

Chapter 21

Digital Earth in Australia



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Abstract Australia must overcome a number of challenges to meet the needs of our growing population in a time of increased climate variability. Fortunately, we have unprecedented access to data about our land and the built environment that is internationally regarded for its quality. Over the last two decades Australia has risen to the forefront in developing and implementing Digital Earth concepts, with several key national initiatives formalising our digital geospatial journey in digital globes, open data access and ensuring data quality. In particular and in part driven by a lack of substantial resources in space, we have directed efforts towards world-leading innovation in big data processing and storage. This chapter highlights these geospatial initiatives, including case-uses, lessons learned, and next steps for Australia. Initiatives addressed include the National Data Grid (NDG), the Queensland Globe, G20 Globe, NSW Live (formerly NSW Globe), Geoscape, the National Map, the Australian Geoscience Data Cube and Digital Earth Australia. We explore several use cases and conclude by considering lessons learned that are transferrable for our colleagues internationally. This includes challenges in: 1) Creating an active context for data use, 2) Capacity building beyond ‘show-and-tell’, and 3) Defining the job market and demand for the market.

Keywords Digital infrastructure · Data cube · National computational infrastructure · National collaborative research infrastructure strategy · Queensland globe

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21.1 Introduction

In this chapter, the authors demonstrate the need for local, champion-based initiatives to support mainstreaming, integration and take-up globally. This includes progress made in the digital earth agenda, and the creation of a repository that can be used by researchers, policy makers, decision-makers and the community at large. The chapter describes the lessons learned in Australia, which are likely to be immediately transferrable and of benefit to other initiatives around the world. The chapter outlines precedents and examples of innovation arising from the need to better manage local resources, and addresses the complexities of environmental stewardship and the extraction and processing of natural resources.

In the global move towards automation, employment and productivity (Manyika et al. 2017), Australia must overcome a number of challenges to meet the needs of its growing population in a time of increased climate variability, from sustainably managing and restoring natural environments to developing resources and optimizing our agricultural potential. Increasingly frequent environmental extreme events such as chronic drought, extreme bushfires, and flooding have catalyzed internationally regarded innovation in this field, in addition to the requirement for large-scale infrastructure planning along the eastern seaboard and in northern Australia (Australian Government 2015), and the national need to report on performance—in relation to people and planetary systems—through the United Nations Sustainable Development Goals (Griggs et al. 2013). Within this context, senior mentors in the field Steudler and Rajabifard reflect that sharing information through a spatial data infrastructure (SDI) can facilitate improved decision-making, where themed images and temporal overlays can quickly engage different communities in common understanding and appreciation of issues and potential solutions (Steudler and Rajabifard 2012; Rajabifard and Cromptvoets 2016).

Fortunately, Australians have unprecedented access to current and historical data about land and the built environment that is internationally regarded for its quality. Australia has been at the forefront in the development and implementation of Digital Earth concepts over the last two decades (Woodgate et al. 2017). In recent years, several key national initiatives have also formalized the Australian digital geospatial journey, shaping its world-leading initiatives and credentials in digital globes, open data access and quality:

- The Cooperative Research Centre for Spatial Information (CRCSI), launched in 2003 and recently transitioned to ‘FrontierSI’, has driven numerous initiatives in research and technological innovation, market and product development, workforce planning and preparedness, and outreach. Three seminal *Global Outlook* reports (Woodgate et al. 2014; Coppa et al. 2016, 2018) provide excellent content for a more detailed exploration of the Australian geospatial progress, in addition to a White Paper on the context and priorities of the future of spatial knowledge infrastructure (Duckham et al. 2017).
- The National Innovation and Science Agenda (NISA), launched in 2015, comprises 24 initiatives. With a AUD \$1.1 billion direct allocation of federal funds,

it influences approximately AUD \$10 billion per annum in government-related expenditure on innovation (Coppa et al. 2018:6).

- The 2026 Agenda (co-chaired by Cockerton and Woodgate 2016, 2017, 2019), developed from extensive consultation, provides the vision and direction to enable the geospatial community to deliver national and global services supporting the NISA. This landmark initiative involved the CRC SI (now FrontierSI), the Spatial Industries Business Association-Geospatial Industry Technology Association (SIBA-GITA), the Australia New Zealand Land Information Council (ANZLIC—Australia and New Zealand’s peak government Council for spatial matters), the Australian Earth Observation Community Coordination Group, Data61 (CSIRO), Landgate, Geoscience Australia, Department of Natural Resources and Mines (Queensland Government), and the Department of Prime Minister and Cabinet.
- Substantial digital infrastructure projects in broadband services around the country, including the National Broadband Network (NBN) and Australia’s Academic and Research Network (AARNet), owned by the Australian universities and the Commonwealth Scientific and Industrial Research Organisation (CSIRO), which provides internet services to the Australian education and research communities and their research partners. AARNet is widely regarded as the founder of the internet in Australia and is renowned as the architect, builder and operator of a world-class high-speed, low-latency network for research and education (AARNet 2018).

Domestically, the country has directed efforts towards world-leading innovation in big data processing and storage (for example, see Dhu et al. 2017), without ownership of substantial resources in space (AAS 2009) and with only-recent establishment of a Space Agency. Furthermore, Australia is large enough for the Earth’s curvature to be important, and its tectonic movement is significant enough to require a dynamic cadaster. Hence, Australia’s digital earth history has been grounded in an emphasis on a planar geometry—where geodetic coordinates (latitude and longitude) are mathematically projected onto a two-dimensional plane using a Universal Transverse Mercator system—in comparison with other chapters in this manual that emphasize the globe.

Within this context, in 2017 the federal government established Digital Earth Australia (DEA), building on the Geoscience Australia ‘Data Cube’ supported by CSIRO, the National Computational Infrastructure (NCI), and the National Collaborative Research Infrastructure Strategy (NCRIS). This includes funding of AUD \$15.3 M/year going forward within the federal budget. When completed, it will provide 10-meter resolution image data nationwide, allowing for multitemporal analyses throughout the stack of co-registered data for as far back as 30 years and as detailed as 16-day intervals.

Looking ahead, Australia has identified its most promising growth sectors for the spatial industry: transport, agriculture, health, defense and security, energy, mining, and the built environment, with the environment requiring special consideration (ACIL 2015; Cockerton and Woodgate 2017). *A significant challenge concerns building capacity for widespread uptake of geospatial technologies and tools across*

these key growth sectors, where open-data use, real-time crowd-sourcing of information, and visualization are integrated within core decision-making processes.

Within this context, this chapter provides commentary on key geospatial initiatives, case-uses, lessons learned, and next steps for Australia, drawing primarily from published material in the public domain and experiences of the Authors. The chapter presents a summary of a number of initiatives, including the National Data Grid (NDG), the Queensland Globe, G20 Globe, NSW Live (formerly NSW Globe), Geoscape, the National Map, the Australian Geoscience Data Cube and Digital Earth Australia. It also highlights key products and projects currently being undertaken by Digital Earth Australia. The chapter includes exploration of several use cases in agriculture, property, education and training, and disaster management, and concludes with a consideration of lessons learned and next steps in Australia.

21.2 An Historical Context of Geospatial Initiatives

It has been a busy two decades for the Australian geospatial community, with a number of key products developed by state and federal governments. As illustrated in Fig. 21.1, these initiatives are indicative of a growing awareness of and appetite

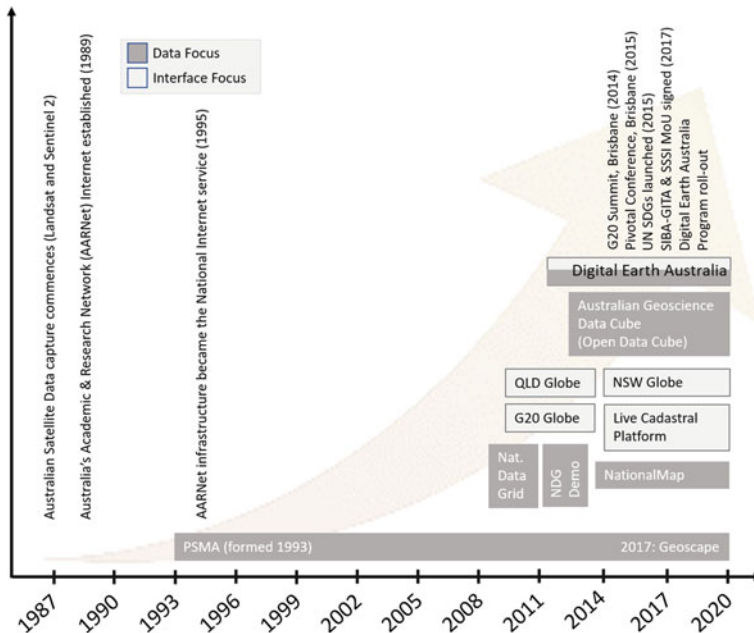


Fig. 21.1 Illustration of the history of digital earth in Australia

for access to data that can result in meaningful decision-making, addressing three important principles for Digital Earth (Desha et al. 2017):

- (1) Open data: Harnessing the potential of open, transparent, rapid access to comprehensive data and information to harvest the plethora of data sets for meaningful problem solving. Australia ranked first on the Global Open Data Index that measures how well nations publish open government data against 14 key categories (Wallace 2017a).
- (2) Real-world context: Decision-making support frameworks that integrate spatial information and sustainable development aspirations, including the United Nations' sustainable development goals. Australia's Open Data Cube (ODC) objectives include building the capacity of users to address these goals in addition to those of the Paris and Sendai agreements (Coppa et al. 2018:84).
- (3) Informed visualization for decision support: i.e., making visual sense of the complex, dynamic and increasingly interrelated systems of today and the future. Among the world's 23 unique virtual globe platforms and four virtual globes that are visualization applications only, Australians have access to an expanding array of support tools (Keyesers 2015), with exciting prospects for user functionality improvements.

In the following paragraphs, we briefly introduce the features of these products, how they have evolved over time, how they are being used to increase end-user take up of geospatial products and services, and the contributions that led to the formation of Digital Earth Australia (Sect. 21.3). Several use cases are also provided in Sect. 21.4.

21.2.1 *National Initiatives*

21.2.1.1 2008–2010: CRC SI's National Data Grid (NDG)

The National Data Grid (n.d.) was developed by the CRC SI to support the spatial enquiry needs of modelers and decision support systems, as conceptualized in Fig. 21.2. The developers had a vision to develop a shared infrastructure that could provide an economical and effective means to integrate spatial information from a variety of sources and formats to support commonly required query, analytical and modeling tasks.

The resultant NDG was essentially an integrated data platform that adopted a grid cell (i.e., raster) based approach to managing spatial information, which could assist professionals with little or no knowledge of geospatial science in performing simple and replicable spatial queries and analyses. It included three components (CRC SI 2009):

- National Nested Grid: a set of standard nested grids with an innovative indexing system to facilitate and promote spatial consistency in a cost-effective manner.

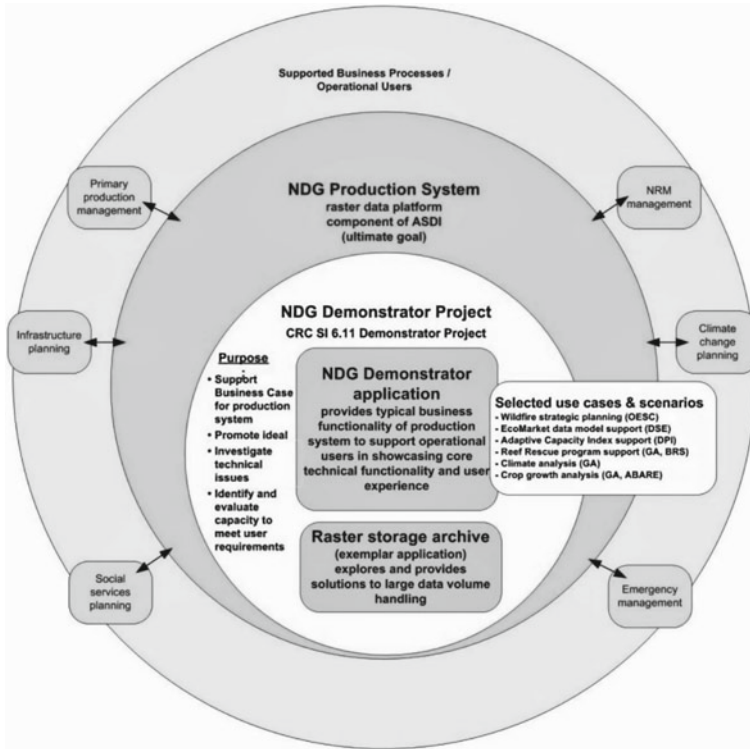


Fig. 21.2 A conceptualization of the national data grid (Source CRCSI 2011)

- National Data Grid Demonstrator Application: a publication data store with a web-based function, rich data querying and data visualization environment for users to access and publish grid cell data.
- National Data Grid Raster Storage Archive: a high-capacity backend data store for efficient and cost-effective storage and management of large datasets.

To raise awareness about the full potential of the NDG, the CRCSI funded the development of an online proof of concept ‘NDG Demonstrator’ (Spatial Vision 2011). Built upon an earlier collaboration into a ‘Platform for Environmental Modeling Support’ (Chan et al. 2008), several scenarios including crop growth, a biodiversity index and climate evaluation were used to showcase the core technical components and opportunities to interact with the product for national and jurisdictional agencies and the public, and opportunities to address scalability issues (CRCSI 2011). IP created in the NDG project was also subsequently used in a pivotal \$3.4 M initiative funded by the Australian Space Research Program to build Earth observation infrastructure enabling processing of the national LANDSAT imagery archive of more than 30 years of data.

21.2.1.2 2014: NICTA's NationalMap

National ICT Australia (NICTA) developed 'NationalMap' for the Department of Communications and Geoscience Australia as a public tool for accessing and mapping open data and users' private data (National Map, n.d.). The NationalMap provides a map-based view of data but does not store data. Selected data viewed on the map is typically accessed directly from the relevant government department or agency.

The initiative was designed with a focus on interoperability and open source code, supporting the government's commitment to policy visualization and open data (NAA, n.d.). It was developed as open source software (available as a GitHub project) using user-centered design methods. Now managed by the Department of the Prime Minister and Cabinet, the open source software is available as a GitHub project. The web front-end uses NICTA's TerriaJS software, which was initially developed by Data61 for NationalMap and has subsequently been used for other projects.

An example of NationalMap use documented in Australia's Digital Continuity 2020 Policy is the Australian Renewable Energy Mapping Infrastructure (AREMI) platform owned by the Australian Renewable Energy Agency (NAA, n.d.). AREMI uses NationalMap to create an open-source, three-dimensional mapping platform to convert and visually display information that works in any modern browser without plug-ins or specialized software on the user's computer. It facilitates evaluation of renewable energy project developments through gathering relevant spatial datasets in one location at the same time. End-user flexibility is key; financiers and investors can ascertain the potential viability of ventures, and project developers can freely access ground and resource measurements to assist with site assessment and design. State and local governments can also use the information to assist with community and stakeholder engagement, tracking and promoting projects, and reviewing and assessing environmental and regulatory planning approvals.

NationalMap requires data to be formatted in a particular way to be machine readable and presented spatially. The Australian Government is continuing to work with agencies to assist with data formatting requirements and compatibility with Australian and international data standards, and have produced the AusGEO CSV standard as a guide to provide consistent formatting.

21.2.1.3 2017: PSMA's Geoscape: Australia's National 3D Data Set

PSMA Australia is an independent and self-funded entity, formed in 1993 by the state governments of Australia to collate, transform and deliver the national government's geospatial data as national datasets (PSMA 2009). The company undertook its first major initiative in 1996, supporting the national Census by providing Australia's first digital national map at the street level.

In 2017, the company launched Geoscape as a suite of digital datasets that represents buildings, surface cover and trees across urban and rural Australia, as shown in Fig. 21.3. Using a reliable geospatial base, the national dataset spatially represents

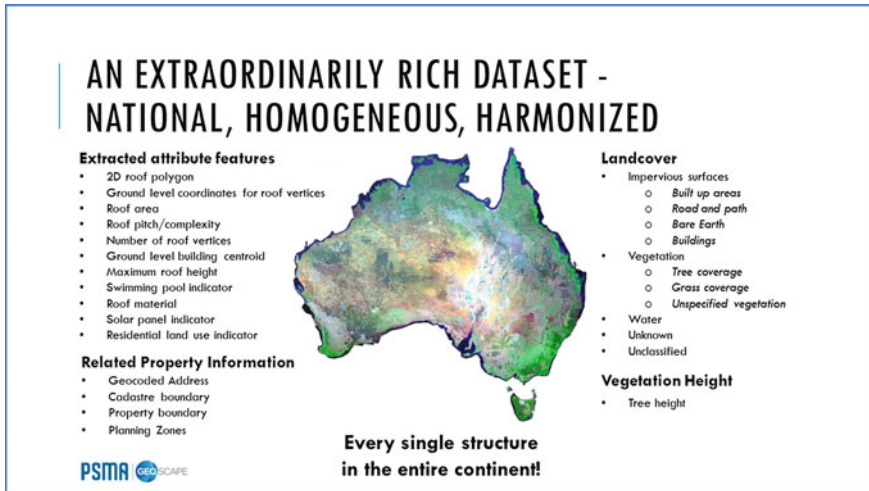


Fig. 21.3 Geoscape product summary (Source Paull and Rose 2017)

every building with a roof area greater than 9 m², for use by industry and government. This is equivalent to approximately 15 million buildings spanning 7.6 million km² across the entire country (Schubert 2017).

The data set links numerous land and property features related to physical structures, land and vegetation, and geographical locations. This includes links to important geospatial reference datasets including geocoded addresses, property data, administrative boundaries, 3D building attributes, land cover details, tree heights, and information on roof materials, swimming pools, and solar panels. It is regularly updated, providing a narrative of the changing landscape, and has links to other PSMA products including G-NAF (addresses), Cadlite (cadastre and property) and Administrative Boundaries (suburb/localities). As PSMA’s CEO Dan Paull reflects in a Geoscape Blog (2017), “*Time and location-stamping have moved data from position to precision, giving a more accurate reflection of the built environment. Organisations can now make sharper decisions with more efficiency and greater confidence.*”

Working in partnership with DigitalGlobe for satellite imagery, the company has used a combination of satellite imagery, crowd-sourcing and machine learning to develop a new process for recognizing and extracting insights from images. The result is an analytics-ready product that is globally replicable and depicts the full built environment (PSMA 2017a). At the time of writing, the roll-out of mapped locations was underway (see <https://www.geoscape.com.au/rollout/>).

The following are two examples showcasing the capabilities of Geoscape:

- The Greater Launceston Transformation Project: Geoscape provides the essential foundational data to enable a cost-effective, accurate solution for smart cities and smart suburbs in the Tasmanian city of Launceston. The *Sensing Value* company is

layering datasets including Geoscape to provide scenario modeling capabilities and visual representations of entire land areas. This is being used to, ‘*model, understand and demonstrate the impact of development decisions, mobility patterns, energy consumption, land use and other strategic and operational insights for urban and regional planning*’ (PSMA Australia 2017b).

- GeoVision™: Developed in collaboration with *Pitney Bowes*, this product is a suite of datasets including Geoscape that combines information on the 3D built environment with information such as addresses, postcodes and ABS Census data. (PSMA Australia 2017c). End users include retail, utilities and construction clients seeking to accelerate decision-making and increase efficiency as well as banking, financial services and insurance users. It aids insurers in risk modeling for setting insurance premiums and assists with telecommunications infrastructure planning.

21.2.1.4 2017: Australian Geoscience Data Cube—‘Open Data Cube’ (ODC)

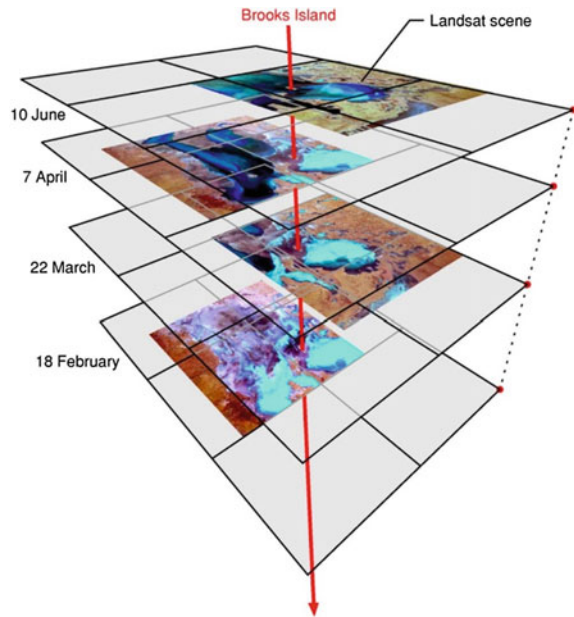
The Australian Geoscience Open Data Cube—otherwise known as the Open Data Cube, (ODC)—aims to realize the full potential of Earth observation data holdings by addressing the big data challenges of volume, velocity, and variety that otherwise limit its usefulness (Lewis et al. 2016). The result of several years of iterations of partnership between Geoscience Australia (GA), the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the National Computational Infrastructure (NCI), it is the first case in which an entire continent’s geographical and geophysical attributes have been made available to researchers and policy advisors. (NCI Australia 2018). It provides users with access to free and open data management technologies and analysis platforms, with the ability to observe historical changes in land use and patterns over time using the infrastructure shown conceptually in Fig. 21.4.

The foundations and core components of the AGDC are (Lewis et al. 2016):

- (1) Data preparation, including geometric and radiometric corrections to Earth observation data to produce standardized surface reflectance measurements that support time-series analysis and collection management systems that track the provenance of each Data Cube product and formalize reprocessing decisions;
- (2) The software environment used to manage and interact with the data; and
- (3) The supporting high-performance computing environment provided by the Australian National Computational Infrastructure (NCI).

This data cube approach allows for analysts to extract rich new information from Earth observation time series, including through new methods that draw on the full spatial and temporal coverage of the Earth observation archives. As noted in the introduction, due to the size of Australia, the Earth’s curvature is important and its tectonic movement is fast enough to require a dynamic cadastre. With an emphasis on a planar geometry, the Data Cube’s flat base is actually an illusion that enables a useful platform to engage with the data.

Fig. 21.4 Conceptual illustration of the data cube, showing Landsat scenes reformatted as spatially consistent tiles of data (Source Lewis et al. 2016)



To enable easy uptake and facilitate future cooperative development, the code was developed under an open-source Apache License, Version 2.0. This approach enables other organizations including the Committee on Earth Observing Satellites (CEOS) to explore the use of similar data cubes in developing countries. Advances in cloud computing and the availability of free and open technologies such as the Open Data Cube (ODC) mean that developing countries without the local infrastructure to process large volumes of satellite data can access data and computing power to build relevant applications and inform decision making.

21.2.2 State Initiatives

21.2.2.1 2013: The Queensland Globe and G20 Globe

The Queensland Globe was created in 2013 by the Queensland Government's Department of Natural Resources, Mines and Energy and was released by the Department as part of the State's open data initiative aimed at increasing the number of publicly available datasets (<https://qldglobe.information.qld.gov.au/>). As the first Australian example of combining Google Earth and government spatial data into a standalone application, it used the familiar Google Earth viewer to find and download free reports and information such as cadastral maps and coal seam gas well and water bore reports.

Subsequently, Google announced they were no longer going to support Google Earth Enterprise, and the new Queensland Globe was developed using the Esri JavaScript API 4.x and Esri REST web services application hosted on Amazon Web Services (AWS) Beanstalk. Its web services were published using ArcGIS Server from departmentally hosted servers. The Globe currently includes 652 data layers from almost every Queensland Government department and is now accessed straight from a browser, so users are no longer required to download Google Earth.

An adaptation of the Queensland Globe, the G20 Globe was produced for the G20 Summit held in Brisbane in 2014. Profiling Queensland to world leaders including Barack Obama and Vladimir Putin, the G20 Globe illustrates the global economic ecosystem from the perspective of Queensland. It shows the value of spatial technology for exploring economic activity in our globally interconnected world across six economic sectors, including agriculture, construction, resources, tourism, science and innovation and education and training. As an exemplar, the G20 Globe reveals the opportunities and competitive advantages in agriculture, construction, resources, tourism, science and innovation in Queensland. It demonstrates the value of open data and the capacity to merge it with digital technology so users can follow economic stories that begin with domestic supply chains and are linked to expansive market demands around the world.

At the time of the G20 summit, Queensland University of Technology went a step further than the Queensland Globe and G20 Globe, developing a state-of-the-art interactive digital display called the CUBE (Fig. 21.5) to teach school children geography and science in an innovative way. Consisting of 48 multi-touch screens across two stories, the Cube is open to the public to view and facilitates opportunities for discovery, visualization and contribution to research projects as ‘citizen scientists’ by experiencing real project scenarios and exploring 21st century challenges (QUT, n.d.).



Fig. 21.5 QUT’s CUBE interactive displays, launched in 2014 and used for community engagement

21.2.2.2 2018: NSW Globe and Live Cadastral Platform

In New South Wales, the state government's Spatial Services initiated NSW Globe and a cloud-based 'cadastre as a service' platform to upgrade its maintenance of the NSW cadastre, including an application that lets the public access cadastral data in real time (Bishton 2018). The new API-based system is targeted at the automated backbone of the development application submission process for councils, reducing duplication of data and effort. Previously, plans were accepted in hard copy and manually scanned whereas the new submission process automatically extracts data and metadata from digital plans, and images are converted to validated LandXML. The DCDB remains the system of record, updated via the new API, and the LandXML and GeoTIFF files are stored in the cloud.

The system is part of a digital transformation of the surveying industry, and the benefits of this system include more efficient land subdivision and reduced cost of development to market. The public will also be encouraged to contribute data to the platform, which supports the NSW Government's spatially digital agenda. Other initiatives such as dMarketplace, a sharing place for data, include a rating scheme for data sources (Wallace 2017b).

21.3 Digital Earth Australia

In 2017, the Australian government launched *Digital Earth Australia* (DEA) to implement the open source analysis platform developed as part of the ODC initiative discussed above. The DEA program contributes code, documentation, how-to guides, tutorials, and support to domestic and international users of the Open Data Cube. As a platform, it uses spatial data and images recorded by orbiting satellites to detect physical changes in unprecedented detail.

Drawing on data from as far back as 1987, DEA translates almost three decades of Earth observation satellite imagery into information and insights about the changing Australian landscape and coastline, providing a ground-breaking approach to organizing, analyzing, and storing vast quantities of data (DEA 2017). Using high-performance computing power provided by the National Computational Infrastructure and commercial cloud computing platforms, DEA organizes and prepares satellite data into stacks of consistent, time-stamped observations that can be quickly manipulated and analyzed to provide information about a range of environmental factors such as water availability, crop health and ground cover. By preparing the data in advance, DEA reduces the cost and time involved in working with the vast volumes of Earth observation data. This analysis-ready data (ARD) are made freely available to users and will enable businesses to innovate and develop information products and applications that can be applied to global challenges.

21.3.1 Product Development for Enhanced Access

DEA provides a suite of information products to the Australian government and businesses. Table 21.1 provides a summary of key products and the following paragraphs describe some of them in more detail (report extracts) to illustrate how, by providing easy access to Earth observation data, DEA can help unlock innovation and capability in government, industry, and the research community (DEA 2018). In the future, there are many opportunities to include other data sets that may be in the public or private domains, such as data collected by sensors installed in machines used by farmers.

Severe floods are a feature of the Australian climate and landscape and are likely to continue with increasing regularity and severity. Water Observations from Space (WOfS) helps understand where flooding may have occurred in the past, which allows for mitigation measures to be considered for reducing future impacts, including proper disaster planning and initiatives supporting communities' preparedness and disaster resilience. WOfS is also an invaluable information source for the Australian Flood Risk Information Portal, which enables flood information held by different sources to be accessed from a single online location.

The fractional cover (FC) product can provide insights for land managers regarding which parts of a property show heavier grazing. DEA is working with the Australian Bureau of Statistics to explore whether this product can provide useful information for land accounting and environmental reporting, and with the Clean Energy Regulator to incorporate FC into its monitoring of Emissions Reduction Fund projects and in potential future ground fraction products that may be of use to industry partners such as FarmMap4D (FarmMap4D Spatial Hub 2018).

Changes in the NDVI over time can be used to identify areas where there has been a sudden decrease or increase in the amount of vegetation. Sudden decreases in the NDVI can be caused by a range of processes including tree clearing, cropping, or severe bushfires. Sudden increases in the NDVI can result from vegetation responding to increased water availability, crop growth, or greening of irrigated pasture.

The knowledge provided by products such as those highlighted in Table 21.1, can contribute to a broad range of applications, including environmental monitoring for migratory bird species, habitat mapping in coastal regions, hydrodynamic modeling, and geomorphological studies of features in the intertidal zone. The surface reflectance tool allows for a more accurate comparison of imagery captured at different times, by different sensors, in different seasons, and in different locations. It also indicates where the image contains missing data, is affected by clouds or cloud shadow, or has been affected in other ways.

Table 21.1 An overview of key DEA products developed in Australia, drawing on data gathered since 1987

Product	Description summary	Key References
Surface Reflectance (Landsat and Sentinel 2)	<ul style="list-style-type: none"> Starting point for many analyses, translating information recorded by an Earth-observing satellite into a measurement of the characteristics of the surface of the earth 	Li et al. (2012); Geoscience Australia (2018e), (2018f)
Fractional Cover (FC)	<ul style="list-style-type: none"> Identifies areas of dry or dying vegetation and bare soil, and allows for mapping of the living vegetation extent (e.g., where animals spend time grazing). Informs a broad range of natural resource management issues 	Scarth et al. (2010); Geoscience Australia (2018b)
Water Observations from Space (WOfS)	<ul style="list-style-type: none"> The world's first continent-scale map of the presence of surface water. Provides insight into the behavior of surface water over time. Highlights where water is normally present, seldom observed, and where inundation has occasionally occurred 	Mueller et al. (2016); Geoscience Australia (2018a)
Normalized Difference Vegetation Index (NDVI)	<ul style="list-style-type: none"> Assesses the extent of living green vegetation. Provides valuable insight into the health and/or growth of vegetation over time. Supports the mapping of different land cover types across Australia 	Geoscience Australia (2018c)
Intertidal Extents Model (ITEM)	<ul style="list-style-type: none"> Information regarding the extent and relative elevation profile of the exposed intertidal zone (between the highest and lowest tide). Complements existing data with a more realistic representation and understanding 	Sagar et al. (2017); Geoscience Australia (2018d)
High and Low Tide Composites (HLTC)	<ul style="list-style-type: none"> Mosaics produced to allow for visualization of the Australian coastline and reefs at high and low tides 	Geoscience Australia (2018g)
Dynamic land cover dataset	<ul style="list-style-type: none"> Nationally consistent and thematically comprehensive land cover reference for Australia 	Geoscience Australia (2018h)

Source References shown in table

21.3.2 Implementing Projects to Enhance Take-up

The DEA platform enables anyone, anywhere, to use the data to inform better decision-making. The platform has the potential to contribute immediate and direct economic benefits to companies, organizations and individuals conducting feasibility studies and assessments, evaluations, monitoring and management activities. A number of high-impact projects have used this platform, and GA aims to increase its use by the wider community, including in regional and remote Australia. The spectrum of Geoscience Australia's current projects is illustrated in Table 21.2, synthesized from the Geoscience Australia Road Map (GA 2018).

21.4 Australian Use Case Examples

In this section, we highlight several use cases spanning agriculture, education and training, and disaster management, including initiatives within the capacity-building work of the ISDE Australia chapter research node. For each use case, we highlight the project objectives, lessons learned and opportunities going forward.

21.4.1 Agricultural Sector—FarmMap4D

The FarmMap4D (formerly known as the NRM Spatial Hub) property management planning platform demonstrates how world-leading time-series remote sensing of ground cover through an online interface can optimize grazing pressure and land conditions, and allow for land managers to make better, more informed decisions. Managers can use the product to view and overlay map layers and generate maps and reports to support more effective land management and planning.

This single source of information is accessed by project managers, contractors, and property managers. The Hub combines the latest geospatial mapping technologies with time-series satellite remote sensing of ground cover in a novel way. For the first time, the sheep and beef industries can use and compare their own data paddock data with government data in a consistent and interactive way, as illustrated in the screenshot of the interface in Fig. 21.6.

Russell-Smith and Sangha (2018) provide an overview of how FarmMap4D can be used to consider emerging opportunities for developing a diversified land sector economy in Australia's northern savannas.

Table 21.2 Current and future DEA projects

Project category	Key current projects	Future projects 'on the horizon'
Land cover & Land use	UN land cover classification system feasibility study Forest cover; Dynamic land cover dataset; Fractional cover; Review of current crop mapping approaches; Irrigated versus Nonirrigated crop extents; Water quality monitoring for sustainable development goals	Water observations from space, Sentinel-2; National intertidal digital elevation model; National wetlands extents map; National land use map integration with DEA; Irrigated versus Non-irrigated crop extents; Broad commodity type crop mapping; NEXIS enhancement; Land degradation Monitoring; NRM requirements analysis; Urban features; Groundwater-dependent ecosystems
Marine & Coastal	National mangrove mapping; Shallow water habitat mapping	Marine turbidity; Ocean color statistical summary; Sea surface temperature statistical summary; Coral bleaching; Coastal change characterization
Change detection	Current projects; Change detection for CER land projects; New approaches to statistical analyses of time series data; Burn extents	–
Analysis-ready data	Sentinel-2 surface reflectance; Landsat ARD Intercomparison and sensitivity analysis; Landsat surface brightness temperature; Surface reflectance validation; Aquatic surface reflectance; Observation density quality assessment; Improving the location accuracy of synthetic aperture radar	Sentinel-1 ARD; Himawari-8 ARD; Sentinel-3 ARD; MODIS ARD; VIIRS ARD; Climate Data; Evapotranspiration
Platform improvement	Automation and orchestration; Cloud storage drivers; Scalability and performance; Documentation; Science algorithm portability	–

(continued)

Table 21.2 (continued)

Project category	Key current projects	Future projects ‘on the horizon’
Data visualization & Delivery	NEII viewer extension; Data publication governance; User experience design; ODC web services development; NCI web services development; GSKY services for national map	Virtual products Web processing Data dashboard
Data management	Collection Upgrade and transition analysis; Automation of the landsat processing pipeline; Cloud computing architecture pilot; Regional copernicus data hub development	Collection one upgrade (actual upgrade); DGGS support; DGGS implementation support; Near real-time landsat processing
Government engagement	Department of the environment and energy needs analysis; Tasmanian government transition to DEA	Interdepartmental grad program
Industry & community engagement	Industry and economic value strategy	FarmMap4D need analysis
International engagement	Support for the group on earth observations; Support for the committee on earth observation satellites; Support for regional development projects; Cambodia open data cube; Open data cube community development	–

Source Adapted from Geoscience Australia (2018)

21.4.2 Education Sector—Research Group (ISDE Research Node, Australia)

Griffith University’s researchers (in Queensland) are working to connect digital-spatial (‘place based’) design and decision-making enquiry for resilient and regenerative cities, building capacity to collectively address planning and governance for future resilience in the face of unprecedented pressures (see Smith et al. 2010; Steffen et al. 2011), including climate change, population dynamics and resource scarcity. Building upon research and experience in sustainable development and engineering, the researchers draw on a strong multidisciplinary research capacity and strengths in educational pedagogy, rapid capacity building and education for sustainable development. The group includes educational and behavioral psychology researchers,

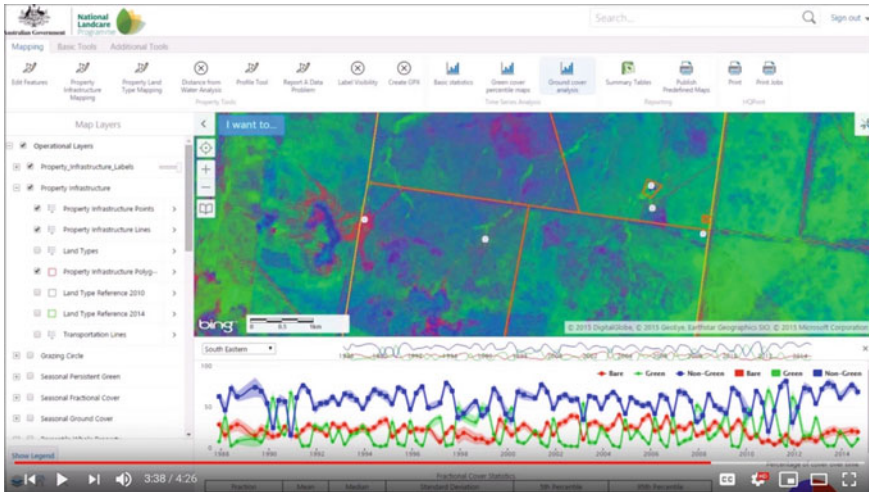


Fig. 21.6 Screenshot of the FarmMap4D interface (Source <https://www.farmmap4d.com.au/>)

industry-facing laboratory technical and management staff, and a growing team of doctoral (PhD) candidates.

21.4.2.1 Capacity-Building System

The Cities Research Institute (CRI) is collaborating with the International Water Centre (IWC) to create an innovative approach to capacity building for Digital Earth products and services, building on the IWC’s success with the water modeling community in Queensland. With an aim of effectively disseminating Digital Earth knowledge and the benefits of use to the Australian professional community for business development and growth, the team is developing a ‘Digital Earth Capacity System’ through which participants can learn about new and emerging capabilities of Digital Earth globally and in Australia, as well as importance, relevance and applications, as illustrated in Fig. 21.7.

Participants engage with Digital Earth experts on trends and opportunities for Australian organizations and ‘learn from doing’ by working with Digital Earth Australia data to assess problems over time. The courses also include case studies of real examples of Digital Earth tools and applications that helped solve complex problems and enhance sustainability. It ranges from introductory courses to advanced support. Building on the data that has been created, participants develop the capacity to understand and use DEA data for applications including the development of evidence-based policies and developing visual aids for strategic decision-making.



Fig. 21.7 Illustrative photos of capacity-building environments within a community of practice context

The expected benefits for government collaborators include the following:

- Coursework being aligned with priority themes and focused on relevant topics
- Independent courses available to wider professional and public policy audiences
- Direct feedback from participants on the best ways to access and apply the tools
- Effective dissemination of knowledge and upskilling of the workforce to facilitate enhanced use of the available high-quality data.

Potential learning outcomes for participants include the following:

- Live interaction via remote immersive collaboration
- Practice in visualizing, interpreting and communicating big data sets
- The ability to engage in professional development from remote locations
- Remote, always-available access to learning resources about using products.

21.4.2.2 Remote Immersive Collaboration Spaces—DENs

The same group of researchers are prototyping two unprecedented cost effective and interactive “Digital Earth Node (DEN)” rooms, facilitating remote-immersive collaboration where the data itself stays local to the users (utilising image rather than data transfer) while collaboration occurs anywhere. In an increasingly connected world, it is a challenge to create virtual meeting spaces to facilitate deep thinking and decision-making that overcome the need to travel, where people can generate, harvest, interpret and share data as though they were physically side by side.

In response to this challenge and in liaison with colleagues in the International Society of Digital Earth (ISDE), ‘Digital Earth Node’ (DEN) engagement spaces have been designed to promote productive thinking and timely decision-making. The following paragraphs summarize the ‘preto-typing’ (i.e., conceptual) and ‘prototyping’ (i.e., pilot) undertaken to conceptualize, design and build the pilot facilities on two Griffith University campuses in Queensland, Australia, and connect them with other

facilities elsewhere (see also Desha et al. 2018). The achievements to date are highlighted with regard to building the potential for immersive thinking environments, as well as next steps for future space development and refinement.

Smart visualization and communication are critical components of any effort to ensure that decision-makers have timely access to complex information and enable holistic problem solving. This has been documented by authors such as Van Wijk (2005) and the ISDE network (Goodchild 2010; Goodchild et al. 2012; Craglia et al. 2012; Roche 2014) and discussed within the geospatial and geo-design communities by seminal speakers including Dangermond (2010), Benyus (2014) and Scott (2017).

Table 21.3 summarizes the key differences that the research team have defined to date in the Digital Earth Node (DEN) rooms and other regularly used interactive video-conferencing tools and facilities. Essentially, the DEN rooms use readily available hardware that is also used for video conferencing, including web cams, audio feeds, touch screens and interactive technologies. However, a breakthrough in software has resulted in the software ‘doing’ the heavy lifting, resulting in almost no differences in the delay for the end-users and unprecedented flexibility in the extent of potential real-time editing and review.

A schematic of the room layouts is shown in Fig. 21.8. The individual room designs are mirrored as closely as possible to provide the user with an ‘extended room’ experience.

Table 21.3 Scope distinctions between conventional video conferencing and the DEN rooms

Video conferencing facility	Digital Earth Node (DEN) rooms
Interactive viewers	Immersive layout <i>with</i> interactive viewers
Remote connection “feels like you are really <i>there</i> ”	Sense of proximity “feels like you are really <i>here</i> ”
Catered to short interactions (usually up to 2 h)	Catered to long interactions (up to many hours)
Heavy hardware + share-screen software	Light hardware + heavy-lifting software

Source Desha et al. (2018)

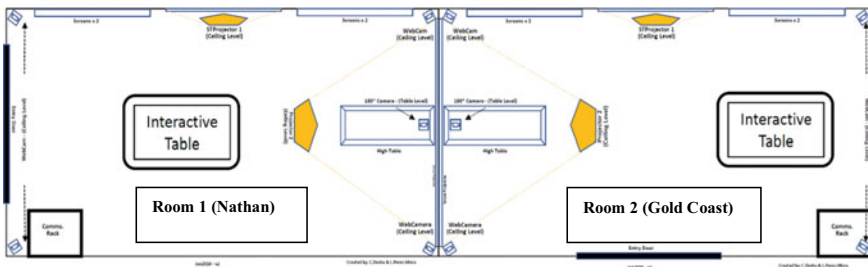


Fig. 21.8 DEN prototype configuration showing ‘Room 1 (Nathan)’ and ‘Room 2 (Gold Coast)’ (Source Desha et al. 2017)

Looking ahead, society must transition towards multidisciplinary and multinational approaches to address the planet's increasingly complex challenges. This requires a process change in collaboration around the world, without further impacting greenhouse gas emissions from the collaboration (primarily through travel). Considering the *Pivotal Principles* for such problem solving in the 21st century referred to in the Introduction to this chapter, the next logical step is to provide Digital Earth Node (DEN) facilities around the world that create 'remote but realistic' personal experiences between researchers and decision-makers to facilitate deep thinking and problem solving.

Efforts towards this end-goal include using the prototypes to inform the installation of a Disaster and Resilience Management Facility (DRMF) within a new building on Griffith University's Nathan Campus (Brisbane) by connecting the prototype DENs with ISDE chapters internationally and focusing on two primary research agendas to engage with the DEN rooms to explore how this technology and scientific knowledge could be harnessed for human and ecological wellbeing:

- Green infrastructure: Using nature and learning from nature to inform the design of resilient cities through analysis of geospatial data sets.
- Crisis communication in disaster management: using technologies to improve response times to optimize the allocation of resources.

We anticipate that this network of global nodes will connect academics, leaders and decision-makers around the globe in a fast, reliable and immersive manner. Colleagues around the world will be able to engage in pragmatic, real-time and rigorous enquiry into challenges and opportunities facing humanity, with application opportunities spanning sectors including education, research, emergency services, crisis management and global communication. This innovative network will be instrumental in developing spatial capabilities to catalyze human and planetary wellbeing. Such precedents of the possibilities will have immediate implications for deep-thinking engagement internationally and provide remote collaboration opportunities that are engaging and better for the planet.

21.4.3 Disaster Management—NSW Volunteer Rescue Association

With the reality that one minute can mean the difference between life and death, the New South Wales Volunteer Rescue Association (NSW VRA) has been exploring opportunities to make the most of existing 'state of the shelf' and emergent geospatial technologies to improve outcomes with regard to what is anecdotally referred to as, 'the right person and/or the right resources being in the right place, at the right time' (Desha and Perez-Mora 2018). This includes recognition that there may be associated critical infrastructure disruption during disasters that makes rescue more critical, including disabled communication networks, internet, and limited or no access to power. Such circumstances require creative solutions to manage the timely

collation and exchange of conventionally 'heavy' data files such as video, photos, location-based mapping assistance and real-time or near-real-time management of large databases.

In 2017, the researchers were introduced to VRA personnel through the Griffith University EcoCentre. Inspired by the Digital Earth agenda and the work of researchers including Van Wijk (2005), Craglia et al. (2012), and Goodchild et al. (2012), they visited other researchers in Japan (Chubu University) and Europe (Joint Research Centre) to experience precedents and discuss possibilities for improving communication in disaster response.

Seeking a solution to these challenges, the researchers and their Digital Earth Node technical team have been working on developing software solutions to improve the way hardware is used and leased, including engaging researchers in different areas to generate better ways to use hardware in the form of a more efficient communication tool. In collaboration with the NSW VRA, data from a number of different sources have been collated and analyzed, including the organization's database and historical anecdotal and solicited feedback from members of the volunteer community of professional volunteers and highly trained emergency management personnel. These data were used to ground-truth potential software solutions, allowing for the team to test solutions for improving the way personnel communicate in remote areas, how personnel deploy information and how personnel manage others in times of need.

Following software development, the first stage of deployment occurred in July 2018 when the team developed a software solution to improve the communication between executive managers and key decision-making personnel and their squads and squad members. This software now allows for the NSW VRA to collect data while in the field during a call out.

The data arising from deployment will be analyzed and processed to establish the next stage of this complex project, the deployment of a DEN (Digital Earth Node) remote immersive collaboration facility in regional NSW (Dubbo). This immersive tool will allow for decision making personnel to locate units or key personal in the field while they are being deployed during challenging times such as floods and bushfires. This will provide better ways to analyze what is happening in the field and aid in deployment of resources to the right locations at the right time. The system will also be able to track activities in real-time and with accuracy to ensure the safety of these professional volunteers.

The data will also be analyzed in an event block to enable a comprehensive report at the end of each incident response. Drawing on the analysis of the data collected by the DEN and devices in the field, the NSW VRA will be able to generate precise reports based on the human behaviors and decisions made. The findings will also allow for the Association to understand how they should improve the way they train their decision-making personnel and prevent mistakes during future events.

The research team is connecting with colleagues in international chapters of the International Society of Digital Earth (ISDE) to ensure that best practices are shared around the planet with other emergency management response teams. Thus, professional international expertise to fix unsolved or permanent challenges will reach remote areas of Australia. Ultimately, everyone, everywhere should have access to a

fully comprehensive system that allows for our ‘local heroes’ to save more lives and provides them with the best safety approach during their high-risk activities.

21.5 Conclusions

This chapter highlighted achievements and opportunities for Australia considering three decades of data capture and enquiry, from local and largely champion-based ad hoc initiatives to mainstreamed integration and take-up globally. This included an historical exploration of practices and experiences in Australia arising from the need to manage local resources better, addressing the complexities of environmental stewardship. With regard to data management and interfaces for meaningful end-user engagement and enquiry, a number of initiatives stand out as exemplar projects for potential adoption elsewhere.

Australian current and future priorities were summarized through a text analysis of the Geoscience Australia roadmap, and two examples from the Australian ISDE chapter highlight the imperative of enhancing end-user take up of the Digital Earth technology through strategic capacity-building initiatives. The authors discussed the mechanisms and challenges of harnessing interoperable information in the form of geospatial data and through systems and processes to add value to the information. Considering these experiences, the benefits of open data and data sharing are realized through careful planning, design and integration, with a focus on upfront iterative design and end-user engagement. Releasing high-value data is an iterative process that requires collaboration and communication with agencies to show the benefits of open data and to support useful data sharing.

Reflecting on the history and examples provided, several ‘turnkey’ capability (workforce and market) considerations are summarized here for Australia’s future and for non-Australians considering their own Digital Earth:

- (1) ***Challenges in creating an active context for data use:*** Decision-makers and researchers are currently grappling with how to harness the common repository to create saleable products (apps and APIs), where analytics is a well-established and supported opportunity for industry, beyond delivering funding for such initiatives via government grants (i.e., teaching the people how to fish).
- (2) ***Challenges in capacity building beyond ‘show-and-tell’:*** In a rapidly emergent industry, it is critical to create the demand for products and services as well as build the capacity to deliver these goods and services. Trust is paramount in this process and must be prioritized when governments test and pilot products and services. There is a need for industry buy-in and for industry investors. In Australia, there is currently no public-private-partner (PPP) model in data adoption beyond advocating for industry to ‘look how good the tool is.’
- (3) ***Challenges in defining the job market and demand for the market:*** In a country where the number of geospatial professionals is insufficient, capacity building is critical and must be addressed urgently (FrontierSI 2018). This includes public

and private sector considerations with regard to the types of skills required and the need for a capacity-building framework to aid in data utilization. We need to find demand for the market, potentially through the development of an active ‘Community of Practice’ across different key sectors, to enable more serious business workflow integration around technology, for example, for farm and water management.

In addition, several considerations relating to efforts and investments made on data and technologies are summarized:

- (1) **Considering open source versus business continuity:** The initial version of the Queensland Globe was created using a Google open source platform, then could no longer be supported by Google. It took time for the Queensland government to find a reliable partner and Esri (proprietary software) was chosen to support the continuity of the project. In hindsight, a hybrid approach could take advantage of open source and proprietary platforms.
- (2) **Sharing knowledge within the context of an open source platform:** Despite progress, most end-users—whether government, business or citizens—do not have the knowledge and/or skills to find, download and use open data directly. This Digital Earth platform relies on a number of technologies and, although the code developed is open source, there is no community of practice to enable or coordinate technical expertise. Hence, coordination and capacity building are needed to help practitioners access and work with the data.
- (3) **Measuring the success of Digital Earth products:** This chapter provided numerous examples of products and the utilization of such products must be evaluated beyond the initial excitement and celebration of their existence. Ways to measure utilization are being explored, including conducting economic benefit analyses. Such metadata about utility is important to demonstrate value and ensure continued maintenance and updating of the Digital Earth Platform to meet the future needs of the community.
- (4) **Enabling access and utility remotely:** In a globally connected world, remote immersive collaboration has the potential to create communities of practice with reduced cost of travel and greenhouse gas emissions, in addition to ensuring data security in discussions and collaboration. This is particularly important when governments internationally are interested in using Australia’s Digital Earth platforms to communicate decisions, upgrade infrastructure, and oversee the safety and wellbeing of citizens.

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