Human Factors in Combat ID – An International Research Perspective [1]

Julie Gadsden – UK MOD Defence Science and Technology Laboratory
David Krause – Defence Science and Technology Organisation, Australia
Murray Dixson – Canadian Forces Experimentation Centre
Larry Lewis – Joint Center for OA, US Joint Forces Command

Abstract

The Technical Cooperation Program (TTCP) has recently completed a multi-national (Australia, Canada, UK, US) Action Group study of fratricide mitigation. Amongst its findings were that the human factors portion of the possible solution space is the least understood but could offer significant cost/benefit. This led to the recommendation that the TTCP nations should increase the level of investment in Human Factors R&D with attention to studies involving:

a. Human decision making and support;
b. The factors affecting preconceived notions of the area of operations;
c. The factors affecting environment and target perception;
d. The effects of morale on combat effectiveness and friendly fire;
e. Human-machine interfaces.

This paper describes the work of the TTCP Action Group, with particular emphasis on the human factors issues. An outline of the recent and current research programme in the UK addressing some of these issues for Combat ID is also provided.

Introduction

Fratricide has been a reality of war for most recorded battles through history. Historically, it has received relatively little attention, since it was considered to be a largely unavoidable cost of fighting wars. The 1991 Gulf War changed that. The remarkably low number of combat casualties, combined with the perceived high proportion of fratricides and a conflict characterised by 'high-tech' or near 'Star Wars' weapons, got people's attention. Fratricide became a high profile issue that was of concern to individual soldiers and national policy makers alike. After similar attention to fratricide after Operation Iraqi Freedom/TELIC, the Technical Cooperation Program (TTCP) took note of this trend and established an 'Action Group' to examine the problem.

The Action Group was established by TTCP's Joint Systems and Analysis Group and included participation by Canada (chair), Australia, UK and US[2]. Its mandate was to provide a broad appreciation of the issues related to the mitigation of fratricide. This included an examination of the trends in fratricide over the period from the first Gulf War to the present and an effort to extrapolate those trends into the future, accounting for the possible effect of network enabled operations (NEO) capabilities. The AG was asked to postulate approaches that could or should be taken to mitigate such fratricide without negatively impacting on mission success or overall casualty rates. The AG13 mandate also included a 'look ahead'

[1] This paper summarises elements of the work of TTCP Joint Systems and Analysis Action Group 13 on Fratricide Mitigation. The AG13 final report (reference 1) and supporting working papers are available to TTCP participating nations via the lead author.

[2] The authors of this paper are the AG13 National Leads. New Zealand did not participate in AG13.

with suggestions for how the TTCP nations should progress the fratricide mitigation issue in terms of future R&D activities and opportunities for collaborative projects.

This paper takes as its theme the human factors issues of Combat ID, derived from the work of AG13 and related analyses conducted in the UK. It starts with some definitions and an outline of the operational context of fratricide based on the analyses conducted by AG13. The historical record of fratricide is considered, including results from the examination of UK Board of Inquiry reports. This is followed by AG13's findings relating to the human factors aspects of Combat ID, including those concerning R&D. Finally, some UK research activities addressing human factors issues for the Combat ID programme are outlined.

Definitions

The three core components of Combat ID are generally accepted by the TTCP nations as being:

1. **Situational Awareness** (SA);
2. technologies which enable the 'shooter' to identify battlefield entities (**Target ID**); and
3. the **Tactics, Techniques and Procedures** (TTPs) which support the Combat ID concepts.

Training is a component of all of these elements, although it is often regarded colloquially as an element of TTPs.

Whilst the title of the Action Group was 'Fratricide Mitigation', all the Action Group participating nations recognise that Combat ID is essentially about operational effectiveness, and the goal of improving combat and mission effectiveness cannot be compromised by the implementation of solutions which aim to reduce friendly fire.

Operational Context

An important context for the Action Group was that today's forces almost always operate within a Coalition environment. Such an environment brings together disparate weapons, platforms and communications equipment, and variations in Rules Of Engagement (ROEs), procedures, training and experience levels, languages, cultural understandings and beliefs. These challenges unfold as being detrimental to combat effectiveness, and indeed are often the root cause of fratricidal incidents involving multinational forces.

Within this context, AG13's work was undertaken to assess where the fratricide issue stands within the TTCP countries. The following findings of the Action Group are of particular note:

- Since the first Gulf War, rates of fratricide have remained roughly the same, at between about 10% and 20% of total combat deaths.
- Broad programmes of R&D covering the three components of Combat ID are in place amongst the TTCP countries but, to date, comparatively few friendly fire mitigation solutions have been fielded. This tends to be due to the problems of delivering compatible solutions across Coalition partners and the affordability of technological solutions. There are variable levels of R&D effort expended against these components but the bulk of the activity has been focussed on technological solutions for Target ID and SA.
- Solutions have been proposed for all Combat ID operational environments but with varying levels of success. Most effort is focussed on the priority areas of ground-to-ground and air-to-ground where fratricide has occurred most frequently.
- Current Combat ID systems that are fielded or are being considered for acquisition are primarily cooperative systems. Non-cooperative systems are now being assessed for their possible utility in operations. They have the advantage of the potential ability to identify enemy and neutrals as well as friends.

- To complement technical solutions, the analysis of friendly fire events indicates that development and adoption by coalition partners of standardized TTPs, Standard Operating Procedures (SOPs) and ROEs, combined with better joint and coalition training, is likely to be the best way to reduce the risk of friendly fire in the short term and is a key component of longer term solutions.
- It is recognized that solutions to friendly fire will require a system of systems approach that must include technology, human factors, TTPs and organisations, with their interactions, as core elements.
- It is AG13's assessment that the human factors portion of the possible solution space is the least understood but could offer significant cost/benefit.
- There are indications that if the principles of NEO are implemented properly (no easy task) then that should result in a reduced risk of friendly fire through improving situational awareness. However, to achieve this, NEO implementation must incorporate lessons learned from operations, to ensure that the right forces get the right information at the right time.

A theme running through the work of AG13 is the importance of human factors in both the root causes of fratricides as well as its mitigating strategies, and yet the AG found that this area was both the least well understood and lacking in significant and coordinated R&D investment in the participating nations.

The Historical Record of Fratricide

Validation of the 10%-20% figure quoted above can be provided by examination of the numbers of fratricides as a proportion of total casualties in recent major combat operations:

- **Operation Desert Storm / GRANBY** (17 January – 28 February 1991):
  - US: 148 total combat deaths, 38 fratricide (26%)
  - UK: 47 total combat deaths, 9 fratricide (19%).
- **Operation Enduring Freedom / HERRICK** (from start of hostilities to 30 April 2002):
  - US: 23 total combat deaths, 4 fratricide (17%)
  - UK: zero combat deaths, zero fratricide.
- **Operation Iraqi Freedom / TELIC** (20 March – 1 May 2003):
  - US: 109 total combat deaths, 19 fratricide (17%)
  - UK: 14 total combat deaths, 6 fratricide (43%).

The figure of 43% for UK fratricides in Operation TELIC is of note because it falls well outside the estimates of 10% to 20%. This range was initially established based on earlier wars, notably World War II, Korea and Vietnam. In those cases, the enemy was considerably more effective than in Iraq. The low military effectiveness of the Iraqi forces during TELIC (as measured by their ability to inflict casualties on coalition forces), combined with the fact that the initial UK involvement was a "relief in place" operation following the US assault, resulted, to some extent, in the low total numbers of UK fatalities. These low numbers lead to a high percentage due to fratricides. Operations GRANBY and TELIC were both characterised by an unexpectedly ineffective enemy (and so low casualties due to enemy action) but incurred expected levels of friendly fire in terms of numbers per military unit per day. These combine to generate fratricide percentages that are higher in relative terms.

Examination of friendly fire data from the three recent operations in Iraq and Afghanistan leads to the following conclusions:

a) The contribution of friendly fire to overall combat deaths was similar in all three operations, with an average of 21% of UK and US combat deaths being a result of friendly fire.
b) The nature of friendly fire incidents was different in the three operations, reflecting differences in the operations themselves:
   - not all friendly fire situations are equal: the environment of a friendly fire event strongly affected the average number of 'killed in action' per incident. On average,

fixed wing air-to-ground incidents tended to produce more fatalities per event than other kinds of incidents;
- by contrast, the number of 'wounded in action' from each incident was independent of the environment;
- although it might be more common in warfighting, friendly fire is still a danger in stability and counter-insurgency operations.

c) In both Operation Desert Storm/GRANBY and Operation Iraqi Freedom/TELIC, UK friendly fire casualties were dominated by US fire (not surprising given that most close air support is provided by the US); most casualties were due to air-to-ground incidents. Barring a significant change in how UK ground forces are employed within a Coalition, this trend could be expected in future operations.

From the human factors perspective, the following recommendations arising from this examination of incidents are of particular note:

- The US should ensure that its ongoing Combat ID efforts include an improved ability to identify ground forces. Note that the emphasis on battlefield entity recognition training for the US stems entirely from the fact that it is US forces who provide the vast majority of air cover in Coalition operations.
- Both UK and US forces would benefit from combined training that reflects the way they expect to operate together in the air-to-ground environment, with a focus on avoiding the occurrence of friendly fire events.
- Attention should be paid in training to adherence to established doctrine and procedures. A common factor in many fratricide incidents is a failure to do this.

UK Analyses of Board of Inquiry Reports[3]

Examination of unclassified reports of fratricide incidents (such as those described in the introduction to reference 2) shows that each incident has a wide range of underlying causes, and that there are similarities in the causes across the different incidents. Whilst technology problems do feature, many causes come from other Defence Lines of Development[4]. Reference 2 discusses the similarities to Professor James Reason's work on safety-critical systems (reference 3), which provides a useful analogy for understanding the failures which lead to fratricide events.

The UK-US analysis discussed earlier examined the trends across a wide range of incidents. In contrast, complementary analysis in the UK has examined a small number of incidents in detail, through an examination of the Board of Inquiry reports, in order to identify causal factors. The aim of this work was:
"to investigate historical causes of fratricide and identify the key causes and contributing factors in order to formulate recommendations for reducing their likelihood in the future and for improved representation of such causal factors in representational models".
The analysis was based on detailed case studies, using a structured approach to the analysis of the data. The intent was to identify key factors which were cited as contributing factors to the incidents, to identify trends and patterns, and to make recommendations about how things could be improved.

[3] This section of the paper is based on work conducted by Claire Outteridge et al, QinetiQ, UK (reference 2). Reference 2 also includes some descriptions of fratricide incidents at the unclassified level and an analysis of their root causes.
[4] The UK Defence Lines of Development are: Training, Equipment, Personnel, Information, Concepts & Doctrine, Organisation, Infrastructure, and Logistics.

Ten fratricide incidents were examined in detail from:

- Operation GRANBY (US Operation Desert Storm) – 1991
- Operation PROVIDE COMFORT (humanitarian aid in northern Iraq) – 1994
- Operation TELIC (US Operation Iraqi Freedom) – 2002/2003.

These incidents were selected on the basis of the detail and reliability of the information sources available. Usually only Board of Inquiry reports will provide sufficient detail.

The analysis of causal factors was based on a categorisation schema developed in earlier work, which had been reviewed by an international workshop as part of the AG13 study. The Fratricide Causal Analysis Schema is a simple structure consisting of 12 high-level causal categories. Each main category is then broken down into associated sub-categories. The high-level causal categories are failures in the areas listed in Table 1. The full schema is shown at Annex A.

Command and control	Pre-deployment preparation
Procedures	Team work
Equipment/technology	Environmental factors
Situational awareness	Communications/information
Misidentification	Platform configuration
Physical/physiological factors	Cognitive factors

Table 1: Causal categories for failures leading to fratricide incidents (top level of the Fratricide Causal Analysis Schema)

This schema provides a consistent approach to analysing fratricide incidents which allows identification of root causes of incidents, and comparison of root causes across incidents. In order to determine the primary causes of any incident it is essential to explore the causal chain of events leading up to the incident. Root causes often originate from decisions made at the higher organisational level. Also, in many cases, errors prior to the actual engagement remain latent and then a later event combines with the latent error to turn it into an active error. There can be a tendency to take too "local and narrow" a view of root causes, and only to consider the direct immediate causes of the event.

Analysis of the chains of events leading to the 10 fratricide incidents, using the described schema, led to the following categorisation of root causes.

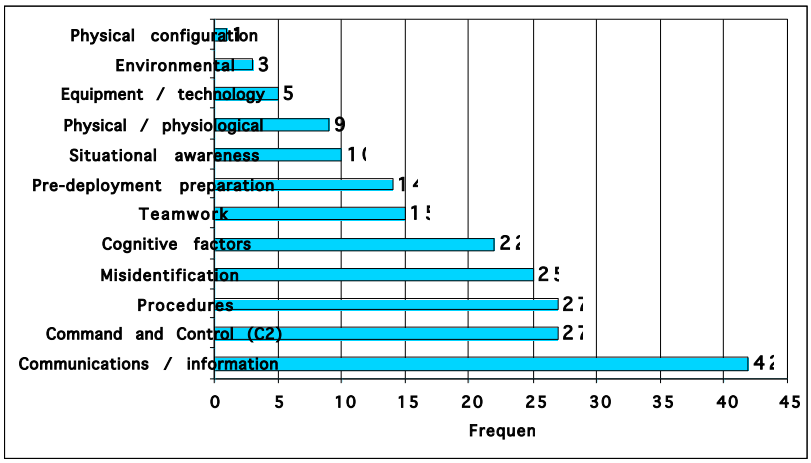

Table 2: Prevalence of causal categories in the sample fratricide incidents[5]

[5] Note that the Communications/Information category does *not* include the equipment or technology aspects, being more concerned with information presentation and procedural issues. Note also that the classification schema includes a high-level category for "situational awareness". In many cases the team found that, although a factor might have contributed ultimately to the development of poor

From these data, and noting that the Communications/Information category is not concerned with technology issues, we can see that the common causes of fratricide are often non-technological in nature, and this indicates the prevalence of human factors issues. The majority of all of the 57 sub-categories in the Fratricide Causal Analysis Schema (see Annex A) were identified across the sample of 10 incidents. The full results of the analysis are documented in reference 4.

AG13 Workstreams

The TTCP JSA AG13 study was divided up into a number of workstreams:

- **Historical Record**: The role of the historical record in understanding fratricide;
- **Mission/Force Effectiveness**: Analysis of the impact upon mission and combat effectiveness of the employment of strategies for fratricide mitigation;
- **Network Enabled Operations/Capabilities**: Analysis of the implications for friendly fire when operating in a network-enabled environment, with examples from current operations;
- **Research and Development**: Analysis of the nations' respective friendly fire related R&D programs, with identification of synergies, gaps and collaborative opportunities;
- **Solutions**: Overview of the nations' current Combat ID solution strategies.

AG13 Conclusions and Recommendations – Human Factors Perspective

Human factors issues arose throughout the work of the AG13 workstreams. The R&D Workstream (reference 5) attempted to produce a snapshot of research in the participating nations, including human factors work, but this proved to be a daunting task. The US R&D programme in particular was considered to be so wide ranging, and conducted by such a broad range of Government and private organisations, that AG13 was not able to gauge the full scope of activity in the human factors area, nor that of work aimed at improved TTPs and training. However, within the bounds of these constraints, AG13 identified the following outstanding issues for R&D in order to promote greater understanding of the human dimension of Combat ID:

- Understanding the human decision-making process.
- Understanding the factors that affect a person's trust in other people and in technology.
- Identifying the key information elements necessary to conduct mission tasks.
- The optimal employment of humans and technology to distribute information and to enable the understanding of circumstances.
- The influence of culture on human behaviour as individuals and in teams.
- The need for learning to keep up with rapid change.

The full set of AG13 conclusions and recommendations is provided in reference 1. Within this list of recommendations the following were identified as particularly relevant to human factors issues within Combat ID, including those stemming from the detailed findings from the R&D workstream.

<u>AG13 Human Factors Recommendations – Operational Capability</u>:

1. Solutions must be developed with a system-of-systems point of view (recognising that the human is a key part of the system).
2. The need for integrated and interoperable solutions should continue to be emphasised, including those involving technologies and TTPs.

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situational awareness, it was often more appropriate to assign the issue to a lower-level category, such as "information sharing, or "coordination". As a result, the frequency analysis appears to indicate that poor situational awareness is less of a significant factor than it actually is.

3. Better training is a potential major contributor to the reduction of friendly fire risk. Training might be improved by:
   a. Wider use of modelling and simulation and distributed synthetic environments to improve the awareness of friendly fire issues and mitigation strategies.
   b. Development and further evolution of platform recognition training systems.
4. Improved training strategies should be adopted (with respect to Combat ID solutions), along with refined TTPs, standardisation or harmonisation of Coalition SOPs, and enforcement of Coalition ROEs.
5. Updated and improved training of operational personnel on new systems and employment strategies should be emphasised. Use the training to build trust in the systems and procedures.
6. The opportunities for inclusion of Combat ID objectives within coalition exercises should be increased.

AG13 Human Factors Recommendations – R&D:

1. R&D must take account of the fact that Combat ID / friendly fire solutions lie both within and across the domains of Target ID, SA and TTPs.
2. A more integrated approach is needed to R&D in human factors and technology solutions.
3. Focussed research is needed in understanding human decision making in complex and stressful situations. Some specific areas for investigation include:
   a. Human decision making/support.
   b. Factors influencing preconceived notions of the area of operations.
   c. Factors that affect perceptions of the environment and targets.
   d. The effect of morale on combat effectiveness and friendly fire.
   e. Human-machine interface principles and design.
4. Collaborative research programmes should be initiated to improve modelling approaches – in particular the human component – thus improving ability to generate the required metrics.

It was also felt that much could be achieved by collaboration across nations and sharing of research results in these important areas.

The UK MOD Combat ID Human Factors R&D Programme

Efforts have been made over recent years in the UK to promote the establishment of a focused and coherent research programme on human factors issues for Combat ID, and to ensure that this is closely integrated with the wider MOD Combat ID research and analysis programme. In the past there has been a tendency to compartmentalise human factors research rather than see it as an essential component of the 'mainstream' research programme aimed at providing insights and information to those responsible for making investment decisions. This trend appears to be diminishing, but pressures on R&D budgets continue to result in human factors research sometimes being seen as a "nice to have", when set against the research in technologies.

The aggregated results of a series of operational studies have recently confirmed the importance of Training and TTPs in improving UK's Combat ID capability. The following requirements were noted as of particular importance:

- Development of coherence between UK and Coalition (particularly US) TTPs and training;
- Joint and coalition training opportunities for UK personnel engaged in delivery and planning of Close Air Support.
- Recognition training for Forward Air Controllers (FACs) and pilots using images from different sensors in different environmental conditions.
- Training for FACs in the use of Link 16 and how their data may be exploited by others.
- Where high-latency SA systems are necessarily employed, development of pragmatic TTPs and training for their use.

Some high impact research work on HF within the Combat ID context has been done in UK in recent years. The key piece of research which has underpinned, shaped and informed the programme was on "Reducing the Risk of 'Friendly Fire' and Civilian Harm: a Human Factors Perspective" (reference 6) by Outteridge et al. The aim of this work, in the wake of the series of fratricide incidents in 2003, was to develop an improved understanding of the human factors which gave rise to friendly fire events. Recurring patterns were identified, including common causes and contributing conditions. Draft training aides were developed aimed at enhancing awareness of the causes of fratricide; these included a Fratricide Briefing Pack, an anti-fratricide aide-mémoire and a Fratricide Incident Causality Checklist. The Causality Checklist has since been developed into the Fratricide Causal Analysis Schema discussed earlier in this paper (see Annex A), which has been used extensively in subsequent work, both in the UK and under TTCP. Follow-on work (reference 7) in 2004 developed the suite of aide-mémoires to meet the needs of different arms, services and roles. A framework for Combat ID training, applicable to different services, was developed, and the existing Briefing Packs were enhanced, identifying how they could be exploited in military training.

In 2006 an opportunity arose to examine the detailed records of UK Boards of Inquiry for a range of fratricide incidents, to explore the underlying causality (reference 4), particularly from a human factors perspective. This work has been described earlier in this paper. The Causal Analysis Schema, developed from the Fratricide Causality Checklist, was used as an analysis tool to categorise the root causes. Also in 2006 a scoping study was initiated to examine what needed to be done for TTPs and training to support the introduction of Combat ID capability (reference 8). This identified the potential key issues and challenges associated with the introduction of a Combat ID capability and made initial recommendations for enhancing training to address these issues. Unfortunately, funding constraints meant that this work could not be progressed, but the aspiration to do so remains.

A further thrust in human factors work has been that associated with the need for a Joint Recognition Trainer system. Reference 9 developed a draft set of user requirements for a recognition training system and sought evidence to show the linkage between recognition training and operational effectiveness. The report concluded that, although a number of laboratory studies have shown that recognition training increases recognition skills when pre- and post-training tests are conducted, a more difficult question is how well this skill translates into operational benefit. Attempts to ascertain any improvement in combat effectiveness through live training exercises are often hampered by small subject group sizes. This study noted that recognition training based on detailed feature recognition of static images may not be the best approach to teaching advanced recognition skills. Research has continued with a pedagogical study (reference 10) which has assessed how recognition tasks are carried out, with some limited trials conducted with an eye tracker to confirm the findings. The study assessed current recognition training and drew conclusions about shortcomings in the methods used. The study also made recommendations on how recognition training could be improved, both in the short and longer term.

Given the importance to the UK MOD of making balance of investment decisions across the three components of Combat ID (Situational Awareness, Target ID, and TTPs), work started in 2004 to develop a model of the Combat ID process which could be used to support such decisions. The INtegrative Combat ID Entity Relationship (INCIDER) model (reference 11) represents a wide range of factors which impact on the ability to effectively identify entities in the battlespace. The key innovative feature of this model is that it represents human factors alongside operational and physical factors (see illustration at Annex B). Human factors represented include pre-set characteristics (such as training and experience) and variable characteristics (such as stress, fatigue and fear), as well as the impact of expectation and pre-mission briefings. Validation of the human factors aspects of this model is being conducted using a series of synthetic environment experiments (references 12 and 13).

In a further piece of current research, interviews are being conducted with UK aircrew and Forward Air Controllers to derive a detailed understanding of the underlying elements that affect operators' decisions when involved in making decisions on weapons release in current air-to-ground operations. This information will be used to both inform and advise on 'quick wins' and longer-term solutions to help mitigate fratricide and to improve weapons release decisions within the currently operational arena.

Finally, work is underway to determine the extent to which data from synthetic training environments can be used to identify, measure and inform users of friendly fire and 'near miss' incidents based on the factors listed in the Categorisation Schema.

In addition to these research activities, UK has been actively involved in the Coalition Combat ID ACTD series of exercises (URGENT QUEST in 2005 and BOLD QUEST in 2007) and has attempted to draw conclusions from these exercises about the operational employment of new technologies as well as the performance of the technologies themselves. Exploitation of such opportunities is key to developing better understanding of how military personnel make targeting decisions in operations, and thus to delivering effective UK, and wider Coalition, Combat ID capability.

Conclusions

This paper has described work conducted under TTCP by Canada, Australia, UK and US on issues and approaches for fratricide mitigation, with particular reference to the human issues. The UK past and current research programme focused on human factors issues for Combat ID has been described. Both the international and the UK research have indicated the importance of human factors in understanding the root causes of fratricide, in introducing mitigating strategies, and in enabling effective targeting.

Acknowledgements

Many researchers in all four participating TTCP nations have been involved in the work reported in this paper, but particular thanks must go to Claire Outteridge of QinetiQ who has led much of the seminal human factors work on this subject in the UK, to the benefit of her fellow researchers and, far more importantly, of UK military forces.

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* The marked reports are available to TTCP participating nations via the lead author of this paper.

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Annex A – Fratricide Causal Analysis Schema

Command and Control (C2)
Commander's intent
Orders
Briefing
Planning
Co-ordination
Disruption of C2

Procedures
Standard Operating Procedures (SOPs)
Rules of Engagement (ROEs)
Fire control and discipline procedures
Doctrine
Navigation

Communications/information
Information presentation
Communication procedures
Communication failures
Language barriers
Information quantity
Information gathering
Information reliability
Information sharing
Auditory overload

Pre-deployment preparation
Rehearsals
Training

Misidentification
Physical features of target
Target recognition training
Combat Identification measures
Actions of target
Restricted vision

Cognitive factors
Decision making
Workload
Expectancy bias
Attention
Risk assessment

Physical/physiological
Fatigue
Stress
Anxiety
Confusion
Fear
Arousal

Equipment/technology
Equipment failure
Weapons handling error
Weapons misuse
Trust and reliance on technology
Communications equipment
Technology misuse

Environmental
Extreme engagement ranges
Weather conditions
Terrain
Time of day

Teamwork
Teamwork behaviours
Roles and responsibilities
Degree of distribution
Shared history
Leadership
Organisational relationships

Situational awareness
Individual
Shared

Platform configuration
Layout of platforms

Annex B – The INtegrative Combat ID Entity Relationship Model (INCIDER)