

JOURNAL OF THE ROYAL NEW ZEALAND AIR FORCE



New Zealand
**DEFENCE
FORCE**
Te Ope Kātua O Aotearoa



PART B

Collection of Air Power Papers, Essays, Articles and Book Reviews

Volume 5 Number 1

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JOURNAL OF THE ROYAL NEW ZEALAND AIR FORCE

Volume 5 – Number 1 – 2019

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COLLECTION OF AIR POWER PAPERS, ESSAYS, ARTICLES AND BOOK REVIEWS

The *Journal of the Royal New Zealand Air Force*, otherwise known as the *RNZAF Journal*, is an official Royal New Zealand Air Force publication, produced by the RNZAF Air Power Development Centre (APDC). The *RNZAF Journal* is the professional journal of the Royal New Zealand Air Force and consists of two parts. *Part A* contains academically credible articles on air power, with the objective of serving as an academic forum for the presentation and stimulation of critical thinking, debate and education on air power. *Part B* contains a broad collection of air power papers, essays, articles and book reviews intended to promote and enhance air-mindedness, encourage professional mastery and stimulate debate and discussion about air power at all levels.

The submission of papers, essays, articles and book reviews for either part is open to anyone, but submissions must be relevant to the employment, or sustainment, of air power. Challenges to conventional thinking and accepted norms are encouraged, as are innovative recommendations or conclusions.

JOURNAL SUBMISSIONS

The APDC will formally call for papers, essays, articles and book reviews for both volumes of the *RNZAF Journal* during October of each year, to be submitted by the first week of the following February. However, articles may be submitted at any time and should be sent to: ohapdc@nzdf.mil.nz

Papers, essays and articles should not normally exceed 5000 words, and shorter submissions are encouraged. Submissions should be in MS Word format using Chicago referencing with footnotes. The use of supporting charts and photographs are acceptable, but may be subject to copyright confirmation before being reproduced within the *RNZAF Journal*. Submissions must only contain unclassified material.

Reviews of air-power-related books, either contemporary or historical, should consist of approximately 300 to 500 words.

To obtain further information on journal submissions, contact the APDC at:

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APDC staff can assist authors at any stage with topic selection, general or specific advice, guidance and direction. Authors are encouraged to liaise with the APDC prior to submitting completed works.

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AIR POWER DEVELOPMENT
CENTRE

The Air Power Development Centre (APDC) researches and disseminates information on air power, from a New Zealand perspective in order to promote awareness on the contribution of air power to the security of New Zealand.

The public are invited to learn more about air power concepts by visiting the APDC webpage on the RNZAF website; either via the link: www.airforce.mil.nz/about-us/who-we-are/apdc, or by writing 'RNZAF APDC' into an internet search engine.



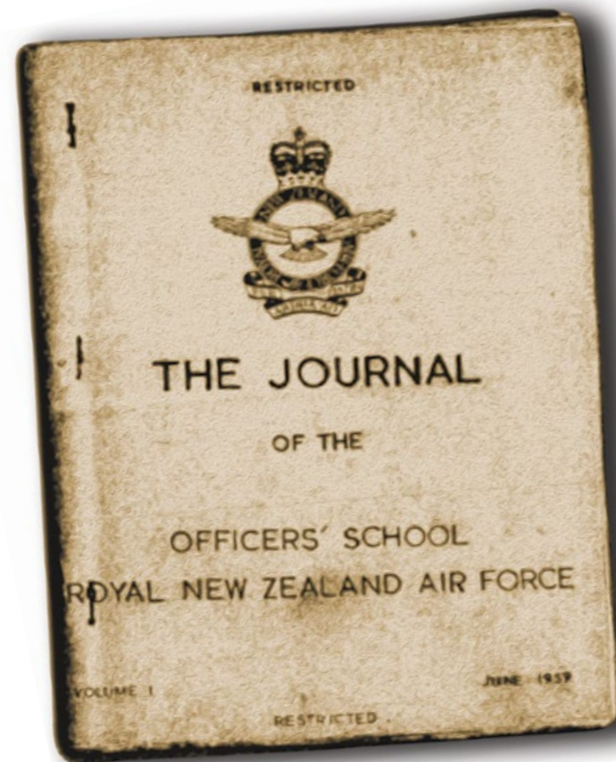
JOURNAL OF THE ROYAL NEW ZEALAND AIR FORCE

PART B

COLLECTION OF AIR POWER PAPERS, ESSAYS, ARTICLES AND BOOK REVIEWS

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INTRODUCTION TO THE JOURNAL OF THE ROYAL NEW ZEALAND AIR FORCE

The *RNZAF Journal* is a modern adaptation of *The Journal of the Officers' School, Royal New Zealand Air Force* of 1959. At the time, it was designed to assist the professional development of officers – but it was short-lived. Today, the need for ongoing professional military education is vital for the development of all personnel, not just officers. All airmen require a comprehensive understanding of air power to ensure the success of military air operations. Therefore, the *RNZAF Journal* was resurrected to create a platform of learning, drawing from history and contemporary warfare, to further our understanding of the application of air power.

CONCEPT OF THE JOURNAL OF THE ROYAL NEW ZEALAND AIR FORCE

The official title of the resurrected *RNZAF Journal* is *The Journal of the Royal New Zealand Air Force* and it will continue in the spirit of the original journal by providing topical articles covering a range of air power-related subjects. These will include, but are not limited to: RNZAF operations, air warfare, humanitarian assistance, technology, capabilities, training, strategy, theory and security. Articles will be sought and drawn primarily from New Zealand Defence Force personnel, academics and interested civilians. Reprints from companion journals and other relevant sources may be published from time to time.

The *RNZAF Journal* consists of two parts, both of which are intended to promote and enhance air-mindedness, encourage professional mastery and generate discussion about air power.

Part A: Air Power Readings contains academically credible articles on air power, with the objective of serving as an academic forum for the presentation and stimulation of critical thinking, debate and education about air power.

Part B: Collection of Air Power Papers, Essays, Articles and Book Reviews contains a broader collection of works that may not readily fall within the constraints associated with an academic journal. The intention of *Part B* is that it will be a forum for all with an investment or interest in air power and, similar to *Part A*, act as a stimulus for thought, debate and discussion whilst also educating.

Part A and *Part B* of the *RNZAF Journal* are stand-alone publications, which will normally be published at the same time, though in 2019 only *Part B* will be produced.

OVERALL

The *RNZAF Journal* is designed to be a means for anyone, no matter who they are, to present and/or digest ideas, views and analysis of air power matters

through researched and reasoned papers, essays and articles. Material published in the *RNZAF Journal* may challenge current thinking, policy and conventions. The opinions and conclusions are those of the authors, not necessarily those of the New Zealand Defence Force or the Government of New Zealand.

COVER

The tūrangawaewae at Ohakea is home to a series of Heke (rafter) patterns that reflect the values and principles of our tūrangawaewae. These in turn are collective reflections of the RNZAF. The Heke design featured on the cover is the Ngutu Kākā – the Parrot's Beak. The Ngutu Kākā represents knowledge, which reflects the ongoing training, education and development that our people receive in support of both their trade requirements and the war fighting ethos of the RNZAF. The colours used in the Ngutu Kākā Heke depict the earthy tones of the Kākā, the native parrot of New Zealand. The Kākā is famous for two things – its high intelligence and its seemingly endless chatter. It is therefore likened to a teacher and the process of passing on knowledge to the student.

Ko te manu kai i te matauranga, nōnā te Ao.

The bird that feeds on knowledge, his is the World.

EDITOR'S NOTES

The Air Power Development Centre is delighted to publish a diverse range of articles by RNZAF personnel, NZDF civilians, and teaching staff from Otago and Massey Universities; while also acknowledging the efforts of contributors who were not published. This 2019 collection of air power essays, articles, and book reviews includes essays on space. This continues from last year's journal, which featured an article on space systems, and recognises the RNZAF's growing role in improving understanding of, and advising on, the space domain.

This edition opens with a thought-provoking essay from Group Captain Sexton who suggests that the RNZAF risks becoming so focussed on introducing new fleets of aircraft that sight of the 'big- picture' is lost. To recentre the pendulum, he presents six tenets for the RNZAF that may well become an enduring guide for present and future Airmen. Group Captain Sexton's organisational tenets for the RNZAF are for it to be a combat capable, flexible, expeditionary, well-led, and partnered force; underpinned by the values and culture of our Airmen. Combined, the tenets describe his view of the underlying philosophy of the RNZAF, and how Airmen should maintain their airmindedness as warfighting professionals. Hopefully this essay will prompt discussion about the proposed tenets, and a decision as to whether they should be formalised within the RNZAF's lexicon.

Wing Commander Foster's paper details his vision of a holistic space strategy for New Zealand. Broad in scope, he includes civil, commercial, and security sectors within his strategy. In effect, his essay moves beyond simply

establishing a whole of government approach to space as he recognises the importance of the commercial sector in developing policy and technology. Wing Commander Foster suggests the New Zealand Space Agency, which was formed in 2016, should be the central agency tasked to develop National Space Policy and Strategy that defines end states, principles and strategic objectives for the holistic use of space. NZDF space effort within his vision includes developing military space doctrine, and launching a small satellite for research and development purposes. Will we look back in ten years time and see this paper as the genesis of New Zealand's space strategy?

Many readers may not realise that 100 years ago in 1919, Lieutenant Colonel A.V. Bettington visited New Zealand to report on the development of air power and submit a plan for the establishment of a New Zealand Air Force. However, the government of the day recoiled at the cost and decided it was impractical to establish a large-scale aviation scheme. Simon Moody reflects on the Bettington Report and its legacy upon military aviation in New Zealand. Mr Moody notes with interest that Bettington correctly identified Japan as a potential centre of unrest in the Pacific, and therefore a future threat justifying the need for military aviation in New Zealand. In Mr Moody's words "Bettington was spot-on and showed a clear understanding of the changing shift of the balance of power in the post-First World War world." This essay helps us to understand New Zealand's historical perspective of military aviation. But, as the oft-said cliché reminds us, 'history repeats'.

Are we today adequately studying changes in the balance of power, and if so, are we investing sufficiently in military air power to counter those potential threats?

The RNZAF aspires to be an information enabled air force that is inter-operable with allied military networks, and thereby able to plug-into fifth generation air warfare operations. What does that mean, what are the vulnerabilities, and what does cyber conflict look like? Brian Oliver takes a peek under the hood of future warfare and finds that the technological advances required to fully exploit the potential of fifth generation capabilities will take some time to mature. Cyber is a military domain in its own right, and the RNZAF needs to start understanding it as a battleground and how warfare is played out within it; especially as we introduce the P-8A Poseidon Maritime Patrol aircraft into the RNZAF fleet. However, Mr Oliver reminds us that the network is vulnerable, and if it is compromised then we will be forced back into fighting a third-generation war. Perhaps the underlying message is that as we become more technological, and reliant on technology, we shouldn't lose our traditional warfighting skills. In other words, we can stop an exercise when computer screens go blank, but that luxury doesn't exist during war.

Isaac Henderson takes us on a journey through the development of airship technology, commercial enterprise, and military applications. Starting from the introduction of powered flight in 1903, Mr Henderson skilfully compares the attributes of early airships to the crude aircraft designs of the day, and finds that it took some time for aircraft technology to advance beyond the capabilities of airships. The science of materials and aerodynamics may now be progressing to the point where the return of airships becomes economically viable, and the designs become suitable for military airlift, airborne surveillance, and disaster relief roles.

As Mr Henderson points out, fully electric and fully solar-powered hybrid airships under development potentially offer environmentally friendly solutions to certain military air operations. So, can we see airships returning to the skies in New Zealand in the future? This paper argues that New Zealand's air power would be enhanced if they did return.

Our series of articles ends with an explanation of space weather phenomena and its effects on aviation. Aircraft, satellites, military communication networks, and electrical grids are vulnerable to the effects of solar flares. Dr Craig Rodger and Harriet George slowly, and carefully, introduce us to the fundamental ideas of solar flares and how they interact with the Earth's ionosphere. The authors then recount major solar events that disrupted high frequency radio communications, which are vital to aviation and military communications, including recent interruptions to air traffic control systems. The authors' passion for the subject shows through with their knowledge of the effects of solar events on military operations during World War Two, the Cold War, and Vietnam. These examples are valid lessons for today, especially as the RNZAF becomes more technological and more reliant on airborne sensors, computer and data networks, and connectivity to space systems; thus space weather forecasting will be vital to the conduct of future air operations. As the authors note, the International Civil Aviation Organization is setting up global space weather centres to provide space weather forecasts. If they are serious about space weather, then arguably, the RNZAF should be too. We are lucky to have Dr Rodger and Harriet George start us on the journey of understanding space weather phenomena. The next phase is up to us, is the RNZAF up to the challenge of integrating space weather forecasting into our operational planning?

The second section of the RNZAF Journal has a number of book reviews. The selection in this edition are historical in context and have some relation to New Zealand or the RNZAF, including a biography of the only New Zealander to reach 5-star rank. Squadron Leader Boyes has been undertaking a fair bit of reading as part of his professional development, and we are fortunate that he has taken the time to give us his thoughts on a number of air power books. Mr Bertosa, who resides in Canada, gives us a critical review of Peter Dye's book on Sir Robert Brooke-Popham, who was Commander-in-chief Far East at the time of the fall of Singapore during World War Two.

This issue of the RNZAF Journal spans the historical, contemporary, technical, and potential future of the RNZAF. It is hoped that readers find the articles interesting, informative, and challenging. That is the point of the RNZAF Journal – it should make us think and reflect. By studying warfare, and in particular, air operations in support of warfare, we can increase our individual – and collective – understanding to that of our peers. The RNZAF Journal has broad readership, not only within the NZDF but also amongst those in the wider community who are interested in air and space power related topics. But the journal is only as good as its contributions, and to ensure it holds its place as a valued publication, we encourage writers to put pen to paper, or fingers to keyboards as the case may be. So, is there a topic, or perspective that interests you, and can you collate those ideas into an essay? If you can, then the APDC wants to hear from you.

J. PHILLIPS
Deputy Editor



SIX TENETS FOR OUR AIR FORCE

Group Captain Shaun Sexton, NZBM

The Government's expectations of the New Zealand Defence Force (NZDF) are detailed in the 2018 Strategic Defence Policy Statement (DPS). It explains priorities, principles and capability requirements in the context of immutable and trending geostrategic considerations. By and large the DPS reaffirms 'successive Governments' fundamental expectations of Defence'.¹ Albeit perhaps with some 'useful ambiguity' and an additional focus on cyber and space capability.² Arguably, because the Statement broadly maintains a long-held trajectory, there is little need for Defence or the Services to change their current plans.

Nonetheless, the DPS does provide a useful inflection point and basis for the Royal New Zealand Air Force (RNZAF) to consider its approach to the next decade or so. This imperative grows because the RNZAF, having emerged from an extended period of introduction into service (IIS) and with another looming, runs the risk of losing sight of the big-picture and focusing on the immediate (and ultimately tactical) challenges of bringing important new equipment into service. What may be lacking during this period of change is a unifying concept of how the RNZAF will deliver air power in the future.

THE AUTHOR

Group Captain Sexton is a RNZAF pilot and qualified flying instructor whose diverse career has included many years flying the UH-1H Iroquois (during which he was awarded the New Zealand Bravery Medal), leading the introduction of the NH90 and A109 into RNZAF service, serving overseas within a range of operational deployments, and performing a variety of staff appointments. He is currently Base Commander RNZAF Base Ohakea.

¹ Ministry of Defence, *Strategic Defence Policy Statement 2018*, July 2018, Wellington: Ministry of Defence, 11. <http://www.nzdf.mil.nz/corporate-documents/strategic-defence-policy-statement-2018.htm> (accessed September 5, 2018).

² Beth Greener, 'Useful ambiguity? New Zealand's Strategic Defence Policy Statement', *The Strategist*, The Australian Policy Institute, (9 July 2018) <https://www.aspistrategist.org.au/useful-ambiguity-new-zealands-strategic-defence-policy-statement/> (accessed December 1, 2018).

This paper seeks to bridge that gap in some small way by proposing six guiding tenets for the RNZAF: *Combat Capable, Flexible, Expeditionary, Leadership, Partnered, Values and Culture*. A tenet is 'a principle, belief, or doctrine generally held to be true especially one held in common by members of an organisation, movement, or profession'.³ These six tenets represent a personal perspective of what is important to the RNZAF and its stakeholders. The tenets are based-on the author's interpretation of enduring doctrine, 2018 Government Policy, and past RNZAF experience; antecedents that suggest the durability and utility of all six. The tenets attempt to strike a balance between the actual and the aspirational. They therefore act as reminder of the RNZAF's past and present nature, while also providing a guide to the organisation's future.

The aim of producing the tenets is to create a model of RNZAF activity that is relevant to delivering the mission now and to preparing for the RNZAF's future mission success. The tenets have potential utility as one element of an RNZAF strategy, or, as a means to assess unit and Service outputs. Importantly, they provide a framework for explaining the nature of the RNZAF internally and externally to many stakeholders. Accordingly, after discussing each tenet, an aspirationally phrased first-person précis is provided to aid understanding and increase usability inside and outside the RNZAF.

COMBAT CAPABLE

Combat Capable is the master tenet. The RNZAF must fulfil its ultimate purpose as an air force, which is to deliver air power. Strategic theorist Colin Gray defines air power as 'the ability to do something strategically useful

³ Merriam-Webster, Web site, <https://www.merriam-webster.com/dictionary/tenet> (accessed January 24, 2019).

from the air',⁴ while United Kingdom doctrine defines it as 'using air capabilities to influence the behaviour of actors and the course of events'.⁵ Ultimately, utility requires an air force that can influence the enemy in conflict, including at the upper end of the security events spectrum where both the threats and the need for a combat viable force are higher.⁶ The *Combat Capable* tenet focuses around two central themes: the three elements of warfighting power (physical, conceptual and moral) as they pertain to the RNZAF; and that combat capability⁷ enables success across the conflict spectrum.

The ability to successfully operate at the upper spectrum of conflict ensures a military force can conduct more benign operations. For instance, No. 3 Squadron NH90s training for combat-related amphibious operations enables amphibious operations in disaster relief situations,⁸ but the reverse is not true. Some may fear being part of an RNZAF that overtly prepares for warfighting because they perceive it as unnecessarily

⁴ Colin S. Gray, *Air Power for Strategic Effect*, (Alabama: Air University Press, 2012), 9.

⁵ United Kingdom Ministry of Defence, *Joint Doctrine Publication 0-30: UK Air and Space Power*, Second Edition, United Kingdom Ministry of Defence, Shrivenham, Wiltshire, 2017, 5. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/668710/doctrine_uk_air_space_power_jdp_0_30.pdf

⁶ New Zealand Defence Force, *New Zealand Defence Doctrine (NZDDP-D)*, Fourth Edition, Wellington: New Zealand Defence Force, 2017, 3. <http://www.nzdf.mil.nz/corporate-documents/nzddp/default.htm>

⁷ The term 'capability' is often used in this paper. It is defined in the comprehensive manner provided for by NZ Doctrine as having six components: Personnel; Research and Development; Infrastructure and Organisations; Concepts, Doctrine and Training; Information Technology; Equipment, Logistics and Resources. See: NZDF, *NZDDP-D*, 65.

⁸ Rebecca Quilliam, 'NH90s Test Waters in Amphibious Exercise', *Air Force News*, Issue 209 (December 2018), 4-5. <http://airforce.mil.nz/downloads/pdf/airforce-news/afn209.pdf>

aggressive for a country like NZ. However, a *combat capable* Air Force is not synonymous with exclusively focusing on preparation for combat in the literal sense, though some preparations of this ilk are essential. However a *combat capable* Air Force does ensure the markedly increased challenges of conflict in the upper spectrum can be met when required. Moreover it provides Government with the breadth of capability employment choices it expects, ranging from Combat Operations to Stability and Support Operations.⁹

The Government expects the NZDF (and thus the RNZAF) to be *Combat Capable*. The first (and it is assumed foremost) DPS principle requires the RNZAF to be 'combat capable, flexible and ready...to deliver military effects'.¹⁰ Moreover, 'the core task of the Defence Force is to conduct military operations, in particular combat operations'.¹¹ For the foreseeable future the RNZAF's combat capabilities will include three of the four air power roles: intelligence, surveillance and reconnaissance (ISR), air mobility and, to a limited extent, strike. The robust provision of these capabilities during military operations requires optimisation of the three doctrinal components of warfighting power; *moral, physical* and *conceptual*.¹² The RNZAF must address each component to succeed in its military endeavours.

⁹ NZDF, *NZDDP-D*, 34. NZDF Doctrine defines 'combat operations' as 'Military operations where the use of force or threatened use of force, including lethal force, is essential to impose will on an opponent or to accomplish a mission.' It defines Stability and Support Operations as 'operations to impose security and control over an area while employing military capabilities to restore services and support civilian agencies'

¹⁰ NZ Ministry of Defence, *Strategic Defence Policy Statement 2018*, 11.

¹¹ Ibid 35.

¹² NZDF, *NZDDP-D*, 59.

Equipment (a key *physical* component) is central to the successful delivery of air power. The *Combat Capable* tenet highlights the need for RNZAF equipment (from garrison to the front-line) to be suitable for the mission. Current equipment must therefore be fit-for-purpose and available in sufficient quantities. Importantly, adaptable timely organisational processes are required that ensure optimal equipment is readily available for future missions. This need for responsive acquisition and IIS systems is captured in the *Flexibility* tenet.

Scale and fiscal constraints are limiting factors for the RNZAF when it comes to the *physical* component, thus the *moral* and *conceptual* components are particularly significant. United Kingdom joint doctrine argues that the *conceptual* component 'sits above' the other two 'not necessarily because it is more important, but because it defines the direction and shape of the others'.¹³ On the other hand, NZDF doctrine does not prioritise the components of warfighting power, rather it highlights the relative importance of the moral plane over the physical plane because conflict is 'human-centred'.¹⁴ However there is no need to prioritise. The key point is that for a small air force with constrained resources in an environment of spiralling military technology and personnel costs, leveraging the *moral* and *conceptual* components of warfighting power is a substantial enabler. Robustly developing both air-minded¹⁵ military airmen and air power doctrine are key mechanisms to achieve this effect. Notably, the RNZAF is moving to address a deficit in this area through Project Mana Tangata which seeks to better prepare personnel to lead and apply air power.

¹³ UK MoD, *JDP 0-30*, 44.

¹⁴ NZDF, *NZDDP-D*, 27.

¹⁵ Air-mindedness is discussed in greater detail as part of the *Values and Culture* tenet.

COMBAT CAPABLE

Combat capability underpins the RNZAF's success across the spectrum of conflict in the face of fog, friction and violence. Our airpower capabilities can operate, survive and succeed in contested and complex conflict environments. Equipment is suitable for the mission and interoperable with joint, interagency and multinational partners. RNZAF air power doctrine (at all levels) is sound, understood and applied by airmen, and aligned with our partners. Our airmen are critical to success because their moral capacity to do what is expected of them when asked, their airmindedness, and their professional mastery underpin the RNZAF's air warfighting capability.



C-130H(NZ) HERCULES DEPLOYING SELF-PROTECTION MEASURES

FLEXIBILITY

Flexibility is the key to air power – an overused adage but apropos nonetheless. Air power doctrine highlights flexibility (RAAF) and agility (RAF) as key attributes of air power.¹⁶ As NZ's only military airpower practitioner, flexibility is central to the RNZAF's success in most things, not least when conducting military operations.¹⁷ This tenet highlights both organisational and mission related value propositions and identifies the need for individual and organisational flexibility to realise these benefits.

The NZDF Operational Tenet of *Inherent Flexibility and Pragmatism* is one of six 'essential elements of NZDF military operations'.¹⁸ It encourages commanders to conduct military operations with 'imagination', 'innovative thinking', and to 'eschew the formulaic and prescriptive in favour of the unpredictable and surprising'.¹⁹ While this doctrine focuses on commanders executing military operations, the attitudes and approach are equally relevant to the RNZAF and its people in non-operational endeavours.

16 UK MoD, *JDP 0-30*, 26; and Royal Australian Air Force, *Australian Air Publication 1000-D: The Air Power Manual (6th edition)*, Canberra: Commonwealth of Australia, 2013, 138. <http://airpower.airforce.gov.au/APDC/media/PDF-Files/Doctrine/AAP1000-D-The-Air-Power-Manual-6th-Edition.pdf>

17 Flexibility's inclusion as a tenet has a wider connotation than purely in its application as an air power characteristic and inclusion does not elevate it above other characteristics.

18 NZDF, *NZDDP-D*, 43. The other five NZDF Operational Tenets are *Warfighting Ethos*, *Joint Effect*, *Principles of War*, *Command Philosophy*, and *Manoeuvrist Approach*.

19 NZDF, *NZDDP-D*, 54.

Gratifyingly, Air Force people often deliver innovative and flexible solutions across the organisation, examples range from a 'world leading initiative' to encourage young women to consider a career in the RNZAF,²⁰ through to saving thousands of dollars in aviation fuel.²¹

New Zealanders are renowned for their ingenuity and versatility – the so called 'No. 8 Wire' approach that is born of colonial pragmatism in scarcity. These cultural roots make *Flexibility* a comfortably intuitive tenet for the RNZAF. For instance, suggesting a desire to be flexible, the motto of an early RNZAF transport squadron was 'anything, anywhere, anytime'.²² Also, the Governor General of Australia's Meritorious Unit Citation awarded to No. 3 Squadron in November of 2002 highlights the 'exemplary flexibility and responsiveness...' that characterised the Squadron's operations in East Timor.²³

Flexibility reflects the Government's desire to obtain the most from NZDF outputs in the *community*, throughout the *nation*, and across the *world*. The Government seeks 'capabilities that enable [the RNZAF] to deliver a broad range of activities that support NZ's overall wellbeing'²⁴

20 New Zealand Government, "Air Force careers for women taking flight," July 20, 2017. <https://www.beehive.govt.nz/release/air-force-careers-women-taking-flight> (accessed December 17, 2018)

21 Phillips, S., 'Innovation of the year', *Air Force News*, Issue 209, December 2018, Wellington, New Zealand, p.12. <http://airforce.mil.nz/downloads/pdf/airforce-news/afn209.pdf>.

22 Royal New Zealand Air Force Air Power Development Centre, *Te Matataua*, RNZAF, Ohakea, NZ, Issue 1, October 2016. <http://www.airforce.mil.nz/downloads/pdf/apdc/temataua-1-concept.pdf>. See also: 'Anything, Anywhere, Anytime: History of the RNZAF's Douglas C-47' <https://c47.weebly.com/> (accessed December 15, 2018).

23 Details of the award can found at: Australian Department of Prime Minister and Cabinet, *Australian Honours: INTERFET/EAST TIMOR, 3 Squadron Royal New Zealand Air Force*, Australian Government. <https://honours.pmc.gov.au/honours/awards/2001145> (Accessed December 19, 2018). A copy the citation itself was provided to the author by the Commanding Officer of No. 3 Squadron via email on 19 December 2018

24 NZ Ministry of Defence, *Strategic Defence Policy Statement 2018*,

and has an expectation that 'individual Defence Force capabilities must, in general, be applicable to a range of tasks'.²⁵ No. 5 Squadron is a typical example of the RNZAF's adherence to this mantra as can be seen from a recent issue of Air Force News where the first three articles each highlight a different 5 Squadron capability set.²⁶

Notably, the DPS refers to the need for adaptable procurement mechanisms to ensure the RNZAF's equipment and capabilities keep pace with changing conflict and rapidly evolving technology.²⁷



"...exemplary flexibility and responsiveness..."

11

25 Ibid, 37.

26 See RNZAF, *Air Force News*, Issue 209, pp.4-9 which captures 5 Squadron's role in a Joint Amphibious exercise, a precision strike exercise, and North Korean UN sanctions monitoring.

27 NZ Ministry of Defence, *Strategic Defence Policy Statement 2018*, 37

Admittedly acquisition and IIS processes are heavily influenced by Defence level policy and procedures, nonetheless the RNZAF must intelligently and actively advocate for its own ends. Without responsive acquisition and IIS processes, and a willingness to challenge 'sacred cows', the RNZAF (and NZDF) risks capture by a cycle of acquisition and IIS for replacement's sake rather than for mission requirements' sake. Not that these are necessarily mutually exclusive, but, as conflict evolves and new challenges emerge vigilance is necessary. One could for instance argue that the RNZAF is well behind traditional partners' remotely piloted aerial system capabilities because it was unable to respond to evolving aerial warfare technology while concurrently meeting the immediate needs of existing equipment upgrades or replacement.

FLEXIBILITY

The RNZAF faces uncertainty with agility and professionalism. Our people are pragmatic and have the ability to meet challenges, ambiguity and hardship head-on so we succeed as an organisation and win during conflict. We optimise our capabilities across the spectrum of air power roles. Our acquisition and introduction into service functions are responsive to changing technology and national security needs. We embrace innovation and creativity in all things..

EXPEDITIONARY

Expeditionary capabilities are a mainstay of the RNZAF's utility in NZ and overseas. This tenet firstly identifies a need for the RNZAF to be ready to effectively, and sometimes independently, operate away from home bases in austere and potentially contested environments. Secondly, it highlights that bases and enabling capabilities are central to the successful delivery of air power.

The maintenance of forces ready to deploy in a timely fashion and execute their mission away from home-station is fundamental to meeting the preponderance of RNZAF outputs. Examples range from a multiday search and rescue mission in the Southern Alps, to joining a large coalition in the Middle-East. Success in these examples, and many others, relies on the leadership, equipment, training, and resources necessary to deploy and operate across a wide spectrum of environmental and conflict scenarios. The *Combat Capable* tenet speaks to the need for RNZAF operations in potentially contested locations. The *Expeditionary* tenet further develops this by capturing the breadth of geography and environments in which the Government requires RNZAF operations. Locations range from the distant harshness of Antarctica through to the archipelagic and tropical South Pacific where NZDF operational independence and leadership is expected. Moreover, the projection of capability further afield is expected, including to the vast Asia-Pacific and even globally.²⁸

The RNZAF has a dual role to play projecting and sustaining deployed military capabilities. Firstly it provides a means to project and sustain a force through its air mobility capabilities, and secondly, it could be the projected force, for instance a maritime patrol task group to North East Asia. In either case, RNZAF capabilities must have the wherewithal to project, sustain and operate away from home stations. When integrated into a coalition, an interoperable deployed element that is reliant (but not burdensome) on partner enabling capabilities will be appropriate. On the other hand, the Government's expectation that the NZDF will conduct independent operations in the South Pacific²⁹ suggests the need for a robust self-sufficient force including enabling capabilities to meet air basing dependencies.

²⁸ NZ Ministry of Defence, *Strategic Defence Policy Statement 2018* Chap 5 for instance.

²⁹ Ibid, 29.

Air power is dependent on air bases and their associated infrastructure and systems, in fact they are 'likely to be the fundamental centre of gravity for air power'.³⁰ The applicability of this assessment to RNZAF Bases in NZ is clear because they are both the heart of the raise, train and sustain function and an operational output node. However, basing requirements also extend to expeditionary operating locations where air power's dependency is equally, if not more, significant. The capabilities and depth of capacity at permanent RNZAF air bases underwrites the RNZAF's ability to establish expeditionary air bases in austere, and perhaps contested, environments.

The RNZAF repeatedly demonstrates its ability to operate in an expeditionary manner, take for instance 3 Squadron's extended tenure in Timor Leste and repeated deployments by 5 and 40 Squadrons to support the destruction of the Islamic State terror group and other Middle East region missions. However, the RNZAF's ability to generate and sustain a forward operating base while sustaining unimpeded operations at NZ bases is a resource challenge that must be addressed given policy expectations. Focusing effort on the criticality of basing and the need to concurrently resource permanent and expeditionary sites, including enablers, will help create capability depth and thus ensure options are maintained for the future. Moreover the RNZAF's ability to ensure unimpeded operations at operating locations needs to prepare to meet contemporary threats. A notable example is the ability to detect and counter the increasingly ubiquitous drone. While NZ legislation provides some protection within the nation's territory, risks remain.³¹ Those risks are far greater in deployed locations where

³⁰ RAAF, *AAP 1000-D*, 142.

³¹ Andrew Shelley, 'NZ needs to tighten control on drones', *Newsroom*, October 12, 2018, <https://www.newsroom.co.nz/2018/10/11/272691/nz-needs-to-tighten-control-on-drones> (accessed December 25, 2018).

it is likely that legislation is either absent or unenforced and malign actors may be present who seek to disrupt operations or gather information.³²

EXPEDITIONARY

The RNZAF succeeds when operating from its NZ bases and from deployed locations. Our capabilities are prepared to promptly, sustainably and independently conduct operations in largely uncontested, but austere, environments in NZ's key areas of interest from the South Pole to the Equator. We can concurrently deploy capabilities that integrate into joint, interagency and multinational forces operating in contested environments globally. In either case, we have the wherewithal to establish and sustain suitable forward operating bases.



³² See for a useful explanation: Harper, Alexander, 20 April 18, 'Drones level the battlefield for extremists', *The Interpreter*, Lowry Institute. <https://www.lowryinstitute.org/the-interpreter/drones-level-battlefield-extremists> (accessed December 19, 2018)

LEADERSHIP

Great individual and organisational leadership is perhaps the most significant enabler of air power capability at the RNZAF's disposal.

As a small air force the RNZAF cannot always bring the latest capabilities or the most people to bear on operations, but it can (and does) offer top-notch airmen of all ranks and trades who are leaders. The leadership qualities of RNZAF people are regularly demonstrated inside the organisation, on operations and in NZ communities. Take for instance the operational leadership recognised in the 2018 New Year's honours list, or the RNZAF's 2017 Airman of the Year.³³ Moreover, the RNZAF is well positioned to leverage continued benefits of quality individual leadership through the NZDF Leadership Development Framework (LDF) which provides progressive leadership learning to the men and women of the RNZAF. However, these leadership fundamentals must be augmented so the RNZAF grows *air warfighting* leaders; a deficit that was recently acknowledged and is to be addressed by Project Mana Tangata which seeks to ready airmen for leading the application of air power.

Inherent in the leadership tenet is the application of the NZDF's preferred command philosophy—mission command.³⁴ Mission command addresses the relationship, communication and understanding between

superiors and subordinates.³⁵ While mission command and leadership are not the same, they are mutually reinforcing. Mission command is enabled by leadership depth, which helps to ensure both the appropriate articulation of intent by superiors, and that subordinates have the leadership wherewithal to interpret that intent and execute the mission. To some extent the application of mission command bridges the individual and enterprise layers of leadership.

At the enterprise level, the NZ Government expects the NZDF to be able to 'operate independently, or lead combined operations' in NZ's territory and 'neighbourhood from the South Pole to the Equator'.³⁶ The RNZAF's role in this outcome ranges from contributing to a joint or coalition mission through to conducting an independent operation—both require appropriate interoperable leadership, and air power command and control functions.

The benefits of air power are derived from '...its inherent characteristics and the *intelligent command* of its flexible and responsive capabilities'.³⁷ Command and control is a 'key enabling air power role' with subordinate elements of 'Air Campaigning' and 'Battlespace Management'.³⁸ Scale and necessity limits the need for the RNZAF to have organic capabilities in some of command and control missions. However, others are fundamental to the effective conduct of unilateral RNZAF missions or when operating as part of a coalition, yet the RNZAF's individual and organisational competence in them is limited. For instance, the RNZAF should attend to increasing its capacity in air power

33 SQNLDR Rhys Evans for leadership on operations with No. 40 Squadron. New Zealand Department of Prime Minister and Cabinet, New Year Honours 2018 – *Citation for the New Zealand Distinguished Service Decoration*, 30 Dec 17, NZ Government. <https://dpmc.govt.nz/honours/lists/ny2018-dsd#evansr>. (accessed December 15, 2018). A/SGT Carlin O'Neil recognised for leadership in his unit and in the community. Rebecca Quilliam, 'Airman of the Year', *Air Force News*, Issue 198, December 2017, Wellington, NZ, 14. <http://www.airforce.mil.nz/downloads/pdf/airforce-news/afn198.pdf> (accessed December 12, 2018).

34 NZDF, *NZDDP-D*, 51

35 Ibid, 52.

36 NZ Ministry of Defence, *Strategic Defence Policy Statement 2018*, 7

37 (Emphasis added). RAAF, *AAP 1000-D*, 42.

38 RAAF, *AAP 1000-D*, 80–84

command and control missions like Air Campaign Planning and Execution, Targeting, and Air and Battle Space Management.³⁹

LEADERSHIP

RNZAF people are leaders in their community, across the nation and globally every day. Mission command is at the forefront of our approach to leading on operations and organisationally. We have the air power command and control (C2) capability and competence to lead operations in NZ and our neighbourhood.

PARTNERED

The RNZAF requires partners to succeed and in many cases those partners need the RNZAF. Partnerships enable Cooperation (a principle of war) between individual services and between coalition partners, which is 'of vital importance in modern-day military operations'.⁴⁰ There are two core elements in the *Partnered* tenet, firstly, partnerships cross organisational, national and international boundaries. Secondly, the RNZAF must be a trusted and interoperable partner that brings value to the relationship.

The RNZAF's most important partners are other elements of the NZDF. The NZDF has deliberately strengthened internal connectivity and collaboration in

order to optimise resources and enhance the NZDF's ability to deliver joint effect.⁴¹ Optimum joint effect ensures the uniqueness of each Service is leveraged collectively to maximise operational success—the whole is greater than the sum of its parts. Joint effect is distinct from two or more Services (or pan-Defence elements) working collaboratively to improve the effectiveness and efficiency of the Defence Force enterprise. However, both outcomes are relevant to this tenet and underscore why the Army, the Navy, and pan-Defence entities are the RNZAF's most important partners. Following close behind the RNZAF's Defence partnerships are those with other arms of Government which create positive interagency effects for the national ends.⁴² These 'NZ incorporated' collaborations are particularly important to Government for delivering *Community* and *Nation* Defence outcomes.⁴³



41 Future 35 Refers: New Zealand Defence Force, *Future 35: Our Strategy to 2035*. <http://www.nzdf.mil.nz/corporate-documents/future35/default.htm> (accessed December 12, 2018).

42 NZDF *NZDDP-D* p.79 lists the NZ Government Agencies that are supported by the NZDF.

43 See NZ Ministry of Defence, *Strategic Defence Policy Statement 2018*, 12 for instance.

39 The RAAF, *AAP 1000-D*, 82–84 explains these air power command and control missions in detail. For those that might argue Targeting is not an issue for the RNZAF given the absence of an air attack force, consider the P3's ISR and bombing capabilities both of which contribute to, or are a product of, effective targeting.

40 NZDF *NZDDP-D*, p.49.

The NZ Government requires Defence to maintain international partnerships in the interests of national and international security. Policy highlights the critical relationship Defence has with its 'close friend and confidante' Australia and notes the importance of partnerships with South Pacific friends, the Five-Eye countries, NATO, and other multi-lateral institutions.⁴⁴ In some cases these relationships are assessed to be 'vital to enabling the realisation of [NZ's] interests, the promotion of our values, and the safeguarding of our sovereignty in a complex and changing world'.⁴⁵ The RNZAF has a role to play in furthering these international relationships through exchanges, exercises, mission contributions, and various air force fora.

The RNZAF adds value to partnerships, although it will never have the wherewithal to offer a comprehensive suite of air power capabilities. The RNZAF is required to constantly find ways to contribute meaningfully with the capabilities it can generate while judiciously seeking support from partners to bridge gaps. *Conceptual* and *physical* interoperability with partners is key to success.⁴⁶ However remaining interoperable, especially with equipment, is increasingly challenging given the escalating sophistication and cost of military hardware.⁴⁷ This is a similar challenge to that identified in *Combat Capable* and it can again be addressed, at least in part, by focusing-on the *conceptual* and *physical* (personnel) elements of warfighting power. In this case strengthening RNZAF human performance with quality doctrine, regular partnered exercises and deployments, and robust military education will enhance interoperability. With

very few exceptions, the values and attitudes that RNZAF people bring to partnered missions are highly regarded. However, to create equitable partnership value and mission success it is also important to ensure professional air power mastery. This need was also highlighted in both the *Combat Capable* and *Leadership* tenets.

PARTNERED

The RNZAF is an essential and valued element of joint, interagency and multinational forces. We have a strong network of partners who trust our capabilities and seek to operate with us because we are interoperable and add value at the individual, unit and organisational level. We embrace partnerships at home in the communities we are part of, among the National agencies we serve with, and among our long-standing and emerging international partners.



⁴⁴ See NZ Ministry of Defence, *Strategic Defence Policy Statement 2018*, 27, 31, 32.

⁴⁵ NZ Ministry of Defence, *Strategic Defence Policy Statement 2018*, 27.

⁴⁶ Moral alignment is also important because if values and culture are too far apart, partnership and cooperation gets harder.

⁴⁷ NZ Ministry of Defence, *Strategic Defence Policy Statement 2018*, 19.

VALUES AND CULTURE

Values and culture support the success of any organisation, especially militaries which require both to underpin their moral warfighting capacity and professionalism. This tenet has four elements: First, the RNZAF embraces the values and culture shared across the NZDF, but it also holds dear the attitudes that make air forces unique, especially airmindedness. Secondly, safety and airworthiness are part of the RNZAF's organisational fibre, but they are not its *raison d'être*. Thirdly, diversity brings strength. Finally, history is important and underpins many of the preceding aspects of this tenet.

Values and culture drive the attitudes and behaviours of RNZAF people and the organisation itself. The RNZAF's values rightly match those of the NZ Army and the Royal NZ Navy because 'the NZDF's culture and set of military values provide the foundation for NZ's unique approach to the conduct of military operations'.⁴⁸ This consistency reflects the enduring, necessary and mutually enhancing relationship the Air Force has with its sister services as expressed in the *Partnership* tenet. Moreover, the RNZAF's values of *courage*, *comradeship* and *commitment* reflect how the RNZAF and its people behave at home, throughout the nation, and across the world every day. Dedication to these values by airmen provides a critical unifying basis that helps to motivate Air Force people to serve and sacrifice.

In contrast to the alignment of NZDF values, unique aspects of the RNZAF's culture serve as a differentiator, especially airmindedness. Airmindedness is 'the sum of an individual's depth and breadth of knowledge and understanding of the characteristics and employment of air power'. It comes from multiple sources including training, experience, and organisational values.⁴⁹ When reflecting on airmindedness US Air Force doctrine opines that 'the perspective of an Airmen is necessarily different; it reflects a unique appreciation of air power's potential, as well as the threats and survival imperatives unique to Airmen'.⁵⁰ An RNZAF of 'air-minded' people is fundamental to RNZAF air power capability and its contribution to the joint effect.

Safety and airworthiness are part of the RNZAF's fibre because they are pervasive and thus more akin to a culture than a task or goal. They are central to the RNZAF's military effectiveness, but they are a means to the end, not the end itself. They enable the RNZAF to achieve its mission 'to provide relevant, responsive and effective air power to meet NZ's needs'.

History and traditions underpin the RNZAF's culture and values. The past provides lessons for the future and creates a unifying perspective to bring RNZAF (and NZDF) people together. Examples include: experiences of past conflicts from which we learn lessons and come together to recall sacrifice; ceremonial events and the flags and symbols associated; memorabilia formally housed in museums or scattered through units; and, messes, clubs and sporting activities.

⁴⁹ RAAF *AAP 1000-D*, 168

⁵⁰ United States Air Force, *USAF Doctrine 1*, Alabama: USAF LeMay Center For Doctrine, 33. https://www.doctrine.af.mil/Portals/61/documents/Volume_1/Volume-1-Basic-Doctrine.pdf

⁴⁸ NZDF, *NZDDP-D*, 16.

Historically the NZ military, and thus the RNZAF, was formed almost entirely of Anglo Saxon and Māori. This ethnic and cultural blend is a combat enabler and has provided the NZDF with a unique and potent people capability over many years. The RNZAF's cultural diversity continues to expand and evolve today. The recent opening of the RNZAF Turangawaewae is a stand-out example of cultural strength coming to the fore. Moreover, in a manner consistent with NZ society, the RNZAF continues to embrace differences in ethnicity, religion, sexual orientation and draws power from the diversity they create.

VALUES AND CULTURE

The RNZAF's culture and values underpin our capability and enable success delivering air power. We consistently leverage our Anglo-Saxon and Māori heritage, along with our contemporary cultural diversity, to strengthen capability and innovation. Safety and airworthiness is a culture we embrace continuously because it underpins mission success. Our airmindedness, combined with the values of courage, comradeship, and commitment are fundamental to our capacity to fight and win in the air.



The tenets of *Combat Capable, Flexibility, Expeditionary, Leadership, Partnered, Values and Culture* are based on the author's interpretation of the RNZAF's history, current doctrine and Government's most recent (but essentially enduring) policy expectations. Their doctrinal and historical basis suggests these tenets are relatively durable and generally held to be true within the RNZAF; at the very least ignoring them is somewhat perilous. Their concise articulation is worthwhile because it provides a clear reminder of the RNZAF's nature and what's important. A strong organisational foundation such as this helps maintain focus on the big picture, which is especially necessary today as the RNZAF embarks on another period of capability IIS. Regardless, defining tenets such as the six proposed here-in gives a unifying concept to guide and focus RNZAF air power now and in the future—they may even provide a useful starting point for a new RNZAF organisational strategy.

In many respects these tenets reflect the RNZAF's successful daily endeavours, but they are also deliberately aspirational. Thus, as highlighted throughout this essay, aspects warrant attention in the interests of improvement. In these cases this optimistic airman hopes the tenets will provide a rallying point and basis for positive progress. Most notable in this regard is the importance of the RNZAF having airminded air warfighting professionals (*Combat Capable, Leadership, Partnered, Culture and Values*)—underscoring the importance of Project Mana Tangata and cogent air power doctrine. Additional improvement efforts could focus on strengthening RNZAF air command and control capability (*Leadership*) and on optimising the organisation's deployed air basing enablers, especially increased counter-drone capabilities (*Expeditionary*). Perhaps most importantly however, the tenets, if understood, developed and discussed among the RNZAF's members and with stakeholders, can contribute to a greater understanding of RNZAF air power and its role on behalf of New Zealanders in the community, nation and world.

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YMCA mobile refreshment truck providing 'Triangle Joe's brew' at an RNZAF forward operating base during the Pacific War
Air Force Museum of New Zealand



Image credit: newshub.co.nz

A NEW ZEALAND SPACE SECURITY STRATEGY

Wing Commander Leigh Foster

INTRODUCTION

“When something is important enough, you do it even if the odds are not in your favor”

Elon Musk¹

In the age of the smartphone, we glance at a screen to check the time, verify our location or work out how to get from A to B by the most expeditious or convenient route. Some 20,000km above us, in Medium Earth Orbit (MEO), circling the earth at several kilometers per second are satellites that can give time accurate to billionths of a second and, through geolocation, position to within a few meters. Chip-sized receivers in devices pick up signals from these satellites doing away with the need for the old systems – maps and watches.

So effective are the Global Navigation Satellite Systems (GNSS) at delivering time and position (two essential services) accurately, dependably and cheaply, that many aspects of the modern world have become reliant on it.

Computer networks, electricity transmission, broadcasting, and telecommunications all require highly accurate and synchronized time across a geographically distributed system. Traceable time, the ability to continuously verify when events take place, is fundamental to financial trading, banking and to enable regulatory oversight and analyse market anomalies. Emergency services, transport systems, supply chains and the general population all rely on the navigation and communication aspects of space-based systems to derive significant benefits. National security institutions, government departments, entertainment firms, research institutes, weather forecasters and the aviation industry all rely on space-based assets to make everyone's life safer and more manageable.

THE AUTHOR

Wing Commander Foster is a RNZAF Air Warfare Officer with a C-130 Hercules background. He has served in numerous operational theatres including the South Pacific, Asia, Antarctica, Afghanistan and Iraq. WGCdr Foster is a recent graduate of the Air War College, Maxwell Air Force Base, Alabama.

¹ Christian Davenport, *The Space Barons: Elon Musk, Jeff Bezos, and the Quest to Colonize the Cosmos* (New York: PublicAffairs, 2018), chap. 12.

Space was once called the final frontier, however, today it is a domain integral to all parts of human activity from commerce and entertainment, to navigation and defence. The growth of this industry and the increasing development in space provides an opportunity for all to benefit – New Zealand (NZ) is not alone here.

The NZ government formed the NZ Space Agency (NZSA) in April 2016 to promote the development of a space industry in New Zealand. The NZSA was also established to regulate the country's growing commercial space industry, and to allow space launches by the New Zealand subsidiary of Rocket Lab, a United States (US) aerospace company.²

The NZSA is the lead government agency for commercial use of space, space policy, regulation and business development in NZ. They are building the regulatory regime, which includes new laws enacted in parliament that provide for the safe, responsible and secure use of space from NZ while meeting international obligations and managing liability arising from the requirements as a launch nation. The government wants the NZ economy to realise the enormous upside of the growing space industry through the economic, social and environmental benefits associated with the use of space. Further, the NZSA is the lead organisation for space-related international engagements and will focus on building closer ties with other national space agencies, potential investors and entrepreneurs, and other government regulators.³ As technologies further improve the world's ability to access and operate in space, and with exciting developments in the private sector continuing to shape and evolve the domain, it is time the NZ government took action.

² Ministry of Business, Innovation and Employment, "New Zealand Space Agency," <https://www.mbie.govt.nz/info-services/sectors-industries/space> (accessed August 31, 2018).

³ Ibid.

Underpinned by subordinate strategies, NZ requires a holistic space strategy across civil, commercial and security sectors. This strategy must focus on diplomacy, affordability and environmental sustainability to ensure focused action. Secure and stable access to space is a critical component of our everyday lives – it is a vital national interest, therefore, a space security strategy which focuses on diplomacy, domain awareness and layered security is essential. This paper will answer the question: how should NZ create a holistic space strategy and what does a space security strategy entail? It will describe why NZ needs a holistic space strategy, what it should be made up of, and explore the specifics of a space security strategy.

PART 1 – HOW DID WE GET HERE?

“What we need to do is always lean into the future; when the world changes around you and when it changes against you – what used to be a tail wind is now a head wind – you have to lean into that and figure out what to do because complaining isn't a strategy.”

Jeff Bezos⁴

Increased space access has made space less stable and secure. As the US, Russia and China augment their space capabilities and the private-sector continues to alter how we get to and operate in space, the space domain is now “congested, contested and competitive.”⁵ Barriers to entry have been lowered and the benefits offered are

⁴ ABC News, “Amazon CEO: ‘Complaining Isn't a Strategy,’” ABC News, September 25, 2013, <https://abcnews.go.com/Technology/jeff-bezos-amazons-earth-ceo-reaches-stars/story?id=20363682>.

⁵ Theresa Hitchens et al., *Toward a New National Security Space Strategy: Time for a Strategic Rebalancing*, Atlantic Council Strategy Paper No. 5, 2016, i, http://www.atlanticcouncil.org/images/publications/AC_StrategyPapers_No5_Space_WEB1.pdf.

now greater than they have ever been. The days of space being a purely military domain are over, and it needs to be thought about strategically by a wide range of international players. Success here could calm diplomatic tensions, enhance human growth into space, and ideally lead to a more stable, peaceful, and useful space domain.

It is important at this stage to give some historical context in order to frame potential strategy in the new space age. The dawn of mankind's space era began in 1957 and the launch of Sputnik-1 by the Soviet Union precipitated a predominantly military and political response, triggering the famous ‘space race’ of the 1960s culminating in the Apollo moon landings. Space was seen as the ‘high ground’ to gain military advantage through surveillance and communications. The economic exploitation that followed in the 1970s focused on civil communications, primarily voice and TV, and Earth Observation (EO) for meteorology and land resources, which was strictly controlled by governments. Accessing space was extremely expensive requiring considerable technological prowess thereby limiting its access to only a few wealthy nations. These spacefaring nations had exclusive access to the advantages that space brings for over four decades.⁶

The balance, however, began to shift with the advent of microelectronics in the early 2000s enabling smaller, cheaper satellites utilising spare launch capacity as secondary payloads to larger, primary payloads. Developments continued throughout the 2000s with small satellites (smallsats) taking on a life of their own – the adoption of up-to-date consumer technology combined with rapid development cycles executed by small, agile teams operating closer to the IT industry

⁶ Martin N. Sweeting, “Modern Small Satellites-Changing the Economics of Space,” *Proceedings of the IEEE* 106, no.3 (2018): 343–44, <https://ieeexplore.ieee.org/document/8303876/> (accessed August 31, 2018).

cycle rather than that of the military/aerospace industry. The smallsat revolution combined with relatively cheap secondary payload opportunities brought about the acronym Low-Cost Access to Space (LCATS) along with the term ‘NewSpace.’

NewSpace is the rapidly evolving community of relatively new private aerospace companies and people working on low-cost, open commercial access to space and spaceflight technologies.⁷ NewSpace aims to leverage economies of scale through lowering usage costs by pursuing markets with high usage rates. Incremental development becomes the standard where the market pays for the next capability development, as opposed to government specifying a requirement and contractors solely working to that requirement. In this model, the government specifies the high-level requirements and industry defines the how. Commercial Off the Shelf (COTS) technology is used in innovative ways to maximise bang for buck without the need for substantial research and development or Non-Recurring Engineering (NRE),⁸ thus spreading costs.

⁷ Dr John S. Kay, “Space Systems, New Zealand and the New Zealand Defence Force,” *Journal of the Royal New Zealand Air Force* 4, no. 1 (2018): 92–93.

⁸ Non-Recurring Engineering (NRE) refers to the one-time cost to research, design, develop and test a new product or product enhancement. When budgeting for a new product, NRE must be considered to analyse if a new product will be profitable. Even though a company will pay for NRE on a project only once, NRE costs can be prohibitively high and the product will need to sell well enough to produce a return on the initial investment. NRE is unlike production costs, which must be paid constantly to maintain production of a product. It is a form of fixed cost in economics terms. Once a system is designed any number of units can be manufactured without increasing NRE cost. Daniel Shefer, Non-Recurring Engineering, <https://pragmaticmarketing.com/resources/articles/non-recurring-engineering> (accessed January 29, 2019).

NewSpace encourages rapid innovation, affordable development, low operating costs, accessibility to a broad range of businesses, shortened timescales but also shorter life. Traditional space systems worked on a 100% success rate for long-term operations in space. NewSpace posits that in many cases 80% of the program goals can be achieved for 20% of the costs.⁹ Missions can be more specific, focused, and use the latest technology rather than long-term and ubiquitous. With lower costs, more risk can be taken with larger satellite constellations further lowering costs, shortening timelines, and creating the added benefit of greater experimentation (which is rare for one-off satellites). This paradigm shift has the ability to stimulate numerous areas of the economy.

The NewSpace and smallsat industry can be broken down into three areas (Figure 1), all of which provide opportunities for NZ to exploit for economic and social growth. Much like the military aerospace model, this model reflects the designer/developer, the flyers/operators, and the processors/analysers of the information. Data is then consumed by the customer internally or externally (likely the New Zealand Defence Force (NZDF) in this case). User applications include security, energy, agriculture, resource management, climate change, disaster management, and remote sensing.

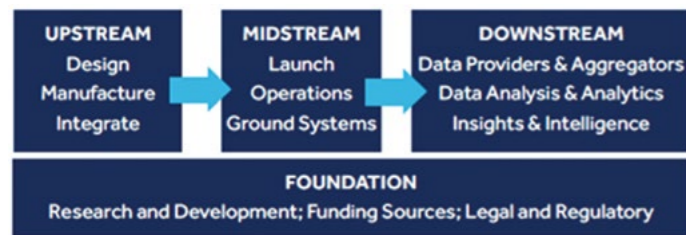


FIGURE 1: The three disciplines in the NewSpace industry

⁹ Kay, "Space Systems," *Journal of the Royal New Zealand Air Force*, 94.

With opportunities noted, it is also essential to understand the threats associated with space-based operations. Satellites and their signals are exposed to the effects of space weather, while the signals themselves are weak and vulnerable to interference. The threats to the systems posed by accidental and deliberate interference and cyberattack are steadily progressing. These threats have created, particularly in the case of GNSS, society-wide single points of failure that can easily be exploited. A space strategy must consider threats including kinetic threats such as anti-satellite weapons (ASATS), robotic arms, and debris, together with non-kinetic threats including space weather, jamming and spoofing. The strategy should include specific goals of mitigating and increasing knowledge of societal dependence thereby improving resiliency when systems are unavailable.

Although it is clear that NZ needs a holistic strategy to achieve the desired interests across civil, commercial and security sectors, what does this strategy look like?

PART II – AN ALL OF GOVERNMENT SPACE STRATEGY?

"Strategy is a fancy word for a roadmap for getting from here to there, from the situation at hand to the situation one wishes to attain...it is the intellectual connection between the things one wants to achieve, the means at hand, and the circumstances."

*Codevilla and Seabury, War: Ends and Means*¹⁰

Establishing a framework is essential for developing and executing in the long term. One framework commonly used in military organisations is the ends, ways and means model. The US Air Force (USAF) defines strategy as "the continuous process of matching ends, ways, and

¹⁰ Angelo Codevilla and Paul Seabury, *War: Ends and Means*, Second Edition, 2nd edition (Washington: Potomac Books, 2006), 97.

means to accomplish desired goals within acceptable levels of risk."¹¹ Further, the USAF states that strategy originates in policy and addresses broad objectives, along with the designs and plans for achieving them. It is, however, believed this model might be insufficient for developing and evaluating complex strategies.

Jeffrey W. Meiser claims that the 'ends, ways, means' method of defining strategy is narrow-minded and thinks it can be improved by defining strategy as "a theory of success" and understanding that "the purpose of strategy is to create advantage, generate new sources of power, and exploit weakness in the opponent."¹² Dr. Richard Rumelt reinforced this in his book *Good Strategy/Bad Strategy* where he concedes good strategy addresses a specific problem, influences clear action and, looks for advantages and opportunities. Further, he emphasises bad strategy is that which fails to address the challenge, contains too much fluff, mistakes goals for strategy, and sets poor objectives.¹³ Therefore, it would seem an expanded version of the ways, means, ends, risk model which focuses on the challenge, sets clear objectives focussed on the specific problem, influences clear action and creates advantage would be the recipe for success.

Any holistic NZ space strategy, therefore, must identify the specific problem, consider the ends, ways, means risk model and include a cohesive approach across the civil, commercial and security environment. This strategy must build a plan attempting to leverage NZ's strengths and outside opportunities and also consider internal weaknesses and external threats. The NZ space strategy

must provide a comprehensive framework for organising All-Of-Government (AOG) efforts to achieve the directed space policy. To ensure the focus is all-inclusive, for the remainder of this paper the term space refers to the industry, the domains that enable operations in space, and the ground-based infrastructure that enables space operations. For example, a ground station used to download remote sensor data is incorporated in the holistic space infrastructure, as is the radio bandwidth to enable download of satellite information.

While the scope of strategy is broadly defined, the desired ends, principles, and strategic objectives need to be defined. The NZ space policy does not clearly articulate a clear vision or desired ends, therefore, until the desired end state is defined the principles and strategic objectives cannot be expanded upon and are outside the scope of this paper – see recommendations. In saying that, the space security strategy must expand upon the specific end state (ends), principles (ways) and strategic objectives from a NZDF security standpoint.

Although the NZ space policy does outline a broad vision for space activities, there is no concise definition to focus strategic efforts or an end state to target. Without this, any complete strategy is "second-guessing" and remains unfocused. The end state needs to reflect enduring space principles which are the values that define how NZ views the use of space. These principles shape the options available to the strategist because the ways and means must support the values of NZ or the strategy risks failure.¹⁴

¹¹ United States Air Force, Air Force Doctrine Volume 1, Air Force Basic Doctrine, 1, <https://www.dctrine.af.mil/Core-Doctrine/Vol-1-Basic-Doctrine/> (accessed August 26, 2018).

¹² Jeffrey W. Meiser, "Ends + Ways + Means = (Bad) Strategy," *Parameters* 46, no.4 (Winter 2016-17): 81.

¹³ . Richard Rumelt, *Good Strategy/Bad Strategy: The Difference and Why It Matters*, 1 edition (New York: Currency, 2011), 77, 94, 97–98, 142, 160.

¹⁴ Dawn M. Githens, "Overcoming the Illusion of Security: Creating a New Spacefaring Security Strategy Paradigm." (Fort Belvoir, VA: Defense Technical Information Center, March 1, 2014), 21, <https://doi.org/10.21236/ADA606580>.

The question must be asked as to why an AOG strategy is required vice separate civil, commercial and security space strategies. NZ is very juvenile in the development of any national space program and therefore has the benefit of learning lessons from those nations that have embarked on the challenges before them. When we look at US space activities, an increasing criticism, especially in the context of China's emergence as a significant actor in space, is that the US lacks a coordinated 'US space strategy'. Moltz, in his article *Space and Strategy: A Conceptual Versus Policy Analysis* states US programs seem to proceed in fits and starts and there is no real direction. Further, he states heated debates take place in Congress and the Department of Defense (DoD) about how best to defend US space assets in an environment described as increasingly contested.¹⁵ Analysts argue China already poses an effective and comprehensive strategy for space: to dominate this environment.¹⁶ Scholars argue the US should have a similar strategy even if it creates a Cold War type scenario. Contrastingly, others see the US flailing due to overspending in military and intelligence space sectors at the expense of broader civil and commercial sectors. They argue the US should reorder its priorities and adopt a comprehensive strategy that attempts to drive a healthy aerospace industry, provide leadership in manned space exploration, and ultimately protect its security interests.¹⁷ Both schools of thought agree the US is failing in the space race and an overarching strategy is needed. As such, a number of academics have written about the importance of creating an integrated policy,

strategy, and regulatory framework to ensure an efficient yet affordable system.

AT Kearney consultancy¹⁸ discusses the benefits to smaller nations of affordable access to space by way of reduced barriers to entry, faster access to returns, and low-cost small satellites. Further, they state countries leveraging these trends to build a viable space industry will create knowledge-intensive jobs, improve their research and innovation capabilities, and strengthen their international standing.¹⁹ However, these countries will still face significant challenges in space. Global competition, limited orbital slots, and radio spectrum bandwidth shortages pose regulatory hurdles. Furthermore, talent shortages can hamper newcomers as they lack the experience and specialised professionals to build a competitive industry. To prevent the siloed application of investment they suggest a holistic approach to meet challenges and exploit opportunities. This approach starts with clear guidance from national leaders addressing the essential elements of a vibrant space program: policy, strategy, regulation, and implementation.²⁰

Strategic Questions

Before a strategy is composed, an articulated end state must be understood and accepted through policy. This policy is yet to be developed – see recommendations. The overarching goal must be coherent with NZ values

¹⁵ James Clay Moltz, "Space and Strategy: A Conceptual versus Policy Analysis," *Astropolitics* 8, no. 2–3 (December 3, 2010): 113–14, <https://doi.org/10.1080/14777622.2010.522935>.

¹⁶ Gordon G. Chang, "The Space Arms Race Begins," *Forbes*, <https://www.forbes.com/2009/11/05/space-arms-race-china-united-states-opinions-columnists-gordon-g-chang.html#6ce7ed357d73> (accessed August 26, 2018).

¹⁷ Moltz, "Space and Strategy," *Astropolitics*, 114.

¹⁸ A.T. Kearney is an American global management consulting firm that focuses on strategic and operational CEO-agenda issues facing businesses, governments and institutions around the globe.

¹⁹ A.T. Kearney, "Launching a Successful Sustainable Space Sector", http://www.middle-east.atkearney.com/paper/-/asset_publisher/dVxv4Hz2h8bS/content/launching-a-successful-sustainable-space-sector (accessed September 9, 2018).

²⁰ Ibid.

and national interests, and understanding must exist as to the diplomatic effect sought, both in and out of space. Significant issues such as risks posed by space debris and Space Situational Awareness (SSA) must be addressed through specific principles linking to the overarching goal.

This section will outline three principal areas essential in developing a more robust approach to strategy development. AT Kearney suggests the most important strategic question facing smaller nations entering space is where to focus their efforts. Nations that focus their efforts allocate resources more efficiently, build capabilities faster, and improve odds of success.²¹ However, before any business/commercial decisions can be made (means) the link back to policy must be clearly understood (ends). The NZ Government's strategic analysis must evaluate where the market will lie, how the geographic position can benefit it, the current international standing, current and future relationships, and how an already active space market will assist. There is certainty that NZ does not aim to dominate the space environment as an emerging space nation, therefore, from a diplomatic standpoint, the strategy will need to clearly define key relationships.

First, the space strategy must rely on *diplomacy* to promote NZ's interest in, and ensure access to, space. NZ will need to continue to be an advocate for secure access to space, and protect interests through participation in international agreements and treaties such as those through the United Nations (UN). Already a ratified member of the Outer Space Treaty (OST – 1967),

NZ has recently joined two councils of the UN Office for Outer Space Affairs (UNOOSA), namely the Peaceful Uses of Outer Space (COPUOS) and the Registration Convention.²² NZ is also party to a further two UN treaties being the Rescue Agreement and the Liability Convention. The NZ Space Agency has also signed a bilateral agreement with the European Space Agency (ESA), and the governments of NZ and the US have a bilateral treaty named the Technology Safeguards Agreement (TSA) which enables commercial entities in NZ to import rocket launch technology and satellites from the US. This TSA enables US space business to consider NZ as a business location and enables the NZ government to recognise US spacecraft standards for launch.²³ One area where NZ had a keen interest was the European Union's now stalled *Code of Conduct for Outer Space Activities* designed to ensure safe access to space and attempts to ensure member states refrain from any action which intends to directly or indirectly, damage outer space objects.²⁴

From a security perspective, New Zealand is a member of the Combined Space Operations (CSpO) Memorandum of Understanding (MOU), signing in October 2015 alongside Australia, Canada, the United Kingdom, and the US. The purpose of CSpO is to strengthen deterrence, enhance resilience, and optimise resources. It enhances participating nations' understanding of the current and future space environment, supports awareness of the space capability to conduct global operations, and provides the military-to-military relationships to address challenges and ensure the peaceful use of space. Focus areas include SSA, support to operations, launch and re-

²² Kay, "Space Systems," *Journal of the Royal New Zealand Air Force*, 98–99.

²³ Ibid, 98–99

²⁴ John J. Klein, "Space Strategy Considerations for Medium Space Powers," *Astropolitics* 10, no. 2 (May 2012): 110–25, <https://doi.org/10.1080/14777622.2012.698929>.

²¹ Ibid.

entry assessment, and contingency operations. Working together to preserve access to space is the fundamental objective which becomes more significant as space becomes more congested, disputed and contested.²⁵

With significant rhetoric regarding the future of the OST and its potentially fickle legal standing, NZ must aim to be at the forefront of any future global agreements that protect international standards and norms to ensure safe access to space and peaceful resolutions of conflict. It will be crucial for NZ to ensure adherence to a rules-based system is reflected in the space strategy as this is critical for secure access to space, minimising potential space debris and accidental collisions, and of course to prevent conflict creation in space. Furthermore, *NZ's diplomatic status and unique geographic location* will need to be emphasised to ensure friends, allies and adversaries understand the proposed benefits. It is vital for nations reliant on NZ for support to understand how they could benefit from the implementation of the strategy, thereby bestowing diplomatic support in the global environment. Although the agreements and treaties provide a clear indication of where NZ's allegiances lie, a strategy must reflect these allegiances to ensure transparency and ongoing dialogue. This may have the added benefit of building the community of like-minded space actors and potential cost sharing.

Second, a vital part of any public strategy is the link to *affordability and feasibility* as the taxpayer will need to understand the potential benefits to the nation. This is particularly important for a space strategy. Moltz points out that a valid option for a future space strategy is the ability to utilise international efforts for major projects which would likely reduce costs.

Moltz points out this has worked for the International Space Station (ISS), but it is vitally important to ensure reliable partners – something that is difficult to predict.²⁶ With the worldwide drive for an SSA system and the subsequent need for a variety of ground station locations, this is one area where NZ could share costs and enable return on investment for the international community. Furthermore, cost sharing could take the form of multilateral networks of Intelligence, Surveillance, and Reconnaissance (ISR), communications, and navigation which should be mentioned in the national strategy and expanded upon in the subordinate space security strategy. As highlighted above, the strategy *must provide the public with proposed benefits* and should *aim to generate buy-in* by way of industry, stakeholders and public support. Equally, the strategy *must make clear the systems that rely on space services and detail the potential effects on the nation if access is denied, disrupted or degraded*. This information will have the benefit of highlighting to the public the gross reliance on space-based systems, thus why continued freedom of access is financially beneficial. The Blackett review made several recommendations to improve the public's resilience to a loss of one of these systems which included education of the public as a priority.²⁷

Additionally, the strategy should look at *how the NZ Government can enable growth* through flexible tax legislation (tax exemptions or reductions), funding for university-based research programs, funding for research and development specific to space systems, and potentially seeding money into private companies to develop AOG solutions. The US DoD has seeded money into the commercial sector for some time with some excellent results.

²⁶ Moltz, "Space and Strategy," *Astropolitics*, 132.

²⁷ Government Office for Science, *Satellite-Derived Time and Position: A Study of Critical Dependencies*, London, January 30, 2018.

²⁵ Kay, "Space Systems," *Journal of the Royal New Zealand Air Force*, 101.

Third, the NZ space strategy must *consider the notion of environmental sustainability*. While space is immense, key areas critical to NZ's interest in space are rather limited, these include the near-earth space, Low Earth Orbit (LEO) and Geostationary Orbits (GEO). There has been a monumental increase in small, micro, nano and cube satellites launched into LEO, and the growth rates are accelerating with the NewSpace age. With low cost access to space and open commercial access, the space ecosystem is changing. The GEO belt is becoming crowded and faces future limitations, the expansion of debris in LEO puts assets at risk, radio spectrum crowding is creating conflicts over broadcast frequencies, and planned missions into cis-lunar²⁸ are raising questions of who should have access to resources.²⁹ For these reasons, any workable strategy must consider the need to address these resource shortages. Therefore, international agreements, with the legal framework to address these issues, are desirable. NZ must at least have a presence in the space environment to influence shaping these agreements and regulations. Drawing parallels to the Antarctic Treaty System regarding peaceful uses of space, use of finite resources, and global implementation and concurrence; NZ must have the ability to maneuver to ensure its voice is heard and actions are taken seriously.

The implementation of the NZ Space Strategy will not be an easy task; however, it will prevent the siloed creation of civil, commercial and security space strategies and bring about synergies focusing on a holistic NZ space policy. A collaborative strategy must create a vision capable of rallying national and international support behind a set of practical priorities, whether that be enhanced situational awareness for NZ and allies, creating business growth opportunities, corporate industry support or population

²⁸ cis-lunar is a term that comes from Latin and means 'on this side of the moon' or 'not beyond the moon'.

²⁹ Moltz, "Space and Strategy," *Astropolitics*, 133.

resiliency, or philosophical goals such as freedom of access, service to earth as a priority, or creating a league of spacefaring nations. It is likely, given the international reliance on space, there will need to be an element of *quid pro quo* in order to create more substantial collective gains in space. Given the worldwide interest in space and the increasingly aggressive rhetoric coming out of the space powers, NZ must assist in the prevention of a kinetic conflict in space that may prevent access for all.

The discussion to date has focused on the broad AOG space strategy, however, to ensure ways, means and ends are synergistically applied, subordinate strategies will need to be formulated across civil, commercial and security. Part III of this paper will focus on the security aspect that will feed into the AOG strategy whilst the civil and commercial strategies are outside the scope of this paper.

PART III – SPACE SECURITY STRATEGY

“New Zealand relies on assured access to space-based systems to support its economic prosperity, maintain public safety and enable the effective deployment and operation of military forces. New Zealand is not unique in this regard, and has an interest in working with its international partners to promote the responsible and peaceful use of space. Of concern to New Zealand are activities, whether man-made or natural, which could lead to significant disruption to space-based systems as space becomes a more congested and competitive environment.”³⁰

New Zealand Defence Force White Paper 2016

³⁰ New Zealand Government, *Defence White Paper 2016* (Wellington: Ministry of Defence, 2016), 30.

The New Zealand Government's Defence White Paper (DWP) 2016 and, more recently, Strategic Defence Policy Statement (SDPS) 2018 explicitly state the need for the NZDF to contribute to NZ's secure access to space-based systems. SDPS 18 stipulates three major capability areas that require attention, one of which is the "Defence contribution to NZ's secure access to space-based systems."³¹ Further, SDPS 18 states:³²

"Space-based systems are increasingly important to NZ's wellbeing and to Defence Force operations. Defence now has an important role in contributing to international efforts to ensure secure access to space-based services. To exercise command and control, navigate and operate battlefield management systems that are interoperable with our partners, the Defence Force is becoming increasingly reliant on information networks and space-based systems. In addition, NZ's space industry has grown substantially in recent years."³³

Additionally, SDPS 18 identifies space, as well as climate change and cyber, as complex disrupters (transnational trends) able to challenge stability in complex ways. It breaks space out further to describe the reliance on space-based systems for situational awareness and providing services including navigation, telecommunications, EO and banking. It describes the significant national security implications a denial of these services can have on economic prosperity and public safety. It details space-based services critical for many parts of military operations and discusses the proliferation (current and

³¹ New Zealand Government, *Strategic Defence Policy Statement 2018* (Wellington: Ministry of Defence, 2018), 8, <https://defence.govt.nz/publications/publication/strategic-defence-policy-statement-2018>.

³² Ibid, 13.

³³ Ibid, 13.

planned) of counter space capabilities, both kinetic and non-kinetic (jamming, spoofing, etc.), and the effect on space assets and debris if they are utilised. Finally, SDPS 18 discusses the increasingly congested and competitive environment, environmental hazards such as space weather, and how a rules-based approach is necessary to ensure access and use of space can be maintained.³⁴

Particular Capability Requirements

SDPS 18 explicitly addresses a Defence contribution to NZ's secure access to space systems as part of the particular capability requirements along with maritime domain awareness and response (which may also utilise space-based assets). Essentially it places secure access success in the hands of international norms that influence behavior in space. It explicitly states NZ needs to promote the international rules-based order, which matches its stance in other domains. Again, explicitly in the text, it states that Defence must ensure it has the right people with the right expertise to contribute domestically to the development of the national space policy as well as internationally through engagement with the Combined Space Operations Centre (CSpOC)³⁵ and the Schriever Wargame^{36,37}.

Finally, SDPS 18 calls for NZDF to explore how space capabilities could be developed and used as part of its capability mix, including as a contribution to NZ's

³⁴ Ibid, 9.

³⁵ The CSpOC is a U.S. led initiative designed to improve coordination between the U.S. and allies, commercial and civil partners for defensive space efforts. The aim is to enhance individual and collective space capabilities in order to expand the overall multi-domain military effectiveness.

³⁶ The Schriever wargame is a U.S. led wargame centred on various combined command and control frameworks to employ and defend space, gain insight into space resiliency, and investigating partnerships for joint and combined operations

³⁷ NZ *Strategic Defence Policy Statement 2018*, 38.

security partnerships; and ensure it can operate effectively in a space-denied or degraded environment. It states that this may include Defence staff to support partners' capabilities that benefit NZ.³⁸

This section has defined the NZ Government directed end state which Defence is empowered to meet. The remaining parts of the paper address the ways and means in which a NZ focused space security strategy should develop.

SO WHAT?

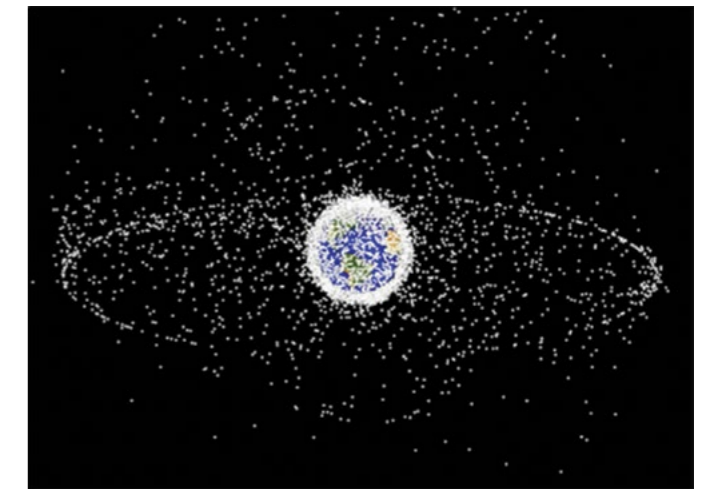
The NZ Government sends a clear message in the aforementioned documentation as to the path forward and provides macro (and some micro) level direction to the Chief of Defence Force and staff regarding prospective NZDF outputs. It is critical to define the ways and means for NZDF to achieve the desired ends. A strategy, more specifically a *space security strategy* will form part of, and lead into, the AOG space strategy discussed in Part II. As such, this section will detail the space security environment, define why we need a specific security strategy and provide recommendations for a future strategy and provide a framework to operate from.

Space Security Environment

Before the likely space security strategy is defined, the space security environment needs to be understood. The reliance on space-based assets across a wide range of sectors brings about an undoubtedly high level of vulnerability. Part of NZDF's mandate is to protect NZ's national interests and advance security; space has rapidly become entwined in both the national interests and national security. It is an integral enabler to protect and advance these interests.

³⁸ Ibid

The 2011 US National Security Space Strategy describes the space environment as "congested, contested and competitive."³⁹ The terms can be broken down further to aid in understanding: congested, as described by the 2012 deputy assistant secretary of defense for space policy Gregory Shulte, in that there is a vast quantity of "stuff" in orbit, including active systems, trackable debris, and other debris. Competitive, based on the growing number of actors in space, including nations, consortiums, and commercial industry. However, it is the contested aspect, defined as the number of actors developing counter-space capabilities and integrating them into doctrine and forces, that drives national security strategy in space.⁴⁰



A computer-generated image of objects in Earth orbit, as plotted by NASA that are currently being tracked. A significant number of the objects in this illustration are orbital debris, meaning they are not functional satellites. The image depicts the concentration of orbital debris populations and is not scaled to Earth. Photo credit: NASA

³⁹ Hitchens et al., *Toward a New National Security Space Strategy*, 15.

⁴⁰ Ibid

As space becomes more congested, it naturally becomes more contested. As of 2011, there were more than 22,000 objects tracked by the US DoD, of which only 1,100 were active satellites (see image below). As at 2017 there were 1,980 active satellites in orbit (as well as 2877 inactive satellites).⁴¹ Thus, the bulk of objects tracked are either debris or inactive satellites. However, there are hundreds of thousands of additional pieces of debris too small to track with current sensors, the estimate being more than 750,000 pieces of debris larger than 1cm. As debris is not maneuverable or removable, it is extremely hazardous to active satellites and can be catastrophic to manned space flight; the situation is only getting worse. The number of objects in orbit has more than doubled since 2000. This increase is, in part, due to the successful Chinese Anti Satellite (ASAT) missile test in 2007 and the collision of the Iridium and COSMOS satellites in 2009. The Iridium collision marked the first accidental hypervelocity collision of two intact spacecraft which exacerbated the space debris issue. This collision and the deliberate ASAT test highlight that space is not a sanctuary and illustrates that intentional and unintentional threats are abundant.⁴²

The risk of in-orbit collisions and kinetic attack are not the only growing threats, and arguably, there are far more common threats.

A senior Air Force General at a speaking engagement to the Air War College class of 2019, highlighted the increasing occurrence of jamming, spoofing, cyber-attacks, and laser attacks and the need to provide a resilient space architecture.⁴³

41 Dave Mosher, "The US Government Logged 308,984 Potential Collisions in 2017 – and the problem could get much worse," *Business Insider*, <https://www.businessinsider.com/space-junk-collision-statistics-government-tracking-2017-2018-4> (accessed January 29, 2019).

42 Githens, "Overcoming the Illusion of Security," 10.

43 Senior Air Force General, "Space Warfighting 2018" (AWC lecture, Air University, Maxwell AFB, AL, September 12, 2018).

A recent British report commissioned to look at public reliance on space-based resources detailed the jamming and interference of PNT in London on a daily basis and suggests it is easily accomplished by in-vehicle jammers. The levels of interference detected by multiple sensors over a four-year period (Feb 2013- Feb 2017) caused GPS receivers to cease operating, or operated at diminished levels affecting users and systems that rely on them.⁴⁴ Furthermore, analysis of GPS jamming events collected during the 'Arab Spring' indicates the emergence of two trends. First, threats no longer emanate from traditional space powers – emerging space nations and non-state actors are increasingly the cause of interference. Second, the trend indicates the number and types of threats are increasing. The reality is that all types of space capabilities are being targeted daily, from government and commercial satellites to navigation, highlighting the contested nature of this domain. Therefore, strategies not addressing space threats or merely attempting to maintain space as a peaceful domain are out of touch with reality.⁴⁵

SECURITY STRATEGY SPECIFICS

To establish the space security strategy, analysis of the ways, means and ends must be undertaken and the most important internal strengths and weaknesses, along with external opportunities and threats extracted. Several authors have published their ideas concerning the essential elements of a space security strategy which has been analysed and applied to the NZ situation. The following section will begin by outlining the analysis of the three most essential security elements for NZ being:

44 Government Office for Science, *Satellite-Derived Time and Position*, 26.

45 Githens, "Overcoming the Illusion of Security," 11.

international engagement, domain awareness, and layered security; provide details of how they would manifest in a NZ strategy, and finally, detail how they link to enable the space security strategy.

International Engagement/Diplomacy

International engagement is critical for secure and safe access to space as it engages both the international military community and the international commercial sector with the aim to share effort and resources, establish standards and policies to enforce responsible behavior, and aid in environmental protection. In space, a single accident or irresponsible incident can have massive ramifications that could affect all spacefaring nations globally. General Raymond, commander [US] Air Force Space Command (AFSPC) stated that there is global interest in preventing a conflict from extending into the global commons of space due to the multitude of interconnected systems that flow through space.⁴⁶ There is a definitive need to establish global standards and the space powers have the most to lose if they do not. These standards must clearly outline security criteria for satellites and ground infrastructure, data sharing requirements, asset sovereignty rights, and define what makes up legal and illegal space weapons.⁴⁷ As such, and in line with SDPS 18, NZ must push towards a rules-based approach promoting the responsible use of space by all nations, which matches the broader interest in reinforcing the international rules-based order.⁴⁸ This process will not be easy given many nations have differing views and values, however, this should not take away the desire to strive for clear, detailed standards that include enforcement mechanisms. These diplomatic terms work

46 Gen Jay Raymond, "Space Warfighting Construct 2018," 15. (<https://www.afspc.af.mil/Portals/3/documents/Space%20Warfighting%20Construct%20Handout%20-%203%20Apr%202017.pdf?ver=2017-04-05-191055-757>.)

47 Githens, "Overcoming the Illusion of Security," 27.

48 *NZ Strategic Defence Policy Statement 2018*, 38.

on a preventative strategy vice a kinetic act, thus are key to the wellbeing of the space environment. A further part of international engagement is the shared responsibility to protect, report and secure.

Given space is considered a shared domain, the global community must share in the protection of it. There is a desire to reduce the vulnerability of space systems and supporting infrastructure, which in turn, affects all space players. There is no need to duplicate all systems, thus as a minimum there needs to be an international organisation that can deconflict orbital slots (other than GEO),⁴⁹ allocate and manage the radio spectrum, integrate domain awareness systems, integrate intelligence sharing capabilities, and promote civil space collaboration. These efforts are designed to reduce costs, share capability, and spread exposure thereby allowing all nations to contribute to secure access to space. AFSPC recognises this and highlights that "each partner brings unique strengths and opportunities in support of the global deter and dissuade goal...developing these partnerships is key to success."⁵⁰ In NZ's case, there is a requirement to align training and operations with its closest allies. At the very least, the NZDF should leverage US training systems to train the initial cadre of space personnel and immediately embed a liaison officer (LNO) into the CSpOC to manage the relationship and build experience. This benefits both nations and would be well received by the US and coalition partners.

Domain Awareness

Domain awareness is arguably the most important of the security elements for secure access to space. Similarly to

49 Geostationary slots are assigned to countries by the International Telecommunications Union (ITU) as they are used for communications and broadcasting, and need deconfliction both in frequency allocation and in collision avoidance.

50 Gen Jay Raymond, "Space Warfighting Construct 2018," 15.

other domains that NZDF operates in (Land, Air, and Sea), to ensure the safe use requires specific awareness, knowledge of potential threats, and an understanding of how to mitigate those threats.⁵¹ Understanding and comprehending space is an extremely challenging task and relies on a global network of input data, assessment of the data, and the distribution of the information to a wide array of users. This collection and dissemination process is termed Space Situational Awareness (SSA). In their Atlantic Council Strategy Paper: *Toward a New National Security Space Strategy*: Time for a Strategic Rebalancing, Theresa Hitchens and Joan Johnson-Freese claim that SSA is a foundational capability of any space strategy.⁵² Given the rise of Russia and China as space powers and the capabilities they possess, SSA continues to occupy a high priority for the US and its partners.

The concept of SSA is important to preserve both manned and unmanned space operations. Traditionally, ground-based radar, electro-optical sensors, and very limited space-based assets have been used as part of the space surveillance network (SSN) to track orbital debris, inactive and active satellites. With the current SSN assets aging and the need for SSA growing, it is vital to explore new ways to ensure proper SSA is maintained to preserve space domain operations.⁵³

With the space environment in low earth orbit becoming more congested, contested and competitive, the need to discover a solution to address how countries can operate effectively in space is paramount. The need for improved SSA has gained international focus in light of recent events, and the question remains ‘how can we utilise

innovative ways to address the orbital debris problem in space?’ The United States SSN currently tracks a significant number of objects including over 2,000 active satellites, and the numbers are sharply trending upwards.⁵⁴

Hitchens and Johnson-Freese state that SSA is also an area ripe for possible leveraging of commercial and foreign capabilities, both to provide resilience and to complicate an adversary’s calculations regarding an attack.⁵⁵ Given NZ’s geographical location and mid-high Southern latitude, a unique source of SSA would provide beneficial data to a coalition SSA module. The US is leading the commercial sector integration into the SSA picture, and current practice has a commercial integration cell in the CSpOC to ascertain potential growth areas. NZ should look to encourage commercial industry to locate SSA resources in NZ and ensure the regulatory and legal permissions are in place. With an LNO in the CSpOC this feed in/out of data could be monitored, and it would create a human touchpoint for areas of growth. Moreover, Gen Raymond stated in March 2015 to the House Armed Services Strategic Forces Subcommittee that Air Force was working on a new tiered SSA sharing strategy “in order to share more information and in a more timely manner... This open exchange of information also supports the US and allied efforts to detect, identify, and attribute actions in space that are contrary to responsible use and the long-term sustainability of the space environment”.⁵⁶ Given NZ’s FVEYs (Five Eyes intelligence alliance) status and position as a member of the memorandum of understanding on Combined Space Operations, it is

likely information can be shared both ways and would be mutually beneficial.

The establishment of a global Space Traffic Management (STM) system is well overdue, however, it requires a capable and robust global SSA architecture first. Once the global SSA architecture is in place, the US is likely to lead efforts in the establishment of an STM capability. Again, this is an area where NZDF, given the skillsets in aviation and traffic management (Air Traffic Control, Capability Branch, integrated Air projects) can assist the NZ civil and commercial sector in creating a framework that collaboratively solves the traffic issue and enables a central space traffic system.

Finally, a comprehensive threat assessment capability must leverage the SSA capability as the unintentional and intentional increase in space threat increases the likelihood of a potential catastrophic event. Threats can take the form of kinetic, non-kinetic, weather and potential collisions. Although the US has robust systems, most satellite operators have little to no capability to evaluate threats, and there is no central organisation to manage traffic or threats. To create a more resilient system, the threat must be detected and action taken. In the case of space weather impacting PNT, early warning through SSA will enable a government to spread the message and improve national resilience. Moreover, early warning of a threat to a satellite will prevent reliance on that satellite as the awareness centre can warn the government or users.

Layered Security

Creating a resilient architecture is key to maintaining safe access to systems and ensuring delivery of space-based resources to users. Resilience can be defined as “the ability of an architecture to support the functions necessary for mission success despite hostile action or adverse conditions.” An architecture is deemed ‘more resilient’ if it can provide functionality with higher probability, shorter periods of reduced capability, and across a broad range of scenarios, conditions, and threats. Resilience may leverage cross-domain or alternative government, commercial, or international capabilities.⁵⁷ In order to maintain secure access to resilient space systems, NZ must establish a layered security architecture as any single safeguard may be flawed, defeated or controlled.

The Pentagon suggests resilience can be defined in four broad areas, each of which can be directly transferred into the NZ context:⁵⁸

1. Avoidance: countermeasures against potential adversaries, proactive and reactive defensive measures taken to diminish the likelihood and consequence of hostile acts or adverse conditions. This can be as simple as secure communications for ground – space control, or as advanced as manoeuvrable constellations of satellites. It could also be the utilisation of backup systems not reliant on space-based capabilities.
2. Robustness: architectural properties and systems design features to enhance survivability and resist functional degradation. This is the antijam capability or the protected cyber environment.

51 Githens, “Overcoming the Illusion of Security,” 27.

52 Hitchens et al., *Toward a New National Security Space Strategy*, 33.

53 Tolulope E O’Brien, “Space Situational Awareness CubeSat Concept of Operations” (Naval Postgraduate School, 2011), sec. abstract.

54 O’Brien, “Space Situational Awareness CubeSat Concept of Operations.”

55 Hitchens et al., *Toward a New National Security Space Strategy*, 34–35.

56 Ibid., 35.

57 US Department of Defense, Fact Sheet: Resilience of Space Capabilities, 2011, https://www.defense.gov/Portals/1/features/2011/0111_nsss/docs/DoD%20Fact%20Sheet%20-%20Resilience.pdf.

58 Hitchens et al., *Toward a New National Security Space Strategy*, 37.

3. Reconstitution: plans and operations to replenish lost or diminished functions to an acceptable level for a particular mission, operation or contingency. Again, this can range from simply having a standby contract with a commercial provider in a HADR situation, to having an on-call satellite launch contract with a provider.
4. Recovery: Space support operations to re-establish full operational capability and capacity for the full range of missions, operations, or contingencies.

It is clear this is a 'deterrence by denial' approach for the US and the US national space security community recognises space-based capability must not constitute a single point of failure of military operations. For NZ it is just as essential, therefore given the likely budget and resource to apply to the situation the NZ Government will need to think innovatively and ensure force resiliency in the event of a disrupted situation. At present, the capability mix that NZDF possesses is over-reliant on space-based resources for some tasks and under-reliant on others – the key is to determine the right capability mix and build the budget accordingly. To create this ideal mix, a layered security model should underpin all capabilities.

The challenge to a layered security model is balancing the reality of space threats, the likelihood of the threat, predicting what the threats will be, and the consequences of a disruption/denial. Ideally, a layered security mix would span the spectrum of responses to include electromagnetic capabilities, physical protection, secondary systems, and disaggregated capabilities. However, given NZ budget and resource constraints this comprehensive and holistic model is unlikely. The NZDF needs to focus on bang for buck activities in space that do not constrain resources in the operation and day-to-day management of the capability. Furthermore, a deterrence posture must be backed up with coalition support as an inability to act invalidates any deterrence policy.

NZ must, therefore, rely on international agreements and partners to strengthen policy and ultimately rely on diplomacy to reinforce its stance.

AFSPC defines space disaggregation as “*The dispersion of space-based missions, functions or sensors across multiple systems spanning one or more orbital plane, platform, host or domain.*”⁵⁹ Dr Peter Wegner et al. propose in their article *How to Make Disaggregation Work* that disaggregation could be the single largest part of resilience and suggest spreading capabilities across diverse platforms creates both tactical and strategic advantage. They suggest that leveraging the commercial sector and buying off-the-shelf capabilities will be both cost-effective and dynamic. On the other hand, Wegner et al. state that COTS is the most vulnerable layer as soft targets to cyber and physical attacks.⁶⁰ Given the vulnerability of COTS systems, a mix of government-owned space capability and COTS may provide the layered security required. It is envisioned this could be 80% COTS and 20% military with the military focus being on systems to sustain military operations when commercial systems may be denied, degraded, or disrupted. These military systems may also fall into areas where commercial capabilities may not operate such as SSA and signals intelligence. The military capabilities could range from an encrypted COTS nanosatellite to a constellation of COTS nanosatellites with multiple ground stations to provide resilience, to a third-party military provider, all of which disaggregate from a single source and provide resilience in space.

Lieutenant Colonel Dawn M. Githens expresses that layered protection must include ground and space-

⁵⁹ Air Force Space Command, *Resiliency and Disaggregated Space Architectures: White Paper*, 2013, 4.

⁶⁰ Dr Peter Wegner, Dr Thomas C. Adang, and Maureen Rhemann, “How to Make Disaggregation Work,” *Air & Space Power Journal* 29, no. 6 (December 2015): 7.

based assets and should span across commercial and international partners.⁶¹ In NZ’s case, the level of space-based security should mirror that of other allies in the CSpOC to ensure collaboration and teamwork and should take on a defensive nature. For ground-based security, NZ has the benefit of geography, ample land, an FAA-certified launch site, and a stable security situation; all of which promote ground-based security.

The final piece of a layered security model is force resilience, the force prepared to operate in a contested, degraded and denied environment. To comprise a resilient force entails educating the force to understand the reliance on space, understand threats to space assets, empowering the force to take responsibility for space operations, and preparing them to operate in an abnormal space environment. This reflects the SDPS 18 posture and must be a line of effort in the space security strategy.

Structure

This strategy embarks on new ground, thus it is critical to ensure the organisation and structure are set up appropriately, and overarching governance is in place. There are a range of actors including the civil sector (Civil Aviation Authority, Foreign Affairs, Intelligence community, etc.), the commercial sector and of course the security sector (NZDF) – each of which has a part to play in the overall space strategy. As such, the strategy needs to be broad enough to incorporate the various parties. The recommendation is the Air Force ‘own’ space from an NZDF perspective and a cadre of personnel from a range of trade backgrounds set up a Space Squadron.

⁶¹ Githens, “Overcoming the Illusion of Security”.

Further, a representative from New Zealand Air Force space unit should be embedded in the NZ Space Agency and, as discussed previously, the CSpOC. Furthermore, it is envisaged that personnel integration within NZDF Capability branch will be critical to the SDPS 18 goal of adapting the procurement process to rapidly changing operational requirements and advances in technology. This aligns NZDF desires with that of the Air Force Space Command Space Warfighting Construct and the need to be responsive to new and changing threats, rapidly integrating new capabilities, and speeding up decision making to deliver multi-domain effects in, from and through space.⁶²

Budget

As Hitchens and et al. state, even the most well thought out space security strategy will flounder if it is not supported by the means to execute it, both in terms of financial resources and appropriate attention by leadership.⁶³ In the NZ case, a strategic assessment in the form of the Defence Capability Plan (DCP) must account for new capability and personnel overheads associated with that capability. Furthermore, a development path must be mapped, and any associated costs accounted for to ensure appropriate core training and growth opportunities are budgeted. The Ministry of Defence must also understand and cater for an increased personnel overhead and assist in the petition to the government for funding as required. Operating in the space environment is inherently expensive and technically challenging; however, if NZDF can attain the proposed end state and, in doing so, benefit other players, it will lower relative costs. Furthermore, with the right capability mix, aircraft operations could be reduced and direct operating costs offset against the space

⁶² Gen Jay Raymond, “Space Warfighting Construct 2018,” 13.

⁶³ Hitchens et al., *Toward a New National Security Space Strategy*, vii.

assets. Ultimately, prudent stewardship of funding and senior leader support is essential to educate treasury and maximise the funding available.

Proposed Strategic Framework

A vision for space security can be extracted and interpreted from SDPS 18, which forms a fundamental part of the space security strategy to align strategic objectives to the outcome – the ends. The vision for the space security strategy is to secure access to space-based systems, exploiting military and civil potential and the mission to ensure that Defence has the capabilities, skills, and relationships to defend New Zealand’s interests in an increasingly congested and competitive environment, working closely alongside the government, international partners and the commercial sector. With a clearly defined vision and mission (ends), the establishment of the strategic objectives (ways) and activities (means) that form the strategy are forthcoming. The strategic objectives are used to focus and streamline efforts in an attempt to address all major areas associated with the security strategy which are again extracted from the DWP 16 and SDPS 18. These objectives focus on the congested, contested and competitive environment and are designed to link directly to the overall space strategy as defined previously. The recommended four space security strategic objectives are depicted in Figure 2 which details the outcomes (ends), objectives (ways) and activities (means) which make up the security space strategy: (1) Support NZDF operations through space, (2) Support and enable AOG space activities, (3) Support international activities to maintain space access, and (4) Enhance space resilience and efficacy.

Figure 2 illustrates how the four strategic objectives are made up of a series of activities that broadly craft the strategy. Although this framework doesn’t directly depict risk, the objectives would ideally be interlinked, thus, the gaps represent that risk.

Figure 3 depicts how civil, commercial, and space security strategies link to the all of government National Space Strategy. Moreover, it depicts how the strategic objectives feed into the space security strategy. It is envisaged that this process is imitated for the civil and commercial strategies.

CONCLUSION

The importance of access to space-based systems for NZ’s security and prosperity has been made clear by Government and the direction is explicit that NZDF needs to invest in space capabilities. To do so, NZDF needs a pragmatic and usable strategy. The analysis conducted clearly highlights some major movements needed and provides the framework under which the strategy should be developed. International engagement, domain awareness and layered security are three fundamental parts of any space security strategy and the NZDF’s security strategy should be no different. Whilst NZDF cannot do it alone, it is a key partner in NZ’s overall space strategy and must enable collaborative efforts to ensure we, as a whole, get this right.

Space is exciting. It is a domain underdeveloped in expertise and exposure for New Zealanders. We, collectively, know how to use the information from space-based assets but we do not understand the environment and the ways, means, ends and risks in developing it. It will take committed people, sound leadership and the resources to make this happen.

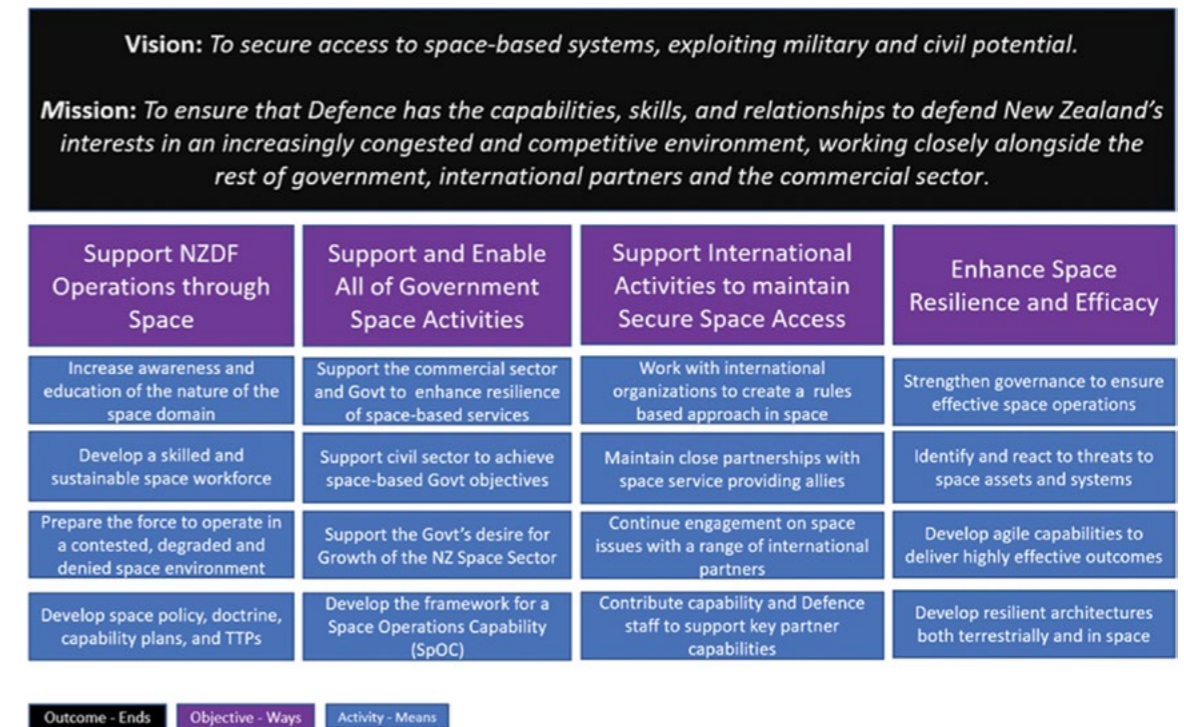


FIGURE 2: Recommended NZ space security strategy framework.

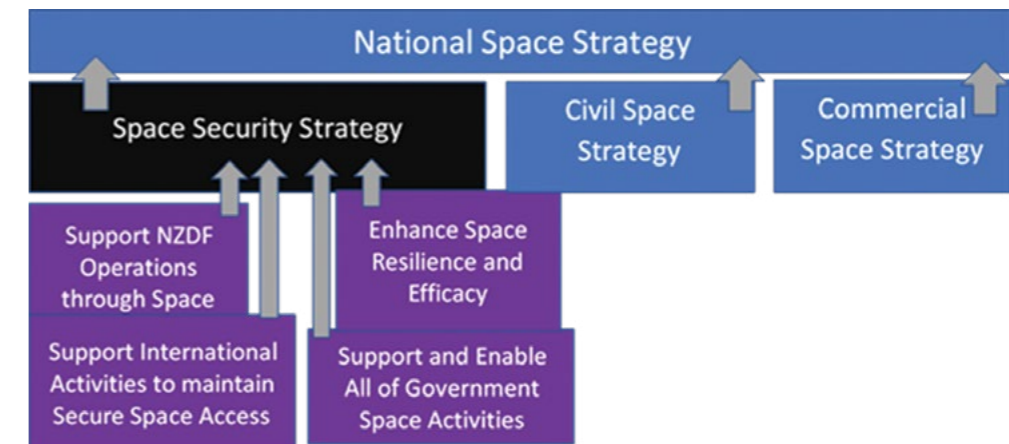


FIGURE 3: Proposed all of government strategic approach

The NZDF will need to be smart about how they enable capability to ensure the front line is supported, how the NZ government is enabled, how international activities are supported to enable continued access including personnel development, and how resilience is built whilst being efficacious. The capability mix is important but so is the rapid acquisition of low-cost assets to enable research and development through a ‘learn as we go’ model – an extremely common model for business in the rapid tech, low cost environment.

The NZDF operating in space is rapidly becoming a reality, it is the domain we need to operate in to stay ahead of the adversary and maximise our competitive advantage. It is a proven force multiplier and required for freedom of action in other domains, something that we, as a small force, cannot afford to compromise. It should not be a question as to whether the NZDF should have a space capability or not, rather a question of how much, how big and at what cost. Having a niche space capability functioning collaboratively with our allies will leverage a significant capability we could not maintain single-handedly. Space and space-based assets will continue to be the ultimate high ground and will make our force stronger, more robust, more efficacious, and ready to face compounding challenges of a scope and magnitude not previously not seen in our neighborhood. Space will enable the NZDF to continue to provide value to the community, nation and world.

RECOMMENDATIONS

1. The NZ Space Agency develops robust National Space Policy and a National Space Strategy defining desired end states, principles and strategic objectives (see Part I).
2. The NZ Space Agency develops supporting strategic plans in the civil and commercial environment.
3. Chief of Defence Force appoints Air Force as lead service for space and Air Force identifies key personnel to establish the capability.
 - (a) NZDF Capability Branch (CAPBR) identifies space as a key capability growth area with associated capability resource and development plans
 - (b) CAPBR works with Air to establish requirements within the PRICIE-AF construct⁶⁴
 - (c) Air Force identifies a Director of Space (DIRSPC)
 - (d) Within PRICIE-AF, Personnel Branch identifies people and funding lines for increased personnel footprint for space cadre

⁶⁴ PRICIE-AF is the NZDF (and RNZAF) acronym for capability development – Personnel, R&D, Infrastructure, Concept of operations, doctrine and collective training, IT, Equipment and Logistics, Airworthiness, Finance

4. NZDF adopts a space security strategy which should include:
 - (a) Synergies with the NZ Space Agency and civil/commercial sector
 - (b) How Defence can support NZDF operations
 - (c) How joint, coalition and interagency effects should integrate
 - (d) How Defence can develop capability and personnel to advance national security interests
 - (e) The identification of vision/mission (ends), strategic objectives (ways) and activities (means)
 - (f) Developing the framework for Air Force to include space doctrinal development
 - (g) Developing the personnel and training plan to align with capability plan including the development of personnel by:
 - (i) Embedding personnel in the CSpOC
 - (ii) Assisting the NZ Space Agency in the formation of civil and commercial strategies
- (h) Directing the Air Power Development Centre to include Space in warfighting domain training
- (i) Set the conditions for the development of operational plans and operational space planning with HQ Joint Force New Zealand J3
5. NZDF develops sustainable capability plans as part of the Defence Capability planning cycle to include:
 - (a) A joint effort with Defence Technology Agency (DTA) to launch a low cost smallsat to LEO for R&D purposes (ASAP to enable rapid learning)
 - (b) Personnel numbers required for funding purposes
 - (c) A balanced capability mix of commercial, other military and own assets

The NZ Space Agency and NZDF promote global engagement with specific emphasis in SSA and traffic management system.

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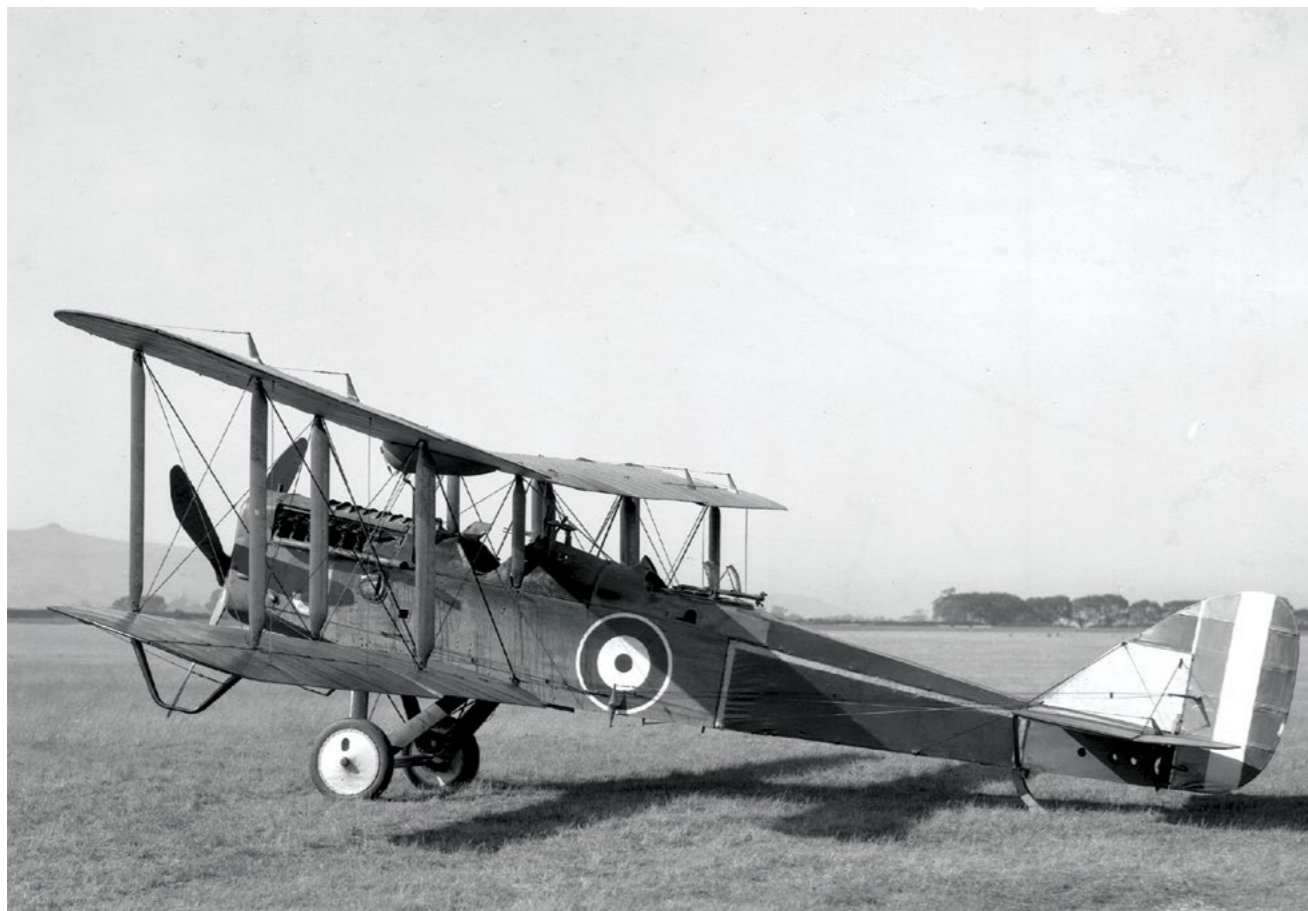
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DH-4 A7929 'J', one of two DH-4s sent to New Zealand as part of Bettington's visit, 1919
Air Force Museum of New Zealand

REFLECTING ON THE BETTINGTON REPORT OF 1919 – A CENTENNIAL LEGACY

Mr Simon Moody

*'A nation thinking in three dimensions will lead and defeat a nation thinking in two,
both in time of peace and war.'*

The Bettington Report, 1919

INTRODUCTION

In terms of origins, the RNZAF has traditionally placed great emphasis on the 1 April 1937 as its true inception date. Whilst this is the case in terms of being a separate service under its own autonomous control, this paper seeks to look at the brief visit to New Zealand in 1919 of Lieutenant-Colonel A.V. Bettington, his subsequent report and what legacies it provided in terms of the potential development of air power in New Zealand. This is not an easy task, as much of the documentation has not survived and even the report itself was lost for a time. By looking at a diverse range of sources, however, it is possible to piece together his visit and come to some conclusions as to the legacy of it.

THE AUTHOR

Simon Moody was born in Dorset, England and studied history, archaeology and archive management at the Universities of Leicester, York and University College, London. He has previously worked with the archives at the RAF Museum and National Army Museum in the UK and written and lectured on their content. He is co-author of *Under the Devil's Eye: Britain's Forgotten Army at Salonika*, published in 2004. He moved to New Zealand in 2009 to become Research Curator at the Air Force Museum of New Zealand at Wigram, Christchurch and is responsible for overseeing the RNZAF archives and research undertaken there.

BEFORE BETTINGTON

The New Zealand Government had shown very little interest in military aviation prior to the arrival of Bettington in 1919. The chief proponent of the need for action up to this point had been Henry Wigram. Wigram was a wealthy businessman and politician who visited Britain prior to the First World War and was inspired by the rapid progress of aviation there and across Europe. On his return he lobbied parliament unsuccessfully to consider the need for a military air arm. Some progress was made prior to the war. A few New Zealand officers learned to fly and travelled to Europe, whilst a military aeroplane 'Britannia' was gifted to the New Zealand Government and demonstrated in Auckland in 1914.

The outbreak of the First World War changed everything. The tiny Royal Flying Corps in Britain grew in expeditionary terms during 1915 and New Zealand became an Imperial source of potential manpower, just as in the case of the New Zealand Expeditionary Force. In 1915, the Walsh brothers founded the New Zealand Flying School at the old mission station at Kohimarama near Auckland. A commercial enterprise, it trained pilots for the British in collaboration with the New Zealand Defence Department. Wigram too followed suit with the creation of the Canterbury Aviation Company at Sockburn in late 1916, run on a similar arrangement. The two schools trained nearly 300 pilots between them by war's end. Moreover, they also created the first aviation infrastructure and assets to exist in New Zealand.



Henry Wigram (left) in conversation with Lieutenant Colonel A.V. (Zulu) Bettington at Sockburn in 1919
Air Force Museum of New Zealand

BETTINGTON AND HIS TEAM

Arthur Vere Bettington (usually known as 'Vere') was born at East London in South Africa on 12 June 1881. He was one of four brothers, all of whom served in the British air services in the First World War. Vere was educated at St Andrew's College, Grahamstown. His introduction to military service came in the Second Anglo-Boer War. He served with distinction in the Cape Mounted Rifles as a sergeant, before joining the Brabant Horse and participated in the siege of Wepener in April 1900. He was awarded a Distinguished Conduct Medal in 1901 and commissioned as a Lieutenant into the Transvaal Mounted Rifles. During the war, he was also mentioned in Lord Robert's despatches twice while serving with the Cape Mounted Rifles. His personal courage and skill (especially in scouting Boer positions) was individually noted by his formation commander General Colville:¹

'To carry out successfully tasks such as those Sergeant Bettington undertook required a combination of qualities that one could scarcely expect to find in a British regular'.

He also served in operations against the Zulu in 1906. In 1911, Vere embarked for England to join his brother Claude, who was learning to fly. He enrolled at the Bristol School in Brooklands. He passed his Royal Aero Club Aviator's Certificate on 15 October 1912, receiving the 'ticket' number 326. It was at this time that he acquired his nickname of 'Zulu', due to his South African origins.

¹ Capt. John Stirling, *The Colonials in South Africa 1899-1902: Their Record*, based on the Despatches (London: William Blackwood and Company, 1907), 111.

By some accounts, he was not a natural pilot. George Handasyde, co-founder of Martynsyde Aircraft Company at Brooklands is alleged to have once remarked:

*'There goes old 'Zulu', heart of a lion, feet of an elephant!'*²

In early 1914, he was commissioned into the Royal Flying Corps and on the outbreak of war was serving with No. 6 Squadron, crossing to Belgium in October. Serving on reconnaissance missions until March 1915, he was promoted to captain and given command of No. 1 Aircraft Park at St Omer, responsible for the supply of machines to the growing RFC in the field.

By early 1917, Bettington was a Major and took command of his first operational squadron, No. 48 at Bellevue on 17 March 1917. Much was expected of the unit, with the brand new Bristol F2A Fighter as its equipment. Initially, the squadron was mauled. It lost four out of six machines on the first patrol and only became effective once tactics were changed to a more aggressive single seater stance. Bettington moved to No. 2 Aircraft Depot at Candas in July 1917 and after promotion to Lieutenant-Colonel remained in command of No. 2 Aeroplane Supply Depot in France until the end of the war. His war service resulted in being made a companion of the Order of St Michael and St George (CMG) and the award of a Legion d'Honneur by the French Government.³

² Peter Wright, "Sons of the Air: Claude, Vere, Egerton and Aylmer Bettington," *Cross & Cockade International* 34, no.1 (Spring 2003), 12.

³ The author acknowledges the detailed biographical research carried out by Peter Wright in the previous footnote.

Bettington's service background is not usually analysed in descriptions of his role in generating the report which still bears his name. Notwithstanding a clear level of personal courage in his soldiering in South Africa, his career in the First World War indicates a clear understanding and aptitude for planning and logistics. Command of several logistical units directly concerned with the supply of aircraft and aircrew indicates he was an example of what Peter Dye describes in *The Bridge to Airpower* as '...a new breed of soldier-technocrat, who combined military values, managerial competence, and business skills.'⁴

The New Zealand team chosen to assist Bettington as his staff was an interesting smorgasbord of skills, experience and background. His accompanying Staff Officer, Major Alfred de Bathe Brandon DSO, MC, MiD was something of a celebrity, having participated in the destruction of two German airships in 1916, achieving fame in the process. Despite this celebrated status in public, Brandon was officially under something of a cloud in 1919. Even as Bettington was en route to New Zealand, RAF criticisms of Brandon's precipitous departure to New Zealand with Bettington and his alleged poor command of two Home Defence units in 1918 were under serious official discussion with the potential for further investigation.⁵ As well as Brandon, there was also Captain J.H. Don, a dentist who had been on attachment to the RAF from the NZEF earlier in 1919. Lastly, Lieutenant Edgar Shand had seen service with the NZEF in Egypt and as an observer with No. 17 Squadron, RFC in Salonika in 1916 before being medically invalided back to New Zealand. On his return he had toured the country giving talks on his war service.

⁴ Peter Dye, *The Bridge to Airpower: Logistics support for Royal Flying Corps Operations on the Western Front, 1914-1918*, (Annapolis, Naval Institute Press, 2015), 163.

⁵ Confidential letter, Brig Gen TCR Higgins, 6th Brigade RAF to the Secretary, Air Ministry, 27 February 1919. Brandon Papers, Air Force Museum of New Zealand (2011/233.11).

THE VISIT

Given the previously lukewarm enthusiasm of the New Zealand Government to suggestions of a permanent air arm, it is perhaps surprising that a request for advice and assistance from the British Government was dispatched even as the First World War was drawing to an end. With over 850 New Zealanders serving or having served with the Royal Flying Corps, Royal Naval Air Service, Royal Air Force and Australian Flying Corps, there would be an influx of experienced airmen returning to the shores of Aotearoa New Zealand. Not all would do so; some such as Keith Park, Roderick Carr and Arthur Coningham would carve out careers in the post-war RAF and rise to high rank. The remainder returning home was a physical resource that could potentially be harnessed, rather than continuing the more theoretical discussions and proposals previously initiated by Henry Wigram.

It has been suggested that the New Zealand Government's greatest interest was allegedly in civil aviation⁶ with the potential military element a possible side effect. This explains a great deal about how Bettington's final report was structured. However, Sir James Allen, New Zealand Minister of Defence was keen to stress that Bettington was primarily in New Zealand 'to advise on the defence aspects of aviation.'⁷

Bettington arrived in Auckland on the Transport *Athenic* with de Bathe Brandon, Don and four mechanics on 19 March 1919. His title, quoted in the press, was 'Air Force Advisor to the New Zealand Government'⁸ and he had been granted the temporary rank of colonel while so

⁶ Suggested by J.M.S. Ross, there appears to be little in the official record to support this.

⁷ *Auckland Star*, "A Flying Expert", Volume I, Issue 69, 21 March 1919 (Papers Past).

⁸ *Evening Post*, "New Zealand Aviation", Volume XCVII, Issue 89, 16 April 1919, 11 (Papers Past).

employed. He himself gave clues as to the broad sweep of the purpose of the visit, reported as saying to the press in Auckland in April 1919:

*'This extension of the use of the aeroplane must be viewed from the widest possible angle as it must open up the country and bring the backblocks settler into closer touch with civilisation....'*⁹

Unlike Ralph Cochrane in 1936, who kept a diary,¹⁰ piecing together Bettington's precise movements during the visit, is quite difficult. After spending some time in Auckland and no doubt visiting the facilities of the New Zealand Flying School at Kohimarama, Bettington and his team visited other areas of the country over the following months, including the facilities of the Canterbury Aviation Company at Sockburn. By the time he submitted his final report on the 31 July, Bettington would have had a thorough knowledge of the existing and potential infrastructure for aviation in New Zealand.

THE REPORT

It is not the intention here to give a detailed description of Bettington's submitted findings.¹¹ Rather it perhaps pays to see which of them had long term value or precursed actual developments.¹² Likewise, the political

⁹ *The Marlborough Express*, "Commercial Aviation", 24 April 1919, 4 (Papers Past).

¹⁰ Held in the archives of the Air Force Museum at Wigram, with photos, correspondence and a scrapbook. 1986/111.

¹¹ Scanned copies of the Bettington Report can be found at www.airforce.mil.nz/about-us/who-we-are/apdc

¹² These are covered in Brian Lockstone's excellent *Into Wind* and David Mulgan's *The Kiwis First Wings*, regarding the impact on Kohimarama. L.M. Noble's older but still useful biography *Sir Henry Wigram* considers the report from the Canterbury Aviation Company perspective.

debates which followed are of less interest from a purely airpower history perspective.

Possibly the most interesting part of the report is the introduction outlining the need for military aviation in the first place (as quoted in this paper's subtitle). He dismissed Germany as a spent force that would no longer pose any threat after the sanctions being negotiated were imposed in imminent peace treaties in 1919. Continuing into the greater geo-political environment, one observation was both astute, remarkable and prophetic:

*'At the end of the present war, an era of deep-seated unrest in the world is likely to follow. It is beyond reasonable conception that all the signatories of the Peace Treaty or even all of the present Allied Nations will be satisfied with the terms it lays down.'*¹³

He went on to single out one particular potential threat:

*'The Japanese may be looked upon as having accumulated as much wealth or net profit, if not more as a result of the last war, than any other nation in the world. They are very progressive, economical, hard-working and clever people. Their country is thickly populated and outlets for their surplus population as well as markets for their goods will be sought by them...the centre of unrest in the world may now be assumed to have moved from Western Europe to the Pacific.'*¹⁴

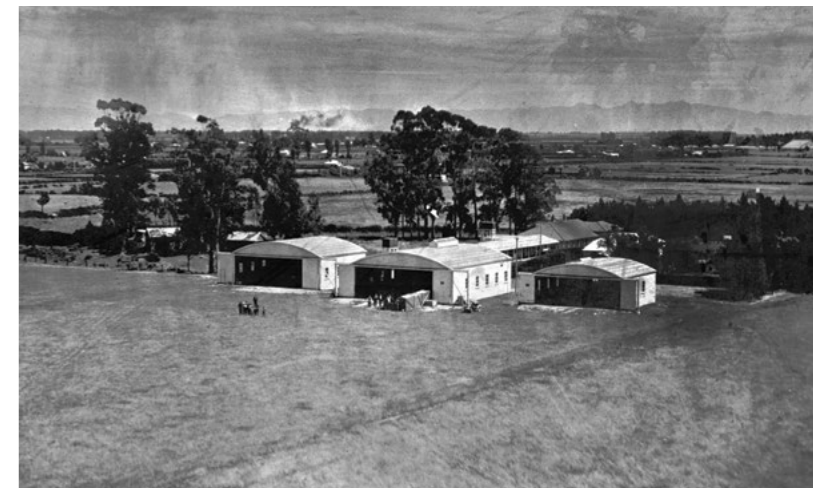
In this at least, Bettington was spot-on and showed a clear understanding of the changing shift of the balance of power in the post-First World War world.

¹³ The Bettington Report, (1919) 2.

¹⁴ Ibid.

In compiling his report, Bettington considered the practicalities of setting up a system of military aviation in New Zealand. He considered strategic, topographical and technological considerations. Broadly, in practical terms, Bettington recommended the following:

- » One reconnaissance/fighter squadron, separate single day and night bombing squadrons, one scout/fighter squadron, one maritime bomber/torpedo squadron, two flying boat squadrons, a depot and two aircraft parks for logistics. All would be held in stasis, with mobilisation possible in time of need.
- » Personnel would consist of some 70 officers and 299 airmen built up over four years of expansion with further personnel drawn from the territorials as required.
- » A Headquarters would be established as would a liaison officer to the Air Ministry in Britain.
- » A series of bases be set up at vulnerable points.



**Sockburn Aerodrome,
home of the Canterbury Aviation Company
Air Force Museum of New Zealand**

He went into considerable detail on the type of machines, engines and other practical matters regarding training, logistics and operational considerations.

Realising the lack of infrastructure existing in New Zealand, it is no surprise the Canterbury Aviation Company featured strongly in the report, there being little doubt that Bettington considered it to be something of a starting point or blueprint for what was required:

‘...great advantage should be taken of and encouragement given to the existing company at Christchurch which possesses a good aerodrome, hangars, living accommodation for mechanics and about 25 pupils, and some machines of the old pattern but still fit for a certain amount of instruction.’¹⁵

Of the Company itself he continued, and also issued a warning:

‘This company appears to be controlled by a patriotic board which did a considerable amount of useful work during the war and which has expressed its willingness to expand to a large degree and, to procure new machines..... Without government assistance in the way of pupils, it does not appear likely that sufficient work will be available in the near future to warrant their continuation in the future.’¹⁶

¹⁵ File: RNZAF Educational Services – The Bettington Report, 1919. Air Force Museum of New Zealand (2006/700).

¹⁶ Ibid.

On the New Zealand Flying School at Kohimarama, Bettington also stressed the patriotic nature of their endeavours during wartime but was less convinced of its long term value to Government-sponsored military or civil aviation:

‘There appears to be no immediate need for the continuation of the School at Auckland (Messrs. Walsh Bros and Dexter Ltd) from the point of view of the Government.’¹⁷

This was perhaps a little unfair, as they had been set up in no less patriotic spirit (but still, ultimately commercial) and arguably had been the most successful in training pilots who got to the front in time to serve, having starting in 1915 as opposed to 1917 in Canterbury. We may also detect Henry Wigram’s very good propaganda here and the fact that a lot of money had been ploughed into Sockburn and its infrastructure. To Bettington, these slick facilities would have looked like the proper European aerodromes he was used to and consequently he considered it favourably.

REACTION

The Report was not made public by the New Zealand Government and it is perhaps no surprise that they felt the plans too financially ambitious in July 1919 when it was submitted. Bettington tried to scale it back on 19 August, by dropping a squadron and reducing personnel. On 21 August, Sir James Allen asked Bettington to reconsider, with a view to concentrating all landplane activity at Christchurch and seaplanes at Auckland. Clearly, the government favoured using as much of the existing aviation assets as possible. Bettington then came back with a request that before more work was done, the

¹⁷ Ibid.

government should actually divulge how much it was prepared to invest.¹⁸ Clearly, some frustration was starting to show on his part. This was refused and Bettington was told to base his scheme on the existing school at Sockburn.

Bettington’s final recommendations were a considerable reduction of his original scheme:

- » The appointment of an Air Advisor to assist the Government.
- » The two schools at Sockburn and Kohimarama should remain and be subsidised by the Government if necessary.
- » First World War veterans of the Royal Air Force should be organised into an Air Force Reserve.
- » Use of a territorial force to make up numbers as required.

The media certainly were interested in Bettington’s work, and in scrutinising those politicians who supported it. *The Mataura Ensign* (amongst others papers) reported on 18 August 1919 emphasising the professed statements of Sir Joseph Ward in encouraging the development of an air force and civil aviation infrastructure, reporting:

‘In his opinion no country that wants to keep abreast of the times can afford to stand out of aviation for long.’¹⁹

No doubt Ward hoped to make political capital in opposition out of Bettington’s visit to New Zealand. The editorial itself went on to describe Bettington’s suggestions but its final sentences rang very true in

¹⁸ Memorandum from Bettington to Sir James Allen, 22nd August 1919. In Personnel File R21099049: Arthur Vere Bettington C.M.G. – New Zealand Staff Corps. Archives New Zealand (Online).

¹⁹ *Mataura Ensign*, “Aviation in the Dominion”, 18 August 1919, 4 (Papers Past).

terms of the crux of the problem as perceived by both politicians and public in an austere post-war world:

‘It is clear that that New Zealand should start and maintain the nucleus of an air force, even though it is on little more than an experimental basis. At the same time any idea of rapidly developing a comprehensive scheme of aerial defence seems quite impracticable in view of the enormous outlay that would be entailed. This does not mean however, that the Dominion can afford to neglect development. The whole matter is one for consideration by the Government.’²⁰

The arrival of four aircraft in August 1919, even as the Report itself was being modified and watered down, also caused lots of interest. Two Airco DH.4 bombers and two Bristol F2b Fighters arrived from Britain on the SS Matatua. They became established at Sockburn, tended to by Bettington’s four mechanics and company staff. Bettington hoped that by demonstrating modern machines and with his report completed, progress could be made. This he did, flying the aircraft and even taking Wigram’s wife for a flight. Whilst short of the 100 Britain had offered and been refused, the aircraft were later gifted to the New Zealand Government, becoming New Zealand’s first true combat aircraft. All that was now required was an air force to use them. It was not to be. The Government sat on the report for several months before finally publicly divulging that, as a header in the *New Zealand Herald* on 23 December 1919 announced:

‘Dominion’s Air Defence. Col. Bettington’s Report. Proposals too Expensive’²¹

²⁰ Ibid.

²¹ *New Zealand Herald*, “Dominion’s Air Defence. Col. Bettington’s Report. Proposals too Expensive” Vol LVI 23 Dc 1919 (Papers Past).

Bettington's efforts seemed to have truly failed. The reason given was that the military experts at the Defence Headquarters:

*'.....are agreed that the aerial branch is going to be increasingly important, but they are disposed to believe that New Zealand should wait for additional information before spending much money.'*²²

To Bettington himself, warm appreciation of his efforts were at least offered, Major-General A.W. Robin, commander of Military Forces, writing to him on 16 September 1919 on his departure:

*'That a more practical result is not in evidence is no fault of yours but entirely due to the unsettled conditions existing as to the future of Defence generally, and also for the future of New Zealand. The valuable reports and suggestions you leave behind will be of the greatest use to New Zealand when the time comes to establish an efficient air service.'*²³

²² Ibid.

²³ Memorandum from Major-General A.W. Robin to Bettington, 16 September 1919. In Personnel File R21099049: *Arthur Vere Bettington C.M.G.* – *New Zealand Staff Corps*. Archives New Zealand (Online).

Despite these sentiments, perhaps the short term impact of the report can be gauged by its apparent temporary loss in the official record of New Zealand. J.M.S Ross, in his brief prehistory of the history of the service in the published official history of the RNZAF in the Second World War, notes in a footnote:

*'The measure of enthusiasm which Bettington's report aroused in New Zealand military circles can be gauged from the fact that by 1920 it had been lost and only odd papers could be found in the Defence Department. Not until 1929 was a complete copy found, in private hands, and placed on file.'*²⁴

Some access to parts of the report must have been possible however, as subsequent developments over the next three years mirrored it strongly.

CONCLUSION

It might be tempting to compare Bettington's experience with subsequent advisory work on the future of New Zealand military aviation. It would, however, be a little unfair to compare the report to the subsequent RAF advisory work of Salmond and especially Ralph Cochrane in 1936 which led to the independent RNZAF being created. Cochrane was assessing a military aviation infrastructure that already existed, albeit on a modest scale, particularly in terms of personnel. Bettington was looking at pure potential and requirements in a more theoretical way and at both civil and military requirements. This makes the two reports almost incomparable.

²⁴ J.M.S. Ross, *Royal New Zealand Air Force*, (Wellington, War History Branch, 1955), 9.

'Zulu' Bettington's visit to New Zealand in 1919 and his subsequent report did not have the impact or desired result, at least in the immediate short-term. As A.W. Robin's parting comments presented earlier suggest, the time was not right for such a major undertaking in post-war climate of austerity and uncertainty. Bettington left New Zealand in September 1919, probably a somewhat frustrated man. He had approached the task with the vision of incorporating New Zealand into an Imperial network of fledgling air forces, each protecting the Empire and supporting each other regionally. He considered his recommendations quite frugal, and must have been surprised at the reaction of the New Zealand Government. Some of the final compromise recommendations about limited flying activities at Sockburn did occur but it was a fraction of what could have happened.

What did happen was that the New Zealand Government was at last exposed to an external proponent of air power, rather than the tenacious but constant local voice of Henry Wigram. Some of the suggestions in Bettington's final (and somewhat watered down) report, did have a trickle-down effect involving gradual and lesser expenditure.

The Government started to 'dip its toe into the water' with the creation of an Air Board to manage both civil and military aviation in 1920 and a request for 20 Avro 504K trainers, nine DH.9a bombers and six flying boats the same year. Whilst the latter two were not delivered, it was progress nonetheless.

Then, in 1923, the Government finally purchased the assets of the now failing Canterbury Aviation Company and the New Zealand Flying School, sweetened by ten thousand pounds of the ever eager Wigram's own investment. This led to the establishment of the New Zealand Permanent Air Force (NZPAF) and territorial New Zealand Air Force (NZAF). Subsequent work and reports led to the Air Force we know today, but it was almost certainly the visit of 'Zulu' Bettington to New Zealand in 1919 which sowed the seed and started the gradual movement towards the establishment of an Air Force in New Zealand just three years later.

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Handing over of Sockburn Aerodrome to the New Zealand Defence Department by the Canterbury Aviation Co. Air Force Museum of New Zealand



Setting up a communications link at Dip Flat Camp, an RNZAF field training facility
 NZDF Official

INFORMATION-ENABLED AIR FORCE – EYE IN THE SKY, OR PIE IN THE SKY?

Mr. Brian Oliver, BA, MPhil

...in the end, for all the exaggerated expectations of the new forms of total war, the fight between military forces still dictated the difference between victory and defeat as it had done in the Great War.

Richard Overy¹

Any intelligent fool can make things bigger, more complex, and more violent. It takes a touch of genius - and a lot of courage - to move in the opposite direction.

E F Schumacher²

INTRODUCTION

The first passage, which refers to the failure of strategic bombing to be decisive in World War Two, could have added ‘...and as it had done in any war.’ Ultimately, war is usually decided by soldiers on the ground engaged in mortal combat, for the simple reason that most wars, at some point in a conflict, are fought over control of territory and/or the resources it holds. New ways of conducting warfare will neither change what the military is for or the nature of conflict, which is characterised by, just as in Clausewitz’s day, ‘violence, chance, and uncertainty’. Add the inevitable ‘chaos’ and ‘fog of war’, and subsequently one starts to get a feel for why technology often struggles to live up to expectations.

THE AUTHOR

Brian Oliver has had a long and varied association with the RNZAF both in uniform and as a civilian. He has a BA in English and History and an MPhil in defence and strategic studies from Massey University. His thesis examined the potential use of UAVs to raise maritime domain awareness in New Zealand’s oceanic areas of interest, Brian’s current interest is on the integration of air power into the future multi-domain operating environment.

¹ Richard Overy, *The Bombing War: Europe 1939-1945* (London: Penguin Group, 2014).

² A German-born British economist and philosopher who articulated the need for intermediate, or appropriate technology, that was people-centred.

For instance, in a similar manner to strategic bombing in World War Two, high expectations were held in World War One for quick firing artillery and machine guns to be decisive on the battlefield, when all they actually did was create the grinding stalemate of trench warfare.

The second passage cautions against the adoption of ever more complex technology solutions for their own sake, as opposed to seeking simpler solutions that work just as well. The New Zealand Defence Force (NZDF) has stated that ‘...our 2025 strategy has singled out as its vision of being an “Integrated Defence Force”...In 2025 we will deploy and operate as a networked combat force’.³ The original timeline was for 2035 but it is believed that it can now be achieved ten years earlier; this is very ambitious, and will require the adoption of high technology equipment, the recruitment and training of highly skilled operators, and come at a huge cost, for what is a small defence force with limited resources. The aim is to be no less than an up-to-the-minute network-enabled ‘combat force’ that can engage in high-end warfare. For the Air Force in particular it implies being able to conduct or engage in, so called fifth generation air warfare, which is the air domain’s particular version of network centric warfare. It is little more than a concept at the moment, and at best, Network Centric Warfare⁴ may merely tip chance to those with superior decision-making capability,⁵ and give us a better look at the fog; the belief of some that wars will be fought, won, and lost, in cyberspace without a shot being fired are delusional.⁶

³ HQNZDF, *2018/19-2021/22 Statement of Intent*, HQNZDF, Wellington, 2018.

⁴ Network Centric Warfare being the overarching term within which the information enabled platforms of a networked combat force operate.

⁵ Craig Stallard, *At the Crossroads of Cyber Warfare: Signposts for the RAAF*, Air University, Maxwell Air Force Base, June 2011, published by RAAF APDC, September 2014.

⁶ Overy, *The Bombing War: Europe 1939-1945*.

It is the stated aspiration of the New Zealand Defence Force that by 2025 it will be an ‘integrated defence force’, and, acting as a component of a ‘Networked Combat Force’ will be an ‘information enabled Air Force’⁷. So what is an integrated defence force, a networked combat force, and an information led air force? Unfortunately no one seems to know specifically, with all literature on the subject couched in generalisms, buzz words and vague assertions that everything will somehow be better, and easier. What is conveyed is that it will be high-tech, comprising networks of computers, sensors, and communications systems enabled through space, with information passed on at the speed of light to everyone who requires it – at least in theory. But what are the risks and vulnerabilities of being so technology dependent, and won’t adversaries have similar capabilities, and how does the NZDF protect their networks from cyber-attacks? So far there is little fact around how it will do it, what it will look like, why the NZDF needs to be ‘networked’, and perhaps most importantly, how it will be better. Some are even touting ‘it’ as the next Revolution in Military Affairs...but what exactly is, ‘it’? This essay will attempt to clear some of the fog around network-centric warfare and explain what it might look like, why NZDF is aspiring to it, and specifically how it might affect the way the Royal New Zealand Air Force (RNZAF) does things.

⁷ Army refer to it as a Network Enabled Army, which seems to place emphasis on the system rather than the product while the Navy take their typical low-key approach simply regarding its ongoing development of information systems as business as usual for the Communications and Electronic Warfare trades, and that it will be part of a networked combat force by 2025.

THE MULTI-DOMAIN BATTLE SPACE

The current obsession of the military towards jointness and the next step up, integration, has blurred what were once quite discrete operating domains within which the single services operated and, when required, co-operated in, usually for a short-duration covering a specific phase of an operation, being termed army co-op or navy co-op. In the last 50 years or so, two more domains have been added; space and cyber-space. At first though they were not really regarded as domains in their own right, they were simply just a medium through which military operations were carried out, specifically through the increasing proliferation of satellites and computers. The almost insidious and pervasive manner in which cyberspace and space have come to influence military operations in that time has now evolved to the point where they are now recognised as domains in their own right, and each, in its own way, has brought as many new problems as it has advantages. So there are now five domains within which the military operate; cyber, land, air, sea and space (CLASS). The multi-domain battle concept breaks the battlespace up into the CLASS domains rather than into service components as current joint doctrines do. The rationale is to complement through synergising rather than adding; each capability enhances the whole while lessening vulnerability and enhancing agility.

In his paper *Fifth Generation Air Warfare*, Peter Layton describes it as comprising four parts, one of which is a network,⁸ which itself consists of four elements or grids, these being information, sensing, effects, and command.⁹ As the RNZAF’s aspiration is to become an information

⁸ The others being a combat cloud, a multi-domain focus, and a fusion warfare construct; this is an excellent paper and highly recommended reading.

⁹ Peter Layton, *Fifth Generation Air Warfare*, Working Paper 43, RAAF, APDC, Canberra, June 2017.

enabled air force, as an element of a networked combat force, it seems the RNZAF is moving toward becoming fifth generation air warfare capable. This extremely ambitious goal will be the essence of the following pages as we explore the risks, pitfalls and advantages this may bring, and how realistic it is to aim for this point, with limited resources in a time of fiscal restraint.

FIFTH GENERATION AIR WARFARE

One of the more recent terms to be added to the ever-changing lexicon of air power is “fifth-generation air warfare;” a term used to describe a concept of operations which is effectively, or supposedly, the next evolutionary step in how air warfare is conducted.¹⁰ The concept is built around a series of information grids that form a network, or networks, where virtually everyone and everything in the battle space is connected, hence the term network-centric warfare. It is based around interconnectivity and near real-time sharing of information.¹¹ Thus the essence of fifth generation air warfare is speed, but the key enabler is connectivity through advanced technology; the goal is improved situational awareness to all users. This is achieved through all the sensors in a system or network, surface and airborne, contributing information into a ‘combat cloud’, which in turn can then be exchanged and distributed as required. A derivation of commercial ‘cloud’ computing, the ‘combat cloud’ is the central repository into which all nodes feed sensed information and from which can be extracted the common operating picture or a user defined operating picture for the operators at the tactical

¹⁰ RNZAF Air Power Development Centre, “Fifth-Generation Air Warfare,” *Te Matataua*, Bulletin, Issue 15, December 2017.

¹¹ Near real-time takes account of delays in processing and transmitting data and bandwidth bottlenecks etc, and implies the difference in time between an event occurring and its electronic record being available to other users of the network; being usually only a matter of seconds.

level. Instead of a crew or individual only being aware of what is happening based solely on their own sensors, the ‘combat cloud’ provides a wide-area, integrated surface and air picture to all who need it, perhaps extending for hundreds of kilometres, vastly improving situational awareness.¹² It can also enable long-range engagement directly or indirectly through passive or remote targeting, which is essential to stealth aircraft. As the cloud can be either physical or virtual, permanent or temporary, it is claimed there is no single point of failure. The point of all this is to gain information superiority in that commanders, and others, can make decisions inside an adversary OODA loop¹³, thus gaining a tactical advantage, so the real focus is the decision-maker and the operator.

Fifth generation air warfare is merely an evolution of how wars are fought. It perhaps has its origins in Gulf War One and later during Operation Allied Force whereby multiple diverse actors were brought together and somehow synergised into a coherent force that eventually achieved the desired results. Both wars were fought against an adversary fielding modern equipment and potentially capable of causing major problems to the alliance/coalition forces. Among other things, these wars saw the operational introduction of high-technology airborne control, surveillance and targeting platforms and unmanned aerial systems, as well as widespread use of precision guided munitions and satellite communications. Clearly a transformation was underway and a new way of thinking and operating has evolved as to how to get the best advantage from new technology, and that is through enhanced C2 networks that can potentially raise the tempo of operations to the point where an adversary just cannot keep up with events. Fifth generation air warfare then is indeed high-technology warfare. That being the

case, it seems to be contextualised in and conceptualised for a conventional, so called, peer versus peer conflict. So in the context of major power conflict, which it is, fifth generation air warfare will be fought at a high-tempo and fast pace, across a vast battlespace with large fielded forces making lots of emissions¹⁴ for the sensors to pick up on and relay this information to whoever needs it in order to make decisions on how best to engage the enemy, before they engage you, which seems to be the point.

The last major power conflict where direct engagement occurred, though in a third-party country but not by proxy, was arguably the Korean War, which resulted in stalemate and is still not resolved. Conflict since has seen a string of limited wars, more recently of which have been hybrid and counter-insurgencies. In such conflicts where high-tech is mostly applied against a low-tech dispersed adversary with no large fielded forces, and virtually no emissions, and usually no air power, fifth generation air warfare will be of limited value, and in fact would not be an appropriate application of air power. One only has to look at the huge technology advantages of coalition forces in general and air forces in particular, in Iraq, Afghanistan, and Syria (coalition and Russian) and the limited effect they have had on the course and duration of the conflicts. Fourth generation air warfare, if there is such a thing, was not decisive in these conflicts so why would fifth generation fare any better. The point being that not all conflicts require a high-tech solution, and while a major power peer versus peer conflict will eventually materialise in the future, there is a very good chance that hybrid warfare and low-technology insurgencies will meantime continue to occupy a large part of coalition operations. This should caution against wholesale adoption of one way of fighting that is not readily adaptable to a range of military operations and circumstances.

¹² APDC “Fifth-Generation Air Warfare,” *Tē Matataua*

¹³ John Boyd’s decision-making cycle of observe, orient, decide, act (OODA).

¹⁴ Layton, *Fifth Generation Air Warfare*.

The wholesale adoption of technology by the major powers, and Western military forces in general is something of a *fait accompli*. While being almost totally dependent on technology is readily acknowledged as exposing vulnerabilities and therefore carries risk, it is considered a greater risk not to have it. A reliance, almost seemingly a blind-faith, in science and technology to win wars is not new. During World War Two the US 8th Air Force in Europe adopted an operational doctrine of unescorted high altitude precision daylight bombing over Germany. By adopting complicated stacked box type aerial formations providing virtually impenetrable mutual defensive cover-fire together with a cutting edge technology bomb-sight, they believed they could fight their way to a target, destroy the target with pinpoint accuracy and minimal collateral damage, and then fight their way home with minimum casualties. It assumed one could scientifically manage warfare, believing they could impose precise and positive control over complex events, but it all proved too mechanistic and prescriptive and they suffered unsustainable losses during the second half of 1943 of up to 20% on some raids.

The Americans saw technology as a panacea and put too much faith in the Norden bombsight, which worked very well during training in the clear blue skies of the California desert but once exposed to European conditions was found wanting. They also failed to acknowledge that air warfare is an interactive process between competing wills, i.e. a duel, and gave too little consideration to what the enemy might have and how they might use it. Unfortunately, this appears to be one of those blindingly obvious clear and recurring ‘guidelines’ that can be taken from history, but which successive generations of military leaders ignore, believing that somehow this time will be different. There is perhaps a reason for this. Taleb remarks that the military, as organisations, are somewhat Asperger’s, or at least mildly autistic. They have difficulty putting themselves in someone else’s shoes or imagining the world based

on other people’s information. Being technological it is perhaps part of the nature of the military not to look back, and not to empathise.¹⁵

NETWORK-CENTRIC WARFARE AND A NETWORKED COMBAT FORCE

The battlefield of the future (looking out 20 years or so), and major power conflict, so called peer-on-peer, is forecast to be characterised by speed and extreme violence. The threat picture will include anti-access area-denial scenarios based around medium and long-range hyper-velocity ballistic missiles, anti-satellite weapons, directed energy weapons, computer network attack, and somewhat inevitably the weaponisation of space (covertly or otherwise). It will be fought across all the CLASS domains and by multiple actors, and communications, as ever, will be key. Complicated data links and automated on-board systems, driven by advanced software applications will unburden aircrew to focus on the main task. Broken data links, and jamming will be automatically compensated for, and machine learning will enable autonomous targeting and tracking, and perhaps even firing. This will all play out under the watchful eye of multi-domain C2 career professionals, rather than short-term personnel on a regular posting cycle.¹⁶ To make all this happen requires information, and lots of it, in fact so much that new ways of processing it will have to be come up with. So once the information is processed into a picture of what is happening, the commander still has to decide what to do and allocate resources to do it; in other words command and control, and speeding up the C2 process is really what it is all about.

¹⁵ Nassim Nicholas Taleb, *The Black Swan: The Impact of the Highly Improbable* (New York: Random House Trade Paperbacks, 2010).

¹⁶ Mark Pomerleau, *Air Force studying the future of coordinated air, space, cyber ops*, www.fifthdomain.com, accessed 22/11/17.

The NZDF is slowly moving towards the point where the speed and distribution of information, and the availability, or access to, or potential to enable, precision engagement technologies within a multi-domain operating environment, will require it to decide whether to develop new concepts of operations from those based on legacy joint warfare models that simply aligned, or required cooperative, largely single-service operations,¹⁷ or whether to align new network-centric concepts of operations with existing joint doctrine models. The NZDF, and the RNZAF in particular with its aspirations to become fifth generation air warfare capable, probably dictates the former course with completely new joint doctrine.

At the heart of a network enabled military force lies a C2 system, which has two basic elements; people who make the decisions and the operators who carry out the missions, and the facilities, equipment, staff functions, and procedures essential to the commander for C2. Command and control is and always has been essentially a human endeavour, and the fact that people can conduct command and control without facilities and equipment, but not the other way round, supports this.¹⁸ Network-centric warfare is not specifically, or solely, cyber operations, internet-centric warfare, or information warfare (though it uses elements of all these functions); it is the fusion, and distribution of information to decision makers at all levels. The network is a conduit that connects the sensors, radios, C2 systems, and situational awareness systems.¹⁹ Network-centric operations are

carried out in and through network-centric warfare, though the ‘network’ is more an enabler rather than a place of warfare, or domain/environment.

The networked combat force plugs into the network as an enabler to conventional operations, while cyber operations are carried out in the cyber domain, of which the ‘network’ is the major component. A network-centric approach to warfare is needed to fit with a multi-domain concept of operations. Layton refers to this bringing together of sensor data as ‘fusion warfare’ and describes it as extremely complex and complicated, which places additional burdens, principally cognitive, on the warfighters.²⁰ This further supports the contention that network/information/cyber-warfare are all people-centric, as information superiority is worthless if decision-superiority cannot be exploited by decision-makers with the cognitive capacity to do so. Fusion refers to combining data, rather than overlaying it, collected from various sensors, formatted, analysed, and presented in the common operating picture, which is one of the commander’s principal decision-making tools. The complexity and complicated nature of this process is problematic at best.

THE NETWORK AND INFORMATION

The relationship between a network and information is quite straightforward; the network is simply that which allows the movement of information to the people who need it, principally decision-makers. So the network, in this case, is basically a number of interconnected computers, machines and operations, while information is just a collection of facts provided or learned about something or someone.²¹ In other words it is passive.

¹⁷ David Deptula, “A New Era for Command and Control of Aerospace Operations,” *Air & Space Power Journal*, July-August 2014.

¹⁸ Peter Morosoff et al, “Joint Doctrine Ontology: A Benchmark for Military Information Systems Interoperability,” *Semantic Technology for Intelligence Defence and Security*, CEUR vol. 1325, 2015, pp. 2-9.

¹⁹ Craig Stallard, *At the Crossroads of Cyber Warfare: Signposts for the RAAF*, Air University, Maxwell Air Force Base, June 2011, published by RAAF APDC, September 2014.

²⁰ Layton, *Fifth Generation Air Warfare*.

²¹ *Oxford Dictionary of English*, online version.

Once this information is processed by the decision-maker, based on their experience and a dash of wisdom, it can be placed in context and thus contribute to situational awareness and perhaps even understanding, though it isn’t always necessary in all circumstances to understand something before you act. Once the information is placed in context, its consequences can be deliberated upon, and armed with something now termed knowledge, which is active, a decision can be made towards a course of action, which may then be transmitted over the network to those who need to know. Quite simple in theory...but not so in practice.

To begin with, there is little in the theory or practice of network-centric warfare, or cyber-warfare, or cyber-operations, or computer network operations, about which there is consensus over its meaning or application; the four different terms at the beginning of this sentence being an example, each of which means something different and the same depending on who wrote it. To some the network is ‘the system’, and to others it is part of the ‘system of systems’. There is also confusion on where ‘cyber’ operations fit; intelligence, space, ISR, C2, information warfare etc. and is it war fighting or support?²² There are few agreed upon definitions, even amongst allies, and so interpretations that are applied in context are more appropriate, and this needs to be borne in mind. It is virtually impossible to describe what a network might look like though we can tentatively describe its desirable characteristics and advantages, and its disadvantages and vulnerabilities.

At the edge of the network are the sensors, or the sources of information. This can be satellite imagery, signals intelligence from an airborne listening post, right down to a field operative using a cell phone. In a large coalition operation with multiple users and platforms ‘plugging’ into the network, it will have to be ‘big enough’ in relation to the scope and duration of the mission. The scale and range of information that is now being provided by intelligence, surveillance and reconnaissance (ISR) assets means that the network must have no bottlenecks or stovepipes, because unless the information is channelled to the decision-maker or operator in a timely manner, its value diminishes rapidly.²³ Similarly they must not have a ‘key’ node that represents a single point of failure, such as a fixed Air Operations Centre; this will require distributed or decentralised (possibly mobile in the forward area) control, or at least the capability, down to the lowest possible level in the event of disruption. To attenuate the potential for disruption the network will have to be robust in resisting cyber-attack in the first instance, and have redundancy built-in as an aid to survivability and recovery in the second instance; contributions to overall resilience.

With the introduction of machine-learning based on artificial intelligence, the potential exists for a system to ‘self-heal’, though as noted by Thomas Killion, NATO’s Chief Scientist, artificial intelligence has yet to make a major impact on military operations.²⁴ Self-heal attributes some magical quality that is perhaps inappropriate in relation to a machine, so self-repair is more accurate as it is largely based on redundancy, not so much individual key items of equipment but rather pathways.

²³ Stallard, *At the Crossroads of Cyber Warfare: Signposts for the RAAF*.

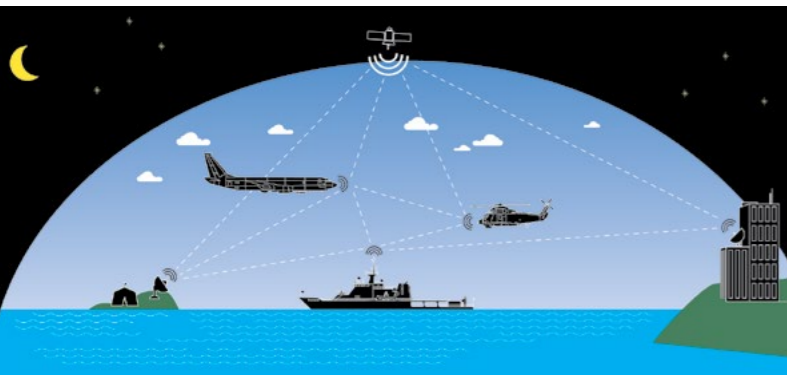
²⁴ Thomas Killion, *How AI, Machine Learning and Big Data is Transforming ISR & C2 Capabilities*, <https://airborneisr.iqpc.co.uk/downloads>, accessed 31 January 2019.

²² Jason Healey, *Why the new Air Force’s cyber and information strategy is a return to the past*, www.fifthdomain.com, accessed 13 February 2019.

It is unlikely any attack will disable an entire network, though it might, so the automated recovery systems will seek out alternate pathways that in effect create new grids or systems which enable essential services to recover quickly by shifting important functions to other nodes, and thus return to the fight as quickly as possible.

DIFFICULTIES AND VULNERABILITIES

Cyberspace is a man-made global domain within the information environment and consists of the interdependent network of information technology infrastructures including the internet, telecommunication networks, computer systems, and embedded processors and controllers; its purpose is to achieve military effects in or through cyberspace.²⁵ By 2025 the NZDF aspires to be a networked combat force that is primarily information led, which it is assumed encompasses the intent to be intelligence-led as well.²⁶



Network-centric operations in the New Zealand regional context
NZDF Official

²⁵ Air Force Smartbook, *Operations & Planning, 2nd Ed., Guide to Curtis E. LeMay Center & Joint Air Operations Doctrine*, The Lightning Press, 2019.

²⁶ Information and intelligence are not the same thing, intelligence being merely one of the information related capabilities or products that would come under, or as an output of, information operations, of which there are several types; it is not helpful to interchange the two without clear context.

The ‘information’ strategy as outlined in the NZDF’s Statement of Intent will be manifested as a common digital platform through the Communications and Information Systems Change and Transformation Project (CIS CTP); the intent being to build and defend a common digital platform. ‘The common digital platform is comprised of the necessary technology (hardware and software), people and processes required to support the Defence Force’s information needs and enable interaction with our partners’. People includes the recently established Defence Information and Communication Services Operations Centre at Joint Force HQ which will give 24\7 support to operations.²⁷ While its initial operating capability is simply to provide information and communications services to Joint and operations, full operating capability may go further, as implied by the stated intent ‘To maintain relevant combat capabilities into the future the Defence Force needs to be able to conduct a broader range of cyber operations’.²⁸ How this might manifest itself remains to be seen, but hints at a cyber-warfare capability, perhaps.

‘The digital platform will enable anywhere anytime access to secure digital services, regardless of the security domain or operating environment. All communications will be delivered with speed from the data centre to the tactical edge’.²⁹ The advantages of being part of a networked combat force have been implied throughout this essay, but as with anything that sounds too good to be true, we must look at what may be any downsides. As the RNZAF, likewise or by necessity, aspires to be an ‘information enabled air force’ as a component of the networked combat force, it is going to be a major user of the network, and subject to the complexities and vagaries of cyber

²⁷ <https://www.reseller.co.nz/article/643534/defence-joins-transformation-train-30-ict-staff-consulted/>, accessed 19 March 2019.

²⁸ NZ MoD, *Strategic Defence Policy Statement 2018*, NZ Government, Wellington.

²⁹ HQNZDF, *2018/19-2021/22 Statement of Intent*.

operations. The above statement of what the common digital platform will do is stated in the simplistic, confident and positive language of peacetime. Unusually, a major cyberspace battle involving ‘Western’ nations has yet to be ‘fought’, and inevitably it will not turn out as predicted or expected though the outcomes will be no different to conventional war in that uncertainty and chaos will reign. Anyone who believes technology will make war less opaque and more subject to rational calculations is delusional.³⁰ So what might have to be overcome?

There are perhaps two ways to explore this; the technical difficulties and the operational difficulties that might arise during conflict. However looked at, there is going to be an exponential growth in data from the proliferation of sensors that lie at the core of fifth generation air warfare. The military’s insatiable demand for ever higher resolution imagery corresponds with increasing demands for bandwidth, but resolution cannot be increased ad infinitum by increasing the bandwidth. A case in point is space-based radar systems, specifically synthetic aperture radar. The huge amount of data they produce is largely processed on the ground and the rate at which the data is downlinked is necessarily very high; rates of 1 billion bits per second (Gbps) are required to avoid unacceptable delays in processing. Currently most data is transmitted in the 300–800 million bps which, while fast, is not fast enough to avoid delays.³¹

There are two approaches to mitigating this problem. Firstly, a number of organisations around the world are developing new high-speed satellite communication

³⁰ Martin van Creveld, quoted in Cyr, “Describing the Elephant: Framing a Discussion on Command and Control,” *ASPJ*, July-August 2014.

³¹ Paolo Quaranta, “Space-based Synthetic Aperture Radar for Remote Sensing,” *Military Technology*, 12/2018.

systems that use laser communications links that have potential downlink rates of 5–10 Gbps. But while such increases would provide a fix for an immediate problem, how long would it take before the military’s appetite for data caught up with the faster downlink rates? It is always the case that the more you have the more you want; this is a never ending battle to stay ahead of requirements that will probably never be won. An analogy might be drawn with computer workstations where over the last 25 years or so processor power has increased exponentially, but most of the gains are absorbed just by running massive applications that eat up processing power and memory. We can certainly do a lot more than we used to, but seemingly not much faster, and productivity gains are not so obvious.

Another approach is that instead of increasing bandwidth, or more likely concomitant with increasing bandwidth, we can also potentially limit what is downloaded. The way to achieve this is through on-board, or on-site, processing of data prior to transmission, so that only that which is of interest is uploaded to the cloud. This may soon be possible with the introduction of artificial intelligence and machine learning that can filter out what is useful from that which is not. While no figures were available as to what percentages of data, on average, were actually useful in an operational context, it is easy to imagine that of the massive amounts of data collected, for instance during an airborne surveillance mission utilising electro-optics over several days, very little of it becomes actionable intelligence.³² On-board processing perhaps would be the ideal as it would unburden operators and analysts from a tedious task. However, the issue of on-board processing is problematic, especially on drones for instance where space and payload

³² Unless of course one is establishing patterns-of-behaviour, where everything is more or less relevant, but still resource intensive to monitor and analyse, which has potential for AI processing anyway.

is limited and additional cooling capacity would be required for the processing machines, which takes up space and adds weight.

Cyber dependency is growing exponentially due to the vector of market forces in the civilian world, and the almost frantic efforts of the military to integrate computer technology into the land, air and maritime domains. Further to this, the relationship between space and cyberspace is symbiotic as all space operations currently depend on cyberspace and critical cyber functions can only be provided by space operations.³³ For an organisation such as the NZDF with limited resources, the technical demands, let alone the costs, will be a major hurdle to overcome. The burden of the work required to make the RNZAF a fifth generation air force, or plug into fifth generation air warfare systems, is daunting and will mostly fall on the Air Communication and Information Systems Branch. They are currently a relatively small and niche branch of the Air Force and will require a significant boost to resources to meet the proposed timelines. And while it seems logical to assume additional funds will become available, and manpower will increase significantly, presumably as a military-civilian mix, in fiscally constrained times such as we currently face, the NZDF will clearly be building a system to a budget and under the assumption they can either recruit a large number of suitably qualified civilian personnel, in an extremely competitive employment environment, or recruit and train a relatively large number of uniformed personnel within five years or so. This is ambitious and carries significant risk. Too often the financial aspects of defence and security are to the fore, and this will always require compromise and entail risk. The author believes that currently the greatest risk to the NZDF and New Zealand national security generally,

³³ Chris Babcock, "Preparing for the Cyber Battleground of the Future," *Air & Space Power Journal*, November-December 2015.

is cyber security. Choosing not to defend your networks adequately, or compromising on grounds of cost are not options to be considered.

SO WHAT MIGHT A CYBER/ENABLED CONFLICT LOOK LIKE?

As previously stated, like all war, cyber war or cyber-enabled war will no doubt be surrounded by chaos and confusion once forces engage. Leading up to a conflict will no doubt come with warning signs at the political and diplomatic level, with an increase in posturing and perhaps even military confrontation, probably over several months. This may or may not be in parallel with increased cyber activity as an adversary tests cyber defences through what are termed cyber-reconnaissance activities. Any attack is also likely to be preceded by a major information warfare campaign that, among other things, engages with military personnel through social media. *Facebook*, for instance, is probably the biggest personnel intelligence database on the planet. As an example, by simply identifying one member of a military unit, big or small, the 'friends' feature would make it relatively easy to potentially map out the entire unit through one person. A recent report revealed that the 'results of an experiment conducted by a NATO Strategic Command Centre of Excellence research team suggest that in the current digital arena an adversary would be able to collect enough personal data on soldiers to create targeted messages with precision, successfully influencing their chosen target audience to carry out desired behaviours'.³⁴ The risks of social media are well understood by Russia and on the 20th February 2019 the deputies of the State Duma 'adopted the final reading of the draft law that bans military personnel from posting

³⁴ Sebastian Bay and Nora Biteniece, *The current digital arena and its risks to serving military personnel*, NATO STRATCOM COE, Riga, January 2019.

about themselves or colleagues online, the use of devices that can distribute audio, photo, video and geolocation data via the internet is also restricted for them'.³⁵ It is likely Russia's upper house will approve it in March 2019 and subsequently signed into law by President Putin.³⁶

Increased cyber activity in itself does not indicate imminent conflict. The analogy of an earthquake is perhaps appropriate in the context of New Zealand; an increase in earth tremors gives us a hint that something big may be about to happen, but we don't know where, when, or how big it is going to be. When, and if, it happens, more than likely most of us will still be unprepared. The probing activities of cyber reconnaissance are unlikely to reveal any major clues as to the cyber capability of an adversary or their ultimate intent. This is deliberate and for a very good reason. The author believes that, during peacetime, no state will ever reveal its cyber offensive capability to any great degree and is without doubt one of its most, if not its most, highly guarded secrets. While attribution, and international law, is an issue in responding to small-scale attacks during peacetime due to software botnets using tens of thousands of 'innocent' third-party proxies, in times of major international tension amongst the great powers such subtle distinctions will fall by the wayside, and collateral damage is likely to be widespread.

A large-scale cyber-attack, especially for the major powers, is possibly a one-time use weapon only to be used in a time of grave national emergency. The reason being that once an adversary shows their cyber hand they themselves are likely to become vulnerable, as it is possible they in turn will reveal openings and opportunities that can

³⁵ Twitter, @state_duma, 4:04am – Feb 20, 2019.

³⁶ <https://www.npr.org/2019/02/20/696396644/russia-moves-to-mask-military-trail-by-telling-troops-to-put-down-smartphones>, accessed 26Feb19.

be exploited. In other words, once an attack has been carried out this may limit their freedom of manoeuvre in the cyber domain, and by default across the other domains, as artificial intelligence systems quickly respond by developing countermeasures through machine learning. This raises the interesting prospect of artificial intelligence based cyber-systems battling it out with no human input - how would that end?!

In a military conflict and depending on the aims of the conflict, be they limited or general, it is likely to open with a discrete and targeted major cyber-attack, possibly on specific national infrastructure services that will cause disruption on the home front. This may or may not produce violent outcomes, which would be followed within a short period of time by a major attack on domestic and regional command and control systems in parallel with, or quickly followed by, a conventional attack, probably within seconds as the window of opportunity opens up. It is unlikely though that a single cyber-attack could disrupt an entire military network permanently, or even for an extended period of several days, provided adequate and robust back-up systems are in place to restore services essential to operations, and nobody starts destroying satellites. Attempts at disruption of satellite communications are a given though, as an adversary seeks to shut down positioning, navigation and timing data.

But even when services are restored, information fidelity will be an issue as spoofing can, and will occur, so how then do you verify information, especially in the context of an individual platform. As kinetic operations increase in parallel with cyber operations, the networks will eventually be degraded to the point where fifth generation air warfare systems, data links and platforms are virtually useless.

As Layton points out, a conflict could soon enough move into retro-warfare, relying on standalone on-board systems, HF radio, manual briefings, paper maps, and a large dose of human-to-human interaction. A reversion to what might be termed third generation air warfare and the principles of mission command, if still capable of fighting that way, would carry increased risk due to severely degraded situational awareness. It would then degenerate into a war of attrition until a third party managed to arrange a cease-fire and arrange peace talks, which would present both sides with the opportunity to rebuild in preparation for further operations, armed with the accumulated wisdom of recent events.

WHAT MIGHT THIS LOOK LIKE FOR THE RNZAF?

The Government ICT Strategy has an overarching vision of the state-sector as a single coherent ecosystem (which is fine if everything is built and operating to the same standard);³⁷ the NZDF is expected to align with this vision. Further to this the New Zealand Government believes the security of cyberspace is a shared responsibility with all elements of New Zealand society. The government largely operates in an advisory capacity and has made it clear that primary responsibility lies with the owner and operator of an information system, and so it is with the RNZAF. The NZDF as a whole is tasked with developing a cyberspace and support capability to ensure it is prepared to defend its networks at home and its operations abroad. The government has been reasonably proactive, has issued various documents and has several initiatives completed or underway, such as: The New Zealand Cyber Security Strategy; National Cyber Policy Office statements; The New Zealand Information Security Manual; the establishment of the

³⁷ NZ Government, *Government ICT Strategy 2015*, <https://www.digital.govt.nz/digital-government/strategy/>

Computer Emergency Response Team; the Government Communications Security Bureau's National Cyber Security Centre (NCSC); the CORTEX campaign;³⁸ plans to develop a Digital Strategy, etc.³⁹ This is highly commendable, but has limited application to the military.

Regardless, the NZDF must seek partnerships with a broad range of civilian agencies and private sector organisations to contribute to cyber security. While warfare is the responsibility of the military, all governments and the private sector carry out cyber 'operations', at times using the same networks, and similar hardware and software. The next generation wireless communications system 5G promises much, further enabling the so-called 'internet of things', and generating massive amounts of internet traffic and data, which can be mined. Due to short range and line of sight technology it will require denser infrastructure based on thousands of 'small cells' in close proximity to serve the dwellers of a large city, which raises privacy and security concerns. No doubt the military would like to take advantage of 5G in the future, but where do you draw the line, if that is even possible? It would be extremely difficult, if not impossible, and undesirable, to quarantine military cyber and communication systems from external networks.

The difficulties the NZDF face can be presented as a paradox; on the one hand they are trying to connect everyone and every platform in the battle space to the network; on the other hand, as a counter to an adversary's electronic warfare and cyber operations, they also have to reduce their emissions in an effort to minimise their electronic signature. So, to become a networked

³⁸ CORTEX is a suite of capabilities delivered through the NCSC that counters cyber threats to organisations of national significance.

³⁹ Department of the Prime Minister and Cabinet: *National Cyber Policy Office Proactive Release April 2018*.

combat force they have to increase their emissions and as a consequence are actually likely to increase their attack surface to an adversary. Wide area networks with numerous transmitting nodes make the likelihood of achieving covert 100% secure communications unlikely.⁴⁰ Cyber vulnerabilities are not restricted to lines of communication. It has been demonstrated during trials and operations that it is possible to disrupt weapons systems and platforms while in flight.⁴¹ ⁴² Industry and the military are only starting to come to grips with this issue and the scope of the threat is not well understood, though the consequences are plain enough and are potentially huge. Suffice to say that cyber-assurance for platforms and weapons systems is of major concern and the potential risks cannot be overstated. Currently there are no industry standards for what constitutes cyber-resilience in aircraft.



Boeing P-8A Poseidon *Original image modified with permission from the Royal Australian Air Force*

The key to cyber supporting air power is the development of an air-minded cyber force and to a lesser degree, a cyber-minded, or at least cyber aware, air force.⁴³ But looking at the bigger picture, how might this sit in the joint arena? The NZDF does not have a joint cyber force as such and rather than having one service being responsible for cyber and associated training, as is going to be the case with space it seems, it may be advantageous, at least initially, for each service to 'grow its own' cyber specialists, so they can support and become specialists in their own environment. Once the single services have a cadre of experienced cyber operators, perhaps then they can look to moving into the multi-domain operating centres.

⁴⁰ Layton, *Fifth Generation Air Warfare*.

⁴¹ USGAO, *Report to the Committee on Armed Services, US Senate, Weapons Systems Cybersecurity*, US Govt, October 2018.

⁴² In December 2011 Iran captured a US RQ-170 UAV by taking over its systems while in flight; while this was denied by the US at the time it was subsequently acknowledged as being a possibility.

⁴³ Stallard, *At the Crossroads of Cyber Warfare: Signposts for the RAAF*.

Centralised command centres, including fixed tactical operations centres, are increasingly being recognised as single points of failure which are vulnerable to cyber, electronic warfare and kinetic attacks, especially in the context of peer versus peer major power conflict. At the very least their construct has to change anyway as the current air operations centre is built around discrete planning and tasking of ISR and force application assets. An integrated approach will require an end to segregation and merging of the planning and tasking function⁴⁴ where platforms have a multi-mission capability such as the P-8A. Subsequently, with the anticipated move to distributed control and multi-domain operating centres, preferably mobile in-theatre, even if part of the network is lost, it would still allow multiple inputs of mission critical data in-flight, assuming the aircraft tactical data links are operating; there are no easy solutions even without adversary interference.

In the current air operations centre and tactical operations centre construct any form of cyber support is external. The move to distributed control in a multi-domain operating environment will require organic support in the form of a cyber planner, who will give a cyber aspect to air operations or an air aspect to cyber operations. The point being that in planning air operations cyber must not be an add-on; an air-minded cyber planner must have a seat at the table from the onset. This will require new concepts of operations to be written to outline how cyber and information and communications technology will support the joint fight in a multi-domain operating environment; though this should not be to the exclusion of single-domain concepts that underpin the joint concepts. A clear doctrinal statement is required to delineate organisational responsibilities to avoid duplication and inter-service

⁴⁴ Deptula, "A New Era for Command and Control of Aerospace Operations," *Air & Space Power Journal*.

bickering. The connectivity of the information age has further muddied the waters in the context of strategic, operational, and tactical, which raises the potential for centralised execution. At the same time it will distribute decision making down to tactical leaders, which will create more uncertainty at higher levels, while reducing it at lower ones.⁴⁵ Any temptation for command to reach forward must be resisted. Centralised control and centralised execution should only be adopted in specific circumstances. Previous Soviet doctrine was based on such a philosophy, which was followed by Iraq in Gulf War One; it does not work.

Whether the RNZAF can become an information enabled air force capable of taking part in fifth generation air warfare is highly contextual. Information, as manifested in the combat cloud, requires data from a variety of sensors to ensure fidelity. Typically, in a stand-alone RNZAF context where a single platform is operating, this will not happen. The RNZAF will not be able to do fifth generation air warfare independently. Fifth generation air warfare is warfare, not humanitarian and disaster relief operations, nor economic zone patrols; it is for fighting high-end conflicts in peer versus peer scenarios. It will only happen as part of a coalition and will require intensive training, such as has not been seen before. The amount of raw data collected and distributed by fifth generation air warfare platforms will be huge. This 'big data' will need to be analysed through machine learning to reveal patterns, trends, and associations, especially related to human activity. It will require significant processing resources that are highly automated using specialist software and applications. Once machine learning has revealed patterns using a predictive model, narrow artificial intelligence applications will give possible courses of action using decision rules based

⁴⁵ Cyr, "Describing the Elephant: Framing a Discussion on Command and Control", ASPJ.

on its own machine learning algorithms, interwoven with additional rules defined by human experts.⁴⁶ Just to process big data is likely to require a separate unit, new processes and, not least, highly skilled personnel to operate it, which will include data scientists as well as analysts.⁴⁷

The NZDF has in the past viewed command and control as one of those invisible intangibles that is just assumed to be there. In the information age this can no longer be the case, as the grid will be central to the fight. Before committing relatively huge amounts of money and resources the NZDF needs to carefully consider what amount of command and control they need, and how much CIS support is required to maintain, operate and defend it. This is a reasonable question in light of combat force connectivity and distributed networks, where everyone supposedly knows everything they need to know; fifth generation air warfare revolves around providing all the situational awareness operators need to complete the mission, with minimal command input.⁴⁸ It may be that RNZAF networks have to be built around supporting, or optimised for, a particular task, which may limit flexibility and which may be further limited by disrupted access to satellite communications in times of major conflict. It may be prudent, sooner rather than later, to obtain an indigenous New Zealand satellite capability, then at the very least the NZDF will not be reliant on third-parties for satellite access. In general terms the bigger something is the more difficult it is to defend. Just like the air domain, you cannot defend all the airspace all the time, and so it is likely to be with cyberspace; focus must therefore be on cyber-defence in line with what is essential for operations. Protecting

⁴⁶ Steven Finlay, *Artificial Intelligence and Machine Learning for Business* (3rd edition), Relativistic, Great Britain, 2018.

⁴⁷ Layton, *Fifth Generation Air Warfare*.

⁴⁸ Ibid.

what is essential is difficult, perhaps only possible if discrete and quarantined excess capacity is built-in and only comes online after the fact in the event of a primary failure⁴⁹ though this would be expensive and represents a gold-plated solution. The NZDF should expect failure and become adept at recovery and response. The effects of a cyber-attack are difficult to model; what might the 2nd and 3rd order effects look like? The only way to do this safely is through red-teaming, which should be regularly exercised.

This raises the question of can the NZDF do anything to stop cyber-attacks in the first place, i.e., cyber-deterrence? Deterrence requires a potential adversary to know what the consequences will be if they carry out an attack, which sews doubt in the adversary's thinking. But this would require a demonstration of capability,⁵⁰ but how can you do this without causing a response - you can't see it until it happens for real, and it would also provide vital intelligence to an adversary about your cyber-capability. The effects of cyber war are not really known with any certainty, so the threat of cyber retaliation may not worry a potential aggressor. And with a weapon that has uncertain effects, how do you apply proportionality in any retaliation? It is perhaps the uncertain effects of a cyber-attack that may deter an aggressor who suffers from similar uncertainty.⁵¹

The New Zealand Government is considering 'mechanisms' that dissuade or deter malicious cyber activities,⁵² which will hopefully carry more weight than

⁴⁹ William D. Bryant, "Resiliency in Future Cyber Combat," SSQ, Winter 2015.

⁵⁰ Edward Geist, "Deterrence Stability in the Cyber Age," SSQ, Winter 2015.

⁵¹ Martin C. Libicki, "Expectations of Cyber Deterrence," SSQ, Winter, 2018.

⁵² DPMC, *National Cyber Policy Office Proactive Release April 2018*.

public condemnation or sending signals as to what is acceptable behaviour, which is the current Government policy;⁵³ one imagines this would not be particularly helpful to the NZDF. There remains much careful thought and work to be done, and much uncertainty, around such a complex concept as an Information Enabled Air Force. In recent times, which are acknowledged as being financially constrained, the trend for the RNZAF has been to procure platforms that are fitted 'for but not with'. This thinking cannot be carried over into the cyber arena as it is likely to create major difficulties for future operations; The RNZAF must have the best people and equipment available as its first responsibility is to protect itself.

CONCLUSIONS

Drawing any meaningful conclusions around an unproven concept, especially one so complex, is fraught with difficulties. One can only speculate, based on the available evidence, as to what might happen, though there are some things that can be stated with reasonable surety. Information enabled warfare, and its sub-set cyber warfare, will occur at the speed of light. Attacks on information and communications systems will come with no warning and may only last a few seconds; consequently the RNZAF has to reshape their thinking of time and space, especially in the context of a response and operational tempo. Therein lies the first issue. Events happening at the speed of light cannot even begin to be absorbed or addressed by humans in a timely manner, even if they had the authority to do so. The consensus would appear to be that to have the slightest chance of minimising a cyber-attack, the RNZAF has no choice but to rely on artificial intelligence and machine learning. Similarly, the RNZAF cannot hope to manually analyse

the huge amounts of data that will be available to intelligence operators and commanders, and once again will rely heavily on automated systems. The complexity of these systems will require not only highly trained technicians but innovative, creative and forward looking data scientists to establish and keep systems, if not ahead of the game, then at least up with the play. The RNZAF cannot afford to maintain the traditional military group think and must allow its people freedom to act and try new things, even if they fail now and again, which they will, such is the nature of cyber and information operations. It must be understood that technology and cyber warfare in particular is moving forward so quickly that by the time you come up with a 100% solution it is probably too late and the game has changed.⁵⁴ The pursuit of excellence in cyber security will be pointless; in the dynamic cyber battlespace, 'good enough' is the new excellent. Bringing together data from many different national and international sources, analysing and fusing this data into something of use to commanders is going to be challenging. Add that any adversary is probably using systems with equal, if not superior performance, and that they will be trying to disrupt your network, it may be insurmountable in practice.

The whole point of an information enabled air force, or network-centric warfare etc., is to get inside an adversary's OODA loop. The weak link in any machine-human interface will always be the human, and until artificial intelligence evolves significantly, which it may not, humans will continue to make most of the decisions. But even if machines are entrusted to make decisions virtually in an instant, there may still be issues. There are, as yet, no rules of engagement for fifth generation air warfare; can the RNZAF trust the integrity of the

⁵⁴ Frank Konieczny, Eric Trias, and Nevin J. Taylor, "SEADE: Countering the Futility of Network Security," *ASPJ*, September–October 2015.

⁵³ NZ Government, *National Cyber Security Centre: Cyber Threat Report 2017/18*, GCSB, 2017.

combat cloud, and if it all goes wrong who is responsible? Fifth generation air warfare, at its heart, is meant to be fought beyond visual range, at high speed, in stealth mode using passive targeting, but it is not a panacea. For instance, it does not prevent an adversary reacting, especially in a long-range air-to-air engagement. Missile launches are readily detectable at long-range by modern infra-red missile warning systems, and this will provide a window of opportunity of perhaps up to 30 seconds or so to launch your own counterattack. And if claims regarding new stealth busting radar prove true, then it is a non-starter anyway. But the engage-effect lag will remain problematic unless someone comes up with 100% guaranteed jamming techniques.

It seems inevitable that eventually cyber, and space, will be discrete components available to the Joint Force Commander, and will operate on an equal footing with the Air Component, the Land Component, and the Maritime component. The Joint Force Commander will want freedom of manoeuvre within cyberspace and be able to project power in and through cyberspace to achieve operational objectives. The cyber, or virtual, domain is not only a key domain for the conduct of operations, but also a, if not the, key enabling domain for operations within the physical domains.⁵⁵ The complexities and sheer scope of cyber operations and communications networks will make it necessary to have military-industrial co-operation, for the simple reason that the private sector is advancing, and has been for some time, much faster than the defence sector.

⁵⁵ Brett T. Williams, "The Joint Force Commander's Guide to Cyberspace Operations," *JFQ*, 2nd Quarter 2014.

The lean and mean processes that a highly competitive private sector operates with are both agile, and responsive to the market, unlike the military where procurement, introduction into service and configuration management processes are glacial. This carries risk in such a sensitive area, but there are no alternatives.

Fifth generation air warfare is extremely ambitious and promises much, but as Layton correctly points out, fifth generation air warfare, and by default, information led air forces, are merely an aspiration that may not ever be achieved as it is currently conceptualised. It is only applicable against a similarly disposed adversary in a well-defined battlespace, and is largely symmetrical. Due to the possible vulnerabilities of the network, which will be constantly attacked from the onset of any hostilities, it may quickly evolve to third generation air warfare and all that entails. If the RNZAF intends putting in a great deal of time and resources into the aspiration of becoming an information enabled air force that can participate in high-end fifth generation air warfare, it may be a good idea to also have a Plan B.



RNZAF Metal Worker preparing to weld a cowling
NZDF Official



People's Liberation Army Air Force personnel arrive to participate in Exercise Skytrain 2018
NZDF Official



Image credit: Lockheed Martin

A NEW ERA FOR AIRSHIPS: ENHANCING NEW ZEALAND'S AIR POWER WITH LIGHTER-THAN-AIR TECHNOLOGY

Mr. Isaac Levi Henderson, BAvMan, PGDipBus (Finance), MAV, AMRAeS

INTRODUCTION

Airships are manoeuvrable, powered aircraft that achieve some or all of their lift through buoyancy. While many will be aware that airships have not been in widespread use since the late 1930s, there have been a number of recent technological developments that are bringing this type of aircraft back to the forefront – highlighting their strengths that were largely forgotten after the 1937 Hindenburg disaster. Knowledge and understanding of historic and modern airships bring about the notion of a new era for both civilian and military applications.

Taking into consideration their advantages and disadvantages, as well as recent technological developments, there is a case to be made for how airships could be used to enhance New Zealand's air power. But first, there is a need to understand the beginning of airships, including an overview of the original airship era and the historical use of airships, particularly in a military context. From this, the advantages and disadvantages of airships can be identified and studied. With recent technological advancements alleviating some of the key disadvantages, potential applications of airship technology can be envisaged for the Royal New Zealand Air Force.

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THE ORIGINAL AIRSHIP ERA: CIVILIAN AND MILITARY USE

While one may think that the first powered, controlled and sustained flight was conducted by the Wright Brothers in 1903, this is only true for heavier-than-air flight. In truth the first powered, controlled and sustained flight was conducted by Count Ferdinand von Zeppelin on the 2nd of July 1900 over Lake Constance using the Zeppelin LZ1.¹ This first flight lasted around 17 minutes² and covered a distance of 5.5km³. Compare this with the Wright Brother's first flight at Kittyhawk that lasted 12 seconds and covered 120 feet⁴ and one can see why the early perceptions of airships were much more favourable than for aeroplanes. However, military observers considered the airship too slow and so Zeppelin continued to develop the technology under private investment.



Maiden flight of LZ1 2 Jul 1900

¹ Editor's note: This is with reference to an aircraft with a rigid structure. Non-rigid airships had made powered, controlled and sustained flights (with varying degrees of success) since 1852.

² Michael Belafi and Cordula Werschkun, *The Zeppelin* (Barnsley, England: Pen & Sword, 2015).

³ John Christopher, *The Zeppelin Story* (Gloucestershire, United Kingdom: The History Press, 2010).

⁴ Clark G Reynolds, "Wright Brothers," in *Salem Press Biographical Encyclopedia* (2018).

After several renditions of Zeppelin designs, the world's first airline (DELAG: Deutsche Luftschiffahrts-Aktiengesellschaft or German Airship Transportation Corporation Limited) was formed in November 1909 to link major German cities with scheduled airship flights. Between 1910 (when the first flight was operated) and the outbreak of World War I (WWI) in 1914, DELAG carried over 34,000 passengers on more than 1,500 flights without a single injury.⁵ Many of these passengers (including aristocrats, military officers and other important figures) were given free tickets to help market the idea of Zeppelins. Passengers had the pleasure of travelling in luxury while viewing the German countryside.

Military interest did pick up, and some Zeppelins were ordered prior to the outbreak of war, with the German army and navy receiving 2 airships each prior to WWI.⁶ At the outbreak of WWI, several commercial airships were requisitioned and orders for airships were made by the German military, with the Zeppelin Company averaging 2 deliveries per month.⁷ At this time aeroplanes were so basic that they presented no serious threat to the German Zeppelins until later on in the war. For example, the Royal Naval Air Service had a fleet consisting of B.E. 2s, B.E. 8s, Sopwiths, Avro 504s, Bristol T.B. 8s, Short seaplanes, a Vickers Gun Bus, and a few Blériots and Henry Farmans – none of which had the speed, altitude or fire power to attack a Zeppelin at its operational altitude.⁸ On the night of 19-20 January 1915, German Zeppelins were used in the world's first strategic air attack (i.e., they tried to defeat the enemy state without

⁵ Dan Grossman, "Delag: The World's First Airline," <http://www.airships.net/delag-passenger-zeppelins>.

⁶ Charles Stephenson, *Zeppelins: German Airships 1900–40* (Oxford, United Kingdom: Osprey Publishing, 2010).

⁷ Belafi and Werschkun, *The Zeppelin*.

⁸ H. G. Castle, *Fire over England: The German Air Raids in World War I* (London, Great Britain: Leo Cooper, 1982).

engaging their military forces).⁹ Strategic attacks were carried out over Southern England (particularly London) and France. Zeppelins conducted 51 bombing raids on England during WWI, killing 557 people, injuring 1,358 and causing £1.5 million worth of damage (roughly \$NZ160 million in today's terms).¹⁰ Airships primarily conducted night attacks, where they had the advantage of stealth. Only 30 were shot down out of the 84 that took part in the war.¹¹

Airships also provided useful platforms for tactical bombing and reconnaissance, such as how they were used to detect and light up enemy ships at night. While airships helped establish some of the key characteristics of air power, their usefulness did diminish during the war as fighter aircraft were eventually able to reach the same altitudes and new types of armaments (e.g., incendiary munitions) were designed to take advantage of the structural delicacy of the craft.¹² By 1917, there were also fixed-wing aircraft capable of strategic bombing, such as the Gotha G.V heavy bomber, meaning that for the first time there was a viable alternative to Zeppelins. Following the war, substantial military investment was lost and the interwar period was once again characterised by civilian uses (although there were ongoing military uses).

In 1919, DELAG began a daily passenger service between Friedrichshafen and Berlin and intended to begin international flights before its airships had to be handed over as part of war reparations.¹³ Other nations were very interested in the development of airship technologies.

⁹ Stephenson, *Zeppelins: German Airships 1900–40*.

¹⁰ Basil Henry Liddell Hart, *History of the World War, 1914–1918* (London, United Kingdom: Faber, 1934).

¹¹ Ibid.

¹² Stephenson, *Zeppelins: German Airships 1900–40*.

¹³ Grossman, "Delag: The World's First Airline."

The general consensus in the 1920s was that aeroplanes were never going to be a suitable vehicle for transoceanic flights and that airships would be the vehicles to service long-distance routes¹⁴ with aeroplanes acting as feeders on short haul operations¹⁵. Such an opinion was reinforced by the continued successes of airships in conducting long-haul operations, with the British R34 airship making its way across the Atlantic in 1919.¹⁶ Aeroplanes would not be able to achieve this feat until Charles Lindbergh's famous flight in 1927.¹⁷

One of the most relevant cases in point for New Zealand was the proposed Imperial Airship Scheme and the subsequent construction of the R100 and R101 airships. Great Britain recognised the value in shortening transit times within the Empire and considered airship routes to South Africa, India, Canada, Australia, and New Zealand.¹⁸ In 1927, Group Captain Fellowes received orders to inspect areas in Australia and New Zealand and advise their governments of potential sites for airship bases.¹⁹ He scouted sites on both the North Island and South Island, but suggested that varied weather patterns made even the best South Island locations problematic.²⁰ His conclusion was that a site in the Bulls/Sanson area would have the greatest potential in New Zealand. Accordingly, a site of around 1200 acres to the west of the main highway and south of the Rangitikei River was chosen for construction of a mooring mast

¹⁴ Nevil Shute, *Slide Rule: The Autobiography of an Engineer* (London, United Kingdom: PAN Books, 1968).

¹⁵ Robert L McCormack, "Imperial Mission: The Air Route to Cape Town 1918-32," *Journal of Contemporary History* 9, no. 4 (1974).

¹⁶ Christopher, *The Zeppelin Story*.

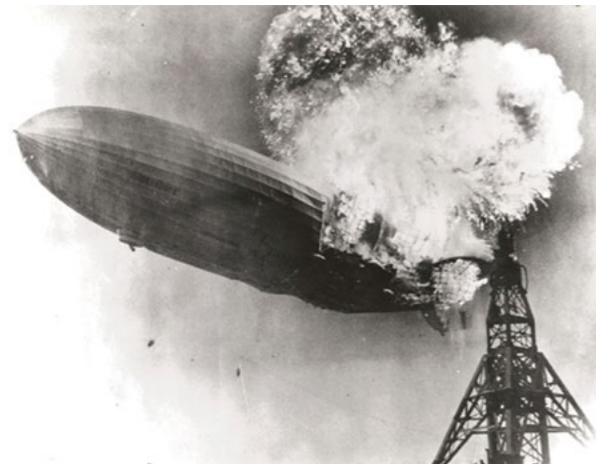
¹⁷ "Lindbergh, Charles Augustus," in *Funk & Wagnalls New World Encyclopedia* (2018).

¹⁸ Alex M Spencer, "A Third Option: Imperial Air Defense and the Pacific Dominions, 1918-1939" (Auburn University, 2008).

¹⁹ Ibid.

²⁰ Ibid.

for a demonstration flight.²¹ This was with the idea to eventually build a full airship base with three mooring towers, airship sheds and hydrogen production.²² There were also several locations suggested in North Auckland,²³ which were suitable for a mooring mast, but not spacious enough for an airship shed²⁴. The Imperial Airship Scheme was eventually scrapped due to the horrific crash of the R101 in 1930.²⁵ While neither airship base eventuated in New Zealand, Fellowes' report still proved useful for the New Zealand government when selecting locations for air bases, with recommended locations eventually becoming the Ohakea and Whenuapai bases of the Royal New Zealand Air Force (RNZAF).^{26,27}



The Hindenburg seconds after catching fire

21 The Airship Heritage Trust, "Airship Sheds: New Zealand - Ohakea," http://www.airshipsonline.com/sheds/New_Zealand.htm.

22 Ibid.

23 Spencer, "A Third Option: Imperial Air Defense and the Pacific Dominions, 1918-1939."

24 Malcolm Fife, *British Airship Bases of the Twentieth Century* (Stroud, United Kingdom: Fonthill Media, 2015).

25 Spencer, "A Third Option: Imperial Air Defense and the Pacific Dominions, 1918-1939."

26 Fife, *British Airship Bases of the Twentieth Century*.

27 The Airship Heritage Trust, "Airship Sheds: New Zealand - Ohakea."

While the British struggled with their airship scheme, there were a number of airship successes. Arguably, LZ 127 *Graf Zeppelin* built in 1928 was the most successful airship of all time. On October 11, 1928, *Graf Zeppelin* began the world's first commercial passenger flight across the Atlantic, arriving in Lakehurst, New Jersey on October 15, with a total flight duration of 111 hours and 44 minutes.²⁸ The craft would also become the first to conduct a passenger-carrying flight around the world (1929), and would come to fly around the arctic (1931) and serve a regular passenger service between Germany and Brazil (1931-1937).²⁹ Over the course of its service *Graf Zeppelin* conducted 590 flights, travelled over one million miles and carried over 34,000 passengers.³⁰ However, its service ceased during a flight from Brazil to Germany, when the pilot was informed of the Hindenburg Disaster.

LZ 129 Hindenburg has the unfortunate accolade of being the best known airship of all time. On May 6, 1937 while landing at Lakehurst, New Jersey, Hindenburg caught fire and was subsequently engulfed in flames killing 36 people (including 1 on the ground), and leaving 62 survivors.³¹ Despite the (relatively) good survival rate for the time, the disaster was caught on camera and was widely publicised globally. Due to time constraints, the crew had disregarded the known risk of electrically charged conditions, allowing a spark to be formed by electrostatic discharge, which in turn ignited free hydrogen.³² While hydrogen clearly played a role in exacerbating the fire, the key issue was that the flight crew were not aware that the doping of

28 Dan Grossman, "Graf Zeppelin History," <http://www.airships.net/lz127-graf-zeppelin/history>.

29 Ibid.

30 "L-127 Graf Zeppelin," <https://www.airships.net/lz127-graf-zeppelin/>.

31 Dan Grossman, Cheryl Ganz, and Patrick Russell, *Zeppelin Hindenburg: An Illustrated History of LZ-129* (Stroud, United Kingdom: The History Press, 2017).

32 Ibid.

the airship's fabric covering was conducive and able to hold electrical charge when wet.³³ Because of this, some researchers downplay the role that hydrogen had in the accident, and instead lay blame entirely on the fabric and doping used.^{34,35} Regardless of cause, airships have seldom been used for passenger services ever since.³⁶

While the airship era had now effectively ended, the United States Navy (USN) still continued to use airships for military purposes until airship flight operations ended on 31 August 1962.³⁷ During the interwar years, the USN experimented with the idea of airships as flying aircraft carriers. In 1929, a hook-on procedure was demonstrated using the USS Los Angeles to show that aeroplanes could 'land' on airships.³⁸ Later, USS Akron and USS Macon were built with internal hangars to house several Curtiss F9C Sparrowhawk biplane fighters, which could take-off and land using a trapeze.³⁹ These were used between 1931 and 1935 with the idea that airships should be used as low-altitude reconnaissance aircraft over water, not continental land masses (with thermals and turbulent air masses).⁴⁰ While both of these large rigid airships were eventually lost to accidents,

33 Ibid.

34 Addison Bain and Wm. D. van Vorst, "The Hindenburg Tragedy Revisited: The Fatal Flaw Found," *International Journal of Hydrogen Energy* 24, no. 5 (1999).

35 Fotis Rigas and Spyros Sklavounos, "Evaluation of Hazards Associated with Hydrogen Storage Facilities," *International Journal of Hydrogen Energy* 30, no. 13-14 (2005).

36 Reginald Hillsdon, "Roles and Economic Considerations," in *Airship Technology*, ed. Gabriel Alexander Khoury (New York, NY: Cambridge University Press, 2012).

37 William F. Althoff, *Sky Ships: A History of the Airship in the United States Navy*, 25th Anniversary ed. (Annapolis, MD: Naval Institute Press, 2016).

38 Ibid.

39 Ibid.

40 Ibid.

the USN did not give up on the idea of lighter-than-air technologies and moved onto looking at non-rigid blimp designs. In World War II (WWII), the USN deployed a fleet of over 150 non-rigid blimps across 15 airship squadrons to act as convoy escorts and antisubmarine patrols over the Atlantic, Pacific and Mediterranean.⁴¹ They were very successful in this role as none of the 89,000 ships that travelled under blimp escort were sunk by enemy submarines and only one blimp was ever shot down (gunfire from a surface U-boat).⁴² On top of the one blimp that was shot down, eight were lost to storms or high winds, and 28 were lost due to ground handling accidents, material failure, pilot error or other causes.⁴³ Over the course of WWII, USN airships conducted 55,900 operational flights, tallied 550,000 hours of flight time and achieved an availability factor of 87%.⁴⁵ Airships were also credited with driving away all submarines from the Mediterranean (using magnetic anomaly detection equipment) and clearing out mines from the waters of Southern France in preparation for the Allied invasion.⁴⁶

41 Louis C Gerken, *Airships: History and Technology* (Chula Vista, CA: American Scientific, 1990).

42 Ibid.

43 Ibid.

44 Althoff, *Sky Ships: A History of the Airship in the United States Navy*.

45 Gerken, *Airships: History and Technology*.

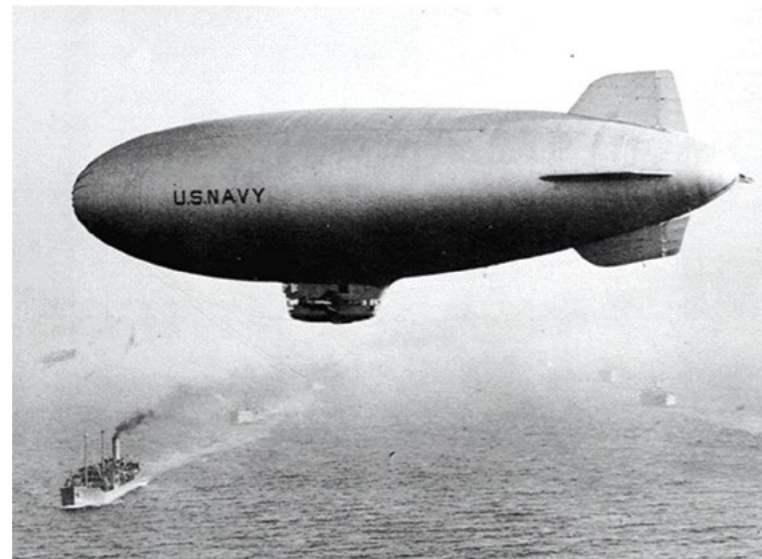
46 Ibid.

Following WWII, there was a decline in the number of airships operated by the USN, however, some were kept operational due to their extreme endurance abilities. For example, in 1957, an N-class airship of the USN set the endurance record for powered flight with a flight of over 9,000 miles lasting 264 hours and 20 minutes (11 days) and encircling the Atlantic non-stop without refuelling.⁴⁷ During the 1950s, airships served a new mission of Airborne Early Warning (AEW). The USN recognised their unique advantages over other aircraft and surface vehicles: endurance, large lift, advanced communications, excellent radar performance (stable and vibrationless environment), and overall operating economy.⁴⁸

This latter point is an important one in terms of taxpayer value – a 1956 USN estimate put operating an airship for AEW cost around half to one third the cost of an aeroplane on the same station.⁴⁹ Despite their unique application, the USN eventually ceased all airship operations in 1962 citing fiscal constraints and the need to prioritise naval programmes by tactical importance.⁵⁰

ADVANTAGES AND DISADVANTAGES OF AIRSHIPS: GETTING THE BEST TRADE-OFF

Like any other technology, airships have some inherent advantages and disadvantages that should be considered when determining their application for different roles (see Table 1).



United States Navy K-class blimp escorting a convoy during WWII

⁴⁷ Althoff, *Sky Ships: A History of the Airship in the United States Navy*.

⁴⁸ Ibid.

⁴⁹ Ibid.

⁵⁰ Ibid.

General Advantages and Disadvantages of Conventional Airship Technology^{52,53,54,55,56,57}

ADVANTAGES	DISADVANTAGES
Lower operating costs than fixed wing and rotary wing aircraft.	Slow cruise speeds compared to fixed-wing aircraft.
Low environmental impact due to low noise and emission output, use of naturally occurring elements and the ability to use solar power and/or electric engines.	Helium is safe and inert, but very expensive to purchase. Hydrogen is very cheap, but also highly flammable.
Very long endurance.	Low altitude limits compared to large fixed-wing aircraft.
Very long range.	Lingering public perceptions about safety.
Can vertically take-off and land (no runway required).	More weather-dependent than large fixed-wing aircraft.
Some safety advantages over other aircraft. ⁵¹	Massive size.
The cabin and on-board facilities can be designed in almost any way.	Limited supply of experienced airship pilots and engineers.
Very stable platform.	Structural delicacy compared to other aircraft.

⁵¹ For example, buoyant lift is not affected by engine failure and the distance between the front of the airship and the cabin means that if there is a collision, the frame will absorb most of the impact without hurting crew and passengers.

⁵² Philip W Lynch, "Hybrid Airships: Intratheater Operations Cost-Benefit Analysis" (Air Force Institute of Technology, Air University, 2011).

⁵³ Steven Recoskie et al., "Experimental Testing of a Hybrid Power Plant for a Dirigible UAV," *Journal of Intelligent & Robotic Systems* 69, no. 1–4 (2013).

⁵⁴ Lockheed Martin, "Hybrid Airship," <https://www.lockheedmartin.com/en-us/products/hybrid-airship.html>.

⁵⁵ Althoff, *Sky Ships: A History of the Airship in the United States Navy*.

⁵⁶ Rajmumar S. Pant, "Transportation of Goods and Passengers to Remote Areas Using Airships: Two Case Studies in India," in *Air Transport Provision in Remoter Regions*, ed. George Williams and Svein Bråthen (Farnham, United Kingdom: Ashgate, 2010).

⁵⁷ Gabriel Alexander Khoury, "Solar Power," in *Airship Technology*, ed. Gabriel Alexander Khoury (New York, NY: Cambridge University Press, 2012).

While conventional airship technology could certainly be considered for certain applications, an interesting alternative that has received considerable attention in recent years is the idea of hybrid airships. While conventional airships produce all of their lift using buoyancy, hybrid airships only produce a majority of their lift with buoyancy, and use direct and/or aerodynamic lift to produce the remainder. The most poignant example at present is Hybrid Air Vehicle's Airlander 10, the largest operational aircraft in the world. This craft is filled with helium to produce buoyancy, can vector its engines to produce direct lift, and the entire aircraft takes the shape of an aerofoil to create aerodynamic lift when moving forward.⁵⁸ Accordingly, hybrid airships can achieve faster speeds and higher altitudes than conventional airships and are much faster than land or sea transportation systems.⁵⁹ The Airlander 10 cruises at 80 knots and can reach an altitude of 20,000 feet.⁶⁰ Despite not being as fast as an airliner or as manoeuvrable as a helicopter, they are more economical than both and have the flexibility of being able to be landed on any (relatively flat) piece of land or on water. The reduction in buoyancy means that they are not as cost effective as a conventional airship and cannot carry as heavy a payload or fly for as long. However, the advantages of speed and manoeuvrability make hybrid airships more versatile. The Airlander 10 can carry a payload of up to 10,000kg.⁶¹ The future Airlander 50 concept could carry up to 60,000kg and cruise at 105 knots.⁶² The endurance of both aircraft is still impressive

at between 4 and 5 days.^{63,64} Accordingly, the technology is scalable according to the operational requirements associated with the aircraft's role.



Hybrid Air Vehicle's Airlander 10

58 Hybrid Air Vehicles, "How It Works," <https://www.hybridairvehicles.com/technical/how-it-works>.

59 Lockheed Martin, "Hybrid Airship."

60 Hybrid Air Vehicles, "Airlander 10 Technical Data," <https://www.hybridairvehicles.com/downloads/Airlander-21.pdf>.

61 Ibid.

62 "Airlander 50 Technical Data," <https://www.hybridairvehicles.com/downloads/Airlander-77.pdf>.

63 Hybrid Air Vehicles, "Airlander 10 Technical Data."

64 "Airlander 50 Technical Data."

Hybrid Air Vehicles is not the only mover in the space of hybrid airships. Solar Ship is another interesting innovator in this space, having the concept of an entirely solar powered airship. Their prototype airship, the Caracal can take-off and land within 100 metres, carry 200kg and fly for 200km all using solar power from panels on top of the wing.⁶⁵ However, one of their future goals is to create the Nanuq with an 80m wingspan, 35,000kg payload and 800km range using only solar power – this will carry more payload than a C-130 Hercules, but at 10% of the cost.⁶⁶ Plimp is another interesting contender, originally building an unmanned hybrid airship and now seeking to build their Model J hybrid airship that will compete with light aircraft and helicopters. Both aircraft are designed to combine the agility, manoeuvrability and hover capability of a drone with the buoyancy of an airship.⁶⁷ The unmanned hybrid airship⁶⁸ is fully electric where the buoyancy provides a consistent source of lift to extend endurance beyond most rotary-winged and fixed-wing competitors.⁶⁹ Its large size means that visual line of sight can be maintained at much larger distances.⁷⁰ The unmanned aircraft is 28 feet long, with a diameter of 7 feet.⁷¹ It can fly up to 40mph, be seen up to 3 miles away and has an endurance of 1 hour while cruising at 30mph and carrying a 5lb load.⁷²

The more recent concept of the Model J airship will boast a petrol-electric motor, be 140 feet long, carry up to 10 people or 2000lbs of cargo, reach a range of 320 miles while cruising at 63mph and endure for over 5 hours without refuelling.⁷³ An added advantage of the Model J in terms of safety is that the aircraft is plummet proof and would take minutes to reach the ground in the event of complete engine failure and would still be fully steerable and capable of landing in any open space or on water.⁷⁴



Plimp's unmanned hybrid airship

65 Solar Ship, "Caracal: Solar Plane," <https://www.solarship.com/caracal.html>.

66 "Nanuq: Cargo Plane," <https://www.solarship.com/nanuq.html>.

67 Richard Wiles, "Utility Airships," *Airship: The Journal of the Airship Association* 195, no. 4 (2018).

68 Image © Egan Airships, published here with permission.

69 Ibid

70 Ibid

71 Plimp, "Specifications," <https://plimp.com/specifications/>.

72 Ibid

73 "Model J Specifications," <https://plimp.com/specifications-2/>

74 Wiles, "Utility Airships."

AIRSHIPS IN THE ROYAL NEW ZEALAND AIR FORCE?

Airships have had limited influence on modern military strategy due to their disadvantages of slow speeds, large sizes, weather and threat vulnerability and ground handling requirements.⁷⁵ However, the combination of technological, engineering and operational developments over the last 50 years, including the advent of hybrid airships, mean that most of these disadvantages have now been alleviated.⁷⁶ Many roles have been suggested in recent years, such as passenger and cargo transport, area control, search and rescue, fishery protection/anti-piracy, counter-insurrection/terrorism, sovereignty enforcement, airborne early warning (AEW), antisubmarine warfare (ASW), mine countermeasures (MCM), command, control and information (C3I), and reconnaissance, intelligence, surveillance and target acquisition (RISTA).^{77, 78}

In 2012, the Department of Defense in the United States commissioned a report on operational concepts for hybrid airships that recommended four key applications within the United States Military. Firstly, based upon experiences in Iraq and Afghanistan, where lives and resources were lost maintaining ground lines of communications (LOCs), the report suggests that hybrid airships could replace many of these LOCs with greater speed and effectiveness as well as saving precious lives and resources.⁷⁹ Secondly, large rotary-wing aircraft that

are currently used to move combat forces around the modern battlefield have high procurement and operating costs and are less resilient compared to hybrid airships.⁸⁰ Thirdly, hybrid airships provide potential for avoiding anti-access defences.⁸¹ Lastly, the characteristics of large flight envelopes and cargo carrying capabilities make hybrid airships suitable for carrying large radar antennae and/or high power jamming equipment that could replace similar equipment found on fixed-wing aircraft.⁸² While many of these roles are interesting and relevant for air power theory and development, this paper will discuss two key areas where hybrid airships could be used to enhance New Zealand's air power.

Large hybrid airships such as the Airlander 10 and Airlander 50 (concept) could provide useful military transports for deploying soldiers, equipment and supplies to combat zones and disaster/emergency areas. While some may assume that such a large craft would not be safe flying in such areas, the threat risk towards hybrid airships is relatively low. Research shows that hybrid airships can withstand hits from anti-aircraft weaponry relatively well. For example, if a medium-sized hybrid airship was hit once, it would take between 36 and 93 hours⁸³ before the airship would be forced to land.⁸⁴ More so, to force it to land within 30 minutes, an estimated 28 S-60 rounds would have to hit the aircraft and a ZU-23-2 would have to hit it 72 times.⁸⁵ Because the helium-filled envelope is only slightly pressurised,

it means that the lifting gas is not forced out even with large punctures, and the helium is inert and cannot be ignited by the munitions.⁸⁶

Apart from combat, the RNZAF also has to periodically deploy resources to disaster and emergency zones, both domestically (e.g., Christchurch Earthquake in 2011) and overseas (e.g., Palu, Indonesia in 2018). In such areas, air transport infrastructure may be damaged and remote areas may be devoid of air transport infrastructure all together. Hybrid airships don't require runways and are generally amphibious aircraft. This means that if runways are not available due to damage or lack of infrastructure, this does not prevent them from providing relief in a timely manner. Unlike fixed-wing aircraft that need a runway to land on and have supplies unloaded and then delivered using land transport, hybrid airships can deliver supplies directly to where they are needed. While this is also true for helicopters, hybrid airships can carry significantly more cargo at one tenth the operating costs⁸⁷ and have the endurance and range to sustain operations for several days without refuelling.^{88, 89} In October 2018, the RNZAF flew a C-130 Hercules to Palu, Indonesia carrying 8.2 tonnes of aid from New Zealand. The aircraft then helped to evacuate 120 survivors, transport 60 tonnes of aid and transport 80 rescue personnel and officials.⁹⁰ Despite the slower cruise speed, an Airlander 50 could carry more payload (up to 60 tonnes) and deliver to areas without infrastructure while also costing less to operate. Procurement costs for hybrid airships are also lower than most fixed-wing military transports. The

Airlander 10 is set to be sold for £25 million (NZ\$48.3 million) per unit. While hybrid airships will not be appropriate in every setting, a hybrid airship could augment the current capabilities of the RNZAF in terms of providing transport to combat zones and emergency/disaster areas.

Another interesting possibility for hybrid airships of many different sizes would be to provide airborne surveillance and reconnaissance of New Zealand's economic interests, something which the RNZAF currently uses the P-3K2 Orion for. Hybrid airships are inherently more stable than fixed wing aircraft and can house larger and more sophisticated equipment. They also have longer endurance and lower operating costs. The ability to maintain airborne surveillance for several days (with onboard crew accommodation) and use more accurate and sophisticated equipment could help enhance the RNZAF's current capabilities. Again, this would be augmenting current capabilities rather than completely replacing fixed-wing aircraft for such operations.

In addition to arguments in favour of hybrid airships' ability to enhance New Zealand's air power, there are two other key arguments in their favour. Firstly, the New Zealand Defence Force (NZDF) has limited resources. If current air power roles can be performed to the same or a higher standard using a more cost-effective means then that would allow the NZDF to use its existing resources in other ways or reduce its overall spending. The NZDF has already been in the process of reprioritising its resources in order to deliver on its strategy and commitments to the New Zealand Government.⁹¹

75 Department of Defense, "Hybrid Airships: Operational Concepts," <https://www.hsdl.org/?view&did=728732>.

76 Zachery B Jiron, "Hybrid Airships for Lift: A New Lift Paradigm and a Pragmatic Assessment of the Vehicle's Key Operational Challenges" (Air University, 2011).

77 Ibid.

78 Hillsdon, "Roles and Economic Considerations."

79 Department of Defense, "Hybrid Airships: Operational Concepts."

80 Ibid.

81 Ibid.

82 Ibid.

83 The actual time depends on the size of round that hits the aircraft. 36 hours is the estimated time if hit by a 57mm round fired from a S-60 anti-aircraft gun whereas 93 hours is the estimated time if hit by a 23mm round fired from a ZU-23-2.

84 Jiron, "Hybrid Airships for Lift: A New Lift Paradigm and a Pragmatic Assessment of the Vehicle's Key Operational Challenges."

85 Ibid.

86 Ibid.

87 Lockheed Martin, "Hybrid Airship."

88 Hybrid Air Vehicles, "Airlander 10 Technical Data".

89 "Airlander 50 Technical Data".

90 Royal New Zealand Air Force, "NZDF Delivers About 70 Tonnes of Aid to Indonesia's Quake Damaged City," <http://www.airforce.mil.nz/about-us/news/media-releases/media-release.htm?guid=%7Bd189e315-c6c1-4a52-a4b3-79c2c857c552%7D.htm>.

91 Sam Sachdeva, "Defence Force Chief Plots Spending Cutbacks," <https://www.newsroom.co.nz/2018/02/14/88667/defence-force-chief-plots-spending-cutbacks>.

The second argument is that the NZDF could drastically reduce its environmental impact by using hybrid airship technologies. In October 2018, the Secretary for Defence and the Chief of Defence Force co-signed the document "The Climate Crisis: Defence Readiness and Responsibilities". Within the document, the NZDF committed to invest in research in science and technological developments around green and sustainable military technology, particularly fuels, energy storage and renewable energy.⁹² Hybrid airships are already far greener than fixed-wing and rotary-wing alternatives, with fully electric and fully solar-powered hybrid airships under development or in prototyping (e.g., Solar Ship). The combination of helium to create buoyancy and solar power to create thrust means that hybrid airships have the potential to operate entirely on renewable energy, something which looks like a much more distant prospect for fixed-wing and rotary-winged aircraft. Rather than having to compromise on capabilities, hybrid airships could enhance current RNZAF capabilities while reducing the environmental impact of the NZDF. This would show New Zealand's citizens and South Pacific neighbours that the NZDF is taking the issue of the climate crisis seriously.

CONCLUSION

Airships have a rich military history and were used as strategic bombers, airborne aircraft carriers, escorts for seaborne vessels, anti-submarine patrols and aerial early warning systems. Airships have a number of advantages and disadvantages that make them unique in comparison to fixed-wing and rotary-winged aircraft. While airships have had little influence on modern military strategy, the emerging technology of hybrid airships presents an opportunity for airship technologies to have a new era in the military. While a number of military roles could be considered, this paper has argued that New Zealand's air power could be enhanced through the use of hybrid airships as military transports and to provide airborne surveillance and reconnaissance of New Zealand's economic interests. This paper also argues that hybrid airships should be seriously considered because of their potential to save costs and reduce the environmental impacts of New Zealand's defence activities. The world is about to enter a new era for airships and the RNZAF should be part of that.

⁹² New Zealand Government, "The Climate Crisis: Defence Readiness and Responsibilities," <http://www.nzdf.mil.nz/downloads/pdf/public-docs/2018/newzealanddefenceassessmentonclimatechangeandsecurity2018.pdf>.

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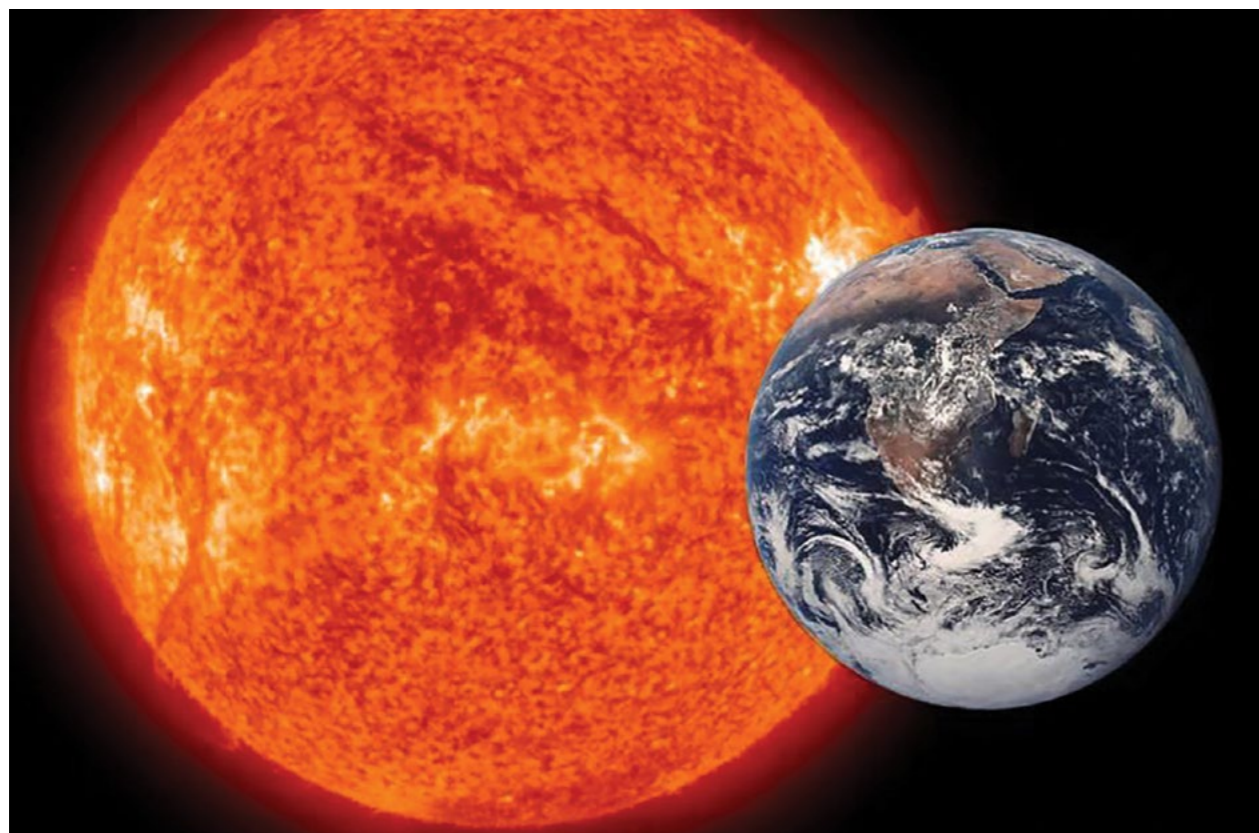
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P-3 Orion being marshalled to stop at Exercise RIMPAC
NZDF Official



SPACE WEATHER AND AVIATION IMPACTS OF SOLAR FLARES

Harriet George and Craig J. Rodger

INTRODUCTION

Space weather phenomena are triggered by events occurring on the Sun and in interplanetary space, and produce impacts in the natural Earth environment ranging in size from the global to the regional scale. Fundamentally, space weather is driven by changes in the Sun's magnetic field and the subsequent consequences of those changes on and around the Earth. The most visible manifestation of space weather is the aurora, which have delighted and fascinated mankind for centuries. However, space weather has a darker side we have only become aware of comparatively recently; space weather disturbances can affect a number of critical technologies, infrastructure, and by extension, the global economy.

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The wide potential impacts of space weather are well summarized by the scientific “road map”¹ developed by the Committee on Space Research (COSPAR)² and the International Living With a Star (ILWS)³ scientific programme to encourage decision makers. This road map identifies three broad impact pathways upon technology.⁴ These produce many downstream impacts, including: energy infrastructure, transport systems, use of GNSS systems, and satellite services. The hazard posed by space weather has stimulated action from organizations well outside of pure research. For example, the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS)⁵ has created an Expert Group on Space Weather. This group has reported that the largest potential socioeconomic impacts arise from space weather driven geomagnetically-induced currents in electrical power networks.⁶ The direct impacts from

a collapse of the electrical power grid during an extreme event come from the damage to the infrastructure and loss of service. The flow-down impacts, which would include the loss of services that rely on the availability of electricity, would have even greater significance. It is the loss of those services in the interconnected economy of the twenty-first century which could quickly lead to extreme impacts. Such loss of power can also result in extensive damage to property and infrastructure, as well as loss of life. New Zealand is well aware of this hazard, with a recent MBIE-funded research project⁷ undertaken by Otago University physicists working alongside Transpower New Zealand.⁸ It is important to note that the power network hazard appears to be most significant for rare and extreme events, which reoccur every 100 to 200 years.

The “alphabet soup” of international bodies showing interest in space weather includes the World Meteorological Organisation (WMO)⁹, who have formed the Inter-Programme Team on Space Weather Information Systems and Services (IPT-SWeISS). One early task for IPT-SWeISS was to provide support to WMO to respond to a specific space weather request from the International Civil Aviation Organization (ICAO)¹⁰ – the provision

1 C. J. Schrijver et al., “Understanding space weather to shield society: A global road map for 2015–2025 commissioned by COSPAR and ILWS”, *Advances in Space Research* 55, no. 12 (2015), 2745–2807.

2 COSPAR was created in 1958 by the International Council for Science in response to the start of the space age. COSPAR seeks to promote international scientific research in space, ignoring political considerations and viewing all questions solely from the scientific standpoint. As such it served a vital scientific bridge during the Cold War.

3 ILWS is a cooperative program in solar terrestrial physics established by multiple global space agencies. It seeks to investigate how variations in the Sun affect the environment of Earth and the other planets. ILWS concentrates on those aspects of the Sun-Earth system that may affect mankind and society.

4 The executive summary of the road map can be found online at: https://ccmc.gsfc.nasa.gov/RoR_WWW/presentations/executivesummary_compressed.pdf

5 COPUOS was set up by the General Assembly in 1959 to govern the exploration and use of space for the benefit of all humanity: for peace, security, and development. New Zealand joined COPUOS in 2016. www.unoosa.org/oosa/en/ourwork/copuos/index.html

6 United Nations Committee on the Peaceful Uses of Outer Space Expert Group on Space Weather (2017), *Report on Thematic Priority 4: International Framework for Space Weather Services for UNISPACE+50 (A/AC.105/1171)*. Available online from: www.unoosa.org/oosa/

oosadoc/data/documents/2018/aac.105/aac.1051171_0.html

7 John Edens article published by Fairfax media online as NZ’s (only) space-weather team to investigate power-grid solar-storm risk (<http://www.stuff.co.nz/science/76510072/nzs-only-spaceweather-team-to-investigate-powergrid-solarstorm-risk>, 8 February 2016).

8 An example of the work coming from this can be found at: C. J. Rodger et al., “Long-term geomagnetically induced current observations from New Zealand: Peak current estimates for extreme geomagnetic storms”. *Space Weather*, 15, (2017), 1447–1460. <https://doi.org/10.1002/2017SW001691>

9 The WMO is a specialised agency of the United Nations for meteorology (weather and climate), operational hydrology and related geophysical sciences. IPT-SWeISS was formed in 2016.

10 ICAO is another United Nations organisation, in this case focused on international air navigation, to foster the planning and development

of space weather forecasting to support global aviation. Here the focus tends to be on the operations perspective, where space weather events can produce degradation or disruption of communications, navigation, and surveillance systems, as well as leading to an elevation in radiation dose levels at flight altitudes.

Given the nature of this publication, in this article we have primarily focused this space weather overview article on solar flares, and the impacts caused by solar flares which are relevant to the aviation sectors. It is important to stress that space weather is a much larger subject area, with potentially very serious impacts over most parts of a technological economy and society. For overviews on the broader subject area, we direct the reader to other recent reports^{11,12}, or indeed to the recent article in *Te Matataua*¹³.

of international air transport to ensure safe and orderly growth.

11 Mike Hapgood, *Space Weather*, IOP Publishing, ISBN: 978-0-7503-1372-8, 2017. Freely available online from <https://iopscience.iop.org/book/978-0-7503-1372-8>

12 Space weather, PostNote, No. 361, UK Houses of Parliament; Parliamentary Office of Science & Technology, July 2010. <https://www.parliament.uk/documents/post/postpn361-space-weather.pdf>

13 Air Power Development Centre, “Cosmic Radiation Effects on Air Operations”, *Te Matataua*, Issue 13, October 2017. Available online from: <http://www.airforce.mil.nz/downloads/pdf/apdc/tematataua-13-cosmiceffects.pdf>

SOLAR FLARES – BACKGROUND

A solar flare is a sudden eruption of electromagnetic radiation from the Sun’s surface. An image of a solar flare is shown in Figure 1. They are typically 10,000 to 100,000 km in size, with an onset time of 10–100 s.¹⁴ Solar flares can last for hours, with more powerful flares lasting longer, and are sometimes accompanied by explosions of large quantities of solar material out into space – the latter is called a coronal mass ejection (CME). The electromagnetic radiation released in flares has wavelengths that range from 10 kilometres (low to very low frequency radio waves) to 10 picometres (X-rays and/or gamma rays). It is not possible to have advance warning of the occurrence of a solar flare as the electromagnetic radiation travels at the speed of light.

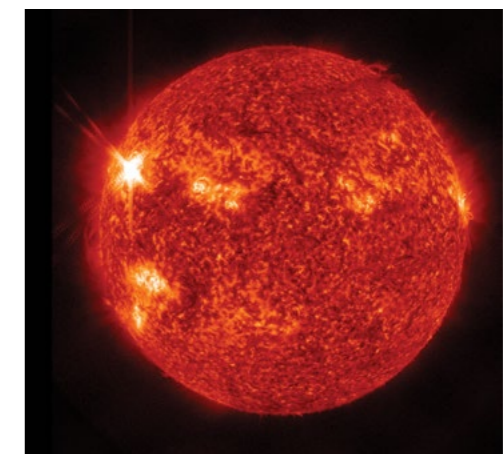


FIGURE 1. Solar Dynamics Observatory (SDO) image of an X1.9 class solar flare which occurred on 3 November 2011
Credit: NASA/SDO

14 John C. Brown, J. C., Dean F. Smith, and Daniel S. Spicer, “Solar flare observations and their interpretations”, in *The Sun as a Star* (NASA. Goddard Space Flight Center, 1981), 181-227.

At best, we rely upon forecasting of potential solar flares. Unfortunately, at this time our forecasting ability is not very good,¹⁵ with a high rate of false positives (i.e., forecasts of a likely flare when nothing occurs). One possible indication of solar flare occurrence is the presence of sunspots, which are darker “spots” on the solar surface. Sunspots are cooler regions of the solar surface,¹⁶ caused by intense bundles of magnetic fields which inhibit the flow of energy from the solar interior. The sunspot-producing magnetic fields can become “tangled”, causing an energy build-up that explodes as a solar flare.

During a solar flare, the amount of X-ray flux emissions from the Sun rapidly increases across several minutes. The X-ray flux intensity then steadily decreases over time. Small solar flares take several hours to return to pre-flare levels of X-ray flux intensity, but large solar flares can take days to return. The X-ray flux from solar flares affects the Earth’s atmosphere, but the increased radiation is completely absorbed before reaching the surface of the Earth¹⁷ – even for the largest possible flares. This means that terrestrial impacts of solar flares are due to the follow-on impacts upon the atmosphere, and in particular the charged part of our atmosphere, which we term the ionosphere.

Solar flares are induced by changes in the complexity or topology of the magnetic field in active regions of the Sun.¹⁸ The magnetic fields in active regions consist of magnetic field lines that extend from the subsurface regions of the Sun to form loops that extend into the Sun’s atmosphere, which is called the solar corona. When these magnetic fields are disrupted, the magnetic energy is released as energetic particles and electromagnetic radiation, forming a solar flare. The details of the origins of solar flares are not fully understood, and there is continuing research in this field. Until this mechanism is understood, a rigorous method of predicting solar flares cannot be developed and we are currently limited to statistical prediction; and the direct detection of solar flares that are occurring at that moment, which comes down to “now casting”.

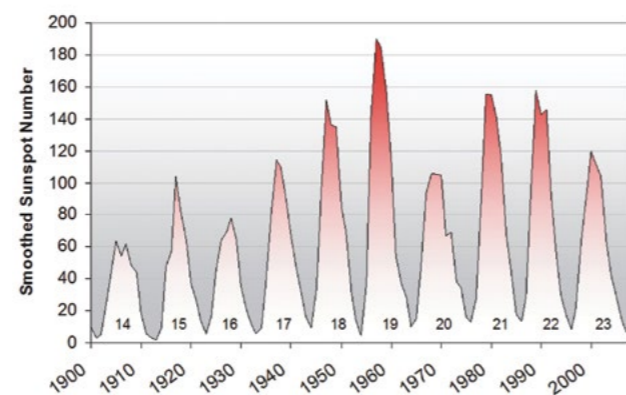


FIGURE 2: Quasi-periodic variation in sunspot number throughout the 11-year solar cycle. Solar flare and CME frequency correlates to sunspot number, with more solar activity occurring during periods of high sunspot number

¹⁸ Sophie A. Murray, S. A., D. Shaun Bloomfield, and Peter T. Gallagher. *The Evolution of Sunspot Magnetic Fields Associated with a Solar Flare* (Springer US, New York, NY, ISBN 978-1-4614-3761-1, doi: 10.1007/978-1-4614-3761-1_5, 2012), 45–57.

¹⁵ K. D. Leka and G. Barnes, “Solar Flare Forecasting: Present Methods and Challenges”, in *Extreme Events in Geospace Origins, Predictability, and Consequences* (Elsevier, doi.org/10.1016/B978-0-12-812700-1.00003-0, 2018), 65-98.

¹⁶ Sunspots can be much cooler than the rest of the solar surface – ~2500°C compared to the typical surface temperature of ~5500°C. As they are cooler, they are comparatively darker. However, note the use of “comparatively”; if the sunspot was isolated, it would be brighter than the full Moon!

¹⁷ Neil R. Thomson, Craig J. Rodger, and Mark A. Clilverd (2005), “Large Solar Flares and their Ionospheric D region Enhancements”, *J. Geophys. Res.*, 110, A06306, doi:10.1029/2005JA011008.

Astronomers tend to say the Sun is not unusual or special (except of course to humanity and as the main energy input into the Earth’s environment). As such it should not be a surprise that flares on other stars have also been observed. These are termed Flare stars, and have been observed since the 1920s. We believe space weather impacts on technology will occur throughout the Universe, affecting alien civilisations as well as ourselves!

Solar Cycle Dependence: The occurrence of solar flares follows the 11-year solar cycle, which is a near-periodic change in solar activity levels that encompasses changes in background radiation levels, sunspot number and solar flare frequency and number. Figure 2¹⁹ shows the change in sunspot number over a range of solar cycles. There are more solar flares at solar maximum than solar minimum; however, it is not clear that the largest solar flares occur during solar maximum.

Solar Flare Classification: Solar flares are classified based on the maximum X-ray flux intensity (I) for X-rays with wavelengths of 0.1–0.8 nm.²⁰ They are divided into five classes – A, B, C, M, and X – with each class being an order of magnitude greater than the preceding one. The five classes are then divided into nine subsections (i.e., X1, X2,... X9) that increase linearly. For example, an X4 flare is four times as large as X1, X1 flares are 10 times larger than M1, and 100 times as large as C1. The classes of solar flares and corresponding maximum X-ray flux are shown in Table 1.

Table 1: Solar flare classification based on maximum solar X-ray flux intensity.²⁰

Solar Flare Classification	Maximum Solar X-ray Flux (Wm^{-2})
X	$I \geq 10^{-4}$
M	$10^{-5} \leq I < 10^{-4}$
C	$10^{-6} \leq I < 10^{-5}$
B	$10^{-7} \leq I < 10^{-6}$
A	$10^{-8} \leq I < 10^{-7}$

The occurrence and magnitude of solar flares are monitored from the Geostationary Operational Environmental Satellites (GOES), which is a system of geostationary satellites that measures solar X-ray flux, among other things. Figure 3 shows the GOES measurements of X-ray flux variations from 6-9 September 2017, during an unusually active time with a number of very large solar flares. The original image was from the National Oceanic and Atmospheric Administration (NOAA) Space Weather Prediction Centre online archive. We have added text to this basic image, labelling all the solar flares in this time period with flux levels of M1 and greater. GOES satellites have monitored the X-ray fluxes at geostationary orbit since 1976, i.e., over 40 years. In that time the largest known solar flare occurred in November 2003, with a magnitude of X45.²¹

¹⁹ International Civil Aviation Organization, Space Weather Effects in Regard to International Air Navigation, Technical report, July 2010. Available online from: <https://www.icao.int/safety/meteorology/iawwopsg/Space%20Weather/Space%20Weather%20Effects%20in%20regard%20to%20International%20Air%20Navigation.doc>

²⁰ NOAA space weather scales, 2009. URL: <https://www.swpc.noaa.gov/noaa-scales-explanation>

²¹ Neil R. Thomson, Craig J. Rodger, and Richard L. Dowden (2004), “Ionosphere gives size of greatest solar flare”, *Geophys. Res. Lett.*, 31, L06803, doi:10.1029/2003GL019345.

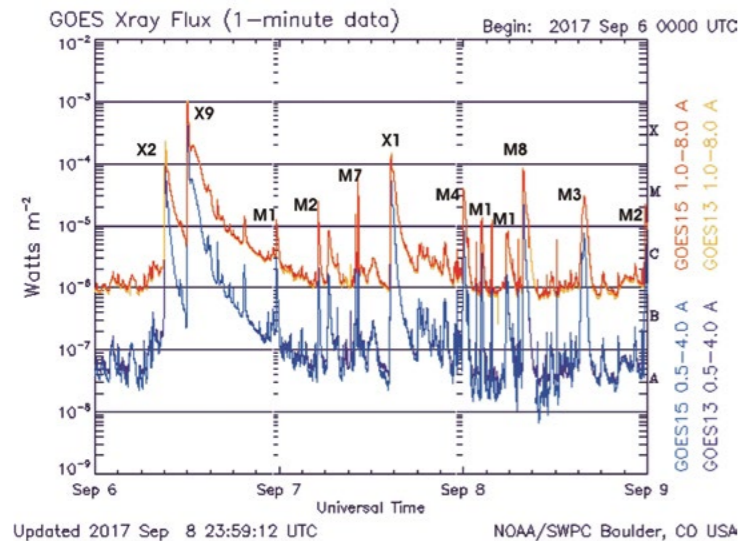


FIGURE 3: Three days of GOES satellite observations of X-ray fluxes, taken from early September 2017. We have added labels for all the solar flares occurring greater than M1. Image Credit: NOAA Space Weather Prediction Centre

The different intensity classes of solar flares have different impacts on Earth – more details around solar flare impacts can be found later in this article. However, for context, X-class flares are large enough to cause long-lasting, widespread high frequency (HF) radio blackouts, while M-class flares only cause short HF radio blackouts. C-class flares have few noticeable effects, while B-class and A-class flares do not affect Earth at all. A-class flares are so weak that they are close to the background flux emissions of the Sun. During solar maxima, when the background X-ray flux is higher than solar minima, A-class flares are essentially invisible. For aviation, advisory thresholds are now being put in place. The moderate warning threshold is for a X1 solar flare, and

severe at X10.²² Moderate conditions are expected to correspond to times when HF communication is “weak”, whereas severe corresponds to “radio blackout or scarcely perceptible HF communications”.

SOLAR FLARES AND THE IONOSPHERE

The Earth’s ionosphere is an ionised region of the upper atmosphere that lies within an altitude band of 60–1000 km above the Earth’s surface. The ionosphere is split into several different regions that are located at different altitudes and have different properties (such as electron number density).²³ Energy inputs into the ionosphere, such as solar radiation and galactic cosmic rays (GCR), maintain the different regions of the ionosphere.^{24,25} The regions of the ionosphere vary from day to night, as shown in Figure 4²⁶, due to the change in ionising factors.²⁷

²² International Civil Aviation Organization, *Manual on Space Weather Information in Support of International Air Navigation*, Doc 10100, 2018. The draft version of this is available from: <https://www.icao.int/airnavigation/METP/Panel%20Documents/Doc.10100.Space%20Weather%20Manual%20FINAL%20DRAFT%20Version.pdf>

²³ Kenneth Davies, *Ionospheric Radio* (Peter Peregrinus, London, 1990).

²⁴ P. M. Banks and G. Kockarts, *Aeronomy*, Part. B (Academic Press, 1973).

²⁵ R. J. Francey, “Electron production in the ionospheric D region by cosmic X-rays”, *Journal of Geophysical Research*, 75(25), doi: 10.1029/JA075i025p04849, 1970, 4849–4862.

²⁶ Information on the International Reference Ionosphere may be found here: <http://irionline.org/>. It can be run online from the NASA Community Coordinated Modeling Center at https://ccmc.gsfc.nasa.gov/modelweb/models/iri2016_vitmo.php

²⁷ Craig J. Rodger, C. F. Enell, E. Turunen, M. A. Clilverd, Neil R. Thomson, and P. T. Verronen, “Lightning-driven inner radiation belt energy deposition into the atmosphere: Implications for ionisation-levels and neutral chemistry”, *Annales Geophys.*, 25, 2007, 1745-1757.

The dayside of the ionosphere consists of (in order from closest to furthest from the Earth’s surface) the D, E, F1, and F2 regions, while the nightside consists of the E and F regions, along with a significantly less dense D-region.

The ionosphere plays a vital role in many radio-wave based communications, navigation, and surveillance systems. For the case of long range radio communication, or over the horizon backscatter radar surveillance, the electrical conductivity of the ionosphere causes the radio waves to reflect. This is useful for applications like medium and long range wavelength communications and radar. Obviously, not all systems rely on reflection from the ionosphere, with some systems making use of direct communication with satellites. This will typically involve high radio frequencies, which can penetrate the ionosphere without significant reflection. However, even during non-disturbed conditions the radio waves are still influenced by the ionosphere as the wave propagates through it. This will likely involve a bending in the path, a slowing of the propagation speed, and/or some level of amplitude decrease. All of these factors can contribute to degradation in system operation. Figure 5²⁸ shows a schematic of the ionosphere altering the propagation of radio waves.

When a solar flare occurs, the intense burst of solar X-ray flux causes a massive increase in ionospheric ionisation rates and hence to the electron number density. This effect is particularly pronounced in the lowest parts of the ionosphere, the D-region. X-rays with wavelengths shorter than 1 nm can penetrate to the D-region where they ionise neutral particles, such as oxygen (O₂) and nitrogen (N₂) molecules, which are the two major D-region constituents. It is fundamentally the changes to the electrical properties of the ionosphere that leads

to many of the impacts to technology systems. Figure 6 shows the output of a NOAA model which calculates the level of ionospheric absorption for HF radio waves caused by solar flares. This particular example is from 6 September 2017 at the time of the largest solar flare shown in Figure 3.

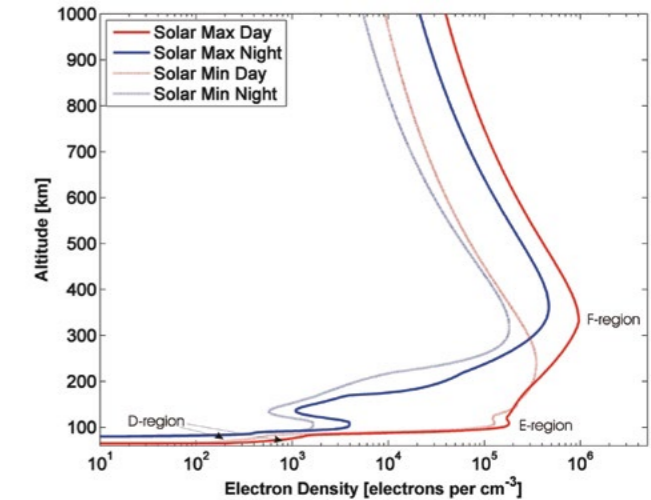


FIGURE 4: Vertical electron density profiles of the ionosphere at different points of the solar cycle with comparison between day and night values. The plot is based on output from the International Reference Ionosphere (2016) for a location in mid-South Island. The electron density at solar maximum is shown with a solid line, and electron density at solar minimum has a lighter line.

²⁸ Image adapted from the US Navy (originally shown at <https://www.nrl.navy.mil/ssd/branches/7630/bsi-weather-modeling>).

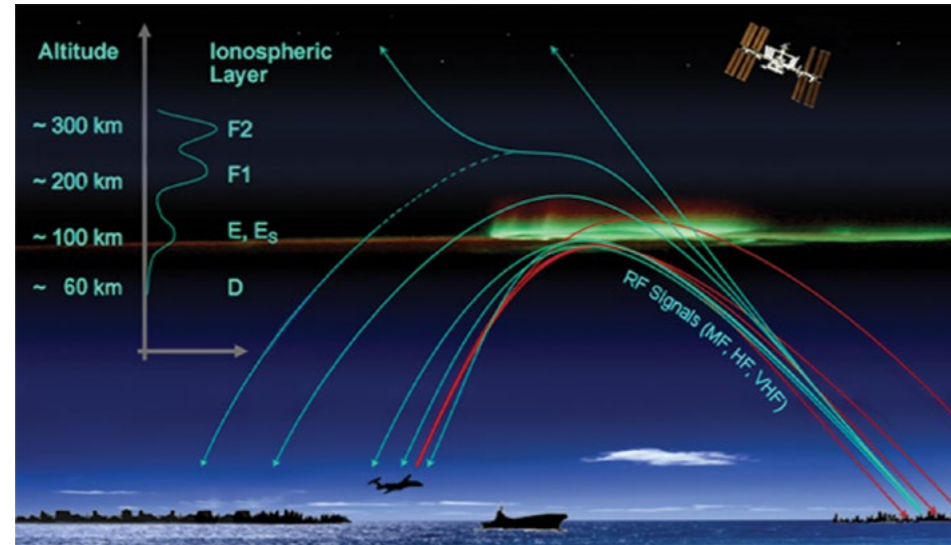


FIGURE 5: The influence of the ionosphere on radio waves.

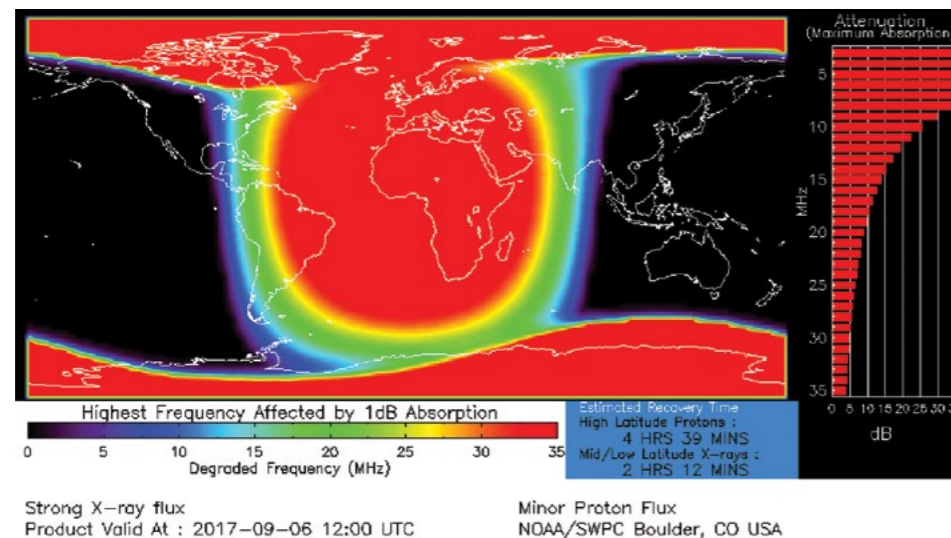


FIGURE 6: NOAA Space Weather Prediction Center calculation of ionospheric absorption on HF radio waves for 1200 UTC on 6 September 2017. This is during the X9 solar flare seen in Figure 3.

SOLAR RADIO NOISE BURSTS

When an eruptive solar event occurs, such as a solar flare, electrons in the solar corona are accelerated to much higher energies than their quiet time levels. The high energy electrons release broadband radio emissions as they accelerate, creating a solar radio burst (SRB)²⁹ These noise bursts are observed across what is essentially the entire radio spectrum, from a few kHz up to hundreds of GHz. The radio emissions during SRBs are approximately 2000 times greater than quiet time radio conditions.³⁰ However, while a noise burst affects a wide frequency range, the response is complex – different solar radio noise bursts can have amplitudes that differ by hundreds to thousands of times between similar frequency bands, with patterns that vary from event to event. This makes it hard to predict exactly what impact any specific noise event will have at a given frequency. At this time we lack a detailed understanding on the triggering and evolution of solar radio noise bursts.³¹ This means that, like solar flares, at this time we cannot predict when a SRB will occur but can only detect them once they have been released.

SOLAR FLARES AND THE IONOSPHERE – TECHNOLOGY IMPACTS

Solar flares have multiple ionospheric impacts that occur over a range of time frames and these ionospheric impacts affect communication and navigation systems in various ways. Electromagnetic radiation, which ranges from X-rays to ultraviolet rays, affects the ionosphere 8 minutes after a solar flare occurs.³² The eight minute time delay occurs because it takes ~8 minutes for electromagnetic radiation to travel from the Sun to the Earth. Solar flares are also associated with blasts of high energy particles, often termed Solar Energetic Particle (SEP) events. In these events there is a particular focus on Solar Proton events which have energy ranges of 1–1000 MeV. The highest energy component travels at nearly the speed of light, arriving at Earth just minutes after the X-rays, with the lower energy protons arriving within hours of the flare. In addition, slower moving ions and electrons are also emitted during solar flares, and these take 20–40 hours to travel from the Sun to Earth³³ in the form of a coronal mass ejection. The electromagnetic radiation causes the ionosphere to experience a rapid increase in ionisation, with different rates of ionisation occurring in different regions, which is called a sudden ionospheric disturbance (SID). It is these ionospheric disturbances that have significant impacts on radio communications and monitoring systems, which in turn have significant social and economic impacts as outlined below.

²⁹ Karl-Ludwig Klein, Carolina Salas Matamoros, and Pietro Zucca, “Solar radio bursts as a tool for space weather forecasting”, *Comptes Rendus Physique*, 19(1), 2018, 36-42, doi:10.1016/j.crhy.2018.01.005.

³⁰ Christophe Marqué et al, “Solar radio emission as a disturbance of aeronautical radionavigation”, *J. Space Weather Space Clim.*, 8, 2018, doi: 10.1051/swsc/2018029.

³¹ Mauro Messerotti et al, “Solar Weather Event Modelling and Prediction”, *Space Science Reviews*, 147(3), 2009, 121-185, doi:10.1007/s11214-009-9574-x.

³² As X-rays are electromagnetic waves, they travel at the speed of light. The Sun is 8 light minutes from Earth, such that it takes the solar flare X-rays 8 minutes to reach the Earth after the solar flare has occurred.

³³ A.P. Mitra, *Ionospheric Effects of Solar Flares* (Springer Netherlands, ISBN 9789027704672, doi: 10.1007/978-94-010-2231-6, 1974).

HF impacts and Aviation: High frequency radio communication is extremely important in aviation. It is commonly used on polar and oceanic routes, as HF radio signals can travel great distances with little information loss;³⁴ line-of-sight VHF communication is not feasible over these distances. Continuous communication with air traffic control (ATC) is a US Federal Aviation Administration (FAA) regulation. Companies that operate out of the USA, or rely on FAA-based regulation, must either ground or reroute planes that depend on HF communication when there is a potential disruption. Pre-flight decisions regarding grounding, delaying, and rerouting flights are made daily, so even short HF disruptions can affect an entire day's flight operations.

HF radio communications on the dayside of the Earth can experience fading, noise, or total blackout during solar flares, with strong correlation between the severity of the communication disruption and the power of the flare. Disruptions typically occur due to the attenuation (rather than reflection) of HF radio signals in the lower ionosphere due to increased ionisation.³⁵ They are also triggered by the decreased signal-to-noise ratio that occurs due to the associated solar radio noise burst. Some of the impacts of solar flares on aviation are shown in Figure 7.

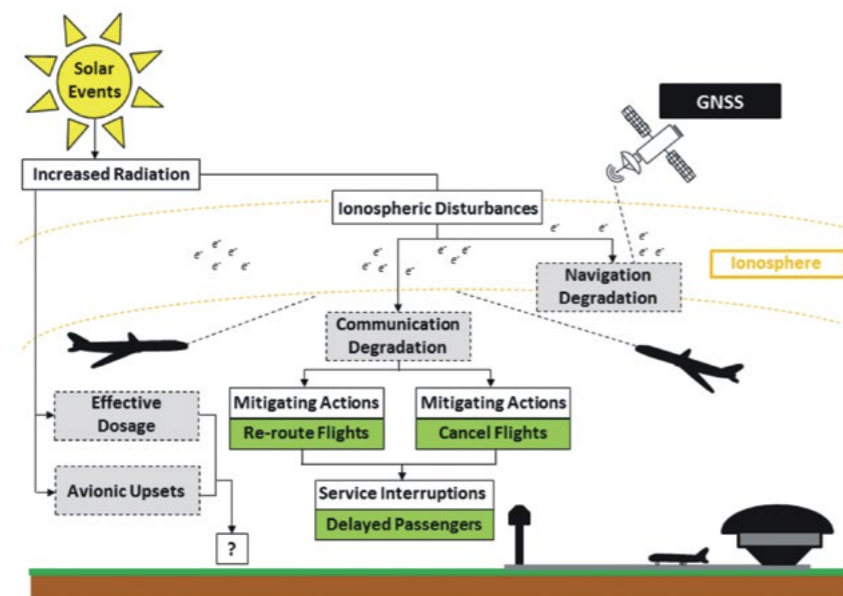


FIGURE 7: Illustration of selected effects of solar flares on aviation.

³⁴ International Civil Aviation Organization, *Space Weather Effects in Regard to International Air Navigation*, ICAO Technical report, July 2010. Available online from <https://www.icao.int/safety/meteorology/iawwopsg/Space%20Weather/Space%20Weather%20Effects%20in%20regard%20to%20International%20Air%20Navigation.doc>

³⁵ Abt Associates, *Social and Economic Impacts of Space Weather in the United States*, Technical report, NOAA National Weather Service, Bethesda, Maryland, September 2017.

The disruptions to HF communication due to electromagnetic radiation generally last for a few minutes to several hours, but typically occur with no advance warning. Charged particles emitted in solar flares (described above as Solar Energetic Particles) can cause longer-lasting disruptions to polar aviation communication – due to the shape of the Earth's magnetic field the Solar Energetic Particles can reach the atmosphere in the polar regions. These particles directly impact the D-region over longer time periods than the X-ray flare itself, increasing the ionisation rate around the poles and consequently disrupting HF communication.

The rerouting, delaying, or cancelling of flights due to potential HF communication disruptions has significant economic costs and social impacts for the passengers. These are undertaken as precautionary measures, as much more serious consequences (such as collisions or crashes) could occur if planes are not able to communicate with each other or with ATC. Rerouting flights to avoid HF communication disruptions requires the movement of flights out of the polar regions, and hence requires longer flying routes. This is expensive due to increased fuel requirements, reduced cargo load, landing fees, and increased employee workload. Flights over the northern hemisphere pole are increasing quickly – in 2015 there were over 15 thousand such flights.

A moderate solar event causes one day of HF radio disruption in the polar regions, which is likely to produce one day of flight rerouting outside of the poles. The importance of effects in the northern hemisphere polar region is relatively recent, starting after Russian airspace opened in 2001 and after long-haul aircraft with sufficient ranges were built. It has been estimated a moderate event would cost USA-based airlines \$0.4–\$5 million. This value is obtained from a cost of \$10,000–\$100,000 to reroute a single polar flight,

40–50 daily polar flights, and an estimate of 90% of polar flights being run by USA-based airlines. An extreme event, which causes HF radio disruptions for 1–3 days extending to lower latitudes (and thus including the continental USA), would require flight cancellations and cost \$1–\$30 million. This would affect 200–700 domestic USA flights, with an estimated cost to flight operators of \$5000 per cancelled flight. As these estimates are purely US focused, they neglect non-US carriers and domestic flights in other countries. Thus this analysis likely provides a reasonable lower limit to the cost of HF disruption from solar flares to aviation.

Solar Radio Bursts and Aviation Impacts: Solar Radio Bursts can impact a range of technologies. For example, SRBs in the very high frequency (VHF) to ultra high frequency (UHF) range affect Global Navigation Satellite Systems (GNSS) transmissions. GNSS broadcast low power signals from an Earth-orbiting satellite to a near Earth receiver – well known examples of GNSS systems are the US GPS and Russian GLONASS constellations. As GNSS signals pass through the ionosphere, they can be impacted by solar flare induced increase in electron number density, i.e., the thickening of the ionosphere. However, the radio noise bursts from solar flares can also directly overwhelm the low power GNSS radio signals. Taken together these factors can lead to decreased local accuracy, all the way to a complete loss in the Positioning, Navigation, and Timing data provided by GNSS.

Solar radio noise bursts can also negatively impact radar systems used in military and civilian applications for airspace surveillance. For example, one of the first published reports of radio emission coming from the Sun concerns the disruption of military radars during World War II.³⁶ However, while the impact of these noise bursts is an old phenomenon, it is still an occasional issue today.

³⁶ J. S. Hey, "Solar Radiations in the 4-6 Metre Radio Wave-Length Band", *Nature*, 157, 1946, 47–48.

For example, a solar radio burst which occurred on 4 November 2015 had significant impacts on air traffic control (ATC) systems in Europe, particularly in Sweden. This SRB has frequencies in the range of 1000 MHz, which encompasses frequencies commonly used for ATC communication. At local sunset on this date, the Secondary Surveillance Radars (SSR) that transmit plane identification, barometric altitude, and sometimes other technical parameters to ATC, experienced disruptions that were most likely caused by this SRB.³⁷ The timing is likely due to the angle of the Sun being in the radar beam, and thus directly “blasting” the radar systems with the solar radio burst.



FIGURE 8: European countries (shown in blue) which reported Air Traffic Control issues on 4 November 2015. It is now recognised these were caused by a series of solar radio bursts.

³⁷ Around this time there were suggestions that the Swedish disruptions might have been caused by “Russian hackers” rather than Space Weather. While a topical suggestion, the radio observations reported by Marqué et al. (2018)³⁰ demonstrate that was actually an example of “fake news”.

The SSR disruptions in Sweden meant that ATC could not receive accurate information from aircraft in the southern part of the country. The radio bursts caused interference-produced “false echoes” in the SSR systems, such that non-existent aircraft were reported in the direction of the Sun to ATC. Some stations became overloaded and experienced loss of aircraft tracks. While the false echoes were only observed within relatively short time windows (14:19–4:34 and 14:47–14:50 UT), they resulted in a de facto partial closure of Swedish airspace and delayed arrivals and departures. The Swedish Civil Aviation Administration (LFV) has reported that similar problems occurred earlier in 1999 and 2003.³⁸

The disruption caused by this event was not limited to Sweden (see Figure 8), although it was most severe there. Belgium also experienced SSR disruptions that took the form of false echoes. The issues in Belgium occurred at similar time as reported in Sweden, but were not as serious – Belgium’s air traffic systems were not as strongly impacted as the ATC control software successfully filtered out the false echoes. Norway’s ATC also experienced false or “ghost” echoes located in the direction of the Sun around the peak of the event at 14:30 UT, but these also did not lead to flight perturbations. Finally, a plane coming in to land at Thule Airbase in Greenland experienced technical issues due to conflicting information from the runway Instrument Landing System and the autopilot. Thankfully, the plane landed without complication.

³⁸ Press release from the Swedish Civil Aviation Administration entitled “Full capacity after 90 minutes radar loss”, available online from <https://www.lfv.se/en/news/news-2016/full-capacity-after-90-minutes-radar-loss>

No reports were noted in other countries (to the best of the author’s current knowledge). It is not entirely clear why – timing and solar angles would have likely favoured impacts in northern parts of Europe, but that does not explain why Finland, Denmark, the Netherlands, and the UK were not included. One possibility is differences in the technological hardware and software in use. It is also possible that the information has not been publicly released, to date.

HF impacts and Disaster Relief: Solar Flare disruption to HF communications is not solely a hazard to aviation. It can also impact systems vital to disaster relief and response. A recent example of the impact of solar flares on disaster relief occurred during September 2017. There was high solar activity in the period during which Hurricane Irma struck the Caribbean – in fact, as shown in Figure 9³⁹ there were 3 large hurricanes in that region at this time. Due to the severe weather conditions, HF radio communication was used to coordinate the disaster relief effort in this region.⁴⁰ A chance conjunction of severe terrestrial weather with strong solar activity involved multiple solar flares and several flare-launched CME impacting the Earth. This solar activity disrupted HF communication while disaster relief workers were attempting to provide critical recovery in the aftermath of Hurricane Irma.⁴¹ HF communication was essential for both disaster response and aviation tracking, so these HF disruptions were a hindrance to those vital efforts.

³⁹ <https://earthobservatory.nasa.gov/images/90918/three-hurricanes-in-the-atlantic>

⁴⁰ Michael Hapgood, “A Wake-up Call from the Sun”, *Eos Earth and Space Science News*, October 2017. URL <https://eos.org/editors-vox/a-wake-up-call-from-the-sun>.

⁴¹ R. J. Redmon et al, “September 2017’s Geoeffective Space Weather and Impacts to Caribbean Radio Communications during Hurricane Response”, *Space Weather*, 16, issue 9, September 2018, 1190–1201, doi:10.1029/2018SW001897.

Two very large solar flares (X2.2 and X9.3) were emitted on 6 September 2017, and a CME associated with an earlier solar flare (magnitude M5.5) also reached the Earth on this date. This resulted in a near-total HF radio communication blackout for up to eight hours. The communications blackout had significant negative impact on the coordination of the disaster relief effort. Just days later, another very large solar flare (X8.2) was emitted on 10 September 2017. This again caused severe disruptions to HF radio communication, lasting nearly three hours. The disruption of communication services during September 2017 due to increased solar activity exaggerated the consequences of Hurricane Irma by slowing the relief effort.



FIGURE 9: Hurricanes Katia, Irma and Jose lined up in the Atlantic on 6 September 2017 in an image captured by the Suomi NPP weather satellite. Credit: NASA

In addition to the disaster relief disruption due to the HF communications blackout on 6 September 2017, French Civil Aviation authorities lost contact with an aircraft operating near French Guyana. The communication breakdown lasted for approximately 90 minutes³⁸ triggering “alert phase” procedures used for missing aircraft⁴².



FIGURE 10: Canadian Navy Vessel HMCS Levis. She was torpedoed on 19 September 1941 20 miles east of Cape Farewell, Greenland. Eighteen crew were lost, but most of the ships complement were rescued by other vessels in convoy SC.44. Credit: Government of Canada.

From the September 2017 events in the Caribbean, it is clear that space weather services need faster access to real time data. It also highlights the value of direct communication between space weather forecasters and customers in order to minimise the terrestrial impacts of space weather.

EXTREME EXAMPLES OF IMPACTS FROM HISTORY

In our last two sections we used recent case studies to demonstrate how large solar flares can lead to significant technology impacts. Recently there has been a strong effort to understand how large, and significant, “extreme” space weather events can be. Much effort has gone into re-examining historical events to better understand the statistics, probabilities, and size of what has already struck us – this is equivalent to understanding the historic record of earthquakes to understand the potential future hazard. In this section, we will briefly discuss a few unusually large space weather events from the last ~80 years that have interesting aspects.

September 1941:⁴³ It is often stated that our susceptibility to space weather comes from our reliance on technology. This is accurate, but it is not necessarily a very “modern” phenomena. That fact is emphasised by the World War II space weather event of mid-September 1941. An unusually large group of sunspots were seen, which produced two solar flares. The flares triggered CME, producing several nights of strong aurora and also disrupting electrical power supply in the northern USA.

⁴² This procedure spans “uncertainty”, “alert”, and “distress”. See for example: <https://en.lvnl.nl/safety/procedures-in-unusual-situations/missing-aircraft-procedure>

⁴³ Jeffrey J. Love and Pierdavid Coisson, “The geomagnetic blitz of September 1941”, *Eos Earth and Space Science News*, 97, 2016, <https://doi.org/10.1029/2016EO0.59319>.

The combination of space weather events had multiple impacts. As expected, the solar flares produced disruption to radio communications, both civilian and military. In the US, which had not yet joined the conflict, radio-broadcast sports commentary of a Brooklyn Dodgers baseball match was interrupted for 15 minutes; causing much distress to the fans.

More important, however, was the implication for Canadian convoy SC.44. This Allied convoy was taking supplies to the UK across the Atlantic, escorted by a destroyer and multiple corvettes. The strong aurora caused the convoy to be clearly visible to U-boats from the Brandenburg wolf pack. One of their number (U-74) attacked, but was initially driven off; at close quarters the convoy escorts could also easily see the U-boat, as conditions were “as bright as day”. The U-boat withdrew, and fired torpedoes at long range, aiming by the light of the aurora. They gained a direct hit on HMCS Levis (Figure 10⁴⁴). Throughout the engagement the captain of U-74 attempted to communicate by radio with headquarters and the other members of the wolf pack; in his war diary he noted “short-wave reception has been very poor and it gradually cuts out altogether”. One imagines convoy losses could have been larger if more U-boats had been summoned.

The bright aurora played a role in multiple military missions. In a story entitled “*Nazi cities hit as northern lights illumine raiders’ goals*”, the Washington Post reported the Royal Air Force raid on a German supply base on the Baltic Sea, while the Chicago Tribune reported Luftwaffe bombing raids on Leningrad⁴⁵ over the title “*Northern lights add eerie glare to war in Arctic*”. Outside of the warzone, in the US most people were

⁴⁴ <https://www.canada.ca/en/navy/services/history/ships-histories/levis.html>

⁴⁵ Leningrad is the city now known as St. Petersburg, Russia.

more focused on the glory of the auroral show – causing a traffic jam of viewers in Chicago!

May 1967:⁴⁶ One of the most extreme space weather potential impacts to date occurred in late May 1967, during a period of high international tension. For most of the scientific community the importance of this event was not recognised until 2016 following the work of Prof. Delores Knipp, formally an officer of the US Air Force, now an academic at the University of Colorado, Boulder. Prof. Knipp is the Editor of the American Geophysical Union scientific journal *Space Weather*, and has recently undertaken a series of studies focused on what can be learnt from recent history.⁴⁷

May 1967 was a high stakes period in the Cold War. It fell during a time of heavy military activity within the so called demilitarized zone (DMZ) in Vietnam, and also in the lead up to the Middle East Six-Day War in early June 1967. During this tense period, the Sun delivered the strongest solar radio burst of the twentieth century, almost pushing us into nuclear war.

By late May 1967 the Sun was displaying some of the largest and most complex sunspot activity of that solar cycle (i.e., that 11-year period). Over a few days multiple sunspot groups were seen to merge. This would have led to more tangled magnetic fields in the sunspot groups – it certainly led to strong solar flare activity, with 76 significant solar flares occurring over two weeks.

⁴⁶ Delores J. Knipp, et al., “The May 1967 great storm and radio disruption event: Extreme space weather and extraordinary responses”, *Space Weather*, 14, issue 9, September 2016, 614–633, [doi:10.1002/2016SW001423](https://doi.org/10.1002/2016SW001423).

⁴⁷ As well as the August 1972 event described in the next section, Prof. Knipp also highlighted the lifelong solar observations of Ms. Hisako Koyama (D. Knipp, H. Liu, and H. Hayakawa, Ms. Hisako Koyama: “From amateur astronomer to long-term solar observer”, *Space Weather*, 15, 2017, 1215–1221, [doi:10.1002/2017SW001704](https://doi.org/10.1002/2017SW001704).

The primary impact came from a “great” white light solar flare which occurred at 1840 UT on 23 May 1967; approximately sunset for European time zones and near local noon in the central states of North America. In the Arctic there was near-24 hour sunlit conditions with the Sun at low elevations.



FIGURE 11: Example of a Ballistic Missile Early Warning System (BMEWS) radar station, part of a network to provide NORAD with early warning of incoming ICBM's. This station is BMEWS Site 2, near Anderson, Alaska, as seen in 1962

The 23 May 1967 solar flare is notable for producing the largest known solar radio noise burst of the twentieth century. This burst, combined with the ionospheric disturbances driven by the X-ray flares, solar particle events, and coronal mass ejections caused critical levels of disruption on important technology systems. In particular, military control and communication were immediately challenged. The high-latitude Ballistic Missile Early Warning System (BMEWS) radar sites (Figure 11⁴⁸), operating at 440 MHz, had been deployed in the early 1960's to provide ~15 min warnings of intercontinental ballistic missile attack against the U.S., Canada, and

the United Kingdom. It is clear the solar radio burst overwhelmed the BMEWS observations. At the same time radio links in central U.S. and Canada, both military and civilian, were subject to significant interference and signal loss.

Such an intense, never-before-observed solar radio burst was interpreted as jamming – and in the mindset of the day, full scale jamming of surveillance sensors was a potential act of war. It was also expected at the beginning of an attack. Very little information has been released to date around the seriousness of this event, and what actually happened in the US strategic command centres. However, there is some instructive context available. The May 1967 space weather event occurred not long after the start of a solar forecasting service, which began operating inside the North American Air Defense (NORAD) Command Cheyenne Mountain Complex⁴⁹ in late 1965. Open material credits the NORAD solar forecasters with providing the information that “calmed nerves and allowed aircraft engines to cool as they returned to normal alert stance”, and that the forecasters were able to provide the information to “convince high-level decision makers at NORAD that the Sun was a likely culprit in contaminating the BMEWS radar signals”. Knipp's article makes much of the importance on the decision to “hold the aircraft” rather than having the bombers take to the skies. She notes that a full-out NORAD aircraft launch would have been very provocative. She also points out that it would be difficult (if not impossible) to recall the bombers in the highly disrupted HF-UHF radio environment during the space weather event.

⁴⁹ Solar forecasting and interpretation was provided by USAF Air Weather Service Fourth Weather Wing Solar Forecast Center, or in acronym speak the USAF AWS 4WW solar forecasters.

⁴⁸ <http://www.loc.gov/pictures/item/ak0486.photos.193581p>

The May 1967 event has been used as an example of the importance of space weather and space environment information to decision makers, turning a “grave situation into a manageable one”.

August 1972:⁵⁰ We will only briefly mention the last case study, as its impact was not aviation-linked. This is another example of recent research into historic events undertaken by Prof. Knipp. Here a space weather event occurred during a sensitive time period in geopolitical relations. Near the end of the Vietnam War, the US government had deployed various military actions with the stated aim of bringing the government of North Vietnam to the negotiating table (and not invading southwards to seek total victory over South Vietnam, as eventually happened). One example of US efforts was the “Christmas Bombing” campaign⁵¹ in mid-late December 1972. A separate activity around the same time was Operation Pocket Money⁵², the deployment of naval mines from the air to blockade Hai Phong harbour starting from 9 May 1972.⁵³ Thousands of mines were deployed, initially near Hai Phong, but expanding over time to include inland waterways.⁵⁴ The Sun comes into

⁵⁰ Delores J. Knipp, D, Brian J. Fraser, M. A. Shea, and D. F. Smart, “On the Little-Known Consequences of the 4 August 1972 Ultra-Fast Coronal Mass Ejecta: Facts, Commentary, and Call to Action, *Space Weather*, 16, issue 11, November 2018, 1635–1643, <https://doi.org/10.1029/2018SW002024>

⁵¹ Also known as Operation Linebacker II. Almost 750 sorties by B-52 heavy bombers were launched against the capital Hanoi and the nearby port city of Hai Phong.

⁵² The operation began as an effort to block the import of provisions, in the hope of slowing the Nguyen Hue Offensive. Also known as the Easter Offensive, this was a fully supported infantry-amour invasion of the South. The blockade became a bargaining chip in the peace negotiations in Paris.

⁵³ At that time Hai Phong harbour was the primary cargo port for North Vietnam.

⁵⁴ <https://www.history.navy.mil/content/history/nhnc/research/library/online-reading-room/title-list-alphabetically/b/by-sea-air-land-marolda/chapter-4-winding-down-the-war-1968-1973.html>

this story in early August 1972.

Between 2 and 4 August 1972 the Sun emitted a series of brilliant solar flares, with associated strong solar energetic particles and coronal mass ejections. All of the space weather impacts associated with this activity were at the upper end of the scale. For example, the high energy protons from the Sun triggered instruments on the Vela satellites, which were monitored in real time as part of the nuclear test ban verification process. Solar power cells on Earth orbiting satellites were also degraded by the solar



FIGURE 12: US Marine Corp CH-53 Sea Stallion sweeps mines from Hon Bay, North Vietnam, on 18 March 1973. Note the junk under sail in the background.

energetic particles. For a long time it has been recognised that had an Apollo Moon mission occurred in this time there would have been an immediate and potentially fatal threat to astronaut safety.⁵⁵

For many years, August 1972 was an event that caused strong scientific interest until the research community moved on. However, just last year, new information was released into the public eye. The arrival of the coronal mass ejections launched from the Sun in early August 1972 triggered very strong magnetic changes at the Earth's surface. At 2054 UT on 4 August 1972 there were very rapid magnetic field changes reported globally. Aurora was seen as far south as Bilbao, Spain, and the magnetic field changes caused issues in North American electricity systems. However, the most dramatic effect known to date concerns the magnetic-influence sea mines deployed in Operation Pocket Money. A US Navy aircraft from Task Force-77 operating near North Vietnam reported "some two dozen explosions" in the naval minefield over a 30 s period. The US Navy rapidly concluded that the solar storm had caused the "premature detonation of over 4,000 magnetically sensitive DSTs (Destructor mines)". In effect, the Hai Phong mine field was actually swept by this space weather event!

This event spurred immediate and long-term actions – from scientists, engineers, and policy makers in the Space Weather field. For the US Navy, dealing with the event was of utmost priority, and the field needed to be reseeded rapidly, placing tremendous strain on US fleet minemen.⁵⁶ The new mine deployment occurred in secret, on the assumption their foes were unaware the

minefield was largely gone. In addition, the U.S. Navy fast-tracked replacement of the magnetic-influence-only mines with magneto/seismic mines.⁵⁰ After the Paris Peace Accord the naval mine fields around North Vietnam were removed between 6 February and 27 July 1973 – both traditional naval mine sweepers and helicopters were used⁵⁷ (Figure 12⁵⁸).

GLOBAL FORECASTING FOR CIVIL AVIATION

As noted in the introduction, the International Civil Aviation Organization (ICAO) requested that the World Meteorological Organisation assist them through the provision of space weather forecasting to support global aviation. ICAO has also released a draft *Manual of Space Weather Information in Support of Air Navigation*.²¹ In November 2018, the Council of ICAO selected three global space weather centres to provide these forecasts. The centres are to be provided by PECASUS consortium (Finland as Lead, plus Belgium, UK, Poland, Germany, Netherlands, Italy, Austria, and Cyprus), by the United States of America and by the ACFJ consortium (of Australia, Canada, France and Japan). In addition, the Council of ICAO indicated that two regional centres, comprising South Africa and a China/Russian Federation consortium, should be established no later than November 2022.

⁵⁷ February 6, 1973: Navy Task Force 78 Begins Operation End Sweep. Available from: <https://www.navalhistory.org/2013/02/07/february-6-1973-navy-task-force-78-begins-operation-end-sweep>

⁵⁸ <https://www.history.navy.mil/content/history/nhhc/our-collections/photography/numerical-list-of-images/nhhc-series/nh-series/USN-711000/USN-711571.html>

⁵⁵ Mike Lockwood and Mike Hapgood, "The Rough Guide to the Moon and Mars", *Astronomy & Geophysics*, 48, issue 6, December 2007, 6.11-6.17, doi:10.1111/j.1468-4004.2007.48611.x.

⁵⁶ <https://www.angelo.edu/content/files/21974-a>

CONCLUSION

Space Weather is a wide field – as our technology changes, so does our susceptibility to the impacts of space weather. Once aurora was only a marvellous display in the skies – nowadays it might be a sign that our communications and navigation systems will be degraded. The field is also a fairly young one – as such there are many knowledge gaps. Our ability to forecast and model are lower than we would like. It is also very difficult to predict how a given technology system will respond to the changing space weather environment – different design and internal algorithms will have different strengths and weaknesses. From a scientific viewpoint the field of space weather is some decades old. However, in the last 5–10 years it has appeared strongly on the "radars" of decision makers. One might say this is a challenging, if very interesting, intersection between science, engineering, and societal need.

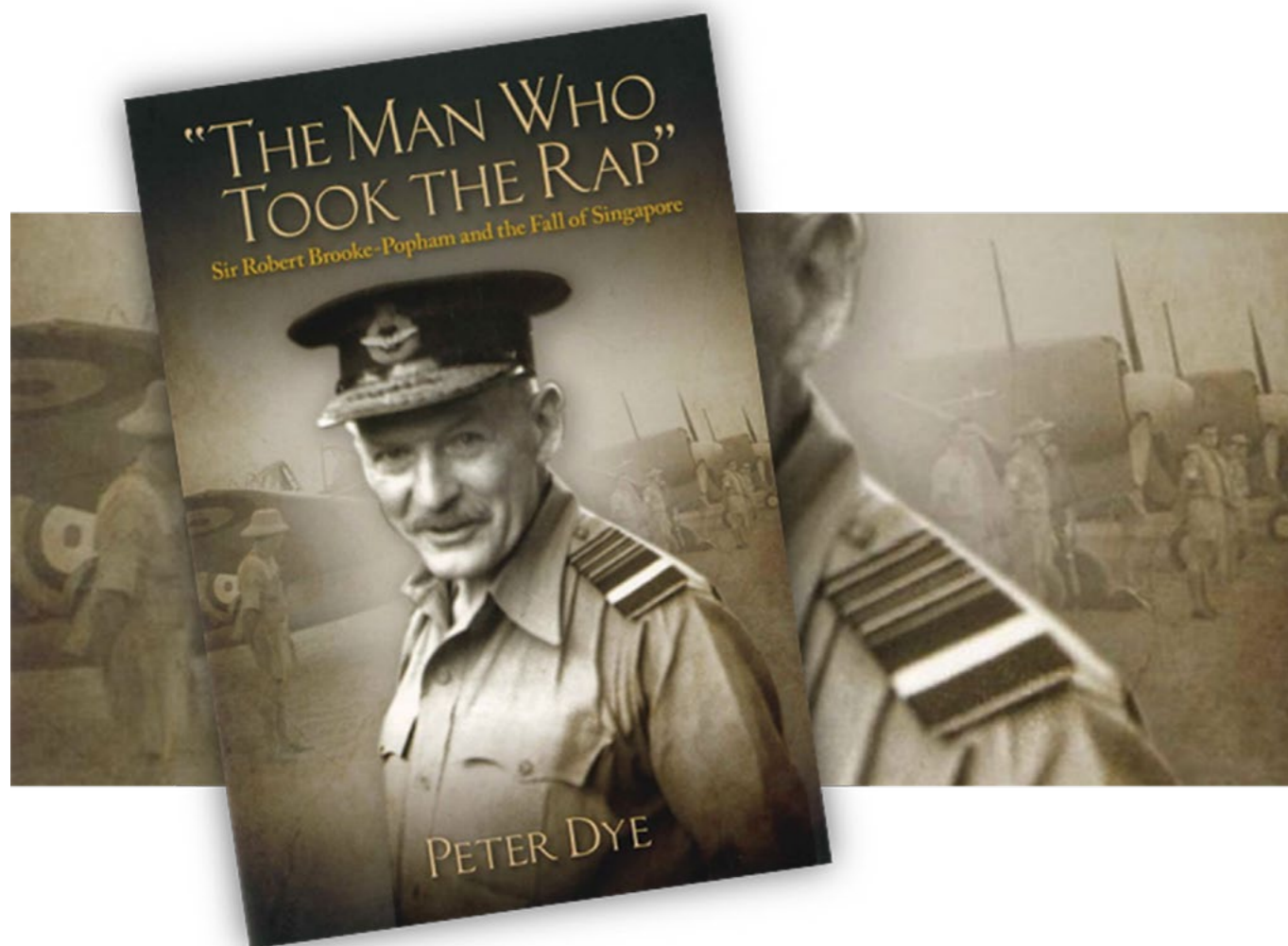
We have not heard the last from the Sun. By definition, extreme events do not happen often – but they will happen. Maybe tomorrow. And then we will see how today's technology and systems cope. The authors feel it is, however, important not to be negative. There is a growing body of knowledge and active work on mitigation processes. Just like for earthquakes, volcanoes, and tsunami, it is important to recognise the hazard and then plan ahead. And we can always look forward to the fact an extreme space weather event should give us wonderful aurora!



6 SQN personnel undertaking maintenance at Marine Corps Base Hawaii during RIMPAC 2018
NZDF Official

BOOK REVIEWS

The following section contains reviews of books relevant to air power.



By Peter Dye, Naval Institute Press, 2018 (ISBN 978-1-68247-358-0)

“THE MAN WHO TOOK THE RAP”:

Sir Robert Brooke-Popham and the Fall of Singapore

Reviewed by Mr Brian Bertosa

The fall of Singapore to the Japanese in February of 1942 has been described as the worst British military defeat since Yorktown in 1781.¹ Like any catastrophe of that magnitude, the loss of Britain’s largest naval base east of Suez, in many ways the keystone of its network of East Asian possessions, immediately prompted a search for an individual to blame. At the time, the target of choice was Air Chief Marshal Sir Robert Brooke-Popham, Commander-in-Chief Far East from November 1940 to December 1941. Recalled to the colours on the outbreak of war at the age of sixty-one, he was described as having “clearly passed his prime” by no less than the official historian of the war in the East, Sir Stanley Kirby.² A more recent writer on the Malayan campaign describes him as “elderly”, “old-fashioned”, and “unsure”.³ The decision to replace him with a younger man was made by Churchill about a month before the Japanese opened hostilities in the Pacific.

Because I find biographies of the so-called “flawed” individuals of history to be much more interesting than those of its superstars, I was thrilled to learn of the impending publication of the first book-length account of the life of Robert Brooke-Popham, and the

result does not disappoint. The author, RAF Air Vice-Marshal (retired) Peter Dye, has chosen to structure his narrative in a way that is very closely aligned with the book’s subtitle, inasmuch as what we have here almost constitutes two books: on the one hand, the all-new biography of Brooke-Popham, of great importance to RAF historiography in its own right; on the other, a highly detailed re-examination of the loss of Malaya and Singapore with an emphasis on the role played by Brooke-Popham, making use of the most up-to-date scholarship as well as previously unexamined Brooke-Popham family papers.

The first half of the book covers the period from Brooke-Popham’s birth in 1878 to the outbreak of World War II, and it must be borne in mind that by that time he had already retired as an air chief marshal and served two years as governor of Kenya. One doesn’t become an air chief marshal for nothing, and although passed over for appointment as Chief of the Air Staff, Brooke-Popham’s list of career achievements is nonetheless impressive. Commissioned into the Oxfordshire Light Infantry in 1898, Brooke-Popham took an early interest in aviation, earning Aviator’s Certificate No. 108 from the Royal Aero Club in 1911. After graduating from the Army Staff College, he was posted as a company commander to the Air Battalion, Royal Engineers, just a couple of months before its absorption into the newly formed Royal Flying Corps. Working closely with Hugh Trenchard through much of the First World War, he was retained as a group captain in the newly created Royal Air Force. With air rank came positions of progressively

¹ J. F. C. Fuller, *The Second World War, 1939-1945: A Strategic and Tactical History* (London: Eyre and Spottiswoode, 1948), 143

² S. Woodburn Kirby, *Singapore: The Chain of Disaster* (London: Cassell, 1971), 56

³ Ronald McCrum, *The Men Who Lost Singapore: 1938-1942* (Singapore: NUS Press, 2017), 70

greater responsibility, among the more important of which were first commandant of the RAF Staff College, Air Officer Commanding Iraq Command—during which time he briefly served as acting high commissioner—and Commander-in-Chief, Air Defence of Great Britain. Upon retirement, Brooke-Popham was serving as inspector general of the RAF.

A particular standout is the chapter covering Brooke-Popham’s tenure as governor of Kenya, written with the same care and attention to detail as the rest of the volume. While military affairs are discussed, particularly with respect to defending the colony against an Italian attack from the north, the bulk of the chapter deals with such non-military matters as colonial labour policy, soil erosion, and economic development, and, as the first examination of this topic of any serious length,⁴ is recommended to students and scholars of colonial Kenya.

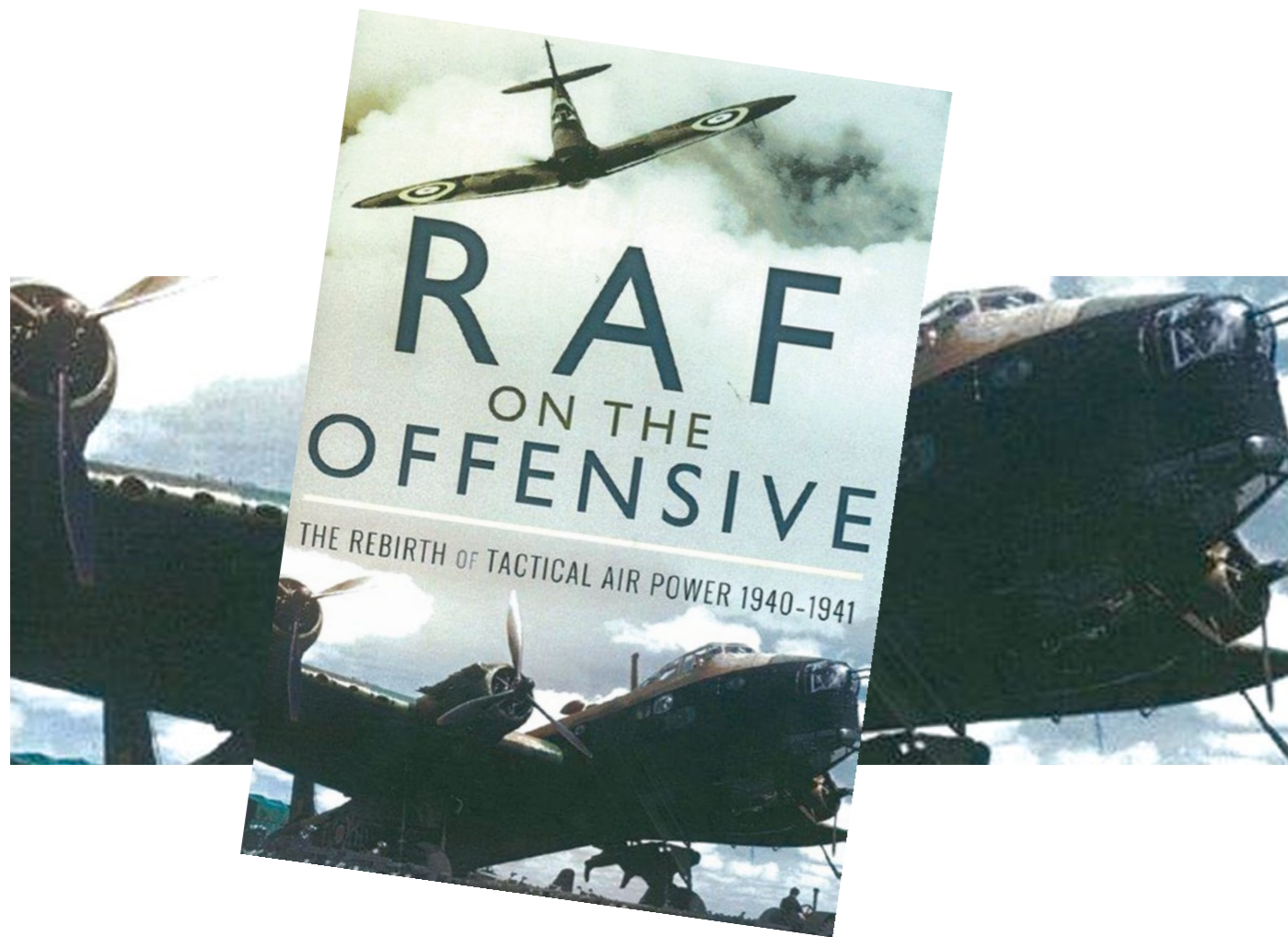
The period of the Second World War is covered from what is literally the midpoint of the main text, further illustrating the idea that there are almost two different books here. The first chapter in this section discusses Brooke-Popham’s important activities after getting back into uniform, including serving as senior RAF member of the British mission to Canada to set up the British Commonwealth Air Training Plan over the winter of 1939-40, followed by a similar mission to South Africa. The chapters up to this point have been arranged chronologically, but upon Brooke-Popham’s appointment as CinC Far East, the tack changes. Because Dye wishes to examine all aspects of Brooke-Popham’s tenure in command, the following nine chapters are arranged thematically, each tackling a different aspect

⁴ The entry on Brooke-Popham in Robert M. Maxon and Thomas P. Ofcansky, *Historical Dictionary of Kenya*, 3rd ed. (Lanham, MD: Rowman and Littlefield, 2014), 40-41 amounts to no more than a paragraph

of the multifaceted responsibility assigned to Brooke-Popham. Among other things, these include improving the defences of Malaya and Singapore, forging alliances with the Americans and the Dutch, providing support to the American Volunteer Group fighting the Chinese, and coordinating a propaganda campaign to deter the Japanese. Included also is an in-depth examination of the factors that led Brooke-Popham to refrain from ordering the launch of Operation Matador, intended to be a pre-emptive overland move into southern Thailand.

On a number of occasions in this part of the book, the author pauses to examine the question of Brooke-Popham’s fitness for command, and the resulting character sketches, of both his subject—almost five years older than the next oldest British commander in theatre—and his many detractors, are arguably the high points of a uniformly excellent volume. While no less a figure than Australian Major General Gordon Bennett, usually contemptuous of British commanders, had nothing but good to say about Brooke-Popham’s efforts, there were many others, just as close to him, who did not. These range from one of his bodyguards, who recalled a man that was “very confused” (p. 259), to the Resident Cabinet Minister at Singapore, Alfred Duff Cooper, who reported home that Brooke-Popham was “damned near gaga” (p. 231). While Dye’s affection for his subject is obvious—to the extent that he sometimes seems willing to defend Brooke-Popham from anything questionable at all—he recognizes that although “Brooke-Popham was neither gaga nor incompetent...it is difficult to disagree with the decision to replace him with a younger man” (p. 236).

The decades since the war have seen the emergence of a more nuanced narrative than the one casting all the blame on Brooke-Popham’s shoulders. It recognizes, among other things, the sheer excellence of the Japanese military at that time, suggesting that no single man, no matter how gifted, could possibly have made a difference to the outcome of the Malaya campaign given the resource constraints imposed on Far East Command by the mother country. The author and publisher, Naval Institute Press, are to be commended for producing what will surely stand as the work of record on this subject for the foreseeable future.



By Greg Baughen, Air World, 2018 (ISBN 9781526735157)

RAF ON THE OFFENSIVE: The Rebirth of Tactical Air Power 1940–1941 Reviewed by SQNLDR Kit Boyes

Greg Baughen is an English and Maths teacher turned historian. He is convinced the Royal Air Force's concentration on ineffectual strategic bombing left the army without adequate tactical support that cost them the Battle of France, and subsequently endangered the defence of the UK: "far from strengthening Britain's military position, the bomber policy had seriously weakened it...in reality it was placing the country in grave danger". That conviction has spread over several works, starting with a quixotic defence of the Fairey Battle. This volume represents the latest in a chronological series of four.

Strengths of Baughen's work are the holistic picture of aircraft production and logistics to support, reliance on original source material and the chronological sweep of the series, starting with the use of tactical air power in the closing stages of World War I, as both sides realised artillery couldn't keep pace with mobile warfare, but aircraft could, and taking us – so far – to the Western Desert realisation that fighter strafing was an effective and low casualty substitute to bombing.

In contrast to Overy's aim to determine what happened,¹ Baughen is confident about what happened, and seeks to persuade as much by repetition as reason. He does not refer often to secondary sources and seems not to directly engage with the historical orthodoxy disputes.

Baughen's central thesis is that the Air Staff concentrated on bombers instead of close air support for the army. It is a thesis simultaneously self-evident and flawed. The army did little to engage air. Strategic bombing was indeed ineffectual in the early stages of the war, and in the later stages it is doubtful attacks on civilians were militarily or morally justifiable. But that does not prove airpower should have primarily been used for close support of the army. Arguably World War II was for the Western Allies foremost an air-sea conflict. Even when provided with overwhelming tactical air support, as Coningham and Tedder achieved in the Western Desert, Italy and Normandy, Western allied ground forces made slow progress against smaller often second-rate German formations.

¹ Overy, Richard, *The Birth of the RAF*, 1918

From the dust jacket notes, Baughen plans to continue his series into the early Cold War. It will be interesting to see how he tackles the role of air power in the surrender of Italy and Japan, in reducing Germany's access to oil, to transport troops to meet the landing at Normandy, and indeed how he views post war strategic nuclear bombers and mutually assured destruction.

There are missed opportunities in Baughen's work. The RAF worked less well with the navy than with the army during this period, and it would have been interesting to see his views on this. Heavy bombers (as Baughen notes in his book accusing the French Air Force of the same failings), are poor at close support for the army. But it takes time to develop and introduce new designs, and by mid-war the allies were irreversibly committed to building heavy bombers. They could not be close support aircraft. But they could and eventually were used to hunt submarines. In *Why The Allies Won*, Overy estimates the Battle for the Atlantic gap was turned by 'a mere 37 aircraft'² – Consolidated Liberator bombers – which is rather less than two days at peak production from the Willow Run assembly line alone³.

It does us good to question preconceptions. Baughen's latest book is valuable in providing a tonic to reading only the account of air enthusiasts, but *RAF on the Offensive* is itself on the offensive against mainstream historiography, and should not be trusted alone as an account of events.

² Overy, Richard, *Why The Allies Won* Plimco 2nd Edtn 2006 at p37

³ Overy, p241



Two A109 helicopters at Dip Flat Camp after a night of snow
NZDF Official



By Mark Lardas, Osprey Publishing, 2018 (ISBN 9781472822444)

RABAU 1943–1944: Reducing Japan's Great Island Fortress Reviewed by SQNLDR Kit Boyes

Japan's largest base in the South West Pacific, Rabaul, held at a peak perhaps 200,000 Japanese. Reluctant to repeat the heavy casualties from their first island landings against far smaller forces, the Allies declined to directly face this force, instead first achieving air superiority then using air superiority to achieve naval superiority, after which on an island, the isolated land forces ceased to be relevant.

The Allies succeeded. The RNZAF was heavily involved.¹ After two years of isolation 140,000 starving Japanese soldiers remained to negotiate surrender to Australians on the World War I era destroyer HMS Vendetta in 1945. The size of the Japanese force trapped is comparable with Von Paulus' 250,000 in Stalingrad – and given the relative size of the Japanese and German armies, one of much greater importance to Japan.

The work outlines how air superiority was central to achieving this.

Lardas and Osprey are not attempting to write history to contest with Gamble.² The book has a magazine style which can be useful in explaining the technology and equipment of combatants. Some illustrations are very useful, however many photos suffer from poor selection and reproduction, especially in controlling contrast. Some diagrams look attractive but may not add greatly to analysis and look like plans of raids rather than what actually happened, even discounting Bob Spurdle's prejudiced account.³ The text on the other hand is not afraid to call out individual pilots for overclaiming.

New Zealand's contribution is frequently mentioned – rather more frequently than the two page index would have you believe. The cover illustration shows the collision between Flyer 1st class Masajiro Kawato and FLTLT John McFarland RNZAF. Both survived the collision but FLTLT McFarland was taken prisoner by the Japanese and subsequently died.

¹ J.M.S. Ross' Official History Royal New Zealand Air Force, Government Printer 1955 covers this especially in Chapter 14 p 199, Oliver Gillespie's Pacific, Government Press 1952 an army centric Official history mentions the campaign briefly, (on page 257), as part of the single chapter about the Navy and Air Force.

² Lardas does refer readers to Bruce Gamble's definitive trilogy on the conflict; Invasion Rabaul, Fortress Rabaul, and Target Rabaul.

³ The Blue Arena, Bob Spurdle, Crecy 1986 p 123-127. "These babies started their usual turn and bomb technique which scattered their eggs harmlessly in the sea", "It would never be countenanced in the RAF – these pilots are bloody cowards!"

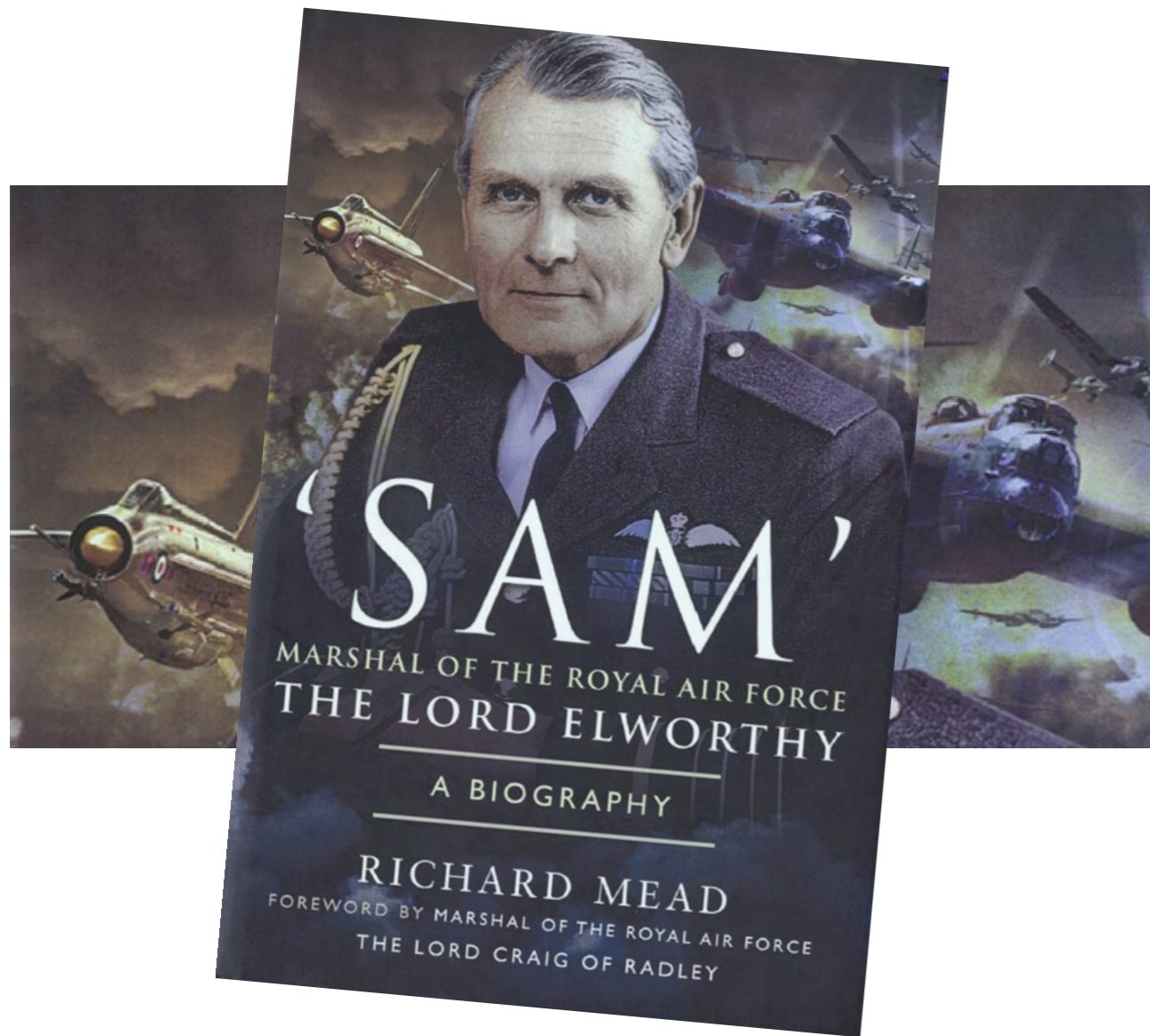
Coverage is avowedly from a western and aviation perspective. This can be a little misleading as naval action was important and even land forces had a peripheral role. Some analysis of Japanese forces is done well, but the local population are hardly mentioned.

There are some curios I was unaware of. The campaign saw the first use of 'attack drones'– the unmanned Interstate TDR-1 drone that broadcast radar altimeter and new-fangled television to a controlling Grumman Avenger a safe distance away from defences. Some 50 were used in action, all against Rabaul. The book includes a nice photo of Edna III, though what is not mentioned is that this drone flew the first successful test mission, (the sole surviving TDR in the US Navy's aviation museum is painted as Edna III).

Rabaul provides an interesting example of the impotence of island based land forces, no matter how large or highly trained once air and naval superiority is lost. It also provides a lesson that air and naval superiority has no fixed front line behind which is safety – small numbers of Japanese aircraft from Rabaul continued to make nuisance attacks on allied shipping until the end of the war. In summary a brief and colourful read, shedding welcome light on a poorly publicised campaign.



RNZAF Airmen preparing to set up a tented camp at Jacquinot Bay, New Britain during the Pacific War
Air Force Museum of New Zealand



By Richard Mead, Pen & Sword Books Ltd, 2018 (ISBN 978-1-52672-717-6)

'SAM' MARSHAL OF THE ROYAL AIR FORCE

The Lord Elworthy: A Biography
Reviewed by SQNLDR Kit Boyes

'Sam' started his military career as the oldest pilot officer in the RAF and ended Marshal of the Royal Air Force Sir Charles Baron Elworthy of Timaru KG, GCB, CBE, DSO, LVO, DFC, AFC, KStJ, in the Guinness Book of Records as the man with the most postnominal letters.

Born in Timaru, the son of a wealthy but distant father, who served as a cavalry officer in World War I. The Elworthy family followed him to London and young Sam flew in a Bristol Boxkite, and later saw a Zeppelin shot down. In New Zealand after the war he saved his own pocket money for a flight in an Avro 504. Elworthy returned to the United Kingdom at the end of the 1920s to study at Cambridge University, after which he was admitted to the bar and worked on the stock exchange. But part time flying with the Air Force reserve appealed more and in 1936 he accepted a permanent commission in the RAF.

Rapid expansion in the immediate pre-war years led to rapid promotion and biplane Hawker Harts gave way to monoplane Bristol Blenheims. From early on he worked with other services, even if frustrated by service politics, (there is a revealing anecdote of the navy manipulating a dive bombing exercise to ensure any aircraft that hit a warship was deemed to have been already shot down – this on the eve of a war in which sea power was determined by aircraft, submarines and cargo ships). From August 1940 to May 1941 Elworthy flew the vulnerable Blenheims with 82 Squadron, firstly as a flight commander and then CO.

His courage was recognised with a DFC and DSO. His talents in administration, management and leadership were recognised by a series of promotions in largely ground postings.

Although Elworthy did not give up flying after 82 Squadron – his 55th birthday was celebrated with a 1000mph flight in a Lightning – the rest of his career was in administration, management and leadership.

Elworthy had the good luck to work for some of the best known air leaders, including helping plan the first 1,000 bomber raids with air power purist 'Bomber' Harris. He also served as Bomber Command's liaison officer to Air Chief Marshal Tedder at Eisenhower's tactically-minded headquarters for Overlord. Post war, he considered leaving the air force for New Zealand, but decided to stay. He was in India at independence, and loaned to Pakistan to help start their air force.

When Iraq announced intent to annex Kuwait in 1961, Elworthy held the tri-service Middle East Command. His detailed planning, logistic preparations and carefully built relationships with other service commanders allowed him to use reach and speed of RAF and RN naval air power to concentrate air and army units in Kuwait, deterring Iraq and delaying a Gulf war until the 1990s.

As he rose to the top of his profession in the 1960s, Elworthy faced the cuts a shrinking economy and empire necessarily demanded with pragmatic realism.

As Chief of Air Staff he helped reduce the RAF by 25,000 to 124,000 and championed the 'island' policy of land based air power over more mobile but vulnerable - and much more expensive - aircraft carriers. Elworthy helped start TSR 2 development, yet he recognised when costs grew and numbers required dropped, it was impractical for the UK to sustain complex fast jet production runs of tens. He agreed with Denis Healy's decision to scrap the TSR 2, and also the transition of nuclear deterrence to submarine based missiles. He disagreed with the decision to scrap the F-111K, but did so privately. With the other service chiefs however he formed a united front against treasury persuading the Prime Minister to drop proposed pay cuts for ordinary ranks.

Many biographies recount leadership in the surplus resources made available for war. This account of leadership in a time of retrenchment may be of benefit to many in the modern world.

Although Elworthy's service was exclusively with the Royal Air Force, he always considered himself a New Zealander and returned 'home' with his family when he eventually retired. Elworthy is the only New Zealander to hold a Five Star command. Given the volumes on New Zealand and British military commanders of lesser achievement a biography of Elworthy fills a large hole, and we can be thankful accountant Richard Mead has turned to writing history in his retirement.

Well written and readable, Mead uses what appears to have been quite sparse personal material adroitly, although on occasion it could have been better footnoted. Twice I was left wondering what the source for a quoted conversation was. The answer was probably to be found in eight hours of videoed recollections made by a sister and nephew or his wife's Audrey's observant travel diary, and we can be thankful for the documentation left by his family.

In any work of this length there are a couple of questionable or incorrect statements. A more classically trained historian would probably have qualified the claim "the combined forces of NATO were invariably weaker than those of Warsaw Pact", while editorial fact checking might have caught the assertion Australia was the only SEATO member to fight in Vietnam.

These are minor quibbles. Sam is an important work well-executed. With such a life to cover 258 pages almost feels too short and I was sorry the book was over. Mead is working on a life of Sir Ralph Cochrane, an early mentor of Elworthy, and of course a crucial figure in New Zealand Air Force history, which is something to look forward to.



An RNZAF aircraft technician inspecting propeller blades for damage after a mission
NZDF Official

