Australia's National
Science Agency

Framework for Spatially Enabled Digital Twins:

Information Paper

February 2021

Queensland Government

ADVANCE QUEENSLAND

Foreword

This Information Paper and associated *Framework for Spatially Enabled Digital Twins* has been commissioned by the Queensland Government to help guide the development and operation of spatially enabled digital twins in Queensland. The Paper and Framework are intended to support the implementation of the *Principles for Spatially Enabled Digital Twins of the built and natural environment in Australia* released by the Australian and New Zealand Land Information Council (ANZLIC) in December 2019.

It is expected that this Framework will be revised and updated through ongoing collaboration with government, industry, research and community stakeholders in Queensland and across Australia.

The Framework is available for other jurisdictions to use should they wish to do so.

CITATION

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CSIRO Data61, Australia.

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Contents

Definitions

- **ANZLIC**: Australian and New Zealand Land Information Council (also known as the Spatial Information Council) is the peak intergovernmental organisation providing leadership in the collection, management and use of spatial information in Australia and New Zealand.
- **APIs:** Application Programming Interfaces (APIs) are data services that allow for automated access between computer applications/systems (including access from a database to a web browser/application).
- **BIM:** Building Information Modelling (BIM) is a process supported by various tools, technologies and contracts involving the generation and management of digital representations of physical and functional characteristics of the built environment. BIM may also be referred to as Asset Information Modelling (AIM), Virtual Design and Construction (VDC), Digital Engineering (DE) and the terms Building Information Modelling or Management are variously used.
- **Data sharing:** Data that is shared securely between organisations (not open data) for access by authorised users.
- **Digital twin:** A digital representation *that models* a real-world object or system. Digital twin platforms could be visualisation, analytic or workflow application functions.
- **Digital twin assured data set:** A collection of data that is managed by a data custodian that is formatted so it complies with appropriate standards and quality levels set by a digital twin
- **Digital twin assured data service:** Digital Twin assured data service is real-time feed from a data source that is made available via an API (application programming interface) and has been assured as fit-for-purpose for use in a digital twin.
- **Digital twin ecosystem:** A federated ecosystem of digital twins connected by open and shared data using visualisation, analytical, modelling and simulation tools. The ecosystem has common authentication and authorisation rules to enable role-based access to securely shared data.
- **Federated digital twin:** A digital twin that is supported by multiple data services usually from multiple organisations, and orchestrated so they can be integrated within a digital twin environment (either visualisation, analytic system or workflow application) and that minimises the need for centralised data replication and storage.
- **Framework for Spatially Enabled Digital Twins:** A framework to support the development and operation of spatially enabled digital twins that are aligned with the *Principles for Spatially Enabled Digital Twins of the built and natural environment in Australia*. This version has been sponsored by the Queensland Government in collaboration with Data61.
- **National Foundation Spatial Data:** A set of datasets that are assembled and maintained under the *Foundation Spatial Data Framework* (FSDF) that provide national coverage of the best available, most current, authoritative source of foundation spatial data which is standardised and quality controlled.
- **Open data:** Data that is released to the public for their use at no charge and supported by an open licence that permits reuse.
- **The Principles for Spatially Enabled Digital Twins of the built and natural environment in Australia** is a set of principles to guide digital twin development and delivery of Australia's digital twin ecosystem. These have been developed by the Spatial Information Council (ANZLIC) in collaboration with governments, industry and research organisations and was released in December 2019 (see Section 2.2).
- **Spatially enabled digital twin:** A digital representation that combines a digital twin with accurate spatial information, such that the digital twin covers a defined geographic space above and below ground and enables digital twins to relate to each, providing real-world context. In this document, it assumes all digital twin references are spatially enabled unless specifically identified otherwise.

1 Information Paper Purpose and Concepts

1.1 Framework Purpose

This is an information paper to support the accompanying *Framework for Spatially Enabled Digital Twins*. The Framework is intended to guide the development and operation of spatially enabled digital twins that align with the *Principles for Spatially Enabled Digital Twins of the built and natural environment in Australia* released by ANZLIC in December 2019.

The Framework is designed to enable an open and collaborative national ecosystem of digital twin platforms, technologies, and services that can interoperate and support each other. It will allow the underlying data services to be discovered, accessed, and used as openly and extensively as possible across multiple digital twin platforms, while sharing private and sensitive data only with authorised users in a secure manner.

The Framework also provides guidance on the development of individual digital twins that are federated, where different sectors and organisations collaborate and multiple data services are coordinated and integrated, to support the needs of users and stakeholders.

The Framework addresses key issues such as creating a general understanding of concepts, adoption of standards and common information architecture, as well as governance arrangements for multi-sector collaboration and social licence from the community.

1.2 Concept of Digital Twins

The concept of 'digital twins', being an advanced digital representation that can model a real-world object or system, has emerged over the last two decades. The intent of a digital twin is to capture data about the physical world to create an accurate digital model that simulates the real-world activity. This twinning process allows the digital model to help provide insights about how to improve the management of physical object or system. This can be done through improved situation awareness, planning for future needs, optimisation of current systems, simulating future scenarios or automated control of physical devices and systems.

The current wave of interest with digital twins is being driven by the greatly expanded way accurate close to real-time data can be collected through a range of improved and increasingly ubiquitous sensing and monitoring technologies, as well as advances in how this data can be integrated and used in sophisticated modelling and simulation computing systems. This has led to the creation of maturity models for digital twins that describe the stages of development from the most basic digital representation of an object or process through to more mature twins that incorporate internet of thing (IoT) sensors and control and even automation of real world activities.

While the uptake of digital twins was originally driven by industrial companies wanting to model the performance and lifecycle of their products, it has now extended to many other domains such as the built environment, natural environment, traffic systems, economic markets, health systems and even humans (eg digital athlete). In many ways, other domains already had developed advanced data modelling and simulation systems that used close-to-real-time inputs well before they were labelled as 'digital twins'.

It is estimated that by 2022 over 75% of large industrial companies that are implementing IoT will have adopted digital twin technology (Gartner 2019).[1] It is estimated that in the next few years billions of things will be represented by either digital twins, software models, and physical systems.

1 Gartner, Gartner Survey Reveals Digital Twins Are Entering Mainstream Use, 20 Feb 2019, https://www.gartner.com/en/newsroom/press-releases/2019-02-20-gartner-survey-reveals-digital-twins-are-entering-mai

Currently, most digital twins are islands of varying capability, not easily discovered, not connected, or able to securely share their underlying data easily with each other. Additionally, most of these digital twins do not accurately reflect their real-world location, so a digital twin model of an individual building cannot be easily integrated into a city-wide digital twin.

1.3 Structure of the Framework for Spatially Enabled Digital Twins

The structure of this framework includes:

- Outline of policy agenda for digital twins
- Future state for an Ecosystem of Digital Twins
- Information and technology framework for federated Digital Twins
- Social framework for federated Digital Twins
- Change and Implementation

Attachments

- Draft Checklist for Alignment to the *Principles for Spatially Enabled Digital Twins of the built and natural environment in Australia.*

2 Policy Agenda

2.1 Introduction

While this framework has been developed to support the adoption of the *Principles for Spatially Enabled Digital Twins of the Built and Natural Environment in Australia*, it also supports and builds on a range of existing relevant government and industry policies such as open data release, data sharing, privacy, security, standards and ethics. These policies are enabled where necessary by government legislation and/or regulation and associated compliance processes.

Some of these policies are focused on either guiding activities within specific government jurisdictions (eg data sharing) while other cover all sectors of society including the private sector (eg management of private information).

As the *Digital Twin Framework* is intended to guide action by all sectors of society, it is necessary to not only reflect any mandatory policies but also address gaps where policy guidance for industry, research and community is not available or underdeveloped.

2.2 The Principles for Spatially Enabled Digital Twins of the Built and Natural Environment in Australia

The *Principles for Spatially Enabled Digital Twins of the Built and Natural Environment in Australia* was developed by the Australian and New Zealand Land Information Council (ANZLIC), in collaboration with government jurisdictions, industry and research organisations, and with support from the Australian Government Department of Industry, Innovation and Science (DIIS). The document was released by ANZLIC in December 2019.

The Australian set of principles draws on the UK's *Gemini Principles* that were developed by the Centre for Digital Built Britain (CDBB), a joint government-research initiative to promote transformation of the construction industry.[2] While these principles were developed for a specific industry sector, they have received considerable interest and support more widely.

The focus of the *Principles for Spatially Enabled Digital Twins of the Built and Natural Environment in Australia* is to ensure that objects in digital twins can be positioned accurately using spatial data of an appropriate level of detail and quality. This will enable digital twins to relate to each other and provide real-world context.

The scope of the *Principles for Spatially Enabled Digital Twins of the Built and Natural Environment in Australia* has been expanded to explicitly include the natural environment but is expected to be relevant to other sectors. The document also addresses the context of Australia's three-tiered system of government that have different roles in terms of managing and providing spatial, built and natural environment data.

The *Principles for Spatially Enabled Digital Twins of the Built and Natural Environment in Australia* outlines a vision of a federated ecosystem of securely connected digital twins and that create value for the Australian economy, society and environment.

> "A federated ecosystem of digital twins would cut across a broad range of government (i.e. Commonwealth, state, territory and local) and industry (e.g. construction, manufacturing, transport infrastructure, utilities) sectors, with no single owner or contributor. The ecosystem could include a combination of data that is open or shared with approved users. To maximise value, the key challenge is to allow data to flow across the ecosystem while maintaining clear data custodianship for contributors, appropriate protections for private, confidential and sensitive information and consideration of commercial impacts, such as intellectual property."[3]

2 Centre for Digital Built Britain, *The Gemini Principles*, 2018, https://www.cdbb.cam.ac.uk/system/files/documents/TheGeminiPrinciples.pdf

3 ANZLIC, *Principles for Spatially Enabled Digital Twins of the Built and Natural Environment in Australia*, p. 13.

The nine key principles for development of digital twins in Australia are shown below:

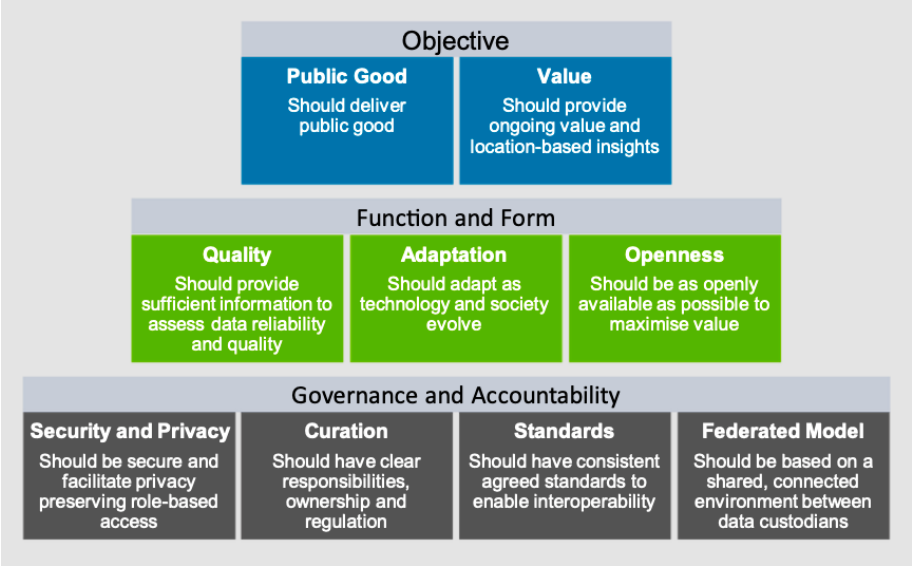

Diagram 1: The nine principles from The Principles for Spatially Enabled Digital Twins of the built and natural environment in Australia.[4]

These high-level principles are intended to help industry, government, and the research sector generate data and develop digital twins in an aligned and cooperative way. The development of a framework and/or roadmap is proposed to ensure the digital twin ecosystem meets the needs of all stakeholders.

Issues for inclusion in a framework include "spatial enablement; connectivity (including appropriate standards); and collaborative agreements on, for instance, governance mechanisms, data sharing and access, and roles and responsibilities… with secondary implementation aspects also requiring shared agreement and guidance include, but are not limited to capability building; and communication and engagement activities".[5]

2.3 Foundation Spatial Data

Open access to authoritative national, standardised, spatial data is a critical enabler for the development of Australia's digital twin ecosystem and assist users to spatially enable digital twins. Foundation spatial data is data upon which other spatial datasets are aligned to, or rely on, or are built upon, and should ideally have more than one of the following characteristics: be geospatial, essential for public safety and well-being, critical for a national or government function or contribute significantly to economic, social and environmental sustainability.[6]

ANZLIC's *Foundation Spatial Data Framework* (FSDF) provides a common reference for the assembly and maintenance of Australian and New Zealand foundation spatial data that support a wide variety of users. Its

https://www.anzlic.gov.au/resources/principles-spatially-enabled-digital-twins-built-and-natural-environment-australia

4 ANZLIC, *Principles for Spatially Enabled Digital Twins of the Built and Natural Environment in Australia*, p. 14.

5 Ibid, p. 22.

6 ANZLIC, *The Australian and New Zealand Foundation Spatial Data Framework*, April 2014 https://link.fsdf.org.au/sites/default/files/FSDF_Resources/One_ANZ_Foundation_Spatial_Data_Framework_Booklet.pdfQueensland Department of Natural Resources, Mines and Energy, *Queensland Foundation Spatial Data Framework*, February 2018, https://www.dnrme.qld.gov.au/?a=109113:policy_registry/queensland-foundation-spatial-data-framework.pdf&ver=3.00

purpose is to deliver national coverage of the best available, most current, authoritative source of foundation spatial data which is standardised and quality controlled.

The *FSDF* identifies ten themes (shown below as diagram 2) each with a profile that details a description of the theme, why the theme is included in the *FSDF*, and the status and future consideration for the theme data. Each theme includes one or multiple datasets contributed by different government jurisdictions or other organisations, standardised and integrated to provide consistent national coverage.

Diagram 2: Foundation Spatial Data 10 themes

The development of spatially enabled digital twins will require enhancement to the FSDF foundation spatial datasets, for example, to include more accurate cadastre (land parcel and property) data that includes 3D (three dimensional) and 4D information (temporal data).[7]

The FSDF foundation spatial datasets will also be required to be provided as data services through APIs from the primary data custodian rather than through static downloads of data files. This means that users of the data have access to the most current and accurate version.

While ANZLIC provides coordination for such improvements to foundation data sets, much of the implementation work is done by the different government jurisdictions through investing resources to support the necessary transformation. This means that the required enhancements to support spatially enabled digitally twins will progress at different paces across Australia.

2.4 Government Data Release and Sharing Policies

Over the last decade, Australian governments have developed a range of policies relating to data release and sharing supported by existing or pending legislation. These focus on the management of public sector data (collected by or on behalf of government programs) and how it should be made available to other users.

These policies generally group data into three categories:

- *Open Data:*
  Open data, by definition, should be freely available, easily discoverable, anonymous, accessible and published in ways and with licences that allow reuse (eg Creative Commons). All Australian national, state and territory governments now have policies that encourage the release of open data by default unless there is a reason not to not do so (eg the data contain private or confidential information).

7 The development of Australia's positioning framework by government jurisdictions is also being guided by the Geocentric Datum of Australia 2020(GDA2020). This was officially defined as Australia's new geodetic datum in December 2017. This new continent-fixed datum will bring the coordinates of Australia's mapped features back into line with global systems in 2020. https://www.icsm.gov.au/gda2020/what-changing-and-why

- *Shared Data*

  Shared data, describes data that contains sensitive information that can only be shared in a controlled and secure way to authorised users for approved purposes. Most Australian governments have introduced policies to encourage data sharing between government agencies, researchers and other trusted users while ensuring there are safeguards in place regarding the use of private and sensitive information.

- *Closed Data*

  Closed data, describes data that contains sensitive information that can only be used within an agency, sometimes only for a specific purpose and group of authorised internal users. The management of such data is sometimes controlled by specific legislation or regulation, as well as general policies and legislation regarding use of private and other sensitive information.

While there has been a lot of activity by Australia's governments with the open release of data and sharing of sensitive data with trusted users, progress in achieving the objectives of these policies has been generally ad-hoc and slow despite some examples of good practice. The Productivity Commission report *on Data Use and Availability* released in March 2017 concluded that Australia lagged in opening up public sector data and that 'lack of trust by both data custodians and users in existing data access processes and protections and numerous hurdles to sharing and releasing data are choking the use and value of Australia's data'.[8]

The Australian Government has introduced Data Sharing and Release legislation to formalise the establishment of an Office of the National Data Commissioner (ONDC) as a central government agency with data policy and coordination responsibilities that will seek to balance the easier sharing of public sector data with appropriate safeguards. This includes a framework for Data Custodians (Commonwealth agencies) to share data based on a purpose test, a risk assessment process using the Five Safes data sharing principles and a common Data Sharing Agreement (based on a standard set of items). The framework also includes a process for creating Accredited Data Users, Accredited Data Service Providers and Accredited Processes which will verify an ability to safely and competently handle data shared by Data Custodians.[9]

The role of the ONDC will focus initially on sharing Australian Government data that includes participation by agencies from other government jurisdictions as Accredited Data Users and Service Providers. It is proposed however that the Australian Government will collaborate with state and territory governments to promote a consistent national approach to data sharing and release, that may even include 'reciprocating state and territory legislation to authorise sharing of data across borders to build a national system'.[10]

While Australian state and territory governments have all developed a range of data release and sharing policies, legislation and guidance documents, they all face similar challenges about how to create and implement more efficient, predictable and secure ways to release and share data.

The adoption of data release and sharing policies and initiatives by Australian local governments is generally more underdeveloped and ad-hoc. It is estimated that less than 15% of local governments have released open data or have published formal data release or sharing policies and procedures.[11] This in part reflects the wide range of capabilities and resourcing between the larger city and urban based councils compared to the smaller suburban and regional councils.

8 Productivity Commission, *Data Use and Availability*, March 2017, p. 2 & 73. https://www.pc.gov.au/inquiries/completed/data-access/report

9 Department of Prime Minister and Cabinet, *Data Sharing and Release: Legislative Reforms Discussion paper*, September 2019. https://www.datacommissioner.gov.au/resources/discussion-paper

10 Ibid, p. 15.

11 Open Council Data, https://opencouncildata.org/

3 Future State: A Digital Twin Ecosystem in Australia

3.1 Introduction

The *Principles for Spatially Enabled Digital Twins of the Built and Natural Environment in Australia* refers to the desired future state of a digital twin ecosystem in Australia, collaborating and sharing data, to create shared value. This section provides a description of the key components of federated digital twins in this ecosystem, as well as the different roles involved, a digital twin maturity model and data sharing stages to help guide progress of organisations and government jurisdictions.

3.2 A Digital Twin Ecosystem in Australia

The *Principles for Spatially Enabled Digital Twins of the Built and Natural Environment in Australia* outlines a vision of a 'digital twin ecosystem for Australia would comprise interoperable data and connected digital twins governed by authentication and authorisation rules to enable role-based access to securely shared data'.[12]

It is described as a federated ecosystem of digital twins that 'cut across a broad range of government (i.e. Commonwealth, state, territory and local) and industry (e.g. construction, manufacturing, transport infrastructure, utilities) sectors, with no single owner or contributor' and where data can 'flow across the ecosystem while maintaining clear data custodianship for contributors, appropriate protections for private, confidential and sensitive information and consideration of commercial impacts, such as intellectual property'.

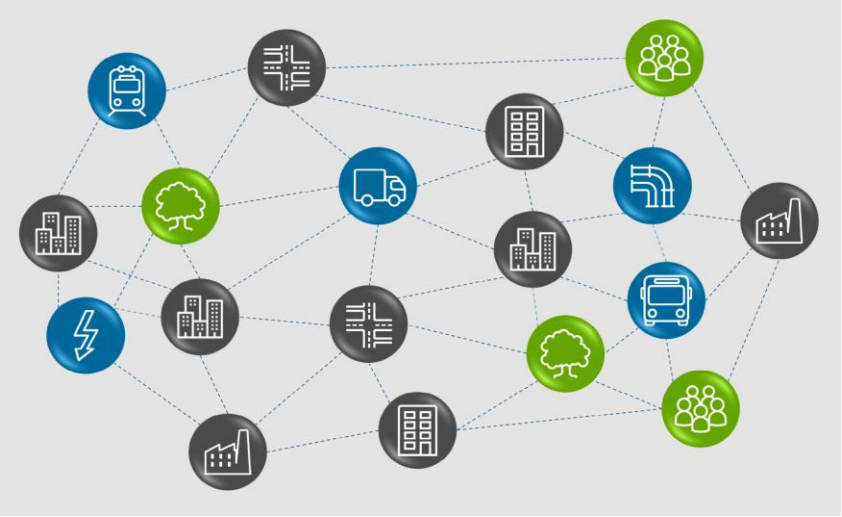

Diagram 7: National Ecosystem of Digital Twins

Key elements of a digital twin ecosystem in Australia include:

- **Agreed rules, protocols and standards** to discover, share and access data, services and capability including agreed approaches for authentication of user identity and role, authorisation to access particular data (or levels of detail/granularity of data), and access conditions (such as access costs, licence and use restrictions).
- Ensuring **data custodianship** and authority remains with the contributing organisation so that custodians can maintain control over shared data, monitor access to and use of their data through role-based access, and maintain authority for their respective functions and data.
- Defining **digital twin-compatible data** (i.e. interoperable, compatible, cross-platform and platform-agnostic) that will allow for digital twins in different sectors and government jurisdictions to mature at different rates

12 *Principles for Spatially Enabled Digital Twins of the Built and Natural Environment in Australia*, p. 13.

and levels of complexity.

- **Seamless integration** of government and non-government data to realise the benefits of combining industry, government, research and community sector data.
- **Maintaining data over time** so that it accurately reflects the current environment and changes in the environment, where responsibility for ensuring data is up-to-date, accurate, quality assured and compatible would reside with data custodians and/or digital twin operators.
- **Customisable, user-driven access to data** in a form that can leverage new technologies and adapt to user needs, such as connecting digital twins in a particular region or city for localised insights.[13]

3.3 Digital Twin Components

The generic components of a digital twin include:

- *Digital Twin Data*
  Digital twin data can come from a wide variety of data types and a wide variety of organisations. Data sources can include foundation spatial data, statistical data, streaming data from Internet of things devices, imagery, etc. Data sources for a digital twin can come from multiple organisations and a data source can be used in multiple digital twins.
- *Digital Twin Data Services*
  Digital twin data services are those that transform and coordinate the different data sources so they are fit for purpose for the use in a digital twin platform. This could involve transforming a file into the required format, making data discoverable and accessible, providing access to authorised users, linking and integrating different data sources, operating a data marketplace for exchange and sale of data, etc.
- *Digital Twin Platforms/Applications*
  Digital twin platforms/applications are systems that ingest the data sources enabled by the data services to perform functions such as visualisation, analytics and/or workflow (supporting decisions and control systems). These functions could be done on specialist platforms, applications or integrated into a single system.
- *Digital Twin Use:*
  Digital twin use is where the digital twin services are consumed by the end users. This can be done either as an open service available for any users or as only within a defined user group.

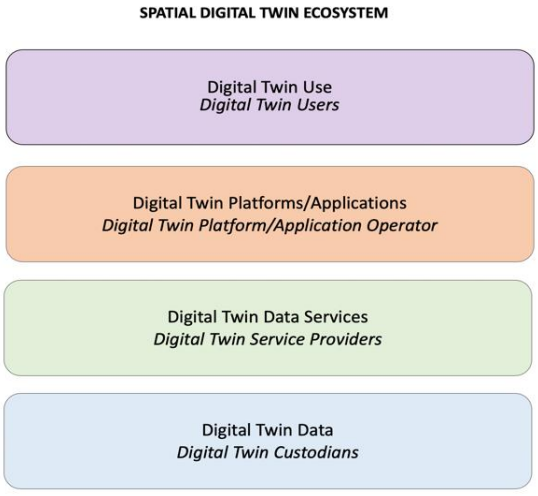

Diagram 3: Generic components of a digital twin service

13 Ibid, p. 13. Note: Data is not always going to be "up-to-date" but it should expose its date transparently to consumers, e.g. reality mesh captured July 2018, and with specific updates to areas as they occur.

The functions of these components, in the context of a federated digital twin environment, is explained in more detail in Section 4.

Digital Twins can operate at different levels of detail from the sub-millimetre level to national and global scales. This is where the different practices of Computer-Aided Design (CAD), Building Information Modelling (BIM) and Geographic Information Systems (GIS) intersect having been used to working at different level of detail mostly using different systems and data formats.

3.4 Digital Twin Roles

There are number of roles organisations can have within a digital twin ecosystem that relate to its component (as listed above). An organisation can occupy a combination or all of these roles.

- *Digital Twin Platform/Application Operator*
  This is an organisation or group of organisations that are responsible for developing, operating and maintaining a digital twin platform or application including its partnerships and engagement with other roles.
- *Digital Twin Data Service Provider*
  This is an organisation that provide Digital Twin Data Services to either Data Custodians or Digital Twin Platform Operators
- *Digital Twin Data Custodian*
  This is an organisation that collects, generates and maintains data for the purpose of carrying out their functions.
- *Digital Twin Data User*
  This is a person or organisation that is the end user of the Digital Twin platform and data that are able to draw insights and decision support about issues of interest.
- *Digital Twin Stakeholder*
  This is a person or organisation that could be impacted by the Digital Twin, either in connection with the supply and use of data that could be personal or confidential.

An emergency service organisation is an example of an organisation that plays multiple roles. This organisation may have purchased and operate a digital twin platform to visualise and analyse emergencies, they may provide a variety of their own data sources into the platform but acquire data sources from other organisations and contract in some functions from a Digital Twin Data Services provider to transform and integrate this data. Alternatively, an environmental agency may supply its data to a number of Digital Twins operated by different groups.

Understanding these different roles is important in developing effective governance and collaboration models. These roles closely align with the data roles outlined by the Office of the National Data Commissioner with the addition of the roles for Digital Twin Platform/Application Operator and Digital Twin Stakeholder. The major difference is that the Australian Government is proposing to accredit some of these roles for access to its data whereas other sectors and jurisdictions may not require this.

3.5 Digital Twin Maturity Model

Maturity models have been developed to describe the different stages of development and capability of digital twins with integrating data to represent, model and control the physical world.

The *Principles for Spatially Enabled Digital Twins of the Built and Natural Environment in Australia* has adopted a six level digital twin maturity model to help guide the development of spatially enabled digital twins for

Australia.[14] This starts at 'Level 0 Locate' that provides the spatial foundation data as the authoritative organising element through to Levels 3 to 6 where the digital twin models are enriched with real-time data that enables decision making, digital control and even autonomous operations. While this maturity model is useful in highlighting the important role of IoT data in bring a digital twin to life (energising and actuating), it needs to also consider the maturity levels progressing from simple visualisation through to more complex modelling and workflow applications (see Section 4.8).

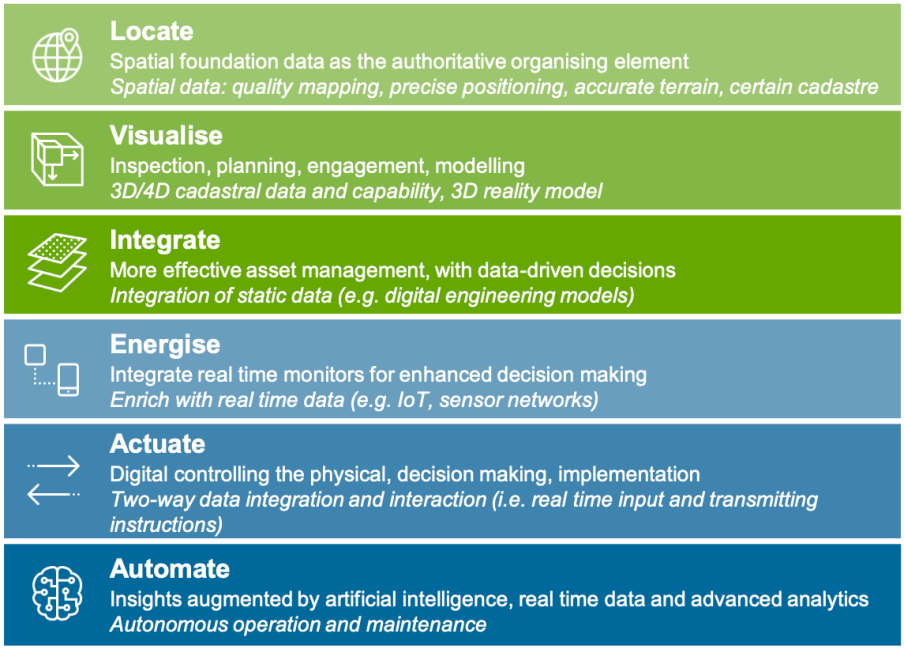

Diagram 4: Spatially enabled digital twin maturity model illustrating the evolution in complexity, connectivity and capability. Integration of dynamic, real time data moves digital twins beyond static data platforms. Maturity levels are not necessarily linear; there are benefits in data upgrades and analytics at any stage.

The ability to realise the benefits of spatially enabled digital twins and use them effectively will depend on their evolving maturity. Creating highly autonomous spatially enabled digital twins is ambitious, and not always necessary, as they can provide significant value in earlier levels of maturity. These include visualisation capabilities from aligning spatial data for design and coordination purposes; planning capabilities from integrating static data such as digital engineering models; analytical capabilities from real time data; and management capabilities that arise from being able to control physical elements through the digital twin.

There are also other aspects relevant to the maturity of digital twins in terms of their role in a national ecosystem of digital twins. This relates to their level of collaboration, openness, adoption of common standards and data sharing with other digital twins as outlined in the *Principles for Spatially Enabled Digital Twins of the Built and Natural Environment in Australia*. Appendix A provides a Checklist for Alignment to the principles as a process for digital twin operators to assess their alignment and maturity in terms of supporting a national ecosystem of digital twins.

14 *Principles for Spatially Enabled Digital Twins of the Built and Natural Environment in Australia*, p.12.
This maturity model was adapted from Institution of Engineering and Technology (IET) and SNC-Lavalin
Institution of Engineering and Technology (IET) and SNC-Lavalin, *Digital twins for the built environment*, 2019
https://www.snclavalin.com/~/media/Files/S/SNC-Lavalin/documents/beyond-engineering/digital-twins-for-the-built-environment-iet-atkins.pdf

3.6 Data Sharing Maturity Stages

As outlined in Sections 2 and 3.4, the success of an ecosystem of digital twins in Australia to deliver public value will depend on the ability of data custodians to easily release or share their data with authorised users in a trusted and secure manner. This needs to be done collaboratively across all sectors while also ensuring private and confidential information is appropriately protected.

A three stage data sharing maturity model has been proposed to help guide the development of spatially enabled digital twins for Australia. These stages are:

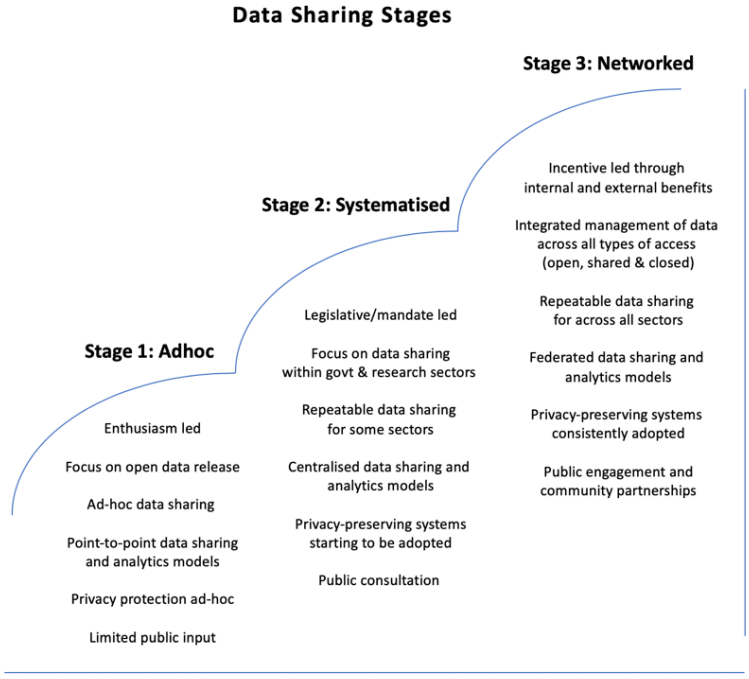

Diagram 6: Data Sharing Stages

- ***Stage 1: Adhoc Data Release and Sharing***
  The stage describes the early period of open data release that was mostly led by enthusiasm from government agencies and where data sharing was mostly adhoc and with limited understand of privacy protection and public consultation (other than through hack events). The dominate model for data sharing is through point-to-point arrangements.
- ***Stage 2: Systematised Data Sharing***
  The stage describes the current period that is led by government legislation/mandates and is focused primarily on data sharing within government and the research sector. For some sectors, repeatable data sharing arrangements are emerging and privacy preserving systems and public consultation are being more widely adopted. The dominate model for data sharing is through centralised arrangements.
- ***Stage 3: Networked Data Management***
  This is an emerging stage where data sharing involves all sectors (government, research, industry and the community) and is being driven less by legislation/mandate and enthusiasm but is more incentive led through the internal benefits to an organisation or from external public value. Organisations manage their data in an integrated manner supporting all modes of access (open, shared or closed). Repeatable data sharing arrangements (such as role based access) and privacy preserving systems are the default position. Also new models for networked governance for data release and sharing are developed incorporating all sectors including community interests. The dominate model for data sharing is through federated arrangements.

Different organisations and sectors, including different government jurisdictions, are at different stages through this maturity model.

3.7 Data Sharing Models

There are three general data models for how data is shared between organisations. These describe both the system architecture about how different ways data is discovered, accessed, integrated, stored and used as well as the institutional arrangements by which data can be shared (eg data sharing agreements and partnerships).[15]

The models include:

- ***Point-to-point*:** where data is exchanged on an ad-hoc basis directly between agencies with little consistency in use of standards, formats and agreements with no shared platforms or intermediaries. This is the default data exchange pattern for most Australian government jurisdictions where each agency is responsible for costs.
- ***Centralised*:** where data is aggregated and/or collected by a central intermediary that has responsibility for transforming it to ensure consistency, providing a uniform interface for users of the data and bearing the cost of doing so. The ABS is an example of this model.
- ***Federated*:** where data is exchanged on a co-ordinated basis between agencies based on the use of standards and/or shared platforms that can process and transform data (eg API gateways, data linkage, etc). Under this model, the source of data remains with the data custodians with a minimum amount of persistent data stored on shared platforms or with an intermediary. This is an emerging model for the government jurisdictions and cross-sector data sharing where the cost is primarily borne by the data provider with some additional funding for coordination and shared platforms.

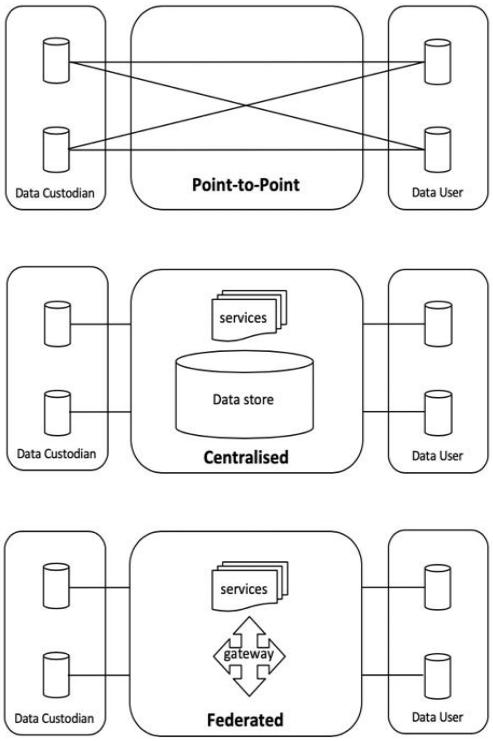

Diagram 5: Data Sharing Models

The Federated model for data sharing is considered the optimal one for developing a national ecosystem of digital twins as it is the most sustainable, flexible and scalable approach to support the required level of data sharing and collaboration. This model also retains the central role of the data custodian in managing their data and enabling data sharing.

The challenge of the federated model of data sharing is that it requires cross-agency/organisation agreement on standardised processes about data quality, metadata, data sharing agreements as coordinating infrastructure to enable automated functions such as data discovery, integrated and access. These responsibilities are described in more detail in Section 4 and 6.

15 These data integration models/architectures are informed by the geospatial interaction models defined by CSIRO for the Australian Government's *Foundation Spatial Data Framework* (FSDF). This framework has been referenced in the 2016 Productivity Commission's draft *Report on Data Availability and Use* 2017.
CSIRO, *A Data Specification Framework for the Foundation Spatial Data Framework*, 2015
https://www.anzlic.gov.au/sites/default/files/files/FSDF-Data_Specification_Framework.pdf

3.8 Key Challenges to be Addressed

There are a number of key challenges that need be addressed to realise the development of an ecosystem of digital twins in Australia. Most of these challenges will take sustained effort over time to address. It is expected that while immediate progress can be made through the promotion of leading best practice examples of digital twins, the development of a national ecosystem of digital twins will take a longer.

The immediate key challenges include:

a) Availability and use of foundation spatial and related data services

Foundation spatial data is required to accurately locate digital twins. This includes the need to update Australia's cadastre data (land and property parcels) so it is more accurate in terms of level of detail (LOD), available on 3D and up-to-date. This is important as Australia's cities are increasingly developed with multistorey buildings and underground infrastructure, the ability to show their positioning relative to corresponding property information in 3D is required. This will allow for example a digital twin of a building based on Building Information Model (BIM) data to be incorporated into a city wide digital twin model. It is expected that as more digital twins emerge, there will be a need for similar improvements in Australia's other foundation spatial and related data services.

b) Increasing the level of data sharing and open data release by making this process easier and removing barriers (for both data custodians and data users)

While there are many government datasets that have been openly released or shared, this process is still relatively ad hoc and unstructured, whilst efficient and fair data markets for commercial data exchange are still immature and suboptimal. There are also significant cultural, institutional, capability and resourcing related barriers to data sharing that need to be addressed to make more relevant data available for use in digital twins. This requires step changes in how data is managed, openly released or shared in an integrated manner not only within government but across sectors.

c) Ensuring trust in the use of private and confidential data with processes and protocols to ensure it is protected and only shared with authorised users

The lack of confidence that our private and confidential data can be protected from unauthorised use is a major concern to many data custodians and other stakeholders. Improved privacy-preserving processes and protocols are required to ensure private and confidential data can be shared safely with authorised user data and that any risks can be identified and mitigated appropriately. This also requires a greater level of transparency about data sharing and public engagement about the benefits and risks to create and maintain the social licence to operate. For example, high resolution reality mesh can see into private spaces of homes, offices and other facilities.

d) Adoption and ongoing maintenance of fit for purpose data by Data Custodians by using common open standards, protocols and quality controls

Currently there is an adhoc approach to the adoption and implementation of open standards by many data custodians, making it more difficult to share important data easily. There are also major deficiencies in how data custodians understand and describe the quality of their data in a consistent manner that it meets the needs of users and stakeholders. This means data custodians and digital twin operators have a responsibility for ensuring their data and services are up-to-date, accurate, quality assured and compatible, such that data is useable and interoperable with other ecosystem data and digital twins.

e) Adoption of a common understanding about digital twins and new governance arrangements that include all stakeholders to help realise shared benefits

The governance of data sharing in Australia currently operates mostly within each government jurisdiction with limited arrangements between government jurisdictions or across multiple sectors. An ecosystem of digital twins that operate across jurisdictions and sectors will need to be supported by new governance arrangements that is more networked and collaborative in nature to incorporate the interests and participation from government, industry, research and community sectors.

e) Sustainable resourcing for enabling coordination, shared infrastructure and data services for digital twins as well for developing capability in less mature and resourced organisations

This will ensure that digital twins and enabling coordination activities, shared infrastructure (eg data directories, access control and platforms) and data services are properly resourced not just for development but also for ongoing maintenance where this is required. There is also a need to ensure that there is appropriate investment and support for developing capability for less mature and resourced organisations (eg resource constrained local councils, etc).

In addressing these challenges, there also needs to be recognition about potential conflicts and trade-offs between potential actions. Examples of this include:

- How to balance the creation of value through the promotion of openness, data sharing and use of data at the right level of detail while at the same time protecting private and sensitive information from inappropriate use?
- How to encourage and incentivise Data Custodians to release and share data that is maintained in a fit-for-purpose manner with quality controls, appropriate metadata and accessible as a data service where the costs may be disproportional to the benefits back to the organisation?
- How to create consistent role-based access across jurisdictions and industry domains where there is no agreed nation-wide definitions of these roles?
- What role is there for mandates and other 'sticks' to promote data release and sharing, adoption of secure and privacy preserving systems, and support for common open standards and shared systems?
- How to create the effective data exchange mechanism that both promotes data release and sharing with no charges but also supports the development of fair and efficient data markets where commercial mechanisms can resource the development and supply of high quality data?
- How to get the right balance between promoting leading examples of digital twin development and value while supporting raising capabilities of organisations and people more broadly?

3.9 Key Success Measures

Key success measures for the implementation of the *Framework for Spatially Enabled Digital Twin* include:

- The quantified benefits and public value created by digital twins.
- The amount of data that is shared between organisations and digital twins that are compliant with the *Principles for Spatially Enabled Digital Twins of the Built and Natural Environment in Australia* and use automated data services (eg APIs).
- There are processes to identify and access high-value data sets within government jurisdictions, industry domains and across sectors.
- The widespread adoption of best-practice privacy preserving data sharing systems and tools.
- The level of transparency about the release, sharing and use of data by digital twins and data custodians. This includes releasing metadata about all open and shared datasets, data sharing agreements and for what purpose and benefit the data is being used.
- The level of public awareness, use and trust of digital twins and associated data sharing and use.
- The level of skills, confidence and resourcing available for less mature organisations such as less capable local government organisations to support and use digital twins

4 Information and Technology Framework: Federated Digital Twins

4.1 Overview

This section outlines the generic functions and architecture for individual digital twins and a federated ecosystem of spatially enabled Digital Twins. These relate to both information and technical functions required to make this model successful.

The diagram below of a federated spatial Digital Twin shows the functions that need to be managed as shared services to support coordination of the Twin's ecosystem of Digital Twin Data Custodians, Digital Twin Data Service Providers, Digital Twin Platform/Application Operators and Digital Twin Users (roles outlined in Section 3.2).

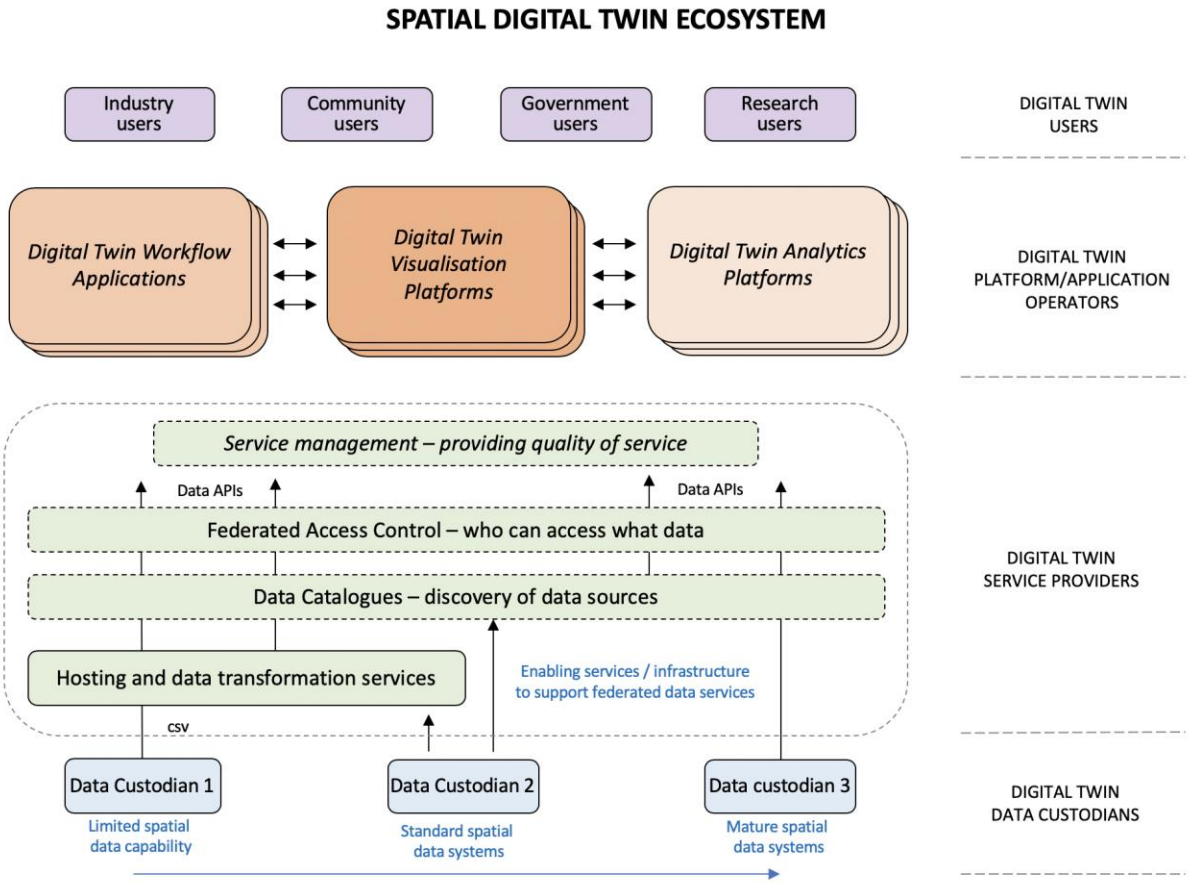

Diagram 8: Federated Spatial Digital Twin Functional Architecture
Beginning from the bottom, the light blue layer shows the Digital Twin Data Custodians who may have different level of capability with providing spatial data services. The light green layer shows the Digital Twin Data Services that may be provided in whole or part by external Digital Twin Data Service Providers. The brown layer above shows the Digital Twin Platforms/Applications that could include Visualisation and/or Analytics Platforms and/or Workflow Applications. The top purple layer shows the Digital Twin Users that could be from industry, community, government and/or research sectors.

4.2 Data Catalogue – Discovery of data sources

The ability to discover available data sources from different organisations for inclusion and use in a federated Digital Twin is a fundamental function. This can be achieved through the use of a data catalogue/registry that provides a list of available data that includes relevant metadata and access arrangements (covering both open and shared data within a closed user group). In turn, each data catalogue/registry should support standards that allow its metadata to be harvested and displayed in other data catalogues/registries.

The data catalogues/registries should provide metadata and general information about other functions including:

- Use of relevant data standards
- Data quality statements
- Data sharing conditions and licensing arrangements (eg what role based access to what category of user)
- Level of private or sensitive information contained in the data
- API access including Quality of Service (QoS)

Integrated processes and systems are required to create and manage consistent metadata allowing data to be easily discovered within an agency, across agencies and from outside government are critical building blocks for data sharing to support a federated Digital Twin.

Government and other data assets need to be both discoverable and in a form that others, whether inside the originating agency, in other agencies, or outside government, can search and access efficiently and accurately.

Discoverability of datasets can be addressed through the use of a data catalogue. The content of many datasets may be sensitive, and therefore access should be strictly controlled. However, the existence of each dataset, and the details of its metadata, should be generally made available on an open basis.[16] This allows potential users to search a catalogue for dataset(s) that might be of use to them and contact the data custodian to request permission to access the data. This process can be automated if the Data custodian has enabled API access for users.

The target end state is to have data catalogues that allow users to discover all relevant datasets held by any agency, understand the content, quality, lineage and schema of the datasets through detailed metadata so they can decide if the dataset is of value. Additionally, there should be a federated process to harvest metadata from agency information asset registries and make this available for searching through whole-of-government data catalogues.

4.3 Data Standards and Quality Control

Data standards should reference where possible existing common and emerging open standards as endorsed through relevant standards bodies. These standards can relate to specific formats for capturing, describing, storing and communicating data or can relate to general management processes related to data and business services.

ANZLIC and the Intergovernmental Committee on Surveying and Mapping (ICSM) have established the Australian and New Zealand, Location Information Metadata Working Group (ANZMDWG) as an advisory group and forum related to location information metadata standards and adoption.[17]

16 The Productivity Commission recommended that "All Australian Government agencies should publish information on their data holdings on a central registry. This would enhance the use of data as it becomes more discoverable, and would reduce duplicated data collection, which burdens government agencies and the public".
Productivity Commission, *Data Availability and Use,* March 2017, p. 290.
https://www.pc.gov.au/inquiries/completed/data-access/report/data-access.pdf

17 ICSM, Metadata Working Group
https://www.icsm.gov.au/what-we-do/metadata-working-group

Data quality is the other key concept critical to the success of a digital twin. Digital twins will require data is made available at a specific quality level necessary to support its intended use cases (eg level of detail, timeliness or availability of data required for end users, etc).

Data quality standards, such as ISO 25012, identify the difference between an internal versus external view of data – one describes inherent data quality (accuracy, completeness, consistency, credibility and currency) versus systems dependent data quality (eg availability, portability, recoverability) with some attributes shared (eg accessibility, compliance, confidentiality, efficiency, precision, traceability and understandability).[18] Other simpler methods of defining data quality focus on the systems, accessibility and presentation aspects of data (eg Tim Berners-Lee's 5 Star Rating which has been adapted for use by the Australian Government's Data Portal data.gov.au and the Open Data Institute (ODI)'s Data Open Data Certificates which has been adopted for use by the Queensland Open Data Portal www.data.qld.gov.au).[19]

Data quality can be defined from two perspectives; from the Data Custodian as data supplier and the other from the data consumer as Digital Twin Data User and/or Digital Twin Manager. While the Data Custodian can describe the quality of their data, this may not accord with the needs of the data consumers. The optimal approach involves communication and agreement between Data Custodians and Data Users about the required level of quality.

There is also a need to define the governance arrangements for selecting data standards and expectations about how data quality is managed, certified and reported. This should include how data standards are promoted, gaps in data standards are addressed and how support for adoption of data standards and data quality levels can be achieved by different digital twin participants.

Digital Twin Platform/Application Operators should work with Data Custodians to provide 'digital twin assured' data services so they are fit-for-purpose by data users of the digital twin (eg a secure, accessible, documented and curated datasets that align with the *Principles for Spatially Enabled Digital Twins of the Built and Natural Environment in Australia* – see Appendix A for details about draft criteria.).

4.4 Federated Authentication and Access Control

A key element of a Federated Digital Twin environment is an agreed, common approach for authentication of user identity and role, and agreed rules around authorisation to access particular data (or levels of detail/granularity of data) within the ecosystem and conditions of access (such as access costs, licence and use restrictions). The approach will define the rules of how digital twins that comprise the ecosystem interact, and will support establishment of federated digital twin-compliant datasets. The federated model will allow data custodians to maintain control, monitoring access to and use of their data within the ecosystem.

Federated Access Control, that incorporates authentication, authorisations and access, enables users of one organisation/domain to access securely data or systems of another organisation/domain seamlessly, and without the need for an additional centralised user access administration.

There are a number of existing services that can be used to support a Federated Access Control solution for Digital Twins including:

- VANguard (Australian Government authentication service);[20]
- State Government identity management and access control services;
- Australian Access Federation (research sector authentication solution);[21]
- Industry based access control services

18 ISO, Data quality model (ISO 25012)
https://iso25000.com/index.php/en/iso-25000-standards/iso-25012
See also ISO 19157:2013 Geographic information — Data quality

19 Open Data Institute, Comparing the 5-star scheme with Open Data Certificates,
https://oldsite.theodi.org/blog/5-star-open-data-certificates-tim-berners-lee

20 Department of Industry, Science, Energy & Resources, VANGuard,
https://www.industry.gov.au/government-to-government/vanguard

21 Australian Access Federation, https://aaf.edu.au/

The Queensland Government has created a Federated Identity Blueprint for whole-of-government federated identity that is intended to span both the public and private sectors, in an effort to transform service delivery. This is intended to guide Queensland agencies in their implementation of "trusted identity management practices" for the sharing of assured identities.[22] The Blueprint seeks to encourage a federated model of authentication for identity, whereby an individual known to one body can be authenticated by another to whom access is being sought by the individual.

The Australian Government is implementing a Trusted Digital Identification Framework (TDIF) that is intended to provide a shared Federated Access Control solution available for all government jurisdictions and non-government organisations (eg utilities, banks, etc). This TDIF includes multiple trusted Identity Service Providers, an authentication exchange, and relying digital services.[23] It is expected that the TDIF will provide the preferred approach over time to providing Federated Access Control solutions for Digital Twins that have users from multiple government jurisdictions, industry, research and community organisations.

Federated Access Control solutions should also define categories of trusted users and service providers to support a more secured and scalable method of data sharing. These categories may include a combination of group and/or role based access conditions, as well as categories of trusted organisations, processes and people. These should where possible map to the ONDC's framework for Accredited Data Users, Accredited Data Service Providers and best practice safe data sharing frameworks such as the Five Safes Framework (see Section 2.4).[24]

4.5 Privacy and secure data sharing

The operators of a Digital Twin need to identify and protect private and sensitive data and ensure it is shared securely and used appropriately only with authorised users. This includes the adoption of best practice policies and procedures to identify sensitive and private data to support safe and secure data sharing (eg Five Safes Framework).[25]

This also includes the adoption of tools and services to assess risks and ensure data is shared at an appropriate level with authorised users. These tools and services will allow data custodians to measure the privacy risks of releasing a dataset, or a subset of a dataset and in what form, based on what third party data might be available to someone accessing that data.[26] There are also tools and services that can control what level of data is made available to different users depending on the level of trust.

The sharing of detailed spatial data presents new challenges in terms of privacy and social licence, even if the spatial data is not directly linked to Personally Identified Information (PII). For example, detailed interior information about a private residence could be linked to a specific person or persons through the use of third party data.

The operators of a Digital Twin also need to adopt appropriate cybersecurity measures to protect private and sensitive data. As a baseline response, they should apply the Australian Signals Directorate's prioritised mitigation framework known as the Essential Eight, to help organisations mitigate cyber security incidents

22 Queensland Government Enterprise Architecture, Federated Identity Blueprint Guideline, May 2017, https://www.qgcio.qld.gov.au/documents/federated-identity-blueprint

23 Digital Transformation Agency, Trusted Digital Identity Framework, https://www.dta.gov.au/our-projects/digital-identity/join-identity-federation/accreditation-and-onboarding/trusted-digital-identity-framework

24 Department of Prime Minister and Cabinet, Data Sharing and Release: Legislative Reforms Discussion paper, September 2019. https://www.datacommissioner.gov.au/resources/discussion-paper

25 ABS, Managing the Risk of Disclosure: The Five Safes Framework, https://www.abs.gov.au/ausstats/abs@.nsf/Latestproducts/1160.0Main%20Features4Aug%202017
See also Australian Computer Society, Privacy-Preserving Data Sharing Frameworks: People, Projects, Data and Output, Dec 2019, https://www.acs.org.au/insightsandpublications/reports-publications/privacy-preserving-data-sharing-frameworks.html

26 Data61, The Re-identification Risk Ready Reckoner (R4), https://data61.csiro.au/en/Our-Research/Our-Work/R4

caused by various cyber threats. The framework is accompanied by a maturity model to help organisations assess their capability.[27]

4.6 Hosting and data transformation services

Hosting and transformation services are required to enable data to be made available in appropriate formats and quality to allow Data Custodians to share their data sources with Digital Twins. This may involve transforming legacy spatial and statistical data into formats suitable for consumption in a digital twin and also enabling data services as APIs. The intention is that downloading data into a digital twin should be the exception with the majority of data accessed directly from the Data Custodian's primary data source. Data Custodians may also require help with converting their data such as 3D and BIM data into open formats that can be used in a Digital Twin service that uses a web browser interface.

Data Custodians may manage these hosting and transformation processes internally if they have the capabilities and business need, while many are likely to use external Data Service Providers to do some or all of them. For organisations with less capability and resourcing capacity, shared service solutions could help them make their data available for use in a digital twin at the appropriate formats and level of quality. This means that organisations such as smaller regional councils that only have data available as spreadsheets or bulk uploads, can contribute these as data services into a digital twin environment.

4.7 Service Management and linkage services

There may also be the need for Service Management functions that can coordinate and manage the quality of data services made available to a digital twin and provide additional data integration and privacy-preserving data services. These include:

- API Gateways that support automated discovery and access to APIs, manage quality of service, notifications and provide performance monitoring of data use and incidents. These functions are important where digital twin users require reliability and quality of service (QoS) in accessing data services. For example, emergency service organisations may require prioritised access to reliable data services when using a digital twin in an emergency.
- Usage monitoring and audit services, that can be provided through a variety of other methods, is important to provide information to Data Custodians and Digital Twin Operators about the use of different data and by category of users. Analytics could be used identify fraudulent users and datasets that have suspect curation practices or data provenance.
- User feedback and quality management: processes should be implemented to track user and stakeholder feedback and requests. This is particularly important in terms of improving the quality of services and identify issues of concern.
- Data linkage services are required to link information that refers to the same entity, object or location from multiple datasets, potentially obtained from different sources. Data linkage services can be grouped into deterministic and probabilistic techniques. Deterministic data linkage determines links between two records in different datasets by applying rules to high quality identifiers common to the datasets. Alternatively, probabilistic data linkage techniques use multiple less structured identifiers to compute the probability that two records refer to the same individual or entity. Both deterministic and probabilistic linkage can be achieved either directly or privately. In direct linkage, a common identifier, likely personal information or derived therefrom, of the two datasets is used to match the corresponding rows. In order to privately link two datasets, the key used for matching must be derived from one or more common identifiers in such a way that personal information is not disclosed and cannot be reconstructed.

27 Australian Signals Directorate, The Essential Eight: Strategies to Mitigate Cyber Security Incidents, https://www.cyber.gov.au/publications/essential-eight-explained

4.8 Digital Twin Platforms/Applications

Digital Twin Platforms are systems that consume the data sources enabled by the data services to perform functions for end users such as visualisation, analytics and/or workflow (supporting decisions and control systems). These functions could be done on either specialist platforms or integrated into a single platform. Stand-alone digital twin platforms are generally operated through on-premise hosting services whereas federated digital twin platforms are generally operated through shared hosting facilities.

4.8.1 Visualisation Platforms

Visualisation services should be able to display the digital twin's data in both 3D and 4D using the enabling data services such as data catalogues, federated access controls, service management and linkage services.

Digital twin visualisation services have traditionally been bundled into integrated proprietary systems with custom client software for end users. Alternatively, digital twin visualisation platforms can also be provided to end users through modern web browsers that can support 3D graphics.

Visualisation platforms can be used as stand-alone services to support situation awareness and interrogation of different digital objects and data in context to provide decision support. They can also be used to help understand data quality and relationships in association with analytic services and workflow applications.

4.8.2 Analytics Services

Analytics services can range from simple statistical processing tools through to more complex modelling, simulation and optimisation systems using advanced analytics such as machine learning and agent based modelling. While simple analytic tools can operate in close to real-time using live data services, most advanced analytic services require offline processing of downloaded data in high performance computing environments. As such, complex analytics generally needs to be done outside of a visualisation platform although the results of the analysis can be exported and displayed once they are available.

Operators of Digital Twin analytics services also need to describe and communicate their data requirements for their analytic systems with Data Custodians (eg they require vector data rather than point data, or data on surface materials and volumes to support fluid modelling of floods, etc). There is also an increasing expectation that advanced analytic services provide transparency about their modelling assumptions, algorithms and adherence to ethical principles.[28]

4.8.3 Workflow Applications

Workflow applications are digital twin platforms that can extend analytic services with workflow functions that allow end users to combine select and interrogate existing and new data to support decisions, compliance or some other function. Workflow systems are generally integrated with a combination of visualisation and analytic services. An example of workflow applications is the ArchiStar application that allows property developers and real estate agents to analyse the development potential of any block of land using an analytics engine.[29]

28 Department of Industry, Science, Energy & Resources, *AI Ethics Principles*,2019. https://www.industry.gov.au/data-and-publications/building-australias-artificial-intelligence-capability/ai-ethics-framework/ai-ethics-principles

29 Archistar, Archistar Property Intelligence, https://archistar.ai/

5 Social Framework: Federated Digital Twins

5.1 Overview

This section outlines the generic social architecture that is required for individual digital twins and the federated national ecosystem of spatially enabled Digital Twins. These relate to the alignment of stakeholder understanding, the support for a shared vision and key concepts and processes related to the development of digital twins, as well as the supporting cultural, policy, institutional and governance processes required. There is also a need to recognise that there are social aspects embedded in the design and development of digital twins, rather than being simply a technological activity. This understanding of the social architecture will increase the chances of digital twins realising benefits to stakeholders and the wider community.

5.2 Commons: shared language, concepts and standards

A critical enabler for the digital twin ecosystem is the adoption of a shared language to describe and understand what digital twins are, how they operate and what impact they can have. This needs to be accompanied by a shared understanding and support for common processes, specifications and standards. This in turn needs to be informed by a shared vision and set of principles as set out in the *Principles for Spatially Enabled Digital Twins of the Built and Natural Environment in Australia*. These elements are what constitutes the 'commons' – the social and technical architecture that underpins collective action and shared public good.

In practice, this means starting with the basics about promoting common terminology among stakeholders and the general public. The language and understanding of terms relating to digital twins varies considerably between different industry sectors and disciplinary domains, as well as public, private and community sectors. Surveys also indicate that the general public has little awareness of or understanding about the development and role of digital twins. A glossary of key terminology should be socialised with stakeholders to facilitate clarity and consistency.

The digital twin ecosystem also needs to be enabled by shared cultural values that promote data sharing, appropriate use, protections and transparency. While there is much good work commenced to promote such values within different government jurisdictions and other sectors, cultural barriers still remain relating to a range of factors such as perceived risks, loss of authority or competitive advantage. Further effort is required to promote awareness about digital twins and the case for change with the general public.

The digital twin ecosystem also needs to promote a common approach and adoption of existing open standards to help ensure the exchange of data within and between digital twins is vendor neutral and unrestricted. There is also a need to continuously identify and promote emerging open standards and suitable defacto solutions that allow for the open exchange of data and platform components.

Data standards also need to be supported by a common information model including data schemas, taxonomies, integration architectures and reference libraries. It is proposed that managers of individual twins will align their information architectures, leading over time towards a more integrated and common national approach.

5.3 Alignment with relevant policies and initiatives

The development of the digital twin ecosystem should identify and ensure the alignment where appropriate with other relevant policies and initiatives. This will ensure that the digital twin ecosystem can build on, leverage and extend where necessary on existing efforts. These are in effect a foundation for the 'commons' required to support the digital twin ecosystem.

These include general government policies and programs relating to open data release, data sharing and related digital transformation of services. It also includes sectoral and industry based initiatives relating to the built and natural environment, at both a national and international level.

Some of the relevant sectoral policies and industry based initiatives include:

- Spatial:
  Foundation Spatial Data Framework (FSDF)[30], Physical Environment Analysis Network (PEAN)31, Emergency Management Spatial Information Network Australia (EMSINA)[32], Australian Geoscience Information Network (AUSGIN)[33], etc
- Building Information Modelling (BIM):
  Australasian BIM Advisory Board (promoting consistent approaches to BIM practices, standards and requirements) [34], *Queensland Government Principles for BIM Implementation* [35], *etc*
- Environmental:
  Environmental Resources Information Network (ERIN)[36], Atlas of Living Australia (ALA) [37], etc
- Cities:
  Australian Government, *National Cities Performance Framework* [38], etc;
- International:
  United Kingdom Centre for Digital Built Britain, *Digital Twin Roadmap* [39], buildingSMART (bSA) (promoting open Building Information Model (BIM) standards) [40], etc.

Australian governments at all levels, also have many relevant policies and initiatives that are aligned and provide support for generic data management relevant for digital twins. State Government groups such as the Queensland Government have developed several high-level information sharing frameworks as part of the Queensland Government Enterprise Architecture (QGEA).

5.4 Data sharing arrangements and licences

The digital twin ecosystem will need to be supported by more consistent data sharing agreements and licences that make it easier and predictable to access and use data. These agreements generally specify what data can be accessed, by who, for what time period and what they can do with it, as well as the safeguards and remedies in place to prevent its misuse. These agreements can also clarify the sometimes confusing and conflicting approaches to licensing compared to assigning copyright or ownership of data to a third party.

Currently, data sharing between organisations generally happens via a patchwork of mechanisms. For Australian governments, sharing non-released data (even when not personal in nature) between agencies and external users is too often a piecemeal process with a mix of different types of data sharing agreements including MOUs, contracts, deeds, letters of exchange, undertakings, licences, head of agency/ministerial agreements, and public interest certificates. Arrangements might be one-off or ongoing, may or may not involve a payment for costs, are typically long and complex and involve negotiation.

There are existing government initiatives to promote frameworks for more consistent data sharing agreements and licences. In March 2016, the Australian Government released guidance for public sector data sharing that recommended a move away from complicated agreements (eg Memorandums of Understanding) to less formal and cumbersome agreements between agencies (eg letters of exchange).

30 ANZLIC, *Foundation Spatial Data Framework* (FSDF), http://fsdf.org.au/
31 Australian Government, Physical Environment Analysis Network (PEAN), https://www.pean.gov.au/
32 Emergency Management Spatial Information Network Australia (EMSINA), https://www.emsina.org/
33 Geosciences Australia, Australian Geoscience Information Network (AUSGIN), http://www.geoscience.gov.au/
34 The Australasian BIM Advisory Board, http://www.abab.net.au/
35 Queensland Government Department of State Development, Manufacturing, Infrastructure & Planning, *Digital Enablement for Queensland Infrastructure: Principles for BIM Implementation*, November 2018, https://www.statedevelopment.qld.gov.au/resources/guideline/infrastructure/bim-principles.pdf
36 Department of Agriculture, Water & the Environment, Environmental Resources Information Network (ERIN), https://www.environment.gov.au/about-us/environmental-information-data/erin
37 Atlas of Living Australia (ALA), https://www.ala.org.au/
38 Department of Infrastructure, Transport, Regional Development & Communications, *National Cities Performance Framework*, https://www.infrastructure.gov.au/cities/national-cities-performance-framework/index.aspx
39 Centre for Digital Built Britain, *The Roadmap to the Information Management Framework for the Built Environment*, https://www.cdbb.cam.ac.uk/DFTG/DFTGRoadmap
40 buildingSMART, formerly the International Alliance for Interoperability, https://www.buildingsmart.org/

In October 2017, the Queensland Government released the draft I*nformation Sharing Authorising Framework: A practical suite of tools for information sharing*.[41] The Framework aims to provide a suite of practical tools and advice for Queensland Government departments who are seeking to establish and manage information sharing agreements. These tools and guidelines are provided for assistance, information and utility only. While some information and guidance provided in the framework communicates other mandatory obligations that may be relevant (e.g. legislation, privacy), agencies are strongly recommended to further investigate these obligations considering their own business requirements, and seek legal/expert advice where necessary.

Despite these policy initiatives, the development and adoption of simple and consistent data sharing agreements has been extremely slow and still requires considerable effort for most agreements. As discussed in Section 2.4, the ONDC has been tasked with developing such agreements aligned to the concept of Accredited Data Users, Accredited Data Service Providers and Accredited Processes, initially for the Australian Government agencies, but potentially for other government agencies and external organisations. The intent is to establish trust in data sharing, potentially supporting repeatable data sharing between multiple organisations based on common agreements.

There is also an important role in promoting an efficient and fair marketplace for the exchange of commercial licensing data relevant for digital twins. Such payments should recognise the value created by private organisations, fostering business growth and innovation. There is a need however to balance commercial interests with broader public good, where the provision of certain open or shared data at no charge may create greater economic and social value than immediate economic return. In such circumstances, especially for public sector agencies, alternative means of compensating the creation of value should be explored.

There is also an opportunity to promote more consistent commercial licensing agreements to reduce the complexity for digital twins acquiring such data from multiple providers. One such commercial agreement was developed as part of AusGOAL, the Australian Governments Open Access and Licensing Framework (as a complementary agreement to the adoption of the Creative Commons licensing framework).[42]

5.5 Privacy and access arrangements

Spatially enabled digital twins pose important privacy issues as they are able to represent physical objects in the real world potentially at a level of detail beyond existing data sources. This can include both the exterior and interior of buildings that could be homes, show sensitive details about critical and vulnerable infrastructure, show the location of people movements that could identify a person or occupancy of a home.

In addition to existing privacy legislative and regulatory obligations, there is a need to develop additional rules about how spatially enabled digital twins should safeguard private and sensitive information. These include:

- Access to BIM data related to building and infrastructure should in principle follow the existing access and consent model for access to these in the real world. For example, if you are not allowed entry into an actual building, you should not be granted access in a digital twin. However, like in the real world, authorised users such as fire and emergency services personnel could access these interiors when responding to an emergency.
- The ingestion of IoT data could pose privacy risks through matching to other data available in a digital twin model such as the location of people in relation to homes, offices or schools. There are a range of emerging procedures that are available to reduce and manage these privacy risks while retaining the utility of the data (eg creation of synthetic data or differential privacy treatments).
- The collection of detailed reality-mesh imagery of city may include intrusive views into backyards or similar private spaces in homes. There will be a need to control what level of detail should be available to the general public or other unauthorised users in such circumstances.

41 Queensland Government Enterprise Architecture, Information sharing authorising framework, March 2018, https://www.qgcio.qld.gov.au/documents/information-sharing-authorising-framework

42 The Creative Commons Global Network, Australia: AUSGoal - Australian Governments Open Access and Licensing Framework https://wiki.creativecommons.org/wiki/Australia:_AUSGoal_-_Australian_Governments_Open_Access_and_Licensing_Framework

- The provision of detailed information about critical infrastructure may need to be restricted on national security reasons (eg internal structural information about defence infrastructure). Such restrictions however need to not unnecessarily restrict use of information that is readily available through other sources (eg location of main electricity transmission lines).

Digital twins should also investigate the ability to determine the Personal Information Factor (PIF) present in existing or linked datasets. This process will assist in identifying not only the existing privacy risks but also potential ones that could be created through additional datasets or analytics.

Another important social function of a digital twin that contains private and sensitive data is to track all access to such data (both authorised and unauthorised). This tracking of use will be useful for Data Custodians to understand the value derived from the sharing of their data.

One other consideration is for digital twin operators to determine whether they have sufficient private or sensitive data required to perform their objectives related to public benefit, so that they don't need to collect further such data or even consider removing and deleting data

5.6 Data custodianship and curation

Data custodianship and curation are critical enabling functions to support a national ecosystem of digital twins. The *Principles for Spatially Enabled Digital Twins of the Built and Natural Environment in Australia* highlight that "clear ownership and responsibilities will enable effective data management and issues resolution for individual digital twins within a digital twin ecosystem and for a digital twin ecosystem as a whole".

There are a number of general challenges to address regarding data custodianship and curation relevant to digital twins.

- Firstly, as mentioned in Section 2, there is a wide range of understanding and capability by organisations regarding these functions. Many organisations still do not have a comprehensive understanding of their data assets, clearly defined and assigned roles for data custodians and supporting roles (eg data stewards), nor mature curation across the data lifecycle (from creation, transformation, use, sharing, archiving or deleting).
- Secondly, there remains a general institutional inertia in many organisations related to both real and perceived risks, costs and lack of compelling case for change regarding open data release or data sharing.[43]
- Many Data Custodians currently have limited understanding of the subsequent use of their data once it has been made available either as open data or shared data. This limits their ability to understand the value from the use of their data and justify necessary costs involved in releasing or sharing this data as well as continued data maintenance costs.
- Finally there are limited processes currently available for Data Users, Data Custodians and other stakeholders to identify high value datasets that should be openly released or shared, promote effort to provide such data at a quality suitable for Data Users (such as through a digital twin), or develop mechanisms to manage how best to resource the supply of this data.

There are also number of additional challenges to address regarding data custodianship and curation relevant to digital twins.

- Federated digital twins are able to create new derived data from the source data and this raises issues regarding ownership and access rights that need to be understood and resolved.

43 Department of Prime Minister & Cabinet, *New Australian Government Data Sharing and Release Legislation: Issues Paper for Consultation*, July 2018, p. 3. https://www.pmc.gov.au/resource-centre/public-data/issues-paper-data-sharing-release-legislation

- There is a need to maintain transparency not just about the source of data but also how it is used. This includes transparency about algorithms and related assumptions embedded in digital twin modelling systems.
- The creation and inclusion of Internet of Things (IoT) raises issues regarding ownership, control and access to such data, especially when that data is collected on behalf of federated digital twin representing multiple stakeholders. The recent experience of Sidewalk Labs in Toronto has created a relevant precedent when concerns about data custody and curation roles sitting with a dominant commercial operator have prompted the creation of data trust to own and control such data on behalf of the city's citizens.[44]

5.7 Governance models

Governance is a vital element of the development, operation and maintenance of digital twins. There will be considerable diversity in how digital twin are developed, governed and managed by their stakeholders. Some may be developed and operated by an individual organisation (government agency, company or research organisation) that can set the rules and processes around how data is used. The majority however will require the collaboration of different organisations in establishing the governance around how a federated digital twin is developed and operated.

The *Principles for Spatially Enabled Digital Twins of the Built and Natural Environment in Australia* proposes that the federated model has a level of consistent governance across different sectors, as well as between industry and government. This needs to acknowledge and align the different governance models that are emerging for digital twins such as government administration/regulation, co-administration/regulation between government and other sectors, sectoral self-administration/regulation (eg through industry or professional associations), or a combination of some of these. How these different governance models operate and the level of consistency requires further examination.

There is also a need to consider how governance models operate over the lifecycle of a digital twin, especially those that are created as part of a building or infrastructure project. Once the construction of such projects is completed, the digital twin model can be either transitioned to be managed by the governance arrangements responsible for the maintenance of such assets or alternatively closed down and archived appropriately.

Governance should also provide mechanisms for overall management of the digital twin ecosystem, promoting collaboration and consistent adherence to standards to support data sharing and interoperability. A federated governance model can operate without the need for a top-down hierarchical governance model that assumes a dominant controlling entity for the entire ecosystem of digital twins.

A federated governance model, while assuming a high degree of collaboration based on mutual trust, alignment to a shared purpose and set of operating principles, is best supported through a high level sponsor that commands respect and authority from the various stakeholders. Such a sponsor may have the reserve power to intervene where appropriate through a range of mechanisms such as regulation, standards setting, purchasing power or control over funding.

5.8 Stakeholder and community engagement

There is also a need to engage with a broader set of stakeholders and the community about the development and operation off Digital Twins. This will not only inform the development of the Digital Twin but help identify and manage potential risks on a collaborative basis. A key activity for the ongoing engagement with stakeholders should be to communicate both the benefits and the issues of concern through the operations of Digital Twins.

44 Sidewalk Labs, *Digital Governance Proposals for DSAP Consultation*, October 2018, https://waterfrontoronto.ca/nbe/wcm/connect/waterfront/41979265-8044-442a-9351-e28ef6c76d70/18.10.15_SWT_Draft+Proposals+Regarding+Data+Use+and+Governance.pdf?MOD=AJPERES

A key challenge for the Digital Twin is the establishment and retention of a social licence to operate from the general public. The development of a high-resolution Digital Twin of the physical world involving people's residences and outdoor spaces may challenge community acceptance relating to privacy and surveillance. Such community concerns need to be understood and resolved through appropriate safeguards. There will be need to actively engage and communicate to the public about the benefits, risks and safeguards related to the Digital Twin.

Digital twins despite the aspiration to fidelity with its physical twin, are abstractions and interpretations that reflect biases and assumptions about how the real world operates, is measured and represented. As such, the governance of digital twins does raise ethical issues about how such biases and assumptions could distort their use and outcomes. For example, a digital twin may reflect existing privileging of certain transport modes if these provide a richer and more accurate source of data compared to other underserved and less recoded transport modes. It is emerging best practice for the governance of digital twins to conduct appropriate ethics reviews to examine such issues and take necessary remedial action.

One of the greatest challenges for digital twins will be to ensure they are not just used for supporting public consultation about planning issues, but do involve the community in their design and operation. Studies of existing data exchange and marketplaces, suggests that these are mostly dominated by either government or commercial led services, with limited input and involvement from the community sector.[45]

45 Box, Paul; Lee, Ashlin; Smith, Gavin; Mackenzie, Adrian; Sanderson, Todd; Reeson, Andrew; Fleet, Robert, *Hunting the Unicorn: the Search for Equitable Urban Data Markets A Landscape Scan and Recommendations for Practice*, September 2019, https://publications.csiro.au/rpr/pub?pid=csiro:EP194743

6 Change and Implementation

6.1 Implementation approach

The implementation of the *Principles for Spatially Enabled Digital Twins of the Built and Natural Environment in Australia* vision and guiding principles is envisaged as a long journey, requiring transformation in how data is released, shared and used safely to create value through a national ecosystem of digital twins. This has been described as 'running a marathon' requiring patience and endurance to tackle the large and sustained effort involved.

The best approach to the development of both individual and a digital twin ecosystem in Australia is through a staged and iterative user-design led development methodology focused on delivering tangible short-to-medium term outcomes to priority needs, while remaining aligned to the longer term vision.

A staged and iterative approach minimises the risks of over-investment in technologies and capabilities that will not be fully utilised, expensive to maintain and potentially be unsustainable. A staged approach more closely aligns with an agile development methodology where there is flexibility to test and verify interim solutions, adjust them to meet existing and emerging user needs and adapt to obstacles.

This approach also encourages a more networked bottom-up process with multiple digital twin projects each able to experiment and develop new capabilities and services yet also encourages them to collaborate and share where possible. This approach also obviates the need for a prescriptive top-down technology program, that have traditionally been difficult and complex to implement successfully in terms of budgets, timelines and meeting user needs.

There also needs to be a step change and sometimes difficult transformation in many social and institutional practices regarding data management, sharing and collaboration to realise the vision of the *Principles for Spatially Enabled Digital Twins of the Built and Natural Environment in Australia*. This requires a range of change management and communication initiatives, some based on existing activities but other ones specific to the development of digital twins.

Whilst a networked bottom-up process is an important driver for change, such as the promotion of a **digital twin community of practice** encouraging best practice and collaboration (described in Section 6.4), other more formal processes to support **the commons of standards** and interoperability (described in Section 6.3), as well as formal **governance and leadership** arrangements (described in Section 6.2).

Section 6.5 addresses some of the additional **key enabling initiatives** that will support and sustain the development and operation of the national ecosystem of digital twins, as well as address critical blockers. This includes capability development; procurement of data and systems; resourcing; enabling services; and the supply of foundation data.

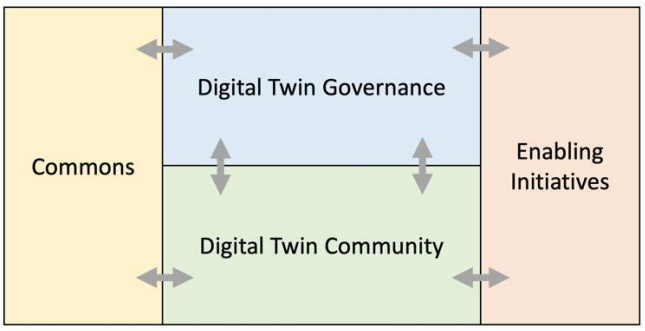

Diagram 9: Implementation Activities for a Digital Twin Ecosystem in Australia.

6.2 Leadership and Governance

As outlined in Section 5.6, the implementation of the *Principles for Spatially Enabled Digital Twins of the Built and Natural Environment in Australia* is best supported through a federated governance model, where an ecosystem of digital twins can collaborate for common good, supported by a high level sponsor for providing national leadership and agreed mandates where necessary.

ANZLIC, has acted as the governance organisation for the development of both National Foundation Spatial Data and driver for the *Principles for Spatially Enabled Digital Twins of the Built and Natural Environment in Australia*. It has also supported collaboration between state/territory governments programs that are developing city/regional digital twin proof-of-concepts and pilots. These activities in turn reflect ANZLIC's mandate, as a federated structure representing multiple government jurisdictions, to provide national leadership in the collection, management and use of spatial information in Australia and New Zealand.

While it is assumed that ANZLIC will continue to support the implementation of the *Principles for Spatially Enabled Digital Twins of the Built and Natural Environment in Australia* through the provision of enabling foundation data sets and the development of official government supported city/regional digital twin platforms, other digital twin governance groups representing other sectoral or industry based interests are likely to emerge.

It is also anticipated that the current city/regional digital twin proof-of-concepts will develop into state and territory jurisdiction wide digital twin platforms led by the respective state and territory governments in collaboration with local government and other stakeholders.[46] The 'public purpose' state/territory digital twins are likely to provide the default public access to a digital twin model and associated datasets relating to the built and natural environments.

Digital twin governance groups will need to take the following action to successfully implement their own service while supporting the wider ecosystem of digital twins:

a) Communication and stakeholder engagement about the adoption of digital twins and the case for change highlighting both the benefits and risks.

b) Identification, release and maintenance of the supply of high value data at the appropriate quality by Data Custodians to support the use in their or other digital twin platforms.

c) Ensuring private and confidential data is protected from unauthorised access and use.

d) The promotion and adoption of the digital twin commons relating to standards, common information models and implementation patterns, and data sharing licensing and agreements.

e) Support and resourcing for capability development and communities of practice; procurement policies; and for shared services to support federated data sharing and access.

f) Track the use of data to understand the demand for data, whether it is supporting the levels of quality required by users.

g) Monitor and communicate the benefits enabled by digital twins back to stakeholders and the general public, referencing progress against key success measures and alignment to the *Principles for Spatially Enabled Digital Twins of the Built and Natural Environment in Australia*.

While a federated governance model based as much as possible on bottom-up collaboration as the default assumption, there is expected to be a need for some government legislation, regulation or policy directive to support improved data release or sharing generally or specifically related to the development of digital twins.

46 Currently state and local government digital twin proof-of-concept and pilot projects are being implemented by the New South Wales, Queensland and Victorian Governments as well as local governments such as Brisbane and Launceston. Many of these governments have expressed an interest in transitioning these initial services into an ongoing operational platform to support their jurisdiction.

For example, mandating by all Australian governments that BIM data conforming to specific standards be made available as part of government funded building and infrastructure would greatly accelerate the provision of this data into appropriate digital twin platforms.

Cross-jurisdictional ministerial groups, such as the Australian Digital and Data Ministers' Meeting would be a suitable sponsor promoting the ecosystem of digital twins in Australia, with respect to providing national leadership of the case for change, as well as providing a unified voice for use of reserve powers where necessary to drive change.[47] In turn, the governance of the state and territory wide digital twin platforms also have an important role in similar leadership and use of reserve powers.

Approaches for implementation could include:

- **Leadership and governance:**

  Governance groups could be established within different government jurisdictions as well as industry sectors, to provide: leadership and coordinate digital twin investments; to identify, release and maintain the supply of high-value quality-assured data; to promote digital twin standards and common processes; to protect private and sensitive data; and to communicate benefits to stakeholders.

  - At a state/territory level, digital twin governance arrangements could be established to coordinate collaboration within and between government jurisdictions, especially with local government.
  - At a national level, ANZLIC could assist guide the enhancement of foundation spatial datasets to spatially enabled digital twins, as well as promote collaboration between jurisdictions to develop relevant standards, common practices and shared infrastructure. Leadership from a range of cross-jurisdictional government agencies and ministerial groups responsible for data and digital initiatives will be important to progress a digital twin ecosystem in Australia.
  - Additionally, leadership from industry and the research sector will also be important, as a collaborative approach across governments, industry, the research sector and the community will help realise the full benefits and best possible outcomes of a digital twin ecosystem in Australia.

6.3 Digital twin commons and standards

The coordination and promotion of the digital twin commons regarding shared language, concepts and standards will need to be supported by both formal governance arrangements of digital twins and also communities of practice. This combines the strengths of formal top-down resourcing and mandates with the bottom-up communities of practice providing important peer-to-peer communication and collaboration.

Some of the tasks to promote the commons include:

a) Engage with stakeholders to socialise and communicate key terms and concepts related to digital twins and the *Principles for Spatially Enabled Digital Twins of the Built and Natural Environment in Australia*.
b) Promote shared cultural values and practices that encourage data sharing, appropriate use, protections and transparency.
c) Identify and promote the adoption of current and emerging standards that are open and/or support interoperability to allow for the open exchange of data and platform components.
d) Develop a common information model including data schemas, taxonomies, implementation patterns, integration architectures and reference libraries.
e) Promoting the adoption of common data sharing agreements and licensing while promoting equitable, effective and efficient data sharing marketplaces

47 The Australian Digital and Data Ministers' Meeting, previously known as the Australian Data and Digital Council (ADDC), has ministerial representation from the Australian Government and all Australian states and territories. Data and Digital Ministers are working to align policies and services across Australia by focusing on:
- Transforming government services around life events
- Reforming cross-jurisdictional data and digital platforms, services and protocols
- Enhancing government capability to build public trust and deliver digitally
- Delivering a seamless digital identity experience for citizens

https://www.pmc.gov.au/public-data/data-and-digital-ministers-meeting

Some of these tasks specifically relate to digital twins such as socialising and communicating key terms and concepts about digital twins, or how to manage access by authorised users to private spaces within digital twin environments. The implementation of other tasks relating to general data sharing and protection should support and extend initiatives already underway.

This work will require resourcing from the formal governance groups for both the national ecosystem of digital twins and individual digital twins. This includes allocating staff and funding to support stakeholder engagement and communication, participation with standards organisations and digital twin specific technical committees, etc.

The 'public purpose' state/territory digital twins can play a key role in implementing these tasks building on an existing level of collaboration between related city/regional digital twin initiatives. This includes staffing and related support where necessary as well as connection to formal governance and control processes to mandate standards and common information model. These groups, working through ANZLIC or similar governance group, should promote a "minimum viable" approach to the development of national-level standards for effective information management related to digital twins.

The community of practice has an equally important role in promoting the commons, especially regarding practical guidance to digital twin stakeholders such as businesses in different industry sectors, local government and the wider community.

Approaches for implementation could include:

- **Digital twin commons and standards**

  The development of an ecosystem of digital twins requires the promotion of common concepts, standards and processes with stakeholders, supported by formal governance arrangements and communities of practice.

  - At a state/territory level, existing processes could be expanded to identify and promote the open release and sharing of priority data, as well as promote the adoption of data standards and standard data sharing agreements, to support the development of digital twins.
  - At a national level, ANZLIC and ICSM could assist develop and implement relevant standards for spatially enabled digital twins particular relating to foundation spatial data. At the same time, cross-jurisdictional government agencies and ministerial groups could play a key role in promoting wider cross-sectoral standards and common practices relating to data release and sharing.

6.4 Communities of practice

The promotion of best practice, knowledge sharing and collaboration related to digital twins could be supported through a community of practice initiative.

Some tasks of the communities of practice includes:

a) Supporting the development and promotion of the digital twin commons regarding shared language, concepts and standards.

b) Promoting shared cultural values that encourage best practice data custodianship associated with data sharing, appropriate use, protections and transparency.

c) Providing practical guidance to digital twin stakeholders such as businesses in different industry sectors, local governments and the wider community.

d) Promoting self-assessment and benchmarking of digital twin project for their alignment to the *Principles for Spatially Enabled Digital Twins of the Built and Natural Environment in Australia* through the use of checklists (see Appendix A).

The initial focus of the community of practice should be to support early developers of spatial digital twins to share lessons, experiences and resources to accelerate the development and maturity of their digital twin initiatives. The current collaboration between state government programs is a good example of this, and could be extended to a wider set of practitioners.

Communities of practice will over time also need to encourage and support other organisations that have less capability to develop digital twin initiatives (see Section 6.5.1).

A collaboration and knowledge sharing website should be developed to support the digital twin community of practice as a place for interaction and shared information and other related resources. This website could also provide a directory of digital twins and related data sets (see Section 6.5.4 Enabling Services).

The digital twin community of practice and related activities such as the website will need funding and resourcing support from the digital twin community and key governance groups.

Key actions for implementation include:

- **Communities of Practice**

  The promotion of best practice, knowledge sharing and collaboration related to digital twins could be supported through Community of Practice initiatives. These could leverage grass-roots interest and existing peer-to-peer activities in knowledge sharing, providing templates/guidance documents and related resources. These Communities of Practice could support both early adopters of spatially enabled digital twins and the needs of less capable organisations over time.

  - At a state/territory level, digital twin communities of practice could be established and resourced involving staff from relevant agencies, local governments, industry and research/education community.
  - At a national level, the current collaboration between state government digital twin programs could be leveraged and expanded to support a national cross-jurisdictional community of practice. Other Communities of Practice could be supported in key industry sectors covering the built and natural environments.

6.5 Enabling Initiatives

6.5.1 Supply of foundation data services

An ecosystem of digital twins will require foundation data services at increasing levels of details and quality to support the needs of priority use cases. This includes upgrades to Australia's cadastral data so objects such as BIM can be accurately positioned in a digital twin platform with the required level of detail and quality. It is expected that as more digital twins emerge, there will be a need for similar improvements in other foundational spatial data and related data services.

These foundation datasets should also be provided as APIs by the primary data custodian rather than through static downloads of data files. This means that users of the data have access to the most current and accurate version.

There is a need to review on an ongoing basis the scope and definition of these foundation data services. Currently ANZLIC, through the Intergovernmental Committee on Surveying & Mapping (ICSM), provides coordination for such improvements to spatial foundation datasets, although much of the implementation work is done by the different government jurisdictions though investing resources to support the necessary transformation.

It is expected that there will be a need for other foundation data services related to specific domains and industries, that are beyond the scope of ANZLIC's foundation spatial data (eg data related to building and digital engineering, the natural environment, health, social issues or the economy).

It is also expected that some foundational data services may involve additional costs to some data custodians (eg Lidar, 3D imagery (or reality meshes). Mechanisms for cost-sharing should be considered, especially if there is a benefit to providing these services free of charge as a 'public good'.

Approaches for implementation could include:

- **Supply of Foundation Data Services**

  An ecosystem of digital twins will require foundation data services at increasing levels of details and quality to support the needs of priority use cases. This includes upgrades to Australia's cadastral data and other foundational spatial data, as well as making data available increasingly through APIs.

- At a state/territory level, digital twin governance arrangements could be established to coordinate collaboration within and between government jurisdictions, especially with local government.
- At a national level, ANZLIC could guide the enhancement of foundation spatial datasets to spatially enabled digital twins, as well as promote collaboration between jurisdictions to develop relevant standards, common practices and shared infrastructure. Cross-jurisdictional government agencies and ministerial groups, could sponsor coordinated actions across jurisdictions and between sectors, particularly to integrate building and environment data into digital twin services.

6.5.2 Shared digital services to support federated digital services

There is a need to provide shared digital services that support federated digital twins by enabling discovery, access, data linkage, data transformation, security and related functions. These are the key coordination and enabling services that allow federated digital twins to operate in a decentralised manner, as well as connect and work together in a national ecosystem of digital twins.

Federated digital twins need to resource and operate a combination of the following shared services:

- Data catalogue for discovery including relevant metadata and data quality statements;
- Federated access controls preferably supporting role based access linked to data sources;
- Data linkage services where required to join data services (some may need to be done in a privacy-preserving way where appropriate);
- Data transformation and hosting services where data custodians are not able to provide their data through APIs or require it to be transformed into a format suitable for use in a digital twin;
- API management services to provide quality-of-service for data services and information about use of data.
- Data security controls (including audit and privacy-protection services).

The national ecosystem of digital twins will need to leverage these services to support integration and collaboration between individual digital twins. For example, data catalogues should be able to harvest metadata from other data catalogues to expose other data services and digital twins, or provide integrated role-based access to other digital twins through a federation authentication and access control system.

Approaches for implementation could include:

- **Shared Digital Services to support Federated Digital Twins**

  Federated digital twin ecosystems need to resource and operate shared services including data catalogues for the discovery of data, federated access controls, data linkage services, data transformation and hosting services, service management tools such as API gateways, and data security controls.

  - At a state/territory level, the Queensland Government's Spatial Catalogue provides the foundation for some of these services supported by Spatial Information and Queensland Government federated authentication service. Further work is required to define both role and group based categories.
  - At a national level, implementation of these shared services could be coordinated through cross-jurisdictional groups, jointly owned entities (provided funding contributions were agreed across the different levels of government) and peak industry bodies, leveraging existing Australian Government initiatives such as data.gov.au, National Map, VANguard and the Trusted Digital Identity Framework (TDIF).

6.5.3 Capability Development

The development of federated digital twins should address the different levels of capability of its contributing data custodians and data users. This means providing practical guidance and assistance to improve their ability to participate and enjoy the benefits arising from federated digital twins.

This guidance and assistance should include:

- Advisory services to guide organisations about contributing to and using digital twin services and developing their internal capabilities;
- Supply of enabling shared digital services (see Section 6.5.2) to support their participation in a federated digital twin.
- Support for skills development at different levels from basic understanding through to more advanced skills related to data custodianship, supply of data services, use of digital twin platforms, etc.

The capability development of some sectors, such as less affluent local governments, community groups and other non-government organisations, will require some level of resourcing to help build their capability through the provision of guidance and supply of enabling digital services.

Approaches for implementation could include:

- **Capability Development**

  The different levels of maturity of data custodians and data users require support to guide and assist them in developing their capabilities to contribute to and use digital twin services.

  - At a state/territory level, Queensland's 77 local government authorities vary widely in capability to contribute, manage and use digital twin datasets and services and some will require support through guidance and enabling digital infrastructure.
  - At the state/territory and national levels, support could be provided for local government to contribute to, use and manage digital twin datasets and services.

6.5.4 Procurement of data and digital technology systems

The way organisations procure data and digital technology systems can drive major change in enabling a national ecosystem of digital twins. This includes:

- how relevant data is procured, either in the creation of data or supply of existing data so they are supplied in open standard formats and fit-for-purpose data relevant to the requirement of relevant digital twins where-ever possible.
- how digital technology systems are procured so that they support relevant open standards. This means that the data ingested and managed in these systems (even if they are proprietary), can be made available to other users in open standard formats.

Australian governments can play a leading role in leveraging their procurement capabilities. Important examples include:

- Mandating the supply of BIM data in open formats in the required level of detail and with spatial positioning data for all relevant infrastructure, building and related capital works. For example, the Queensland Government is leading with the requirement for BIM data to be supplied for major infrastructure projects worth over $50 million (though not yet specifying it be supplied in an open standard).[48]

48 Queensland Government Department of State Development, Manufacturing, Infrastructure & Planning, *Digital Enablement for Queensland Infrastructure: Principles for BIM Implementation*, November 2018,

- Purchase and major upgrades of all geospatial and related data management platforms should support open geospatial data standards, support interoperability with other systems and where possible provide data access through APIs. This can be done through traditional procurement of proprietary digital technology systems or through procurement of open source solutions.
- Requiring that relevant data sources and models be made available when commissioning environmental impact, planning and transport studies so that the data and modelling assumptions can reused and tested in digital twin environments.
- Supplying relevant data services (either created or procured by governments) in open licensing formats or using a standard commercial licence to remove friction in use of this data.
- Resolving IP issues related to the supply of certain data so that an appropriate balance is stuck between rewarding the creators of certain data such as BIM, while ensuring that the data is accessible and used to create public benefit.

Approaches for implementation could include:

- **Procurement Policies**

  Australian governments can play a leading role in leveraging their procurement capabilities to support the development of a national ecosystem of digital twins.

  - Mandating the supply of Building Information Modelling (BIM) data in open formats in the required level of detail and with spatial positioning data for all significant infrastructure, building and related capital works.
  - Ensuring that the purchase and major upgrades of all geospatial and related data management platforms should support open geospatial data standards, interoperability and provide data access through APIs.
  - Requiring that data and modelling created through environmental impact, planning, transport and related studies be made available where possible as either open or shared data for use in digital twins.
  - Adopting open licensing formats or using standard commercial licences when providing data services (either created or procured by governments) to users to remove friction in the use of this data.
  - Resolving intellectual property (IP) issues related to the acquisition of certain data such as BIM so that an appropriate balance is stuck between rewarding the creators of this data and providing a greater level of access and use.

  Jurisdictional responses include:

  - At a state/territory level, the Queensland Government is leading with the requirement for BIM data to be supplied for major infrastructure projects. Further steps can be taken to address other procurement and data acquisition activities across the Queensland Government.
  - At the national level, these procurement initiatives could be achieved through specific priority initiatives such as the cross-jurisdictional response to the Building Confidence Report and co-ordination of common procurement policies.

6.5.5 Resourcing

Finally, resourcing will be required to support the change and implementation activities from the key stakeholders supporting the development of the national ecosystem of digital twins. While as much of this resourcing can be leveraged from existing funding and activities, there will be a need for some additional funding for new or expanded activities.

This includes:

- Digital twin commons and standards;
- Communities of practice and collaboration;
- Supply of foundation data services;
- Shared digital services to support federated digital twins;

- Capability development.

Australia's governments have a leading role in providing resourcing for digital twin commons and standards and supply of foundation data services for digital twins. Government funding, at a national, state and territory level, will also be required for capability development and digital services to support digital twins, particularly focused at local government and community groups with less capability and internal resourcing.

Industry, research and government sectors have a shared role in resourcing digital twin commons and standards as well as communities of practice.

Appendices

Appendix A:

Draft Checklist for Alignment to the *Principles for Spatially Enabled Digital Twins of the Built and Natural Environment in Australia*

Principle 1:	**Public Good**
Key Objective:	Digital twins should deliver public good, including by facilitating open access to non-sensitive data across the Australian economy and shared access with approved users.
Criteria	a) Does the Digital Twin provide 'public goods' to users and society? (A service that is provided to all members of society, either by the government, research or private organisation, without exclusion or detracting from others using it). For example, can anyone access the Digital Twin and/or its non-sensitive data without charge nor impacting on the utility to other users?

Principle 2:	**Value**
Key Objective:	Digital twins should provide ongoing value to the Australian economy, by enabling industry, governments, the research sector and the community to use them to better understand and manage the built and natural environment.
Criteria	a) Has the value that the Digital Twin will deliver to specific groups immediately, in the short-medium term, and long term been identified? b) Has a process to track and communicate the value of the Digital Twin been established? c) Has engagement with stakeholders been undertaken to create trust and ensure social licence to operate? d) Have sustainable funding and processes been arranged to maintain the Digital Twin's currency, relevance and value?

Principle 3:	**Quality**
Key Objective:	Users can assess data reliability and quality, including aspects such as the collection environment, relevance, timeliness, accuracy, coherence and consistency, interpretability, and accessibility, in relation to its intended use.
Criteria	a) Has a process been established so Data Custodians can provide 'digital twin assured' data that is fit for purpose for end users and that is supported by quality and reliability descriptors? b) Has a process been established for Data Custodians to improve the quality of data and metadata that is needed to support their users? c) Will the Data Custodians provide information to users about the levels of data quality and reliability of 'digital twin assured' data services that is transparent, defined and measurable? (eg ODI's Open Data Certificates, etc).

Principle 4:	**Adaptation**
Key Objective:	Digital twins and a digital twin ecosystem need to be able to adapt and develop as the world evolves (e.g. society, technology, requirements, information management, data science, cyber security).
Criteria	a) Do Digital Twin operators and Data Custodians have appropriate governance, processes and technology that can adapt to meet changing needs of users or new external challenges?

	b) Is there an appropriate plan for the Digital Twin's technology platform to be developed, complemented with new technologies/services or replaced to meet new requirements? c) Do the Digital Twin's technologies allow for all relevant data and features to be exported out of the existing technology platform/s into an alternative one?

Principle 5:	**Openness**
Key Objective:	Digital twins and a digital twin ecosystem should be as openly available as possible, that is, comprise open or shared data supported by open standards, to ensure they create the most value possible across the economy.
Criteria	a) Does the Digital Twin and Data Custodians provide metadata so it is discoverable to anyone? b) Does the Digital Twin and Data Custodians provide potential users with information about its role-based access to different categories of data? c) Does the Digital Twin and Data Custodians provide open access to it and all its non-sensitive data? d) Does the Digital Twin and Data Custodians allow users to export/consume its data through open licensing agreements (eg Creative Commons)? e) Does the Digital Twin and Data Custodians allow users to export/consume its data through a standard form of commercial licensing agreements (eg AUSGOAL Restrictive Licence)?

Principle 6:	**Security and Privacy**
Key Objective:	Digital twins and a digital twin ecosystem for Australia must be 'secure by design', enabling data security, privacy protection and a role-based access approach.
Criteria	a) Does the Digital Twin and Data Custodians have policies and processes that ensure private and sensitive data are identified, secure and protected? (eg does the Digital Twin use a standard methodology such as the Five Safes to assess and manage these risks?). b) Have the Digital Twin's Data Custodians determined the agreed rules for role-based access to different levels or granularity of data? c) Does the Digital Twin have a standard approach for authorisation to access data and authentication of user identity and role? d) Does the Digital Twin allow users with sensitive data to being this into a trusted Digital Twin environment in a secure and simple way?

Principle 7:	**Curation**
Key Objective:	All parts of digital twins and a digital twin ecosystem should have clear and transparent ownership, governance, responsibilities and regulation to support the creation, maintenance and responsible use of relevant data.
Criteria	a) Does the Digital Twin have clear and transparent ownership, governance, responsibilities and rules to support the creation, maintenance and responsible use of relevant data? b) Has the Digital Twin identified the Data Custodians for all their data resources and developed ongoing processes to enable them to provide relevant metadata as well as provide feedback on data use? c) Does the Digital Twin have a process to work with stakeholders to identify high-value datasets that are required to support their users? d) Does the Digital Twin support Data Custodians and users to acquire appropriate skills and competencies?

Principle 8:	**Standards**
Key Objective:	Agreed open standards and industry best practice for data and digital twins should be adopted, with agreed cross- platform and platform-agnostic architecture models to ensure overall interoperability, compatibility and functionality.
Criteria	a) Does the Digital Twin support agreed open standards and best practice to allow users easy access to the platform and data sources? b) Does the Digital Twin support agreed cross-platform and platform-agnostic architecture models to ensure overall interoperability, compatibility and functionality with other Digital Twins? c) Does the Digital Twin and Data Custodians provide standards based APIs (supported by appropriate Quality of Service levels)? d) Does the Digital Twin collaborate with other Digital Twin operators and standards organisations to develop and promote standards to support interoperability? e) Has the Digital Twin spatially located its objects at an appropriate level to support key use cases?

Principle 9:	**Federated Model**
Key Objective:	Digital twin operators and data custodians should support a federated model where data and services can be connected and shared in a flexible and responsive manner.
Criteria	a) Does the Digital Twin support a federated model with their Data Custodians directly providing their data where they have the capability? b) Does the Digital Twin provide enabling shared hosting and transformation services to enable less capable Data Custodians to provide data? c) Does the Digital Twin support agreed governance mechanisms including the sharing of data, services and processes to support collaboration with other Digital Twins?

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