POINTER
JOURNAL OF THE SAF

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January 2021

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ABSTRACT

Klaus Schwab, founder of the World Economic Forum, contended that the Industrial Revolutions (IRs) were the main driving force behind technological improvements. In the same vein, the author considers that the Singapore Armed Forces (SAF), through various transformations, is now capable of executing integrated full spectrum operations. Looking ahead, the author believes that the SAF faces two overarching challenges. Firstly, being faced with increasingly Volatile, Uncertain, Complex and Ambiguous (VUCA) situations, the SAF needs to automate its decision-making process in view of the tremendous amount of intelligence data. Secondly, the SAF would be contending with an impending manpower crunch—one which would see a 30% reduction in its enlistees by 2030. This threatens its Full Force Potential. To overcome these challenges while maintaining a qualitative edge over its regional neighbours, the SAF may have to harness the 4th IR technologies, such as machine learning and predictive maintenance, to enhance its warfighting efficiency and effectiveness.

Keywords: *Security, Challenge, Manpower, Effectiveness, Efficiency*

ANTHROPOCENE AND THE INDUSTRIAL REVOLUTIONS.

The concept of Anthropocene, defined as the most recent period in Earth's history where human activity was deemed to have caused significant impact on its geology and eco-systems, has gained much traction in the scientific world. Ostensibly, Anthropocene could be traced back to the Industrial Revolution (IR) which started from the mid-18th century onwards and saw the transition from manual production methods to new manufacturing processes involving the use of steam powered machines.[1]

Klaus Schwab, founder of the World Economic Forum (WEF), contended that there have been three other industrial revolutions. The 2nd IR saw the use of electricity to enable mass production. The 3rd IR saw the automation of these production lines and made possible advances in electronics and computers. In recent years, we are at the cusp of the 4th IR, the Digital Revolution or Industry 4.0, which essentially is 'characterised by a fusion of technologies that is blurring the lines between the physical, digital and biological spheres.'[2] Through it all, advancements in technology continue to be the main driving force behind the industrial revolutions, allowing changes to take place at an unprecedented pace.

TRANSFORMATION OF THE SAF

The SAF, in a very similar context to the Industrial Revolutions which are characterised and defined by human activities, underwent multiple phases of modernisation since its inception. Entrusted with the mission to take over Singapore's defence as the British forces were pulling out of Singapore after our independence, the SAF stood up. The SAF has since continually evolved to keep in tandem with the ever-evolving operational demands. The 1st Generation SAF focused on laying strong fundamentals, building a credible defence force from ground zero, and providing Singapore with basic defence. The 2nd Generation SAF, from the early 1980s to late 1990s, continued to build on the fundamentals laid upon by the previous generation and modernised the SAF's three Services—the Army, Air Force and Navy.[3] For example, the Republic of Singapore Navy (RSN) acquired the Victory class missile corvettes to provide seaward defence and protect Singapore's Sea Lines of Communications (SLOCs).

The horrific 9/11 terrorist attack on mainland

On the Singapore Maritime Crisis Centre's (SMCC) watch floor, a dedicated team of data analysts work 24/7 to look through shipping records, ship crew manifests and even online comments and social media postings. They look for anomalies in the data for evidence that point to potential threats targeting Singapore.

United States (US) made the SAF realise that it had to update its Concept of Operations (CONOPS), which focused primarily on defending against conventional conflicts. Besides terrorism threats, the post-9/11 period saw significant changes to the security landscape, which included other unconventional threats such as piracy and cyber-security. The surge in operational demands arising from external developments, emergence of advanced warfighting technologies and reality of finite resources, propelled the SAF to reconsider and revamp its development trajectory. To remain relevant in the ever-evolving operational landscape, the SAF embarked on its 3rd Generation transformative journey in 2004 to become an integrated network-centric fighting force to prepare it for new security challenges.[4]

Full Spectrum Operations

Today, the SAF stands ready to conduct integrated Full Spectrum Operations locally and globally, including: 1) Joint Operations in which conventional warfighting falls under, 2) Coalition Operations where the SAF engages in interoperability training with foreign partners, and 3) Operations Other than War (OOTW) such as humanitarian aid and disaster relief, peace support or counter-terrorism operations.[5] The SAF's ability to conduct Full Spectrum Operations is made possible with dedicated and trained personnel who are armed with the right equipment.

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CHALLENGES FACED BY THE SAF IN THE FUTURE

As the SAF marches onwards after celebrating 50 years of National Service, it is timely to do an inventory stocktake on its current position and look ahead to identify challenges beyond its immediate horizon. Firstly, the author feels that the SAF will need to enhance its warfighting effectiveness through the adoption of 4th IR technologies that have become more prevalent and affordable, lest it loses its technological and qualitative edge over its regional neighbours. Secondly, it was forecasted that the SAF would be facing an impending manpower crunch, with up to 30% manpower reduction. This could potentially impede its ability to continue performing full spectrum operations at its current scale and operational tempo. The latter challenge means that there is a greater imperative for the SAF to continue investing and utilising technologies as force multiplier.

ENHANCING THE SAF'S EFFECTIVENESS

As the defenders of Singapore's peace and security, the SAF will be operating in an increasingly VUCA environment, both globally and domestically. This poses unique challenges, and requires military leaders to be quick on their feet and make decisions on the fly. They would need to shorten their decision-making 'Observe, Orient, Decide and Act' (OODA) loop. To do that effectively, operational commanders need to have a global situational picture of the battlefield, one that has high fidelity and resolution when requested. To that end, the SAF has fielded an increasing number of sensors to the battlefield, including 'eyes-in-the-sky' Unmanned Aerial Vehicles (UAVs) such the Heron-1 which achieved Full Operational Capability (FOC) status in the RSAF in March 2017.[6] The deployment of these high-tech sensors generates valuable Intelligence, Surveillance and Reconnaissance (ISR) data which would feedback to the command posts for the operational commanders to sense-make, effectively enabling pervasive battlefield awareness across all echelons, from the boots on the ground all the way to the various operational commanders. Subsequently, the commanders would then decide on the most appropriate shooter, such as the High Mobility Artillery System (HIMARS) from the Army, or the F-15SG from the RSAF, to prosecute the identified targets. The ability for the commanders to have a say in the pairing selection of the sensor-shooters provides improved operational flexibility to the SAF, affording them additional options such as scalability of firepower required depending on the area of operations and conditions such as risks of collateral damage. This enhances the overall effectiveness of the SAF's warfighters.

However, the employment of such sensors is not without challenges. The sensors generate and relay a staggering amount of ISR data. This poses distinct challenges to a commander: 1) the need for a robust Command and Control Information System (CCIS) and intelligence analysts to process and analyse the huge influx of data transmission in a short time frame, and 2) integrating the different data sources and mapping it onto a coherent global situation picture—one that could be easily and swiftly understood by the commanders to enable them to make decisions.

To address the first challenge on huge data transmission, a multi-prong technological approach is required.

Cloud Computing

The data transmission requirement would inherently demand huge storage space with quick data retrieval capabilities. With technological advances, the cost of storage space in the form of hard disks have decreased significantly from '$500,000 per gigabyte in 1981 to less than $0.03 per gigabyte today.'[7] While this addresses the aspect of huge data storage requirement generated by the sensors, there are limitations on how this data can be retrieved expediently from a traditional hard disk. In fact, the data would also need to be accessed securely from dispersed locations by multiple users simultaneously. In that regard, the SAF can look towards the adoption of cloud technology that has been become prevalently used and integrated into many facets of our lives in the civilian world already. Think of the Apple iCloud, Google Drive, Amazon Cloud Drive, or Dropbox.

Cloud computing offers more than mere information storage and retrieval capabilities. In the broadest concept, cloud computing is the storage and processing of data through applications over the internet instead of utilising the end user's computer hardware.[8] In that regard, it is possible for military applications, including but not limited to imagery analysis, target acquisition and tracking, or post-strike battle damage assessments, to be carried out over the internet in a secure server. With the software applications running online instead of running on each individual user's hardware, their system's hardware would no longer be the limiting factor affecting the speed of processing, and this typically allows the programmes to run faster.[9] Most importantly, cloud computing allows for simultaneous access by multiple users regardless of where they are in the world. Through the automated processing of these huge amount of raw data, a first cut assessment of the data could be scrubbed through in-real time as the ISR mission is on-going. This drastically reduces the amount of mundane 'starring at the screen' tasks that is required to be clocked by the analysts, and instead frees up their capacity to review information that have already been assessed to be of higher significance, requires confirmation or decision-making by a human expert.

Having multiple sources of data input from the various surveillance sensor hardware operating in-theatre would pose data fusion and inter-operability challenges. This issue is compounded when the battlefield comprises of assets from multi-nation coalition of nations and services, each using their own ISR asset, and each equipped with a myriad of sensors of different nature. For example, information sources could be in the form of photos, videos, signal intelligence and each of them would have different file formats. This makes implementation of the cloud computing option challenging at best, and probably next to impossible. As such, for an effective cloud computing option to be implemented, it is essential for a common set of standards to be promulgated. This would then enable the envisaged concept of pervasive unified battlefield awareness to become a reality, allowing the various information sources to be presented on a common global and coherent global situation picture. Commanders could then be constantly apprised with timely intelligence updates and recommendations from analysts, allowing them to shorten their decision-making OODA loop. Troops on the ground would also have access to up-to-date intelligence and situation updates, knowing where their friendly assets are, hence reducing chances of fratricides, while enabling them to concentrate their firepower to prosecute enemy targets.

As the defenders of Singapore's peace and security, the SAF will be operating in an increasingly Volatile, Uncertain, Complex and Ambiguous environment, both globally and domestically.

To deliver greater combat power using less manpower, the SAF has been investing in assets like the Hunter, a fully digitalised armoured fighting vehicle that requires just a three-man crew.

DECREASING LABOUR WORKFORCE FROM 2030

Moving forward, the author highlights that an even greater challenge that the SAF need to contend with would be the result of a social issue—Singapore's low and declining birth rate, which will lead to a decreased manpower pool for the SAF and hence its inevitable manpower crunch. This sentiment was also highlighted by Defence Minister of Singapore, Dr Ng Eng Heng, who noted that demography is the SAF's greatest challenge.[10] To be specific, this is a strategic issue which would not have immediate impact on the SAF in the near term but would have tremendous consequence on the full force potential and warfighting effectiveness of the SAF from 2030 onwards. The SAF has less than 10 years to prepare itself for this manpower issue. To better appreciate the impending manpower shortage that the SAF would be contending with in the future, it is essential to take a holistic look at the manpower situation of the SAF in the earlier days.

DECREASING MANPOWER POOL FOR THE SAF

Declining Total Fertility Rate (TFR) in Singapore.

In the early 2000s, the SAF saw the increased conscription of full-time National Servicemen (NSF) enlistees when the children of baby-boomers reached enlistment age. This included the cohort of males born in the Year of the Dragon in 1988 and this reached a peak of 21,000 enlistments in 2011.[11] Since then, the Total Fertility Rate (TFR) for Singapore has fallen from the peak 1.96 births per female in 1988 to 1.20 in 2016.[12] Consequently, the number of SAF's enlistees is expected to decrease gradually and revert to the 1990s level of around 15,000 NS enlistees annually.[13] Hence, the number of NSFs would gradually shrink by a third by 2030.[14] The decreased TFR will result in a decreased supply of labour manpower in Singapore, leading to stiffer manpower competition for the SAF, private and public sectors.

Effects on Full Force Potential for Joint Operations

Notably, when a military unit falls below 69% strength due to major losses or deficiencies, it would be deemed as 'combat ineffective'.[15] The decrease in enlistees by a third from 2030 onwards would have adverse impacts on the SAF's Full Force Potential and warfighting effectiveness to conduct Full Spectrum Operations, especially Joint Operations. Fortunately, Singapore was never focused on competing with its potential aggressors in that aspect.[16] The SAF, always cognisant of the fact that Singapore has limited manpower resource which needs to be delicately balanced with both the public and private sectors, had instead leveraged on defence science and technology as force multiplier—to 'do more with less' and be more operationally efficient.[17] This has been the SAF's mantra since its formative stage. For instance, the RSN's newest Littoral Mission Vessels (LMVs), which replaces the existing Fearless-class Patrol Vessels, only needs 23 sailors instead of the 30 required previously. This was made possible by employing increased levels of automation and remote monitoring.[18]

While technology may alleviate the manpower crunch through automation, certain aspects of Joint Operations will still require a critical mass of soldiers. For instance, the RSAF may be able to soften and neutralise land targets from the aerial domain via strategic strikes, but the subsequent land campaign would still require a sizeable number of ground troops. In addition, even the most technologically advanced military hardware and weapon systems in the SAF would still need man-in-the-loop maintenance on a regular basis.

The 4th IR technology could offer enhanced *operational efficiency* and *resource optimisation* through the application of 'machine learning', a key element of Artificial Intelligence (AI) technology. Machine learning seeks to automatically learn patterns and identify anomalies from embedded smart sensors and device that tracks various parameters such as temperature, pressure, vibration and humidity levels.[19] An application of the AI technology would be predictive maintenance for machines.

Reaping Operational Efficiency

One application of predictive maintenance in machine learning would be to reap operational efficiency. Through the employment of sensors, it can sense the severity of biofouling on the RSN vessels' hulls and recommend a cleaning schedule that maximises the fleet's availability for operations, while minimising its downtime and costs. Biofouling is the accumulation of microorganisms, plants or animals on wet surfaces of a ship's hull. The build-up of biofouling on the hulls of the vessels poses significant problems, including increased drag when it is moving through the water, hence requiring more fuel to propel it. The cleaning process is labour intensive and requires the vessel to be out of

ME2 Benny Chew replacing the LED module in the wing position light of the F-15SG.

operational use for protracted periods of time. The RSN's marine engineers would have the flexibility to identify and decide on the optimal point in time to clean the vessel's hull. This results in reduced manhours needed to clean the vessel and improved fuel efficiency, without compromising on the RSN's operational requirements.

Resource Optimisation

Another benefit of predictive maintenance would be the cost avoidance arising from unplanned maintenance downtime by: 1) forecasting when the machines would fail, and 2) ensuring availability of spares, support equipment and manpower for its expeditious recovery. This could be seen in the Autonomic Logistics Information System (ALIS), the fleet and lifecycle management software employed by Lockheed Martin for its F-35 Joint Strike Fighter (JSF) programme. The ALIS adopts a system-of-system approach towards fleet management by fusing maintenance, supply chain and sustainment information into a single system to support the operations of the F-35 JSF.[20] Beyond fleet management capabilities, the ALIS also supports aircraft's operations, scheduling of pilots and mission planning, making it one of the three major components of the aircraft, along with the engine and airframe.[21]

Traditionally, aircraft maintenance adopts the philosophy of preventive maintenance—the inspection and maintenance of aircraft at scheduled intervals based on past reliability data, and hence is independent of its actual serviceability. In addition, when repairs or corrective maintenance are required, they tend to be reactive in nature—failures occur first before the logistics system, including the maintenance and supply elements, responds.[22] This makes sense, considering that aircraft are high-value assets, and failure to its flight critical systems can result in catastrophic outcomes, including loss of the aircraft and lives. In addition, there are no sure means of predicting when the failures will ultimately occur. Adopting a more cautious approach, preventive maintenance often results in wastages in both Materiel and Maintenance Manhour (MMH) perspectives because the parts are prematurely replaced or serviced.

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In contrast, the JSF's ALIS enables maintenance to be performed only when necessary, resulting in up to 50% manpower savings.[23] This is made possible by its Prognostics and Health Management (PHM) system and onboard sensors that continuously monitor its health status. This allows the ALIS to proactively predict and detect imminent failures.[24] Spares would be indented automatically, and the number of maintenance crew required to rectify the defect would be made known beforehand. In fact, knowing when the defect would occur and when the spares and manpower are available would allow the maintenance Squadron the flexibility to plan its maintenance schedule with consideration of its operational requirement. For example, if ALIS highlighted that the aircraft would require maintenance amidst an upcoming exercise, the maintenance crew can make the decision to perform the maintenance prior, hence ensuring the serviceability and availability of the aircraft for operations. With the ability to effectively predict defects and decreased Mean Time To Repairs (MTTR), the ALIS has the potential to maximise aircraft fleet availability and reduce manpower costs.[25]

Predictive maintenance is the key to reducing maintenance and logistical costs while optimising fleet availability. However, setting up and maintaining systems such as the ALIS is complex, entails huge costs and may have security risks. The ALIS was estimated to cost a staggering $16.7 billion over the F-35 JSF's planned 56-year life cycle. In addition, having the main servers of the ALIS located in a single facility at Fort Worth, Texas, essentially means that there is a single point of entry for all data inputs. The failure of ALIS, with its all-encompassing functions necessary to sustain the aircraft's logistical, maintenance and mission-planning operations, will have severe consequences on the aircraft fleet, and could potentially lead to its fleet grounding.[26] Most importantly, any foreign operator of the F-35 JSF will undoubtedly be at the mercy of the US Government should they decide to switch off local access to the ALIS whenever they ever disagree with how the made-in-USA jets are deployed. Without the ALIS, the fleet would eventually be grounded as it can only operate up to 30 days without it.[27]

CONCLUSION

The SAF has come a long way since its inception. As the SAF continues marching onwards in its quest to defend Singapore's way of life, there are challenges that are creeping up beyond the horizon, including the need to effectively harness intelligence from a sea of data, and a manpower crunch arising from Singapore's changing demographics. Through the years, technology has been an effective enabler for the SAF, allowing it to punch above its weight. However, as the SAF advances alongside with 4th IR, we must not be afraid of the disruptive nature of the 4th IR, and instead learn to embrace and utilise these technologies to the SAF's advantage.

BIBLIOGRAPHY

Anastasios, Tsoutis. 2006. *An analysis of the Joint Strike Fighter autonomic logistics system.* Thesis, MONTEREY, CALIFORNIA : Calhoun: The NPS Institutional Archive.

n.d. *Anthropocene.* Accessed December 31, 2017. http://www.anthropocene.info/.

Chirgwin, Richard. 2016. *F-35's dodgy software in the spotlight again.* April 26. Accessed February 16, 2018. https://www.theregister.co.uk/2016/04/26/f35_dodgy_software_again/.

Coughlin, Tom. 2016. *The Costs Of Storage.* July 24. Accessed January 7, 2018. https://www.forbes.com/sites/tomcoughlin/2016/07/24/the-costs-of-storage/#72a447aa3239.

Department of Statistics Singapore. 2017. *Statistics.* September 27. Accessed January 20, 2018. http://www.singstat.gov.sg/statistics/visualising-data/storyboards/population-trends.

Global Security. 1997. *Operational Terms and Graphics.* July 27. Accessed February 4, 2018. https://www.globalsecurity.org/military/library/policy/army/fm/101-5-1/f545-aca.htm.

Griffith, Eric. 2015. *What Is Cloud Computing?* April 20. Accessed January 7, 2018. http://sea.pcmag.com/networking-communications-software/2919/feature/what-is-cloud-computing.

History.com. n.d. Accessed December 2017, 2017. http://www.history.com/topics/industrial-revolution.

Klein, Andy. 2017. *Hard Drive Cost Per Gigabyte.* July 11. Accessed January 7, 2018. https://www.backblaze.com/blog/hard-drive-cost-per-gigabyte/.

Lockheed Martin. n.d. *F-35 Ligntning II - Focus on Sustainment.* Accessed Feb 11, 2018. https://www.f35.com/about/life-cycle/sustainment.

MAJ Jacques Wei-Ren, Erasmus. 2015. "Full Spectrum Operations - A Viable Strategic Posture for the SAF? ." *Pointer, Journal of the SAF*, 11-20.

MINDEF. 2012. *Reply by Minister for Defence Dr Ng Eng Hen to Parliamentary Question on Singapore's Declining Birth Rate and Impact to the Singapore Armed Forces.* November 12. Accessed January 20, 2018. https://www.mindef.gov.sg/oms/imindef/press_room/official_releases/ps/2012/12nov12_ps.html.

Ministry of Defence. 2013. *MINDEF.* August 20. Accessed January 1, 2018. https://www.mindef.gov.sg/oms/imindef/key_topics/3rd_generation_saf.html.

Ng, Jun Sen. 2016. *SAF will overcome manpower issues through technology: Defence Minister.* July 01. Accessed February 18, 2018. http://www.asiaone.com/singapore/saf-will-overcome-manpower-issues-through-technology-defence-minister.

Ng, Kelly. 2015. *SAF reorganising to tackle challenge of hybrid warfare.* June 30. Accessed February 16, 2018. https://www.todayonline.com/singapore/spore-modernising-defence-systems-meet-future-challenges.

Parameswaran, Prashanth. 2015. *Singapore's Biggest Military Challenge.* July 02. Accessed January 20, 2018. https://thediplomat.com/2015/07/singapores-biggest-military-challenge/.

Republic of Singapore Navy, MINDEF. 2017. *Our Ships.* Accessed February 18, 2018. https://www.mindef.gov.sg/oms/navy/Our_Ships.HTM.

Schatsky, David, Navya Kumar, and Sourabh Bumb. 2017. *Deloitte Insights - Intelligent IoT.* Dec 12. Accessed Feb 11, 2018. https://www2.deloitte.com/insights/us/en/focus/signals-for-strategists/intelligent-iot-internet-of-things-artificial-intelligence.html.

Schwab, Klaus. 2016. *World Economic Forum.* January 14. Accessed January 1, 2018. https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/.

Shalal, Andrea. 2016. *Risks seen with Lockheed's F-35 fighter logistics system.* April 16. Accessed February 16, 2018. https://www.reuters.com/article/us-lockheed-fighter/risks-seen-with-lockheeds-f-35-fighter-logistics-system-idUSKCN0XB2IA.

Shalal-Esa, Andrea. 2012. *Insight: Lockheed's F-35 logistics system revolutionary but risky.* November 16. Accessed February 16, 2018. https://www.reuters.com/article/us-lockheed-fighter-logistics/insight-lockheeds-f-35-logistics-system-revolutionary-but-risky-idUSBRE8AF09L20121116?feedType=RSS.

The Straits Times. 2017. Mar 15. Accessed January 7, 2018. http://www.straitstimes.com/singapore/rsafs-new-drone-heron-1-now-combat-ready.

Timothy, Fallon , Mahal Devinder, and Hebden Iain. 2009. "F-35 Joint Strike Fighter Structural Prognosis and Health Management an Overview." *Bridging the Gap between Theory and Operational Practice.* Springer, Dordrecht. 1215-1215.

Tucker, Patrick. 2016. *F-35 Will Fly Despite Auditor's Fleet-Grounding Warning.* April 17. Accessed February 16, 2018. http://www.defenseone.com/technology/2016/04/f-35-will-fly-despite-auditors-fleet-grounding-warning/127561/?oref=defenseone_today_nl.

United States Government Accountability Office. 2016. *F-35 Sustainment - DOD needs a plan to address risks related to its central logistics system.* https://www.gao.gov/assets/680/676576.pdf, United States Government Accountability Office.

Weisgerber, Marcus. 2017. *Defense Firms to Air Force: Want Your Planes' Data? Pay Up.* September 19. Accessed February 16, 2018. http://www.defenseone.com/technology/2017/09/military-planes-predictive-maintenance-technology/141133/.

Wikipedia. n.d. *Wikipedia.* Accessed January 1, 2018. https://en.wikipedia.org/wiki/Industrial_Revolution.

Wilson, J.R. 2014. *The future of computing is in the cloud.* November 10. Accessed January 20, 2018. http://www.militaryaerospace.com/articles/print/volume-25/issue-11/technology-focus/the-future-of-computing-is-in-the-cloud.html.

ENDNOTES

1. n.d. Anthropocene. Accessed December 31, 2017. http://www.anthropocene.info/.
2. Schwab, Klaus. 2016. World Economic Forum. January 14. Accessed January 1, 2018. https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/.
3. Ministry of Defence. 2013. MINDEF. August 20. Accessed January 1, 2018. https://www.mindef.gov.sg/oms/imindef/key_topics/3rd_generation_saf.html.
4. Ibid.
5. MAJ Jacques Wei-Ren, Erasmus. 2015. "Full Spectrum Operations - A Viable Strategic Posture for the SAF? ." Pointer, Journal of the SAF, 11-20.
6. The Straits Times. 2017. Mar 15. Accessed January 7, 2018. http://www.straitstimes.com/singapore/rsafs-new-drone-heron-1-now-combat-ready.
7. Klein, Andy. 2017. Hard Drive Cost Per Gigabyte. July 11. Accessed January 7, 2018. https://www.backblaze.com/blog/hard-drive-cost-per-gigabyte/.
8. Griffith, Eric. 2015. What Is Cloud Computing? April 20. Accessed January 7, 2018. http://sea.pcmag.com/networking-communications-software/2919/feature/what-is-cloud-computing.
9. Wilson, J.R. 2014. The future of computing is in the cloud. November 10. Accessed January 20, 2018. http://www.militaryaerospace.com/articles/print/volume-25/issue-11/technology-focus/the-future-of-computing-is-in-the-cloud.html.
10. Ng, Kelly. 2015. SAF reorganising to tackle challenge of hybrid warfare. June 30. Accessed February 16, 2018. https://www.todayonline.com/singapore/spore-modernising-defence-systems-meet-future-challenges.
11. MINDEF. 2012. Reply by Minister for Defence Dr Ng Eng Hen to Parliamentary Question on Singapore's Declining Birth Rate and Impact to the Singapore Armed Forces. November 12. Accessed January 20, 2018. https://www.mindef.gov.sg/oms/imindef/press_room/official_releases/ps/2012/12nov12_ps.html.

12. Department of Statistics Singapore. 2017. Statistics. September 27. Accessed January 20, 2018. http://www.singstat.gov.sg/statistics/visualising-data/storyboards/population-trends.

13. MINDEF. 2012. Reply by Minister for Defence Dr Ng Eng Hen to Parliamentary Question on Singapore's Declining Birth Rate and Impact to the Singapore Armed Forces. November 12. Accessed January 20, 2018.

14. Parameswaran, Prashanth. 2015. Singapore's Biggest Military Challenge. July 02. Accessed January 20, 2018. https://thediplomat.com/2015/07/singapores-biggest-military-challenge/.

15. Global Security. 1997. Operational Terms and Graphics. July 27. Accessed February 4, 2018. https://www.globalsecurity.org/military/library/policy/army/fm/101-5-1/f545-aca.htm.

16. Ng, Kelly. 2015. SAF reorganising to tackle challenge of hybrid warfare. June 30. Accessed February 16, 2018. https://www.todayonline.com/singapore/spore-modernising-defence-systems-meet-future-challenges.

17. Ng, Jun Sen. 2016. SAF will overcome manpower issues through technology: Defence Minister. July 01. Accessed February 18, 2018. http://www.asiaone.com/singapore/saf-will-overcome-manpower-issues-through-technology-defence-minister.

18. Republic of Singapore Navy, MINDEF. 2017. Our Ships. Accessed February 18, 2018. https://www.mindef.gov.sg/oms/navy/Our_Ships.HTM.

19. Schatsky, David, Navya Kumar, and Sourabh Bumb. 2017. Deloitte Insights - Intelligent IoT. Dec 12. Accessed Feb 11, 2018. https://www2.deloitte.com/insights/us/en/focus/signals-for-strategists/intelligent-iot-internet-of-things-artificial-intelligence.html.

20. Lockheed Martin. n.d. F-35 Ligntning II - Focus on Sustainment. Accessed Feb 11, 2018. https://www.f35.com/about/life-cycle/sustainment.

21. United States Government Accountability Office. 2016. F-35 Sustainment - DOD needs a plan to address risks related to its central logistics system. https://www.gao.gov/assets/680/676576.pdf, United States Government Accountability Office.

22. Anastasios, Tsoutis. 2006. An analysis of the Joint Strike Fighter autonomic logistics system. Thesis, MONTEREY, CALIFORNIA : Calhoun: The NPS Institutional Archive.

23. Ibid.

24. Timothy, Fallon , Mahal Devinder, and Hebden Iain. 2009. "F-35 Joint Strike Fighter Structural Prognosis and Health Management an Overview." Bridging the Gap between Theory and Operational Practice. Springer, Dordrecht. 1215-1215.

25. Anastasios, Tsoutis. 2006. An analysis of the Joint Strike Fighter autonomic logistics system. Thesis, MONTEREY, CALIFORNIA : Calhoun: The NPS Institutional Archive.

26. Shalal, Andrea. 2016. Risks seen with Lockheed's F-35 fighter logistics system. April 16. Accessed February 16, 2018. https://www.reuters.com/article/us-lockheed-fighter/risks-seen-with-lockheeds-f-35-fighter-logistics-system-idUSKCN0XB2IA.

27. Chirgwin, Richard. 2016. F-35's dodgy software in the spotlight again. April 26. Accessed February 16, 2018. https://www.theregister.co.uk/2016/04/26/f35_dodgy_software_again/.

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