White paper

Delphi study findings

Convergence, alignment and integration of Operational and Information Technologies in organisations with Engineering Asset Management functions

Professor Andy Koronoios
Dr Jing Gao
Anastasia Govan

School of Information Technology and Mathematical Sciences
Faculty of Engineering, IT and the Environment

February 2013

Table of contents

Executive summary

Engineering Asset Management (EAM) manages risks when maintaining and replacing critical built asset infrastructure such as water, transport, sewerage and power services. Frameworks to manage such assets are important to the Australian economy as the estimated value of built assets in Australia in 2010 was $600 billion dollars (Australian Asset Management Collaborative Group, 2011) and much of Australia's critical infrastructure relies on operational technology (Beggs, Griffith, 2012).. The concept of EAM is different from other business functions such as finance because engineering assets exist as objects independent of contracts between legal entities (Amadi-Echunda et al., 2010) and are of a specialised nature (Koronios, et al., 2009). Such specialisation has led to the identification of Operational Technology.

Operational Technology (OT) can be found within asset intensive organisations that have hardware or software that detect or cause a change through the direct monitoring and or control of physical devices, processes and events is used. An example is Supervisory Control and Data Acquisition (SCADA) systems monitoring the performance of water or energy utility assets. Due to the nature of OT it is likely to be implemented and managed by engineering areas of organisations separate to information technology (IT) functions (Steenstrup, et al., 2011; Jaffe, et al., 2011). Both technologies share the inherent characteristic of information, although IT is characterised by non-real time decision information and OT by real time asset performance information, commonly classified as data. Although some Australian organisations converged OT and IT some time ago (Wise, 1999), the convergence, alignment and integration of the two technologies has been defined by Gartner since 2006 (Zumic, 2007; Steenstrup, 2008) and recognized as occurring by *(*Zimmerman and Fraser, 2007). Aspects of convergence, alignment and integration of OT and IT forms the basis of recent research by University of South Australia and the Centre for Information Engineering Asset Management.

The research objective is to fill gaps in the body of knowledge of vendors, consultants and engineering asset management organisations in relation to when, whom, why and how organisations should undertake OT and IT convergence, alignment and integration activities and if an Information Governance would bridge the gaps and facilitate the activities. A review of the literature and subsequent study of practitioners' perspectives through Delphi study has confirmed existing knowledge, questioned some aspects and provided new insights from the practitioners' perspective whilst taking vendor and consultant views into consideration. The findings of the Delphi study and comparison to the current literature appear in the paper below and will be supplemented by case study research during 2013.

The Delphi study identified the following recommendations for organisations converging, aligning or integrating OT and IT;

1. Organisations should plan for convergence when external factors such as a corporate vision and consolidated industry standards are in place. Organisations should prepare by analysing business needs and objectives, plan including research available options and develop a convergence strategy. The vendors role includes selling a vision of convergence to organisation.
2. Organisations should move to convergence when there is consensus between business and IT functions within an organisation. Convergence is established when vendors provide hardware which is IP addressable and has the same chips and routers as provided in other parts of the organisation. At this point Engineering and IT should provide input into application development.
3. Organisations should move from convergence to alignment when the hardware is in place but applications and information are disparate. Alignment is established when architectures are aligned. These tasks are undertaken by Engineering and IT with advice provided by vendors
4. Organisations should move from alignment to integration when market competition and need for cost savings arises**.** Integration is characterised by enterprise wide data exchange. These tasks are undertaken by Engineering and IT with advice provided by vendors

The Delphi study also identified the following success factors for organisations converging, aligning or integrating OT and IT;

1. Operational (such as data exchange for maintenance decisions) not business imperatives (such as legal, financial or reputational risks; alignment for management decisions & security concerns) drive convergence, alignment and integration activities.
2. Information Governance does not facilitate convergence, alignment and integration activities. The need for governance of information by operational areas of the organisation drives the activities to be undertaken.
3. The vendors role is to dictate and provide IT based hardware and systems. Engineering and Information Management areas of organisations provide input into systems development by vendors and IT and Engineering manage vendors.
4. Engineers shouldn't be responsible for converging, aligning and integrating OT and IT. This should be a combined IT and Engineering or just IT responsibility.
5. Hardware is already converged to IT standards upon provision to organisation by vendor. The organisations challenge is to integrate the data as OT and IT information structures are often different.

1. Background

Engineering Asset Management refers to maintaining and replacing built asset infrastructure such as water, transport, sewerage, health, land management, mining and energy sectors. Caring for asset health and planning for replacement has evolved in the past thirty years into an integrated, holistic framework incorporating human resource management, project management, engineering, maintenance planning and enablers such as the people, processes, technology and information governance (Sethis and Sethi, 1990; Burns, 2000; Sklar, 2004; Government Asset Management Committee, 2004; Schneider, 2006; British Standards Institute, 2008; Too, 2010; Amadi, 2010; Australian Asset Management Collaborative Group (2011). Such a holistic framework is crucial to the success of managing the built asset environment (Too, 2010; IDC, 2010) worth $600 billion to the Australian economy (Brown, 2011).

As part of the drive to a holistic model the operational and information technologies traditionally separately managed by the engineering, operational and information technology areas of organisations are converging, aligning and integrating (Lin et al., 2007; Waddington, 2008; Koronios et al., 2009, Thomas, 2009; Haider, 2010; Steenstrup, 2010; Institute of Public Works engineering Australia, 2011; Strenstrup, 2011; Berst, 2011Steenstrup, 2012) at a time when information volumes and number of information stores in organisations is growing (The Economist, 2010; McKinsey Global Institute, 2011; Manyika, et al., 2011; Friedman, 2012; Lohr, 2012; World Economic Forum, 2012). If such fragmented operational and information technology environments and the responsibility and authority for them can be defined; legal, financial and reputational risks can be reduced (Humphrey, 2003; McManus, 2004; Parekh, et al., 2007; DuBois and Tero, 2010; May Business School, 2011).

Figure 1: Gartner OT and IT convergence, alignment and integration activities [1]

Despite the reduction in risks, research into how information governance can assist operational and information technology to converge has been minimal (Frolov, 2009; Hayler, 2011). The specific gaps in the current research on OT & IT convergence include identifying the criteria for when to balance authority and responsibility for the governance of information between Information Technology and other areas of the organisation and identifying the criteria for if and when organisations should converge, align and integrate OT and IT. There is also a plethora of existing standards, models, legislation and case law for governing information, technology, and related staff and processes (Hillard, 2010) that do not identify which components are the most appropriate for the unique EAM environment.

[1] Source: Steenstrup, K. et al. (2008). IT and OT: Intersection and Collaboration. Gartner.

2. Operational and Information Technology convergence

Operational and Information Technology systems, people and processes have traditionally been managed separately (Jaffe et al, 2010; Steenstrup, 2010). Distinguishing components of each technology appear in Figure 2 below. The disparateness of control systems such as SCADA, corporate drives, email accounts, hardcopy files, mobile devices, finance, asset and human resource systems and proprietary dependency of technology tiers such as databases, servers and processors which weaken control and expose organisations to legal, financial and reputational risks can be reduced (Humphrey, 2003; McManus, 2004; Parekh, et al., 2007; DuBois and Tero, 2010; May Business School, 2011).

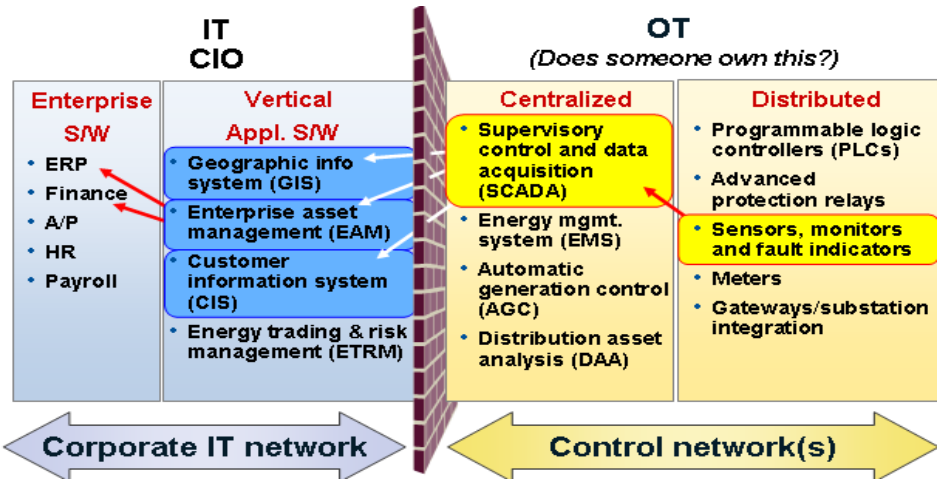


Figure 2: Differences between Information and Operational Technologies [2]

Many have identified benefits of converging information repositories such as OT and IT systems and staff support areas across the asset management lifecycle (Lin, et al., 2007; Thomas, 2009; Institute of Public Works Engineering Australia, 2011; Waddington, 2008; Strenstrup, 2011b; Koronios, et al., 2009; Berst, 2011 Haider, 2010). Benefits include reduced hardware and network requirements, integrated life cycle management, reduced licensing costs, data quality improvements from automation, leveraging outsourced maintenance arising from use of the cloud and same skilled information technology staff, improving strategic decision making from retrievable holistic single dashboard view of the organisations information and improving competitive use of utility assets (Streenstrup, 2011a; Torchia, 2011; Newman, 2011; Lin, et al., 2007; Jaffe et al, 2010; Bonnet, 2010).

At an engineering operational level Parekh et al. (2007) argues the convergence of operational and information technologies provides enhanced delivery of utility services. Vendors such as Ventyx are providing converged operational and information technology platforms that converge operational transactional throughput information from systems such as SCADA with billing systems (Jaffe, 2011; Berst, 2011; Rhodes, 2011). An operational example of convergence is represented in figure four below. The figure represents the complex and unique EAM environment of a smart grid. A smart grid converges asset performance data (the operational technology systems) with real time consumption and billing information (the information technology systems). Jaffe et. al. (2011) indicates the gaps of such a formative converged environment include funding, technical convergence of technology architectural layers and governance of complex components. Benefits from implementation of such a converged environment can only be realised by applying an information governance framework holistically across the integrated environment as information is the consistent factor throughout such an EAM context.

---

[2] Source: Steenstrup, K. et. al. (2010). Operational technology Convergence with IT: Definitions. Gartner.

A clear definition of a converged technology is challenging to ascertain. Whilst Gartner indicates convergence is integration of platform, programming language and standards (Steenstrup, 2010), IDC defines convergence as the percent of data centre storage, memory, server nodes, network I/O, and virtual OS images that can be deployed from a pooled collection (Villars & Perry, 2011). For the purposes of this research Gartner definitions are used to holistically encompass the people, process and technology aspects of an asset intensive organisation's information environment. What is inherent in OT and IT, converged or not, is information required for decision making.

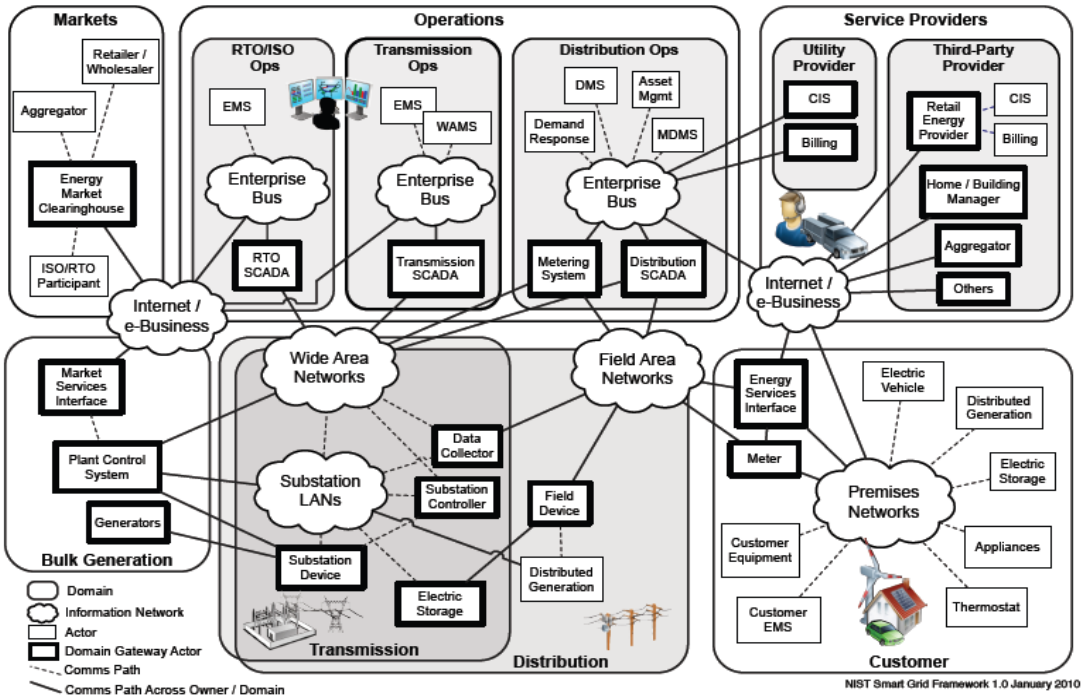


Figure 3: Convergence of Information and Operational Technology in an energy grid context[3]

[3] Source: Office of the National Coordinator for Smart Grid Interoperability . (2010). NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 1.0 . National Institute of Standards and Technology : Gaithersburg

3. Research methodology

3.1 Delphi research method

The Delphi research method was chosen as appropriate for the current research as it has been used since the 1950's in information system contexts (Walsham, 1995) for technical forecasing (Helmer, Dalkey and Descher, 1959; Gordon and Helber, 1964; Cornish, 1977). Delphi facilitates anonymity whilst determining consensus of experts between opposing groups in areas of organisations such as Engineering and IT (Sitt-Ghodes and Crews, 2004; Powell, 2003; Turoff, 1970). The challenge is to define an expert and when consensus is reached.

Since the inception of Delphi studies in the 1950's a best practice guideline for deployment, when consensus is reached or data analysis has not been identified (Hasson, Keeney and Mckenna, 2000). Hsu and Sandford (2010) indicate an expert is defined as one highly trained and possing expertise in the area of study. Optimal participant numbers varies widely in the literature from 15 (Stitt-Gohdes and Crews, 2004; Burns, 1998) to thirty (Delbeq, Vandenven and Gustafson,1975). There is also a lack of agreement as to the importance or not of continuous participation between rounds on the reliability or validity of the research results (Crisp et al, 1997; Buck et al.,1993; Powell, 2003; Stitt-Gohdes and Crews, 2004) is important. Indentifying consensus is equally contested. Early Delphi studies (Dalkey; 1969; Linstone and Turoff 1975) indicate three rounds and recent studies two rounds (Proctor and Hunt, 1994; Beech 1997 and Green et al, 1999) depending upon percentage drop out of 20% between rounds.

Measures of central tendancy such as correlation coefficients, percentages, mean, median, and Inter Quartile Range (IQR) have been used to identify consensus in Delphi studies (Chandler, 1996; Dalkey, 1969 and Linstone and Turoff, 1975; Santos, Araújo and Correia, 2012; Turoff, 2002; Raskin, 1994; Rayens & Hahn, 2000; Von Der Gracht, 2008). Percentages were not used in the current research as no consensus on the percentage point consensus was identifiedcould be found in the literature ranging from more than 15% change in mean score between rounds and 51% - 100% identified as the consensus point (Stitt-Gohdes and Crews, 2004; Hasson, Keeney, McKenna, 2000; Green et al (1999); Sumsion, 1998; Loughlin and Moore, 1979 and Mckenna, 1994).

To facilitate the current research meeting the research objectives of credibility, fitting, auditable and confirmable (Lincoln and Guba, 1985) and construct, internal and external validity and replication (Yin, 2009) The Interval Quartile (or interquartile) Range (IQR) was calculated as this has been used to indicate consensus in original Delphi studies (Dalkey, 1969; Linstone and Turoff, 1975) and recent studies in IT contexts.. An IQR of less than 1 with closer to 0 representing higher consensus. These three statistics were taken into account when ranking with highest ranking given to a high mean, standard deviation closest to 0 and an IQR less than 1.

A summary of statistical signs provided throughout the research appear below.

Mean	**Standard Deviation**	**Interquartile Range**	**Number of responses**	**Likert scale**
$\bar{x}$	σ	IQR	n	1 = Never 5=Always

Table 1: summary of statistics described in the paper

3.2 Participant details

In the first round thirty experts from twenty seven Australian consulting, utility, mining, councils, IT solutions, planning and development government agencies and engineering manufacturers agreed to respond to six open ended questions relating to convergence, alignment and integration of operational and information technology in organisations with engineering asset management functions. Fifteen responses (50%) were received over four weeks in October and November 2012. Twelve responses were received via email, two were elicited via telephone calls and one by social media. Three respondents indicated they could not continue as the questions did not relate to their organisations functions. Other non respondents indicated that they were not familiar the convergence of operational technology and information technology to adequately respond providing a self determining activity of ensuring expert input.

Responses were thematically analysed and provided rankings of key terms for use in round 2. A Likert scale was added to the questionnaire to facilitate identification of consensus. Twelve individuals of the fifteen participating in Delphi questionnaire for round one responded (80%) to eight questions relating to to answer questions covering .when organizations should converge, align and integrate OT and IT, whom should be responsible, why and how organisations should undertake such activities and if information governance could facilitate convergence, alignment and integration activities in organisations with engineering asset management functions. Responses from consultants, energy utilities, government asset providers, mining and councils were received over three weeks in November and December 2012. Eleven responses were received via email and one via telephone.

For round 3, those responding to round 1 and or 2 were invited to respond. An individual email inviting changes to round 2 responses were provided to sixteen respondents noting group consensus statistics and individual responses by question. Those not responding by end of January were followed up with a phone call on January 24th and 25th 2013. Of the sixteen invited to respond, 10 responded (62.5% down from 80% in round 2) from consultants, energy utilities, government asset providers, mining and councils to eight Four changes were made by respondents between rounds one and two and these did not alter consensus rankings from round 2. An almost 20% drop in responses between rounds indicated there would be little benefit from undertaking subsequent rounds particularly where the same depth of concept description means overselling is a risk to busy experts (Linstone and Turoff (2002; Goodman, 1970).

4. Results

4.1 Who undertakes convergence, alignment and integration activities?

Who undertakes the convergence activities focuses on two relationships, one external to the organisation and the other internal.

Comments from respondents for round 1 indicated a lack of agreement in regarding the role of vendor and organisation in convergence, alignment and integration activities. Later rounds confirmed consensus that vendors converge technology, particularly the hardware tier, and organisations align and integrate OT and IT. fically addressing this topic was added for rounds 2 and 3. As a Likert scale was not used for this question the IQR was not calculated. Respondents were also in consensus that vendors undertake convergence activities when identifying criteria for moving from convergence to alignment, cross validating response reliability between the two questions.

Responses		$\bar{x}$	**(σ)**	**%**	**(n)**
Round 3Yes	8 (1)	1.58	.9	66	12
Round 2 Yes	7 (1)	1.64	.92	63	11
Round 2 Partial	3 (2)			27	11
Round 2 No	1 (3)			9	11

Table 2. Responses confirming Gartner statement that vendors responsible for convergence and organisations are responsible for alignment and integration activities

Respondents were also surveyed as to if IT or Engineering areas of an organisation would be best suited to undertake the alignment and integration activities of OT and IT. Group consensus indicated that a combined responsibility should always occur, that maybe IT should be responsible for the tasks but never Engineering on their own.

RESPONSE	$\bar{x}$	**(σ)**	**(IQR)**	**(n)**	**ORDER ROUND 1**	**LEVEL OF POSITIVE CONSENSUS**
Combined	4.73	.47	-0.5	11	2	Strong
IT	3.5	.97	-1	10	1	Medium
Engineering	2.78	.67	-1	9	2	Low

Table 3: Group consensus indicating a combined IT and Engineering effort to undertake alignment and integration activities

4.2 Why should organisations align and integrate Operational and Information Technologies?'

Respondents agreed that increased reliability and efficiently exchanging and managing information and data to be the top reasons why organisations align and integrate OT and IT. The group were in consensus that single platform and decreasing costs as reasons why organisations should align and integrate OT and IT. Comments provided by respondents in round two indicate that operational drivers such as information and data volumes and not management factors such as cost drive why organisations align and integrate and that single applications may not be achievable due to inherent differences such as data in OT systems and information in IT systems. Rankings changed between round 1 and subsequent questionnaire rounds. Single platforms was mentioned the most in round 1 thematic analysis but ranked last in relation to consensus in statistical calculations in subsequent rounds

Consensus was also not achieved in relation to identifying increased security as the reason organisations align and integrate technologies.

RESPONSE	$\bar{x}$	**(σ)**	**(IQR)**	**(n)**	**ORDER ROUND 1**	**LEVEL OF POSITIVE CONSENSUS**
Efficient exchange of data and management of information and data	4.55	.52	-1	11	3	Strong
Efficient management of information	4.45	.69	-1	11	4	Strong
Increased reliability	4.36	.67	-1	11	2	Strong
Decreased cost	3.55	.82	-1	11	3	Medium
Single platform	3.09	.83	0	11	1	Medium
Increased security	3.55	1.29	-1.5	11	3	No consensus

Table 4: Information and data management identified as top reasons why organisations align and integrate OT and IT

4.3 How should organisations go about aligning and integrating Operational and Information Technologies?

Respondents identified that activities should always be a joint business effort with organisations undertaking business analysis. Mean scores indicated that standardised platforms were not never or always required. Cost was also identified as a non factor for the question identifying when organisations should move from convergence to alignment activities. No consensus was reached in relation to vendor involvement. Cost and vendor rankings changed between round 1 and subsequent rounds, although not significantly.

RESPONSE	$\bar{x}$	(σ)	(IQR)	(n)	ORDER ROUND 1	LEVEL OF POSITIVE CONSENSUS
Business analysis	4.36	.81	-1	11	1	Medium
Joint business effort	4.27	.79	-1	11	2	Medium
Standardised platforms	3.64	.81	-1	11	1	Medium
Vendor involvement	3.45	1.04	-1	11	3	No consensus

Table 5: Organisations should undertake business analysis and have a joint business effort when moving from convergence to alignment activities

4.4 What criteria would indicate organisations should move from converging to aligning Operational and Information Technologies?

Respondents were in consensus that organisations should always move from converging to aligning activities when hardware is consistent but applications are disparate, when business needs are accounted for but recognising one size solution does not fit all organisations.

Whilst rankings did not change between round 1,2 and 3 questionnaire responses, responses confirmed rankings of items.

RESPONSE	$\bar{x}$	(σ)	(IQR)	(n)	ORDER ROUND 1	LEVEL OF POSITIVE CONSENSUS
Hardware consistent but applications disparate	4.09	.7	-.05	11	1	Medium
One size not fit all organisations	4	.77	-1	11	2	Medium
Business needs accounted for	4.36	.81	-1	11	2	Medium
Costs	3.45	.82	-1	11	2	Medium
This is only done by vendors	2	1	-1.5	11	2	No consensus
This happens at vendor not organisational level	2.27	1.19	-2	11	2	No consensus

Not clear where line is	3.18	1.33	-2	11	2	No consensus

Table 6: Organisations should move from convergence to alignment activities when hardware is consistent and business needs are accounted for

4.5 What are the technology (software, hardware, communications) , organisation (Culture, business context) and people (recruitment, skills, training) related success factors for aligning and integrating Operational and Information Technologies?'

Analysis of responses appear below by success factor.

4.5.1 Technology factors

Due to low consensus in the two highest ranking items from round 1 in round 2, the next highest four ranking elements from round 1 were added for round 3 (identified by italics in the table below). Two responses were received with analysis appearing in the table below indicating minimal change to consensus identification.

RESPONSE	**ROUND 1 ORDER**	**ROUND 2 ORDER & GROUP MEAN SCALE RESPONSES**	**ROUND 2 LEVEL OF POSITIVE GROUP CONSENSUS**	**ROUND 3 CHANGES 1=NEVER 5 =ALWAYS**
Interoperable solution	1	3.82	Low	
Acceptance of Open Source solutions	2	3.09	No	
Remove reliance on closed source software	*3*	*N/A*	*N/A*	*1*
Best of breed acquisition approach	*3*	*N/A*	*N/A*	*1 and 4*
Thin clients	*3*	*N/A*	*N/A*	*1*
Wired Ethernet	*3*	*N/A*	*N/A*	*2*

Table 7: Re identification of technology success factors for aligning and integrating OT and IT

A third element of Best of breed acquisition approach was added to from round 3. This did not change ranking order or consensus outcome from rounds 1 and 2 as no consensus was identified and the result potentially skewed as one of the two respondents (which is not representative of the sample) is a hardware and software vendor.

There was no change to the order of ranking between rounds 1 and 2 but standard deviation and IQR scores for acceptance of open source solutions indicates consensus was not achieved for this item. Mean scores around 3 for both items indicates respondents did not think organisations should always or never account for both items.

RESPONSE	$\bar{x}$	(σ)	(IQR)	(n)	ORDER ROUND 1 and 3	LEVEL OF POSITIVE CONSENSUS
Interoperable solution	3.82	.87	-1.5	11	1	Low
Acceptance of Open Source solutions	3.09	1.04	-2	11	2	No consensus
Best of breed acquisition approach[4]	2.5	2.12	-1.5	2	3	No consensus

Table 8: Limited consensus on top three success factors to consider when aligning and integrating OT and IT

4.5.2 Organisational factors

Differences in order of item ranking between round 1 and 2 responses is Strategic vision increased in ranking from 5th to 2nd and the importance always to organisations of standards (open data, communications) dropped from1st to 4th. Agreed enterprise level architectures moved from 2nd to 1st with a IQR of 0 and low standard deviation, indicating consensus on this item remained between the two rounds.

Consensus was not achieved on the response Systems thinking analysis. One respondent in round two mentioned this item several times in round 1 responses but did not respond to questionnaires in subsequent rounds.

RESPONSE	$\bar{x}$	(σ)	(IQR)	(n)	ORDER ROUND 1	LEVEL OF POSITIVE CONSENSUS
Agreed enterprise level architecture	3.91	.54	0	11	2	Strong
Strategic vision	4.27	.47	-0.5	11	5	Strong
Research, plan and execute	4.45	.69	-1	11	3	Medium
Standards (open data, communications)	4.18	.6	-.5	11	1	Medium
Manage as a project	4.18	.75	-1	11	3	Medium
Mutual collaboration	4.09	.71	-1	10	4	Medium
Robust framework	3.91	.7	-0.5	11	5	Low
Systems thinking analysis	4	1	-1.5	11	5	Low

Table 9: Top ranking organisation success factors when aligning and integrating OT and IT.

[4] Responses received in round 1 and 3 were used to calculate and therefore add the third element

4.5.3 People factors

The only response that indicated organisations should always account for an item with consensus indicated by the standard deviation and IQR was input from all. Further research will be undertaken regarding appropriate training as the standard deviation and IQR scores conflicted as to if consensus was achieved or not as the SD is below 1 and mean responses indicate the activity should always occur but consensus was not achieved due to spread of responses.

Although ease of use and engineering and IT role to catalyse business change indicated consensus, responses were clustered around organisations neither always or never accounting for these items.

RESPONSE	$\bar{x}$	**(σ)**	**(IQR)**	**(n)**	**ORDER ROUND 1**	**LEVEL OF POSITIVE CONSENSUS**
Input from all	4.27	.9	-1	11	2	Medium
Ease of use	3.55	.82	-1	11	2	Medium
Engineering and IT role to catalyse business change	3.64	.81	-1	11	2	Medium
Appropriate training	4.18	.87	-1.5	11	1	Low
Acknowledged office of CIO	3.73	1.01	-1.5	11	2	No consensus

Table 10: Top ranking people success factors organisations should account for when aligning and integrating OT and IT.

4.6 What criteria would indicate organisations should move from aligning to integrating Operational and Information Technologies?'

Organisations should always move from alignment to integration when market competitiveness requires it. Respondents also were in strong consensus that organisations should also move when data use requires it and when IT and OT architectures are aligned, although answers were polarised more towards 'never'.
This is the only question were mean responses indicating consensus, although responses being distributed and understanding of the question improving between round 1 and 2, indicated that it is an activity not always done by organisations and not vendors. Respondents either did not have consensus or identify that organisations should always move from alignment to integration when cost is not an issue, when standards are aligned, when business and IT have consensus.

RESPONSE	$\bar{x}$	**(σ)**	**(IQR)**	**(n)**	**ORDER ROUND 1**	**LEVEL OF POSITIVE CONSENSUS**
When market competitiveness requires it	4.36	.67	-1	11	2	Strong
When data use requires it	3.82	.75	0	11	2	Medium

When IT/OT architectures aligned	3.82	.75	0	11	2	Medium
This is only done by organisations and not vendors	2.36	1.21	-.5	11	2	Low
When cost is not an issue	3	1.26	0	11	2	Low
When standards aligned	3.82	.98	-1.5	11	2	Low
When business and IT have consensus	3.91	1.14	-1.5	11	2	No consensus
Not clear where line is	2.5	1.43	-2	10	1	No consensus

Table 11: Organisations should move from alignment to integration activities when market competition requires it

4.7 How can information governance (IG) facilitate convergence, alignment and integration of Operational and Information Technologies?'

Top rankings changed between rounds. The round 1 top rank, 'governance informs strategy', moved down to second place ranking in round 2.

RESPONSE	$\bar{x}$	**(σ)**	**(IQR)**	**(n)**	**ORDER ROUND 1**	**LEVEL OF POSITIVE CONSENSUS**
Facilitate enterprise level technology change coordination	4.18	.75	-1	11	4	Medium
Governance informs strategy	4.09	.83	-1.5	11	1	Low
Identifying operations	3.64	.92	-1	11	4	Low
When a uniform approach by Information Technology and Information Management	3.64	1.21	-0.5	11	2	Low

required						
Identifying who owns the data	4.09	1.14	-2	11	3	No consensus
Facilitate agreement on hardware and software	3.27	1.19	-2	11	3	No consensus

Table 12: How information Governance may facilitate OT and IT convergence

5. Comparison of research results to existing literature

The main legal, financial and reputational drivers cited for why organisations undertake IT and OT convergence include integrated and timely provision of information for managing people, processes and technology; cost of running parallel architecture; security and reliability. Whilst these aspects focus on management drivers, the current research identifies operational drivers rank much higher. Experts in the current study identified the need to manage information and data and increase reliability as the highest ranking drivers. In fact the need to efficiently exchange data and manage information was the highest, positive consensus item in all three rounds of the Delphi study.

The importance of governing information and data is embodied in many forms of information, technology and engineering literature. There is an abundance of these (Hillard, 2011, Thomas, 2009) including information standards (such as MIKE 2.0, Knowledge Management and Records Management), IT standards (such as COBIT) Engineering information and data exchange particularly for smart grids (PAS55 and CIP), frameworks (such as Gartner, IBM and IDG). The recent debars regarding the implications of big data (Devenport et al., 2013; WEF, 2012; The Economist, 2010; Romero, 2010) also highlight the importance of governing information. The economic benefits and formulas for evaluating and managing such volumes have been debated for over twenty years by well known management theorists (Drucker, 1995;Davenport, 2005; Prusak & Davenport, 1997; Strassmann, 1999; Kaplan & Norton, 1996; Knapp, 1998; Sveiby, 1997; Danigelis, 2012; The Economist, 2010).

The Delphi study results reinforced through strong practitioner consensus that Information Governance facilitates enterprise level tech change. Whilst one of the original research questions was how Information Governance facilitates EAM organisations to converge, align and integrate OT and IT, the need to govern information and integrate to a single platform drives the activities, not an activity that is applied later. Enterprise Information Management is crucial to a successful EAM strategy in asset intensive organisations (Williams, 2011, Parekh, 2007; Vegas, 2011;Caonato, 2013; White, 2007; Debois, 2012; Caldwell, 2011; Nicolett & Proctor, 2011, Logan, 2012) and for realising interoperability in critical service infrastructure such as water and energy grids (Parekh, 2007; Romero, 2011;Torchia, 2011; Office of the National Coordinator for Smart Grid Interoperability, 2010; Steenstrup, 2012; McDonnell Group, 2012) driven by smart meter data transfer. For example a recent Congressional Research Service report in the united states cited up to $50 billion dollars will be spent in the US alone on deployment of smart meters and 100 million smart meters will be deployed worldwide in the next five years (NIST, 2010) making information and governance of such through interoperable standards a major driver. The necessity of interoperable of standards and technology architecture tiers was identified by research participants and will be included in further research in the form of case studies of the Victorian energy smart meter rollout.

The findings should not be surprising as the need to manage information (prevalent in IT systems such as billing) and data (prevalent in OT systems such as SCADA and Telemetry) is the reason why the systems exist. The underlying issues in aligning and converging is the inherent structural differences of data and information in the two technologies. Cost has been cited as a driver for converging, aligning and integrating OT and IT in the asset management literature (Parekh, 2007; Zimmerman and Fraser, 2007) but did not rate highly in the current study. Instead, respondents indicated cost as a factor for not integrating OT and IT into a single platform due to the structural differences between data and information, although interoperability of standards and IT architecture were ranked by experts. .

Steenstrup (2012) reported a trend for increasing integration tasks but project spend was on less costly projects and was undertaken by organisations with high financial value.

Along with cost, security risks in relation to OT and IT system integration in EAM environments is also prevalent in the current literature but was not a high consensus item in the current research results. Security of particularly OT interfaces to IT networks in organisations is currently the subject of several newspaper articles, conferences and papers (Zimmerman and Fraser, 2007; Kernick, 2012a; Griffith, 2012; Barwick, 2013 Chaudary, 2012; Beggs, 2012; Mahoney, 2013) and reduce virus threats such as Stuxnet protruding from poorly architected and firewalled OT systems residing on organisation's IT networks . The increase in recent writing on the topic coincides with the federal governments announcement of a Cyber Centre for Australia.

People, process and technology and information drivers are recognised as management elements to improving organisations (Leavit, 1965; Rockart & Morton, 1984; Zimmerman and Fraser; 2007; Anzia; 2011; Nuku and Rusu, 2011; Inge 2010) and are key pillars to an integrated asset management strategy (Too, 2010; Sklar, 2004; Mays Business School, 2011; Humphrey, 2003; Brown et al 2011;Yeoh, Koronios and Gao, 2007). Training, communication (Esteves, 2002) , management support for IT are often mentioned in management literature relating to IT projects they did not rank highly by experts in the current research. What did rate highly was integration and alignment of OT and IT should be an enterprise wide task by Engineering and IT staff. Such interaction between these parts of the organisation has been recognised as increasingly occurring in recent Gartner (Steenstrup, 2012) and Rockwell studies (Zimmermann and Fraser, 2007) surveys on OT and IT integration by asset intensive organisations.

Operational drivers such as interoperability and particularly reliability ranked much higher in the current study. Interoperability is related to the discussion above regarding integration of architecture tiers between IT and OT so will not be revisited here. Reliability is an inherent characteristic of OT systems more than IT systems due to the operational role of OT to ensure supply of critical services such as power, water and post and performance of assets which facilitate the delivery of the critical services (Williams 2011, Zimmerman and Fraser, 2007; McDonnell Group. (2012), Steenstrup, 2013).

5.1 How EAM organisations converge, align and integrate OT and IT

Findings in the current research also indicated operational factors instead of management factors rated higher in expert consensus when identifying how organisations should converge, align and integrate. Whilst analysing business needs and planning is mentioned in the literature expert consensus provided further contributions to the body of knowledge by identifying specifically the need for a convergence strategy and enterprise wide planning with particularly IT, Engineering and Records areas of the business before organisations approach vendors for particularly converged hardware solutions. The importance of technology did not rate highly, in fact little consensus could be identified on factors such as acceptance of open source solutions, best of breed acquisition approach and thin clients identified in the thematic analysis following round one open ended questions to participants. Open source, particularly in relation to standards has been identified in the literature ((Torchia, 2011; Office of the National Coordinator for Smart Grid Interoperability, 2010; Steenstrup, 2012; McDonnell Group, 2012; International Electrotechnical Commission, 2007) along with modelling and programming using object oriented design (Fishwick, 1996), integration

framework for systems (Zackman, 1987), rule language following Event, Condition and Action (ECA) paradigm (Choi, 2000) and SOA (Parekh, 2007). Large financial gains have been reported by Santos in recent years by deploying an open source OT and IT integrated architecture (Fran, 2011; OSIA, 2011).

5.2 Who is involved with converging, aligning and integrating OT and IT

A discussion on how organisations should converge, align and integrate IT naturally leads to whom should be responsible for the activities. A unique contribution of the current research findings is that although participants did agree with Gartner's notion that vendors conduct convergence activities (Steenstrup, 2010), they did identify this should occur exclusively in terms of hardware (provision of IT hardware to replace proprietary OT hardware) but organisations expect to have input into vendor software solutions. Participants were also in consensus with Gartner (Steenstrup, 2010) that organisations align and integrate technologies but vendors would be expected to provide advice at these stages.

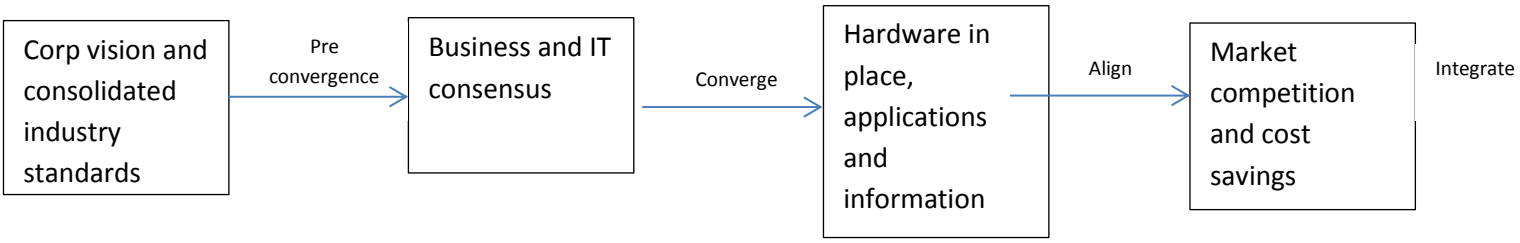
The literature suggests that EIM should be a shared responsibility across the organisation (Parek, 2007). In early advice about OT and IT convergence Gartner argued IT is best suited to be responsible for integration and alignment tasks (Steenstrup, 2008) due to the maturity of governing the environment (for instance by applying COBIT) Gartner (Steenstrup, 10) and Rockwell (Zimmerman and Fraseer, 2007) analysts now recognised a joint approach with Engineering to leverage the OT and engineering strengths of reliability, business impacts, information flows, granuality and quality (Steenstrup, 2008; Boone, & Ganeshan, 2008; Haider, 2011; Newman, 2011). Although articles written by engineers on convergergence of OT and IT (such as Fishwick, 1996) argue engineers should be responsible for the OT tasks, none of the engineers responding to the current study identified this. Consensus was clustered around a joint Engineering and IT responsibility. Participants consistently highlighted throughout the Delphi study the need for analysis of business through a joint business effort.

5.3 When organisations should align and integrate OT and IT

Gartner and Rockwell have identified maturity models for OT and IT convergence, alignment and integration but have not identified when such tasks should be undertaken by asset intensive organisations. The greatest contribution of the current research on expert consensus to the body of knowledge is that organisations should start by having a corporate vision, consolidated by industry standards. The importance of industry standards that are interoperable is highlighted in the current literature and cases of OT and IT convergence such as the Victorian smart meter rollout (Pearson, 2009). When organisations have business and IT consensus the organisation should move from convergence to alignment activities. This should occur when hardware is consistent but applications are disparate still. Business needs should be accounted for and organisations recognise they will need the input of vendors as one system supported by a single vendor will not fit all asset intensive organisations business processes. Organisations should move from alignment to integration when market competitiveness requires it. Identifying what sort and size of organisations achieve this maturity level has been identified by Gartner (Steenstrup, 2012) as very large

organisations spending millions of dollars and may be further validated by case study research.

A summary of when organisations should move to convergence, alignment and integration appear below.



6. Recommendations for industry

The Delphi study identified the following recommendations for organisations converging, aligning or integrating OT and IT.

1. Organisations should plan for convergence when external factors such as a corporate vision and consolidated industry standards are in place. Organisations should prepare by analysing business needs and objectives, plan including research available options and develop a convergence strategy. The vendors role includes selling a vision of convergence to organisation.
2. Organisations should move to convergence when there is consensus between business and IT functions within an organisation. Convergence is established when vendors provide hardware which is IP addressable and has the same chips and routers as provided in other parts of the organisation. At this point Engineering and IT should provide input into application development.
3. Organisations should move from convergence to alignment when the hardware is in place but applications and information are disparate. Alignment is established when architectures are aligned. These tasks are undertaken by Engineering and IT with advice provided by vendors
4. Organisations should move from alignment to integration when market competition and need for cost savings arises**.** Integration is characterised by enterprise wide data exchange. These tasks are undertaken by Engineering and IT with advice provided by vendors

The Delphi study also identified the following success factors for organisations converging, aligning or integrating OT and IT;

1. Operational (such as data exchange for maintenance decisions) not business imperatives (such as legal, financial or reputational risks; alignment for management decisions & security concerns) drive convergence, alignment and integration activities.
2. Information Governance does not facilitate convergence, alignment and integration activities. The need for governance of information by operational areas of the organisation drives the activities to be undertaken.
3. The vendors role is to dictate and provide IT based hardware and systems. Engineering and Information Management areas of organisations provide input into systems development by vendors and IT and Engineering manage vendors.
4. Engineers shouldn't be responsible for converging, aligning and integrating OT and IT. This should be a combined IT and Engineering or just IT responsibility.
5. Hardware is already converged to IT standards upon provision to organisation by vendor. The organisations challenge is to integrate the data as OT and IT information structures are often different.

7. Conclusion

Responses from the Delphi rounds will inform case studies of how, why and when organisations that have hardware or software that detect or cause a change through the direct monitoring and or control of physical devices, processes and events (such as SCADA and telemetry systems) convergence, integration and alignment OT and IT and if information governance facilitated these activities. Data from the Delphi study and case studies and current literature will be analysed to inform a design and conjecture theoretical contribution to the body of knowledge on converging technologies and information governance.

This report combines influential literature and practitioner consensus of why, when and how engineering asset management organisations should converge, align and integrate and whom should undertake the activities internal or external to the organisation. The document is a consolidated snapshot of practitioner perspectives for application by vendors, consulting firms, engineering and Information Technology decision makers.

8. Author contacts

Please contact the researchers for any enquiries or feedback.

Anastasia Govan Kuusk Doctoral Candidate University of South Australia anastasia.kuusk@unisa.edu.au Phone: 0428836405	Professor Andy Koronios Head of School Computer and Information Science University of South Australia andy.koronios@unisa.edu.au Phone: 08 830 23352	Dr Jing Gao Senior Lecturer Computer and Information Science University of South Australia jing.gao@unisa.edu.au Phone: 08 830 23082