Digital Connected Globe (DCG) – Concept Paper

1. OVERVIEW

The Digital Twins (DTs) have the potential to elevate decision making to a new level. Simulation and evaluation of different alternative scenarios will enable data driven decisions and support the way to more effective policies, better response to emergencies and improved planning.

Recognizing the tremendous business opportunity from the introduction of DTs multiple industries are actively creating DTs for their products, processes, and organizations. European industry champions, expand on their Internet of Things (IoT) strategy and are among the leaders in this emerging competitive market.

The establishment of a rich, complex, and well-connected ecosystem of innovation and co-creation is a key success factor. Space has unique capabilities in two of the essential DT related assets: connectivity and data. Moreover, building on its reputation for cutting edge technology and experience in complex partnering, ESA can play an active role in this emerging ecosystem. Europe can become the best practice example in exploiting large scale, complex and interconnected DTs to support policy decision making, leveraging the connectivity and data infrastructures and space solutions with the European industries benefiting from this market opportunity.

The proposed Digital Connected Globe (DCG) industry-driven ARTES initiative will evolve in four axes:

1. Engage non-space and space industries to partner and co-develop solutions, forming a European DT ecosystem around connectivity and data solutions.
2. Explore the right architecture and governance models for an ecosystem supporting the creation of new applications exploiting the industry DTs and taking benefit from space solutions. Defining effective ways to broker information, support the deployment of relevant assets and facilitate the development of new innovative applications and services using DTs with added value from space. These can be services for smart cities, multi-mode logistics, etc.
3. Promote industry-led DT asset evolution, making existing DTs available for co-innovation of solutions with the space sector. Focus on facilitation and highlighting the use of satellite connectivity and space data in these solutions.
4. Continuous expansion to further industry verticals, as the digital transformation proceeds and technology capabilities evolve.

2. ABBREVIATIONS

ARTES	Advanced Research in Telecommunications Systems
DT	Digital Twin
DCG	Digital Connected Globe
DTE&U	Digital Twin Earth & Universe
AI	Artificial Intelligence
ML	Machine Learning
DL	Deep Learning
ESA	European Space Agency
OTT	Over The Top
GAIA-X	European Association for Data and Cloud
IoT	Internet of Things
SME	Small and Medium Sized Enterprise
VR	Virtual Reality
AR	Augmented Reality
SPL	Strategic Programme Line
TIA	Directorate of Telecommunications and Integrated Applications
GPL	Generic Programme Line
AO	Announcement of Opportunity
RfI	Request for Information
MNO	Mobile Network Operator
HPC	High Performance Computing
RfI	Request for Information

3. RATIONALE

3.1. The Power of Digital Twins (DTs)

Digital Twins (DT) play a key role in the Digital Transformation, supporting the seamless interconnection between the physical and the digital world.

The introduction of the Digital Twin paradigm can help address the major challenges of our time. Leveraging the unprecedented amounts of generated data, simulating complex scenarios, and evaluating the outcomes they are a powerful tool to support policy makers towards better decisions, manufacturers to new and improved products, organizations to more efficient processes, and ultimately consumers to enjoy better products and services, and citizens to a better daily life.

This is a new cyber-physical paradigm of information and knowledge sharing, going far beyond the established mechanisms to query, download and process data locally. It's made possible by the fast, ubiquitous connectivity, driving up the demand to have everything, everywhere and always connected.

High precision digital models are required, which capture both the natural and the human made environment. DTs are under development, making use of earth observation data as input to climate modelling and in support to simulations of what-if scenarios. DTs also exist which produce twins and models of infrastructures and processes related to economy and society and the underlying information and communications technologies. Roads and vehicles, buildings and complete cities, vessels, ports, and transport logistics chains, products and the manufacturing processes today are all relying on digital solutions and are pieces in the puzzle of these twins and models. So are the people commuting, working, producing, and consuming goods and services. Everything is or can be "linked" to its digital counterpart. Technology evolutions in data acquisition and processing, seamless almost real-time connectivity, and advances in AI (ML/DL) and automation have entered the real world and require DT solutions, helping to optimize real world solutions, to identify smarter transport solutions, e.g. using connected mobility.

The industry is already engaged in creating and monetizing value in the digital realm DT of the real world can help to reduce cost, to provide safer and greener solutions. This translates into business opportunities for a DT service industry.
Two key concepts around DTs are the drivers for the idea of the DCG.

Digital Twins are more than data. A DT is a digital replica of a physical entity, bridging the physical and digital world, implementing an automated data exchange between physical and digital entities, in both directions (Figure 1). Therefore, the digital replica captures the actual state of the specific physical asset and insights, decisions and actions can be performed on it, by acting on its digital counterpart. The advances in digital technologies (Connectivity, Big

Data, Machine Learning, Automation) enable this merge of digital and physical. Closely aligned to this is the vision of the next generation of communications (6G) for a unified experience across physical, digital, and biological worlds.

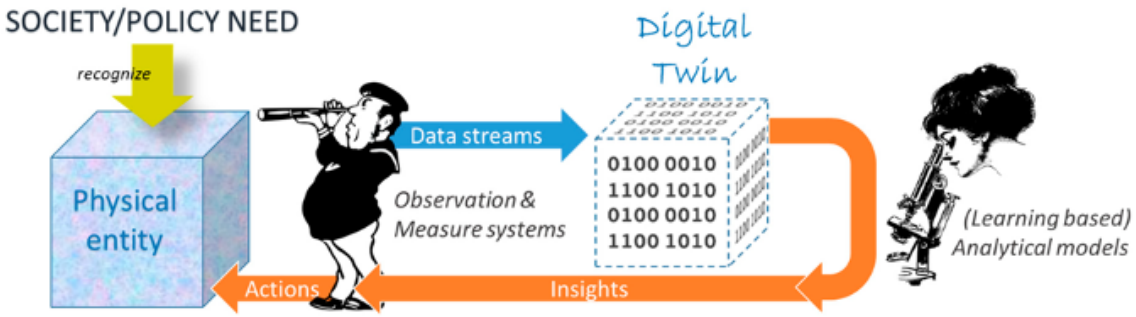

Figure 1 - The Digital Twin archetype (from Nativi et.al. (2021))

Combining elementary DTs to form "complex" DTs, which replicate increasingly advanced systems is a fascinating opportunity for the industry. Collaboration and co-creation between different organizations and maybe also different industries is now possible in a digital environment, opening new ways of innovation.[1] It is in these "system" DTs, DTs which can act in federation, and which are capturing increasingly complex aspects of key verticals, where industry analysts forecast the highest growth potential. [2]
Later in this paper a couple of illustrative examples of this approach are sketched.

3.2. The DCG focus is the human made environment

The DCG aims to establish the bridges between non space activities and the space community for the benefit of both in this new opportunity. It is an industry-led initiative and focuses on the interconnected information-based economy and society. People and assets, industrial products, and processes are linked to the digital realm, enabled by increasingly available IoT devices and information streams and a fabric of seamless communications and computing capabilities.
Synergies with initiatives around the creation of digital replicas of the natural environment will be leveraged to enable better and more powerful simulations, supporting data driven solutions to challenges in several domains, like smart cities, multi-modal logistics, and many others.(see Figure 2)

[1] Bridgestone already shares digital models of tyres with car manufacturers, Virtual Tyre Modelling.
[2] System digital twin to account for a larger share of the digital twin market by 2026 (Markets and Markets)

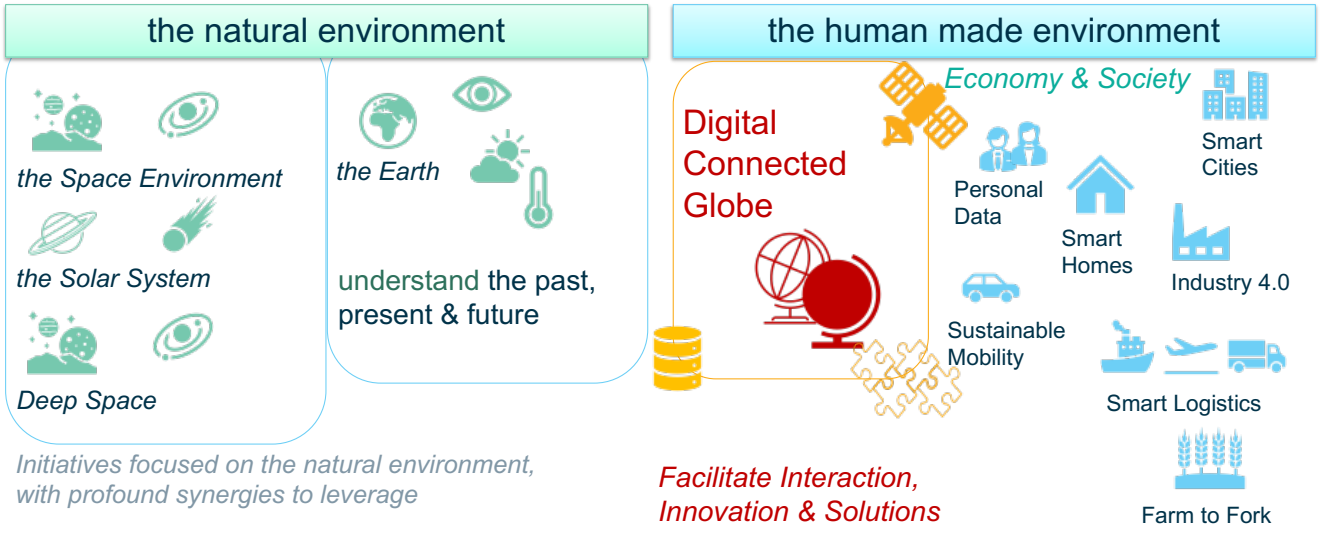

Figure 2 - The DCG focus is the human-made environment

3.3. The Importance of an Innovation Ecosystem

Data is continuously generating actionable intelligence, increasing the need for ubiquitous connectivity, and highly automated secure transactions (Figure 3). Supporting this evolution existing DTs span a widening range of industries, with companies at various stages in their digital transformation, and moving with different speed in their adaption.

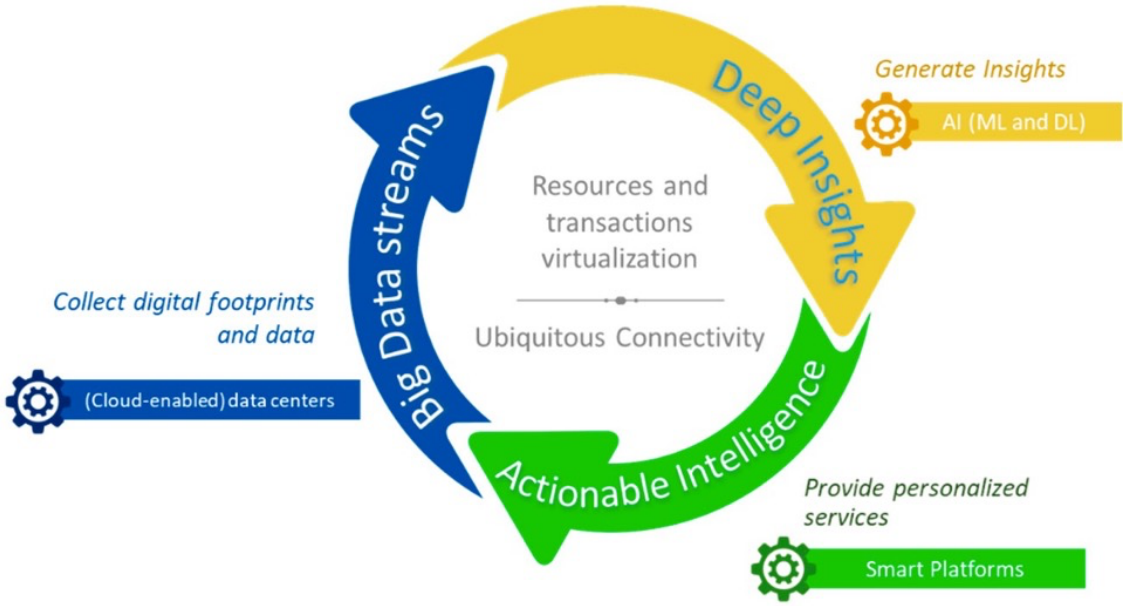

Figure 3 - Generating actionable intelligence from data streams. (Nativi et.al. (2021))

Gaining a competitive edge in the digital transformation, where the classical “make or buy” decision becomes more likely a “make, buy or partner” decision, a supportive ecosystem is essential for success. It fosters collective innovation and produces new competitive solutions.

Therefore, actions are needed along three lines:

1. Facilitation for establishing innovation ecosystems, to support flexible collaboration, enabling the rapid development and validation of new ideas, services, and business models.
2. Accessible quality data, the fundamental asset for creating DTs. Making data available and creating the right regulatory framework(s) for ownership, sharing, and usage.
3. Infrastructure, to de-risk the substantial investment in data lakes, AI models and algorithms, HPC, and connectivity.

Europe is already undertaking major initiatives in the infrastructure and data areas, recognizing both the need to support the industry in the significant technology investment required and in setting an efficient framework for data management and sharing (in terms of regulation and standardization).
The first line – the ecosystem – is not and cannot be a completely "controlled" paradigm. An ecosystem "evolves" to serve its stakeholders, who need to see clear gains from partnering. The capabilities and governance need to be highly adaptive and match the emerging needs. It is therefore a key objective of the DCG initiative to create and support such eco-system and a variety of actors in different domains of the digital economy.

3.4. The Position of Space in the DTs Ecosystem

The DCG aims to introduce and establish space solutions and industry in the existing and evolving DTs ecosystem for mutual benefit. The space community has a privileged position, for two primary reasons:

1. Connectivity, with the emergence of multi-orbit, multi-element connectivity constellations space-based connectivity will increasingly become part of terrestrial connectivity solutions.
2. Data from earth observation, geographical positioning, timing services are of immense value for complex DTs.

ESA, being an inter-governmental, not-for-profit organization, with a reputation of neutrality, enabler, and facilitator, bringing cutting edge technology and reliable complex partnering experience, has the right profile to assume a leading role in establishing space as part of the much wider DT ecosystems landscape in Europe.

4. GOALS AND OBJECTIVES

The DCG aims to include space in existing DT solutions to improve decision making for policy makers, public and private operators, and industrial process owners and to implement more cost effective and greener digital solutions. Acute challenges will be better understood and responded to with more confidence. Planning for future evolution and developments in the real digital world will better serve the needs of industries and public stakeholders once multiple scenarios are possible to simulate before policies and strategies are decided.

This ambition will be supported through the development of brokering platforms in partnership with the space and non-space industry already active in DTs or planning to become active.

5. EXPECTED OUTCOME

5.1. Develop and Establish Brokering Solutions for DTs

Data and increasingly connected data and information is the main asset in the context of digital transformation initiatives and therefore data and metadata brokerage is an actively researched topic, with evolving concepts and architectures[3]. With the DCG the target is to go beyond data, considering the DTs themselves as digital resources, which should be managed. As an example, the manufacturer owns the generic "model" of the DT, but the instance of the DT may be purchased together with the physical object. A large-scale industry solution, an operative or administrative process can involve several DTs from different vendors and industries, interacting with each other.
Innovation around the capabilities, functionalities, and modes of co-creation between the DTs and their owners is at the core of the DCG.
The DCG activities will help the industry to:

1. Define the right platform architectures for managing a library of DT assets and establishing the brokering capabilities and advanced interoperability between various DTs.
2. Establish and validate viable business models, which can support the implementation, operation, and evolution of DT brokering platforms.
3. Define effective governance models for DT brokering platforms.
4. Design, develop and operate the brokering platform(s).
5. Identify the gaps in their DT offerings and design, develop and validate the upgrade technology, product, and system solutions, including the satellite communication components.
6. Identify and develop innovative applications leveraging their DTs.
7. Perform demonstration towards pre-operational services with verticals of technology, products and applications leveraging the DCG.
8. Advertise DT meta-data and relevant assets, facilitating exchange between stakeholders.

5.2. Addressed Stakeholders

The DCG will create the right environment, becoming the glue, for efficiently establishing the links between the various stakeholders, who are assuming different roles in the ecosystem, such as:

1. Producers, most notably vendors creating DTs of their products, seeking to add a digital component in their offering,
2. Designers, who are creating DTs of processes, leveraging the DTs of products.
3. Data Providers, who generate quality data to support or complement DTs.

[3] Fraunhofer – Metadata Broker https://www.dataspaces.fraunhofer.de/en/software/broker.html

4. Innovators, exploiting DTs to solve increasingly complex problems, offering solutions and consultation.
5. Value Add Service Providers, which exploit DTs, to deliver new over the top (OTT) services.
6. Owners, having the legal rights to the DT, possibly through their purchase of a physical product or through separate agreements.
7. Consumers, who want better and additional services from DT enhanced products and processes.
8. Policy makers, who seek to use cutting edge capabilities, so that they can take better data supported decisions.

Figure 4 attempts a graphical representation of these roles.

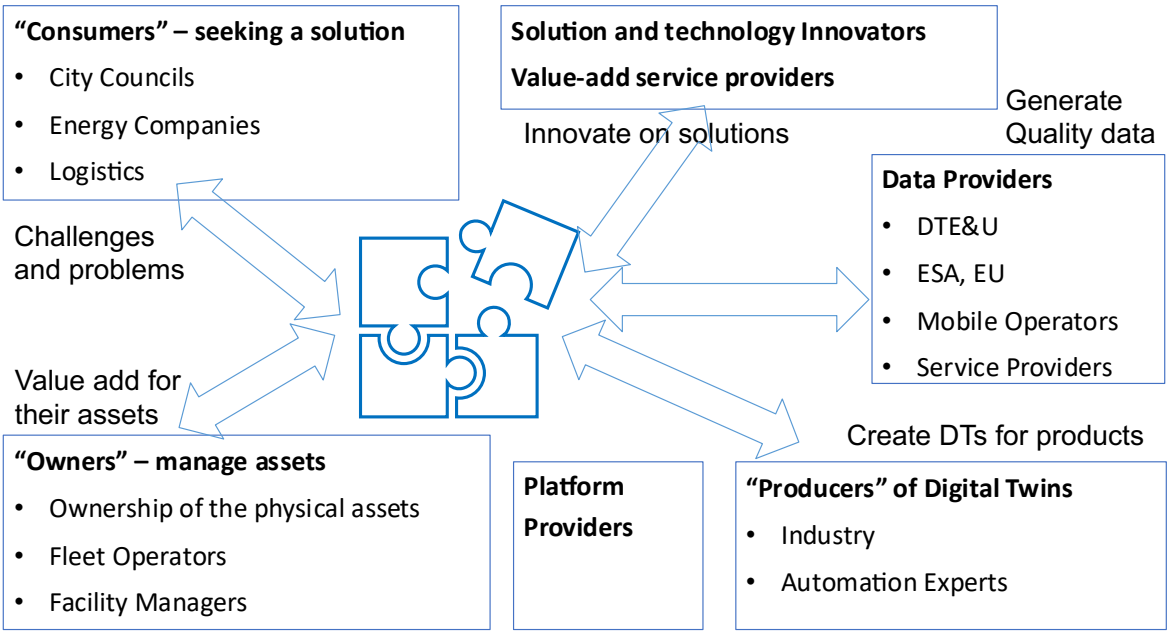

Figure 4 - An Ecosystem for Digital Twins

5.3. Position the Space Industry in the DT Ecosystem

Solutions exploiting the capabilities of DTs are pushing connectivity needs, especially in terms of reliability and accessibility. They are therefore a primary driver for introducing and expanding the use of satellite-based connectivity.
Moreover, the space community assets (EO, meteorological data, …) will gain visibility and their use will be promoted via the DCG. Serving the industries to create increasingly complex DTs, will increase their use – especially outside the traditional space related use cases.
Interesting new and demanding use cases both in terms of satcom and space data are sought for in the scope of the DCG.
This will foster increased cooperation between the space ecosystem and the wider industry, delivering value to consumers, and opening new digital revenue streams for the DT owners.

5.4. Develop New Applications and Services

The DCG initiative invites to create innovative applications and services, as well as forging new business models. It will address a wide range of stakeholders in the different roles described (see addressed stakeholders above).
The scope explicitly addresses capabilities in various directions:

1. Formulate and communicate problems and requirements towards the community, inviting solution proposals
2. Digital processes to support agreements / contracts
3. Digital processes to support co-creation

Therefore, on one side, policy makers and "consumers" are invited and supported in expressing and communicating their needs through the DCG capabilities. In parallel, on the other side, the owners of DTs, innovative startups and universities, and organizations with "the right data", are invited and supported to cooperate in developing solutions.

6. INDICATIVE EXAMPLE USE CASES

To illustrate the idea of combining DTs in a more complex "higher level" digital replica of a system, two indicative example use cases are outlined.

6.1. Maritime and Logistics Domain

Accurate life-like simulation of the activities and processes of a port, combining:

1. DTs from vessels including space-based ship-routing (owned by shipowners, created by shipyards)
2. DTs from cranes and loading / unloading systems (cargo lifts, transport, …) in the port (owned by port authorities or operators, created by the vendors)
3. Accurate port maps, maybe 3D maps, meteo data
4. Digital processes and protocols, complying to regulations and legislation
5. People working on the port, data from their mobile phone usage, activity records, anonymized as needed (from MNOs).
6. And many more…

Port authorities can evaluate different scenarios for the development of the port. What if scenarios for new regulations, expansion plans, changes in use and many more. Bringing in the correlations with climate, weather conditions and accurate water level measurements to assess the impact. Data supported detailed proposals are delivered.
Ship operators seeking to optimize in port activities, as cargo loading and unloading, maintenance and repair services, etc.
Logistics companies can optimize their end-to-end activities, executing required actions in the "digital" realm, leveraging high degrees of automation capabilities, saving time and cost.

6.2. City and Smart Mobility Domain

Accurate simulation of a city, combining:

1. DTs from public transport including connected vehicles (owned by bus or tube companies)
2. DTs from cars in the city (taxis and ride-sharing companies, created by automotive)
3. Accurate city maps, 3D maps, meteo data, pollution data
4. Data from mobile phone usage, or other activity records, anonymized as needed (gathered from the Mobile Networks Operators, or private companies).
5. Data from malls and public places, for example ticket controls can provide information on the number of people visiting a venue (event management companies)
6. And many more…

City authorities can model the way citizens behave and evaluate different scenarios. What if scenarios for traffic management when new public transport routes are introduced. City development planning, repurposing of areas and construction guidelines. Anticipate the environmental impact of decisions, and so on.

MNOs can optimize their service availability, by deploying intelligent mechanisms, that can respond to changing demand as people move from housing to work districts, concentrate in a stadium for an event, and more.

Ride-sharing and multi-modal transport providers can leverage on improving their service offerings form the accurate models of commuting modes.

Emergency response teams can study different scenarios, for evacuating the city in case of a major natural disaster (earthquake, flood, volcano eruption, wildfire), providing relief response and planning how to build up alternative resources rapidly and effectively.