testing

This custom board design used standard library parts, but one-to-one tests were conducted before PCB fabrication to verify that the parts on hand matched the prospective board. No discrepancies were noted in this test.

After receiving the initial circuit board from the manufacturer, the first procedure involved electrical conductivity tests as described in [Appendix]. This test discovered an unwanted short connecting the IMU power supply to ground; continued conductivity measurements allowed location and repair of a hair-line copper filament shorting the target trace to a ground plane.

When the board had been tested, the power supply components were installed first to verify the operation of this important section of the board. Burn-in testing procedures as described in [Appendix] were applied for 24 hours at the rated design load, and the supply outputs continued to function at the desired voltages. After populating the remaining components, simple test programs were uploaded to the microcontroller to test each part of the board independently. Notable tests as mentioned in the [Appendix] included GPS location precision and IMU head tracking performance.

## Phase 2 PCB – Headset Sensor Board

Feedback from Phase 1 indicated that the head tracking system generally worked well. Phase 2 thus re-used a large fraction of the Phase 1 system board for handling the IMU and GPS sensors. The USB connector was re-purposed for communications with the Intel® board, and this opportunity was taken to reduce the PCB dimensions to lower the mass of the headset.

Unintentional EMI emissions were controlled using the same methods documented for the Phase 1 PCB. Since the microcontroller was unchanged from Phase 1, the routing for that critical area of the PCB was also unchanged; see section 4.5.1 for details.

### Power Supply

With the removal of the XBee, the peak current draw of the board now remains within the 500 mA USB maximum load [13]. A single 3.3 V voltage regulator sufficient to handle 500 mA now supplies the microcontroller and GPS [16] as shown in Figure 3. Bulk capacitors and decoupling capacitors were used once again from experience with the Phase 1 PCB. The separate regulator for the IMU was also retained in its original location.

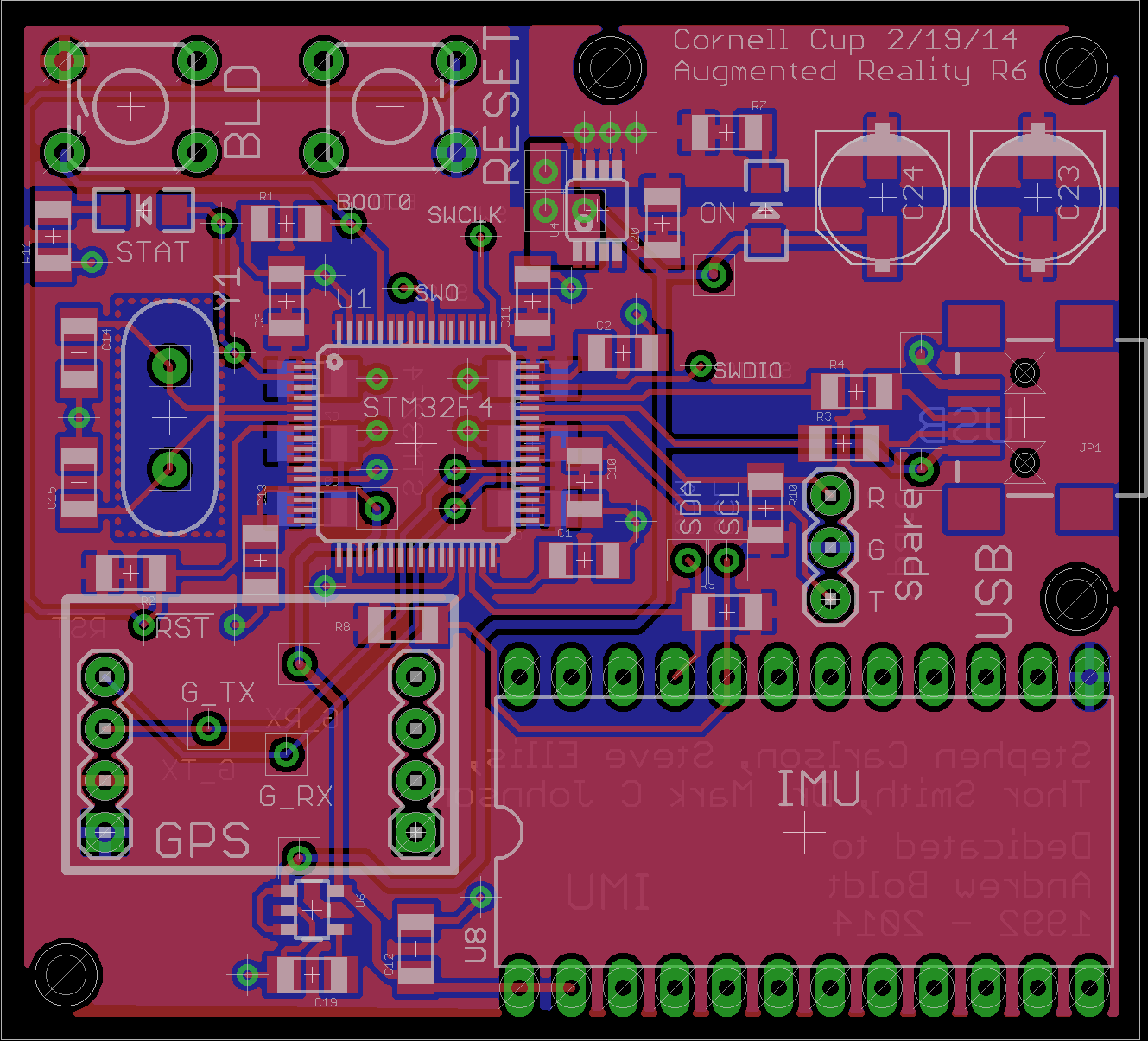


Figure 3: Power supply of the Phase 2 sensor PCB

### Fabrication and Testing

After fabrication and population, testing as conducted in section 4.5.3 revealed no issues with this design. As the board was an evolution of the Phase 1 design, knowledge from that successful design proved invaluable to the rapid design and success of this PCB.

## Phase 2 PCB – Power and Fuel Gauge Board

With the introduction of the Intel® Atom™ board for powering the Phase 2 graphics rendering, a substantial revision to the power supply was required. As the necessary battery to achieve the design metrics became too heavy to meet the headset design mass, the entire power supply was moved to the backpack unit with the Atom™ board. Since the sensors need to remain on the user’s head, the Phase 1 PCB was bifurcated into a dedicated power supply.

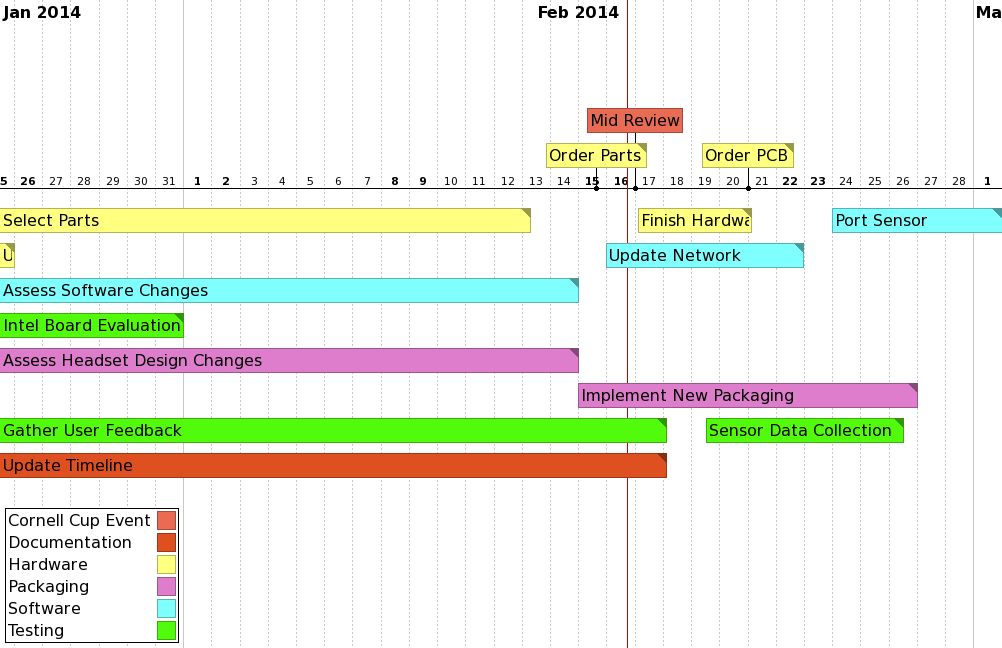
This board had a new design, needing to incorporate battery charging, monitoring, and voltage regulation for a much higher power system. Its mass was still a concern, as the backpack still had to target a wearable design mass. Connectors for USB communication, the battery, the charger, and the power output were also incorporated on the sides of the board. As this board was also fabricated by OSH Park, the specifications from section 4.5 were used.

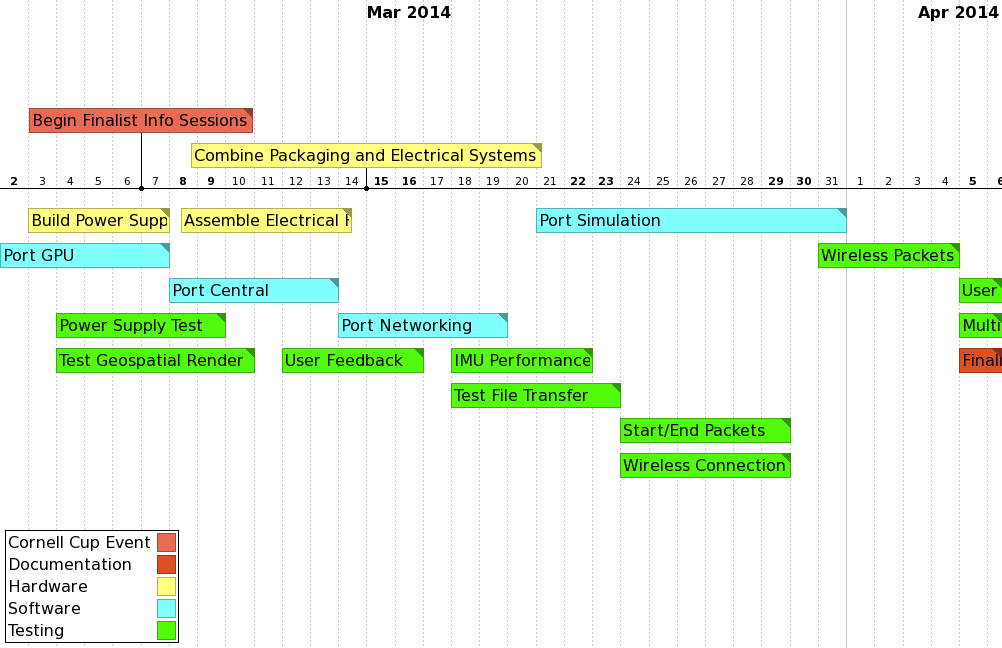
### Power Supply

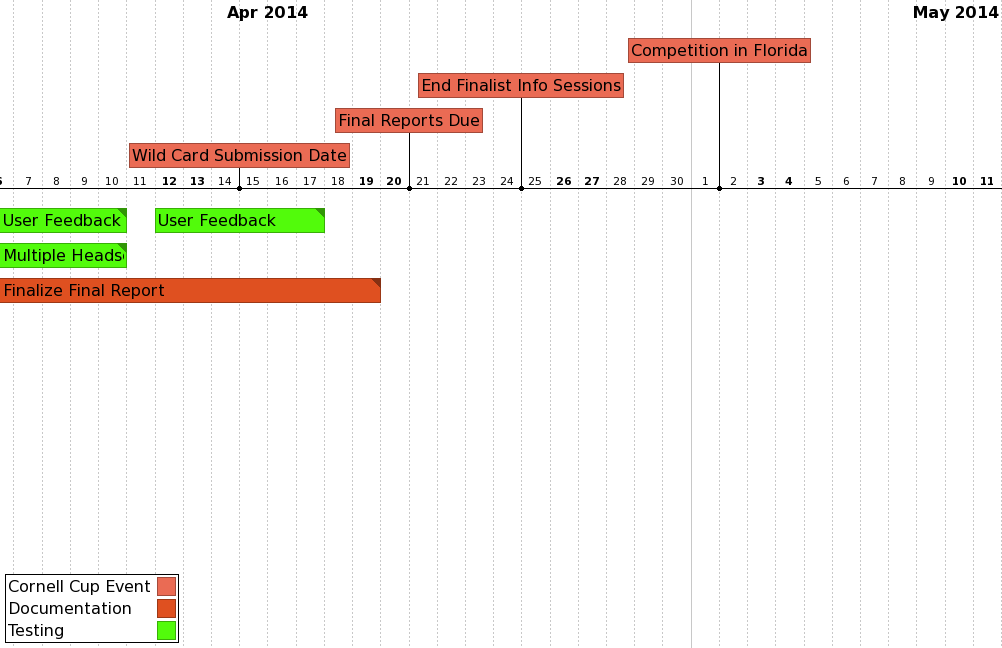
### Microcontroller

# Project Execution

## Timeline







### Adjustments

## Budget

### Bill of Materials

Table 10: Bill of materials for Phase 2 design

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Digi-Key Part Number | | Description | Footprint | # | Per Unit | Cost |
| LVK12R010DERCT-ND | | Res 0.5W 10mOhm | 1206 | 1 | $0.50 | $0.50 |
| 490-6521-1-ND | | Cap 4.7uF 50V Ceramic | 1206 | 3 | $0.76 | $2.29 |
| P16460CT-ND | | Cap 180uF 16V Low ESR | Panasonic E | 1 | $2.32 | $2.32 |
| 490-3367-1-ND | | Cap 2.2uF 50V Ceramic | 1206 | 2 | $0.39 | $0.78 |
| CTX406-ND | | Crystal 8MHz 20pF | HC-49US | 2 | $0.36 | $0.72 |
| 160-1889-1-ND | | LED Blue | 1206 | 1 | $0.38 | $0.38 |
| 475-1407-1-ND | | LED Green | 1206 | 2 | $0.11 | $0.22 |
| P68.1KBCCT-ND | | Res 68.1K 0.1% | 1206 | 1 | $0.79 | $0.79 |
| P5.76KBCCT-ND | | Res 5.76K 0.1% | 1206 | 1 | $0.79 | $0.79 |
| P100KBCCT-ND | | Res 100K 0.1% | 1206 | 1 | $0.79 | $0.79 |
| P34KBCCT-ND | | Res 34K 0.1% | 1206 | 1 | $0.79 | $0.79 |
| P499KBCCT-ND | | Res 499K 0.1% | 1206 | 1 | $0.79 | $0.79 |
| P215KBCCT-ND | | Res 215K 0.1% | 1206 | 1 | $0.79 | $0.79 |
| P2.43KBCCT-ND | | Res 2.43K 0.1% | 1206 | 1 | $0.79 | $0.79 |
| ED2992CT-ND | | Mini USB Connector | Special | 2 | $0.87 | $1.74 |
| 497-11767-ND | | STM32F405RGT6 | TQFP 64 | 1 | $11.45 | $11.45 |
| 497-13631-ND | | STM32L100RBT6 | TQFP 64 | 1 | $4.37 | $4.37 |
| 576-1827-5-ND | | Regulator 3.3V 500mA | MSOP 8 | 1 | $2.35 | $2.35 |
| 576-1281-1-ND | | Regulator 3.3V 150mA | SOT-23-5 | 1 | $2.01 | $2.01 |
| LM2936MP-3.3/NOPBCT-ND | | Regulator 3.3V Low-Iq | SOT-223-4 | 1 | $1.78 | $1.78 |
| DS2782E+-ND | | Fuel Gauge IC | TSSOP 8 | 1 | $7.46 | $7.46 |
| 296-20523-ND | | Power Module 12V 3A | Special | 1 | $17.70 | $17.70 |
| 497-12918-ND | | 9-DOF IMU Breakout | DIP 24 W | 1 | $27.60 | $27.60 |
|  | |  |  |  |  | $89.20 |
| Items available from the Senior Design lab include: | | | |  |  |  |
|  | Cap 0.1uF Ceramic | | 1206 |  |  |  |
|  | Cap 1uF Ceramic | | 1206 |  |  |  |
|  | Header Breakaway Female | | 0.1 |  |  |  |
|  | Header Breakaway Male | | 0.1 |  |  |  |
|  | Res 4.7K 5% | | 1206 |  |  |  |
|  | Res 10K 5% | | 1206 |  |  |  |
|  | Res 6.8K 5% | | 1206 |  |  |  |
|  | Res 22 5% | | 1206 |  |  |  |
|  | Res 1.5K 5% | | 1206 |  |  |  |
|  | Cap 39pF Ceramic | | 1206 |  |  |  |
|  | Cap 470pF Ceramic | | 1206 |  |  |  |
|  | Cap 10uF 16V | | Panasonic D |  |  |  |
|  | Cap 22uF 16V | | Panasonic D |  |  |  |
|  | PCB Button | | Special |  |  |  |

### Expenditures

### Funding Sources

Table 11: Sources of funding for Phase 2 design

|  |  |
| --- | --- |
| Cornell Cup | $1500 |
| Purdue University | $300 |

## Mid-Review

## Process Understanding

# Recommendations and Next Steps

# Glossary

* **Augmented reality**: a system which overlays a computer generated image on top of real world objects so that both are simultaneously perceptible
* **Global positioning system (GPS)**: a sensor which receives signals from a global network of satellites to determine absolute position on the Earth’s surface
* **Electromagnetic interference (EMI)**: a disturbance in an electrical circuit induced by electromagnetic radiation from other circuits in proximity
* **Equivalent series resistance (ESR)**: the non-ideal resistance of real electrical components, acting as if this resistance value was placed in series with the device
* **Inertial measurement unit (IMU)**: a sensor which reports velocity, orientation, and gravitational forces
* **Inter-integrated circuit interface (I2C)**: a two-wire bidirectional synchronous serial communications system which connects multiple *master* and *slave* electronic parts through an addressable protocol
* **Printed circuit board (PCB)**: a substrate which supports and connects electrical components through an etched network of conductive traces
* **Serial peripheral interface (SPI)**: a fast four-wire bidirectional synchronous serial communications protocol used to interface two or more electronic parts
* **Virtual reality**: a system which fills the user’s entire field of view with a computer generated image to the exclusion of the real world

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# Survey Responses

# Appendix

## Performance Measures

Table 12: Performance metrics for evaluating Phase 1 and Phase 2 implementations

|  |  |  |  |
| --- | --- | --- | --- |
| Metric | Phase 1 Results | Phase 2 Target | Phase 2 Results |
| Mass | Headset: 1.3kg | Headset: 1 kg  Backpack: 3 kg | Headset: 1.2kg  Backpack: ~2.5kg |
| Power | 3 hours | 3 hours runtime | ~4 hours |
| Location Precision\* | ~1.5 meters | 2 meters | ~1.5 meters |
| Wireless Range | 200 meters | 80 m, line of sight | 200 meters |
| Display Refresh | 10 FPS | 20 FPS | 20 FPS |
| Network Refresh | Unimplemented | 20 FPS | 60 FPS |
| Usability | Turnkey startup | User can start and use without a technician | Turnkey startup |
| Simultaneous Device Limit | 5-6 | 16 | 32+ |
| Head Tracking Latency | 100 ms | 50 ms\* | 50 ms |

## Test Plans

### Range Test

### Latency Test

## Assembly and Construction

Constructing a headset for this project is a fairly simple but quite laborius process. At a high level, the basic steps are to mount a screen and reflector to a suitable enclosure, construct and mount to the helmet a set of aluminum mounting rails, mounting the display assembly to the mounting rails, and then constructing and mounting a sensor enclosure to the rails.

### Rail Assembly

Due to the difficult of mounting hardware directly to a hard hat, a system of rails must first be mounted to facilitate the rest of construction. The material used will be aluminum angle bar with 1/8” thickness and ½” length.

### Display Assembly

This part will vary quite a lot depending on the type of display being used and how it will need to be mounted. We have created headsets using two different displays and the procedures for earch were drastically different.

### Reflector

To achieve the desired augmented reality effect, a sheet of semi-transparent, semi-reflective material is required. In this case it will be a sheet of polycarbonate with a reflective film applied on one side, and a tint film applied to the other side to mitigate brightness issues. A sheet of approximately 6”x4”x1/8” must be cut out. Several holes must be drilled for mounting purposes. Two will be near the bottom corners, which will be used for wire loops to hold the reflector at the correct angle. Four more will be along the top edge, for hinges which secure the reflector to the front of the headset. After the sheet has been cut to the correct size and the holes drilled, a sheet of reflective film the same size as the plastic needs to be cut out and applied as per the directions supplied with film. Then the tint film is to be applied to the other side in the same way. Be mindful that the reflective side needs to be facing the user once everything is assembled.

### Sensor Assembly

The sensors used to measure the user’s location and head orientation reside on their own circuit board which must be mounted to the headset. This is accomplished by mounting the PCB inside of its own enclosure and mounting that enclosure to the rear portion of the rail assembly on the headset. The enclosure used will be a 5”x2.5”x2” ABS project box.

### Mounting the PCB to the enclosure

In order to mount the PCB to the enclosure, several holes will first need to be drilled.

### Mounting the enclosure to the rail

### Materials required

|  |  |
| --- | --- |
| Material | Quantity |
| Hard Hat | 1 |
| Angle aluminum, 1/8” thickness, ½” leg | 3’ |
| Project Box, 4”x6”x2” | 1 |
| Project Box, 5”x2.5”x2” | 1 |
| Zip ties | Many |
| Screws | Many |