# Tactical Up-Armored Vehicle - Automatic Distress Detection System (TUV-ADDS)

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***Abstract* — TUV-ADDS is multi-sensor platform which will be monitored by a team of microcontrollers in order to detect the characteristics which would indicate if an Implemented Explosive Device (IED) had detonated in close proximity to an up-armored wheeled tactical vehicle, or if that vehicle has rolled over. This system intent is to alleviate the protocols which U.S. armed forces are tasked with when a vehicle is hit by an IED or is involved in a rollover, and to allow first responders earlier notice of a distressed vehicle. TUV-ADDS will incorporate use of an accelerometer, temperature sensor and flash sensor to qualitatively determine if an explosion occurred, and an accelerometer will be used to detect rollover. A MCU will be used to compare the data measured from the sensors to predetermined thresholds, once these thresholds have been exceeded then GPS coordinates will be sent to a control center stating the vehicle is in distress.**

***Index Terms* — IED, microcontrollers, rollover, sensors, vehicles, military.**

## I. INTRODUCTION

TUV-ADDS is a system which is designed to be relevant to our armed forces fighting in the Iraq and Afghanistan theaters. While TUV-ADDS is not a military grade system, research of military vehicles and the difficulties that the military has with some of their vehicles was performed and the system design is intended to be relevant to the vehicles and users that would benefit from a system of similar characteristics. Sgt. Irizarry, Eduardo, who served in the U.S. Marine Corps from June 2004 – May 2011 and recently returned from Afghanistan, stated with the knowledge he gained from being involved in dozens of IED strikes, both directly and as a first responder, that with the implementation of a system of this scope to military operations could allow for more efficient tactical and strategical employment of assets, personnel, equipment, vehicles, and weaponry.

The system is similar to the popular civilian system OnStar© as it automatically communicates a distress signal to a designated command center after recognizing that a vehicle is in distress. This system has a two-phase design; phase one being the recognition of certain characteristics of a distress-causing event through specific sensor values that quantify the event. The second phase is the system will automatically and accurately communicate that there is a vehicle in need and the position of where that vehicle is to command center.

### *A. Recognizing a Distressed Vehicle*

The way TUV-ADDS will recognize if a vehicle is in distress such as the vehicle shown in Fig. 1, is through a sophisticated network of sensors. The system will sense and monitor certain percentage increases such as vertical displacement, flash, and heat to indicate an IED blast. For rollover indication, an accelerometer will be used to sense if the vehicle is overturned. These sensors will collect the data, which then the system will analyze and conclude whether the information combined is an indication of a distressed vehicle.

Fig. 1. Picture of a Distressed Vehicle

### *B. Communicating Distress*

After recognizing the vehicle has been involved in a distress situation based on the specified criteria, TUV-ADDS will wirelessly communicate that an incident has occurred to the command center. This will be achieved by applying the use of a Global Positioning System (GPS) device and wireless communication capability to the design. This feature will allow for occupants of the distressed vehicle to focus on other tasks rather than communicating for support themselves.

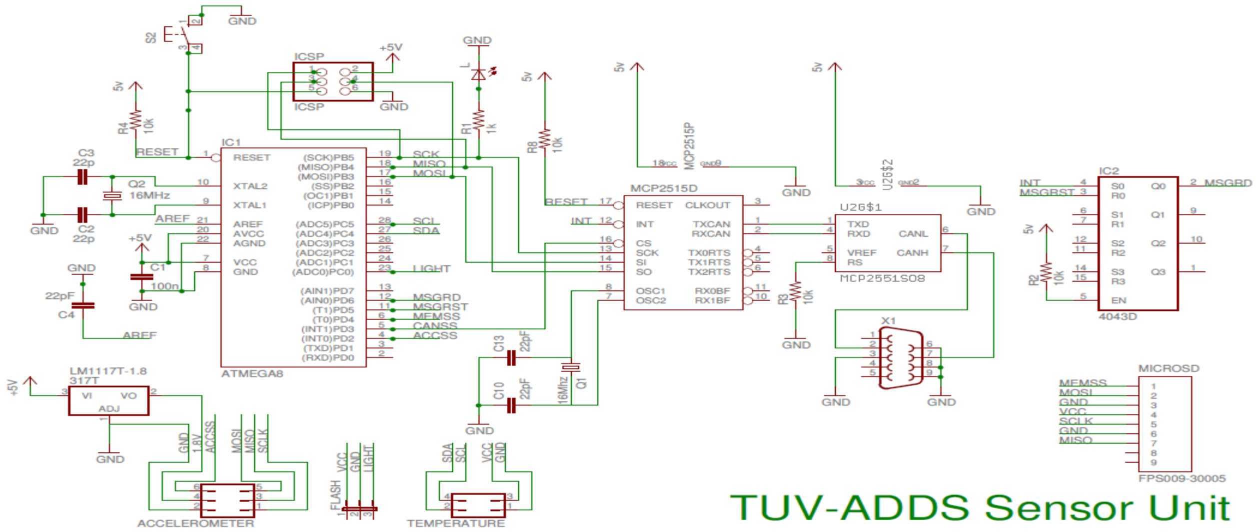


Fig. 2. TUV-ADDS Sensor Unit Schematic

## II. Design Summary

The design for this project was split into modules to organize all the hardware.

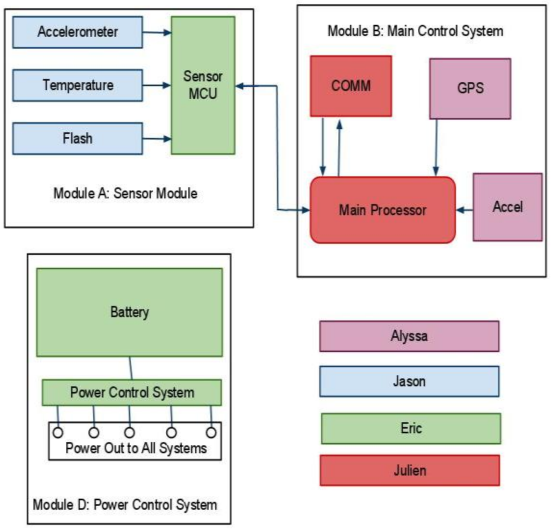


Fig. 3. Hardware Block Diagram/ Work Break Down

Fig. 3 shows the main components of the system and the modules they lie in as well as the hardware work break down structure for the project.

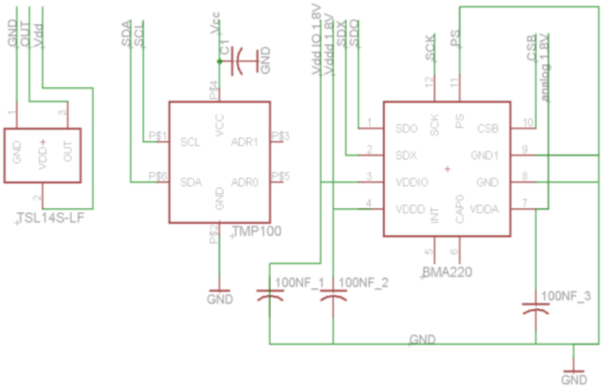


Fig. 4. TUV-ADDS Sensor Schematic

## III. Design Components

### A. Module A — Sensor Module

This module will be further broken down into two (2) main components as shown in Fig. 3; the sensor MCU and a sensor circuit board which will contain the accelerometer, temperature Sensor, and a Photodiode as shown in the schematic in Fig. 2. The design will have the sensor MCU in a more secure and less venerable area on the host vehicle. The Sensor MCU will be used to collect and interpret data from the various external sensors as shown in Fig. 4 and will transmit the data to the main processor once an IED blast has occurred.

An accelerometer was chosen to detect any significant jarring, or change in motion, which would make this component well suited for aiding in recognizing an explosion or rollover. The team understands from conducted research, when an IED strike occurs there is significant propulsion of the vehicle in a specific direction in a very short span of time. The accelerometer we have chosen is the MMA7260QT, manufactured by Freescale Semiconductor; this is a three-axis low g accelerometer with an analog interface.

The accelerometer is a three axes accelerometer with a scalable sensitivity from +/-1.5 to +/- 6g's. This sufficiently meets the requirements set by the group and will also fall nicely with in the budget.

The temperature sensor was implemented to detect thermal energy released from an IED. The team acquired five Texas Instruments temperature sensors. The model is the TMP100, Digital Temperature Sensor with I2C Interface. Our testing procedure will call for a temperature sensor capable of measuring a temperature of near 70°C; this is well within the maximum operational temperature listed at 125°C. The IC temp will take the temperature at the surface of the board and the board intern will be placed on the host vehicle in a location suitable to pick up on any thermal energy applied by our testing procedure. As, the temperature will be taken from the sensor board only low power sensors will be applied to the development of this project. This is an attempt to prevent erroneous heat sources. The TMP100 was selected as it can operate in what TI calls high-speed mode, defined as frequencies above 400 kHz. The Idea behind this is to have a better chance of transmitting data before it could be render inoperable due to an IED blast of any destructive heat sources.

Another source of energy that team has decided to measure is the admittance of luminance, which would released from an IED. The photodiode sensor chosen for this design is the TSL14S-LF light to voltage converter. This particular sensor is an analog sensor, as a digital one was more difficult to logistically come across. This Photodiode sensor is manufactured by Texas Advance Optoelectronic Solutions. The photodiode has a linear output which will allow for consistent voltages to the microcontroller. This photodiode is capable of detecting in the range of 320nm to 1050nm. This should be more than wide enough to respond to and lighting conditions which will be chosen for testing; including infrared and ultra violet light.

All of these individual sensors will be connected to one Atmel Atmega 328 which will also be used to control the CAN network as well as store the data gathered. The storage device on the sensor module will be a 1Gb standard micro SD card and the raw sensor data as well as a timestamp will be loaded on each system cycle. This will serve to act as a 'Black Box' in the event of catastrophic failure, allowing the user to recover the exact parameters of the event even if the comm. System goes down before a report can be issued. The Atmega 328 will be run via a boot-loader as this will speed the development cycle of the product.

### *B. Module B — Main Control System*

The TUV-ADDS Main Control System will utilize an Atmel ATmega2560 processor. This processor is used in the Arduino Mega development board for initial prototyping until the main control PCB can be created. Atmel describes the use of an external 16MHz crystal buffered with two capacitors. The Main Control Unit will be versatile utilizing many different communication protocols (as seen in Fig. 5) as well as flexible to allow any updates. The processor will be accessible through a ICSP as seen in Fig. 7. It is also vitally important to maintain a stable voltage source. An entire subsection of the TUV-ADDS is dedicated completely to power supply. The processor will connect directly to the Power Supply System to draw a steady five volt supply.

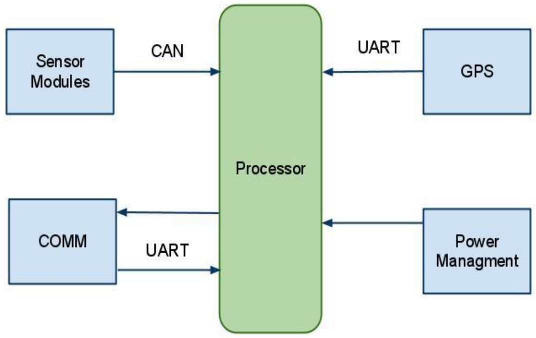


Fig. 5. Processor Tasks

The XBee module has been proven to be an excellent product. The module is susceptible to burn out from high (relatively speaking) signals. If there were to be a large spike in a signal that was slightly higher than five volts, the module could burn out. This situation can be easily avoided by using a five volt compliant buffer (see Fig. 6). The buffer will take a signal based around a five volt average and shift it down to 3.3 volts.

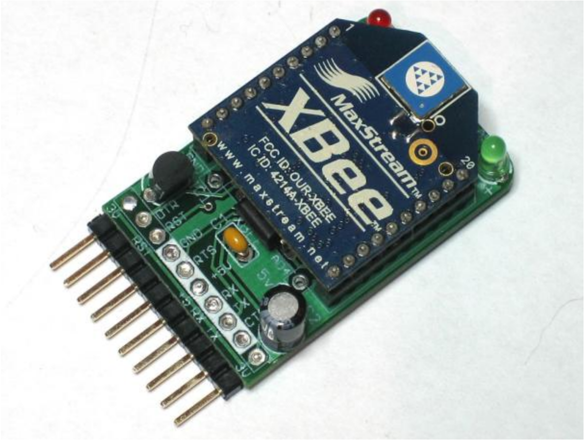


Fig. 6. XBee with 5V/3.3V Buffer Break-out Circuit

The GPS will be required to be accurate and get readings as fast as possible. The LS2301 unit will communicate with the main processor through UART (TTL). Both system have UART capabilities so attaching the GPS unit to the processor will be as easy as connecting the output of the GPS to a GPIO port on the processor.

One of the TUV-ADDS requirements is that the system will detect vehicle rollover. This can be easily detected using a 3-axis accelerometer. If the accelerometer is offset by nearly 180° of a set threshold for a long duration of time (30 seconds or more), then it can be assumed that the vehicle has rolled over. This accelerator is an analog component.

### *C. Module C — CAN*

If the controller determines that a sensor input is outside of user defined nominal readings it will forward an error report, which contains the nature of the event, to the main processor via the CAN controller communicating with a proprietary CAN protocol. The CAN controller is required to implement the software level of CAN communication, while the CAN transceiver is required to ensure the physical CAN layer is within the ISO 11898-2 standard. The CAN network will be run at 125 Kbps due to the error rejection that this speed allows for as well as the low volume nature of the data being sent over the line. The integration of the CAN network into the sensor node can be seen below in Fig. 8. [1]

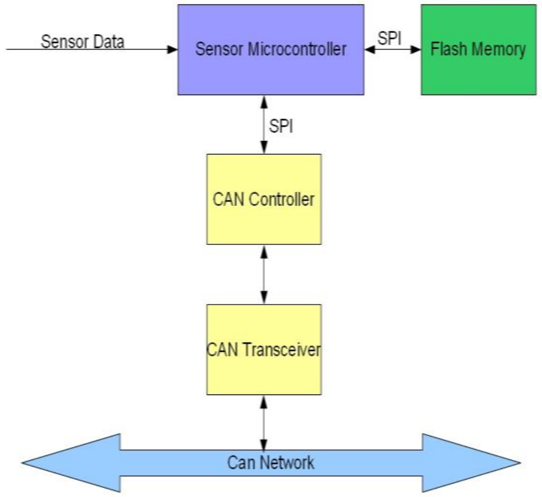


Fig. 8. CAN Flow diagram

TUV-ADDS will be utilizing proprietary CAN communications protocol consisting of an extend frame of length 5. This packet will give the current system time, the time of the event and the nature of the detection. The system will be implemented using a combination of the MCP2515 can controller paired with an ATmega 328 to control the functions of the 2515. The physical layer of the CAN system will be implemented with a 2551 as recommended in Microchips App Notes [2]. Along with error reporting the CAN network will be used to synchronize time between the controller and the nodes as well as maintain status reports from the sensor nodes. The CAN network is flexible and allows for the addition of other nodes with little to no change of the physical layer in the vehicle.

### *D. Module D — Power Control System*

The power control systems requirements are directly related to the devices selected for this project. However, the 9v max output of the vehicles battery limited the maximum operating voltage of the devices chosen. The power control system will consist of the LM2940CT-5, LM1117T-1.8 and LM1117T-3.3 low dropout voltage regulators for 5v, 1.8v and 3.3v supply voltages as in Fig. 9. Due to the existence of a 9v DC battery on the vehicle the connection to the voltage regulators can be direct.

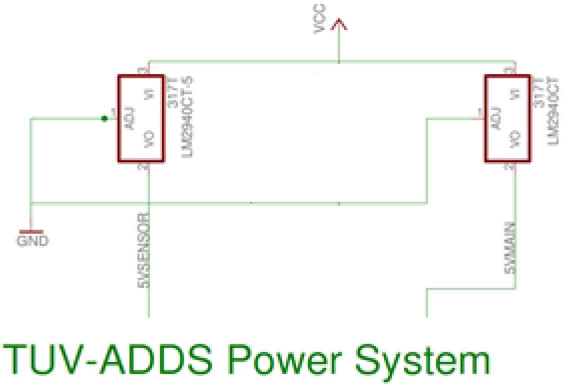


Fig. 9. TUV-ADDS Power System Schematic

### *E. Module E — Software*

Proper software is the only true compliment to a well designed hardware system. The TUV-ADDS system cannot function up to required specifications without some sophisticated software development. This development will be handled in two theaters: first, the sensor MCU and interfacing it with the main processor through a CAN bus; second, the main processor and the wireless interface with the ‘virtual’ command center. Fig. 10 below displays this connection between the systems.

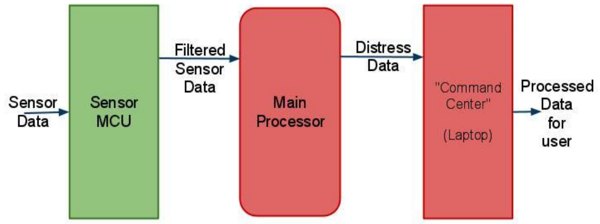


Fig. 10. Software Block Diagram

The main processor as well as the sensor MCU will be prototyped on an Arduino development board. The User Interface will be the only interaction with the user. The UI will display the vital information sent by the TUV-ADDS in the event of distress. The UI used in the TUV-ADDS system will be run using an Event Monitor designed and run with the Processing Programming Language. The monitor will only display information with there is a distress event.

The main processor will be responsible for many functions including I/O using several different communication protocols like CAN bus and UART. Many of the processes (as seen in Fig. 11) required will be run as an interrupt. The processor will have to differentiate between both hardware and software interrupts and place a certain priority on the interrupt request. It will then place the interrupt request on a priority stack (if need be).

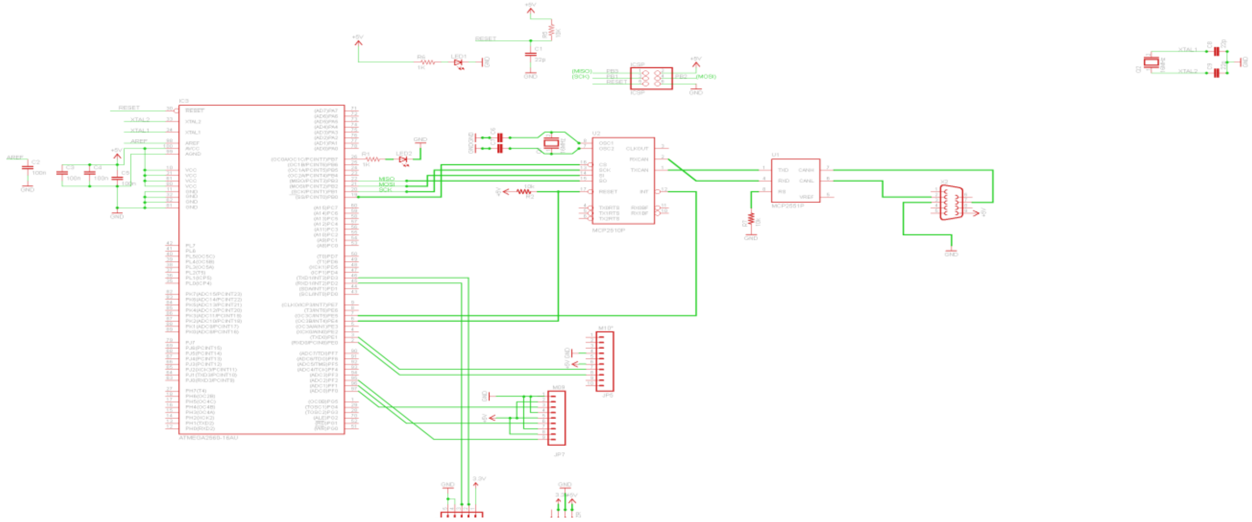


Fig. 7. Main Control Unit Schematic

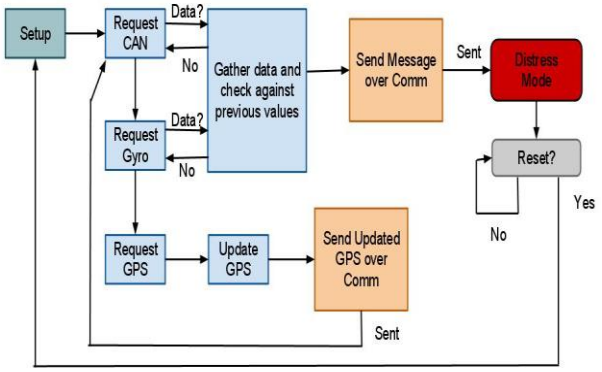


Fig. 11. Main Processor Software Flow

The CAN has a set run routine and its functionality is dictated by values written into various registers via SPI communications. Due to this, no software routines will be written for this chip specifically but rather it will be interfaced with the sensor microcontroller and functions will be written for the ATmega (seen in Fig. 12) which will serve to operate the MCP2515 via SPI.

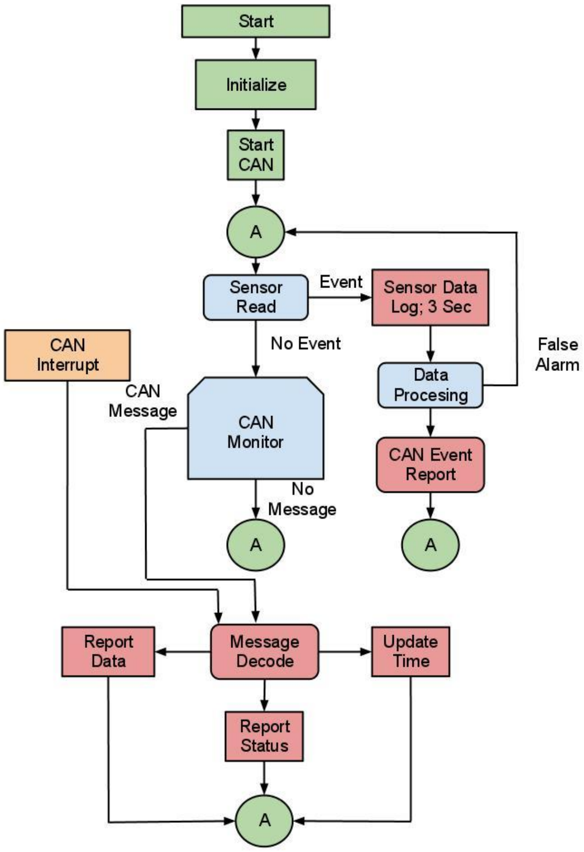


Fig. 12. CAN Software Diagram

The ATmega2560 can communicate to the RF unit using any of the four UART lines available. Some of the available libraries allow several individual bidirectional point-to-point connections. It will also simplify the packet and parsing needed to send large amount of data over a short timeframe. The components of the library are initiated in a way that is similar to Java or any other class driven language.

The GPS unit and accelerometer components will both have to connect to the processor through two of the four UART connections. The software for these devices will be nearly exactly the same except for which pins on the processor they are connected to. The ATmega can easily read in a buffer of data from the UART lines. The software will have to convert the raw data into something useful such as an integer, character, string, or array.

The command center will be written with Java, which is an Object Oriented language. The system will only utilize the basics of the Graphical User Interface (GUI) capabilities that Java has. The command center modem will connect to the command center (computer) using a TTL-232R USB to TTL Serial cable. This cable has a USB to TTL converter embedded directly into the cord. This will allow to XBee module to “talk” directly to the Java software passing all data through an Atmel processor. The processor will wait for an available message from the vehicle, organize the data, and finally send the data serially to the Java software. The XBee can communicate directly to the Java software through a serial port and the TTL cord, but the module does time-out the network to save power. The processor will ‘wake-up” the XBee while it is getting the data ready to send.

## IV. PROTOTYPE CONSTRUCTION

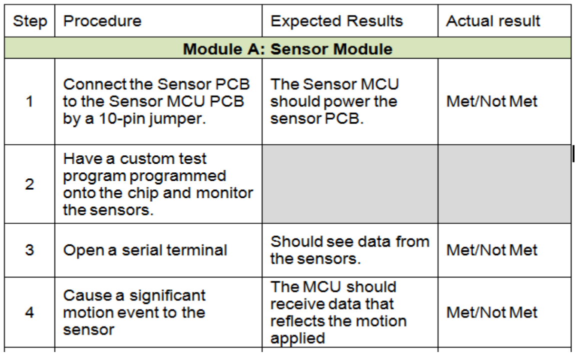
The system will use several Printed Circuit Boards (PCB) modulated into three sections: The sensor MCU, the main control unit, and a sensor modules. The sensor MCU will contain the Atmel micro controller and the CAN-bus. The main control unit will contain the ATmega, accelerometer and XBee-PRO and the three unit the sensor module which will contain the accelerometer, photodiode and temperature sensor. We will also implement the power regulators as needed to supply the appropriate voltage to each part.

The software that will be implemented in the design of the PCB layout will be EAGLE CAD. This software package includes a schematic editor that is used for the design and layout of the board. EAGLE will also allow us to create schematic diagrams of the circuits we will be construction during the design of TUV-ADDS.

For our prototype we will be using a Power Wheels (Fig. 13) vehicle as a platform to host our system. The Power Wheels we noted there was quite a bit of room in the “engine compartment.” This area would be the best place to securely mount the main control unit and sensor MCU required for operation of the system. The Sensor PCB will be places which is exposed and venerable to such explosions. The sensor PCB and the Sensor MCU will be connected using a standard 15 pin D-sub connecter.

## V. TESTING

The test plan will consist of testing each component individually, in a modular fashion, to make sure they work correctlyas shown in Fig. 14. After all the components of a module are tested and verified that it operates as the team has expected, the process of combining each component into a working module will begin. Once a module has been successfully constructed and assembled the testing all of the modules individual will then take place to ensure that the module works before integrating the modules into a complete system. After all the modules are tested individually and verified if functions as the team expected, they will all be combined into a complete system and system verification testing will take place; focusing on the operation of the software and the system as a whole unit.



| Step | Procedure | Expected Results | Actual result |
|---|---|---|---|
| **Module A: Sensor Module** | | | |
| 1 | Connect the Sensor PCB to the Sensor MCU PCB by a 10-pin jumper. | The Sensor MCU should power the sensor PCB. | Met/Not Met |
| 2 | Have a custom test program programmed onto the chip and monitor the sensors. | | |
| 3 | Open a serial terminal | Should see data from the sensors. | Met/Not Met |
| 4 | Cause a significant motion event to the sensor | The MCU should receive data that reflects the motion applied | Met/Not Met |

Fig. 14. Example of TUV-ADDS Test Plan

Module E, software, will be tested differently than the other modules. The software will be tested and debugged as it is written. Then when the system is integrated together, the system verification tests will test that the software correctly works with the hardware. Module D, power supply system, will only be tested at a component level because the module is simply several of the same components operating separately.

Fig. 13. Power Wheels

When testing TUV-ADDS as a system, it will be attached to a vehicle that will suite its needs and it will be put through simulated IED hits and a rollover event to see if the system works correctly by communicating to the command center that it has been in a distressful even. The system will also be tested to make sure it is accurate by having it go through events that simulate non-distress events that should not set the system to alert for help such as rough terrain, as well as an event simulating an unusually hot day. This will give the team proper assurance that the system is working to the goals and objections desired. It is wanted to have a system which will minimize false positive distressing signals, as this would be counterproductive to the intensions of this system.

The team plans on using a Wii Nunchuck breakout adapter (see Fig. 15) that will connect directly to the microcontroller. The microcontroller will attach to the switches in the Power Wheels. This will allow the team to drive the Power Wheels with the Wii Nunchuck.

Fig. 15. Wii Nunchuck Adapter with Nunchuck

For testing the system of the event of an IED blast, we will construct a platform that will quickly accelerate the vehicle in the upward position while simulating the heat with a blow dryer and the flash with a flashlight to see if these combinations of characteristics will trigger a call to the system for assistance as it should. When testing the rollover aspect of the system, we will simply manually cause the vehicle to turn completely on its side and this should alert for assistance after the specified time amount has been reached.

## VI. CONCLUSION

TUV-ADDS was designed with the idea of helping the men and women of the armed forces perform their duties with a convenient safety feature. With the creation and integration of this system, the need for reliable distress communication for these men and women, that face the obvious danger, in the Middle East everyday was kept in the mind. The system design is a network of sensors and the supporting hardware and software that will be integrated to meet this need.

Throughout this semester, significant knowledge has been gained about design and component choices as well as the military and Government relevance to our project. The experience of gathering data about different parts and comparing data sheets as well as collaborating with each other has been very beneficial to the team as we prepare to enter the professional world of engineering.

## ACKNOWLEDGEMENT

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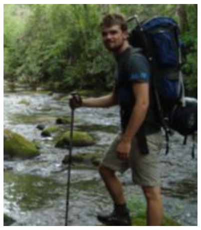
## BIOGRAPHIES

Julien Mansier is currently a senior at the University of Central Florida and will receive his Bachelor's of Science in Electrical Engineering in December of 2011. He will be working for Cummins in the control systems department for the off-highway/industrial division.



Eric Nachtigal is currently a senior at the University of Central Florida and will receive his Bachelor's of Science in Electrical Engineering in December of 2011. He is currently treasurer of the outlanders club as well as a member of the rock climbing club and has hobby's including scuba diving, backpacking, and skydiving He will be working for Texas Instruments as part of their Analog Applications global rotation program beginning February 2012.

Jason Skopek is currently a senior at the University of Central Florida and will receive his Bachelor's of Science in Electrical Engineering. To date he has focused his education on power systems and has worked for a local company to oversee the power distribution of mobile vehicle systems. He has also interned for an engineering company to help model ark flash studies. He is very interested in many areas in the spectrum of electrical engineering, not just power systems, and will be exploring career paths as well as full time employment.

Alyssa Almanza is currently a senior at the University of Central Florida and will receive her Bachelor's of Science in Electrical Engineering in December of 2011. She is heavily involved in the UCF section of the Society of Women Engineers and currently works for the U.S. Army PEO STRI. She hopes to continue her career in the defense industry and serving the warfighter.

## REFERENCES

[1] Microchip Technology Inc., "Controller Area Network (CAN) Basics," AN713 datasheet, 1999.

[2] Microchip Technology Inc., "Stand-Alone CAN Controller with SPI Interface," MCP2515 datasheet, 2010.