White paper

KNOW, THINK, COMMUNICATE — KEY ELEMENTS OF VIRTUAL AUSTRALIA

Prepared for the Cooperative Research Centre for Spatial Information by:

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PURPOSE OF THIS DOCUMENT

This white paper examines the concept of 'Virtual Australia' from the perspective of the emerging technologies that will have a profound impact on the way in which information, including spatial information, will be used over the next decade or two. It considers what Virtual Australia (VA) might be and do, and proposes basic research and development that might advance its achievement and/or be of interest to CRC-SI. There is also a background discussion on the nature of innovation, considered a necessary preface to the arguments advanced in this paper. The paper will help guide the future research investments of the CRCSI.

CRCSI STANDING COMMITTEE ON VIRTUAL AUSTRALIA

The CRCSI has established a Standing Committee on Virtual Australia that will work to maintain the currency of thinking in this paper. The Standing Committee comprises:

Ian Bishop	(CRCSI Science Program Manager Visualisation, UMelb)
TO Chan	(Principal Spatial Policy Officer, SII, DSE)
Clive Fraser	(CRCSI Research Director, UMelb)
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Bruce Thompson	(CRCSI Director, and Director of Spatial Information Infrastructure, DSE)
Peter Woodgate	(CRCSI CEO)

READERS NOTE

This is a long paper. Each section begins with a *précis*, which sets out the key points and conclusion of the section without explanatory detail or support. Readers satisfied with the key points and conclusions may skip the body of the section. The Executive summary represents an aggregation of the *précis* from each section of this paper.

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ABSTRACT

Virtual Australia (VA) is not a well defined or agreed concept. This discussion paper conceptualises VA as:

a virtual [digital] **model containing and representing all non-trivial objects and their contextual environment — from blue sky to bedrock — in** [real world] **Australia.**

It describes a scenario for VA, one or two decades from now, in which the locations and conditions of non-trivial objects and their environment are updated automatically through a combination of remote sensing and wireless communication technologies in support of a 'Supranet'. It then examines the concept of the 'Supranet', (Magrassi, Panarella, Deighton and Johnson, 2001) — a pervasive information network, based largely on wireless technology, linking the physical world to a virtual model in real time — and develops and discusses three principal characteristics of the Supranet:

- the ability to have or collect specific information (**know**);
- the ability to process information (**think**); and
- the ability to **communicate** that information.

If, in the near future, any/all non-trivial devices are at least to some limited extent able to know, think and communicate the potential for **object autonomy** is realised.

Object autonomy describes the capacity and capability that can be embedded in network devices, providing a heterogeneous network model consisting of many simple, but pervasive, sensor nodes interacting with more complex higher level nodes including sophisticated databases, applications, processes and workflows. The extent to which these outcomes can be realised will be an indication of the extent to which a construct such as VA can fundamentally alter existing information management principles and practice.

The nature of innovation and change are examined, to assist the CRC-SI in articulating its research and innovation strategy, and to assist CRC-SI participants in addressing the potentially adverse impacts of some innovation.

The current state of the spatial information industry is described, prior to an examination of information management trends that will transfer into the spatial information industry from the mainstream information technology industry.

The concept of VA is reviewed in the light of the spatial information industry context. Approaches to CRC-SI research are identified prior to an examination of potential research areas the CRC-SI may wish to pursue. Conclusions are then drawn with respect to the potential for achieving VA.

1 EXECUTIVE SUMMARY

Introduction

Virtual Australia (VA) is not a well defined or agreed concept. This discussion paper conceptualises VA as a virtual [digital] model containing and representing all non-trivial objects and their contextual environment — from blue sky to bedrock — in [real world] Australia. More pragmatically it may be defined as an information system that provides complete, correct and current information about Australia to anyone, at any time, at an affordable cost. For VA to be effective it will need to have complete, correct and current information content.

A scenario for Virtual Australia

Ten to twenty years from now VA will be an everyday part of life, with economic, social and environmental application and benefits. This discussion paper includes a ten to twenty year scenario for VA to demonstrate to readers what VA might be like when implemented, and to showcase some of its prime benefits and characteristics.

The Supranet

The Supranet, a concept developed by Gartner, is mapped out as the template for VA. The key feature of the Supranet is that it represents an order of magnitude evolution of the internet, to the point where every non-trivial object in this physical world has a virtual (digital) representation in the virtual (digital world). The Supranet is a complex network structure of sensors, devices, databases, models, all interacting at the same speed (real-time) and with the same complexity as the real world.

Objects in the Supranet **know** (at least what and where they are), **think** (they have computing power), and can **communicate** (telecommunications, increasingly wireless). The Supranet allows us to model, interact with and in some cases control the physical world.

Issues: innovation and change processes

For the CRC-SI to achieve its innovation and commercialisation goals, it should understand the nature of innovation and commercialisation. In addition to its research and innovation programs the CRC-SI will need to strategically articulate its participant portfolio to ensure innovation and commercialisation successes.

Section 5.1 (evolution and punctuated equilibria) demonstrates that technical or technological innovation by itself may fail (or the realisation of its benefits be substantially delayed or reduced) if institutional, economic and social impacts are not addressed. The conclusion is that the CRC-SI will need to consider institutional, organisational and societal issues if its innovation and commercialisation endeavours are to be successful.

Section 5.2 (chasm theory) fleshes out how and why innovation might not succeed. It describes sustaining and disruptive technologies, and why established players and markets may not react appropriately to disruptive technologies, while start ups may exploit them to achieve market position. The conclusion is that the CRC-SI will need to explicitly develop and model the approach and culture of its participants if its innovation and commercialisation endeavours are to be successful.

Issues: the Information Management environment

Information Management will be a major function and concern of VA. The Information Technology focus is shifting from process to information. Data integration, mixed workloads and Grid computing are fundamental technological enablers for this approach. Data switches, data hubs and data suites represent progressively more sophisticated and powerful approaches to information management systems.

Yet the full potential of the data suite approach is unlikely to be achieved in the short or medium term due to organisational and institutional/political considerations with respect to the proprietary nature and value of information. However we can still make significant progress towards the data suite model, and the data suite approach may be implemented for selected key sub-domains such as emergency management/counter-terrorism or asset management.

The spatial information industry context

The innovation and commercialisation issues are placed in the context of the current spatial information industry environment. In summary, the industry is undergoing an evolutionary change from Geographic Information System silos to spatially enabled applications. As technology development plateaus, content and content quality is becoming more critical. Open structures and open standards may drive significant structural change for both industry participants and their target markets.

Review

In review, VA is a distributed heterogeneous network of sensors, devices and symbols or tokens representing the real world. VA will allow modelling, interaction with and control of the real world, and it will be deployed for significant, complex events as well as for small scale, mundane every day activities.

While the technology and resources — processing, content and communications — exist to enable VA, the economic and institutional shifts it will both cause and require are not yet defined, let alone adequately addressed. The arrival of Oracle, Google, Yahoo and Microsoft in the spatial arena indicates at least the potential for a business case to advance towards VA.

CRC-SI research for Virtual Australia

VA offers a range of research approaches to CRC-SI: VA as a vision, or scene-setter, VA as a demonstrator (research framed within VA characteristics) and incremental VA (research aimed at achieving parts of VA).

Potential research areas

Research opportunities are proposed, with brief details in terms of background, potential model, potential components, potential research partners, and intended outcomes or commercialisation opportunities.

Conclusion

VA as an evolutionary process for current information management principles and practice is not hard to imagine. A fully implemented VA is less achievable in the short to medium term.

However, it is possible to create commercial Data Suites and Data Hubs that deliver near real-time business information. The complex nature of spatial information and the enormous data volumes needed to describe Australia magnify the challenges, but do not fundamentally alter the nature of the challenges — the same principles apply. There is no fundamental reason why the same approach could not be successfully applied to deliver the VA vision of complete, correct and current information for Australia.

The arrival of major IT/IM forces such as Google, Microsoft and Oracle in the spatial arena herald the first step in the migration of spatial into the world's general IT/IM systems and indeed the first major step towards VA.

The key significance of the spatial component of VA is not to be underestimated. Whilst spatial information and spatial technology are still poorly understood and under-appreciated, it will soon be imperative for the wider community to gain this understanding and appreciation. The spatial industry has the opportunity and responsibility to provide strategic direction, to take the running in advancing towards VA, and to capitalise on the presence of Google, Microsoft and Oracle.

VA offers opportunities to the CRC-SI in terms of both a strategic vision and as the focal point for highly innovative research and development:

- the development of an architecture, or framework, for a complete, current and correct virtual model of Australia;
- data acquisition and analysis (rather than its storage and retrieval, which can be addressed by appropriate IT architecture);
- depiction of the data in four dimensions with full topological and modelling capabilities; and
- the ability for mobile users to access this four dimensional information in near-real time.

2 INTRODUCTION

Précis *VA is not a well defined or agreed concept. This discussion paper initially proposes VA as a virtual [digital] model containing and representing all non-trivial objects and their contextual environment — from blue sky to bedrock — in [real world] Australia. This definition can then be more pragmatically cast as an information system that provides complete, correct and current information about Australia to anyone, at any time, at an affordable cost.*

For VA to be effective it will need to have complete, correct and current information content.

Virtual Australia (VA) can be defined as:

> *an information system that provides complete, correct and current information about Australia to anyone, at any time at an affordable cost. The central concept here is that VA provides an accurate description of the external reality it describes, namely Australia. This notion includes the possibility that VA might actually be an interconnected collection of largely autonomous information systems operated by different organisations. The potential benefits of such a system are clear in areas such as disaster relief, national security and resource management.*

The value derived from VA will depend primarily on the extent to which the data it provides is indeed **complete**, **correct** and **current**.

2.1 Completeness

VA describes Australia's environment, its economy and its society. This would encompass all land and marine territories, including all items of interest below the ground, on the ground and above the ground, from 'blue sky to bedrock'. Items of interest below the ground include mineral resources, geological features and built infrastructure. Items of interest on the ground include landform, water resources and vegetation. Items of interest above the ground include weather systems, flying aircraft and locust plagues. At any point above or below the ground the land use and its consequences form a vital component of our picture of VA.

Conceptually VA is complete in breadth, depth and detail. It is complete in breadth because it describes all of Australia's land and water (the X and Y dimensions). It is complete in depth because it describes all items of interest in Australia (all the layers, the Z dimension).

It is complete in detail because it describes all items in sufficient detail to support critical business processes using existing data, archived data and modelled data (temporal, the 4th dimension). These data are supplemented by transaction, modelling and processing capabilities (encapsulated in appropriate security and commercial wrappers). VA will support discovery and study of relationships between any elements within it. For example the system can be used to study nationwide coastal shipping trends and their relationship to changing land use patterns over time. VA not only supports predefined business processes but also allows users to answer whatever questions seem important at a point in time. VA supports holistic data mining and analysis across both spatial and non-spatial data elements.

2.2 Correctness

VA provides data of sufficient quality that it is suitable for use in critical government and private sector business processes. Examples of such critical processes include the management of terrorist events, bushfires, earthquakes, tsunamis, the dispatch and tracking of emergency vehicles, the tracking of aircraft, ships and vehicles, weather patterns and locust plagues among others. In short, the system provides information of sufficient quality that life and death decisions can be made based upon it.

2.3 Currency

VA provides data of sufficient currency to support critical use in government and private sector business processes. Much of the data held in VA will change very slowly. However other data will change very rapidly, for example data on the position of vehicles, fire fronts and weather systems.

While it is relatively simple to define a concept like VA, it is infinitely more complicated to implement it. In practice the volume of information needed to populate such a system and the complexity of the processes needed to underpin it means that the system could only be progressively implemented as technology, funds and science permit. In this regard there is no discrimination made between spatial data and non-spatial data, both structured and unstructured. However, the notion that all data is codified is fundamental to the assumption of VA. In this context, tacit information and data become the most problematic.

3 A SCENARIO FOR VIRTUAL AUSRALIA

Précis *Ten to twenty years from now VA will be an everyday part of life, with economic, social and environmental benefits. The purpose of this section is to demonstrate to readers what VA might be like when implemented, and to showcase some of its prime benefits and characteristics.*

Ten to twenty years from now spatial data/information is just like any other commodity item — electricity or water— which is continuously available. Any customer can access it whenever and wherever it is needed and by whatever means (devices) available.

The networks used to support the distribution of data/information are not restricted. It includes extremely fast Internet, wireless networks that use a wide range of spectrum of electromagnetic signals such as infrared, microwave, short, medium and long range radio signals etcetera.

All non-trivial objects will contain intelligent devices that among other things know their locations in relation to the rest of the world and provide signal/data about their locations and current status. For example, the litter bin at the northern corner of junction of Smith and Jones Street is full; the level of the bacterium E. Coli at Dights Falls along the Yarra is above threshold. On the one hand the data is collated centrally to build up the information base about our socio-economic and natural/built environments for analyses, modelling and decision making. On the other hand the data is also broadcast so that nearby receiving devices such as a PDA (or its successor), allowing customers or members of the public to query nearby objects of interest in real time.

All contextual datasets that together describe the environment, built or natural, are updated in real time/near real time by automated data/information gathering /extraction/manipulation processes using remotely sensed data as well as data emitted by intelligent objects (perhaps 'direct sensing'). These datasets have their own archiving regimes that allow real time and historic data to be accessed and presented to meet the specific needs of customers who can pay for information they access via a wide range of charging regimes and payment methods.

Data is all standard-based, flexible enough to be interoperable with new standards agreed to by professional/industry/sectoral bodies. Data can be aggregated in various ways to meet specific locational extent needed by a customer and can easily integrate with other datasets for informed decision making based on known quality criteria.

There are a range of standard based systems that allow customers to:

- Search for data;
- Search for services;

- Search for a collection of integrated data & services that allows informed decisions; and
- Search for friends, relatives and other collaborators, share information in real time and come to a joint decision on what to do where.

Data quality and services are packaged and communicated so that customers know at the outset the relevant fitness for purpose, accuracy, liability, privacy and other legal and institutional issues and the levels of service they are entitled to.

The demands of the customers are intelligently recognised and processes initiated to expand the repertoire of data and services available.

This scenario describes an environment in which VA may function, and provides a context for its conceptualisation.

4 THE SUPRANET

Précis *The Supranet is, effectively, the conceptual precursor of VA. The key feature of the Supranet is that it represents an order of magnitude evolution of the internet, to the point where every non-trivial object in this physical world has a virtual (digital) representation in the virtual (digital world). The Supranet is a complex network structure of sensors, devices, databases, models, all interacting at the same speed (real-time) and with the same complexity as the real world.*

Objects in the Supranet know (at least what and where they are), think (they have computing power), and can communicate (telecommunications, increasingly wireless).

The Supranet allows us to model, interact with and in some cases control the physical world.

Virtual Australia (VA) as proposed in this discussion paper is substantially based on the 'Supranet', a term and a concept developed by the Gartner Group to describe the overlap of the physical and virtual worlds. Magrassi et al, (2001) list the following characteristics of the Supranet:

- *Many physical objects will be coded and … uniquely identifiable*
- *Intelligent devices will be embedded in physical objects of all sorts …*
- *Intelligent devices will increasingly be networked via the (mostly) wireless Internet*
- *As a consequence all [non-trivial] physical objects, animals and human beings carrying intelligent devices will also be networked, in addition to being identifiable*.

Gelernter (1991) provides an earlier and equally compelling vision of the Supranet, which he describes as 'mirror worlds' — complete digital models of some part of reality. Disregarding contemporary bandwidth and software constraints, he allows these digital worlds to be kept in synch with the real world in real time, allowing assessment and management of real world entities via their digital equivalents. While this is not currently practical, there exists no theoretical barrier to its achievement. Indeed, Gelernter's vision:

> *came a step closer to reality in the last few weeks when both Google and Yahoo published documentation making it significantly easier for programmers to link virtually any kind of Internet data to Web-based maps and, in Google's case, satellite imagery.' (Markoff, 2005).*

Omitted from both descriptions, although implicit in both, is the capability for location. Thus, for the emerging 'always on[1]' nature of wireless technology, the context provided for any physical object can include:

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1 'Always on' is a consequence of the packet switched digital architecture of current mobile telephony, under which users pay only for actual data transmitted, not for the time

- Identity (who/what the physical object is);
- Location (where the physical object is); and
- Time (when the physical object is).

Magrassi et al (2001) consider the Supranet to be truly pervasive and ubiquitous — billions of intelligent, networked devices allowing direct connection between software and the physical world.

What are the consequences of the Supranet? What will it mean to have effectively labelled, enabled and connected every non-trivial physical object in our world? What does this massively distributed information generating and processing network do to our existing concepts of information management and application? A physical object that knows where it is, who/what it is, and the time it exists in may not be a candidate for passing the Turing Test[2], but is nevertheless an intelligent object, and certainly smart enough to fulfil its function. Enhance this object with some information processing capacity (computing capacity), and the ability to communicate this information (telecommunications) and it becomes considerably more powerful and effective. Yet, once again, the vast majority of these objects do not need to be very intelligent, requiring only a level of functionality well within that provided by modern mass produced computer chips. Kelly (1997) describes these mundane objects and their equally mundane tasks:

> *A tiny chip plastered inside a water tank on an Australian ranch (sic) transmits only the telegraphic message of whether it is full or not. A chip on the horn of each steer beams out his pure location, nothing more: "I'm here, I'm here." The chip in the gate at the end of the road communicates only when it was last opened: "Tuesday."*

The ubiquitous presence of such intelligent devices in our environment must have consequences for the way information is collected, stored, processed and distributed.

Object autonomy is central to the function of VA — each object having identity, processing and communication functions necessary to fulfil its functions, and interact with other objects. These three elements (identity, processing and communication) are discussed in the following three sections, prior to considering them integrally as enablers of object autonomy.

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connected. Consequently, communication devices can be left permanently connected, removing latency and simplifying connection processes.

2 The Turing test as proposed by Alan Turing suggests that a device which from its responses cannot be distinguished from a human should be considered intelligent.

4.1 Knowledge and Identity

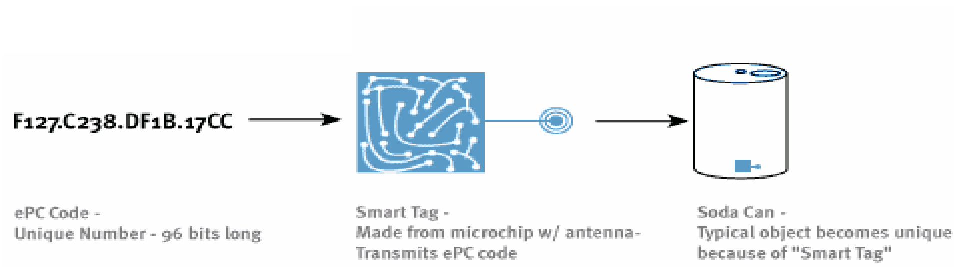
Some level of knowledge is essential for the objects within VA, with identity being the core of that knowledge. For the purposes of this discussion paper identity is defined broadly to be the set of attributes or characteristics necessary for an object to perform its basic functions. Establishing unique identity is fundamental:

> *'if all objects and individuals had their own unique code linked to a network address, an essential element of the Supranet would be realized: all individuals and large portions of the physical world would be defined in the virtual world as well'. Magrassi et al, 2001.*

Identity in the physical world is addressed at many levels — names, postal and property addresses, brands, common names, any number of arbitrary and auto-generated identifiers. However, for the purposes of VA, it would be possible to identify all objects (whether persons, manufactured objects or natural objects) in two broad clusters:

- class codes — for classes (not individual objects) such as the European Article Number (EAN) or the Universal Product Code (UPC) (anonymous, 2005b)[3]; and
- Individual codes — for individual objects, such as the electronic Product Code (ePC) for use in conjunction with Radio Frequency Identification (RFID) chips[4]. Figure 1 shows the relationship between ePC, RFID (smart tag) and the individual article (anonymous, 2005a).

Figure 1: Individual article identification



Identity in the digital, or Internet, world is currently part of the Internet Protocol. The current version in use on the Internet is IPv4, and the version most likely to provide for the potential requirements of VA is IPv6. IPv6 will provide a 128 bit

3 The European Article Number, or EAN, is the International product marking barcode standard. Its general use is in scanning, item level inventory and identification. The Universal Product Code, or UPC, is a similar standard commonly used in North America.

4 The electronic Product Code (ePC) provides a unique code for any/every object of interest. RFID is an actual electronic tag able to communicate its ePC wirelessly (Anonymous, 2005a).

address space (that is, one third of a duodecillion, or 340,282,366,920,938,463,463,374,607,431,768,211,456 addresses), and provide for auto-configuration of IP addresses for all network-aware devices (Fink and Perkins, 2000, and Anonymous, 2005f). Despite the size of this number, it is inadequate in terms of VA — by way of illustration 128 bit addressing would only provide addresses for every square metre of the earth's surface; additional address space would be required for everything else.

4.2 Processing

What level of processing 'intelligence', for example, does a fire extinguisher need? In its current context none; in the context of VA, perhaps:

- Type — description of model and functionality;
- Age — how long since the last service;
- Condition — empty, or full?
- Location — a user can be directed to the extinguisher.

The first three are intrinsic to the device, the last extrinsic. The combination of these information elements allows the fire extinguisher to engage autonomously (that is, in a programmatic sense) in a network environment — **if** the extinguisher is within its service period, and **if** it is full, **then** it broadcasts its availability to other VA elements, **or** has its existence and status recorded by other VA objects, such as a databases. **If** the extinguisher is beyond its service period, **or** is empty, **then** it can withdraw availability, **and** notify an asset management resource.

This level of logic processing is well within the capacity of even the simplest processor chip available today, albeit with the addition of communication capability. Embedded processors, which would be the stuff of VA, currently cost as little as US$1.80 each. The Intel 8088, used in the first IBM compatible PC in 1981, has become one of the workhorses of the embedded processor market, with tens of millions of such chips embedded in a broad range of consumer items. Table 1 (from Hersch, 1997), while a little dated, demonstrates the size of the low-end embedded processor market and, as evidenced by the size and continuing growth of the 8-bit controller market, that processor performance is not the main issue — *what use is a 16-bit processor in a toaster?* (Hersch 1997).

Table 1: Worldwide microcontroller shipments 1990-2000 (in millions)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
4-bit	778	906	979	1,036	1,063	1,110	1,100	1,096	1,064	1,025	970
8-bit	588	753	843	1,073	1,449	1,803	2,123	2,374	2,556	2,681	2,700
16-bit	22	38	45	59	106	157	227	313	419	501	585

In contrast, Table 2 (from Yeung, 1998) demonstrates the relatively small size and composition of the emerging market for high-end (32 and 64-bit) embedded processors — about 5% of the 4.25 billion low-end market.

Table 2: Emerging market for high-end embedded processors

Sample Emerging Applications:	Volume in 2001 (million units/year)
Digital TV (DTV)	20
Digital Satellite System (DSS)	27
Game Consoles and Arcades	30
Digital Video Broadcast (DVB)	16
WinCE Multimedia (Browser)	5
Network Routers	2.6
LAN / WAN cards	3-7
Cellular Base Stations	6
Digital Communications(ASDL)	4.8
Ink-Jet and Laser Printers	77
Multi-function Equipment	5
Digital Copiers	5

4.3 Communication

Wireless technology broadly describes the technical and technological infrastructure developed for radio communications. The current focus is on wireless as a substitute or complement to the existing 'wired' infrastructure, largely comprised of relatively few low bandwidth global infrastructures (the internet) and many higher bandwidth local infrastructures (Local Area Networks and Wide Area Networks). A very large component of the application of current wireless infrastructure is for voice over mobile telephony, with data an increasing volume of traffic. The combination of wireless technology as an enabler and applications as content is broadly described as mobile commerce (m-commerce).

Mobile commerce is significant in terms of market size, technology and economic impact. The mobile telephony market *is 'the largest consumer market ever: nearly as many of these devices are now in use as televisions and computers combined'* (Anonymous, 2001a). The technology is equally impressive — *'mobility represents the next major business and technical discontinuity facing large enterprises, and will revolutionize information'* (Redman, Delcroix, Harris, Mogull, and Monroe, 2001) while the scale of the potential economic impact is intimidating: *'operators of third generation wireless networks must deliver a vast choice of streaming media at affordable prices or face one of the biggest financial disasters in history'* (Scadlock, 2001). Cost constraints in communication are also present for location, with GPS (Global Positioning Systems) chipsets also still in the high range.

However, the economics of mobility are changing: '*soon [US] $35 mobile phone chip sets will allow phones to be included in a wide range of appliances such as washing machines, refrigerators and heating systems*' (Anonymous, 2001b).

The market for mobile chip sets will continue to grow, and the cost will continue to decline as economies of scale are realised. Moreover, the cost of communication will not entirely preclude the development of the Supranet, but restrict its initial application to a smaller subset of higher value objects rather than a broader range of low value objects. So we may not see devices such as white goods as part of the Supranet for some time, but prime high value objects, including people (by extension, through personal mobile devices) and vehicles should be in the early adopter phase.

There are currently three main areas of development in wireless technology:

- Personal area networks based on Bluetooth;
- Wireless Local Area Networks, generally based on standard network protocols defined as part of IEEE 802.11; and
- Wireless Wide Area Networks, based on the cellular networks developed for mobile telephony.

In conjunction these three levels of wireless functionality have the potential to provide comprehensive mobile and distributed communication and computing capability.

This discussion paper does not propose to further discuss the technology of wireless in any level of detail; it simply assumes that wireless capacity and capability will at some point arrive at a level sufficient to provide comprehensive mobile and distributed computing and communication necessary for VA.

4.4 Object autonomy

In summary, object autonomy based on knowledge/identity, process and communication, can be readily, if not pervasively, achieved now.

What does this level of functionality provide, and what are the benefits and impacts of object autonomy? Perhaps the major impact is simply the scale and volume of transactions, processes and tasks that autonomous objects can achieve, without recourse to human intervention. These fall into two broad groups:

- Control and execution of physical tasks and actions; and
- Workflow/coordination tasks.

There are many existing examples of the former, especially in industry. SCADA (Supervisory Control and Data Acquisition) systems are used to monitor and operate complex industrial and mechanical operations, including power plants. Less complex implementations monitor the natural environment, such as stream monitoring devices informing flood warning systems and regulating drainage and storage networks. VA might not radically advance beyond the concepts already in play with SCADA, but would require a radical increase in the number and scale of such implementations. This might increase the complexity and benefits achieved from them by increasing the number of elements informing the process, and the flexibility of such implementations by allowing ad hoc and configurable networks to be formed.

Such sensor networks are being established, as the following excerpts demonstrate (Broad, 2005):

> *In the wilds of the San Jacinto Mountains, along a steep canyon, scientists are turning 30 acres of pines and hardwoods in California into a futuristic vision of environmental study.*
>
> *They are linking up more than 100 tiny sensors, robots, cameras and computers, which are beginning to paint an unusually detailed portrait of this lush world, home to more than 30 rare and endangered species.*
>
> *…more than $1 billion in networks of sensors planned not only for the land but places like the Hudson River and the deep Pacific.*
>
> *…gains could rival those from the introduction of instruments like microscopes.*
>
> *In the years and decades ahead, scientists want to deploy millions of these kinds of devices over large tracts for long periods, opening new windows on nature.*
>
> *…a mote [autonomous sensor] could work for five years, transmitting up to 325 feet away. The nodes of the network automatically look for neighbours and compensate if some fail. Mr Conan added "It's like taking the wires out of a big chunk of the internet".*

The scale issue is potentially highly rewarding — currently the difficulty in modelling or managing complex systems (weather, groundwater flows, controlling fertiliser application) is compounded by the relative sparsity and simplicity of the sensors that can be brought to bear. More, more effective and more versatile sensors will improve these modelling and operational processes. However, the overall benefit is not likely to be through high profile, complex operations, but in the widespread, marginal and cumulatively significant benefits coming from tens or hundreds of millions of simple devices unceasingly and reliably performing trivial mundane tasks, from optimising fuel use in engines to opening doors, from cooking toast to filtering water, from eco-observation to crop management.

However, once devices have satisfied their immediate, base level objectives, there is the opportunity for additional, higher level benefits. Take the example of the fire extinguisher used earlier — by combining its knowledge of its location with the locational knowledge of other elements it is possible for example, to evaluate compliance with building regulations, that may require one extinguisher per floor, or that all parts of building be within a minimum distance from a fire extinguisher. Such opportunities to resolve higher level issues present themselves when the fabric of VA achieves a sufficient density.

Workflow and coordination tasks offer equal opportunity for benefits, primarily through improved communication. It is difficult to quantify, and perhaps equally difficult to overstate, the time and resources wasted through missed appointments and deliveries, uncoordinated activity and out-of-sequence process. No industry sector or process is immune from delays and losses caused by such events. The network of communicating devices that forms VA can mitigate some of these misadventures. Consider something as ordinary as having a refrigerator delivered. The provider can't tell you exactly when it will be delivered, until they've contacted the transporter who may be able to provide you with a half day envelope. You take a half-day off work, the refrigerator doesn't arrive. The process is repeated, with inefficiencies and cost accruing to all parties.

Now consider the VA potential: your personal digital assistant (PDA), with your personal schedule, initiates a planning process with the transport company's scheduler (your Bluetooth enabled PDA tapping into the provider's Wireless LAN, then connecting to the transport company via mobile telephony). No suitable delivery time can be agreed, so your spouse's schedule is checked (again by mobile telephony). Again no suitable delivery time can be agreed, so the transport scheduler queries your house's capability to accept unattended delivery (it can, the doors are part of a household Bluetooth network that can be controlled remotely). A time is agreed for unattended delivery, with the transport company offering to either make use of a one-time password authorised entry (generated by you) to the house at the agreed time, or to contact your PDA for permission and entry when it reaches the house.

This distributed scheduling operation can be accomplished in little more time than it takes to process the payment. The benefits of such functionality are immediately obvious at a personal level, and can be order of magnitude greater for complex planning and logistical operations in industry and the broader economy. Removing or reducing the latency and contingency factors that are built into all our processes and operations would provide significant savings to our economy.

4.5 Contextual Mapping

Paper-based mapping was constrained to context mapping — the user took a generic product such as a topographic map or navigational chart, and applied it to a specific problem or issue, with the specific problem or issue remaining (and being resolved) in the mind of the user. The Supranet expands the reach of 'mapping' from generic context to include specific elements, from background only to background and foreground. This does not, of course, reduce the significance of context — it remains an essential component of problem solving and effective operational processes.

In a Supranet, each node of non-trivial object can scan its immediate environment for information, process the information in relation to its identity and location, then react/respond locally or trigger actions elsewhere where other decision may be required. To be appropriate the response must be made in the context of the wider environment that is up-to-date. Depending on the scale involved, the environment can be a house/factory, a number of farms, a catchment, a state/nation, a region/continent, or global.

Advances in remote sensing are providing computer networks the eyes and ears they need to observe their physical surroundings. There are two main groups of remote sensing technologies. The first includes sensors that are sometimes called 'smart dust', or 'motes'. They detect physical changes in pressure (vibration), temperature, light, sound, or chemical concentrations and then send a signal to a computer that does something in response. Scientists expect that billions of these devices will someday form rich sensory networks — the Supranet — linked to digital backbones that put the environment itself online (Hoffman 2003).

The second provides far-reaching environmental profiles that come from satellite-based remote sensors in space. For example, the bus-sized Terra satellite, sent into orbit by the Earth Observing System (EOS) at NASA in December 1999, is measuring 16 of 24 parameters known to play a role in determining climate. These parameters include aerosols, clouds, temperature, vegetation, and radiation. To increase resolution, satellites and planes carry 'active' sensors that obtain data from lasers and radar that are shot down to target areas and reflected back to an on-board detector. Advances are also being made in hyperspectral remote sensing, which extracts greater amounts of data from reflected radiation than currently used technologies. These sensors yield precise measurements of chemicals in the atmosphere and, according to NASA scientist Jim Closs (Schmidt 2000), will allow scientists to double, or even triple, the number of parameters currently monitored.

To illustrate, contextual information (the environment) collected by these two groups of remote sensing technologies can support a decision in regard to the sale of a farm by a sheep farmer. A local business person who also owns the local dairy processing plant is interested in taking over the farm. While she knows that there is good potential, she is not sure of the big picture and decides to engage a local agricultural consultant to advise her with the help of VA as part of a global information infrastructure. By talking to the business person and by accessing information through VA the consultant pieces together the following picture:

Earlier in the year, the sensors in the diary processing plant indicated that one of the two sets of operational machinery, introduced 10 years ago, is suffering from a gradual but consistent reduction in milk processing capacity because of failing irreplaceable parts. The diary processing plant is the only *plant in the region that draws its milk from a number of nearby farms that keep herds of Friesian, Jersey and Kerri Dexter dairy cows.*

The main dairy farms in the region are located at the northern and eastern part of a catchment that is made up of a wide variety of landscape systems and supports remnant woodlands and a riparian system of high conservation value and other non-dairy agricultural activities such as stone fruit orchards in the west, and vegetable farms, beef and wool farms in the south.

According to information from the Bureau of Meteorology and Department of Primary Industries the surrounding milk producing regions have been badly affected by a drought that has been spreading for the last 7 years. Based on the rising temperature in the Pacific Ocean, the long term prediction is for an imminent "el nino" which is going to sustain the drought, if not making it worse.

Two years ago the drought spread to the north-western corner of the catchment. It is already seriously affecting a very productive dairy farm of a friend of the business person, who owns a large herd of Friesian and is a major supplier to the milk processing plant. This threatens to reduce the productivity of the plant. The Dairy Council's statistics indicate that similar plants in nearby regions have been operating below capacity because of the drought. This suggests that the local plant is unlikely to source milk from outside despite the good road network connecting to adjoining regions. This significantly impacts the long term viability of the plant.

At the same time the sheep farm has been producing wool in the last 50 years. In recent years the international wool price has declined to rock bottom. Remote sensing data suggests that Australia's competitors' herds of sheep are growing and their pastures are in good condition. With continual poor demand worldwide it is unlikely that the price of wool will improve. Likewise based on current and archived remote sensing data available despite the drought the sheep farm has been producing pasture that is of sufficiently good quantity and quality for dairy cows. However the herd of sheep has been shrinking in the last 3 years. According to the records of the Department of Primary Industries the herd is being decimated by a sheep parasite living in the blood which is being tracked in the individual sheep's tag.

The above information leads the consultant to recommend the business person to partner with her friend, the owner of dairy farm at the north-western part of the region to take over the sheep farm and convert it to a dairy farm for the existing herd of Friesian cows. Based on available productivity figures the consultant may even be able to advise that the option could provide a 30% increase in supply of milk to the plant. This option would then help the business person to decide to upgrade the ageing set of machinery to a more cost-efficient model that increases the plant capacity by 50% and the profit by 10%.

The above information of local, national and global environments for the sheep farm, dairy farm and the dairy processing plant helps the business person to make informed decisions based on good science and reliable information. The information packaged in terms of the scale and time of the environments in question should be easily available through VA. It is meant to provide 1, 2, 3, 4-D contextual mapping of the environments at the appropriate scale to aid informed decision making.

5 ISSUES: INNOVATION AND CHANGE PROCESSES

Précis *For the CRC-SI to achieve its innovation and commercialisation goals, it should understand the nature of innovation and commercialisation. In addition to its research and innovation programs the CRC-SI will need to strategically articulate its participant portfolio to ensure innovation and commercialisation successes.*

Section 5.1 (evolution and punctuated equilibria) demonstrates that technical or technological innovation by itself may fail (or the realisation of its benefits be substantially delayed or reduced) if institutional, economic and social impacts are not addressed. The conclusion is that the CRC-SI will need to consider institutional, organisational and societal issues if its innovation and commercialisation endeavours are to be successful.

Section 5.2 (chasm theory) fleshes out how and why innovation might not succeed. It describes sustaining and disruptive technologies, and why established players and markets may not react appropriately to disruptive technologies, while start ups may exploit them to achieve market position. The conclusion is that the CRC-SI will need to explicitly develop and model the approach and culture of its participants if its innovation and commercialisation endeavours are to be successful.

5.1 Evolution, and punctuated equilibria

Before discussing what VA is and approaches to its development, it is useful to examine the nature of innovation and technological advance.

Innovation is not a simple process, and rarely does any significant technical or technological innovation occur without attendant alterations to the social and economic fabric that innovation will impact.

Modern theory considers evolution to be a stop-start process, with long periods of little or no activity punctuated by a few significant events — *punctuated equilibria* (Gould and Eldredge, 1977). Mokyr (1990: 351—352) describes similarities between evolution and the economic history of technology, going on to propose that any radical advance in technology is usually

> *'the beginning, not the end, of a prolonged process of improvements and modifications'.*

David (1990) also develops this theme, providing a detailed case history built around the discovery, development and implementation of the electric motor. While the initial discovery and development of the electric motor in the mid-late 19th century can be considered a radical advance, it wasn't until the early 1930's that the electric motor began to assume the fundamental and ubiquitous place in our economy and society that it now holds. Mokyr's *'prolonged process of improvement and modifications'* took, in this case, sixty years. What were the underlying causes of this slow uptake? David (1990) considers that, in large part, the causes were economic and administrative, and due to intellectual inertia. The predominant power source prior to the electric motor was the water wheel, with transmission to machinery via belts and pulleys. This mechanical transmission model imposed severe constraints — the longer the transmission the greater the energy loss, resulting in mills being built directly on the power source, usually in multi-storey configurations. Hence the centralised power plant became enshrined — manufacturers, industrialists, even entrepreneurs found it easier to visualise one large electric motor, and a mechanical belt and pulley system feeding hundreds of sewing machines, than to consider hundreds of sewing machines, each with its own electric motor.

When confronted with the opportunity to replace the central power resource with a distributed array of smaller self-powered devices, contemporary accounting and business practice meant that the longer term amortisation/depreciation of the expensive and existing overheads would be economically preferable to greenfield investment in electric motors. Hence, despite the enormous advantages offered by the electric motor, the contemporary mindset and business practices meant that adoption was limited and intermittent for about sixty years — a sudden radical advance, followed by a long tail of improvements and modifications. Moreover, many of these improvements and modifications were not to the device itself, but to the economic, intellectual and administrative environments applicable to it.

The enduring nature of these conventions and institutional arrangements are illustrated by our continuing use of the term ‘overheads’ to describe these types of business costs.

Telecommunications and computing can also be considered radical advances in technology, with wide ranging potential benefits and consequences at least to the level of the electric motor. Each has also experienced a long tail of modification and improvement; telecommunications over a period of one hundred years and computing over a period of fifty years (if the valve-based machines of the 1940’s are accepted as the inception of computing).

If the convergence of telecommunications and computing is also considered as a radical advance in its own right, then it too will have its tail of improvement and modification, and we too are inured in a cocoon of existing economic pressures, business practices and mind sets that preclude a clear picture of the real potential. In short, will we be able to visualise a contemporary technological advance equivalent to millions of small electric motors supplanting a few large water wheels?

The CRC may be able to facilitate such a shift in perception, through consideration of VA. However, if it does so it must encompass commercial and institutional impediments, targeted research, and demonstrators that address commercial/institutional issues as well as technological components.

5.2 Chasm theory

Christensen (1997) describes the two types of change that impact technology as sustaining and disruptive change. Sustaining changes almost always improve the performance of established products along the dimensions that mainstream customers historically valued. Most advances in any particular industry are sustaining in character and seldom precipitate innovation or the failure of firms leading those industries.

Occasionally however, innovations emerge that offer a different value proposition — disruptive change. Disruptive change characteristics are typically:

- cheaper;
- simpler; and
- more convenient to use (perhaps having a near term trade-off in reduced performance)

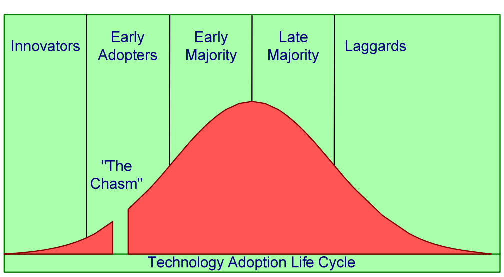
Two fundamental outcomes of disruptive change are:

- while user expectations of what should be delivered are not changed, the delivery mechanism and architecture may change fundamentally. The functionality grows, to eventually outpace the functionality of the previous offering; and
- the value-add delivered almost always creates a new revenue streams, going to a new player.

5.3 Adoption of Technology

The adoption lifecycle of emerging technology is perhaps best described by one of the worlds leading thinkers on technology marketing, Geoffrey A Moore, in his Technology Adoption Lifecycle Model.

Figure 2: Moore's Technology Adoption Lifecycle Model



Moore describes the model as a spectrum of demand for change between continuous and discontinuous innovations. He also introduces the market development 'chasm' as a void where many technologies disappear before they enter the mainstream market place.

The dynamic pace of the technology industry has many examples of products that on face value offered much promise. A classic example is the Apple Newton, which promised to revolutionise palm-top pen-based computing. It solved portability and mobility problems suffered by workers in the field, but failed. More recently the dotcom bust showed us that the promising ASP model for delivering software as a service also couldn't cross the market development chasm.

Christensen (1997) argues that a larger chasm exists for established participants (than for new entrants) seeking to address disruptive threat. Moreover he observes that when the functionality of the disruptive change catches up with the functionality of the status quo, the leaders of the older technology may cease to exist.

An example of this type of disruptive change is in the database industry leading up to 1985 when Cullinet led the market with their IDMS product. Oracle entered the database market with its architectures based on the disruptive Client Server technology. For Cullinet to compete on the newer disruptive technology they would need to do so covertly, as admission that IDMS was based on outdated architectures would imperil existing revenue and customer share. Cullinet management continued to resource revenue generating projects and placed less importance on those that didn't. In short they knew what had succeeded in the past and perpetuated those strategies. Christensen (1997) describes this as the "resource allocation profit maximisation decision". This trade-off has been the fundamental of the past success for any market dominant player; however, it also where innovators gain ground.

The CRC-SI is not solely premised on disruptive change — it can pursue research that incrementally improves existing processes, applications and services as well as innovation. However, the CRC-SI will certainly precipitate some disruptive change, and the VA model potentially represents significant disruptive change.

Likewise, CRC-SI participants are not entirely established players or new entrants. This means that for the CRC-SI to be successful, participants with established positions must understand the nature of the resource allocation profit maximization decision in order to successfully cross the chasm.

6 ISSUES: THE INFORMATION MANAGEMENT ENVIRONMENT

Précis *Information management will be a major function and concern of VA. The Information Technology focus is shifting from process to information. Data integration, mixed workloads and Grid computing are fundamental technological enablers for this approach. Data switches, data hubs and data suites represent progressively more sophisticated and powerful approaches to information management systems.*

Yet the full potential of the data suite approach is unlikely to be achieved in the short or medium term due to organisational and institutional/political considerations with respect to the proprietary nature and value of information. However we can still make significant progress towards the data suite model, and the data suite approach may be implemented for selected key sub-domains such as emergency management/counter-terrorism or asset management.

There is a range of information management (IM) and information technology (IT) issues and trends that need to be considered in developing an approach to Virtual Australia (VA).

All developers of operational information systems (whether spatial or aspatial) face the challenge of providing complete, accurate and timely information. Such systems include Enterprise Resource Planning (ERP, human resources, finance and administration), Customer Relationship Management (CRM) applications, and so on.

Recent efforts have targeted solutions delivering the 'Real-Time Enterprise' — a concept analogous to VA but organisational in scope rather than geo-political. The objective is the same: to create a system that provides complete, correct and current information for all relevant events and objects.

While IT has traditionally been viewed primarily as a tool for enhancing the efficiency of defined business processes, the Real-Time Enterprise focuses on information — the integration of business information as well as business processes.

Recent technology developments are enabling the realisation of the Real-Time Enterprise concept. The key areas are Data Integration, Mixed Workloads and Grid Computing. The key approaches to managing data in these three areas are Data Switches, Data Hubs and Data Suites.

6.1 Data Integration

Traditional IT systems require different technologies to manage different data types, including structured data (names and addresses), unstructured data (documents, emails and images), and complex data like XML and spatial. This is a significant impediment to the delivery of complete, correct and current business information. Real-Time Enterprise requires businesses to integrate both their processes and their information, so that business processes are not fragmented by technology boundaries that cause delays and devalue the information.

Commercial off the shelf technology is now available to provide integration of all types of data and seamless business processes.

6.2 Mixed Workloads

Real-Time Enterprise captures business events in real-time, and understands and acts on these events in real-time. These activities translate into three types of computing workloads:

- transactions that capture business events and create new data.
- analysis that provides insight and understanding of the data.
- collaboration that enables users to cooperate as they act on the data.

When end-users act on the data they create new business events that generate new data. This completes the information lifecycle and creates a business feedback loop.

The Real-Time Enterprise requires that data be integrated so that all three types of work — transactions, analysis and collaboration — can be simultaneously performed against shared data. Historically these IT workloads always had to be separated, with the result that data had to be copied from transactional to analytical systems and from analytical to collaborative systems. Time delays associated with this data movement were a key impediment to the delivery of complete, correct and current business information.

It is recognised that in practice the vast array of data that comprise VA will not be co-located in the foreseeable future, if ever. The reality of this situation gives rise to three incremental, and progressively more sophisticated, methods of data management; data switches, data hubs and data hubs.

6.3 Grid computing

Grid computing enables mixed workloads to be performed against consolidated data using collections of low-cost hardware elements. Grids of disposable hardware elements replace high-cost, dedicated servers and storage, delivering dramatic improvements in scalability and availability while also lowering costs. In this context grid computing assumes the hardware elements are all physically co-located to ensure the delivery of the most rapid processing response.

6.4 Data Switches

A data switch is the use of the web to access distributed stores of spatial data without actually bringing the data together. The central switch only holds metadata. Processing times are slow and some applications cannot be run at all. It is the most common method of data management at present being the earliest of the evolutionary paradigms. It is the least likely method for the delivery of the vision of VA because it cannot deliver complete, correct and current information, and it is unable to combine the data with sufficient flexibility and performance to support sophisticated, ad-hoc complex analysis where the large datasets are not physically co-resident in a centralised database.

6.5 Data Hubs

Data Hubs allow businesses to achieve a single point of truth using two-way synchronisation between existing applications and a centralised master database. Data Hubs integrate the information while the majority of business functions continue to be supported by existing applications.

For example, the global credit card approval system uses the Data Hub method to ensure that consumers using their credit cards anywhere in the world can gain credit approval in seconds. Financial institutions pass information about the credit-worthiness of their customers to a global service provider that operates a credit data hub. The Data Hub delivers a high quality of service, offering near constant availability and response times of just a few seconds. End-users benefit from global access to credit and economies of scale ensure that the cost per transaction is very low.

This same concept is now being applied to mainstream business applications in order to improve data quality without forcing migrations to new environments. The Data Hub method is one that could be considered for the design of VA.

Data Hubs act as a stepping stone, providing businesses with a means of progressively migrating towards the Data Suite concept, which remains the ultimate goal. Data Hubs are a relatively new concept in IT, but one which has already been shown to deliver significant value.

6.6 Data Suite

The data suite is a network of two or more inter-connected processors with each processor capable of storing parts of the same database running distributed applications in a grid arrangement. The system is scalable so that as new processors are added additional processing capacity is gained in a directly linear relationship. The Data Suite method has been used to great effect by many commercial organisations.

Commercial off the shelf solutions are now available that combine the ability to perform mixed workloads against consolidated data on a grid computing platform. This means that even large global organisations can now have a single point of truth that provides complete, correct and current information affordably and reliably with all required datasets physically located on the one hardware platform. In the context of the realisation of the concept of VA the Data Suite method offers the best opportunity to provide the real-time delivery of the information products that make up VA. Its main limitations are the practical difficulty of bringing together (in the one grid network) all the applications and data that are likely to be required of VA, and operating off the existing legacy systems.

It may be however that a selected number of applications in the emergency services, disaster management, and defence areas can be managed with through a data suite. The data hub approach is therefore likely to enjoy great growth for the vast majority of other applications.

7 THE SPATIAL INFORMATION INDUSTRY CONTEXT

Précis *The innovation and commercialisation issues outlined in the previous section are placed in the context of the current spatial information industry environment. In summary, the industry is undergoing an evolutionary change from Geographic Information System silos to spatially enabled applications with the focus shifting from process applications to enterprise systems. Content, and content quality, are becoming more critical as technology development plateaus. Open structures and open standards may drive significant structural change for both industry participants and their target markets.*

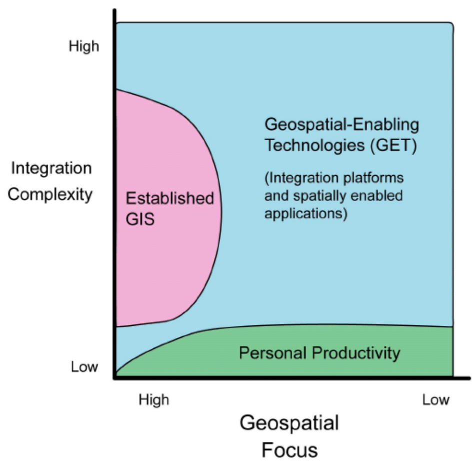
Since 2002 Information Technology Architectures have seen a consolidation phase, with a focus on Internet delivered solutions and the paramount value of content, as opposed to process, as an area of competitive advantage.

In the spatial information industry during this same time there has also been evidence of consolidation, a broadening of the definition of GIS to Spatial (reducing the significance of the G in GIS, and absorbing the G into the mainstream IS framework), and acknowledgment that the quality of spatial data and its content is paramount.

The focus given to spatial information from database vendors such as Oracle and IBM goes beyond their ability to store the information in a corporate database. Location based services and spatially enabling business applications have created the need to merge spatial queries with business queries resulting in an innovative dimension to reporting on data. IDC (anonymous, 2002) reports movement away from proprietary spatial systems in favour of an Open Standards approach. Moreover they note that Oracle currently commands above 90% of the spatial database market share. Jahshan and Kinne (2005) contend that Oracle leads this sector because of its implementation of the ISO TC211 standard that extends SQL to include spatial capabilities. This makes integration with SQL based business applications simpler and platform compatible.

In essence, spatially enabled business applications are where the productivity and competitive advantages lie for businesses. Figure 3 (Jahshan and Kinne, 2005) shows the potential for spatially enabled applications against that for established GIS.

Figure 3: Potential for spatially enabled applications



We are now observing the maturation of the old GIS paradigm and the emergence of database driven spatial applications or spatially enabled applications. Further, if this change were having an affect then we should be able to see some sort of signs or market indicators.

Treacy and Wiersema (1995) identify the signs of a failing value proposition as 'bolt on tactics' or 'temporary quick fixes' and go on to explain this in terms of the 'Road Map to Oblivion'. Companies displaying this behaviour have reached a threshold with respect to their current value proposition and in order to maintain revenue growth, include strategies which extend their perceived performance without addressing the real issue of reduced value.

The two market leaders in Australia have in the last three years exhibited market development behaviour that signals downward pressure on their existing revenue streams and product lines (Jahshan and Kinne, 2005) that is akin to that described in Treacy and Wiersema (1995). The current market leaders owe growth and repeatable revenue largely to shipping a product. The change to server side analytics and spatial information in an open standard database removes or reduces the value proposition of desk top client software.

7.1 Industry Challenges

Clearly the spatial industry is not immune to change and is currently is coming to terms with many challenges which affect the value, user base and application of its technology. These are broadly identified by:

- Low Cost Internet and Intranet Mapping tools (Google, Microsoft Virtual Earth, NASA World Wind)
  - user base beyond the limits of any of the mainstream vendors; and
  - didn't use mainstream vendors (low barrier to entry)

  This fundamentally changes the user expectation of what web mapping should deliver. The existing vendor platforms look staid and outdated overnight. This means vendors have to reengineer their platforms or face user desertion.
- Data
  - data delivery through tools like Google Earth and NASA World Wind shows that, for the business and consumer markets to embrace the

industry, content is of paramount importance. This poses the challenge and opportunity to the Australian industry of how this will be delivered.

- Stale technology stacks
  - offering convoluted product add-ons;
  - upgrades difficult to discern from previous versions; and
  - proprietary cul de sacs - proprietary formats to protect the technology stack (vendor lock-in).
- 3D (all current GIS vendors have a code base limited to 2D or 2.5D)
  - cadastre, topographical data management and subterranean datasets are demanding 3D management environments; and
  - spatial databases are all capable of storing true 3D data.
- IT departments are consuming GIS
  - applying corporate standards to Spatial Data;
  - opening data to other business applications (enterprise systems);
  - making data more important than the application;
  - taking a Process Solution (GIS) to an Enterprise Solution;
  - enabling true ISO vendor independent Spatial Databases (Oracle, Progress, IBM DB2); and
  - demanding open standards – no vendor "lock in", reducing specialist requirements.

These challenges undermine the value of the current GIS applications as they expand the potential user community without the need to utilise the incumbent's technology. Database vendors stand to gain most as they add business value in ways traditional GIS vendors aren't. The entry of Microsoft in the open database arena will signal the end of the existing GIS application vendor dominance.

The challenge of the chasm is not only relevant to the vendors, but to the industry as a whole including, of course CRC-SI participants. Each participant needs to ask how this will impact its future, and is its skill base sufficient to meet the challenges of the future.

The opportunity to leverage the investment of the global Information Systems (IS) players presents a real opportunity for the spatial industry to embrace the changes and deliver solutions based on the new paradigm. The GIS vision has been for ubiquitous mapping everywhere. The IS industry has woken up to the GIS/mapping opportunity, and the sheer weight of the IS industry players will either consume the existing players, or drive them back into the data capture/maintenance niche where GIS began.

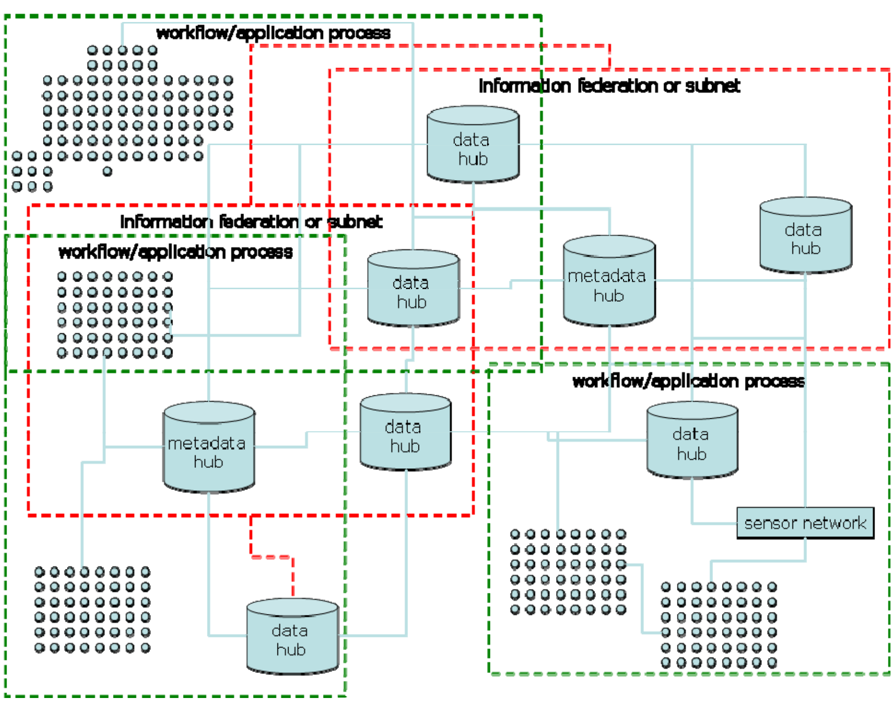
8 REVIEW

Précis *VA is a virtual [digital] model containing and representing all non-trivial objects and their contextual environment — from blue sky to bedrock — in [real world] Australia. VA will allow modelling, interaction with and control of the real world, and it will be deployed for significant, complex events as well as for small scale, mundane every day activities.*

While the technology and resources — processing, content and communications — exist to enable VA, the economic and institutional shifts it will both cause and require are not yet defined, let alone adequately addressed. The arrival of Oracle, Google, Yahoo and Microsoft in the spatial arena indicates the potential for progress towards a business case for VA.

In review, Virtual Australia (VA) is proposed as a is a virtual [digital] model containing and representing all non-trivial objects and their contextual environment — from blue sky to bedrock — in [real world] Australia. This distributed, heterogeneous network will include simple sensors, complex databases, applications, work flows and complex processes that will enable analysis, modelling and visualisation, as well as the actual manipulation or control of physical world objects. The defining characteristic of VA is that it should provide a digital model containing a digital representation, or equivalent, of every non-trivial object in the physical world.

Figure 4: VA as a distributed, heterogeneous network



The deployment of VA will, of necessity, be both as high-minded as environmental monitoring and management through networks of environmental sensors and as base (but equally beneficial) as optimising daily activities through the collaborative deployment of people and processes — the refrigerator delivery.

The technology and resources — processing, content and communications — exist to enable VA, but the economic and institutional shifts it will both cause and require are not yet defined, let alone adequately addressed. Consequently a full business case for VA is not going to appear in the immediate future. However, the arrival of Oracle, Google, Yahoo and Microsoft in the spatial arena appears set to change this, or at least provide an additional revenue stream as an impetus:

> *'There are billions of dollars of commerce down the road', said Chris Churchill, chief executive of Fathom Online, a search-engine advertising firm based in New York. It will all be an advertising-supported model, which is an epiphany for many people." (in Broad 2005)*

Whether static or dynamic, all elements of VA share a common unifying, and enabling characteristic: location, which is increasingly recognized by key IS vendors as offering competitive advantage. The importance of the spatial element (the defining element of VA) in the mainstream IT industry and in society in future cannot be underestimated.

9 CRC-SI RESEARCH FOR VIRTUAL AUSTRALIA

Précis *VA offers a range of research approaches to CRC-SI: VA as a vision, or scene-setter, VA as a demonstrator (research framed within VA characteristics) and incremental VA (research aimed at achieving parts of VA).*

There is a range of approaches CRC-SI can adopt for Virtual Australia (VA):

9.1 Nothing

VA as proposed in this discussion paper may not be considered appropriate or relevant to the CRC-SI.

9.2 VA as a vision statement

The VA concept of a distributed heterogeneous network can be further investigated, to provide a future vision that sets the scene for more grounded research and development in specific program areas. This would place VA at some indefinite point in the future, effectively as a 'stretch goal', with little or no impact on research activities other than to set a general direction.

9.3 VA as a demonstrator

VA might function as an integrating and uniting principle, linking research program elements.

9.4 Incremental VA

VA in an end state, with a complete equivalent digital representation of the physical world, is not achievable any time soon, and perhaps not ever. However, as the San Jacinto Mountains monitoring project shows (Broad 2005), small parts of the world can be captured, to a certain level. Similarly, some facets of the whole world may be able to captured at a high level, providing some components of the VA end state that can be incrementally advanced.

10 POTENTIAL RESEARCH AREAS

Précis *Research opportunities are proposed, with brief detail in terms of Background, Potential mode, Potential components, Potential research partners, Outcome or commercialisation opportunity. These are indicative only and represent no commitment from the CRCSI.*

There is a range of research opportunities presented by the VA concept, in two broad areas. The first is high level investigation into the feasibility and structure/architecture of VA. The second is more applied research into more operational components of VA. The latter has the potential advantage of offering more immediate implementation/commercialisation opportunities, while contributing to building the overall picture of what VA might be.

The following sections propose some potential areas. Potential research partners beyond the current CRC-SI participants are also suggested.

10.1 Feasibility and structure of VA

There is considerable research required to establish the feasibility and optimal structure of VA. The CRC-SI may elect not to pursue this area, in favour of applied research that might provide direct benefits as well as incrementally developing the feasibility and structure of VA.

10.2 Environmental monitoring network

Background: The San Jacinto Mountains sensor network project cited earlier demonstrates the potential for environmental monitoring. The objective would be to implement a versatile sensor array capable of informing multiple environmental issues, and supporting an integrated response, rather than the single issues analysis and modelling approach that is currently more the norm.

Potential model: A relatively high density sensor network embedded into an environmentally significant area.

Potential components: Multifunction sensor components and/or single functions sensors coupled in collaborative networks, combined with existing natural resources, environmental and land use data; time series modelling and visualisation of the investigation area.

Potential research partners: federal and state environmental management agencies, sensor producers.

Outcome or commercialisation opportunity:

- Acceptance by governments and interest groups of sensor networks coupled with spatial information systems as a more effective environmental management process.

- Implementation of sensor supported spatial information systems for environmental management.

10.3 Urban monitoring network

Background: The Australian Bureau of Statistics (ABS) spends about $180 million every five years to produce a Census of Population and Housing. The Census is the core Australian socio-economic asset — the Basic Community Profile generated from it provides age, ancestry, income, education, computers and Internet usage, family type, housing circumstances and other important characteristics at small area level. Significant value is derived from the Census in strategic planning, government service delivery, marketing, and in almost every area of demographic planning, forecasting and modelling. Yet is essentially based on a static snapshot generated every five years, and the snapshot is based on where we, as a population, sleep — not where we work, play or study. This model hasn't changed significantly since William the Conqueror's Domesday Book recorded all people, farms and production levels in England. This made sense in a feudal society where workers were tied to and lived in the production centres, but does not appropriately represent a modern information society. Where we work, how we get there, where we shop, what we do for recreation and leisure are as valuable (arguably more valuable) than where we live. All these attributes have a spatial distribution and variation not addressed by the static Census process.

What value could be provided from a dynamic spatial analysis of selected representative small areas communities, observing and recording home, work, travel, recreational and other activity?

Potential model: Investigate the recording of location and activity undertaken by targeted 'opt-in' communities to assess the LBS and technological requirements and feasibility, and document the potential commercial value of the information generated.

Potential components: Personal GPS enabled devices such as the LPOD, coupled with spatial overlays and GPS log analysis/interpretation/inference to allocate behaviour/purpose to individual's location (for example, shopping, recreation, commuting).

Potential research partners: ABS and jurisdictional transport and infrastructure planning agencies, marketing industry.

Outcome or commercialisation opportunity: Implementation of spatially enabled activity based surveys to provide detailed socio-demographic information products.

10.4 Logistics/coordination

Background: Industry and economy overall suffer significant inefficiencies and costs through ineffective coordination. This is particularly the case where resources, materials and personnel are being assembled from multiple providers.

For example, tradespeople often travel significant distances to construction sites on the expectation that materials have or will be delivered to allow operations. More effective real time location and tracking of resources would allow improved scheduling, and allow resources to be diverted to other tasks if other required resources or materials are not available.

Potential model: Investigate the capacity to monitor and alert resource providers to changes in availability or arrival times to reduce downtime. Allow participants to establish the status and location of all other resources and materials for a given project.

Potential components: RFID and GPS units for materials, transportation and participants, coupled to a coordinating spatial information system providing a Microsoft Project-like view of availability and status.

Potential research partners: Transport/logistics industries, retail and commercial sector.

Outcome or commercialisation opportunity: Implementation of dynamic scheduling systems for targeted industry sectors — construction industry, retail/commercial logistics, fulfilment and delivery systems.

10.5 Regulatory compliance and reporting

Background: There is a range of regulatory compliance and reporting requirements that have a spatial component. Building and planning codes are prime examples — many building regulation requirements are based on proximity or other spatial relationships, and planning instruments are generally based on planning scheme zones. The Building Code of Australia might, for example, specify that for Class 5 buildings no habitable part of any floor may be further then 18 metres from a fire rated exit door. The architect or engineer’s drawings (usually digital) will classify the building as Class 5, specify the exit door as fire rated, and show that no habitable part of the floor area is more than 18 metres from the fire door. This digital specification can be mapped onto the physical world, ensuring real world compliance — see Figure 5:

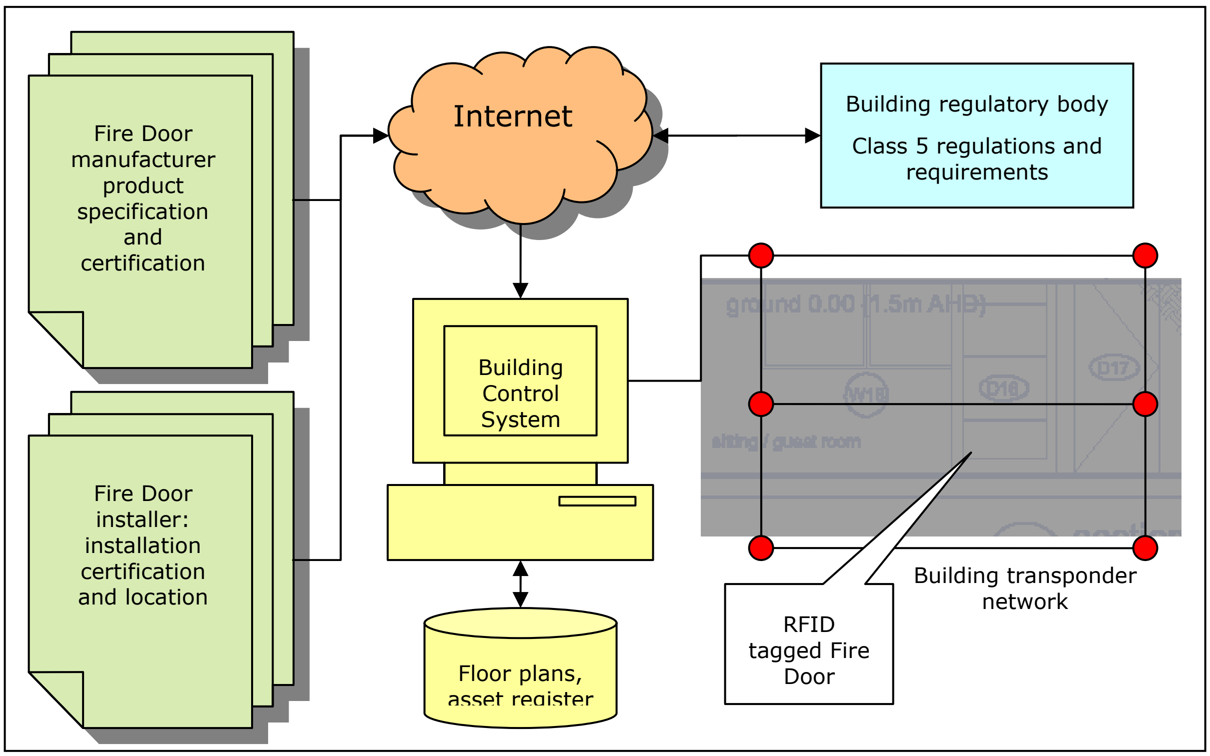
This requires:

- The exit door manufacturer to fit an RFID to the product that identifies it, and provides a web service ‘lookup’ to fire rating information/certification (web services);
- The exit door installer to record the location of the exit door and provide it to the Building control system (location based services, web services);
- The Building control system to:
    - ‘know’ that it is Class 5, and must comply with the requirements of the Building Code of Australia for Class 5 buildings;

- be loaded with the as-built engineering and architectural drawings, so that distances and intended locations are known;
- poll, on an ongoing basis, for the continuing existence of building elements in spatial relationships necessary to satisfy BCA Class 5 requirements, and notify regulatory bodies of continuing compliance or breach.

(expert systems or applications, web services).

Figure 5: Building regulatory compliance



Potential model: Investigate capacity for GPS and transponder networks to 'map' RFID enabled objects into regulatory and compliance systems.

Potential components: Composite networks of sensors, transponders, GPS and RFID devices mapped to spatial information systems and CAD data, work flow and notification processes.

Potential research partners: CSIRO, building regulatory agencies, construction industry, manufacturers.

Outcome or commercialisation opportunity: Implementation of spatially enabled regulatory compliance systems as part of building and asset control systems.

10.6 Automated feature/attribute extraction to provide regular current information of the environment

Background: With changing climatic conditions, it is expected that the incidence of natural disasters (drought, severe rain/hail storm, changing temperature and rain profiles) will increase. With the continual degradation of the environment there will be more land erosion, salinity and degradation of the hydrological systems, the management of the rural and urban environment will increasingly be automated based on a strong knowledge base to help policy makers and land planner/managers to tackle the very complex web of land management issues. This knowledge base will rely on automated features and attributes extraction from aerial and satellite imagery to continually update the biophysical urban and rural environments. This includes updating the type, quantity, quality and distribution of crops, live stocks, natural vegetations, commercial/residential buildings, street furniture and various utility assets etc.

Potential model: Investigate the combination of various aerial/satellite imagery technologies, to automatically extract features and attributes to provide accurate and up-to-date information about specific land systems in the rural and urban environment.

Potential components: Hardware, software, networks, automated features and attributes extraction and QA processes to receive, process, distribute, integrate and store vast quantities of new and archived, raw and processed data of aerial photographs, LIDAR, multi-spectral imageries.

Potential research partners: State and Federal agencies responsible for mapping, environment/natural resources management, rural and urban planning, and primary industry, universities, CSIRO, imagery acquisition and processing companies, local governments, utilities companies

Outcome or commercialisation opportunity: Implementation of data updating systems for various framework datasets and key business datasets in a no. of disciplines and industries.

10.7 Asset management

Background: To be further investigated

Potential model: To be further investigated

Potential components: To be further investigated

Potential research partners: To be further investigated

Outcome or commercialisation opportunity: To be further investigated

10.8 Bio-security

Background: As there is national quarantine restrictions on what can and cannot be imported into Australia, so to there are differing restrictions on what can and cannot be transported into each state in regards to both flora and fauna. There are a wide number of disparate systems and information gathering tools being developed in each jurisdiction to manage and restrict the growth of diseases, weeds, etc. Pests such as these are often transported on goods being moved from one location to another. There are serious inefficiencies in the use of information (particularly spatial) between both the transport industry, quarantine, plant health and generally the state jurisdictions that result in the loss of revenue through time lost from processing information, movement of pest and infections across jurisdictions.

Potential Model: To be further investigated

Potential Components: To be further investigated

Potential research partners: To be further investigated

Outcome or commercialisation opportunity: To be further investigated

10.9 Traditional IT and Spatial: interoperability and open standards

Background: Spatial has had a long and hard road in proving its usability from an everyday usage point of view and until recently has really been the domain of the 'GIS specialist' and required specialist technologies to utilise it. With technology and information system development racing ahead and a strong worldwide push towards the use of open standards and interoperability we have finally reached a point where spatial can now be utilised through new technologies by the everyday worker, but the key to this usage will be in the up-take by the traditional IT sector in building it into everyday business solutions. Spatial provides opportunities for business to draw from multiple sources of information to build solutions to enhance decision-making and management in areas ranging from asset management, marketing, stakeholder engagement, finance, banking, education, etc. The key to the general business world's utilisation of spatial will be the connectivity and interoperability of multiple information collection tools and the power to bring all this information together in a meaningful and useful system.

Potential Model: Investigate the technological and interoperability issues in relation to the use of spatial in traditional IT systems by targeting non-GIS traditional organisations and IT development partners to assess the LBS and technological requirements and feasibility of the move of spatial into these areas.

Potential Components: GIS specialist software and systems, coupled with IT based business systems, GPS, RFID, etc.

Potential research partners: ICT CRCs (eg National ICT Australia), IT development, finance sector, asset management, etc organisations, Academia (both Computer Science & GIS).

Outcome or commercialisation opportunity: Improved uptake of spatial in the wider business community, interoperability and development in Open standards across GIS and IT.

10.10 Three-dimensional GIS

The current architecture of GIS systems is based on a two dimensional typology. Objects are comprised of points, lines and polygons. Analyses are conducted in two dimensions. The primary concession to the three dimensional world is the improved ability to depict quasi three dimensional images through visualization technologies. However these are 'dumb' images that allow very little intelligent analysis. The movement to fully functional, three dimensional GIS is a massive development issue that will not be solved for some years. Nevertheless it is a critical requirement for the full realization of VA.

There are many examples today where 3-D GIS would make a huge difference to Australia. Imagine if we could represent multi-story properties on title in 3-D; boundaries, infrastructure, valuation, services and so on. Or if we could construct a picture of a catchment from blue sky to bedrock showing land use, ground water, conservation reserves, rural houses, power lines and so on. The potential comes into focus when we superimpose a terrorist bomb blast in the first example and a wildfire in the second. Real-time response and recovery management would be vastly improved.

Potential Model: CRC-SI has three of the largest GIS vendors as its partners; Intergraph, ESRI and Mapinfo. Consideration should be given to a strategic approach to these companies to discuss their intentions with respect to 3-D GIS and the role that the CRC-SI could play.

Potential Components: 3D modelling and analytical capabilities, 3D navigation and ad hoc query capabilities.

Potential research partners: GIS vendors Intergraph, ESRI and Mapinfo.

Outcome or commercialisation opportunity: 3D GIS capacity and capability to market with one or more existing GIS vendors.

10.11 Advance hyperspectral remote sensing: Geostationary and Hyperspectral satellites

The civilian world has enjoyed the use of orbiting imaging satellites since the late 1960s. Progressive improvements in resolution, the frequency of orbit and the spectral properties now see satellites with sub-metre pixel resolution, daily revisits and multi-spectral capabilities that provide several channels from the visible part of the electromagnetic spectrum through to the middle infrared.

Two significant developments now loom. The first is geostationary satellites — imaging satellites that remain permanently over the same area of the earth imaging constantly 24 hours a day. Astrovision (a startup company) proposes to place the first of these satellites over Australia sometime in the next 4 – 5 years (subject to funding). It would have a best pixel resolution of 250 metres and would collect three images a second. Its constant surveillance offers the first civilian approximation of real-time imaging.

The second major development is the introduction of hyperspectral imaging satellites. Hyperspectral instruments offer at least a couple of hundred spectral channels and are therefore extremely information rich. Their ability to discriminate features such as plant type and health, soil chemical properties, infrastructure and so on is an order of magnitude better than the existing multi-spectral satellites — so much so that non-scientists refer to their ability to provide 'finger-print' like resolving abilities. There is currently one experimental hyperspectral satellite with an uncertain future, Hyperion, and no operational hyperspectral satellites. A Japanese consortium including NEC Toshiba and Itochu Corporation are currently undertaking a feasibility study and market analysis with the purpose of deciding whether to build and launch a hyperspectral satellite within the next four years.

Potential Model: Much research needs to be undertaken to prove up products. Collaborate with geo-stationary and hyperspectral platform consortia to identify and prove up commercial processes and applications.

Potential Components: Platform outputs processing and 'productising', telemetry (the large continuous stream of data from the satellite), rapid image rectification with preparation of products for dispatch in near-real time, and developing techniques to detect moving objects such as ships, vehicles, fires, weather, disasters, military operations and so on.

Potential research partners: Astrovision (in the process of joining the CRC-SI), others, such as the Japanese platform consortia including NEC Toshiba and Itochu Corporation.

Outcome or commercialisation opportunity: Image processing and productisation processes, techniques and applications, end-use products and services.

10.12 Augmented reality

Augmented Reality is a form of Virtual Reality that makes use of head-mounted displays, or modified optical instruments to superimpose meaningful virtual images onto the user's view of the real world. Conceptually, augmented reality questions the need to model those components of the environment that are not changing when an actual image can be used. It was also the concept behind photomontage techniques used in the 1960s and 70s with computer graphics superimposed on photographs (Bureau of Land Management, 1980). However still images do not permit either the camera or objects in the view (cars, trees in the wind) to move.

Off-line augmented reality uses video as the source of existing images. Nakamae et al (2005) consider that a video sequence can provide an excellent representation of existing conditions. The sequence might involve the camera panning across the landscape, zooming on an object of interest or being driven along a street. They have successfully overcome a range of difficulties related to camera location, occlusion, lighting and moving objects.

The ultimate augmented reality (and the only type according to some authors – eg. Azuma et al 2001) is for the graphic superposition to occur in real-time via a partial head-mounted display. This allows change to be seen directly in conjunction with existing conditions from any location, and in any direction, to which the user moves. Piekarski and Thomas (2005) look specifically at the potential roles for real-time augmented reality in environmental planning: for example, building design while on-site.

Potential Model: Improve the usability and acceptance of augmented reality. There are two possible approaches. Firstly, where positioning, alignment, occlusion etc are done by the positioning and computational equipment the requirement is to reduce component bulk, power demands and latency effects. Secondly, investigate a lower grade, less dynamic product which gives the user a great role in calibration and alignment. In this case low end potential exists via conventional PDA level equipment.

Potential Components: While good positioning and orientation data can now be garnered from GPS and MEMS configurations the equipment remains bulky – especially for individual use – and issues such as latency (the delay between personal movement and the graphics catch-up) still affect the ease and convenience of use.

Potential research partners: To be determined.

Outcome or commercialisation opportunity: Likely areas of continued development and application are in medicine, engineering, construction and entertainment. Reduction in the size and weight of components will open up additional possibilities and new users in tourism information, environmental reconstruction, agriculture, planning, landscape management, security and so forth.

11 CONCLUSION

VA as an evolutionary process for current information management principles and practice is not hard to imagine. VA as a fully implemented virtual model of all non-trivial objects in the physical Australia is less achievable in the short to medium term.

However, it has now been shown that it is possible to create commercial Data Suites and Data Hubs that deliver near real-time business information. The complex nature of spatial information and the enormous data volumes needed to describe Australia magnify the challenges, but do not fundamentally alter the nature of the challenges — the same principles apply. There is no fundamental reason why the same approach could not be successfully applied to deliver the VA vision of complete, correct and current information for Australia.

The arrival of major IT/IM forces such as Google, Microsoft and Oracle in the spatial arena herald the first step in the migration of spatial into the world's general IT/IM systems and indeed the first major step towards VA.

The key significance of the spatial component of VA is not to be underestimated. Whilst spatial information and spatial technology are still poorly understood and under-appreciated, it will soon be imperative for the wider community to gain this understanding and appreciation. The spatial industry has the opportunity and responsibility to provide strategic direction, to take the running in advancing towards VA, and to capitalise on the presence of Google, Microsoft and Oracle.

VA offers strong opportunities to the CRC-SI in terms of both a strategic vision and as the focal point for highly innovative research and development. The largest opportunities appear to lie in four areas:

- the development of an architecture, or framework, for a complete, current and correct virtual model of Australia;
- data acquisition and analysis (rather than its storage and retrieval, which can be addressed by appropriate IT architecture);
- depiction of the data in four dimensions with full topological and modelling capabilities; and
- the ability for mobile users to access this four dimensional information in near-real time.

The most ambitious definition of VA is as a model that provides complete, correct and current information about Australia via an information system that supports a wide variety of critical processes of national importance. Such processes rely upon the real-time integration of many types of data for purposes such as emergency relief and disaster management. Much of the technology needed to allow this most ambitious realisation of the concept exists today and it is expected that significant growth will occur in the data suite and data hub technology approaches.

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