Tactical Datalink: Enabling Effective Coordination Between Forward Air Controllers and Close Air Support

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***Abstract* — Enabling Forward Air Control (FAC) through the Tactical Data Link (TDL) is an essential capability in modern military operations, providing effective Close Air Support (CAS). The modern TDL-based FAC system can enable faster, more reliable, and more secure communication between pilots and ground forces. Moreover, it can enhance decision-making, situational awareness, and tactical planning and reduce the risk of friendly fire. However, implementing a TDL-based FAC is challenging and includes digitising the conventional voice-based CAS-FAC communication systems. This paper shares insights on the ongoing development and experiments with digitising the conventional voice-based FAC process using the Link-ZA TDL specification. The results indicate that this indigenous TDL can enable an effective TDL-based FAC with superior accuracy and shortened latency compared to voice. The study recommends developing TDL-based FAC using protocol gateway systems and digitisation decision considerations.**

Keywords— Forward Air Control (FAC), Close Air Support (CAS), Tactical Datalink (TDL), Link-ZA

I. Introduction

As a function of Command and Control (C2), effective coordination between the Forward Air Controller (FAC) and the Close Air Support (CAS) aircraft is a crucial factor in the successful execution of an air strike [1], as it requires both accurate and timely data exchange between the two forces to engage a target and prevent strikes on friendly troops and non-combatants [2],[3]. However, traditional CAS-FAC operations are based on voice communications and, therefore, susceptible to the inefficiencies of such a communication media [4][5].

These voice limitations lead to investigating the use of other media modes for CAS-FAC operations. For example, CAS-FAC operations experiment with Tactical Datalink (TDL) instead of voice [6] through digitising the CAS-FAC procedure from speech to data [7], using multimedia, including the exchange of imagery [8],[9]. [5]. These voice limitations lead to investigating the use of other media modes for CAS-FAC operations. For example, CAS-FAC operations experiment with Tactical Datalink (TDL) datalink instead of voice [6] through digitising the 9-Liner CAS-FAC procedure from speech to data [7], using multimedia, including the enhancing the exchange of use of UAVs and video imagery [8],[9] downlink streaming capabilities [10], [11].

Given the advent of new and emerging technologies that are predominantly data-driven [12], Defence must explore ways to leverage this potential. Some studies have employed simulation techniques to determine the effect of TDL-based CAS-FAC operations; Nevertheless, most of these investigations were based on TDL, such as the NATO tactical link, with Link-16 being the popular [13],[14]. However, NATO restricted access from specific nations to Link-16, prompting those countries to develop their TDL standard. As a result, the effect of using other TDLs for FAC to support CAS is to be further investigated.

The South African National Defence Force (SANDF) is also developing and using its own TDL for interoperability between its different arm services [15]. Moreover, through the Council for Scientific and Industrial Research (CSIR)[1], the SANDF is investigating the effective use of modern technologies to enhance its capabilities to execute CAS operations [16], including their use in CAS-FAC missions.

The study is an ongoing effort by the SANDF and the CSIR to develop and experiment with these TDL-based CAS-FAC capabilities for the SANDF to support these operations. In particular, the study shares insights into developing the TDL FAC system using Link-ZA specification. Accordingly, it intends to furnish Defence with recommendations on the feasibility of modern communication technologies in augmenting missions and operations.

The paper is structured as follows: it begins by describing the development of the TDL FAC system based on the Link-ZA protocol, followed by the experiment's material and methods. Subsequently, the results are presented, their significance is discussed, and concluding remarks are made.

[1] The CSIR is one of the leading scientific and technology research, development and implementation organisations in Africa. Constituted by an Act of Parliament in 1945 as a science council, the CSIR undertakes directed and multidisciplinary research, technological innovation as well as industrial and scientific development to improve the quality of life of the country's people. The CSIR is committed to supporting innovation in South Africa to improve national competitiveness in the global economy. Science and technology services and solutions are provided in support of various stakeholders, and opportunities are identified where new technologies can be further developed and exploited in the private and public sectors for commercial and social benefit. The CSIRs shareholder is the South African Parliament, held in proxy by the Minister of Science and Technology (www.csir.co.za).

II. DATALINK-BASED FAC USING GATEWAYS

As stated earlier, this study is an ongoing effort to establish datalink capability interoperability in the Defence [17]. Most of the studies focused on the tactical data of the datalink capability model. For example, some focused on the MAC protocol to enhance the transmission of imagery data [13], while others investigated the impact of different coding algorithms on the performance of the Link-16 waveform [18]. However, studies focused on the higher levels of the datalink capability model. For example, focusing on the impact of interoperability capability on Doctrinal processes [19]. This study focused on the information and application layer of the datalink capability model, particularly using protocol gateways [20].

Software-based gateways systems for integration and interoperability are gaining popularity [20]. As such, this experiment used a gateway system to facilitate the communication between the FAC and CAS. Fig. 1 shows the high level of the proposed datalink-enabled system. The FAC systems are comprised of hardware and software components; this includes the computer, the required applications, and the hardware to exchange the tactical over an RF link. The software implements one of the doctrines for the FAC, referred to as the CAS brief.

A. Equipment and Applications

The digital-aided CAS-FAC system can employ the following hardware equipment:

- Computer/Tablet (hardware)**:** A typical specification computer (laptop) used to run the required applications: FAC application, Gateway, and the Link Control System (used for radio interfaces).
- **Voice Communication Radio:** a voice communication radio to the CAS platform, used to convey tactical messages that were decided to remain on the voice channel
- **FAC (software):** The FAC application (user interface and backend processing) implements the 9-Line brief to automate the FAC process, thus enhancing communication efficiency, precision, and overall operational effectiveness.
- **Gateway-GW (software):** As such, the FAC system utilizes the services of specific gateway software services developed in-house for interoperability between the Link-ZA-compliant nodes [21].
- **RF System (hardware and software)**: A Link-ZA-compliant UHF radio used to exchange digitized tactical messages in the form of a 9-Line brief over the RF link. This equipment includes the *required* applications to program and configure the radio.
- **CAS Platform UHF radio:** A CAS platform or node fitted with the compatible Link-ZA radio to the FAC system. In addition to the compliant radio, this platform is equipped with a C2 application to compose, view and exchange Link-ZA tactical messages.

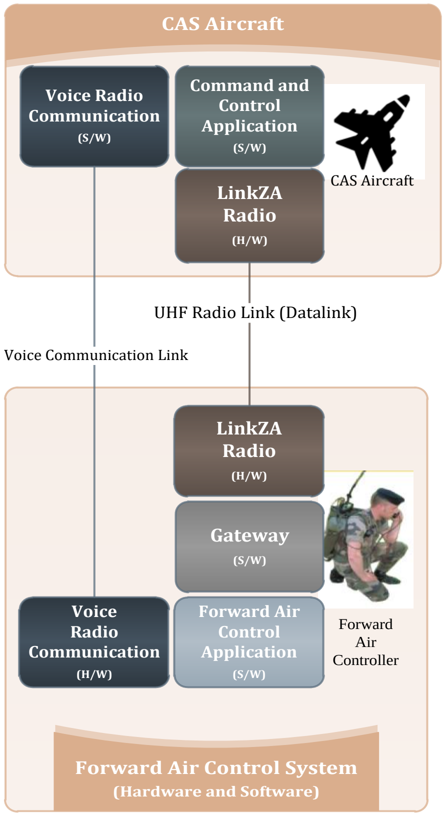


Fig. 1 Proposed datalink-based FAC.

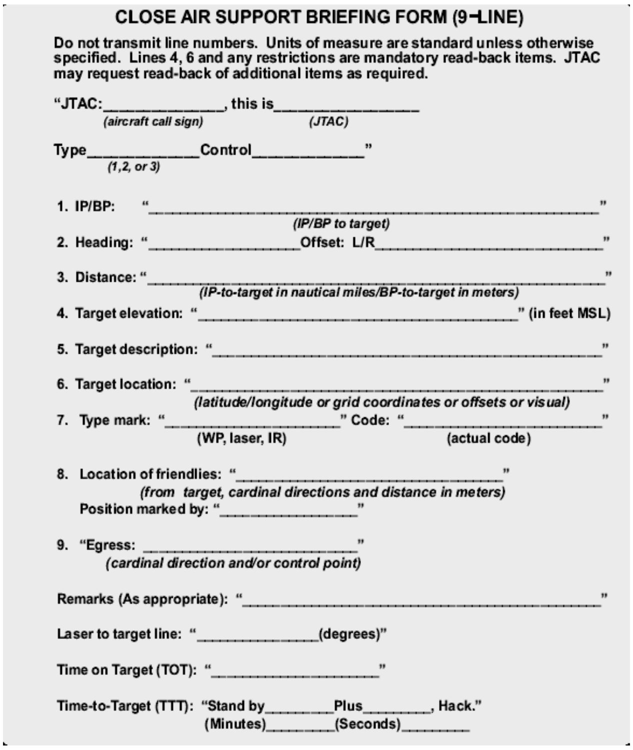
B. Standard CAS briefs

Standardised doctrines are already in place to ensure smooth communication between FAC and pilots and collaboration between various groups or nations, and there are also standardized CAS briefs to enable this. One of the reference points is the information and protocols or sets of instructions outlined in the US Department of Defense's "Joint Publication 3-09.3: Close Air Support (CAS)" for this very purpose [22]. This guide specifies different CAS briefs that can be used for various scenarios, including a 9-Line and 5-Line CAS Brief used for FAC. These briefs are detailed blueprints to pinpoint target engagement, protect innocent lives, and boost teamwork between ground and air crews [6], [22].

i. 9-Line CAS brief

In today's warfare, it's imperative to have clear communication between soldiers on the ground and aircraft in the sky. One tool that helps with this is the 9-Line CAS Brief. These are set of instructions for support from the air. Different countries might use slightly different versions, but for our study, we used the version commonly used in the US, known as the JTAC version [23].

This 9-Line brief has nine main points (hence the name). It details where friendly soldiers are, the target, which weapon to use, when to attack, and where the allied forces are. The idea is to give pilots all the information needed to carry out their missions without accidentally harming their forces [6], [22],


CLOSE AIR SUPPORT BRIEFING FORM (9-LINE)

Do not transmit line numbers. Units of measure are standard unless otherwise specified. Lines 4, 6 and any restrictions are mandatory read-back items. JTAC may request read-back of additional items as required.

"JTAC:__________, this is__________
(aircraft call sign) (JTAC)

Type__________Control__________"
(1,2, or 3)

1. IP/BP: "__________" (IP/BP to target)
2. Heading: "__________Offset: L/R__________"
3. Distance: "__________" (IP-to-target in nautical miles/BP-to-target in meters)
4. Target elevation: "__________" (in feet MSL)
5. Target description: "__________"
6. Target location: "__________" (latitude/longitude or grid coordinates or offsets or visual)
7. Type mark: "__________" Code: "__________" (WP, laser, IR) (actual code)
8. Location of friendlies: "__________" (from target, cardinal directions and distance in meters)
   Position marked by: "__________"
9. "Egress: __________" (cardinal direction and/or control point)

Remarks (As appropriate): "__________"

Laser to target line: "__________(degrees)"

Time on Target (TOT): "__________"

Time-to-Target (TTT): "Stand by______Plus______, Hack."
(Minutes)______(Seconds)______

Fig. 2 Example of a 9-Line CAS brief form [22]

i. The 5-line CAS brief

Every mission is unique, as are the tools and briefs tailored for them. For example, there's the Close Combat Attack (CCA) brief, one that can aid in more than one situation. This can be seen in the Rotary-Wing Close Air Support 5-Line Brief or the 5-Line LASER CAS Brief, a variant of the CCA brief. There are cases where the 9-Line CAS brief may not be used, like in the case of the 5-Line LASER CAS Brief where it is used exclusively for missions involving laser-guided support from aircraft. This brief narrows the essentials into five clear points, giving pilots a concise rundown: the exact location of the target, who is operating the laser, and the type of assistance required.

Compared to the 9-Line brief, one of its main benefits is its concise nature, ensuring faster communication in time-sensitive situations. However, it's crucial to understand that transmitting this brief isn't the same as giving a pilot the go-ahead to take action. The clearance to fire or engage remains a separate command, ensuring checks and balances are in place for operational safety [23].

III. EXPERIMENT

As stated herein, the experiment's objectives were to assess the feasibility of Link-ZA to enable datalink-based FAC in terms of data exchanged accuracy and acceptable latency for CAS-FAC operations. However, the Link-ZA protocol comprised hundreds of messages, therefore; the messages were grouped into specific categories based on their purpose and media type:

- **Free Text**: a free and unstructured message used to send a text message
- **Own Position**: structure message used to send FAC position to the CAS pilot node, and vice versa
- **Target Allocation**: structured messages that are used to send target location information to the CAS pilot
- **Image**: structured messages used to send images and related information to the CAS pilot and vice versa.

Experiments were conducted in a laboratory setting. These experiments were centred on developing, integrating and testing the FAC application using the Link-ZA viewer simulator simulating the aircraft platform. The main objective of the research was to evaluate the feasibility of the Link-ZA datalink-based FAC for CAS operations and test multiple configurations or mappings of the 9-Line CAS brief into Link-ZA messages. Some configurations send the 9-Line brief as a Link-ZA image, sending it as multiple and different Link-ZA messages or as a combination. Specific simulation scenarios were devised and carried out, influenced by the detailed doctrine outlined in the references [22]. It's important to highlight that, even within the datalink transmission mode, some parameters or brief lines were still transmitted over the voice channel; this concept is detailed further in this document.

A. Data Transfer and Accuracy Test

This test assessed the accuracy of exchanged tactical data messages between the FAC and the CAS pilot node. In other words, to determine the error rate through manual verification methods.

For datalink, this coordinated effort was achieved by compiling and sending (receiving), through the FAC application, pre-defined tactical messages to the CAS pilot over the RF link. Upon receiving the tactical messages, the CAS pilot would then compare the received tactical messages with the expected ones (pre-defined). For voice, using the same message parameters for comparison, this was conducted using the onboard voice communication radios to send the tactical messages using voice, and the receiving pilot compared the received message from voice with the expected one. In both cases, the number of times an error was observed or a message different from the expected was received was recorded.

B. Data exchange latency Test

This test aimed to assess the latency experienced during tactical data exchange. To determine the duration for the CAS pilot node to receive the complete message. This procedure also factored in the number of re-transmission requests for comparison purposes, particularly in the voice exchange.

For both voice and datalink, using the same pre-defined tactical messages and parameters as in the accuracy test, this test was achieved by manually timing the message exchange, i.e., from when the message is sent to when the CAS pilot node entirely receives the message. This procedure also factored in the number of re-transmissions due to incomplete message parameters on the receiving node.

C. Digitized FAC Messages

For this experiment, we focused on the 9-Line CAS brief because by addressing it, the results can be used as a benchmark to achieve the same results on the other related CAS briefs, such as those related to the CCA brief.

To minimize disruptions in the execution of the 9-Line procedure, and after conceptual considerations, it was decided to select 9-Line message parameters to digitize, i.e., to retain others on voice. These message parameters were selected based on various factors, including impact, criticality, and update rates.

For example, one of the crucial factors of the 9-Line brief exchange process is the initial authentication between the pilot and the FAC. This interaction serves as a verification step between the two parties. However, this is traditionally a routine verbal. Therefore, it was decided to retain the traditional voice execution. Moreover, this ensures that authentication is between humans and not an automated system, such as a bot. This approach also ensured that we re-used the effective parts of voice communications and minimized the training requirements for the CAS pilots when migrating to a datalink (hybrid) FAC operation.

IV. RESULTS

A. Data Transfer and Accuracy results

The results data exchanged accuracy test are presented in detail in Table 1. Both voice and datalink procedures could transmit the tactical messages defined in the 9-Line brief. However, compared to voice, the datalink transmitted the messages accurately without re-transmission requests. Moreover, using the datalink, image messages were also transmitted. The latter was also used to send the entire 9-Line brief as an image to the CAS pilot node, reducing the number of transmissions to one.

TABLE 1
EXCHANGED MESSAGES ACCURACY TEST RESULTS

Exchanged messages from the FAC to the CAS Pilot		
Message Category	***Voice***	***Datalink***
Free text messages	✓	✓
Own Position messages	✓	✓
Surface Track Messages	✓	✓
Target Allocation	✓	✓
Image (not part of the 9-Line CAS brief form)	N/A	✓

The FAC could receive continuous situational tactical messages from the assigned CAS simulated aircraft node using the datalink. This is an improvement on the FAC processes as it allows the FAC to do calculations based on in-time information received from the platform. The messages are the platform's status and own position. This capability is not possible with voice. This capability of receiving updated data from the aircraft simulated platform contributes towards a complete and accurate situational awareness for both FAC on the ground and the airborne CAS pilot. Fig. 3 shows a snapshot from the FAC application, depicting the FAC personnel, CAS aircraft and target locations.

B. Data exchange latency results

Through the gateway, the FAC application proved highly efficient in providing time-sensitive tactical messages (Location-based) within the required updates rate. These update rates depend on various factors, including the display options in the CAS aircraft cockpit, the experience, and the pilot's ability to process data accurately and expeditiously. The benefit of employing a software-based FAC is that it enables this required update rate to be easily configured on demand.

Fig. 3 CAS-FAC situational awareness picture displayed on the FAC application (displayed: FAC, CAS aircraft and the target locations)

C. Selective Digitization and Data Mapping

The results and observation of executing the previous tests also indicated that the conceptually selected 9-Line brief message parameters to digitize contributed to not only the accuracy of the digitized process but also to minimizing disruption in the execution of the process. In other words, the digitized parameters ran in the background and in an automated manner, requiring minimum effort from the FAC.

TABLE 2
9-LINE BRIEF SELECTIVE DIGITIZATION DESIGN DECISIONS

#	Selective digitization of the 9-Line brief (main parameters)		
	9-Line brief	***Datalink***	***Voice***
0	Type and Control	X	
1	IP/BP	X	
2	Heading	X	
3	Distance	X	
4	Target Elevation	X	
5	Target Description		X
6	Target Location	X	
7	Type Mark	X	
8	Location of friendlies	X	
9	Egress	X	

From the table above, only the target description line of the brief is left on voice. This is due to the sensitivity and importance of its content, and it is so to ensure clarity and immediate feedback, which will ensure mutual understanding and reduce misinterpretation. The exact reasons were applied in deciding to leave the remarks on voice, as in Table 3.

TABLE 3
9-LINE BRIEF SELECTIVE DIGITIZATION (REMARKS)

Selective digitization of the 9-Line brief *Remarks* parameters		
9-Line brief Remarks	***Datalink***	***Voice***
Remarks (As Appropriate)		X

Selective digitization of the 9-Line brief *Remarks* parameters		
9-Line brief Remarks	***Datalink***	***Voice***
Laser-to-Target line (LTL) – in degrees and magnetic	X	
Time-on-Target (TOT).	X	
Time-to-Target (TTT).	X	

The selective digitization approach allowed for real-time and in-time data exchange. This feature was instrumental in offering automatic recalculations, which proved to be critical in the timely detection of potential threats like those associated with the "danger close". While such alerts still require voice communication for effective communication, their detection was automated, further emphasizing the importance of merging digital and voice communication in enhancing the effectiveness of the overall FAC process.

D. *Different Configurations*

Since the experiments were conducted using different configurations, it is important to highlight the observations made, particularly comparing the implications of using a Link-ZA image to transmit the 9-Line CAS brief and using multiple Link-ZA messages to do the same. Some of the noticeable advantages of transmitting the 9-Line CAS brief as an image are as follows:

- **Integrity of Information**: An image preserved the spatial arrangement and relationship between the brief lines. This ensured that the CAS pilot node saw the information in its original format.
- **Efficiency**: Sending a single compressed image was faster and more efficient than sending multiple text messages at a specific interval.
- **Simplicity**: One image proved to avoid the potential of missing one of the individual messages or having them arrive out of sequence, which may be due to transmission delays.
- **Context**: Visually presenting the entire 9-Line CAS brief allowed for an immediate understanding of the complete information without waiting for all separate messages to arrive sequentially.

However, the transmission of an image alone did not significantly improve the whole FAC process compared to using multiple Link-ZA messages. The CAS pilot node still has to manually extract the information and plot them on their respective on-board display system. However, sending the brief lines individually using the tactical datalink allowed the simulated onboard systems to assign the data for the CAS pilot node automatically.

V. Discussion

The results of the experiments indicate that the proposed datalink-based CAS-FAC system can augment and enhance the traditional non-integrated, voice-based approach.

A. *Link-ZA as an enabler for datalink-based CAS-FAC*

The Link-ZA communication can be an enabler of datalink-based capabilities. The experiment demonstrated the feasibility of employing a datalink-based system based on the Link-ZA communication protocol to support CAS-FAC operations. The performance of the proposed Link-ZA-based datalink CAS-FAC system is comparable to that of the Link-16-based systems [16],[17], with acceptable transmission latency and accuracy for such operations. [16], [17], with acceptable transmission latency and accuracy for such operations. Moreover, using a datalink for FAC operations provides additional data to enrich the situational awareness picture, such as the passive CAS aircraft statutes and position, exchanging images and related data. This further emphasises Link-ZA's need and potential to enable or transit other ineffective voice or analogue systems to the efficient and accurate datalink mode of data exchange.

B. *Interoperability of CAS-FAC using gateways*

The Link-ZA protocol can also enable a connected and integrated C2 deployment. Software-based gateways are the preferred approach [25], allowing flexibility to share tactical data with C2 nodes (other than the CAS-FAC pair). These results also mean that the Link-ZA protocol, implemented through the gateway, can enable a network-centric C2 deployment, including many data sources, enriching the data quality for informed decision-making. In addition, the locally developed gateway enables sharing tactical data to the legacy, non-digital platforms, as it contains the necessary translation modules, ensuring an up-to-date situational awareness picture. Moreover, the gateways enable sharing of other media types, such as video and data, and can easily integrate into modern, high-performance commercial systems.

C. *Selective digitization of the CAS-FAC process*

While the presented multimedia CAS-FAC system performed better than the conventional voice-only system, the results also indicate that not all the steps/activities should be digitised. In other words, some of the 9-Liner activities [7], the FAC process, should either remain on voice or use both voice and data. This observation suggests that when digitising systems, an assessment of the impact of such an activity should be investigated. For instance, a risk-based approach can determine the elements or activities to digitise while ensuring that the doctrine supports them.

D. *Limitations and Future Research*

Although the study contributes to digital transformation capabilities in Defence, it has limitations. The experiment was conducted with a Link-ZA-compliant platform, which might have different link synchronization requirements. However, this implies that the FAC application must be tested on different Link-ZA platforms to ensure it can be easily configured to accommodate them. To achieve the best results, more work can be done on improving the configuration or mapping of the 9-Line CAS brief to tactical data messages. The tests might look at options such as sending the track message parts of the brief lines individually and a Link-ZA image instead of multiple text messages at an interval. This will require a radio channel that supports both the transmission of image data and time-sensitive data like the track messages on the same channel or the use of multiple radio devices in parallel.

VI. Conclusion

The recent military conflict has highlighted the importance of military capability development sovereignty, and South Africa is no exemption. This study shared insights into the ongoing development of a digitally aided FAC system using a specific datalink to support CAS operations. In particular, the data-exchange process using the Link-ZA communication protocol. It demonstrated and highlighted that Link-ZA can be an enabler for datalink CAS-FAC operations, using protocol gateways and selective digitization of the FAC process.

This research aid in the understanding of using TDLs to modernise the conventional, sometimes analogue or voice capabilities in the Defence. In other words, it contributes to the transformation of Defence capabilities towards the modern, digital, and interconnected capabilities brought by technological advancement. For example, selective digitization suggests a digitization strategy or an approach.

While the results and observations from this experiment significantly contribute to the understanding of tactical datalinks in the Defence context, the experiment focused on a single and proprietary link, Link-ZA. Therefore, the results do not apply to other links, such as Link-16. However, this limitation is also the identified gap in the literature, i.e., most of the studies are based on Link-16.

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