

Extract of Chapter on "ELEMENTS OF SYSTEM ENGINEERING & IT ARCHITECTURE"

Copyright © 2017, Innov8or Solutions Ltd, All Rights Reserved.

In the complex world of technology today, almost no company can produce any new product or services without the assistance or partnership of other organisations. It is fundamentally necessary to understand what you are buying, why you are buying it, the compromises and risk you are accepting by making those decisions, and then finally the effect on your room to manoeuvre in the future. Figure 21 gives a high level view of the operating environments and key factors that should be taken into consideration when making technology system choices.

PRIMARY ITEMS	COTS Commercial off-the-shelf (COTS) is a term that refers to non-developmental items (NDI) sold in the commercial marketplace and used or obtained through contracts. It is usually an off-the-shelf hardware or software product tailored for specific uses, made available to the general public, designed to be readily available and user friendly. Generally considered to be cheaper, general purpose, short design-to-production cycles, larger user base to uncover and fix defects, provides current technology solutions. They may not be suitable for specific roles, environments, meet specific requirements, fit you to market trends/obsolescence issues and doesn't support any code level modification. Examples: Hardware (Computing - HP/DELL/Apple; Applications - Microsoft Office/Anti-Virus Software; Bases - VME/PC/PCI Processors - Sun/INTEL; Disk Drives - Western Digital/Hitachi; Peripherals - Printers/Monitors/Keyboards/Scanners); Software (Operating Systems - UNIX/Windows/OS2; Databases - Oracle, Sybase, SQL; Graphics Packages); Firmware (Software in Gateways/Routers/Firewalls).	MOTS Modified/Minority off-the-shelf (MOTS) is a type of software solution that can be modified and customized after being purchased from the software vendor. MOTS is a software delivery concept that enables source code or programmatic customization of a standard packaged, market-available software. MOTS is a software delivery concept that enables source code or programmatic customization of a standard packaged. Considerations: Organisations/businesses need the enduring capabilities to specify requirements, design, document, develop, test, certify, upgrade, release, support, upgrade, update, withdraw, managed baselines capabilities plus the surrounding infrastructure, test tool/packages, third party supplier support.	ISV An independent software vendor (ISV) is an individual or business that builds, develops and sells consumer or enterprise software (e.g. SaaS). Although ISV provided software is consumed by end users, it remains the property of the vendor. An ISV is also known as a software publisher and builds primarily builds backend, system level applications for specific niche markets or business verticals (finance, marketing, education) and not for laptop use. Examples: Software applications that run on some or all backend platforms, like Windows, Linux or Apple. Applications developed by an ISV range from basic utility or productivity applications to enterprise class business process applications, including customer relationship management (CRM), enterprise resource planning (ERP) and automation.	GOTS/NOTS/Niche/Bespoke GOTS (government off-the-shelf) products are typically developed by the technical staff of the government agency for which it is created. It is sometimes developed by an external entity, but with funding and specification from the agency. Bespoke agencies can direct control all aspects of GOTS products, these are generally performed for government purposes. NOTS (NATO off-the-shelf or niche off-the-shelf, depending on the context) product is developed by NCIA (for NATO Consultation, Command, and Control) to meet specific requirements for NATO. In the more general context, niche off-the-shelf refers to vendor-developed software that is for a specified and narrow market segment, in comparison to the broad market for COTS products. Considerations: A bespoke solution will be designed to fulfil whatever requirements you have, with the obvious advantage of being tailored to suit the needs of your organisation, but it will come at a cost. Don't underestimate the degree of specialist expertise, components, services and the availability items when you go down the route of niche products. Tailored bespoke solutions often add further risks and costs regarding system through life support/upgrades, dealing with obsolescence and interfaces / integration with other systems.
	ICI Invested Corporate Infrastructure (ICI) is the fundamental hardware IT building blocks that underpins the success of the entire organisation or business that help deliver the customer solutions and provide the business, legal, safety and environmental information technology that allow the business to function effectively and efficiently. It is the base upon which COTS, MOTS, ISV and GOTS/NOTS is either hosted or accessed by users and systems. Having the right infrastructure at the right time is critical to business success, and it should be underpinned by a Technology Strategy, multiple Technology Roadmaps and funded and resourced implementation/delivery projects, with technically skilled and competent motivated teams that are delivery focused.	HCI Human Capital Investment (HCI) is the recognition of the value people bring to businesses, however there is a need for the people to have the right leadership, right skills, aptitudes for change, training and refresh training in order to setup, manage, use, fit the COTS/MOTS/ISV tools and techniques, which includes not only people internal to the organisation, but also the end users, partners, suppliers and support agencies. The maturity of the business will affect all these issues.	Cultural Fit Cultural fit deals with how your technology and people fit together with the culture of the organisation: the characteristics, behaviours, assumptions/language and values/technicals that exist within the organisation's culture. You want technology and people whose values, beliefs, outlook and behaviour can seamlessly fit in with your organisational culture, to allow a good cultural fit. Failure to consider this will result in disharmony, stress, added pressure, broken workflows, reduced outputs and a negative effect on the business bottom line.	Managed Services An information technology (IT) services provider essentially manages and assumes responsibility for providing a defined set of services to its clients either proactively or as the MSP (not the client) determines that services are needed, typically on a proactive basis and under a subscription model based on a set of Service Level Agreements (SLAs), Operational Level Agreements (OLAs), Key Performance Indicators (KPIs) if done properly. Organisations have difficulties defining services, measuring them (especially across multiple boundaries), manage expectations and finally negotiate change/adjustments. When done incorrectly they result in lost production, specific service delivery, costs unnecessary time and money, and deteriorates trust and working relationships.
TERTIARY ITEMS	Technology Strategy/Roadmaps Technology should not be procured for the sake of it. It should be aligned to a Technology Strategy which is the overall plan which consists of objectives, principles and policies relating to use of the technologies within a particular organisation. Such strategies primarily focus on the technologies themselves and in some cases the people who directly manage those technologies. The strategy can be implied from the organization's behaviors towards technology decisions, and needs to be written down and communicated. Technology roadmaps are plans that matches short-term and long-term goals with specific technology solutions to help meet those goals. There are plans that applies to a new product or process, or an emerging technology.	WBP Business process management (BPM) is a systematic approach to making an organization's workflow more effective, more efficient and more capable of adapting to an ever-changing environment. A business process is an activity or set of activities that will accomplish a specific organizational goal. Within Business Processes (WBP) is the processes of providing EEE capabilities in terms of people, products, processes & performance.	Shelfware Shelfware is not a derogatory term and may apply to any software, but those that are widely popular and used. Software becomes shelfware depending on the user and not on the software itself, but in the case of shelfware and blueware, it also often becomes shelfware because there is often no need or desire to use the software. One major reason software becomes shelfware is when companies license more software than they actually need because of either a good discount or inability to plan the actual number of required users.	Licensing and Data Rights Licensing and Data Rights - COTS Software is usually distributed under license (a per-user fee is typical); COTS documentation is normally copyrighted; distribution as part of another product usually requires special arrangements and a copy fee; Software source code and designs for hardware are usually proprietary and protected by copyright or patent - even after it is no longer distributed. Tenderers may offer a variety of different structures for licensing agreements and consideration needs to be given as to which is most appropriate for the institution. This is especially important with regards to future requirements. Licenses may be offered on a per user basis, per server or unlimited licenses for the organisation. Whatever is offered it is important to consider the effect of future fluctuations. Furthermore thought needs to be given as to how easy it is for the business to manage and control the licenses it is granted and to ensure that it is never under-licensed.
	Legacy Applications Legacy applications another issue that keeps CIO's up at night. The rip and replace approach is expensive and time consuming, difficult to justify and risks interrupting business activities. Constant technological change often weakens the business value of legacy systems, which have been developed over the years through huge investments. Despite issues of obsolescence, increasing support costs and inadequate documentation they continue to be used due to the lack of clear roadmaps, the use of legacy wings or screen scraping, because of their unique position within business processes or because they contain invaluable competitive advantageous knowledge and historic data.	Legacy Data All architects have to live with questionable legacy data designs and work around the problems they present. What legacy data exists, do you want to migrate, do you need to store, how do you deal with inconsistencies, gaps or incorrect data. The hardest part of migrating to the cloud is dealing with legacy enterprise email archives and personal email archives. Don't under estimate the scale of this problem.	Data Ownership Companies can't do anything if they don't own the data they create. The key point to take away from data ownership issues is that it all boils down to the contract, which states who owns the data. Applications and hardware infrastructure are largely irrelevant, because it is the data that drives business and decision making, and that can live on almost any platform these days. Avoid vendor lock-in, make sure you have a secondary data copy in some other commercial vehicle, write clauses to cover the events such as data loss, data is stolen or providers go bankrupt, and define it properly.	Future Environments Current and Future Data and Application Migration / Market Forces / New Standards / Legal & Environmental Changes / New Competitors - We can't predict the future and what technology changes are around the corner, but we can take steps to mitigate the effect of change. Follow Government Recommendations (see Government Digital Services (GDS) on a page), have a Technology Strategy and Roadmaps, develop a tailored Enterprise Architecture Framework and follow it, make your systems modular with clearly defined boundaries and interfaces to allow them to be evergreen (swapped out with minimal effect on the rest of the business), avoid vendor lock-in and help your users by providing common and consistent user interfaces to reduce training, minimize knowledge loss and assist with intuitive use of your systems, otherwise people will either not use them or find workarounds.

Figure 21: High Level of Key Technology Factors

Follow recommended published best practices where you can, as they have often been lessons learnt through very painful and costly processes of doing things the wrong way. Table 12 provides once such example, however there are lots available to those that are willing to invest a little time and effort to unearth them and take appropriate actions.

Government Digital Services (GDS) on a Page

Aims	<ol style="list-style-type: none"> 1. Job is digital transformation of government 2. Always start with user needs 3. Remain Agile 4. Work to a set of Design Principles 5. Ensure government data is good data
Principles	<ol style="list-style-type: none"> 1. Start with user needs - Do research, don't make assumptions 2. Do less - Govnt do only Govnt work; Reusable and Shareable Platforms 3. Design with data - Data driven-decisions; prototype & iterate after live 4. Do the hard work to make it simple - It is hard work to make things simple 5. Iterate. Then iterate again - Release MVP early; test with users; reduce risks 6. This is for everyone - Accessible design is good design; Build for User Needs 7. Understand context - think hard about the context of using the services 8. Build digital services, not websites - It all adds up to what people need 9. Be consistent, not uniform - Same Language; Same Design Patterns 10 Make things open: it makes things better - Share code, designs, ideas, intentions, failures
Elements	<ol style="list-style-type: none"> 1. Service Toolkit - Standards; Design & Style; Components; Monitoring; Buying 2. Digital Marketplace - Buyer's Guide; Templates; Writing Reqsmt; Shortlisting & Evaluation 3. Introducing Verify - a new way to prove who you are online 4. Introducing Notify - will reduce the need for many services to post letters to people 5. Common Technology Services - Apps; End User Compute; Hosting; Identity & Integration; Networks; Service Management 6. Buying - G-Cloud, Digital Outcomes and Specialists or Crown Hosting Data Centres framework

Table 12: One Example of IT Best Practice

We often forget that data and knowledge exist in different forms within the technology stack, and what you can do with it depends on where it exists and what standard or form it has been created within. Figure 22 is a modified example of the traditional 7 layer ISO, that attempts to show the interconnection of data within the standards, processes, applications and IT systems. There are many interpretations of this in the literature, and this is only one view point, and others may be more applicable. The key to a lot of things in life is to tailor what you need, keep or reinforce the good stuff, remove or reduce the bad stuff, and bear in mind in different environments and circumstances, priorities and previous criteria may well change.

Copyright © 2017, Innov8or Solutions Ltd. All Rights Reserved

11 Stage (Modified) Open Systems Interconnection (OSI) Data Model				
Layer		Protocol Data Unit (PDU)	Example Protocols/Standards	X-Layer
User Layer	10. Gov/Legal Compliance	User/Sector/Governmental/Legislation	ISO, British Standards, NATO STANAG, International Mil-Std	Enterprise Architecture
	9. Org/Political/Sector	User/Organisational/Political	Def-Stan, JSPs, Service Design Packages & Patterns, ICDs	
	8. User/Financial/Function	User (Capability Mgmt/Standards Board)	RFC, MODAF, DLoD TEPID-OIL, FRC 102, UK GAAP	
Host Layer	7. Application	Data (App Method/Protocols)	TLS, FTP, HTTP, HTTPS, SMTP, SSH, Telnet	Security Service, Mgmt Functions, MPLS, ARP, DNS
	6. Presentation	Data (App/Network format translation)	CSS, GIF, HTML, XML, JSON, S/MIME	
	5. Session	Data (Local/Remote App Connections)	RPC, SCP, NFS, PAP, AppleTalk	
Media Layer	4. Transport	Segment (TCP) / Datagram (UDP)	NBF, TCP, UDP	Security Service, Mgmt Functions, MPLS, ARP, DNS
	3. Network	Packet (Datagrams on same network)	AppleTalk, ICMP, IPsec, IPv4, IPv6	
	2.5 MPLS	Multiprotocol Label Switching (MPLS)	IP Packets, Native ATM, SONET, Ethernet frames	
	2. Data link	Frame (Node Transfer/Error Correction)	IEEE 802.2, L2TP, LLDP, MAC, PPP, ATM, MPLS	
1. Physical	Bit (Raw Data/Encoding)	DOCSIS, DSL, Ethernet Physical Layer, ISDN, USB		

Layer	User/Software	Hardware Platform Components	System Software	X-Layer
11. Info Layer	User Generated Artefacts	Compute Hardware	Graphical User Interface (GUI)	Encryption & Info Handling
	Templates/Forms	Compute Memory	Operating Systems & Firmware	
	Rule Sets/Filters	Data Store Storage/Databases	Device Drivers	
	Workflows/Processes	Connectivity Elements	Mgmt Utilities (Service Access, Sign-in, Security, Cyber, Backup, Recovery)	

Figure 22: 11 Stage (Modified) OSI Data Model

Data in a very simplistic viewpoint exists in four main electronic forms, as depicted in Figure 23. When computers were first developed, data existed in mechanical form in terms of transient wheel/cog settings, but when the ability to capture and save data arrived on disks, it was in the form of Transferable Formatted Protocol Data (TFPD). The vast majority of data that we access today is in this form. As more complex systems were developed, we started putting data in containers, in the form of Containable Application Based Data (CABD) that was accessible through specific applications and queries. The arrival of the 'interweb' made Linkable Web Resources Data (LWRD) possible, and static data was now reachable around the world. We are entering a new age of Requestable Web Resources Data (RWED) where we can make requests and receive replies, from which we can make decisions that result in actionable workflows, trigger events or set up alerts.

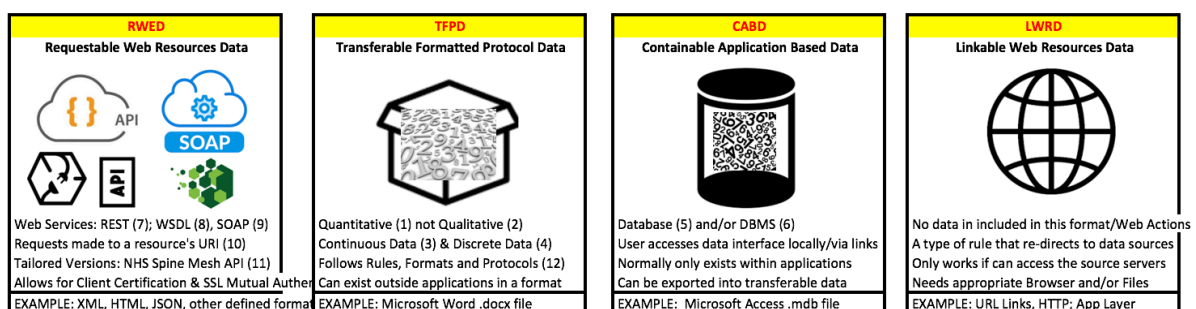


Figure 23: Data Main Forms

In this world of ever present data, we often overlook that fact that every piece of data we access has to be created, hosted, protected, powered, paid for by someone, maintained and cared for. We may think of the application server which we need to connect to, but how much thought is given to the surrounding systems that need to be in place in order to support the application server and to allow it to do its job. Figure 24 shows a generic hardware view of some typical servers and user access devices that are needed to access data. The viewpoint is not supposed to be comprehensive, only illustrative in that fact that for every application server there are multiple (30 in this case) back-end systems that need to be architecture, designed, funded, built, housed in a building, supported and maintained, to make the system work. Get any of it wrong and it could have catastrophic business impacts, cause large delays, costs lots of money to get right and take critical resources off other important activities thereby having huge knock-on effects that could take years to recover.

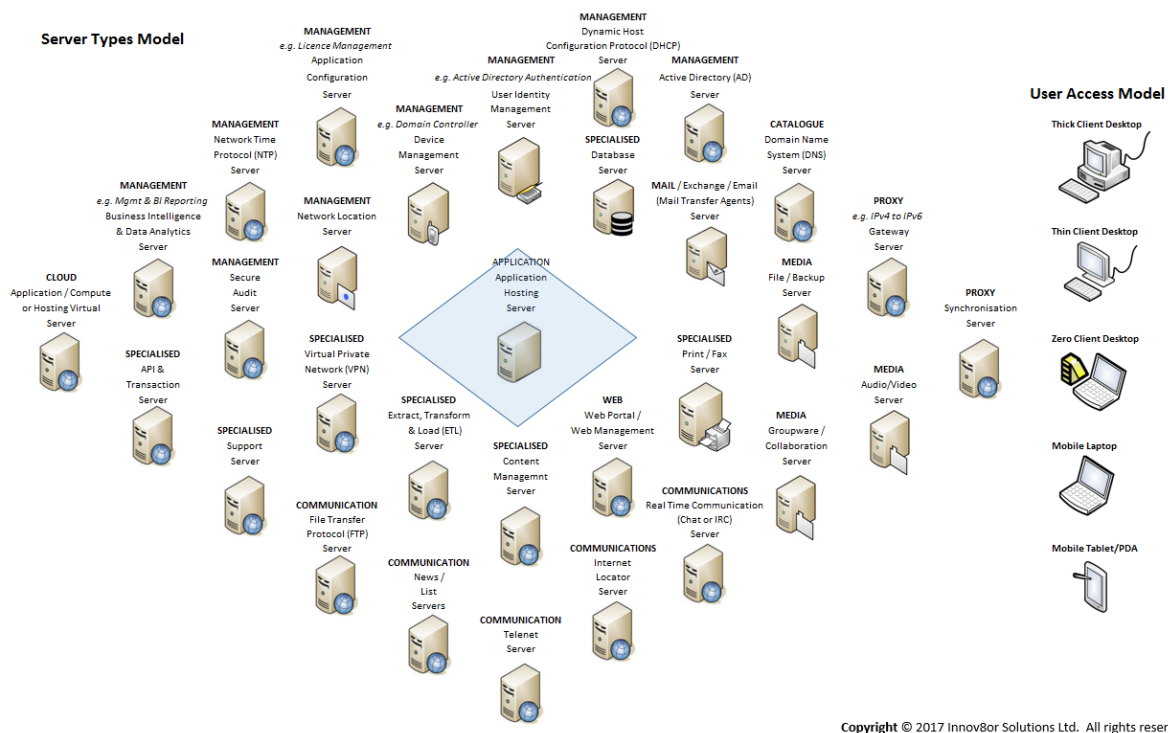


Figure 24: Elements of IT Architecture – A Server and User Access Viewpoint

Data is nothing without the people who are empowered to create it, classify it, cluster it, store it, access it, modify it, keep it up to date, aggregate it, ask the right questions of it, apply the right tools to it, apply the right techniques to it, sift it, process it, optimise it, filter it, analyse it, enrich it, check it, contextualise it, learn from it, make decisions on it and ultimately seek to gain business or personal value from it. These people need to be trained and re-trained in order to allow them to keep data mining to obtain the best business value, and recognise that however good the systems are ... Rubbish in, still equals rubbish out.

The advent of big data means the right balance has to be achieved between personal and organisational data privacy and ensuring that people obtain the full value from the data. We have never had so much data at our finger tips, but there is a danger that we could be drowning in data but starved of information and knowledge. We need to surround data with processes, procedures and workflows in order to go through the 6 stages of data maturity, as displayed in Figure 25. Starting off at the Identifying, Dreaming and Imagination Phase

(coloured Yellow), working through the Collating, Realist and Planning Phase (coloured Orange) leading to the Critical Challenge Phase (coloured Red) where the Go/No Go decision is made to commit further resources to the idea. If successful, it enters the Setting Conditions for Action Plans Phase (coloured Green), followed by the PDCA Method Phase (coloured Light Blue) and ultimately ending up in the Benefits Realisation Phase (coloured Dark Blue), all the time data is matured through systems and processes.

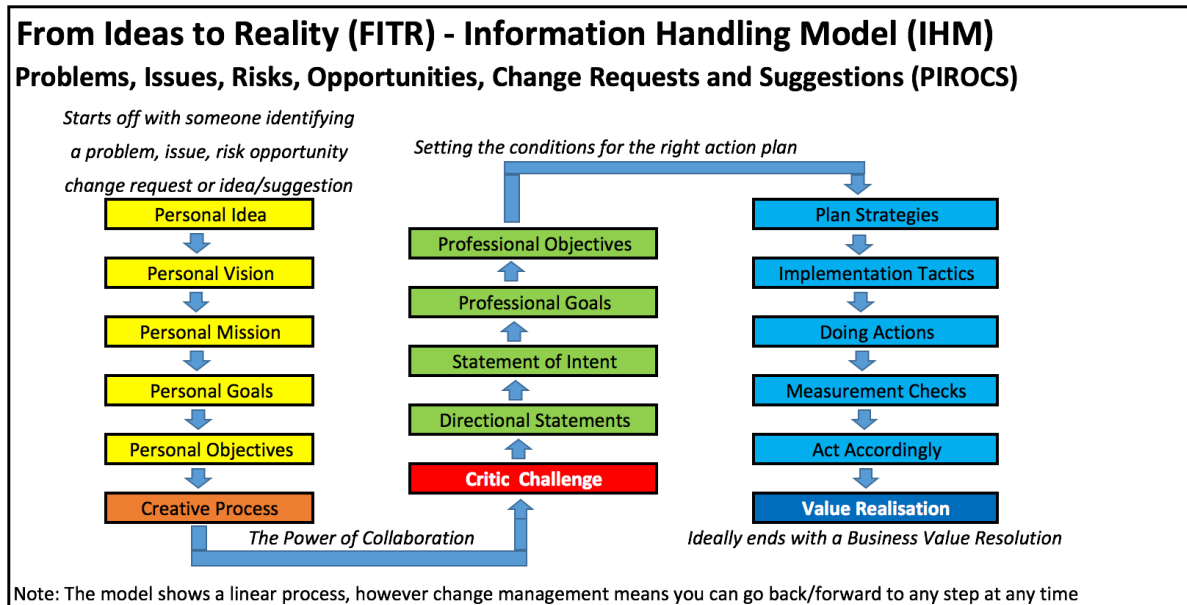


Figure 25: The From Ideas to Reality (FITR) Information Handling Model (IHM)

Traditional it was very clear what needed to be done to resolve a problem (IR1), as shown in Figure 26. As systems become more complex, inter-dependencies explode, emergent behaviours arise and not all the variables are known or even identifiable at the start, then IT Architectures are needed to augment human capabilities and help develop progressive solutions (IR6). Without the right people/processes, tools/architectures and techniques/methodologies there are plenty of scenarios (IR2 to IR5) that lead to failure or incomplete solutions.

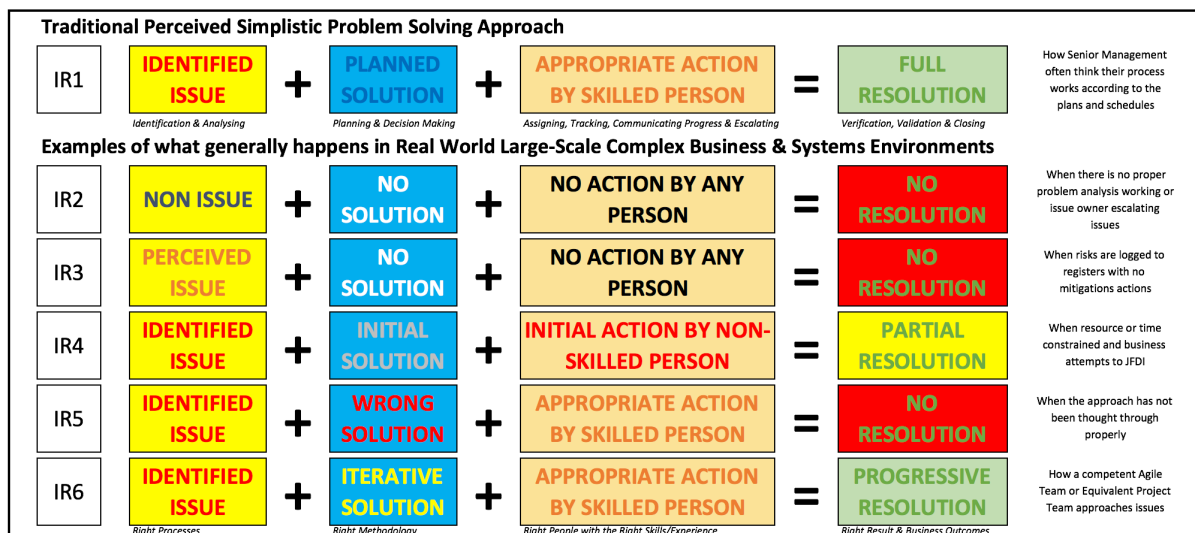


Figure 26: Approaches to Problem Solving

System Engineering can be considered the interdisciplinary approach and method to enable the realisation of successful systems from the point of view of satisfying the needs of the end users (in-service personnel), the customers (budget holders and setting of requirements), the business (achieving profit margins, maintaining/enhancing reputation and delivering capabilities) and other stakeholders (political, legal, safety and environmental). It is a proven structured comprehensive approach to solving today's complex technical challenges, particularly those related to the design and development of highly sophisticated systems, such as aircraft, ships, automobiles, telecommunications networks, energy infrastructures or information management systems. It is the role of the Systems Engineering Department to integrate all the key elements in a system including hardware, software, firmware, people, information, techniques, facilities and services, to achieve the required system capability (functional and non-functional) and performance.

It is not an exact science, there are multiple methods, taxonomies and standards, however whatever specific approach is adopted, but to be successful it normally needs the following elements:

- an analytical approach to model, understand, quantify and characterise problems;
- ability to understand customer needs and define functional plus non-functional requirements;
- creativity to explore innovative 'out of the box' approaches and solutions;
- to take a holistic view of the problem space;
- an awareness and knowledge of the many disciplines that impact on system design;
- strong communication and team building skills, because it is team sport to get the solution across the line;
- leadership skills to help motivate, train, mentor and provide purpose, plus people skills to give people autonomy and develop mastery of the skills needed to do the jobs.

Society has an expectation that technology will help us solve our biggest and world spanning societal problems ahead, however in order to do this we must:

- Understand, listen and sympathetic to the world we live in and its constraints and limitations to bounce back to the negative things we do to it;
- Find holistic synchronised solutions that have the ability to take into account a lot more eventualities and responses than we understand today, through detailed observation, critical analysis and iterative learning;
- Protect against unintended consequences, and provide solutions that are smarter, have a less impact on the environment being resource efficient and sustainable, self organising, robust, modular, safe and secure;
- Develop our understanding of the emergent and resultant behaviours of complex systems that will help us solve the problems;
- Finally look at ourselves, our behaviours/attitudes/needs/expectations, our skills and ability to create an evolving, diverse workforce that has the capability to use more complex tools, capacity to embrace change, can innovate and respond to competitive pressures.