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The Digital Landscape Twin

— *Joint Perspective for BIM, LIM, and GIS*

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Digital Twins

Digital Twins

- A **real object** of interest is represented by a **digital counterpart**, the Digital Twin, and data on operating states and changes is accumulated **over the entire life cycle**.
- Concept developed in the context of **Industry 4.0**
- Development / implementation started over 10 years ago
  - first in the fields of mechanical engineering, aerospace, space flight, energy technology, automotive engineering
- A digital twin is connected to its real, physical counterpart via sensor observations
  - in Industry 4.0 via the **Internet of Things (IoT)**

Digital Twin – Definitions (1)

- Definition of the German Informatics Society:
  - *A **digital twin** is a **digital representation of a tangible or intangible object or process** from the real world in the digital world.*
  - *It is irrelevant whether the counterpart already exists in the real world or will exist in the future.*
  - *Digital twins enable a **cross-cutting exchange of data.***
  - *They are more than just data and **consist of models of the represented object or process and can also contain simulations, algorithms and services** that describe or influence the properties or behavior of the represented object or process or offer services about it.*
- Source: https://gi.de/informatiklexikon/digitaler-zwilling/

Digital Twin – Definitions (2)

- Definition according to Deloitte Consulting: „Industry 4.0 and the digital twin – Manufacturing meets its match“. Deloitte University Press, 2017)
  - *A digital twin can be defined, fundamentally, as an **evolving digital profile of the historical and current behavior of a physical object or process** that helps optimize business performance.*
- Further statements from the same source
  - *The digital twin is **based on massive, cumulative, real-time, real-world data measurements across an array of dimensions**. These measurements can create an evolving profile of the object or process in the digital world that may provide important insights on system performance, leading to actions in the physical world such as a change in product design or manufacturing process.*
  - *Clearly, the world of a physical process (or object) and its digital twin analogue are **vastly more complex than a single model or framework** can depict.*

Digital Twins in Industry 4.0

The digital twin for each specimen of a turbine comprises

- Model data, manufacturing specific data
- Logs of all measurements recorded during operation (operating and performance data)
- Maintenance reports

Image source: https://www.ibm.com/blogs/internet-of-things/iot-digital-twin-revolution/

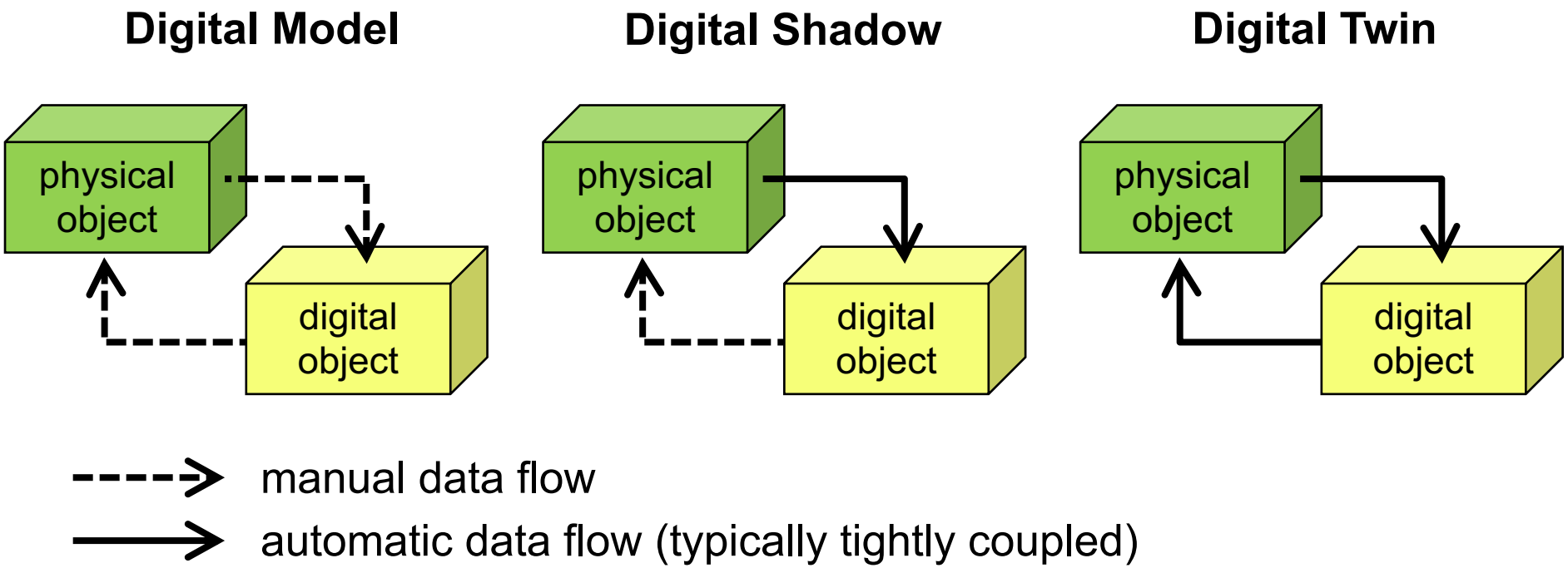
Imagesource: https://new.siemens.com/global/de/branchen/windenergie/equipment/digitalisierung.html

Benefits of Digital Twins (1)

- Comprehensive cumulative **documentation** of real objects
  - Specimen-specific properties (dimensions, calibrations, etc.)
  - Measurement of properties during operation
- Calculation / **estimation of the system state** and **system performance**
  - Derivation of indicators based on the data of the digital object
- Applications
  - **Monitoring and control** of physical objects and systems
  - Hazard detection, **detection of exceptional conditions**
  - Operation optimization, **predictive maintenance**
- **“What-if“ scenarios**
  - Modification of the digital twin according to the scenarios and estimation of the impact on the system

Categories of Digital Twins

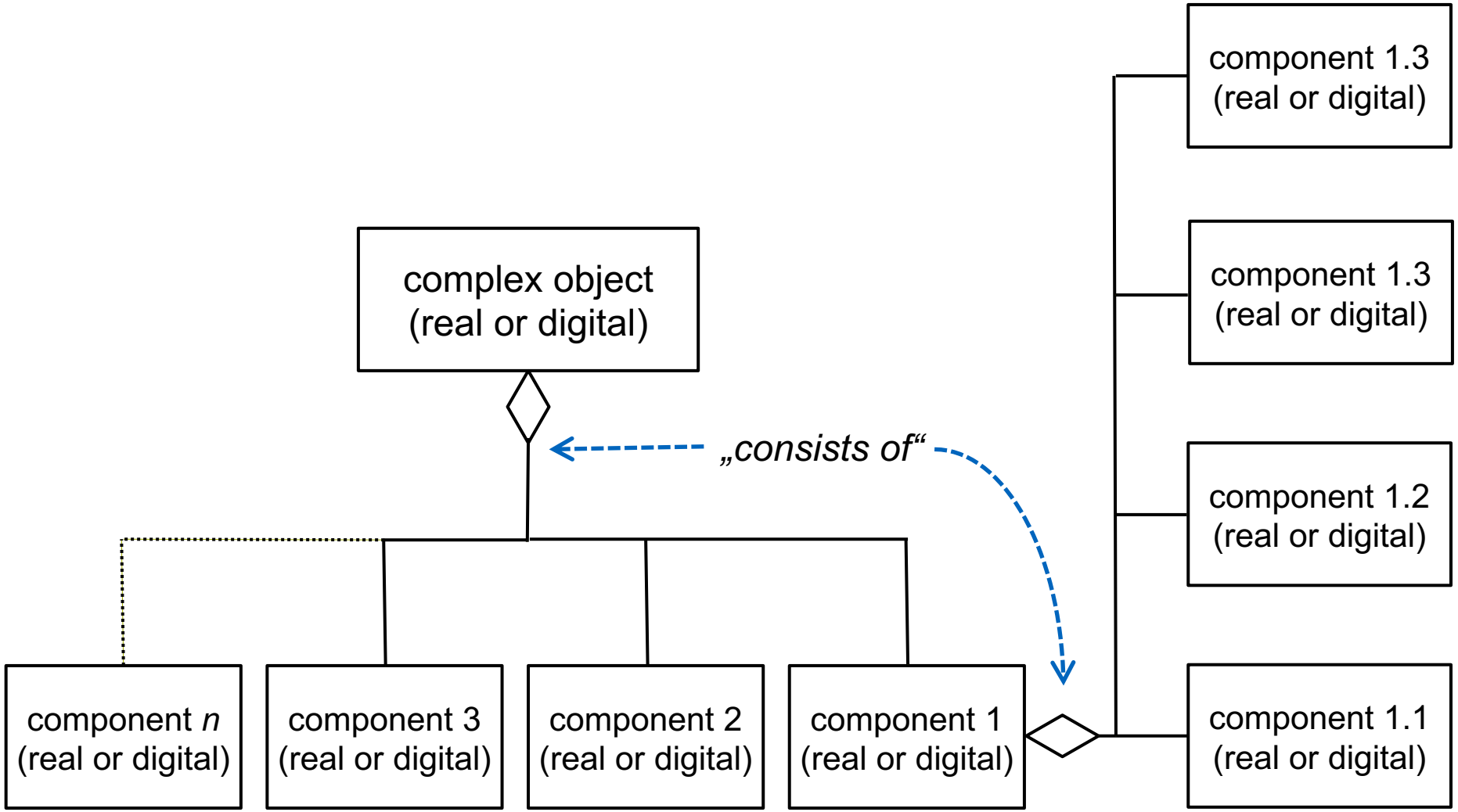
- often a distinction is made according to the degree of interconnection between the physical and digital object
  (but this is debated)



Benefits of Digital Twins (2)

- **Design** of real systems with the help of digital objects
  - First, digital objects are planned, which are subsequently built as real products;
  - Estimation of costs as well as material and energy requirements
- **Simulation** of real systems on the basis of digital objects
- **Construction** of real systems based on digital objects
  - Construction plans are derived from digital objects
  - Production processes are derived and optimized
  - Monitoring of the manufacturing process by comparing the current production status with the digital model
  - Digital manufacturing: control of production equipment for fully automated manufacturing of physical objects (e.g. 3D printers)
- Conclusion: high benefit in all phases of the life cycle!

Hierarchical View (1)



Hierarchical View (1)

solar module

component 1.3
(real or digital)

city district

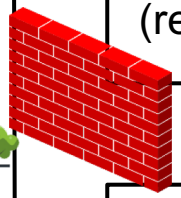
component 1.3
(real or digital)

roof

complex object
(real or digital)

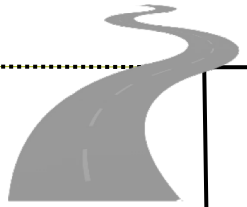
„consists of“

component 1.2
(real or digital)



wall 2

component *n*
(real or digital)

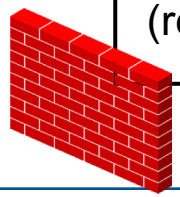


component 3
(real or digital)

component 2
(real or digital)

component 1
(real or digital)

component 1.1
(real or digital)



wall 1

charging station

road A

road B

building

Hierarchical View (2)

- Objects of the city or landscape consist of separate parts
  - buildings consist of walls, windows, rooms, roofs, etc.
  - roads consist of lanes, bike lanes, sidewalks, etc.
  - the power grid consists of cables, transformers, switches, etc.
- Parts in turn consist of parts and so on
  - ➔ aggregation hierarchy
- In principle, each part can or must have its own digital twin
- The digital twin of the city or landscape is thus composed of
  - the Digital Twins of the components of the city
  - the relationships between the individual digital twins

Information Aspects of Urban / Landscape Objects

- **Identity** (Objects are delimited from each other and can be named individually)
- **Classification** / assignment to a type
- **Spatial properties** (location, orientation, shape, extent)
  - derived quantities such as area, volume, height, width, etc.
- **Thematic properties** / domain specific data
  - information of general relevance to this type of object
  - subject/domain-specific information (price value, energy requirements, CO2 emissions, maximum speed, etc.)
- **Metadata** (“data about data“)
  - Accuracy, timeliness of data; ownership, rights to use data; collection method, collector, etc.
- **Temporal aspects** (dynamics / changes over time)

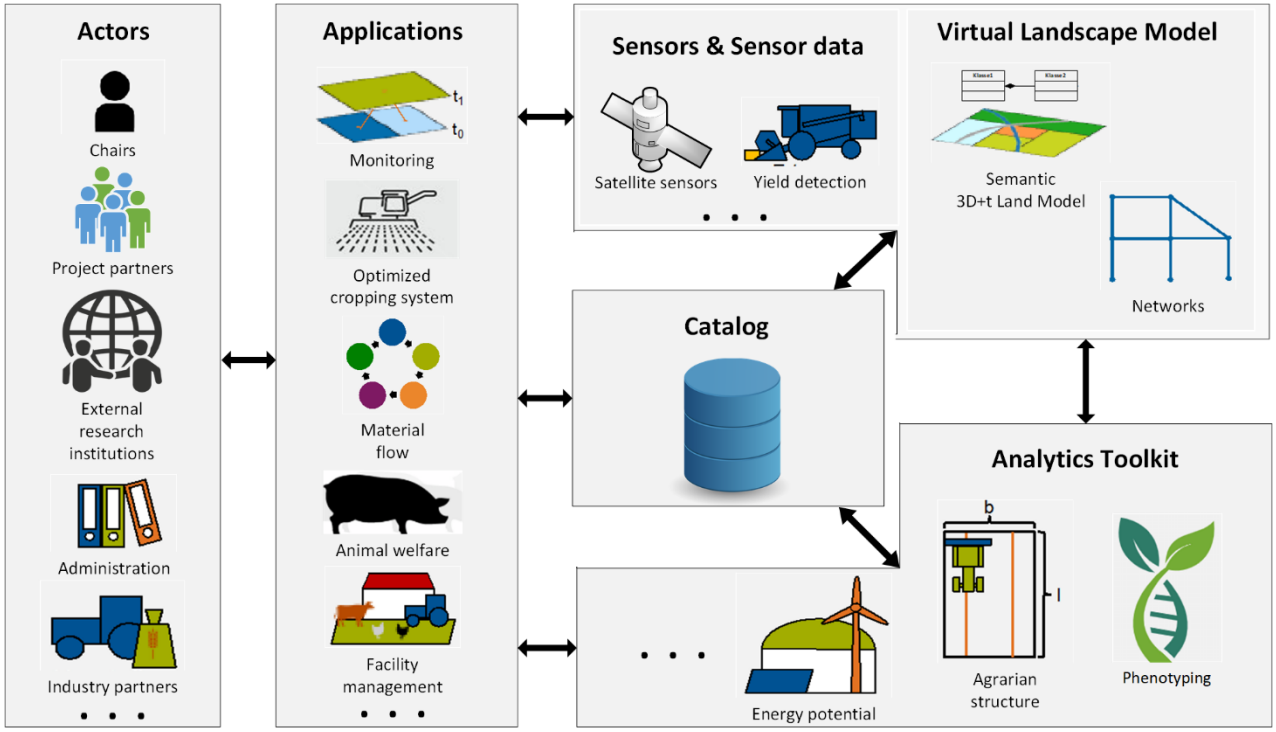
How this relates to BIM, LIM and GIS?

BIM, LIM, GIS and the Digital Landscape Twin

- BIM and LIM are based on digital modeling of the real world
- *„Yes, but 3D point clouds are also digital models of the real world“*
  - the same is true for all other kinds of GIS data incl. maps, 3D meshes
  - this is also true for virtual reality models and digital images
- The key lies here in the term „Information“ in BIM and LIM
  - the digital models explicitly represent real world objects and not just their appearance or their geometry
  - information models can be queried for objects of the real world
- Many of the important information aspects are covered by BIM and LIM → „Yeah! So they are the digital twins!?“
- Unfortunately not…

Smart Rural Area Data Infrastructure - SRADI

- Multidisciplinary information infrastructure
  - Multiple Stakeholders – Multiple Applications – Distributed Information Resources
  - Consequent usage of international standards of the Open Geospatial Consortium (and others) to facilitate interoperability
  - **No single platform!** – rather an infrastructure of platforms / resources



Catalog

- Core component of the distributed Digital Twin
- Establishes semantic relations between diverse distributed resources
- Manages information on “individual physical things” level
- Manages stakeholders and organizations

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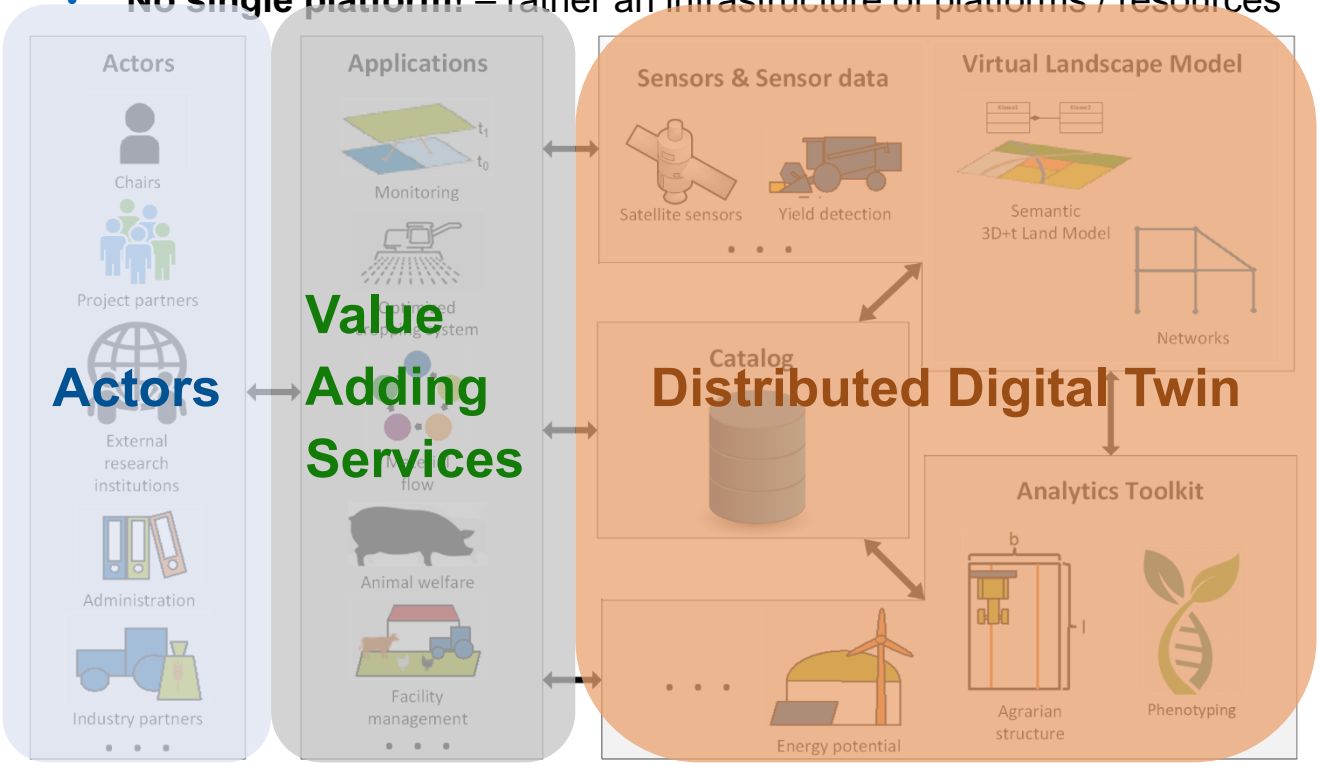

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Closing Observations (1)

- In many cases users and stakeholders are not interested in BIM, LIM, or GIS **per se**
  - instead, they are interested in (or in need of) a digital twin (and its promises…)
  - often integration with real-time data and analytical tools is required, which is not in the scope of BIM nor LIM
- The scope of either BIM, LIM, or GIS is too narrow to consider one of them *THE* digital twin of the landscape
  - regarding the modeled aspects covered by the data models
  - regarding the way, how these models abstract the real world (e.g. georeferencing) and how the according datasets are being created
  - regarding the sustainable maintenance of such models
  - VR models, 3D point clouds, 3D meshes could also serve as DTs

Closing Observations (2)

- Is Landscape Information Modelling just an extension of BIM data models (**LIM = BIM^{+}**) **?**
  - be aware that behind BIM there stands a modeling paradigms that is well suited to deal with generative, parametric models and which has strong limitations regarding coordinate reference systems
  - it is very difficult to generate BIM models automatically from observations (also because of data model complexity)
  - BIM models cannot fully be managed (edited, updated) in GIS nor in spatial database management systems. Can you manage larger landscape models in a BIM system?
- The DLA community should think about **re-coining the term "Landscape Information Modeling"**
  - not as an extension of BIM or GIS in the first place (it may adopt principles)
  - and considering the specific needs of the profession and data providers

Closing Observations (3)

- The **digital landscape twin** will comprise many kinds of digital models of the physical reality
  - it depends on the applications and use case, which kind should be used
  - sometimes it may be sufficient to just use 3D meshes or a BIM model
  - sometimes it may be sufficient to use a landscape information model
  - sometimes a combination of LIM, BIM, and e.g. point clouds or VR models will be needed
- The digital landscape twin is rather an infrastructure than just a collection of models