D5.3a – TERTIARY SYSTEM DESIGN

Project Acronym:	**Smart RRS**
Project Full Title:	**Innovative Concepts for smart road restraint systems to provide greater safety for vulnerable road users.**
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SUMMARY:

This document provides a summary of the current design options and decisions for a Tertiary safety system for the Smart Road Restraint Systems project.

Note this document is incomplete and reflects the only the current design status not the final design description.

Contents

References

No.	Reference, description
[1]	**D5.1 Concept requirements for Smart RRS Tertiary Safety System**; *57536-17aProvisional20Nov09 - D5-1 Requirements.doc*. The document in which the top level requirements are identified for the Tertiary System.
[2]	**D5.2 – Tertiary System Architecture**; *57536-17b Provisional 01Jun10 - D5-2 Tertiary System Architecture.doc*. The document which proposes a system architecture and expands the requirements for the different modules within the Tertiary System.
[3]	**Tertiary Sensor Selection**; *57536-17c Ver 1 28May20 Tertiary Sensor Selection.doc*. This document describes the process and conclusions for the tertiary sensor selection process.

1. INTRODUCTION

This document is intended to capture current design options and key design decisions for the Tertiary Safety System based on the Tertiary requirements [1] and Tertiary architecture [2] documents.

The figure below gives an overview of the system and is intended as a reminder of the top-level components of the system.

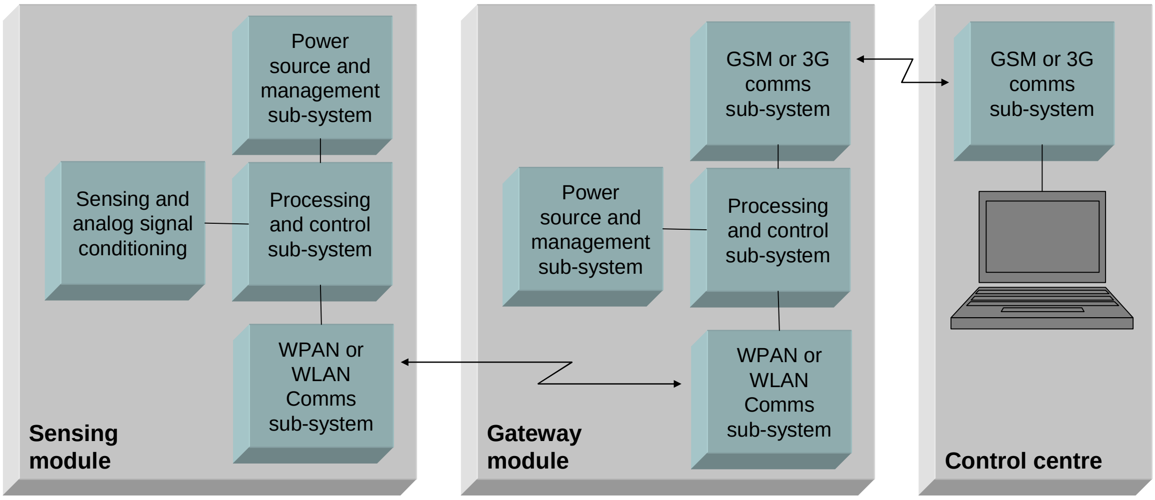

Figure 1: Tertiary System Overview

This document is live and at an early stage of writing.

2. SENSING MODULE

2.1 SENSING SUB-SYSTEM

Narrowing down the type of sensor to use has been undertaken via a process called the Analytical Hierarchy Process. This process and its conclusions were documented in reference [3]. For reasons of low quiescent power consumption, this process narrowly favoured some form of acceleration switch. MEMS accelerometer technology came a close second because of the low cost and versatility of these devices.

Some important (interrelated) parameters are still to be determined – namely the sensitivity or threshold of the devices, the range of measurement and the frequency response. These will need to be determined experimentally or possibly through the use of modelling. Current data that we have is limited to a motorcyclist colliding with the lower motorcyclist protection rail giving peak accelerations of the order of 20-30 g. It is anticipated that cars and heavier vehicles will cause higher accelerations. On the other hand there will be significant advantages to the system triggering at much lower g-levels.

2.1.1 ACCELERATION SWITCHES

Low cost devices with many g-ranges available and different latching capabiliites

Candidate companies include:

- Inertia Switch Incorporated: http://www.inertiaswitch.com/index.html
- ASSEMtech Europe Ltd: http://www.assemtech.co.uk/main/office_uk.asp
- Hamlin Electronics http://www.hamlin.com/featuredapplications.cfm

2.1.2 ACCELEROMETERS

Low cost devices with wide choice of g-ranges, number of axes, and low power modes and frequency responses up to > 1 KHz.

Candidate suppliers include:

- Analog Devices
- Freescale
- Etc.

The primary advantage of an accelerometer sensor over a switch is the availability of more "information" in the crash signature. The primary disadvantage is the need to periodically power the sensor in order to determine whether an event has taken place.

2.2 PROCESSING SUB-SYSTEM – HARDWARE

2.2.1 OVERVIEW

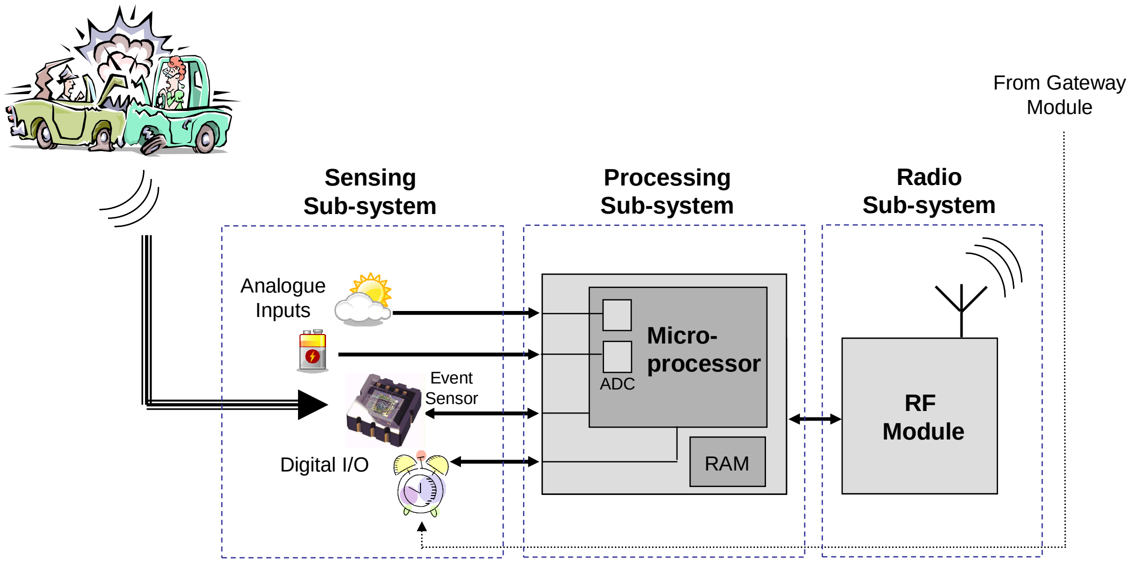

Figure 2: Tertiary sensing module overview

2.2.2 HARDWARE PLATFORM OPTIONS

TRW Conekt have a number of embedded computing platform designs which have been developed within previous projects one of which, it is hoped, will be able to be re-used for Smart RRS. These are:

- T-FORK [*TRW FPGA-oriented reconfigurable computing*] platform which is a high power, flexible, FPGA based embedded computing board.
- WISD [*Wireless Sensing Devices*] platform which is based on an MSP430 low-powered TI microprocessor.
- OVERMOCS [*Overload Monitoring of Vehicle Structures*] platform – again based on the MSP430 microprocessor.

For lowest power / complexity, the Sensing Module could be based on a low-power processor such as the TI MSP430 (as per the WISD and OVERMOCS platforms), without the need for additional hardware (such as a hardware accelerator or an FPGA which may be needed for more complex signal processing). Ideally, the signal processing occurring at the sensing module will be sufficient to identify the occurrence of a crash event and some measure of its magnitude. If more processing capability is required in order to do this, additional hardware (such as a hardware accelerator or an FPGA) could potentially be included on the sensing module. Since actual crash events are expected to occur only rarely (perhaps once per year or even less?), the overhead associated with doing sufficient processing on the Sensing Module to identify a crash and to derive other “crash characteristics” data may not be too much, if the system can be maintained in a suitable low-power “sleep-mode” until required to process data. (This will to some extent depend on how often the system “checks” to see if [or otherwise determines that] a crash is occurring, and what processing it needs to do to confirm the occurrence of a crash: for example, if the system checks every few ms to see if a crash is taking place, and also needs to do frequency analysis each time to confirm that the crash is or is not occurring, then this will be a large power overhead for the Sensing Module)

A more “power-hungry” option for the Sensing Module could be to use an available hardware platform, such as the TRW Conekt T-FORK board. Whilst these platforms are not intended for low-power operation, they are already available (saving on hardware development costs), and provide sufficient processing power (probably) both for the Tertiary Safety System requirements and any additional Primary Safety System processing requirements which it may be necessary or desirable for the Sensing Module to perform as part of the complete Smart-RRS system functionality. Use of one of these platforms for the purposes of the demonstrator system would enable the system requirements (in terms of processing capability, power, transmission characteristics, etc.) to be investigated, without initial constraints imposed by a deliberately low-power, low-capability system, with a view to optimizing the system for low-power operation at a later date.

The Tertiary sensing module is more likely to require one of the lower powered options.

2.2.3 INTERFACES

Likely inputs to the processing unit include the crash sensor(s) as well as additional measurements to intermittently monitor the status of the system. At this stage

Analogue

- Accelerometer
- System voltages (particular battery)
- Sunlight sensor?

Simple Digital I/O

- Acceleration switch

Digital bus

- Accelerometer (many devices provide output on SPI or I^2C interfaces) as an alternative to an analogue output.
- Interface to RF module.

2.3 PROCESSING SUBSYSTEM – FUNCTIONAL

At a top level these are the tasks that need to be performed by the processing sub-system of the Tertiary sensing module.

- Detect when an event has happened and awake from low power mode.
- Analyse the event to determine:
    - Is it really a crash event?
    - What category of event is it (approximate magnitude or crash energy).

      Note that the algorithms for doing this are yet to be determined. These are dependent on obtaining crash acceleration data for a number of crashes at a number of locations along the barrier. The key questions that need to be answered are: (i) what will be the range of accelerations we are likely to see, (ii) within what frequency range will carry the most useful information, (iii) over what range of barrier will a crash be detectable and (iv) what is the best way of analysing the crash signal to obtain a measure for the “magnitude” of the crash.

- Report the event via the module's radio sub-system communicating:
    - Location identifier
    - Timestamp
    - Event category.
- Periodically synchronize the module's clock with the gateway module (this function may possibly be performed by the radio sub-system).
- Periodically measure diagnostic information and report back to the gateway module via the radio sub-system.

Note that how "periodically" depends on the accuracy of the module's internal clock and the accuracy with which the timestamp needs to be reported.

A oscillator drift of 30 ppm require an update approximately every hour in order to maintain the desired timestamp accuracy of 0.1 s. It would seem appropriated to that diagnostic information could be transmitted at the same time as timestamp synchronization.

2.4 RADIO SUB-SYSTEM

Choice of RF sub-system is closely linked to the choice of gateway module. The two need to be matched in order to reduce interoperability problems. See section 3.1 for more information.

Candidate RF sub-systems are as shown in Table 1.

Table 1: Current RF Sub-system candidates

Supplier	Unit	RF Standard	Range	Notes
Adaptive Wireless Solutions	E-Senza SenzaBlock SB110-IO or AI OEM modules	802.15.4 compliant 2.4 GHz	250 m	Only simple digital I/O or analogue interfaces seem to be available at present.
Adaptive Modules	Variety of potential modules. E.g. Xbee Pro modules	ZigBee 2.4 GHz	Varies. For some modules, beyond 1 km	
Laird Technologies	Various Bluetooth modules including: TRBLU23-00200	Bluetooth	>300 m	Simple AT interface over UART.

2.5 POWER SUBSYSTEM

The key decision here for the Tertiary System is: can we get a significant number of years (10+) using a battery?

Figure 3 below shows the clear advantage of using a switch triggered system. For a D-size Lithium Thionyl Chloride primary cell (see section 2.5.1, debajo de) in excess of 10 years lifetime might be possible.

Some discussion of power scavenging design issues is nonetheless included in the following sections.

Assumptions
1. ADXL345 accelerometer with MSP430 microprocessor.
2. No other current consuming sensors on the module (e.g. photodiode used as solar sensor).
3. Radio sub-system is a Laird Technologies module e.g. TRBLU23-00200
4. Radio sub-system can be turned off for the majority of the time.
5. Ignore current requirement in crash event - it is so infrequent.
All that matters is that there is sufficient capacity to power the device when the time comes.

Device	Quiescent Current / A	Active Current / A
ADXL345	1.00E-07	1.50E-04
MSP430	1.20E-06	2.70E-03
Radio sub-system	0	2.00E-02

Scenario 1 — System wakes up to monitor the ADXL345 for 5 ms in every 10 ms
System wakes up once per hour to measure and transmit status and re-synchronize clock.
Assume transmitter on time of 20 s

	Consumption / Ah/h
Event detection	
ADXL345	7.51E-05
MSP430	1.35E-03
Hourly transmission	
MSP430	1.50E-05
Radio sub-system	1.11E-04
Total Ah/h	0.001551761
Total Ah/day	0.037242267
Total Ah/ year	13.59342733

Scenario 2 — System dormant until crash occurs; it is woken by a passive switch.
System wakes up once per hour to measure and transmit status and re-synchronize clock.
Assume transmitter on time of 20 s

	Consumption / Ah/h
Event detection	
ADXL345	1.00E-07
MSP430	1.20E-06
Hourly transmission	
MSP430	1.50E-05
Radio sub-system	1.11E-04
Total Ah/h	0.000127411
Total Ah/day	0.003057867
Total Ah/ year	1.116121333

Figure 3: Current consumption calculations

2.5.1 BATTERY TECHNOLOGY

- Lithium thionyl chloride D-cells can provide up to 19 Ah as a primary power source.
- Chemistry for rechargeable cells TBD – likely to be lithium or lead-acid. Questions over nickel metal hydride longevity.

2.5.2 SOLAR PANELS

- Wide range available from many suppliers, monocrystalline, polycrystalline, amorphous etc.
- Max size 100 cm^2 (i.e. approximately commensurate with the size of the sensing module).
- Open circuit voltage / short circuit current characteristics set by demands of battery and control circuitry

2.5.3 CONTROL ELECTRONICS

Assuming a solar powered or augmented system, the control electronics potentially needs to undertake photovoltaic set-point or even maximum power point tracking (MPPT) control, DC-DC conversion and battery charging control. A number of solutions exist for this including:

- LTC3108 from Linear Technology (suitable for small solar cells and thermoelectric generators)
- LTC3105 from Linear Technology
- LT3652 from Linear Technology (up to 2A)
- Maxim 856 and Maxim 982 (see Maxim Application Note 484).

3. GATEWAY MODULE

3.1 GATEWAY UNIT

The aim is to purchase a COTS gateway module suitable for the requirements of both the Primary and the Tertiary safety systems. We are currently in discussion with a number of suppliers of "gateway module" hardware which could potentially be suitable for the Smart-RRS applications. Details of these various suppliers and their product offerings are summarized in Table 2: those shown in green are what appear to be the most promising options at the moment.

Discussions with these suppliers are continuing: it is anticipated that a decision will be taken on the best choice of gateway module hardware shortly.

Supplier	System	COTS?	UK Base?	Notes
Apoideas	Low-power GPRS sensor nodes (no intermediate gateway)	No - development kit only	Yes	The sensor nodes transmit directly via GPRS to control centre (no intermediate gateway module). Apoideas have low-power technology for such a system. Questions over speed of connection (for Smart-RRS primary system requirements)?
Adaptive Wireless Solutions	E-Senza integrated gateway module and wireless sensor modules	Yes	Yes	COTS solution which seems to do what we want. New (more integrated) version of gateway module due out in April 2010.
Radiocrafts / Wavecom	M-Bus / ZigBee enabled integrated GSM / GPRS / EDGE gateway module	Yes	No	New product. Seems to do what we want.
Testech	Embedded gateway modules (ZigBee / WiFi to GSM / GPRS) + integrated sensors (inc. accelerometers)	Yes, or custom-built modules to customer specifications.	No	COTS devices available, but Testech specialize in doing custom solutions for particular customer requirements. Could do gateway module + assist with sensor modules.
Arira Design / Savi / STMicro	DASH7 STM32 RFID HDK base board as system Gateway (and sensor module?)	No - development kit only	No	STM32 RFID HDK base board is available as a development board. Can include integrated sensors (but separate sensor modules not available?)
Arch Rock	IPsensor Node +	Yes	?	Web-based system rather

Supplier	System	COTS?	UK Base?	Notes
	Arch Rock IP-based wireless mesh network			than GSM/ GPRS. Coventry University's experience is that it is quite difficult to get set up. Also requires expensive kit at the gateway module.
WirelessLogic	For Gateway to Control Centre end, provide solutions for secure, fixed-IP routing	Yes	Yes	Technology suitable for the gateway to control centre end of the system.
Micro-Technic	SBC-2800 module with integrated GSM / GPRS modem (no intermediate gateway)	Yes		Single-board computer module with integrated GSM / GPRS and various I/O options (for sensors, etc.) An alternative to the Apoideas solution. Same questions about connection speed may apply.
Beanair	BeanGateway	Yes	No	
Low Power Radio Solutions	Various proprietary short- and long-range radio modules and modems	Yes	Yes	
Telegesis	Primarily ZigBee modules	Yes		Links with various suppliers involved in smart metering applications
Adaptive Modules	Distributors of a wide range of wireless modules. WiMetry cellular comms concentrator: ZigBee – 3G / GPRS connectivity. Have also developed µ-weave gateway system with Amscreen and Comtech.	Yes	Yes	Amscreen / Comtech (Lancashire): µWEAVE Gateway - Intelligent GSM/GPRS gateway enabling the remote machine to communicate reliably with µWEAVE software via the GSM/GPRS network and the Internet. It offers data logging, alarm processing, scheduling, configuration and robust communication.
Wireless Logic	M2M aggregator of data SIMs, and provider of secure fixed –IP connectivity over	Yes	Yes	Links with Sequoia (supplier of various wireless modules / GPRS modems).

Supplier	System	COTS?	UK Base?	Notes
	private APN using 3G and GPRS			
Laird Technologies	Various wireless modules including soon-to-be-released “Access Point Gateway” product	Yes	Yes	Access Point Gateway – release mid-2010: embedded Linux OS with open source Lua scripting language for user-defined operation. Initially incorporating Bluetooth wireless link to GSM / GPRS.
Jennic	Various wireless modules and kits Development kits available for e.g. intelligent lighting system	Yes		Applications include smart metering and intelligent lighting systems including 2.4 GHz wireless – GPRS gateway-based systems
Telit	Loads of M2M / wireless stuff, including cellular GSM / GPRS modules	Yes		Various relevant applications of Telit components in customers systems – e.g. smart metering

Table 2 : Potential Suppliers of Gateway Modules and Product Descriptions

3.2 POWER SUB-SYSTEM

See options for sensing module (section 2.5, por encima de). Power requirements will be higher than for the sensing module so it is anticipated that energy scavenging will be required.

4. CONTROL CENTRE SUB-SYSTEM

The requirements are yet to be reviewed and completed hence this level of detail is not available.