



SURFING THE DIGITAL WAVE

Engineers, Logisticians and
the Future Automated Airbase

Peter Layton

© Commonwealth of Australia 2020

This work is copyright. Apart from any use as permitted under the Copyright Act 1968, no part may be reproduced by any process without prior written permission. Inquiries should be made to the publisher.

Disclaimer

The views expressed in this work are those of the author and do not necessarily reflect the official policy or position of the Department of Defence, the Royal Australian Air Force or the Government of Australia. The Commonwealth of Australia will not be legally responsible in contract, tort or otherwise, for any statements made in this document.



NATIONAL
LIBRARY
OF AUSTRALIA

A catalogue record for this book is available
from the National Library of Australia.

ISBN: 9781925062397
9781925062458 (online PDF)



Published and distributed by:

Air Power Development Centre
F3-G, Department of Defence
PO Box 7932
CANBERRA BC 2610
AUSTRALIA

Telephone: + 61 2 6128 7041
Facsimile: + 61 2 6128 7053
Email: airpower@defence.gov.au
Website: www.airforce.gov.au/airpower

FOREWORD

Since the dawn of aviation, airbases and air power have been indelibly linked. Airbases, however, have long been overshadowed by the greater fascination with flying machines and those who operate them.

As the digital transformations disrupting industry and society take hold on airbases, we must look past such platform-centric notions of air power. Artificial intelligence, machine learning, big data, the internet of things, robotics, 3D printing, human augmentation – and more – are set to find a place on future airbases, and the integration of such technologies demands a systematic approach.

Beyond the hype, the greatest impact of leading edge technologies may be on Air Force's people. The digital transformation of the airbase will fundamentally change extant Air Force understandings of the nature of 'work'. Among the first to feel this wave break will be engineers and logisticians, who, with long career development cycles, may need to embrace the digital transformation sooner rather than later. This paper argues they should start now.

Dr. Layton's work discusses the technologies involved in the approaching digital transformation, explores what an automated airbase might comprise, suggests possible future geostrategic contexts within which these advanced airbases might operate, highlights the new roles future engineers and logisticians might have on such airbases, and then outlines the broad skills these individuals may require. This paper continues the aim of *Beyond the Planned Air Force* to prompt thinking about the pressures that might prompt Air Force to change in the medium to long-term.

Airbases seem set to be digitally disrupted. Such disruption will significantly enhance the nation's ability to generate air power but in so doing will fundamentally change the work all of us – particularly

engineers and logisticians – do in supporting air power. The time is now to think afresh about our airbases and their people's future

Jarrold Pendlebury, PhD
Group Captain,
Director Air Power Development Centre
March 2020

ABOUT THE AUTHOR

Dr Peter Layton, PhD is a RAAF Reserve Group Captain and a Visiting Fellow at the Griffith Asia Institute, Griffith University. He has extensive aviation and defence experience and, for his work at the Pentagon on force structure matters, was awarded the US Secretary of Defense's Exceptional Public Service Medal. He has a doctorate from the University of New South Wales on grand strategy and has taught on the topic at the Eisenhower College, US National Defence University. For his academic work, he was awarded a Fellowship to the European University Institute, Fiesole, Italy. He is the author of the book *Grand Strategy* and several books on air power and emerging technology published by the Air Power Development Centre.

ACKNOWLEDGEMENTS

The author would like to thank Rob Crowe, Graeme Davies, Fred Bament, Phil Sixsmith and Desiree Watson for their thoughtful comments and advice in the writing of this paper.

CONTENTS

<i>Foreword</i>	<i>iii</i>
<i>About The Author</i>	<i>v</i>
<i>Acknowledgements</i>	<i>vi</i>
Introduction.....	1
1. Building Block Technologies	9
2. The Future Automated Airbase	27
3. The 2030+ World Inbound	45
4. Engineers and Logisticians: Future Roles, Future Skills.....	61
Conclusion	71

INTRODUCTION

There is a wave of digital transformation disrupting industries globally. Many companies are trialling self-driving electric vehicles, autonomous urban air taxis are being developed, artificial intelligence has become mainstream, ‘big data’ is in vogue and augmented reality games are now consumer items. Today’s digital transformation is now all pervasive and accelerating.

Defence forces in general, and air forces in particular, can no more hide from this digital transformation than any other industry. There has been considerable discussion about this digital revolution transforming how nations make war.¹ Less considered is how the digital revolution will change the business of defence forces generating military power on a day-by-day basis. In addressing such change within air forces, the airbase is central.

Air power has always required airbases. These are the tangible foundation of the application of military power from the air. Without them, aircraft could not be made ready for war, operate from or be sustained on combat operations. In a very real sense, airbases translate military potential into military force. They are, as the air historian Robert Higham wrote in a play on the word ‘basis’, the “bases of air strategy”².

-
- 1 There are numerous such sources referenced in Peter Layton, *Algorithmic Warfare: Applying Artificial Intelligence to Warfighting*, Canberra: Air Power Development Centre, 2018; and Peter Layton, *Prototype Warfare, Innovation and the Fourth Industrial Age*, Canberra: Air Power Development Centre, 2018.
 - 2 Robin Higham, *Bases of Air Strategy: Building Airfields for the RAF 1914-1945*, Shrewsbury: Airlife Publishing, 1998.

Air wars are fought from airbases. In this, airbases are fundamentally different to army barracks or naval ports from which brigades and warships sally forth to fight in some distant field or ocean. This status as a war fighting entity is being reinforced in an era where there are no rear areas and attacks can be made globally, by states or non-state actors, by kinetic means or by cyber. The warfighting function of airbases means they are not just suitable pieces of real estate but rather a complicated amalgam of people with diverse skill sets and highly specialized machines.

Since the dawn of military aviation early last century airbases have been subject to technological change. This latest disruption has two subtle differences to many earlier changes. Firstly, the transformation is not being wrought by a change in the aircraft type the base is supporting. Air Force's legacy fleets of F-35s, P-8s, C-17s, KC-30As, Tritons, future Sky Guardians and more will still be in service in the 2030s. Until their final withdrawal from service, these aircrafts' maintenance will be much as it is today. Instead, today's digital transformation is large-scale disruption at the airbase level that changes *how* work is done not so much *what* work is done.

Secondly, this is not a change wrought by one technology alone. Rather, it is the combination of numerous new technologies surfing in on a massive digital wave. These technologies are many and varied, and include artificial intelligence, big data, cloud computing, the internet of things, autonomous vehicles, robotics, 3D printing and human augmentation. Operating together, these technologies generate combinatorial effects, boosting the capability and impact of each technology far more than if they are used in isolation. Arguably this will create exponential change, where the rate of change rapidly

escalates as more and more new technologies join the mix.³ The next fifteen years look set to being a period of non-linear change on airbases.

For those working on today's airbases and for military people in general having such technologies present in the workplace might sound like science fiction and a matter for the distant future of several decades hence. Airbases, though, are not stand-alone entities existing separate to their parent societies. Even airbases may need to move with the times. Other Australian industries have already decided to.

Digital transformation is impacting Australia's major seaports, supermarket chains, mail distribution, construction industry and even deep into our homes.⁴ The path that such transformation can take is becoming evident in the Australian mining industry. A recent study sees the application of digital technology in this industry sector across this decade in three stages.

3 *Digital Transformation Initiative: Unlocking \$100 Trillion for Business and Society from Digital Transformation*, Cologny-Geneva: World Economic Forum in collaboration with Accenture, May 2018, p.6.

4 Susan Muldowney, *Behind the scenes at Australia's first fully automated international shipping container terminal*, Create: Engineering Australia, ember 2019, <<https://www.createdigital.org.au/behind-australias-first-fully-automated-international-shipping-container-terminal/>> ; Simon Johanson and Patrick Hatch, *Pick, pack and stack: the robot warehouse has arrived*, Sydney Morning Herald, 30 March 2019, <<https://www.smh.com.au/business/companies/pick-pack-and-stack-the-robot-warehouse-has-arrived-20190329-p518t4.html>> ; *The Rise of Robots in Real Estate*, Property Australia, 23 July 2019, <<https://info.propertycouncil.com.au/property-australia-blog/the-rise-of-robots-in-real-estate>> ; Ben Wilmot, *All sorted: robots to help deliver Australia Post mail*, The Australian, 24 October 2019, <<https://www.theaustralian.com.au/business/property/all-sorted-robots-to-help-deliver-australia-post-mail/news-story/d8f7c6caf5fa6711a91c2e8445cb05f1>>; Menachem Domb, *Smart Home Systems Based on Internet of Things*, 28 February 2019, <<https://www.intechopen.com/books/internet-of-things-iot-for-automated-and-smart-applications/smart-home-systems-based-on-internet-of-things>>

In today's mining industry many companies have embraced automation involving individual, mainly semi-autonomous vehicles developed as proprietary products by a handful of Original Equipment Manufacturers (OEM) and which are not interoperable.⁵ In the mines of 2025 there will be smart sensors, autonomous vehicles, limited self-learning systems and some equipment from different OEMs that can operate together. In 2030 and beyond, mines will feature autonomous machines working with other autonomous machines to complete tasks. Open source platforms will integrate readily with other similar platforms allowing machine-to-machine communications and real-time data exchange so they can self-learn and make decisions.⁶

Keeping up with the surrounding society is not necessarily a good argument for Air Force embracing digital disruption. However, it does raise the possibility that by 2030 airbases may be lonely outposts of 20th Century technology in a 21st Century world. The capabilities of the

-
- 5 An understanding of the present digital transformation of the Australian mining industry may be found in: Nick Toscano, *Rise of the machines: Why Australia's miners are racing for automation*, Sydney Morning Herald, 30 November 2019, <<https://www.smh.com.au/business/companies/rise-of-the-machines-wh...australia-s-miners-are-racing-for-automation-20191129-p53ffo.html>> ; Ry Crozier, *Rio Tinto to build new 'intelligent' mines*, IT News, 19 June 2018, <<https://www.itnews.com.au/news/rio-tinto-to-build-new-intelligent-mines-494651>>; Darren Gray, *No one behind the wheel: The new workforce driving Australia's mines*, Sydney Morning Herald, 27 April 2019, <<https://www.smh.com.au/business/companies/no-one-behind-the-wheel-the-new-workforce-driving-australia-s-mines-20190411-p51dd2.html>> ; Sarah Hiltion, *Mining giant BHP goes digital in race for survival*, Nikkei: Asian Review, 15 February 2019, <<https://asia.nikkei.com/Business/Company-in-focus/Mining-giant-BHP-goes-digital-in-race-for-survival>> ; Daniel Gleeson, *BHP's Jurgens presents big picture automation plan*, IM: International Mining, 27 June 2019, <<https://im-mining.com/2019/06/27/bhps-jurgens-presents-big-picture-automation-plan/>>
- 6 AlphaBeta, *Staying Ahead Of The Game*, Prepared for NERA and METS Ignited, April 2019, pp. 9-10, <https://www.alphabeta.com/wp-content/uploads/2019/11/191106-mets_automation_report_web.pdf>

digitally transformed Australian defence national support base may need to be dumbed down when entering Air Force airbase boundaries.⁷ If such incompatibilities arise, it suggests that the airbases will be unable to obtain the full benefits of the fourth industrial revolution. Technological stagnation may have a price.

In considering this, other Australian industry sectors have embraced digital transformation to improve productivity; the ‘doing more with less’ mantra. The application of advanced digital technologies to airbases would be similar in that the aim would be to generate greater airpower from fewer numbers of people. Australia in regional population terms is a small country living in a neighbourhood of giants, to borrow Coral Bell’s evocative expression.⁸ Air Force has similar constraints in always wanting—and often needing—to do more than its limited manning can allow. Automated airbases offer one way to move people away from dull, dirty, dangerous jobs into duties that can make better use of their imagination, creativity and innovation.

Importantly the aim of generating greater airpower from fewer numbers of people is not just one for peacetime airbases. Automation as a concept is equally applicable to Australia’s northern bare bases; much fewer people would be needed to activate them if the robots are already there, just waiting to be switched on. More distant airbases may need air transportable automation to go ‘live’ but technically this seems eminently doable. Creating forward deployed automated airbases appears practicable.

Moreover the converse is also likely to be true. Others will undoubtedly embrace airbase automation to enhance their generation of air power. Australia may also need to do so simply to remain competitive with potential adversaries.

7 I am indebted to Desiree Watson for this observation.

8 Coral Bell, *Living with giants: Finding Australia’s place in a more complex world*, Australian Strategic Policy Institute: Canberra, April 2005.

This paper initially discusses some of the more important new digital technologies that are likely to form some of the building blocks of tomorrow's airbases. This is then used in the second section to develop a picture of future airbase possibilities so an understanding of the nature, scope and magnitude of the potential shift can be gained. Both sections look to the third horizon.

The first horizon is today's way of doing business and which forms the foundation for the future, the second is the medium term that builds from today and represents achievable change while the third is longer term and envisions a new and different future.⁹ In looking beyond today's short-term issues, a vision of what could be can stimulate thinking about future possibilities and what would need to change to make them real. Imagined futures underpin innovation and modernisation; they exert a powerful pull on practical people.

Automating the airbase will impact all the 'practical people' working there. These individuals have a wide range of diverse skills; there are numerous employment categories and occupational groups needed to make an airbase function. However, to keep this paper within manageable bounds, two particular categories of 'practical people' have been selected for deeper consideration: engineers and logisticians. Considering the impact on these two categories of the digital transformation is useful in itself but also suggests how other categories and occupational groups may need to evolve.

There is more to an air force than its airbases. Nevertheless, it's at the tactical level of the airbase that the biggest changes to individual daily work demands and patterns will occur. It is at the airbase—where the rubber hits the ramp—that a good understanding of digital transformation can be gained, able to inform our thinking about

9 'Enduring Ideas: The three horizons of growth', *McKinsey Quarterly*, December 2009, <<https://www.mckinsey.com/business-functions/strategy-and-corporate-finance/our-insights/enduring-ideas-the-three-horizons-of-growth>>

its impact on all and, in particular, future engineer and logistician activities.

The future, however, is not static. There are even newer technologies on the horizon that may further impact airbases while the wider geostrategic context continually evolves. A single imagined future would be a fragile basis for devising a robust picture of what future engineers and logisticians could be doing on an automated airbase. Accordingly, the paper's third section develops four alternative futures that provide a coherent, connected and plausible range of possibilities that future engineers and logisticians are likely to operate within.

The paper's fourth section then combines the future airbase possibilities with the alternative futures to suggest specific new roles engineers and logisticians might be undertaking in operating the automated airbases of the 2030+ period. The new roles do not all need to be done in-house; however, some appear critical to retain. The section concludes with some thoughts on the skills engineers and logisticians may need in tomorrow's digitised world.

1.

BUILDING BLOCK TECHNOLOGIES

“Computers are useless. They can only give you answers.”

Pablo Picasso,
Interview with William Fifield, 1964

Any listing of emerging digital technologies will be by its nature inherently incomplete and quickly dated. Recent research by the World Economic Forum and Accenture discerned seven technologies of particular note to digital transformation, while disclaiming comprehensiveness.¹⁰ In comparison, the latest Gartner Hype Cycle highlights 29 emerging technologies that companies should be actively investigating.¹¹ Moreover, there are new technologies continually arising as new areas for research and exploitation open up.

The technology areas discussed in this chapter were chosen as being particularly pertinent to the airbase industry of generating aircraft sorties. These are artificial intelligence, big data, cloud computing, internet of things, autonomous operations and robotics, 3D printing and human augmentation. Unsurprisingly, these technologies also

¹⁰ Digital Transformation Initiative, *op.cit.*, p.7.

¹¹ Kasey Panetta, ‘5 Trends Appear on the Gartner Hype Cycle for Emerging Technologies’, *Gartner*, 29 August 2019, <<https://www.gartner.com/smarterwithgartner/5-trends-appear-on-the-gartner-hype-cycle-for-emerging-technologies-2019/>>

feature across the digital transformations underway and planned for many industries.

The technologies discussed may be considered a core onto which other and newer technologies are progressively grafted. The discussion here can only be a snap-shot in time. Technological change is ongoing and brought into consideration when devising the alternative futures in Chapter 3.

ARTIFICIAL INTELLIGENCE (AI)

The key to modern AI is machine learning. Instead of programming the computer with each individual step it must take to solve a problem, machine learning uses algorithms that make inferences from the data provided to teach itself. The computer's machine learning algorithms, rather than external human computer programmers, create the rules the AI uses. With different training data, the same learning algorithm can be used to generate new rules and instructions appropriate to new tasks. In general, the more data used to train the learning algorithm the better the rules and instructions devised.

There are two principal machine learning methods: supervised or unsupervised. In supervised learning the learning algorithms are given labelled data. For example, photos of transport aircraft labelled 'transport aircraft' are fed through the algorithm so it can devise the rules for classifying such pictures in the future. Supervised learning requires people to categorize and tag the data.

Unsupervised learning uses unlabelled data. In this method the machine learning algorithm identifies patterns for itself in the data it is fed. The catch is it is inherently difficult to know what data associations the learning algorithm is actually making. Unsupervised learning includes reinforcement learning and generative adversarial network

approaches. The current state-of-the-art is deep learning, where algorithms are stacked in layers to create an artificial “neural network”.

Neural networks can improve their performance over time as they continually train themselves on new data received while in operation. They learn ‘on the job’ and so are capable of emergent behaviour that may surprise – for good or bad. In contrast, traditional unsupervised machine learning continues to rely on the original dataset training undertaken.

On the job training has led some AI to start well but steadily become erratic as it continually retrains. Conversely, AI trained using a single fixed dataset gives more predictability but it is less able to manage environmental change.

AI can now address some specific problems more consistently than humans or programmable computers. In this, AI is probabilistic, providing confidence-weighted responses but not necessarily giving the same result every time. AI seems best at enhancing efficiency. It can quickly identify patterns and detect items hidden within very large unstructured data troves - important as 80% of the world’s data is unstructured - and seems well suited to help humans optimise engineering and logistics designs and operations. The main problem is that AI’s decision-making logic is quite opaque, especially so in AI using neural networks. It seems that the options are to have higher accuracy answers, or a clear understanding of how the computer determined them, but getting both together is not possible.

In broad terms, current generation AI is effective in four main areas¹²:

1. **Identifying.** This involves classifying what something is (e.g. diagnosing an issue given the symptoms, indications and warnings) and determining how items are connected (e.g.

12 This listing is derived from: MMC Ventures, *The AI Playbook: The step-by-step guide to taking advantage of AI in your business*, Barclays UK (BUK) Ventures: London, 2019, p.16, <<https://www.ai-playbook.com/>>

relationships between data). Examples include image and face recognition, change detection and the geo-location of images.

2. **Grouping.** This involves clustering, where provided data can be analysed to determine correlations and subsets e.g. evaluating which factors cause a specific problem. An example is pattern-of-life analysis.
3. **Generation.** This involves creating an image or text when given an input e.g. recognising speech and appropriately responding.
4. **Forecasting.** This involves predicting future changes given time series data e.g. predictive maintenance, determining when a machine will fail.

Humans have traditionally done these tasks, sometimes with computational assistance. Where AI adds value is doing these tasks more effectively and efficiently, at much higher speed, without capacity constraints and possibly without human involvement. The benefits AI brings can then be condensed to efficacy, velocity and scalability.¹³

Such attributes mean that AI-enabled systems can be given greater autonomy, allowing applications like autonomous land vehicles and swarming. The key issue in granting semi- or full autonomy is whether the decisions being made in undertaking the specified function can be based on data. AI analyses data using algorithms to make decisions. In broad terms, this means that, first, problems need to be of a type able to be measured so the appropriate data can be collected, and second, that these problems can be reducible to algorithms. Many problems can meet these two criteria.

There are circumstances though when humans may produce better results. AI machines can be quite brittle, being generally unable to

13 David Kelnar, *The State of AI 2019: Divergence*, Barclays UK (BUK) Ventures: London, 2019, p.135, <<https://www.mmventures.com/wp-content/uploads/2019/02/The-State-of-AI-2019-Divergence.pdf>>

handle minor context changes. Moreover, they have poor domain adaptability in that they can struggle to apply knowledge learned in one context to another. Humans are also considered better at inductive thought: being able to generalise from limited information. Humans generally make better judgments in environments of high uncertainty.¹⁴

BIG DATA

AI learns from data; the more the better. Older programmable technology machines can only use structured data that is carefully organised for inputting into relational databases e.g. spreadsheets. Such databases are easily and quickly searchable using simple algorithms. Structured data is purposefully formatted to fit the requirements of the computer systems being used. The Internet-of-Things involves widespread multiple-type sensor dispersion many of which produce structured data allowing ready machine-to-machine communication.

In contrast, unstructured data does not fit into the fields of row-column databases. Unstructured data files can include e-mail messages, documents, social media, videos, imagery, audio files, presentations and webpages. Such data may be generated by humans or by machines such as unmanned reconnaissance platforms and remote imagery devices.

AI for the first time can analyse both structured and unstructured data, giving it meaning in terms of relationships, patterns and associations. Without AI, most of the world's zettabyte data collection would be wasted. However, while large data troves are needed to train AI, the quality of the data being used is equally—maybe more—important.

¹⁴ Peter Layton, *Algorithmic Warfare, op.cit.*, p.72.

Poor quality data can mislead AI making its outputs dubious. AI needs data that is standardized, normalized, verified, enriched and has duplicated data deleted; much of this process falls under the umbrella term of data wrangling. In 2015, the US Department of Defence for the first time prioritised data quality over data quantity.

In this data storage has a role to play. There should be only a single data view even if the data is stored across multiple disparate systems. In achieving this, good data hygiene is crucial. The data should be clean, that is mostly error-free. In contrast, dirty data includes redundant data, erroneous data, incomplete data and outdated information. Google, Amazon and Facebook have invested significantly in data scrubbing to maintain good data hygiene for their AI systems.

Data diet concerns suggest being cautious about whether AI outputs can be trusted. Learning machines train on big data; the datasets they use can impact in several ways. First, if the dataset is too small then the AI may gain a skewed or incomplete understanding of the issue. Second, the algorithms being trained are not determining facts about the world but rather about the dataset. Third, feeding AI large datasets may not allow it to determine which of the many decisions that need to be undertaken to complete a complicated task are actually critical. Last, for a variety of reasons the datasets used to train AI can be biased making the outputs less trusted.

Organisations need to have sophisticated data strategies that address data availability, collection, hygiene and governance.

CLOUD COMPUTING

Today almost everything digital is connected to the cloud, storing and accessing data and programs from external sources rather than from the device's own hard drive. In the late 1990s, a cumulus cloud drawing was used to represent the internet and so 'cloud' became a metaphor for accessing services over the internet. The cloud can be public or private although in practice many clouds are hybrids. Clouds seemingly make device location irrelevant with, instead, connectivity the issue. Issues of data sovereignty and low latency-critical usages may run counter to this.

Proponents assert that cloud computing is more resilient, secure, scalable, agile, responsive and supportive of information sharing than own device hard drive storage or using hardware servers on small local area networks. The disadvantages include: first, the cloud may crash or become unavailable preventing access and sharply degrading an organisation's ability to function; second, privacy limitations given the cloud service provider can readily access cloud data; third, the cloud infrastructure is owned and determined by the service provider; and last, customisation options are inherently limited.

Many current cloud computing technologies are not optimized for AI and machine learning. For example, the data fed to intelligent machines from the cloud needs to be of the machine-required quality; good cloud data hygiene is essential. There are inherent challenges in cleaning, standardizing and normalizing data accessed in real-time from many different applications and sources including classified, private, public, domestic, international, human and machine. Military clouds represent particular challenges, as they must be accessible by others in harsh electronic countermeasure environments.

Edge computing addresses some of these issues—particularly latency, privacy, security and bandwidth—by placing some data processing power at a network's edge rather than retaining it in

a distant centralised cloud facility. In this way, computing can be done at or near the origin of the data, instead of relying on the cloud at the remote centralised facility. Edge devices often act as an entry or exit point into different networks i.e. into different clouds. The Internet of Things has significantly elevated the importance of edge devices.

INTERNET OF THINGS (IoT)

The IoT is a large-scale network of interconnected devices (things) exchanging information machine-to-machine, that is without human involvement. In the civilian domain, the things connected to the internet are expected to be around 50 billion in 2020. Many of these are simple devices like motion sensors, thermostats, lighting, meters and imaging devices; more complicated devices include smart TVs, speakers and appliances, wearables and industrial robots.

IoT networks allow remote monitoring and control but can generate vast amounts of data. For example, the Airbus A-350 airliner has some 6,000 sensors, generating 2.5 terabytes of data every day it operates. A way around this is to connect the IoT network to an edge device that can assess the data in real-time, forward the most important information into the cloud and delete the remainder, thereby saving on storage and bandwidth costs.¹⁵

Extending this, the data that is passed to the cloud can then be wrangled to become 'big data' that AI can learn from and discern relationships and patterns about. The AI can then determine a more

15 Duncan Stewart and Jeff Loucks, 'Bringing AI to the device: Edge AI chips come into their own', *Deloitte TMT Predictions 2020*, 9 December 2019, <<https://www2.deloitte.com/us/en/insights/industry/technology/technology-media-and-telecom-predictions/2020/ai-chips.html>>

optimal way to operate the sensors or other distant ‘things’ and send commands to the edge device gateway to pass to the specific ‘things’.

Such a process is found in logistics management where IoT sensors can exchange cargo-handling data in real-time from loading onto a transport vehicle, the cargo’s condition, en-route passage progress, transshipment details, delivery scheduling, cargo offloading and delivery. AI can further analyse this data to derive useful management information on quality compliance, routing option assessment, transport fleet usage and sizing, workforce performance and safety. The overall logistics system can then be optimised for the most efficient performance. This two-way interconnection of diverse digital devices like AI, big data cloud computing, edge devices and IoT is sometimes termed an IoT ecosystem.¹⁶

Implementing IoT connectivity on a large scale will require the emerging 5G communications network. Compared to older networks, 5G offers enhanced mobile broadband, massive machine-type communications, and ultra-reliable, low latency communications. 5G uses higher data transmission frequencies that provide massive capacity but due to atmospheric attenuation have very limited range. In airbase applications, 5G may be set up as an island, within which there is a very dense deployment of IoTs using it, and connected by fibre-optic cable to a national broadband internet service.

For such applications there are AI diet and security issues. The numerous dispersed simple IoT sensors represent potential false data input points given they often lack the computing power to host sophisticated cyber security software and that the risks of some

16 Alan Taliaferro, Ryan Ernst, Usman Ahmed, Anupama Harollikar, and Shiladitya Ray, *Creating IoT ecosystems in transportation: Logistics companies are looking to connect IoT technologies to traditional systems*, Deloitte Insights, 2019.

network protocols such as IPv6 are uncertain.¹⁷ Smart cybersecurity systems running on the edge devices that feed IoT sensor data into the cloud may need to include managed threat detection, anomaly detection and predictive analysis.

Cyber security concerns however, extend well beyond AI data matters. Considered conceptually, IoT has been described as:

“the greatest mass surveillance infrastructure ever conceived [able to pass collected data to] the original manufacturer, the information services we subscribe to, national security agencies, contractors, cloud computing services, and anyone else who has broken into, or been allowed into, the data stream”¹⁸

A recent US Defense Science Board study considered that addressing this required an AI driven autonomous system able to detect large-scale IoT intrusions by monitoring the bulk network traffic to find compromise indicators hidden within the torrent of normal traffic.¹⁹

17 David Holder, *Common misconceptions about IPv6 security*, Asia Pacific Network Information Centre (APNIC), 18 March 2019, <<https://blog.apnic.net/2019/03/18/common-misconceptions-about-ipv6-security/>> ; Preston Gralla, *IPv6 Is Finally Ready for Prime Time. Now What?*, Symantec, 29 May 2019, <<https://www.symantec.com/blogs/feature-stories/ipv6-finally-ready-prime-time-now-what>>

18 Julia Powles, ‘Internet of things: the greatest mass surveillance infrastructure ever?’, *The Guardian*, 16 July 2015, <<https://www.theguardian.com/technology/2015/jul/15/internet-of-things-mass-surveillance>>

19 *Report of the Defense Science Board Summer Study on Autonomy*, Office of the Under Secretary of Defense for Acquisition, Technology and Logistics, June 2016, pp. 87-91.

ROBOTICS AND AUTONOMOUS OPERATIONS

In recent years, there has been a step-up in robotic capabilities. Previously, automated machines could carry out solely the specific task they had been programmed for. Now varying levels of autonomy are being introduced. Many robots are fixed-place industrial machines or consumer appliances that undertake repetitive operations quickly, tirelessly and without endangering humans. New developments are focusing on making robots mobile.

Today most mobile robots use remote control (aka tele-operation). Many hundreds of such robots were used in Iraq 2004-2010 for reconnaissance and bomb disposal tasks with the Russians and others now making remotely controlled tanks. The original systems were tethered or line of sight but wireless networks now significantly extend this.

Israel has built an extensive semi-autonomous unmanned vehicle system to patrol along the country's borders. Since 2015, heavily modified Ford F-350 trucks have patrolled along specified roads or off-road paths continually relaying imagery from day/night sensors back to a remote control station over broadband data links. These Elbit Segev Unmanned Ground Combat Vehicles can navigate around most obstacles by themselves although the remote operator has the option to drive the vehicles through wireless.

Most autonomous vehicles are similar in following predefined paths through very well mapped areas. The numerous large dump trucks used in Australian mining sites effectively run on autopilot using precise navigation systems to remain exactly in the right position in space. These also have a short-range sensor able to detect objects suddenly appearing immediately in front of the vehicle and bring it to a safe stop. Autonomous trains are broadly similar.

A similar concept but in three dimensions is followed by Airbus's aircraft inspection drone. A small drone flies a predefined inspection

path around the aircraft, capturing images using an on-board camera. The high quality pictures obtained are compared against a digital model of the aircraft to determine any visual damage on the aircraft's surface and then presented to an operator for confirmation. A laser-based obstacle detection sensor on the drone ensures safety.²⁰

The considerable work underway on autonomous cars extends these earlier ideas although at the cost of considerable complexity. Cities will be mapped in three dimensions to a very high degree of fidelity. The cars will navigate using enhanced GPS technology across this digital map while coordinating their route with road traffic infrastructure like traffic lights and other autonomous vehicles. The cars will know where they are relative to fixed and mobile hazards with a high degree of accuracy and completeness. For safety the cars will also have some short-range sensors to detect pedestrians and stop if needs be. These cars are autonomous but not in the same manner as humans, who use 'on-board' sensors to find their way not highly detailed digital mapping.

The need for accurate location data makes the emerging national network of ground station infrastructure known as the National Positioning Infrastructure Capability (NPIC) important. This system will improve the accuracy, integrity and availability of satellite navigation across Australia and its maritime zones. While current commercial satellite navigation gives about 5-10m accuracy, the NPIC will improve this to within 3cms in areas with mobile phone coverage. Beyond mobile phone coverage, the satellite navigation signal is corrected to within 10cms using the associated Australian

20 *Airbus launches advanced indoor inspection drone to reduce aircraft inspection times and enhance report quality*, Airbus, 10 April 2018, <<https://www.airbus.com/newsroom/press-releases/en/2018/04/airbus-launches-advanced-indoor-inspection-drone-to-reduce-aircr.html>>

Satellite-Based Augmentation System.²¹ Amongst those benefiting include autonomous trains and ships.

3D PRINTING

3D printing, or additive manufacturing, is a technology that creates a three-dimensional shape by printing layer upon layer as guided by a digital drawing or model. In contrast, traditional subtractive manufacturing technology produces a desired shape by removing layer by layer from a piece of material. 3D technology means there is no longer a need for specific tooling for manufacturing items. Production batch sizes can be small or on-demand without significantly impacting production efficiency.

F-35 parts and drones are being produced using 3D printing while the US Naval Air Systems Command has already approved some 1000 printed parts for fleet use. In the future, units in the field, at sea or when deployed to distant bases could print their own spares, becoming semi-independent of the logistics supply chain. Maintenance spares resupply seemingly might become a connectivity issue reliant on receiving a part's digital design rather than a material transportation one.

While appealing, this vision would bring with it considerable complexity. In addition to connectivity would be the part's 3D design integrity, having available the quality and quantity of raw materials required by the design and type of 3D printer, an ability to test the part printed to confirm it meets design specifications and adequate

21 *Understand Positioning Australia*, Geoscience Australia: Symonston, <<https://www.ga.gov.au/scientific-topics/positioning-navigation/positioning-australia/understand-positioning-australia>>

uninterruptable power across what might be a long printing cycle. There could be cost/effectiveness trades to be made between having an on base 3D printing capability, maintaining stockholdings of the OEM made part and accepting the delays inherent in ordering new parts through the supply chain. This may mean having two different, separate logistics systems: the conventional approach that encompasses ordering and delivery, and the other using 3D printing making parts on base.²²

Beyond such issues, printing equipment and parts to order may be technically feasible but it also depends on whether the original equipment manufacturers will allow their intellectual property to be used in such a way. They may prefer customers to wait while the company prints the parts in a large distant factory under a more traditional business model.

Airbus has found 3D printing cost-effective for making parts for legacy aircraft either when needed in very small numbers or when the supplier has left the industry. There can be significant costs involved as the part may need to be redesigned to be manufactured using 3D printing and then certified. Airbus's preferred business model is a small number of large part suppliers having several different types of 3D printers, each able to print on demand pre-approved designs using various materials.²³

Support contracts would need reconceptualising to take full advantage of 3D printing possibilities.

22 I am indebted to Rob Crowe for raising this issue.

23 James Pozzi, 'Airbus Seeing Value of 3D Printed Parts', *MRO-Network*, 14 May 2019, <<https://www.mro-network.com/print/22181>>

HUMAN AUGMENTATION

Humans can wear a variety of digital technologies to enhance their capabilities. Technologies under active development and in service include Virtual Reality (VR), Augmented Reality (AR) and intelligent wearables.

As their acronyms suggest, VR and AR are related visualizing technologies. Whereas VR uses a closed headset that presents a completely digital environment, AR shows a user digital information overlaid on an image of the real, physical world. VR is often used for immersive design and demonstration, where a digital version of a physical structure or object allows a user to 'be there' and experience a design, building or object as if they were physical.

AR is commonly used in creating a hand's free workflow where a person sees digital information superimposed onto the work environment and does not need to walk away to retrieve advice or instructions. This digital information can be manual data or, more usefully, design drawings that are overlaid over the image of the part being examined. Some AR applications involve capturing the expertise of experienced workers that is then turned into a step-by-step video with voice instructions for others to copy via an AR interface. Software services company PTC claims that such AR training devices can lead to up to 50% faster technician training time. Moreover, the company asserts connecting workers to an AR platform will make them more flexible as they can be quickly shifted from task to task through on-the-job training using AR.²⁴

Today, conventional repair of complicated machines often has an artisanal quality characterized by tacit knowledge and a high level of

²⁴ Daphne Leprince-Ringuet, 'AR and VR are about to change the way you work, so get ready', *ZD Net*, 4 December 2019, <<https://www.zdnet.com/article/ar-and-vr-are-about-to-change-the-way-you-work-so-get-ready/>>

competence that employees developed through imitative learning on the job. Now the digital model of the item being produced is the real director of the repair process with its highly detailed instructions provided on call to all the maintenance and support staff through diverse digital media including tablets, VR and AR. This allows the linearity of the traditional maintenance process to be sidestepped. Staff can now work across the item being fixed with different skills and roles working together simultaneously all coordinated and connected through the item's digital model. This overall approach is compatible with the contemporary 'gig economy' business practices that hires staff as needed and dismisses them when the piecework is complete.

Intelligent wearables encompass three broad areas: cognitive augmentation, status monitoring and physical augmentation. Wearables may be worn in conjunction with VR and AR. Wearables can provide cognitive augmentation by capturing critical information in real time which combined with seamless communication can give individuals immediate, remote expert assistance, problem diagnosis and real-time guidance.

Wearables can monitor individual status using fitbit-like devices common in consumer society; data from these can be aggregated to provide a complete facility-wide picture and support AI optimisation, pattern detection and relationship construction. For example, Australian mining company field staff have smart baseball caps that monitor their brainwaves to measure and warn of approaching fatigue. Individuals and their supervisors are required to develop fatigue management plans while collective data is used to improve workflow design and tasking.²⁵

Wearables can also augment physical capabilities with considerable work underway in exoskeletons. Exoskeletons can be either passive, without actuators, motors, or batteries, or active which do. Passive

25 Digital Transformation Initiative, *op.cit.*, p.16

exoskeletons are lower cost and used mainly in the construction and manufacturing industries to reduce fatigue and thus increase work endurance.²⁶

In contrast, battery-powered active exoskeletons are designed to allow individuals to more easily lift heavy weights. The Sarco Guardian XO full-body exoskeleton for example amplifies operator strength by a 20:1 ratio, making a 45kg load feel like a 2.25kg one; battery life is eight hours. A demonstration at USAF's Mobility Guardian 2019 air transport exercise included one-person placing a simulated 55kg missile onto an aircraft wing store rack, moving 50kg pallets of ammunition boxes and lifting a 40kg tire onto a simulated truck axle.²⁷ Boeing has successfully trialed active exoskeletons to reduce fatigue on repetitive tasks, such as overhead drilling.²⁸

In the broader digital transformation all seven technologies interconnect continually exchanging data, information and intelligence either machine-to-human or machine-to-machine. It is this combination that makes the seven technologies transformational. Applying these to develop a picture of future airbase possibilities can help illustrate the nature, scope and magnitude of the potential transformation ahead. Crucially, this will directly inform our

26 An indication of passive exoskeleton capabilities available is given at this company website: <https://eksobionics.com/eksoworks/> See also: Jean Thilmany, 'Exoskeletons For Construction Workers Are Marching On-Site', *Constructible*, 27 February 2019, <<https://constructible.trimble.com/construction-industry/exoskeletons-for-construction-workers-are-marching-on-site>>

27 *Sarcos Robotics Begins Delivery of Guardian XO Exoskeletons*, RBR: Robotics Business Review, 10 December 2019, <<https://www.roboticsbusinessreview.com/news/sarcos-robotics-begins-delivery-of-guardian-xo-exoskeletons/>>

28 Eric M. Johnson, *Tim Hepher, Boeing goes bionic to roll out more Dreamliners*, Reuters, 2 Feb 2019, <<https://www.reuters.com/article/us-boeing-787-dreamliner/boeing-goes-bionic-to-roll-out-more-dreamliners-idUSKCN1PQ4X7>>

understanding of the tasks future engineers and logisticians will need to be doing.

2.

THE FUTURE AUTOMATED AIRBASE

“And he sees the vision splendid, the sunlight plains
extended...”

Banjo Patterson,
Clancy Of The Overflow, 1889

Individual technologies are interesting in themselves. However, gaining an understanding of the full overall effect they may have requires placing them together operating in context. To comprehend the roles engineers and logisticians might be undertaking around 2030+ this paper situates the context in a future airbase generating aircraft sorties. By that time, digital transformation may have changed today’s airbase business model very considerably. The possibilities and the uncertainties mean that this chapter, in aiming to communicate a narrative about the future, is somewhat speculative.

Such speculation is not uncommon. The possibilities that digital transformation might bring have been examined in multiple studies and reports across numerous industry sectors. In a recent analysis, the World Economic Forum and Accenture researched digital transformation across twelve diverse industrial sectors.

In looking across these twelve, the sector that appears closest to the airbase sortie generation industry is the mining industry. In this, the effect of new digital technologies on the mining industry is the progressive movement of mining companies towards each adopting

a business structure of a centralised command centre directing several remote robotic mining sites. The range of technologies in this digital transformation includes those discussed in the previous chapter: artificial intelligence, big data, cloud computing, internet of things, autonomous operations and robotics, 3D printing and human augmentation. For this paper, the mining industry has a further advantage as a potential real-world, easily-accessible model given that Australian mining companies are at the forefront of implementing this industry sector's digital transformation.

The digital transformation technologies may be similar in the mining industry but airbase operations are distinctly different in generating sorties, not extracting earth. However, few studies have been undertaken in the defence sector with seemingly even fewer on digitally transforming airbases. There are some exceptions, including USAF's Flightline Maintenance 2030 concept and the Republic of Singapore Air Force's (RSAF) Smart Airbases of the Future.²⁹ Selectively combining these with the mining industry's experience and concepts can help inform our speculations.

The overall principle guiding the development of an automated airbase is reducing the level of human involvement required to a minimum. There are cost/effectiveness issues implicit in this; however, it is a useful underpinning objective.

In terms of design, the future airbase will need to be developed to be compatible with legacy aircraft. This induced lag in capabilities is unavoidable. Beyond 2030+, when new aircraft enter service

29 An overview of the USAF concept is given at Slide 8 and its accompanying notes: MAJGEN Allan E. Day (USAF), *The Future of Air Force Logistics*, 2018, <[https://daytonwrightafcea.wildapricot.org/resources/Documents/1%20Maj%20Gen%20\(Sel\)%20Day.pptx](https://daytonwrightafcea.wildapricot.org/resources/Documents/1%20Maj%20Gen%20(Sel)%20Day.pptx)> ; An overview of the RSAF concept is at: *Fact Sheet: The Republic of Singapore Air Force's Smart Air base of the Future*, MINDEF Singapore, 2 March 2018, <https://www.mindef.gov.sg/web/portal/mindef/news-and-events/latest-releases/article-detail/2018/march/02mar18_fs4>

they may incorporate features that take greater advantage of what a digitized airbase may offer. Over the longer-term, the impact of digital transformation on military aviation is likely to be re-conceptualising the aircraft and the airbase as a single, tightly integrated entity, and designing each accordingly.

There are four principal areas expected to be central to the digitalisation of the mining industry over the next decade.³⁰ These areas are used below to structure the discussion about a future automated airbase. However, an important aspect not included within these four areas is that each airbase needs to be modelled digitally.

Such a “digital twin” would provide a very detailed representation of the airbase in terms of design and operation. It would provide insights into the inner workings and operation of the airbase, be used to simulate possible operating scenarios, and aid understanding of the impact of changes. In a conceptual sense, machines and people would operate within the digital twin, continually drawing on its sole-truth knowledge of the whole airbase. Moreover, this data exchange would be two-way with the digital model updated in real-time as machines and people moved.

30 Digital Transformation Initiative, *op.cit.*, p.4.

AUTOMATION, ROBOTICS AND OPERATIONAL HARDWARE

In the future airbase, digitally enabled equipment will perform activities that have traditionally been carried out manually or with human-controlled machinery. In today's mining industry these activities can now involve autonomous trucks and ancillary vehicles, continuous mining machinery, drones, autonomous trains, autonomous ship loading and smart sensor networks.

On an airbase all vehicles could be made autonomous given the airbase's digital twin mapping and the very high accuracy location data gained through NPIC. No vehicle needs to be self-aware, simply able to navigate around known obstacles to reach a nominated desired location and then perform its function. Each vehicle would also need an obstacle detector to ensure it stopped if an item or person suddenly appeared on its path.

Autonomous vehicles could include forklifts, aircraft tow motors, general maintenance vehicles, air operations vehicles and ancillary motored ground support equipment. Fuel trucks, cargo loaders and power units could also be autonomous, positioning themselves as appropriate and then connecting themselves to the aircraft. People could then inspect the setup up either at the flight line, or through some remote means, and authorize fuel delivery, cargo loading or power on respectively. Weapons could also be transported and loaded by autonomous systems.

The few people working on flightlines and parking aprons could each be assisted by a small personal autonomous vehicle, following them around carrying equipment and consumables. The US Army has recently chosen the General Dynamics Land Systems' Multi-Utility Tactical Transport (MUTT) for its squad-level unmanned ground

vehicle program.³¹ This small eight-wheeled electric vehicle will follow the squad around the battlefield carrying equipment and supplies, or be able to be sent off autonomously to a specified location. A smaller version of this could be every maintainer's or logistician's associate on the flight line.

In the wider community, with its much more challenging roadways, the accident rate with autonomous vehicles is expected to be less than currently with manned vehicles. On an airbase, the autonomous vehicle accident rate should be minimal.

Autonomous vehicles can also carry smart sensors and be remarkably small. Visual inspections of aircraft are time consuming, particularly of large aircraft. The Airbus drone discussed earlier can fly autonomously around an aircraft and undertake a close visual inspection. The Invert Robotics robot has been designed to be able to crawl over an aircraft's skin and use high definition cameras to find flaws; ultrasound and thermographic sensors will be added shortly. Rolls Royce is researching miniature, cockroach-inspired robots that can inspect inside engines and perhaps undertake repairs.³² Less adventurously the RSAF and Airbus Singapore envisage a fixed sensor

31 Jen Judson, 'Here's the robotic vehicle that will carry equipment for US troops', *Defense News*, 31 October 2019, <<https://www.defensenews.com/land/2019/10/31/heres-the-robotic-vehicle-that-will-carry-equipment-for-us-troops/>>

32 *The future of MRO: emerging technologies in aircraft maintenance*, Uniting Aviation, 1 August 2019, <<https://www.unitingaviation.com/strategic-objective/capacity-efficiency/the-future-of-mro-emerging-technologies-in-aircraft-maintenance/>>

field deployed inside a hardened aircraft shelter or at the entranceway to a hangar that aircraft could taxi through or be towed across.³³

In commercial aviation smart sensors have been fitted for more than a decade to aircraft engines to send information back to the airline's maintenance facility while the aircraft is in flight. The more than 6000 sensors on the A-350 airliner takes that to a new level with in-flight reporting across much of the aircraft's structure and systems albeit the concept remains the same: to generate big data for analysis.

The USAF Flightline Maintenance 2030 concept applies the smart sensor reporting to military aircraft that in-flight or on the ground would send data to the maintenance organisations information system. Today's transport aircraft and fighters already pass similar, if more limited, data post-flight. These aircraft are manually connected to download data retrieval devices; this overcomes some security issues but at the cost of creating some inefficiencies.

The C-130J aircraft has 600 IoT sensors fitted, producing 72,000 rows of data per flight hour. The data these produce is recorded, downloaded post-flight, transmitted to a global 'big data' repository in the US, wrangled to make useable, and finally analysed using AI machine learning to predict future equipment malfunctions and failures.³⁴ The F-35 will take this a step further with its forthcoming Operational Data Integrated Network (ODIN) that is based in the cloud and designed to quickly deliver data on aircraft and system performance under heightened cyber security provisions. The new

33 *Smart Airbases of the Future*, National Archives of Singapore, 2018, <<https://www.nas.gov.sg/archivesonline/data/pdfdoc/20180302001/Infographic%20RSAF%20Smart%20Airbase%20caa%2028%20Feb.pdf>> ; *"Hangar of the future" getting closer to enhance aircraft maintenance*, MRO Services, 2 February 2018, <<https://www.mroglobal-online.com/hangar-future-getting-closer-enhance-aircraft-maintenance/>>

34 *Lockheed Martin revolutionizes aircraft maintenance with the SAS Platform*, SAS, <https://www.sas.com/en_us/customers/lockheed-martin.html>

B-21 bomber may advance beyond this to have encrypted in-flight maintenance sensor reporting that provides near-real time information and perhaps in-flight repair, especially in terms of software updates and fixes.

The collection of vast amounts of data by smart sensors is intended to expedite maintenance when the aircraft lands but more crucially to allow predictive maintenance. Using AI machine learning the 'big data' troves can be analysed to predict when an item will fail, allowing maintenance immediately before that time. Unscheduled maintenance now becomes scheduled maintenance; both maintenance effectiveness and efficiency are maximised. The approach used for predictive maintenance of 1950s origin KC-135 air tankers is to use algorithms developed by USAF Materiel Command for analysing both recently implanted on-board sensor and historical data.³⁵

Smart sensors would not just be deployed on aircraft but as well across the base continually updating the digital twin so everybody could immediately understand the airbase's status, capabilities and capacities. AI machine learning would be able to use this 'big data' to optimize a base's activities in near-real time as well as to predict problems.

In the field of logistics the location, quality and quantity of all consumable and non-consumable stocks would be known in real-time including when resupply from off base was anticipated. This combined with predictive maintenance would allow efficient use of the base's multiple 3D printers to keep on-base stock levels of appropriate items at the desired level. Ideally the base would be self-sufficient in

35 Brig Gen Steven J. Bleymaier, *Condition Based Maintenance Plus (CBM+)*, July 2019, <<https://www.sae.org/events/dod/attend/program/presentations/Bleymaier.pdf>> ; Jared Serbu, *Air Force has high hopes AI can boost aircraft readiness, cut maintenance costs*, Federal News Network, 23 July 2019, <<https://federalnewsnetwork.com/dod-reporters-notebook-jared-serbu/2019/07/air-force-has-high-hopes-ai-can-boost-aircraft-readiness-cut-maintenance-costs/>>

necessary items to allow air operations for a nominated period, holding both enough 3D printer raw materials and adequate stockholdings of items that could not be 3D printed.

AUGMENTED WORKFORCE

The benefits of digital transformation can flow onto humans particularly in terms of connectivity. This is useful at airbases that tend to be characterised by large open areas with dispersed facilities and parking aprons. In the mining industry two distinct streams have emerged: intelligent wearables on the in-field production workers, and remote operations using staff distant to the mine controlling mine activities.

On a future airbase most staff on duty will be fitted with a suite of connectivity devices including switchable AR/VR glasses, hands free wireless communication, voice-activated machine control, fitbit-like devices monitoring health, location reporting and an in-built warning system to inform about approaching autonomous vehicles and other pop-up hazards. This suite will give each individual push-pull access to immediate, remote expert assistance, problem diagnosis tools, task instructions and, when desired, on-the-job training. Two-way human and machine interaction will mean everybody's location and status on the airbase will be known allowing AI to support task optimisation and quick response to developing situations. In a sense, humans will become an extension of the automated airbase's sensors.

Mining companies now run mines remotely from thousands of kilometres away. The autonomous systems at the mine site are monitored with smart sensors while the IoT and video feeds provide additional situational awareness. The remote operations staff authorise specific autonomous system activities when appropriate, problem solve, coordinate with company external agencies and advise

maintenance technicians near the mine if systems start degrading or failing. Overall mine productivity has been significantly improved, while the support needed for workers at a remote mining facility has sharply reduced as the number of staff needed there fall.

The remote operations concept could be applied to airbases on two levels: first, at the base level, where all base activities are controlled from a single on-base location or, second, at the operational level where a remote operations centre controls several distant airbases simultaneously. For a military force where hostile kinetic and cyber actions are expected, implementing both options would be preferred, including covert back-up facilities on the base and stand-by operations centres at distant dispersed locations.

An area of human augmentation that is not yet in service with the mining industry is the use of exoskeletons. While autonomous vehicles directed by humans could take over many manual tasks on airbases there may be times when humans lifting and moving loads will be necessary. Exoskeletons might be particularly useful in cargo staging areas, supply repositioning, aircraft external store placement and reducing staff fatigue in some maintenance tasks, including overhead work.³⁶

36 Captain Alan Morford, *Aerial Port Of The Future*, Headquarters Air Mobility Command, 2018, <https://res-3.cloudinary.com/eventpower/raw/upload/v1/18loa/presentation_files/ikwcppr1ihub2zhkmiv.pdf>

NEXT-GENERATION ANALYTICS AND DECISION SUPPORT

The role of AI, machine learning and big data will be pervasive across future airbases. Several examples of how they may be used have already been discussed. In the mining industry AI, machine learning and big data are used in intelligence analysis, in simulation to enhance decision-making and training, to predict problems through evaluating real-time and historical data, and to optimise the overall production chain from resource to market.

Airbases continually produce very large paper and electronic data troves, complemented by being able to access external sources across the nation and the world. This data comes from a variety of disparate sources and needs to be properly 'wrangled' before it is suitable to be analysed by the AI machine learning to pick out hard to discern items, derive relationships and build patterns of behaviour.

On an airbase data would initially be ingested into a data lake, a low-cost, large-capacity computing environment that stores and manages unstructured and semi-structured data. In the data lake the purpose of the data has not yet been determined, that is the data is 'raw', although is easy to access and update. Such raw data is used for AI machine learning. Data lakes require management by data scientists to ensure appropriate quality and governance measures are in place to avoid creating a data swamp.

The raw data when processed flows into data warehouses that hold and manage the high quality data, able to be easily and readily used by all staff when executing their tasks. Processed data is used in the charts, spreadsheets and tables that most employees at a company can read; it is thus rigid in its format requirements. Processed data only requires that the user be familiar with the topic represented to be understood; however, it is more complicated and costly to change than raw data. By storing only data used for a specific purpose within the

organisation, data warehouses save on storage costs by not retaining data that may never be used.

The need for sophisticated data management is readily apparent but as earlier discussed machine learning, whether supervised or unsupervised, is a complex task as well. Moreover, there are significant issues associated with areas like data labelling, reinforcement learning, generative adversarial networks, deep learning and neural networks. This means that to some extent distinctions made between AI and big data are more apparent than real. There are considerable overlaps given each is shaped by, and relies on, the other. In considering the generic skills required, there are perhaps six core AI/big data duties³⁷:

1. **Data Scientists.** Data scientists focus on gaining insights from data using scripts and mathematical techniques and are able to manipulate data across different programming languages to find solutions to defined problems. They typically possess an academic background, are able to implement new ideas emerging from basic research, generally produce reports rather than applications, and sometimes lack wider development and AI skills. Data scientists require a versatile skill set and include professionals from the disciplines of Computer Science (data mining, machine learning or computer programming), Mathematics, Operations Research (quantitative analytics, statistics or regression and correlation) and Information Theory.
2. **Data Engineer/AI Machine Learning Engineer.** These specialized engineers understand data and can code AI models that are derivatives of systems already created. They focus on engineering not research, and can devise code for applications and solutions to go live.

³⁷ This listing is derived from MMC Ventures, *The AI Playbook*, op.cit., p. 25.

3. **Deep Learning Researcher/AI Machine Learning Researcher.** As the title suggests, they focus on research, not building business applications. These specialist researchers are usually strongly academic, normally with post-doctoral experience, and look to push the boundaries of technical solutions. They will generally have only limited practical experience in translating their work into live applications.
4. **Head of Data.** Heads of Data have the necessary management and technical expertise to be able to lead and work hands-on with their team to produce reports and applications. Heads of Data understand the fine distinctions between varying data sets and have data strategy responsibilities. Their teams may include data analysts who collect and interpret data about specific topics of importance to the business, determine trends or patterns in complex data sets, develop ways to optimise the quality of statistical results and maintain databases.
5. **Head of Research/Head of AI.** This is a research-focused position with enough experience to lead a team and in some cases be able to assist the conversion of research team output into live applications.
6. **Chief Scientist/Chief Science Officer.** These positions have extensive experience in business as well as AI, they determine AI strategy and production pipelines, and work with a company's Chief Technology Officer to execute the firm's AI strategy. They generally report directly to the CEO and have experience as a board level strategist.

In developing a future airbase there may be considered four different functional roles where each of the six core duties noted have different levels of involvement. MMC Ventures in their 'The AI

Playbook’ develop a most useful table that concisely summarises this; it is repeated here:³⁸

Level of Involvement for Each Role Against Each Duty				
Duty	Roles			
	Research	Engineering	Production	Strategy
Data Scientist	Medium	Medium	Low	Low
Data Engineer	Low	High	High	Low
Machine Learning Researcher	High	Low	Low	Medium
Head of Data	Medium	Medium	Medium	Medium
Head of AI	High	Medium	Medium	Medium
Chief Scientist	High	High	Medium	High

‘Strategy’ in this table is in the business sense and mainly concerned with planning including identifying problems appropriate for AI to solve, clearly defining each problem, allocating resources, determining the approach to solve each problem and considering high-level workforce, security and maintenance issues. Strategy as used here then continually runs across the three other roles. In automating an airbase, the process would follow the research – engineering – production line.

Importantly in AI, big data and machine learning the four roles are never finished. The process incessantly repeats. Machine learning means that the system is self-evolving requiring continual testing and recertification. More mundanely, there’s always additional data being

38 This listing is derived from MMC Ventures, *The AI Playbook*, op.cit., p. 25.

gathered and new technologies emerging requiring incorporation and integration. Even at the airbase level, addressing next-generation analytics and decision support will demand a highly specialized workforce continually working across all four roles.

INTEGRATED ENTERPRISE, PLATFORMS AND ECOSYSTEMS

The autonomous vehicles, 3D printers, smart sensors, wearables, big data, AI machine learning and more all need to be interconnected to achieve the future airbase. This is a multidisciplinary activity that is social in the sense that it involves building complicated networks to be used by humans. The cloud forms the backbone into which all-else plug and exchange data. In this information and operational technology convergence, 5G, the fourth industrial revolution and cyber security feature.

Information Technology (IT) and Operational Technology (OT) are coming together via the IoT, which connects objects and machines to the cloud using embedded computing devices such as radio frequency identification chips. The virtual and the physical world are being merged and become able to be understood and controlled through digital devices. For the future airbase to work, everything whether virtual or physical will need such connection.

The IT/OT connection to the future airbase cloud will (at least) use 5G. USAF is moving to install 5G on several airbases partly to help build its envisaged “base of the future” where humans and machines seamlessly interact.³⁹ At the moment, attention is focusing on

39 Rachel S. Cohen, ‘Fast-Forward with 5G’, *Air Force Magazine*, July 2019, <<https://www.airforcemag.com/article/fast-forward-with-5g/>>

providing 5G not across the whole airbase, as this can be a large area, but rather in the particular maintenance and logistics locations that 5G usage will bring the greatest return. This is a '5G island' approach that will lower costs and risks but may impede some digital transformation options. Outer base security for example could be undertaken by integrating autonomous vehicles, AI machine learning, big data, IoT and sensor fields. This might be problematic if the 5G coverage forms too small an island.

The deep connectivity 5G brings also has implications for the future airbases functioning within the emerging fourth industrial revolution (4IR). 4IR envisages the airbase being deeply electronically connected with its industry suppliers and becoming the centre of the production process. Engineers and logisticians will be able to adjust order specifications not only before they place orders with their external suppliers but also during design, manufacturing, assembly, and testing. This means that they can be deeply involved in customising the desired hardware and software to be optimal for their needs and operating environment. Moreover, this flows through from the design to the in-service phase where engineers and logisticians can readily implement reliability improvements and carefully plan to achieve on-time logistics support.⁴⁰

On cyber security hinges whether the future digitally transformed airbase is a realistic option. In peace or war, cyber attack is a daily occurrence. Cyber security is sometimes conceptualised as a defended wall that keeps intruders at bay; however, to best operate, the future airbase will have numerous cyber entry points. Airbase cyber defenders may simply need to accept that attackers will almost always be within the virtual walls and instead use AI to hunt them down and prevent

40 For further information on the 4IR see: Peter Layton, *Prototype Warfare, Innovation and the Fourth Industrial Age*, Canberra: Air Power Development Centre, 2018.

them interfering. If the airbase cannot operate adequately in the presence of such attacks, it will be unable to perform its warfighting functions using its automated systems.

SOME IMPLICATIONS

A digitally transformed airbase may be able to generate more sorties faster and with considerably fewer people than now. Robot turns of serviceable aircraft, including refuelling and weapons loading, may be possible. Predictive maintenance may make unscheduled maintenance rare, or at least uncommon. Real time stock tracking will make logistics planning easier with 3D printing offering the beguiling possibility that the airbase might be able to resupply itself for some items. An airbase may become seemingly uninhabited, with its personnel mostly at some less visible control centre that manages engineering and logistics' tasks.

Such a concept changes the airbase from being a facility to being a machine, and a very complicated one at that. The base being integrated can almost be viewed as a single entity that comprises deeply interconnected hardware, software and humans. The flow on is that while fewer people will be needed to make the airbase generate sorties, there will be a need to have dedicated, well-trained airbase maintainers with new cutting edge skillsets including robot engineers, data scientists and system integrators. This is a major shift that will change what engineers and logisticians do at airbases.

In this is a buried issue about hardware and software. Hardware is now more reliable than previously and this will further improve with predictive maintenance but, nevertheless, it is becoming relatively less important in the operation of a machine or system. Software is now king. The digital airbase with its visions of autonomous machines, IoT and smart sensors is a little misleading in unintentionally drawing attention away from software maintenance.

Maintaining software is fundamentally different to maintaining hardware. A piece of hardware when repaired becomes like all others of its ilk; no more action is then needed. Repairing a software problem though is not the end of the issue, rather that software fix now needs replicating across the fleet. The emerging dominance of software creates another shift that impacts the duties engineers and logisticians undertake at airbases.

Another less obvious matter is electrification. The digital technologies discussed are all powered by electricity, with some such as data storage requiring significant amounts. Moreover, by 2030+ manned and unmanned air vehicles may be increasingly electric powered.

On 10 December 2019, the world's first all-electric commercial seaplane flew, a Harbour Air DHC-2 Beaver floatplane with an electric engine developed by Australian company MagniX. Electric aircraft advances may mean that by 2022, small nine-seater passenger aircraft are undertaking short-haul (500-1,000km) flights. Late in the decade, small-to-medium 150-seat planes could be flying up to 500 kilometres. Short-range (100-250 km) VTOL aircraft might become viable in the 2020s possibly replacing helicopters in certain roles.⁴¹

Airbases will ideally generate their own electricity to meet their requirements through a blend of renewables, batteries and gas-powered generators. The base will have its own grid managed by an AI power demand system which integrates power data from all sources and takes automated steps to increase generation, reduce

41 Jake Whitehead and Michael Kane, 'Get set for take-off in electric aircraft, the next transport disruption', *The Conversation*, 24 April 2019, <<https://theconversation.com/get-set-for-take-off-in-electric-aircraft-the-next-transport-disruption-114178>>

consumption, or redirect energy from other sources.⁴² This will be a major step forward in making airbases much more resilient in times of conflict when attacks on national power systems can be expected, most likely using cyber means. Moreover, airbases would also then be less impacted by natural disasters.

Whether in crisis or conflict, there will be occasions when it would be advantageous for an airbase to be able to seal itself off and become semi-independent and self-sufficient for a time. Digital transformation unexpectedly offers some hope of making this practical.

This chapter has focussed not just mainly on technological aspects but also generally taken a positive view. However, there are obstacles to change that, when combined with some emerging issues, cloud the digital transformation possibilities somewhat. The next chapter will bring these in to make the perspective more rounded.

⁴² Colin Cockcroft, *Powering the Electrified Battlespace*, QINETIQ Australia, 2019, pp 22-23, <<https://secure.teamdefence.info/filerequest.php?id=1007043>>

3.

THE 2030+ WORLD INBOUND

“We’ll all be rooned,” said Hanrahan,
“Before the year is out.”

Patrick Joseph Hartigan,
Said Hanrahan, 1921

Airbases are likely to be transformed by extensive digitalisation just like many other industry sectors have been and are being. However, the future is always uncertain; it remains dynamic. Our predictions may or may not eventuate. Good or bad circumstances might be encountered, sometimes simultaneously.

Around us, technology continues to progress and the wider geostrategic environment erratically evolves. The possibilities seem endless and this makes a single imagined future a flimsy basis for devising a robust picture of what future engineers and logisticians could be doing. A way around this predicament is through using an alternative futures approach that can provide a blurry but bounded image.

This chapter builds four alternative futures. The first section identifies two key drivers that will shape the future context within which digitally transformed airbases will operate. One driver relates to technological uncertainties and the other to geostrategic uncertainties. The second section then uses these drivers to build and describe the

four alternative futures. Within one of these imaginary worlds, or more likely some combination of them, tomorrow's airbase engineers and logisticians are likely to work.

DEFINING UNCERTAINTIES

Technological Drivers

Current and emerging digital technology is in many respects remarkable, particularly when compared against earlier technologies and their now-accepted shortcomings. These new technologies though have several deficiencies in some fundamental areas. By 2030+ these may be addressed, or they may not be.

Today's robots are optimised for a single function; multi-purpose would be much better. Moreover, today's robots to a considerable extent rely on knowing where they are, not on sensing the environment around them. Devising sensors that robots can use to correctly and reliably discern the world around them has proven hard.

The biggest issue though is that today's robots have trouble working with people. For machines to work with people they would need to be able to know what people are doing and how they – the robot – can help them. Conversely, humans would need to know what the robot is about to do next.

Humans working with humans – or even with dogs and horses – is a well understood activity but humans working easily and naturally with robots still needs considerable development. Even with the more advanced forms of AI, like neural networks, humans can't really understand their outputs or how they were obtained, and thus are not able to anticipate robot behaviour.

Today's robots are mainly used to reduce the time taken to complete a task. This usually involves a machine doing the part of the task it is

best at, like repetitive actions, and then a human finishing the task off. The machine and the humans then complete tasks sequentially, one after the other, rather than together in parallel. Dyno Nobel's head of mining and automation, Paul Terry observes that modern "automation is not so much about the reduction [in numbers] of people, it's about separating the interaction between people and the machines."⁴³

If people were able to work with machines as they work with other people, innovation could be expected to sharply accelerate. At least for a while, a brave new world of possibilities would open up as brand new ideas emerged and were tried out. Novelty would be the new normal and innovation rampant.

Conversely if people remain working using machines technological progress looks set to plateau. There will still be considerable innovations but these will be within – not beyond - the current technological paradigm. Application of current technology to new tasks will then be the model. Some see this as already beginning with forecasts of an emerging AI 'autumn' and possibly even a return to 'winter'.⁴⁴ AI has had two winters before when enthusiasm and funding declined: 1974–1980 and 1987–1993.

Today, people are using machines. They are not working with them. A key uncertainty for 2030+ is whether this will change. Within this broad driver there is a secondary issue: data openness.

Given the importance of data, it's possible that futures where data access is restricted will be futures where humans remain working using machines. Conversely futures characterized by open data might favour

43 Salomae Haselgrove, *Differential energy shapes the modern miner's role*, Australian Mining, 19 December 2019, <<https://www.australianmining.com.au/features/differential-energy-shapes-the-modern-miners-role/>>

44 Sam Shead, 'Researchers: Are we on the cusp of an 'AI winter'?', *BBC News*, 11 January 2020, <<https://www.bbc.com/news/technology-51064369>>

futures where humans work with machines. The working using/with machines driver might be a surrogate for closed/open data futures.

Extending this, in a closed data world the owners of large data troves are likely to be the state or large corporations. The implication is that digital innovation will be mainly by large entities. In contrast, in an open data world, extensive data sharing could be expected to drive digital innovation at all levels of a society. Small companies and even individuals could be deeply involved. The working using/with machines driver might also be a proxy for who dominates society: the state, large corporations or individuals.

GEOSTRATEGIC DRIVERS

Military technology is used within a geostrategic context. Today's international system seems to be moving away from the 1990-2010 years of deepening globalization towards a new era of nationalism. The stress on nation-state identity and sovereignty, the increasing protectionism, the shift away from the liberal rules-based order towards unilateral action, the increase in conflict and rancour, and the growth of covert action both kinetic and cyber all seemingly foretell of an emerging, hard-edged, self-interested nationalism.

Given such a new nationalism, the world could become multi-polar with several feuding blocs, or even fragment. Every state might then consider itself alone, privilege self-reliance and seek self-sufficiency through autarkic state policies. Conversely the world may change course, returning to a desire to deepen globalization and seek profit from cooperating. The tangible economic gains from globalization may become more enticing than the perceived security gains from nationalism.

A key uncertainty for 2030+ is whether globalization or autarkic state policies will prevail. Within this broad driver there is a secondary

matter: the level at which collaboration occurs. In a globalizing world, states, companies, non-government organisations and individuals collaborate internationally. Conversely in an autarkic world, these varying levels of a society will be focused mainly on collaborating at the national level, within their country.

The implication is that the type and rate of digital technology innovation might vary not just with whether data is closed or open, but also at what level collaboration can occur. Innovation is affected by critical mass in terms of the process and mechanics of moving new ideas into in-service products. International collaboration with its large critical mass across almost all technology areas is likely to drive rapid innovation across a very broad field. In contrast, domestic collaboration will be most innovative in narrow, niche areas where critical mass can be purposefully constructed; it could also be relatively slow.

It's worth noting that domestic-only collaboration may also be forced upon states. Today's cyber world is in turmoil with a real possibility the Internet may fragment into several so-called splinternets where only like-minded states have deep interconnectivity. The introduction of 5G may accelerate such fragmentation.

China's Huawei 5G technologies given their cost and quality may become the standard across much of South East Asia, Central Asia, the sub-continent, Africa, South America and the Middle East. The Western competition, Nokia and Ericsson, may sell only into wealthy developed nations.⁴⁵ Given security concerns over Huawei and the possibility of technological divergence, global interconnectivity will suffer over time. Such fragmentation will inevitably hinder innovation.

In extremis, cyber security concerns may drive states further into autarkic policies. In a closed domestic environment, cyber security including at airbases can be much more readily ensured than if deep

45 Samsung is also involved but to a noticeably lesser degree than the three noted.

connectivity exists with others internationally. This is a particularly important issue in matters of defence and security.

ALTERNATIVE FUTURES

The various uncertainties, continuities and possibilities that have been discussed can be usefully combined using the scenario matrix planning methodology. This uses two selected key uncertainties to derive four quadrants, each an alternative future qualitatively different from the others in a logical, non-random way.

The four alternative future worlds are constructed around two broad uncertainties: firstly, people working either using or with machines, and secondly, the international system being globalised or autarkic. These uncertainties lead to four possible worlds labelled: Big Business Rules, Brave New Wild West, Walled Garden and DIY Disruption. These worlds are briefly described in the Figure 1; a more detailed narrative follows.

None of these four worlds is considered more probable than the others. Instead the intent is that the future that actually occurs is broadly captured somewhere within the wide span of possibilities the four worlds' described encompass. For example, the engineering and logistics support of the Air Force from states beyond Australia could vary for many reasons across the continuum from full support to none. In many future contingences, it may be somewhere between the two extremes although it's not possible to know where at this stage. Accordingly, the worlds are so developed to allow the similarities and differences between them to be explored, helping address what engineers and logisticians might be doing in 2030+.



Figure 1: Alternative Airbase Futures 2030+

BIG BUSINESS RULES

In the Big Business Rules world, large corporations dominate and are mainly focussed on sustaining stable profits over the longer term. The big corporations drive innovation with this determined mainly by what is in their perceived best interest. Big data is the new oil, being bought and sold in a way that maximises the company's return on investment. Considering big data as a finite resource has meant that cyber security is strong and robust. This is a world that favours authoritarian states; their active management of their societies can provide the stability large corporations prefer.

The era's catchphrase is 'sustainable profit maximisation'. The large corporations take a long-term view and so make arrangements with other companies on dividing up markets. Smaller competitors are bought out or marginalized to ensure a more stable market environment. Technology then tends to be developed for use within a market agreed with others on geographic or functionality grounds. IP is jealously guarded. This means that in the digital domain, integration is mostly within a company's products not the wider environment.

The promise of 3D printers has been partly met. The big corporations have set up very large 3D printer facilities across the globe. Orders for goods able to be 3D printed are fulfilled by the facility closest to the customer. However, 3D printers for individual use are now more expensive and less capable having been seen as a source of potential competition and thus needing restricting.

This is a secure and settled world for engineers and logisticians whose professions are respected in this corporatist milieu and have become guild-like. Standardisation across units and airbases is prized; the mission should fit the equipment, not the equipment the mission. The equipment choices for each operational role are limited to being between two or three large companies. In practice, however, incompatibilities between different company products mean that

earlier decisions drive future purchases. Customers tend to be locked into specific companies.

Air Force has limited agency in this world where large corporations rule although there are perceived upsides. The big investments made in specific major platforms are almost preordained but they are safe. The platforms are highly capable and there is little competition that could unseat them in the near-to-medium term as the large corporations wouldn't allow such a business destabilising move. Platform replacement dates are effectively known from when they are first acquired given the large corporation's long-term sustainable profit approach drives their protracted R&D efforts.

At the unit and base level, people come and go but the platforms, albeit with some modifications, go on for decades. The times favour outsourcing to the large corporations many maintenance and logistics functions. Airbases are optimised for efficiency.

The market structure means that equipment can't really be modified solely for local requirements. However, with companies looking to maximise profits long-term, placing engineers and logisticians at no cost to the company inside its facilities to influence from the inside proves efficacious. Production line alterations and fleet wide upgrade packages are made that make them more useful for all. Grasping the nettle, Air Force places a sizeable percentage of its engineers and logisticians offshore—some 25%—in germane large corporations ensuring more operationally relevant equipment, higher skilled individuals, deeper organisational knowledge and expertise, and better retention. It's a policy sold as 'if you can't beat 'em, join 'em'.

BRAVE NEW WILD WEST

The Brave New Wild West world sees diverse, dissimilar groups ranging across states, large commercial organisations, small companies, civil society groups, non-government organisations and individuals all working with machines. Innovation is widespread as the many different groups are now able to actively devise new ways of using the widely shared, freely available data to address their varied and disparate needs. Managing such rampant cross-border collaboration has proven difficult for all countries but especially so for the authoritarian states. These now seem outmoded in the new freewheeling era.

The era's catchphrase is 'individualization and customisation.' The message is that machines should be made that meet an individual's needs precisely, not meet many peoples' needs only broadly. While duplication is prevalent with new machines often addressing the same needs, such competition acts as a further spur to innovation. Extensive 3D printing resources across all levels of society mean existing machines can be tailored relatively quickly and cheaply. This is being encouraged by manufacturers' making their product's digital twins freely available.

A significant gain from this digital twin accessibility is the deep seamless integration of many products across society. Incompatibilities between proprietary software and systems are now just a memory. An unexpected consequence, however, is that software development has become less profitable as protecting the IP is problematic. Hardware is now favoured as its IP can be easier to protect. A downside of the widespread openness is that cyber security is now a nightmare.

This is a dynamic world for engineers and logisticians although constant change brings its own demands. Each unit and each airbase now expects its machines to be tailored in both hardware and software terms to meet its specific mission needs. This expectation becomes feverish when a crisis emerges. The frequent tailoring makes it hard to

keep up with the many different new interfaces that all the continually evolving machines need to retain the essential deep integration across the whole Air Force. Software and hardware design skills are at a premium in both professions. Airbases are optimised to manage technological change.

A particular issue is managing big data to meet the continually changing demands arising from new missions and new machines, given all systems now need the most-up-to-date data to perform at their peak. Professional data scientists are imperative but the era's open data usage and its widely accepted importance means many people receive data management training in the early stages of their education.

Air Force has its own dilemmas. The big investments made in major platforms are a constant concern. The platforms are highly capable but they could be made obsolete overnight with the increasing rate of innovation. Major platform development cycles and innovation are now well out of sync, instead favouring the development of small, numerous, innovative low-cost machines and systems that can be constantly replaced or updated. At the unit and base level this places pressure on maintainers staying up-to-date on the latest equipment's demands and on the logisticians managing the ever-changing maintenance item and consumable requirements.

WALLED GARDEN

The Walled Garden world is an era of hard-nosed, zero-sum nationalism where states are harshly self-interested. The state drives innovation determined mainly by what is in its perceived national interest. Big data is zealously protected as important to national security but shared as necessary with large domestic companies that can ensure good cyber security. In this world, keeping data within the country is considered essential. The national intranet provides good broadband services within Australia but, with relatively few gateways to the outside world, little data is exchanged with offshore parties.

The era's catchphrase is 'we'll look after ourselves.' Smaller states are at a distinct disadvantage in that they have difficulty accessing global technologies and financing. Size becomes a quality all of its own as it allows large states to become self-sufficient in most aspects. Technology is mainly developed for national use. Large companies are the principal conduits for innovation as only they have the resources to move from research into development and then into production.

In the defence industry sector there is a small number of large Australian companies around each of which cluster dependent SMEs focussed on innovation. The state shares data with each large company as appropriate to the undertaking they are being engaged for. The small number of large defence companies each has particular specialities that the state wishes to keep them viable in; competition is, at best, limited.

The large companies have embraced the fourth industrial revolution and created 5G islands around their main facilities. Innovation is mainly limited to software and to the particular hardware that 3D printers or other forms of advanced manufacturing can create. Lean manufacturing is crucial given low quantity production runs.

This is a dichotomous world for engineers and logisticians. On the one hand they are cut off from global developments, but on the other collaboration within Australia is excellent and there is interesting

and nationally important work always underway. Integration of new or modified equipment and systems across the defence force is a straightforward engineering issue with Australian companies freely exchanging data and digital twins. Logistics is continually optimised to support a small Air Force undertaking operations only from established in-country airbases.

Air Force and the Australian defence companies have become interdependent; both need each other. Long-term force structure development is eased given the stress on outcomes rather than value for money. Even so, in a world where finance is scarce defence forces try to retain large platforms and systems in service as long as they can, making use of in-country upgrades to maintain operational capabilities. Such upgrades can be technically challenging making software and hardware design skills valuable to both Air Force and industry. Moreover, gaining access to foreign IP to allow software integration onto overseas-sourced platforms is difficult, hampering their upgrade programmes.

The limited number of skilled personnel nationally means that the Air Force and the large companies try to share their staff and expertise to maximise results. Instead of outsourcing, Air Force and the large companies now have blended staffing where government and civilians work alongside each other. This policy applies not just at the deeper level maintenance facilities but also at the operational level including the flightline. Airbases are optimised to train and develop engineers and logisticians, giving them the background expertise useful in later design, manufacturing and acquisition positions.

DO-IT-YOURSELF (DIY) DISRUPTION

The DIY disruption world is a world where diverse and dissimilar groups across society are working with machines. While separated from global developments, these groups deeply collaborate with each other to address national problems through technological innovation. Big data is shared with all across the nation within a reasonably effective domestic cyber security regime. Innovation is focussed mainly on vulnerability mitigation and resilience with the intention to make a more robust Australian society.

The era's catchphrase is 'innovation makes us tougher'. Smaller states are at some disadvantage given their poorer economies of scale compared to large countries. This is at least partly overcome by widespread adoption of fourth industrial revolution concepts across society. This take-up is accelerated by 5G nation-wide, open data policies, good domestic cyber security and widespread 3D printer proliferation.

The result is a swirling mass of SMEs across the nation engaged in continual innovation albeit with some limitations. Technological innovation is mainly limited to software and to specific hardware suitable for 3D printers or other forms of advanced manufacturing. Large companies are flailing, being slow to innovate, having trouble handling the complexities of continual change and possessing high cost structures.

The SMEs share their digital twins allowing others to integrate their innovations into new systems. However, they lack ready financing now global sources are inaccessible and this pushes them towards favouring small-scale innovations and not generally considering major platform possibilities. The SMEs frequently adopt a 'push' strategy of devising new innovations and then convincing the customer of their value, instead of building something in response to well-defined market needs - that is, a 'pull' strategy.

This is a vibrant world for engineers and logisticians albeit geographically limited. In this world there is significantly less tailoring of existing equipment and much more replacing it with new more innovative machines and systems. Maintaining an integrated force is an ongoing challenge although with the SMEs all within Australia, collaboration and exchanging data is uncomplicated.

Air Force is facing gradual platform obsolescence as acquiring innovative new items rather than upgrading the old becomes an accepted force structure development strategy. To mitigate this, Air Force is keen on innovations that operate readily and easily in conjunction with the existing large platforms, such as off-board sensors and unmanned wingmen. This neatly exploits this world's technological paradigm of working with machines.

Paradoxically, this makes the units and bases the hub of Air Force innovation. At the base level is where the overwhelming majority of the tactical level expertise resides that many SME's wish to access. This is important from a national perspective, as keeping unremitting innovation going is necessary to achieve the desired vulnerability mitigation and resilience. If innovation slows, then national robustness in the face of the continually evolving external challenges may weaken. Airbases are optimised for innovation.

The four alternative futures taken individually may present a complex picture, although some similarities between them are evident. In all likelihood the actual 2030+ world will be an amalgam of all four, but the particular combination that finally eventuates is inherently uncertain at this time. However, the alternative futures provide a shared understanding of the range of contexts within which the future digitally transformed airbase is likely to operate.

The future is now not simply a churning mass of possibilities but a realm able to be comprehended and planned to. The four worlds can usefully inform our thinking about what engineers and logisticians will be doing in the future Air Force of 2030+.

4.

ENGINEERS AND LOGISTICIANS: FUTURE ROLES, FUTURE SKILLS

“I hope that they end up being strategists, designers, optimisers of systems”

Thought Leader 3, 2019.

The future integrated airbase can be considered a complicated machine comprising deeply interconnected hardware, software and humans. The machine metaphor will doubtlessly appeal to engineers both professionally and intellectually. Logisticians, however, may find it less alluring. That may be a mistake, as state-of-the-art warehouses are in some respects miniature versions of what future airbases will be. Logisticians working in this specialty field may be in front: they may be the harbingers of a digital airbase spring.

Warehouses have traditionally involved mainly manual, ‘blue collar’ occupations with some limited management positions. However, with manual occupations being transformed through digital technology, this balance shifts. The future warehousing staff will need to be skilled in the operation and maintenance of machines rather than in receiving goods, sorting, stacking, loading and delivery themselves.

State-of-the-art warehouses already feature real-time monitoring of inventory; real-time ordering using technologies such as AI machine learning, the cloud, big data and IoT; order picking by advanced

robotics; and stock movement by autonomous vehicles. Some warehouses are now embracing 3D printing to meet the numerous, but erratic, one-time requests for spare parts and so save on carrying large part inventories for older equipment. Logistics control towers have been introduced that integrate digital information from numerous sources and use big data analytics to provide a real-time 'big picture' of the complete supply chain, including transportation activities.⁴⁶ Drone delivery is in the final trial stage in several industries across several countries and there is now movement towards human augmentation through staff using advanced wearables and exoskeletons.⁴⁷

The logistics' workforce is becoming more specialised, requiring widespread digital literacy and involving new occupations, like data analytics. In the change in the workforce from mainly manual labour to mainly automation, there is now a shortage of middle level managers who can understand the whole supply chain, operate the digital logistics warehouse and comprehend maintenance activities and requirements.⁴⁸

In functional terms, future airbases are likely to be more like today's automated warehouses than existing airbases. As machines take on more mundane jobs, it seems humans will shift towards operating and maintaining the machines. Today's focus on using machines may change towards working with machines but this remains an uncertainty as discussed in the last chapter. For the near-medium future machines will generally work separately to people.

46 Stefan Schrauf and Philipp Bertram, *How digitization makes the supply chain more efficient, agile, and customer-focused*, Strategy&: PwC Network, 7 September 2016, <<https://www.strategyand.pwc.com/gx/en/insights/digitization-more-efficient.html#Download>>

47 For a discussion on cargo drone delivery in austere environments see: Peter Layton, *Australia's New Regional Context: Pacific Island Futures and Air Power Possibilities*, Canberra: Air Power Development Centre, 2020 pp. 63-67

48 *Queensland Transport and Logistics Workforce: Current and Future Trends*, Department of Transport and Main Roads: Brisbane, November 2018, pp. 21-22

The first section in this chapter draws on the earlier automated airbase discussions to determine new key roles that future engineers and logisticians may be working within beyond 2030. However, recognising that a role is important does not necessarily mean Air Force needs to undertake such work in-house. Accordingly, this section applies the new key roles to the four alternative worlds to address which areas might be kept in-house and which out-sourced. Included is a tabular summary of the important roles in which Air Force engineers and logisticians should develop expertise. The second and rather brief section is a tabular summary of the important skills necessary.

FUTURE KEY ROLES

There seem several key roles future engineers and logisticians may be working in. The technologies in these areas have been explained in the earlier chapters with their possible utility in future airbases noted. The new key roles discerned are:

1. systems of systems network development,⁴⁹
2. big data and machine learning,
3. robotics and autonomous vehicles,
4. augmented workforce technologies possibly including exoskeletons,
5. 3D printing, and
6. electrification.

49 The term 'systems of systems' as used here is defined "as a set or arrangement of systems that results when independent and useful systems are integrated into a larger system that delivers unique capabilities." Defense Acquisition Guidebook (2017), Fort Belvoir: US DoD Defense Acquisition University, Chapter 3, para 2.3., <<https://www.dau.edu/tools/dag>>

In each of these roles, future engineers and logisticians will be involved in the operation of the machines involved, be able to address ongoing hardware and software issues and understand and direct maintenance activities. Such a listing immediately raises the question about whether these can't all, or at least in part, be outsourced rather than be done in-house by Air Force.

This is an important decision. Developing the necessary expertise within Air Force would be a considerable effort. Conversely, outsourcing may not deliver the capabilities and capacities necessary in the 2030+ period. This is also a decision that cannot be delayed too long. Changing existing recruiting, training and education approaches and structures takes time. If not commenced at or before the optimum time, properly trained and educated engineers and logisticians will not be available when required in the needed numbers.

This dilemma can be simplified to deciding whether to do something now or instead do nothing. There are several possibilities what that 'something' might involve. This is an issue that can be thought through by considering the four alternative worlds and their different glimpses of possible futures.

The starting argument of this paper was that airbases are not simply a collection of buildings, equipment and supplies but instead have a warfighting function; they are the foundation of the application of military power from the air. Air power is generated by airbases. Moreover, airbases being a critical part of a nation's air power have historically been subject to attack, a trend that seems set to continue. The development of long-range precision guided missiles and offensive cyber operations suggests even airbases far in the traditional rear area could be engaged by hostile entities.

Given this, the role of 'systems of systems' network development is an essential area to retain within Air Force. It is the core airbase functionality in the era of digital transformation; all else depends on it. All the many other digital technologies plug into and interact across this network, which includes the central command and control

node. The control tower concept in logistics warehouses is similar, albeit smaller in scale and ambition. The ability to design, develop, implement, certify, maintain and continually evolve the airbase's overarching systems of systems network is critical to Air Force across all four worlds.

Importantly, these networks are not just machine-to-machine in operation, humans are also integrated, not to replicate robots but for their human qualities. Humans bring creativity, innovation, imagination and breadth of knowledge. These skills are in sharp contrast to the more mundane abilities of robots to do repetitive tasks, ceaselessly perform manual labour and, if AI, quickly find knowledge in enormous data troves. The airbases' systems of systems network is as much a social network as anything else. This means that the network staff will need good collaboration and communication skills.

The systems of systems network is central across all worlds; however, the Big Business Rules world is somewhat restricting. In this world creating, maintaining and evolving the airbase's systems of systems network will be constrained within the small number of big corporation's product lines. The tweaking to adapt the systems of systems network to Air Force needs may be limited to minor software changes. The exception is if non-corporation hardware suppliers can access adequate proprietary data to build an interface that allows plug and play albeit this may be costly.

The big data and machine learning role is more nuanced than the systems of systems function. The big data and machine learning role is essential across all four worlds but in the Big Business Rules and Walled Garden world might be fully or partly outsourced respectively. In both these worlds placing engineers and logisticians in the companies providing this service might give Air Force adequate knowledge. In the former world that would probably be offshore, in the later within Australia.

The other two worlds, Brave New Wild West and DIY Disruption, in being strongly innovative will be turbulent ones for the development

of big data and machine learning. Contracting to an external provider would be problematic given rapid change. Instead, Air Force might be best served by retaining the function in-house to ensure long term expertise is developed, keeps being continually updated, new paths are taken as new technologies emerge and the individuals concerned can be hung onto through retention programs as required.

Two worlds could feature outsourcing with two others less so. Even so, big data and machine learning is pervasive across the digital transformation. Air Force should deeply consider developing and retaining substantial expertise in-house in this area. Air Force staff having deep knowledge of the technology may provide reassurance that the answers provided are appropriate for Air Force's needs, even if they can't be explained. The combination of big data and AI can have many failure points unless a high attention to detail is maintained. Having committed, long-serving, highly experienced staff can help ensure this.

The big data and machine learning role is one where individuals matter. Some people working in this area will probably be:

“pivotal people - those that contribute outsized...value to their organisation. They will be hard to find and difficult...to keep. ... Organisations will need to pay careful attention to the employee value proposition – the reasons why these extraordinary people were attracted to working with them in the first place.”⁵⁰

Retention may be easier in the Walled Garden and DIY Disruption worlds as global employment options will be closed off. Even so, in the former, large companies will use enticements and, in the latter, SME entrepreneurialism may prove attractive. Across all four worlds, the big data and machine learning role may be one where a porous boundary approach might be adopted. Individuals would work for Air Force

50 *Workforce of the future: The competing forces shaping 2030*, PWC, 2018, p.31

long-term but move into and out of industry, and perhaps academia, in a carefully considered manner.

The robotics and autonomous vehicles role is a complicated one that will involve numerous different kinds of vehicles. In the Brave New Wild West and DIY Disruption worlds there will be constant change as new, innovative, more useful vehicles are continually devised. In the Big Business Rules and Walled Garden worlds, the situation would be more stable. The crucial issue though is the integration of these vehicles within the airbase's systems of systems and retaining this capability within Air Force was discussed earlier. The maintenance of the vehicles might be outsourced to vehicle providers.

The problem that this sets up is that robotics and autonomous vehicles providers will have little incentive to be innovative, an issue especially pertinent to the inventive Brave New Wild West and DIY Disruption worlds. There is an argument for Air Force to keep some expertise in-house to be able to adequately contract. More important, perhaps, is to stay abreast of new technological developments and their idiosyncrasies to be able to knowledgeably push robotics and autonomous vehicles providers. Given integration is key, perhaps some individuals in the systems of systems functional area might also include robotics and autonomous vehicles in their already multi-disciplinary training and education.

This approach might be duplicated in the augmented workforce technologies role, also important across all four worlds. Many of the wearables may be commercially sourced, effectively being disposable consumer goods. Exoskeletons will not be throw-aways but like autonomous vehicles may be many and varied and best maintained by a contractor. Integration remains the more important role for Air Force to retain in-house.

The 3D printing role is important in all worlds and involves integration to the supply chain, operation of the printers and maintenance. The printers will be diverse in design and capability, and be sourced commercially. An approach similar to that suggested for the

two previous roles is an option, especially for the Big Business Rules world. However, 3D printing is a complicated process with significant design, material, manufacture and certification issues.

To get the optimum result from 3D printing for Air Force, and then sustain this as equipment and logistics demand changes, will require dedicated effort. The 'one size fits all' approach of commercial contracting will not give Air Force the complete logistics package that 3D printing makes possible. This is especially the case if prototype warfare concepts are adopted; and there would a strong push for this in the Brave New Wild West and DIY Disruption worlds.⁵¹ On balance, a mixed in-house/outsourced solution may be appropriate until the Brave New Wild West and DIY Disruption worlds as possible futures are comprehensively ruled out.

The final new key role is electrification, which runs across all four worlds. Electricity will power the future airbase much more than today. This change is not optional in that electricity is the power source for digital technologies, but at the same time it's a power source that can now be cost-effectively generated on or near the airbase – unlike liquid petroleum fuels. The extent Air Force personnel should be involved depends on judgments made about certainty, robustness and resilience of supply, for without electricity the airbase will cease operations. At the least, there is an argument for having a small cadre of Air Force staff with the necessary expertise to contract out acquisition and maintenance activities to external organisations and provide oversight.

The preceding discussion about the six new key functional areas is summarized in the table below:

51 For prototype warfare concepts see: Peter Layton, *Prototype Warfare, Innovation and the Fourth Industrial Age*, Canberra: Air Power Development Centre, 2018.

4. Engineers and Logisticians: Future Roles, Future Skills

New Future Role	In-house	Outsourced	Notes
'Systems of systems' network development	Retain at all costs		Critical core functional area encompassing designing, developing, implementing, certifying, maintaining and evolving the digital airbases' systems of systems networks
Big data and machine learning	Retain using porous boundary approaches		Individuals move into and out of industry and/or academia but stay Air Force long term.
Robotics and autonomous vehicles	Retain expertise to integrate robots and vehicles into systems of systems	Everything else outsourced	
Augmented workforce technologies possibly including exoskeletons	Retain expertise to integrate wearables and exoskeletons into systems of systems	Everything else outsourced	
3D printing	Half retained	Half Outsourced	Adjust if Brave New Wild West and DIY Disruption worlds ruled out
Electrification	Cadre	Everything else outsourced	Requires judgments on certainty, robustness and resilience of supply

SKILLS REQUIRED

Assessing these roles and noting the earlier discussions suggests that a tentative range of skills that future engineers and logisticians should have can be developed. In that regard, a recent study by the Australian Council of Engineering Deans usefully examined future skills requirements through the Delphic approach of interviewing numerous highly regarded thought leaders.⁵² This approach's strength is that these talented and experienced individuals can provide

52 Caroline Crosthwaite, *Engineering Futures 2035: A Scoping Study*, AECD, April 2019.

well-considered, well-informed opinions. The downsides include it may simply represent the profession’s mainstream view or may be only that held by the more senior members of the profession and not the younger staff who are the future. Accepting those qualms, the study’s final list of skills fits well with the discussion across this paper.

Combining the AECD study and this paper suggests the future knowledge, skills and attributes needed for engineers and logisticians are:⁵³

Continuing Requirement	Greater emphasis needed in future
Technical expertise (but balanced equally across hardware and software aspects)	Human-focused, big picture systems of systems thinking
Problem definition	Problem finding, including critical thinking ⁵⁴ and design thinking ⁵⁵
Problem solving	Creativity and innovation
	Digital intelligence
	Collaboration
	Adaptability

53 The AECD study skill table is at p.45 *ibid*. It includes communication and resilience in the ‘greater emphasis’ column, does not stress a hardware software balance and does not include design thinking.

54 Stephen E. Wright, ‘On Critical Thinking: It Takes Habits of Mind and Patterns of Inquiry’, *ASPJ: Air & Space Power Journal*, Vol. 33, Iss. 4, Winter 2019, pp. 63-71.

55 Aaron P. Jackson (ed.), *Design Thinking Applications for the Australian Defence Force*, Joint Studies Paper Series No. 3, Australian Defence College: Canberra, 2019.

CONCLUSION

A digitally transformed airbase will be able to generate more sorties, faster and with considerably fewer people than now. Robot turns of serviceable aircraft, including refuelling and weapons loading, could be possible. Predictive maintenance will make unscheduled maintenance rare, or at least uncommon. Real time stock tracking should make logistics planning easier, with 3D printing offering the beguiling possibility the airbase could resupply itself for some items. Airbases may seemingly appear uninhabited with its personnel mostly at some less visible control centre that manages engineering and logistics' tasks. A less obvious matter is that digital technologies are powered by electricity with some, such as data storage, requiring significant amounts.

Such a concept changes the airbase from being a facility to being a machine, and a very complicated one at that. The base being integrated can be conceived as a single entity comprising deeply interconnected hardware, software and humans. While a digitally transformed airbase would need to be backwards compatible with legacy aircraft, beyond 2030+ new design aircraft entering service may incorporate features that take greater advantage of what a digitized airbase may offer. Over the longer-term, the impact of digital transformation on military aviation is likely to be re-conceptualising the aircraft and airbase as a single tightly-integrated entity, with each designed accordingly.

The flow on is that while fewer people may be needed to make the airbase generate sorties, there will be a need to have dedicated, well-trained airbase maintainers with new cutting edge skillsets including robot engineers, data scientists and system integrators. This is a major shift that will change what engineers and logisticians do at airbases.

In looking past 2030, the biggest issue is that today's robots have trouble working with people. For machines to work with people they would need to be able to know what people are doing and how they – the robot – can help them. Conversely, humans would need to know what the robot is about to do next. Even with the more advanced forms of AI, such as neural networks, humans can't really understand their outputs or how they were obtained, and thus are not able to anticipate robot behaviour. Today, people are using machines. They are not working with them. A key uncertainty for 2030+ is whether this will change.

Technology is used within a geostrategic context. Today's international system seems to be moving away from the 1990-2010 years of deepening globalization towards possibilities of a multi-polar world with several feuding blocs or even fragmentation. Every state might then consider itself alone, privilege self-reliance and seek self-sufficiency through autarkic state policies. Conversely the world may change course, returning to deepening globalization and seeking absolute gains from cooperating. A key uncertainty for 2030+ is whether globalization or autarkic state policies will prevail.

Four alternative future worlds can be constructed around these broad uncertainties titled: Big Business Rules, Brave New Wild West, Walled Garden and DIY Disruption. None is considered more probable than the others. Instead the intent is that the future that actually occurs is broadly captured somewhere within the wide span of possibilities the four worlds' cover. For example, the engineering and logistics support of the Air Force from states beyond Australia can vary for many conceivable reasons along a continuum from full support to none. In most future contingences, it may be somewhere between the two extremes although it's not possible to know where at this time.

Combining the automated airbase and future worlds discussions it's possible to discern several new key roles that future engineers and logisticians may be employed in. These are:

1. 'systems of systems' network development,
2. big data and machine learning,
3. robotics and autonomous vehicles,
4. augmented workforce technologies possibly including exoskeletons,
5. 3D printing, and
6. electrification.

In each of these roles, future engineers and logisticians may be involved in the operation of the machines involved, be able to address ongoing hardware and software issues and understand and direct maintenance activities. Some though may be outsourced rather than done in-house by Air Force.

The 'systems of systems' network development is an essential role to retain within Air Force. It is the core airbase functionality in the era of digital transformation; all else depends on it. All the many other digital technologies plug into and interact across this network, which includes the central command and control node. The ability to design, develop, implement, certify, maintain and evolve the airbase's overarching systems of systems network is crucial to Air Force across all four worlds.

The big data and machine learning role is more nuanced although essential across all four worlds, even if fully or partly outsourced. Given big data and machine learning is pervasive across the digital transformation, Air Force needs to deeply consider developing and retaining expertise in this area. This is a role where individuals matter; some will be "pivotal people" making out-sized contributions. Accordingly, across all four worlds, the big data and machine learning role may be one where a porous boundary approach to manning might be adopted. Individuals would work for Air Force long-term but move

into and out of industry and perhaps academia in a carefully planned manner.

The robotics and autonomous vehicles role is a complicated one that will involve numerous different kinds of machines. However, integration is key, perhaps some individuals in the 'systems of systems' role might also include robotics and autonomous vehicles in their already multi-disciplinary training and education. This approach might be duplicated in the augmented workforce technologies role, also important across all four worlds.

The 3D printing role is important in all worlds and involves integration to the supply chain, operation of the printer and maintenance. On balance, a mixed in-house/outsourced solution may be appropriate.

The final new key role is electrification, which runs across all four worlds. The extent Air Force personnel should be involved depends on judgments made about certainty, robustness and resilience of supply for without electricity the airbase will cease operations. There is an argument for a small cadre of Air Force staff.

There is a wave of digital transformation disrupting industries globally. While military airbases have been little impacted so far, it is only a matter of time. Digitalisation is inevitable with only the timing uncertain. With it, the roles engineers and logisticians will be doing, and the skills they need, will change. Now is the moment to start thinking about how to make that transition in time to meet the digital airbase revolution.

SURFING THE DIGITAL WAVE

Engineers, Logisticians and the Future Automated Airbase

There is a wave of digital transformation disrupting industries globally. While military airbases have been little impacted so far, it is only a matter of time. With it, the roles of engineers and logisticians will change. Now is the moment to start thinking about how to make that transition in time to meet the oncoming digital airbase revolution.

This change will be brought about by the combination of numerous new technologies surfing in on a massive digital wave. These technologies include artificial intelligence, big data, cloud computing, the internet of things, autonomous vehicles, robotics, 3D printing and human augmentation. The rate of change is likely to rapidly escalate as more and more new technologies join the mix.

Dr. Layton's paper discusses the technologies involved in the approaching digital transformation, explores what an automated airbase might comprise, postulates possible future geostrategic contexts within which these advanced airbases might generate air power, highlights the new roles future engineers and logisticians might be doing on such airbases, and then outlines the broad skills these individuals may require. The next fifteen years look set to being a period of exciting, non-linear change on airbases.

