Characterisation of Combat Identification Technologies

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Abstract—Network centric warfare combines sensors, communications, and computation systems with tactics, techniques and procedures to provide battlespace awareness. An element of this awareness is the ability to identify friendly combat entities, known as Combat Identification (CID). This paper describes current technologies used in combat identification and defines technology groups that will play a role in both current and future CID implementation.

Index Terms—Military information systems, Command and control systems, Identification of persons, Object recognition

I. INTRODUCTION

This paper presents an initial characterisation of technologies relevant to the development of improved Combat Identification (CID) capabilities for the Australian Defence Force (ADF), particularly for operations in the land environment.

To simplify analysis of the large number (in excess of 25) of technologies identified as potentially-relevant to CID, the technologies were grouped as follows:

- Group 1 – Passive signalling devices.
- Group 2 – Active signalling devices.
- Group 3 – Interrogation / response systems.
- Group 4 – Situational Awareness (SA) systems.
- Group 5 – Recognition training systems.
- Group 6 – Emerging technologies.

The grouping scheme used was informed by previous work undertaken in this area [2].

The candidate technologies considered in this study include all known CID-related technologies including Combat Identification Panels (CIPs), Thermal Identification Panels (TIPs), Infrared (IR) spectrum encoded flasher lights (Phoenix Lights), IR-reflective tape (Glo-tape), radar beacons, Radio Frequency (RF) tags, Radio-Based Combat Identification (RBCI), Battlefield Target Identification Device (BTID), Dismounted Soldier Identification Device (DSID), Optical Combat Identification System (O-CIDS), Identify Friend-or-Foe (IFF), and Battle Management Systems (BMS) aimed at improving situational awareness at the tactical level.

Also considered are various other technologies that may, in time, have some CID-related utility. This includes mature technologies currently used for other purposes, such as Automatic Dependant Surveillance-Broadcast (ADS-B), and emerging technologies, such as micro-electromechanical systems (MEMS), nanotechnology and biomimetics.

Each CID technology is characterised in terms of target cooperation, warning method, operating spectrum, effective range, power consumption, life-span, applicable platforms, employed role, environmental constraints, and costing data.

Each candidate technology is also assigned a technological maturity in accordance with the newly-introduced Australian Defence Department Technology Readiness Level (TRL) scale [3] to support ongoing risk assessment by the Defence Science and Technology Organisation (DSTO). The assignment considers both the ‘standalone’ readiness of the technology and the technology readiness of a system which incorporated this technology for CID purposes. This is necessary because, for example, whereas certain Radio-Frequency Tags (RF Tags) could be considered reasonably mature in their own right, their use in a CID system involving aircraft radar systems recognising the tag signals and displaying CID data to the aircrew is still a considerable way from operational fielding and is thus not as mature.

Due to the human-centric nature of CID, and hence the importance of understanding the interplay of each technology with people, the human issues associated with CID are also explored. This supports subsequent assessment of the Human Systems Integration (HSI) advantages and disadvantages of each technology, and how each technology contributes to situational awareness using Endsley’s definitions [4].

II. Fratricide, CID and the Human Dimension

A. Fratricide

Fratricide is 'the employment of … weapons and munitions with the intent to kill the enemy … that results in unforeseen and unintentional death or injury to friendly personnel' [5]. Since the Vietnam War, Australian forces have recorded no fratricidal events; however, the risk to Australian forces participating in coalition operations is considered to be increasing due to a variety of factors [6].

B. Combat Identification Elements

CID is widely considered to comprise three elements, with Tactics, Techniques and Procedures (TTPs) providing the human aspects binding Situational Awareness (SA) and Target Identification (Tgt ID) technologies.

TTPs are composed of the doctrinal concepts that units apply in combat (tactics), the tactics for small units applied in specific circumstances (techniques), and the courses of action describing specific tasks (procedures) [7]. TTPs, doctrine, and Rules of Engagement (ROE) contribute substantially in guiding the human decision-making in CID.

There have been many attempts to define SA with perhaps the most useful one-sentence definition coming from Endsley – 'The perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and projection of their status in the near future' [8].

Tgt ID is an ambiguous term that refers to the 'technologies enabling real-time feedback from potential targets' [9] and the 'process for determining the friendly, enemy, or neutral character of a detected person or objects' [10]. The reason the term is ambiguous is that it is more commonly used to provide a binary target engagement decision ('shoot / do not shoot') rather than identification of the various entities that may be encountered on the battlefield, such as civilian non-combatants or personnel or vehicles from non-government organisations. In many cases, the 'Tgt ID' solution only provides positive identification of friends, and so using this term suggests that any non-positive identification must be an enemy [11].

C. The Human Dimension

Incorrect CID, and in the worst consequence, fratricide, rarely occurs solely as a result of technology failure. This is the case even when systems are highly automated, such as when the United States Navy warship *USS Vincennes* shot down an Iranian commercial airliner in 1988. Analogous events in the civil arena include the serious safety breaches at the Three Mile Island and Chernobyl nuclear power plants.

In both Persian Gulf wars and in Afghanistan, although aircraft were fitted with co-operative CID systems, there were still instances of fratricide (for example, see [12]). Investigation of accidents and safety incidents invariably identifies a human factor [13]: Humans invent, design and build the technology, and develop and apply the TTPs and doctrine.

The United States Army human factors program (Manpower-Personnel Integration – MANPRINT) was developed to manage the reality of accelerating technology and the increasing complexity of human-machine interaction. MANPRINT encompasses seven domains [14]:

- Manpower,
- Personnel,
- Training,
- Human factors engineering,
- System safety,
- Health hazards, and
- Soldier survivability.

Consideration of the MANPRINT domains in potential application of the various CID technologies identifies a number of issues and risks in each case; however, significant limitations in our understanding of how these technologies interact with humans remain.

Firstly, some technologies are relatively new, or, at least, their use in CID applications is new. Consequently, human performance with these is poorly understood and further experimentation, trials and measurement are needed.

Secondly, and more problematically, our understanding of the nature of interactions between CID technologies and humans in the complex and rapidly changing modern battlespace is hampered by uncertainty about the future vertical and horizontal integration of CID technologies and other combat systems, both within the ADF land (Army) environment and across the ADF air and maritime (Joint) and multinational (Combined) environments.

III. Technology Groups

A. Group 1 – Passive Signalling Devices

Passive signalling devices enable CID of friendly units without any action or response by the person or platform carrying the device. The technologies in this group include:

- Infrared paint and tape,
- Identification panels, and
- Smoke markers.

Infrared paint and tape are visible through both Image Intensification (II) and Thermal Imaging (TI) equipment. The nature of paint and tape provides flexibility of application and being relatively inexpensive, use is widespread. II reflective tape is seen as a bright spot when illuminated whereas TI reflective tape is white or black when viewed through TI sensors.

There are two types of identification panels: the combat identification panel (CIP) and the thermal identification panel (TIP). Both are flat or Venetian-style rectangular panels of either cloth 'day-glo' fabric or low emissivity thermal tape, with the key difference being end-use: Combat identification panels are primarily used for ground-to-ground identification while thermal identification panels are primarily used for air-to-ground identification.

Smoke flares and smoke grenades come in a variety of colours and can be used to mask the exact location of people and equipment to frustrate enemy targeting and also provide an identification marker for friendly forces out to a range of a few kilometres. However, smoke is only useful as a screening tool on calm, clear days in a relatively clear battlefield environment.

B. Group 2 – Active Signalling Devices

Active signalling devices 'emit electromagnetic energy to facilitate SA' [15]. The technologies contained in this group include:

- Infrared beacons (such as infrared strobes or infrared-encoded spectrum flashers),
- Chemical lights (in infrared and visible range), and
- Reflective signalling devices that use a third-party source of energy (the Sun).

Infrared beacons, also called infrared strobes or infrared-encoded spectrum flashers, use infrared light to emit a signal that can be viewed through night vision equipment at ranges of 10 kilometres or more. Some IR beacons emit a flash at a constant rate while others can be coded in the field.

Chemical lights come in a variety of visible colours and infrared spectrum. The infrared chemical lights are visible through night vision equipment. The different colours provide the ability to reduce the risk of compromise.

Signalling devices reflect light from a mirror or a highly polished metal surface and can be seen further than 20 kilometres. They are used by aiming the signalling device at the sun and then tilting toward the direction required for the signal.

C. Group 3 – Interrogation / Response Systems

Interrogation / response systems enable positive identification through 'the process of query and response' [16]. The technologies in this group include:

- Radio Frequency identification tags (RF tags),
- Radar Beacons (RACONs),
- Battlefield Target Identification Devices (BTIDs),
- Individual Combat Identification Devices (ICIDs),
- Optical combat identification devices (such as O-CIDS),
- Identify Friend or Foe (IFF) / Secondary Surveillance Radar (SSR) systems,
- Radio Based Combat Identification (RBCI), and
- Automatic Dependant Surveillance-Broadcast (ADS-B).

Radio Frequency Identification technology, implemented as RF tags, uses wireless radio communications to automatically identify objects or people without the need for line-of-sight or contact. Further, an RF tag can also operate as a data carrier, where information can be written to the tag. RF tags can be passive, semi-passive, or active.

Radar beacons, also called radar transponders or radar transponder beacons, typically operate at X-Band (I/J-Band) as navigational aids and to identify landmarks on a radar display. The radar beacon is an interrogator / transponder system where the beacon is the transponder and the radar is the interrogator. Some operate over the S-Band. The display of the beacon on the radar is stronger than a normal return with a length corresponding to a few miles encoded as a Morse character.

Battlefield Target Identification Devices are secure millimetre-wave combat identification systems conforming to North Atlantic Treaty Organisation (NATO) Standardisation Agreement (STANAG) 4579. The devices are interrogator / transponder systems that can identify a friendly vehicle within five kilometres.

The Individual Combat Identification Device, formerly known as Combat Identification for the Dismounted Soldier (CIDDS), is a US military program of activities to develop an interrogator / transponder package for individual soldiers. ICID employs a directional laser interrogation query and a secure omni-directional radio transponder response integrated into the weapon and helmet respectively. Some components of this development program were rolled into the US Land Warrior development program while others remain within ICID.

The Optical Combat Identification System (O-CIDS) is an example of the Optical Combat Identification Device technology family. O-CIDS is an interrogator / transponder system intended to be used for positive identification of soldiers, vehicles, and aircraft. O-CIDS uses a pulse code modulated eye-safe laser to interrogate targets. A friendly response is composed of a retro-reflected portion of the interrogating laser pulses. O-CIDS claims a correct identification probability of greater than 99% and range performance with obscurants that exceed those identified by NATO STANAG 4579 and target ranging beyond 10 kilometres.

The Identify Friend or Foe system, known in the civilian world as the Secondary Surveillance Radar, is a widely-used radar beacon interrogator / transponder system that uses 1030 MHz for interrogation and 1090 MHz for reply. Additionally, the system operates in a variety of modes for both civilian and military uses. The system provides automatic interrogation and response for ships and stations to determine details about an incoming aircraft. Operational modes 1 and 2 are reserved for military mission and personal data. Mode 3/A is the standard air traffic control mode and used in conjunction with Mode C, providing automatic altitude reporting, to control air traffic. Mode 4 is a secure channel for military use. Further modes are being developed, such as Mode S, providing unique addresses for more than 16 million aircraft in a control zone, and Mode 5, intending to provide combat identification data in addition to Global Navigation Satellite System (GNSS) position reporting.

Radio Based Combat Identification is an interrogator / transponder 'implemented as a software package applied to software defined radios' [17] on current-generation radios such as the Single Channel Ground and Airborne Radio System (SINCGARS) and future generation radio, such as the Joint Tactical Radio Systems (JTRS).

Automatic Dependant Surveillance-Broadcast is similar to SSR in that aircraft and vehicles transmit their positions in a standard navigational format. ADS-B equipped vehicles broadcast their satellite-based position across a digital datalink to provide low-altitude and ground situational awareness where conventional radar is hampered. Additional data can be included in the automatic broadcast, including airspeed, altitude, manoeuvring information, and other telemetry data. The data is updated and broadcast several times a second.

D. *Group 4 – Situational Awareness (SA) Systems*

Situational awareness systems ensure timely dissemination of the 'operating picture', including combat identification information, across the combat force. These systems are built as systems of systems using a variety of identification technologies integrated through TTPs and provided to users in a suitable format. Many of these systems display near-real time location and command and control information on a digital map.

The key operational difference between SA systems and all Tgt ID technologies is information latency: Whereas the latter typically provides near-immediate CID feedback directly from the potential target, SA systems typically suffer from a 'lag' such that the reported position of an entity may be several minutes out of date.

The specific systems described in this group as examples of SA technologies include:

- Blue Force Tracking (BFT),
- Joint Blue Force Situational Awareness (JBFSA) program, and
- Battlefield Command Support System (BCSS).

A variety of other systems exist, both under development and on the market.

Blue Force Tracking is a satellite-based tracking and communications system adapted from commercial use that interfaces with US Force Battle Command Brigade and Below (FBCB2) system. BFT aims to enhance own-force ('blue') situational awareness, facilitate command and control and assist with airspace deconfliction.

BFT user positions are automatically updated by satellite at user-defined intervals and BFT users can track other BFT-enabled platforms on a computer screen. The system architecture is distributed and independent of organisational structure. BFT also provides an alternative over-the-horizon communications capability through the provision of text messaging between BFT nodes.

Planning is also enhanced through the use of digital map overlays to identify a variety of graphical controls, such as pickup and landing zones, flight corridors, restricted operating zones, and fire support coordination measures.

During recent operations in Iraq, the US Army issued BFT to both the Australian and British Army units to improve coalition interoperability.

The Joint Blue Force Situational Awareness Advanced Concept Technology Demonstration (ACTD) is a US program to develop situational awareness systems that provide an accurate user-defined common operating picture, and the manipulation of data between strategic, operational and tactical levels. The JBFSA technology demonstration program intends to use current SA systems and technologies to enhance own-force situational awareness, including logistics and asset tracking.

Battlefield Command Support System (BCSS) is an Australian Army system intended to support brigade and below command and control as follows:

- Battle-map SA, including GPS based positioning.
- Terrain analysis, both two and three dimensional.
- Structured messaging over a variety of in-service high and low capacity communications links.

BCSS is built on modified off-the-shelf technology and integrates a range of specialist applications.

BCSS continues to be progressively fielded and improved through an on-going 'spiral' development activity [18]. BCSS saw active service in East Timor in the late 1990s.

E. *Group 5 – Recognition Training Systems (RTS)*

Recognition training systems aim to increase the ability of soldiers and, in some cases, aircrew, to recognise potential targets through visible, thermal, and other observation systems. These systems are most often used for training of personnel before battle; however, some are now being adapted for use in the field. Although RTS have been classified separately from the SA systems, the real effect is that soldiers gaining proficiency through recognition training systems develop level 1 SA that is 'embedded' in their mental models. This situation somewhat blurs the distinction between the effects generated through RTS and the effects generated through SA systems when the operating environment is complex terrain. The technologies (systems) identified in this group include:

- 'Insight',
- Recognition of Combat Vehicles (ROC-V), and
- Combat Identification Training System (CITS).

'Insight' is a British family of software tools and relational databases to train personnel in identification of air, land, and sea platforms. The system may be linked to a range of additional databases to provide visual training across a variety of disciplines from explosive ordnance disposal to economic exclusion zone vessel tracking.

Recognition of Combat Vehicles is a US military software application that trains personnel in the identification of US and allied combat vehicles. A key feature of ROC-V is the presentation of vehicle signatures though a range of in-service visual and thermal weapon sights. The ROC-V system also trains the soldier in how to use the thermal sensor image controls to find targets and enhance their thermal identification signatures.

The Combat Identification Training System is a NATO initiative to develop and deploy a web-based vehicle recognition training system. Contributing nations provide standard image formats of vehicles for inclusion. The system will be employed under the US-led multinational Coalition CID (CCID) ACTD program to train participants to recognise 'friendly' platforms prior to the Military Utility Assessment (MUA) activity scheduled for September 2005.

F. Group 6 – Emerging Technologies

Group 6 technologies are those still emerging from the laboratory that, later rather than sooner, could have a role to play in CID. None are being developed specifically for CID purposes; however, they all show some promise for employment in a CID role. The technologies contained in this group include:

- Visualisation technologies,
- Image recognition techniques and technologies,
- Micro-electromechanical systems (MEMS),
- Nanotechnology, and
- Biomimetics.

The impact of Biomimetic and nanotechnology on all aspects of weapon and equipment will be considerable and likely to surpass any other developments. Some Group 6 technologies are already in limited development. As these technologies evolve they will likely be gradually assimilated into military forces in a variety of ways.

IV. CONCLUSIONS

A. Adversary Technology / Capability Threat

The threat posed by adversary technology or capability can vary across potential future theatres of operations. The threat posed by an enemy to the disruption of CID capability is reliant on whether the difference in technology is great or small. For example, if the enemy does not have night vision equipment, then group 1 and 2 technologies would suffice for the bulk of CID in the land environment, especially when working within land forces and air-to-ground CID capability is not needed.

With increased adversary technology or capability there is a higher likelihood of detection, interception and 'spoofing' (mimicking) of CID signals. For a low-technology adversary, the detection and interception of interrogation / response systems would be difficult. These same systems may become seriously disrupted or ineffective given a high-technology adversary and a dense electronic warfare environment. On the other hand, low-technology CID solutions may provide an easy way for the adversary to mimic friendly CID patterns, while interrogation / response systems provide additional safeguards.

B. Environmental Constraints

Environmental constraints are a key factor in assessing the suitability of the various CID technologies. Foliage, dust, humidity and battlefield obscurants need to be considered as these may have detrimental technical and operational effects; for example, long-wave IR systems are severely degraded by humidity. Further, environmental aspects may also play a role in the interpretation of the result displayed or the systems used for displaying the results.

C. Power Requirements

Power requirements are one of the major constraints in deploying CID technologies to soldiers due to the weight of batteries and the need for the logistics system to continually provide them. In the case of vehicle-mounted systems, the problem is eased if the fitted CID systems draw power from the vehicle electrics.

With the exception of the IR flashers, the CID technology groups 1 and 2 do not require power for operation, other than the power requirements for viewing devices. These viewers are already fielded and, hence, fielding of group 1 and 2 technologies would likely not impact battlefield power requirements. In all other cases, power is required.

D. Platform Applicability

The applicable platforms for each identified technology are soldiers, vehicles, aircraft, ships, and boats. Very few technologies claim to cover the scope of platforms required for the complex future warfighting environment. Those few that do offer the promise of multi-platform applicability, specifically RF tags and RBCI, are the subject of ongoing development programs.

E. Human Factors

Present CID technology contributes almost exclusively to Level 1 and Level 2 SA, according to Endsley's levels:

- **Level 1** – Perception of the elements in the environment.
- **Level 2** – Comprehension of the current situation based on the synthesis of disjointed Level 1 elements.
- **Level 3** – Projection of future status through knowledge of the status and dynamics of the elements (Level 1) and a comprehension of the situation (Level 2).

This means that the various technologies aid in perceiving cues to the presence of an item of interest, such as a person, combat vehicle, aircraft, or ship.

Some of the systems are passive, such as aids fitted to soldiers or vehicles to indicate to an observer that they are friendly, that is, not a target. Some are external to the soldiers and vehicles and interrogate platforms or collect data from other systems to actively cooperate in understanding whether or not it is a friendly vehicle. If a system cannot 'see' a recognisable pattern then it cannot discriminate if the potential target is an undifferentiated friendly, enemy or non-combatant.

F. Technology Incompatibility

Each technology was assessed against each technology to see whether they can be used together or separately as a system. If the systems cannot be used either together or separately as a system without interfering with each other, they are incompatible. If there is no apparent incompatibility, they are marked as compatible. Where there is the potential for incompatibility, they are identified as having a potential for incompatibilities.

There are many technologies within groups that potentially interfere with other technologies in those same groups. Generally, technologies across groups do not pose much interference. There are no confirmed incompatibilities between technologies; however, several of the radio frequency technologies may be incompatible when further analysis is performed, specifically with respect to frequency clashes and coalition jamming activities.

APPENDIX – TECHNOLOGY CHARACTERISATION DATASHEET

The focus of the research underpinning this paper was the creation of standardised datasheets for each CID technology considered. Analysis made at individual technology level is provided in datasheet format, with a summary for each group provided separately.

Characteristic	Value or description
Technical characteristics	
CID element addressed	Which of the three elements of CID (TTP, SA or Tgt ID) the technology addresses.
Role	Role that the technology is, or would be, employed in: Ground-to-air, Air-to-ground, or Ground-to-ground.
Applicable platforms	Applicable platforms for the technology, such as aircraft, armoured vehicles, soldiers, etc.
Effective range	Effective operating range of the technology.
Operating spectrum	Operating spectrum of the technology, such as RF, laser, visible, infrared, audible, etc. Where available, operating frequencies or wavelengths have been noted.
Power consumption	Power consumption of the technology.
Life-span	Life-span of the technology in terms of material degradation, battery life or other limits on life-span.
Target cooperation	Whether or not operation depends on active cooperation by the would-be target, such as retransmitting a signal, to support identification as a 'friendly'. Characteristic is either 'cooperative' or 'non-cooperative'.
Warning method	Method by which the CID information is communicated to the operator or user.
Environmental constraints	Environmental constraints, such as bad weather, daylight or humidity.
Costing data	Known costing data related to the technology.
Human Systems Integration	
HSI advantages	HSI advantages of the technology.
HSI disadvantages	HSI disadvantages of the technology.
Endsley SA Level	Endsley SA level.
Technology readiness	
Assessed technology TRL	Assessed 'standalone' TRL for the technology.
Rationale for technology TRL	Rationale for the assessed 'standalone' TRL.
Assessed system TRL	Assessed TRL for a CID system based on the technology.
Rationale for system TRL	Rationale for the assessed system TRL.

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