Support Engineering and Innovation

How the Armed Forces need to exploit technology to improve engineering support and deliver improved Operational Effectiveness.

Our Support Solutions are not optimal. We need to understand what prevents an optimal support solution being deployed.

Support problems are complex, but there is little doubt that the root causes can traced back to technical and commercial policy and practice. Our procurement processes are flawed, and the effects of these flawed processes are exacerbated by the MoD's commercial policies and practices, but this paper confines itself to discussing the technical aspects only. A separate paper will be prepared to discuss the impact of commercial policy and practice on the development and deployment of innovative and effective support.

A "Skunkworks" for Support Engineering

Ideally, we need a 'space' in which to experiment, to innovate, a Support Engineering "Skunkworks", an environment where ideas can be trialled and developed, where some initiatives are allowed, indeed expected, to fail. If such an establishment were in the control of the Front Line Commands [FLCs] it would enable them to address support issues "pan service" rather than on a disparate platform by platform basis. Any such solution should be associated with a wider a process, and a culture, that facilitates an ongoing process of evolution of ever more effective in-service support solutions.

Such a process of constant evolution requires information, it requires us to learn from experience, to exploit information and data. There is a common theme, we will find that a lot of the available technologies facilitate our ability to create, to collect, to manage, and to manipulate information. This introduces both an opportunity and a significant risk, the risk being the tendency to seek an "IT Silver Bullet"; such approaches have gelded promising programmes in the past and they rarely deliver the desired results. Rather, we should strive to realise significant improvements, quickly and at low risk, via a series of less ambitious "baby steps", by utilising mobile devices and by deploying 'off the shelf' technologies in an intelligent and innovative manner.

As we identify improvements they must be captured, and so we need formal mechanisms for managing the "Corporate Knowledge". This is a role for Defence Standards and JSPs, but more is needed; training materials can also perform this role and we could learn from the US DOD and their Reliability Information Analysis Center (RIAC) who provide advice, tools and a series of publications addressing support (not just reliability) issues.

(The publications are produced on behalf of the RIAC by a company called Quanterion
https://www.quanterion.com/products-services/publications/quanterion-developed-riac-products/

NB: The RIAC is being consolidated into the Defense Systems Information Analysis Center [DSIAC]
https://www.dsiac.org/

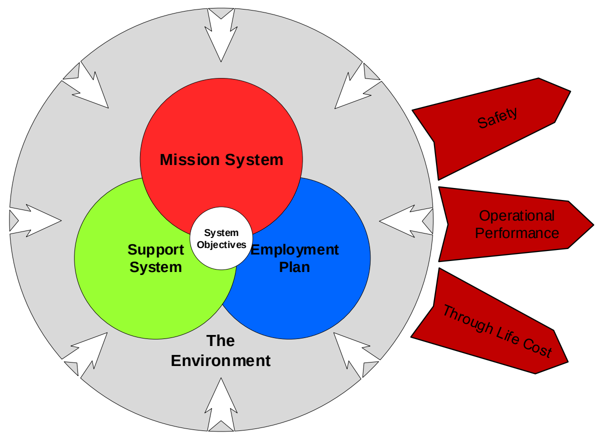
Support Innovation and the Development Process

The UK Armed Services need to commission, and to maintain, supportable Mission Systems: they need Support Systems that complement those Mission Systems; and an Employment Plan that defines the applicable operating scenarios. The Mission System and the Support System designs must take cognisance of the Employment Plan and vice versa. These three elements can be regarded as the "Total System"; the design of the Total System determines operational effectiveness and through life cost.

The Total System Concept:

The concept of the Total System has been addressed in more detail in other papers, suffice to say here that the Mission System is the hardware that we are interested in, it may be a fleet, a platform or an individual equipment. The Support System is the entire support infrastructure, including all organic and contractor elements, and the Employment Plan defines how the Mission System will be employed, where, what enemy action we expect, (we need to know what battle damage is likely so as to inform our Damage Modes and Effects Analysis [DMEA]), how often, how long for, etc., (think Mission Profiles).

The Total System must be 'designed' so as to be optimal, in terms of Operational Performance and Through Life Cost. Likewise the "**Support Solution**", which can be regarded as being comprised of the Support aspects of each of the three elements of the Total System design, must be optimal, or as optimal as is reasonably practicable.



The Total System is complex, the elements all interact with each other, hence implementing effective Support Engineering is challenging, it must consider a great many factors. Effective Support Engineering relies therefore on employing Systems thinking and Systems Engineering concepts, it relies on having ready access to a lot of information.

A Support System that does not take cognisance of the Employment Plan, one that is over dependent on contractor support, does not take account of the realities of war. The old mantra, "Prepare for war, adapt for peace" must prevail.

The Total System Definition Environments:

If we are to analyse (and optimise, within the given constraints) the Total System from a support perspective, if we are to maintain and update the 'design' of the Total System, as a result of learning form experience or because we are taking advantage of new technology, then it is clear that we need a mechanism, or mechanisms, for capturing descriptions of each of these elements. That is there needs to be a Mission System Definition Environment [MSDE], a Support System Definition Environment [SSDE] and an Employment Plan Definition Environment EPDE]. These are notional means of managing the data and information associated with each element of the Total System.

(Some tools exist for managing Mission System information, e.g. a Logistic Support Analysis Record [LSAR] (or Logistic Information Record [LIR]) could be considered to be a MSDE, but these are generally based on very old standards, of limited functionality and very user unfriendly. Aspire has developed a very sophisticated tool that is the equivalent of an MSDE. Oddly, there does not seem to be any commercially available tools that fulfil the role of an SSDE or EPDE. Aspire are developing an integrated set of such tools, based on elementary versions of the SSDE and EPDE which were developed some years hence, and are in use today).

We must not fall into the (common) trap of considering this need for information only in the context of new development and procurement programmes however. The three elements of the Total System shown above share one characteristic, that is they are all constantly changing.

The Evolution of the Total System:

The Mission System ages, it behaves differently in different environments, it is used for purposes not foreseen when it was designed, parts become obsolete, it is modified, and we find, through experience, that it doesn't perform as per the specification. It has failure modes and damage modes that were unforeseen, some predicted failures don't occur, it may not be as robust or as reliable as we hoped, etc.

The Support System changes as the support organisations evolve, different blends of organic and contractor support come into and out of vogue, new technology becomes available, other technologies become obsolete, and so forth.

The Employment Plan alters constantly due to changes in Foreign Policy, the threats change and new threats emerge, our enemies, and potential enemies, evolve their tactics and their technologies, the geographical areas in which our Armed Forces operate change.

This means that no Support Solution, no matter how well designed, will remain optimal, or anywhere near optimal, unless we are constantly testing and adjusting it, unless it is constantly evolving. In the world of defence if we are not moving resolutely forward, we are, inevitably, going backward, there is no such thing as stasis. If we are not moving forward faster than our enemies and potential enemies, any advantage that we enjoy will be degrading

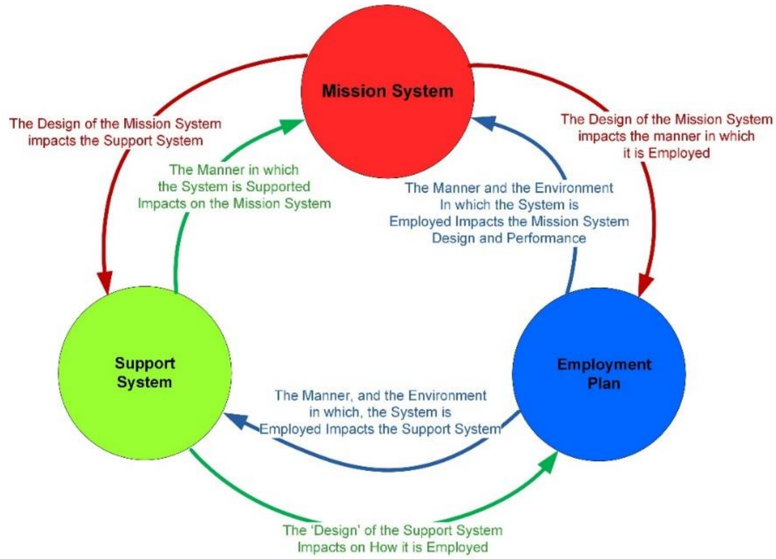


Figure 1 - The Elements of the Total System interact in a complex manner

Learning From Experience [LFE] is therefore a vital aspect of Support Engineering and there must be a closed loop process comprised of:

- ❑ The analytical process;
- ❑ The use of the results of that analysis in-service;
- ❑ The gathering of data during the in-service phase;
- ❑ The analysis of the in-service data;
- ❑ The updating of the Support Solution.

Support Analysis:

The Support Analysis process requires us to analyse the Mission System, (defined in the MSDE), to determine the optimal maintenance requirements. As intimated above, when this is done, we must take cognisance of the operational context, noting that there may well be a range of operational scenarios that must be considered.

These are essentially a set of management assumptions, they need to be recorded, ratified and there should only be one version that is common to all analysts, they need to be recorded in a manner that renders them readily accessible, hence the need for an EPDE). Now the analyst can determine:

- ❑ What will fail?
- ❑ What the likely Damage Modes are?
- ❑ Why they occur?
- ❑ When? …and …
- ❑ How ? – i.e:
    - o What is the failure process?
    - o How long does it take?
    - o How often does it occur?
    - o What is the impact of a Failure Mode/Damage Mode, how critical is it in operational, financial and safety terms?

We then must decide what we are going to do about the failure or the damage, we can determine the optimal response, i.e. for failures, can we intervene before the system fails or should we let the system fail and then repair it? Our response will depend to a large degree on whether we have access to technology which will enable us to track the failure process.

In both cases, we may use the insights we gain to influence future designs.

Informing Support Strategy:

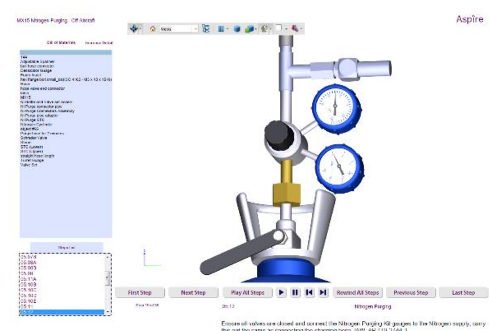
Once we have determined our approach we can define appropriate maintenance tasks and identify the resources required to carry them out. We can design an optimal Support System: the system required if we are to implement these tasks; a system that puts the right stuff in the right place in the right condition, in the right quantities, at the right time. This Support System will need to be defined: we will need to identify risks and opportunities; stakeholders, assumptions and performance metrics; we will need to take cognisance of lessons identified [LI's] on past systems, what works and what doesn't work. This will be required for all aspects of the Support System, e.g. Supply Support, Training, Technical Publications, etc, hence the need for an SSDE.

If we utilise commercial technologies, we can manage this process using intelligent systems, our MSDE database should be able to handle an equipment, fleets, fleets within fleets and families of platforms, and do so efficiently without duplication of effort or information. Such analytical tools should be able to output "Camera Ready" documents, as well as Web, Kindle, Word, PDF, PowerPoint, Excel, or Mind-map "ready" outputs if required, pretty much at the push of a button. It should be possible to produce documents with any required numbering system, with any trade structure, any zonal numbering convention, etc that the client requires; they should be able to choose any, or all of them. Consider the impact of this in world where the UK Government's concept of the Type 31e Frigate holds sway, a world in which complex systems are designed with the wider marker, with exportability, in mind. Such a system would enables any updates to the support solution to be output and to be published immediately after an analysis has been updated and ratified.

Aspire has developed and deployed just such a system on a major UK Defence programme.

Visualising Support Data:

Similarly, by using methods that are (more or less) ubiquitous in the commercial world, support data can be merged with CAD data to produce Technical Publications with embedded, manipulatable, 3D graphics. Such Technical Publications can be used as training aids, to enable maintainers to "Train Forward". Information can be constructed so that it can be presented, not just as an electronic technical publication, but also as training notes, slide packs, conventional 'Page Turner' publications, or conventional hardcopy, all derived from the same data source, at virtually no additional cost.



The ability to embed manipulatable 3D graphics is now a standard feature in both Apple's iBooks Author and in Microsoft's Word and Outlook applications. Aspire has produced PDF documents, readable in Adobe Reader, with embedded 3D graphics, and has experimented, successfully, with embedding interactive CBT type graphics into the same documents. These documents utilise Java and xml technologies, this approach enables many variations of the documents to be produced from a single data source.

Quantifying Support Improvements:

Much of the Support information required to support this development activity is "Qualitative" in nature, and hence effectiveness, and the degree of any improvement realised, is difficult to quantify (consider how difficult it is to measure the quality of a Technical Publication for instance). One of the most effective ways of deploying qualitative metrics is to ask simply, "is this new solution better than the solution we have today?" but this depends of course on having suitable "qualitative" feedback from the field.

Support Engineers also utilise "Quantitative" metrics, but, because we are managing high levels of uncertainty, these tend to be statistical measures (reliability metrics for example) which are wholly dependent on the existence of historical field data.

In the context of Support Engineering historical data, LFE, are indispensable to the engineering process. The development process is therefore wholly dependent on the in-service phase, and vice-versa of course.

Support Innovation and the In-Service Phase

Effective Support Engineering requires us to collect and to manage a lot of data, effective information management is clearly a critical aspect of Support Engineering. There is significant scope for the application of innovation in this area, but we must avoid the trap of collecting data for data's sake. Any data we collect must pay its way, it must be used effectively to improve support and to lower through life cost. If this isn't seen to happen, individuals and organisations lose faith and lose interest.

Similarly, the process of managing data, and of gathering data, has to be made as unobtrusive and as "frictionless" as possible. In both cases, if this is not achieved then either the data will not be collected or it will be done badly. The quality of the data therefore degrades and hence its utility is limited, so it cannot be used effectively, and thus will establish a vicious downward spiral.

Fortunately, this is not just an issue faced by the Defence sector; commercial organisations invest significant amounts into the assets needed to deliver information and to harvest performance and customer data. Accordingly, they have developed an array of technologies and methods to facilitate this process.

The Data-Centric Commercial Sector:

Consider how easy it is to buy something on Amazon, to review their vast catalogue, to select, to order, to pay, to hire, to arrange delivery, to download, to track the progress of the order, to comment or to complain about the service.

You can design a photo album on your computer, pay for it, and have it printed and delivered to your door, all within a period of a few days. Similarly, you can publish a book, promote it and sell it on line and copies will be printed and despatched to your customers "on demand". 3D printing and additive technology, is rapidly developing along a similar path.

Support Engineering can make effective use of many of these technologies. Many are mature, low cost and readily available. They can be utilised quickly and cost effectively, but they need to be combined with a robust data management and manipulation capability (consider how well the Internet of Things [IoT] would operate without IoT software protocols).

Towards Defence Data Exploitation:

If this is approached pragmatically, with a dash of common sense and innovation, it will not require significant investment to realise very significant improvements in the effectiveness of Defence support.

Consider an operational unit, and assume the Unit has:

- A Maintenance Management System [MMS] which details the required scheduled maintenance and which records details of any scheduled maintenance and corrective maintenance that has been carried out
- Access to some form of electronic publications
- A supply system
- A configuration management system

Collectively, we can regard these as the Support Management System.

Modern maintenance schedules are complex. A Crew Chief has to take account of the operational tasking in both the short and medium term; the ability of the available platforms to meet certain roles; the medium and long term support requirements; equipment lives; the slots available for depth servicing; the need to rotate platforms through training units and WFM long term storage; and possibly the need to manage the fleet up to its OSD, as a viable fleet. Juggling so many variables is beyond the capabilities of a china-graph planning board or a pegboard; there are too many variables, risks and uncertainties. However, the Crew Chief could use a simulation tool, a model deployed as a day to day management tool, to determine the optimum strategy.

Modern simulation tools are very capable, and relatively (relative to past tools) cheap and easy to use. Those that enable an "Agent Based" approach are of particular relevance to the Defence Sector. For example, each individual platform in a large fleet can be represented in such a model, their characteristics can be modified as a result of their use on operations and as a result of support activities. Such models enable the effects of a decision, over an extended period of time and as a result of various feedback mechanisms, to be determined. Something beyond the typical spreadsheet model. Simulation models are used, in the main, to solve a particular problem, but we believe that they have a growing role as day to day management tools.

Aspire produced such a tool to enable the Tucano Fleet to be managed at the level of individual sorties in order to ensure that the fleet reached its planned OSD.

By utilising tried and tested technology, the Crew Chief could, when tasking each of his crew select all the relevant information required for each crew member that day. Relevant data can be extracted from the MMS, the Supply and Configuration Management Systems and the Electronic Technical Publications suite and downloaded onto a mobile device, in a coherent format. All the tools and test equipment, the spares and consumables, that are required could be presented in consolidated lists.

Connectivity and Communication Challenges:

Much of the innovative technology available today relies on the availability of some form of communication system to link it all together, a key element of this is of course the Internet, but there are other elements, such as the IoT protocols mentioned above.

The Defence sector brings its own challenges of course; the need for security, the lack of bandwidth when on operations, etc. Aspire has developed a toolset, EPIC, which utilises xml and xslt technology and can be used to manage the transfer, and transformation of data from various sources. For example, data can be extracted from a database and presented as a word or PDF document, an Excel Spreadsheet, an HTML 5 website, a Mind Map or a Kindle file (or all of them).

In conjunction with a mobile device EPIC can export a snapshot of data to the device, for use by a maintainer offline. It can be used in conjunction with IoT protocols and utilise web services on a public connection, or work on closed private networks as the occasion demands. EPIC can be used to export and sync all the offline data, collected on a mobile device during maintenance activities, back into the appropriate elements of the Support Management System.

Enabling the Engineer:

The maintainer could collect the required oils, greases, adhesives etc from the ready use consumables store. If each consumable had an NFC label, that could be scanned as it was selected, using capabilities built into a standard mobile device. The maintainer could reorder items which were running low by pressing the relevant “Dash” button located in a convenient position, or just submit a request through their mobile app.

In the tool store each item could be identified with an RFID, and the maintainer could attach a scanner to his tablet and scan them out.

Figure 2 - Beacons, Sensor RFID, RFID, and NFC tags can all be deployed to enhance Support effectiveness

In both instances, as the items were selected and scanned, the list on the tablet could indicate that that selection had taken place (e.g. changing the colour of text). When the task is finished the reverse process can be carried out to scan items back into the relevant stores. Not only does this allow for seamless inventory and equipment management, but this information could also be used to update maintenance task descriptions and analyse whether more items should be stocked.

Interactive Instructions:

If the task is complex, or the maintainer is unfamiliar with the procedure, they could “rehearse” the procedure on their device, watching each step of the process with its 3D graphics, like a video, before tackling the task ‘live’.

It is now fairly routine for 3D images, derived from a CAD system or generated in a drawing package, to be incorporated with technical information. Most commercial CAD systems have features that facilitate this. It is relatively easy to incorporate images into a PDF file which can be read using the standard, free, Adobe Reader. The latest versions of the MS Office suite enable simple 3D images to be inserted. Apple’s iAuthor (free) allows sophisticated publications to be created, including the use of 3D graphics, video, audio, etc which are inserted using drag and drop. 3D images can be associated with a prose description of the maintenance activity, including warnings and cautions, the individual parts in a 3D drawing can be associated with part information, so that the Part No, NSN, etc are displayed when they are selected. We have barely started to understand the possibilities in the world of Technical Publications and Training that these technologies enable, many of these capabilities can be accessed with minimal investment. The development processes adopted by the Defence sector to address both Training and Technical Publications do need to be subject to a critical review however.

Intelligent and Dynamic Procedures:

If the required activity includes a complex condition monitoring task, or a fault-finding logic to be followed (i.e. a procedure that required a series of measurements or observations to be made) the electronic documentation can be presented in the form of a contingent questionnaire. The procedure can instruct the maintainer to make an observation or take a reading, the information being recorded on the device. The procedure will then present the appropriate next step depending on the result of the observation. The procedure in this instance also doubles up as a dynamic data collection 'form'.

This would require two concepts to be merged; both the technical capability to capture and manage these workflows on a mobile device, and the ability to generate the technical publication and maintenance task information in a logical format that the device can "use".

Aspire has developed a system that enables complex "contingent" questionnaires to be created and "pushed" to a specified mobile device [Android only at present]. The system is used for making surveys of facilities, the surveyor follows the questionnaire, making notes, picking selections, taking photographs, etc as required. Progress can be tracked, the process paused etc as required. On completion the data is uploaded, when a connection is available, to a server, associated data is included, e.g. Position, time and date, surveyor, etc. A range of reports can be generated, some for internal use, others for the client, client access is controlled via the server. At present, the Survey Application enables keyboard, camera and GPS information entry, but there is no technical reason (nor any significant technical risk) to prevent thermal images, audio, vibration sensor data, data read from an NFC or IoT devices from being included.

The second concept is simply that of using an electronic technical publication generated, using xml, direct from the Maintenance Task Analysis [MTA] process. The MTA process breaks a task down into a series of steps and identifies any associated resource requirements.

Extending the System:

At appropriate stages in the maintenance process the maintainer can collect 'data', using a wide range of off-the-shelf technologies, by taking a picture with a thermal imaging camera attached to, or built into his mobile device, they could use endoscopes attached to the mobile device, or take vibration readings using the device's internal capabilities or via an attached accelerometer, etc. The maintainer can take notes using the key board, audio recording, voice transcription, or by attaching photos or videos as appropriate.

Figure 3 – A wide range of technologies can be deployed: external or built in Thermal cameras; data bus adapters; external or built-in vibration sensors and endoscopes.

Low end Endoscopes are cheap, they could be installed wherever there is a difficult to access item that needs to be inspected, and left in place permanently. Versions are also available that link to a mobile device via blue tooth or WiFi.

Electronic Tagging:

An RFID bonded to the equipment can perform the function of an Engineering Record Card, using an RF scanner attached to the mobile device the relevant data, serial number, mark, mod state etc, can be copied from the equipment and associated with any maintenance data that has been collected, this can be collated with the time and date, and with the details of the maintainer (identified via their ID card or log-on). Location data may also be incorporated, using GPS if available, or by using an IoT beacon; for example an IoT beacon could indicated whether a task was being conducted on the workshop floor or in a particular servicing bay.

In theory the only information required on the equipment itself is its serial number, all other data associated with this serial number being held on a central server somewhere. In practice however, the information on a server may not always be available, the server may not have been updated. Redundancy in the system will reduce the potential for error, for data loss, and will mitigate against those situations when gaining access to the 'master' data is not possible, for whatever reason.

Note: the automotive industry are now embedding RFIDs into components, such as a body panels, during the manufacturing process.

Automatic Condition Reporting:

Some modern equipment can report their condition automatically, electronic BIT data can be accessed from a data-bus via a blue tooth adapter, or by interrogating sensor RFIDs which can measure temperature, pressure, current, voltage, or which count operations. There are hydraulic hoses that can detect their own degradation and report via WiFi or cable to a central monitoring system.

Modern cars and trucks are fitted with an OBD2 data bus, (On Board Diagnostics). A few pounds will purchase a blue tooth adaptor for this data bus, apps to interpret and present the data can be downloaded for free. The adapter is fitted to the OBD2 connecter and the performance of your engine can be continuously monitored via your mobile device, fault codes can be interpreted and reset if necessary.

This approach could be extended to other data buses and BIT systems, the “intelligence” being provided by the app on the mobile device, this should be cheap, readily updated, and available to anyone with the requisite credentials.

The Hydraulic hoses (EATON LifeSense) are of course more expensive than standard hoses but the argument is that they are cheaper in TLC terms due to the longer average life achieved, and the reduced maintenance costs.

The Engineer’s Mobile Toolkit:

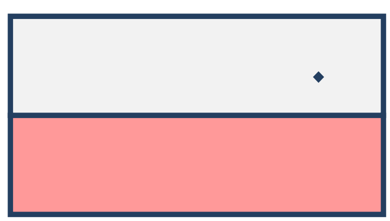
With a mobile device and few attachments, the maintainer can now carry a sophisticated set of test and measurement equipment in their pocket. Such an approach will enable, or re-enable, the technician, it also means that we can, make the gathering of data “frictionless”. A maintainer can make a measurement or take a reading at any time, in response to a formal scheduled task, because the maintainer has concerns about the equipment they are working on, or simply because an opportunity presented itself, for example when panels are removed for what-ever reason.

Note: the technology introduced above is only a sample of what is available, and we should be aware that such “low end” technologies are developing very rapidly. Consider; Alexa and Hive technology (which enable very sophisticated remote control), gesture control, virtual and augmented reality; face, retina, and finger print recognition, etc. Some are more mature than others, some have obvious roles, others less so, but it is time to stop asking ”*What need does this satisfy*?” and instead we need to ask “*Can this technology impart an advantage*?”.

But it is what we do with that data that is really important.

Predictive Analytics:

The immediate action would be for the maintainer to compare a performance measurement with a known “good” standard and, should the equipment be out of spec, the maintainer could then call up the relevant rectification routine and implement some corrective action.



A single data point can’t tell us much…

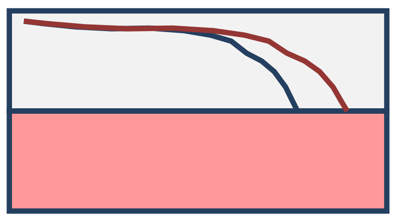
All the data that has been gathered will be uploaded and collated with all other relevant data via the Support Management System. (Simple performance data may also be stored on the RFID attached to the equipment as well).

The consolidated data will indicate if an equipment is trending towards failure, this will allow a timely intervention to be planned.

With more data, we start to see patterns…

The ability to predict failure, and hence to plan the rectification process, has a profound impact on operational availability and on the quantities of resource that are needed.

Over time, the "Dynamics of Failure" of the system will become apparent, that is in Reliability Centred Maintenance [RCM] terms, we would be able to visualise the P-F Curve, and the scheduled maintenance regime could then be refined. If environmental data was also collected, then, over time, the impact of differing environments (e.g. dry and dusty, warm, wet salty) on the failure dynamics could be determined. This would enable future scheduled maintenance regimes to be adjusted dynamically, depending on the operational environment.



Once we know the pattern, we can build predictive models of failure.

If the feedback is effective, if the analytical systems we discussed earlier in this paper can produce outputs which are ready for use, which can be readily imported into the in-service Support Management Systems, then the cycle times for updates can be reduced to days and weeks, rather than, months and years.

A Workplace Social Media:

Innovative technical publications, utilising audio, video, 3D images, Augmented Reality, etc would facilitate effective repairs even on complex systems and on tasks with which the maintainer is unfamiliar. Communication tools, derived from Social Media systems such as YouTube, Facebook, Blogs, Vlogs, and Twitter, can be deployed which would enable the maintainer to communicate with others performing the same or similar tasks recently, enabling them to compare notes or to ask for advice, a dynamic "Kit" magazine.

There are a range of mechanism by which this "social" interaction could occur, including the use of what are essentially private versions of Twitter, Facebook etc. Some communications can be implemented using IoT protocols, the potential for Blogs and Vlogs is self-evident. The information presented could be filtered depending on the user, the equipment, the date posted, etc.

It is the ease of accessing, the immediacy, and the speed at which such information networks can operate and that is particularly attractive.

Technology Enabling Analysis:

And hence we have come full circle, back to the analysis. We can establish a process that not only enables the maintainer, it also makes the gathering of feedback data more or less 'frictionless'. We can establish a virtuous cycle of continuous improvement, we can readily adapt to changing operational demands, to the availability of new technologies, to organisational change. We can improve the effectiveness of support, dramatically, whilst driving down through life cost.

The final argument above demonstrates the importance of acquiring and managing feedback data, with it we can establish a remorseless, ongoing, cycle of support improvement, the term "Data Exploitation" is being used in the Air Environment.

If the data gathered during the In-Service Phase can be seamlessly fed back into the analytical process, back into the analytical tools, that are used when developing the support solution in the first instance, then the speed of response could be very rapid. This rapidity would not only enable any benefits to be realised quickly, it would also encourage the support organisation and individuals to report more accurately, more completely, and with greater alacrity.

Summary

This article is by no means intended to offer a comprehensive list of technologies which should be exploited by the defence engineering community, nor does it provide a rigorous strategy for the implementation of these idea. All we can hope to achieve in one article is to spark ideas and debate.

To summarise the article, we have identified below 5 general areas or problems where these technologies and approaches can add value, along with 5 "challenges" to the industry.

The five key areas for technology exploitation

- Facilitate the analysis process
- Present appropriate information to the maintainer
- Make the maintainer's job easier
- Gather data in a "frictionless manner" and…
- Feed data back into the analytical process.

The five challenges to defence engineering innovation

Utilise robust, cheap, readily available off the shelf technology to make quick gains in defence support.

- Most of the ideas described above can be realised using technologies at Technology Readiness Level 8 or 9, and many have already been implemented, to some degree, by ourselves and others in the industry.

Enable / re-enable the engineer to facilitate optimal support.

- Any technology which can be exploited to make the engineer's job easier, will in turn make the whole system of support function more effectively.

Improve feedback and data exploitation.

- Establish new and better methods to collect data "in the field" and use it rapidly to effect system improvements.

Enable an agile and open approach to innovation.

- If improvements can be made incrementally, in a series of low risk, low cost baby steps (and with visible early successes), then we may see improvements in longer term capability growth.

Support Engineering needs a place to experiment, e.g. the Support equivalent of a Skunkworks

- Somewhere that will enable that formidable blend of technical and domain knowledge, pragmatism, innovation and above all imagination to come together. This Skunkworks could in practice be comprised of an Operational Unit operating an appropriate fleet of platforms, a supportive DE&S PT, and a supportive OEM.

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