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**Big Data and Systems Thinking: Implications  
for the Singapore Armed Forces as a  
Learning Organisation**

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# BIG DATA AND SYSTEMS THINKING: IMPLICATIONS FOR THE SINGAPORE ARMED FORCES AS A LEARNING ORGANISATION

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## ABSTRACT

With the emergence of highly disruptive technologies alongside the geostrategic shifts occurring in the last few years, the author feels that the Singapore Armed Forces (SAF) will have to change the way it functions to stay ahead of the curve. He adds that the SAF will have to adopt a forward-thinking approach and be ready for technological innovations that can potentially enhance our operations, or even transform the basis of how we work. With the ever changing global landscape, regional stability is bound to be affected, alongside the increasingly uncertainty of the future. The author highlights that it is therefore crucial that the SAF recognises emerging strategic trends, as well as changes and prepare for the uncertainties. In this essay, the author examines two contrasting disciplines—Big Data and Systems Thinking—and considers how the SAF stands to gain in many areas by adopting a Systems Thinking approach to harnessing Big Data.

*Keywords: Big Data; Systems Thinking; Data Analytics; Disruptive Innovation; Decision Making*

## INTRODUCTION

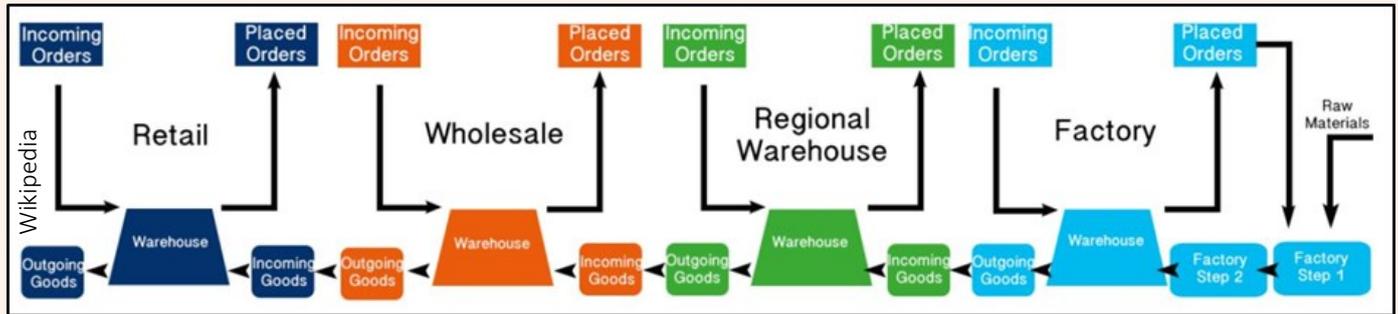
The past decade has seen significant and unexpected shifts in international relations and security. Donald Trump is now the 45<sup>th</sup> President of the United States (US) and China is becoming increasingly confident. In Europe, the peace that had long held since the end of the Second World War was broken abruptly by the annexation of Crimea by Russia in 2014. Thereafter, the impotent sanctions against Russia by the North Atlantic Treaty Organization (NATO) to free Crimea forced a rethink of strategic objectives and defence postures for small European nations.<sup>1</sup> In addition, the shock Brexit referendum also cast fresh doubts on the relevance of the European Union (EU) as a political union and economic bloc.<sup>2</sup> In the Middle East, the rapid spread of the Islamic State of Iraq and Syria (ISIS) has also shifted the security emphasis of many states towards countering extremist Islam and self-radicalised terrorists in their own countries. Yet at the same time, traditional flashpoints such as territorial disputes in the South China sea and North Korea's nuclear threat remain.

In this increasingly volatile, uncertain, complex and ambiguous environment, how can the SAF maintain strategic foresight, anticipate change and prepare for uncertainties? This essay explores two seemingly contrasting disciplines, Big Data and Systems Thinking. It posits that amidst the uncertain environment, the SAF stands to gain in many areas by adopting a Systems Thinking approach to harnessing Big Data. First, it will

examine the Big Data phenomenon which is an emerging field which favours the indiscriminate mining of data to derive insights, and contrast it with Systems Thinking, a more traditional approach to understanding complexity. Next, it elucidates how these two fields can complement each other, and proposes a unifying Systems Thinking approach to Big Data. Finally, it will expound on two areas in the SAF that will benefit from this data strategy and outlines what the SAF needs do to realise these capabilities.

## WHAT IS BIG DATA?

The proliferation of the term 'Big Data' only happened within the last two decades when technology companies such as International Business Machines Corporation (IBM), Google and Facebook started to utilise vastly improved data storage and processing capabilities to harvest and analyse large amounts of data from the internet and social media.<sup>3</sup> It has been hailed as a disruptive innovation that will change the way businesses operate.<sup>4</sup> While the data itself has always been out there, Big Data technology was enabled only because of Moore's law and cost economies which have made storage and processing much more affordable. In terms of definition, some refer to Big Data as a 'holistic information management strategy that includes and integrates many new types of data,' while others have described it as 'high-volume, high-velocity and high-variety information assets that demand cost-effective, innovative forms of information processing for enhanced insight and decision making.'<sup>5</sup> In general, It is



*The Beer Distribution Game.*

believed that by harvesting and analysing large amounts of data, correlations can be derived, errors within data can be reduced, and insights can be uncovered to enable and enhance decision-making.

In terms of success stories, Big Data has been widely credited with many amazing feats such as helping Google predict the H1N1 flu trends in 2009, ensuring the success of the Obama/Biden political campaign in 2012, and even propelling the German football team to World Cup success in 2014.<sup>6</sup> Commercially, It has also enabled companies such as Amazon to revolutionise the book-selling industry through its customised book recommendation algorithm, and allowed social media platforms like Facebook to monetise its huge user base through targeted advertising strategies. As a disruptive innovation, Big Data has also proven its worth by helping online retailers such as Amazon overtake traditional retail giant Walmart in market value, force the closure of brick and mortar stores, and transform the retail landscape.<sup>7</sup> In Singapore, Big Data is gaining traction, and there is increasing emphasis on building data analytic capabilities to capitalise on this emerging technology.<sup>8</sup> However, in spite of the many successes of Big Data, not many organisations are able to benefit or have invested in such capabilities. In fact, research has shown that more than 72% of businesses and organisations are still not able to fully exploit the data they collect or possess.<sup>9</sup> In an increasingly data-driven world, not adopting the technology can spell the difference between success and failure.

## SYSTEMS THINKING

The field of Systems Thinking can be traced to the 1920s when the idea of holism first emerged.<sup>10</sup> If Big Data was the key to understanding correlations, then Systems Thinking would be the process of understanding the causalities behind those correlations. Simply defined, a system may be a set of interrelated elements that form a unified whole, or serve a function such as a banking system, the water cycle, an ecosystem, or the solar system.<sup>11</sup> Systems thinking is

therefore the cognitive process of understanding how the elements are inter-connected, and how they influence each other. The term is also used to refer to tools such as causal loop diagrams, behaviour-over-time graphs, and simulation models that can help to map and explore dynamic complexity in systems.<sup>12</sup>

One of the most well-known Systems Thinking tool is the *Beer Game* which uses a supply chain simulation to illustrate how an unco-ordinated system attempting to optimise itself at the micro-level often leads to sub-optimisation at the macro-level.<sup>13</sup> Another popular Systems Thinking tool is the system archetypes which describe common and usually recurring patterns of behaviour in organisations that often lead to negative outcomes.<sup>14</sup> Systems thinking has also being used in the restructuring of many large organisations such as the Singapore Prison Service transformation in the early 2000s.<sup>15</sup> In general, Systems Thinking is useful when one is attempting to understand the behaviour of complex situations, or is trying to find leverage points to deal with messy problems.

If there is a drawback to Systems Thinking, it would be the fact that efforts to fully understand a large and complex system can be too overwhelming and laborious. As a result, the challenges encountered during a Systems Thinking approach can lead to temptations to reduce complexity through reductionism. Reductionism or reductionist thinking happens when a person analyses a complex system in terms of its simple constituents.<sup>16</sup> In the end, they may end up looking for general principles, ignore subjective elements, and focus only on simpler parts where linear and single causality can be established. In many cases, reductionist thinking is even inevitable due to limited processing capacity and data available.

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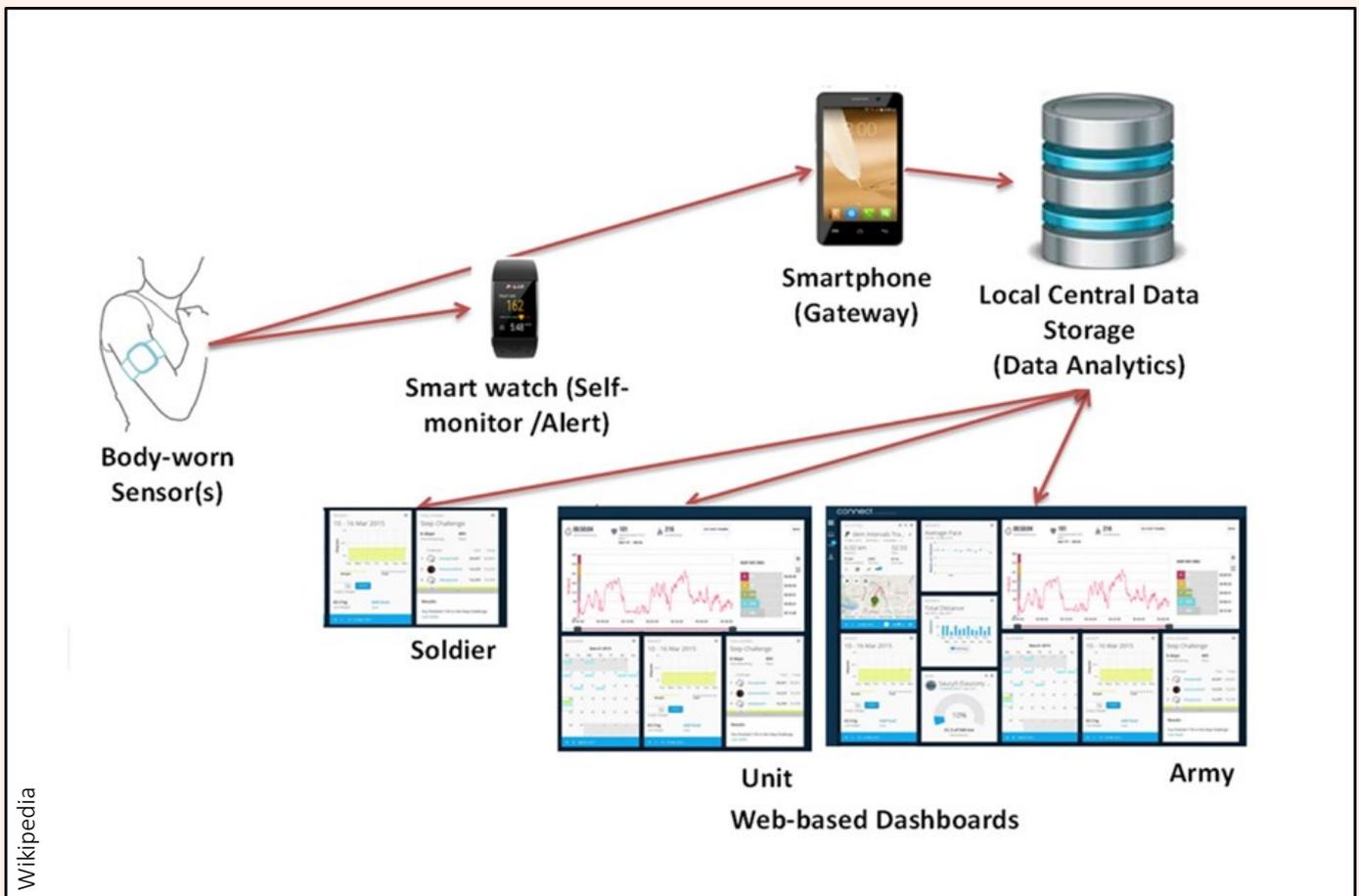
## SYSTEMS THINKING AT ODDS WITH BIG DATA?

The main reason why Big Data appears at odd with Systems Thinking is that Big Data emphasises the establishment of a correlation within factors without the need to establish causality. On the other hand, Systems Thinking demands that relationships within a system be mapped out so that causalities can be seen more clearly.<sup>17</sup> In the commercial applications of Big Data, correlation alone is often sufficient to drive business decisions. For example, if Amazon realises that the buyers of Book A would also like Book B, it can simply recommend Book B to future buyers of Book A without needing to understand why this was happening. With Big Data capabilities developing at an increasing rate, some proponents have even gone so far to say that Big Data will spell the ‘end of theories’ as data correlation alone will be able to explain everything without the need for conventional scientific methods of inquiry.<sup>18</sup>

While these two fields may seem at odds with each other at first glance, Big Data and Systems Thinking can actually complement each other. If we see Systems Thinking as the approach to understand complexity within a system, then Big Data provides the means to validate the understanding by helping to

establish the relationships between elements in the system. For example, in analysing a new problem, a Systems Thinking approach typically requires behaviour-over-time graphs to be drawn by analysts to build the causal theories before effort is expended to gather real data.<sup>19</sup> When these are established, the analysts can then deploy Big Data tools to collect and process large amounts of data such that the causal theories can be validated or disproved. Through an iterative process of going back and forth between theory-building and data analysis, the analysts then establish a better understanding of what was happening. Compared to a haphazard and indiscriminate data mining approach which would require far larger quantities of data to produce reliable results, a Systems Thinking approach allows targeted collection of data to model the structural characteristics of the underlying system.<sup>20</sup>

The other reason why Big Data complements Systems Thinking is because the technology allows Systems Thinkers to expand their scope and boundaries when examining a system. In conventional approaches, Systems Thinking requires a boundary to be determined before examining elements within the boundary due to limits in capacity and paucity of data. Therefore, factors that may affect the system but fall outside the boundary



Wikipedia

The Data-Driven training management system is used to optimise soldier combat performance through the data gathered and analysed.

may not be uncovered, or could even be ignored altogether. For example, the discovery of the Butterfly effect by Edward Lorenz in 1969 showed that even seemingly insignificant causes can have large effects on a complex system.<sup>21</sup> By adopting Big Data to Systems Thinking, Black Swan events that may not have been known to affect a system could potentially be uncovered by ingesting more data to reveal their correlations.<sup>22</sup> Therefore, the advance of Big Data technologies can afford System Thinkers to be more holistic in their analysis.

### WHY BIG DATA AND SYSTEMS THINKING ARE RELEVANT TO THE SAF?

In 2003, then Permanent Secretary (Defence), Mr Peter Ho, spoke about 'a time of disruptive change' following the September 11 attacks by Al-Qaeda and the 'revolution of military affairs' seen during the first Gulf War.<sup>23</sup> The shifts in geopolitical events in recent years, the proliferation of the ISIS terror group, and the emergence of new disruptive digital technologies suggest that the world is again undergoing a time of change. Within Singapore, we are beginning to feel the effects of a slowing economy and low birth rate. At the same time, we are also seeing data-enabled businesses like Uber disrupting traditional taxi services, and data companies like Alibaba reshaping commerce. In order to operate effectively in an uncertain future and scarce resources, the SAF must stay ahead of these strategic shifts, remain agile, and be a champion of innovative technologies. It must therefore seek to understand and adopt disruptive technologies or risk being fundamentally surprised by them.

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Without the means to collect data indiscriminately like Google or IBM, the SAF needs a strategy to better understand what kind of information can answer the questions that it is after, and what kinds of new insights can be found in the data that it already has. A Systems Thinking Big Data approach provides the SAF with the means to guide our data collection efforts, and at the same time allows us to re-examine the data that we already generated. This digital extraction of knowledge will enable the SAF to sense-make better,

enhance our decision making, and provide us with a competitive advantage over our potential adversaries. At the same time, a data strategy will be an enabler for further digital innovations such as Artificial Intelligence (AI) which can vastly improve the efficiencies of our decreasing workforce. The convergence of Big Data with AI is necessary as the automation of smarter decision-making is the next evolution of Big Data development.<sup>24</sup>

### APPLICATIONS OF A SYSTEMS THINKING BIG DATA APPROACH

The first area that can benefit immediately from the application of a Systems Thinking Big Data approach is in intelligence gathering and sense-making. As intelligence works to understand the context of the operating environment and to reduce uncertainties, its processes seek to find and fuse different sources of information into a coherent picture in a timely manner. The traditional way of intelligence analysis and research require practitioners to study a topic in-depth, gradually piecing together an understanding of the topic by collecting samples of data, analysing their significance, and deriving assessments. Much like a scientific hypothesis, intelligence often requires making an 'educated guess' based on prior knowledge and observations. It is a painstaking process that required exactitude due to the paucity of information available for analysis. With the advent of the internet and increasing proliferation of social media platforms, blogs, media broadcasts, and other forms of open source intelligence (OSINT), it will be increasingly difficult to process all the information available timely using traditional methods of analysis and research due to their overwhelming quantity. If we persist with the traditional methods, we would end up getting into a state of paralysis by analysis.

Applying a Systems Thinking Big Data approach allows an analyst to quickly hypothesise a general understanding of the situation that he or she is studying through a systematic approach, and then deploy Big Data technology to collect large amounts of data to validate or disprove the hypothesis derived. Compared to the traditional approach, it is much faster, more comprehensive, and less prone to errors from within the collected data due to the large quantity. However, such an approach would naturally involve some degree of messiness in the data collected, thereby trading some levels of exactitude for completeness of information.

Besides the amount of data that can be obtained for analysis, applying such an approach also facilitates further technological innovations such as AI, and machine learning to be implemented as the ingested data would be cleansed and properly structured.<sup>25</sup> The result of automation and machine learning would lead

to higher efficiency and reduced manpower as machines can handle the mundane tasks of data collection, archiving and anomaly detection, freeing up human capacity to do higher value analysis and research. As data becomes increasingly important as a source of comparative advantage, a Systems Thinking approach to Big Data in the field of intelligence will bring the SAF to a new level of sense making, facilitate information sharing and unlock further innovations. The holy grail of such an approach would be to minimise or even eliminate the uncertainties in the fog of war due to incomplete or unavailable information.

### RE-EXAMINING DARK DATA IN THE SAF

Another area in the SAF that would benefit from a Systems Thinking Big Data approach would be the re-examination and secondary value extraction of dark data in the SAF. Dark data is operational data that the SAF already collects, processes and stores in the course of regular activity, but generally fail to use for other purposes.<sup>26</sup> In many areas such as logistics and maintenance, air and sea surveillance, training and simulation, and operational control of assets, the SAF generates huge amounts of data daily in our command and control information (C2I) systems. Most of these data would be processed for their primary purposes, reported, archived and left to sit in storage. However, besides their primary purpose, there could be secondary uses for these data which can be even more valuable than their primary use. However, unlike social media platforms such as Facebook or Twitter where data is created and curated on the same platform, existing and legacy computer systems in the SAF are likely not designed with data analytics in mind. It is therefore up to Systems Thinkers to re-imagine what secondary values can be extracted from these data, design interfaces to bring them together, and derive new insights from their analysis.

In cases where data sources are owned by the same entity, the process to bring them together could be straightforward. The difficulty in such cases would be in framing the possible problems that can be solved by the available data, something that not even the greatest computers in the world can help. For example, in the area of military operations research and campaign planning where the problem statements are usually clearly identified, a Systems Thinking Big Data approach would be possible to bring together data from a variety of sources such as training simulators, large scale exercises, logistics, and even external sources such as computer gaming networks to provide an accurate and realistic model for military planners to work with. Without this approach, operations researchers often have to rely on simple mathematical models derived from first principles, and design experiments to test the

accuracy of these models.<sup>27</sup> Similar to the example in intelligence, using a Big Data approach may be able to reveal insights or uncover important factors that had previously not been considered by the researcher.

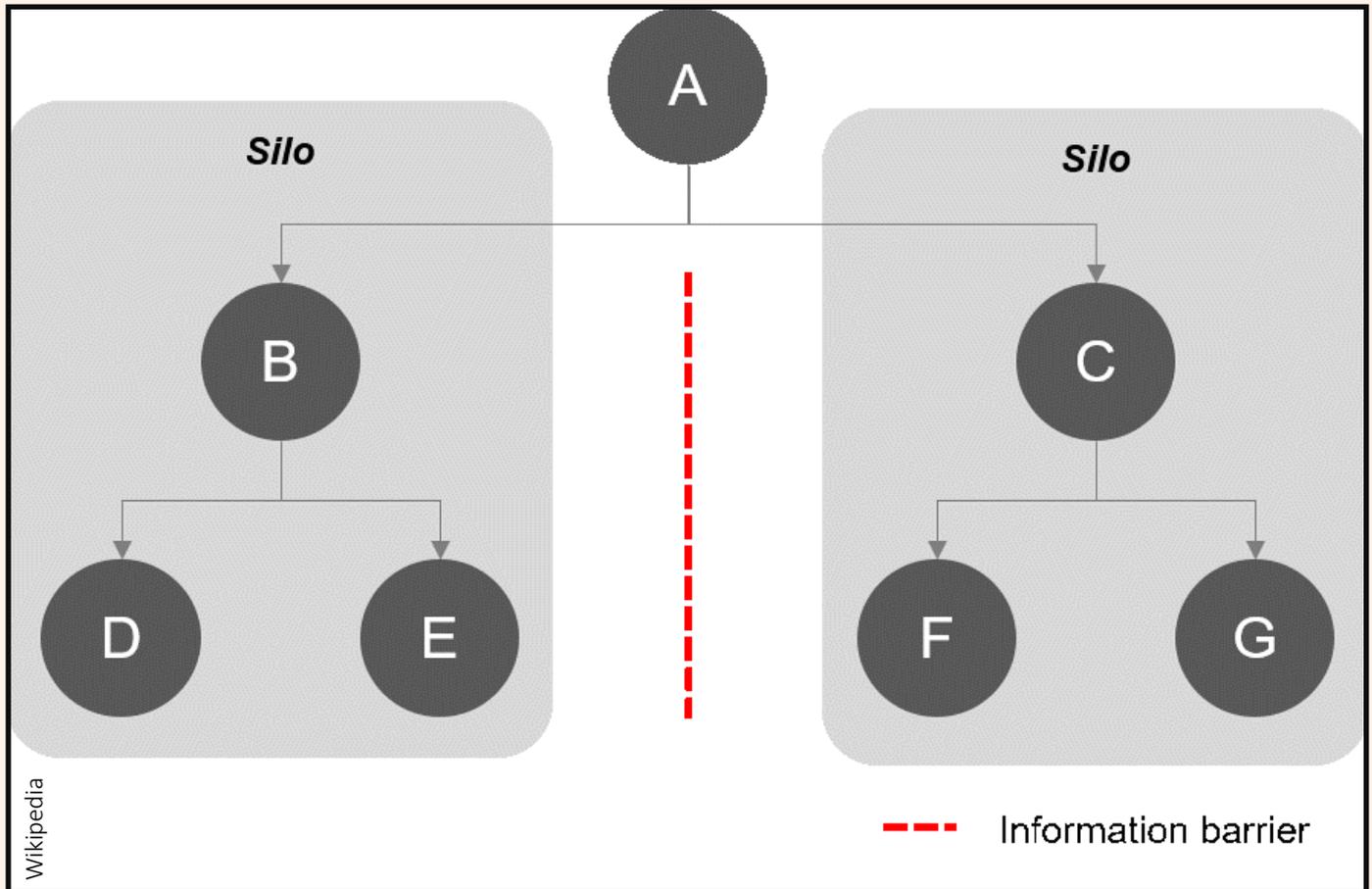
In cases where the data sources are spread across different data owners, the challenge is in convincing stakeholders and eliciting commitment from them to share their data before new value can be unlocked. One such successful example involving the SAF is the National Maritime Sense-making Group (NMSG) which is made up of various government agencies and stakeholders in the shipping industry concerned with maritime security. By conducting analysis on their shared data, the NMSG was able to extract new insights by pooling data they each owned, and was often able to discover anomalies in shipping traffic that needed further investigation.<sup>28</sup> These discoveries would not have been possible without an understanding of the data required and commitment from different stakeholders to contribute their data.

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### WAY AHEAD FOR IMPLEMENTING A DATA STRATEGY

For a large organisation like the SAF, a Systems Thinking Big Data journey would not be straightforward. In order to realise new capabilities, the SAF needs to do more than just acquire new technologies or systems. It needs to first break down existing mental models and adopt new ones that will prepare it for the new paradigm. The foremost task would be to overcome inhibiting mental models such as a Silo Mentality where entities do not wish to share information with each other despite being in the same organisation.<sup>29</sup> This breakdown of silos can only happen through strong leadership support and information security assurances to safeguard shared data.

Thereafter, we would need to create a culture of data-based decision making and an analytic mindset. In an age where everything can be measured, quantified and analysed to gain new insights, we would have to move from a qualitative decision-making model to a more quantitative based one. At the same time, our



Typical information silos in a hierarchic structured organisation.

people must be more data-driven, questioning what new insights can data provide, how we can get more data, and how we can better analyse our data. In the process of acquiring new war-fighting systems, data integration from those systems must also become a principal consideration and not an afterthought. We need to create structures within the organisation to synergise data right from the onset.

Another important step is to create a critical mass of Systems Thinking and data analytics expertise within the SAF. Future strategists would need to be proficient in both fields in order to better sense-make the world and chart the path for the organisation. One possible approach is to create a small specialised group with Systems Thinking and Big Data skills and allow them to move across various SAF entities to provide consultation, find leverage points to improve the system, and new value in dark data. As there will be competing demands for these skills in the commercial sector, we cannot rely only on recruiting new people to fulfil these roles. Much like how Microsoft Word and Excel skills have become baseline requirements for office workers, we must retool and equip our people with the new skills so that they are capable of thinking in systems, processing and visualising Big Data.

Last but not least, in terms of the developmental approach to Big Data systems, we would have to consider between in-house software development vis-a-

vis outsourcing or acquiring commercial off-the-shelf products to achieve our objectives. At the same time, we have to carefully contemplate data anonymisation and access control requirements in order to address privacy and security concerns during the developmental process. While it appears easier to outsource or licence software and technologies than to develop our own, there might be core skills in data analytics that can be better sustained if we chose a self-developmental approach. Concomitantly, an in-house developmental approach may also allow us to better control data access and security throughout the entire process.

## CONCLUSION

The geostrategic shifts occurring in the last few years, and the emergence of highly disruptive technologies herald a new time of change. To stay ahead of the curve, the SAF has to think ahead and be ready for technological innovations that can enhance our operations or fundamentally change the way we work. However, technology such as Big Data is not a universal panacea nor a crystal ball to predict the future. It has to be guided by a strategy for knowledge extraction.

In the fictional classic, *The Hitchhiker's Guide To The Galaxy*, it took Deep Thought, a supercomputer the size of a small city, 7.5 million years to arrive at the answer of 42 to the ultimate question of life, the

universe, and everything. However, as no one actually knew what the ultimate question to life, the universe and everything was, nobody could make sense of the given answer. Likewise, the promise of Big Data depends not just on technology in finding that needle in the haystack, it also depends on the readiness of the questioner to make sense of the answer. Through a Systems Thinking Big Data approach, we will be able to better understand the subjects that we are interested in, create the structures necessary, and invest in the means to get the data we need. Only by combining an understanding of the system and exploiting enabling technologies can we hope to find and understand the answers that we are looking for.

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