

Digital Ecosystems for Digital Twins of the Earth:

the Destination Earth case

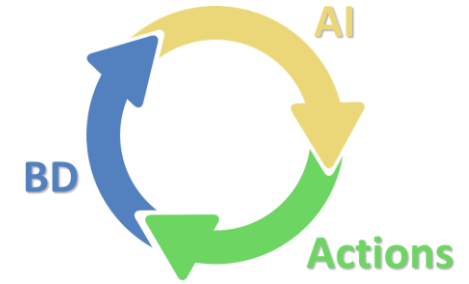
EODC Annual Workshop

09 Jun 2021

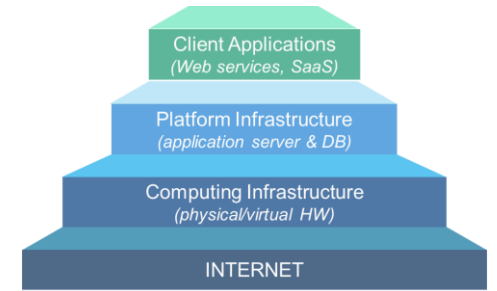
Stefano Nativi and Max Craglia

A shift of paradigm (from data exchange to network resources orchestration)

- Build on the flexible and convergent use of online resources
 - **Datasets** and sensors
 - **Infrastructure capabilities** (e.g. network, storage and computing capacities)
 - **Analytical models/services** and Application software (e.g. AI ones)
- (Geosciences) Digital Ecosystem
 - *A holistic view of a diversity of autonomous and distributed organizations sharing a common virtual environment and a set of digital resources to survive, thrive, and co-evolve*
- Digital Twins of the Earth
 - *Digital replica of an Earth system component/structure, process, or phenomenon by merging digital modelling and real-world observational continuity (natural and societal sensing data streams)*



Society Datafication



Computing virtualization

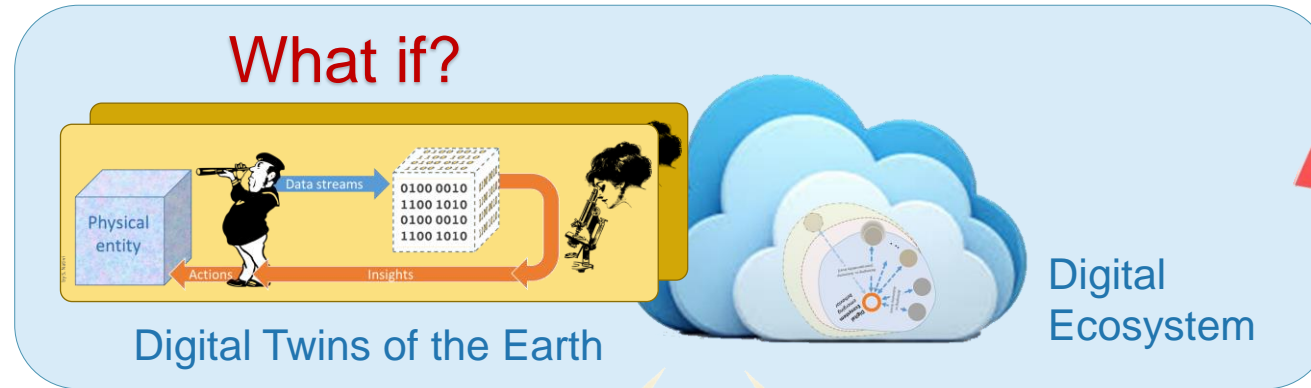
The Twin transitions

Merging the physical and the digital worlds

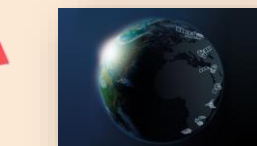


Sustainable and resilient society

European and International initiatives and Programs



Enable



Destination Earth



Green Data4All



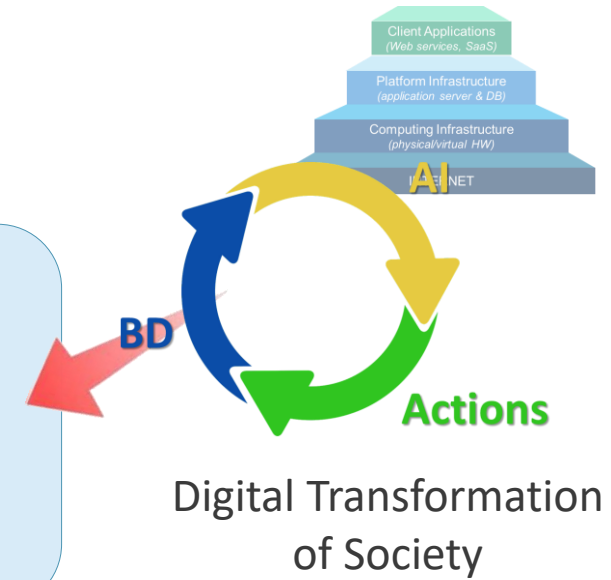
Regional GEO



Copernicus services



...



Digital Twins of the Earth Applications and Programs

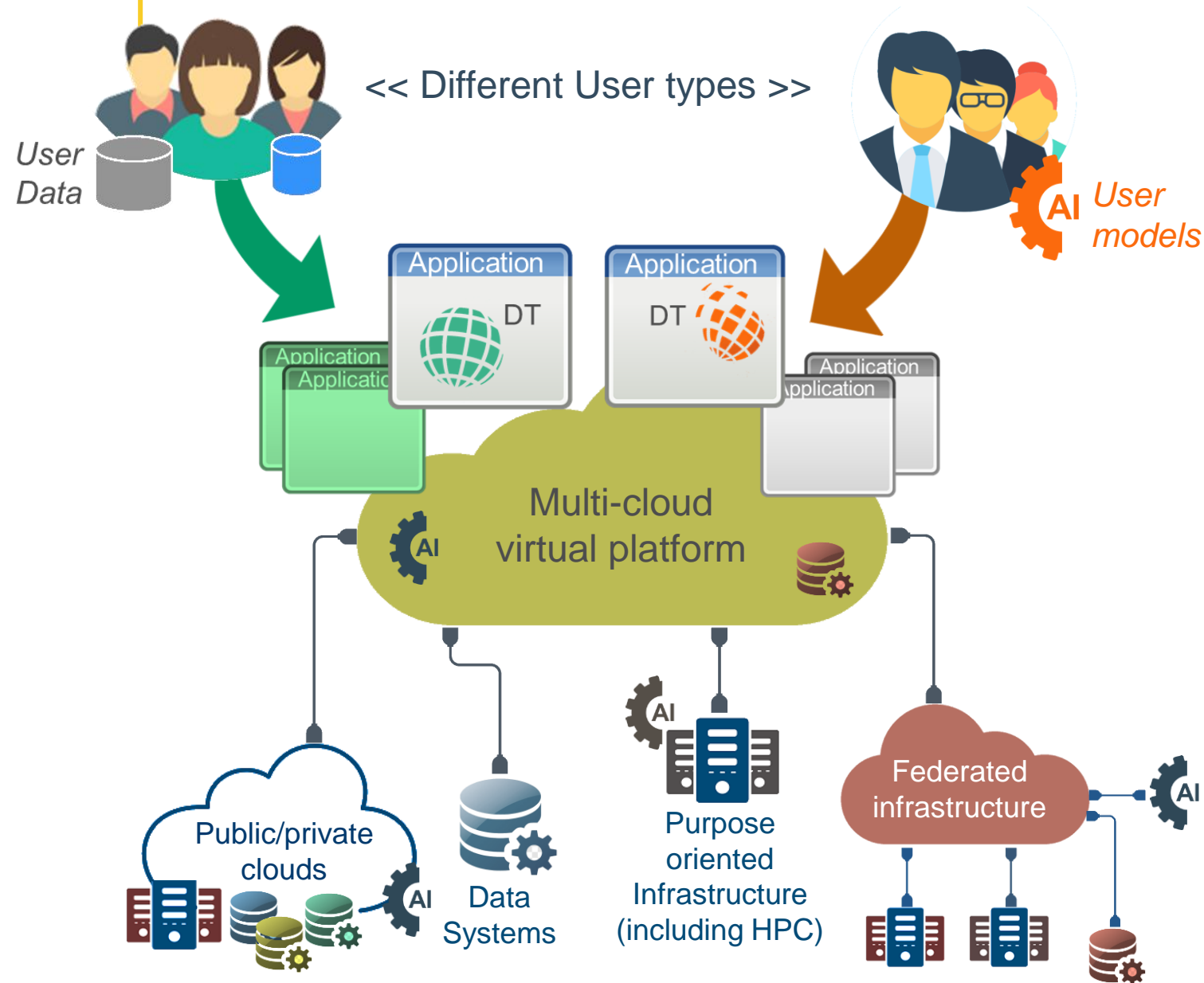
Main research and innovation areas	Examples of significant activities	Main research and innovation areas	Examples of significant activities
Earth System Modeling/Digital Earth	<ul style="list-style-type: none"> • EU H2020 CRESCENDO project • DATA TERRA (French project) • Advanced Earth System Modeling (A-ESM) • Digital Earth: Towards Smart Modeling (German initiative); • CMIP Phase 6 (International project) • OneGeology 4.0 (International project) • Deep Time Digital Earth (DeepTime) • Space Climate Observatory (SCO) • NSW Digital Twin (Australian project) • USA NSF EarthCube initiative • Descartes Labs: Digital Twin of the Earth • Destination Earth initiative • International Society for Digital Earth 	Extreme natural phenomena monitoring	<ul style="list-style-type: none"> • Modular Observation Solutions for Earth Systems • EU H2020 ExtremeEarth project • Destination Earth initiative of the European Commission
3D Imaging	<ul style="list-style-type: none"> • AI4GEO (French project); • 3DExperienceCity (French project) • CO3D (French project) 	Food Security monitoring	<ul style="list-style-type: none"> • EU H2020 ExtremeEarth project
Water and Drought monitoring	<ul style="list-style-type: none"> • SWOT downstream program • Drought Watch (ESA funded) 	Pollution monitoring	<ul style="list-style-type: none"> • Knowledge Hub to analyze and simulate organic carbon
Forest monitoring	<ul style="list-style-type: none"> • Forest Inventory Program 	Smart cities/City Twins	<ul style="list-style-type: none"> • EU H2020 DUET (Digital Urban European Twins) • City of Zurich (Swiss project) • 3DExperienceCity (Virtual Singapore and Virtual Republic of Helsinki) • Helsinki Digital Twin (Finland project); • Digital Twin Cadaster – Victoria (Australian project) • 3DExperienceCity (French project); • PortForward: the Digital Twin of the port of Rotterdam • Open Mobility Foundation (OMF) (USA initiative); • Digital Built Britain (United Kingdom initiative); • Cambridge initiative (United Kingdom initiative); • Many other smart city projects all around the world (Yingtan, Amaravati, Waterfront Toronto);
Ecosystems monitoring	<ul style="list-style-type: none"> • ECOTWIN: Towards the digital twin of ecosystems • Nosvillesvertes (French initiative) 		<ul style="list-style-type: none"> • ZeroGravity UrbanAI (Finland project); • PortForward: the Digital Twin of the port of Rotterdam • Open Mobility Foundation (OMF) (USA initiative); • Cambridge initiative (United Kingdom initiative); • EU H2020 LEAD (Digital Twins for low emission urban areas)
Maritime simulation and monitoring	<ul style="list-style-type: none"> • Kongsberg; • Marine data streams capabilities 		<ul style="list-style-type: none"> • EU H2020 SPHERE project
Polar region monitoring	<ul style="list-style-type: none"> • EU H2020 ExtremeEarth project 	Smart Energy	<ul style="list-style-type: none"> • EU H2020 SPHERE project; • Kongsberg (Norway project)
		Climate Change adaptation strategies in urban areas	<ul style="list-style-type: none"> • LIFE-IP AdaptInGR (EU and Greek funded project)

Digital Ecosystems for Digital Twins



- Enable DTs generation
- Support DTs access and build applications on them
- Provide online resources
Orchestration and Chaining
- Support online Analytical
software access and use

Digital Ecosystem for Digital Twins



A system-of-systems
made up of enterprise
systems

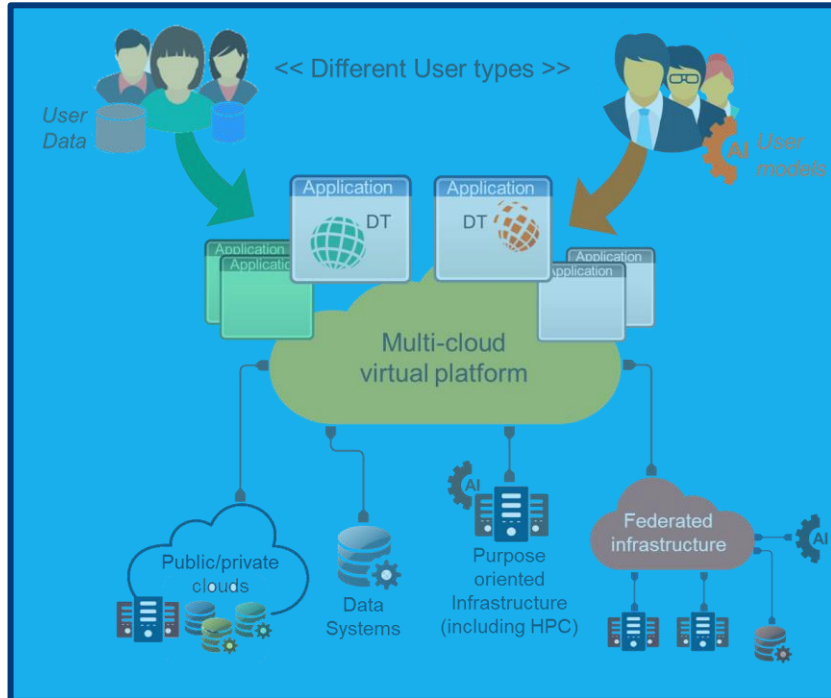
Internet is the
ecosystem environment

Digital Resources
sharing and
orchestration

Provide open scalability
(Multi-cloud)

Digital Ecosystem Principles and Patterns

Enabling role for a
European EO and
Geospatial data space



Modularity

Flexibility

Content and digital Diversity

Evolvability

Viability

Enterprise systems
autonomy

Ecosystem principles and patterns

■ **Modularity**

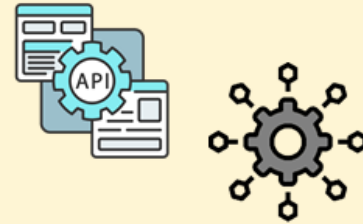
■ **Flexibility**

■ Content and digital Diversity

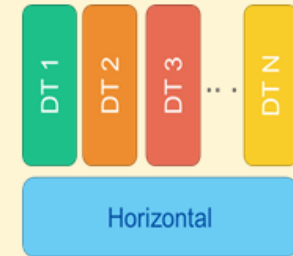
■ Evolvability

■ Viability

■ Enterprise Systems autonomy



Support
heterogeneous use cases and digital services by applying both **Resources (ROA)** and **Services-oriented (SOA)** approaches



Decouple the **DTs** and the **Multi-cloud virtual platform** (by open APIs)

Ecosystem: a highly dynamic system

Modularity

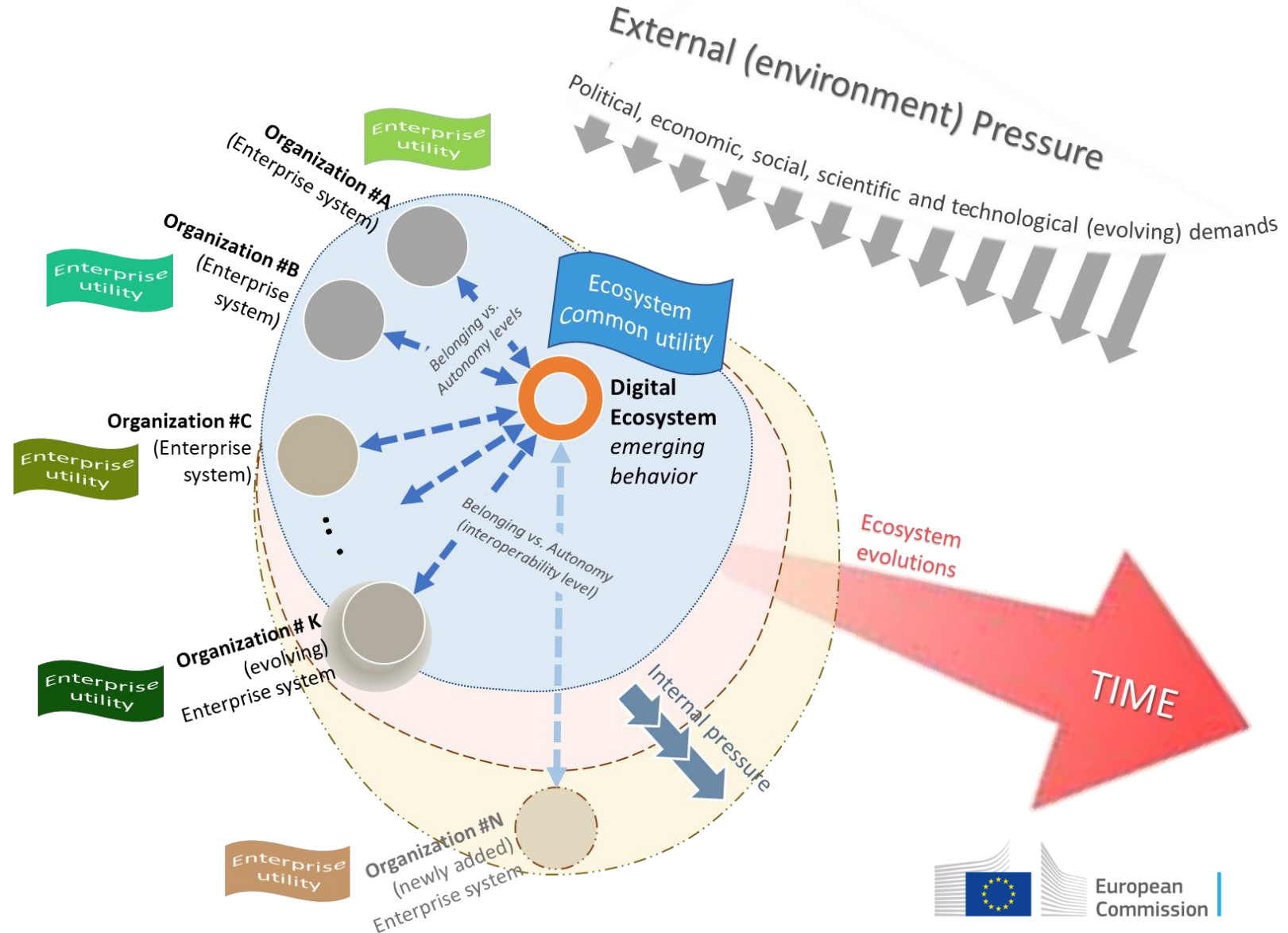
Flexibility

Content and digital Diversity

Evolvability

Viability

**Enterprise Systems
autonomy**



Ecosystem: must be a viable system

Modularity

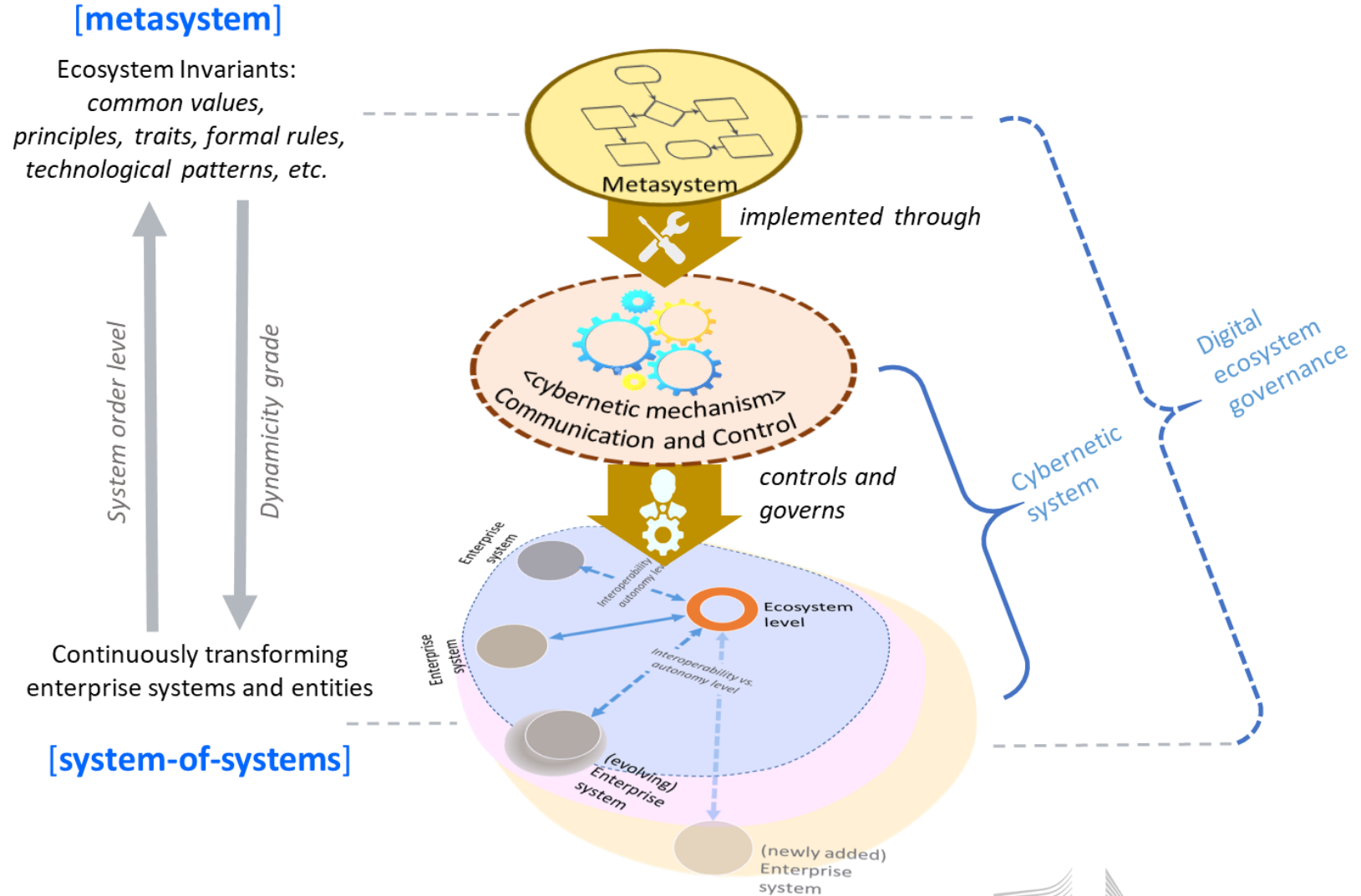
Flexibility

Content and digital Diversity

Evolvability

Viability

Enterprise Systems
autonomy



The Ecosystem paradox

Collaborating and yet autonomous systems/organizations

Modularity

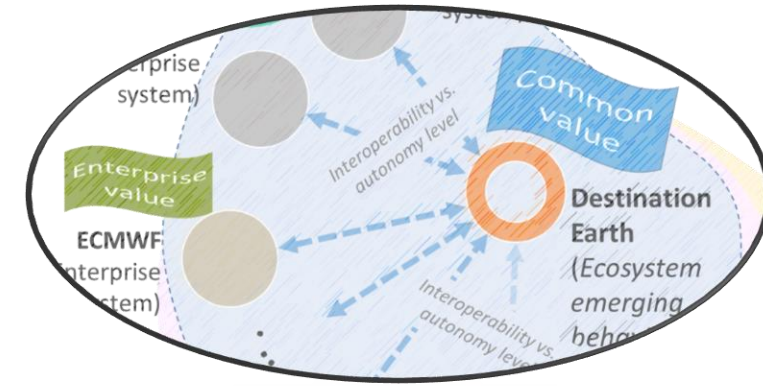
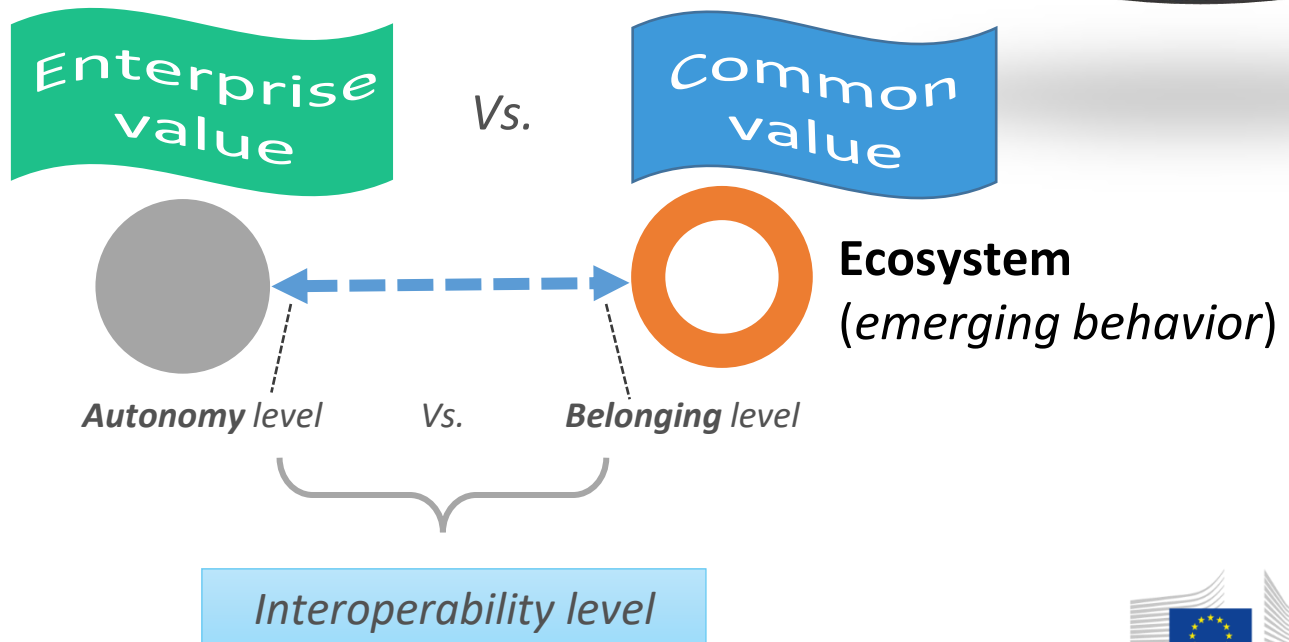
Flexibility

Content and digital Diversity

Evolvability

Viability

**Enterprise Systems
autonomy**



Ecosystem principles and patterns

Modularity

Flexibility

Content and digital Diversity

Evolvability

Viability

**Enterprise Systems
autonomy**



Recognize a
(technological)
**Ecosystem Common
Value** pursuing that
via a (technological)
Governance Style



Define **a range of
acceptable
Autonomy vs.
Belonging
(interoperability)
levels** to achieve the
**Ecosystem Common
Value and the
Enterprise Values**



Define **Metasystem
invariants
(Interoperability
Traits and Formal
Rules)** and apply
them through
**controls and
governance
mechanisms/tools**

Ecosystem (Technological) Governance styles

- **Virtual ECOSYS**

- No central management authority and no agreed upon purpose



- **Acknowledged ECOSYS**

- Recognized common objectives, a central management, but constituent systems retain their fully autonomy

- **Collaborative ECOSYS**

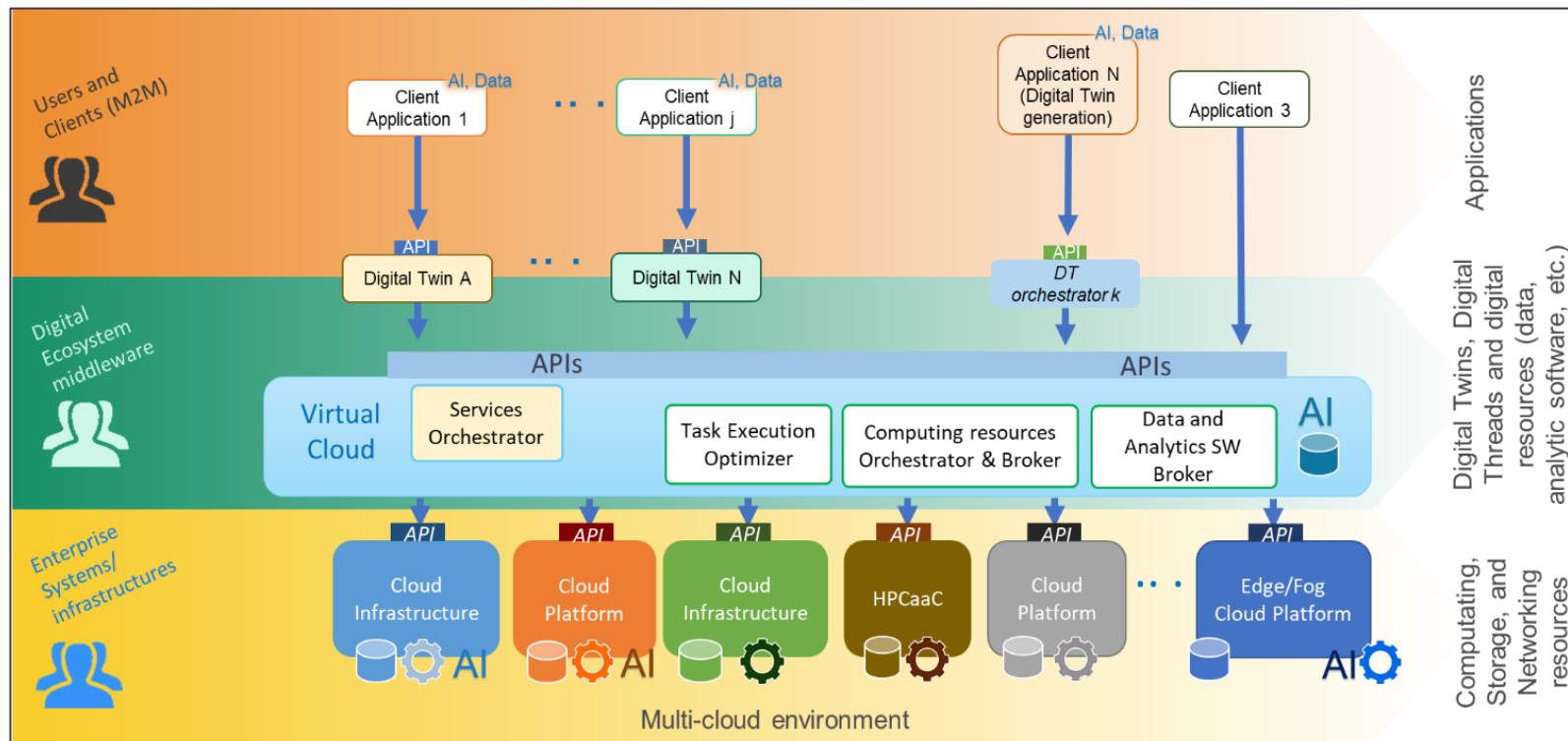
- Recognized common objectives, a designed ecosystem manager and devoted resources, constituent systems still retain most of their autonomy (more or less voluntary effort)

- **Directed ECOSYS**

- An integrated ECOSYS centrally managed with devoted resources to fulfill specifically agreed purposes

The Destination Earth Proof-of-Concept (principles in action)

- **Joint effort:** DG JRC, ECMWF, ESA, EUMETSAT
- **Multi-cloud framework** implemented through virtual cloud technologies
- Ansible scripts, **ClusterAPI**, **Kubernetes**, and Virtual Earth Laboratory technologies



Co-designed logical architecture

Presented and discussed in a dedicated workshop (Nov 2020)

Publications

- DG JRC study to support DG CNECT on Destination Earth
 - [Destination Earth: Ecosystem Architecture Description](#)
 - **Publication Year:** 2021
 - **JRC Publication N°:** JRC124168
 - **Authors:** NATIVI Stefano, CRAGLIA Massimo
 - [Destination Earth: Use Cases Analysis](#)
 - **Publication Year:** 2020
 - **JRC Publication N°:** JRC122456
 - **Authors:** NATIVI Stefano, CRAGLIA Massimo
 - [Destination Earth: Survey on “Digital Twins” technologies and activities, in the Green Deal area](#)
 - **Publication Year:** 2020
 - **JRC Publication N°:** JRC122457
 - **Authors:** NATIVI Stefano, DELIPETREV Blagoj, CRAGLIA Massimo
- Peer-reviewed journals
 - [Digital Ecosystems for developing Digital Twins of the Earth: The Destination Earth case](#)
 - **Publication Year:** 2021
 - **Journal:** Remote Sensing
 - **Authors:** NATIVI Stefano, MAZZETTI Paolo, CRAGLIA Massimo



Conclusions

- The digital transformation of society provoked a **paradigm shift moving physical resourced into the virtual world**
- The development of a **cyber-physical world is essential to make human development sustainable** and save the planet.
- **DE and DT of the Earth are innovative and synergetic instruments** living in such a world, essential to make our society “smart”
- DE has an enabling role for **developing the European Green Deal data Space**
- To this aim, **DE design and implementation must consider a set of principles** and apply well-recognized patterns
- To survive and thrive, **DE must be governed as viable system-of-systems** by using cybernetic instruments

Thank you



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