Luggage Link

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***Abstract* — The main objective of this project is to demonstrate the tracking capability of a single Luggage Tracking Unit (LTU). This device is configured to record GPS fixes every 15 minutes and transmit the data to the user via text message or email. Ambient light is detected using a phototransistor that indicates if the luggage has been opened. A barometric pressure sensor is used to determine when the airplane is taking off or landing, and therefore avoid the use of cellular communication in order to comply with FAA regulations. A GPS server is implemented that hosts OpenGTS, an open source software, allowing users to login and observe the current and previous locations of their luggage.**

***Index Terms* — Tracking, GPS, GSM, cellular network, OpenGTS server, phototransistor, barometric pressure.**

I. Introduction

According to the March 2012 Air Travel Consumer Report published by the U.S. Department of Transportation, in January of 2012 there were 139,118 reports filed for mishandled luggage in the United States. While the statistic has decreased slightly since January of 2011, with a total of 181,608 reports filed, the problem of lost, delayed, or otherwise mishandled luggage is a significant one [1]. It should also be noted that this statistic only represents claims of mishandled luggage for domestic flights within the United States. Thus, these numbers represent only a fraction of the total number of incidents occurring each month on international flights from the U.S., as well as the countless other flights happening worldwide around the clock.

The Luggage Tracking Unit is able to record the current location of the user's luggage using the Telit GM862 with GPS capabilities [4]. To keep the user up-to-date on the status of their luggage, a number of events are sensed and recorded by the LTU. One such event is triggered when the luggage is opened and ambient light is sensed by the phototransistor, which generates a rising edge signal to the input pin of the microprocessor. A second triggering event happens throughout variations in barometric pressure. These changes signify fluctuations in altitude while on an aircraft. A pressure sensor converts absolute pressure to DC voltage. This output signal provides analog voltage to an input pin on the microprocessor. In order to detect changes in altitude that signify whether the aircraft is ascending or descending, the microprocessor's program compares several consecutive pressure readings and calculates the rate of change of the pressure. If a rate value above the threshold is detected, the GSM cellular module on the LTU is disabled to conserve power.

GPS fixes and events are stored in flash memory, and status updates and notifications will be sent to the user via text message and/or email at certain time intervals. Data will also be transmitted to a GPS server to be displayed on a map, signifying the current location of the LTU. Users with internet access will be able to log in to their account to determine the location of their luggage and view other LTU data.

II. System Concept Diagram

As seen in Fig. **1**, the LTU logs and stores GPS fixes and other data. Once in range of cellular network, it sends text messages and/or emails and uploads data to the GPS server. A user with internet access can log in to the web portal and view data logged by the LTU as well as a map display of where the unit has been.

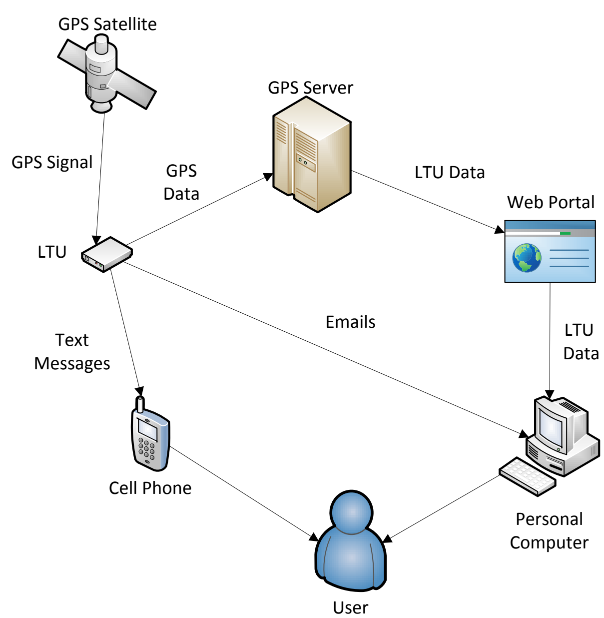

Fig. 1. System Concept Diagram

III. Luggage Tracking Unit Design

Hardware Requirements

From a hardware perspective, the LTU design fulfills the following requirements: small form factor, highly portable, affordable, and reliable. It provides accurate position via GPS, stores digital data, and provides cellular communication for sending text messages, emails and GSM data. It also contains a rechargeable battery capable of operating for several days, as well as a means for recharging the battery.

A programmable microcontroller serves as the central processor for all LTU operations and functions. The microcontroller determines when a connection is made to the cellular network, which data to send, where to send the data, and when to send it. The microcontroller also requests GPS fixes, sends and receives data to and from memory, sets power modes for all components, senses digital signals from the phototransistor, and reads analog voltage levels from the pressure sensor.

All major internal components are mounted on a printed circuit board (PCB). The physical dimensions of the PCB are designed and manufactured to fit within the enclosure.
The GPS Module provides real-time position tracking accurate to within +/- 15 meters. It also provides velocity information accurate to within +/- 0.2 meters per second.
The GSM Module transmits SMS text messages and email alerts with GPS coordinates and other pertinent information. As depicted in Fig. **2** the GSM module contains an externally accessible slot for a subscriber identity module (SIM) card.

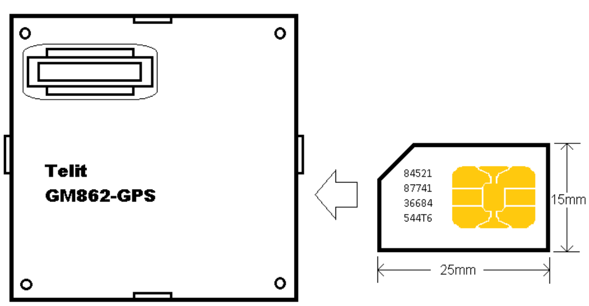

Fig. 2. Mini-SIM card dimensions – GM862-GPS

Antennas are required for the GPS and GSM components. Both antennas have the capability to obtain signal reception while inside a multistoried building. This ensures the LTU will be able to receive GPS satellite signals and GSM network signals while inside an airport terminal.

LEDs are used to provide visual indication for GSM network status, GPS status and LTU status. The green LED represents GSM network, the red LED represents LTU status, and the yellow LED represents GPS status. The GSM status LED turns on and flashes at short intervals when searching for a GSM network. Once network connection is established, the intervals between flashes are longer. The GPS status LED turns on and flashes at intervals based on its current mode of operation: short intervals for getting connection and long intervals while receiving GPS fixes. The LTU status LED flashes at different time intervals depending on the function or section of the program currently being executed.

A rewritable flash memory mounted to the PCB allows GPS fixes, light detection events, and pressure change events to be stored.

A rechargeable Lithium Ion battery provides power to all components for at least 72 hours. A power adapter and a charge manager are used for all power regulation and battery charging. An external power port is used for recharging the battery. A power port with a small form factor was chosen in order to prevent debris from entering the port and minimize the possibility of damage to the port. A two position switch is in place to turn the device on and off.

A two-piece enclosure houses the PCB. The enclosure contains apertures for the Mini Universal Serial Bus (USB) port, On/Off switch, and LED indicators. The enclosure is made of plastic and its dimensions are within the requirement of 4”x 4”x 1”.

IV. Software Requirements

A TI MSP430 microcontroller handles the interaction of the various components on the PCB. The microcontroller possesses all necessary features such as clock generators, watchdog timers, and commands for sending and receiving data to and from different hardware components. The MSP430 also features multiple modes of serial communication, including UART, SPI, and I^2C. UART and SPI are used for communication between the GM862 and Atmel memory chip, respectively [5].

A GPS server, provided by OXXUS.net, is implemented and hosts the open source OpenGTS server software. The servers functions as a communication node between the LTU and the user. The server is configurable for communication with multiple LTUs and provides the capability to receive and process data from those LTUs. The GPS server also distributes data to the web portal for retrieval and analysis by the user [2].

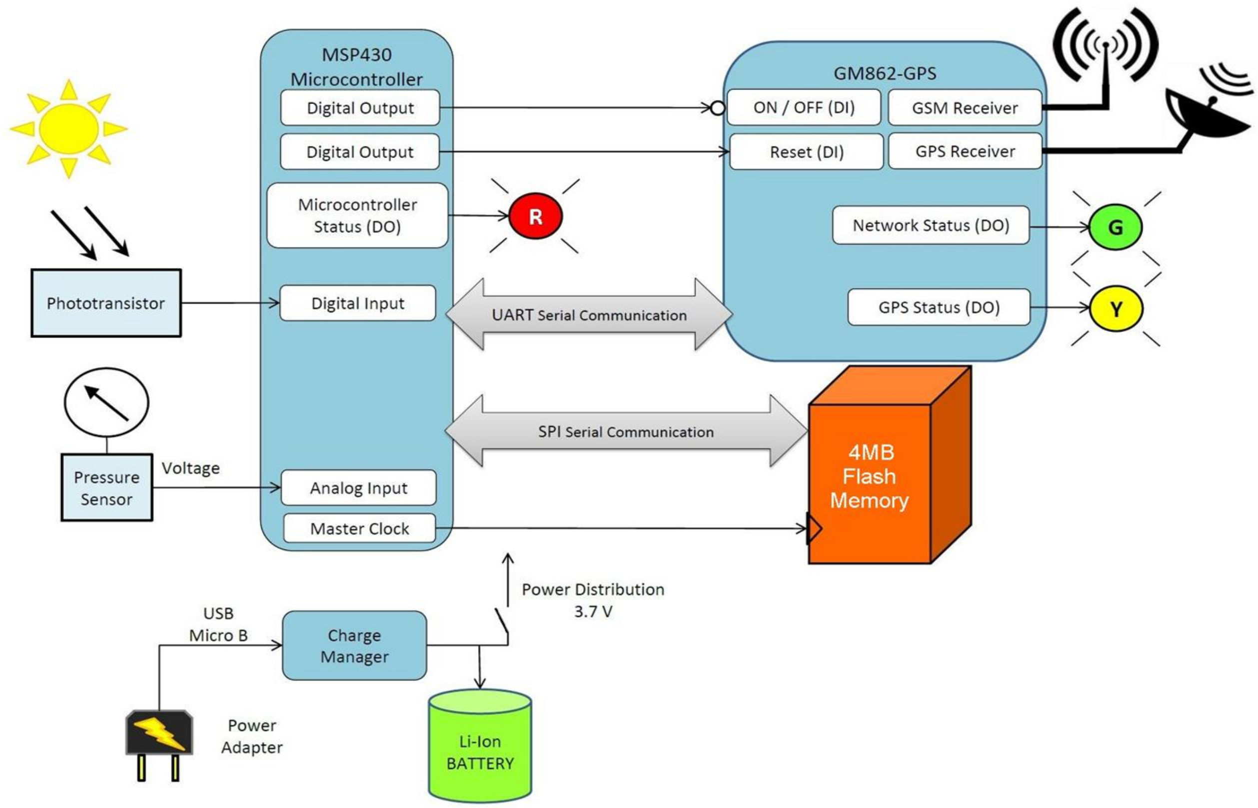

Fig. 3. Hardware Block Diagram

V. Hardware Block Diagram And Components

Fig. 3 depicts an overview of interconnections for the hardware components. The microcontroller serves as the central controller for handling all communications. Moreover, the microcontroller monitors the subsystems in order to coordinate sequences of operation and minimize power consumption. The microcontroller interfaces with the GM862 via Universal Serial Communication Interface (USCI) [6]. The microcontroller communicates with the flash memory using Serial Peripheral Interface (SPI). For Network status and GPS status, two digital outputs provided by the GM862 are utilized. These digital outputs control two LEDs: a green LED for GSM network status and a yellow LED for GPS status. A red LED is connected to an output pin on the microcontroller to indicate different states of the LTU. The microcontroller also monitors the barometric pressure sensor through an input pin that reads analog voltage levels. A different pin, set for digital input, is connected to the phototransistor. The GSM and GPS antennas are connected to the SMA receptacles on the GM862. The connections are made via coax cables and MCCX male connectors. The two-position switch turns the LTU on and off and controls the power distribution throughout the PCB. The charge manager and the USB Micro B receptacle utilize the 5 VDC from the power adapter to charge the Li-Ion battery properly.

In order to turn the GM862 on and off, an output pin on the microcontroller is connected to the on/off pin of the GM862 and provides the required two-second digital low signal. Our first LTU prototype is seen in Fig. **4** with the cover removed.

Fig. 4. LTU Design and PCB

The following is a list of components that have been selected because they are compatible with the same voltage level of 3.7VDC. This strategy prevents the need for power regulators and voltage dividers.

A. Microcontroller

Device: MSP430 ultra-low-power 16-bit microcontroller.
Part Number: MSP430G5223
Manufacturer: Texas Instruments.
Description: 16-bit RISC CPU, 16-bit registers, 16-bit timers, 10-bit analog-to-digital (A/D) converter, 16 IO pins, support USCI, UART and SPI.
Power: 1.8 V to 3.6 V.

B. GPS and GPRS/GSM Module

Device: GPS receiver and GPRS digital communication.
Part Number: GM862-GPS
Manufacturer: Telit.
Description: Quad-band GSM/GPRS modem with 20-channel high sensitivity silicon radio frequency (SiRF) Star III GPS receiver. 13 IO pins, serial link through UART (RS-232)
Power: 3.2 V to 4.5 V.

C. GSM Antennae

Device: Active antenna for Cellular communication
Part Number: FXP07.09.0100A
Manufacturer: Taoglas
Description: Flexible GSM antenna, 83% efficiency.

D. GPS Antennae

Device: Active antenna for GPS reception
Part Number: GPS3620
Manufacturer: EAD
Description: Compact internal GPS patch, LNA gain 29dB.
Power: 2.5 V to 5 V.

E. Memory

Device: 4-megabit data flash memory IC
Part Number: AT45DB041D
Manufacturer: Atmel
Description: RapidS Serial Interface SPI Compatible up to 66 MHs, two SRAM Data Buffers (256/264 Bytes), Low-power dissipation.
Power: 2.5 V to 3.6 V.

F. Pressure Sensor

Device: High Accuracy, Absolute Pressure Sensor IC
Part Number: MP3H6115A
Manufacturer: Freescale Semiconductor
Description: Pressure range 150 PA to 115kPA (2.2psi to 16.7 psi), temperature compensated, fast response < 1.0 ms, Accuracy 1.5% Vfss.
Power: 2.7 V to 3.3 V.

G. Phototransistor

Device: Silicon NPN Phototransistor
Part Number: BPW85A
Manufacturer: Vishay
Description: Silicon NPN phototransistor with high radiant sensitivity to visible and near infrared radiation, fast response, T-1 plastic package.

H. LEDs

Devices: Red, Green, Yellow 3mm LED
Part Number: SSL-LX3044IC, SSL-LX3044GC, SSL-LX3044YC
Manufacturer: Lumex
Description: Through hole LED, 100 mcd luminous intensity, 30 deg viewing angle, dome lens shape, T-1 plastic package.

I. Battery

Device: Rechargeable Lithium Ion Battery.
Part Number: UBP002
Manufacturer: Ultralife
Description: 3.7V, rechargeable Lithium Ion Battery, 900mAh, high energy efficient, thin shape, wide operating temperature range. Charge voltage 4.2V.

J. Charge Manager

Device: Single-chip Li-Ion charge management IC
Part Number: BQ24024
Manufacturer: Texas Instrument
Description: Low dropout charger design for single-cell Li-Ion packs, pre-charge conditioning, battery detection. Charge regulation voltage of 4.2V.

K. Other Components

Resistors: 470Ω, 4.1KΩ, 10KΩ, 47KΩ, 51KΩ
Capacitors: 0.1μF, 0.47μF, 0.47pF.
Zener diode: 6.2V, 500 mW
NPN bipolar transistor
50 pin connector
USB micro B receptacle
Switch 2-position
IC socket 20 pin

VI. Microcontroller and Cellular Module Communication

Fig. **5** shows the schematic diagram for Universal Serial Communication Interface (USCI) between the microcontroller and the GM862 cellular module. The implemented protocol is based on RS232 with one transmit line, one receive line, 8 bit data, one stop bit, and no parity bit. Because the UART protocol is used, there is no flow control.

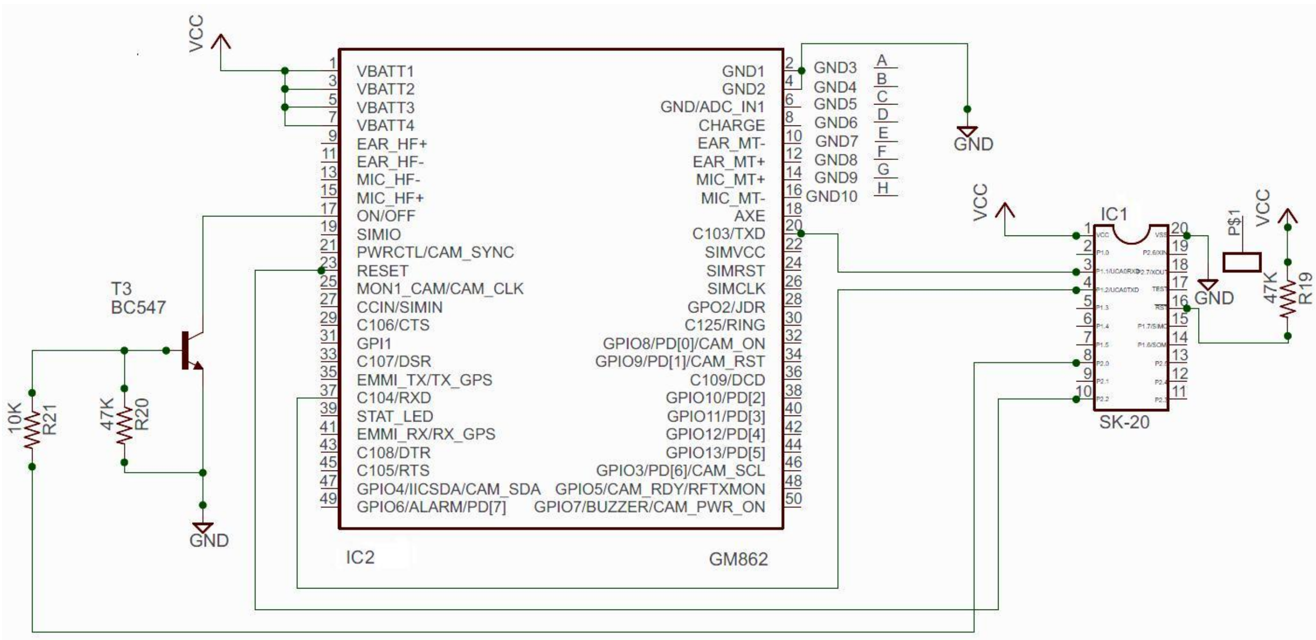

Fig. 5. Microcontroller and Cellular Module USCI Schematic Diagram

VII. Microcontroller and Memory Communication

Fig. **6** shows the schematic diagram for the SPI bus between the microcontroller and the memory chip. The implemented protocol is based on a synchronous serial data link data operates on a full duplex mode. The microcontroller is the master and the memory is the slave. 5 lines are connected between the two ICs. The Chip Select (CS) line is used to enable and disable the memory. Two other lines are used for sending and receiving data. Another line is used for a clock to be used by both devices in order to synchronize all data. The last line is for allowing the microcontroller to reset the memory. Write protection is not used and therefore has been connected to Vcc.

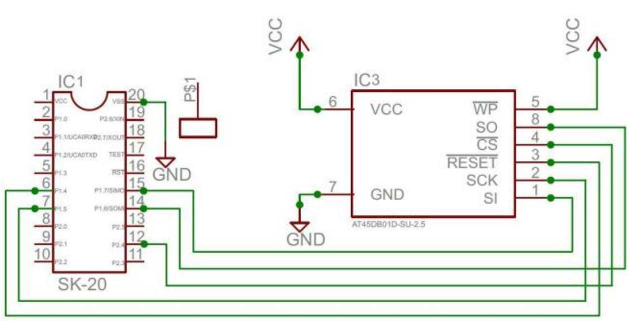

Fig. 6 Microcontroller and Memory SPI Schematic Diagram

VIII. Ambient Light Sensor

Fig. **7** shows the schematic diagram for the ambient light detection. A PNP phototransistor is connected to the input pin of the microcontroller. The gain has been calculated by adjusting resistor R8 to 4.1KΩ. When no light is present, no current is flowing through the transistor which, in turn, keeps pin 5 of the microcontroller at a logical zero (low). When ambient light is present, current passes through the transistor, and once the voltage threshold of 2.2V is surpassed across resistor R8, a logical high is read by the microcontroller. It is important to note that pin 5 of the microcontroller must be configured as an input pin.

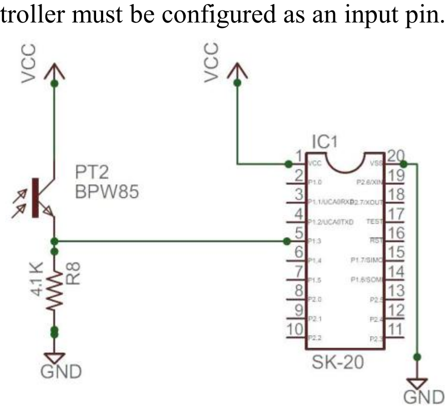

Fig. 7. Phototransistor Schematic Diagram

IX. Barometric Pressure Sensor

Fig. 8 shows the schematic diagram for the barometric pressure sensor. The IC is connected to the input pin of the microcontroller. Pin 2 of the microcontroller is set to read analog voltage. The microcontroller uses the Analog to Digital converter to generate a digital value for all calculations. The output pin 4 of the pressure sensor also has a capacitor and a resistor that functions as a low bypass filter thereby avoiding any high frequency transients.

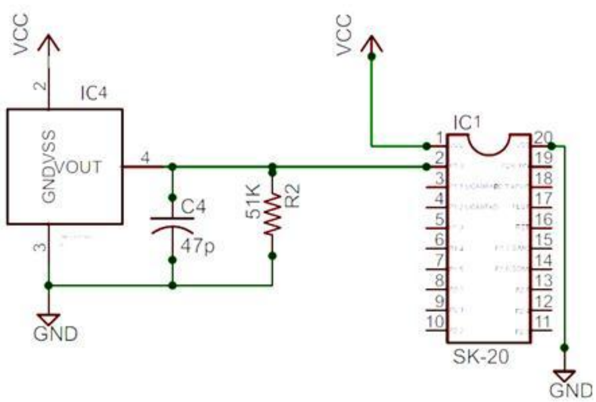

Fig. 8. Pressure Sensor Schematic Diagram

X. Functional Architecture

A. GSM Module

Fig. **9** depicts a block diagram of the LTU operation cycle. When the LTU is powered on, the GM862 is also powered on by the microcontroller. Once the GM862 is powered on, the GSM and GPS modules both enter full power mode by default. A simple command is then sent to the GM862 to verify communication between the microcontroller and GM862. Upon verification of this communication, the GSM and GPS modules are immediately commanded into a low power mode and an operation cycle is initiated. “Operation cycle” is the name given to the series of tasks that are executed by the LTU every certain number of minutes. The first task executed in the operation cycle is communication test. This is the same test that is run when the LTU is first powered on. After the communication test, the GPS module attempts to obtain a GPS fix. If a GPS fix is successfully obtained, the data is saved in the LTU’s memory and transmitted to the user according to the notification settings. If the GSM module is not able to send the data, error reports will be stored in memory and the GSM module will reenter low power mode. During the next operation cycle, the LTU attempts to send any messages that were unsuccessfully sent in the previous operation cycle as well as any new messages generated in the current operation cycle.

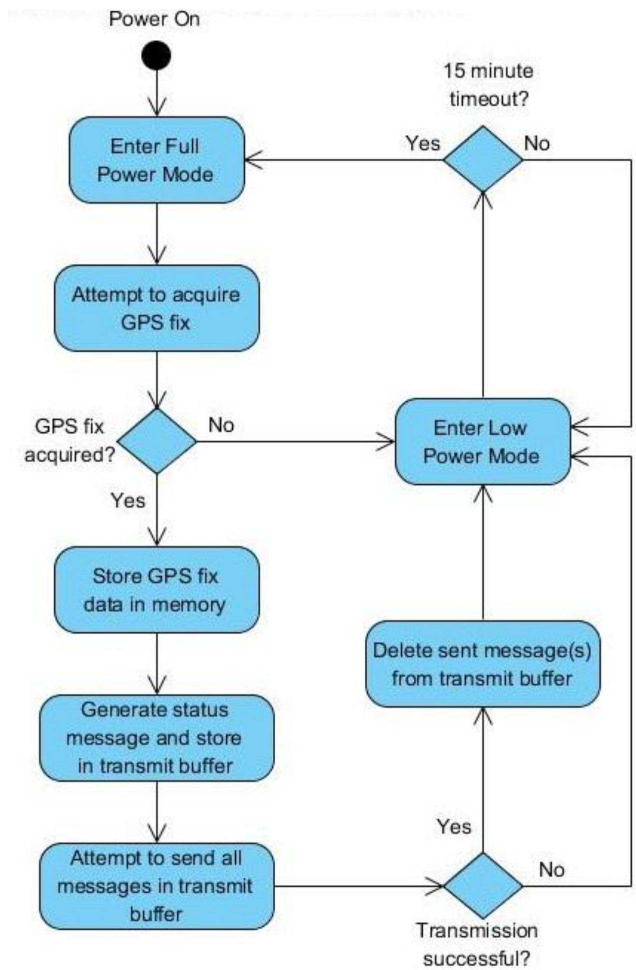

Fig. 9 LTU Operation Cycle Activity Diagram

If all conditions for transmission are met, the GSM module attempts to connect to and register with any available GSM network. If the module successfully connects to a network, it will transmit all messages in the transmit buffer at that time. Once the messages have been sent, the module returns to a low power mode. If a network is not found, or if a network is found but the signal strength is too weak to connect, the module is allowed a maximum of 3 attempts. If, after three attempts, the module has not successfully connected to a network, an error report is generated and the module returns to a low power state.

Once the module enters the low power mode, a 15-minute timer begins. When the timer reaches zero, the GSM module reenters full power mode and begins the network acquisition and message transmission process again.

B. GPS Receiver

The activity cycle of the GPS receiver is very similar to that of the GSM module. The GPS receiver is powered on when the LTU is powered on and is initially in full power mode. Once communication with the GM862 has been verified, the GPS module is commanded into low power mode. Unlike the GSM module the GPS receiver has no restrictions for use onboard a commercial airplane. For this reason, it is not necessary to check any conditions before the module is allowed to search for available GPS signals. If a sufficient number of GPS satellites are in range, enabling a successful GPS fix, the data obtained is processed into individual buffers, stored in memory, and compiled into a message to be transmitted by the GSM module. Once the data has been stored in memory, the GPS receiver will reenter lower power mode in order to minimize power consumption. In the case that the receiver is not able to immediately acquire a GPS fix, it is allowed two more attempts to do so. If three attempts are made and a successful GPS fix has not been obtained, the receiver reenters a low power mode. [3]

After the GPS module enters the low power mode, a 15-minute timer is started. This is the same timer that controls the GSM module operation. When the timer reaches zero, the GPS receiver will reenter full power mode and begin the GPS satellite acquisition and data storage process again. The activities performed by the GSM module are summarized in the activity diagram in

Fig. **10**.

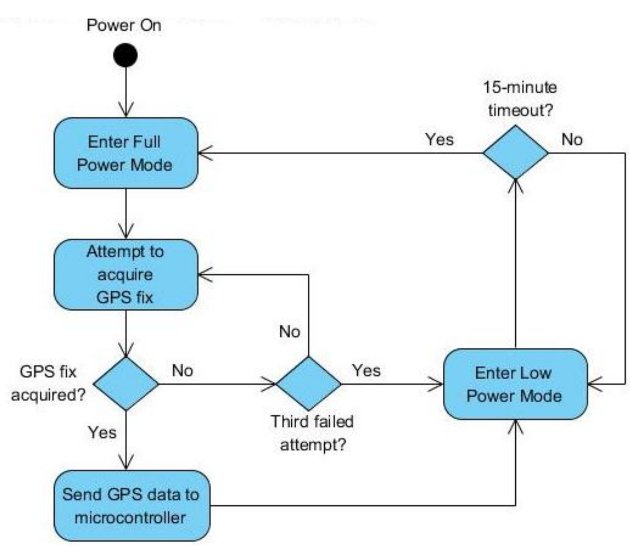

Fig. 10. GPS Module Activity Diagram

C. Ambient Light Detection

If the luggage containing the LTU is opened, exposing the LTU to light, the phototransistor triggers an interrupt that sends an alert to the user. The light sensor interrupt is essentially configured as a digital interrupt. It is tied to the light sensor's input pin on the microcontroller and is triggered when a logical one (high) is sensed on that pin. In addition to sending an alert to the user, the interrupt also logs a record of the event in the memory module for reference purposes.

D. Altitude Detection and Barometric Sensor

A safety mechanism is implemented using a pressure sensor to prohibit the GSM module from transmitting messages while on an airplane. On passenger airplanes the cabinet and cargo areas are pressurized to what is referred to as "cabin altitude". Most aircrafts maintain a cabin altitude of less than 8,000 ft (2,400 m). This pressure is converted to analog voltage by the pressure sensor, and its output is connected to the ADC input pin on the microcontroller. An analog to digital converter provides a means for this voltage to be interpreted by the software. A trend can be observed by comparing the most recent analog to digital conversion to the previous one. A decreasing trend indicates less pressure and, therefore, increasing altitude. An increasing trend indicates more pressure and, therefore, decreasing altitude. The microcontroller's infinite loop contains a section that checks for the rate of change in pressure. If three consecutive changes in rate are detected in an increasing or decreasing trend, a flag is set to indicate that the LTU is on an aircraft, and the luggage is landing or taking off, respectively. An algorithm in the software scans for a rate of change above a threshold in order to avoid any noise or changes in pressure not related to the cabin pressurization.

XI. Power Consumption

In order to save battery power and extend the life of a single charge, a power-saving mode and an active mode have been implemented in the microcontroller software. During power-saving mode, the LTU consumes less than 5 mA, while in active mode it consumes about 478 mA. The battery capacity is 900 mAh. If the unit enters active mode 4 times per hour for 1 to 2 minutes, the battery could last for at least 6 days.

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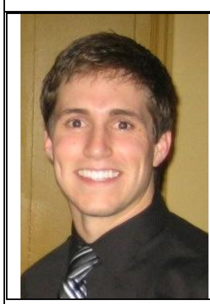
BIOGRAPHY

David Farrell is a senior Computer Engineering student at the University of Central Florida. For the last 3 years, he has worked as a student intern at Lockheed Martin Missiles and Fire Control in Orlando. After graduating in December of 2012, he plans to pursue a career in engineering with either Lockheed Martin Missiles and Fire Control or the U.S. Government. Outside the classroom, David leads the college ministry at his church and enjoys participating in short term mission trips, playing sports, and spending time with family.



Evan Husk is a senior Computer Engineering student at the University of Central Florida. He is currently conducting research and writing an undergraduate thesis under the supervision of Dr. Avelino Gonzalez. The research and thesis is on *Imitating Individualized Facial Expressions in a Human-Like Avatar through a Hybrid Particle Swarm Optimization – Tabu Search Algorithm*. After completing his thesis and graduating in December of 2012, he plans on furthering his education by pursuing a master's degree in systems engineering at the University of Florida. He wishes to work as a systems engineer in the defense industry or in the field of electronic sales. In his free time, Evan likes to play sports, fish, and spend time with his family.

Jose Mousadi is a senior Electrical Engineering student at the University of Central Florida. For the last 6 years he has been working as a Project Engineer and Electrical Designer at GTE, LLC. in Orlando, Fl. Previously, he worked as a Panel Builder at G&T Conveyor, Inc. This hand-on approach has aid him acquired extensive knowledge in industrial control systems and instrumentation geared towards the power generation and energy sector. Lately he has designed, developed and managed auxiliary systems used in Gas and Steam Turbines as well as other OEM products. In his free time, Jose likes to travel and spend time with family.

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