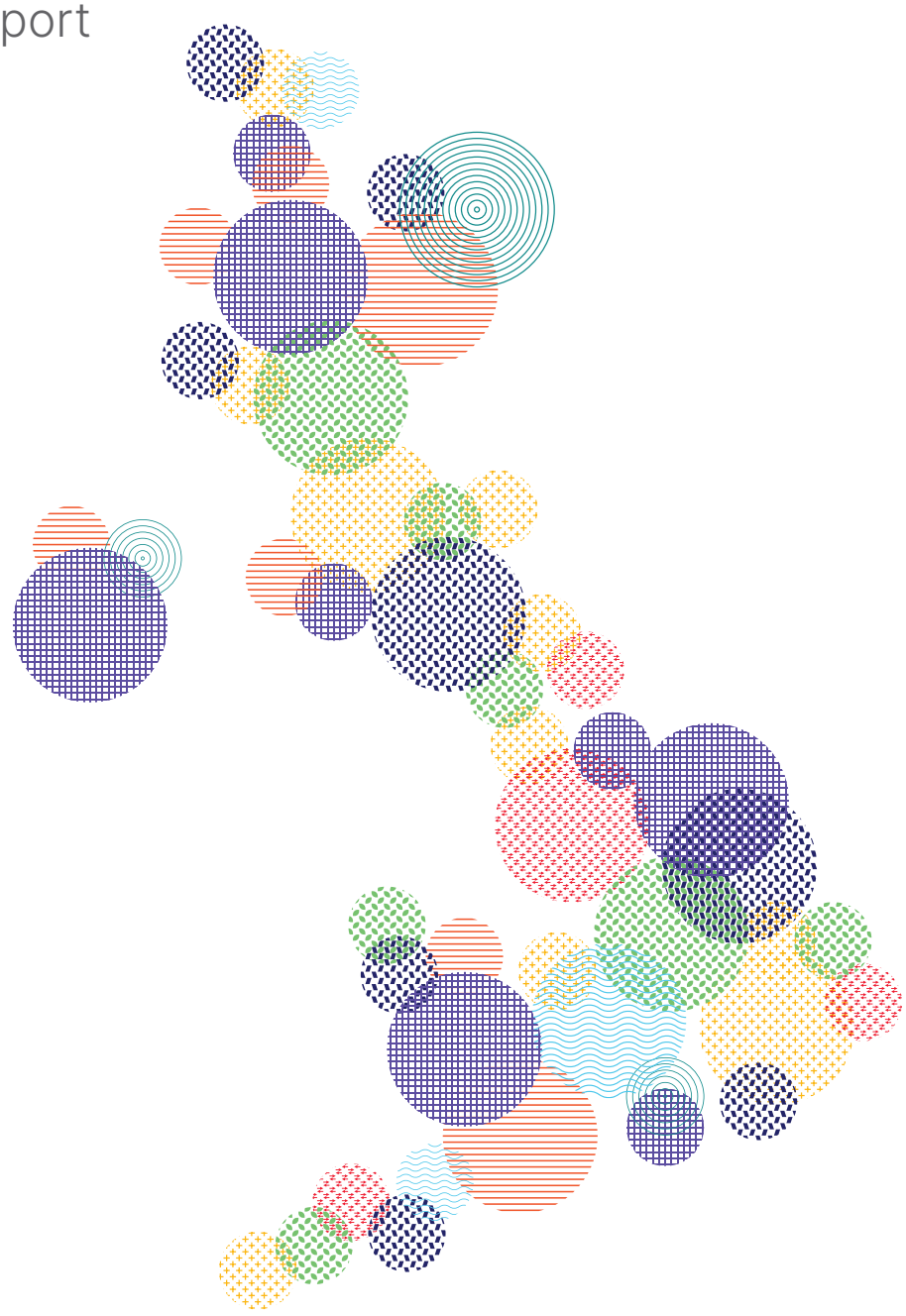
NATIONAL DIGITAL TWIN PROGRAMME

The approach to delivering a National Digital Twin for the United Kingdom

Summary report



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Centre for Digital Built Britain

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Foreword

Sir John Armitt
Chair, National Infrastructure Commission

Our report Data for the Public Good set out a bold vision for the role of data in changing how we think about, plan for and deliver infrastructure.

Two-and-a-half years on from publication, great strides are being made in realising that vision.

And what an exciting prospect it is. As a Commission, one of our roles is to encourage new thinking about infrastructure from policy makers and providers.

Data will undoubtedly have as big an impact on UK infrastructure as the steam engine or steel reinforced concrete.

It has the power to open our eyes to new ways of doing things that reduce costs, protect the environment, improve safety and increase reliability.

But data can only be truly transformative if we can collect it effectively and, crucially, agree on how we share and use that data to create the best outcomes for everyone.

In other words, we all need to be talking the same language.

That's why it's positive that our roadmap towards a UK digital twin – via greater collaboration, new standards, and strong leadership – is helping create a grammar and a vocabulary of sharing that everyone in the industry can use.

A shared understanding of data usage will catalyse change in every sector and encourage firms to invest in new approaches and techniques.

And the more organisations which choose to and help expand the adoption of this framework for information sharing, the sooner we'll reach our shared goal.

Overview

The National Digital Twin programme, led by the Centre for Digital Built Britain and the Digital Framework Task Group (DFTG), is playing a key role in the digital transformation of the UK's infrastructure and built environment.

Following the publication of Data for the Public Good by the National Infrastructure Commission in 2017 [1], the Centre for Digital Built Britain (CDBB) has been tasked by HM Government to develop the National Digital Twin (NDT) programme to create a smart nation that will improve lives, strengthen our economy and have a lasting positive effect on the environment that will benefit future generations.

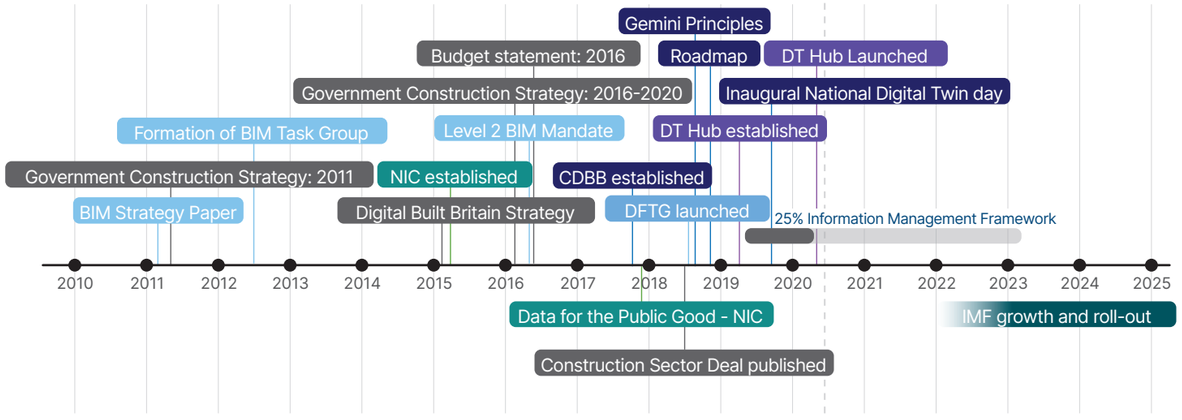


Figure 1: National Digital Twin timeline [2]

The Data for the Public Good report recommended:

1. **A National Digital Twin** to create an ecosystem of connected digital twins that will enable better outcomes from our built environment
2. **An Information Management Framework** to enable secure data sharing and effective information management
3. **A Digital Framework Task Group** to provide coordination of key players across government, academia and industry, including the Alan Turing Institute and Open Data Institute to deliver an information management framework and enable a National Digital Twin.

CDBB's vision is to bring together existing and evolving digital twins to create a data-led approach to managing the systems of infrastructure across the built and natural environment guided by the Gemini Principles [3]. The UK is already on a journey of digital transformation and we invite you to join us as we work towards a National Digital Twin.

Example ways in which digital twins can benefit society

Model changing climates to enable services to create effective, co-ordinated contingency plans

Reduce the environmental impact of construction and manufacturing industries

Improved decision making that enables our critical infrastructure to operate effectively during a time of national crisis

What is a digital twin and what is the National Digital Twin?

A **digital twin** combines data describing the physical in a digital format. Within the built environment, a digital twin is a realistic digital representation of assets, processes and systems.

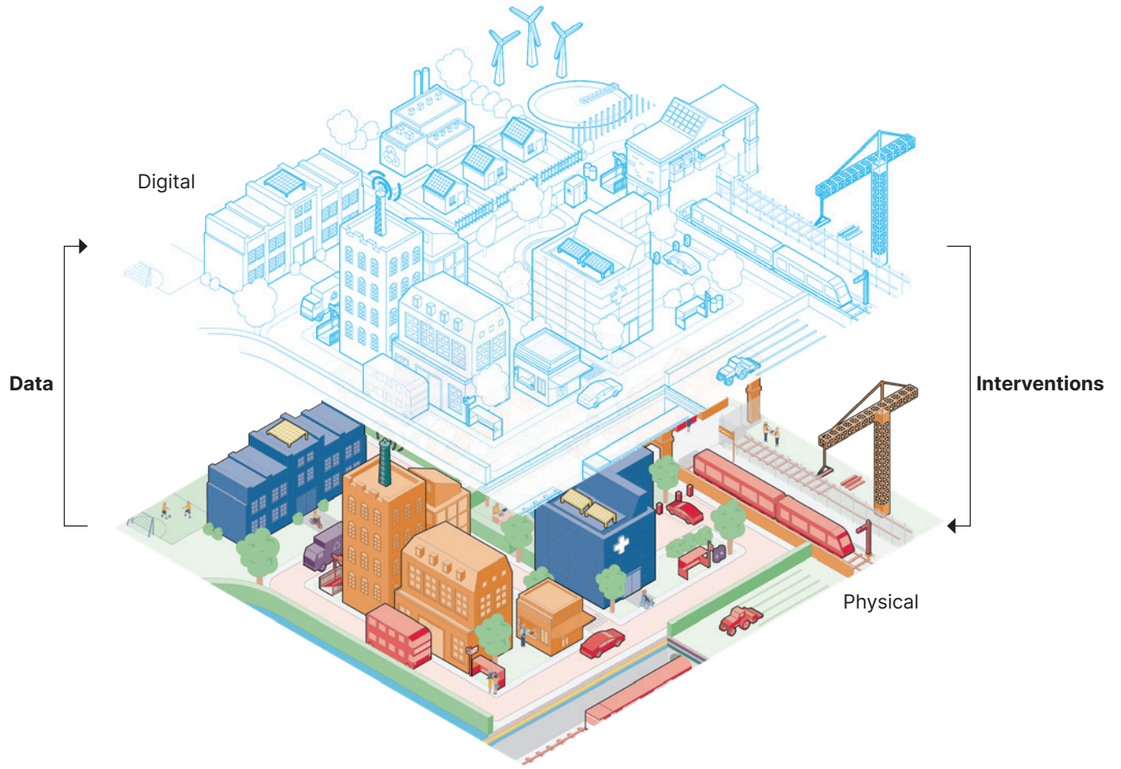
The defining characteristic of a digital twin is its data-connection to the physical twin, which can be updated to inform decision making. Digital twins enable both retrospective analysis of what has happened before and testing in the digital realm in order to accurately predict the possible outcomes of an intervention in the physical. Such actions provide valuable insights leading to more informed decision making, saving time, money and resources. Consequently, the use of digital twins can improve the performance of our infrastructure assets and networks making the entire system more sustainable and cost-effective. Connecting digital twins to create the National Digital Twin will enable these benefits to be realised at a national level.

The **National Digital Twin** will not be a single large model but an ecosystem of connected digital twins which can enable system optimisation and planning across sectors and organisations.

For example, the National Digital Twin could model the effect of staggered working hours on transport and energy networks at a national and local level.

The National Digital Twin will enable the integration of people, data and technology creating value for the owners of built environment assets, their customers, and society. Digital twins can act like connecting cogs in a system which enables the realisation of greater value through the connection between individual cogs rather than as isolated systems. A different approach to doing something developed in one digital twin can cascade through the system to realise benefits and cost savings across multiple organisations. A system of digital twins that can communicate with each other securely will increase the performance and resilience of the built environment.

An ecosystem of connected twins - the National Digital Twin



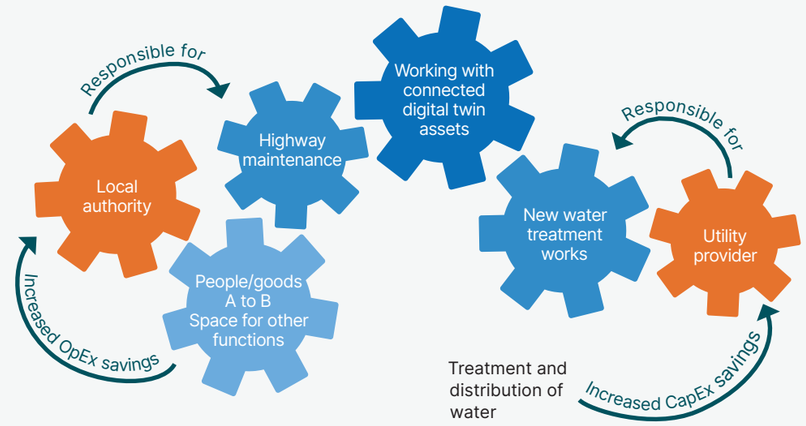


Figure 2: Connected twins

What benefits can be gained through connections?

- Better informed decisions
- Reduced environmental impact
- Understanding the representation of communities in datasets
- Improved responses to new regulation
- Improved productivity
- Secure, resilient, data sharing
- Facilitating new business models
- Measure the impacts of interventions over time
- Enabling the circular economy

The Gemini Principles

In 2018 we created the Gemini Principles to build consensus for the development and ongoing evolution of the National Digital Twin.

The principles create alignment within the programme and keep the focus firmly on the overall objective which is to deliver genuine public good.

The Gemini Principles have been welcomed around the world, as they provide a framework for ensuring digital strategies and digital twins have **CLEAR PURPOSE**, are **TRUSTWORTHY, FUNCTION EFFECTIVELY** and also consider future connectivity.

These principles can be used as a guide by:

Policy makers

to consider how 'smart' initiatives gather the right information and public support to address social issues such as climate change, resilience, future mobility and social inequality.

Asset owners and operators

to understand the potential of shared data for their business.

The investment community

to de-risk investment and open conversations about the wider value of data.

Industry

to create value and compete based on common principles.

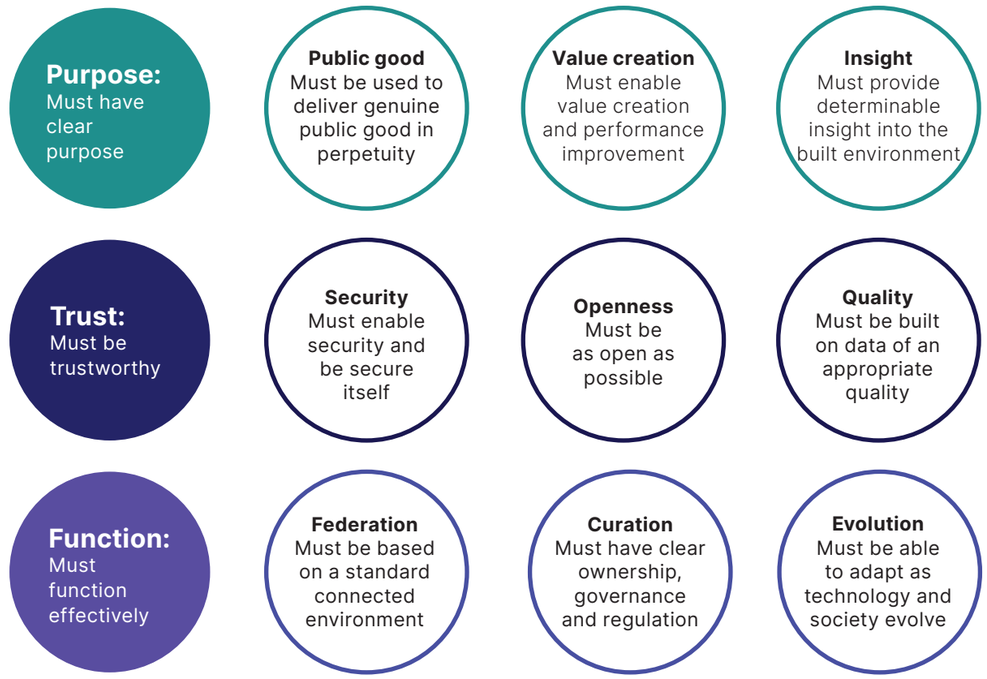


Figure 3: The Gemini Principles

What is the Information Management Framework?

The way that digital twins are connected is important in ensuring security and the promotion of resilience of assets and systems.

The goal is to establish a common language by which digital twins of the built and natural environment can communicate securely and effectively. We're collaborating with the nation's leading digital innovators from industry and academia to develop a language for digital twins to communicate with each other in the context of the National Digital Twin.

Now that digital twins are gaining traction in the built and natural environment, the necessity is emerging to link them together to make cross-sector observations, decisions and interventions, and to evaluate the impact of those interventions. Enabling the secure, resilient and reliable integration of twins from different domains and allowing the valuable sharing of information, is the key ambition of the NDT programme.

The Information Management Framework (IMF) will support secure and resilient sharing and integration of data and models across the built and natural environments at a national level. It is complex, with the significant task of supporting:

- Simultaneous use by multiple parties
- Consistently structured machine-readable data rather than, for example, PDF files
- Confidence in data provenance and therefore risk appropriate interpretation of outputs
- Consistent definitions for assets perceived differently by different users e.g. lighthouse or bridge and methods of translating between them
- Integration of data across infrastructure sectors and to other data sources; e.g.
    - Combining both current and historic data
    - Asset criticality
    - Environmental and meteorological models
    - Attributes related to the legal and regulatory contexts within which the assets operate.

Example:

Context is everything: learning from the Tadcaster bridge failure

How could a composite, integrated digital twin of a local area improve the resilience of the wider region?

Bridges and other assets make up key elements of national infrastructure, but some are more vital than others. The impact of a single critical asset failure can have far-reaching consequences beyond just the immediate area. In making asset management, having better information improves decision making.

In a set of floods that struck the north of England in 2015, the Tadcaster bridge in North Yorkshire was taken out of action when its structure became unstable. The bridge failure impacted movement, utilities, communications and power services over a huge area, and fracturing a gas main that necessitated the evacuation of hundreds of residents. The information necessary to flag the bridge as flood risks had existed at the time, but it was held in disparate data sets across different organisations, hindering pre-emptive action.

If we just look at just the road network of Tadcaster (figure 4), or the road and social infrastructure (figure 5), without the context of geographic information (figure 6), the significance of that bridge to the community cannot be seen. When the bridge collapsed, it created a split in the community and necessitated long detours for the duration of the thirteen months of repair.

Recent developments in remote sensing and predictive modelling are helping to monitor bridge performance, such as InSAR [4] and predictive group maintenance for multi-system networks [5]. These techniques can help predict collapses before they happen, enabling better maintenance of critical assets where, like the Tadcaster bridge, systems of systems interconnect in a single point of vulnerability.

What if we could map out the interdependencies of different systems, building a composite model to test how critical events could impact infrastructure and the wider area, monitoring preparedness and prioritising efforts to shore up vital structures? By simulating disasters and major events, we could build more targeted guidance for first responders, and build in tools to allow for early detection. Furthermore, what if we could, following such interventions, use a digital twin to measure the impact of the interventions and justify the investment?

Figure 4: Road network of Tadcaster

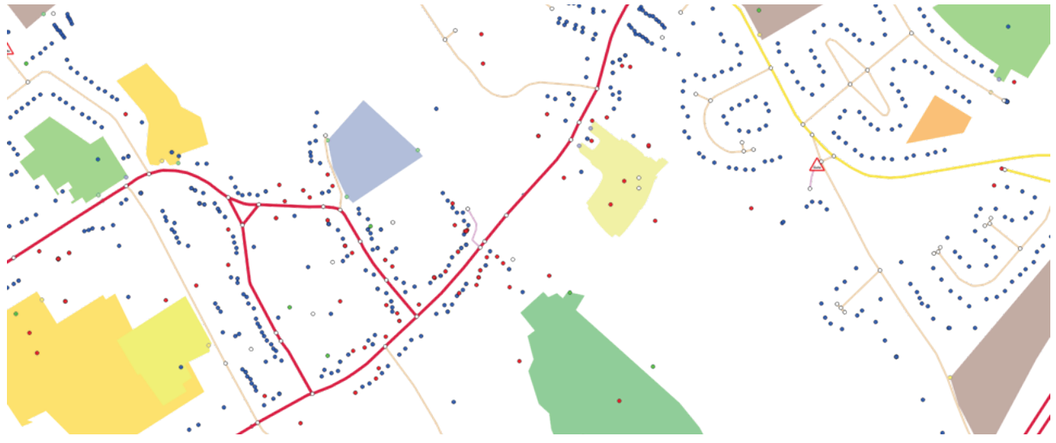


Figure 5: Road network with social infrastructure

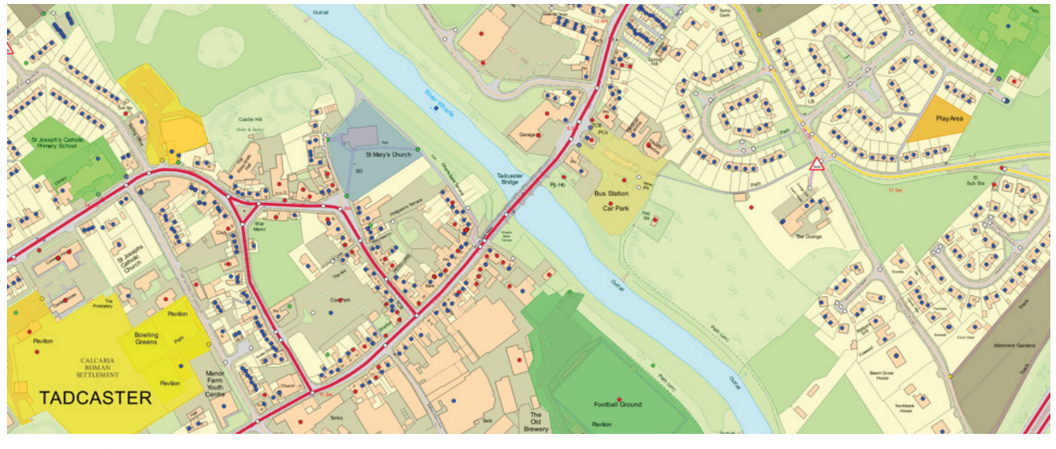


Figure 6: Road network with social infrastructure and geographic information
Image credit for figures: Ordnance Survey

The right approach

The National Digital Twin programme is consulting with experts from the fields of information management, mathematical and computation modelling of complex systems, the built and natural environment sectors and national, as well as regional and local infrastructure. Through this consultation we have developed an approach to the Information Management Framework (IMF) which comprises:

Foundation Data Model (FDM)

A consistent, clear ontology for the digital twin ecosystem: a structure for sharing and validating data

Reference Data Library (RDL)

Common references, or vocabulary that enable the secure sharing of high-quality data: the common language for describing digital twins

Integration Architecture (IA)

Design and build of the digital systems that manage the connected digital twins: the glue that can link twins together.

The IMF will bring together the standards and data exchange protocols that will allow this ecosystem to create a National Digital Twin from a nation of digital twins. Throughout the development of the IMF, security and protection of personal data is essential to connecting twins in the right way.

The IMF will bring together the standards and data exchange protocols that will allow the ecosystem of connected digital twins to be created.

Throughout the development of the IMF, security and protection of personal data is essential to connecting twins in the right way. The NDT programme will be delivering the standards that will allow this ecosystem to function, not the platforms themselves.

In order to demonstrate the capability of the Commons, we will work with built environment owners and operators through the DT Hub member community to test this approach. This may include developing early iterations of the IMF in order show the possibility and explore the challenges and benefits of a National Digital Twin.

A National Digital Twin enabled by an Information Management Framework

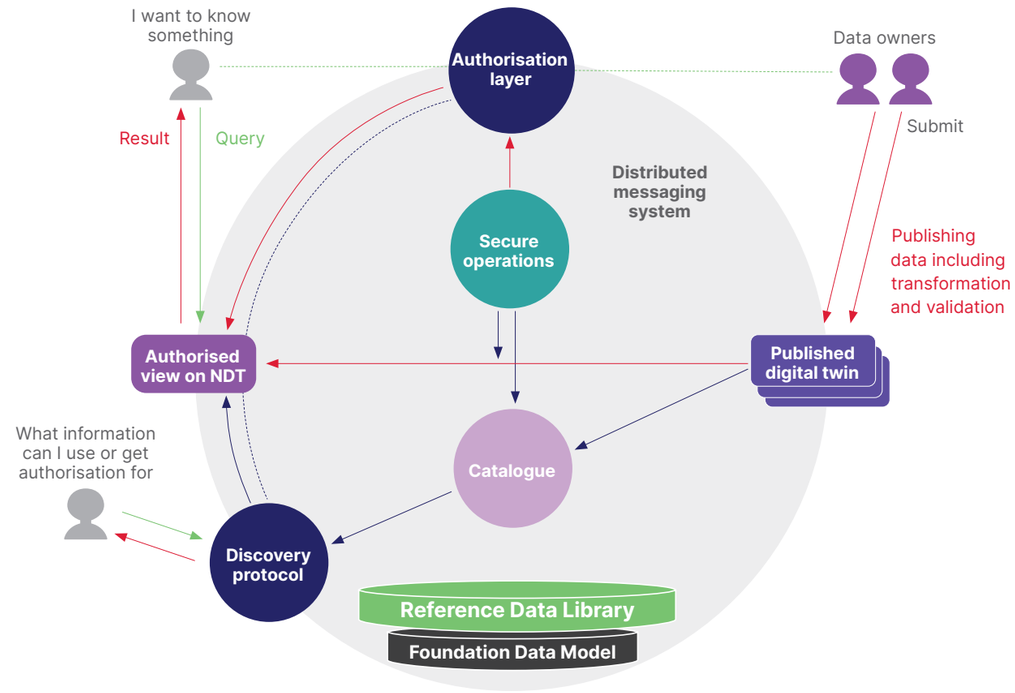


Figure 7: Elements of an integration architecture

Figure 7 shows how the IMF would enable a National Digital Twin from a nation of digital twins.

A national programme built on national consensus

We welcome industry feedback on the proposed approach. It will be important to harness diverse thinking across sectors to develop an approach which is inclusive and flexible and creates impetus towards the National Digital Twin.

The details of the technical approach are set out in, 'Pathway to an Information Management Framework' published at

www.cdbb.cam.ac.uk

If you would like to understand more about the National Digital Twin programme, please visit the CDBB website for further information

www.cdbb.cam.ac.uk/national-digital-twin-programme

If you would like to register your interest in being involved with the programme, we encourage you to register your details with the Digital Twin Hub (DT Hub) – the collaborative web-enabled community for those who own or are developing a digital twin.

www.cdbb.cam.ac.uk/DFTG/NDTHub

The National Digital Twin can only be achieved, and made a success, through the power of collaboration and a shared purpose.

References

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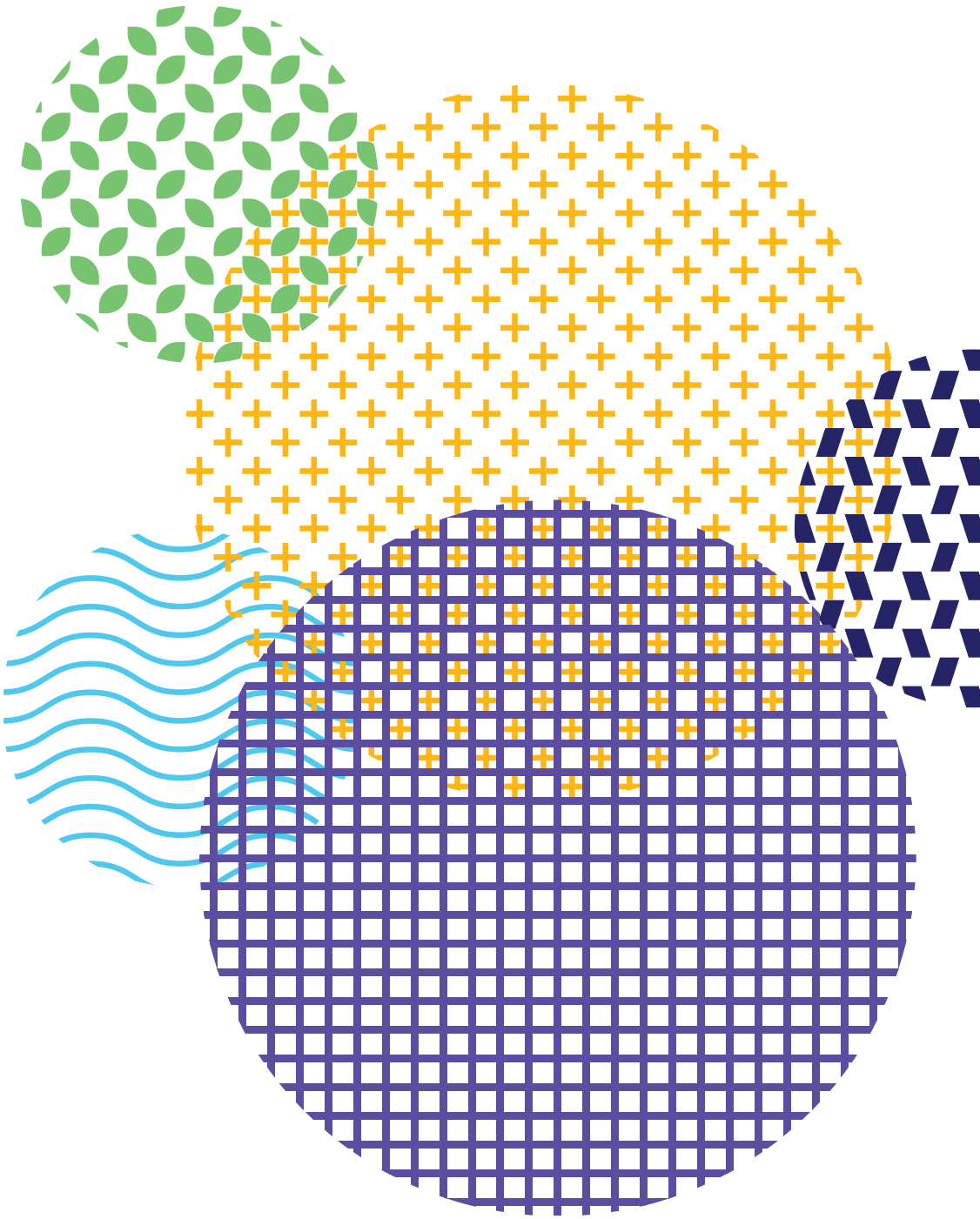

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