THALES

Powering our future soldiers – another major challenge

By John Foley and Amyas Godfrey

12:57

Lieutenant Hackett checked his watch, it was just before 1300 hours; 1257 to be precise. The young platoon commander had been out for over 60 hours, patrolling the left flank of the Battle Group's Area of Operations. He and his men had spent the last two days clearing woods and securing various rocky outcrops, while the 'real' action was happening to the east. Alpha Company had been engaged in a running battle with paramilitaries in the villages along the river. Bravo Company, Lt Hackett's company, was securing the flank. It was tiring work, all on foot.

He had just put his platoon into a hasty harbour when he received a message from Battle Group HQ, via his Company Commander. B Company was to move to a 'Forming Up Point' at the head of the valley, ready to launch an assault on the main concentration of paramilitary activity. His excitement was slightly dampened by the sudden requirement for admin. He was supposed to be resupplied this afternoon, but in order to arrive before 0400 the next morning he would have to move out in 40 minutes time, or risk being late. His mind raced through all the obvious checks. Ammunition: they hadn't engaged with the enemy so ammunition was fine. Rations: they'd brought enough rations to last an extra 24 hours, so that was good. They could refill water on the way from streams. It was the state of their batteries that weighed most on his mind.

They had moved out from the Company Admin Area on Monday night, 2100 hours. It was Thursday, their batteries had been running for 64 hours. At this rate Lt Hackett's radio would die in 8 hours' time, right in the middle of his move to the FUP.

The Power Supply Challenge

The rapid and ever increasing expansion of new technology in the commercial world is also providing the means to offer very significant enhancements in the capabilities of the dismounted soldier, especially in the information domain. This is commonly referred to as the "Future Soldier System". Technology offers major benefits but also brings additional challenges in the dismounted domain. This article explores one of the most significant of those challenges – the need to provide and maintain power for all this additional technology.

As individuals in today's world we have all become accustomed to a routine of keeping our many personal devices and electronic toys topped up with power. It is not generally regarded as a major issue. We are never that far away from a power outlet and we all carry chargers, or ensure they are readily available to us when needed. We may even carry a modest recharging device to cover any short period we cannot get to an available power source. It is not the same for a dismounted soldier.

Currently soldiers' devices are typically powered by a diverse range of batteries; some rechargeable (secondaries) and some not (primaries). Mostly, they are powered by primaries apart from specific high consumption items, such as unit radios[1], which may be supplied with their own bespoke secondary battery. The current position has evolved gradually from a background where there was very little need for power, apart from the unit radios. However, as technology has offered more and more devices in a form factor which can be carried and used by dismounted soldiers, the overall power demand has steadily increased. This has all occurred through a series of stove-piped procurements, each providing real user benefit but each also dealing with each new power need in its own way. ►

Several decades of ever-increasing provision of electronic devices has - in most national armies - spawned a plethora of diverse battery types and created a steadily growing logistics problem. With the widespread emergence of many more information-centric capabilities, along with power-hungry data bearers, this growing logistics issue is set to explode into a major logistics problem for all dismounted users so long as technology continues to be tempting to militaries in improving situational awareness, precision and connectivity.

Primary batteries are also used inefficiently. Where once it seemed practical to augment soldier's equipment with a device or two that could run on commercially purchased AA or AAA batteries, the reality of becoming reliant, or at least highly desirous, of using a wide range of electronic devices meant that not only did soldiers have to significantly increase the amount of spare AA/AAA batteries that they carried they also would completely replace all of their batteries before they started any new patrol or task, regardless of how much charge was in them.

In 2011 an Army Research Laboratory study found that on a typical 72-hour mission in Afghanistan, a U.S. Soldier carried 70 individual batteries, making up 20 percent of the weight a Soldier carries in operations. What's more, the study also found than US military spent, on average, more than $150,000 on batteries per year per deployed infantry battalion. This was second only in financial expenditure to munitions[2].

So what is the potential impact of continuing down this route of powering commercial-off-the-shelf (COTS) electronic devices, or uncontrolled proprietary battery supply per device in the future? Soldiers will face an ever-increasing load of mixed battery sets to carry and frequent battery replacement tasks to complete interrupting the tempo of operations. The logistics chain will need to keep increasing the weight and bulk of replacement batteries loads projected forward, at very significant cost and in a world of ever increasing public and political scrutiny the environmental impact of churning through so many batteries in an ill-considered and throw-away manner will only increase pressure on the military to rationalise and deal with this issue.

Operations aside, training budgets will also have substantial increases in power costs with the attendant requirement to prepare soldiers to use diverse electronic devices. Commanders will need increasing focus on tracking power availability and status, across all levels, to ensure that their scope of activity does not become limited by battery supply. Training has already unofficially started to include serials such as 'running out of batteries', amongst basic section battle drills. Any credible military needs to avoid the scenario where the forward provision of batteries starts to limit the speed and extent of dismount activity in a manner reminiscent of the lack of fuel famously limiting tank activity in previous conflicts.

Meeting the Power Challenge - What can be done?

There are a number of actions that militaries can take to address this situation. Some practical, but their adherence could stem the growth of use of technology; others deal significantly with the problem but require a new direction for the adopter. Many of them can be done in conjunction with or in support of each other. However for any military to fully exploit the incredible growth in sensor quality, digital capability, connectivity, and software enabled effect, there is a need to address power management across the board, taking all options into consideration. These options are:

- ✓ **Rationalise Battery Need**. Concentrate on one predominant battery type (e.g. on AA's, as done in Canada some years ago). This alleviates some issues but individual device power-requirements vary and cannot all be met with AA's (even Lithium AA's). This is because the power capacity with the AA package is not great and the user still would be required to carry a large number of spares and manage frequent battery replacement tasks. Also the cost and logistic burden of projecting enormous numbers of AA batteries forward in theatre remains massive. This approach alone offers limited benefit.
- ✓ **Minimise Power Demand**. This remains a key strategy. The introduction of every new dismounted soldier device or capability needs to be carefully analysed to quantify the power demand implications. Introducing new capabilities without fully understanding their impact on the soldier power burden must be avoided at all costs. Any overarching dismounted Soldier System Integrator role, whether internal or outsourced, would need to prioritise power demand along with weight, bulk, cognitive burden and reliability in assessing new device suitability. However, recognising the need for users to benefit from new technologies will inevitably bring increasing power demands.
- ✓ **Operate Centralised Power**. As dismounted power demand increases it will meet the critical threshold at which operating a centralised power system offers compelling advantages. Some people would say that it already has met this threshold. Using a central battery provides the basis for ensuring a common power module not just on one person but across all users within a unit and it can be a secondary battery so that all the cost, user load and logistics benefits of operating a recharging power delivery regime can be accessed. Additionally the higher power density of a larger battery reduces soldier load and the increasing availability of modern smart batteries will also allow users to track their own power status. This approach does introduce new challenges, most notably single point of failure and the need for a recharging infrastructure, but these are manageable and are discussed in more detail below.
- ✓ **Manage Power Effectively**. Users recognise the danger of running out of power at critical times. Its management is now a significant task along with managing ammunition, water, and rations. The availability of battery status data from smart, rechargeable batteries can now provide a means to greatly reduce this management task. Commanders at every level can access the power status data from all users within their responsibility (section, platoon, company) and use this to manage their

resupply more effectively, if they have a data capable communications infrastructure in place. This is only really effective when all users have a common power module so that these can be tactically exchanged to allow heavy power users to benefit from spare capacity on light power users, thus sharing the power load around the team and giving the commander power distribution options. This requires both rifleman and commanders to operate centralised power systems with common power modules. Users with high power demand might operate with two batteries while the less loaded riflemen carry just one, with both benefitting from a completely common power module using a common recharging infrastructure.

Power and Data – Mutually Supporting Challenges

This article is focussed on soldier power and discussion on data distribution around and between soldiers is a major topic in its own right. However the delivery systems on soldiers for power and data will typically share a common hub and usually share a common distribution system (via wires or other conductors). The case for centralised power and shared data are therefore mutually supporting such that when you introduce one, the delta "cost" of introducing the other becomes marginal.

There is the possibility of sharing data around a soldier by use of wireless technology, which would not so easily lend itself to also distributing power from a central hub. This wireless approach has its own significant concerns, most notably with security and signature but also with power consumption. The use of wireless technology greatly increases power demand and, ironically, increases the case for centralised power and a wired power network around the soldier.

The benefits of providing a common data system to allow soldier devices to share data, in an open manner, are well known and the case for introducing this in our "information-centric" world is compelling. Once the decision is made to adopt a soldier data network then the case for also introducing a central power system is overwhelming and the benefits of sharing power-related data once you've introduced a centralised power system negates any debate for making savings by not introducing a data sharing system. The two are mutually supporting and together are greater than the sum of their two parts.

The opportunity to prepare for, introduce, and harness emerging technologies which require a data sharing system in order to mitigate most of the concerns around power hungry devices is compelling . The Internet of Things, Digital Identity, Artificial Intelligence (AI) and Autonomy all benefit from data sharing (with decent connectivity) whilst contributing to power management. A smart battery that can send updates about its status, linked to an individual or unit, and utilising at various points along the chain of communications AI to support logistics, resupply, and operational planning (based on GPS locations as shared on a data enabled network) where options are presented to commanders is a new reality that can be brought into being by the adoption of a soldier system which is both power and data sharing.

Even without a shared data system the case for centralised soldier power is very strong from both a tactical and financial perspective. Combined with a data system it is compelling.

Huddled behind a fallen tree, surrounded at a distance by his platoon in 'all-round-defence', Lt Hackett had just issued his 'warning order' to the section commanders. "Prepare to move in 35 minutes, 1 Section leading off". The soldiers were to get as much food in them now as they could as it looked like they had a 10 hour march ahead of them. "If we make good progress we may get a rest in" he added – seeing the look on the Section Commander's faces.

"Any chance of a resupply, Boss?" asked Sergeant Jones as the Section Commanders disappeared into the trees. "Working on it, but I think we need to prepare for not", replied Lt Hackett as he sat down and got out his command display, a smartphone-like device that he kept tucked into a pouch on his chest.

Opening up the Power Management App on his device Lt Hackett took off his glove and touched the icon marked 'own power'. Immediately it brought up a diagram showing the current state of his own central battery and all of the attached ancillaries which were drawing power from it. "20%", he muttered under his breath. That's all he had left including the spare which he had swapped out earlier the day before. They could recharge using the solar sheets, but this would delay their departure and even two hours of charging would only add 15%, and it would push them hard to make the FUP in time.

Using the 'estimate' function, the App quickly calculated how long the Platoon Commander could continue on his current rate of power usage. Eight hours and seventeen minutes. That would take him to 2132 hours. "Not nearly good enough – especially if we run into some trouble on the way", he thought to himself. For the next few minutes he played with the estimate by turning off various ancillaries one at a time and weighing up in his mind the risks. He optimised his system to squeeze out an extra 50 minutes. He also told his system not to power his target designator when it was connected, it would have to work off of its own back up battery which had about an hour of life. He didn't want to forget in the heat of the moment and drain his depleted battery unnecessarily, that could be a disaster.

The Challenges with Moving Ahead

The strongest current case is to introduce a wired[3] Power & Data (P-D) infrastructure on all soldiers in order to get the full benefits of both centralised power and shared data. The implications of introducing wireless links can subsequently be explored in a controlled fashion, initially for weapon and helmet links to the main torso sub-system where the need for a non-umbilical power and data link is greatest from an ergonomic and practical point of view. Hand in hand with the adoption of a P-D Infrastructure on the soldier would also have to be a practical and appropriate data enabled communications infrastructure, with attendant cyber-security and encryption, to ensure that the data is truly shared and made available to whomever (or whatever in terms of AI algorithms and autonomous decision making systems) to augment and increase capability.

However it would be remiss not to address the natural and practical concerns raised by the introduction of centralised power. These are:

1. **Single Point of Failure:** Centralised power can fail for a number of reasons. Cable/connector damage through battlefield trauma or 'wear and tear', or even battery failure through fault or through drain of battery power. In centrally powered soldier systems critical modules, such as the voice radio, or a weapon sight, can be fitted with small, local, back-up batteries providing a limited period of functionality in the event of central power failure. These are rarely needed, remain topped up from the central source and add little to the user burden.
2. **The recharging infrastructure:** This can be provided in supporting vehicles, bases and in various user portable devices, offering diversity of power replenishment sources at a much lower overall burden on both users and on the logistic train. It provides users a basis for power scavenging and ad hoc replenishment (e.g. solar). It also offers major cost savings. Moving to a rechargeable infrastructure is not a trivial transition but it is inevitable as dismounted soldier power demands grow.
3. **User Burden:** Clearly there is a cross-over point in power demand below which users are better with multiple, discrete batteries and above which the use of centralised power is compelling. The quantified calculation of this precise point is complex. It depends on the range of devices issued to various user roles and the duty cycles for those devices throughout the user missions, as well as the anticipated duration of those missions. It also depends on the weight-delta incurred with the centralised system. However with sensible system weights and ever increasing device power demands that cross-over point can be shown to already be exceeded for current users. This is especially the case when the user cognitive burden of managing battery replacements and the logistics burden of providing those replacements are factored in.

What makes a good soldier power system ?

Whilst the benefits of adopting a soldier-worn power system are clear it is only when you get to properly integrating the hardware physically onto the human that the challenge really becomes apparent. Physical integration onto the soldier is critical, and bedevilled by a myriad of trade-offs, tight tolerances, and seemingly infinite use cases.

Firstly there is the human to consider. The need to provide some form of wired connectivity between devices located around the soldier and a central power source poses a significant problem which cannot be solved by festooning cables around the user's load carriage and leaving it for them to sort out. People do not make for uniform platforms onto which to hang 'framework' electronics (i.e. power and data systems). Different heights, shapes, lengths of torso, all contribute to different cable lengths and placement of connectors. Vehicles don't have this problem to the same extent. Any useful centralised power system must be provided in a form which can be seamlessly adapted to fit into or around the user's existing load carriage system without creating any new problems for them. The design of a user-centric physical distribution system is immensely important to the successful introduction of centralised power.

Secondly there is the job. Dismounted soldiers lead a most uncomfortable existence when in the field – and one not readily tailored to electronics and technology. Equipment fitted around soldiers needs to be able to withstand a harsh life and be sufficiently robust to remain reliable through its full lifetime. Dismounted soldiers will, understandably, have no patience with a system which periodically deprives them of power to many of their devices, simply because of the environment in which they are asking the technology to operate. There are complex trades between robustness and weight, such as immersion in water, where one metre for 30 minutes seems reasonable and affords you one type of connector, but three metres for 3 hours would require different connectors.

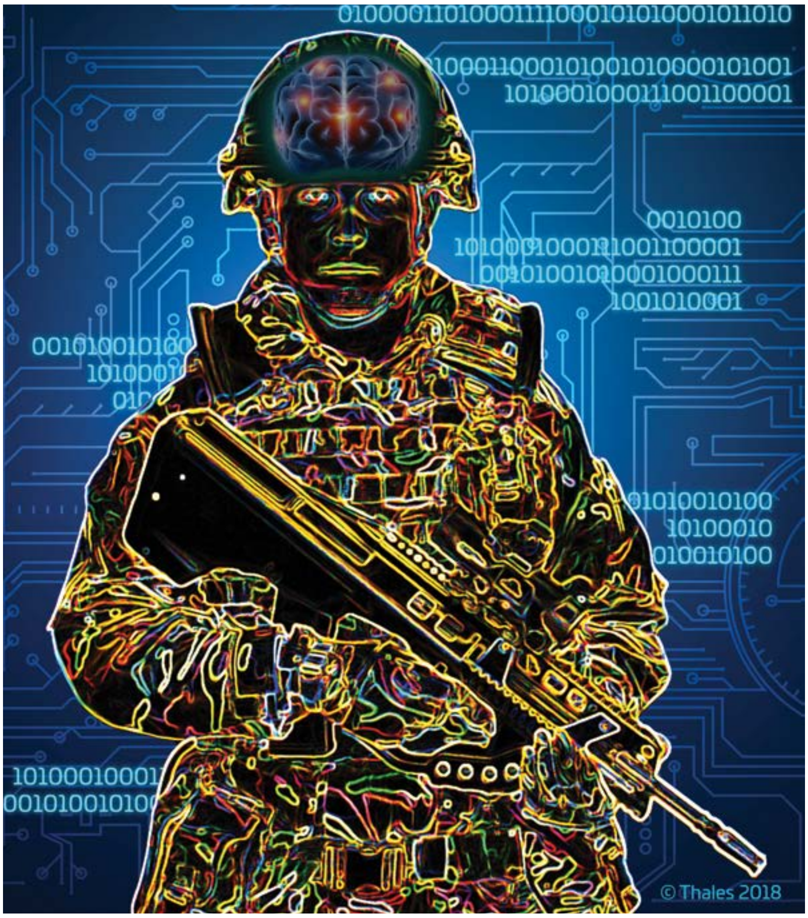
Then there is the flexibility of use. There is no "correct" or "optimum" distribution of devices around a soldier. Their life is too complex for that. Systems optimised for different roles and command levels, undergoing different missions, require the freedom to let users adjust device locations. A useful centralised power system must cater for this. Through life system management (e.g. maintaining reliability and maintaining an acceptable EMC profile) might require that the actual device locations be managed at unit level rather than complete freedom for every user, but this would still allow optimisation for roles and missions. The terrible truth of soldier systems is that no two soldiers are alike in size, responsibility, role, mission, operating environment, experience, or capability. Any system design must be cognisant of this and aim to deliver the least amount of resistance to letting the soldier continue to do their job.

This means that design parameters such as **Size, Weight, Power & Cost (SWAPC)** are paramount for everything worn by a soldier and so there are some critical trades to be considered in determining the optimum design:

- **Central Hub Ports:** How many ports are enough? Too few will need early upgrades or multiple daisy-chained hubs. Too many adds unnecessary size, weight and cost.
- **Plastic or Metal:** The material that the housing for

the hub is made of has a number of knock on effects depending which one you choose. Weight and cost are lower for plastic but it is also less robust and vulnerable to EMC degradation.

- **Simple Physical Attributes:** The presence of an On/Off switch on the central hub may seem like an obvious choice but the inclusion of one in the design adds non-trivial bulk, weight and cost. But can you operate sensibly without one? Everything involved in the soldier system must be properly interrogated in this way to earn its place on what should be a very lean system.
- **Intelligent battery charging:** Not a trivial cost but immensely beneficial to the user to be able to charge any form of Smart[4] battery from whatever power sources are available. A thorough test against typical ‘battlefield missions’ and scenarios will tease out many opportunities in which ‘scavenging’ power for recharging batteries has a significant impact on mission duration, logistics, and operational effectiveness.
- **Battery-Agnosticism:** The procurement of suitable batteries will be a major through-life cost driver so it is important that the choice of battery is not unduly constrained by some design aspect of the central power system. It is also important that the battery choice can be changed so that the units operating the system are not locked into a single supplier. Flexibility here will provide ‘wins’ for both the through-life cost as well as the operational flexibility.
- **Common Batteries:** Having all users within a unit using common, interchangeable batteries maximises the ability for commanders to redistribute them during tactical ‘re-orgs’ in order to share the overall power burden and to ensure the most critical user systems are kept operational. It also simplifies the logistic and recharging tasks.
- **Access to Battery Data:** The central power system needs to access and share all the relevant data available from Smart batteries so that it can be collated and viewed by remote commander systems. The power data display in a commander system should provide an intuitive view of its own power status and the power data from all users in the defined “Community Of Interest” (COI) so that optimum decisions can be made on how to manage and redistribute the remain power. As this procedure becomes better understood and practiced at a user level, layers of AI and autonomy of the system, can be introduced to improve tempo and reduce cognitive burden further.



What Real Difference Will it Make for Users?

Imagine a (military) world where commanders at every level have access to power status information for all relevant[5] users presented in an intuitive way which provides each commander with an instant understanding of the limitations each user/sub-unit will face from diminishing power and all the options for modifying consumption or redistributing power. Perhaps even greater impact will be on the ‘Quarter Master’s’ chain where the universal adoption of common battery modules (or ones with common interfaces) will greatly simplify the whole process of arranging power re-supply for each user, not to mention the potential for interoperation with other forces.

For individual users the whole task of managing their own power will be greatly simplified. Instead of needing to swap out multiple device batteries users will simply need to swap one, or maybe two, main system battery modules.

Major through-life cost savings will benefit all users . “*Digital power management*” will ensure that the whole ►

command and re-supply chain can track power status and redistribution options at every level from individual soldiers through section, platoon and company in order to ensure operational options, in this data-centric era, are not compromised by unanticipated power shortages or limitations.

Now that is a world worth taking on the challenge for.

"Stepping off in 15 minutes, Boss", said Sgt Jones, taking a knee beside his platoon commander. "All the sections have fed and are packing up, ready to move."

Lt Hackett was just putting the finishing touches on his route to the FUP, slightly adjusting the waypoints on his mapping App. Selecting the sub-units and higher units to send it to, he ticked off his three sections, B Company Ops (this covered the OC, 2IC, CMS and CQMS in one and made it available to the other platoons to see on their maps), and his Platoon Sergeant, he pressed 'share' and instantly the route and any specific instructions went out. Sgt Jones' radio buzzed immediately. "Is this the route?", he asked, fishing out his device.

"I'm hoping that battalion will be able to resupply us 'on route', but in the meantime I think that we have enough battery power in the platoon to get us to the FUP and a couple of hours after", suggested Lt Hackett.

"Are we going to do a 'top to bottom' swap?", asked Sgt Jones. "Have to. To make sure we're covered. Some of the riflemen are on 70-80%, but the section commanders are down at 35%. I'm on 20%", replied Lt Hackett. "Ditto, I'm on 25%", said Sgt Jones. "I noticed", ventured the young Platoon Commander and with that he re-opened his power management App and looking at the 'platoon battery management' page pressed 'Swap – Full Swap – Optimised', and then pressed send. Instantly a message went around the platoon notifying all of the soldiers with the most charge left in their common core batteries to swap with those with the least. Thankfully for the sake of time the software worked out who should swap with whom based on charge, average use per new recipient, and even GPS based co-location. Immediately little messages appeared on Section Commanders and Section 2ICs devices, who immediately started to relay these instructions to their teams.

Nearby, one of the riflemen in platoon headquarters who was packing up his kit, turned to Lt Hackett, holding up his black metal mug. "Want a brew before we step off, boss?"

"Thanks, Redders", he said reaching out for the mug, "and while you're at it, give me your full battery, the App says that we're swap buddies".

Just then a message came in to Lt Hackett's radio, leaving a message banner on his device. 'Resupply at Grid UR 5492 5231, 2030hrs, UAV, batteries'. "Brilliant", he said glancing at the headline of the message, "The system has worked out from the route that I just posted the best place to resup us some batteries, the QM is sending them via drones."

And with that Lt Hackett downed the rest of the mug of tea and handing it back to Private Redfern, he exclaimed, "Nothing like a brew to recharge the batteries!" ∎

John Foley is a Thales Senior Expert in the field of Soldier Systems and has been active in this domain continuously since the NATO NIAG Sub-Group 48 Soldier Study in 1993-4. He subsequently led the UK industrial consortium (Pilkington, Racal & Royal Ordnance) which delivered the UK FIST Technology Demonstrator programme for DERA (1998-2000). He was Technical Director for the Thales Team which won and delivered the Cat-A FIST programme (2003-15), which included a comprehensive Main Gate submission on FIST-C4I and subsequently delivered the CLB (Casualty Locator Beacon) UOR which implemented many of its features. He is now fully involved in leading the development of a suite of Thales Soldier System products and in developing a Thales Soldier System Architecture Model which will be used to guide the definition of soldier-related activities and ensure coherence across Thales's multi-national and multi-functional organisational structure.

Amyas Godfrey was the Thales Product Line Manager for Soldier Systems from 2014-2018. During this period he was involved in the concept, design and initial trials and experimentation of the new suite of Thales Soldier System products including the vision for a future Soldier System. He is a former British Army Infantry Officer with operational and training instructor experience and has now worked in the Land Defence area within Thales since 2009. Previously he was the Head of the UK Armed Forces Programme at RUSI where he conducted analysis and research into the operational, doctrinal, procurement and training performance of the British Military.

1. "Unit radios" are long range radios used to manage overall Command & Control, such as Bowman dismount radios in the UK, rather than the personal role radios at individual soldier level.
2. T'Jae Gibson, Army Research Laboratory, 15 Mar 2011
3. "Wired" covers all forms of conductive linkage not just conventional cables.
4. Assuming we are dealing with Li-ion batteries then for safety reasons the Intelligent charger needs to be able to dialogue with the battery in order to charge it safely so it needs to be a Smart battery. It would need to be a Smart battery anyway to provide status data.
5. System manager can decide and set up which users are "relevant" to each Commander.