Generic mobile device deployment for Aerospace Ground Support Equipment HUMS implementation

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Abstract

The economics of mass production now delivers highly capable generic mobile device products (smartphones and tablet computers) that are readily able to meet many of the HUMS demands of aerospace ground support equipment monitoring. Sophisticated sensor inputs such as GPS, accelerometer, and gyroscope devices are standard equipment on inexpensive modern mobile computing devices. Significant CPU resources, large memory storage, and flexible network communications capabilities, make such devices a competitive hardware choice for HUMS implementation.

We outline core systems-level considerations relevant to deployment of generic mobile devices to the ground support equipment HUMS application. This systems engineering approach emphasizes the trade-offs involved in vehicle systems hardware integration, crucial algorithmic tasks, and network fixed infrastructure, to provide a workable HUMS solution. We discuss HUMS benefits to operator management, maintenance management, and fleet management as applicable to the aerospace GSE sector. Key distinctions are identified between the civilian and defence HUMS system requirements for such equipment.

Carefully managed deployment can provide an economic systems outcome for aerospace GSE HUMS by exploiting generic mobile devices. Ultimately this approach allows HUMS equipment coverage in what might otherwise be uneconomic situations. Crucial HUMS system flexibility components are maximized by the approach.

Keywords: HUMS, Ground Support Equipment, AGSE, Android, IOS, On Board Diagnostics Port, OBD

Introduction

A systematic analysis of HUMS technology options must necessarily start with consideration of system-level HUMS requirements. HUMS can be broadly considered as providing input to:

1. Operator Management
2. Maintenance Management, and
3. Fleet Management.

In the Aerospace Ground Support Equipment (AGSE) context, all three of the above benefit from HUMS data. We should additionally note that the ways in which similar AGSE items are used in the civilian and defence sectors is often markedly different. The most obvious distinction is the use of equipment at consistent high levels of activity in commercial airfield settings, with equipment allocation based around peak demand requirements in the defence setting translating to much lower overall equipment activity levels. This observation is potentially significant when considering the upper-level HUMS for AGSE system requirements.

Broadly speaking, any HUMS system for AGSE must:

1. **L**og parameters and data of interest from the AGSE item;
2. **E**xtract data from the AGSE item on appropriate schedules and in response to demand events;
3. **A**nalyze raw HUMS data to provide useful information;
4. **R**eport HUMS information to relevant stakeholders on suitable periodic schedules;
5. **N**otify relevant stakeholders of significant events in timely fashion.

The tasks of analyzing HUMS data to provide input to regular reporting and additional notifications, is largely a software processing concern. The requirements of this analysis are determined in consideration of the objectives (or overall customer requirements) relating to operator management, maintenance management, and fleet management, coupled with the capabilities of the HUMS logging and data extraction approaches implemented, and accounting for existing customer processes, in place for the HUMS customer management tasks (the system context view extending beyond the direct HUMS system view).

The delivery of a functional HUMS system to any customer must ensure that sufficient emphasis is placed on software tailoring to ensure that reports and notifications match the system objectives embodied in the upper-level customer requirements. This represents a non-trivial development effort that can't be ignored. Most customers will no doubt find that even if they are able to deploy a fully COTS hardware solution with highly sophisticated and flexible COTS back-end software component, there is still a significant amount of tailored system integration effort to be performed. Our point is simply to note the level of the integration effort likely to be required, and the fact that this should not be underestimated. The current paper largely focuses on the HUMS equipment potentially able to be deployed on AGSE items, and the benefits that generic mobile device deployment might have in supplying a cost-competitive overall HUMS solution in the AGSE context.

Generic mobile devices have high levels of capability related to data logging and data extraction (communications capabilities). This paper attempts to outline some of the benefits of using generic mobile devices for HUMS for AGSE, along with drawing attention to a couple of the possible pitfalls of such an approach. HUMS systems deployed on more sophisticated equipment items (large mining machines, aircraft, or major military fighting vehicles) have marked benefits that more readily justify their deployment costs in a straight-forward fashion. Large numbers of identical fleet items, operating in moderately sized groups, helps improve the overall HUMS implementation cost equation. A similar positive business case is not obvious for many AGSE items, and minimising the overall deployment cost becomes crucial if we are to maximise value from HUMS in these contexts.

Sophisticated demands and massive economies of scale have translated to highly capable generic mobile devices being readily available economically. Adapting such devices to HUMS application may enable HUMS solutions to be delivered to a greater pool of equipment items than is otherwise possible via more specialist hardware design approaches.

This paper attempts to raise familiarity with the concept of adoption of generic mobile devices for HUMS for AGSE. We expect that in the future, concrete examples of generic mobile device use for AGSE HUMS will be able to be reported. Certainly there are a number of global movements that are expected to deliver more widespread use of generic mobile devices for HUMS-related applications.

HUMS sensor technologies

For sophisticated equipment, we are accustomed to thinking about HUMS in terms of a small network of sensor devices strategically positioned on the equipment item of interest. Data from these sensors is monitored and logged by a central control unit that is also likely to perform primary data analysis and provide for any required Human-Machine Interface.

High-value equipment items, or those requiring extreme reliability, justify the expense of deployment of such sensor networks, and the associated development of sophisticated algorithms to provide for prognostic HUMS outputs (in many cases). Lower value items such as many AGSE items, present a less-attractive proposition for involved HUMS integration, but there are significant reasons to expect benefits from more modest HUMS implementations.

Many modern mobile devices (phones and tablets) come equipped with GPS sensors, accelerometers, gyroscopes, and sensors that provide a wide range of vibration frequency measurement at a distance (microphones). Most such devices couple these sensors with highly capable processors and large amounts of non-volatile memory. Multiple communications protocols such as 3G/4G, WiFi, Bluetooth, and USB, are usually supported. Highly capable visual and touch interfaces are now obviously commonplace. Both Available USB ports and the microphone/earpiece socket can be exploited to interface to a small number of additional sensors/devices mounted on the AGSE item as part of the overall HUMS system solution. A strong developer ecosystem exists, both for Android and IOS devices.

Highly capable mobile devices with perhaps a 5 inch screen are now widely available with retail pricing as little as $200 (Just one affordable, highly capable device is the Kogan Benq Agora 4G[1]). In developed countries a significant amount of interest appears to be directed toward competition at the premium end of the mobile device market, helping to squeeze prices downward for devices with second-tier capabilities (that might fully meet most anticipated HUMS application demands). The push toward low-cost, yet capable, devices is also being driven by rapid uptake of mobile communications technologies in many developing nations. The associated massive economies of scale are extremely promising for the prospect of further device cost reductions to be steadily observed over the next few years.

Core HUMS data in the AGSE context

The first question to ask with regard to generic mobile device deployment for AGSE HUMS, is to what extent the embodied mobile device sensors meet the AGSE HUMS data capture requirements. In turn, this requires assessment of what the overall HUMS system requirements are. We must then ask what limitations generic mobile devices might place on HUMS implementation for AGSE, and whether the cost benefits of the generic mobile device route to HUMS, provides for an overall positive equation.

With reference to the primary HUMS objectives of supporting operator management, maintenance management, and fleet management, and in the context of AGSE, our primary

HUMS requirements translate to those associated with usage frequency. Usage is closely correlated with physical movement of the AGSE items, although we must be aware that there are times when equipment is being used even though it is stationary and may be switched off.

To obtain primary usage data of this type we can't rely on operator interaction to provide updates on equipment usage status. An operator sign-on and sign-off process would clearly provide valuable raw data, but should perhaps not be regarded as 100% reliable even in the situation where machine interlock mechanisms force operator sign-on. We must instead deduce AGSE status from movement and location raw data. Such data is readily provided by GPS, accelerometer, gyroscope, and compass sensors, such as present on many generic mobile devices. The accuracy required of such raw data is no more demanding in the AGSE HUMS context than in the broader mobile device application environment. However, we do need to be aware that AGSE may operate in situations where GPS satellite visibility is poor. In such situations reliance on Inertial Navigation System techniques exploiting gyroscope and accelerometer input may be necessary to provide more accurate positional data, to the extent that this is required by the overall HUMS system requirements of the customer.

Noting that HUMS for AGSE is likely to be of broadest interest where implementation and other system sustainment costs are tightly constrained, we suggest that any HUMS data capture sensors in addition to those readily available on generic mobile device platforms, need to be carefully considered. Where a CAN bus exists on the AGSE platform, a simple interface device can allow the mobile device to log selected CAN data. Beyond this, we are able to interface to other specific-purpose sensors on an as-needed basis. The value provided by additional raw data must be weighed against the costs associated with design, provision, and installation of the extra equipment, including any wiring harness construction costs, and accounting for the pragmatics of installation access (ability to provide work access to difficult to reach locations of the equipment, and the AGSE item down-time necessary).

We believe that the basic sensor technologies of GPS, accelerometer, gyroscope, and compass (where this is present), provides for a strong match to primary HUMS requirements in the AGSE context. Similarly, the flexible CPU, storage, input (touch-screen), display, audio output, and communications capabilities of generic mobile devices, aids ready implementation of a fully-functional HUMS system for AGSE. There are, however, some concerns emerging from this potential route to low-cost HUMS implementation for AGSE.

Functional limitations of the generic mobile device HUMS option

The communications capabilities of generic mobile devices translates to very few, if any, restrictions on the ability to transfer HUMS data from AGSE items to the central data repository and data processing system. A significant amount of flexibility is possible in the architecture and design of the HUMS data extraction system. There is no significant advantage gained from more dedicated-purpose HUMS systems in regard to data communications. We note that there is a need for the communications subsystem to allow bi-directional communications, most obviously for firmware updates, but also potentially to meet other systems-level requirements.

The HMI (Human-Machine Interface) capability of generic mobile devices is also highly flexible, being able to readily match functionality of specially designed HUMS hardware devices. Device requirements for robustness and weather protection are related primary areas where upper-level system requirements may translate to careful device selection or design attention.

Modern mobile devices are generally very efficient in terms of power management, using sleep modes effectively to reduce power consumption when full device capabilities are not required. The overhead of a full-featured operating system is proven to be negligible in this regard. It has been developed to be so, out of necessity of preserving battery life in the competitive mobile device market. The risk of a software problem causing high power drain in a locked or semi-permanent fashion is fairly remote. Mobile devices are by default extensively tested in the presence of extremely poor software engineering practices through third-rate app developers. Even so, software lock-up conditions seem to be rare events. There is good reason to suggest that continued improvements in limiting catastrophic glitch events will occur, but mobile devices that have not been switched off, or required a reboot for many months, if not years, is a far more common expectation than it may have been as little as two years ago.

Poor software development is clearly able to cause bugs that translate to a loss of system functionality, no matter what platform hosts the application code (eg. generic mobile devices or specially designed hardware). However, there is little reason to suggest that the complexity of a fully-featured operating system as found on a generic mobile device, translates to an increased risk from poor software, given the effective extent of testing of the core platform provided by many millions of users.

The obvious concern with the adoption of generic mobile devices for the HUMS application for AGSE, is related to device robustness to harsh operating conditions, primarily temperature extremes. We assume that suitable weather-resistant enclosures can be employed, and that display visibility requirements are able to be met by a selection of devices available on the market. However, there is little direct control over device component selection where a design and manufacturing process of specialised HUMS equipment is substituted by the use of generic mobile devices. Fortunately mobile device manufacturers and component suppliers can be assumed to be generically aware of the advantages of components that retain functionality in temperature extremes. Experience of battery degradation due to extreme temperatures is common to many mobile device users. Most users are also likely to appreciate the risk of damage to sophisticated mobile device electronics from extremes such as allowing a phone to bake on the dash of a closed car in the hot sun.

Provision of components and circuitry that would continue functioning in this extreme case (in full sun on the dash of a closed vehicle), is unlikely to be economic. The secondary requirement that a device might return to functionality once sufficiently cooled is more realistic. An engineering design trade-off exists between component and circuitry robustness to temperature extremes and component cost. However, the low and decreasing cost of generic mobile devices will make paying for a significant number of age-related device failures compare favourably with the alternative of more specialised HUMS hardware deployment. Ultimately it is a systems engineering consideration, assessing the overall system requirements in association with a Total Cost of Ownership (TCO) perspective.

Additional System Flexibilities

Exploitation of HUMS devices with strong communications connectivity and superior HMI interfaces, such as provided by the generic mobile device route (or other means), can allow additional capabilities to be added to the implemented system. Depending on our perspective, these additional functions may be considered to be distinct from the HUMS system or part of an expanded HUMS system concept.

The most significant augmentation functionality concerns the use of communications capability of the HUMS system to facilitate smoother work-flow practices within the existing work environment. Tasking priority changes can be transmitted to equipment operators in real-time (assuming the communications systems capability exists). Communication in the return direction can facilitate equipment operators logging work status updates or requesting tasking clarifications.

The level of benefit provided by exploitation of HUMS system capabilities in this way is highly dependent on specific details of the organisation operating the system, and the organisation's adaptability for change. This includes many personnel-related systems issues such as the need for training associated with new operational procedures, and whether impacted user groups view new system capabilities to be acting in their interests.

A key benefit of the generic mobile device implementation approach is that it provides a ready avenue for organisations to trial new functionality and adopt this over time. Tapping into a large pool of external application developers allows an organisation the possibility of taking complete control of their HUMS system and evolving this over time as the organisation adapts. More specialist hardware solutions often incorporate development environments that are specialised enough to restrict the available pool of developers substantially. Even a small learning curve can translate to only larger development activities being economical, creating a major barrier to the concept of a steadily evolving system that is tightly tuned to the organisation, and not simply a reflection of a particular supplier product line. Of course the business model issues relating to specialist hardware solutions providers also can't be ignored. There may be little interest in from many suppliers in facilitating an open-access system that can be tailored to individual organisations and allowed to evolve.

Application to Mining and Construction Industries

As already mentioned, high value equipment items such as large mining machines, are likely to readily benefit from dedicated hardware HUMS solutions. However, just as a generic mobile device technology option provides an economic HUMS approach for AGSE, it also allows the possibility of extending the reach of HUMS more widely within industries such as mining and construction. Of particular consideration here might be extension of tracking functionality to general-purpose vehicles such as utility and four-wheel-drive vehicles that provide "run-about" functions. In some instances these vehicles experience high levels of operator abuse due to the lack of a single individual being held accountable for their condition. An affordable HUMS solution providing operator management functionality (operator sign-on, etc.), may pay significant dividends. Fleet management and maintenance management functionality may also be of general benefit, with particular value to select customers.

In a number of environments the ability to track when the crew-transport vehicle is spending too long parked outside the local lunch facility can result in important productivity improvements. Other application examples vary, and it is not difficult to consider the potential benefits arising from a flexible, easily expanded platform. A small organisation engaged in road-safety management, for instance, can hope to economically identify when signs were placed, and in what location, to facilitate sign retrieval and provide for incident audit capability.

Anticipated Global Technology Evolution

The HUMS for AGSE sector has close parallels with other developments in progress towards readily available fleet telematics solutions[2], such as those involving small hardware devices connected to the vehicle On-Board Diagnostics port[3]. A number of global development efforts are targeted towards the use of sensors such as GPS and accelerometers whether via smart-phone platforms or otherwise, to provide information to vehicle owners, insurers, and fleet managers.

The high capability and ultimate ubiquity of mobile phones, suggests that the role of such devices will be observed to increase significantly in these areas over the next several years.

Conclusion

This paper has attempted to outline primary considerations and promote discussion in relation to the adoption of generic mobile devices for HUMS in AGSE context. We note that this application is likely to require a very cost-effective HUMS solution in order to meet the broadest HUMS market requirements in both the civil and defence sectors.

The very low price and high capabilities of generic mobile devices make them worthy of detailed consideration for adoption where, even in the very recent past, special-purpose hardware was previously the only option. Nonetheless, some challenges to the use of generic mobile devices for such HUMS applications remain. We are hopeful that the role of generic mobile devices for HUMS will become clear over the next one or two years. The prospect of widely available economic HUMS solutions for AGSE is exciting enough to take the generic mobile device option seriously.

References

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