Towards Architectural Coordination for Digital Twins

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Novel Direction

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Outline

1. Motivation
2. Planning challenges
3. Architectural coordination (novel direction)
4. Further novel directions
5. Conclusion

Motivation – Scope of entities «twinned» by DTs

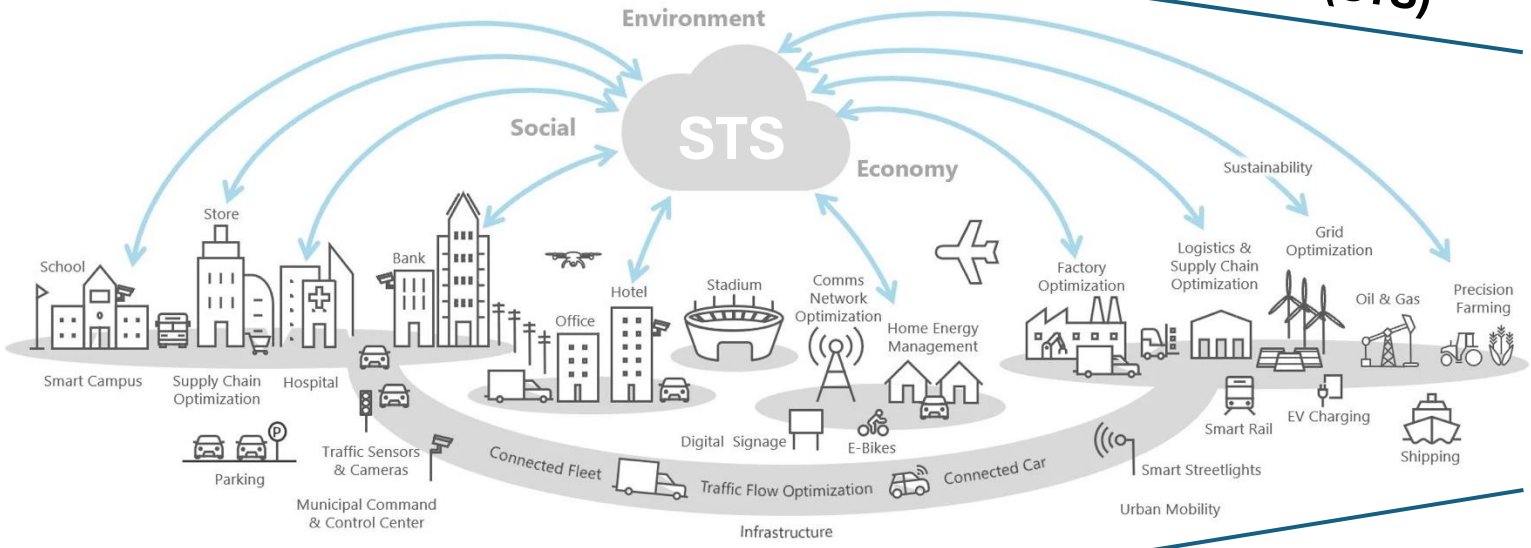
Physical Entity

bi-directional data flow

Virtual Representation

Physical Entities

Socio-technical Systems (STS)

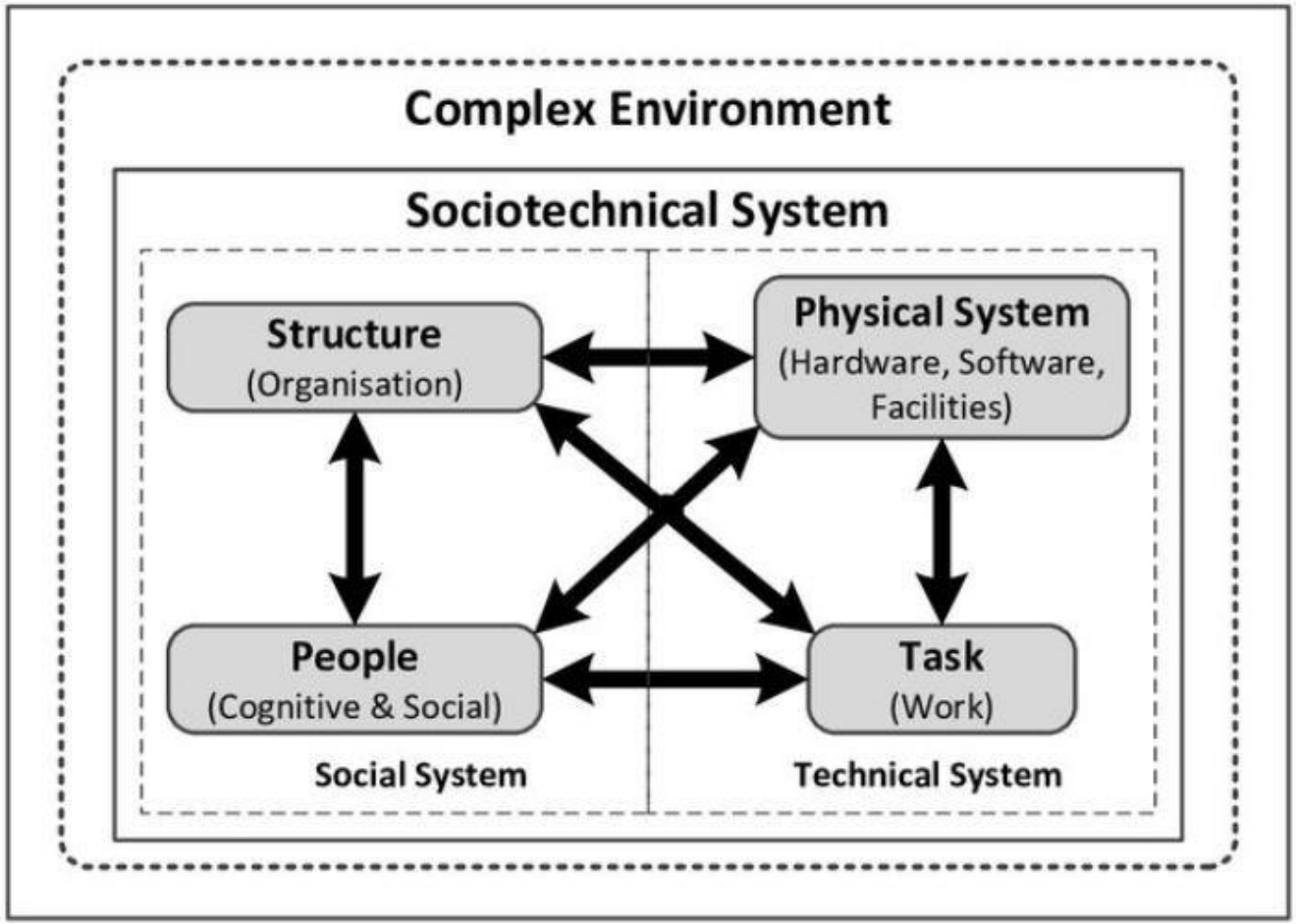


Urban Planning

Nochta, T.; Wan, L.; Schooling, J. M.; Parlikad, A. K.: A Socio-Technical Perspective on Urban Analytics: The Case of City-Scale Digital Twins. Journal of Urban Technology28 (1–2), pp. 263–287, 2021.

Source: https://www.ascr.at/wp-content/uploads/2022/03/2022-UC15-DE.pdf / https://azure.microsoft.com/de-de/blog/connecting-urban-environments-with-iot-and-digital-twins/

Socio-technical systems



DTs are considered to have a potential **added value** towards a variety of complex **decision-making problems**

Adopted from Bostrom, R. P. & Heinen, J. S. (1977). MIS Problems and Failures: A Socio-Technical Perspective. Part I: The Causes. *MIS Quarterly*, *1*(3), 17.

Added value for complex decision-making problems

DTs are a class of **advanced (active) information systems**, and should, in an enterprise context, be treated as an **integral part of the larger portfolio of information systems**.

Enable their users to **take informed decisions** pertaining to «twinned subject» and often even allow them to actuate these decisions.

Functionalities integrated into DT: Advanced digital models, symbolic and sub-symbolic AI, optimisation, simulation, and visualisation techniques.

Planning challenges for Digital Twins

Ad-hoc & isolated development

Kawas, D.; Connolly, T.: Digital Twin Business Maturity Model - A Digital Twin. 2024. / Rasheed, A.; San, O.; Kvamsdal, T.: Digital twin: Values, challenges and enablers from a modeling perspective. 2020.

Lack of user engagement

Qi, Q. et. al.: Enabling Technologies Tools for Digital Twin. 2021. / Opoku, D. -G. J. et. al; Barriers to the Adoption of Digital Twin in the Construction Industry: A Literature Review. 2024.

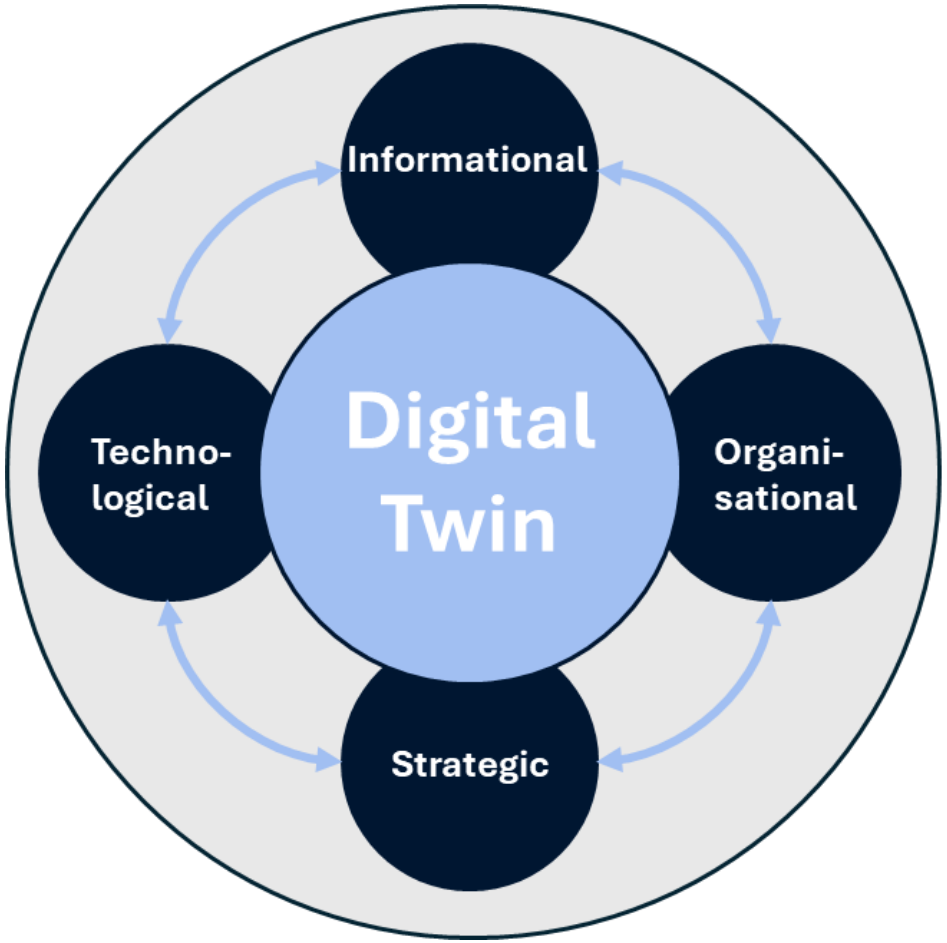
Fragmented data ecosystems

Bukhsh, Z. A.; Stipanovic, I.: Predictive maintenance for infrastructure asset management. 2020. / Oliveira, M. I. S.; Lóscio, B. F.: What is a Data Ecosystem?. 2018.

Potential for synergies in the IT landscape

Lick, J.; Disselkamp, J.- P.; Kattenstroth, F.; Trienens, M.; Rasor, R.; Kühn, A.; Dumitrescu, R.: Digital Factory Twin: A Practioner-Driven Approach for Integrated Planning of the Enterprise Architecture. 2024.

Architectural coordination for DT



Enterprise Architecture Management (EAM)

Provide structured approaches to align technological, information, and organisational architectures to strategic objectives.

Enable informed decision-making in managing and coordinating structural planning challenges in enterprises, and their portfolio of information systems.

Op 't Land, M.; Proper, H. A.; Waage, M.; Cloo, J.; Steghuis, C.: Enterprise Architecture – Creating Value by Informed Governance. Springer, 2009.

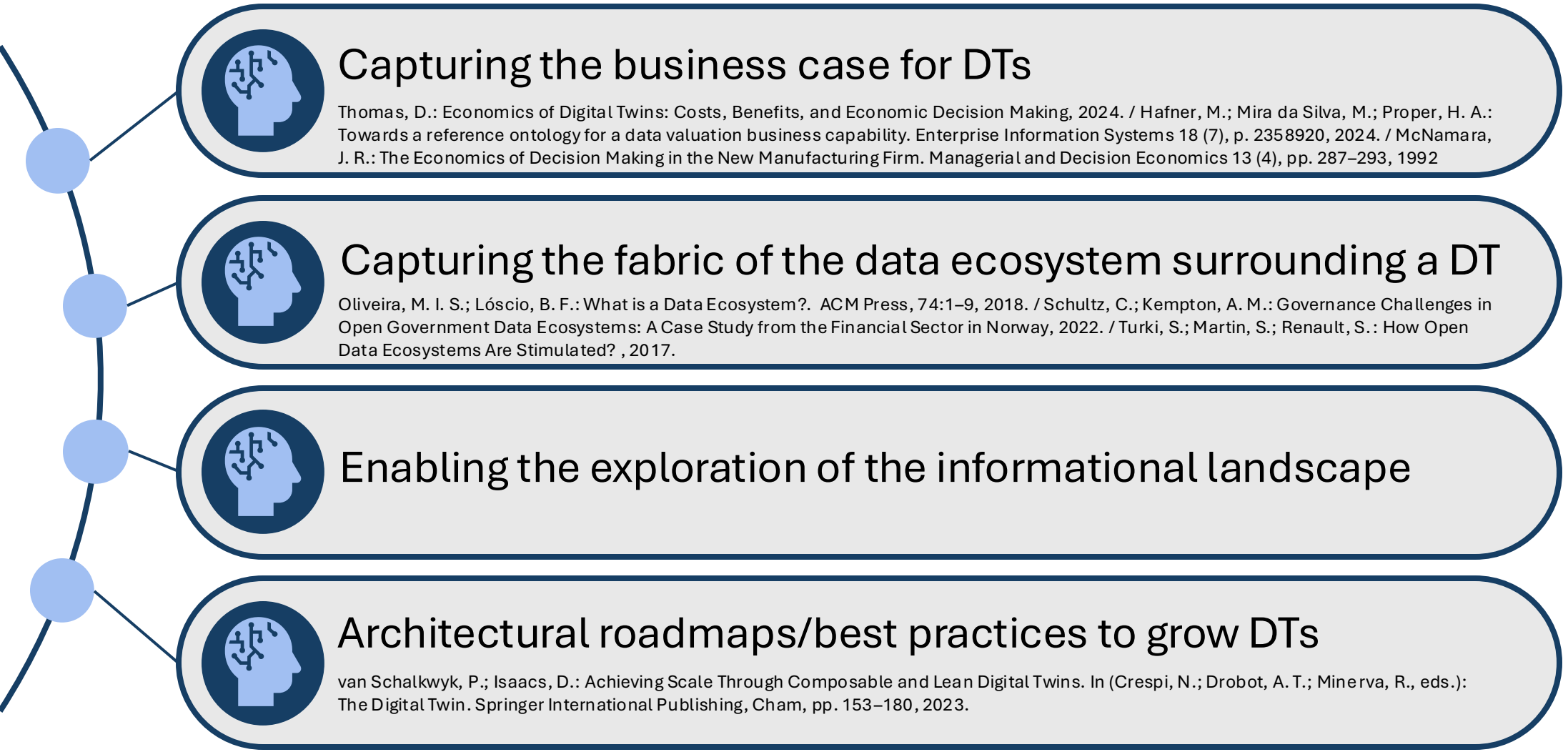
Value of adopting a broader EAM perspective

EAM uses architectural models as a key instrument to…

1. manage, ensure coherence and coordinate structural planning challenges in (digital) transformation of organisations
2. specify high-level design of IS/IT solutions to business needs and manage their overall coherence within the IS/IT landscapes
3. coordinate among relevant stakeholders and ensure overall coherence and alignment of initiatives

Proper, H. A.; Winter, R.; Aier, S.; de Kinderen, S., eds.: Architectural Coordination of Enterprise Transformation. Springer, 2018. /
Proper, H. A.; Wagter, R.; Bekel, J.: On Enterprise Coherence Governance with GEA: A15-Year Co-Evolution of Practice and Theory. Software and Systems Modeling 22 (2), 2023.

Further novel directions



Capturing the business case for DTs

Thomas, D.: Economics of Digital Twins: Costs, Benefits, and Economic Decision Making, 2024. / Hafner, M.; Mira da Silva, M.; Proper, H. A.: Towards a reference ontology for a data valuation business capability. Enterprise Information Systems 18 (7), p. 2358920, 2024. / McNamara, J. R.: The Economics of Decision Making in the New Manufacturing Firm. Managerial and Decision Economics 13 (4), pp. 287–293, 1992

Capturing the fabric of the data ecosystem surrounding a DT

Oliveira, M. I. S.; Lóscio, B. F.: What is a Data Ecosystem?. ACM Press, 74:1–9, 2018. / Schultz, C.; Kempton, A. M.: Governance Challenges in Open Government Data Ecosystems: A Case Study from the Financial Sector in Norway, 2022. / Turki, S.; Martin, S.; Renault, S.: How Open Data Ecosystems Are Stimulated? , 2017.

Enabling the exploration of the informational landscape

Architectural roadmaps/best practices to grow DTs

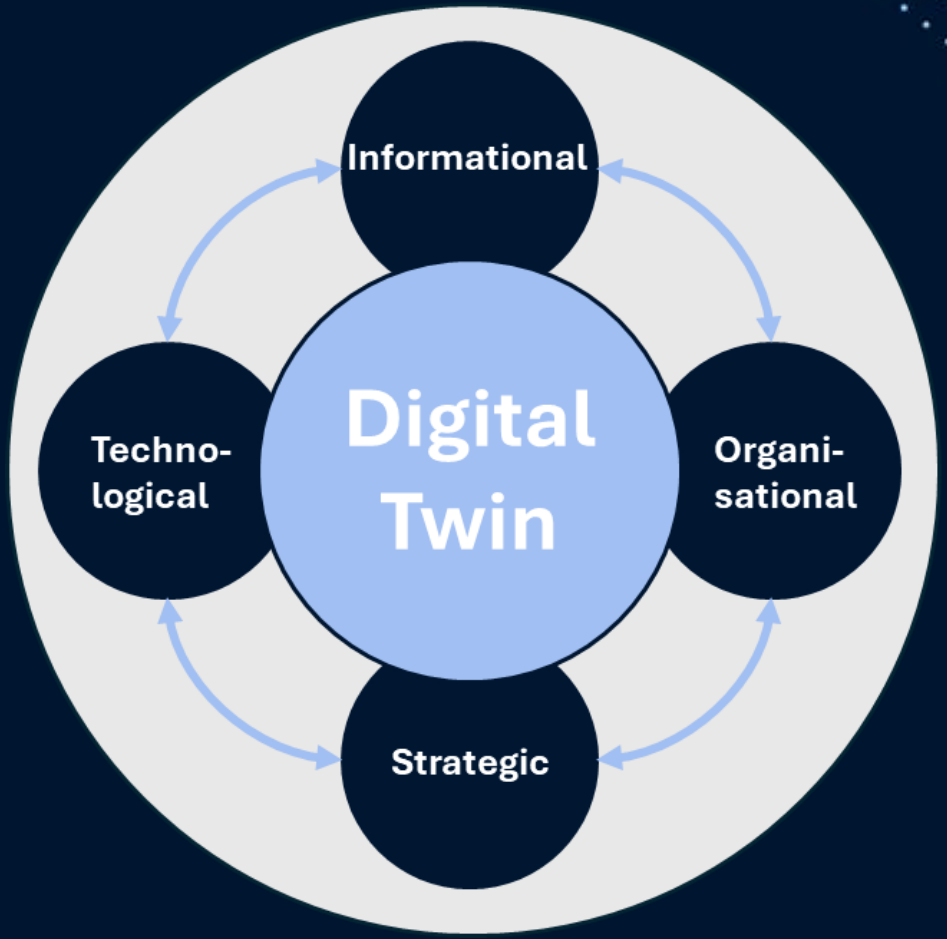
van Schalkwyk, P.; Isaacs, D.: Achieving Scale Through Composable and Lean Digital Twins. In (Crespi, N.; Drobot, A. T.; Minerva, R., eds.): The Digital Twin. Springer International Publishing, Cham, pp. 153–180, 2023.

Conclusion

This paper contributes to…

- positioning the development, deployment, and evolution of Digital Twins (DTs) as a matter of architectural coordination within the broader Enterprise Architecture Management (EAM) context.
- the view of DTs not as monolithic systems, but as modular chunks of functionality.
- integrating these modular DT components into the broader (inter-organisational) IT landscape.

Thank you for your attention!



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