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The Development of a UK Tactical Datalink for Time-Sensitive Targeting with Maximum Interoperability

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ABSTRACT

UK air-to-ground targeting against time-sensitive targets, or Close Air Support targets, has until recently been performed based upon information passed to the 'shooter' by voice. Modern weapons facilitate the shooter being able to stand off from the target at a distance where he may well not be able to bring his own sensors to bear. Furthermore, recent confrontations have been conducted within short distances of non-combatants, often in rapidly changing urban environments. Thus within the UK QinetiQ has progressed the development and installation of a tactical datalink for over-the-air transmission of targeting data using standard in-service air and ground radios. Moreover this has been performed in such a way as to afford maximum interoperability with UK, US and NATO equipment. The Improved Data Modem (IDM) has become a generic description of the datalink type employed for this application. Since datalinks and general methods of digital communication are numerous, QinetiQ has made significant efforts not to continue this proliferation but to integrate the IDM with current in-service digital communication methods and current Command & Control software applications.

1.0 INTRODUCTION

The strengths of the aircraft, particularly the fast jet, are clear and have been discussed widely elsewhere. Meilinger [Meilinger 2003], to give but one reference, himself quotes predecessors who foresaw the strengths of the aircraft as being its ubiquity (meaning unconstrained in the third dimension), speed, range, potency and flexibility. This paper addresses one method of making use of those strengths.

One of the most demanding tasks for an air-to-ground aircraft is to prosecute unplanned targets rapidly. This may involve a time urgency due to the target being time-sensitive or time-critical, or due to the request for fire being associated with Close Air Support (CAS) [Jane's IDR 2004]. CAS may involve the target's close proximity to friendly forces or non-combatants. Any air-to-ground attack may require the shooter to accept a degree of risk from enemy ground-based air defence: this may range from small arms fire, through man-portable air defence systems to mobile surface-to-air missiles and up to fixed SAM sites. The lethal height and range of these defence systems [Jane's 1998] varies from a few thousand feet and a few miles, up to over 100,000 ft and 100 miles. The location of fixed sites is generally known, but the location of other sites can change rapidly, and thus may not be known. The situation is exacerbated for the attacking aircraft if the call for fire takes it to an area where intelligence concerning enemy disposition is relatively scant.

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Up to the 1990s the air-to-ground weapons of all airforces were predominantly, and generally entirely, ballistic in nature. They may have been 'dumb' (or 'iron') bombs, rockets, or bullets. Nevertheless, whether they fell away from the aircraft, or were fired from the aircraft, or were self-propelled after leaving the aircraft, they were all subject to gravity and all were fired forward. This meant that the weapons were generally aimed through the aircraft's Head-Up Display in the 10 degree forward cone. This, in turn, implied that the pilot was 'eyes on' to the target, and thus had the potential to make visual confirmation of the target before releasing the weapon. Since the 1990s there has been a steady and significant move away from ballistic weapons toward intelligent, or precision-guided weapons, with this implying varying degrees of stand-off. This is exemplified in Table 1 [RAF Review 2002], [AWST 2003] which shows the percentage of precision-guided weapons used in recent confrontations.

Table 1: Percentage of precision-guided weapons used in recent confrontations

Operation Place/Date	No. of weapons	% Precision-Guided
Desert Storm, Gulf '91 (UK: Op Granby)	155,816	7 19
Deliberate Force, Bosnia '95	1,026	70
Allied Force, Kosovo '99	23,000	35
Enduring Freedom, Afghanistan 2001	17,471	57
Iraqi Freedom, 2003 (UK: Op Telic)	29,000 802	68 84

Apart from the 'blip' in the Bosnia statistic (due to the use of a small number of weapons used in particular geographic/operational circumstances) it may be seen that the use of precision-guided weapons is growing significantly. However, the sensors on board the shooting aircraft have not kept pace with the stand-off capability of the weapons, with the consequence that the shooter may not be able to bring his sensors to bear on the target at the appropriate time and range to allow the full stand-off capability of the weapon to be utilised. The problem is exacerbated if the attacking aircraft approaches at low altitude, an eventuality for which the RAF trains if the target area has not been 'sanitised'. As a particular example, there could be certain occasions when use of the Brimstone weapon may fall into this category.

The method chosen by QinetiQ to mitigate the growing shooter-to-target problem is to implement a digital datalink between the 'sensor' (the platform or person with the target knowledge but without the weapons) and the 'shooter', so that targeting data may be passed rapidly and accurately to the shooter. This was deliberately chosen to be based on the IDM – an acronym describing a datalink utilising, but not necessarily confined to, standard air and ground radios in service for voice transmission purposes. UK research and development with the IDM has been widely described elsewhere [Edwards 2002], [Edwards 2004]. The IDM could thus work both Havequick and encrypted if the radios themselves were so enabled. The intention was to minimise the time and maximise the accuracy of the passage of data from the sensor to the shooter. The first specific problem on which QinetiQ chose to concentrate was the passage of targeting data from a Forward Air Controller (FAC) or Tactical Air Control Party (TACP) to a fast jet. This has been performed for decades by voice, and the information summarised in a '9-line brief', so called because it occupies 9 written lines and is transmitted by voice in that form. The information is written down by the aircrew, with it being mandatory to read back some of the parts of the 9-line. The NATO standard for the 9-line brief is AJP 63-1, carrying the information required by the attacking aircraft, as follows:

- Initial Point
- Target Bearing
- Target Distance
- Target Position
- Target Elevation
- Target Description
- Attack Heading
- Closest Friendly Forces Position
- Time On Target

The passage and confirmation of this information by voice can take many minutes. Therefore QinetiQ concentrated with some urgency on solving this immediate UK problem. The work performed for this purpose, plus the ensuing explicit tactical datalink work, are summarised in the following section.

2.0 SUMMARY OF EXPLICIT DATALINK WORK PERFORMED

Over a 5-year period a considerable amount of work has been performed in both the air and the ground environments. This section summarises the airborne aspect of the work, the ground aspect and finally the data protocols employed.

2.1 Airborne Datalink Development and Implementation

2.1.1 Jaguar Aircraft Integration

An IDM was installed into a research Jaguar T Mk IIa in 1998. The IDM's attractions at the initial stage of the research programme were manifold; in particular it:

- enabled digital communication via standard aircraft radio
- was flight-proven
- was available for loan from the UK Attack Helicopter 9AH) Integrated Project Team (IPT)

After productive testing in the research aircraft, an installation was performed in a Jaguar GR-3a to enable operational evaluation of the IDM. Successful research and development resulted in a Jaguar fleetwide fit with the IDM, which is in fact line replaceable with the AH IDM. The Jaguar installation is highly integrated and allows the aircraft to receive and send various air-to-ground targeting data, particularly the NATO standard 9-line brief (AJP 63-1). This is achieved largely through HOTAS (hands on throttle and stick) control.

Not all the 9-line data are used on the Jaguar: the Initial Point (IP) and target bearing/distance are less important now aircraft navigation aids are more accurate. Nowadays it is rarely necessary for well-equipped aircraft to fix their position via an IP. Additional data displayed in the Jaguar CAS page are laser code and various freetext information. An example Jaguar display is shown in figure 1, with the parametric data reflecting the FAC's input at the top of the display and the target position (central triangle), attack heading (3 o'clock line from the East to the target) and closest friendly troops (short 10 o'clock line) shown on the moving map.

Further to the initial 9-line brief implementation the Jaguar has been upgraded to include an intra-flight capability and a Suppression of Enemy Air Defences (SEAD) capability. These have been achieved by mechanising the appropriate data words in the appropriate protocols (see 2.3), and then integrating those data words with the aircraft's avionics in a manner conducive to good Human/Machine Interface (HMI) principles. The consequences are that the Jaguar is able to receive, display and attack/avoid SEAD targets, and also automatically transmit, receive and display wingman information. The latter has proven to be very useful in assisting situational awareness in a flight of similar aircraft. Moreover the intra-flight capability is also compatible with the Apache helicopter, so that a UK Jaguar aircraft can see the position of an Apache helicopter (as long as the frequency and address are selected): an example is shown in figure 2.

Figure 1: Jaguar 9-line Brief and Map Display

Figure 2: Jaguar Intra-Flight Display

2.1.2 Harrier Aircraft Integration

In early 2003 a Harrier GR7 Urgent Operational Requirement to receive a digital 9-line brief was issued. QinetiQ would have liked to offer a Jaguar type of solution. However, although QinetiQ writes the Jaguar Operational Flight Programme (OFP), thus can achieve a quick turnaround and clearance on Jaguar updates, the same is not applicable to the Harrier, the OFP for which is not controlled by QinetiQ. Therefore QinetiQ offered a solution based on its work with a handheld iPAQ personal organiser. Within a few weeks QinetiQ had performed a variety of safety-of-flight tests on the iPAQ, covering temperature, vibration, EMC, rapid decompression and night vision goggle compatibility. Flight clearance, including software safety, was given urgent attention, and the system flight-tested and brought into service within the desired timescale. This enabled digital targeting interoperability with UK and US FACs. Figure 3 shows the iPAQ Harrier Tactical Data Receiver (HTDR) mounted at the bottom right of the Harrier GR7 coaming.

Figure 3: Harrier GR7 Tactical Data Receiver at bottom right of coaming

2.1.3 Cabin Environment Aircraft

A classified walk-on digital targeting capability in UK cabin-environment aircraft has also been demonstrated.

2.2 Ground-Based Datalink Development and Implementation

In conjunction with the development of the airborne datalink capability QinetiQ integrated a ground-based capability. This deliberately facilitated maximum interoperability with current UK in-service equipment. The modem was housed in a PCMCIA card, which itself was contained in a rugged PC which was 80% common with the hardware specified by the UK for the Fire Control Battlefield Information System Application (FC BISA). The PC is known as the Termite, and is shown in figure 4 (at bottom left), together with the GPS receiver (far right), laser rangefinder (top) and ground-to-air radio (2nd from right) with which it interfaces. A windows-driven Graphical User Interface enables target input by hand, either stand-alone or together with the interconnected equipment. The equipment is over-the-air compatible with a variety of aircraft, including the Jaguar, Harrier, F-16 and Apache.

Figure 4: UK FAC Digital Targeting Equipment

2.3 Protocols Employed

2.3.1 Tacfire and AFAPD

The initial communication protocol chosen to give a digital targeting capability to the Jaguar was Tacfire. This is a US artillery-based, generally low data rate, protocol. It was used because it was in-service and was the most readily available, documented protocol, although its employment then was generally limited. The more dominant IDM-employed protocol was the Air Force Applications Programme Development (AFAPD). This was used both in its generic form in the F-16 and in a Boeing-modified form for the AH-64. At the time of the initial research requirement there was insufficient information available regarding AFAPD, thus research commenced with Tacfire. Subsequently QinetiQ has performed a considerable amount of AFAPD-based software work; this has been performed predominantly using the maximum available radio bandwidth of 16 kbits/sec.

2.3.2 Variable Message Format (VMF)

VMF is accepted within the Requirements and Planning communities as being the equivalent to the Euro, in that it will supersede the various protocol equivalents of the Mark, Guilder and Franc etc. It is a robust (Golay and Reed-Solomon Forward Error Correction) protocol facilitating the transmission of variable length messages. Many in-service platforms will migrate from extant protocols such as Tacfire and AFAPD to VMF, and new platforms will be prescribed to use VMF, with a possible legacy interoperability with AFAPD. VMF is one of the J-series protocols, together with Link-16 and Link-22. Since the early 1980s the use of Link-16 and its JTIDS bearer has burgeoned. However, the frequency band allocated to JTIDS covers a variety of commercial applications, thus its peacetime use is limited by the frequency allocating authorities. High Link-16 terminal costs and limited network allocation drove the US Army to pursue VMF. Over the next two decades the other US services 'bought in' to VMF and it migrated through being an initially Joint VMF (JVMF) with the Army and Marine Corps, back to purely VMF when all the US services adopted it. VMF and its use are defined in three documents, as follows:

- MIL-STD-6017
- MIL-STD-188-220: Interoperability Standard for Digital Message Transfer Device Subsystems
- MIL-STD-2045-47001: Connectionless Data Transfer Application Layer Standard

The QinetiQ Targeting Group is working to the second two standards at issue standards B and C.

The strong point of VMF is its flexibility. The weak point of VMF is that its flexibility introduces numerous areas of indeterminacy which, unless precisely defined and agreed by the transmitting and receiving parties, render interoperability impossible. It is to be hoped that the 'D' standard of the documentation will achieve its stated aim, that of achieving forward compatibility, i.e. each standard after 'D' will be backward-compatible with the preceding standards from 'D' onwards.

3.0 NETWORK ENABLED CAPABILITY (NEC) & NETWORK CENTRIC WARFARE (NCW)

3.1 Definitions and Background

NEC and NCW are associated with integration and collaboration in the battlespace. The initiatives intend a realisation of the fact that a campaign may be more efficiently undertaken not necessarily by greater quantity or quality in the allied component parts, but by linking them in such a fashion that the whole is a far more efficient and effective use of the sum of the parts. Much is written about NCW and NEC, thus little is written in the following summaries, sufficing only to give an indication of the intent of the two initiatives. Realisation of NEC and NCW is a significant challenge, in that it requires the linkage of a large number of disparate datalinks, carrying different types of information with varying degrees of staleness. Furthermore various C2 software applications must also be linked, taking into account that data therein, and data from the various links, will sometimes place the same object in a different position. Thus timely data aggregation and consolidation must be performed in real time across a broad area, taking into account that the data may be inconsistent, i.e. conflicting in time, quality, position etc.

3.1.1 NCW

Network Centric Warfare is a US initiative aimed at improving and utilising information interoperability in wartime. Alberts [Alberts 2001] describes NCW as involving networking in three domains. In its fully mature form it possesses the following characteristics:

- Physical domain. All elements of the force are robustly networked, achieving secure and seamless connectivity and interoperability
- Information domain. The force has the capability to share, access and protect information to a degree that it can establish and maintain an information advantage over an adversary. The force has the capability to collaborate in the information domain, which enables a force to improve its information position through processes of correlation, fusion and analysis.
- Cognitive domain. The force has the capability to develop high quality awareness and share this awareness. The force has the capability to develop a shared understanding, including commanders' intent. The force has the capability to self-synchronise its operations. In addition, the force must be able to conduct information operations across these domains to achieve synchronised effects in each of the domains.

It may be appreciated from the above definitions that the concept of NCW will be significantly non-trivial to realise across the entire military infrastructure, which may comprise hundreds of thousands of 'units', from the tactical level (a platoon, or even one soldier) upwards. In an earlier publication Alberts [Alberts 1999] cites Metcalfe's Law, which states that the value of a network increases as the square of the number of nodes. Thus for ~ 10^5 nodes the network is of high value, but the implementation of NCW presents a significant challenge due to the number of communication paths.

3.1.2 NEC

Network Enabled capability (NEC) is now a familiar UK tenet (a web search produced 23,900 results, the first [MoD page http://www.mod.uk/issues/nec/] of which quoted the DCDS (EC) definition on 8 November 2001 as "*The ability to gather knowledge; to share it in a common and comprehensible form with our partners; to assess and refine it to turn into knowledge; to pass it to the people who need it in an edited, focussed form; and to do it in a timescale necessary to enable relevant decisions to be made in the most economic and efficient manner*"). A similar MoD site [MoD site, resources] provides a NEC working definition as "*Linking sensors, decision makers and weapon systems so that information can be translated into synchronised and overwhelming military effect at optimum tempo*".

Further quotes from the same reference encapsulate the official view as to what NEC will provide, viz:

"NEC allows platforms and C2 capabilities to exploit shared awareness and collaborative planning, to communicate and understand command intent, and to enable seamless battlespace management. It will underpin decision superiority and the delivery of rapid and synchronised effects in the joint and multinational battlespace."

Major General Rob Fulton
Capability Manager (Information Superiority)

30 April 2002

and

NEC *"encompasses the elements required to deliver controlled and precise military effect rapidly and reliably. At its heart are three elements: sensors (to gather information); a network (to fuse, communicate and exploit information); and strike assets to deliver military effect. The key is the ability to collect, fuse and disseminate accurate, timely and relevant information with much greater rapidity (sometimes only a matter of minutes or even in 'real time') to help provide a common understanding among commanders at all levels"* - Secretary of State for Defence, Strategic Defence Review, New Chapter, July 2002.

NEC shares the same tenets as NCW concerning robust networking, information sharing and improved synchronisation to improve mission effectiveness. However, NEC does not seek to place the network at the centre of capability in the same doctrinal way as NCW, it only has value when set in an operational context (i.e. it enables the work of others) and it is concerned with evolving capability through pragmatic steps towards a coherent framework.

In order to achieve a true NEC, the MoD must raise its profile and empower the NEC authority to be able to enforce, as well as observe and advise. In the meanwhile the UK's Niteworks programme is in the vanguard of demonstrating NEC viability and a way ahead. QinetiQ not only plays an important Niteworks role but the Targeting Group has approached its tactical data link work with awareness and due diligence to the tenets of the UK MoD's NEC. In particular, this has meant continuing to use one of the main datalinks accepted by the UK as being within the NEC policy, and working to integrate that datalink with other links and applications with which interoperability is a desirable requirement.

4.0 DATALINK INTEGRATION

In seeking to confine the IDM-associated TDL research to conform to the UK MoD's NEC principles it is essential to utilise the prescribed VMF protocol and to seek to improve interoperability with other in-service and de facto C2 and C4 applications. There follows a short description of two research items which exemplify this. The first describes data translation between two NEC-accepted links and the second describes datalink integration with a Command and Control system.

4.1 IDM / Link-16 Translation

Link-16 is a well established datalink, with greatly accepted operational utility, enabling a large network of users to exchange a variety of data in near-real-time in a secure fashion. Its capability to advertise the presence and position (Precise Participant Location Information – PPLI) of all users in the battle area is so well accepted that the US policy generally requires that if you do not have Link-16 you cannot join the party (battle). It does have negative aspects, particularly that it is heavy, large and expensive: it also requires careful use in a peacetime, training environment because the frequency spectrum within which it hops (960 – 1215 MHz) is shared by other critical air traffic equipment. Nevertheless, its benefits significantly outweigh its disadvantages and it is now operationally critical. However, this research has concentrated on the problem of getting targeting information, frequently from the ground, to the attacking aircraft. For this purpose no man-portable Link-16 terminal yet exists, nor is there any plan that UK FACs and Tactical Air Control Parties (TACPs) will be issued with them. This was a strong reason for choosing the IDM approach to digital air-to-ground targeting. Furthermore, at that time (1999) no UK front line ground attack aircraft was fitted with Link-16, nor was that likely to occur in the near future. In general IDM and Link-16 are complementary in their functionality and application.

Since both of the above links will exist operationally for many years to come, and since IDM-equipped aircraft are implicitly unable to transmit a Link-16 PPLI, QinetiQ undertook a programme to show the ability to translate between the two links in near real time. For that purpose a data translator was written to translate between various IDM-associated protocols (section 2.3 refers) and Link-16. In order to minimise the number of data conversions the translator used an intermediate data format, as shown in the schema of figure 5 and the equipment interconnection diagram of figure 6. It can be seen that this method, as employed with the four data protocols in figure 5, requires four back-and-forth conversions. If all translations were direct, the four protocols would have required six back-and-forth conversions. The addition of a further protocol requires just one additional back-and-forth conversion via an intermediate format, but four if translating directly. Furthermore, an intermediate format greatly eases the significant problem of the different data word definitions being different in the different protocols. The consequence of this is that data do not map one-for-one. For example, a single word 9-line brief IDM message requires four J-series Link-16 messages.

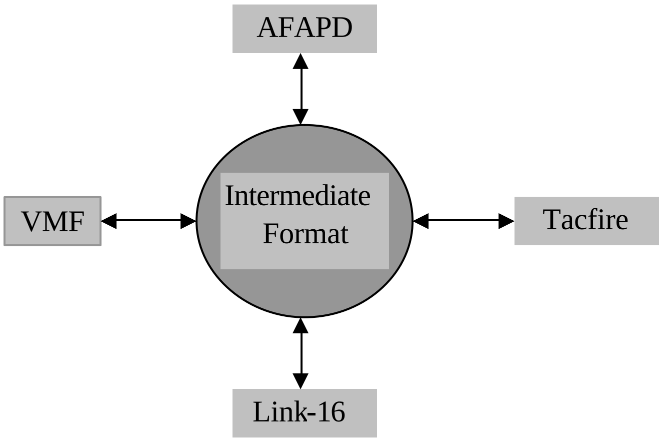

Figure 5: Selected Data Translation Schema

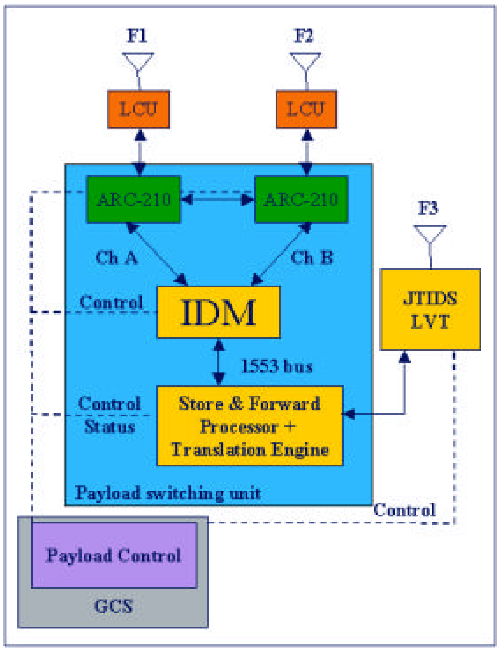

Figure 6: Data Translation Diagram

QinetiQ designed and flew a translator as shown above. It was designed to be flown in a Predator UAV, and the first two stages of the translator did indeed so fly in the USA. However, the third and final stage of the demonstration flying occurred after the September 11 terrorist attacks, with the result that a Predator was not available for demonstration/trials flying. Thus a cabin environment aircraft was secured for use at late notice, with the airborne translator payload nevertheless employed under ground control as if it were in a UAV. The payload is shown pictorially in figure 7.

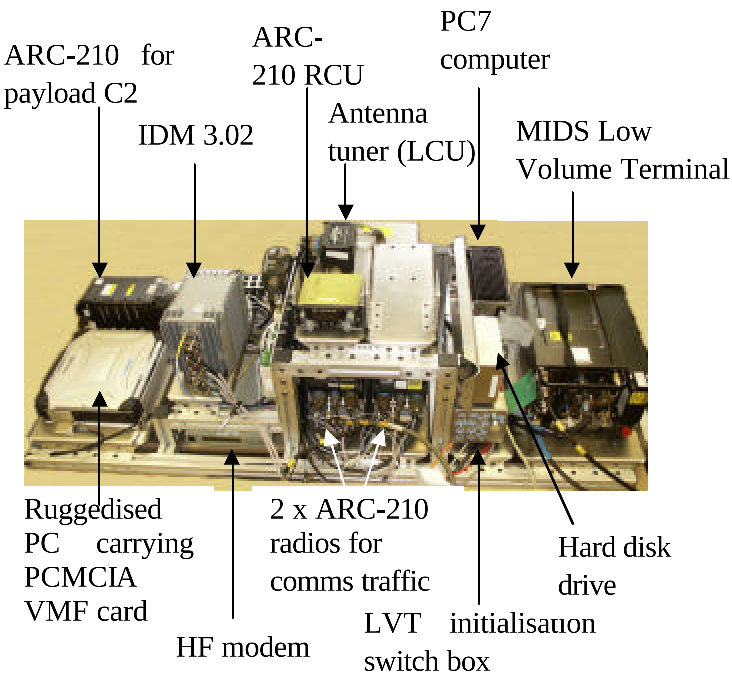

Figure 7: Photograph of Data Translation Payload

The trials flying was totally successful. Various data were translated in near real time with aircraft in flight. A UK fast jet and helicopter both transmitted their present position data via their radio and IDM. The in-flight data translator converted the IDM-originated position into a Link-16 PPLI message, so that the fast jet and helicopter became visible in the Link-16 Recognised Air Picture (RAP) and were seen by two cabin environment Link-16-equipped military aircraft.

Data translation as described is far from common place, but is becoming accepted as potentially operationally viable. Various translation engines are available in the USA and UK. The difficulty and skill lie not so much in the specific translation, although this is not easy (e.g. matching and compensating for time differences in the component input data required to formulate one translated output message); the primary issue to address is which data should be translated, and to whom the results should be transmitted.

4.2 Datalink Integration with a Command and Control Application

A significant problem which NEC and NCW aim to solve, or at least alleviate, is the issue of friendly fire. This is characterised as either wrongly explicitly targeting your own forces, or inflicting casualties due to collateral damage. It is, therefore, a good thing to improve Command and Control situational awareness by being able to view by all means possible the position of a requested 'target' with respect to ownforce disposition. Such integration is not novel. Nevertheless QinetiQ took a further step toward increasing situational awareness with a demonstration of the integration of a digital request for airborne fire (via a 9-line brief) with a generic Command and Control application. This laid a foundation and was a precursor to show the feasibility of further integration in which operational data could be integrated directly with Link-16-derived and IDM-derived data directly within an operationally-used C2 application. The initial work demonstrated an incremental step in both an air and ground capability.

4.2.1 Ground Integration

A demonstration was performed on the Salisbury Plain Training Area in late 2004. A C2 application was running, displaying blue force data which were being generated synthetically in real time, because in the short timescale of the programme it had proven to be not possible to acquire live blue force data (figure 8, Item 1). The data were stored on a server and accessed regularly by the C2 application. A digital 9-line brief was sent over the air from a FAC in precisely the same fashion as would be sent directly to a fast jet (figure 8, Item 2). However, in this case the 9-line brief was received over the air in the C2 control room, translated to the Extensible Markup Language (XML) and placed on the server (figure 8, Item 3). XML was chosen due to its general availability and acceptance and its being the format of choice in similar US work. The intention of XML is that it be easily useable over the internet (as is the more widely known HyperText Markup Language [HTML]), that it support a wide variety of applications and that it be compatible with the Standard Generalised Markup Language (SGML).

The server flagged to the C2 operator that new (target request) data had been received (figure 8, Item 4), and the operator then accessed the data and viewed the target in context with the blue force disposition. The operator could then either refuse the target strike request (if the target was co-located with, or close to, a blue force position) or sanction the request . This caused either an ‘Accept’ or ‘Reject’ message to be sent over the air to the FAC (figure 8, Item 5/6). If the request for a target strike was accepted, then the 9-line was sent over the air to a fast jet in the same format as that generated by the FAC originally. However, in addition to the 9-line brief, the C2 operator also sent the closest blue force locations over the air to the fast jet (figure 8, Item 6). The recipient of the 9-line brief, in this case a Harrier GR7, received the 9-line brief as he would have from a FAC. In addition his data receiver had been modified for this exercise in order to depict on a map the positions of the target and a number of blue force locations, as described in section 4.2.2.

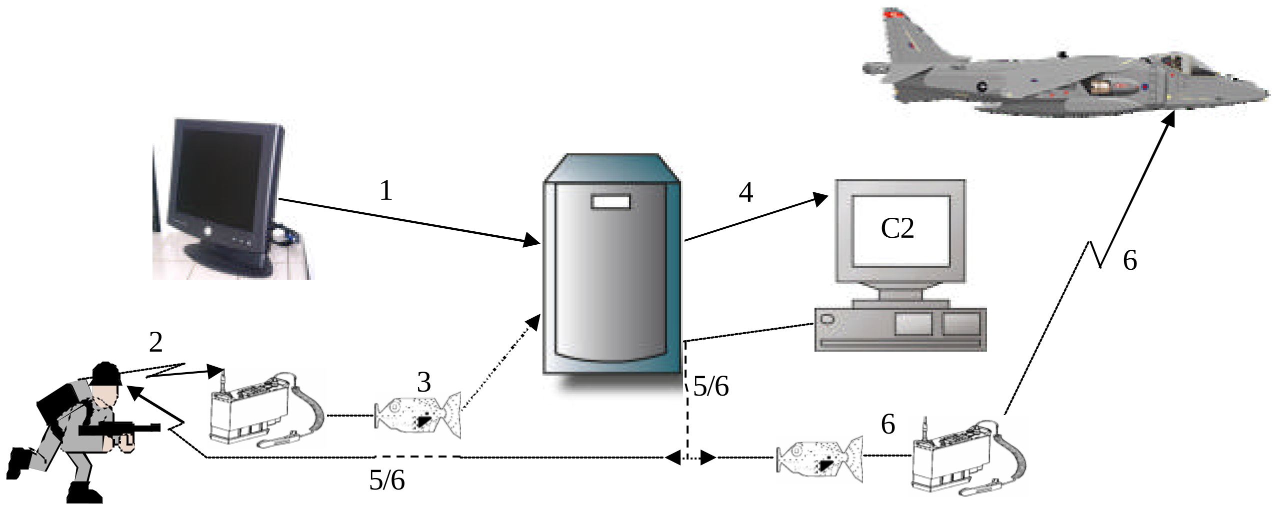

Figure 8: Datalink / C2 Application Data Flow

4.2.2 Aircraft Integration

The short timescale of the work dictated that the airborne equipment to be modified must be simple and self-contained – there was insufficient time to modify an aircraft datalink installation which was highly integrated with the rest of the aircraft avionics. Thus the Harrier iPAQ software was upgraded to receive blue force data and to display a map, with target and blue force coordinates overlaid. The received 9-line brief is shown in figure 9. The pilot need only then touch the screen to display the map (figure 10), centred on the target position (triangle) and showing the attack heading (east/west line to the right of the target) and blue force data (circles). For this demonstration alone the FAC position was depicted as the double circle to the North of the target. Finally, request from the Fast Jet and Weapons Operational Evaluation Unit pilot resulted in the display of a 1 km circle, centred on the target to enhance situational awareness.

Figure 9 : HTDR 9-line Display

Figure 10: HTDR Target Area Map Display

5.0 CONCLUSIONS

The work summarised herein has shown that it is possible to equip ground and air forces inexpensively with a standard datalink for the passage of targeting and positional data. The datalink is included in the UK's NEC policy.

It is possible to translate data in real time between disparate datalinks, which are included in the UK NEC policy. This holds promise for an NEC implementation, if the UK chooses to adopt it.

It is possible to integrate over-the-air data quickly with a Command and Control application via a standardised XML protocol which gives potential interoperability with US applications. This facilitates the reception and consolidation of over-the-air red and blue force data, leading to over-the-air transmission of a digital tasking to a 'shooter' showing local red and blue force disposition. This also holds promise for NEC application.

The above have been demonstrated with varying degrees of operational simplicity, i.e. few assets and little data. There is more work to be performed to render the above operationally applicable, but the concepts have been shown to be technically feasible.

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