ELEVATION AND DEPTH 2030

Powering 3D Models of Our Nation

Elevation and Depth Information Coordination and Innovation for Australia - A National Strategy

Consultation draft
December 2017

ICSM
ANZLIC COMMITTEE ON SURVEYING & MAPPING

Vision

A consistent nationwide digital elevation and depth model that people can interrogate with other information to better understand the dynamics of our environment, make sense of uncertainty, and provide a basis for community safety, economic growth and sustainable living.

Call for Submissions

ICSM invites your comments on this consultation document.

Your feedback will help us make informed decisions on the final version of this strategy, ensuring its relevance to the needs of industry, government and the community.

Please assist us in getting this important strategy right.

Submissions can be made via email to **elevation@ga.gov.au** or email to **icsm@ga.gov.au**

Written submissions can be sent to
ICSM Chair, GPO Box 378, Canberra ACT 2601 Australia.

Contributions are welcome from all interested organisations and people.

The closing date for submissions is 30th March 2018.

Michael Giudici, ICSM Chair

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Purpose of this Document

Elevation and Depth 2030: Powering 3D Models of Our Nation has been prepared by the Permanent Committee on Topographic Information; a subcommittee of the Intergovernmental Committee on Surveying and Mapping.

The purpose of this consultation draft is to seek broader community input and support for the Elevation and Depth 2030 strategy which sets the direction for consistent nationwide elevation and depth information. The strategy considers where our current elevation and depth information falls short of community expectations and anticipates the consequences of missing key growth opportunities in the future.

Elevation and Depth 2030 is the second ICSM strategy to examine the trends and articulate a vision of what the community will require of location information in the coming years; the first being Cadastre 2034.

Elevation and depth information is critical to public safety, climate change studies and industry automation, and yet it is one of the most underutilised government data assets. The size, cost and complexity of elevation and depth data makes it difficult to acquire, curate, process and interpret, and as a consequence, it is largely used only by expert data analysts.

Being able to visualise our environment as a 3-dimensional model is one of the most significant ways we can help people make sense of their location. It is time to shift our attention to promoting and coordinating investment in the innovative use of elevation and depth data.

To make a difference to our future, we must fundamentally change the way elevation and depth data is managed, and consider new ways to collect, curate, and enable access and use for all Australians.

ANZLIC will use this strategy to transition the Elevation and Depth theme in the ANZ Foundation Spatial Data Framework (FSDF) to become a more valuable asset.

Your input is essential to achieving a step change in policy, process and attitude towards modelling and visualising our Australian landscape, physical infrastructure and underwater terrain. Help us get this strategy right by letting us know if you share our aspirations.

- Do you agree with our view?
- Do our goals and objectives reflect you own aspirations?
- How important is elevation and depth data to you?
- What can you contribute to realising a new era in terrain modelling?
- Do we have your support to make fundamental changes?

Information on how you can participate is available on the inside cover of this document. Your feedback will inform the final strategy. I look forward to your involvement.

Michael Giudici
Chair, Intergovernmental Committee on Surveying and Mapping

Elevation and Depth 2030

Powering 3D Models of Our Nation

What is elevation and depth information?

Elevation and depth is the digital representation of the Earth's surface or a point affixed to it, above or below a specified reference datum typically related to sea level.

Elevation and depth data is collected using a range of sensors; including laser, sound navigation and ranging (sonar), radio detection and ranging (radar), light detection and ranging (LiDAR), optical remote sensing and surveying techniques to derive spot heights, raster surfaces, contours and digital models of terrain and subterranean features [1].

Elevation and depth measurements usually describe bare earth positions but may also describe the top surface of buildings and other objects, vegetation structure, or submerged objects.

Elevation and depth data is stored as a three-dimensional array or as a continuous surface such as an image, triangulated irregular network, point cloud or contours. Elevation and depth data may also be represented in other derivative forms such as slope, aspect, ridge and drainage lines, and shaded relief.

Elevation and depth information is fundamental to emergency management, climate change studies, water security, urban planning and defining maritime and administrative boundaries.

Why is elevation and depth information important?

Elevation and depth information is fundamental to emergency management, water security, environmental management, climate change studies, maritime navigation, natural resource exploration, urban planning, engineering and construction [2], and defining maritime and administrative boundaries [3].

Whether you are navigating a 400,000 tonne bulk carrier through a busy port, optimising the design and location of the next billion dollar infrastructure project, exploring for gas and mineral deposits, or predicting the behaviour of a bushfire - a precise understanding of elevation and depth is critical to good decision making, economic prosperity and community safety.

Why should we care about a National strategy?

Elevation and Depth 2030 anticipates that the needs of the community, industry and governments will change significantly over the next decade, as concerns about climate change, community safety, the environment and increasing urbanisation place pressures on government to deliver good policy and decision making that rely on elevation and depth information. There is already a disparity between what we have and what will be required in the near future. International studies [4] indicate that elevation and depth needs to be more accurate, comprehensive, available and transparent.

Precise elevation and depth information will be a keystone of our future knowledge-based digital economy.

Precise elevation and depth information will be a keystone of our future knowledge-based digital economy. This information is already integrated into decision making around navigation, defence, planning and disaster management, and its utility will expand in the future as artificial intelligence and machine-to-machine interactions are increasingly used to support human reasoning through knowledge inferencing.

However, government capacity to deliver enhanced data is declining due to budget constraints and skills shortage [5]. This is driving the need for effective cross-government collaboration and industry partnerships, and the need to embrace new technologies to capture, process and distribute elevation and depth information services using continuous and automated processes.

Concerns for practitioners are twofold; firstly how to overcome the challenges associated with establishing a cooperative data supply chain in such a complex data network environment, and secondly, how to achieve an effective supply chain when emerging technologies are likely to realise a disruptive paradigm shift in the way data is collected and used.

If digital elevation and depth information is to take its rightful position as mission critical data in Australia's future digital economy, then we need to create an environment that is more open to innovation, collaboration and on-demand knowledge discovery.

The value of this strategy is that it recognises these challenges and the significance of opportunities ahead, and proposes key goals and actions as a way to move forward. These goals and actions are allied with the Cooperative Research Centre for Spatial Information (CRCSI) research agenda [6] and the 2026 Agenda [7] that will move the focus of government from data supply to a knowledge-focussed environment where:

- consumers are able to use intelligent search capabilities to query elevation and depth data in real-time;
- automated spatial analytics are applied continuously to monitor environmental change and predict future events;
- 3-dimensional mobile applications are mainstream technologies used by non-experts; and
- elevation and depth data is captured and processed in real-time using automated sensing techniques [4].

The Elevation and Depth 2030 strategy considers these challenges in the context of a future Australian Spatial Knowledge Infrastructure (ASKI) [6] and goals of the Foundation Spatial Data Framework (FSDF) [1]. It provides a blueprint for success that all levels of government can work towards.

The overarching direction and strategic framework is designed to bring collaboration, coordination and consistency to custodians, suppliers and users. The notion is that each jurisdiction can take this high level strategy and work towards achieving the goals identified according to their unique situation and circumstance. This includes New Zealand, which shares the same vision and goals through ANZLIC and ICSM, but which has a different physical environment and therefore distinctive elevation and depth use cases and priorities, such as those associated with intensive earthquake monitoring, mitigation and recovery.

Importantly, this strategy makes clear what government must deliver, and provides industry, business and the community with a picture of what they can expect in the future.

The overarching direction and strategic framework is designed to bring collaboration, coordination and consistency to custodians, suppliers and users.

How does this strategy align with the Foundation Spatial Data Framework?

The FSDF provides a common reference for the assembly and maintenance of a variety of foundation datasets including Elevation and Depth, to serve the widest possible variety of uses [1].

Elevation and Depth 2030 aligns with FSDF objectives, such as deriving national elevation products from more finely-detailed data and the integration of high resolution datasets, such as LiDAR to improve accuracy.

This strategy builds on previous work performed under the umbrella of the National Elevation Data Framework (NEDF) established to provide decision makers, investors and the community with access to the best available elevation and depth data. NEDF achieved several significant milestones Including: ICSM LiDAR Acquisition Specifications and Tender Template; Lidar quality assurance tool (QA4LiDAR); discovery and access via the improved NEDF Portal, the National Elevation Information System (ELVIS); and National Elevation Data Audits in 2007, 2009 and 2011.

Elevation and Depth 2030 offers the leadership and direction for the FSDF Elevation and Depth Theme moving forward. It clarifies how the various partners and projects can be connected to achieve the best outcome for Australia.

With agreed strategic direction, meaningful short term targets and measures will be established, along with a sequence of activities to help focus key efforts towards implementing this strategy and enhancing the FSDF Elevation and Depth Theme.

Imagine 2030

Being Prepared is Anticipating What's to Come

Rapid urbanisation, an aging population and the evolution of smart cities is driving an appetite for 3-dimensional information to adapt to vertical living lifestyles and optimise our use of resources.

Humanity will change more in the next 20 years than in all of human history [8]. Appreciating the likely trends and influences will help us to position our elevation and depth information to take advantage of new technologies to better provide for community safety, economic growth and sustainable living.

In 2030, a semantic-rich 3 and 4-dimensional virtual world, built on elevation and depth information, is anticipated as being the foundation for our knowledge networks.

Daily life will be sustained through an enveloping array of Internet technologies; wearable devices will be fully integrated into everyday life; and information about the world around us and our relationship with it will be delivered dynamically. We can already see this occurring with hourly weather reports, traffic alerts and proximity-based marketing.

Every sensor in the Internet of Things (IoT) has a position in 3-dimensional space, with elevation and depth information providing vital context for these devices and their relationship with other objects. Energy conservation, waste management and parking systems are some of the sensors being used to better manage city operations – be it turning lights off when not in use, knowing when public bins are to be emptied or letting people know where there are free parking bays. This wealth of knowledge, combined with elevation data, will drive limitless future applications supporting decision making and more sustainable lifestyles.

While it is difficult to predict new and emerging applications, the following trends will impact on the way we respond as an industry.

Accelerating Urbanisation

Rapid urbanisation, an aging population and the evolution of smart cities is driving an appetite for 3-dimensional information to adapt to vertical living lifestyles and optimise our use of resources.

Projections indicate that 72% of the Australian population will live in cities by 2053; with Sydney, Melbourne and Perth doubling in size and one in eight people aged 65 and over [9]. This poses fundamental questions and a change in the mindset of policymakers and innovators about who will be living in these cities and what their needs will be.

What we do know is that managing city growth will require 3-dimensional models to design for sustainability, such as height restrictions, setbacks, overshadowing and wheel chair access. Already airports are using 3-dimensional models to monitor trees likely to penetrate airspace near runways [10].

Two-dimensional maps are no longer adequate for urban planning and construction design, particularly where age-friendly cities require detailed design considerations for all generations. Virtual design and construction teams have embraced the value of Building Information Models (BIM) and are now discovering the value of drone mapping technologies for point cloud surveys that provide highly accurate elevation measurements compatible with BIM software [11].

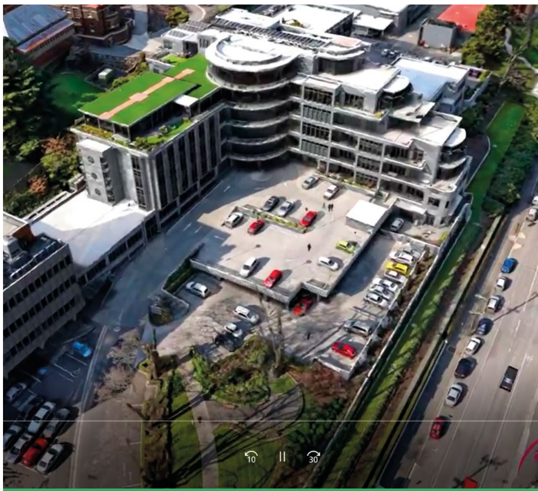
Our growing penchant for vertical lifestyles will require new services that are suited to apartment living. By 2030, drone delivery will be commonplace and standard delivery addresses insufficient. Drones will require a dynamic 3-dimensional representation of the target destination, such as an apartment balcony [12], as well as a rich 3-dimensional understanding of the environment it traverses.

With dynamic 3-dimensional models, councils will be able to consider new development corridors, visualise their future impact and make incremental adjustments to master plans. This will be important. Trends change and spatial economics studies show that new technologies are likely to reduce transportation costs and travel times meaning people will have more choice about where they live and work [13].

New Acquisition Systems

Capturing and updating digital elevation and depth datasets is a significant challenge today. Not so in the future. Smart transport networks, sensor equipped driverless cars, drones, and autonomous vessels and ocean sonar systems are likely to constitute a large source of elevation and depth information for targeted applications.

Autonomous vehicle and vessel positioning systems, combined with detailed point cloud mapping and image recognition capabilities, will be key enabling technologies for the localised capture and augmentation of 3-dimensional data [14]. While BIG data processing may be an ongoing challenge, crowdsourcing from vehicle sensors will achieve a highly detailed digital elevation and depth model that can be updated in real-time [15, 16].



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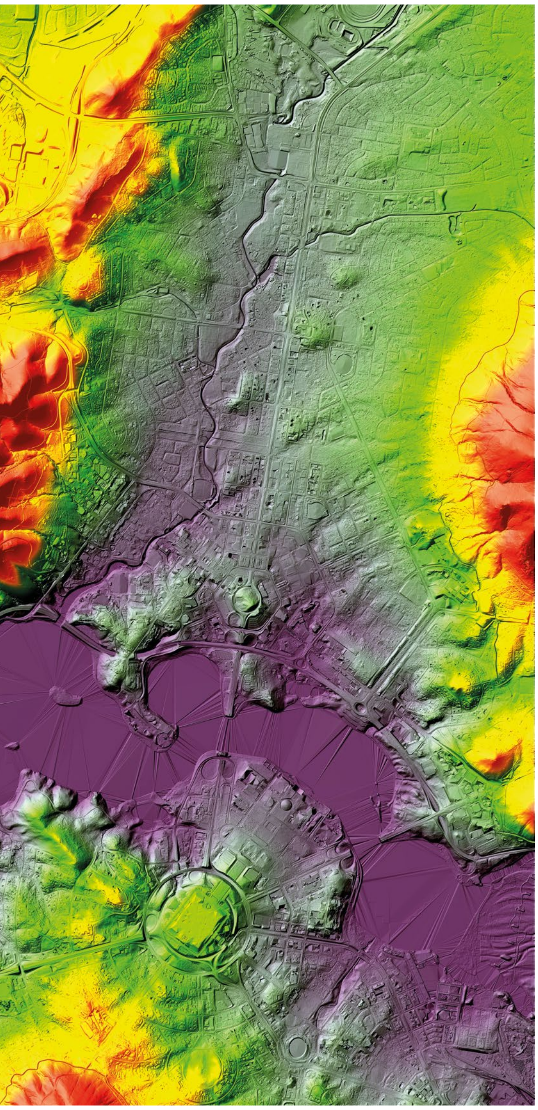


Achieving capture consistency across the government and commercial sectors, maximising business value through data reuse, and increasing investment potential will require sustained interoperability, regulatory and participatory frameworks to be established from the outset. This includes policies surrounding individuals' privacy [17] and intellectual property rights associated with repurposing data for other applications.

On-demand Knowledge

We have entered the on-demand revolution [18] where users expect personalised and logic driven answers, not links, when they interact with information systems. People want to be able to pose complex questions, such as "when will the fire reach my place", and they will want these questions answered with reliability.

Predictive and machine-learning environments are evolving, as is the capability to answer complex questions in a way that is contextually appropriate to the user. End-user profiling, used prolifically in online marketing, has a role in spatial analytics. For instance "will a location be flooded?" has different context when asked by an emergency responder, home owner or insurer.

Artificial intelligence and spatial analytics will deliver reasoned and predictive answers to complex problems [19]; "Where do I position my windfarm?" and "What is the optimum design?" Understanding height above ground is a key data input to answering these types of questions.

Machine-learning technologies will be how volumes of elevation and depth data, in combination with other information, can be processed quickly to answer questions that involve the complexities of slope, aspect, and terrain structure, all of which have a dynamic element.

In the future, users will require an unprecedented trust in data, thus asserting the need for information warrantability and provenance transparency for all distributed data. For computer generated answers to become actionable knowledge, users must first believe the information to be true. Questions like "Which road should I take to avoid a fire blocking my path?" will need to include an acknowledgment of the likelihood of an answer being correct.

Immersive Knowledge Environments

With increasing computational and network transmission capacity, immersive visualisations are set to transform the way people do business and manage their social lives. These models clearly show the physical dimensions of objects and their distance in relation to other objects. Combined with historical imagery, elevation models reveal patterns in the way we use and modify land and this knowledge can be used to forecast future impacts.

Immersive visualisation through virtual and augmented reality will be a key tool for the next generation of jobs and commercial transactions.

Virtual exploration of detailed BIM and real-time vision through roaming drone sensors spidering the environment will be components of the future elevation and depth knowledge infrastructure. Future use of 3-dimensional models will include applications as diverse as mine sites, ports and other significant infrastructure pre-construction and post-rehabilitation, as well as detailed models for market gardeners assisting them with tracking the growth and health of crops. Individuals will be able to better manage their property by being able to visualise the location of underground utilities.

Being Prepared

This convergence of trends will inevitably be part of our future; afuture in which the elevation and depth industry has a significant and active role to play.

Autonomous vehicles, drones, smart cities applications, immersive environments, and the Internet of Things, with city-wide sensors connecting people with locations and services, are just the beginning of far more integrated systems of government that require digital elevation and depth models to create a richer experience for our community.

By 2030, this on-demand knowledge will be entrenched in society and, with it, elevation and depth information will be seamlessly integrated into mobile applications and personal digital assistants [20] for broader professional and personal decision making.

For this to happen, elevation and depth data, combined with orchestrated real-time spatial analytics, must become a mainstream capability. This requires a cultural shift in thinking from hardcoded data analytics to open query interfaces.

Virtual exploration of detailed BIM and real-time vision through roaming drone sensors spidering the environment will be components of the future elevation and depth knowledge infrastructure.

Working Towards a Better Future

Permanent Committee on Topographic Information

It is essential that we position our elevation and depth information to provide an accurate seamless 3-dimensional representation of our land and marine environments that can be used in perpetuity.

It is crucial that our elevation and depth information grows in maturity to become a driving force behind economic growth and sustainable development, community resilience, environmental management and business productivity.

Not all sectors and businesses in Australia are making full use of the potential that digital elevation and depth information has to offer. Yet this information underpins smart cities initiatives, business innovation and intergenerational wellbeing.

It is essential that we position our elevation and depth information to provide an accurate seamless 3-dimensional representation of our land and marine environments that can be used in perpetuity.

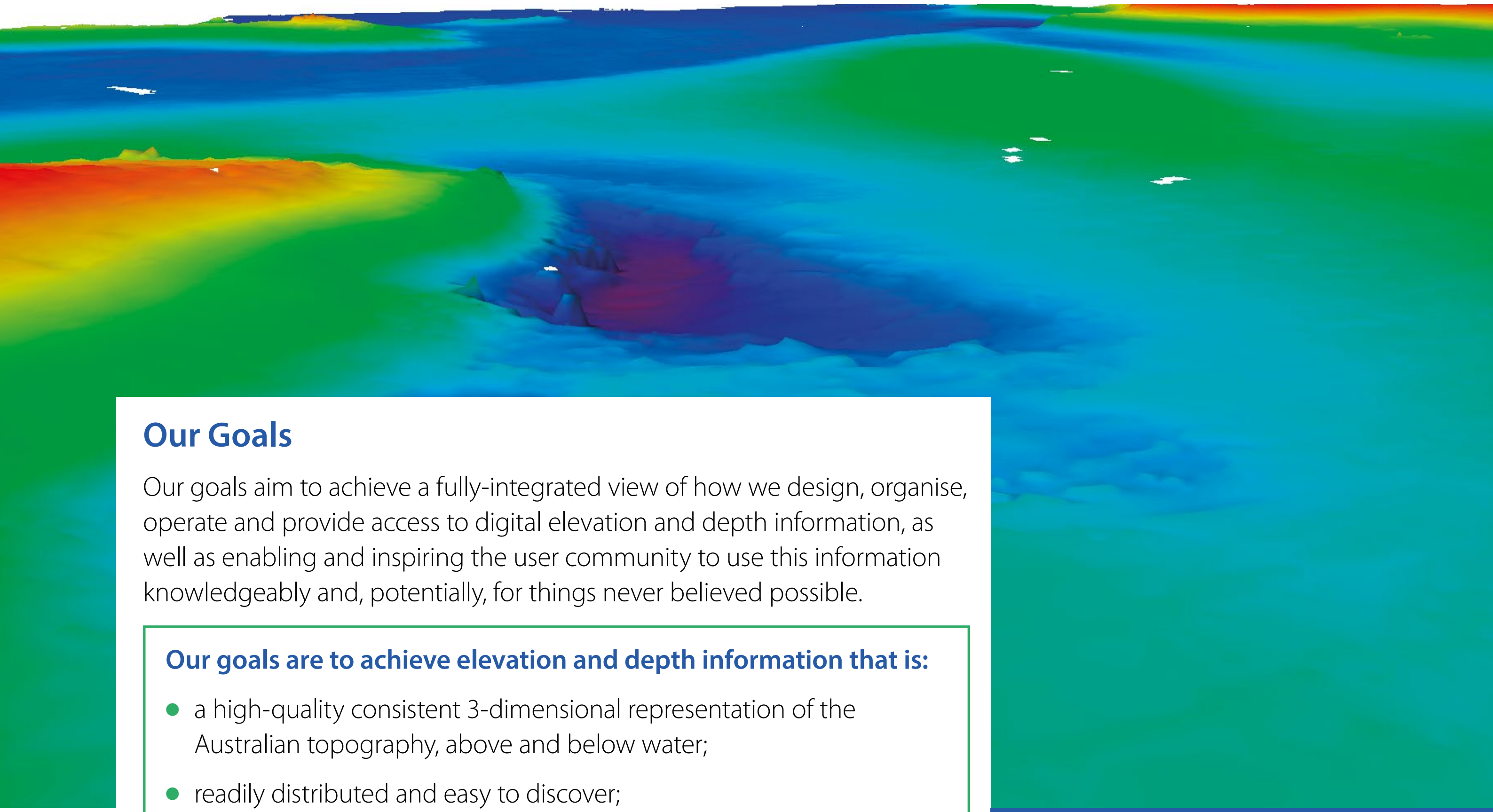
Being able to detect and visualise marine navigation hazards, understand our exposure to flood waters, assess climate change impacts, deliver cost effective engineering projects, and conduct productive mining and gas exploration; depends on having accurate models of our environment.

Our Vision

Our vision for Elevation and Depth 2030 recognises that our land, waterways and oceans are at the centre of human activity and economic growth, and that the more knowledge we have about our environment, the better able we are to make wise policy decisions, sound investments and well-informed lifestyle choices.

Our vision is:

A consistent nationwide digital elevation and depth model that people can interrogate with other information to better understand the dynamics of our environment, make sense of uncertainty, and provide a basis for community safety, economic growth and sustainable living.



Our Goals

Our goals aim to achieve a fully-integrated view of how we design, organise, operate and provide access to digital elevation and depth information, as well as enabling and inspiring the user community to use this information knowledgeably and, potentially, for things never believed possible.

Our goals are to achieve elevation and depth information that is:

- a high-quality consistent 3-dimensional representation of the Australian topography, above and below water;
- readily distributed and easy to discover;
- a nationwide digital model able to be integrated and visualised dynamically with other information and systems;
- easily queried and used widely to acquire knowledge; and
- managed within an infrastructure that embraces connectivity, sustained value-based management and collaboration.

The overarching objectives and strategic actions and innovations required to achieve these goals are detailed in the following sections.

Our Role

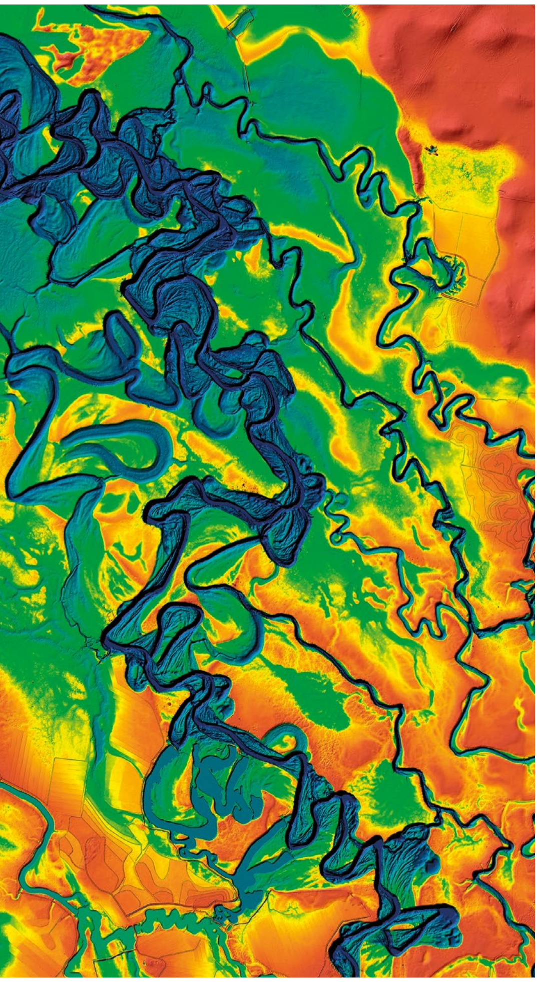
This strategy will be delivered through collaborative effort. We will use policy settings to drive the agenda forward, engage with stakeholders at the highest levels and use a core range of communication activities to ensure the vision and goals are not only words on paper but become a shared reality.

This strategy will be delivered through collaborative effort.

Hence our mission is:

To promote and support innovation through the leadership and standards necessary to deliver a consistent nationwide digital elevation and depth infrastructure that can be leveraged to find sustainable solutions to meet emerging needs and opportunities.

This strategy sets our direction and a pathway. In practice, a variety of projects will provide the necessary momentum to achieve the objectives and, while much behind the scenes activity will be happening, the intent and timeline will be communicated broadly through ICSM and FSDF programs.



Our Guiding Principles

The following principles will guide our governance, decisions and actions, and make complex collaboration possible. Our final cause and end goal is to deliver a seamless user experience. This will be achieved through:

- **Trust** – We will deliver this strategy through a collaborative effort that recognises common needs and aspirations, and builds a culture based on trusted partnerships.
- **Consideration** – Our approach will be sensitive to compliance obligations placed upon each party by pre-existing legislative, policy and administrative frameworks.
- **Commitment** – We are committed to enhancing the long-term value of investments through careful targeting and prioritisation to create a critical mass of elevation and depth data within repositories.
- **Value Focus** – We will involve our stakeholders in decisions about priorities that will deliver tangible benefits and greater value for users.
- **Sustainability** – Our actions, innovations and programs will be designed with sustainability in mind from the outset and consider the adaptability of our data, technology, policies and people.
- **Transparency** – We will use transparent decision-making processes so that the 'what' and 'why' are known and readily understood.
- **Pragmatism** – Challenges will be addressed through open communication networks, focusing on what is possible and taking action to find solutions.

Simon Costello
Executive Sponsor, Permanent Committee on Topographic Information, ICSM.

Graham Hammond
Chair, Permanent Committee on Topographic Information, ICSM.

Case for Change

Key decisions are made daily across Australia that rely on elevation and depth information, ranging from immediate preservation of life and property, to long-term planning and sustainability. Traditional supply chains are struggling to service these needs. Changing economics, technologies and community expectations demand a transformational improvement on this current state.

Stimulating Economic Sustainability

A range of stakeholders across all tiers of government, industry and business are spending millions of dollars in collecting, storing, distributing and applying elevation and depth information. These investments are isolated and many end users find it difficult to discover what is available, and what might best suit their needs.

With diminishing budgets, increased competition for funding and a fragmented user-base, this current situation is unsustainable. While technological advancements are driving the cost of data acquisition down, elevation and depth information is still extremely expensive to acquire and systems are costly to develop and maintain, and curating the vast volumes of data is complex and expensive.

With better planning, coordination and collaboration, these isolated investments could be harnessed to create significant savings, afford increased scope for reusability and deliver greater user value through:

- making it easier to discover existing and planned projects;
- avoiding duplication of effort;
- co-investing in data acquisitions and systems; and
- applying data and product standards to enhance reusability.

Studies in the United States have documented a clear link between elevation and depth data and the nation's economic prosperity. These assessments illustrate how a coordinated nationwide high-resolution elevation capture program can deliver annual benefits of between USD$0.69-1.2 billion (at a benefit cost ratio of 4.6:1) with the potential to generate a further USD$13 billion annually in new benefits that span the economy [4].

Benefits to the United States economy are so compelling that funding has been re-prioritised from the national high-resolution orthoimagery program to accelerate the development of the 3D Elevation Capture Program.

Those areas afforded significant productivity improvement and financial benefits are flood risk management, infrastructure and construction management, natural resources management, agriculture and precision farming, and water supply and quality.

Studies in the United States have documented a clear link between elevation and depth data and the nation's economic prosperity. A simple benefits transfer would see approximately $100 million of direct improvement to the Australian economy from a proportionate investment.

Accurate knowledge of port elevation and depth, in conjunction with tide and vessel information has potential to increase export opportunities

These application areas are directly transferable to needs in Australia, and a simple benefits transfer would see approximately $100 million of direct improvement to the Australian economy from a proportionate investment [21].

Domestically, Australian shipping ports have demonstrated that accurate knowledge of port elevation and depth, in conjunction with tide and vessel information has the potential to increase export opportunities in the order of $300 million per annum for some ports [22].

In Queensland, 3dQLD estimates that up to $2.1 billion of economic benefit can be realised over 20 years through the use of federated 3-dimensional models of the natural and built environment that have high positional certainty, and a 3D cadastre that includes all rights, restrictions and responsibilities (RRR) [23].

Economic benefits derived from elevation data are being realised globally. In Tacoma USA, a potential catastrophic event was avoided through the identification of a surface rupture near a USD$735 million suspension bridge using LiDAR data [22], and in Alaska, aviation safety was improved using high-resolution elevation models for cockpit navigation and flight simulators [24].

Slope data derived from LiDAR is being used by engineers at the University of Berlin to reduce fuel consumption by anticipating gradients ahead. It is estimated that these types of driver assisted technologies could save USD$24.5 billion[1] in fuel consumption for consumers in the USA [25]. In addition, TomTom® is working with car and truck manufacturers to build systems that warn drivers of steep curves and dangerous conditions ahead [26].

These are just some of the examples of how elevation and depth information is being used innovatively to achieve economic growth, and improve community safety and wellbeing. To realise the full potential of this data, a well-coordinated plan for data acquisition and reuse is required; one that can be sustained in the longer term.

Changing Expectations

Community needs and user expectations will demand a new approach to the way elevation and depth data supply and value chains are managed.

There is an increasing community expectation and demand from business start-ups for more accessible, accurate and reliable information to power position-informed applications and services. When sourcing this information from government there is a parallel expectation of authoritativeness and warrantability under open data licensing.

New entrants to the elevation and depth information supply chain, such as micro-drone companies and crowdsourcing through mobile devices, offer an economical source of data, but pose potential challenges when it comes to data storage, accuracy, warrantability and liability.

[1] at an average of USD$3.50 per gallon

An increasing and diverse user base presents new challenges for information specification, coordination, and access and licensing. Traditional uses remain an imperative, but greater utilisation and uptake of information into new markets such as motion simulation (urban, aeronautic and heavy vehicle), mobile app development, indoor mapping and many others, is becoming just as important.

Better business processes, systems, coordination, communication and marketing are required to move forward. An expansion of the market place will afford vendors and innovators opportunities to further commercialise data assets and offer solutions to a new technology-savvy customer base. This is good for growth in the commercial sector, as well as stimulating investments in new technologies for social and business applications.

Maintaining Technological Relevance

Legacy storage formats and systems are hampering integration, queryability and discovery of existing elevation and depth data. Current systems often use proprietary data formats and bespoke file structures located on internal servers or offline USB devices. This is limiting the full exploitation of elevation and depth information.

In order to solve tomorrows complex problems, information must be self-describing, machine-readable, formatted so it can be interpreted meaningfully, and readily discoverable and dynamically accessible online. Interoperability with high-performance computing formats such as netCDF, and developing industry standards such as BIM, are a prerequisite for meaningful data integration with information systems that manage 3 and 4-dimensional information.

The current siloed approach to project acquisitions is not conducive to national scale knowledge-based products, spatial analysis, and leveraging the opportunities of super computing and big data. A more holistic approach to the programmed collection, specification and storage, and curation of information will yield benefits for researchers and policy makers tackling continent-wide and regional issues, such as climate adaptation and environmental resource management.

To be internationally competitive in the digital economies of the 21st century, Australia needs to be fully GNSS enabled and ready with accurate national 3-dimensional mapping capabilities to capitalise on all that new positioning accuracies have to offer. Australia is uniquely poised to take advantage of existing and future positioning satellites, but needs mapping and elevation data accurate to centimetres rather than metres to realise full advantage.

To be internationally competitive in the digital economies of the 21st century, Australia needs to be fully GNSS enabled and ready with accurate national 3-dimensional mapping capabilities to capitalise on all that new positioning accuracies have to offer.

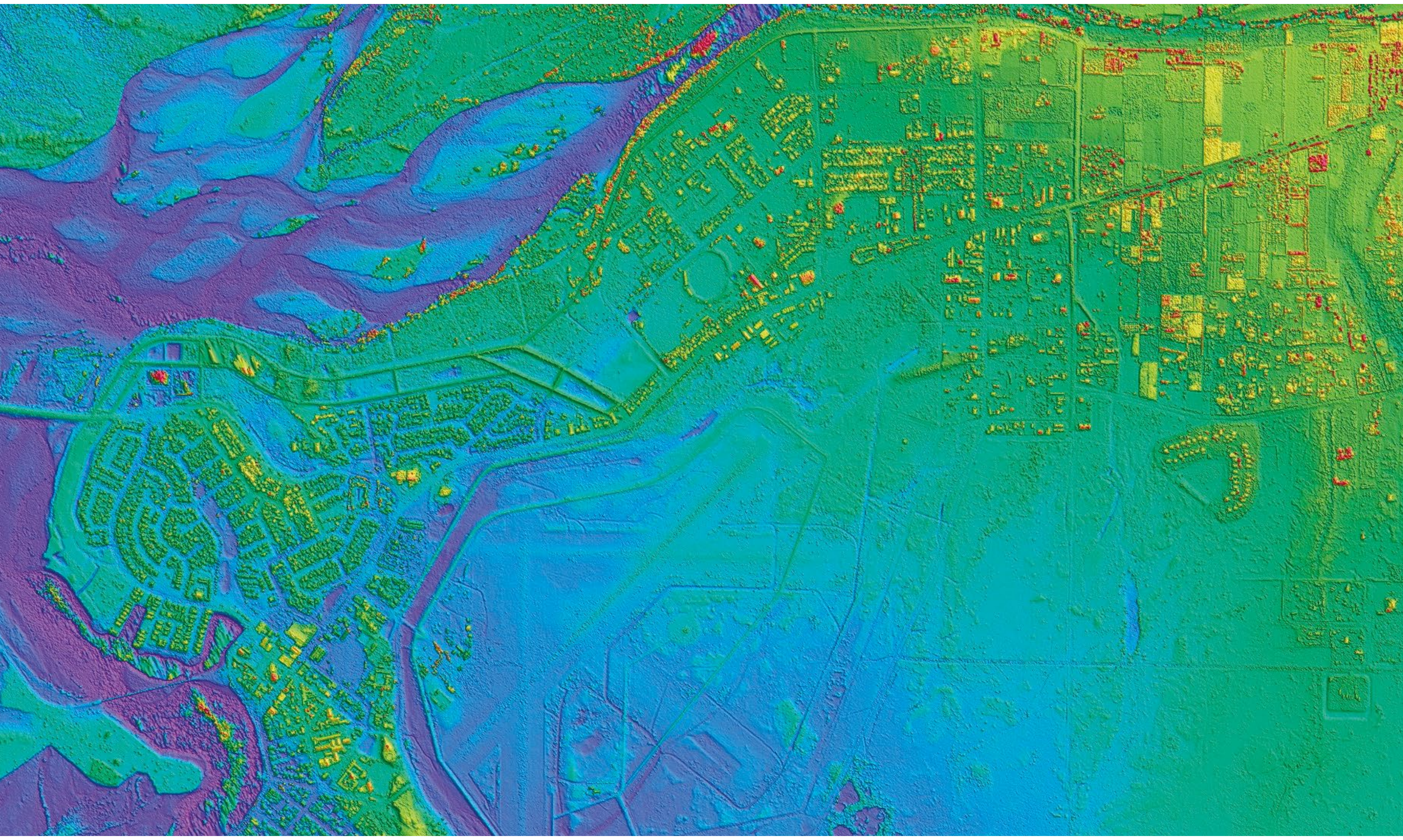
The Strategic Framework

The framework expresses the goals required to achieve a consistent and coordinated approach to the transformation of the Australian Elevation and Depth Infrastructure by 2030.

This strategy presents a forward looking framework built on cross-sector collaboration that accommodates individual jurisdictional differences and promotes efficient and cost-effective sustainable elevation and depth data management practices (Figure 1).

The framework expresses the goals required to achieve a consistent and coordinated approach to the transformation of the Australian Elevation and Depth Infrastructure by 2030.

The actions and innovations espoused put the user first in terms of future product design, building skills in the use of digital elevation and depth information, and in making data accessible so that knowledge can be extracted easily.



Vision
Recognises the more we know about the environment the better able we are to make wise decisions.

A consistent nationwide digital elevation and depth model that people can interrogate with other information to better understand the dynamics of our environment, make sense of uncertainty, and provide a basis for community safety, economic growth and sustainable living

Guiding Principles
Make complex collaboration possible.

Trust — Commitment — Sustainability — Pragmatism — Consideration — Value Focus — Transparency

Goals Define what we seeking to achieve.	High Performance Data	Unified Discovery and Distribution	Advanced Integration and Visualisation	Knowledge On-demand	Sustained Value
Actions and innovations Put us on the right path to achieving our goals.	Nationally agreed standards, quality and specifications High-Res DEM Automatic change detection for targeted capture Machine-readable data provenance Common vertical datum Real-time capture methods National Geoid Model	Unified data coordination Cost benefits analysis for data storage Data processing services Datum transformation and transmission Communicate data quality Business operating model for data repository Awareness raising communications plan	User-focussed reference groups Non-proprietary products and services Wide range of 3D products (surface variations and accuracies) Product release mechanisms that promote usage Innovation workshops and hack-a-thons Active promotion of elevation and depth models	Linked Open Data practices Natural language processing Semantic Web standards and machine—readable formats to support BIG data processing and semantic querying Domain ontologies Orchestrated spatial analytics End-user computer profiling	Undertake a value assessment Business model and partner-driven investment framework Annual data acquisition plan Adopt national standards, policies and guidelines End-user engagement Education and training program
Outcomes Will guide our governance, policy setting, standards, research programs and the design of our future systems.	Reliable and trustworthy Common reference frame Superior coverage and improved productivity Real-time Data Acquisition	A virtual data repository Optimised investment and discoverability Nationwide data inventory management system More variety	A range of nationwide 3D models and times series visualisations Economic development Entrepreneurial mindset	Knowledge-based services Machine-readable information Real time spatial analytics	Cohesive program Consistent acquisition Sustained investment and value Shared expertise and resources Growth in graduating professionals

Figure 1: Strategic Framework

Goal 1: High Performance Data

A high-quality consistent 3-dimensional representation of the Australian topography, above and below water.

Achieving an accurate and continuously-updated nationwide model by 2030 will be a challenge. New methods are required to routinely collect and validate high-precision data.

Objective

To enhance the consistency, quality, coverage, accuracy and timeliness of elevation and depth data to create a nationwide 3-dimensional model as a foundation for other information.

New methods are required to routinely collect and validate high-precision data. Elevation and depth data is currently derived using a narrow range of technologies. This is likely to change in the future with disruptive technologies, such as drones and autonomous vehicles and vessels, becoming a mainstream addition to the arsenal of devices able to produce 3-dimensional models of our natural and manmade environment.

In this emerging state, the key gaps our capability will be to manage and curate the exponential growth in data volumes, understand and track data provenance, be able to combine heterogeneous datasets, and seamlessly integrate height and depth datums across near shore zones. Adopting data standards and quality models will be critical to success.

Outcomes

- Reliable data that the user community trusts
- A common reference system comprising dynamic and vertical datum
- Superior coverage and improved productivity from increased capture rates and higher density measurements
- Real-time data acquisition technologies

Actions and Innovations

- Develop a set of nationally agreed data and exchange standards, quality criteria and specifications for a more consolidated approach to data management, maximised utility and interoperability
- Create a nested high-resolution nationwide digital elevation and depth model using data collected from heterogeneous data sources
- Adopt automatic change detection methods to prioritise capture for urban and vulnerable regions
- Automatically capture machine-readable data provenance to better manage metadata, lineage and datum epochs
- Establish a common vertical datum for both land and sea elevation data to facilitate climate change studies across the littoral zone
- Investigate real-time sensor capabilities, such as drones and autonomous vehicle acquisitions to broaden collection methods and deliver automated updates
- Improve the National geoid model using airborne gravity to deliver a more accurate relationship between satellite positioning system, derived heights and the true land surface

Enablers

- ICSM Permanent Committee on Topographic Information to lead, sustain and be accountable for achieving an enhanced elevation and depth model
- Clearly defined roles and responsibilities for suppliers
- Adoption and adherence to standards and quality models
- Coordination with relevant agencies, industry groups and community
- Investment in research and development
- A sustainable business model (see Goal 5)

Benefits

High-performance elevation and depth information will result in

- The user community having a strong sense of trust in elevation and depth information; and
- Improved public safety through more accurate information and a better understanding of risks to maritime navigation and exposure to natural hazards, such as flood and fire.
- Better management of our built environment and natural resources

Better Data – Better Outcomes

Better elevation and depth data is the foundation for better knowledge, enabling better decisions and thus better outcomes. This philosophy is encapsulated in many industry applications, one of which is Geoscape - an award-winning dataset providing a digital representation of Australia's built environment [27].

According to Dan Paull, CEO PSMA Australia "Geoscape is an analytics-ready, 3D built environment dataset providing location-based insights for every address in Australia. It combines advances in satellite imagery, machine learning and big data processing to capture building footprints and heights, roof construction, surface cover, tree heights, the presence of solar panels and swimming pools and more."

The competitive advantage that precise coverage of the built environment offers the insurance industry is compelling. Companies can accurately calculate the level of risk and loss potential for home insurance and make a fairer assessment for consumers, potentially reducing premiums in low risk areas [28].

Floods are the costliest and most frequent natural disasters in Australia [29]. Accurate topography has been identified as the most important factor in flood risk mapping and determination of water surface elevations [30].

Accurate data about seafloor bathymetry is critical for safe maritime navigation, deep sea mining and sea-bed infrastructure positioning, such as intercontinental communication lines, and oil and gas pipelines.

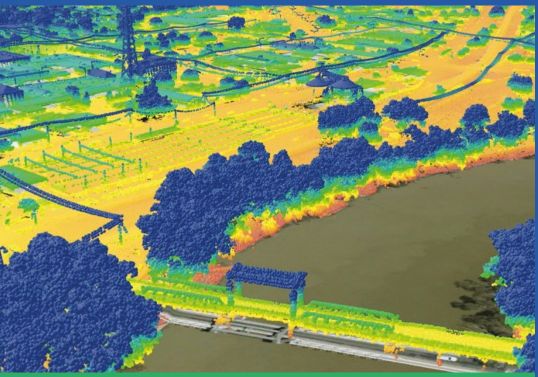
With land-based mineral deposits becoming less economic through lower mineral grades, higher production costs, increasing community relocation costs and big environmental impacts, sea floor mining is becoming a more attractive option.

Bathymetric surveys using multi-beam sonar are the most common way of collecting this important data. Seafloor sulphide deposits [31], manganese nodules [32] and sub-sea oil and gas fields can be commercially attractive if the sea floor bathymetry is favourable. An underwater chasm could render nearshore gas fields uneconomic if pipeline connection to existing onshore processing plants is not viable.

Bathymetric surveys such as the search for flight MH370 in the Indian Ocean revealed many seafloor features for the first time, and the application of this type of rich data for maritime safety will increase significantly as companies, such as BHP, move to crewless vessels for the transportation of goods [33].

Goal 2: Unified Discovery and Distribution

Elevation and depth information that is readily distributed and easy to discover.



A virtual repository and unified distribution outlet will create a more open market place – one where people can readily discover government and commercial elevation and depth information.

Objective

To implement a virtual data repository and unified distribution outlet for nationwide elevation and depth information, so that people can discover all government and commercial project data in one place.

There are significant benefits for government in having a unified infrastructure – be it options for shared resourcing, a joint storage solution, shared processing services and a common distribution channel for the vast quantities of data typically associated with elevation and depth information.

An online outlet will create a more open market place – one where government and commercial elevation and depth information can be discovered without users having to research multiple sources to determine the best available data. With improved access, market diversity will expand and usage levels increase.

Outcomes

- A virtual repository and identifiable point of truth for harvesting and reusing nationwide elevation and depth information.
- Optimised investment and discoverability of elevation and depth data and services.
- A nationwide elevation and depth data inventory management system.
- An increase in the range and scope of 3-dimensional information that can be used for a variety of purposes.

Actions and Innovations

- Enhance existing technology infrastructure to serve as the data coordination and distribution outlet for nationwide elevation and depth information.
- Conduct a cost benefits analysis for a nationally managed data storage option for jurisdictions wishing to participate.
- Provide data processing services to increase the utility of information through a consistent infrastructure interface.
- Develop a strategy and method for transforming data to end-user datum epochs and/or transmitting dynamic datum coordinates.
- Specify standards for communicating data quality and fit-for-purpose.
- Develop a sustainable business operating model and supply chain strategy for the virtual data repository and online outlet.
- Develop a communications plan to raise awareness of the outlet and its content.

Enablers

- Strong government, industry and community partnerships.
- Commitment to transparency reforms and sharing principles.
- Data access and interoperability frameworks.

Benefits

Having a unified infrastructure for distributing and discovering elevation and depth information will result in:

- reduced complexities in finding and retrieving data from multiple sources, and a better understanding of what elevation/depth data is available across Australia;
- policy driven productivity improvement across the government sector due to improving the storage, management and distribution of data, better economies of scale and elimination of duplication;
- government partners being able to reduce business risks and overheads and be able to concentrate on other activities and opportunities;
- commercial partners having an alternative outlet for their data and services; and
- an enhanced level of economic development attributed to increased levels in the usage of elevation and depth information.

ELVIS Rocks Elevation

Discovering elevation and depth information just got a whole lot easier with ELVIS; a production grade prototype developed to provide unified access to cross-jurisdiction data.

Accessing elevation and depth information is currently a challenge because it is distributed from many access points and through different providers. Knowing where to find the best data relies on personal networks and sometimes guesswork.

With Geoscience Australia's Elevation Information System (ELVIS) the nation's elevation and depth data assets can be discovered in one location.

James Johnson CEO, Geoscience Australia says "ELVIS is a great example of using open source technology to deliver real value to land managers, engineers, planners and researchers. Importantly, it is cutting out time wasted in running around to different agencies searching for data."

Spatial Services NSW is the first jurisdiction to join the ELVIS fan club, and for very good reason, with savings of $190,000 in its first year of use.

Links to NSW elevation and depth data are available through ELVIS [34]. Knowing that this information is available has had the added benefit of avoiding government duplication. Agencies can reuse existing data rather than fund new acquisitions.

The NSW experience has now created a movement with other jurisdictions coming on-board.

Geoscience Australian is looking to extend ELVIS to the commercial sector. Commercial dataset coverage will be included in the map viewer with links to the actual data provided by the companies themselves. While different licencing arrangements may apply, the user has the added benefit of being able to find the data in one place.

The CRCSI is working on research that explores what can be done with the data once it is found. The Open Spatial Analytics Research Program [35] is developing rapid spatial analytics capabilities that can be shared and reused via the ELVIS platform across different professional domains.

According to Peter Woodgate, CEO CRCSI, "soon anyone will be able to share, adapt and remix spatial analytics using scientific workflows. This will go a long way to unlocking unexplored value in Australia's elevation and depth information".

Goal 3: Advanced Integration and Visualisation

Nationwide digital elevation and depth models seamlessly integrated and visualised in everyday systems.

Objective

To create nationwide 3-dimensional models comprising times series data that can be integrated with other information and routinely used for evidence-based decision making and business innovation.

Three-dimensional modelling has changed the presentation world of architectural and landscape design. However, 2-dimensional maps are still used in the majority of decision-support applications.

A step change is required. There are significant advantages in using 3-dimensional and times series visualisations when it comes to dealing with multidimensional problems as they help people to make sense of complex data. Waterways management is improved by visualising flow volume and velocity estimates of a network, and police use urban models in the prevention of terrorism [36] and coordination of high-profile events.

It is time to put 3-dimensional capabilities in the hands of everyone. These models overcome language barriers and require no instruction for interpretation. Already, city councils are using them as a public consultation tool for new urban designs and for refining development proposals [37].

City councils use 3-dimensional models as a consultation tool for new urban designs and for refining development proposals.

Outcomes

- A range of nationwide models that provide 3-dimensional and times series visualisations for end user applications.
- Economic development powered by 3 and 4-dimensional digital elevation and depth models.
- An entrepreneurial mindset across the government, business and community sectors where digital elevation and depth models are concerned.

Actions and Innovations

- Establish/strengthen user focussed reference groups for growth industries to understand critical needs and establish use cases.
- Adopt non-proprietary formats and web services to accommodate non-expert users and improve interoperability.
- Cater for multiple user requirements with surface model variations including bare earth, tops of structures, tree canopy, water level, lake bed, etc.
- Develop various models to suit different application accuracy requirements ranging from low resolution Digital Elevation Models (DEMs) for continental scale applications, to high resolution survey accurate DEMs for urban applications.

- Use product-release mechanisms that make it clear to users what licensing and legal restrictions apply.
- Continue to digitise historical imagery and create elevation models at various epochs to support climate change studies
- Conduct innovation-focussed workshops and hack-a-thons to raise awareness of elevation and depth data models and their application.
- Actively promote nationwide digital elevation and depth models through the FSDF and related programs.

Enablers

- Value assessment and economic analysis of elevation and depth information (see Goal 5).
- An intellectual property culture that supports innovation and investment.
- A business model and investment framework for data acquisition and product development (see Goal 5).

Benefits

Being able to seamlessly integrate and visualise our land and underwater systems in 3-dimensions will result in:

- better use and integration of digital elevation and depth models in Smart Cities initiatives, business processes and social applications;
- an increase in the number of non-experts using digital elevation and depth models;
- enhanced ability to use digital elevation and depth models for analysing complex relationships, trends and patterns across a broad spectrum of applications; and
- economic growth and productivity through transformational business processes where 3-dimensional models are deployed.

The Power of a Picture

Australians love the beach, with 80 percent of our population residing near the coast. The Climate Council warns that future sea level rise could see over $200 billion of this infrastructure at risk [38]. But what does this actually mean for me and my way of life?

To answer this question, the CRCSI and NGIS have collaborated to create the Coastal Risk Australia web application. This service helps the community visualise the impacts of predicted sea level rise.

According to Paul Farrell CEO NGIS, "Maps are a universal language that everyone can understand. Coastal Risk Australia allows every Australian to visualise our climate change future with pinpoint accuracy, and gain a better understanding of how rising sea levels will affect our coastline, neighbourhoods and favourite places".

The City of Adelaide has taken the visualisation concept fully 3D to help the community envisage the City's future [37].

Anyone can download the free viewer and immediately interact with a high definition 3-dimensional representation of the city, with photo-realistic models of buildings and natural features.

Adelaide's 3D City Model enables users to understand proposed urban design, transport and planning concepts, as well as streamlining the overall process for building approvals and public consultation. People can conduct simple shadow analysis, measure vertical and horizontal distances, and overlay street names, cadastral boundaries and planning information.

The city model allows for a multifaceted analysis of options where problems and solutions can be discovered and addressed quickly and efficiently - delivering time, safety and cost benefits.

The information is available through an open license for anyone to download and use in a desktop GIS. The application also allows data to be integrated with a range of other location information to conduct high value analysis.

Goal 4: Knowledge On-demand

Elevation and depth information that is easily queried and used widely to acquire knowledge.

Elevation and depth information combined with spatial analytics has a critical and underpinning role in delivering knowledge on-demand. As yet this data is an untapped commodity.

Objective

To develop spatial analytics capabilities so that elevation and depth information can be interpreted to answer questions in real-time and on any internet-enabled device.

Smart technologies have created an 'On-demand Revolution' and venture-capital in the on-demand economy is expected to rise exponentially [39]. People today want knowledge at their fingertips. Already smart mobile devices can deliver information with just a few finger taps or by voice command. This suggests data sharing and analytics combined with mobile devices will bring real change to the knowledge-economy by transforming human knowledge to machines.

Elevation and depth information combined with spatial analytics has a critical and underpinning role in delivering knowledge on-demand. As yet this data is an untapped commodity.

Outcomes

- Knowledge-based services through open query applications.
- Machine-readable elevation and depth information that can be interpreted semantically.
- Automated and orchestrated spatial analytics for real-time query processing.

Actions and Innovations

- Adopt Linked Open Data practises for exposing, sharing and connecting elevation and depth information to support intelligent search capabilities and knowledge inferencing.
- Engage in natural language processing research to case study the execution of open queries in relation to elevation and depth datasets.
- Adopt Web 3.0 standards and machine-readable formats when publishing elevation and depth data to support BIG data processing and semantic querying.
- Develop domain ontologies for specific applications, such as fire and flood knowledge domains, to enable prediction and scenario modelling to answer questions quickly and reliably.
- Develop Process Ontologies to orchestrate height and depth-related spatial analytics workflows to link and process information automatically.
- Engage in research into end-user computer profiling to take into account the characteristics and preferences of the person asking the question.

Enablers

- Partnerships with research organisations to develop spatial analytics and semantic web capabilities.
- Semantic Web[2] and domain ontology standards, and vocabularies.
- A research and development program focussed on our Nation's priorities.

Benefits

Elevation and depth information that is queryable will result in:

- improved decision making effectiveness and better decisions for government, businesses and the community;
- increased user satisfaction through accelerated discovery of knowledge and the flexibility to ask unanticipated questions;
- economic growth when combined with business intelligence systems; and
- ability to provide knowledge services as part of the increasing on-demand economy.

Knowledge Powered Critical Decision Support

Aurora Firewatch is the Western Australian government's technologically advanced bushfire early warning system able to predict fire behaviour from near-real time information and produce customisable simulations using a range of input data, advanced fire spread algorithms and cloud computing power [39].

A key input to fire modelling is information derived from radar, LiDAR and aerial surveys, such as DEMs, terrain slope and aspect, vegetation type [40]. This data, used in conjunction with ignition points, wind, weather and moisture information, are necessary for modelling, prediction and management of fire hazards.

Aurora Firewatch instantly delivers fire professionals a vector of where a fire could go in the next 48 hours, which directly assists in critical decision making for suppression resources, and community evacuation and protection. The better the quality and resolution of inputs such as elevation data, the better the modelling and decisions that can be based upon them.

Estimates for the economic impact of single bushfire events can be upwards of $3 billion [41], and by 2020 the total cost of bushfires to the Australian economy could be as high as $18 billion annually.

Considering the potential for loss of life, significant cost of fire-fighting, and the devastation to buildings and infrastructure, the use of elevation information powered applications such as Aurora Firewatch have a significant economic, ecological and social pay-off.

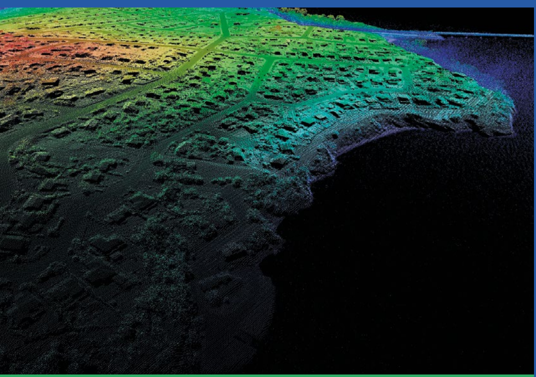
According to Jodi Cant Chief Executive Landgate "Aurora is a technologically advanced and potentially lifesaving early warning system. With high quality elevation information from LiDAR, detailed simulations are possible – this leads to better outcomes for the community".

Combined with mobile phone compatibility, SMS alerts and other spatial information, Aurora Firewatch has the power to deliver life changing knowledge on-demand incident management teams at any location. Timing critical decisions such as 'to stay and defend' or 'to evacuate early' can be dramatically improved with the predictive capability of this system and the use of elevation data.

[2]Semantic Web also referred to as Web 3.0 or The Web of Data

Goal 5: Sustained Value

An elevation and depth information infrastructure that embraces connectivity, sustained value-based management and collaboration.



Continuing with the status quo is not an option if we are to realise the full socio-economic potential of our elevation and depth information at a continental scale.

Objective

To establish strategic alliances and trusted partnerships across the entire supply chain to create and sustain the socio-economic value of elevation and depth information for the community.

There is a need for an alternative approach to better meet the Nation's requirement for enhanced elevation and depth data. If we continue with a project-driven decentralised approach, it is unlikely that we will achieve complete nationwide high-resolution coverage by 2030.

In the future, cooperation between government agencies, industry, academia and, potentially, the community, will take the form of a unified collection program and shared investment framework.

Outcomes

- A cohesive Elevation and Depth Program serving National interests as well as State and Territory needs.
- Nationwide consistency in elevation and depth data acquisition.
- Sustained investment and value of elevation and depth data, products and services.
- Shared technical expertise and resources for data acquisition, processing and distribution of data and derived products.
- Sustained growth in graduating professionals.

Actions and Innovations

- Undertake a value assessment of elevation and depth information to identify tangible, intangible, financial and non-financial benefits to society.
- Develop a business model and partner-driven investment framework with a clear understanding of the value proposition to government, industry, business and research sectors, and society.
- Establish a nationwide annual data acquisition schedule and 5 year program for forward planning to increase efficiency and eliminate duplication.
- Adopt National standards, policies, guidelines and roles and responsibilities for the acquisition, management, quality control and release of elevation and depth information.
- Regular engagement with user groups through forums and surveys to understand their evolving needs across a broad spectrum of applications.
- Review education and training programs to ensure the profession has the necessary skills to capture, manage and leverage elevation and depth information as techniques and technologies evolve.

Enablers

- ICSM Collaborative Heads of Agreement.
- ANZ Foundation Spatial Data Framework Elevation and Depth Theme.
- National Elevation and Depth Technology Infrastructure.
- Elevation and Depth Program Coordination.
- A collaborative governance model with well defined roles and responsibilities for supply chain participants and committees.

Benefits

An Elevation and Depth Infrastructure that embraces connectivity, sustained value management and collaboration will result in:

- cultural change that delivers the benefits of shared resources;
- greater engagement between commonwealth and jurisdictions;
- reduced unit collection costs through economies of scale;
- the socio-economic value of elevation and depth information to the community being sustained in the longer term; and
- professional development to strengthen capacity to apply new technology and capabilities innovatively.

Collaboration and Coordination Cutting Costs

Over $1 million in savings – that's the estimated value of CaptureWA, a coordinated program to acquire enhanced elevation and LiDAR data over Western Australia [42].

Most jurisdictions have highly refined data collection programs similar to Western Australia's CaptureWA program, such as the Victorian Coordinated Imagery Program [43]. These programs have been delivering value and savings for many years. It's now time to scale up collaboration and coordination in the community interest, nationally.

There are many benefits in having a coordinated acquisition program with the major advantage being a reduction of overall costs. This is realised through reducing duplicated data acquisition, avoiding duplicate systems and storage and harnessing economies of scale.

In WA this duplication of effort is estimated to be up to tens of millions of dollars a year [44].

Ongoing capture programs are positive for industry. They provide a pipeline of work for competitive tender and expand the volume of projects by enabling the aggregation of user needs and funds that would otherwise be uneconomic and make acquisition problematic for smaller organisations, such as local governments.

Many jurisdictions operate panel contracts, allowing organisations to selectively bid on work that suits their business model and capabilities as well as the opportunity to provide value added services. The budget of some programs may warrant the investment in new tools and technologies, underpinning growth in business capabilities.

There are also benefits derived from having a single contract and project management process, and standards for data capture. These result in greater quality and accuracy, standardised products that a broader user-base can leverage, and better collaboration in business applications covering the same geographic area.

Jurisdictions have also combined resources to develop common contracting templates, standards and tools, such as the CRCSI LiDAR quality assurance tool, which efficiently and effectively checks LiDAR dataset quality [46].

Delivering the Strategy

The delivery model recognises that our desired outcomes can be achieved through more than one collaborative approach.

The Delivery Model

The community has an expectation that government information and services will be delivered seamlessly.

They are not concerned about which agencies or levels of government deliver the services, but rather that they have access to a consolidated view of all available sources - government, industry and community gathered data. They also expect that this information can be relied upon to make sound investment and lifestyle decisions.

To meet community expectations the elevation and depth service delivery model of the future will be characterised by:

- clear custodianship and stewardship;
- a mix of authoritative and crowdsourced data with clearly defined information origin;
- seamless nationwide access to multi-agency data;
- the integration of government information in understandable forms;
- a financially sustainable acquisition and distribution delivery model;
- a knowledge proposition, not just a standard information offering; and
- a customer-centric service delivery approach where feedback is embedded at key delivery points.

The goals identified in this strategy are aligned with a culture of innovation and coordination along the elevation and depth information value chain. This is depicted in Figure 2.

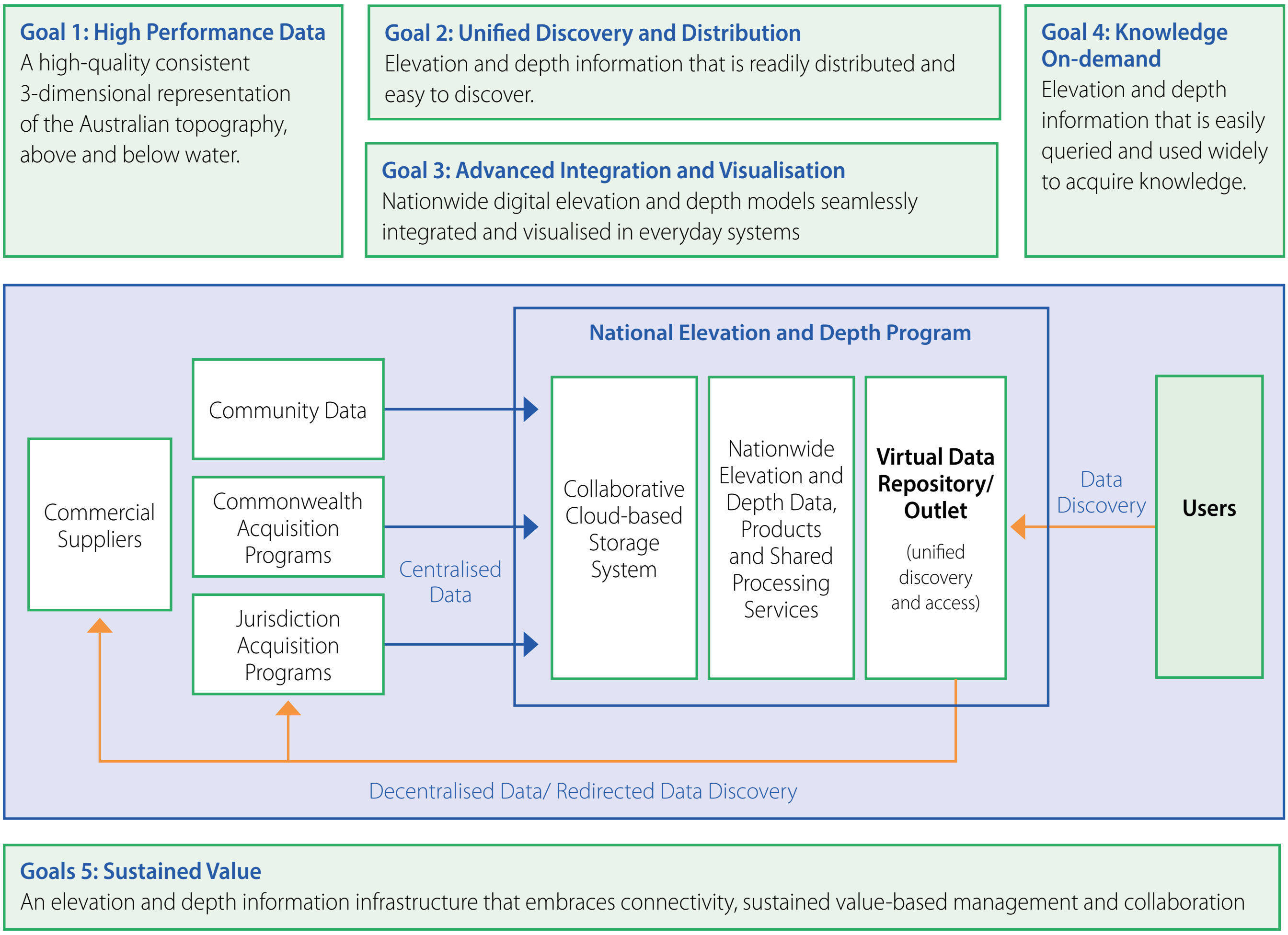


Figure 2: Service Delivery Model for Nationwide Elevation and Depth Data, Products and Services

The delivery model recognises that our desired outcomes can be achieved through more than one collaborative approach. Our attitude to collaboration will be flexible enough to allow for different participation levels. The Delivery Model incorporates three methods of engagement that may be considered by partners ranging from:

- the co-ordination of activities (acquisition, storage, and/or dissemination) across entities with sharing of responsibility and decision making; or
- merging activities (acquisition, storage, and/or dissemination) to a single entity or functional responsible unit; and/or
- contracting data acquisition out to third parties; and
- creation of a new entity i.e. Elevation and Depth Program.

Our attitude to collaboration will be flexible enough to allow for different participation levels.

The Collaborative Governance Approach

Delivery of the actions and innovations identified in this strategy will require a collective effort and solid foundation for governance including direction setting, management, oversight and engagement.

This strategy cannot be delivered by government alone. To achieve our vision and goals, all stakeholders need to work together if we are to realise social, economic and environmental sustainability through a better understanding of the shape of our land, elevation of our physical infrastructures, and the depth of our nearshore sea floor and oceans.

The proposed governance framework interconnects stakeholders through cross-sector collaboration, industry partnerships, academic alliances, community participation and national cooperation (Figure 3).

Stakeholders are recognised as having a shared commitment to the guiding principles for the Elevation and Depth Program and its coordination, agree to comply with policies, standards and guidelines, and are accountable for certain responsibilities.

In working together, we can consider both national and jurisdictional interests along with the interests of the commercial and community sectors; at the same time recognising that groups may choose to opt out of certain aspects.

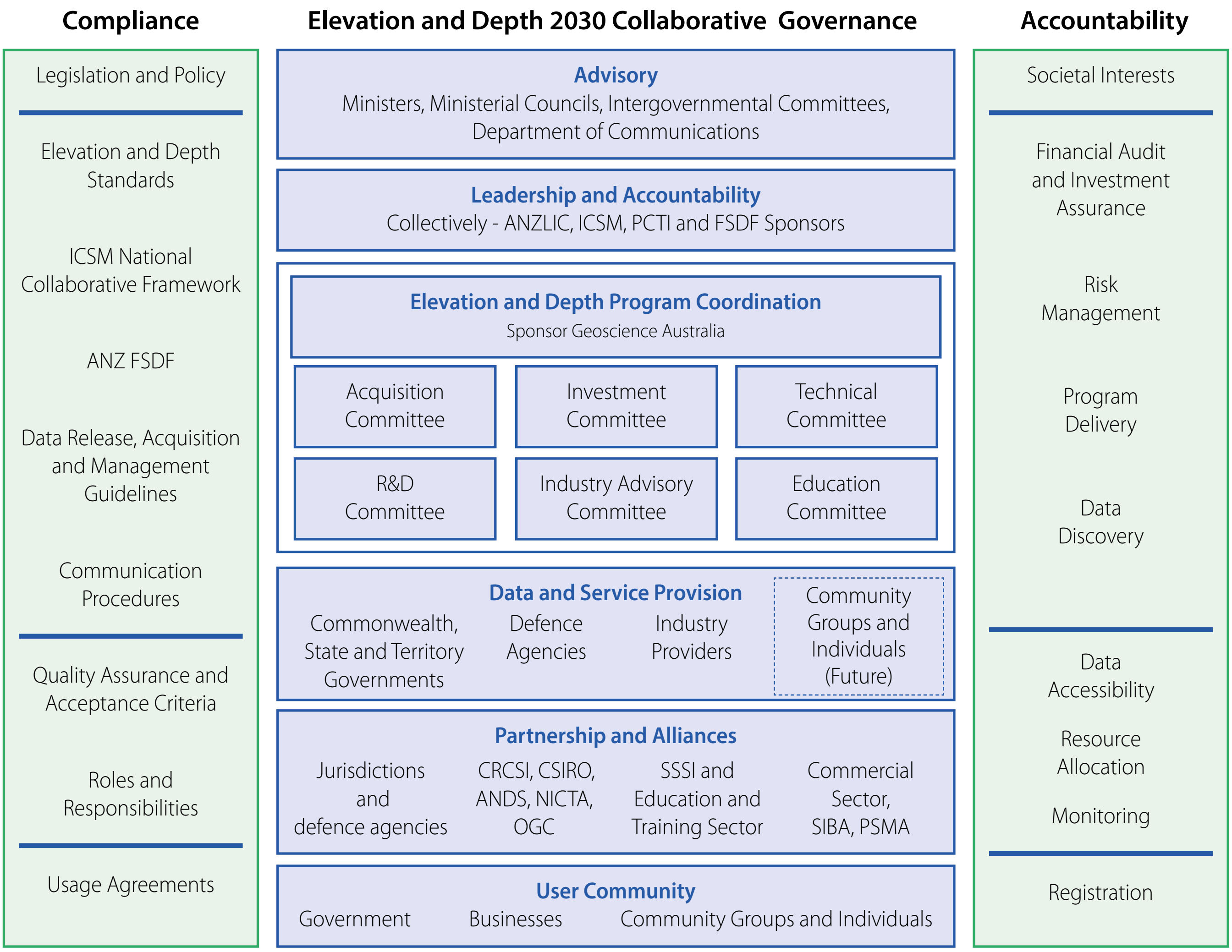


Figure 3: Collaborative Governance

The inter-relationship between the relevant implementation bodies is illustrated in Figure 3 and includes the following functions:

- **Advisory:** Ministers, Ministerial Councils, Inter-governmental committees and the Commonwealth Department of Communications that are pursuing data sharing coordination as well as portfolios that rely on elevation and depth information for policy setting and decision making, such as disaster management, environment, natural resources and defence.
- **Leadership and Accountability:** Collectively, the Australian and New Zealand Spatial Information Council (ANZLIC), the Intergovernmental Committee for Surveying and Mapping (ICSM), the Permanent Committee for Topographic Information, and the Foundation Spatial Data Framework Theme Sponsors including cross-jurisdiction business sponsors and technical experts who provide counsel for data investment, integration and sharing.
- **Elevation and Depth Program Coordination:** Program activities are sponsored and supported by Geoscience Australia, with jurisdiction commitment and education and training sector alliances maintained through several committees responsible for the annual data acquisition program, investment program, technical enhancements, research and development, industry engagement and continuing professional development.
- **Data and Service Provision:** Jurisdictions are responsible for the capture and maintenance of elevation and depth information according to agreed quality standards, and make this information available as part of the effort towards consistent nationwide coverage. Commercial providers are encouraged to make their data holdings discoverable through the virtual data repository so that people know what coverage exists. In the future, the community will be encouraged to contribute elevation and depth information, freely or commercially.
- **Partnerships and Alliances:** The governance model recognises that multi-sectoral and multidisciplinary partnerships and alliances are required to achieve our vision and goals including jurisdiction and defence agencies, research and development, education and training, and commercial ventures.
- **User Community:** Underpinning the efforts to deliver a coordinated elevation and depth program are our users' needs and aspirations. We will seek to understand our users by monitoring and measuring usage, utilise message schedules to inform them when updates and new products occur, survey their needs at regular intervals, and run support events to facilitate the use and reuse of elevation and depth information.

Commercial providers are encouraged to make their data holdings discoverable through the virtual data repository so that people know what coverage exists.

Note to Fellow Professionals

Bridging the gap between our current capability and what is required poses some significant challenges. The following notes for professionals considers these challenges and proposes a way to move forward. Issues arising are:

- how to deliver the best value for money;
- making the transition to a unified system;
- managing the heterogeneity arising from multiple sources and technologies;
- preparing for the semantic web;
- adapting business models, licensing and legalities; and
- positioning for growth areas.

Achieving the goal of a seamless and highly accurate 3-dimensional model of Australia raises many questions and challenges.

Being Pragmatic about Investment

Achieving the goal of a seamless and highly accurate 3-dimensional model of Australia raises many questions and challenges.

It is not practical, or economic, to capture the same resolution and quality over the entire country, using the same technology. Perceptions of what data is fit-for-purpose and what accuracy is optimal varies from geographic location to location, and from user to user.

Addressing user needs with respect to geographic coverage, accuracy and resolution (or point spacing) will be a function of getting the most effective return on investment, and will likely mean that the level of precision required for urban areas is not needed in remote desert regions.

These issues will be resolved upfront through user consultation and careful planning through the Elevation and Depth Program Coordination.

Transitioning to a Unified System

Many jurisdiction capture programs are running very successfully, and yet there are significant benefits for all Australians in moving to a more unified system including:

- financial savings through reduced duplication and opportunity costs,
- productivity improvement and business innovation through increased access to highly accurate continental scale products currently not possible,
- improved customer servicing through an ability to easily locate information
- increased safety and community wellbeing through improved accuracy of elevation and depth information
- a broadening of the knowledge economy and increased development opportunities that will accelerate the on-demand society

While these benefits are recognised widely by professionals and supported at the ANZLIC executive level, a value assessment is required to supply the necessary evidence needed to support individual jurisdiction business cases in transitioning to a nationally coordinated data supply chain approach.

In all jurisdictions, growth of the digital knowledge economy is significantly dependent on the quantity, quality, accessibility and usability of information and the knowledge that can be derived from it (4). Financial savings for jurisdictions are associated with increased economies of scale. Not only are there cost benefits in reduced ITC, less administration and potentially increased buying power, but resources can be re-directed to focus on value added services or other core business obligations. Better relationships with key customers and stakeholders are achieved by assisting them to solve business problems rather than supplying data that possibly requires further manipulation.

Established State and Federal agreements, such as the *ICSM Collaborative Heads of Agreement* that underpins the National Topographic Information Coordination Initiative (under the governance of ANZLIC and ICSM), are the vehicle to achieving cross-jurisdiction agreement.

A plan and timeline needs to be formulated to ensure all supply chain actors are engaged, and activities are coordinated through the elevation and depth FSDF Theme Road Maps and other initiatives, such as the 2026 Spatial Industry Transformation and Growth Agenda.

At the inception stage, the viability and business case must be established, and stakeholders commit to the direction. This will require progressive thinking around funding and budget allocations for data acquisition, system management and revenue flows. As elaboration occurs, technical analysis of the technologies available to facilitate a unified system, including cloud service providers (storage and computing power), network and communications, and collaboration platforms[3] needs to occur.

Operational issues around user and customer request coordination, contract letting and management, data quality auditing, and data management

Many jurisdictions are reviewing their ITC systems for efficiency gains. This is an opportune time to consider a more unified approach.

[3]With a preference toward open source technologies, to ensure perpetual openness.

workflows will need examination. Current procedures within jurisdictions could be synthesised into a streamlined process.

Many jurisdictions are reviewing their ITC systems for efficiency gains. This is an opportune time to consider a more unified approach. By leveraging the significant supply chain analysis undertaken by the FSDF LINK in collaboration with jurisdictions, it is now possible to understand existing data assets, why they are collected, how they are organised and who the customer is. These supply chain management concepts can be extended to jurisdictions to manage workflows and better understand customer needs.

Ongoing communication and demonstration of early wins will be critical to building momentum. A transition window will be required once the technology and governance aspects are solved. This period will enable the merging of rolling and fixed jurisdiction programs, and provide time to transition supplier contracts to the appropriate authority.

Managing Heterogeneity

Imagine the number of knowledge services and variety of applications that could be offered if elevation and depth information can be interpreted semantically.

Having different resolution data presents problems when it comes to creating seamless nationwide elevation and depth products. The solution generally involves some form of generalisation to smooth out variability.

There are significant technical challenges to structuring, nesting and integrating heterogeneous 3-dimensional surveys at a continental scale. While methodologies that employ information pyramiding, data conflation, generalisation and averaging techniques exist, there are no open scalable processes - leaving a gap for open production-grade tools for seamless data integration.

Automated spatial analytics tools for assembling nationwide elevation and depth products are being investigated by the CRCSI. Managing data heterogeneity requires universal rule-based data management to establish what data is ‘best’ when conflicts arise between two datasets, such as different survey attributes, reported accuracy, date of capture, point spacing or resolution of data, and the capture technology employed.

While research continues to address the automation aspects of aggregating heterogeneous data, much can be done by introducing data standards to ensure consistent interpretation and use including operational elements such as naming conventions, file storage structure, file formats and database systems (triangulated irregular networks, binary grids, ASCII text, point clouds or rasters), feature representation and the classification of features from LiDAR pulse return data or topographic contouring methods.

Becoming Semantic Web Ready

Answering the next generation of multi-faceted queries will require our data and information to be semantic web ready. The semantic web is largely about making information machine-readable, enabling automatic linkages between data, and giving the data qualities so computers can interpret meaning, draw inferences and self-describing relationships, and know what to do with them.

The Semantic Web Resource Description Framework (RDF) format is what makes possible the translation of human knowledge into a format that can be actioned by a computer.

Imagine the number of knowledge services and variety of applications that could be offered if elevation and depth information can be interpreted semantically. This could range from simple questions, such as "what is the highest hill?" to complex queries such as "which locations are suitable for a mobile phone tower?"

In the context of elevation and depth data, there are five key things that need to occur to be Sematic Web ready:

- information provisioned[4] using the Resource Description Framework (RDF) format and a Uniform Resource Identifier (URI);
- a base vocabulary that clearly defines the meaning of elements through a collection of consistent terms;
- a base ontology that provides the common reference or vocabulary for expressing the meaning behind data using relationships and rules;
- process ontologies to capture the workflow knowledge to execute and run the spatial analytics to process a query automatically; and
- certainty about the quality, and therefore 'trustworthiness' of the requested information in the context of the user's query.

Dealing with Legalities

The evolution of the geospatial information marketplace, from basic sales to potentially complex multi party license arrangements, presents challenges and opportunities for elevation and depth information.

The increasing creation of derivative, aggregated and software as a service products, from a range of information sources, means that licenses are now significant legal documents containing many rights and restrictions.

In moving to a more collaborative environment, there are many issues that need to be considered, particularly given the open data policies of the Commonwealth and most State governments, and the increase in volunteered geographic information.

From the perspective of suppliers, concerns relate to what warranties will suppliers grant to end users. Does the Licensor have legal responsibility to the licensee if the information is insufficient for its intended purpose? Are suppliers liable if their information is used to break the law, or injure a third party? And how do suppliers distribute data openly when it may contain third party data or crowdsourced information?

From the perspective of value adders, concerns relate to what guarantees can they attribute to their value added products or analysis results when the products they produce may be derived from variable accuracy digital elevation models? Is there an acceptable level of risk?

Given the versatile nature of elevation and depth information, in that information captured for one purpose can be used for a multitude of others, these legal aspects must be considered at the point of acquisition, distribution and end use. A supplier will often only provide warranty against

Legal aspects must be considered at the point of acquisition, distribution and end use.

[4]Provisioned refers to custodians exposing data in Semantic Web format without having to specifically configure systems or modify data structures

the specification of capture, which even then does not always guarantee fitness for purpose.

Evolving regulatory regimes around the operation of remotely piloted aerial systems (drones) will be required. This is a critical and ever changing area, particularly where privacy is concerned. Specific advice will need to be sought from legal authorities to bring clarity around these issues as we move to increasing high resolution data. Policies and strategies will be required to assist suppliers to meet their compliance responsibilities.

Positioning for Growth Areas

City services are one of many manually intensive data collection industries where automated capture of elevation and depth data can make a significant difference to productivity and service efficiency.

A heightened awareness of user needs is required to make the most strategic investments in data collection. User needs are currently serviced in a user pays self-funded model. However, this approach does not maximise the full potential of data investments for the broader economy. Once purchased information is generally not shared and therefore not reusable.

Many industries have the same requirements for data, but the business case for one sector alone makes the investment uneconomic.

It is only when the broader benefits of many sectors are aggregated that financial justification for national scale programs becomes feasible. This concept further supports the need for an economy wide business case and value assessment.

Take the following industries with nationwide applications and manually intensive processes for data collection:

- City Services – Planning and optimisation of transport corridors, population centres, resource transportation and utilisation, and environmental impact;
- Health - Habitat mapping of disease agents (ticks, mosquitoes, birds) to identify areas of standing water, and water or air modelling in outbreak scenarios;
- Wind power - Modelling wind regimes and to determine ideal placement of wind turbines;
- Precision agriculture – Using slope, position and aspect to minimise soil erosion, detect areas of solar heating, and identify landform variations, soil wetness and nutrient availability to better manage chemical treatments and improve productivity;
- Ocean Science and Policy - Using bathymetric surveys to ensure safe and efficient maritime transportation, alert scientists to ongoing and potential beach erosion, sea-level rise and subsidence, manage marine reserves and fish stocks, and support studies into marine ecosystems;
- Forestry management – Assessment and monitoring of natural and cultivated woodland stock and health for preservation or sustainable tree harvesting; and
- Natural resource exploration and exploitation – Desktop visualisation and analysis of options, feasibility and impacts.

Each sector requires high-quality information over large geographic areas and yet, when considered together it becomes clear that they have similar data needs. Therefore co-investment in data acquisition is possible and far more economical.

Conclusion

This strategy is about leadership and our capacity to take positive steps to achieve our vision for consistent nationwide digital elevation and depth models that people can interrogate with other information to better understand the dynamics of our environment and make sense of uncertainty.

It is also about strengthening cross-government collaboration, and industry and community partnerships to achieve high performance nationwide elevation and depth models as a basis for community safety, economic growth and sustainable living.

A solution is to use our elevation and depth information resources from across the government and commercial sectors to make tactical and strategic decisions to reduce risk and create stronger communities. This means making our elevation and depth information more accessible and usable – not only within government but also within the wider community.

The prospect of autonomous acquisition sensors holds promise of more accurate and real-time elevation and data becoming available. Real-time data streaming, combined with improved spatial analytics will move our industry towards on-demand knowledge systems.

This is important. The on-demand economy is becoming too big to ignore and will evolve to be a major player in the global economy [46]. Economic activities centred on online platforms are attracting significant consumer attention, and businesses are increasingly embedding spatial data as a fundamental part of their operations.

The future is about delivering a seamless consumer experience when seeking information. Machine-readable formats and Linked Open Data will enable meaningful inferences to be drawn from models that show the vertical relationships between people and their surroundings.

As leaders and community members we are faced with major decisions to respond to today's challenges. Climate change, disaster risk reduction and responsive urban planning require a coordinated effort across the many elements of government and the private sector.

This strategy is about meeting these challenges head-on by adopting revolutionary methods for collecting, storing, and disseminating information, and ultimately delivering actionable knowledge to the community.

Your voice is important for getting this strategy right.

The prospect of autonomous acquisition sensors holds promise of more accurate and real-time elevation and data becoming available.

Appendix A

Explanation of Terms

Term	Definition
3D Photomapping or Photogrammetry	The science of making measurements from images or photographs, especially for recovering the positions of surface points in 2D or 3D.
Bathymetry	Science of measuring water depths (usually in the ocean) to determine the shape and depth of underwater terrain.
Data Management	Managing the storage and use of data from the time they are generated or collected, maintaining their integrity, security and useability, and ensuring that it can be discovered and reused by others for as long as it is required. The term is taken to mean all of the actions needed to maintain data over their entire lifecycle and over time for current and future users. Data management encompasses both data archiving and data preservation.
Domain Ontology	Models a specific domain (e.g. Flood, windfarm, and sea level rise). It is a vocabulary and specification for the conceptualisation of a given domain. It represents the particular meanings of terms as they apply to that domain.
Drone	An aircraft [or aircraft-system] that is flown from a remote location without a pilot located in the aircraft itself. The term drone is commonly used in popular culture but is referred to as a Remotely Piloted Aircraft System (RPAS), Unmanned Aerial Vehical (UAV) and Unmanned Aircraft System (UAS) by the International Civil Aviation Organisation (ICAO) and Civil Aviation Safety Authority (CASA).
Hydrography	Science that deals with the measurement and description of the physical features of the oceans, seas, lakes, rivers, and their adjoining coastal areas, with particular reference to their use for navigation.
Interoperability	The ability of different information technology systems and software applications to communicate, to exchange and integrate data accurately, effectively and consistently, and to use the information that has been exchanged.
Linked Open Data	Structured data (that is released under an open licence, which does not impede its reuse for free) that can be interlinked and become more useful through semantic queries.
Machine learning	A type of artificial intelligence that provides computers with the ability to learn without being explicitly programmed.
Metadata	Structured data that describe a data resource, analogous to cataloguing data held by libraries, museums and archives. Metadata aids classification, management, discovery, and use of data by people or by automated processes. Metadata may include data attributes such as type, structure, size, title, content, provenance, creation date, author or location.

Term	Definition
Ontology	A set of concepts and categories in a subject area or domain that shows their properties and the relations between them.
Orthoimagery	An orthoimage is a raster image of the Earth's surface, from either satellite or airborne sensors that has been geometrically corrected to remove distortion caused by camera optics, camera tilt, and differences in elevation.
Provenance (Data or Information)	Documents the inputs, entities, systems, and processes that influence data of interest, in effect providing a historical record of the data and its origins
Semantic Web	An extension of the World Wide Web that enables people to share content beyond the boundaries of applications and websites. Information is given well-defined meaning, better enabling computers and people to work in cooperation.
Spatial Analytics	Broad application of processes and techniques to interrelated spatial data to extract meaning and resolve problems.
Spatial Information	Spatial Information describes the physical location of objects or phenomena and the metric relationships between them.
Topography	Configuration (relief) of the land surface; the graphic delineation or portrayal of that configuration in map form, as by contour lines; in oceanography the term is applied to a surface such as the sea bottom or surface of given characteristics within the water mass.
Ubiquitous	Present, appearing, or found everywhere
Web 3.0	Broadly defined as connective intelligence; connecting data, concepts, applications and ultimately people, of which the semantic web is a key component.

Appendix B

Glossary of Abbreviations

Acronym	Explanation
ANZLIC	The Spatial Information Council of Australia and New Zealand. Comprises a senior representative of the national governments of Australia and New Zealand and the six States and two Territories of Australia. See www.anzlic.org.au
ASKI	Australian Spatial Knowledge Infrastructure. A network of data, analytics, expertise and policies that assist people, whether individually or in collaboration, to integrate in real-time spatial knowledge into everyday decision making and problem solving
BIM	Building Information Model. Describes the process of designing a building collaboratively using one coherent system of computer models rather than as separate sets of drawings.
CRCSI	Cooperative Research Centre for Spatial Information. The key collaborative research body in the Australian spatial information industry.
DEM	Digital Elevation Model. A generic term for digital topographic and/or bathymetric data in all its various forms. Unless specifically referenced as Digital Surface Models (DSMs), the generic DEM normally implies elevations of the terrain (bare earth z-values) devoid of vegetation and manmade features represented across a regular grid.
DSM	Digital Surface Model. An elevation model of the natural and built features on the Earth's surface showing the topmost reflective surface (e.g. tree canopy)
DTM	Digital Terrain Model. A DEM that has been technically improved with break-lines or mass points at an irregular interval (relative to a regular gridded DEM) to more accurately represent the landform.
ELVIS	Elevation Information System. Run by Geoscience Australia.
FSDF	Foundation Spatial Data Framework. Provides a common reference for the assembly and maintenance of Australian and New Zealand foundation level spatial data in order to serve the widest possible variety of users.
GA	Geoscience Australia
GIS	Geographic Information System.
GNSS	Global Navigation Satellite System.
GPS	Global Positioning System.
ICSM	Intergovernmental Committee on Surveying and Mapping, a Standing Committee of ANZLIC. See www.icsm.gov.au.

Acronym	Explanation
IfSAR	Interferometric synthetic aperture radar. Remote sensing technique that uses difference in returning phase waves to generate a digital elevation model.
IoT	Internet of Things. The inter-networking of physical devices, vehicles, buildings and other items with electronic capabilities to collect and exchange data.
LADS	Laser Airborne Depth Sounding. Also called Bathymetric LiDAR.
LiDAR	Light Detecting and Ranging. LiDAR is defined as an airborne laser system, flown aboard rotary or fixed-wing aircraft, that is used to acquire x, y, and z coordinates of terrain and terrain features that are both manmade and naturally occurring. LiDAR systems consist of an airborne GPS/GNSS with attendant GPS/GNSS base station(s), Inertial Measuring Unit (IMU), and light-emitting scanning laser.
netCDF	Network Common Data Form. Is a set of software libraries and self-describing, machine-independent data formats that support the creation, access, and sharing of array-oriented scientific data.
NGIS	Australian spatial services consulting company.
PSMA	PSMA Australia Limited is an unlisted public company owned by Australia's federal, state and territory governments. Its role is to integrate spatial data sourced from these jurisdictions, and through commercial arrangements with other entities, to create national foundation datasets that include address, property, administrative boundaries and built environment data. See www.psma.com.au
PCTI	Permanent Committee on Topographic Information. A subcommittee of the ICSM concerned with a coordinated approach to topographic data collection, management and delivery.
RDF	Resource Description Framework. A model for encoding semantic relationships between items of data so that these relationships can be interpreted computationally. RDF is the primary foundation for the Semantic Web.
SMS	Short message service. Text communication method over a communication network.
TIN	Triangulated Irregular Network, a type of digital elevation model with irregularly spaced height points, compared with a grid representation, which has regularly spaced points in a square pattern.
URI	Uniform Resource Identifier. A string of characters used to identify a resource connected to the internet. Such identification enables interaction with representations of the resource over a network, typically the World Wide Web, using specific protocols.

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