University of Idaho Formula SAE

Telemetry Package Cost Analysis
and Recommendation Report

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I. Introduction

The purpose of this report is to recommend various configurations for a real-time telemetry package. The telemetry package will include the following systems:

1. A real-time data acquisition system.
2. Wireless real-time data transmission system.
3. Track mapping system.

Problem Definition

Dr. Edwin Odom and the University of Idaho Formula SAE (UIFSAE) design team have requested a telemetry package to help analyze performance data of the vehicle and driver. Dr. Odom believes this package will enhance vehicle development and become showpiece for the team. As a showpiece, it will help increase vehicle’s scoring in competition.

The package will have a data acquisition system with sensors to log vital data such as engine revolutions per minute (RPM), speed, lateral acceleration, straight-line acceleration and engine temperature. Dr. Odom did not specify a minimum number of sensors. As the number of sensors increases the data acquisition system becomes more versatile and complete. The data acquisition system will output digital signals.

A wireless transmission system will send signals from the data acquisition system to a laptop base station. The wireless transmission system will transmit a minimum distance of 1 kilometer (km), line of sight. A data rate of 14.4kbps will ensure adequate data are transfer.

Scope

The telemetry package has two system areas. The systems are (1) the data acquisition system and (2) the wireless transmission system. Each system area has its own criteria as follows:

1. Data Acquisition system
   A. Cost
   B. Number of Channels/Sensors
   C. Frequency of Measurements

2. Data Transmission
   A. Range
   B. Cost
   C. Data Rate

II. Data Acquisition (DAQ) System

The systems chosen for study are as follows:

1. Race Technology’s DL90
2. Race Technology’s DL1
3. Real-time DAQ system based on the Rabbit 3000 microcontroller.

Cost

A DAQ system will record various engine and performance parameters using sensors. The sensor package will not change with the system chosen, and will not be included in this cost analysis. Cost should be minimized and will be weighted 40%.
Race Technology DL90

The DL90 costs $720.00 through the manufacturer [2]. We believe that by UIFSAE working with the company and developing a wireless real-time solution a discounted or donated unit may be possible.

Race Technology DL1

The DL1 costs $900.00 through the manufacturer [2]. We believe that by UIFSAE working with the company and developing a wireless real-time solution a discounted or donated unit may be possible.

Rabbit 3000 Microcontroller

The Rabbit 3000 is a 16-bit 55.5 MHz microcontroller with over 56 digital inputs/output (I/O) pins and 6 serial ports. These microcontrollers sell in pairs for $29.00 [3]. Additional circuitry would be required to create a DAQ system from these microcontrollers. This additional circuitry has an estimated cost of $60.00 [1]. This system will cost approximately $89.00.

Intel 196 Microcontroller

The Intel 196 is an 8-bit 20MHz microcontroller with 40 digital I/O pins and a serial port. These microcontrollers sell individually for $10.68 [4]. Additional circuitry would be required to create a DAQ system from these microcontrollers. This additional circuitry has an estimated cost of $60.00 [1]. This system will cost approximately $70.68.

Number of Channels/Sensors

Each sensor will require one channel on the DAQ system. The number of channels for this DAQ system should be maximized. The number of channels available will be weighted 30%.

Race Technology DL90

The DL90 has 1 digital input, 2 analog inputs, a GPS input and a built in accelerometer [2].

Race Technology DL1

The DL1 has 8 analog inputs, 4 wheel/shaft speed inputs, dual RPM inputs and a GPS unit [2].

Rabbit 3000 Microcontroller

The Rabbit 3000 has over 56 digital inputs [3]. An analog to digital converter (ADC) will convert sensor inputs to an 8-bit digital output giving each microcontroller seven channels. Using two microcontrollers will provide 14 channels. Using more microcontrollers will scale the number of channels accordingly.

Intel 196 Microcontroller

The Intel 196 has 40 digital inputs [4]. An analog to digital converter (ADC) will convert sensor inputs to an 8-bit digital output giving each microcontroller five channels. Using two microcontrollers will provide 10 channels. Using more microcontrollers will scale the number of channels accordingly.

Frequency of Measurements

Frequency of measurements determines the accuracy of data available for analysis. The frequency of measurements should be as high as possible. Frequency of measurements will be weighted 30%.
Race Technology DL90
The DL90 outputs data in real-time at a rate of 100Hz [2].

Race Technology DL1
The DL1 outputs data in real-time at a rate of 100Hz [2].

Rabbit 3000 Microcontroller
The Rabbit 3000 has an internal clock frequency of 55.5 MHz [3]. A Rabbit 3000 microcontroller based DAQ system would be capable of approximately 4,000 measurements per second.

Intel 196 Microcontroller
The Intel 196 has an internal clock frequency of 20 MHz [4]. An Intel 196 microcontroller based DAQ system would be capable of approximately 1,000 measurements per second.

**Conclusions**
A summary of the DAQ system alternatives is given in tabular form as follows:

<table>
<thead>
<tr>
<th>Alternative</th>
<th>Cost [$]</th>
<th>Channels /Sensors</th>
<th>GPS Included</th>
<th>Frequency of Measurements [Hz]</th>
</tr>
</thead>
<tbody>
<tr>
<td>DL90</td>
<td>720(-)</td>
<td>5</td>
<td>Y</td>
<td>100</td>
</tr>
<tr>
<td>DL1</td>
<td>900(-)</td>
<td>15</td>
<td>Y</td>
<td>100</td>
</tr>
<tr>
<td>Rabbit3000</td>
<td>89.00+</td>
<td>14+</td>
<td>N</td>
<td>4,000</td>
</tr>
<tr>
<td>Intel 196</td>
<td>70.86+</td>
<td>10+</td>
<td>N</td>
<td>1,000</td>
</tr>
</tbody>
</table>

The Intel 196 will provide the lowest cost alternative. The Rabbit 3000 based DAQ system’s higher frequency of measurement and greater number of channels offset its incremental cost making it the preferred alternative for data acquisition. If a discount or donation were possible, the Race Technology systems would be the best alternative with an integrated GPS system and rapid implementation time.

**IV. Data Transmission System**
The data transmission systems chosen for study are as follows:
1. MaxStream 900 MHz RF development kit
2. Cirronet 2.4GHz RF frequency hopping spread spectrum (FHSS) system
3. Neteon 2.4GHz Wi-Fi (802.11b) embedded system

Range, cost and data throughput will determine the data transmission system used. The system requires two transceivers, one onboard for sending telemetry data and one connected to the PC for reception.

**Range**
The range requirement for the telemetry package is 1 kilometer. Range will be weighted 40%.

MaxStream
MaxStream’s RF development kit has a range of approximately 7 miles [5].

Cirronet
Cirronet’s RF FHHS system has a base range of 3000ft. The range of the Cirronet system extends over 1 mile with a higher gain antenna [6].
Neteon
Neteon's Wi-Fi system has a base range of 210m. This range extends to over 1 mile with a higher gain antenna [7].

Cost
Cost will be weighted 40% and should be minimized.

MaxStream
The MaxStream RF development kit is available at an educational price of $125 if purchased by October 31. The development kit includes two transceivers and test/configuration software [5].

Cirronet
The Cirronet RF FHSS transceiver is available as an OEM unit for $125 each [6].

Neteon
The Neteon Wi-Fi system costs $199 for a single OEM module with a 2dB antenna [7].
An optional 5dB antenna will extend the range of the Cirronet and Neteon systems to 1km and is available for $40 [6]. An 8dB fiberglass antenna will extend the range to over 1km and is available for $70 [8].

Data Rate
Transmission data rate measures the data transfer rate of the wireless connection. Serial input/output (I/O) data rate measures the data transfer rate of the physical serial interface between a device and the transceiver. The maximum data rate of a transmission system is the lesser of the two rates. The minimum data rate for the system is 14.4kbps. Data rate will be weighted 20%.

MaxStream
The MaxStream RF system has a transmission data rate of 19.2kbps and a serial input data rate of 57.6kbps [5]. For this system, the transmission data rate will limit the maximum data rate.

Cirronet
The Cirronet unit has a transmission data rate of 460kbps and a serial I/O data rate of 203.4kbps [6].

Neteon
The Neteon Wi-Fi system has a transmission data rate of 11Mbps and a serial I/O data rate of 230.4kbps [7].
Most PC’s with serial ports have a serial I/O data rate of 120kbps, which would be the maximum data rate limit of the Cirronet and Neteon systems. Using a serial to USB adapter, the maximum data rate of these systems increases to 230.4kbps.
Conclusions

A summary of the data transmission system alternatives is given in tabular form as follows:

<table>
<thead>
<tr>
<th>Data Transmission</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
</tr>
<tr>
<td>MaxStream Development Kit</td>
</tr>
<tr>
<td>Cirronet OEM Module</td>
</tr>
<tr>
<td>5dB Antenna</td>
</tr>
<tr>
<td>Serial to USB 2.0 adapter</td>
</tr>
<tr>
<td>Neteon OEM Embedded Wi-Fi</td>
</tr>
<tr>
<td>5dB Antenna</td>
</tr>
<tr>
<td>8dB Antenna</td>
</tr>
<tr>
<td>Serial to USB 2.0 adapter</td>
</tr>
</tbody>
</table>

The MaxStream development kit will provide the required range at minimal cost. The increased data rates of the Cirronet and Neteon systems compared to the MaxStream is not enough to overcome their increased costs. The MaxStream is the preferred alternative for data transmission at low cost.

V. Track Mapping

By using lateral acceleration and wheel speed data, software can create a map of the track. This method will work, but provide a very inaccurate map. Over time, the error in the system continues to grow and compounds to the point where the map becomes useless. In order to fix this problem we can use a GPS system. The problem with a system based solely on GPS is that the accuracy of a commercial unit is no less than 100m. By using two GPS receivers, the relative position of each is accurate up to 5m. By using a map generated using two GPS receivers and then combining/smoothing it with the results from the accelerometers, an accurate map can be generated. The solutions found are as follows:

<table>
<thead>
<tr>
<th>Accelerometers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Part#</td>
</tr>
<tr>
<td>ADXL202</td>
</tr>
<tr>
<td>ADXL210</td>
</tr>
<tr>
<td>ADXL311</td>
</tr>
</tbody>
</table>

Using either of the Race Technology systems will not require an accelerometer or a GPS system.
VI. **Recommended Configurations**

Three configuration alternatives were derived from the cost analysis to represent possible budgets for the telemetry package. The three alternatives represented are (1) the alternative with the lowest cost, (2) the alternative with the best performance and (3) the alternative with the fastest implementation time.

### Lowest Cost

<table>
<thead>
<tr>
<th>System</th>
<th>Description</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Acquisition</td>
<td>Rabbit 3000</td>
<td>89.00</td>
</tr>
<tr>
<td>Wireless Transmission</td>
<td>MaxStream 900MHz RF</td>
<td>125.00</td>
</tr>
<tr>
<td>Track Mapping</td>
<td>GPS/Accelerometer</td>
<td>292.67</td>
</tr>
<tr>
<td>Misc</td>
<td></td>
<td>60.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>$556.67</td>
</tr>
</tbody>
</table>

### Best Performance

<table>
<thead>
<tr>
<th>System</th>
<th>Description</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Acquisition</td>
<td>Rabbit 3000</td>
<td>89.00</td>
</tr>
<tr>
<td>Wireless Transmission</td>
<td>Cirronet 2.4GHz RF FHSS</td>
<td>340.00</td>
</tr>
<tr>
<td>Track Mapping</td>
<td>GPS/Accelerometer</td>
<td>292.67</td>
</tr>
<tr>
<td>Misc</td>
<td></td>
<td>60.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>$781.67</td>
</tr>
</tbody>
</table>

### Fastest Implementation

<table>
<thead>
<tr>
<th>System</th>
<th>Description</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Acquisition</td>
<td>Race Technology</td>
<td>720-900</td>
</tr>
<tr>
<td>Wireless Transmission</td>
<td>MaxStream 900MHz</td>
<td>125.00</td>
</tr>
<tr>
<td>Track Mapping</td>
<td>Integrated</td>
<td>0.00</td>
</tr>
<tr>
<td>Misc</td>
<td></td>
<td>60.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>$905.00 – 1085.00</td>
</tr>
</tbody>
</table>

If DAQ Donated: $185.00

### References