# Challenges and Opportunities Associated with University Collaboration in Electronic-Warfare Research

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***Abstract*—Collaboration between defence forces, defence industry and universities is becoming ever more important in the field of electronic warfare (EW). EW deals with operations the electromagnetic spectrum (EMS), and as such, covers an extremely broad range of technologies. This observation, coupled with the extremely rapid advances in commercial uses of the EMS, means that it is no longer possible for defence forces and defence industries to adequately monitor developments in all technologies relevant to EW. University researchers play a major role in driving new EMS technologies, so collaboration with university researchers is thus essential to remain abreast of trends which affect EW. However, the different roles of defence forces, defence industry and universities lead to a number of potential obstacles to achieving meaningful collaboration. This paper reviews some of these challenges, makes suggestions as to how they can be overcome, and highlights some successful examples from around the world.**

***Keywords*—Collaboration, research and development, research initiatives, electronic warfare (EW), and defence industry.**

## I. Introduction

Electronic warfare (EW) is an increasingly important capability within defence forces as a result of the dramatic increase in the use of the electromagnetic spectrum (EMS) for communications and sensing. The increased criminal, and even military, use of commercial communications [1] have made control of the EMS – the main goal of EW – increasingly challenging and important, even outside traditional military roles.

The main challenge associated with EW is the extremely wide range of relevant technologies. Almost every specialist field within the disciplines of Electrical, Electronic and Computer Engineering is relevant to the exploitation of the EMS, making it extremely difficult to adequately monitor and respond to technological changes. The increasing relevance of rapidly-changing commercial wireless systems further complicates this task.

This paper argues that collaboration with academia is essential to ensuring that both defence industry and defence forces remain abreast of modern EMS technologies, both military and commercial. The opportunities inherent in such collaboration are believed to be very attractive to all parties, but notable challenges exist. Some of these challenges are highlighted, and potential solutions are proposed.

Section II seeks to motivate the need for university collaboration by highlighting the benefits to all stakeholders. Some of the challenges associated with initiating and sustaining such collaboration are highlighted in Section III, along with possible solutions. A number of models for collaboration are highlighted in Section IV, and a brief conclusion is provided in Section V.

## II. Benefits of Collaboration

Some of the benefits which will arise from collaboration between universities and the EW community are highlighted in this section. The benefits to universities are highlighted first followed by a consideration of the benefits to the EW community.

### A. Collaboration Benefits to Universities

One of the perennial challenges confronting universities is that of obtaining sufficient funding to continue their activities. While the commercial electronics industry has provided significant funding to universities over the last decade or two, the current global economic pressures have reduced this funding somewhat. Despite the current pressure on defence budgets, EW spending has proven surprisingly robust [2] in light of the ever-increasing importance of EW. While competition for such funding will remain significant, the mere fact that such funding exists represents an opportunity for universities.

A further important consideration is the large number of technological challenges facing the EW community. While the term EW is usually understood in a military sense, the increasing criminal use of the EMS means that civilian EW is likely to become increasingly important. Additionally, many technologies initially developed for military applications have found their way into civilian systems. Lastly, the relevance of many technologies to EW means that university researchers will in most cases not have to dramatically change their research field to participate in EW research. There is thus a tremendous opportunity for universities to leverage their existing expertise to achieve significant impact in the EW community.

### B. Collaboration Benefits to the EW Community

The traditional role of universities focuses on two main functions: education and research. Often, these two roles are

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This work is based on the research supported in part by the King Abdulaziz City for Science and Technology (KACST) and the National Research Foundation of South Africa (NRF) (Grant specific unique reference number (UID) 85845). The NRF Grantholder acknowledges that opinions, findings and conclusions or recommendations expressed in any publication generated by the NRF supported research are that of the author(s), and that the NRF accepts no liability whatsoever in this regard.

TABLE I
PROPOSED INITIATIVES TO ADDRESS GAPS IN THE EW COMMUNITY [4], AND POTENTIAL UNIVERSITY CONTRIBUTIONS TO ACHIEVING THESE GOALS.

| Initiative | Description | University contribution |
|---|---|---|
| Increase EW capabilities | Develop capabilities to achieve desired effects. | Development of high-risk, but potentially high-reward technologies |
| Develop a spectrum enterprise workforce | Create a well-trained and well-organised community of EW professionals. | Education and training |
| Improve personnel standards | Establish certifications related to critical EW skills. | Education and training |
| Develop EW leadership | Grow leadership that understands EW and its importance. | Education and training |
| Set system standards | Develop standards to increase the effectiveness of EW-system procurement and use. | Investigate the interoperability of EW systems and predict future requirements |
| Advance doctrine and concepts | Ensure that lessons learnt are properly captured and disseminated. | Education and training, and prediction of future requirements |
| Establish EW doctrine | Develop a useful, common understanding of EW and its role. | Development of new concepts |
| Define electromagnetic spectrum control EMC | Expand the understanding of how all activities in the EMS affect all other activities. | Investigate the effect and use of EW systems |
| Develop IO doctrine | Understand and exploit the complementary, but different, capabilities of information technologies (e.g. EW, cyber, etc.). | Investigate the capabilities of each new technology |

complementary, with research being used as a vehicle for education.

The educational role of universities has the potential to greatly increase the skill levels of civilian and military personnel. The increasing complexity of military systems means that highly-skilled military personnel are becoming an ever-greater advantage [3]. In 1944, this realisation led Field Marshall Erwin Rommel (the legendary "Desert Fox") to state:

> "Dash and doggedness alone no longer make a soldier … he must have sufficient intelligence to enable him to get the most out of his fighting machine."

While it is not always possible to obtain training specifically in EW from universities, many topics relevant to EW are part of the overwhelming majority of university curriculums.

The research function of universities has two important results:

- university staff are often more aware of the latest technology trends than their military and industry counterparts, and
- the opportunity to exploit the creativity and energy of students and their supervisors increases the likelihood of developing innovative new systems and concepts.

The importance of being involved with developing future technologies is highlighted by the following comment from the pioneering computer scientist, Alan Curtis Kay:

> "The best way to predict the future is to invent it."

Having access to individuals who are considering future technologies as a routine part of their employment is thus extremely valuable to determining what the future holds. Furthermore, universities tend to have experts in the majority of the technologies relevant to EW systems, so university collaboration can also increase the range of technologies which can be monitored.

The energy and creativity of students is legendary – often for the wrong reasons – and having the opportunity to exploit this tremendous resource can only be beneficial to the EW community. Large organisations tend to have momentum which makes it difficult to change direction or to consider radical new ideas irrespective of their potential. Having access to dynamic students who are unaware of organisational biases is one way to ensure that the status quo is continuously critically evaluated and challenged.

A further benefit to utilising students is that the cost of hiring a Masters or Ph.D. student is five to ten times lower than the cost of hiring an engineer. Additionally, funding a student also provides access to the knowledge of the student's supervisor through the supervision process at no additional cost. Universities are thus the ideal environment in which to undertake high-risk, but potentially high-reward research.

Elder recently proposed the initiatives listed in Table I to address gaps within the EW community [4]. As can be seen, the traditional academic roles of education and research are well positioned to make a significant contribution to the majority of the proposed initiatives.

## III. CHALLENGES WITH UNIVERSITY COLLABORATION

While there are a number of potential benefits to EW collaboration with universities, there are also a number of unique challenges. This section highlights some of these challenges along with suggestions on how they can be overcome.

### A. *Secrecy*

The importance of EW means that much work on EW is classified. This is a significant obstacle for universities as they are measured on the number and quality of publications they produce in the open literature.

While secrecy concerns can be a major challenge, a clear, shared understanding of which aspects of EW are crucial to the advantage offered by EW is the main factor in resolving such concerns. While information on operational systems is classified, the initial results from research projects which will not be used operationally is generally unclassified. Cases between these two extremes become more complex, but clear guidelines and an open, honest, trusting relationship between the stakeholders based on a mutual understanding of the roles and responsibilities of each can largely eliminate secrecy concerns.

### B. *Student Quality*

University research is largely undertaken by students with supervisors providing high-level guidance. While this can be a significant benefit as outlined in Section II-B, some students are inevitably better than others.

One implication of this observation is that even when a research project is completed, it might not be clear whether poor outcomes are a result of the underlying technology or the quality of the student or students who undertook the research.

A number of possible mitigation strategies can be applied. Firstly, the supervisor plays a major role in determining whether a student reaches their full potential or not. Secondly, allocating critical projects to universities should not be the rule, so that the effect of poor outcomes is minimised. Lastly, it should be recalled that postgraduate students are significantly cheaper than equivalent engineers, so greater risk is acceptable.

### C. Duration of Projects

The duration of university research projects is often limited by the duration of a student's studies, while military development timescales can be on the order of a decade or more. This mismatch needs to be carefully managed.

One approach to minimising the impact of shorter university project durations is to encourage students to undertake Honours, Masters, Ph.D. and postdoctoral studies to lengthen the time the student works on a project. This approach also allows senior students to share their knowledge with their younger colleagues thereby ensuring continuity.

Another key mechanism to ensure knowledge retention after students complete their studies is closer collaboration between the various stakeholders. Such collaboration means that the most important results of university research are more widely disseminated and captured. For example, collaboration between industry and universities is crucial in technology projects, while collaboration between the military and universities is equally crucial where doctrine is involved.

### D. Lack of EW Background and Experience

It is rare for universities to have extensive knowledge of EW, making it difficult to ensure that the research conducted is relevant to the EW community.

The role of the supervisor is crucial here, as this person plays a significant role in a student's growth and work. University researchers with either a knowledge of EW or a willingness to learn more about EW should thus be given preference in EW collaborations wherever possible.

However, the relationship between the EW community and the university researcher is arguably more important than any other factor. The EW community should not regard universities as junior partners or mere subcontractors. This point is perhaps best summarised by the following comment from Dwight D. Eisenhower, the supreme commander of the Allied forces during the D-Day landings in World War II, and later, American president:

> Researchers are "more likely to make new and unsuspected contributions to the development of the Arm if detailed directions are held to a minimum."

Given that one of the potential benefits of collaborating with universities is their deep knowledge of a broad range of topics relevant to EW, allowing universities freedom is crucial to the success of such collaborations.

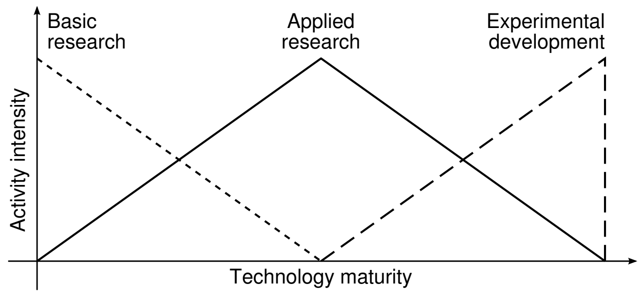



Figure 1. Research phases (adapted from [6]).

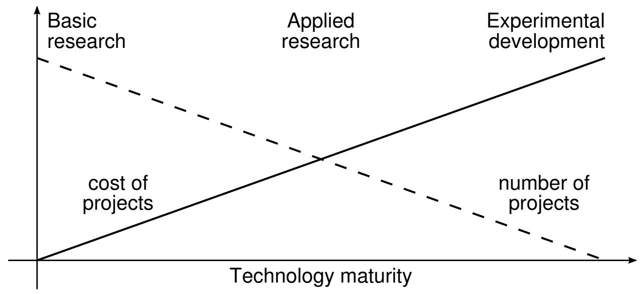



Figure 2. The cost and number of projects associated with each phase of research.

However, universities should not undertake work which has no relevance to the EW community. The chief scientist in the United States Air Force (USAF) from 1957 to 1958, George E. Valley summed this point up when he stated:

> "If a project isn't pushed by a competent operational type, it will not necessarily fail, but it will flounder..."

While it is possible to ignore operational requirements in the short term, this is not sustainable, and such collaborations will inevitably fail in the long term.

## IV. Models for Collaboration

Overcoming the challenges in Section III is seen to require good relationships between the various stakeholders. This section begins with a brief discussion of the complementary roles of these stakeholders and ends with a consideration of three possible models for collaboration.

### A. Stakeholder Roles

The Frascati Manual issued by the Organisation for Economic Co-operation and Development (OECD) [5] provides a useful starting point for discussing the roles of the various members of the EW community.

The three different phases of research defined by the Frascati Manual are [5]:

- Basic research: Research intended to increase knowledge without targeting a specific application.
- Applied research: Acquire new knowledge with a specific goal.
- Experimental development: Exploiting existing knowledge to develop new systems and services.

As shown in Figure 1, there is a natural progression from one type of research to another. Furthermore, the eventual success of any research programme from an operational perspective

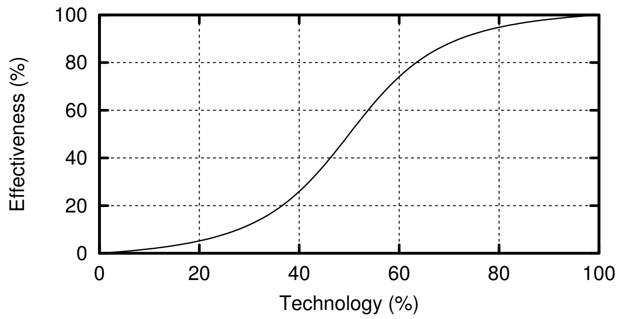



Figure 3. Conventional view of the relationship between technology and effectiveness (adapted from [7]). The scales are relative to the best existing technology and effectiveness.

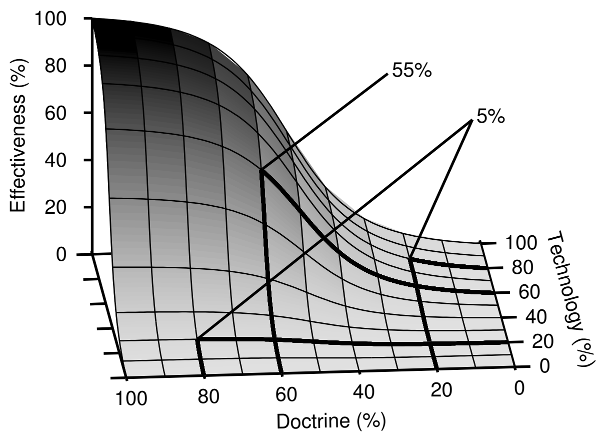



Figure 4. Contour plot showing the relationship between technology, doctrine and effectiveness (adapted from [7]). The scales are relative to the best existing technology, doctrine and effectiveness.

depends on all research phases being successfully completed and advanced to the next.

Figure 2 considers how the number of different research projects and the cost of these projects varies as technology matures. The nature of basic research means that many basic research projects will fail to progress further as the outcome of research is inherently unknown before the research is completed. However, the small number of projects which progress further is acceptable because basic research projects are usually relatively inexpensive – though there are notable exceptions. At the other extreme, the majority of experimental development projects must be successful due to the high cost associated with such projects.

The major drawback of the model in Figs 1 and 2 is that it only considers research up to the point where a new product or service is developed. Increasing the level of technology is implicitly assumed to lead to increased effectiveness as shown in Figure 3. However, Figure 4 shows that doctrine also plays a crucial role in the effective execution of operations [7]. Excellent technology with poor doctrine and excellent doctrine with poor technology are both less effective than the combination of good technology and good doctrine.

It is in attempting to address this requirement for both excellent technology and doctrine where the differences between various collaboration models arise.

### *B. Collaboration Models*

*1) Default Behaviour:* Figure 5(a) shows the default behaviour which will occur in the absence of any means of encouraging EW collaboration. The size of each arrowhead is an attempt to convey the level of communication in each direction.

The strongest relationships in this case are between the military and industry. The relationships with universities are much weaker, thereby making it difficult to realise the potential benefits outlined in Section II.

*2) Georgia Tech Research Institute (GTRI):* The GTRI [8] in the United States of America (USA) attempts to overcome the limitations of the default model by strengthening the relationship between industry and universities as shown in Figure 5(b). In this case, stronger collaboration between industry and academia is used as a vehicle to increase collaboration between academia and the armed forces.

The main benefit of this approach is that the collaboration between academia and industry is greatly strengthened. This allows industry to be more strongly involved with basic research and academia to be more aware of the industry requirements.

The greatest danger of this approach is that GTRI can potentially be seen as competition by both academia and industry. However, this concern is manageable as the long-term success of GTRI clearly demonstrates.

*3) Technological Institute of Aeronautics (Instituto Tecnológico de Aeronáutica) (ITA):* The ITA in Brazil [9] is an engineering university which operates under the auspices of the Brazilian Air Force. Both military and civilian students study through the ITA, and the ITA staff includes both civilians and military officers with postgraduate qualifications.

The most valuable aspect of this approach is that it addresses the weakest link in the default model shown in Figure 5(a).

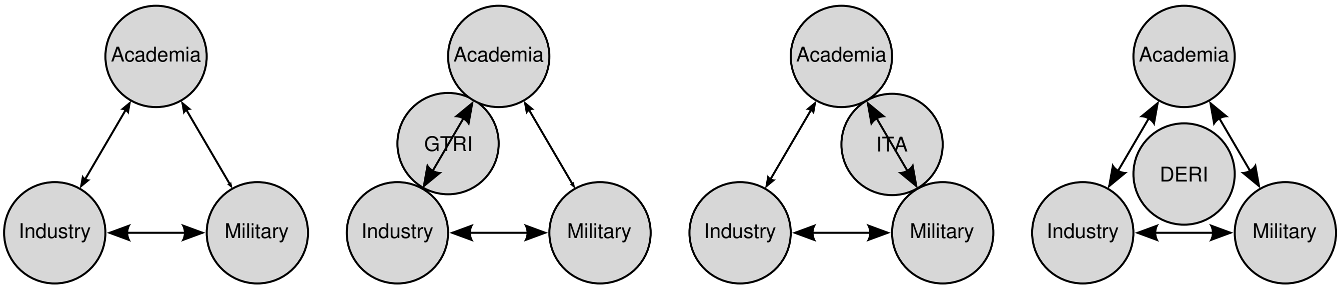
The greatest challenge here is the fact that the ITA staff consists of both military officers and academics. While this does allow far better relationships between academia and the military to be formed, it can be challenging to simultaneously grow both military and academic career paths.

While industry is part of the current reality in Brazil as shown in Figure 5(c), this was not true when the ITA was formed in 1950 [9]. A portion of the aerospace and defence industry in Brazil grew out of research conducted at the ITA, clearly demonstrating how this model has allowed the development of a capable defence industry in support of local requirements. The mixture of military and civilian students means that the relationship between industry and the military is likely to remain strong into the future.

*4) Defence evaluation and research institute (DERI):* A DERI is an organisation that exists as a separate entity whose role is to support all stakeholders in the military environment (and, by extension, the EW community) as shown in Figure 5(d).

The greatest strength of this model is that it acknowledges that relationships between all entities in the military environment must be strong to achieve success. In facilitating collaboration between all parties, it is possible to achieve excellent communication between all stakeholders.

A DERI can fill a bridging role between organisations. For example, a technology conceived at a university can be developed from the initial concept stage to a technology demonstrator by a DERI. In this way, a DERI can ensure that promising concepts in academia can be passed on to industry




(a) Default. (b) GTRI. (c) ITA. (d) DERI (adapted from [6]).

Figure 5. Simplified representations of the relationships between EW organisations. Arrowhead size indicates level of communication.

without requiring industry to invest significant funds in risky new technologies.

However, there are a number of challenges which must be overcome for the full potential of a DERI to be achieved.

Perhaps the most significant challenge is that all parties must accept the role of a DERI. It is crucial to ensure that all stakeholders see a DERI as a facilitator which adds value rather than another level of bureaucracy to be overcome. The latter outcome arises when a DERI becomes an end in itself rather than a means to an end. For example, a DERI should not seek to control the relationships between stakeholders, but rather to strengthen and assist such relationships, and if this is not possible, not to needlessly interfere.

There is also the risk that a DERI can be seen as competition by other stakeholders, so care must be exercised to ensure that this does not happen. For example, a DERI can be seen as competition to industry if a DERI markets products to secure additional funding to grow its capabilities. Such situations can be avoided by bearing in mind that a DERI's main role is to support other role players, and not to replace them. The example above can avoided by ensuring that a DERI's products are complementary to those of industry, thereby strengthening all stakeholders by allowing them access to technologies which would not otherwise be available.

Another important consideration is that the relationship with each stakeholder must be as unique as the stakeholders themselves. This is crucial because the facilitative role of a DERI can only be successfully accomplished if a DERI properly understands all stakeholders' unique expectations and requirements. For example, there could be a temptation to consider universities as subcontractors which are comparable to industry, but this view is incompatible with the research and educational goals of academia. This difficulty can be overcome by having individuals in a DERI focus mainly on interactions with only one or two stakeholders. However, this can lead to DERI having the same misunderstandings and conflicts internally as it is trying to address externally. Fortunately, addressing misunderstandings within an organisation is usually easier than addressing those same misunderstandings between organisations.

## V. Conclusion

This paper has endeavoured to show the benefits of collaboration between universities, defence industries and defence forces in the field of EW, and to highlight the unique challenges faced.

Significantly, benefits are accrued to all parties by simply exploiting the strengths of each. Universities potentially gain access to additional funding while undertaking research which has the potential to make significant impact. The EW community stands to gain from both the education capabilities and the research programmes of universities.

However, there are a number of unique challenges associated with such collaboration. Many of these challenges stem from a misunderstanding of the roles of the various stakeholders, and the resultant temptation to assume that the role of one stakeholder is identical to another. Some models for overcoming these challenges are considered, and examples of successful collaborations are highlighted.

## Acknowledgment

The author wishes to gratefully acknowledge the insights gained though many discussions with individuals at CSIR DPSS and the University of Pretoria. In particular, he would like to express his sincere thanks to Francois Anderson, Dr Jan Roodt, Christo Cloete, Pieter Goosen, Prof. Johan Hanekom, Prof. Wimpie Odendaal, Prof. Johan Joubert, Lt Col Dr Ricardo Santos and Prof. Sunil Maharaj.

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