Digital Twins in the Living Environment

Investment theme Wageningen University & Research

Dick de Ridder, Jene van der Heide, Willem Jan Knibbe

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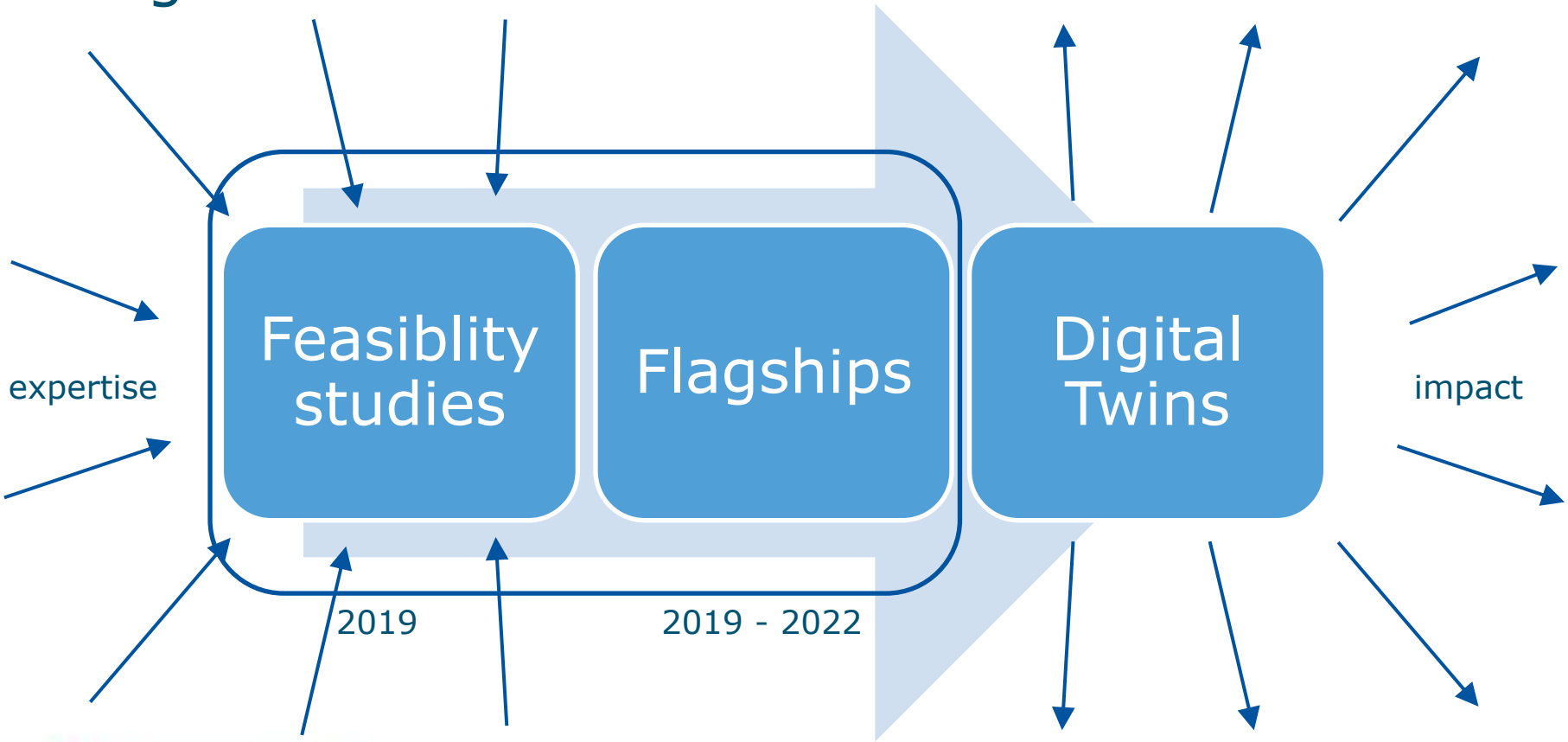
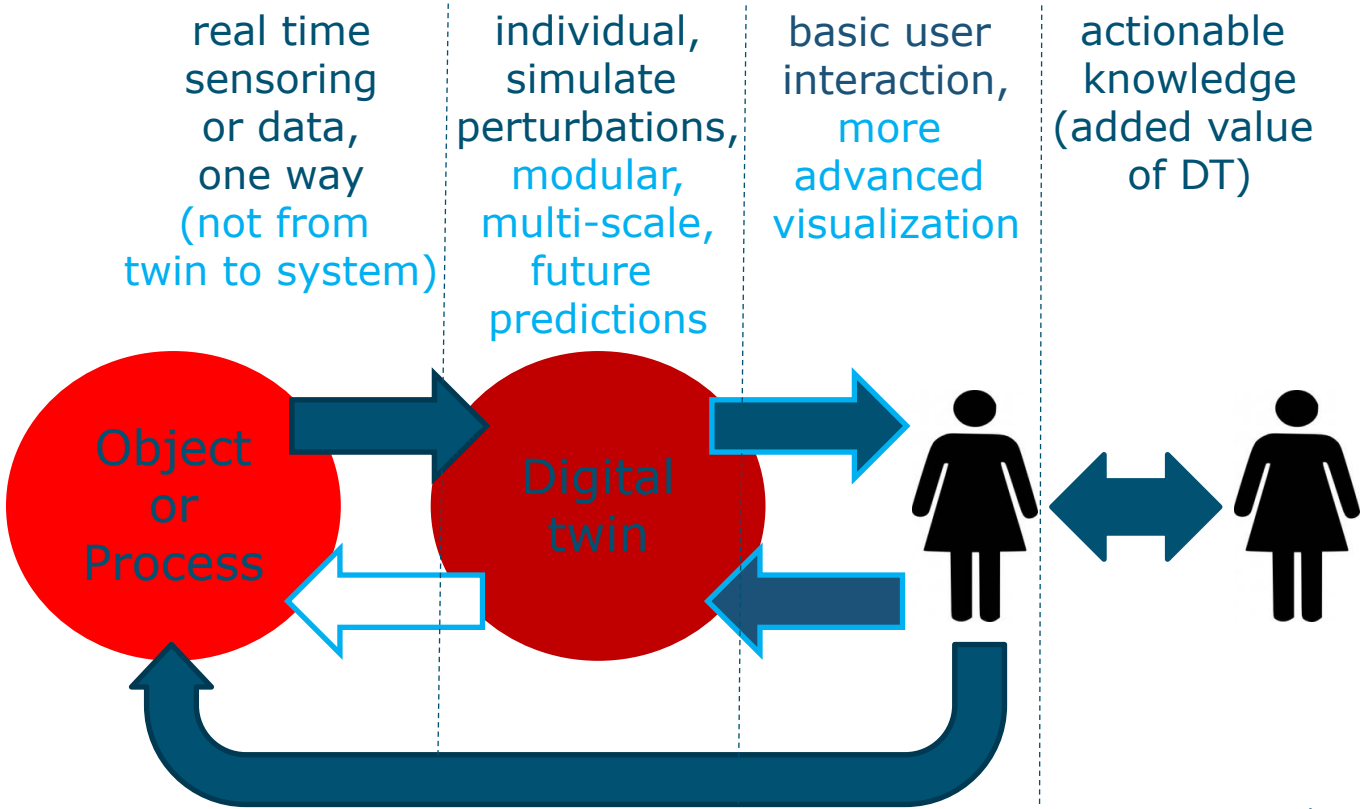
The program

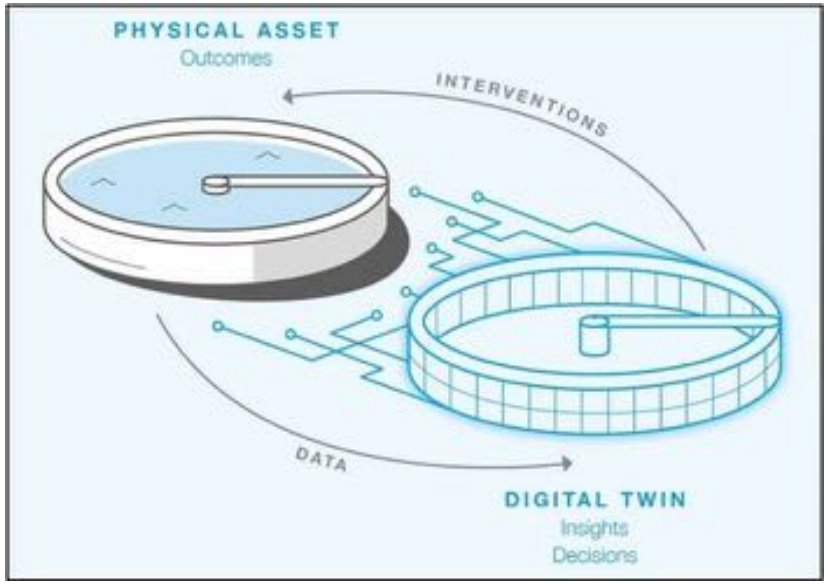
Program evolution



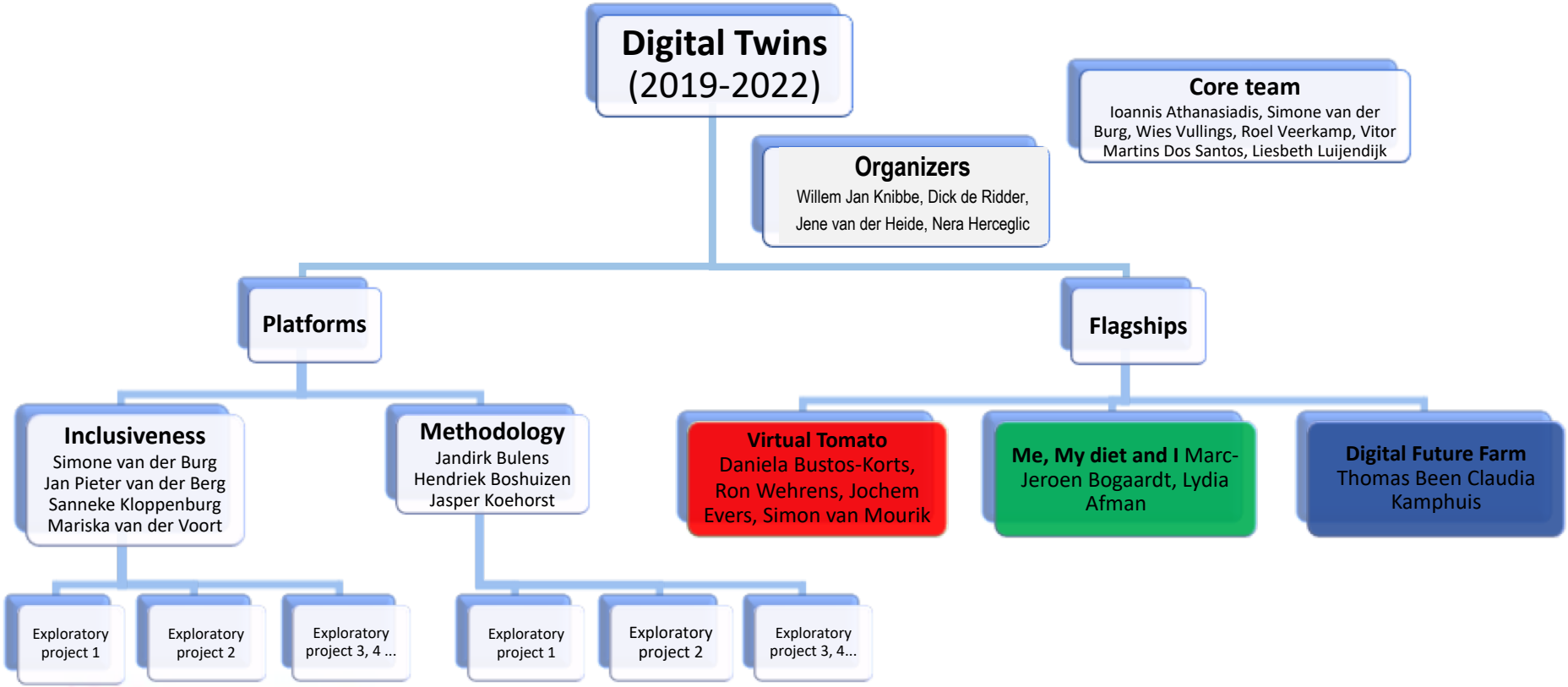
Digital Twin distinguishing features



Exploring a new concept in a complex domain



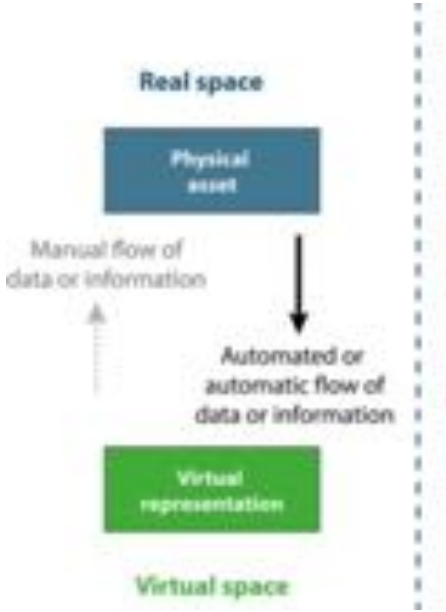
Program organization



What is a digital twin?

Digital landscape

Brett Metcalfe



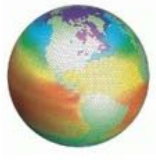
Real world

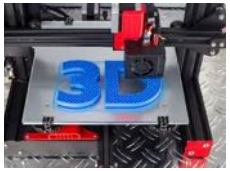
Communication either manually or ***automated***

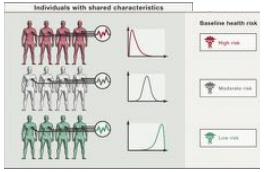
Virtual world

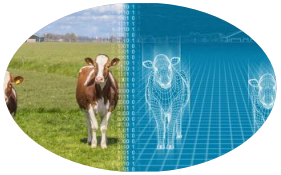
Based upon: Fig. 4 Tekinerdogan & Verdouw 2020

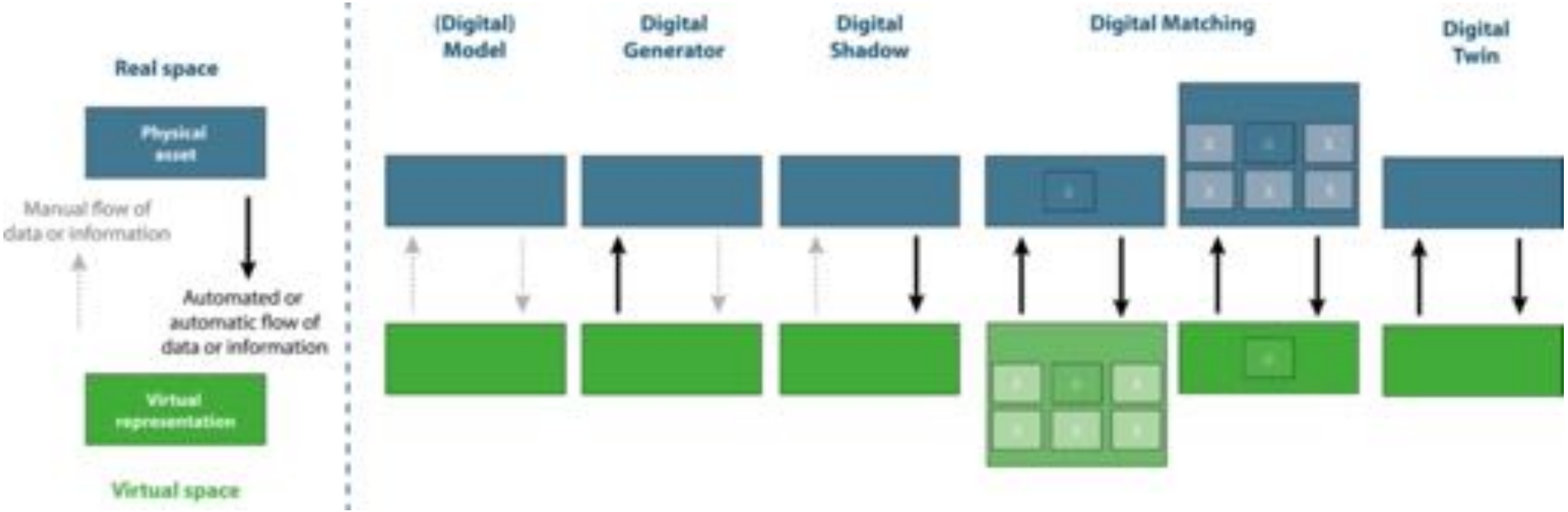
https://doi.org/10.3390/s20185103











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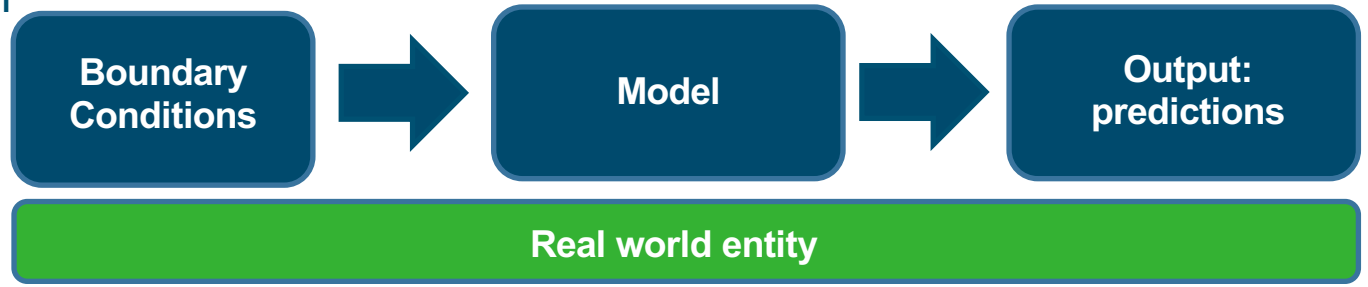
Digital Landscape

Based upon: Fig. 4 Tekinerdogan & Verdouw 2020

https://doi.org/10.3390/s20185103

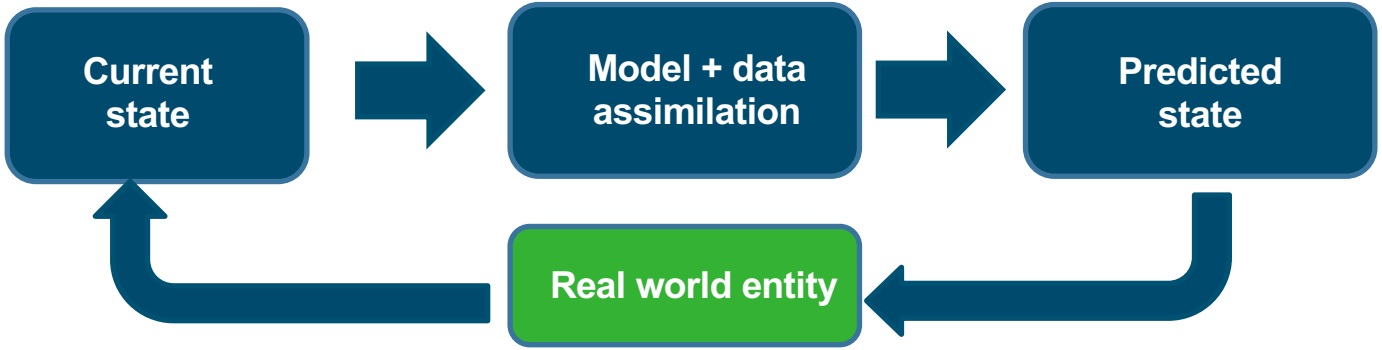
What's the difference…

Model

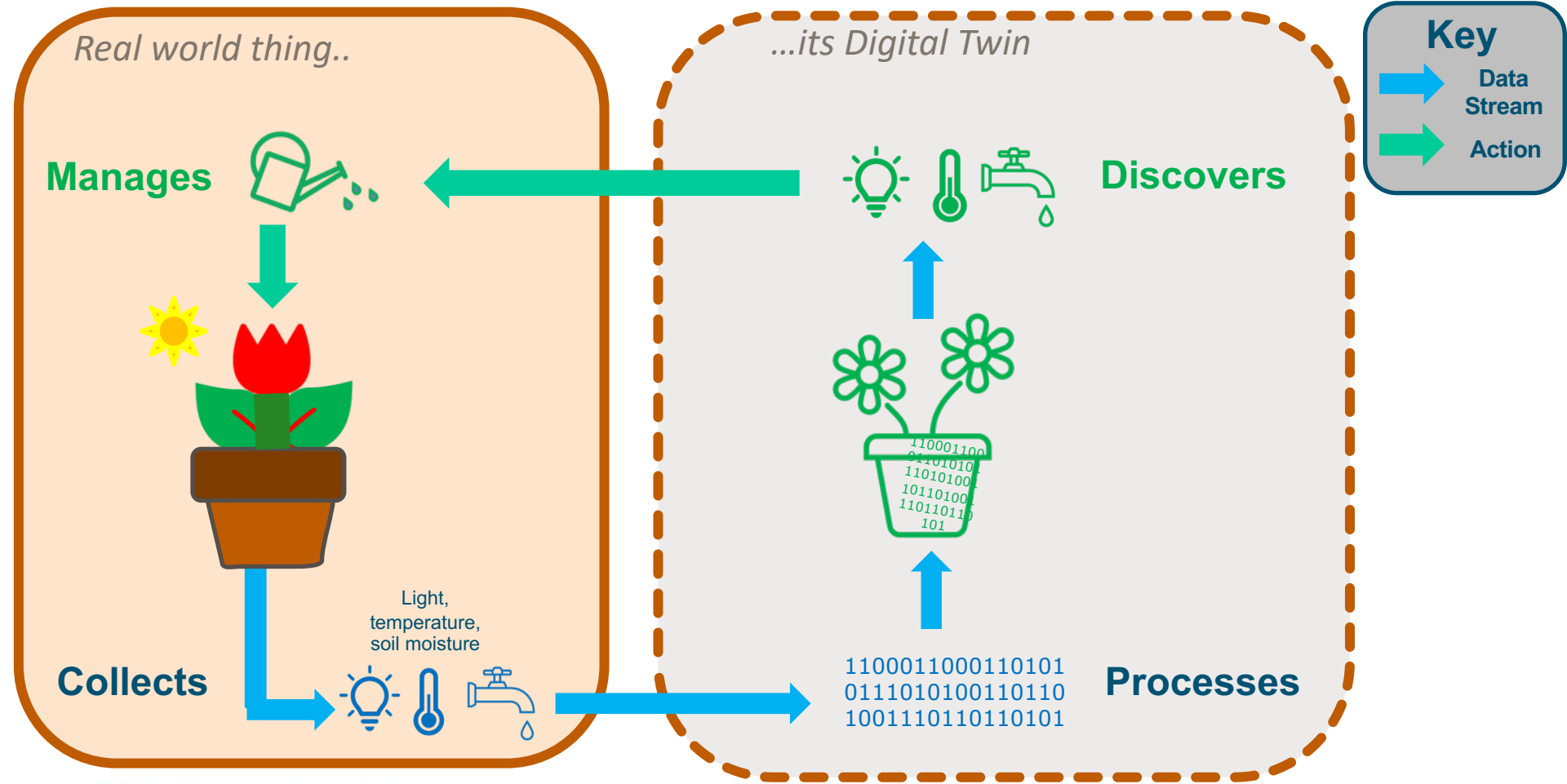


Fixed 'state' of real world

Digital Twin



Dynamic 'state' of real world



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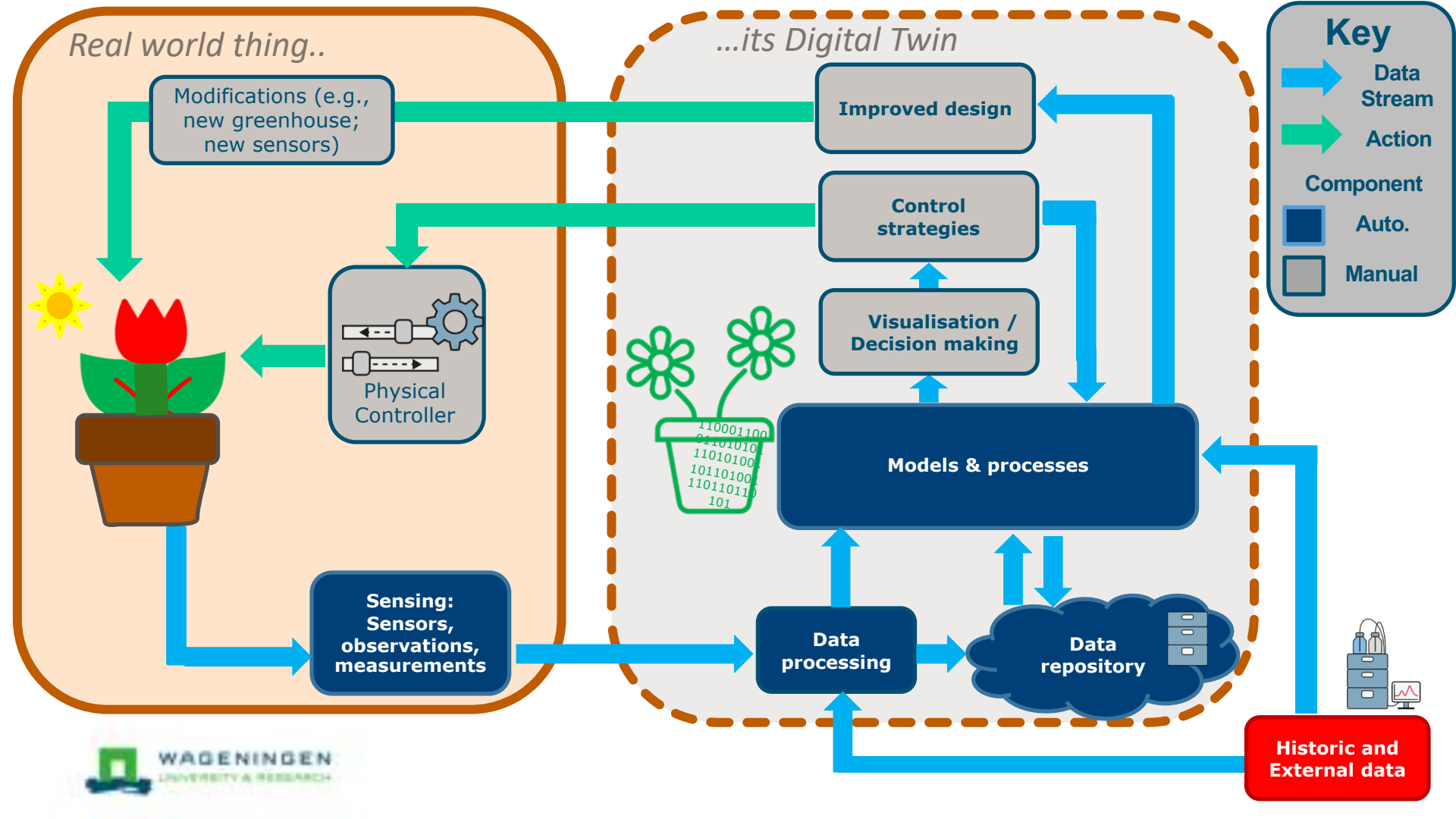
What is a Digital Twin?

Terms from: Boje et al. https://doi.org/10.1016/j.autcon.2020.103179


Real world thing..
Modifications (e.g., new greenhouse; new sensors)
Physical Controller
Sensing: Sensors, observations, measurements
...its Digital Twin
Improved design
Control strategies
Visualisation / Decision making
Models & processes
Data processing
Data repository
Historic and External data
Key
Data Stream
Action
Component
Auto.
Manual
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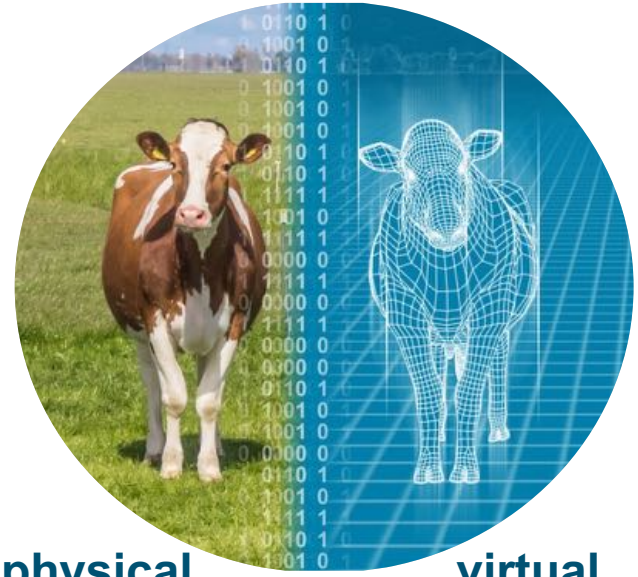
Digital Twin Definition

Ambiguous definitions abound. However, to be a Digital Twin requires:

- **A virtual copy of a physical asset**

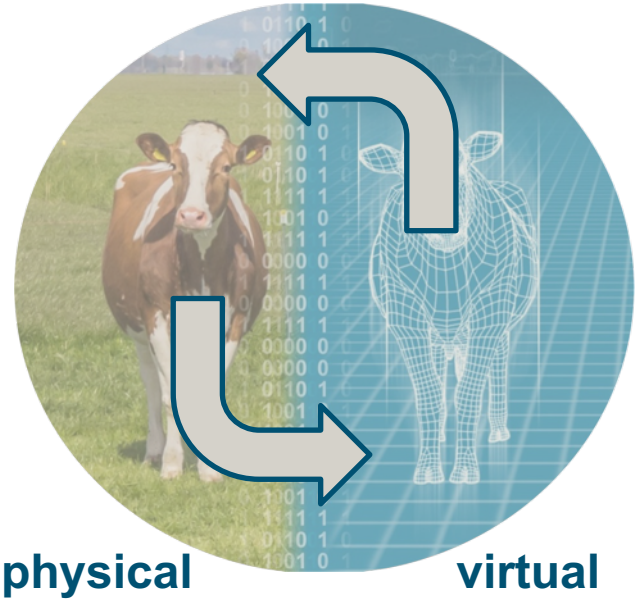


physical **virtual**

Digital Twin Definition

Ambiguous definitions abound. However, to be a Digital Twin requires:

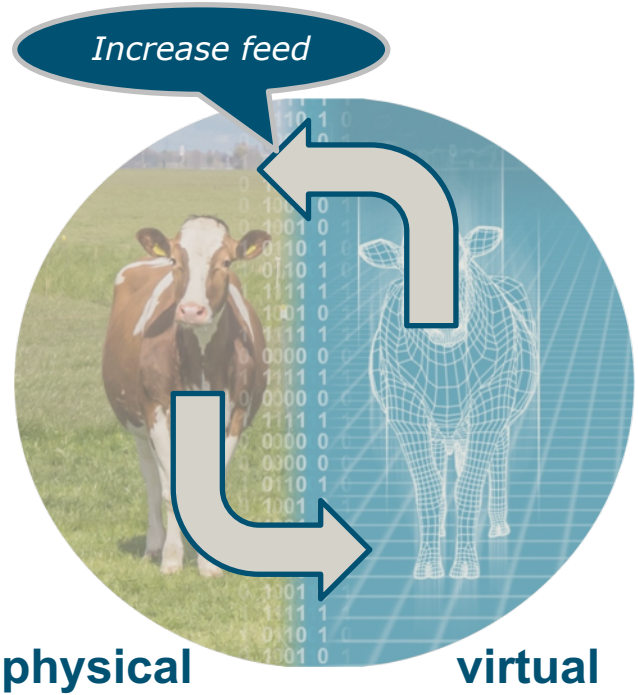
- **A virtual copy of a physical asset**
- **Two-way interaction between virtual and physical assets**



Digital Twin Definition

Ambiguous definitions abound. However, to be a Digital Twin requires:

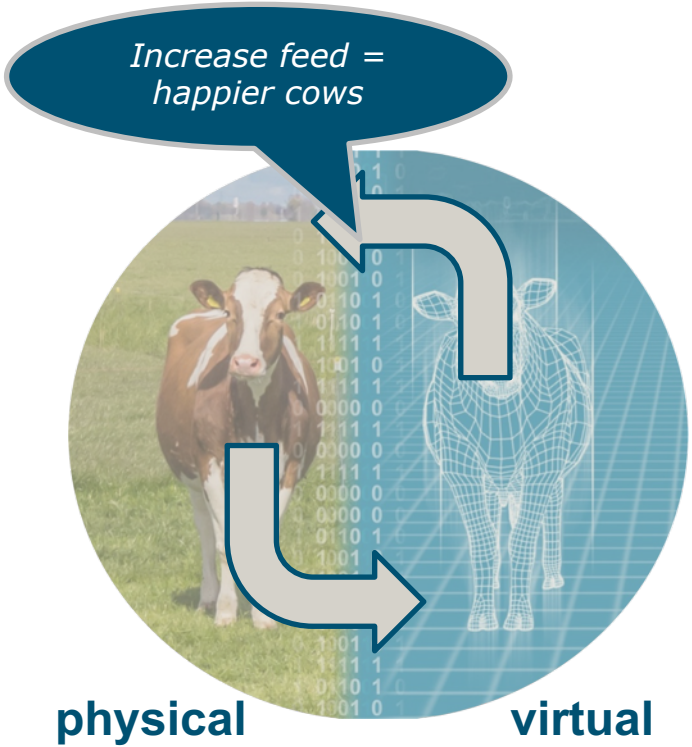
- **A virtual copy of a physical asset**
- **Two-way interaction between virtual and physical assets**
- **Interaction must initiate some feedback**



Digital Twin Definition

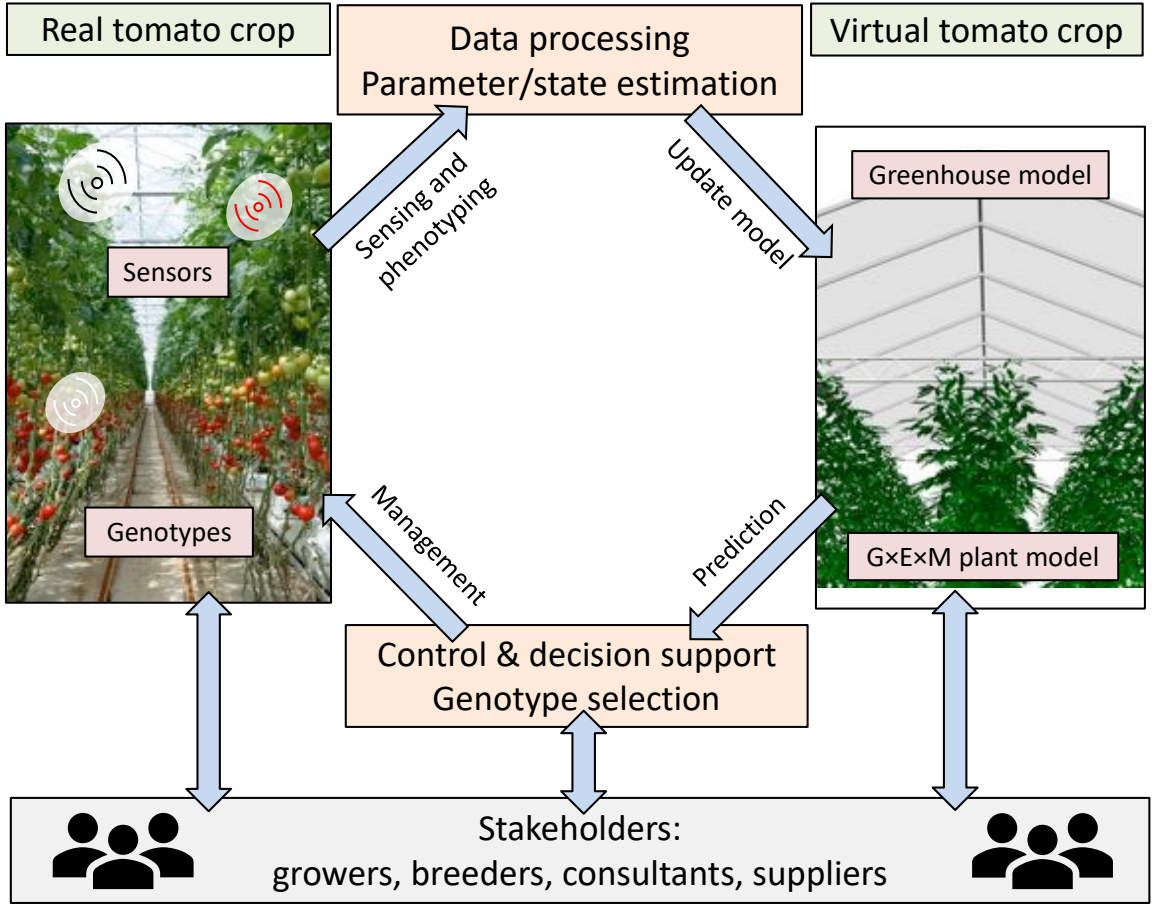
Ambiguous definitions abound. However, to be a Digital Twin requires:

- **A virtual copy of a physical asset**
- **Two-way interaction between virtual and physical assets**
- **Interaction must initiate some feedback**
- **Decision making process based on <u>actionable knowledge</u>**



Flagship projects

Virtual Tomato Crop



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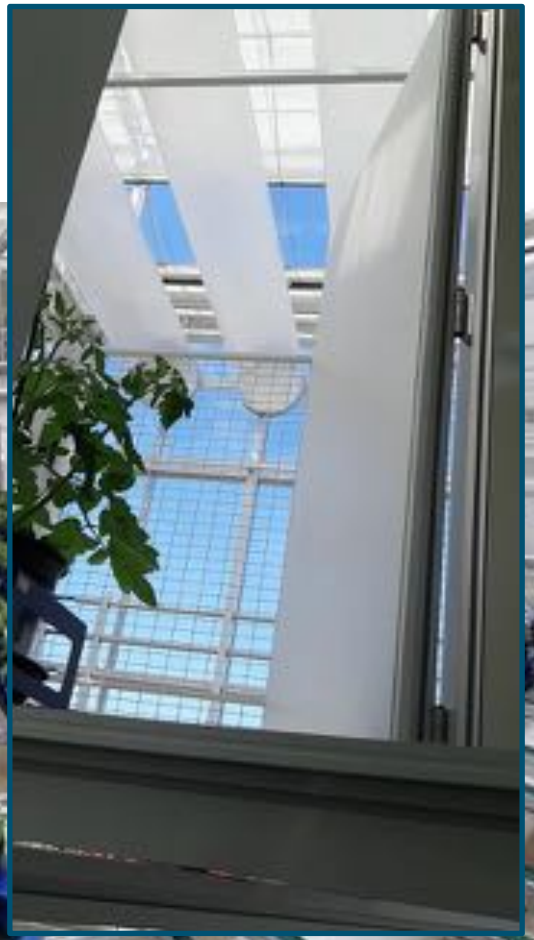
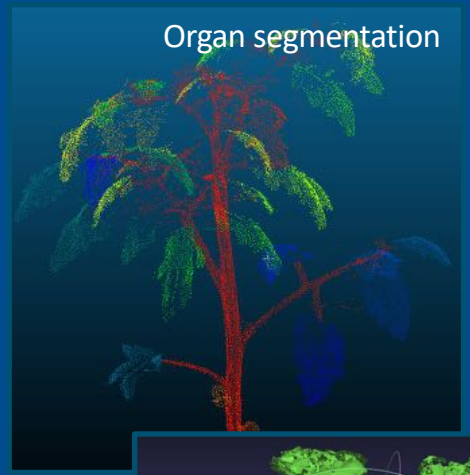
Plant measurements

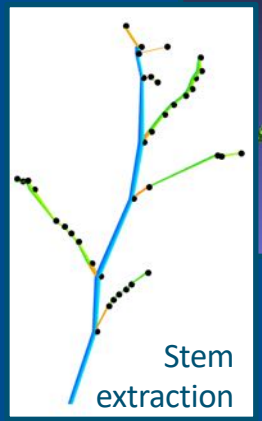
Plant measurements



3D sensor-based plant phenotyping & model parameter updating

Data acquisition





Phenotyping

Parameter derivation

Updating tomato simulation model

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….. and lots of handwork

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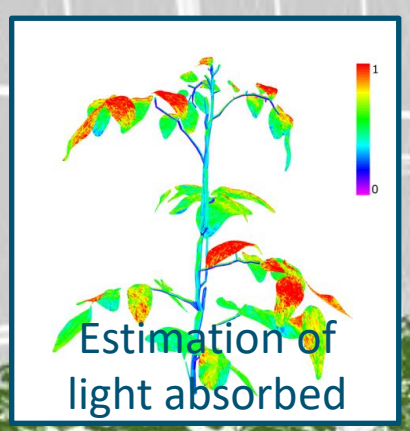
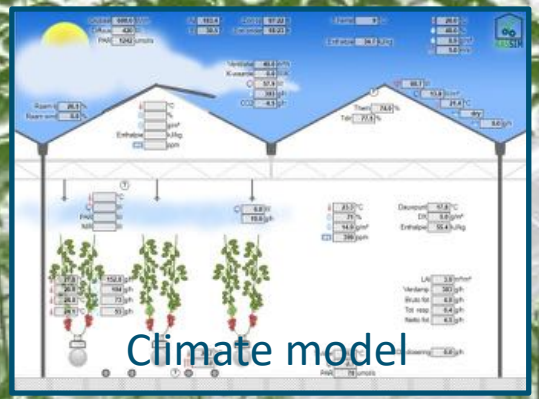
Tomato and greenhouse climate simulation model



Estimation of light absorbed



Climate model

Environment

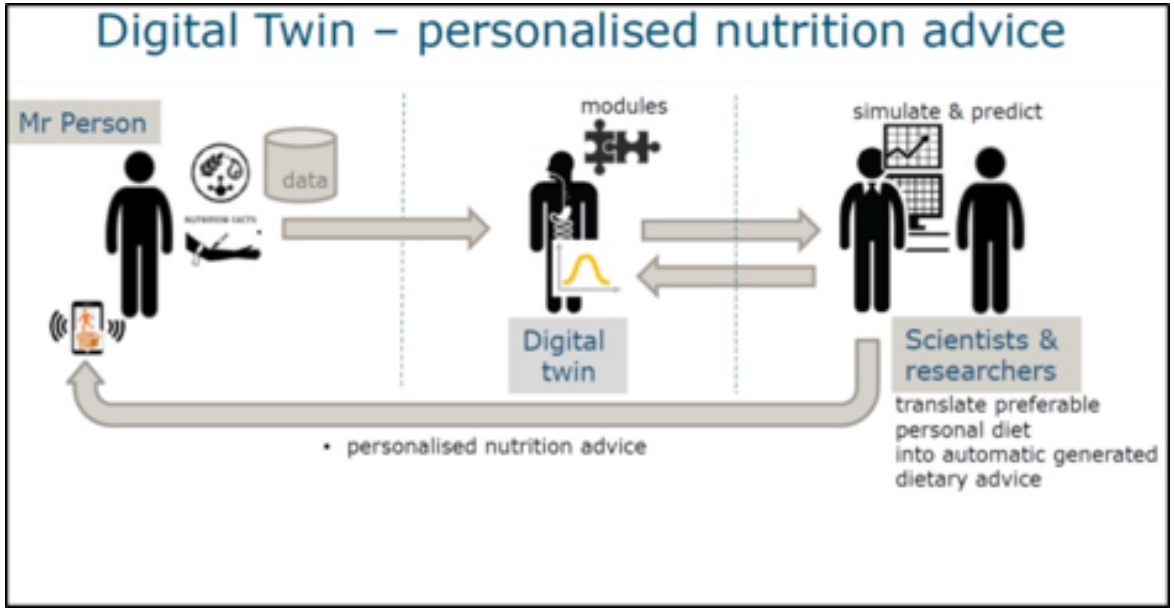
Crop

Plant model

Me, My Diet, & I

OVERALL OBJECTIVE:

- To develop a digital twin that will give personalized dietary advice to reduce the personal after-meal triglyceride (fat) response.



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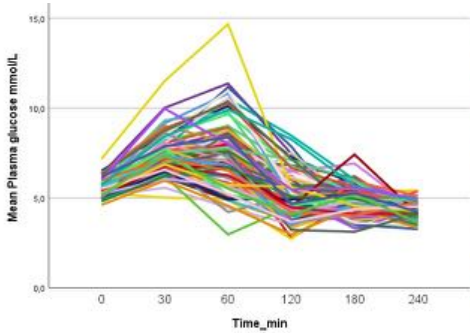
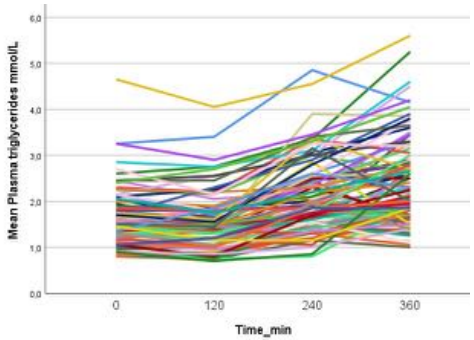
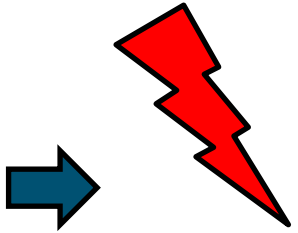
Context of Me, My Diet & I

Dietary advice for the general population

People respond different to the same foods/diet

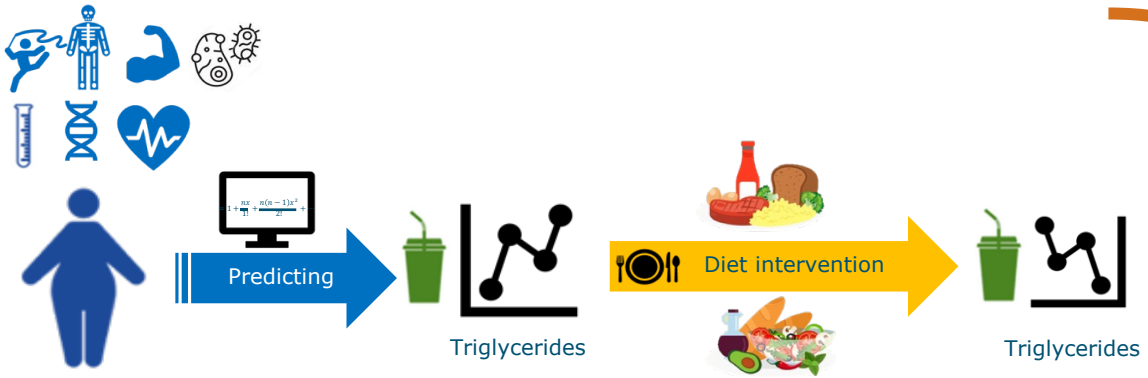


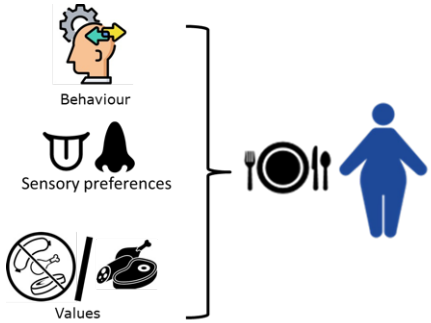




Cardiovascular disease and Diabetes Type II

Three grand challenges





I: Algorithm predicting personal postprandial response and the predicting the best diet to reduce this response

+

II: Algorithm/Rules including behaviour, preferences and values

+

III: Ontology to translate intake into dietary advice

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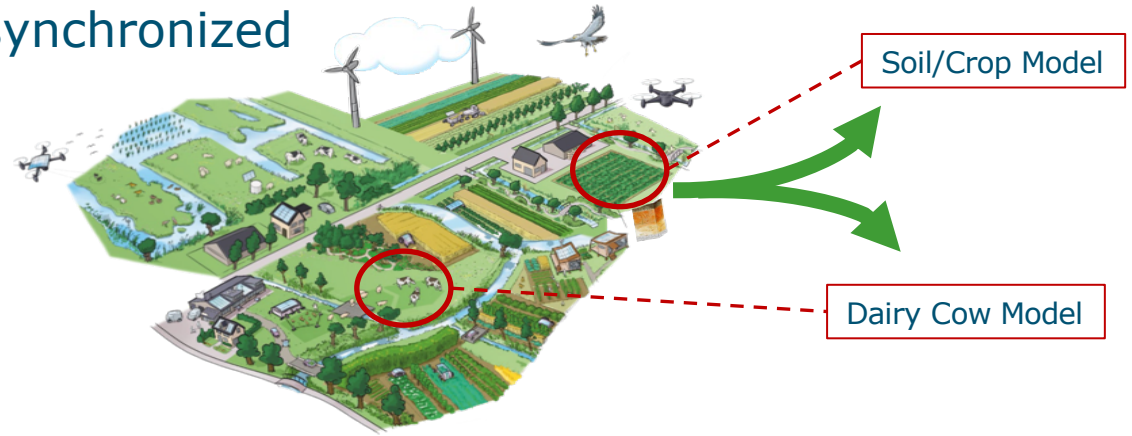
A Digital Twin for a Digital Future Farm

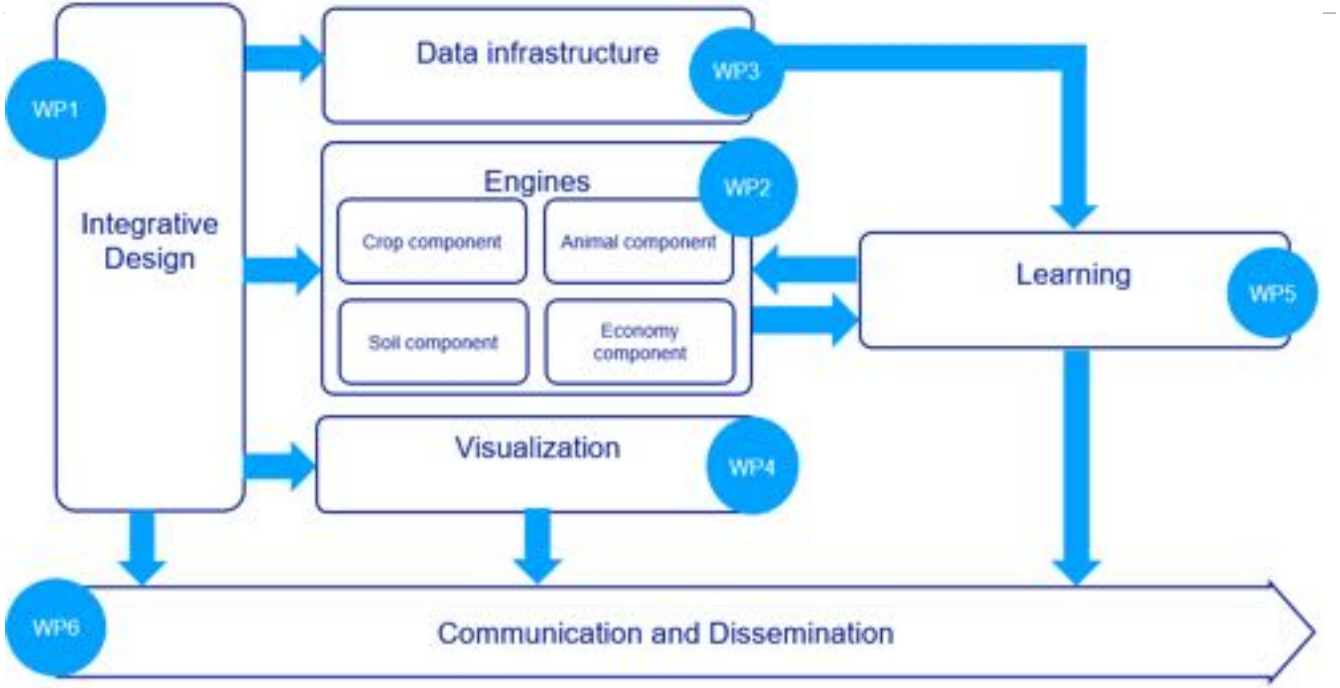
A dynamic model of a physical object with emphasis on:

(1) the connection between the physical object and its model, and

(2) the use of real-time data from the physical object to keep the model synchronized

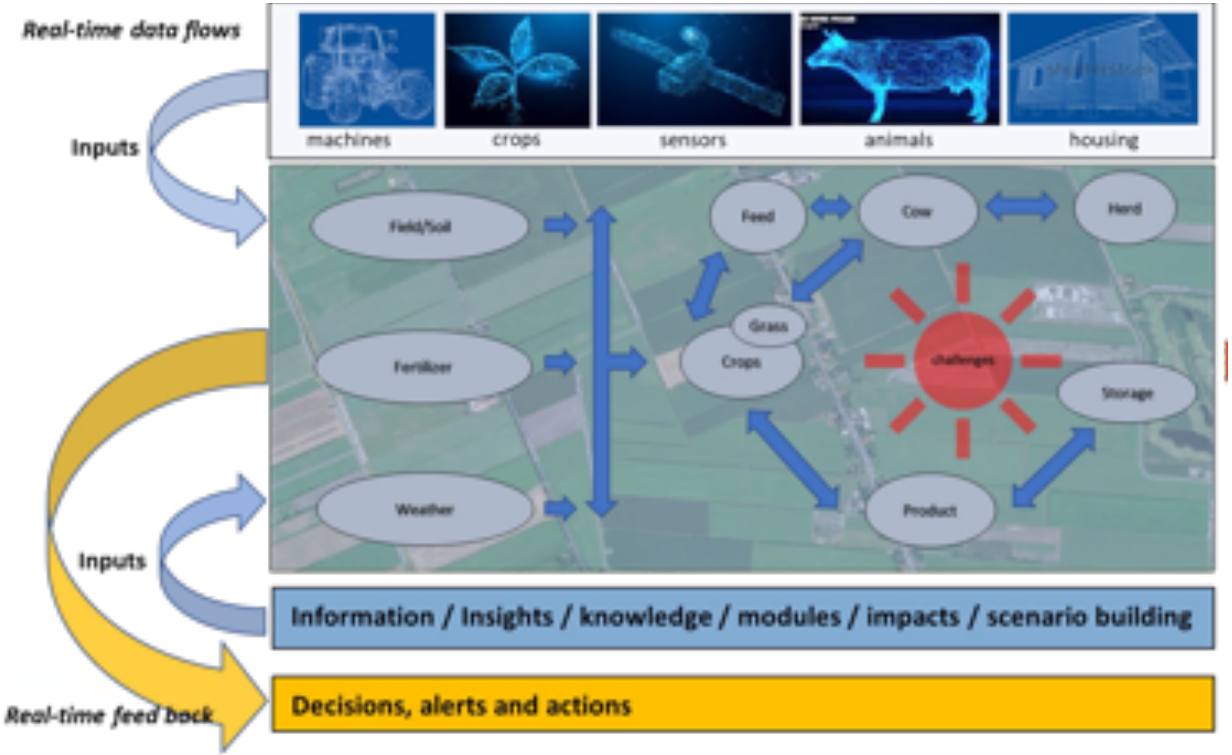


Work packages in DFF project



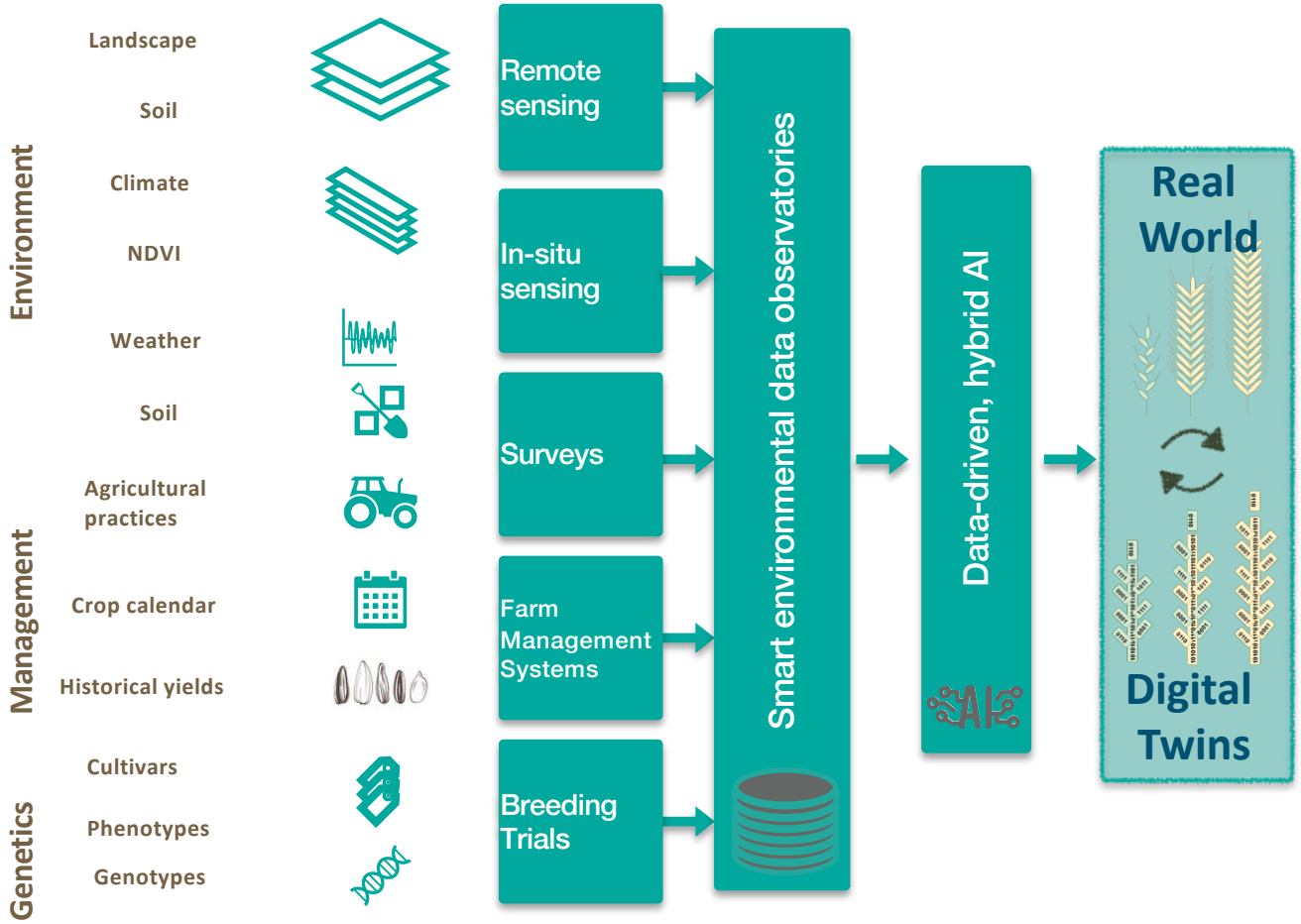
DFF focusses on Nitrogen

twinning the N-cycle for farmers & researchers

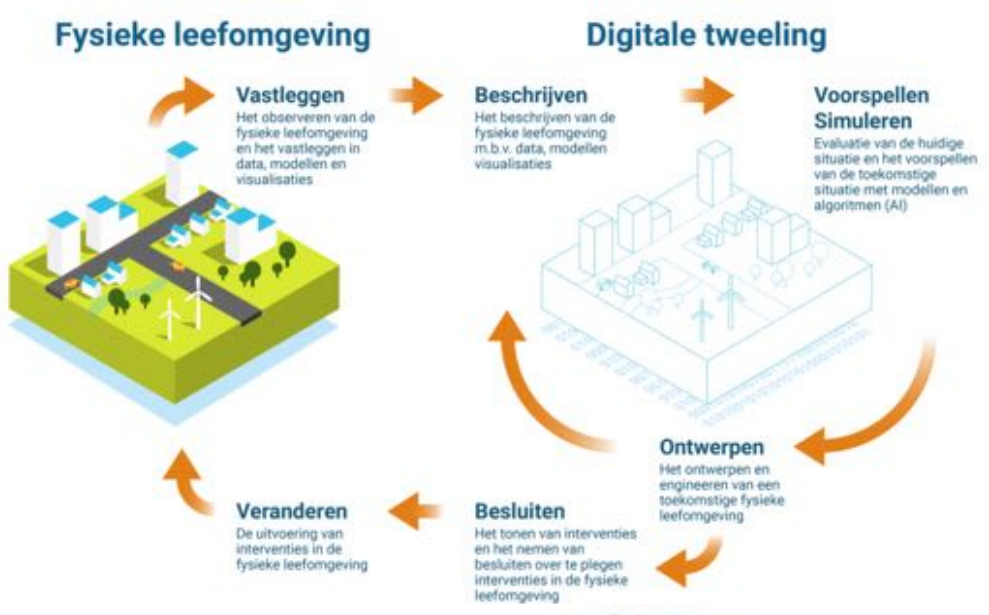


Scientific and societal potential

Scientific potential



Societal potential



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Future challenges

Maturity levels

Collects data

Context (data storage, historic data)

Models + predictions

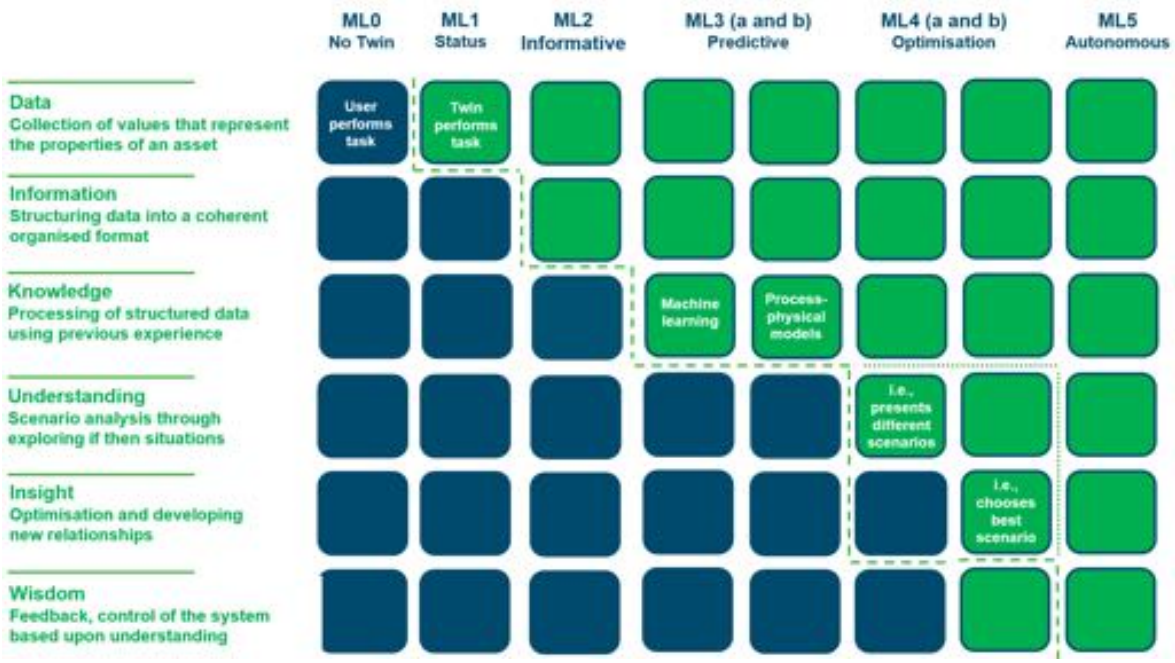
Exploration (scenario testing, interaction)

Optimisation

Autonomous

Using the maturity index

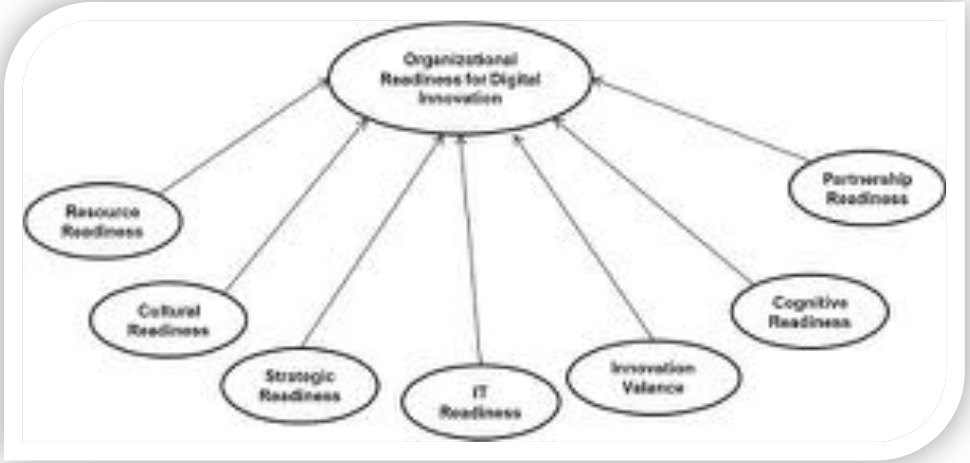
The maturity index is not the same as…



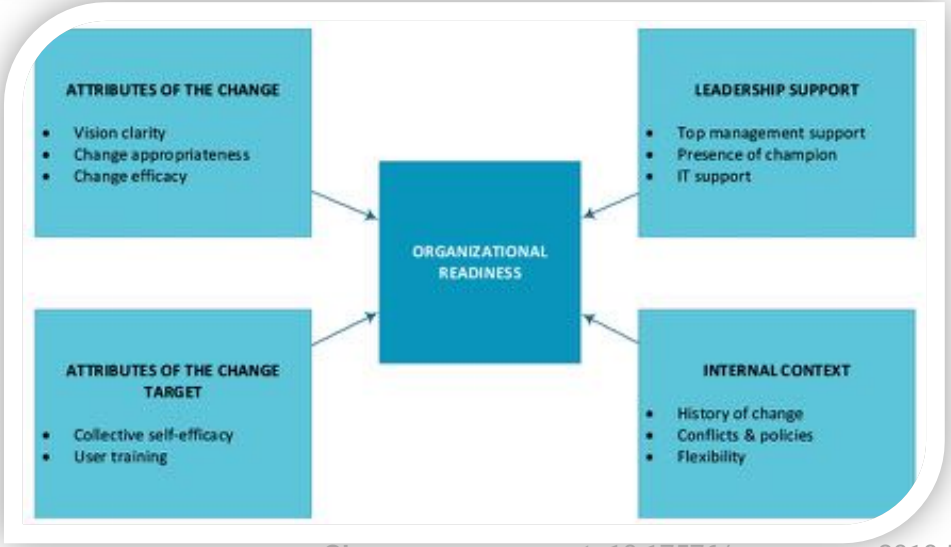
Readiness

The maturity index is not the same as…

- **Organisational readiness (i.e., change management, leadership, preparation)**



Organisational readiness: https://doi.org/10.1016/j.im.2018.09.001



Change management: 10.17576/pengurusan-2018-52-16

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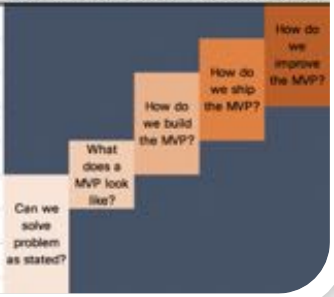
Readiness

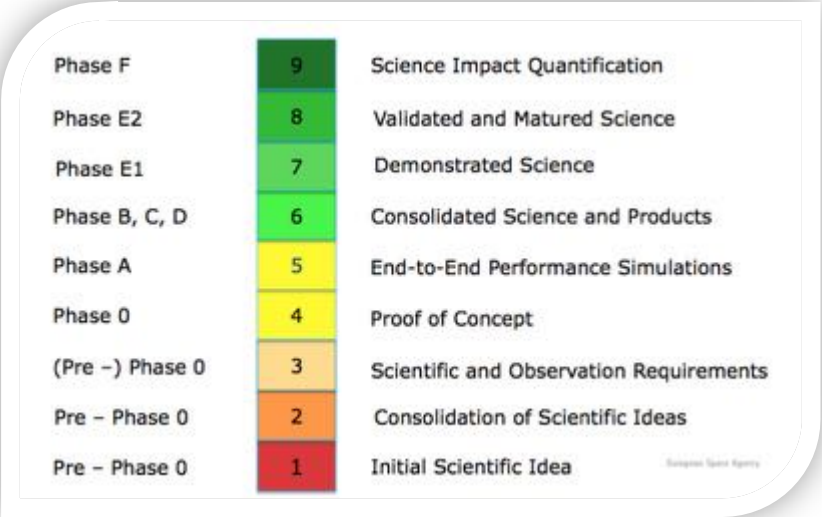
The maturity index is not the same as…

- **Organisational readiness (i.e., change management, leadership, preparation)**
- **Scientific readiness**

	Index	Technical Readiness Level	Product Readiness Levels	Data Science Readiness Levels
Delivery	9	System Proven in Operational Environment	System Running in Production	System Proven in Operational Environment
	8	System Complete & Qualified	QA Passed & Ready for Staging Environment	System Compete & Qualified
	7	Prototype Demonstrated in Operational Environment	Beta version in limited Staging Environment	Prototype Demonstrated in Operational Environment
	6	Technology Demonstrated in Relevant Environment	In QA	Algorithm Integrated in Development Environment
	5	Technology Validated in Relevant Environment	Tests passing in Development Environment	Algorithm Validated against Production Data
Discovery	4	Technology Validated in Lab	Tests passing on Development Machines	Algorithm Validated against Sample Data
	3	Experimental Proof of Concept	Tests cases written with full coverage	Experimental Proof of Concept
	2	Technology Concept Formulated	Technology Concept Formulated	Data Explored, Described, and Documented
	1	Basic Principles Observed	Need or shortcoming identified	Algorithm Design & Development



Data science readiness: https://towardsdatascience.com/the-call-for-a-data-science-readiness-level-3355d6d8a1bb



(ESA)Scientific readiness: https://missionadvice.esa.int/wp-content/uploads/2020/05/Science_Readiness_Levels-SRL_Handbook_v1-1_issued_external.pdf

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Readiness

The maturity index is not the same as…

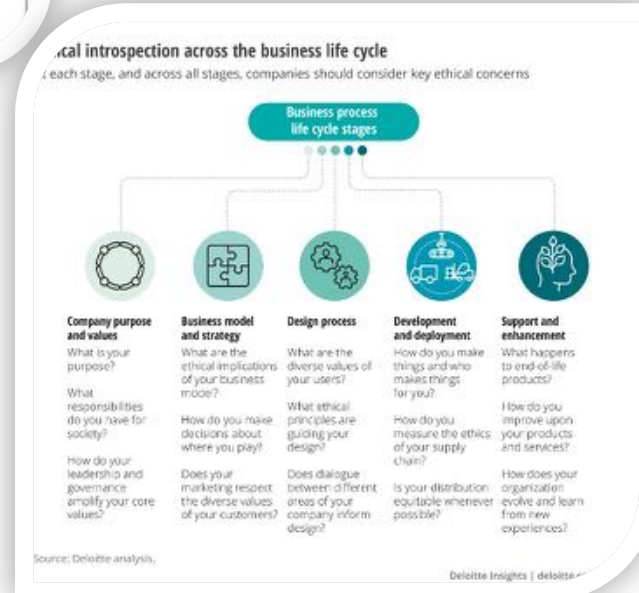
- **Organisational readiness (i.e., change management, leadership, preparation)**
- **Scientific readiness**
- **Ethical 'readiness' (e.g., technological ethical scorecard)**

Ethical Concern	Relevant CFREU Articles
Rights of individuals	Article 3 – Right to the integrity of the person Article 6 – Right to liberty and security Article 7 – Respect for private and family life Article 8 – Protection of personal data
Educational rights and freedoms	Article 13 – Freedom of the arts and sciences Article 14 – Right to education
Non-discrimination rights	Article 20 – Equality before the law Article 21 – Non-discrimination Article 22 – Cultural, religious and linguistic diversity Article 23 – Equality between men and women Article 24 – Rights of the child Article 25 - Rights of the elderly Article 26 – Integration of persons with disabilities
Environmental concerns	Article 37 – Environmental protection
Justice	Article 47 – Right to an effective remedy and to a fair trial Article 48 – Presumption of innocence and right of defence Article 49 – Principles of legality and proportionality Article 50 – Right not to be tried or punished twice

Ethical Assessment:
10.1108/14779961111123223

Technological ethical scorecard:
https://ieeexplore.ieee.org/document/5996290

https://www2.deloitte.com/us/en/insights/industry/technology/ethical-dilemmas-in-technology.html

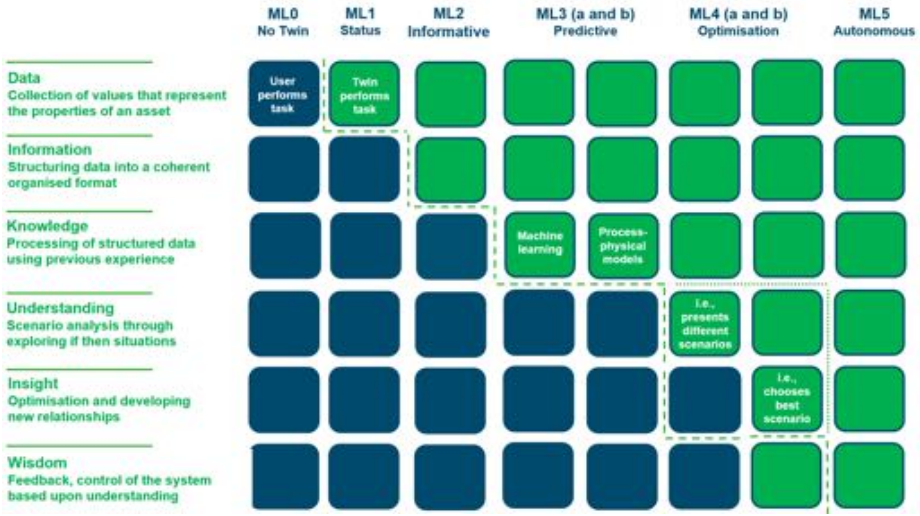


Data

Machine learning

Autonomy

Some low maturity levels are much more harder to do/obtain than higher maturity levels.



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Technological Readiness

Technological Readiness

'basic' research project /experimental

applicative solution

- TRL 1 – basic principles observed
- TRL 2 – technology concept formulated
- TRL 3 – experimental proof of concept
- TRL 4 – technology validated in lab
- TRL 5 – technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)
- TRL 6 – technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)
- TRL 7 – system prototype demonstration in operational environment
- TRL 8 – system complete and qualified
- TRL 9 – actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

https://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf

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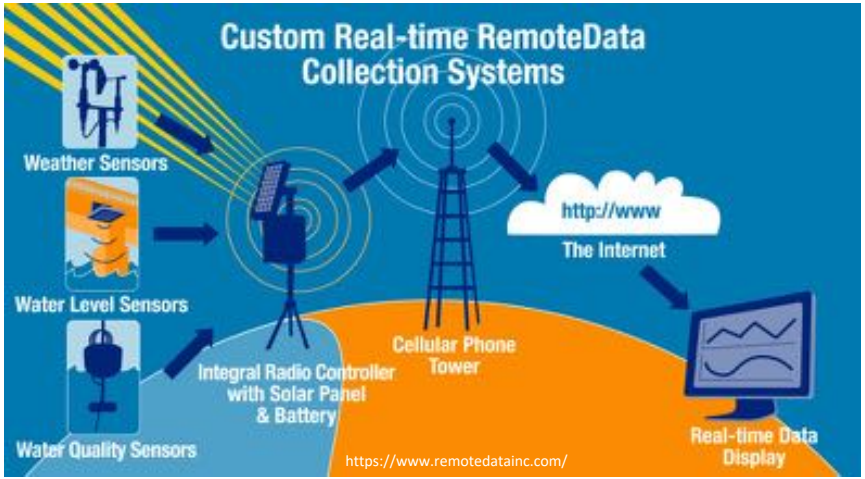
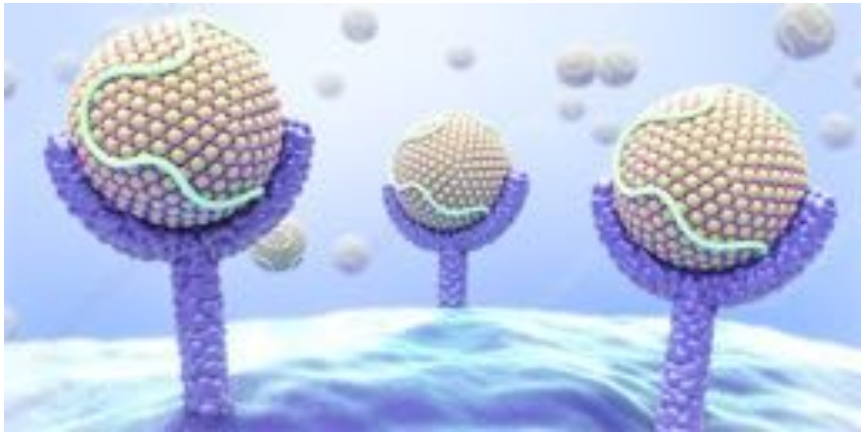
Some low maturity levels are much more harder to do/obtain than higher maturity levels.

Connection between data collection, ingestion, and processing. Lack of a framework.

Automated data collection, e.g., of biological cells is expensive or not currently feasible.





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Technological Readiness

Exploring the potential of data to improve the quality of life

www.wur.eu/data

data@wur.nl

Any questions?