

Dissertation

Cloud Solution Strategy for Engineering Analysis

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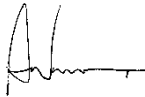
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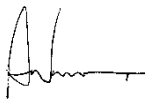
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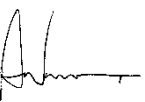
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Thanks to the The Company for their patience with me in completing this work. The contribution of interviewees & survey respondents has been crucial and for this I am grateful. Finally, thanks for the expert, salient guidance from Dr Roisin Mullins.

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Glossary

Common Term	Link	Expanded Term / Description
ADAS		Advanced Driver Assistance Systems
Ansys	https://www.ansys.com/	Ansys – Simulation Software
Autodesk	https://www.autodesk.co.uk/	Autodesk – Engineering Software
AWS	https://aws.amazon.com/	Amazon Web Services – Cloud
Azure	https://azure.microsoft.com/en-gb/	Azure - Cloud
CAPEX		Capital Expenditure
CATWOE		Customers, Actors, Transformation Process, World View, Owners, Environmental Constraints.
CCM		Cloud Controls Matrix
COBIT	https://www.isaca.org/resources/cobit	Control Objectives for Information and Related Technologies
CSA	https://cloudsecurityalliance.org/	Cloud Security Alliance
CSFs		Critical Success Factors
CST	https://www.3ds.com/products-services/simulia/products/cst-studio-suite/	Computer Simulation Technology
HPC		High Performance Computing
HVAC		Heating Ventilation Air Conditioning
IaaS		Infrastructure as a Service
IDC	https://www.idc.com/about	International Data Corporation
IES	https://www.integratedsoft.com/	Integrated Engineering Software
IET	https://www.theiet.org/	Institute of Engineering & Technology
ITIL	https://www.axelos.com/	Information Technology Infrastructure Library
Ltd		Limited
MATLAB	https://www.mathworks.com/	MATLAB

MSC	https://www.mscsoftware.com/	MacNeal-Schwendler Corporation
NAFEMS	https://www.nafems.org/	National Agency for Finite Element Methods and Standards
Nimbix	https://www.nimbix.net/	Nimbix
NIST	https://www.nist.gov/	National Institute of Standards & Technology
NPV		Net Present Value
ODCA	https://www.opendatacenteralliance.org/	Open Data Center Alliance
OPEX		Operating Expense
PaaS		Platform as a Service
RAM		Random Access Memory
ROI		Return of Investment
S&C		Smart & Connected
SaaS		Software as a Service
SLA		Service level agreement
SSM		Soft Systems Methodology
SUoM		Standard Units of Measure
TCO		Total Cost of Ownership
TOGAF	https://www.opengroup.org/togaf	The Open Group Architecture Framework
VPN		Virtual Private Network
XaaS		Anything as a Service

Abstract

This study examines the changing technology drivers, value creation, structural changes and financial aspects of digital transformation in The Company with special attention to computation for engineering analysis. Fundamental technologies and associate terminologies are reviewed in order to level the understanding of digital transformation. Key stakeholders were surveyed and interviewed to better appreciate the current state, expectations and potential for computation and other cloud based services. Measures are identified to aid benchmarking of the current and potential solutions. Recommendations are made to migrate the primary engineering analysis tool to a SaaS solution in order to improve access, reliability, elasticity and scalability amongst other attributes. Consideration is given to the additional analysis tools in the company and how computational demands can be satisfied for them with respect to performance and financial efficiencies. The work reveals a gap between the strategic approach to IT services, infrastructure and support today and the emerging needs of the organisation. Recommendations are made to consider a CIO, a Strategy for IT and establish visible status and metrics for the currently unknown tools and services landscape.

1 Introduction

1.1 The Purpose

This investigation considers the future needs of the Company¹ relating to cloud computing. There will be a specific focus on the engineering analysis needs for the Company and a view of other types of cloud based services and needs in the business will also be captured for context.

The primary aim is to recommend a cloud based solver solution that can support engineering analysis in the coming years but is considerate of the evolution in the rest of the business. Solutions and recommendations for the entire company are not in scope however these are considered where appropriate to help promote a more constructive discussion about enterprise service tool management in the Company and to bring robustness to the proposed engineering solution. The secondary aim is to provide a method and framework for a holistic review of the cloud enterprise strategy for the Company.

1.2 The Company

The Company is a large multinational cooperation specialising in sensor design and manufacture for multiple markets. These include automotive, aerospace, industrial and medical. The Company has an annual revenue in excess of 3.5 billion US dollars, over 20,000 employees and operates in 11 countries around the world. They have an aggressive growth plan which is reliant on success in emerging technologies over the next 3-4 years. This will rely on leveraging existing technologies and IP in the business for new applications and developing new skills

¹ Where “The Company” or “Company” is used to protect the identity and business information relating to this work

and knowledge to compete in new areas. The Company is on the NYSE is governed by a board of directors. Operation of the business is overseen by the CEO and an executive leadership team comprised of a Chief Financial, Technical, Strategic, Supply Chain, Human Resource & Legal Officers and several vice president roles aligned with market segments. (Note, there is no Chief Information Officer, this will be explored in later sections.)

1.3 The Approach

This work will help summarise and clarify the systems and associated terminology common to cloud computing and enterprise solutions in business. It will present the industry trends and provide comparison of the Company status. It will explore the financial aspects of our solutions today and the potential alternative technology and business models. The value of solutions will be discussed and considered against the Company vision. Engineering leaders and IT leaders will be engaged to establish views, needs and aspirations in the Company. The consumers (engineering population) will be surveyed to understand current needs & satisfaction levels. Incumbent suppliers will be approached to demonstrate technology & solutions that align with Company needs. Recommendations will be made for the Company to consider ahead of their next Annual Planning cycle.

1.4 Objectives

- Clarify the digital transformation landscape for the organisation
- Assess the state of cloud services in The Company
- Assess the demand & satisfaction for computation in Engineering
- Recommend actions for Engineering computation services in the Company

- Recommend steps The Company can take to compliment IT service delivery and business strategy

2 Literature Review

2.1 Digital Transformation

Digital Transformation is a popular phrase in business today. This is perhaps over utilised to describe anything that is a change from the traditional way of doing things however, it has a specific scope. Hess et al. (2016) writes that “it is concerned with changes digital technologies can bring about in a company’s business model, which results in changed products or organisational structures or in the automation of processes. [...] (The) conceptual framework for formulating digital transformation strategy identifies the four key dimensions of every digital transformation endeavour: (a) *The use of technologies* reflects a firm’s approach and capability to explore and exploit new digital technologies. (b) *Changes in value creation* reflect the influence of digital transformation on a firm’s value creation. (c) *Structural changes* refer to the modifications in organisational structures, processes and skill set that are necessary to cope with and exploit new technologies. (d) The *financial aspects* dimension relates to both a firm’s need for action in response to struggling core business as well as its ability to finance digital transformation endeavour.”

The IDC (2020) states that Digital Transformation (DX) is at the center of modern organisational structures. There are four key technologies that both drive and enable Digital Transformation (Haque, 2020, p. 12):

2.1.1 Cloud computing

Haque goes on to highlight that Cloud computing is the first and most crucial enabler for digital transformation, the other 3 coming in sequential order as shown in subsequent sub-headings.

Research and literature is consistent in underlining the necessity of cloud strategy for a CIO. This should lead to meaningful, self evident value for the business. (Abdula, et al., 2018)

This will be explored in more detail in later sections. The resumption of the literature review will aid familiarity with the key topics in cloud computing and digital transformation.

2.1.2 Big Data: Trends, Patterns, Behaviours, Interactions

Data is a valuable asset and outgrowing traditional database and warehouse models. It is a combination of organised and unorganised data that can be searched, analysed and used to support predictive modelling. Gartner (Gartner, n.d.) initially presented the 3Vs of Big Data which are Volume, Velocity & Variety. This was later expanded by the industry to include Veracity, Complexity & Variability and is referred to as the 5Vs (as “complexity” is an inconvenient break of alliteration).

Benefits of big data for business can include increased visibility of the customer, security awareness, reduced burdens on data warehousing, use of analytics for price optimisation, improvement of operational efficiency, preventative maintenance & guidance, introducing recommendation engines for internal and external users (akin to “you may also like” on a streaming platform), enabling the internet of things.

2.1.3 Artificial Intelligence (AI): Machine Learning, Robotics, Deep Learning

AI can still seem like sci-fi to many, but it is very much part of today’s business. There is plenty of hype and increasing awareness, studying applications and understanding key points of human value contribution in a company is essential to appreciate the value of AI. Beside the cacophony of views around AI, it is very real

for business; a CIO survey looking at AI implementation in industry during 2015-2019 noted a 270% increase (Gartner, 2019).

AI is the combination of Machine Learning (ML), Deep Learning (DL) and Data Science. DL is the architecture by which the machine will operate (think) and ML is the statistical tool set to explore the data. Data Science touches on all layers and is mainly focussed on the mathematical tools used.

AI can bring substantial benefits to business: automating processes, gaining insights through data analysis, and engaging with customers and employees (Haque, 2020, p. 25). More tangible examples might include:

- Automating routine processes and removing drudgery to free up valuable human resource
- Enabling real-time insights to internal operations performance
- Improving threat detection in the digital landscape
- Transforming IT infrastructure to optimise services

2.1.4 Internet of Things (IoT): Computing Devices, Connected Systems

In short, IoT is the integration of data from different devices via the internet. Many devices communicate or connect with each other to bring a user insights on an individual device (component), system (machine), or network (factory, city, ...).

There are four key elements involved in the IoT:

- Sensors – device measuring something of interest
- Connectivity – Gateways that enable the secure sharing of sensor data
- Data Processing – clouds or servers that enable the query or calculation of collective data sets

- User Interface – applications that allow a use to visualise or interrogate everything in that is connected and the sum of the data

2.2 Cloud Computing & Characteristics

It is important to understand what cloud computing is and what it does. There are 3 realms to consider: Characteristics, Service Models & Deployment Models. This is well defined by the National Institute of Standards and Technology (NIST) (Mell & Grance, 2011).

2.2.1 Characteristics

It is essential to keep the following characteristics in mind when considering the adoption of cloud with respect to one's business.

2.2.1.1 Rapid Scalability or Elasticity

Scaling of resource is per the real time need, not a fixed design based on a predicted peak use. In other words, the company can quickly add or reduce computing or storage capacity to meet the transient demand.

2.2.1.2 Resource Pooling

Where several clients can be serviced from the same resource. In the case of the Company this would remove the need for domain integration before acquisitions or partners could utilise the primary cloud resources. It also applies at a macro scale where regions or sites can share the central resource and remove or reduce the complexity of site license configuration.

2.2.1.3 Broad Network

Ensuring the resources can be accessed on a multiplicity of digital devices, not just on premise desktop computers. Provided there is internet, a device and the staff member using said device can be effective regardless of location. Whilst having precedent, this is perhaps never more pertinent to the new world we are working in post Covid-19.

2.2.1.4 On-Demand

The self service of resource; the service provider is not involved in the use or consumption of the cloud resources. Typically, a portal is setup by the provider to enable a company to manage the level of use, approved devices, etc.

2.2.1.5 Measurement

The resource is inherently metered and as such allows for automatic optimisation and control of the resource. User accounts, storage, bandwidth, processing power can all be configured with respect to measurement.

2.2.2 Cloud Computing Taxonomy

The taxonomy has been develop from the NIST tool by the IT community. Jackson & Goessling (2018) effectively map this out in their graphical model of cloud taxonomy.

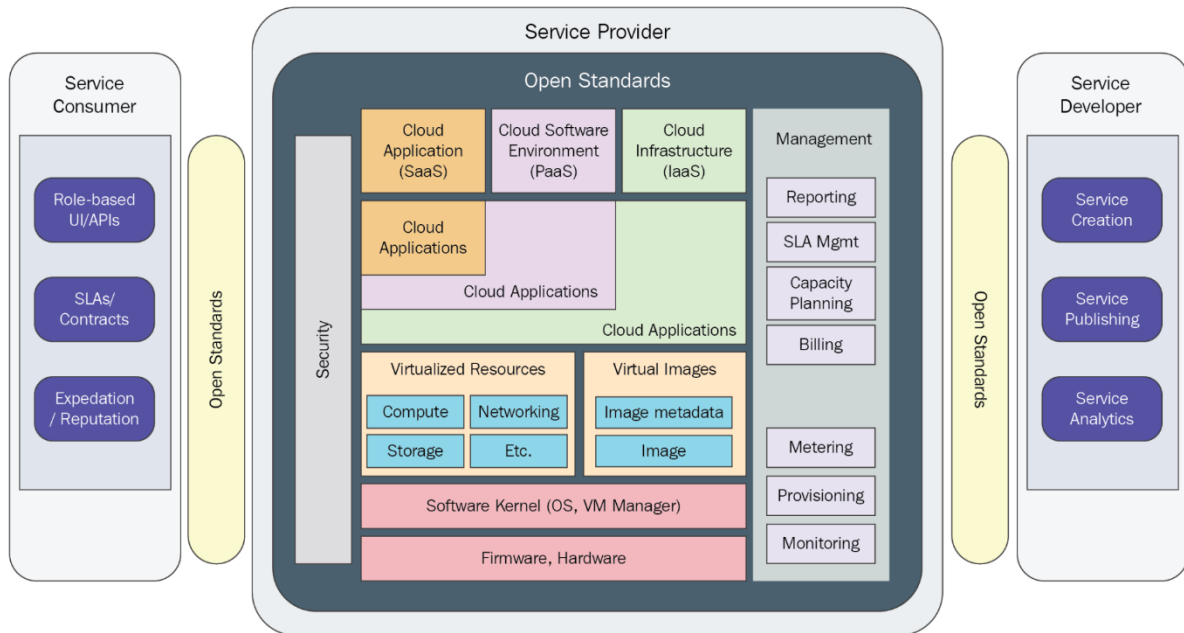


Figure 1 - Jackson & Goessling's (2018) Cloud taxonomy model

2.2.3 Cloud Service Models

- **Infrastructure as a Service (IaaS)**

The foundation layer and home to storage, computing resources, networks etc. This is where the Company's IT group leverage *Azure & Viptela* today for virtual servers and infrastructure.

- **Platform as a Service (PaaS)**

Sitting on top of IaaS this layer enables application deployment.

- **Software as a Service (SaaS)**

Stacked on the prior services, this allows the consumer (employees or customers) to use applications on the cloud via internet connected devices. *Workday* is a prominent example of this in The Company.

- **Anything as a Service (XaaS)**

Crucially avoiding an awkward overly enunciated acronym, XaaS is the ready term used to describe the cloud delivery model. Consumption can be per user, per unit of time or per unit of use (e.g. data transfer). This is where the Company's engineering analysis cloud, *Nimbix*, sits today.

2.2.4 Cloud Deployment Models

- **Private**

As implied, this is a wholly owned cloud environment establish on the premises of the host or the client. Typically more expensive due to the investment to establish and support, but the most secure environment.

- **Public**

An infrastructure designed for the use of any individual or organisation.

- **Hybrid**

Combining two or more types of cloud. Useful for rapid upscaling or complimenting existing cloud or infrastructure capacity with other cloud spaces.

- **Community**

A collective of users that share standards for security or legislation.

Government departments would operate like this; separate environments but on the same private infrastructure.

- **Multi**

Where multiple cloud spaces and providers are used to provide storage or computing in a single architecture. This can be used effectively to get the unique benefits from each service.

- **Gaia-x**

A 2018 innovation to allow EU countries to move data across borders whilst preserving digital sovereignty. Not technically a cloud but a federated infrastructure. (GAIA-X, 2020)

Jackson & Goessling (2018) provide excellent use case evaluations for cloud models in chapter 6 (p. 113-114) of Architecting Cloud Computing Solutions.

2.2.5 Cloud Ecosystem

2.2.6 Benefits & Challenges of Cloud

Haque (2020, p. 62) comprehensively explores the benefits of the cloud in his book. Chang, et al., (2015, p. 10) effectively summarise the risks of cloud adoption explored in previous work by Catteddu & Hogben (2009), Khajeh-Hosseini, et al., (2012). Yan (2010) provides a summary on the advantages & challenges of cloud computing with useful scenario based descriptions to aid relateability.

These combined assessments are adapted and shown in Table 1 - Benefits & challenges of cloud.

Table 1 - Benefits & challenges of cloud

Benefits	Challenges
Increased Agility	Security – sensitive information outside the premises
Consumption based Delivery	Compliance
Elasticity	IT Operating Model – governance and responsibilities get blurred
TCO & OPEX Smoothing	Service Assurance – flexibility to adapt to business demand
Accessibility	Consistent Performance – cross platform issues
Innovation & Currency	Financials – business model readiness
Sustainability	Integrations – cost to join up
Visible and Contractual SLAs	Vendor Lock In – being held to ransom with a flawed design
Portability	Cloud Expertise – skills not present in IT today, investment cycle to upskill within the company is prohibitive and lags the evolving needs
No Maintenance Cost	Change Management – running the transition is crucial and needs expertise that may not be present in the incumbent IT org.
Availability Guaranteed	Adoption
Cyber & Physical Security	Performance – less than expected due to ineffective scope of needs or provider capability
Disaster Recovery	Connectivity – reliant on a fast, stable internet connection
DevOps	
Futureproof	
More Business Focus	

For key cases, mitigation approaches, indicators and alternatives are published by Chang, et al. (2015).

2.2.7 Cloud Infrastructure Management

Moving to a cloud requires thorough evaluation of the business and potential solutions. Moving and managing multiple clouds in parallel with traditional IT infrastructures would exceed most of the incumbent IT resources and skills. This is well recognised in the industry and a growing market of infrastructure/enterprise management is established.

2.2.8 Cloud Service Brokerage

Aggregators bundle a variety of service into a singular interface. Integrators bring value by automating within and across a variety of environments. Customizers adjust or modify the existing solutions.

In general, brokers bring expertise and experience to their customer as well as an ability to negotiate with more intelligence and scale. CSBs are an effective way to align a more traditional IT function with the business ambitions relating to cloud and digital transformation.

2.2.9 Governance & Change Management

The change to cloud can be complex, but some of the common drivers are:

- New knowledge required
- Dynamic nature of Infrastructure
- New cloud service management tools
- Rapid Innovation and fast moving market
- New management models

- Distributed Ownership
- Continuous optimisation

The technology is not the only change, as with most technology adoptions, the culture and mindset will also evolve. Jackson & Goessling (2018) accurately capture these in Table 2 - Transitions in affected domains of cloud migration.

Table 2 - Transitions in affected domains of cloud migration

Domain	Transition From	Transition To
Security Framework	Infrastructure-centric	Data-centric
Application Development	Tightly Coupled	Loosely Coupled
Data	Mostly Structures	Mostly Unstructured
Business Processes	Mostly Serial	Mostly Parallel
Security Controls	Enterprise responsibility	Shared Responsibility
Economic Model	Mostly Capex	Mostly OPEX
Infrastructure	Mostly Physical	Mostly Virtual
IT Operations	Mostly Manual	Mostly Automated
Technology Operational Scope	Local/Regional	International/Global

Haque (2020, p. 117) highlights 3 stages of change as; Application, Network, Security.

2.3 Business Analysis

2.3.1 Drivers, Metrics & Use Cases

TOGAF provides a thorough overview of ODCA (Open Data Center Alliance), CSA (Cloud Security Alliance), Information Technology Infrastructure Library (ITIL), Control Objectives for Information and Related Technologies (COBIT), ISO 20022 with respect to Software, Business and Operational metrics. In short, “KPIs are used to measure the achievement of Critical Success Factors (CSFs) and so many metrics may be measured. However, only the most important of these are defined

as KPIs and used to actively manage and report on the process, IT service, or activity. KPIs should be selected to ensure that efficiency; effectiveness, and cost-effectiveness are all managed. (The Open Group, 2013)”

2.3.2 Return on Investment

There are only four ways to increase revenues or lower costs: decrease investment, increase revenue, decrease costs associated with the activity, reduce the time required to attain revenue (Jackson & Goessling, 2018, p. 79).

A benchmarking study completed by the same authors highlighted variation of 700% in performance and 3200% in pricing for the same configurations across multiple providers. This highlights the complexity of consideration, the many metrics that describe the environment and factors that surround performance such as; quality, security, support, and many more. Mulder (2020) provides a “single Pane of Glass View” concept to aid comparative evaluation of cloud solutions; this is a fundamental part of Enterprise Architect systems and their ability to manage multi-cloud environments (this is explored further in 2.2.9 Governance & Change Management). Therefore, KPIs become crucial to aid the description of any potential or incumbent cloud solution.

In short, ROI is a function of time, cost, quality and the ability to optimise the margin.

2.3.3 KPIs

The Open Group’s Guide on Cloud Performance Metrics (2013) groups KPIs as Business, Operational or a hybrid of the former. It then classifies the metrics as; Technology, Security, Sustainability, Service & Orchestration, Development & Operational, People & Organisation, Financial, Marketability and finally Legal & Contractual.

This landscape is effectively mapped out in the TOGAF Cloud Performance Metrics Framework.

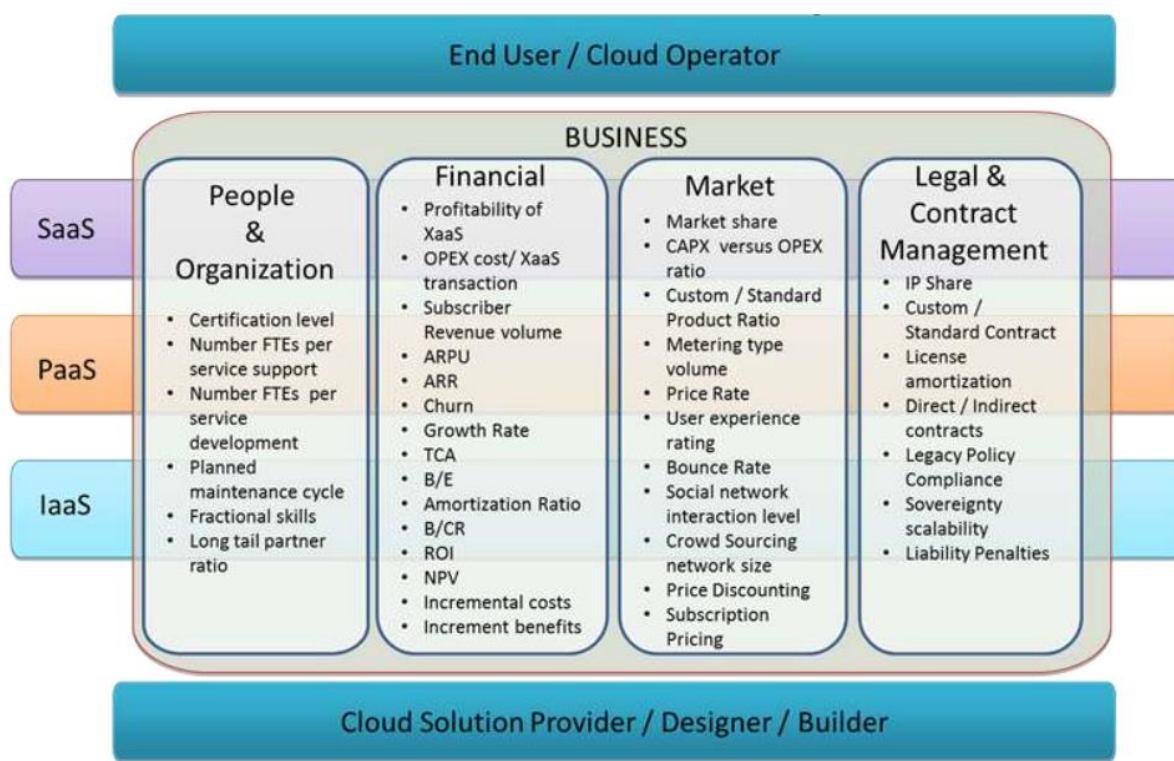


Figure 2 - TOGAF Cloud Business Framework

Key attributes are also an important consideration here and are thoroughly expanded upon in the TOGAF guide, these have been adapted from the guide in Table 3 - Attributes of Cloud.

Table 3 - Attributes of Cloud

Key Functional Attributes	Standards-based	Design once, deploy many
	Virtualisation	Atomic vs Molecular
	Versatile Deployments	Amount of re-used standard deployments
	Elasticity & Scalability	Responsive but with large shoulders
	Density	Shared middleware
	Security and Isolation	Tenants vs isolation
	Persistence & Resilience	Intelligent workload management.
	Simplicity	Self-service, Appliance, Hosted
	Integrated	Extends beyond Cloud Boundaries
Key Non-Functional Attributes	Time to Deploy	
	Density	Number of tenants
	Elastic Scale	User response vs load
	Resiliency (security/ isolation)	Ability to run under adverse conditions
	Runtime Performance	Performance of many cases, loads, SLAs.
	Time to Genesis	Time to enable service
	Cost	OPEX v CAPEX
	Persistence	Session maintenance between consumer & provider.
	Accessibility	Identity & access management

In terms of usable metrics, TOGAFs Guide for Cloud Performance (The Open Group, 2013) details an extensive range of metrics and examples in chapter 5 under the previously mentioned classifications.

Jackson & Goessling (2018, p. 87) Provide further direction on KPIs in chapter 4 of their book and group them as technological, business or economic.

2.3.4 Total Cost of Ownership & Total Economic Impact

Total cost of ownership (TCO) as mentioned in 2.2.6 is seen as a key benefit for cloud. Most vendors provide TCO analysis or calculators to aid the comparison of traditional on premise computing and cloud solutions. However, TCO does not consider some key factors that, whilst difficult to quantify, can still be recognised as having significant impact on business performance. AWS (2019) dig into these factors in more detail to allow consideration by a prospective customer / business.

- Lost productivity
- Missed innovation
- Technology refresh cost
- Increasing technical debt
- Longer time to results
- Risk management

Rescale (2019) also highlight the failings of applying TCO evaluation to dynamic environments, suggesting it is at best misleading. Essentially, cloud solutions have no capacity threshold and are not bound by realtime load relationships.

Forrester (2020) builds on the TCO idea but considers the cumulative net benefits for the business in a Total Economic Impact (TEI) assessment. Several business cases are studied by Forrester with risk adjustment, ROI, and NPV against Cost Benefit analysis. Appendix A of the Forrester report explains each aspect of the TEI in fundamental terms.

2.4 Executive Decisions for Architecture

Cloud technology is a solution to an economic problem, not a technical one. The design of any cloud solution considers the economic efficiency as much as the performance. Jackson & Goessling (2018, p. 63) pose 5 key questions to aid the consideration of cloud in a business:

- What are the non-negotiable constraints and characteristics?
- What are the economic attributes and their impact?
- How does this affect the strategy?
- What is the discriminating technical attributes and characteristics?
- Is there abnormal or excessive risk associated and does it affect economics?

Further more, the size of the company, relevance in sector, geography (and local economics, skills, regulations, energy & risks), legislation & requirements need to be evaluated.

2.4.1 Economics

Pricing is not the primary concern, it is part of the equation but not representative of value. A balanced review must be undertaken to understand the value of the solution to the business and in context of the total cost of ownership of any past or potential solutions.

2.4.2 Technology

Moving away from traditional hardware based discussions (servers, connections, databases etc) to solution focussed discussions in context of the business and business strategy is crucial.

2.4.3 Risk

Risk and the economics are strongly linked and as such need a balanced view. Low cost typically correlates with the amount of risk being adopted. One key change in perspective here is the scale of expertise available via cloud services to address administration, security, support and engineering of the solution versus what a company traditional has to provision for.

2.4.4 Culture

Even with the best solution, adoption is not a given. Adopting cloud is a change like any other and will typically involve many aspects of the business, not just IT. As such, the strategy, roadmap, and vision are crucial to helping the workforce to understand, adapt and successfully migrate in line with overarching objectives. It needs to make sense for users as much as it is useable.

2.5 Implementation & Managing the Transition

This is typically and primarily designed by IT. Other functions must be included but IT should own the solution implementation and manage the transition.

Broadly speaking, strategies include:

- Competitive advantage: Reinvention of relationships, rapid innovation of products & services or improved business model.
- Improved decision making: leveraging improved analytics, improved sharing of data across application and exploitation of data driven decisions.

- Collaboration across systems: deeper integration of operations and development and into the other aspects of the organisation. The location and utilisation of knowledge across the business.

(Dietz, et al., n.d.) provide a 4 phase approach to deployment which clearly denotes the responsibilities & involvement between Engineering, Management, IT & the Cloud provider.

Phase 0: no cloud

Phase 1: Cloud for Overflow

Phase 2: Hybrid Cloud and On-Premise

Phase 3: Full Cloud Migration

The Company is operating at differing phases across many functions today. This adds to the complexity of cloud management in the Company. It should also be noted that each phase relates to a different economic, risk and value model.

Haque (2020, p. 119) describes 3 pillars of Organisational, Technological and Environmental Context that are transected by Governance and Change management as a means to set the scene for a business. The subsequent framework, assessment and migration are bespoke to any business and require executive oversight.

It's been indicated many times in the research thus far, but a CIO led IT strategy is key to digital transformation in a company. With specific reference to the cloud, there are some key executive steps to successful adoption.

- 1 Make a Cloud-First Commitment
- 2 Know Your Cloud Economics
- 3 Discover the Inner-workings of you Application Estate

- 4 Perform Security and Governance Gap Assessment
- 5 Plan for Continuous Compliance

2.6 Strategy

Abdula, et al. (2018, p. 31) present the key considerations for strategy development in an adapted input-process-output kind of schematic.

Table 4 - Considerations for strategy development

Key Considerations = Inputs:	Adoption & Transformation Dimensions = Process:	Prescriptive Steps to Develop a Cloud Strategy = Outputs:
Service Types	Culture Organisation	Business Objectives
Deployment Models	Security & Compliance	Portfolio Analysis
Roles	Architecture & Technology	State Definition
Controls	Emerging Innovation Spaces	Approach Selection
Vendor Management	Methodology	Readiness Assessment
	Service Management & Operations	Execution Roadmap
	Governance	

It is beyond the scope of this particular study to analyse all of the Considerations, Dimensions and Steps above however there are a few worth briefly exploring as their relevance is pertinent to the Company throughout the working layers.

- Culture & Organisation
 - The cultural aims from the Company in the last 12 months have included; innovation, collaboration, flexibility.
- Emerging Innovation Spaces
 - The Company has clearly mapped it's innovation plans in the reach for share in ADAS, Electrification and Connected markets. The innovation challenges may be different but the need to move fast, think different, work different is omnipresent.
- Business Objectives
 - Abdula, et al. (2018), Haque (2020), Jackson & Goessling (2018) all discuss objectives but these can commonly be categorised as:
 - **Competitiveness** – ability to differentiate and respond to market
 - **Agility** - Ability to pivot, react and respond repeatedly and sustainably to demand. Crucially, this needs to be a trait that is present across all business functions – the Company is only as good as it's weakest part.
 - **Speed** – the rate of innovation, time to market, delivery.
 - **Efficiency** (operational cost saving) – as implied, reduce the expenditure and capital required to achieve or increase the revenue streams.
 - **Focus** – the ability to invest precisely, time & money, on the delivery of the core business. End to end cost awareness.
 - The Company regularly states these aims in varying language and context but speed and efficiency were more frequently stated in the current corporate objectives, the “5 in 5” slide [not shareable].

- Portfolio Analysis
 - No singular view of suppliers, utilisation, variety or assessment is available today in the Company.
- Execution Roadmap
 - Mulder (2020) provides a template for business roadmap in *Multicloud Architecture and Governance* founded on common drivers such as; revenue, margin, volume, time to market, satisfaction, ROI. A variety of ways to approach the cloud are explored including: rehost, replatform, repurchase, refactor, rearchitect, rebuild, retire and retain. The associated strategies are then categorised as:
 - Traditional – Lift & shift or modernise or a mix to leverage the traditional IT setup. Mainly IaaS focussed.
 - Rationalised – PaaS & SaaS are included to benefit from native IaaS technology.
 - Dynamic – Fully cloud native and as such, fully dynamic or agile & scalable.
 - No such roadmap is present today in the Company despite clear evidence of growing spend, utilisation and reliance on cloud services.

2.7 Market & Industry

The following table summarises industrial examples of cloud deployment for engineering analysis and the impact on specific simulation cases (details can be explored in the references):

Table 5 - Industrial examples of cloud computing impact

Company / User	Cloud Impact Case	Reference
Callaway Golf	Reduced from 15hr singular to 1.5hr x3 parallel	(Penguin, 2015)
NEC Soft	Reduced from 9 days singular task to 7hr x20 parallel	
Rolls Royce	Reduced by a factor of 5	(Gentzsch & Yenier, 2014)
FLSmith	Reduced from 5 days to 2 days	
Poyry Energy GmbH	Reduced from 5hr to 3hr	
Lobo Engineering	Reduced from 800hr to 24hr	

2.8 Further reading

See appendix IV Recommended Reading Topics.

3 Methodology

Early research within the Company quickly established an absence of standard metrics or reporting associated with effective IT operations. As such a mixed mode of cohort analysis, meta-analytics, qualitative surveys and interviews (Marr, 2016) were the dominant means of assessing the status, needs and perspectives of Engineering leaders (responsible for business delivery), Engineers (active users), the IT team members, suppliers, and industry contacts/references. This constituted a phenomenological approach to the research. Internal interviewees were selected purposively based on their role. External interviews were sampled by convenience.

No personal credentials were associated with responses, relationships were by function only and as such, disclosure of this method was in line with protection and standards for ethics already establishing in the Company.

The small sample sets relating to the IT, supplier and industry groups introduce reliability concerns for trend analysis however the potential for bias in each case has been stated and interpretations are sensitive these conditions.

The portfolio analysis (adapted from Jackson & Goessling, 2018) was used to help categorise topics of discussion in an interpretivist approach which was then used for thematic analysis of the responses.

Table 6 - Portfolio Analysis Template

Portfolio Analysis					
Technology		Business Value		Risk	
Design	Mitigation	Cost	Time to market	Maturity	Compliance
Stack	Democratisation	Criticality	Mitigation	Security	SLA fulfilment
Integration				Control	

3.1 Engineering Management

Engineering leaders in each of the key business units in Company were surveyed to gauge their horizon for computational needs, data warehousing and big data

insights. The following questions were used to survey this demographic.

1. *Are you aware of cloud based services being used around <The Company> today? Name the top 3 you know of.*
2. *What cloud tools are your teams using today for engineering & why?
(Consider data, services & computing)*
3. *Have you considered moving any of your traditional engineering software, data needs or computing needs to the cloud; if so, what & why?*
4. *What are the key problems or risks to moving to cloud solutions?*
5. *Do you have clear metrics that demonstrate the loading of existing engineering tools (licenses) and or computational needs (performance) in your organisation today?*
6. *Are cloud services (software, data, computing) at any level, an essential part of your organization's ability to succeed?*
7. *Are you aware that the cloud can provide more cost effective & more rapid ways to deliver software, computation and data handling (compared to our traditional approaches)?*
8. *Can you accurately state the total cost (amortization, depreciation, maintenance, relative performance, uptime, etc) of specialist computing (servers or high performance computers), data handling (database servers for example) and software (licenses, leases, maintenance etc) for your engineering organization today?*
9. *Do you expect IT to lead the provision & management of cloud services in the same way they provide Office 365 for example?*

Subsequently, some guided follow up discussion was had with key respondents.

3.2 Engineering Staff

Engineering staff were surveyed as follows (logic branching not demonstrated):

1. *Do you run any kind of calculations, analyses or other computationally intensive processes?*
2. *What software tools are you using for you calculation or analysis needs?*
(Select all that apply)
3. *How often do you run the software tool that you use most frequently?*
4. *Does your local hardware/computer meet your needs?*
5. *What hardware do you have today? (Select one from the list below.)*
6. *What hardware specification do you need and why?*
7. *If you use remote-computing solutions (local servers or cloud), do they satisfy your needs?*
8. *If you answered "No" to the question above, please describe what problems you're experiencing with remote computation in the field below.*
9. *Do you have any other comments or thoughts that you'd like to share?*

This was a primary source for determining the need for computation.

3.3 IT Team

Interviews with key members of the IT function were held to explore & establish their strategy, metrics and ways of working today. Anonymity was assured in this case as

the feedback from this group was seen to be controversial. It is suspected that residual anxiety of exposure in interviewees despite ethical assurances may have biased the responses. Sample questions included:

- What is the IT strategy for Company?
- What is the cost to operate IT today?
- How many servers do we run, what is the total cost of ownership?
- What is our split between on physical, virtual or cloud services?
- What KPIs do we have that drive improvement or flag problems?
- What are the top needs in the business today from your perspective?

3.4 Suppliers

Established supplier representatives were engaged to review & clarify models and provisions in cloud and computational services. Commercial negotiation was not possible at this point and so idealised pricing was the core of discussion and should enable a level of comparison to be drawn in terms of performance or coverage and financially. This activity was used as a primary source for determining the possible solutions and was a notably difficult area to achieve transparency. Motivations to sell from this group will have biased responses and as such, care has been taken not to make direct inferences.

3.5 External References

Analysis of existing research and contacts was used to discover best practices and agnostic examples of deployment.

The authors contacts in these groups were both convenient and purposeful (not exhaustive) and used to explore ratios for simulation resources in particular. These contacts were independent of The Company and can be treated as having no bias.

4 Results

4.1 Company

Today, the Company already operates in a hybrid/multi cloud fashion. This is not entirely by design but through innovation needs. IT efforts have been focussed on core enterprise tools and services, as such, Azure is utilised extensively for virtual server and data centres in parallel with on-premise server solutions to sustain the primary business tools. An initial effort to migrate IT services to cloud in 2017 incurred unexpected costs and a further change in infrastructure design to regain control of costs & efficiencies (this was perhaps indicative of a lack of expertise in The Company and a lack of Understanding of The Company's operations). Workday, Salesforce and Office 365 are visible examples of SaaS in The Company today. However, the growth in cloud services in other areas, notably engineering, is not aligned with an IT strategy.

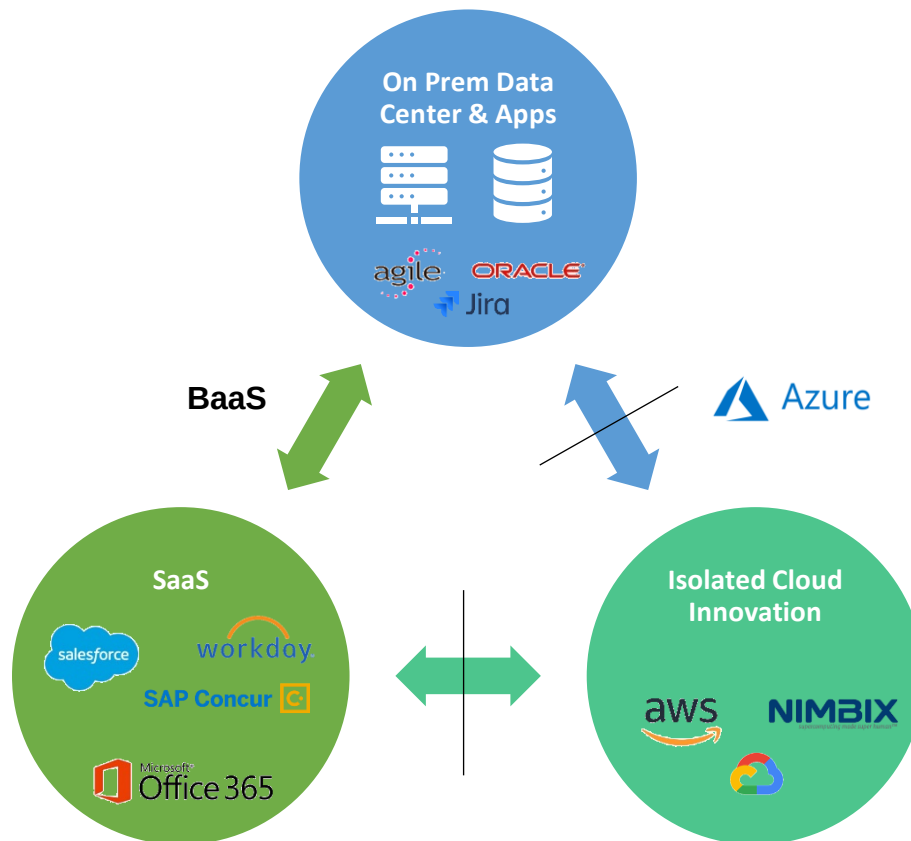


Figure 3 - Cloud landscape in The Company today

Considering **Error! Reference source not found.** as the only map including cloud activity the following challenges are evident:

- Missing visibility (activity, growth, dependency not known)
- Uncontrolled cost (no tracking of total costs, no commercial activity for VFM assessment)
- Uncontrolled risk (especially for security and resilience)
- No measure of performance (no idea if good enough, suitability or alternatives)
- High barriers to integration / connection of information

Subsequently it is clear that future planning for solutions should include:

- Visibility & Transparency
- Alignment with stakeholders
- Governance to optimise the provision & protect the company
- Central support for cloud initiatives

Multi-cloud architectures are inherently challenging to manage with a traditional application, infrastructure and service focussed IT team unable to see up the stack or across stacks. This lack of visibility and cross functional awareness within the team and for the wider business (typically the internal customer or innovator) makes optimisation impossible today.

Table 7 - The Company's Portfolio Analysis

Portfolio Analysis					
Technology		Business Value		Risk	
Design	Mitigation	Cost	Time to market	Maturity	Compliance
Stack	Democratisation	Criticality	Mitigation	Security	SLA fulfilment
Integration				Control	

Discussion with IT highlighted their focus on Cost, Security and Control.

Table 8 - Thematic analysis of IT interviews

Respondent	Cost	Security	Control
1	"..budget reduction is expected year on year so it's not in our interest to add more tools"	"Our priority is to keep The Company secure"	"...applications are often not suitable for enterprise but engineering use them anyway"
2	"...cost is the main focus. I can't think of a case where we value performance and pay more for it."		"I don't have any way to show you everything that is being used. We have a good grip on key systems but no sight of what real tool useage is."
3	"Security should be paramount, functionality second and cost third"		
4	"It is the job of the users to justify the value, not IT"		
5	"IT is underfunded, a second thought. We are not able to do what we need to."	"We have a good security record but we definitely compromise a lot of integration for this."	"We have excessive control of core systems and no control of many others. It's an odd mix."

Discussion with Engineering highlighted focus on Design, Time to market, Stack & Democratisation.

As the primary functions leading the investment in cloud services to date, there is a clear lack of analysis for Risk and some components of business value. There is a distinct lack of collaboration and overlap on the assessment of solutions.

4.2 Engineering Management

21 managers were contacted (representing a wider group of ~50), 8 responded (38%) across the various business units in The Company giving at best a confidence interval 16 at 95% level; as such, this data should be treated with caution. Of the respondents, the following measures could be made:

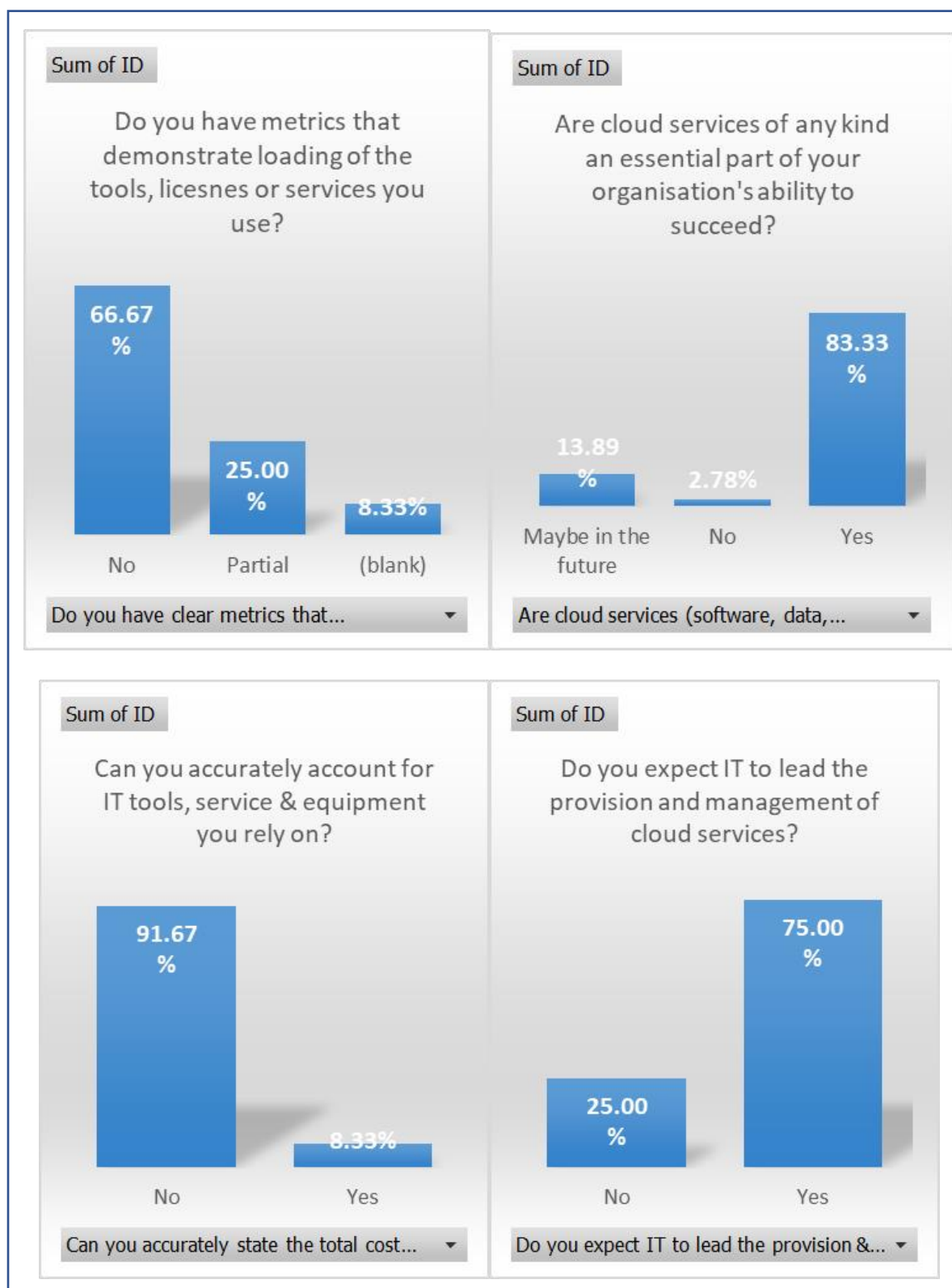


Figure 4 - Engineering Leadership Responses

Feedback from engineering leadership highlighted:

- Limited to no understanding of total costs for incumbent tools or potential tools
- Appreciation of potential but not able to quantify
- A recognised need to do “something” with cloud
- Acknowledgement that incorporating digital transformation was key to future success for engineering
- Recognition that it is not a one tool solution
- Expectation that IT should be showing strategic leadership in this area

4.3 Engineering Staff

Of a population of ~2100, 300 responded to the survey on computational needs.

This results in a confidence interval of 5 at 95% level and is therefore reliable.

As per Figure 5 - Demographic of Engineering Staff, Design & Process Engineering departments accounted for the majority of the responses. Mechanical, Software, Electrical and Process engineers account for ~70% of the responses.

As per Figure 6 - Analysis / Computation Needs within Engineering Staff, 70% of respondents are running analysis and therefore, consuming computation of some kind. 66% of that group are running computation of some kind every day or routinely during a week – this is a significant portion of the group.

67% of confirmed analysis users are satisfied with their hardware. But where those users are not satisfied, the reasons (needs for improvement) are almost equally split across the main factors for computer performance shown in Figure 8 - Desired Improvements in Computational Hardware.

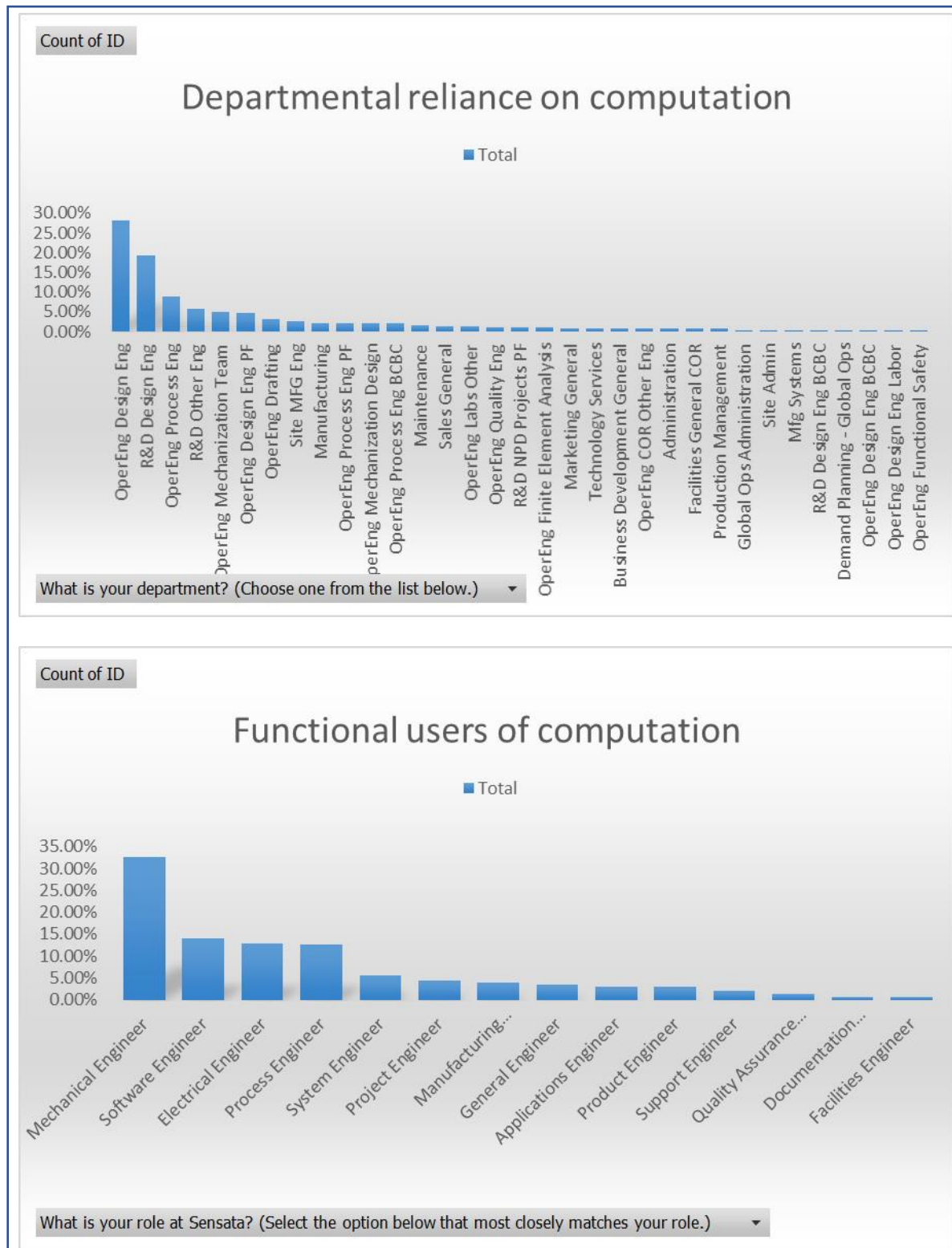


Figure 5 - Demographic of Engineering Staff

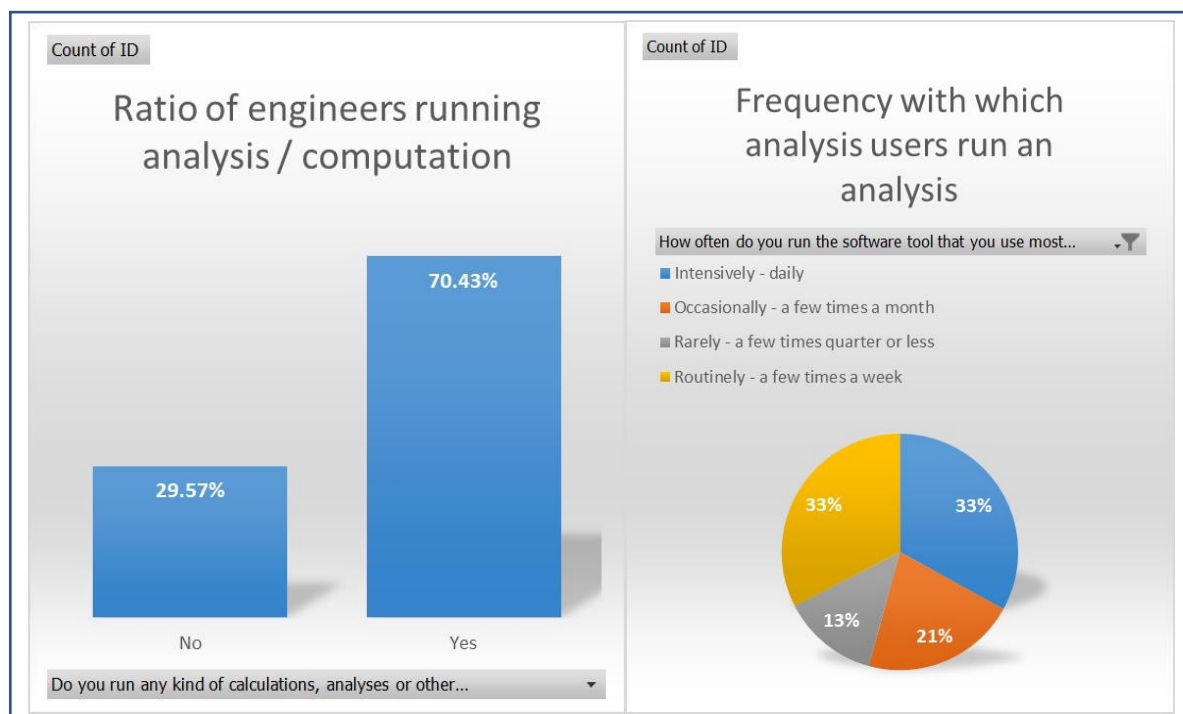


Figure 6 - Analysis / Computation Needs within Engineering Staff

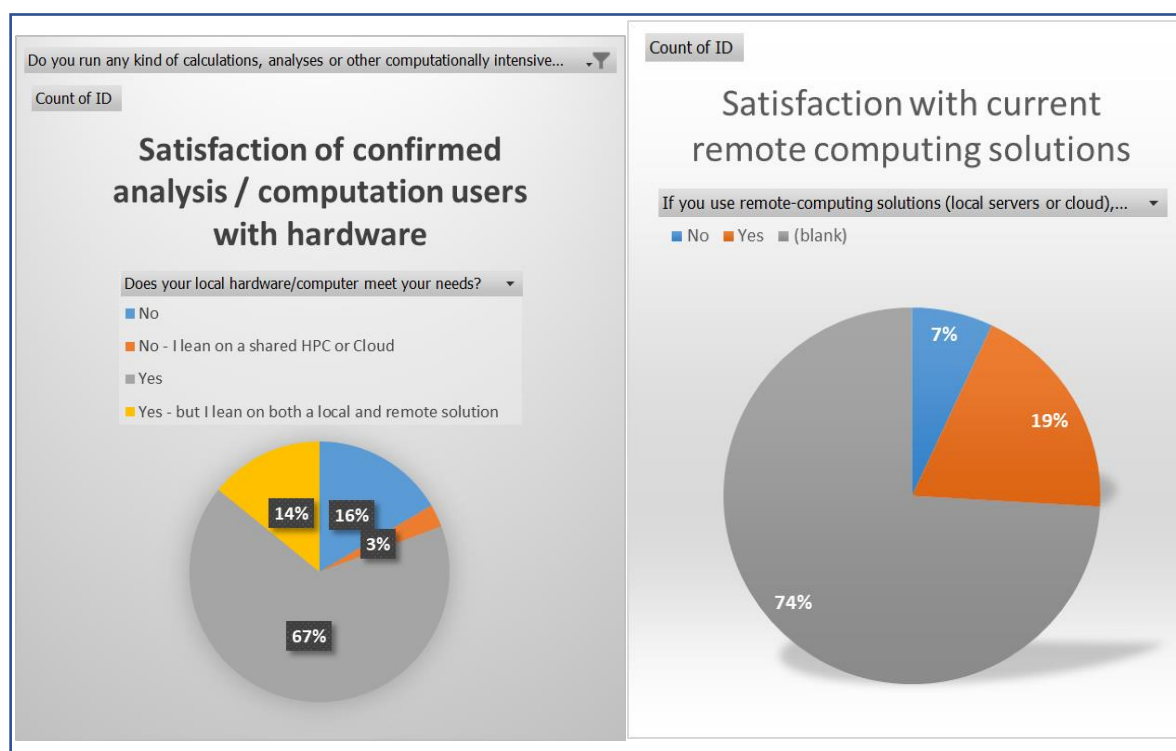


Figure 7 - Engineering Staff satisfaction with Computation Resources

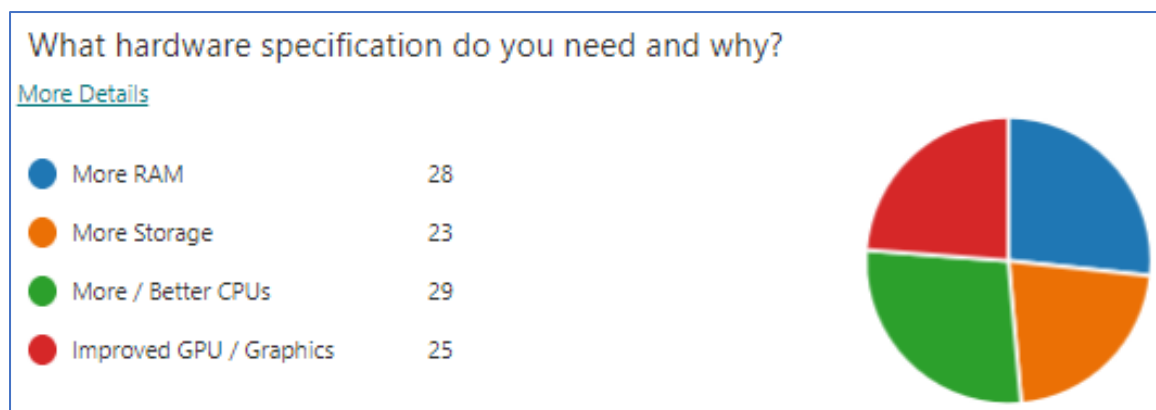


Figure 8 - Desired Improvements in Computational Hardware

In relation to the dissatisfaction with remote computation solutions (including on premise HPCs and cloud solutions) a heat map of terms is shown in Figure 9.

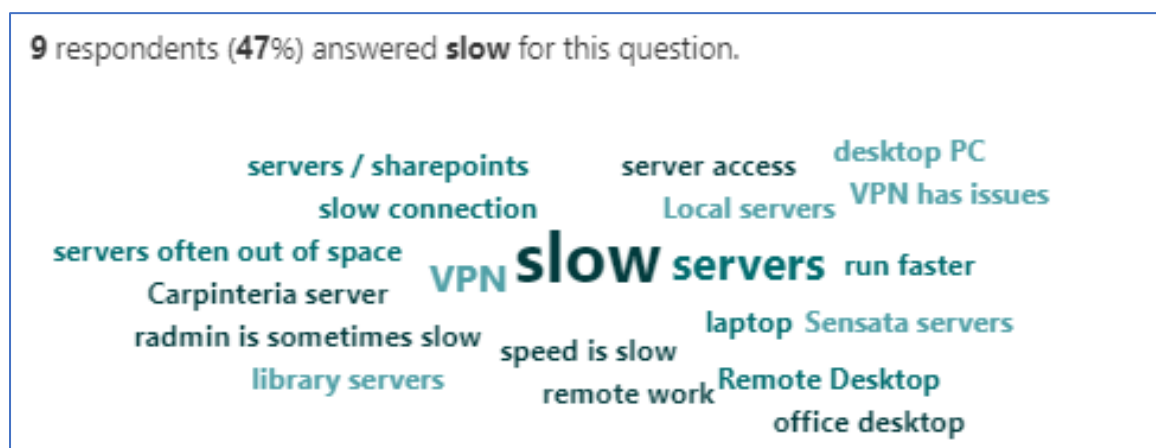


Figure 9 - Common terms referenced in relation to dissatisfaction with remote computation

Interrogation of the feedback on remote solutions revealed connectivity, speed and workflow frustrations as the main source of dissatisfaction.

Further interrogation of the open feedback from engineering staff allowed categorisation of 4 topics:

- Hardware (25%) – a comment relating to issues or frustrations with hardware performance

- Software (67%) – referencing to software not listed as a common or known engineering application by the survey authors (IT and the author of this work)
- Infrastructure (7%) – referencing issues with VPN, speed of transfer, permissions, access, up-time/resiliency & availability of licenses
- Policy – referencing frustrations with how equipment and software is provisioned and managed

4.4 Suppliers

Each supplier has a clear bias to promote their own solution, this bias is important to acknowledge in review of their solutions. Commercial information is not included here, instead, a relative indication has been used to aid review in future sections.

Tool providers are going through their own transformation as the demand for complicated multi-software solutions grows. This has led established tool suppliers to embrace a level of open interface to allow communication with competitor solutions. In parallel third party vendors providing interface solutions are growing and often acquired by the larger incumbent providers. This acknowledgement of needing to work with the competition is not reflected in the cloud strategy. For cloud computation, each vendor is exploiting the incumbent streamlining of solving within the toolset to gain advantage. This is good for the end user but not ideal for a business such as The Company where several different tools / providers are in use.

Cloud services with simulation tool providers are generally priced higher than tool agnostic cloud service providers such as Nimbix or Rescale. Competitive pricing comes with scale and in the context of the portfolio being negotiated. Buying into a simulation tool cloud solution brings value to The Company in terms of speed, ease

of use, reduced admin & increased resiliency but will not achieve the economies of scale, adaptability or commercial competitiveness desired in all cases.

4.5 Engineering Simulation Review

4.5.1 Internally

2020 provided an accelerated test of the Company infrastructure and it's ability to cope with remote working. The on premise HPC cluster that carries out computation for the full time analysis group was limited by the ability to load data to and from the machines for remote users. Remote Desktop Protocol (RDP) was almost inoperable due to latency. VPN stability and bandwidth generated instability in software license handshakes between host servers and remote users.

Problems with VPN performance were accentuated by the global wave of users coming on an off line per site. The workflow was adapted to work around issues with secure access, syncing to data repositories and connection to federated tools and systems. In short, what were previously occasional annoyances became perpetual barriers to performance.

Our incumbent cloud computation provider, intended to be a 'plan b' be in such cases was also impacted by the company infrastructure requirements, primarily the speed to load data via our secure domain and VPN.

The problems above were experienced differently and selectively depending on the location of users, their load and working configuration. As such, the priority of concern was different for our dispersed group of SMEs working on simulation.

The work flow differences highlighted here provide a good basis to consider the contributing factors affecting the efficiency of simulation.

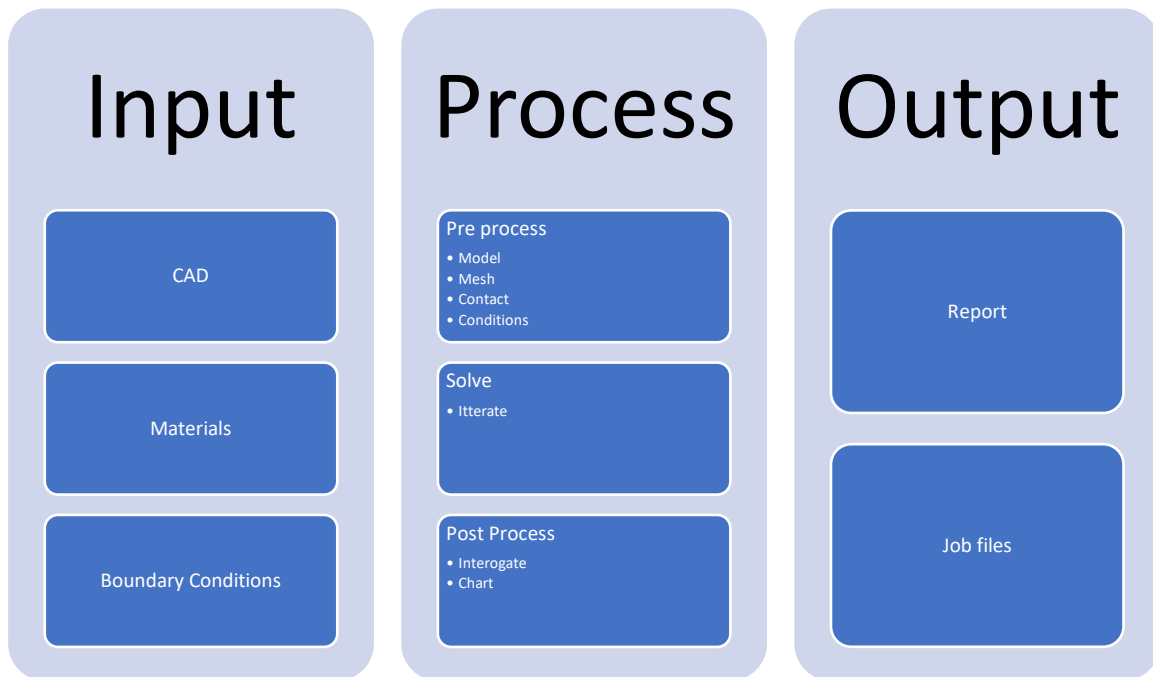


Table 9 - Workflow in Simulation - Blocks

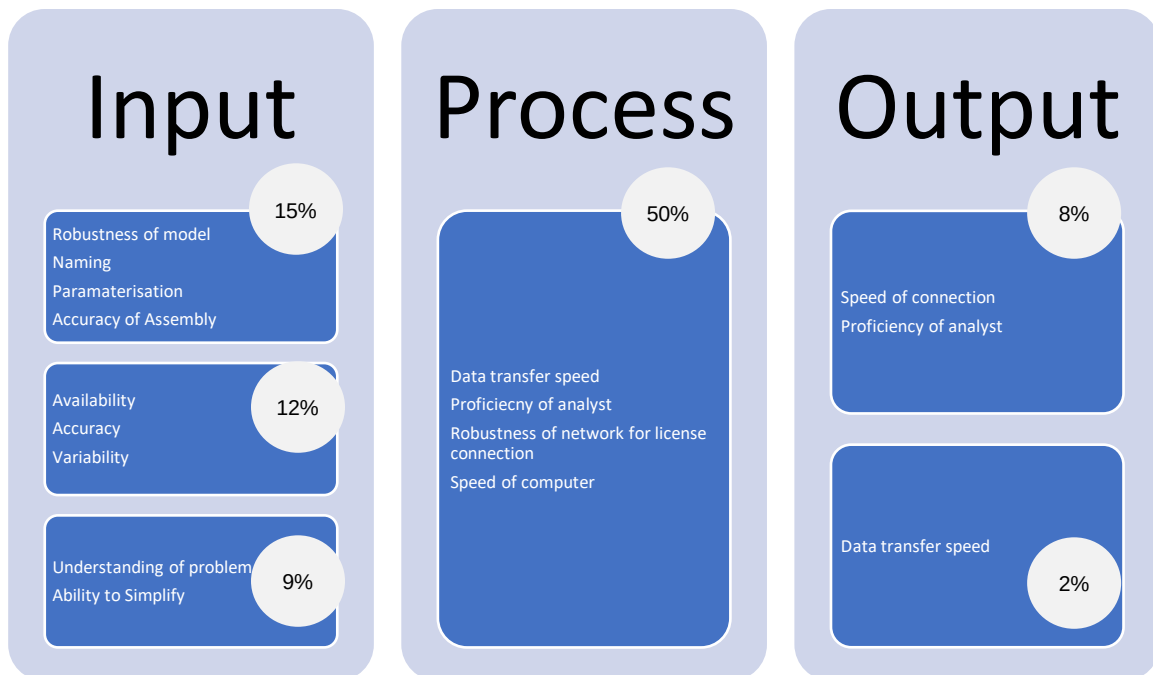


Table 10 - Workflow performance factors in Simulation

The single biggest area of opportunity is the processing speed. However, this is not a simple or linear calculation. Firstly, it is assumed that the supporting hardware is appropriate for the processor which is the primary focus of consideration for computational speed. But memory, motherboard, storage speed and type should all be considered when it comes to assessing hardware optimisation for the application and task.

Lipasti (2010) lays out the fundamentals of Performance and Cost considerations for computing architecture and clearly demonstrates the difficulties in calculating and comparing pure computational solutions.

Moore's law (the doubling of transistors on chips every 2 years) has been broadly interpreted as the doubling of processing power every 2 years. Transistor count is one of 8 major factors in processor speed; device dimension, doping concentration, voltage, current, capacitance, delay time per circuit, power dissipation per circuit and power density (Dennard, et al., 1974). The power dissipation factor is notably a squared term highlighting the non-linear relationship between scale, power demand and subsequent thermal management which extends to the environment and brings system & cost, limitations & considerations.

However, as noted in Table 10 - Workflow performance factors in Simulation, the computational performance is tied to the transfer speed, the ability to get data to and from said machine via the company infrastructure or in and out of said infrastructure.

The more computation we can do at source the more we can eliminate system level latencies, such as transfer speeds to the host. This concept is part of what is driving the continuation of computing performance increases; edge computing.

4.5.2 Externally

The authors discussions with simulation leaders during the Institute of Mechanical Engineers Simulation & Modelling 2018 Integration Optimisation and Validation Initiatives (IMECHE, 2018) can be summarised in the following categories:

- Scale – Simulation Engineers & Analysts are growing rapidly in number
 - Jaguar Land Rover (JLR) had tripled their CFD efforts since 2010.
- Democratisation – an ideal view for businesses but requires investment in skills to govern and regulate the non-specialist, widespread efforts
- Interoperability – enabling the transfer and connectivity of data between tools and therefore specialists will accelerate innovation

These are not new ideas for The Company but they are a step change in how engineering analysis is approached and funded.

A NAFEMS online presentation & discussion (Schnitger, 2021) looked at the trends and possibilities for engineering simulation towards the year 2030. Schnitger's analysis of the industry reinforced the growing complexity of problems and the increasing need for expertise, tools and hardware. Furthermore, speed, agility, intuition, experience were seen as key to a successful future with simulation in business. Physics insights will continue to grow in their criticality to business success and as such will become on a par with financial results. Tools and compute capacity needs are proportionate to roles and time in the life cycle that they are utilised, SaaS solutions help deliver the right tools at the right time with the right performance. Digital transformation is a business wide venture, not possible to do in isolation, by nature, everything needs to be digitised and connected; at the very

least in the entire CAE landscape needs alignment from geometric modelling,
through physics solving to twins.

5 Discussion

5.1 Industry trends

5.1.1 IT strategy and Enterprise Management

Enterprise Architecture (EA) Tools are designed to solve the growing complexity of enterprise management for companies and their IT department. EA tools now provide a shared, enterprise wide repository and operating model for change.

Enterprise architecture and technology innovation leaders should select EA tools that support long-term business transformation, modernization and innovation goals (Gartner Research, 2020). Gartner lists some of their top 3 leaders by customer satisfaction in this new market as:

- MEGA International – HOPEX
- LeanIX – Enterprise Arcitecture Suite
- Ardoq - Ardoq

Forrester (2020) analysed 4 companies and measured a 232% ROI and risk adjusted NPV of \$1.9M with the implementation of BetterCloud Enterprise Architecture SaaS. Benefits were observed over 3 years in; employee onboarding / offboarding & security, employee status management, SaaS security compliance, security risk avoidance, IT management and support. Detailed metrics and calculations are published and could be used to help establish key measurements in The Company today.

A State of SaaSops in 2020 report (BetterCloud, 2020) surveyed 676 IT professionals across as many businesses of which >30% were in technology, manufacturing or telecoms. Key findings included:

- The main motivations for deploying a Enterprise Architecture Management tool are to increase productivity & reduce costs.
- Typical IT to staff ratio was 1:89 across industries and is reducing.
- Optimal security does not compliment optimal productivity, but most companies leaned toward productivity.
- The 3 crucial challenges to solve were; the administration of users, securing sensitive data, managing the applications in use.
- Since Covid-19, the new priorities for IT include; make IT decisions that directly impact profitability, better secure remote workplaces and their performance, make IT's role more prominent.
- Enterprise Architecture tools are most interesting because they; improve security, improve ease of use / admin, integrate to the technology stack.

SaaS as a trend is on the up. 73% of organisations state 80% of their applications would be SaaS by 2020 (bettercloud). It is also recognised that there are new “more amplified” challenges for IT with managing SaaS. As such, IT roles, processes and budgets are being rethought.

	2019	2020	2021	2022
Cloud Business Process Services (BPaaS)	45,212	43,438	46,287	49,509
Cloud Application Infrastructure Services (PaaS)	37,512	43,498	57,337	72,022
Cloud Application Services (SaaS)	102,064	104,672	120,990	140,629
Cloud Management and Security Services	12,836	14,663	16,089	18,387
Cloud System Infrastructure Services (IaaS)	44,457	50,393	64,294	80,980
Desktop as a Service (DaaS)	616	1,203	1,951	2,535
Total Market	242,697	257,867	306,948	364,062

BPaaS = business process as a service; IaaS = infrastructure as a service; PaaS = platform as a service; SaaS = software as a service

Note: Totals may not add up due to rounding.

Table 11 - Worldwide Public Cloud Service Revenue Forecast (Millions of US Dollars) (Gartner, 2020)

	2020 Spending	2020 Growth (%)	2021 Spending	2021 Growth (%)	2022 Spending	2022 Growth (%)
Data Center Systems	214,985	0.0	228,360	6.2	236,043	3.4
Enterprise Software	465,023	-2.4	505,724	8.8	557,406	10.2
Devices	653,172	-8.2	705,423	8.0	714,762	1.3
IT Services	1,011,795	-2.7	1,072,581	6.0	1,140,057	6.3
Communications Services	1,349,891	-1.7	1,410,745	4.5	1,456,637	3.3
Overall IT	3,694,867	-3.2	3,922,833	6.2	4,104,906	4.6

Table 12 - Worldwide IT Spending Forecast (Millions of U.S. Dollars) (Gartner, 2021b)

Gartner research identifies top trends impacting infrastructure & operations in 2021 as follows: (Rimol, 2020)

- Anywhere operations
 - 48% of employees expected to work from home even after the pandemic forcing more flexible and resilient business solutions.
- Optimal Infrastructure
 - Programmable infrastructure that allows for evolution with the business demands.
- Operational continuity
 - Continuous, global services. New tools will be required to support this level of continuity.
- Core modernisation
 - Infrastructure needs coordinate on and off premise with minimized legacy drag. The modernisation plans should account for shifting skill requirements.
- Distributed Cloud
 - Distributing cloud resources and shift the burden of support to service providers through flexible locations reduce latency.
- Critical Skills versus Critical Roles
 - There is a shift from infrastructure roles to collective skills. Culture changes are needed to make this happen.

Gartner also identifies infrastructure innovation as a key driver for enterprise resilience and business growth in a post pandemic world; four capabilities are outlined: (Gartner, 2020)

- Cost intelligence – the ability to show the enterprise how to release capital through cash, time & creativity
- Workforce transformation – I&O teams with a wider skills base than traditional teams
- Platform Ops – brining people, process and technology together and promote culture shift to customer centric digital solutions in the enterprise. Customer-in rather than technology-out view.
- Marketing – reliability is not enough; value of solutions needs to be measured.

The key takeaways from Sid Nag's (2020) analysis on "How Pandemics Impact Cloud Migration Today, Tomorrow & Beyond" are shown in Figure 10.

Key Takeaways

- "16% of organizations believe their business can continue as normal in the new pandemic era, which means that the majority don't believe they can go on normally."
- "We identified three cloud migration imperatives to help IT leaders manage their cloud migration journey in this new era of pandemics:"
- **Cost optimization imperatives:** Track costs, understand billing anomalies, optimize underused resources and perform smarter instance allocation.
- **Business continuity imperatives:** Establish and ensure your business continuity model is built to continuously respond to your needs in a remote, ever-changing environment.
- **Security imperatives:** Institute a cloud security framework designed to enable you to move from temporary remote workers to a full-time remote workforce..

Figure 10 - Key Takeaways on Pandemics Impacting Cloud Migration. (Nag, 2020)

IT operational spend in The Company today is \$44M (corporate financial analysis April 2021). According to Computer Economics Avasant Research data (Computer Economics Avasant Research, 2021), this ratio is equivalent to a high tech \$1.7bn revenue company or a \$3.1bn revenue manufacturing company. Where The Company sits needs further consideration on two fronts:

- The type of business
- The shadow costs hidden in other areas of the business

5.1.2 Computational Performance

Innovation, Agility & Flexibility are more important to The Company than ever with the challenges 2020 has brought to business and the subsequent global acceleration of Electrification and Connected projects primarily for the Automotive Sector. Global electric vehicle stock (excluding two/three-wheelers) grows by 36% annually, reaching 245 million vehicles in 2030 – more than 30 times above today's level.

(Iea, 2020)

Taking a slightly longer term view (beyond 3 years) there are concerns about the sustainment of performance growth for computing. Hardware (storage & processors) are already reaching their limit as “Moore's Law has largely ended, so compute performance has hit a plateau at the CPU level” according to Justin Boitano (senior director of enterprise and edge computing at Nvidia (Gillin, 2019). Alternatives are seeing big investment by leaders like Amazon, Microsoft and Google combining hardware technologies with AI to optimise performance. Facebook's Open Compute Project being supported by Microsoft's Project Olympus hardware optimisation serving as one prime example (Deutscher, 2016). Whilst there is quantum computing technology in use with IBM, Alibaba, IonQ and other cloud research platforms, it is not ready for wide spread industrial use (Haley, 2019). There are many additional concerns with quantum (mainly security) that will ensure a healthy separation is kept between company data and quantum services beyond the 3 year outlook of this work.

5.2 Hybrid & Multi-cloud Solutions

There is both a need for multiple cloud systems to operate in parallel with traditional on-premise systems, and business value in doing so. There are distinct needs across The Company not all of which can be aligned to one solution.

Today, the optimal tool is chosen for and by the driving function. This is typically not considerate of existing tools in the company and the possibility to find efficiencies by trading some functional performance with economic scale. As such, a variety of clouds are running with potential overlap / redundancy or even offering resilience opportunities, but they are effectively running in isolation and neutering those potential benefits.

IT need to take a lead in assessing A) demonstrating the landscape of tools and services today B) supporting assessment of tools in a corporate risk, value & technology framework.

A CSB Aggregator may be a better way to gain operational needs and win back financial benefits with a multi-cloud environment.

5.2.1 Service

Company department heads have clearly voiced a range of needs that are best serviced with a range of cloud vendors at this time. However, there is no measurement in place of the quality, robustness of value of service they are receiving. Whilst functionality is being serviced, business interests are being overlooked in most cases as there is almost no way to routinely review the effectivity of the product investment.

A common frustration is that the Company IT and applications teams are not resourced sufficiently to support all the functions in assessment of their needs. This should be of particular concern for security.

5.2.2 Resilience

Multi-cloud deployments offer redundancy in case of hardware/software failures and avoid vendor lock-in (Mulder, 2020).

5.2.3 Security

Security concerns can justify different solutions depending on the data or activity being handled. Overarching policies are in place but there is no supervision or accountability for many applications. Further more, these policies are well intended but often inconsiderate of emerging needs, this perception is given more context in the conclusions.

5.2.4 Economy

Although presenting more complication in account management, competition is preserved and with effective metering; needs can be spread to the portfolio more cost effectively.

5.3 Engineering Analysis (Simulation):

The Company has moved from component and small product assembly design to being significant system developers and partners. This has changed the scale and complexity of analysis needs. Further more, the company has been migrating into emerging markets and bringing additional uncertainty to the design process as there

is little legacy to rely on in these new applications. The demand and justification for simulation has never therefore been so vibrant.

5.4 Cloud for Simulation

Azure allows for Windows and Linux development. This serves the stack development for Connected business units. GPU and CPU computation is possible and this allows for optimal choice depending on the physics solver. Azure is the established choice for our key engineering analysis tools (Ansys, MSC, StarCCM+, Matlab, Autodesk, JIRA and more) and as such is a low risk, easy to adopt provider. Azure is also the cloud partner for aforementioned businesses ensuring future development is aligned and robust. Azure is the cloud backbone for many of The Company's existing key business management & operation tools such as Workday, Salesforce and Office 365.

However, for computation, Azure is more like an IaaS than a SaaS solution, as such there is more reliance on The Company and its users to setup and administer the various tools & connections with that environment. The hesitancy IT shows for this model reflects the lack of maturity and capacity in The Company in this area; vendor application clouds are the preferred choice today. This may indeed be a more robust solution but adds admin and inefficiency to the commercial management and a complexity to manage user issues. In essence, resource migrates to supplier management whilst securing a variety of cloud base computation options.



Figure 11 - Relative useable computation with cloud instances

The more cloud instances you introduce, the less effective you become in terms of the relative computation power that is useable. In other words, only users of the corresponding software can tap into the native cloud space. Sourcing more clouds with each software brings usability benefits within the application (typically reduces or smooths the workflow) but adds more management overhead, complexity of information flow between tools and potential cloud redundancy. This model will likely cost more, as such budgets will be stretch and so purchasing the right scale of cloud for each tool may be limited and impact on the effectivity of service for users (reduced ROI). This is true for computational and data clouds. Where The Company is on the curve shown in **Error! Reference source not found.** is not measurable today but the trajectory is agreed to be toward the right with pace.

5.5 Measuring Success

Ghahramani, et al. (2017) provide reasoned methods & formulae for assessing the following key characteristics of computational resources:

- Performance
- Availability
- Reliability
- Elasticity
- Scalability

Further more, in acknowledgment of the criticality of resource monitoring this same paper (pg 14) documents capabilities of cloud monitoring tools including *CloudWatch*, *Azure Watch*, *CloudStatus*, *Realiza Hyperic*, *Nimsoft*, *Monitis*, *Aneka*, *CloudKick* and *Up.time* against the aforementioned characteristics and additionally considers Timeliness, Interoperability & Portability.

5.6 Impact assessment

In order to effectively provide a measurable comparison, the computational costs for the Simulation Centre have been isolated from the total computational costs in The Company as there are too many unknowns for the later. The Company has invested \$140k in computing hardware for it's dedicated simulation team over the past 4 years. (These machines are used 98% for solving, less demanding pre and post processing is completed on less expensive machines.) A further \$30k in upgrades, storage and routine repairs has been spent in the same period. The infrastructure to support this computing cluster includes a dedicated room, HVAC, UPS and cabinets reaching another \$40k in capital and \$10k per annum to run. The energy consumption is continuous as the machines are only dormant for repairs, essentially, running 24 hours a day every day; annual energy costs for this group of machines is \$14k.

This does not include the resource commitment from plant & facilities or IT in supporting the on premise hardware. IT in The Company was unable to produce cost of ownership for physical assets such as servers of HPC. Industry figures suggest for a company of our size, the cost to sustain an individual server is approximately \$5k per year (adapted from *Motivations and IT roadmap for Cloud HPC*, Dietz, et al., n.d.).

In total it is estimated to cost the Company upwards of \$90k per year to run & support 10 full time simulation servers.

Beyond the specialist team, The Company has a network of simulation users with much less capable computers at their disposal. Fortunate ones will have a higher specification engineering computer around \$6k and serving 4 years. Most will be running with a \$1.5k laptop.

It has been clearly established that after preparation, speed of computation is the most significant factor in affecting the value of simulation. A simple model considering number of simulation users, capability of hardware and time suggest that we have X hours of project time lost to “slower than possible” simulation.

Users: 25 Ansys users, 10 full time, 15 part time (30% average). = U

Typical job: 20 hours solve, 4 iterations, 750k nodes = T

Load: 300 jobs per year = N

A 20% improvement in computational speed could release 1200 hours of engineering time for additional simulation, almost 7 months of work for a full time analyst. In other words, as year passes, we lose almost half a year of an engineer's time in productivity terms.

In terms of computing, hardware performance has the single biggest influence on solving speed. Solver performance suffers from a life cycle compounded by:

- General efficiency drop
- Increasing calculation size (job complexity)
- Increasing background demand (parallel processes for OS, security etc)
- Increasing stretch on investment cycle (prolonging the used life of hardware)

Whilst Moore's law may be ending (based on transistor count) the model is still generally fulfilled by the deployment of ML or similar software engines that take up the lag in terms of manufacturable improvements. It is clear to see the compound effect of industry performance (driven by demand in computation / complexity of problem solving) and reduced efficiency in our own hardware. This is demonstrated in **Error! Reference source not found..**

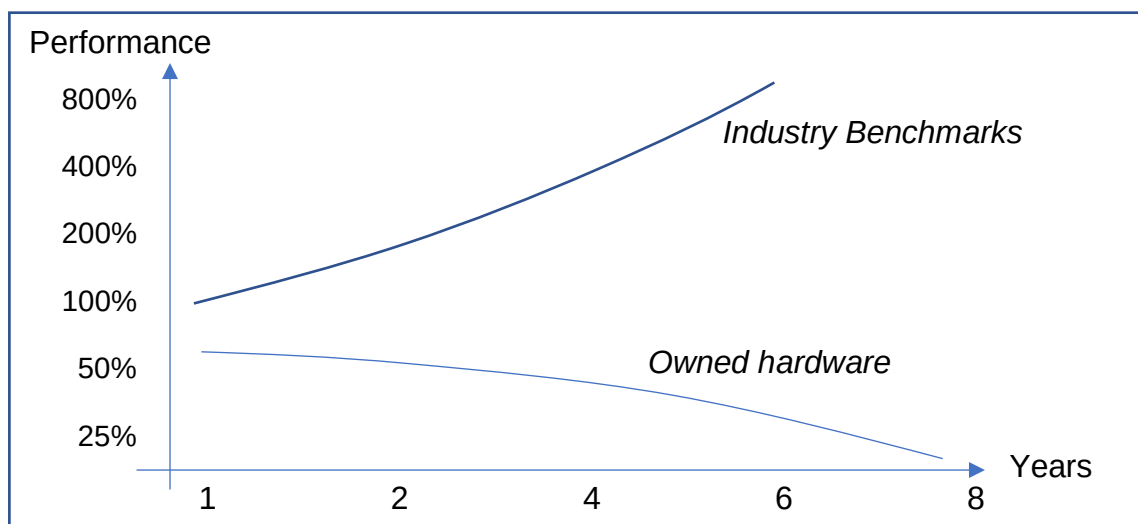


Figure 12 - Divergence in computational performance

Also, in an attempt to reduce capital costs, hardware is often purchased below the industry standard at that time, typically 60% of potential performance specification. Beside not being good value for money when contrasting the cost or resource and

licensing that is reliant on computational performance; managing hardware renewal at this rate is not feasible for the Company.

In short, costs today are considered as hardware and software. Hidden costs, not routinely accounted for, are as follows: Outages, UPS, Power, Cooling, Maintenance, Security, Recovery, Queues, Back-Up, Staffing, Facilities, Depreciation, Insurance.

6 Conclusions

Scale of computation needs in The Company are growing rapidly in both the complexity of problems being solved by the individual, the number of individuals solving problems, the variety of tools required and the interoperability of tools & solutions. Computational performance dictates the efficiency with which human resource skills, software licenses and facilities costs are consumed.

The current user or function led approach to tool or service selection is not considerate of the incumbent landscape technologically or commercially. Cost of a tower computer is commonly perceived and utilised as the sole operational cost for analysis. This is primarily due to a lack of monitoring, visibility and reporting. This most significantly affected by a lack of strategic importance and coordination.

The aim of this work was to identify a roadmap in support of cloud computing for simulation in engineering analysis. This was to be respectful and symbiotic to the organisation strategy, in particular, the IT strategy for enterprise. It has subsequently become clear that the organisation does not have a strategic plan to consider the evolution of IT from a service provider to a strategic partner.

Assessment of the IT organisation by team members (or externally) was challenging as there was no internal awareness of a model, strategy or roadmap they were working to. Referencing some industry standards such as Gartner's I&O Model (Immateriell, n.d.), The Company's IT professionals suggested they are firmly in the first pillar (awareness) of a 5 step model to maturity.

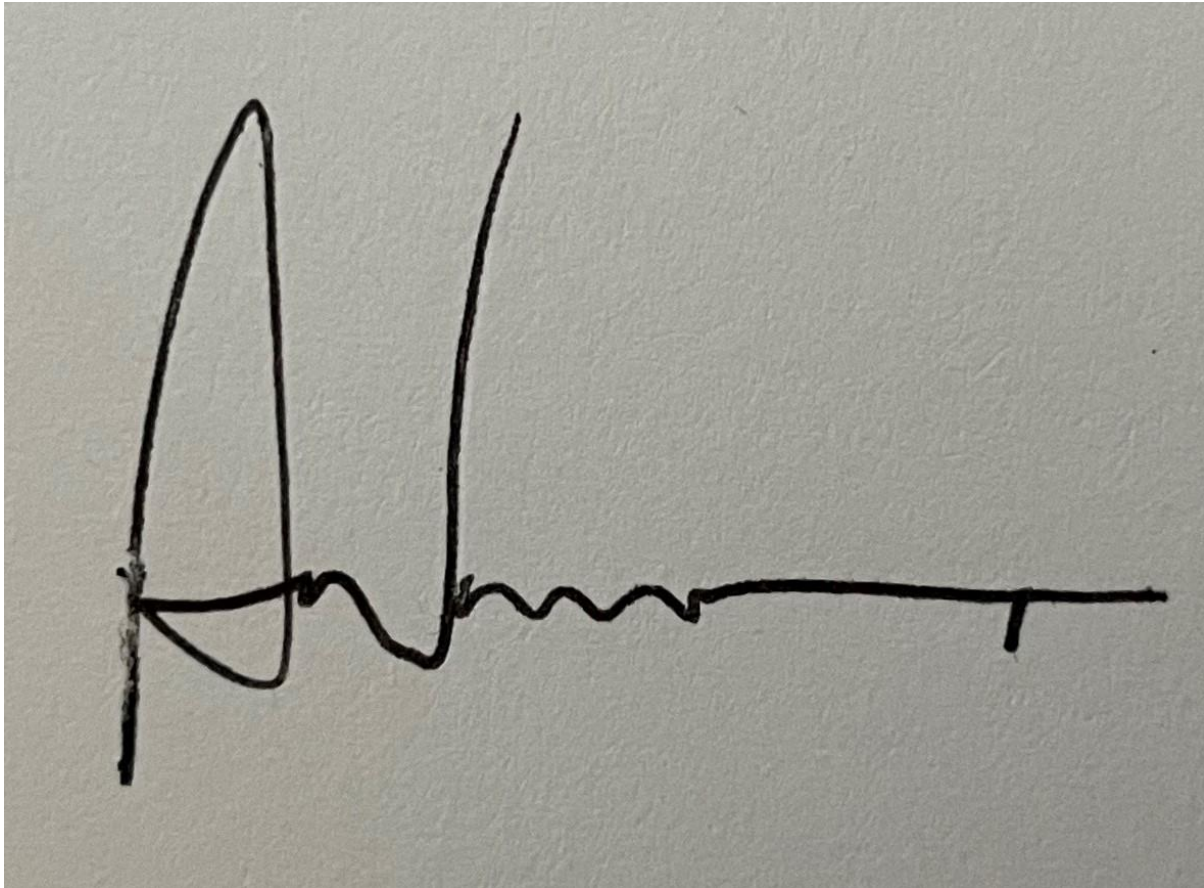
Both IT professionals and engineering leaders in the company identified the need for IT to work as a business partner (maturity level 5) in order to be successful in delivering the company's strategic vision.

The surveys & discussions collectively referred to company policies and controls as frustrations in progress relating to how people want or need to work. This could be explored further but is reflective of Greiner's (1998) Growth Model where *control & red tape* are growing pains for a maturing organisation in which a key warning of crisis is when the aforementioned policies or controls become goals instead of a means. The solution offered by Greiner is to focus on coordination and collaboration with success characterised by the presence of simplified control mechanisms, real-time information systems and cross functional problem solving.

Consistent sentiment was present in interviewees that our status today is a consequence of how the IT function has been considered at the board level and is reflected by the absence of a CIO. As such, the IT organisation is not positioning (scale, skills or strategy) to proactively build technology solutions that compliment the ambitions of the company; of which special reference should be made to:

- transforming operations (industry 4.0),
- smart & connected market verticals (the critical stack which is entwined in the company and exposed to the market as data insight & services) and finally,
- digital transformation of the business which (the infrastructure & services that meet the changing work requirements and styles for a digitally transforming company).

Accentuation of the last point has come about through the impact of Covid-19 on working habits and reliance on adap



connectivity.

6.1 Engineering Analysis

6.1.1 Migrate ANSYS simulation software to Enterprise License Agreement (SaaS) model

The simulation manager can make a sound proposal on how to advance the approach to providing software and hardware solutions for engineering simulation. This will still be of benefit to the business. However, without metrics and reporting on the total state of IT services there will be missed opportunities to maximise value generation.

It is clear that a SaaS solution for the primary engineering simulation tool (ANSYS) provides the flexibility needed to adapt to the emerging and unknown technical demands in engineering. It also provides the elasticity (varying capacity) needed

(primarily in licenses) in parallel with almost immediate access to alternative tools and computation capacity (cloud) that can come with each new project, problem or idea. Due to the unavailability of performance indicators, rates & costs for IT services today, industry norms have been used to demonstrate the potential financial benefits. SaaS makes sense at a balance sheet level and provides the company the means to reach further and faster on new opportunities – new value.

Pure computing capacity is not specific to ANSYS, many engineering tools rely on computational power. As such, there is opportunity to bring efficiencies in sharing that capacity in a common platform. This may not serve all tools but would be an effective overspill platform for some and continue to add to efficiencies.

Understanding the true potential is again reliant on establishing metrics within the company for today's loading, utilisation and cost of ownership. However, using the ANSYS model as a reference, looking at supply base's incumbent cloud technologies and including some anecdotal evidence from user groups an initial proposal can be made for further consideration.

This approach will remove a significant maintenance burden on IT, the engineering applications team & Simulation CoE leadership:

- 120 hours per year saved in license access management (impacting IT, Eng Apps & CoE)
 - 60 line items managed per location (~10) per user (~100)
- 30 hours per year saved in contract management (impacting procurement, finance, management)
- 40 hours per year saved on connectivity optimisation (impacting IT, CoE management)

- 100 hours per year saved in lost work due to Company connectivity problems
(impacting users)

Almost 300 hours per year is estimated to be saved across various functions by moving away from the traditional on premise licensing approach for this single application. The time reduction in response to new needs in the business (agility) is estimated to be around 90 days on average.

Table 13 - On-premise vs Enterprise Licensing for ANSYS

	ANSYS Licensing Today (On premise)	ANSYS Enterprise Agreement (Cloud)
Performance	Limited by available hardware & hardware age. Limited by available licenses (very lean).	Continue to utilise on premise hardware. Additional in session cloud capability gives immediate access to much more powerful computing.
Availability	User level administration of access, complex and cumbersome. Tied to VPN which can be a bottleneck.	All tools, all users, globally.
Reliability	Many access errors due to convoluted access and permissions schemes and infrastructure.	Simplifies workflow to internet connection critical path only.
Elasticity	None.	Highly elastic with anticipated elasticity provisioned for at outside and more on demand if needed.
Scalability	At significant cost outside the budget plan = >1yr latency.	Highly configurable. Cloud capacity allows for burst on demand.
Timeliness	As above.	Can react in days.
Costs (direct)	-	+ 15% increase in opex
Costs (indirect)	+ hidden cost of IT support, procurement and time lost in ability to change	'- reduced cross functional burden '- reduced time to responds
Value	Critical to success. Potential limited by traditional perspective of stress analysis.	Much wider impact on systems, integrated workflows and multi platform solutions and design exploration.

6.1.2 Investigate an agnostic company wide could platform to support other tools

Leveraging cloud capabilities within certain applications can make sense for ease of use and to provide coherent monitoring of usage levels. However, taking this approach for all tools will generate a larger problem with managing the multiplicity of reports and contracts. An Enterprise Management tool such as that posed in section 2)c will go a long way to visualise, report & control this environment. A balance is to be found in creating affinities with the largest tools and finding common services to support the smaller tools and populations where appropriate. Security is also an important factor to consider here and may outweigh the size of the user group.

Nimbix is already provided by the Simulation group for general Engineering use however, due to lack of central ownership, this has not been well promoted or adopted and has not slowed the rise of independent cloud instances around engineering.

User feedback on Nimbix is also poor (see appendix II) but hard to entirely separate from Company infrastructure issues (connection reliability, VPN need, speed etc). A new benchmarking study should be undertaken to understand the current market offerings. The following requirements should serve as a brief for a Request for Information (RFI) and/or Quotation (RFQ) with procurement support.

- Cloud based solving to consider the following tool sets as a minimum:
 - Abaqus, MSC, Matlab, Faraday, CST, Solidworks
- Selectable performance configurations
 - CPU, GPU, RAM, Storage
- Low latency remote sessions

- Compatible with Remote Solve Machine (RSM) protocols or similar
- Real time reporting to include load, type, user and cost metrics.

6.2 Initiatives to Support Change

It is essential for The Company to re-think the approach to IT delivery in order to realise efficiencies in operations and development. The reliance and integration of functions on tools, connectivity, accessibility, management and analysis of data & information, collaboration through virtual spaces has never been more. In this study, the focus has been on engineering but the issues presented can be observed in other areas of the company. The needs of engineering outpace the ability of the current IT model to adapt. This has driven an increasing number of hidden investments that have taken root; by the time these become necessary for IT to engage with, it is often too late to adjust the commitments and reliance on the unvetted (from IT & security point of view) tools and systems. This results in financial, governance, and security risks that are not being measured. The lack of measurement capability & visualisation or mapping on the array of tools actually in use (users, license loading, etc) makes for an almost impossible state to a) report on b) control.

The Company should consider:

1. Establishing a Cloud or Digital Transformation Centre of Excellence (CCoE) to help the company transform.
 - a. Oversight of strategy, planning, design & deployment, innovation and value creation.

- b. Operating as functional, advisory and prescriptive entities. (Hutchinson, 2017)
- 2. Establishing affinity groups to harmonise IT, Engineering Apps and all other hidden resources supporting applications, services, data or stack work.
- 3. Map what is actually running in the company (including rogue tools) and work with finance to attribute wholistic costs and manage them.
- 4. Establish benchmark cost metrics (dollar per hour rates) for on premise HW support, SW support and Infrastructure support.
- 5. Work with affinity groups to focus on opportunities to:
 - a. Integrate tools or data sets
 - i. Knowledge is money, connect people and tools to the right data sets
 - b. Migrate appropriate tools, services or infrastructure to cloud
 - i. Efficiency – use the metrics to drive cost of operation or ROI decisions relating to future needs and current burdens
 - ii. Capability – enable users with solutions that they can't normally justify or utilise in the time frame of a traditional budgetary cycle
 - iii. Connectivity – utilise secure connections that are not reliant on the current VPN bottleneck. This will be important to make remote HPC on cloud a reality.
 - c. Amalgamate tools
 - i. Economy of scale, clean up the portfolio & remove redundancy

Some of the key business areas possibly impacted by digital transformation have been tabbed on the X & Y axis of Figure 13. The goals for engineering analysis are populated.

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This map format has been adapted from the Project Management Institute's guidance for change management (Garfein, et al., 2013).

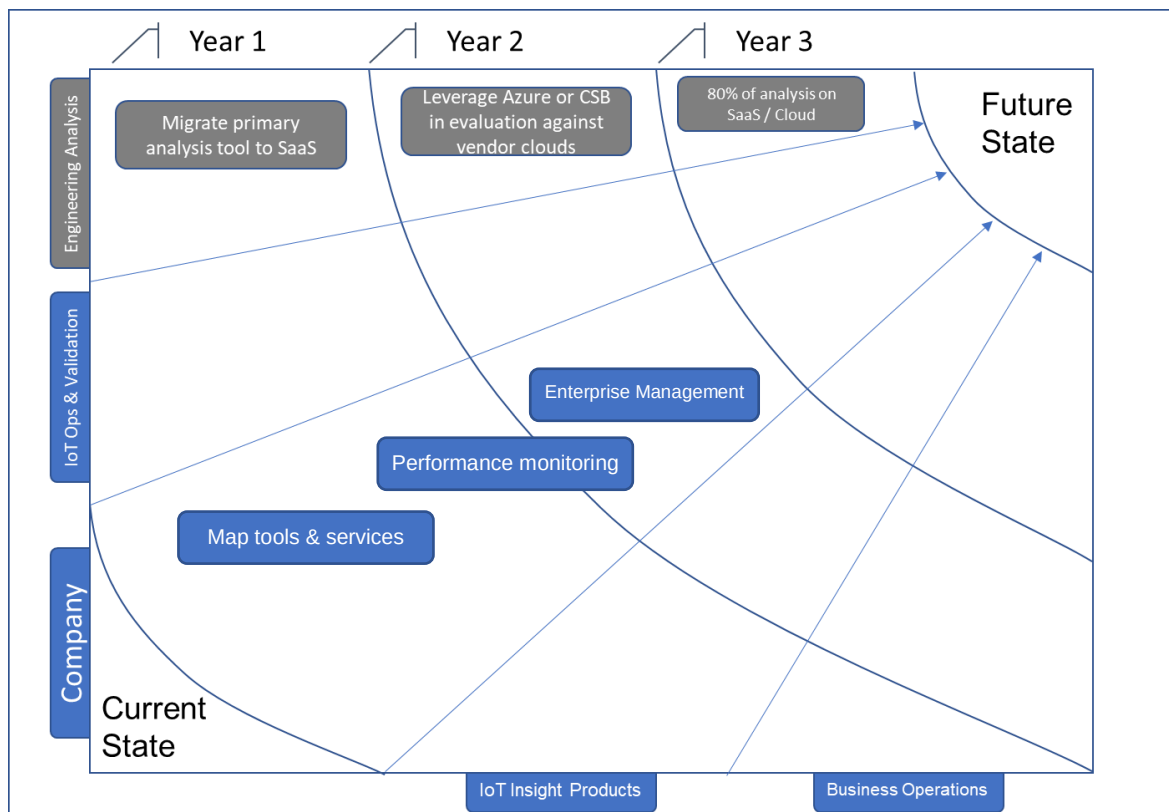


Figure 13 - Possible Strategic Change Map for Digital Transformation

7 Recommendations for Engineering Simulation

Computation

The following recommendations are actionable items that should be delivered in the 6month period following this report. The other considerations discussed in the prior conclusions need further work and would be impactful in the longer term.

7.1 Migrate ANSYS simulation software to Enterprise (SaaS) model

This will enable the agility and innovation with respect to licensing across The Company. Furthermore, the cloud component will increase performance capability for a wider user group have no or insufficient hardware today and add elasticity for current HPC ANSYS users. The Cloud component will remove criticality from the unsatisfactory Nimbix solution and allow time for a coordinated enterprise cloud computation vendor to be selected.

7.1.1 Option A – 2021 Enactment

If possible, accelerate the change within current financial year to deliver capability and capacity across the organisation to support speed of innovation.

- Finalise ELA (Enterprise License Agreement) July 2021
 - Reconfigure equivalent value of licenses in use today
 - Maintain Mechanical, CFD, Maxwell, HFSS
 - Enable OptiSlang, Granta, SCADE and Cloud
 - Increase HPC
 - Consider Minerva
- ~\$60k USD per month in credit against current amortisation

- Continue to use Nimbix as the general cloud computation solution to end of term. Consumption is less than predicted due to usability issues, this is not a trend that The Company should expend effort to correct.

7.1.2 Option B – 2022 Cycle

Follow Option A except for the premature suspension of current contract and credit potential. This will fit more conveniently with the budget cycle of the company but will delay much needed adoption of tools & services for the engineering teams.

7.2 Move IT towards strategic partnership model

As a first step, IT should establish content metamodels as per the TOGAF framework (TOGAF, n.d.). This will help demonstrate the criticality of IT services & architectures to consumers (internally & externally) and aid review of associated funding in The Company.

A maturity model for IT should also be established to demonstrate the status of what *is* and what *should be*. The model should examine the following categories as a minimum:

- Culture / Organisation
- Architecture + Technology
- Methodology
- Security + Compliance
- Emerging Innovation Spaces
- Service Management + Operations
- Data Science + Governance

Alternatively, the six elements of transformation (IBM, 2020) could be focussed on if digital transformation was a strategic priority.

- People
- Process
- Technology
- Compliance
- DevSecOps
- Operations

There is value in digital transformation for The Company but it can not be a business by business approach. The Company should seriously approach this subject from a board level and review CIO, CFO and CTO interactions. Ensuring their shared objectives are not penalising the other.

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Appendices

I Engineering Leadership Survey Data

ID	Are you aware of cloud based services being used around XXXXXX today? Name the top 3 you know of.	What cloud tools are your teams using today for engineering & why? (Consider data, services & computing)	Have you considered moving any of your traditional engineering software, data needs or computing needs to the cloud, if so, what & why?	What are the key problems or risks to moving to cloud solutions?	Do you have clear metrics that demonstrate the loading of existing engineering tools (licenses) and/or computational needs (performance) in your organisation today?	Are cloud services (software, data, computing) at any level, an essential part of your organization's ability to succeed?	Are you aware that the cloud can provide more cost effective & more rapid ways to deliver software, computation and data handling (compared to our traditional approaches)?	Can you accurately state the total cost (amortisation, depreciation, maintenance, uptime, etc) of specialist computing (servers or high performance computers), data handling ...	Do you expect IT to lead the provision & management of cloud services in the same way they provide Office 365 for example?
1	Teams, SharePoint, OneDrive	Teams for meetings, collaboration on documents, SharePoint for project Document storage. OneDrive for general Cloud working space	no, not for other applications as mentioned above	Security and robustness in case of network issues. We should be able to work off line.	No	No	Yes	No	Yes
	I'm interested in the purpose of this survey; the move to cloud hosting will happen naturally, and will be multi-faceted as each tool will have its own 'cloud' depending on the provider of the tool. I don't see a practical situation in which all XXXXXX Engineering tools are on one 'cloud'. When using the term 'cloud' I have defined it as 'not on-premise hardware', as there are, and will continue to be, many different cloud instances for different tools. Some thoughts on possible outcomes: - We need IT/Cybersecurity to support us moving tools to the cloud and get comfortable with the privacy/security provisions available - If there is a desire to keep on-premise hardware for all tools, we need to address as this is an outdated model. A few functions could be justified to stay on-prem long term e.g. highly-sensitive data stores or certificate authorities. - I do not see our corporate IT department being staffed to provide effective support for all our engineering tools, so we will continue to support from our DevOps team to ensure we have the right level of control to support our Sharepoint Teams	- MS Office - JIRA (soon) - Jama - Gitlab (hosted today but considering transition to cloud)	The move to the cloud is well underway for most tools. This is either because the provider is actively encouraging it (like JIRA stopping support for their hosted product) or because we see a better performance/cost/support option for using a cloud instance or because there is no sensible alternative (like using MS Azure for S&C platform). There will be some use cases where tools need to stay on local machines, for example tools which need access outside of the office (e.g. for vehicle testing) or where the compute requirements don't require anything larger than standard laptop hardware.	Minimal beyond a typical IT burden of completing the transfer. Typically cloud-hosted solutions have enterprise-grade security already in place, which is better than what we would have have on-premise (we need IT team support to review and support this). Overall, many engineering tools are well on their way to being cloud hosted in the case that the cost/performance/maintenance drivers make it suitable. The move to a hybrid working model when folks will not be in the office makes cloud hosting more attractive (as opposed to tunnelling in through VPN).	Partial	Yes	Yes	No	No
3	Teams	none	Solidworks, it's still a zbook required to run it	latency / slow response		Yes	Yes	Yes	No
4	Yes, all related to S&C customer and engineering dev data. Not sure if we use Atlassian on cloud platform, also good question for the new Xirgo team. Work based data storage & Teams on MS cloud. Office 365 Teams	Small exposure to tool specific cloud with Nimblex. S&C cloud activity out of the Antrim teams. See above Atlassian & MS comment above.	I have not considered moving to cloud based. No. There are export controls wrapped around most of our data warehousing, so we seem limited in our ability to do this.	NA	No	Yes	Yes	No	No
5	Teams	n/a	See #3.	Bandwidth, inconsistencies between desktop and cloud. Updates lost because of poor remote internet access. Cyber security and product specific assigned keys.	No	Maybe in the future	Yes	No	Yes
6	Yes: SharePoint, MS Teams, Workday Teams	Goldfire (Technical search), & Studio (automating data analysis), Workday Learning	Power BI	No specific consideration. It would be cost driven.	No	Yes	Yes	No	Yes
7	MS tools generally Office 365	None that I am aware of			Partial	Yes	Yes	No	Yes
8	Don't know		Would like advice on this	Standard change, disruption to capability	No	Yes	Yes	No	Yes

Engineering Staff Survey

Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Q21	Q22	Q23	Q24	Q25	Q26	Q27	Q28	Q29	Q30	Q31	Q32	Q33	Q34	Q35	Q36	Q37	Q38	Q39	Q40	Q41	Q42	Q43	Q44	Q45	Q46	Q47	Q48	Q49	Q50	Q51	Q52	Q53	Q54	Q55	Q56	Q57	Q58	Q59	Q60	Q61	Q62	Q63	Q64	Q65	Q66	Q67	Q68	Q69	Q70	Q71	Q72	Q73	Q74	Q75	Q76	Q77	Q78	Q79	Q80	Q81	Q82	Q83	Q84	Q85	Q86	Q87	Q88	Q89	Q90	Q91	Q92	Q93	Q94	Q95	Q96	Q97	Q98	Q99	Q100	Q101	Q102	Q103	Q104	Q105	Q106	Q107	Q108	Q109	Q110	Q111	Q112	Q113	Q114	Q115	Q116	Q117	Q118	Q119	Q120	Q121	Q122	Q123	Q124	Q125	Q126	Q127	Q128	Q129	Q130	Q131	Q132	Q133	Q134	Q135	Q136	Q137	Q138	Q139	Q140	Q141	Q142	Q143	Q144	Q145	Q146	Q147	Q148	Q149	Q150	Q151	Q152	Q153	Q154	Q155	Q156	Q157	Q158	Q159	Q160	Q161	Q162	Q163	Q164	Q165	Q166	Q167	Q168	Q169	Q170	Q171	Q172	Q173	Q174	Q175	Q176	Q177	Q178	Q179	Q180	Q181	Q182	Q183	Q184	Q185	Q186	Q187	Q188	Q189	Q190	Q191	Q192	Q193	Q194	Q195	Q196	Q197	Q198	Q199	Q200	Q201	Q202	Q203	Q204	Q205	Q206	Q207	Q208	Q209	Q210	Q211	Q212	Q213	Q214	Q215	Q216	Q217	Q218	Q219	Q220	Q221	Q222	Q223	Q224	Q225	Q226	Q227	Q228	Q229	Q230	Q231	Q232	Q233	Q234	Q235	Q236	Q237	Q238	Q239	Q240	Q241	Q242	Q243	Q244	Q245	Q246	Q247	Q248	Q249	Q250	Q251	Q252	Q253	Q254	Q255	Q256	Q257	Q258	Q259	Q260	Q261	Q262	Q263	Q264	Q265	Q266	Q267	Q268	Q269	Q270	Q271	Q272	Q273	Q274	Q275	Q276	Q277	Q278	Q279	Q280	Q281	Q282	Q283	Q284	Q285	Q286	Q287	Q288	Q289	Q290	Q291	Q292	Q293	Q294	Q295	Q296	Q297	Q298	Q299	Q300	Q301	Q302	Q303	Q304	Q305	Q306	Q307	Q308	Q309	Q310	Q311	Q312	Q313	Q314	Q315	Q316	Q317	Q318	Q319	Q320	Q321	Q322	Q323	Q324	Q325	Q326	Q327	Q328	Q329	Q330	Q331	Q332	Q333	Q334	Q335	Q336	Q337	Q338	Q339	Q340	Q341	Q342	Q343	Q344	Q345	Q346	Q347	Q348	Q349	Q350	Q351	Q352	Q353	Q354	Q355	Q356	Q357	Q358	Q359	Q360	Q361	Q362	Q363	Q364	Q365	Q366	Q367	Q368	Q369	Q370	Q371	Q372	Q373	Q374	Q375	Q376	Q377	Q378	Q379	Q380	Q381	Q382	Q383	Q384	Q385	Q386	Q387	Q388	Q389	Q390	Q391	Q392	Q393	Q394	Q395	Q396	Q397	Q398	Q399	Q400	Q401	Q402	Q403	Q404	Q405	Q406	Q407	Q408	Q409	Q410	Q411	Q412	Q413	Q414	Q415	Q416	Q417	Q418	Q419	Q420	Q421	Q422	Q423	Q424	Q425	Q426	Q427	Q428	Q429	Q430	Q431	Q432	Q433	Q434	Q435	Q436	Q437	Q438	Q439	Q440	Q441	Q442	Q443	Q444	Q445	Q446	Q447	Q448	Q449	Q450	Q451	Q452	Q453	Q454	Q455	Q456	Q457	Q458	Q459	Q460	Q461	Q462	Q463	Q464	Q465	Q466	Q467	Q468	Q469	Q470	Q471	Q472	Q473	Q474	Q475	Q476	Q477	Q478	Q479	Q480	Q481	Q482	Q483	Q484	Q485	Q486	Q487	Q488	Q489	Q490	Q491	Q492	Q493	Q494	Q495	Q496	Q497	Q498	Q499	Q500	Q501	Q502	Q503	Q504	Q505	Q506	Q507	Q508	Q509	Q510	Q511	Q512	Q513	Q514	Q515	Q516	Q517	Q518	Q519	Q520	Q521	Q522	Q523	Q524	Q525	Q526	Q527	Q528	Q529	Q530	Q531	Q532	Q533	Q534	Q535	Q536	Q537	Q538	Q539	Q540	Q541	Q542	Q543	Q544	Q545	Q546	Q547	Q548	Q549	Q550	Q551	Q552	Q553	Q554	Q555	Q556	Q557	Q558	Q559	Q560	Q561	Q562	Q563	Q564	Q565	Q566	Q567	Q568	Q569	Q570	Q571	Q572	Q573	Q574	Q575	Q576	Q577	Q578	Q579	Q580	Q581	Q582	Q583	Q584	Q585	Q586	Q587	Q588	Q589	Q590	Q591	Q592	Q593	Q594	Q595	Q596	Q597	Q598	Q599	Q600	Q601	Q602	Q603	Q604	Q605	Q606	Q607	Q608	Q609	Q610	Q611	Q612	Q613	Q614	Q615	Q616	Q617	Q618	Q619	Q620	Q621	Q622	Q623	Q624	Q625	Q626	Q627	Q628	Q629	Q630	Q631	Q632	Q633	Q634	Q635	Q636	Q637	Q638	Q639	Q640	Q641	Q642	Q643	Q644	Q645	Q646	Q647	Q648	Q649	Q650	Q651	Q652	Q653	Q654	Q655	Q656	Q657	Q658	Q659	Q660	Q661	Q662	Q663	Q664	Q665	Q666	Q667	Q668	Q669	Q670	Q671	Q672	Q673	Q674	Q675	Q676	Q677	Q678	Q679	Q680	Q681	Q682	Q683	Q684	Q685	Q686	Q687	Q688	Q689	Q690	Q691	Q692	Q693	Q694	Q695	Q696	Q697	Q698	Q699	Q700	Q701	Q702	Q703	Q704	Q705	Q706	Q707	Q708	Q709	Q710	Q711	Q712	Q713	Q714	Q715	Q716	Q717	Q718	Q719	Q720	Q721	Q722	Q723	Q724	Q725	Q726	Q727	Q728	Q729	Q730	Q731	Q732	Q733	Q734	Q735	Q736	Q737	Q738	Q739	Q740	Q741	Q742	Q743	Q744	Q745	Q746	Q747	Q748	Q749	Q750	Q751	Q752	Q753	Q754	Q755	Q756	Q757	Q758	Q759	Q760	Q761	Q762	Q763	Q764	Q765	Q766	Q767	Q768	Q769	Q770	Q771	Q772	Q773	Q774	Q775	Q776	Q777	Q778	Q779	Q780	Q781	Q782	Q783	Q784	Q785	Q786	Q787	Q788	Q789	Q790	Q791	Q792	Q793	Q794	Q795	Q796	Q797	Q798	Q799	Q800	Q801	Q802	Q803	Q804	Q805	Q806	Q807	Q808	Q809	Q810	Q811	Q812	Q813	Q814	Q815	Q816	Q817	Q818	Q819	Q820	Q821	Q822	Q823	Q824	Q825	Q826	Q827	Q828	Q829	Q830	Q831	Q832	Q833	Q834	Q835	Q836	Q837	Q838	Q839	Q840	Q841	Q842	Q843	Q844	Q845	Q846	Q847	Q848	Q849	Q850	Q851	Q852	Q853	Q854	Q855	Q856	Q857	Q858	Q859	Q860	Q861	Q862	Q863	Q864	Q865	Q866	Q867	Q868	Q869	Q870	Q871	Q872	Q873	Q874	Q875	Q876	Q877	Q878	Q879	Q880	Q881	Q882	Q883	Q884	Q885	Q886	Q887	Q888	Q889	Q890	Q891	Q892	Q893	Q894	Q895	Q896	Q897	Q898	Q899	Q900	Q901	Q902	Q903	Q904	Q905	Q906	Q907	Q908	Q909	Q910	Q911	Q912	Q913	Q914	Q915	Q916	Q917	Q918	Q919	Q920	Q921	Q922	Q923	Q924	Q925	Q926	Q927	Q928	Q929	Q930	Q931	Q932	Q933	Q934	Q935	Q936	Q937	Q938	Q939	Q940	Q941	Q942	Q943	Q944	Q945	Q946	Q947	Q948	Q949	Q950	Q951	Q952	Q953	Q954	Q955	Q956	Q957	Q958	Q959	Q960	Q961	Q962	Q963	Q964	Q965	Q966	Q967	Q968	Q969	Q970	Q971	Q972	Q973	Q974	Q975	Q976	Q977	Q978	Q979	Q980	Q981	Q982	Q983	Q984	Q985	Q986	Q987	Q988	Q989	Q990	Q991	Q992	Q993	Q994	Q995	Q996	Q997	Q998	Q999	Q1000	Q1001	Q1002	Q1003	Q1004	Q1005	Q1006	Q1007	Q1008	Q1009	Q1010	Q1011	Q1012	Q1013	Q1014	Q1015	Q1016	Q1017	Q1018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[illegible]

III Recommendations for The Company

- 1) CIO for The Company essential to transform IT to business partner
 - a. The Company is breaking into IoT, Industry 4.0, Data Insights, both in terms of internal operations & external offerings and adapting to a way of working that is more reliant on remote collaboration. This is driving huge change in what is considered in product development, production environments, customer engagement and product type (non -physical, selling data or software). All of these are heavily intertwined with the IT fabric of the Company; what we can achieve will be shaped by the information technology capability in the business. Priorities might include:
 - i. Enabling The Company to operate proficiently and collaboratively regardless of where people are.
 - ii. Mapping and reporting on our services & solutions to ensure capability, economy and security.
 - iii. Building a robust insight platform that protects the Company data whilst maximising the value of that data for customers internal & external.
 - iv. Develop IT strategy that reflects the rapidly changing demands of the business
- 2) Following from the suggested priorities in previous section, a strategy for IT is an obvious absence. Without this strategy, the Company will continue to see diverging and increasing approaches to software, services and infrastructure that are inconsiderate of governance, commercial or security management.

Today, the IT function does not have the capacity (resource or funding) to support the new and developing needs being driven by the business and developed by engineering teams. Reviewing how the IT function supports these emerging technologies in partnership will be important for long term robustness of solutions. Leaving engineers to setup new tools and systems (whilst encouraging innovation) is adding risk to security, stability and effectivity. There is no method for innovators or IT to see what is happening (for systems, services and software) across the company today. Making this activity visible in a consolidated way is essential for effective development and procurement.

- a. Companywide audit of applications and services
 - i. The size of the Shadow IT ² in the company is not known today but anecdotally referred to as common and significant. Auditing what is in use could be a first step in providing visibility of known and hidden tools and services. This might reveal opportunities for efficiencies, scale, addressing security concerns or help shape what the Company cares about for enterprise management and IT strategy/priorities.
- b. License Monitoring & Analysis Software as a minimum
 - i. This is the minimum step needed to enable application owners and IT to understand activity & loading and make the right choices about license renewals, additions, models or permissions in terms of performance and cost. This

² Refers to IT devices, software and services outside the ownership or control of IT organizations (Gartner, n.d.)

understanding is fundamental to considering alternative configurations or service models and realising efficiencies in delivery of tools. This should not be limited to engineering tools.

c. Implement Checklist for Cloud

- i. Any investment in a cloud solution should at the least consider a basic checklist of considerations. Such a checklist has been adapted from proposals by Haque (2020, p. 247).

d. CSB or Enterprise SaaS Management

- i. To maximise efficiencies associated with managing the growing software and services in Company. SaaS management will give a view to IT of activity in the Company. This will allow effective decision making on which tools to adjust, deploy, migrate to their own cloud solution or to run with a generic cloud solution. Either way, enterprise monitoring is required to understand the loading and potential opportunities to reshape the licensing levels, scale of computing and scale of data needs. Enterprise management software can also bring many efficiencies through admin reduction (such as automation of onboarding and offboarding processes for example); this underlines the need to assess the potential in the context of business strategy as there are wide reaching cross functional opportunities and implications – these technologies are not exclusively about IT.

- 3) The Company, with the aid of a strategy, should encourage IT & Procurement to re-evaluate supply of tools and services against Kraljic's model (Have, et al., 2003). In the case of engineering analysis alone, these should be

classified as strategic products and as such become partnerships rather than competing contracts.

IV Recommended Reading Topics

The reading so far has been in aid of levelling the general business familiarity with digital transformation and with specific focus on cloud technology. The following subject areas will be of interest for The Company where a wholistic review of cloud and transformation is undertaken.

- Cloud Transformation Acceleration
- Cloud Operational Excellence:
- Target Operating Model (TOM)
- Cloud Operating Model (COM)
- Cloud Service Management (CSM)
- CSM Value Streams
- CSM Process
- CSM Governance
- Modern Service Management (MSM)
- Cognitive Service Management
- Digital Service Management (DSM)
- Service Integration and Management (SIAM)