Saxton Transportation Operations Laboratory
Task 3.5 – STOL Vehicle Build Documentation

Project Number: DTFH61-12-D-00020

Submitted: September 30, 2013

Version: 1.0

CONTENTS

1 INTRODUCTION

The following document provides the final vehicle build documentation (Subtask 3.5) of the Saxton Traffic Operations Lab (STOL) project. This documentation does not provide detailed project background; which is available within previous Task 3 deliverables. As a companion to this document, a separate STOL Operating Manual has also been produced. For most users, the STOL Operating Manual should be the primary reference. This document is intended for system developers who require additional, more detailed, information on the installed systems. In many cases, both documents should be used in combination.

1.1 PURPOSE

The intent of this document is to provide the final design documentation for the Cadillac SRX vehicle builds, including the software documentation, bill of materials, and subsystem operating manuals. Manuals are generally provided via links to the internet; however, a zip file of manuals has also been provided.

1.2 SCOPE

Rather than develop new Cooperative Adaptive Cruise Control (CACC) system from scratch, the vehicles leverage the existing factory Adaptive Cruise Control (ACC) system. The equipment developed during Task 3 permits the SRX vehicles to receive instructions via cellular communication (server ACC), Dedicated Short Range Communications (DSRC), or from the experimenter control station to automatically alter the vehicles' pre-existing ACC system (desired speed and headway). The factory ACC algorithms and safety systems are the last link and ultimately control the vehicles. Software modifications to the CACC system are readily enabled through configuration files and an onboard C++ development environment that allows experimenters to make changes in the field.

The reader is reminded that Task 3 was intended to develop the base vehicle to enable testing in the STOL. The first vehicle application of the vehicles is conducted under Task 2. While the vehicles were built to satisfy the needs of Task 2, the specific algorithm and implementation details will be developed and executed by the Task 2 team. As such, the software system within this manual is subject to change and should be revised over time as appropriate. The emphasis of this documentation is also on the relatively stable base architecture rather than implementation details which are likely to change.

2 SYSTEM OPERATION OVERVIEW

Operationally, the vehicles' CACC system may be used either independently or within a platoon of vehicles traveling together. When acting independently, the CACC accepts information sent by the infrastructure to affect the ACC operation. When following a vehicle, the CACC system continues to accept information from the infrastructure; however, behavior may be partially guided by the factory ACC, which manages the safe gap to the lead vehicle using a ranging sensor. The factory ACC also imposes limitations on the acceleration and braking levels that can be achieved. The relative contribution of the factory ACC algorithms depends on the logic inserted by the researchers.

When a message is received from the infrastructure (or experimenter laptop, if message emulation is being used) it is processed and turned into commands that are relayed to the vehicle's ACC system. The following is the process flow for activating CACC:

1. Driver/experimenter enables CACC application via experimenter interface. This action can be performed prior to starting the trip. The system can be run in three different modes: ACC Off, User or Server.
2. When desired, the driver engages CACC via factory control (located on the steering wheel of the SRX).
3. When in user mode, the laptop GUI (described in the operating manual) may be used to alter the ACC settings.
4. The CACC display indicates one of the following status on Server Mode:
    a. CACC ‘ready’ but no information available from infrastructure. When CACC is in ‘ready’ mode, the factory ACC system will function as usual.
    b. CACC ‘engaged’ and receiving relevant information from the infrastructure. When CACC is in ‘engaged’ mode, the vehicle will adjust its ACC settings according to commands from the infrastructure.
5. When in CACC mode, the vehicle may be driven in isolation or in a group. When in isolation, the system will adhere to the infrastructure commands. When in a group, the system will strive to adhere to the infrastructure commands; however, if a slower lead vehicle is present, the factory ACC system may control the vehicle’s speed to maintain a safe headway.
6. When new infrastructure information is received and acted upon by the CACC, the display will be updated with the proper parameters (Speed, Headway).
7. The system will continue to operate in CACC mode until the driver cancels the application. Since the CACC utilizes the factory ACC, canceling the function can be performed by pressing the “cancel” button on the ACC control or simply tapping on the brake.

The factory ACC system is always the last component in the vehicle control chain. As such, if the capabilities of the factory system are exceeded, vehicle control will be transferred back to the driver. **Any driver of this vehicle should be aware that control may be transferred back at any time. As such, drivers should always be alert to changing conditions and completely prepared to resume full vehicle control.**

As indicated throughout this document, the vehicles are configured with an open architecture to allow researchers to develop custom algorithms for controlling the CACC. The control software is configured to provide experimenters with the ability to make changes in the field by employing a set of configuration files, a development environment, and access to data elements collected from the vehicle sensors. Because of this open architecture, **software developers must be cognizant of potential unintended consequences and ensure safe operation will be retained. The vehicles should only be driven by trained engineers and are not for use with naïve participants.**

3 System Layout

The following diagram (Figure 1) depicts the base layout of the overall vehicle builds with blocks for each major subsystem including: 1) Central Processing Stack; 2) OEM Vehicle Components and Command Interface; 3) Connected Vehicle; 4) Sensors, 5) Data Acquisition, and 6) Power Distribution.

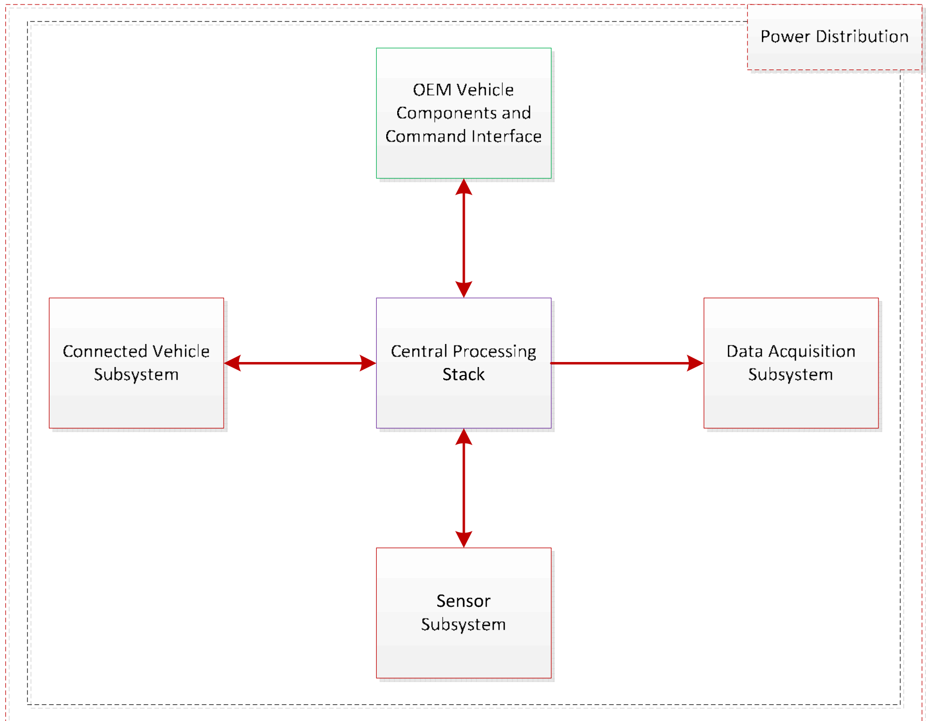


FIGURE 1: SUBSYSTEM LAYOUT

The subsystems are comprised of the following hardware components, each of which will be discussed in detail within this document.

1) **Central Processing Stack**
   a. Embedded computer
   b. User interface
      i. Experimenter laptop for configuring vehicles
      ii. VGA display for monitoring system operation
      iii. Speaker/Amp
   c. Wireless router
   d. USH Hub
2) **OEM Vehicle Components and Command Interface**
   a. Vehicle CAN Network splice
   b. Factory ACC controls
3) **Connected Vehicle**
   a. 4g LTE cellular modem
   b. DSRC Onboard Equipment (OBE)
   c. Combined DSRC and GPS antenna
4) **Sensors**
   a. GPS w/ DGPS capability
   b. GPS antenna
   c. Front radar
   d. Rear radar
5) **Data Acquisition**
   a. NextGen embedded Data Acquisition System (DAS)
   b. Forward Camera
   c. Rearward Camera
   d. Accelerometers and Gyros
6) **Power Distribution**
   a. Power Rail
   b. On/Off "Kill" switch
   c. Battery Charger

The components introduced above are physically organized and interconnected as depicted in the following wiring diagram (Figure 2). The physical layout of the components does not necessarily coincide with the way in which subsystems are parsed. For example, although the cellular modem is part of the Connected Vehicle Subsystem, it is physically attached directly to the Central Processing Stack (CPS) and not the OBE. To simplify the diagram, ground connections of the power distribution are not depicted.

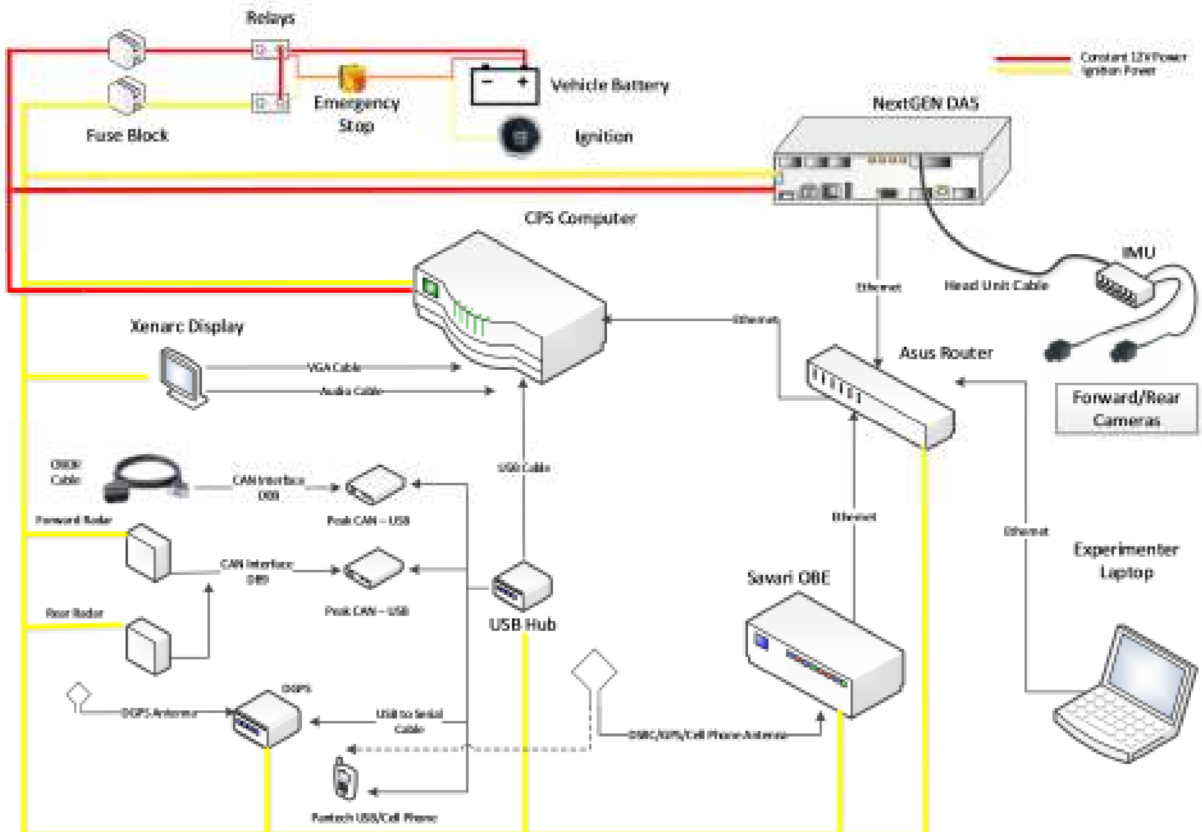


FIGURE 2: WIRING DIAGRAM DEPICTING PHYSICAL LAYOUT OF COMPONENTS

4 SUBSYSTEM DESCRIPTIONS

The preceding sections provided a high-level overview of the system function and layout. This section is dedicated to the provision of installation details, software descriptions, and specifications for each of the subsystems.

4.1 CENTRAL PROCESSING STACK

The central processing stack (CPS) consists of an automotive-grade embedded computer with the ability to connect with numerous components over standard interfaces. A small VGA display, with touch-screen and speaker capabilities, provides the CACC status information to the driver. In addition, a Dell experimenter laptop is provided to allow for control and configuration changes in the field. In general, the CPS provides a flexible computation backbone that integrates the various system components and performs the computations necessary to implement the applications and delivery of data to the Data Acquisition System (DAS).

4.1.1 EXPERIMENTER LAPTOP

The experimenter laptop allows the user to directly interface with the CPS, DAS, and other future components. The laptop is attached to components over the hub, either wired or wireless, and may be used to access the Linux based CPS over a terminal connection, or the DAS through a GUI executable. The GUI provides an interface to monitor the system functions and control the DAS (e.g. start and stop data recording).

The experimenter laptop is a Dell Latitude E6420 model with a Windows 7 operating system. The specific features of this model are listed in Table 1 below. The laptop specifications are provided in Appendix 5.4.2, and at the following website: http://www.dell.com/downloads/global/products/latit/dell_latitude_e5430_spec_sheet.pdf.

TABLE 1: LAPTOP FEATURES

Description
Intel Core i7 Processor
DDR3 SDRAM (1333Mhz)
Mobile Intel QM67 Express Chipset
14.0" HD (1366x768) Anti-Glare LED
7200 rpm SATA Hard Drive
Removable DVD-ROM
4-Cell (40Whr) Lithium Ion Battery
10/100/1000 Gigabit Ethernet
Dell Wireless 1530 (802.11 a/g/n) Interface

The experimenter laptop can be connected to the control system through an Ethernet jack located on the passenger (right) side of the vehicle as shown in Figure 3 below.

FIGURE 3: EXPERIMENTER LAPTOP AND ETHERNET HOOK-UP

4.1.2 EMBEDDED COMPUTER

The embedded PC located within each vehicle integrates the various systems, gathers vehicle measures, operates the algorithms, and programs the desired ACC settings. The embedded computer (Figure 4) operates on a Linux based operating system and a C++ based control system. This platform allows flexibility for incorporating both the current and future project goals.

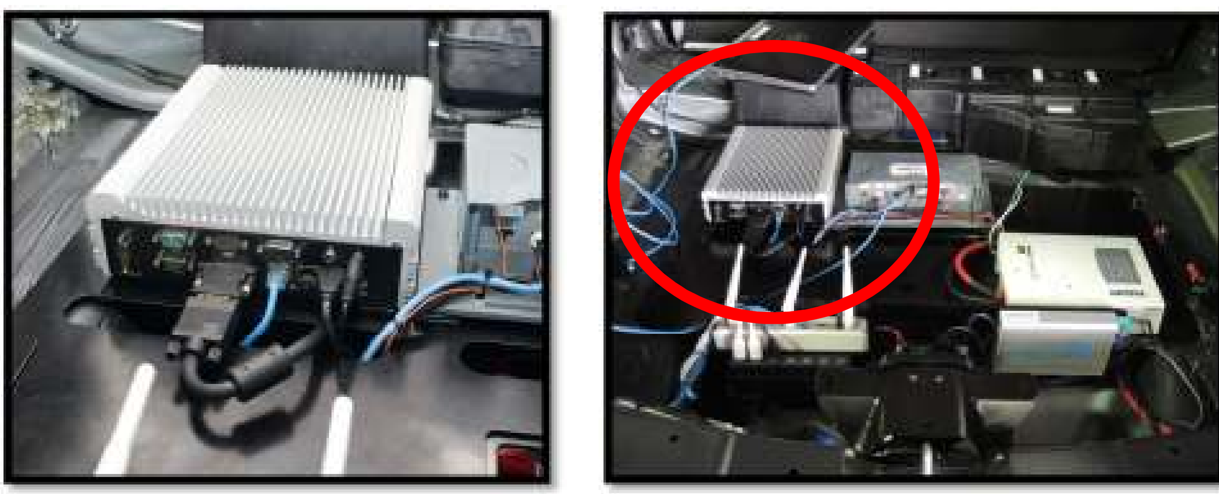


FIGURE 4: AXIOMTEK EBOX310 CPS EMBEDDED COMPUTER AND INSTALL LOCATION

The STOL CPS Linux Machine is an Axiomtek eBOX310-830-FL model running Ubuntu Linux release 12.04 32-bit operating system. The eBOX310-830-FL compact in-vehicle box computer is for in-vehicle use. The unit is powered by an Intel® Core™2 Duo processor with the Intel® 945GME and ICH7M chipsets. The embedded computer supports 2 PCI express mini cards, and is equipped with one 2.5" SATA drive bay and CAN Bus support.

The specifications are provided in Appendix 5.4.1 and at the following website: http://www.axiomtek.com/Download/Spec/ebox310-830-fl.pdf.

The embedded computer is installed in the spare tire well of each vehicle and is fastened to the metal equipment plate (Figure 5) as shown in Figure 4 above. It is powered by a constant 12V and wired through the fuse block into the vehicle battery. The embedded computer has a 12V ignition trigger for turn on. **Ignition Fuse Block, fuse #8; Constant Fuse Block, fuse #7.**

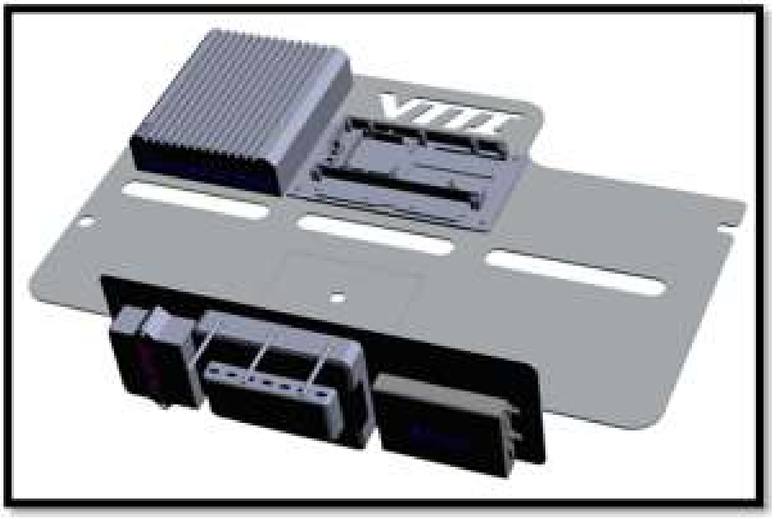


FIGURE 5: METAL EQUIPMENT PLATE DRAWING

4.1.3 CPS Base Software

The STOL CPS Linux Machine has Ubuntu 12.04 32-bit installed. The packages listed in Table 2 are required to be installed on the STOL CPS Linux Machine in order to compile and run the STOL application correctly.

TABLE 2: REQUIRED CPS PACKAGES

Package
Openssh-server
Libxml2-dev
Libboost-all-dev
Libgtk-3-dev
Libncurses5-dev
Libcurl4-openssl-dev
Screen
libuniconf4.6_4.6.1-2buld1_i386.deb
libwvstreams4.6-base_4.6.1-2build1-i386.deb
libwvstreams4.6-extras_4.6.1-2build1_i386.deb
wvdial_1.61-4build1_i386.deb

The STOL CPS Linux Machine uses the Peak-USB-CAN interface. The current development uses driver release 7.8 which can be found at the following link: http://www.peak-system.com/fileadmin/media/linux/.

To compile the driver, follow the instructions found in Table 3 below.

TABLE 3: PEAK CAN DRIVER INSTALL INSTRUCTIONS

Procedure
tar -xzf peak-linux-driver.x.y.tar.gz
Go to the driver folder
Run sudo make
Run sudo make install
Run sudo pcan_make_devices 2

The SocketCan utilities are useful to debug/test the transmission and reception of CAN messages using the Peak-USB-CAN interface.

To compile the SocketCan utilities, follow the instructions found in Table 4 below.

TABLE 4: SOCKETCAN UTILITY INSTRUCTIONS

Procedure
mkdir socketcan
cd socketcan
svn checkout svn://svn.berlios.de/socketcan/trunk
cd trunk/can-utils
make

4.1.4 Installation

In order to install the STOL Application on the STOL CPS Linux Machine, the proper vehicle package must first be copied. The vehicles were configured with the correct packages when they departed VTTI; however, the information below may be used to re-install packages if needed. It is recommended to use a FTP Client such as FileZilla for this purpose. The following table shows which package should be copied to each vehicle.

Package Name	Description
stol_gray_1.4.0_i386.deb	Package for SRX Gray
stol_green_1.4.0_i386.deb	Package for SRX Green
stol_silver_1.4.0_i386.deb	Package for SRX Silver

The package files are provided on a plan.io repository. To obtain an account for plan.io repository, please contact Liz White at ewhite@vtti.vt.edu. Software updates should be committed to the repository to ensure version control and permit collaboration between developers.

The STOL Application package files should be transferred to the STOL CPS Linux Machine at this location: **/home/stol/.**

Execute the following command to install the package on the Green SRX, for example:

Command
sudo dpkg -i stol_green_1.4.0_i386.deb

The package will deploy the source code in the following location: **/home/stol/stol**. After copying the source code the package script will compile and generate the proper executable files.

Note: Proper login information is required to install the application packages. Refer to the Operating Manual for the user/password information.

4.1.5 Software Compiling

The following section describes how to compile the source code to generate the STOL executable file. It is the responsibility of the user to make source code backups before attempting to modify or develop new software modules.

The STOL application source code is installed with the STOL application package. In order to compile the source code, run the following commands.

Commands
cd /home/stol/stol/
make clean
Make

The STOL UI source code is installed with the STOL application package. In order to compile the source code, run the following commands.

Commands
cd /home/stol/stol/stol_ui
make clean
Make

4.1.6 CPS Main Application

VTTI has developed a C++ Application to capture all data originating from the OBE, DGPS, Forward/Rear Radar and Vehicle Network. This application maintains global structures for each data element which can be accessed by two methods:

1. User Datagram Protocol (UDP) Packet Streaming
    - All the variables can be streamed by UDP using a specific port. This streaming will handle several packet sequences to allow all the variable contents to be transmitted. Also, the UDP streaming will be configurable to allow selection of which data elements should be transmitted.

2. Shared Object/Function Access
    - For developer purposes, VTTI is providing a Shared Memory Access to read / write in different software modules. We have provided a "header file" which contains a function list to use. For example:
        i. GetGPSData(*buffer_pointer)
        ii. GetRadarData(*buffer_pointer)
        iii. GetOBEData(*buffer_pointer)

The STOL application comes with a user interface called STOL UI which is a clear example on how to interface with the various modules and their shared memory. The STOL UI had been used to demonstrate system data sharing functionality. *Please refer to the GIT repository on Plan.IO for the source code for the STOL UI and STOL Main application.*

The STOL Main application will accept information from a simulated roadside element (either via experimenter laptop or via cellular) to receive information about the desired speed and headway for the SRXs. The system will then command the factory ACC to follow the desired parameters. A flow diagram of the main application state machine is shown in Figure 6.

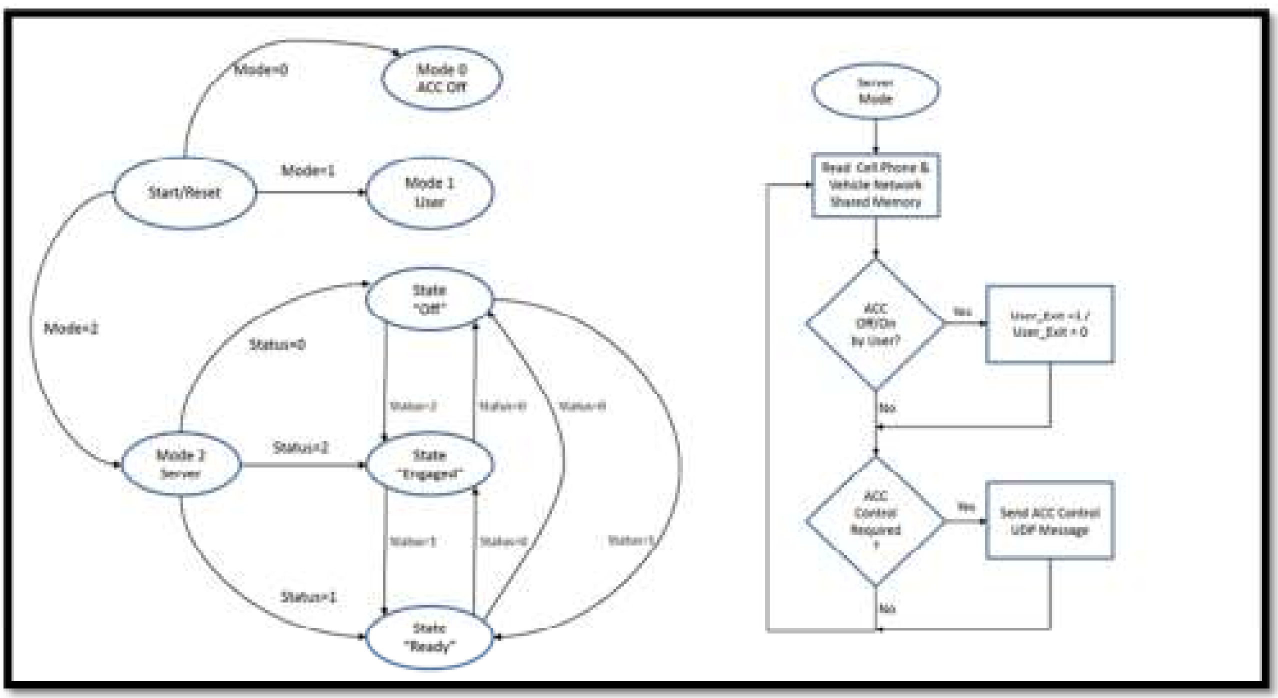


FIGURE 6: MAIN APPLICATION STATE MACHINE

4.1.7 CPS Software Interfaces and Modules

To access the CPS, the user will execute the PuTTy application to Telnet/SSH into the CPS. From the terminal, the user may access any configuration files and/or applications that are associated with the CACC operation. Code can be created, edited, and compiled from the terminal using standard Linux tools (e.g. Vi or Vim). A "Driver Package" has also been provided that contains the header and compiled shared objects. The developers can use their own Linux systems to build/customize the applications and upload by FTP to the CPS.

VTTI has also provided an executable that will interface with the CPS to provide a real-time viewer of the published variables. This will allow the experimenters to verify system functionality before and during experiments. These procedures are described further in the STOL Operating Manual.

The software development for the STOL project was based on C++. It uses a configuration XML file to setup the different hardware interfaces connected to the CPS machine. It also provides some debugging/error logging to help software developers to test and debug the current release.

The following diagram (Figure 7) illustrates the communication protocols between key data sharing components. The connections do not represent the physical routing (e.g. the hub is not present) but rather depict the flow of communication (see Figure 2 for routing).

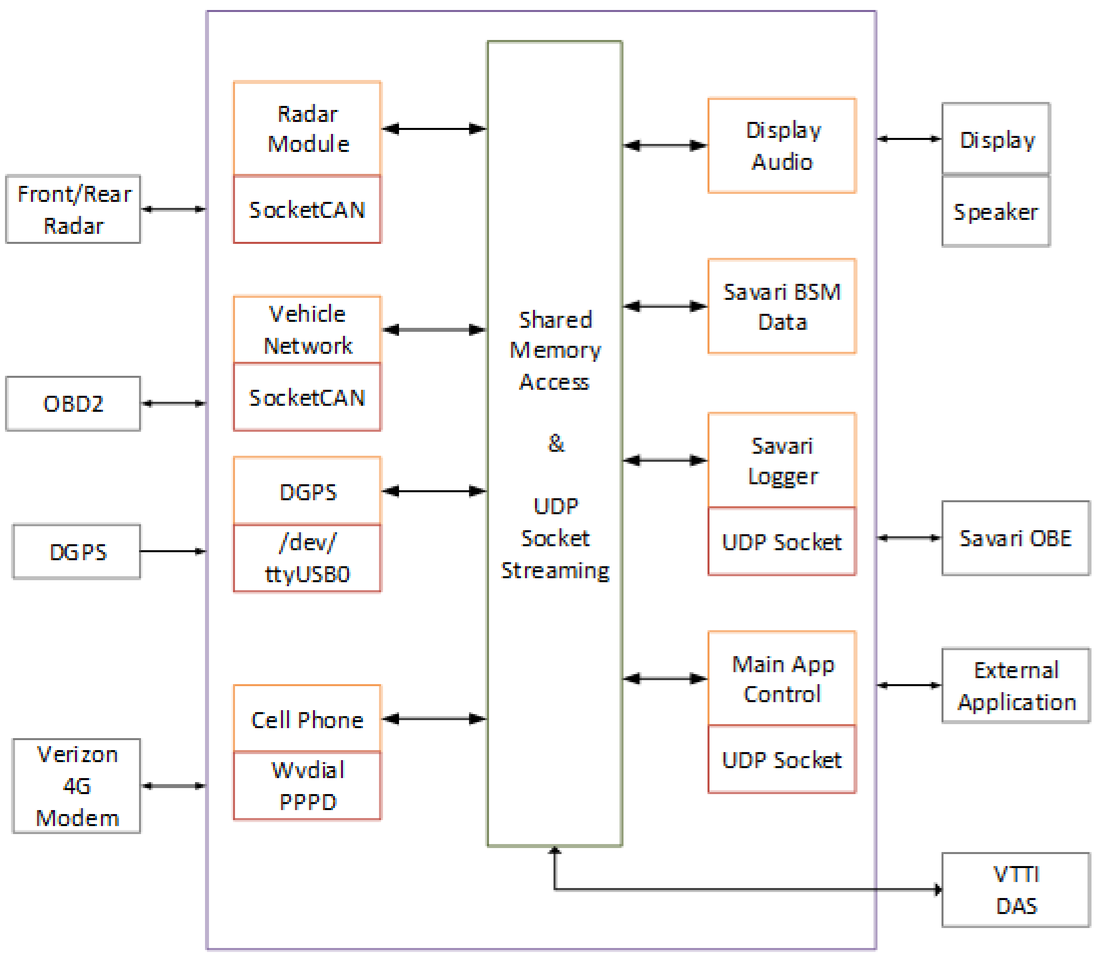


FIGURE 7: SOFTWARE MODULE DIAGRAM

4.1.7.1 Shared Memory Module

Each software module uses a shared memory software component to write or read data. The current implementation uses Mutex to control, read and write operations. Table 5 describes the shared memory keys and Mutex Names for each module.

TABLE 5: SHARED MEMORY KEYS AND MUTEX NAMES FOR EACH MODULE

Module	Shared Memory Keys	Mutex Name
Front Radar	/stol_front_radar	stol_front_radar_mutex
Rear Radar	/stol_rear_radar	stol_rear_radar_mutex
DGPS	/stol_dgps	stol_dgps_mutex
Vehicle Network	/stol_vehicle_network	stol_vn_mutex
Savari Logger	/stol_savari_logger	stol_sl_mutex
Display	/stol_display_shm	stol_display_mutex
Cell Phone	/stol_cellphone_module	stol_cellphone_mutex

Table 6 lists the code snippets for the hpp/cpp files to create and access the shared memory.

TABLE 6: CODE SNIPPETS FOR HPP/CPP FILES

Header for doStuff.hpp:

```
#include "sharedmem.hpp"
// Posix shared memory will create a file in /dev/shm with memory contents
// all regions should start with a forward slash and have descriptive names
#define DOSTUFF_DATA_P      "/stol_dostuff_shm"

class doStuff{
private:
...
 //shared memory
  SharedMem<DoStuffDataType> shmDoStuff;
  DoStuffDataType *DoStuffSharedData;
  boost::interprocess::named_mutex mutexDoStuff;

  void writeToSharedMemory();

public:
  void GetData(DoStuffDataType *)

}
```

Source for doStuff.cpp

```
#include "doStuff.hpp"

doStuff::doStuff():
  pDoStuffData(),
  //The following should be passed to the SharedMem constructor:
```

```
  // - a string with the contents of the region name, must start with a forward slash
  // - a boolean, 0=read only (POSIX_READ_ONLY), 1=read/write (POSIX_READ_WRITE)
  // - any other options for shm_open, these get or'ed into the options (see man page)
  // - a boolean indicating verbosity
  shmDoStuff(DOSTUFF_DATA_P,POSIX_READ_WRITE,0,1),
  mutexDoStuff(open_or_create,"stol_dostuff_mutex"){

...

  DoStuffSharedData = shmDoStuff.createSharedMemory();
  cout << "Shared memory for radar ready" << endl;
}

void doStuff::writeToSharedMemory(){

  if(mutexDoStuff.try_lock()){
    GetData(DoStuffSharedData);  //all data transfer handled in canned GetData function
    mutexDoStuff.unlock();
  }
  else
    cout << "locked out!" << endl;
}
```

4.1.7.2 UDP Socket Streaming Module

The STOL application uses the UDP Socket Streaming software component to stream each module's data to external systems (i.e. the DAS) or to receive data from external sources. Table 7 shows the current UDP Port assignment per module. The port number used by each software module can be changed on the **stol_config.xml**.

TABLE 7: UDP PORTS FOR EACH MODULE

Module	UDP Streaming Port	Notes
Radar	6001	Output to VTTI DAS
DGPS	6003	Output to VTTI DAS
Vehicle Network	6004	Output/Input from VTTI DAS & Main Application
Savari Logger	39001	Input from Savari OBE
Display	6006	Output to VTTI DAS
Cell Phone	6007	Output to VTTI DAS
Main Application	7000	Input from External Application

The following are code snippets for the hpp/cpp files to create and use the UDP streaming socket.

TABLE 8: CODE SNIPPETS FOR HPP/CPP FILES

Header for doStuff.hpp
#include "udpsocket_port.hpp" **#define** DOSTUFF_UDP_BUFFER_SIZE 255

```
class doStuff {
private:
  //vars to setup udp socket
  std::auto_ptr<UDPSocket> udpSocket;     //deconstruct-safe pointer type
  std::string ipAddress;
  int udpPort;
...
}
```

Source for doStuff.cpp

```
#include "doStuff.hpp"

//class constructor
doStuff::doStuff():
...
//use this for a send-only udp socket:
udpSocket = std::auto_ptr<UDPSocket>(new UDPSocket
("DoStuffBox",6013,"10.10.50.100"));
//use this for a send/recv udp socket:
//  this function takes ---
//      1. module name (for error messages)
//      2. port number on remote computer
//      3. ip address on remote computer
//      4. local port to bind to for incoming data
//      5. size of buffer for receiving packets
udpSocket = std::auto_ptr<UDPSocket>(new UDPSocket
("DoStuffBox",6013,"10.10.50.100",6013,DOSTUFF_UDP_BUFFER_SIZE));
//use this for a recv-only udp socket:
udpSocket = std::auto_ptr<UDPSocket>(new UDPSocket
("DoStuffBox",6013,DOSTUFF_UDP_BUFFER_SIZE));
...
}

//function to send packet
void doStuff::sendStuffOverUDP(){
  std::vector<char> data;
  std::string header("DO_STUFF_HEADER");

  //push header to vector
  for(std::string::iterator it = header.begin(); it < header.end(); it++)
    data.push_back(*it);

  //now data
```

```
  data.push_back((uint8_t)data_1);
  data.push_back((uint8_t)data_2);
  data.push_back((uint8_t)data_3);

  //now send it
  udpSocket->sendData(data);
}

//function to receive packet
void doStuff::recvStuffOverUDP(){
  std::vector<char> data;
  int length;

  if(udpSocket->isSocketAlive()){
    if(udpSocket->recvData(data) > 0){
      //test code
      if(data.size() > 0);
        std::string temp(data.begin(),data.end());
        cout << "Data recieved from udpSocket:" << data.size() << " - " << temp <<
endl;

    }
    else {
      //socket is dead - try to re-bind the socket?
    }
  }

  return;

}
```

4.1.7.3 Software Setup and Location

To start the STOL Application (“mainapplication”), run the following script at startup: /home/stol/stol/.

In order to allow the application to find the GPS device regardless of where the operating system assigns it, run the following script: /etc/udev/rules.d/. This rule assigns a symbolic ID of DGPS to the differential GPS device.

The startup script for the PeakCAN driver is: /etc/rcS.d/S90can

The S90CAN file contents are listed in Table 9 below.

TABLE 9: S90CAN FILE CONTENTS

S90 Script Contents
sudo modprobe can
sudo modprobe can_raw
sudo modprobe can_bcm
sudo modprobe vcan
sudo ifconfig can0 up
sudo ifconfig can1 up

4.1.7.4 Cell phone Modem Setup

In order to configure the cell modem properly, the following files and paths are required:

FILE	EXECUTE	OWNER
/etc/ppp/peers/wvdial	x x x	root:root
/etc/rc.local	x x x	root:root
/etc/udev/rules.d/81-usbmodem.rules	x x x	root:root
/usr/local/bin/connmodem.sh	x x x	root:root
/usr/local/bin/removemodem.sh	x x x	root:root

These files are system specific:/etc/wvdial.conf.

The wvdial.conf file must be edited to reflect the modem's phone number in the username string.

Username=<**MODEM PHONE NUMBER**>@vzw4g.com

The rc.local file calls the dialer for the modem.

The 81-usbmodelm.rules, connmodem.sh, and removemodem.sh files are used by udev to handle the modem and associated processes if it is removed or plugged in with power on.

4.1.7.5 Network Setup

In the GUI under *System Settings>Network>* click on the *wired connections* and then *options button.* Be certain that *Connect automatically* is not checked. In order to have the Ethernet network configure properly the following files and paths are required:

FILE	EXECUTE	OWNER
/etc/iproute2/rt_tables		

These files are system specific:

FILE	EXECUTE	OWNER
/etc/ppp/ip-up	x x x	root:root
/etc/network/interfaces		

4.1.7.6 INTERFACESSETUP

The following manually sets up eth*n*. (Italicized items are system specific.)

auto eth*n*
iface eth*n* inlet static
address <*assigned ip address*>
netmask <*netmask*>
gateway <*gateway*>

The following sets a DNS to be used. This will be written to resolv.conf.

dns-nameserver 8.8.8.8 ;(or local DNS server)

4.1.7.7 IP-UP SETUP

This file needs to be edited with specific IP information and needs execute privileges.

Assume we are at address 10.10.50.211, gateway 10.10.50.1, and device eht0.

With this information we can add new routing information and rules for this routing in /etc/ppp/ip-up.

First add a rule for directing packets to and from our IP to the routing table *internal*:

ip rule add from ***10.10.50.211***/32 table internal
ip rule add *to* ***10.10.50.211***/32 table internal

Now provide the information for the routing table, the local sub net/24 and default gateway:

ip route add ***10.10.50.0***/24 dev ***eth0*** src ***10.10.50.211*** table internal
ip route add default *via* ***10.10.50.1*** dev ***eth0*** table internal

Then start up the *route –n* command which should return something similar to the results in Table 10 below.

TABLE 10: KERNAL IP ROUTING TABLE

Destination	Gateway	Genmask	Flags	Metric	Ref	Use	Iface
0.0.0.0	0.0.0.0	0.0.0.0	U	0	0	0	ppp0
10.64.64.64	0.0.0.0	255.255.255.255	UH	0	0	0	ppp0
10.10.50.0	0.0.0.0	255.255.252.0	U	1	0	0	eth0
169.254.0.0	0.0.0.0	255.255.0.0	U	1000	0	0	eth0

If the new routing table and rules are applied the *ip rule show* command, it should return something similar to the results shown in Table 11 below.

TABLE 11: IP RULE SHOW RESULTS

0:	from all lookup local
32764:	from all to ***10.10.50.211*** lookup internal
32765:	from ***10.10.50.211*** lookup internal
32766:	from all lookup main
32767:	from all lookup default

The RT_TABLES file establishes a new routing table **internal.** This table will be populated with the rules and routing from ip-up.

4.1.8 VGA Display and Speaker

The VGA display unit indicates whether the CACC system is active or inactive and also provides real-time status updates. The Feelworld FW 5D display is a 7" touchscreen LCD monitor that offers a VGA input and AV output. This unit has a built-in speaker and touch screen capabilities to allow the researcher to interact with the system if future needs arise.

The VGA display is mounted in the passenger side cup holder allowing for easy maneuverability away from the driver. It is powered through the ignition and connected to the CPS through a VGA and Audio (AV) cable. The VGA cable runs from the display to the rear of the vehicle and is connected to the CPS by a DVI to VGA adapter. The audio cable runs from the display to the rear of the vehicle and is connected directly to the CPS and is a 1/8-inch male connector. The monitor is powered through ignition power. **Ignition Fuse Block, fuse #1.**

Specifications for the VGA display can be found in Appendix 5.4.3 and at the following website: http://feelworld.en.alibaba.com/product/725287132213678288/FEELWORLD_5_inch_Photography_HD_LCD_Monitor_FW_5D_O.html.

FIGURE 8: FEELWORLD FW 5D 7" DISPLAY

4.1.8.1 VGA Display Interface

The VGA interface provides very simple content in order to mitigate the opportunity for driver distraction. This display is not critical and can simply be switched off if desired. The content is displayed in six quadrants with minimal visual clutter as shown in Figure 9 below.

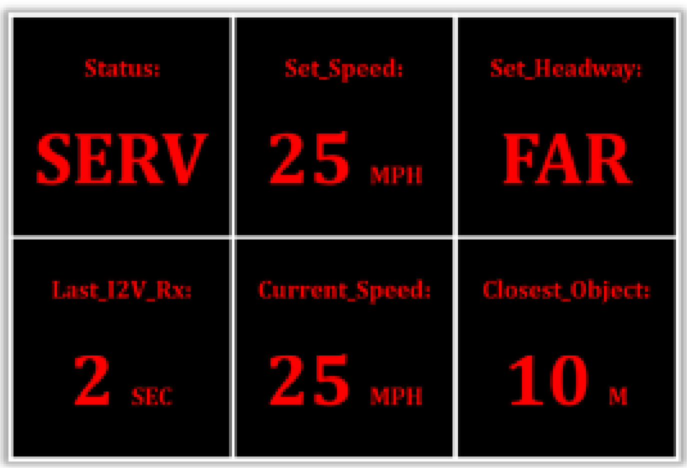


FIGURE 9: DISPLAY INTERFACE

The quadrants are populated as indicated below:

- Status: Provides the current mode of the CACC system
    - CACC “ACC Off”: CACC is turned off
    - CACC “User Mode”: CACC is controlled by the user using UDP ACC commands.
    - CACC “Server Mode”: CACC is controlled by the server. The STOL application will query the server for Speed/Headway based on the current configuration (GPS or Speed based).

- Time from Roadside Rx (Last_I2V_Rx): A time counter displayed in seconds that indicates when the last communication was received from the roadside. The minimum time displayed is 2 seconds.
- ACC/CACC Set Speed: The most recent speed (mph) that was communicated by the roadside during the last Rx.
- Current Speed: Current vehicle speed (mph)
- CACC Set Headway: Displays the most recent headway (Near, Medium or Far) that was communicated by the roadside during the last Rx.
- Current Vehicle Headway: Displays the current headway (Near, Medium or Far) to the lead vehicle.

4.1.8.2 STOL Display Module Software

The following section describes the software module for the VGA display, referred to as the STOL Display Module. The software module diagram is shown in Figure 10 below.

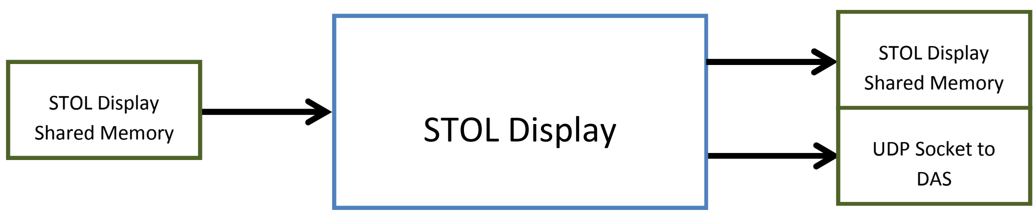


FIGURE 10: VGA DISPLAY SOFTWARE MODULE DIAGRAM

The STOL Display Module creates a display on the monitor using the GTK library. The entire control algorithm is manipulated through the data stored in the Shared Memory. The number of rows and columns displayed on the screen is configurable; the program has been optimized for a 2x3 Layout. The display will update every 250ms, at which point the audio tone will be played, if applicable. The full_screen_flag takes priority, when enabled, and will cause a full screen image to be displayed; the image is specified through the Sel ID stored in image_sel. When not in full screen image mode, each cell's type can be either 0 = none, 1 = label (text), or 2 = image. The cell's contents are stored in cell_content, which will either be a string of text or a Sel ID for an image. When the cell_type is 1 = label (text), the cell_content can utilize a special format of: <Name>\n<Value> <Units> (ex. "Current_Speed:\n25 MPH"). In this format all text is size 24 font, except for the output value, which is size 72 font. The default text color is "red". The text_color can be changed for each grid and the string should match the Pango Markup Format. Play_Audio is a flag to signify the audio file, specified by the Sel ID in audio_sel. This flag must be set each time the audio is to be played. Each of these variables are shown in Table 12 below.

TABLE 12: SHARED MEMORY DESCRIPTION

Variable Name	Type	Units
full_screen_flag	uint8_t	0=normal, 1=fullscreen
image_sel[MAX_LENGTH]	char	none
cell_type[NUM_ROWS][NUM_COLS]	uint8_t	0=none, 1=label, 2=image
cell_content[NUM_ROWS][NUM_COLS][MAX_LENGTH]	char	none
text_color[NUMS_ROWS][NUM_COLS][COLOR_LENGTH]	char	none
play_audio	bool	0=off, 1=play once

audio_sel	char	none
Defines:		
NUM_ROWS = 2		
NUM_COLS = 3		
MAX_LENGTH = 80		
COLOR_LENGTH = 30		

The XML configuration for the STOL display module is shown in Table 13 below.

TABLE 13: XML CONFIGURATION

Tag	Description
UDPPort	DAS UDP Forwarding Port
IMAGE_LIST	Contains a list of Images
IMAGE	The Filename for an Image and its Selection ID, which is the Value used in Image_Sel and Cell_Content when Cell_Type is 2=Image
AUDIO_LIST	Contains a list of Audios
AUDIO	The Filename for an Audio and its Selection ID, which is the Value used in Audio_Sel

An example of the XML parameter setup for the STOL_Display Module is shown in Figure 11 below.

```
<STOL_Display>
  <UDPPort>6006</UDPPort>
  <IMAGE_LIST>
    <IMAGE sel="0">/etc/display/sample_files/VTTI_black.jpg</IMAGE>
    <IMAGE sel="1">/etc/display/sample_files/merge.jpg</IMAGE>
    <IMAGE sel="2">/etc/display/sample_files/stop.jpg</IMAGE>
    <IMAGE sel="3">/etc/display/sample_files/yield.jpg</IMAGE>
  </IMAGE_LIST>
  <AUDIO_LIST>
    <AUDIO sel="0">/etc/display/sample_files/ImminentWarning.wav</AUDIO>
  </AUDIO_LIST>
</STOL_Display>
```

FIGURE 11: EXAMPLE XML PARAMETER SETUP

The UDP datagram is described below.

Destination IP Address: 10.10.50.100
Destination UDP Port: 6006
Delimiter:Whitespace
Format:

HEADER ("STOL_Display") VARIABLE_NAME(ASCII) VARIABLE_VALUE(ASCII) VARIABLE_NAME(ASCII) VARIABLE_VALUE_STRING(ASCII)**\0** …

An example UDP datagram is shown below:

STOL_Display Full_Screen_Flag 0 Image_Sel 3**\0** … Cell_Type_1_1 1 Cell_Contents_1_1 Current_Speed:\n25 MPH**\0** ... Play_Audio 0 Audio_Sel 0 …

4.1.9 Wireless Router

The wireless router provides connectivity to the various devices communicating over Ethernet. In addition, the router can be configured in "Router Mode" to allow wireless devices to access the vehicle network or in "Repeater Mode" to permit wireless communication from the hub to an internet hot-spot. The hub is a commercially available ASUS RT-N16 Wireless-N300 Router (Figure 12).

The router is installed in the spare tire well of each vehicle and is fastened to the metal equipment plate as shown in Figure 12. It is connected to the CPS through an Ethernet cable. The Savari OBE, NextGEN DAS, and experimenter laptop are directly connected to the router. It is powered through ignition, using a Lind DC Voltage Regulator. The usb hub is connected to the same Lind Voltage Regulator **Ignition Fuse Block, fuse #6.**

Detailed specifications are provided in Appendix 5.4.4 and at the following website: http://www.asus.com/Networking/RTN12/#specifications.

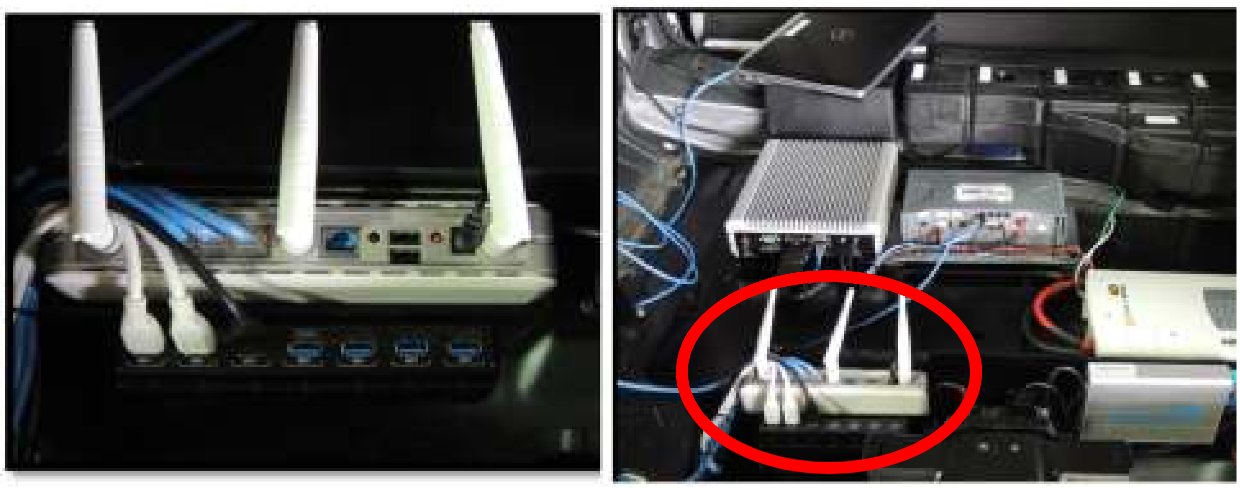


FIGURE 12: ASUS RTN16 WIRELESS ROUTER AND INSTALL LOCATION

4.1.10 HUB (USB)

The Superspeed 3.0 USB hub is the interface between the embedded computer and the front and rear radars, cell phone module and DGPS. It is located in the rear of the vehicle attached to the equipment plate (Shown in the left-hand picture in Figure 12). It is powered through ignition, using a Lind DC Voltage Regulator. The wireless router is connected to the same Lind Voltage Regulator. **Ignition Fuse Block, fuse #6.**

Detailed specifications are provided in Appendix 5.4.5 and at the following website: http://www.newegg.com/Product/Product.aspx?Item=9SIA1HE0G60465.

FIGURE 13: SUPERSPEED 3.0 USB HUB

4.2 OEM COMPONENTS AND COMMAND INTERFACE

The OEM vehicle components and command interface subsystem defines how automated longitudinal control is achieved for the CACC application. The team has developed a mechanism to provide inputs to the factory ACC system based on the researcher-developed application(s) running within the CPS.

The second purpose of connecting to the vehicle's factory network is to read data from the onboard sensors. Modern vehicles have a number of data elements that are published to the vehicle network. Each available data element is extracted from the data stream and sent to the CPS for processing.

4.2.1 ACC COMMANDS AND DISPLAYS

The CPS is not only attached to the vehicle's network to permit reading the sensor data, it is also connected to the factory ACC system to emulate the driver inputs into that system. To enable this limited concept, the CPS is connected to an I/O interface that converts the command into a signal that is recognized by the factory ACC as a driver input. The I/O interface may take one of two forms depending on the detailed vehicle architecture.

The CPS is connected to the vehicle Controller Area Network (CAN) and is capable of directly changing the ACC settings by emulating the driver inputs (i.e. button presses). This allows for controlled system inputs: the user can directly input a new set speed rather than incrementally increasing the speed by a set amount.

The factory ACC buttons are used to control the functions of the CACC. The CACC functionality is first enabled on the experimenter laptop, and then the driver simply presses the center button to the right (shown in Figure 14 below) to turn the system on. Once on, the driver presses the 'set' button by pushing down on the center button (shown in Figure 14) to enable the CACC. At this time, the vehicle will initially travel in an ACC mode at the current speed. The system will adjust its behavior when content is received from the roadside (or simulated roadside for the purposes of the Task 3 demonstration). The driver will be able to manually adjust the set speed and headway;

however, as soon as the manual inputs terminate, the system will once again attempt to follow the commands received by the roadside. The following are the ways to terminate the manual ACC override:

- Pressing the brake
- Turning the ACC module off
- Pressing the ACC Cancel button.

FIGURE 14: FACTORY ACC CONTROLS ON THE SRX – *MOUNTED TO STEERING* WHEEL

The factory system displays the current set speed on a multi-function display embedded within the instrument panel with a message "Cruise set to XX mph", as shown in Figure 15. A green lamp located on the speedometer indicates that ACC is activated. Both of these displays are fully functional in CACC mode as well.

FIGURE 15: FACTORY ACC DISPLAYS - *EMBEDDED WITHIN THE INSTRUMENT PANEL*

4.2.2 CAN Network Splice and Connection to CPS

The CAN network is connected through an OBDII connection to a PCAN USB through a DB9 connection (shown in Figure 16). The cable is connected into the USB hub which runs to the CPS.

Detailed specifications are provided in Appendix 5.4.6 and at the following website: http://www.peak-system.com/Produktdetails.49+M578cbdb898b.0.html?&L=1&tx_commerce_pi1[catUid]=6&tx_commerce_pi1[showUid]=16.

FIGURE 16:PCAN MODULE

4.2.3 Data Elements from Factory Network

The team worked with TORC Robotics to reverse engineer the message definitions for relevant data elements published on the vehicle's CAN network (See Appendix 5.2 for a complete list).

4.2.4 Vehicle Network Software Module

The vehicle network software module diagram is shown in Figure 17 below.

FIGURE 17: VEHICLE NETWORK SOFTWARE MODULE DIAGRAM

The Vehicle Network Module's primary functions are to read and write to the vehicle CAN bus. Reading CAN data and reporting it is handled by the module in the main Process() function, which is executed by the main program every cycle. The writing is handled by a separate thread that handles the critical timing of sending ACC commands to the vehicle's CAN network.

The Process() function will do three things each time it is called. First it reads all available CAN messages from the buffer and extracts the variables found in Table 14 below. Second, it monitors a UDP command socket for any requested commands from the other modules or outside systems. Lastly, it sends all important data to the Data Acquisition System (DAS) for collection.

The UDP command socket processes incoming commands and writes them to an ACC control object that monitors progress towards the requested speed or command. If a set speed is requested, the ACC control object will use feedback from the vehicle CAN network to ensure that the speed is reached. The ACC control object communicates commands to the CAN write thread to ensure that the proper number of commands and timing are achieved.

TABLE 14: SHARED MEMORY - MAIN OBJECT DATA

Variable Name	Type	Units
brakePedalPosition	double	%
brakeLight	bool	0=Off, 1=On
leftTurnSignal	bool	0=Off, 1=On
rightTurnSignal	bool	0=Off, 1=On
xAccel	double	m/s^2
accelPedalPosition	double	%
accData	acc_data_t	See acc_data_t variable data
yAccel	Double	m/s^2
yawRate	Double	Deg/sec
gearShifter	Enum	Park = 1, Reverse = 2, Neutral = 3, Drive = 4
brakePedalPressure	Double	kPa
wheelSpeed[4]	Double	Km/h [0] = Left Front, [1] = Right Front, [2] = Left Rear, [3] = Right Rear
vehicleSpeed	double	Computed Average of 4 wheel speeds
throttlePosition	Double	%

TABLE 15: SHARED MEMORY - ACC_DATA_T OBJECT DATA

Variable Name	Type	Units
accActiveFlag	bool	0=Off, 1=On
headwayButton1	bool	
headwayButton2	bool	
accStatus	Enum	No press = 1, resume=2, set = 3, acc on/off = 5, cancel =6
accSwitchCounter	Int	
headwayButtonCounter	Int	
accSwitchCheck	int	
headwayButtonCheck	Int	
accHeadwaySetting	Int	1 = Near, 2 = Mid, 3 = Far
accSpeedSetpoint	Double	Km/h

TABLE 16: XML CONFIGURATION

Tag	Description
Debug	Debugging Information 0=Disabled, 1=Enabled
CAN_Device	Device Name to be used to get Radar Data
DAS_UDPPort	DAS UDP Forwarding Port

An example of the XML parameter setup for the Vehicle Network Module is shown in Figure 18 below.

```
<VehicleNetwork>
  <Debug>0</Debug>         <!-- 0=OFF, 1=ON  -->
  <CAN_Device>can1</CAN_Device>      <!-- linux device name  -->
  <DAS_UDPPort>6004</DAS_UDPPort>
 </VehicleNetwork>
```

FIGURE 18: EXAMPLE XML PARAMETER SETUP

ACC Commands are called by sending a simple 9-byte message to the Vehicle Network Module's UDP Command Socket. The first 7 bytes must be the header (shown in Table 17 below), followed by a command byte, and followed by the requested set speed. The values shown below may be ORed together to change a command and gap setting on the system or a gap setting and a set speed. Because commands may conflict with each other, the following precedence should be followed for sending commands:

1. Requesting a specific gap setting is unaffected by other commands or set speeds. It may be sent individually or with any other command.
2. If the speed byte is set to a value that is between the minimum and maximum allowable speeds (set in STOL software, but generally 20MPH and 100MPH) then the ACC control object will ignore any other individual commands and adjust the speed accordingly.
3. If there is no valid speed in the speed byte, then the system will send the lowest value command in the following order: On/Off, Set/Coast, Resume/Accel, Cancel, Adjust Gap. In other words if a command is set such that the Resume/Accel and Cancel command bits are set, then the system will "push" the Resume/Accel button and ignore the Cancel command.

TABLE 17: UDP ACC COMMAND PROTOCOL

Header (7 bytes)	Command (1 byte)	Speed (1 byte)
ACCCTRL (Ascii values)	0x01 = On/Off 0x02 = Set/Coast 0x04 = Resume/Accel 0x08 = Cancel Speed 0x30 = Adjust Gap Setting 0x40 = Set Gap NEAR 0x80 = Set Gap MID 0xB0 = Set Gap HIGH	Requested Speed in MPH

4.3 CONNECTED VEHICLE SUBSYSTEM

The Connected Vehicle Subsystem provides the ability for the SRX vehicles to communicate with the roadside as well as other vehicles. Although Task 2 will only require cellular communications, future efforts are expected to use DSRC as well. The cellular system is designed primarily for 4g LTE connectivity while the DSRC supports 5.9GHz in compliance with the USDOT specifications and industry standards.

4.3.1 4G LTE CELLULAR MODEM

A Verizon 4G LTE cellular modem was used in the vehicles. The Verizon 551L is a 4g LTE modem is available with Linux drivers and offers a simple USB interface to the computer. The cell modem is installed behind the driver rear fuse panel access.

Detailed specifications for the modem are provided in Appendix 5.4.7 and at the following website: http://cache.vzw.com/multimedia/mim/vzw_usb_551l_modem/usb551l_manual.pdf.

FIGURE 19: VERIZON 4G LTE USB MODEM 551L

4.3.1.1 Cell Phone Module Software

Figure 20 illustrates the cell phone module software.

FIGURE 20: CELL PHONE MODULE SOFTWARE DIAGRAM

The cell phone module is run every two seconds in its own thread; in the meantime the thread is asleep. Once an object of the cell phone class is declared it performs a general variable initialization and extracts configuration information from the **stol_config.xml** file.

The cellphone module can request CACC commands (speed and/or headway) based on two different modes, Speed Based and GPS Based, which are defined by the ACC_Type parameter in the **stol_config.xml** file (shown in Table 18 below).

While the vehicles are connected, the cell phone process first polls the server and determines the ACC Status: 0=OFF, 1=ON, 2=Engaged. If the status is "Engaged" the server is polled again to request the current speed and headway based on the ACC_Type parameter from the configuration file. When the ACC_Type value is set to 1 (Speed Based), the cell phone process will request only speed from the server. When the ACC_Type value is set to 2 (GPS Based), the cell phone process will provide the current vehicle GPS position to the server which will reply back with a specific speed and headway. This process is illustrated in Figure 21 below.

The CPS requests a speed and/or headway based on the Vehicle ID assigned on the cell phone module XML configuration. The links currently being used to request these commands are shown in Table 18.

TABLE 18: ACC_TYPE

MODE	ACC_TYPE	Request Links
Speed Based	1	*"funnel.vtti.vt.edu/~zeb/jp_speed.php?car_id=1"*
GPS Based	2	*"funnel.vtti.vt.edu/~zeb/jp.php?lat=37.183911&lon=-80.384411"*

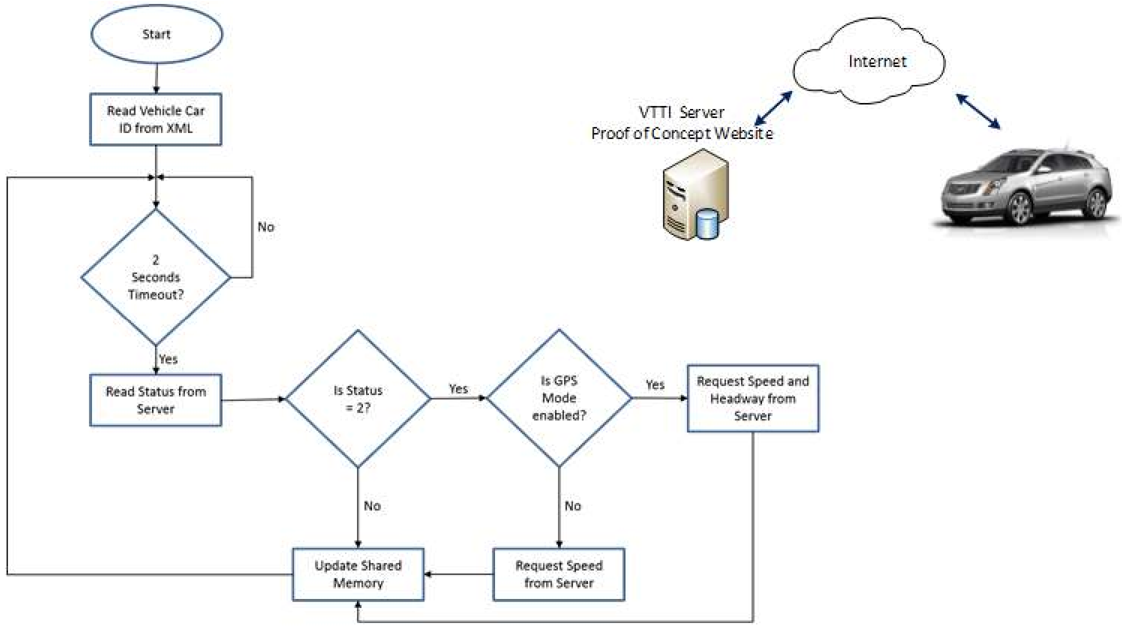


FIGURE 21: CELL PHONE CONNECTIVITY

If there is a problem communicating with the server a message is sent to the log file and a "ServerActive" flag goes up until a connection with the server is reestablished. There is also a time value (Last_I2V_Rx) that represents when the last communication with the server was. This will continue to increase until a server connection is established.

Once the speed and headway are determined, a UDP packet containing the speed, headway, ACC status, ServerActive flag, and Last_I2V_Rx are sent to the DAS. These values are then updated in shared memory.

TABLE 19: CELL PHONE MODULE SHARED MEMORY DESCRIPTION

Variable Name	Type	Units
ACCstatus	int	
speedMPH	int	MPH
ACCheadway	int	
speedKPH	uint8_t	KPH
ServerActive	bool	
last_i2v_rx	uint32_t	Seconds

The cellphone module uses the tags shown in Table 20 to setup the xml configuration.

TABLE 20: CELL PHONE MODULE XML CONFIGURATION

Tag	Description
ACC_Type	1=Car ID, 2 = GPS Location
Debug	Debugging Information 0=Disabled, 1=Enabled
DASUDPPort	DAS UDP Forwarding Port

VehNetUDPPort	Vehicle Network UDP Port for sending ACC messages
carID	Vehicle ID assigned for Server Communications

The example in Figure 22 below sets the cell phone module to use the CarID to request the speed from the server (ACC_Type =1). The debugging information is disabled. The DAS UDP Port is setup to 6007 and the Vehicle Network UDP Port to 6004. The vehicle ID is setup to 2.

```
<CellPhone>
  <ACC_type>1</ACC_type>
  <Debug>0</Debug>
  <DASUDPPort>6007</DASUDPPort>
  <VehNetUDPPort>6004</VehNetUDPPort>
  <carID>2</carID>
 </CellPhone>
```

FIGURE 22: EXAMPLE XML PARAMETER SETUP FOR CELL PHONE MODULE

4.3.2 DSRC Onboard Equipment (OBE)

The Savari MobiWAVE™ OBE supports a variety of potential applications for future uses of the SRX. The hardware is designed as a flexible open platform based on Linux. The OBE features a 500Mhz processor, 256MB of memory, 512MB of compact flash disk space, dual radios, and a GPS receiver. Detailed specifications for the MobiWAVE™ OBE are provided in Appendix 5.4.8 and at the following website: http://www.savarinetworks.com/products_mobiwave.html.

The OBE is installed in the spare tire well of each vehicle and is fastened to the metal equipment plate as shown in Figure 23. The OBE connects to the wireless hub through an Ethernet cable. The DSRC/GPS antenna connects directly to it. **Ignition Fuse Block, fuse #2**

FIGURE 23: SAVARI MOBIWAVE™ OBE AND INSTALLATION

At present, Task 2 does not anticipate the use of DSRC. As such, the hardware is provided; however, no custom messaging was developed. The OBE will be transmitting and receiving standard Basic Safety Message (BSM) packets which will be parsed by the CPS for use in applications as desired.

4.3.2.1 Savari OBE Software

The software module diagram for the OBE is depicted in Figure 24 below.

FIGURE 24: SAVARI OBE SOFTWARE MODULE DIAGRAM

The Savari OBE module receives host vehicle (HV), remote vehicle (RV), and wireless safety (WSM) messages from the Savari OBE through a UDP socket on port 39001. Host and remote vehicle messages are part of the BSM packet protocol. WSM messages are part of VTTI OBE firmware and can be decoded on the STOL CPS Linux machine; however, there is no current support for WSM message transmission. Once a message is received, the module decodes the message and updates its respective shared memory with the data.

The Savari OBE uses a Vehicle ID value inside the BSM packet to identify which vehicle is transmitting BSM/WSM packets over DSRC. Please refer to Table 21 for the ID assignments.

TABLE 21: VEHICLE ID ASSIGNMENT

Vehicle	ID
Gray SRX	96
Green SRX	97
Silver SRX	98

Please refer to the SAE2735 documentation for the BSM packet units/variables. The Savari OBEs run a VTTI OBE software which follows the BSM variable definitions. The WSM messages (VTTI proprietary WSM Packet) will be decoded and their contents will be updated on shared memory but its structure will not be covered in this section as WSM packets are not currently used.

TABLE 22: SHARED MEMORY - HOST VEHICLE (HV)

Variable Name	Type	Units
MessageCount	uint32_t	
VehicleID	uint64_t	
SecMark	uint64_t	

Latitude	double	degrees
Longitude	double	degrees
Elevation	double	meters
PRNDL	uint32_t	
VehicleSpeed	double	kph
SteeringWheelAngle	double	
LongitudinalAccel	double	m/s^2
LateralAccel	double	m/s^2
VerticalAccel	double	m/s^2
YawRate	double	Deg/sec
BrakeActive	uint32_t	0=Off, 1=On
BrakeAvailable	uint32_t	0=Off, 1=Available
Sparebit	uint32_t	
TractionalControl	uint32_t	
ABS	uint32_t	
StabilityControl	uint32_t	
BrakeBoost	uint32_t	
AuxBrake	uint32_t	
VehicleWidth	uint32_t	meters
VehicleLength	double	meters
OBECounter	uint64_t	Rolling Counter
GpsSpeed	double	kph
AntOffsetX	uint32_t	cm
AntOffsety	float	cm
VehicleType	uint8_t	1= Vehicle, 2= Bike

TABLE 23: SHARED MEMORY - REMOTE VEHICLE (RV)

Variable Name	Type	Units
vehicle_index	unsigned char	
rvMessageCount	uint32_t	
rvVehicleID	uint64_t	
rvSecMark	uint64_t	
rvLatitude	double	degrees
rvLongitude	double	degrees
rvElevation	double	meters
rvPRNDL	uint32_t	
rvVehicleSpeed	double	kph

rvSteeringWheelAngle	double	
rvLongitudinalAccel	double	m/s^2
rvLateralAccel	double	m/s^2
rvVerticalAccel	double	m/s^2
rvYawRate	double	Deg/sec
rvBrakeActive	uint32_t	0=Off, 1=On
rvBrakeAvailable	uint32_t	0=Off, 1=Available
rvSparebit	uint32_t	
rvTractionalControl	uint32_t	
rvABS	uint32_t	
rvStabilityControl	uint32_t	
rvBrakeBoost	uint32_t	
rvAuxBrake	uint32_t	
rvVehicleWidth	uint32_t	meters
rvVehicleLength	double	meters
rvOBECounter	uint64_t	Rolling Counter
rvGpsSpeed	double	kph
rvAntOffsetX	uint32_t	cm
rvAntOffsety	float	cm
rvVehicleType	uint8_t	1= Vehicle, 2= Bike

The Savari OBE streams BSM/WSM packets to the STOL CPS Linux Machine at 10 Hz. The UDP packet structure is shown below. The packet structure will not be covered in this section as it was not developed for the STOL effort.

TABLE 24: OBE UDP DATAGRAM DESCRIPTION

Byte 0	Byte 1	Byte 2 -3	Byte 4 - X
Header	Type	Size	DATA

4.3.2.2 SAVARI BSM DATA SOFTWARE

The Savari BSM data software module is depicted in Figure 25 below.

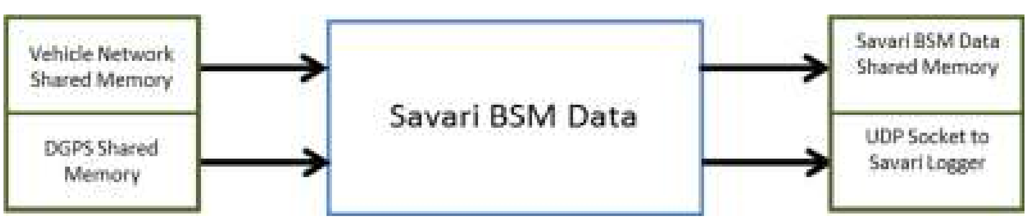


FIGURE 25: SAVARI BSM DATA SOFTWARE MODULE DIAGRAM

The Savari BSM data module retrieves information from shared memory, puts it in the BSM structure that is predefined by Savari, and sends that data to the Savari OBE over UDP (10.10.50.25:5007). The mapping of shared memory data to specific variables in the BSM is shown in Table 25 below; anything not listed is unpopulated.

TABLE 25: CURRENT ASSIGNMENTS FOR BSM VARIABLES

BSM Part	Type	BSM Variable	Source Module	Source Variable	Source Type
1	uint32_t	transmissionstate	VehicleData	gearShifter	gear_shifter_status
1	double	speed	VehicleData	vehicleSpeed	double
1	double	longaccel	VehicleData	xAccel	double
1	double	lataccel	VehicleData	yAccel	double
1	double	yawrate	VehicleData	yawRate	double
1	uint32_t	wheelbrake	VehicleData	brakeLight	bool
2	uint32_t	leftturnsignal	VehicleData	leftTurnSignal	bool
2	uint32_t	rightturnsignal	VehicleData	rightTurnSignal	bool
2	double	throttle_pos	VehicleData	throttlePosition	double

TABLE 26: BSM SOFTWARE SHARED MEMORY DESCRIPTION

Variable Name	Type	Units
secmark	int32_t	none
latitude	double	degrees
longitude	double	degrees
elevation	double	meters
transmissionstate	uint32_t	1=Park, 2=Reverse, 3=Neutral, 4=Overdrive, 5=Drive, 6=Drive1, 7=Drive2, 8=Drive3, 9=Drive4
speed	double	m/s
heading	double	degrees
angle	double	degrees
longaccel	double	m/s^2
lataccel	double	m/s^2
vertaccel	double	m/s^2
yawrate	double	degrees / s
wheelbrake	uint32_t	0=off, 1=on
wheelbrakeavailable	uint32_t	0=not available, 1=available
traction	uint32_t	0=not active, 1=active
abs	uint32_t	0=not active, 1=active
stabilitycontrol	uint32_t	0=not active, 1=active
brakeboost	uint32_t	0=not active, 1=active
auxbrakes	uint32_t	0=not active, 1=active
width	uint32_t	cm
length	double	cm
event_hazardlights	uint32_t	0=not active, 1=active

event_absactive	uint32_t	0=not active, 1=active
event_tractionctrlloss	uint32_t	0=not active, 1=active
event_stabilityctrlactivated	uint32_t	0=not active, 1=active
event_hazardbraking	uint32_t	0=not active, 1=active
event_airbag	uint32_t	0=not active, 1=active
lowbeam	uint32_t	0=not active, 1=active
highbeam	uint32_t	0=not active, 1=active
leftturnsignal	uint32_t	0=not active, 1=active
rightturnsignal	uint32_t	0=not active, 1=active
hazardlights	uint32_t	0=not active, 1=active
autolightcontrol	uint32_t	0=not active, 1=active
dtimerunlights	uint32_t	0=not active, 1=active
foglights	uint32_t	0=not active, 1=active
parkinglights	uint32_t	0=not active, 1=active
lightbarinuse	uint32_t	0=not active, 1=active
wipers_swfnt	uint32_t	0=not active, 1=active
wipers_rtfnt	uint32_t	0=not active, 1=active
wipers_swrear	uint32_t	0=not active, 1=active
wipers_rtrear	uint32_t	0=not active, 1=active
throttle_pos	double	percent

The UDP Datagram for the BSM software is described below.

Destination IP Address: 10.10.50.25
Destination UDP Port: 5007
Delimiter: Whitespace
Format: HEADER (“Savari_BSM_Data”) VARIABLE_NAME(ASCII) VARIABLE_VALUE(ASCII) …

An example UDP datagram is shown below.

Savari_BSM_Data … latitude 37.189346 longitude -80.396533 elevation 638.556 …

4.3.3 DSRC AND GPS ANTENNA

A MobileMark MGW-410 DSRC antenna was selected as it combines GPS, WiFi, DSRC, and cellular all in one compact antenna. This surface mount antenna is configured with three cables to connect with individual devices. Detailed specifications are provided in Appendix 5.4.9 and can be found at the following website: http://www.mobilemark.com/shop/item.asp?itemid=1224.

The antenna cable is run through the radio antenna slot on the top of the vehicle as shown in Figure 26. It connects to the Savari OBE and the cell module.

FIGURE 26: MOBILEMARK MGW-410-3C3C3C2C-WHT-180

4.4 Sensor Subsystem

The sensor subsystem includes add-on equipment to provide precise vehicle global locations (via GPS) and relative position to nearby vehicles (via radar). Although the OBE has a built-in automotive-grade GPS (which is sufficient for Task 2), a higher-accuracy DGPS is included to support future needs. The BSM data obtained by the OBE may also be used to compute the relative position and speed of equipped vehicles; however, radar is needed to measure the relative position and speed of unequipped vehicles. Both front and rear radar were installed, thus providing a window into the leading and following traffic behavior. Data from these sensor systems is available on the CPS.

4.4.1 High Accuracy GPS

Although not necessary for Task 2, the STOL vehicles were equipped with a high-accuracy GPS that is capable of receiving future correction data from the base station presently being constructed at TFHRC (or other correction sources as deemed appropriate). The Novatel FlexPak-G2 with OEMStar DGPS was installed in the STOL vehicles. This unit offers a compact, robust enclosure with serial interfaces for sharing data with the CPS. It has an RMS accuracy of 1.5 meters in single point L1 mode and 0.5 meters when operating with differential corrections.

The Flexpak is located in the rear of the vehicle attached to the equipment plate. The Flexpak connects to the USB Hub through a USB to serial cable. **Ignition Fuse Block, fuse #3.**

Detailed specifications for the FlexPak-G2 with OEMStar are provided in Appendix 5.4.10 and at the following website: http://www.novatel.com/assets/Documents/Papers/FlexPak6.pdf.

Figure 27: FLEX6-G2L-R0G-TTR FLEXPAK6 WITH G2LR0GTTR FIRMWARE

4.4.1.1 DGPS Software

The DGPS software module diagram is depicted in Figure 28 below.

FIGURE 28: DGPS SOFTWARE MODULE DIAGRAM

The DGPS module connects to a serial interface (/dev/ttyUSB0) to read and write to the DGPS hardware. The DGPS module requires that an initialization packet be sent for both position and velocity. These initialization packets determine how often the position/velocity data are streamed over the serial port and also the respective offset between each packet. These parameters can be set in the **stol_config.xml** file.

When the vehicle is turned on, the DGPS module is in a waiting state. The module remains in this state for three seconds and then sends an initialization message to the DGPS system through a serial port. The module then waits for one second and then sends another message to initialize the position period and offset. After an additional 200ms, a velocity period and offset initialization message is sent. The DGPS module then enters the "ready" state and begins polling the serial port for messages sent from the DGPS system. Once a message is received from the system it is parsed and the respective pieces are distributed to the shared memory module and sent with a UDP socket to the DAS.

TABLE 27: DGPS SHARED MEMORY DESCRIPTION

Variable Name	Type	Units
posTimeStatus	Enum	Refer to dgps_base.hpp
posWeek	uint16_t	gps_week

posMiliSec	uint32_t	milliseconds
posStatus	Enum	Refer to dgps_base.hpp
posType	Enum	Refer to dgps_base.hpp
latitude	double	degrees
longitude	double	degrees
altitude	double	feet
latStdDeviation	float	stdev
lonStdDeviation	float	stdev
altStdDeviation	float	stdev
posDiffAge	float	
posStatusAge	float	seconds
velTimeStatus	Enum	Refer to dgps_base.hpp
velWeek	uint16_t	gps_week
velMiliSec	uint32_t	milliseconds
velStatus	Enum	Refer to dgps_base.hpp
velType	Enum	Refer to dgps_base.hpp
velDiffAge	float	
horiSpeed	double	meters/second
heading	double	degrees
vertSpeed	double	meters/second

TABLE 28: DGPS XML CONFIGURATION

Tag	Description
position_period	DGPS Position Data Packet Refresh rate in seconds
position_offset	DGPS Position Data Packet Offset in seconds
velocity_period	DGPS Velocity Data Packet Refresh rate in seconds
velocity_offset	DGPS Velocity Data Packet Offset in seconds
DAS_UDPPort	DAS UDP Forwarding Port

The example in Figure 29 sets the DGPS module to stream position data every 100ms with a zero second offset for the packet transmission. It also sets the velocity position data streaming period to 100ms. There is an offset of 50ms between the position and velocity data packet transmission.

```
<DGPS>
<position_period>0.1</position_period>
<position_offset>0.0</position_offset>
<velocity_period>0.1</velocity_period>
<velocity_offset>0.05</velocity_offset>
<DAS_UDPPort>6003</DAS_UDPPort>
</DGPS>
```

FIGURE 29: EXAMPLE XML PARAMETER SETUP FOR DGPS MODULE

The DGPS UDP packet is sent to the VTTI NextGen DAS at 10 Hz. It contains the ASCII values for each variable from the shared memory.

An example UPD datagram is shown below:

Destination IP Address: 10.10.50.100
Destination UDP Port: 6003
Delimiter: Whitespace

Format: HEADER (“GPS”) VARIABLE_VALUE(ASCII) VARIABLE_VALUE(ASCII) …

TABLE 29: DGPS SOFTWARE UDP STRUCTURE

UDP Structure	
Latitude	**Sent First**
Longitude	
Altitude	
PosTimeStatus	
PosWeek	
posMiliSec	
PosStatus	
posType	
latStdDeviation	
altStdDeviation	
posDiffAge	
posStatusAge	
velTimeStatus	
velWeek	
velMiliSec	
velStatus	
velType	
velDiffAge	
horiSpeed	
Heading	
vertSpeed	**Sent Last**

4.4.2 GPS ANTENNA

The Novatel GPS-702 GGL antenna is paired with the FlexPak-G2 with OEMStar. The antenna provides single-frequency GNSS capabilities permitting GPS and GLONASS signal reception. Detailed specifications for the Novatel GPS-701-GG are provided in Appendix 5.4.11 and at the following website: http://www.novatel.com/products/gnss-antennas/high-performance-gnss-antennas/gps-702-ggl/.

The GPS antenna is connected to the Flexpak through a Novatel GPS-C006 cable with TNC male plug connectors. The cable runs through the radio antenna slot on the roof of the vehicle.

FIGURE 30: NOVATEL 702-GGL GPS ANTENNA

4.4.3 FRONT AND REAR RADAR

The Smart Microsystems (SMS) Universal Medium Range Radar (UMRR) Type 29 (Front: UMRR-0A0303-1D0307, Rear: UMRR-0A0303-1D0307) were used for the front and rear radars. The UMRR radars provide detailed object information using direct measures of range, radial speed, and angle. These measures are processed by the tracking algorithms that assign object IDs and provide parameters for each ID as they change over time. For each object, the radar provides x-position, y-position, x-velocity, y-velocity, object type (moving, stationary, leading), and lane. The UMRR initiate tracking and report measures for vehicles at ranges from 1 to 160 meters with a FOV of +/- 18 degrees at an accuracy of <2.5% or +/- 0.25 m (whichever is greater). The radars utilize the frequency hopping method, so when they detect that another device is using the same frequency; they select the next available frequency. Detailed specifications for the UMRR are provided in Appendix 5.4.12 and at the following website: http://smartmicro.de/images/smartmicro/automotive/UMRR%20Automotive%20Type%2029%20Data%20Sheet.pdf.

The front and rear radar are connected to the CPS through a PCAN USB connection as shown in Figure 31. **Ignition Fuse Block, fuse #4.**

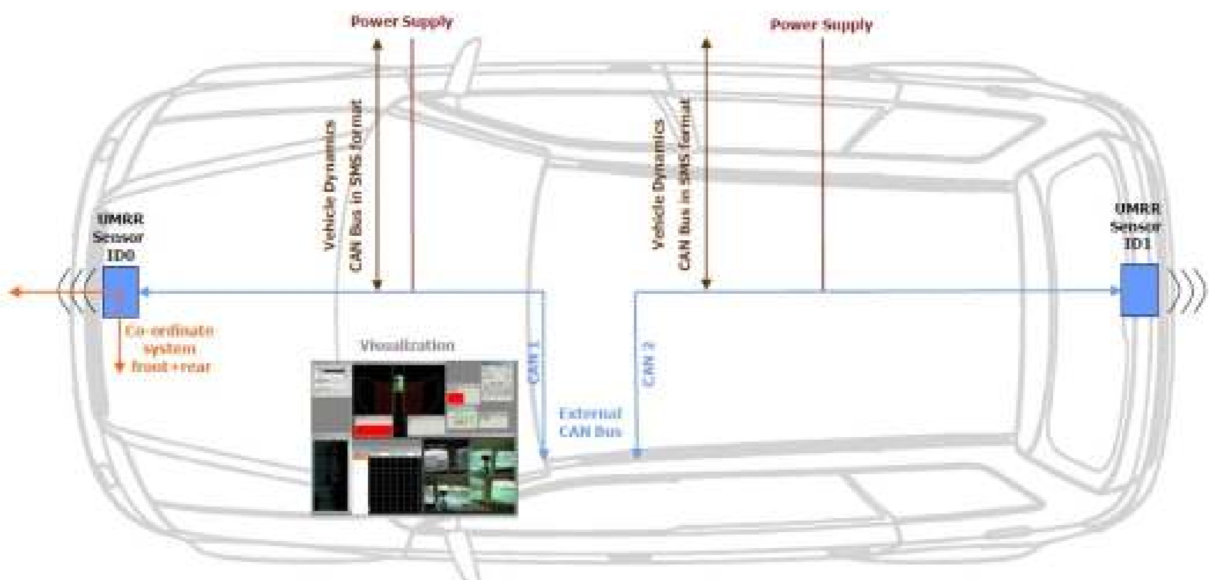


FIGURE 31: RADAR CONNECTIONS

The front radar is located behind a fabricated front license plate as shown in the figures below.

FIGURE 32: FRONT RADAR INSTALLATION

The rear radar is located below the rear bumper in a custom mount as shown in Figure 33 below. Both the front and rear locations were chosen as to be unobtrusive.

FIGURE 33: REAR RADAR INSTALLATION

The radar tracking firmware within the two sensors will differ to compensate for the direction of travel. This firmware is custom to VTTI and therefore will not be discussed further in this document. The radar sensors coexist on a single CAN network.

4.4.3.1 RADAR SOFTWARE

The radar software module is depicted in Figure 34 below.

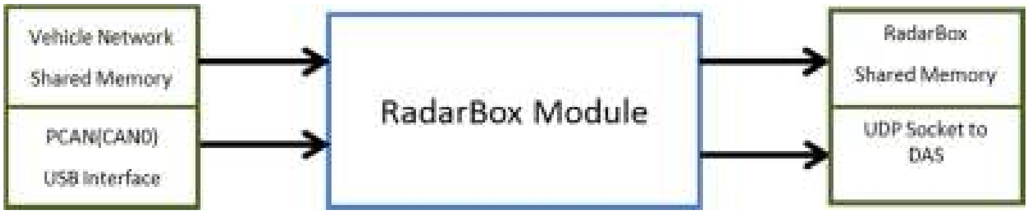


FIGURE 34: RADAR SOFTWARE MODULE DIAGRAM

The Front/Rear Radar module interfaces one of the USB/CAN (can1) interface on the STOL CPS Linux Machine. This module uses the SocketCAN driver to poll CAN messages from the specific bus. Each radar (Front/Rear) uses different base address (0x500 for Front and 0x600 for Rear) and both can be supported on the same busThis section will describe which variables are included on the shared memory and how they are transmitted to VTTI NextGen DAS. This module requires some parameter definitions from the **stol_config.xml** file which will be explained in the following section.

Figure 35 shows the X/Y coordinate system for the front radar sensor. The following variables use this coordinate system:

- Xrange[i] and Yrange[i]
- Xvelocity[i] and Yvelocity[i]

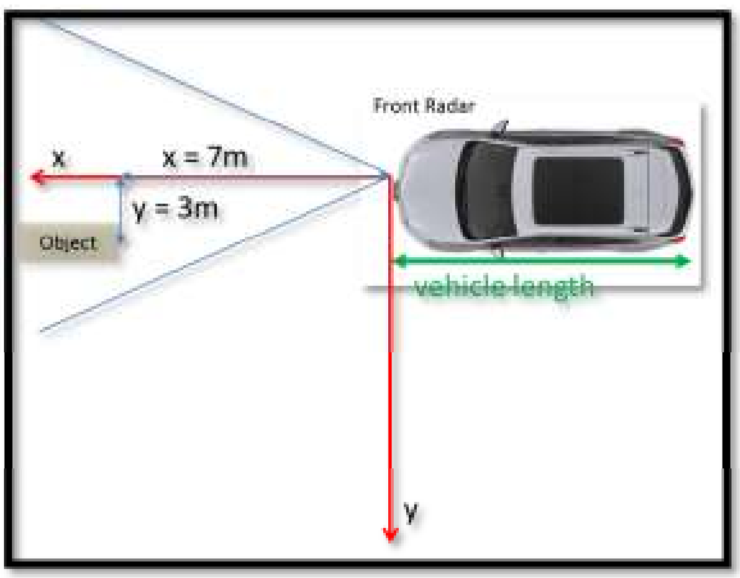


FIGURE 35: FRONT RADAR ORIENTATION

Figure 36 below shows the X/Y coordinate system for the rear radar sensor. The following variables use this coordinate system:

- Xrange[i] and Yrange[i]
- Xvelocity[i] and Yvelocity[i]

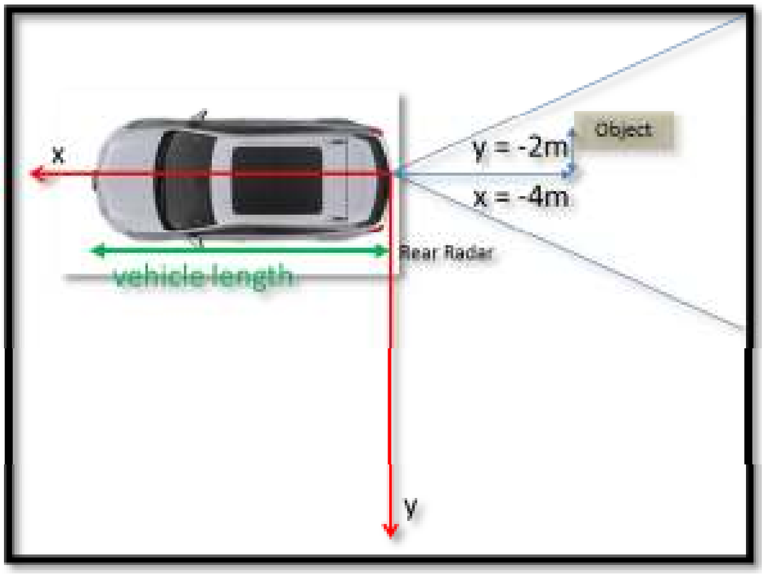


FIGURE 36: REAR RADAR ORIENTATION

TABLE 30: RADAR SHARED MEMORY DESCRIPTION

Variable Name	Type	Units
radar_no	int	0=Front, 1 = Rear
sensorStatus	int	0=Normal, 4=Simulation
systemMode	int	0=Unequal, 1=FMSK, 2=PDHS, 3=PDHM
sourceDevice	int	ID in the network
maxRange	int	Maximum Range in meters
timestamp	uint_32t	milliseconds
numObjects	int	Number of Object in the list
numMessages	int	Number of Messages per object
tScan	uint8_t	milliseconds
cycleCount	uint32_t	Current value of cycleCount
Xrange[i]	float	Meters
Yrange[i]	float	Meters
Xvelocity[i]	float	meters/second
Yvelocity[i]	float	meters/second

objectID[i]	uint8_t	ID number
objectType[i]	uint8_t	Refer to radar_base.hpp
objectLead[i]	bool	1= Lead Vehicle
objectMoving[i]	bool	0=Stationary, 1=Moving
closestObject	float	Meters

The following tables describe the XML configurations for the radar module.

TABLE 31: RADAR XML CONFIGURATION - MAIN TAG

Tag	Description
Debug	Debugging Information 0=Disabled, 1=Enabled
CAN_Device	Device Name to be used to get Radar Data
DAS_UDPPort	DAS UDP Forwarding Port

TABLE 32: RADAR XML CONFIGURATION - FRONT RADAR TAG

Tag	Description
MaxObjects	Maximum number of objects to be tracked
Guardrails	0=Enable Guardrails Detection, 1= Disable Guardrails Detection
RawTargets	0=ON, 1=OFF
Resolution	0=16mm, 1=32mm

TABLE 33: RADAR XML CONFIGURATION - REAR RADAR TAG

Tag	Description
MaxObjects	Maximum number of objects to be tracked
Guardrails	0=Enable Guardrails Detection, 1= Disable Guardrails Detection
RawTargets	0=ON, 1=OFF
Resolution	0=16mm, 1=32mm

The example shown in Figure 37 below provides an example XML parameter setup for the Radar Module.

```
<RadarBox>
  <Debug>0</Debug>          <!-- 0=OFF, 1=ON  -->
  <CAN_Device>can0</CAN_Device>      <!-- linux device name  -->
  <DAS_UDPPort>6001</DAS_UDPPort>
  <Front_Radar>
    <MaxObjects>8</MaxObjects>    <!-- 4-32 -->
    <Roadway>1</Roadway>      <!-- 0=ON, 1=OFF -->
    <RawTargets>1</RawTargets>    <!-- 0=ON, 1=OFF -->
    <Resolution>1</Resolution>    <!-- 0=16mm, 1=32mm -->
  </Front_Radar>
```

```
  <Rear_Radar>
   <MaxObjects>8</MaxObjects>   <!-- 4-32 -->
   <Guardrails>1</Guardrails>   <!-- 0=ON, 1=OFF -->
   <RawTargets>1</RawTargets>   <!-- 0=ON, 1=OFF -->
   <Resolution>1</Resolution>   <!-- 0=16mm, 1=32mm -->
  </Rear_Radar>
</RadarBox>
```

FIGURE 37: EXAMPLE XML PARAMETER SETUP FOR RADAR MODULE

The RadarBox UDP packet is sent to the VTTI NextGen DAS from each sensor (front/rear) every 50ms. The UDP packet is a simple packet wrapper over the CAN packet with a header (“Radar”) as shown in Table 34.

TABLE 34: RADAR MODULE UDP DATAGRAM DESCRIPTION

Byte 0 -4	Byte 5 - 6	Byte 7	Byte 8 – 15
"Radar"	CAN_ID(0x500)	DLC	DATA

4.5 Data Acquisition Subsystem

VTTI’s NextGen DAS provides a complete solution precisely targeted at the specific needs of vehicular data collection. Data is predominately delivered to the DAS by the CPS over an Ethernet connection. The DAS is also integrated with forward and rearward facing cameras, allowing video data collection while the vehicle ignition is in the “on” position and the DAS has data recording has been switched on. The DAS is also equipped with an accelerometer and gyroscope to measure vehicle dynamics independently of the vehicle sensors.

The final component to the DAS is a site-server or “data slurping terminal”. This includes a hard drive dock located at the STOL that provides the means to download data directly from the DAS onto a server. Data is harvested from the vehicles by removing the hard drive from the DAS, and subsequently inserting the hard drive into the drive reader which initiates an automated download, making files available on share accessible by a network connection.

4.5.1 NextGen Embedded DAS

The NextGen is a flexible embedded architecture that includes a number of I/O features customized to meet the needs of a multitude of research projects, including those envisioned for the STOL. The DAS is powered by the vehicle’s 12v system and draws less than four amps during operation. Specific to this effort, the DAS communicates directly with the CPS via Ethernet through UDP messages. The Ethernet port provides the ability for high bandwidth and low latency communications with the CPS. The UDP packets contain a stream of data intended for archival and subsequent analyses. These packets are received by the DAS at a minimum rate of 10Hz where they are choreographed, time-stamped, and archived to a non-volatile solid state hard drive. All collected data is choreographed using a precise real-time clock and written to a solid state hard drive which requires a physical key for removal from the system.

The DAS is installed in the spare tire well of each vehicle and is fastened to the metal equipment plate as shown in Figure 38 below. The DAS connects to the CPS through an Ethernet connection to the wireless router. The DAS connects to constant power with an ignition trigger. **Ignition Fuse Block, fuse #7. Constant Fuse Block, fuse #8.**

FIGURE 38: NEXTGEN INSTALL LOCATION

4.5.2 FORWARD AND REARWARD CAMERAS

The Inmotion cameras (in30S1N1L38) were used for both the forward and rearward cameras. The small CCD camera (36mm x 36mm) provides a high quality image with noise reduction and light compensation technologies that allow the camera to operate across a wide range of operating conditions. Detailed specifications for the cameras are provided in Appendix 5.4.13 and at the following website: http://www.audioauthority.com/downloads/manuals/seawolf_atm_manual_rev2.4.pdf.

Figure 39: Compact Inmotion Camera - in30S1N1L38

The cameras were mounted inside the vehicle windscreens to protect them from the elements. The forward camera was mounted in a custom plastic pod next to the rear view mirror in the front of the vehicle as shown in Figure 41.

FIGURE 40: FORWARD CAMERA

The rear camera was mounted in the rear of the vehicle attached to the back window as shown in Figure 41.

FIGURE 41: REARWARD CAMERA

Both cameras are connected to the VTTI DAS through a custom VTTI cable for data collection. The cable for the front camera routes to the left of the vehicle, tucked under the headliner. It is run securely down the A-pillar and plugs into the IMU that is securely mounted to the factory Engine Control Module (ECM) underneath the driver side dash. The rear camera is run through the A-pillar and plugs into the same VTTI cable. The cameras are powered through the DAS.

4.5.3 Accelerometers and Gyroscopes

The DAS measures acceleration along the translational and rotational vehicle axes. These measures are available as an independent measure for data analysis uses. The inertial measurement unit (IMU) which contains the accelerometers and gyroscopes is a low-cost unit designed and constructed by VTTI. Detailed specifications for the gyroscopes and accelerometers are provided in Appendix 5.4.14.

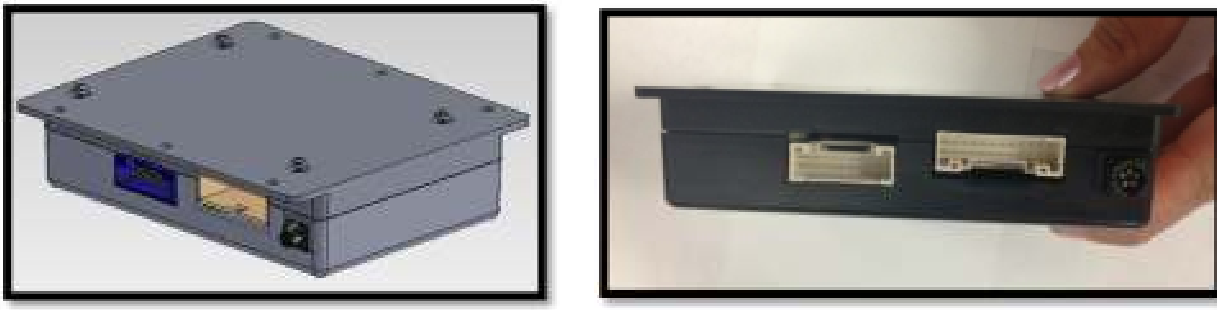


FIGURE 42: ACCELEROMETER AND GYROSCOPE PACK

The IMU is mounted on the driver side of the vehicle underneath the dashboard. It is secured to the factory ECM. The orientation of the VTTI IMU is very important, with the plugs facing the rear of the vehicle, and the tabs for the plugs facing the right side of the vehicle. The IMU is powered through the DAS.

FIGURE 43: IMU INSTALLATION

4.5.4 DATA HARVESTING TERMINAL

The DAS archives data to a removable solid state hard drive (HD). Data will be retrieved from the DAS by removing the hard drive and inserting it into a dock attached to the data harvesting terminal. The data harvesting terminal has been configured by VTTI to automatically download and pre-process data from the hard drive.

The workflow monitors the dock for the presence of a HD. When a HD is detected, the workflow will initiate the data download and publish updates to a webpage. The workflow then communicates with servers at VTTI to coordinate the post-processing of the raw data. This process includes decrypting the data files, performing some basic quality control verifications, containerizing the H.264 video, and resampling the asynchronous data to a flat format in which samples are reported on a 10Hz clock. To enable this process, the server requires a relatively unfettered high-speed Internet 2 connection for the harvest terminal.

The data harvest machine selected for this function is a Dell R240 Intel Xeon Processor (2.2 Ghz E5-2430) with 16GB of memory and 4 1TB hard drives in a RAID 5 configuration. The custom HD dock referred to as a "toaster" or "slurper" is shown in Figure 44. The toaster has a 4-drive capacity and is provided with the necessary power and USB connections. Specifications for the server may be found in Appendix 5.4.15 and can be found at the following website: http://www.dell.com/us/business/p/poweredge-r420/pd.

FIGURE 44: DELL R240 RACK SERVER AND HD DOCK FOR USE AS A DATA HARVEST MACHINE

More detailed instructions for the data harvesting terminal can be found in the **Error! Reference source not found.**.

4.6 Power Distribution Components

Power distribution for the system is provided by an appropriately sized and fused +12v cable running from the vehicle battery to a power rail in the rear of the SRX. A local ground connection was identified and attached to a rail for the -12v connections. Finally, a third rail provided a source of ignition switched +12v for the components which require power only when the vehicle is operating. The components were configured such that automatic shutdown occurs when the vehicle ignition is switched off. This will reduce the probability that components are not inadvertently left running; thus draining the battery.

On occasion, it may be desirable to operate the equipment without the vehicle running. To enable this feature, the key will need to be in the “on” position; however, the engine should not be started. When operating with the engine off, the vehicle must be connected to a wall charger. To simplify this process, a battery connector was installed for readily attaching a charger. The power distribution is depicted in Figure 45 below.

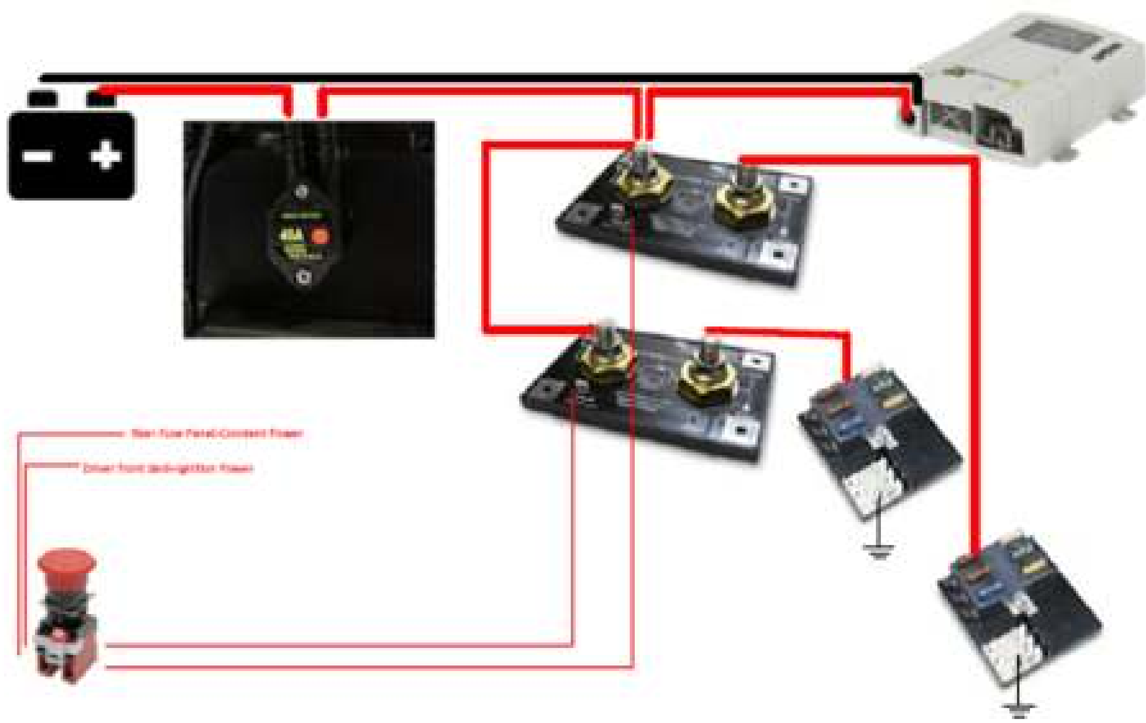


FIGURE 45: POWER DISTRIBUTION

4.6.1 Fused Power Rail

The power rail provides a convenient way to hook up VBattery, VIgnition, and Ground and it provides additional unused power taps for expansion in the future for additional hardware. A mid-range manual reset 40 amp panel mount circuit breaker, a solid state 100 amp DC switch contactor inpower and two ATO/ATC fuse blocks (8 gang with ground terminal) were installed in each vehicle. Detailed specs can be found in Appendix 5.4.16, 5.4.17, and 5.4.18 and at the following websites, respectively:
http://www.waytekwire.com/item/46976/mid-range-manual-reset-40-amp/,
http://www.waytekwire.com/item/44401/solid-state-100--amp-dc-switch/
http://www.waytekwire.com/item/46061/ato---atc-fuse-block-8-gang/.

FIGURE 46: POWER COMPONENTS, FROM LEFT TO RIGHT: CIRCUIT BREAKER, DC SWITCH, FUSE BLOCKS

4.6.2 On/Off “Kill” switch

A standard emergency system kill switch was mounted in easy reach of the driver, in the center console near the gear shifter as shown in Figure 47. The switch is connected to the main power and will immediately power off the entire CACC system in case of an emergency.

To engage the button (which will kill power) simply press down. To disengage (and return power) pull up and twist to the right, following the arrows on the button.

FIGURE 47: OMRON EMERGENCY STOP SWITCH

It is important to be cautious when using the emergency stop switch. It is designed to be easily accessible, and easily used. As a result, it is possible to accidentally engage the button, killing all power to the system and interrupting any work. The switch is an Omron Electronics Inc. A22E-M-01 Emergency Stop Switch. Specifications can be found in Appendix 5.4.19 and at the following website: http://www.ia.omron.com/data_pdf/data_sheet/a22e_ds_csm1265.pdf.

FIGURE 48: EMERGENCY STOP SWITCH WIRING

4.6.3 Battery Charger

A Xantrex Truecharge2 battery charger is provided with the vehicles to easily attach to wall power. This allows the system to operate without depleting the vehicle battery reserves. The battery charger provides 10A of continuous power and is smart enough to ensure the battery is not overcharged. Detailed specifications can be found in Appendix 5.4.20 or at the following website: http://www.xantrex.com/documents/Battery-Chargers/TRUECharge-2/DS_TC2_20_40_60_20110303.pdf.

FIGURE 49: XANTREX TRUECHARGE2 BATTERY CHARGER

The battery charger is installed in the spare tire well of each vehicle and is fastened to the metal equipment plate as shown in Figure 49. Any standard 3 prong power extension cable may be used. Plug into a standard 20 amp household circuit. It is recommended that the vehicle be parked indoors while using the charger, as the power cable exiting the rear of the vehicle may prevent the rear hatch from shutting. The battery charger power port is located in the rear driver-side floor, and is depicted in Figure 50 below.

FIGURE 50: BATTERY CHARGER POWER PORT

4.6.4 Cooling System

The cooling system is located in the rear of the vehicle to the right of the equipment plate. It is powered through ignition. The fans are designed to move 32 cubic feet of air per minute, per fan, under optimal conditions. There are two fans per vehicle. The cooling system has been thoroughly tested and shown to keep the system at normal operating temperatures under normal conditions. It is important for the rear lid to be completely closed while the vehicle is in use in order to ensure the cooling system is able to operate properly. The cooling fan assembly instructions, parts list, and installation pictures are shown in Figure 51 below. **Ignition Fuse Block, fuse #5.**

Detailed specifications can be found in Appendix 5.4.21 or at the following website: http://www.orionfans.com/media/parts/dcblowers/odb1232-12hb.pdf.

Qnt	Item	Part #	Sorce
2	Fan	OD8600FT-12HB	Digi-Key
1	Rear Support	8975K822	McMaster
2	Blade Cover	19155K44	McMaster
1	Nose Cone	1773K11	McMaster
2.5'	Tube	5666K17	McMaster
1"	Aluminum Tape	76145A61	McMaster
6	screw	99461A310	McMaster

FIGURE 51: COOLING FAN INSTALLATION

TABLE 35: ESTIMATED POWER CONSUMPTION OF AFTER-MARKET PARTS

Part	Power Consumption (Watts)
CPS	39.15
DAS	33.75
USB Hub	10.13
Wireless Hub	13.5
Savari OBE	16.2
Cooling	21.32
DGPS	.6
Display	5
Total	139.65 watts
	@13.5V

5 Appendix

5.1 Bill of Materials

List of Materials in each Vehicle	Quantity
Connected Vehicle Subsystem	**4**
Verizon Pantech 4G LTE Cell Modem wwan375_USB-UML290	1
MobileMark OBE DSRC/GPS Antenna and 3 associated cables	1
Novatel GPS Antenna 702 GGL	1
Novatel GPS-C006 Cable	1
CPS Subsystem	**9**
ASUS RT N16 wireless router	1
EBOX310-830/CANBUS Automotive Grade CPS Computer	1
Xenarc 7" VGA Display - 705TSV-B	1
STOL vehicle monitor mounting arm	1
Superspeed 3.0 USB Hub W/ USB 3.0 Cable and Power Adapter	1
Power adapter for USB Hub	1
Wireless USB Adapter for CPS PC	1
USB Flash Disk for SD Creator Machine	1
eSATA Adapter for SD Creator Machine	1
DAS Subsystem	**7**
Forward camera pod	1
Rearward camera pod	1
IMU (accelerator and gyro pack)	1
NextGen DAS	1
SS hard drive for DAS	1
Cooling System	**14**
12-Volt DC Duct Fan 230 CFM, for 4" Duct Dia, 5-1/4" X 6" X 4-3/16"	2
Rear support for cooling fan	1
Blade cover for cooling fan	2
Nose cone for cooling fan	1
Tube for cooling fan	1
Aluminum tape for cooling fan	1
Screws for cooling fan	6
Miscellaneous	**13**
Lind DC Regulator - WY1250-2691	1
PCAN USB adapter PCAN IPEH-002021	1
Equipment plate for equipment installed in trunk	1
Rapid prototype part - E-stop plate	1
SMS adapter - Connects USB hub to mobile mark antenna on vehicle	1
Miscellaneous brackets and equipment mounts	1

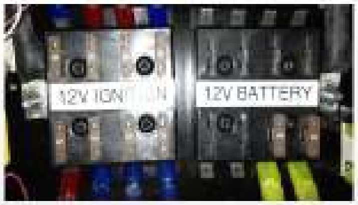
Ethernet Cable	2
USB to Serial Cable (Connects Flexpak to USH hub)	1
Miscellaneous mounting components	1
VGA Cable for HMI	1
AV Cable for HMI	1
Cable retainers	1
Power Subsystem	**7**
Emergency push button	1
Xantrex Truecharge2 Battery Charger 40A	1
12v cable	1
40Amp Circuit Breaker	1
Solid State 100A DC Switch Contactor Inpower	1
ATO/ATC Fuse Block 8 Gang with Ground Terminal	2
Sensor Subsystem	**7**
Flexpak6 GPS with G2LROGTTR Firmware	1
GPS antenna mounts	1
Radar	2
Rear radar cover	1
Rear radar mounting plate	1
Front fabricated license plates	1

List of Other Materials Provided (total)	Quantity
4 slice Toaster / Slurper	1
DELL PowerEdge R420 site server	1

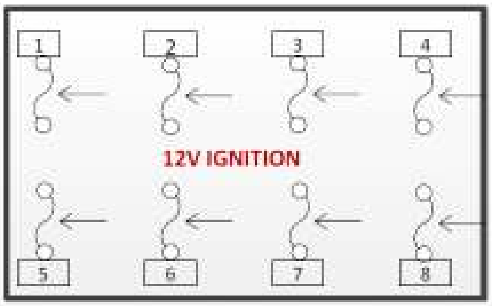
5.2 Vehicle Network Variables

CAN ID	Data Description	Bit(s)	Length (bits)	Scaling/Units	Notes
0x0BE	Brake Pedal Position	1.7-1.0	8		
0x140	Brake Light	0.6	1		0 = off, 1 = on
0x140	Left signal	2.2	1		Left signal select (not feedback, hazards do not update)
0x140	Right signal	2.3	1		Right signal select (not feedback, hazards do not update)
0x17D	Vehicle Acceleration	3.3-4.0	12	signed 12 bit number	x acceleration, not yet correlated to units
0x1A1	Accelerator Pedal Position	6.7-6.0	8		full range percentage (0-255)
0x1E1	Headway Button State1	2.7 - 2.6	2		0 = not pressing gap adjust, 1 = pressing gap adjust button
0x1E1	Headway Button State2	3.1 - 3.0	2		1 = not pressing gap adjust button, 3 = pressing gap adjust button
0x1E1	ACC Switch State	5.7 - 5.4	4		0x01 = no press 0x02 = resume / speed increase 0x03 = set / speed decrease 0x05 = on/off 0x06 = cancel
0x1E1	ACC Switch Counter	5.3 - 5.2	2		increments each time message is sent (0-3)
0x1E1	Headway Button Counter	5.1 - 5.0	2		increments each time message is sent (0-3) (not always synchronized with the 5.3 - 5.2 counter)
0x1E1	Cruise Ctrl Switch Check	6.7 - 6.4	4		= 16 - ACC Switch State - ACC Switch Counter
0x1E1	Headway Button Check	6.3 - 6.0	4		= 16 - Headway Button State2 - Headway Switch Counter
0x1E9	Lateral Acceleration	0.3-1.0	12	signed 12 bit number	
0x1E9	Yaw rate	4.3-5.0	12	signed 12 bit number	
0x1F5	Gear selection	3.2-3.0	3		0 = in between gears 1 = park 2 = reverse 3 = neutral 4 = drive
0x214	Brake pedal pressure	0.1 - 1.1	8	unknown units	brake pedal pressure
0x348	Left Front Wheel Speed	0-1	16	1/32 kph	
0x348	Right Front Wheel Speed	2-3	16	1/32 kph	
0x34A	Left Rear Wheel Speed	0-1	16	1/32 kph	
0x34A	Right Rear Wheel Speed	2-3	16	1/32 kph	
0x3D1	Throttle position	1	8		throttle position
0x370	ACC Active Flag	2.7	1		0 = inactive, 1 = active
0x370	ACC Headway Setting	2.6 - 2.4	3		1 = near, 2 = mid, 3 = far
0x370	ACC Speed Set-point	2.3-3.0	12	1/16 kph	

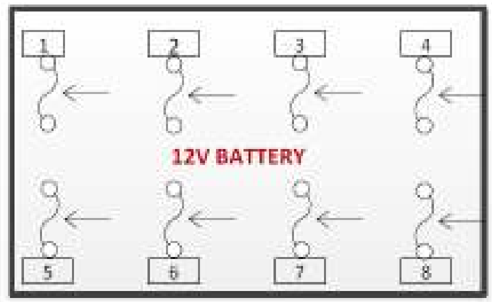
5.3 Fuse Panel Diagram



STOL Fuse Panel Diagram



1: Monitor (5 amp)
2: Savari (5 amp)
3: Flexpak (5 amp)
4: Radar Power (5 amp)
5: Ventilation (5 amp)
6: USB/Wifi (5 amp)
7: DAS Ignition (5 amp)
8: CPS Ignition (5 amp)



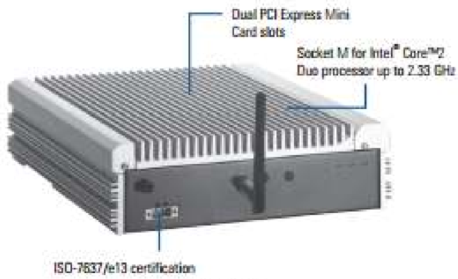
1: Empty
2: Empty
3: Empty
4: Empty
5: Empty
6: Empty
7: CPS Constant (5 amp)
8: DAS Constant (5 amp)

5.4 PART SPECIFICATIONS

5.4.1 EMBEDDED COMPUTER

eBOX310-830-FL

Fanless Embedded System Featuring Socket M Intel® Core™2 Duo Processor up to 2.33 GHz for Vehicle PC



▲ Front view

Features

- Socket M for Intel® Core™2 Duo/ Core™ Duo/ Core™ Solo/ Celeron® M up to 2.33 GHz
- Intel® 945GME + ICH7M chipset
- ISO-7637 Pulse1/2a/3a/3b/4/5a vehicle standard
- Wide-range vehicle power supply with ignition control
- Fanless operation design with full feature I/O
- High performance DDR2 SO-DIMM max. up to 2 GB
- Supports 2 PCI Express Mini Cards
- One 2.5" SATA drive bay and CompanctFlash™ slot
- Optional CAN Bus support

▲ Rear view

Specifications

Standard Color	Silver-Black
Construction	Aluminum extrusion and heavy-duty steel, IP40
CPU	Socket M for Intel® Core™2 Duo/ Core™ Duo/ Core™ Solo Celeron® M up to 2.33 GHz processor
System Memory	1 x 200-pin DDR2 SO-DIMM max. up to 2 GB
Chipset	Intel® 945GME + ICH7M
BIOS	Phoenix-Award 4M Git with RPL/PXE boot ROM
System I/O Outlet	2 x RS-232 (COM 2/3) 1 x RS-232/422/485 (COM 1) 1 x DVI-I for DVI & CRT output 1 x Audio (Mic-in/Line-out) 1 x PS/2 keyboard/mouse 2 x 10/100/1000Mbps Ethernet (Realtek RTL8111B) 2 x USB 2.0 3 x SMA type connector opening 1 x VDC power input connector
Watchdog Timer	255 levels, 1 ~ 255 sec.
Storage	1 x 2.5" SATA HDD drive bay 1 x CompactFlash™
Expansion Interface	2 x PCI Express Mini Card (USB + PCI Express signal) 1 x SIM slot
System Indicator	1 x green LED for system power-on 1 x orange LED for HDD active 1 x green LED for Power status
Power Supply	DC12V mode: Operating voltage: DC9 ~ 16V Start voltage: DC13V or higher DC24V mode: Operating voltage: DC18 ~ 32V Start voltage: DC26V or higher
Power Consumption	12V @ 2.9A 24V @ 14A
Operating Temperature	-10ºC ~ +50ºC (32ºF ~ 122ºF) (with W.T. HDD)
Storage Temperature	-20ºC ~ +80ºC (-4ºF ~ +176ºF)
Humidity Vibration Endurance	10% ~ 90% , non-condensing 2 Grms with HDD (5 - 500 Hz, X, Y, Z directions)
Dimensions	224.1 mm (8.82") (W) x 250 mm (9.84") (D) x 66.5 mm (2.62") (H)
Weight (net/gross)	3 kg (6.61 lb) /3.8 kg (8.37 lb)
Certification	CE, e13, ISO-7637, EN60950 compliance
EOS Support	XPE, WinCE, Linux

* XPE: Windows® XP Embedded

Ordering Information

Standard	
eBOX310-830-FL	Fanless embedded system with DC12V rating, socket M for Intel® Core™ Duo/ Core™2 Duo/ Core™ Solo/Celeron® processor
eBOX310-830-FL-24V-RC-DC	Fanless embedded system with DC24V rating, socket M for Intel® Core™ Duo/ Core™2 Duo/ Core™ Solo/Celeron® processor
eBOX310-830-FL-CAN	Fanless embedded system with CAN bus, socket M for Intel® Core™ Duo/ Core™2 Duo/ Core™ Solo/Celeron® processor

Optional	
CPU	Up to 2.33 GHz
2.5" SATA HDD	40 GB or above
DDR2 SO-DIMM	256 MB ~ 2 GB
CompactFlash	256 MB or above
Wifi module	
Wifi+Bluetooth	
3G module	
GPS module	
Graphic accelerator codec	

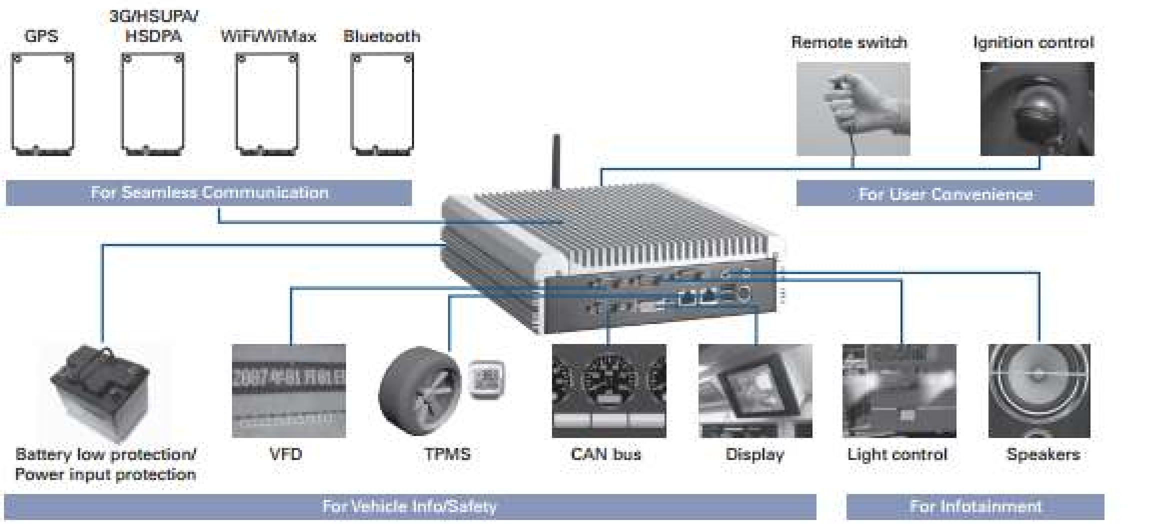
*Specifications and certifications are based on options and may vary.

Packing List

1 x quick manual
1 x driver CD
1 x Y cable for PS/2 keyboard/mouse
1 x screw pack
4 x foot pad
4 x HDD anti-vibration damper
1 x wall mount bracket
1 x remote power switch

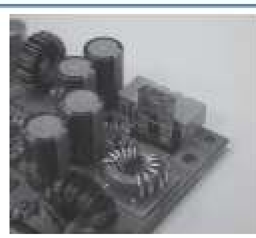
* All specifications and photos are subject to change without notice.

Expansion & Installation



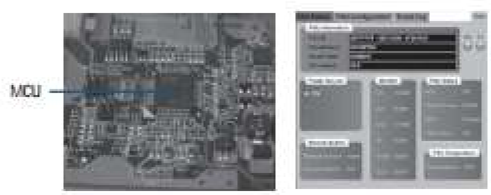
Power Protection

DC Version
ISO7637 pulse1/2a/3a/3b/4/5a
OVP (over voltage protection)
UVP (under voltage protection)
OCP (over current protection)
OTP (over temperature protection)
OPP (over power protection)
OLD (over load protection)
SCP (short circuit protection)
Reverse protection
Battery-low protection

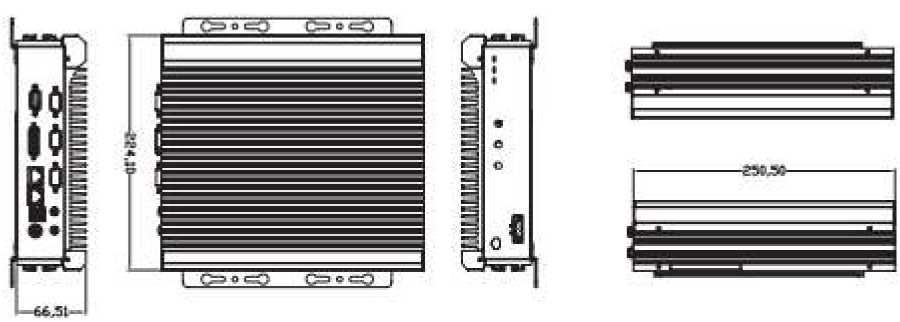


Programmable Setting

Built-in MCU micro processor for power control
Ready tool for below function modification:
- On-line monitoring of power & temperature status
- Ignition-control counter setting
- Thermal protection setting
- Battery-low protection setting
- Event log file for easy debugging



Dimensions



* All specifications and photos are subject to change without notice.

5.4.2 Laptop

Feature	Technical Specification
Processor Options	Intel® CoreTM i3, i5 and i7 up to i7-35xxM; Intel® Celeron® Bxxx processors
Operating System Options	Genuine Windows® 7 Home Basic[2,5], Genuine Windows® 7 Home Premium Genuine Windows® 7 Professional, Genuine Windows® 7 Ultimate Linux Ubuntu 11.10
Memory[6] Options	DDR3 SDRAM 1600MHz 2 slots supporting 2G, 4GB, 8GB[13] DIMMs
Chipset	Mobile Intel® HM77 Express Chipset with Broadcom LOM and TruManage™ Mobile Intel® QM77 Express Chipset with Intel LOM and vPro™
Graphics[7] Options	Intel® HD Graphics 3000 for Intel Core i3/i5/i7 2xxxM and Celeron® processors Intel® HD Graphics 4000 for Intel Core i3/i5/i7 3xxxM processors
Display	14.0" HD (1366x768) Anti-Glare LED 14.0" HD+ (1600x900) Anti-Glare LED
Storage[8] Options	7200 rpm SATA up to 500GB Encrypted 7200 rpm 320GB[3] Mobility Solid State up to 128GB Dell Fast Response Free Fall Sensor (standard on the motherboard)
Optical Drive Options	DVD-ROM, DVD+/-RW
Multimedia Options	High quality speakers, Stereo headphone/Microphone combo jack, Integrated noise reducing array microphones, Optional integrated HD video webcam and Dell Webcam Central software
Battery Options	4-cell (40Whr) Lithium Ion battery with ExpressCharge™ 6-cell (60Whr) Lithium Ion battery with ExpressCharge™ 9-cell (97Wh) Lithium Ion battery with ExpressCharge™ 9-cell (87Whr) 3 Year Limited Hardware Warranty[9] Lithium Ion battery 9-cell (97Wh) Extended battery slice
Power Options	65 Watt or 90W AC Adapter, 65W BFR/PVC Free AC Adapter[2], 90W Auto/Air DC adapter (optional)
Connectivity	10/100/1000 Gigabit Ethernet **Wireless LAN Options:** Intel® Centrino® Advanced-N 6205, Intel® Centrino® Ultimate-N 6300, Dell Wireless™ 1504 (802.11g/n 1x1), Dell Wireless 1540 (802.11n 2x2) **Mobile Broadband[10] & GPS Options**: Dell Wireless 5630 Multi-mode HSPA-EVDO Mini Card (Gobi™ 3000) with A-GPS[2], Dell Wireless 5560 Single-mode HSPA Mini Card with A-GPS[2] **Bluetooth Option:** Dell Wireless 380 Bluetooth® 4.0
Ports, Slots & Chassis	Network connector (RJ-45), USB 2.0 (1), USB3.0 (2) – 1 USB 3.0/eSATA combo, Stereo headphone/Microphone combo jack, Memory card reader, 54 mm ExpressCard, Docking Connector, VGA, HDMI, 1 Full and 2 Half Mini Card Slots, Optional SmartCard Reader[11]
Input Device Options	Single pointing or backlit dual pointing keyboard (Note: Fingerprint Reader tied to backlit keyboard only) Multi-touch Touchpad
Dimensions & Weight[12]	Width: 13.78"/350mm Height: (front/back) 1.18"/29.9mm to 1.28"/32.5mm Depth: 9.45"/240mm Starting weight: 4.5lbs/2.04kg (with 4-cell battery and airbay)
Regulatory and Environmental Compliance	Regulatory Model: P27G Regulatory Type: P27G001 ENERGY STAR 5.2 (Windows OS), EPEAT registered[11]
Systems Management	DASH, Intel® vPro™ Technology's advanced management features (optional, requires Intel WiFi® Link WLAN), TPM 1.2[3]
Warranty & Support Services	Limited Hardware Warranty[9] Standard 3-year Next Business Day On Site Service after Remote Diagnosis[4]. Optional 3 year Dell ProSupport offers premium support from expert technicians and 24x7 global availability[4].
Configuration Services[4]	Factory Image load. BIOS Customization. Hardware Customization, Asset Tagging and Reporting.

5.4.3 VGA Display

Description	
Product Name:	5 inch Photography HD LCD Monitor
Model:	FW-5D/O
Display Screen:	5 inch digital panel
Specification	
Dot Resolution:	800*480 pixels (1920*1440 optional)
Brightness:	350cd/m²
Contrast Ratio:	500:1
Aspect Ratio:	16:9/4:3(adjustable)
Color System	PAL/NTSC
Backlight:	LED
Viewing Angle:	70°/70°(L/R),50°/70° (U/D)
Input Voltage:	DC6-24V(XLR DC Connection)
Input Signal:	HDMI,Video,Audio
Output Signal:	HDMI (optioanl)
Unique Feature:	**built-in viewfinder , Focus Assist**
Power Consumption:	≤7w
Operation Temperature:	-20~55°C
Storage Temperature:	-30~65°C
Unit Size:	146(L)mm X 100(W)mm X 46(H)mm
Unit Weight:	260g
Application	**Accessories**
camera, film field,etc.	• HDMI cable(HDMI to Mini HDMI)
	• Sun shade
	• Hot shoe mount
	• F970 battery Plate
	• User manual
	• Battery (ptional)
	• BNC cable (ptional)
	• DC 12V power adapter (ptional)
	• LP-E6 battery Plate , Panasonic D28 series battery Plate (ptional)

5.4.4 ASUS WIRELESS ROUTER

Network Standard	IEEE 802.11b, IEEE 802.11g, IEEE 802.11d, IEEE 802.3, IEEE 802.11i, IPv4
Product Segment	N300 complete networking; 300Mbps
Data Rate	802.11b : 1, 2, 5.5, 11Mbps 802.11g : 6,9,12,18,24,36,48,54Mbps 802.11n : up to 300Mbps
Antenna	Detachable dipole antenna x 2
Operating Frequency	2.4GHz
Encryption	64-bit WEP, 128-bit WEP, WPA2-PSK, WPA-PSK
Firewall & Access Control	Firewall: NAT and SPI (Stateful Packet Inspection), intrusion detection including logging Logging: Dropped packet, security event, Syslog Filtering: Port, IP packet, URL Keyword, MAC address Authentication: MAC address Access Control
Management	UPnP, DNS Proxy, DHCP
Utilities	Device Discovery: Discover router in network and help user to invoke Web Configuration page EZSetup: Help you to setup wireless and Internet connection easily Firmware Restoration: Restore firmware while system enters rescue mode
Ports	1 x RJ45 for 10/100 BaseT for WAN, 4 x RJ45 for 10/100 BaseT for LAN
Button	WPS Button, Reset Button
Power Supply	AC Input : 110V~240V(50~60Hz) DC Output : 12 V with max. 1 A current
OS Support	Windows® 8 , 32bit/64bit Windows® 7 , 32bit/64bit Windows® Vista , 32bit/64bit Windows® XP , 32bit/64bit Mac OS X Linux
Environmental	Operating Temperature: 0 °C to 40 °C (32 °F to 104 °F) Storage Temperature: -20 ° to 70 ° C (-4 °F to 158 °F) Operating Humidity: 10 % to 90 % (Non-condensing) Storage Humidity: 5 % to 95 % (Non-condensing)
Dimensions	179 x 119 x 37 cm (WxDxH)
Weight	300 g
Package Content	RT-N12 * 1 RJ45 Cable * 1 Support CD * 1 Antenna * 2 Warranty Card * 1 Power Supply * 1

5.4.5 HUB (USB)

This new SuperSpeed 7 ports hub delivers convenient connection access for USB 3.0 fans. Equipped with both a 12V 3A power adapter and built-in surge protection, this hub keeps your devices connected and powered up safely all day long. Its sleek, compact design and high performance make this Uspeed hub an excellent companion for busy techies on the go.

Feature:

- SuperSpeed USB 3.0 supports transfer rates up to 5 Gbps - The actual transmission speed is limited by the setting of the device connected; Backward compatible with USB 2.0/1.1
- Plug and play
- Supports hot swapping
- No install driver needed
- LED indicators display the status of DC power supply and USB connections
- 7 USB 3.0 ports with built-in surge protector
- Smart chip power management allows devices to communicate idle states and latency tolerance for progressively lower power states and subsequently increased performance and power efficiency

Specification:

- Compatible with:
- Windows XP, Windows Vista, Windows 7, Mac OS(Mac OS does not support usb 3.0 by now,can only use it as a usb 2.0 hub)

Package Content:

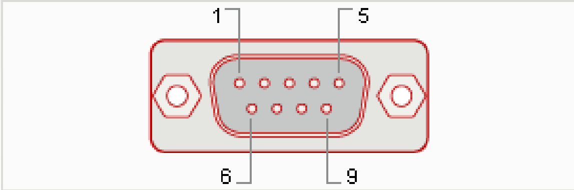
- 1 X USB 3.0 7 Ports USB Hub
- 1 X USB 3.0 Cable
- 1 X 12V 3 A Power Adapter

5.4.6 PCAN Module

Specifications

- Adapter for USB connection (USB 1.1, compatible with USB 2.0)
- USB voltage supply
- Bit rates up to 1 Mbit/s
- Time stamp resolution approx. 42 µs
- Compliant with CAN specifications 2.0A (11-bit ID) and 2.0B (29-bit ID)
- CAN bus connection via D-Sub, 9-pin (in accordance with CiA® 102)
- NXP SJA1000 CAN controller, 16 MHz clock frequency
- NXP PCA82C251 CAN transceiver
- 5-Volts supply to the CAN connection can be connected through a solder jumper, e.g. for external bus converter
- Extended operating temperature range from -40 to 85 °C (-40 to 185 °F)

Pin assignment D-Sub



Pin	Pin assignment
1	Not connected / optional +5V
2	CAN-L
3	GND
4	Not connected
5	Not connected
6	GND
7	CAN-H
8	Not connected
9	Not connected / optional +5V

5.4.7 Cell Modem

Product Specifications

General

Name:	Verizon Wireless USB551L Modem
Model:	USB551L Modem
Approvals:	FCC (North America); FCC Single Modular Approval; CDG
Weight:	35 g (1.23 oz)
Dimensions (with USB folded out):	88 mm x 35 mm x 12 mm (3.46 in x 0.98 in x 0.47 in)
Wireless Network– Dual Mode:	LTE CDMA 1X/EV-DO Rev A
Chip Set:	QUALCOMM® MDM9600
Interface Type:	Type A USB Port

Technology/Bands

Technology:	LTE; CDMA Rev A, Rev 0, 1XRTT
Band Designation:	LTE with receive MIMO; 700 MHz CDMA 1X/EV-DO RA; 800/1900 MHz

Environmental

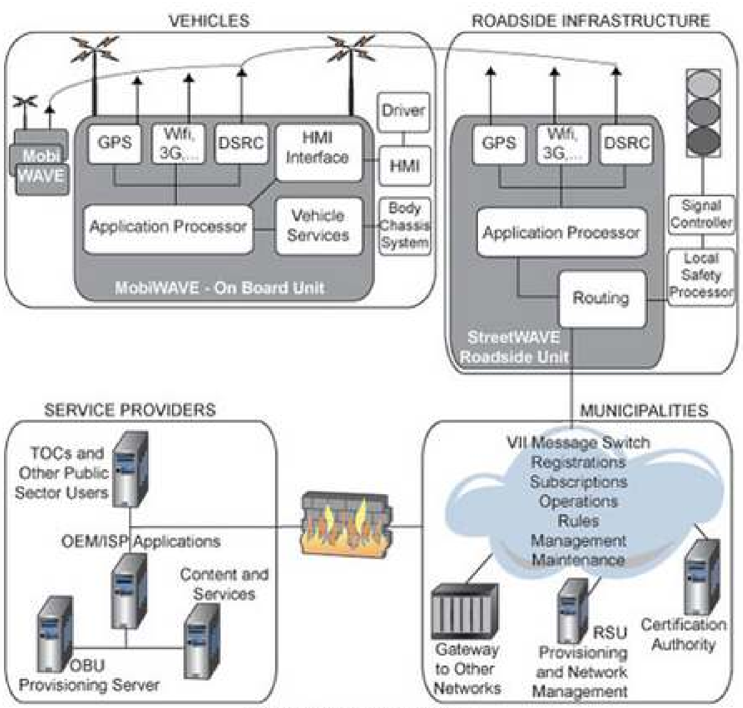
Operating Temperature:	0° C to +45° C (32° F to 113° F)
Storage Temperature:	-20° C to +65° C (-4° F to 149° F)
Relative Humidity:	5% to 90% over operating temperature
Drop:	1 meter drop, no damage – fully operational
Vibration Stability:	5 Hz to 500 Hz, 0.1 octave/second

5.4.8 Savari OBE

Product Specifications for S100

Processor	500Mhz AMD Geode LX800
Memory	256MB DDR DRAM
Storage	512MB Compact Flash
DSRC Radio	IEEE 802.11a 5Ghz, 600mW 28dBm TX, -94dBm RX Sensitivity
WiFi Radio	IEEE 802.11b/g 2.4Ghz, 400mW 26dBm TX, -97dBm RX Sensitivity
Channel Width	5/10/20/40 Mhz
DSRC Antenna	5dBi@5GHz RP-SMA
WiFi Antenna	3dB @ 2.4GHz RP-SMA
Ethernet	One (1) 10/100 (RJ-45) port with Auto Uplink™
Console	standard RS-232C interface with DB-9 male connector
Power Supply	15V, 1.2A DC jack or Power over Ethernet. Car power adapter (12v, 2Amps)
Temperature	-31C to +75C
Form Factor	16cm X 10cm
GPS	SiRF STAR III e/LP, 20 channel, USB based. Accuracy: 5m 2D RMS w/ WAAS, 10m 2D RMS w/o WAAS
Bluetooth	Class II (10mtrs) USB dongle, 1 mW, +4 dBm TX power
Standards Compliance	IEEE 802.11 a/b/g/n, IEEE 802.11p, IEEE 1609.3, IEEE 1609.4
Security	WPA2, WPA, AES-CCMP, TKIP, 64/128bit WEP, IEEE 802.1x, MAC, IPSec & SSL
3G	AT&T 3G Sierra Wireless USB modem

System Architecture



VII System Architecture

5.4.9 DSRC / GPS ANTENNA

MobileMark
antenna solutions

US Office: Tel: 800-648-2800 or +1.847-671-6690
UK Office: Tel: (+44) 1543 459555
www.mobilemark.com

Surface Mount Multiband MIMO WiFi, Public Safety 4.9 & GPS

- Model SMW-410: 4 cable feed multiband
- Covers GPS, MIMO WiFi, 2.4/5.0 GHz, Military 4.4 or Public Safety 4.9 GHz
- 4 antennas in 1 radome; saves time and money by reducing the number of installations

Black Case

4-Cable Multiband

Mag-Mount

The SMW-410 Series Antennas features 4 elements in one antenna radome. The unique feature of this model is that it offers two identical high gain elements covering 2.4 GHz & 4.9-6.0 GHz. Of the remaining two elements in the SMW-410, one is used for GPS at 1575 MHz and the other covers 2.1-2.5 GHz & 4.4-6.0 GHz. All three elements offer an impressive 5 dBi gain.

This antenna is designed for applications that combine GPS with 2-cable or 3-cable MIMO WiFi, Public Safety at 4.9 GHz or Military at 4.4 GHz.

For the GPS interface, the antennas are outfitted with 15 feet (4.5 meters) of RF-174 cable. The remaining three elements are fed with 15 feet (4.5 meters) or low loss RF-195 cable.

The antenna is housed in an impact resistant radome made from ASA. It has been rated for shock and vibration as well as water ingress and will stand up to harsh weather or to rough treatment.

The antenna can be ordered as a surface mount antenna or as a mag-mount antenna.

Model Configurator

SMW-410-□ □□□□- □□-□

Cable/Connector 1
Cable/Connector 2
Cable/Connector 3
Cable/Connector 4
Color
Cable Length in Inches (eg. 12 or 180)

Example: SMW-410-3C3C3C2C-WHT-180
MGW-410-3C3C3C2C-BLK-120

Specify "SMWG" or "MGWG" instead of "SMW" or "MGW" for GPS/Glonass combination antenna.

Cable Options: Code	Cable	Connector Options: Code	Connector	Color Options: Code	Color
1	RG-58	A	TNC	WHT	White
2	RG-174	B	Mini UHF	BLK	Black
3	RF-195	C	SMA		
4	RG-188	D	SMB		
7	LMR-100	E	MCX		

(Other Configurations available.)

Specifications

Frequency & Gain:	
Cable 1	2.1-2.5 & 4.4-6.0 GHz, 5 dBi
Cable 2	2.4 & 4.9-6.0 GHz, 5 dBi
Cable 3	2.4 & 4.9-6.0 GHz, 5 dBi
Cable 4 (GPS)	1575.42 +/- 2 MHz, LNA: 26dB
	5 dBi nominal RHCP
VSWR:	2:1 max over range
Nominal Impedance:	50 ohms
Maximum Power:	20 Watts (max)
GPS	
Amplifier Bias:	2.7 to 5 VDC
Noise Figure:	2.0 dB max, 1.7 dB typical
Current:	20 mA max, 10 mA typical
GPS & Glonass Option:	1575 MHz & 1612 MHz
Case:	4.2"D x 3.2"H (107 mm x 81 mm) add ½" (1.3 cm) for mag base
Case Material:	White or Black UV resistant ASA
Cable:	
Cables 1 - 3	Separate RF-195 15 ft (4.5 meters)
Cable 4	RG-174, 15 ft (4.5 meters)
Connector:	SMA Plug (Male)
MGW Mounting:	Magnet Mount
SMW Mounting:	Threaded metal stud 3/4" dia. x 1/2" long (19 mm x 13mm) for 1/4" (6mm) thick metal; supplied with gasket and nut
	Other length studs available
Operating Temp:	-40° to +85° C
Shock &Vibration:	IEEE1478, EN 61373, MIL-810G, TIA 329.2-C
Dust/Water Ingress:	IP67

US Office & Headquarters: 3900B River Rd., Schiller Park, IL 60176, USA
UK Office: 8 Miras Business Park, Keys Park Road, Hednesford, Staffs. WS12 2FS, UK

Specifications subject to Change without notice (6/2013)

5.4.10 DGPS

Enclosures — FlexPak6™

Performance[1]

Channel Configuration
120 Channels[2]
Signal Tracking

GPS	L1, L2, L2C, L5
GLONASS	L1, L2
Galileo	E1, E5[3]
GIOVE-A/GIOVE-B (test)	
Compass[4]	
SBAS	
QZSS	
L-band	

Horizontal Position Accuracy (RMS)

Single point L1	1.5 m
Single point L1/L2	1.2 m
SBAS[5]	0.6 m
DGPS	0.4 m
L-Band	
VBS	0.6 m
XP	0.15 m
HP	0.1 m
RT-2™	1 cm+1 ppm
Initialization time	<10 s
Initialization reliability	> 99.9%

Measurement Precision (RMS)
Fully independent code and carrier measurements:

	GPS	GLO
L1 C/A code	4 cm	8 cm
L1 Carrier phase	0.5 mm	1.0 mm
L2 P(Y) code[6]	8 cm	8 cm
L2 Carrier phase[6]	1.0 mm	1.0 mm
L2C Code[7]	8 cm	8 cm
L2C Carrier phase[7]	0.5 mm	0.5 mm
L5 Code	3 cm	-
L5 Carrier phase	0.5 mm	-

Maximum Data Rate[8]

Measurements	100 Hz
Position	100 Hz

Time to First Fix

Cold start[9]	<50 s
Hot start[10]	<35 s

Signal Reacquisition

L1	<0.5 s (typical)
L2	<1.0 s (typical)

Time Accuracy[11]	20 ns RMS
Velocity Accuracy	0.03 m/s RMS
Velocity[12]	515 m/s

Physical and Electrical

Dimensions	147 x 113 x 45 mm
Weight	337 g

Power

Input voltage	+ 6 to +36 VDC
Power consumption[13]	1.8 W

Antenna LNA Power Output

Output voltage	5 VDC [+5%/-5%]
Maximum current	100 mA

Connectors

Serial	DB9
USB	Mini-AB
Ethernet, CAN, I/O	DB-HD15

Communication Ports

1 RS-232	921,600 bps
1 RS-232 or RS-422	921,600 bps
1 USB port	12 Mbps
1 CAN port[14]	1 Mbps

1 Ethernet port supporting:

- 10BaseT/100BaseT networks
- Direct TCP/IP & UDP connectivity
- NTRIP (v2.0) client and server

1 I/O Port (PPS, Event1, Event2, VARF, ERROR, Position Valid)

Environmental

Temperature

Operating	-40°C to +75°C
Storage	-40°C to +85°C
Humidity	95% non-condensing
Random Vibe	MIL-STD-810G (7.7g)

Vibration (operating)

Random	MIL-STD-810G (7.7g)
Sinusoidal	SAE J12117 (4g)
Bump	IEC 60068-2-27 (10g)
Shock	MIL-STD-810G (40g)
Immersion	IEC 60529 IPX7
Compliance	FCC, CE, Industry Canada

Features

- Field upgradeable software
- 20 Hz measurement position data rate
- PAC multipath mitigating technology
- Differential GPS positioning
- Differential correction support for RTCM 2.1, 2.3, 3.0, 3.1, CMR, CMR+ and RTCA
- Navigation output support for NMEA-0183 and detailed NovAtel ASCII and binary logs
- Auxiliary strobe signals, including a configurable PPS output for time synchronization and mark inputs

Included Accessories

- Serial cable (null)
- I/O cable
- USB cable
- Automotive 12 VDC power adapter

Optional Accessories

- GPS-700 series antennas
- ANT series antennas
- Ethernet, CAN and I/O breakout cable
- Serial cable (straight)

Firmware Options

- RT-2
- L-Band
- ALIGN®
- GL1DE®
- SPAN®
- RAIM
- API
- NTRIP v1.0 and v2.0
- 100 Hz output rate[8]

5.4.11 GPS ANTENNA

Features

- L1/L2
- L-Band capable
- GPS + GLONASS & BeiDou (B1 only) signal reception
- Excellent multipath rejection
- Highly stable phase center
- RoHS compliant

Benefits

- Enhanced differential performance with L-Band reception
- Choke ring antenna performance without corresponding size and weight
- Reduces equipment costs and need for future redesign
- Flexible placement and precision positioning

Attributes

General Info	Width/Diameter (mm)	185.00
	Height (mm)	69.00
	Weight (g)	500.00
Constellation	GPS	
	GLONASS	
	BeiDou	
Tracking	Max Num of Frequency	Dual
	L-Band	
	SBAS	
	QZSS	
Antenna Form Factor	Pinwheel	
Antenna Mounting	Pole	
Performance	LNA Gain (dB)	29

Stable Phase Center

The phase center of the GPS-702-GGL remains constant as the azimuth and elevation angle of the satellites change. Signal reception is unaffected by the rotation of the antenna or satellite elevation, so placement and installation of the antenna is easy.

Durable, Future-Proof Design

Features a durable, waterproof housing and meets MIL-STD-202F for vibration and MIL-STD-810F for salt spray. Sharing the same form factor as our other high performance GPS-700 series antennas, the GPS-702-GGL antenna is compact and lightweight, making it highly portable and suitable for a variety of environments and applications.

5.4.12 Front and Rear Radar

Parameter	Value	Unit
Sensor Performance		
Max. Range on Pedestrian	50[I]	m
Max. Range on Passenger Car	160[I]	m
Minimum Range	1	m
Range accuracy	Typ. < ±2.5% or < ±0.25m (bigger of)	%, m
Radial Speed Interval	-70 …+70[V]	m/s
Minimum abs. Radial Speed	0.1	m/s
Speed accuracy	Typ. < ±0.28	m/s
Angle Interval (total field of view)	-6 …+6 (El.); -18 …+18 (Az.)[II]	degree
Update time	<= 50	ms
Environmental		
Ambient Temperature	-40 ... +85	degree C
Shock	100	g_{rms}
Vibration	14	g_{rms}
IP	67	
Pressure / Transport altitude	0…10.000	m
Mechanical		
Weight	330	g
Dimensions	See 1.7	
Model No.	**0A0301-1D0307**	
DSP Board – Antenna Identification	0A0301-1D0307	
Housing Identification	050602	
General		
Power Supply	7 ... 32[III] 3.7	V DC W
Frequency Band	24.0…24.25 FCC15.245, EN300440 compliant	GHz
Bandwidth	< 100	MHz
Max. Transmit Power (EIRP)	20	dBm
Interfaces	CAN V2.0b (passive)[IV] RS485 half-duplex	
Connector	8 Pin plug Binder Series 712	CAN, Power, RS485

[I] Typical values; may vary to higher or lower values depending on clutter environment. All values given for bore sight. Please note that the Radar system – like any other sensor system – although being well optimized and providing excellent performance, will not achieve a 100% detection probability and will not achieve a false alarm rate equal to zero.

[II] Total field of view is angle interval where reflectors can be detected; 3dB field of view is narrower.

5.4.13 Forward and Rearward Cameras

SPECIFICATIONS

Image Sensor	⅓" DPS M8800	
Signal System	PAL / NTSC	
Effective Pixels	758 x 540 pixels	
Resolution	690 HTVLe	
Min. Illumination (Sensor)	0.1Lux (F1.2, 50IRE, 30fps, 2850°K, Colour)	
S/N Ratio	50dB	
White Balance	Auto, 2000°K~11000°K	
Dynamic Range	120dB Max, 101dB Typical	
Electronic Shutter	1/50 ~ 1/100000 PAL (1/60 ~ 1/100000 NTSC)	
Fast Shutter	Normal, 1/100, 1/200 sec	
Video Output	1.0V p-p, 75Ω	
Power Supply	12VDC ±10%	
Power Consumption	1.7W	
Dimensions (mm)	36H x 36W x 32D	
Weight	80g	
Operating Temp	-10°C~50°C	
Operating Humidity	90% non-condensing	
Order ID	PAL	NTSC
2.5mm	in30S1P1L25	in30S1N1L25
2.9mm	in30S1P1L29	in30S1N1L29
3.8mm	in30S1P1L38	in30S1N1L38

5.4.14 Accelerometer and Gyroscope Specifications

A. Accelerometer Specifications:

Symbol	Parameter	Test conditions	Min.	Typ.(2)	Max.	Unit
FS	Measurement range(3)	FS bit set to 0	±1.7	±2.0		g
		FS bit set to 1	±5.3	±6.0		
Dres	Device resolution	Full-scale = ±2 *g* T = 25 °C, ODR1=40 Hz		1.0		mg
		Full-scale = ±2 *g* T = 25 °C, ODR2=160 Hz		2.0		
		Full-scale = ±2 *g* T = 25 °C, ODR3 = 640 Hz		3.9		
		Full-scale = ±2 *g* T = 25 °C, ODR4 = 2560 Hz		15.6		
So	Sensitivity	Full-scale = ±2 *g* 12 bit representation	952	1024	1096	LSb/g
		Full-scale = ±6 *g* 12 bit representation(4)	316	340	364	
TCSo	Sensitivity change vs temperature	Full-scale = ±2 *g* 12 bit representation		0.025		%/°C
Off	Zero-g level offset accuracy(5),(6)	Full-scale = ±2 *g* X, Y axis	-100		100	mg
		Full-scale = ±2 *g* Z axis	-200		200	
		Full-scale = ±6 *g* X, Y axis(4)	-100		100	
		Full-scale = ±6 *g* Z axis(4)	-200		200	
TCOff	Zero-g level change vs temperature	Max delta from 25 °C		0.2		mg/°C
NL	Non linearity(4)	Best fit straight line X, Y axis Full-scale = ±2 *g* ODR = 40 Hz		±2		% FS
		Best fit straight line Z axis Full-scale = ±2 *g* ODR = 40 Hz		±3		
CrAx	Cross axis(4)		-5		5	%

B. Gyroscope Specifications:

Parameter	Test Condition	Typical Specifications	Unit
Measurement Range	4x OUT (amplified)	±100	°/s
	OUT (not amplified)	±400	°/s
Sensitivity	4x OUT (amplified)	10	mV/ °/s
	OUT (not amplified)	2.5	mV/ °/s
Sensitivity change versus temperature	Delta from 25°C	0.037	%/°C

5.4.15 Data Harvesting Server

Processor

Intel® Xeon® processor E5-2400 product family

Processor sockets:
2

Internal interconnect:
Intel QuickPath Interconnect (QPI) link: 6.4GT/s; 7.2GT/s; 8.0 GT/s

Cache:
2.5MB per core; core options: 4, 6, 8

Operating System

Microsoft® Windows Server® 2012
Microsoft Windows Server 2008 R2 SP1, x64 (includes Hyper-V®)
Novell® SUSE® Linux Enterprise Server
Red Hat® Enterprise Linux®
Virtualization options:
Citrix® XenServer®
VMware® vSphere® ESXi ™
Red Hat Enterprise Virtualization®

Chipset

Intel C602

Memory[2]

Up to 384GB (12 DIMM slots) 2GB/4GB/8GB/16GB/32GB DDR3 up to 1600MT/s

Storage

Maximum internal storage:
Up to 16TB

Hot-plug hard drive options:
2.5" SATA, nearline SAS, SAS (15K, 10K), SAS SSD, SATA SSD
3.5" SATA, nearline SAS, SAS (15K)
Self-encrypting drives available

Cabled hard drive options:
3.5" SATA, nearline SAS, SAS (15K)

Drive Bays

Up to eight 2.5" hot-plug SSD, SAS, or SATA or up to four 3.5" hot-plug SAS, SATA, or SSD

Slots

2 PCIe slots:

With two processors:
One x16 PCIe slot with x16 bandwidth, half-length, half-height
One x16 PCIe slot with x16 bandwidth, half-length, full-height

With one processor:
One x8 PCIe slot with x4 bandwidth, half-length, half-height
One x16 PCIe slot with x16 bandwidth, half-length, full-height

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Network Controller

Embedded NIC:
Broadcom® 5720 Dual Port 1Gb LOM

I/O adapter options:

1Gb Ethernet:
Broadcom 5720 Dual Port 1Gb NIC
Broadcom 5719 Quad Port 1Gb NIC
Intel I350 Dual Port 1Gb stand-up adapter
Intel I350 Quad Port 1Gb stand-up adapter

10Gb Converged Ethernet:
Brocade® BR1020 Dual Port 10Gb CNA
QLogic® QLE8262 Dual Port 10Gb DA/SFP+
Broadcom 57810S Dual Port 10Gb Base-T CNA
Broadcom 57810S Dual Port 10Gb DA/SFP+ CNA

10Gb Ethernet:
Intel X520 Dual Port 10Gb DA/SFP+ server adapter
Intel X540 Dual Port 10Gb Base-T adapter

FC8/FC4 HBA:
QLogic QLE2460 4Gb Single Port FC HBA
QLogic QLE2462 4Gb Dual Port FC HBA
QLogic QLE2560 8Gb Single Port FC HBA
QLogic QLE2562 8Gb Dual Port FC HBA
Emulex® LPe-12000-E 8Gb Single Port FC HBA
Emulex LPe-12002-E 8Gb Dual Port FC HBA
Brocade 815 8Gb Single Port FC HBA
Brocade 825 8Gb Dual Port FC HBA

Power

Platinum efficiency 550W and 350W power supplies
Silver efficiency cabled 550W power supply
Auto-ranging power supplies

Availability

High-efficiency, hot-plug, redundant power supplies; hot-plug hard drives; TPM; dual internal SD support; fan fault tolerance; optional bezel; luggage tag; ECC memory, interactive LCD screen; ENERGY STAR® compliant

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Chassis

Form factor:
1U rack

5.4.16 Circuit Breaker

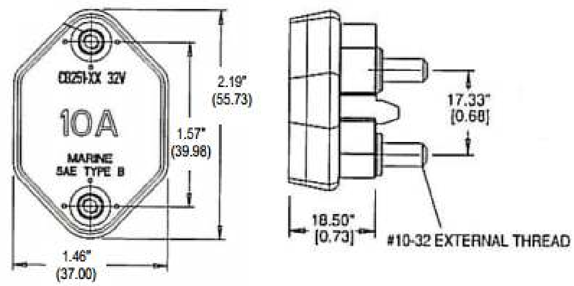
Mid-Range Circuit Breakers

Amps	Switchable w/ Manual Trip Push Button Stock No.	Automatic Reset Stock No.
10	46970	46950
15	46971	46951
20	46972	46952
25	46973	46953
30	46974	46954
35	46975	46955
40	46976	46956
50	46977	46957

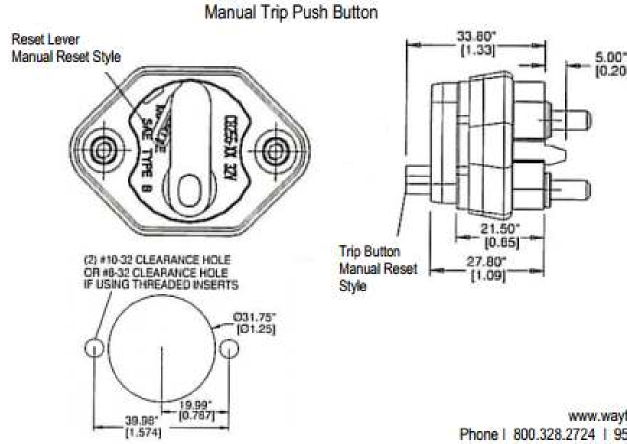
Features:

- Body Material: UL Rated 94V-0 thermoset plastic body, cover has a black thermoplastic elastomer overmold
- Voltage: 32 volts
- Interrupt Rating: Circuit Protection: (2.5kA) per ABYC E-11
- Operating Temperature: -40°F to 185°F (-40°C to 85°C)
- Termination: #10-32 threaded studs
- Single Pole Thermal Type Breakers
- Torque Rating: 24in-lb (2.7Nm) max
- Mounting Torque Rating: Panel mount with either #8-32 threaded inserts or #10 clearance holes. 18in-lb (2.0Nm) max
- IP66, SAEJ553; ABYC E-11; SAE J1171

Automatic Reset



Manual Trip Push Button



UNCONTROLLED DOCUMENT
Updated 5/5/10

www.waytekwire.com
Phone | 800.328.2724 | 952.949.0765
Fax | 800.858.0319 | 952.949.0965

5.4.17 DC Contactor

Solid State DC Contactors

Stock No.	Max Current Type A Mounting	Max Current Type B Mounting
44401	100	75
44402	150	100
44403	200	125

Type A Mounting: Aluminum plate 0.125"x16"x16" or larger
Type B Mounting: wood, plastic or free air

Features:

- Combination of low on-resistance solid-state switches and high current fly back diodes provides outstanding surge current capability for starting high in-rush current loads
- Provides maximum voltage spike suppression for high inductive loads
- Sealed Metal Case: anodized aluminum case, 4 corner mounting hole pads provide required connection to ground
- Control Input utilizes 1/4" male disconnects
- Compact Size and Low Profile - space saver
- Status LED indicator: displays steady on when contactor is on and operating normally, or flashes when contactor has automatically turned off as a result of a detected fault such as loss of ground, over-current, under-voltage or over-temperature
- 100% Solid State Construction
- Automatic Over-Current, Under-Voltage and Over-Temperature Faulty Shutdown Protection
- Loss of Ground Detection
- Use with alternator type battery boots

Specifications:

- Max current rating at 110°F (43°C)
- Operating Voltage Range: +7.5 to 20.0 volts
- Case Maximum Temp: +185°F (85°C)
- Low battery voltage trip: 250 milliseconds
- Over-current trip: 100% to 110% of rated amperage for 500 milliseconds
- Logic Power Current Draw w/status LED off: 80 milliwatts
- Logic Power Current Draw w/status LED on: 150 milliwatts
- Turn-on Delay: 25 milliseconds
- Turn-off Delay: 25 milliseconds
- Control Connector Type: 0.25 inch male Faston blade terminal
- Control Input Voltage: >+8.0VDC to activate, <+4.0 VDC to deactivate
- Control Input Resistance: 120K Ohm to ground
- BAT+ to LOAD Terminal Leakage Current: 75 microamps max.
- Weight: 0.40 lbs (0.181 kg)
- Dimensions: 2.85 (72.29 mm) x 4.35 (110.49 mm) x 1.10 inches (27.94 mm)
- Power Terminals: Two (2) 3/8—16 threaded stainless steel studs, with brass contact pads for low contact resistance, and locking nuts.

5.4.18 Fuse Block

- 8 gang light-weight fuse block/fuse panel for accessory use
- Use with standard ATO/ATC or ATOF fuses or blade type circuit breakers
- Maximum current for all circuits is 100 amps
- Recessed fuse contacts help prevent shorting of circuits
- Includes ground terminals

5.4.19 EMERGENCY STOP SWITCH

Characteristics

Item		Type: Emergency Stop Switches — Non-lighted model: A22E	Lighted model: A22EL
Allowable operating frequency	Mechanical	30 operations/minute *3	
	Electrical	30 operations/minute *3	
Insulation resistance		100 MΩ min. (at 500 VDC)	
Dielectric strength	Between terminals of same polarity	2,500 VAC, 50/60 Hz for 1 min	
	Between each terminal and ground	2,500 VAC, 50/60 Hz for 1 min	
Vibration resistance *2		10 to 55 Hz, 1.5-mm double amplitude (within 1 ms)	
Shock resistance	Destruction	1,000 m/s²	
	Malfunction *2	250 m/s² max.	
Durability	Mechanical	300,000 operations min. *3	
	Electrical	300,000 operations min. *3	
Ambient operating temperature *1		–20 to 70°C	–20 to 55°C
Ambient operating humidity		35% to 85%	
Ambient storage temperature		–40 to 70°C	
Degree of protection		IP65 (oil-resistant) *4	IP65 *4
Electric shock protection class		Class II	
PTI (tracking characteristic)		175	
Degree of contamination		3 (EN60947-5-1)	

*1. With no icing or condensation.
*2. Malfunction within 1 ms.
*3. Setting and resetting once is counted as one operation.
*4. The degree of protection from the front of the panel.

5.4.20 Xantrex Battery Charger

20A, 40A and 60A 12-volt Multistage Battery Chargers

Electrical Specifications (@ 25°C unless otherwise noted)	
Models	**TRUE*CHARGE2* 20 / 40 / 60**
Output current (nominal)	20 A / 40 A / 60 A
Output voltage (nominal, depending on settings)	
· **Charge**	14.2 - 15.5 Vdc
· **Float**	13.4 - 13.8 Vdc
· **Equalize**	16 Vdc
DC output connections	Three
AC input voltage*	90-265 Vac 47-63 Hz 120 Vac, 230 Vac, 240 Vac nominal
Temperature compensation	Three settings
Charger efficiency	> 80%
Battery type	Gel, Flooded, AGM, Pb-Ca
Minimum recommended battery bank size	40 Ah / 80 Ah / 120 Ah

General Specifications	
Models	**TRUE*CHARGE2* 20 / 40 / 60**
Operating temperature**	0 to 60°C
Storage temperature	-40 to 80°C
Battery connection	Three positive terminals One negative terminal
Dimensions (H x W x L)	**20 A & 40 A** - 2.8 x 6.7 x 9.8" (70 x 170 x 250mm) **60 A** - 3.5 x 6.7 x 13.4" (90 x 170 x 340 mm)
Weight	**20 A & 40 A** - 4.8 lb (2.2 kg) **60 A** - 9.9 lb (4.5 kg)
Warranty	Two year
Part Numbers	804-1220-02 / 804-1240-02 / 804-1260-02

Accessories	
Remote panel	**808-8040-01**
Battery temperature sensor	808-0232-01

Regulatory Compliance

CSA E60335-2-29, UL1564, and UL1236 including the Marine Supplement, drip test, and Ignition Protection ratings. CE Marked for the Low Voltage Directive (safety) and the EMC Directive. Complies with IEC 60335-2-29 including Australian deviations. Ingress protection rating IP32 per EN/IEC 60529. Complies with FCC Part 15B and Industry Canada ICES-003 Class B emissions limits. Complies with ABYC A-31

*90 - 104 Vac ± 4 Vac output de-rated to 80% of full load current

**Output current derates above 50°C (except 40A model which derates above 40°C)

Highly Accelerated Life Tested (HALT) to -20°C

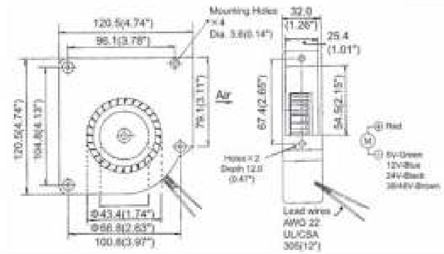
Note: Specifications subject to change without notice.

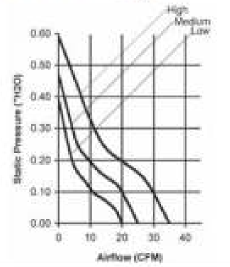
5.4.21 Cooling System Blowers

DC Blowers

12, 24, 48V
120x32mm (4.7" x 1.25")

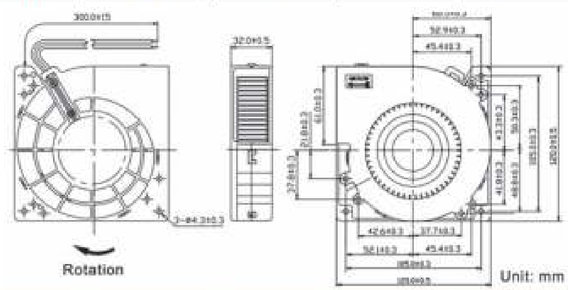
ODB600PT

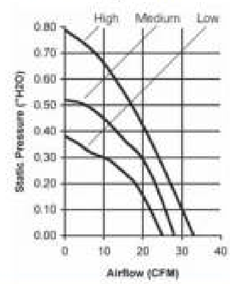




Model Number	Speed (RPM)	Airflow (CFM)	Noise (dB)	Volts DC	Voltage Range	Amps	Max. Static Pressure ("H_2O)
ODB600PT-12HB	3000	35	49	12	8~14	0.60	0.59
ODB600PT-12MB	2500	25	42	12	8~14	0.47	0.47
ODB600PT-12LB	1800	20	30	12	8~14	0.20	0.39
ODB600PT-24HB	3000	35	49	24	10~29	0.37	0.59
ODB600PT-24MB	2500	25	42	24	10~29	0.30	0.47
ODB600PT-24LB	1800	20	30	24	10~29	0.20	0.39

ODB1232





Model Number	Speed (RPM)	Airflow (CFM)	Noise (dB)	Volts DC	Voltage Range	Amps	Max. Static Pressure ("H2O)
ODB1232-12HB	2600	33	55	12	6~14	0.79	0.92
ODB1232-12MB	2300	28	49	12	6~14	0.53	0.83
ODB1232-12LB	2100	25	48	12	6~14	0.41	0.66
ODB1232-24HB	2600	33	55	24	12~28	0.43	0.92
ODB1232-24MB	2300	28	49	24	12~28	0.36	0.83
ODB1232-24LB	2100	25	48	24	12~28	0.25	0.66
ODB1232-48HB	2600	33	55	48	24~55	0.22	0.92
ODB1232-48MB	2300	28	49	48	24~55	0.18	0.83
ODB1232-48LB	2100	25	48	48	24~55	0.16	0.66

Frame & Impeller
PBT, UL94V-0 Thermoplastic

Power Connection
Two lead wires 300mm (12")

Life Expectancy (L10)
Ball Bearing 60,000 hrs
Sleeve Bearing 30,000 hrs

Motor
Brushless DC, polarity protected, locked rotor protected (current limited), auto restart

Insulation Resistance
Min. 10M at 500VDC

Dielectric Strength
1 minute at 500VAC / 1 second, max leakage 500 microamp

Operating Temperature
Ball Bearing
-20C ~ +80C
Sleeve Bearing
-10C ~ +50C