Unleashing the Machines: The AI & Robotics Revolution in Industry

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Luleå University of Technology

Director R&D Sisteplant

Industry 4.0 data is mostly machine generated data

Volume | Velocity | Variety | Variability


Turning This

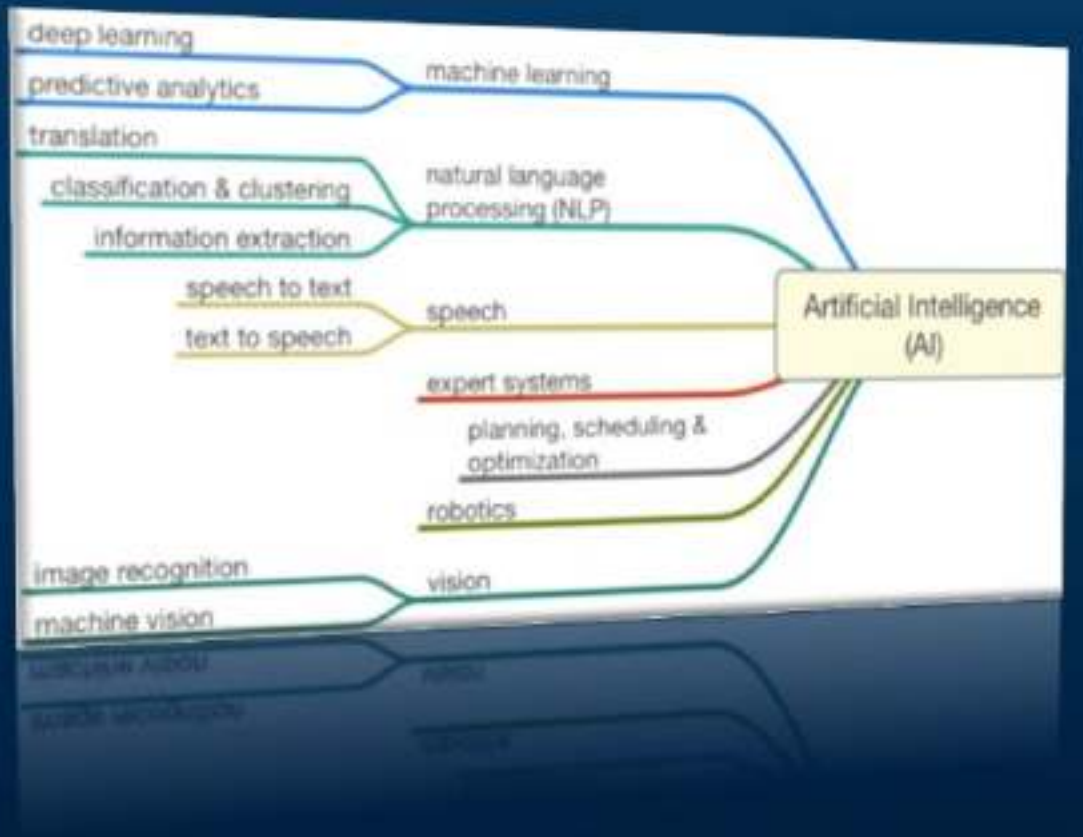

splunk > Ondemand-Online
Search
Columbus
Logan
Home Sec
Prov
ACNS
ccp-images
Ops
unclassified
Logan Live Dashboard
MBytes by Channel
MBytes
12:00 AM
Thu Aug 30
2012
6:00 AM
12:00 PM
6:00 PM
Time
BBCAM_HD
CNN_HD
CSN_HD
View results
Errors by Channel
Event Types
Events
9:45 PM
Thu Aug 2
2012
9:46 PM
9:47 PM
9:48 PM
end
start
url
View results
Source Zone
Volume in MB
Distribution
GOOGLE-PLUS-BASE
WEB-BROWSING
DNS
trust
0
View results
To These


J.A.R.V.I.S
21
19:40
21 Tuesday

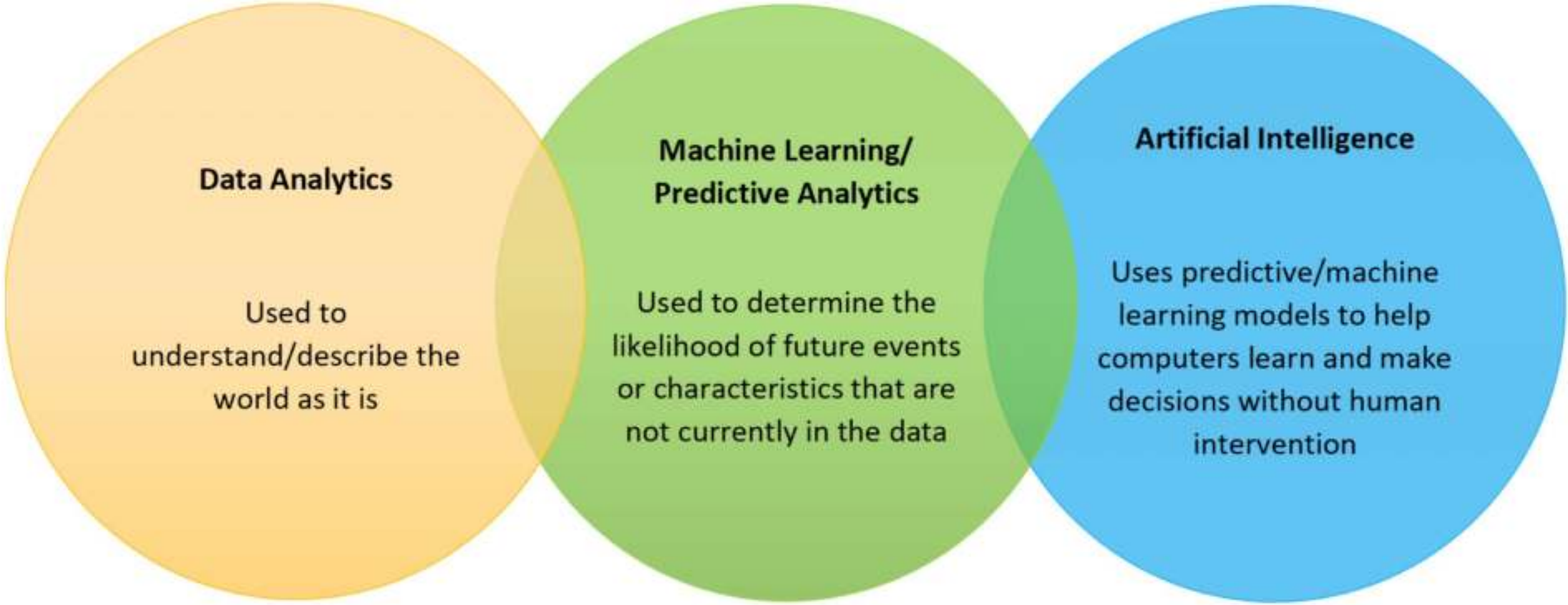

AI IN THE INDUSTRY

AI DEFINITION

Artificial intelligence (AI) is the ability of a computer or computer-controlled system to perform tasks commonly associated with intelligent beings.



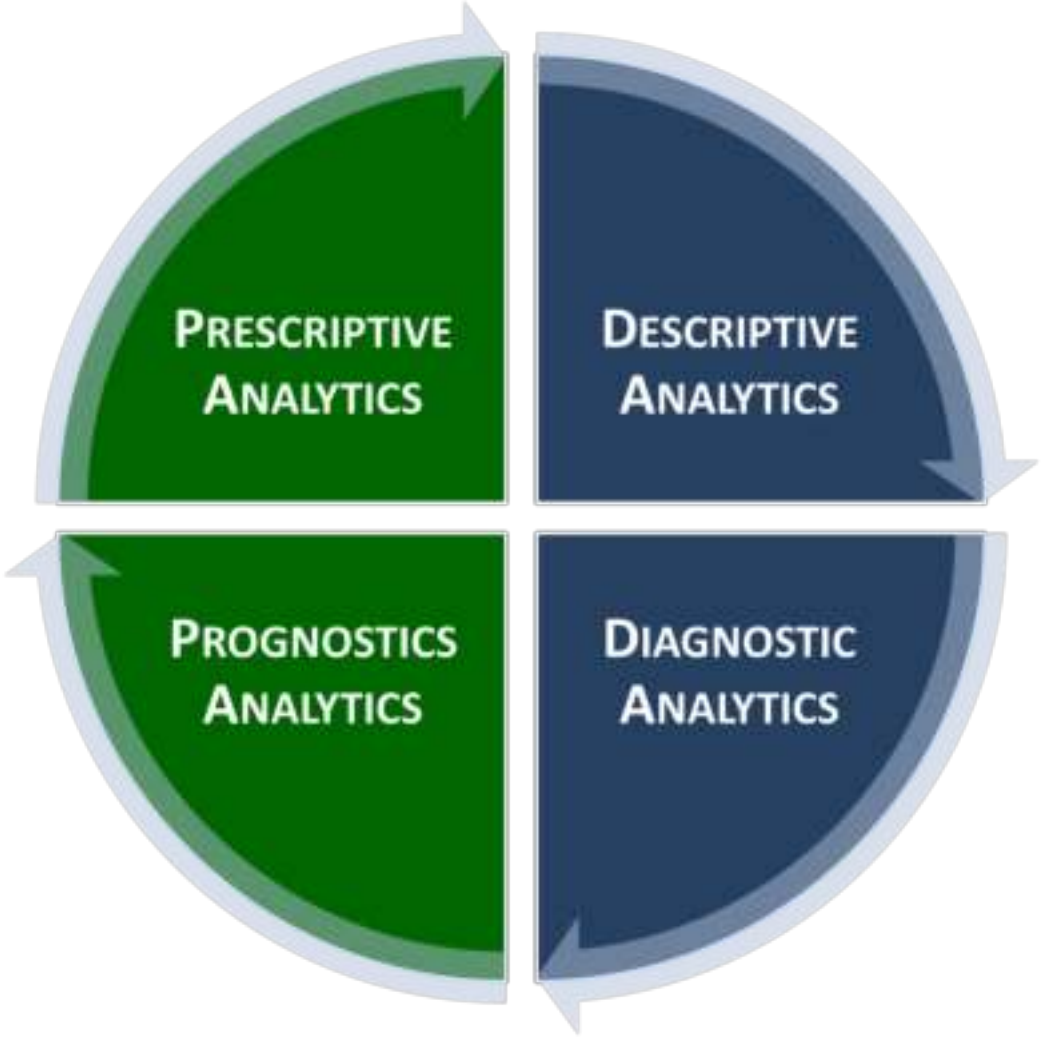
LULEÅ UNIVERSITY OF TECHNOLOGY



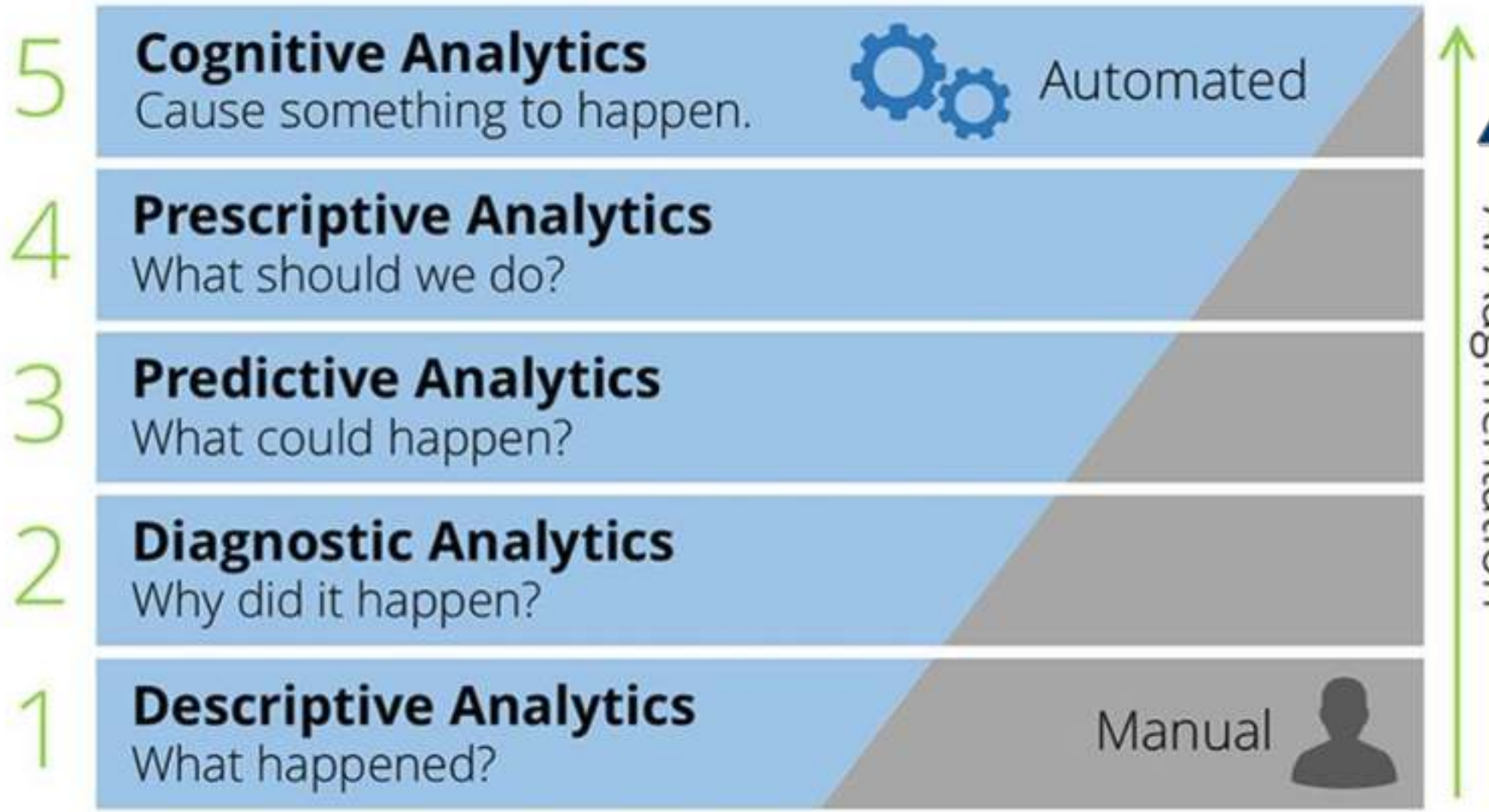
Artificial Intelligence vs Machine Learning vs Data Analytics

The need to go deeper in analytics

- **Now casting**
  - 1) What happened in the past
  - 2) Why something happened
- **Forecasting**
  - 3) What will happen in the future
  - 4) What need to be done next



Analytics and expectations also change



The challenge in Descriptive analytics

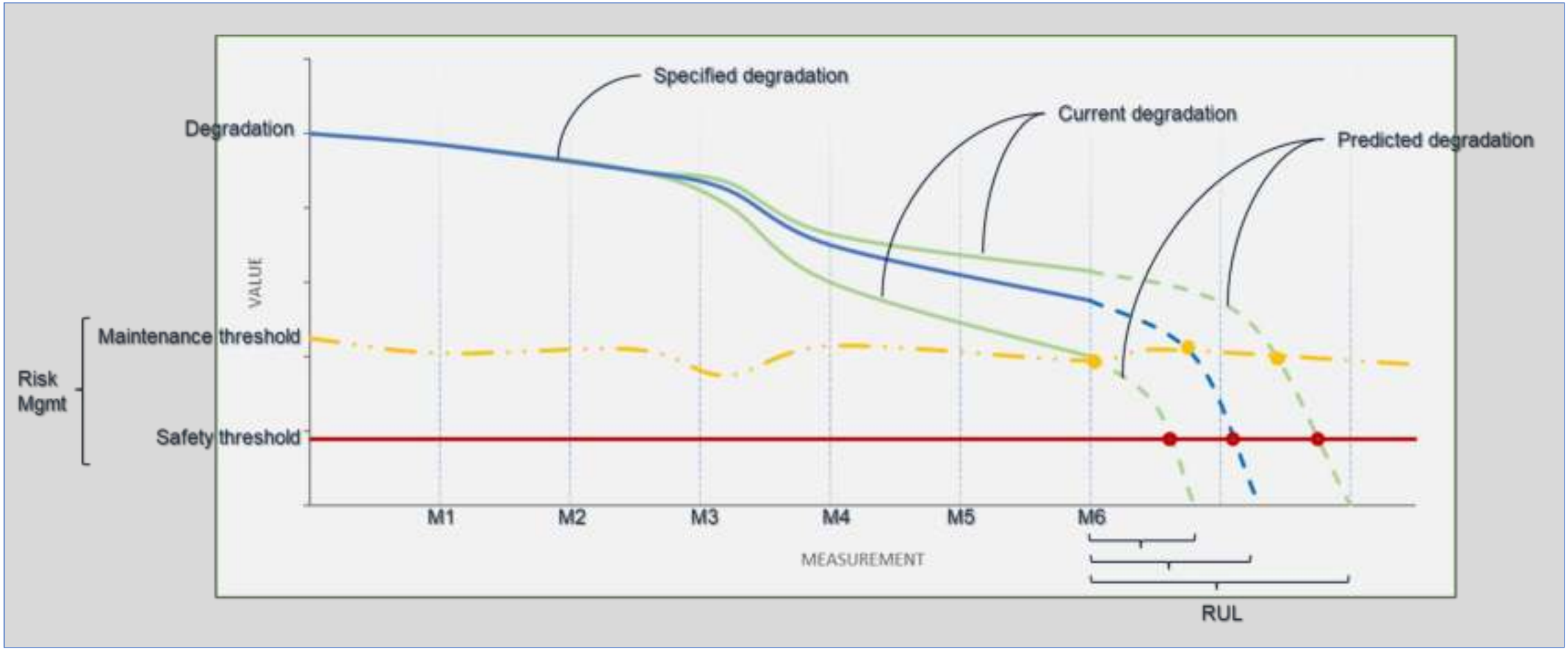
What is context awareness?

- “An application’s ability to adapt to changing circumstances and respond according to the context of use”

- Issues in context awareness system implementing
  - How is context represented?
  - How frequently does context information have to be consulted?
  - What are the minimal services an environment needs to provide to make context awareness feasible?
  - …

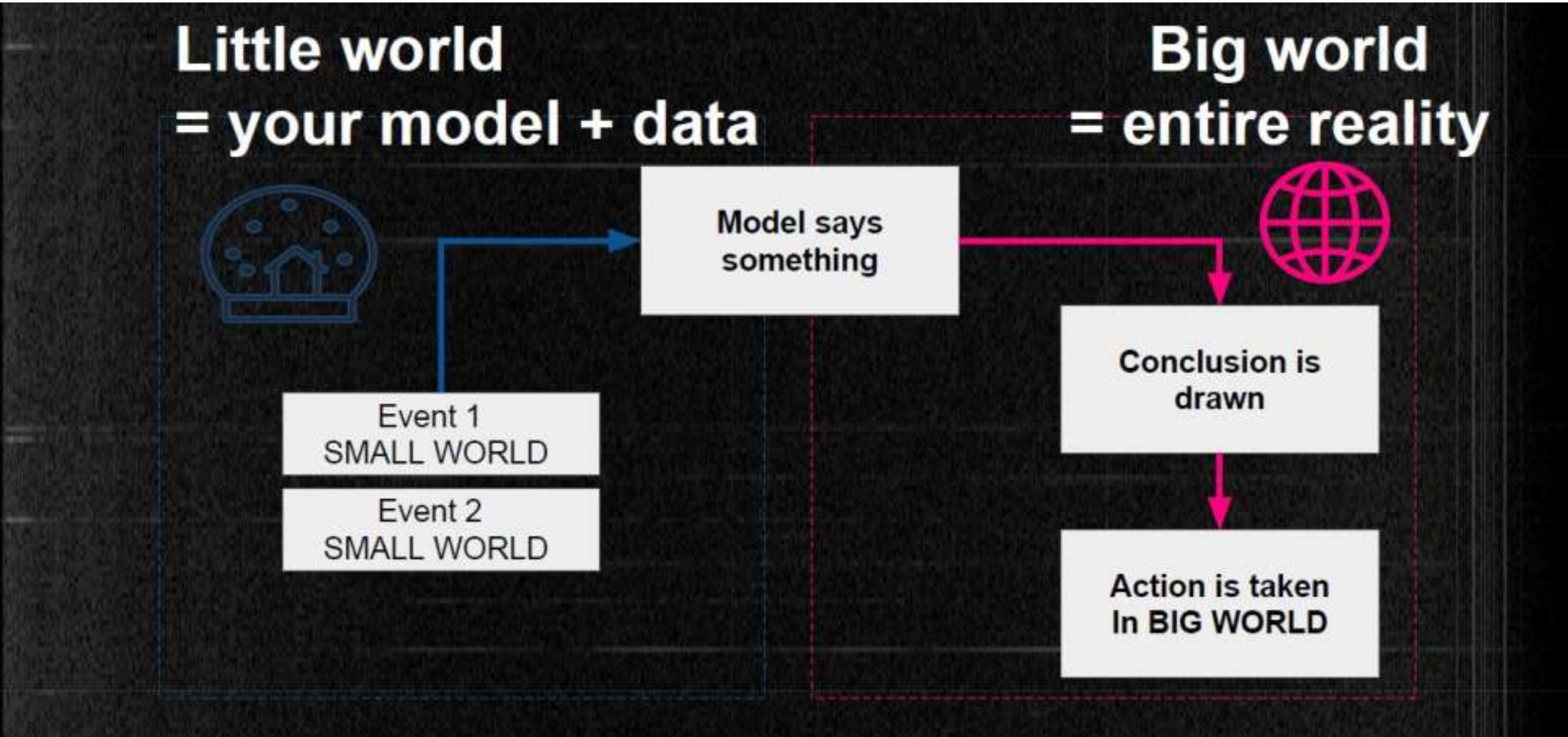
“Black Swan Event: An event or occurrence that deviates beyond what is normally expected of a situation and that would be extremely difficult to predict.”

RUL prediction



The swan song

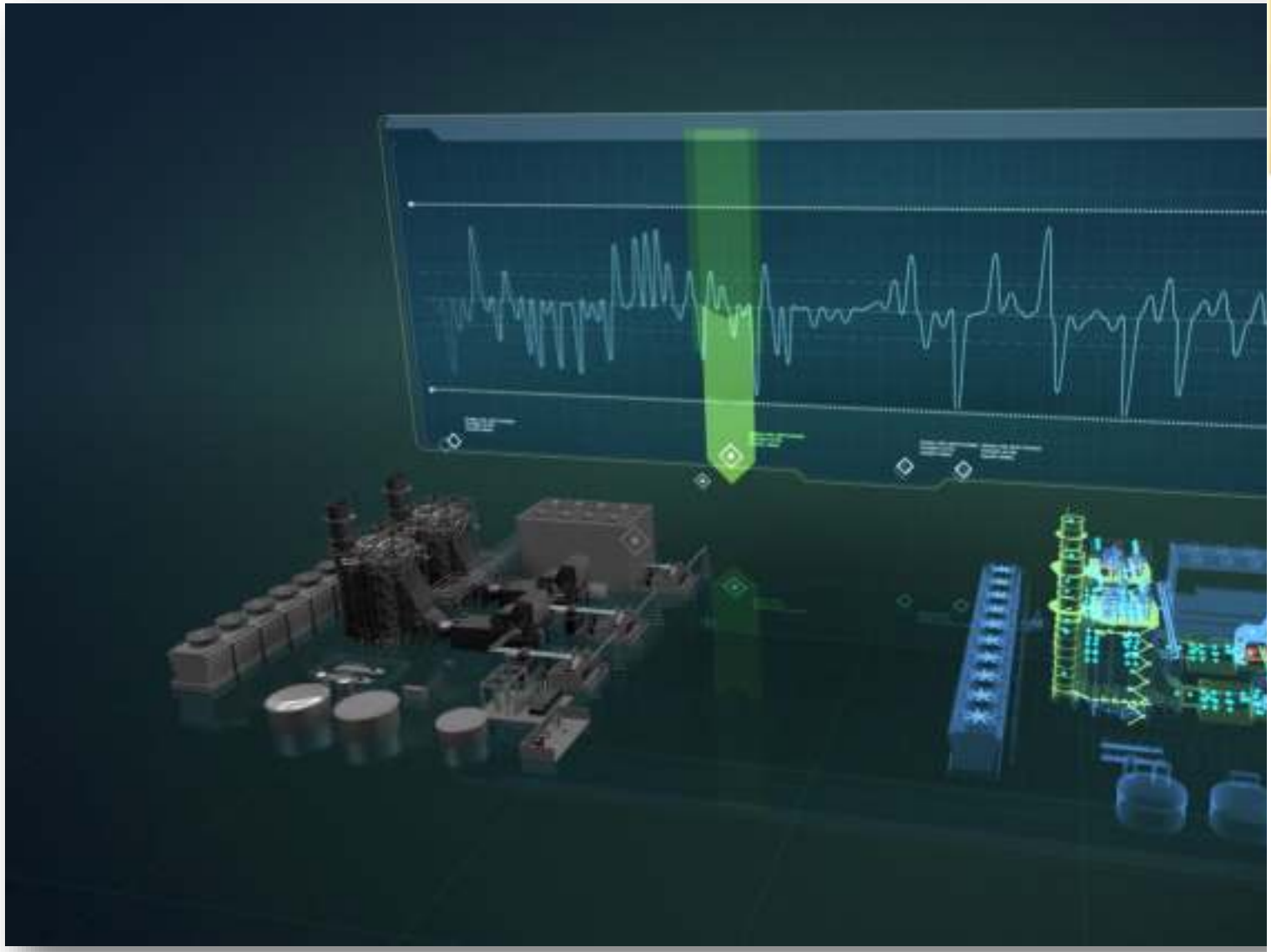
Is my model enough?

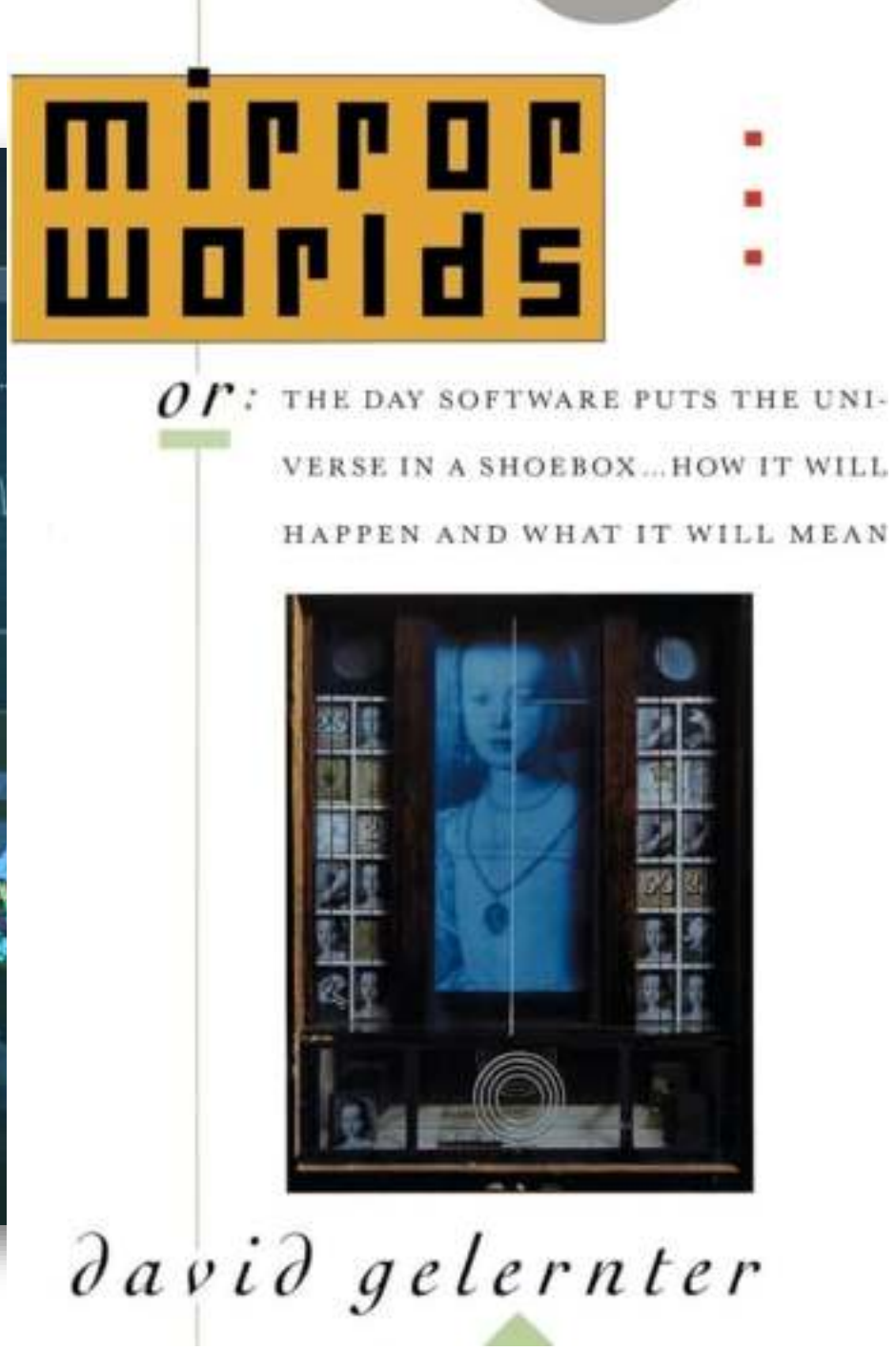


The prescriptive challenge

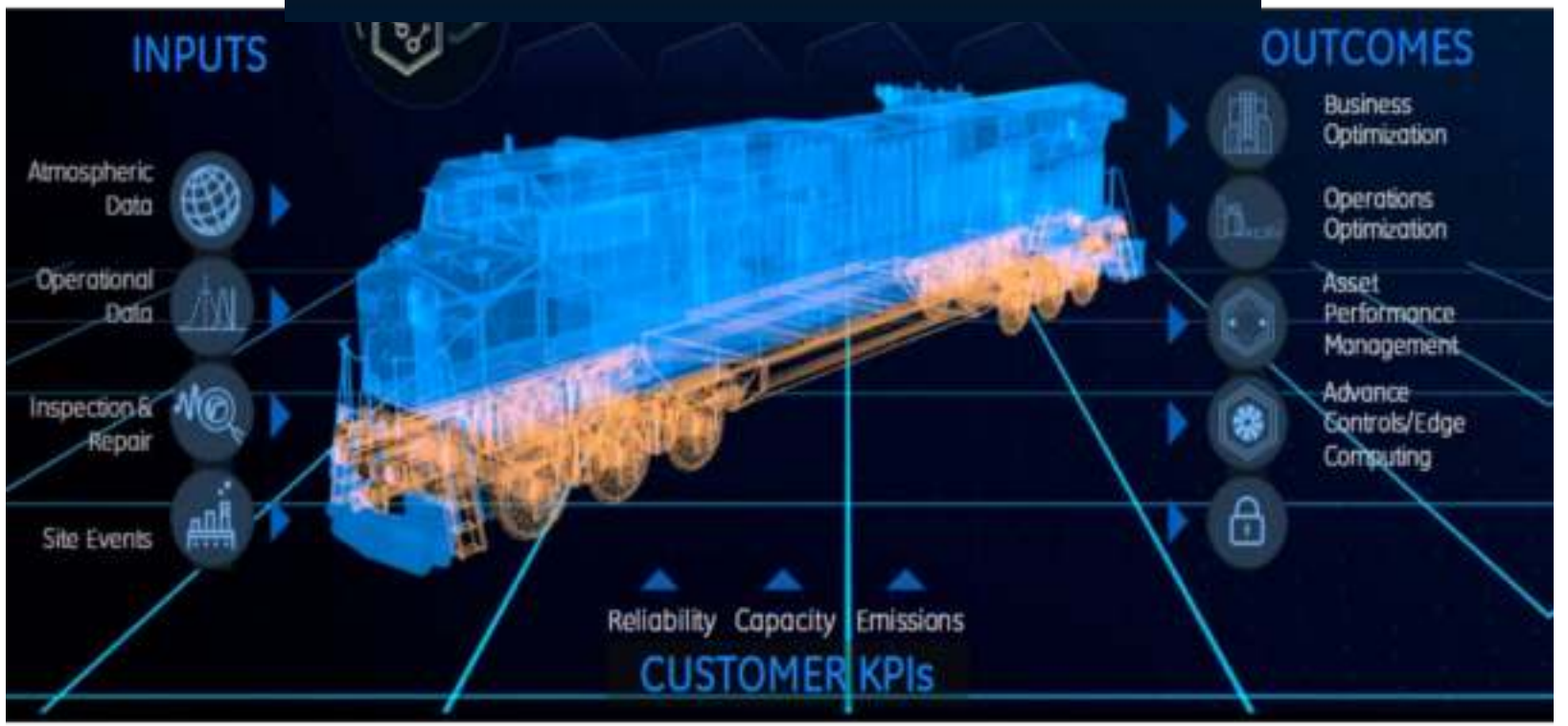

Research
challenge

Digital Twin





The twin as a service provider




The picture of Dorian Gray
The challenge in DT

Digital Twin

SWEDISH STANDARD SS-ISO 23247-3:2021

Automation systems and integration — Digital twin framework for manufacturing — Part 3: Digital representation of manufacturing elements (ISO 23247-3:2021, IDT)

Language: Approved: 10/6/2021 Edition: 1

ISO STANDARD ISO/IEC 30173:2023

Digital twin — Concepts and terminology

Language: Approved: 11/8/2023 Edition: 1

SWEDISH STANDARD SS-ISO 23247-2:2021

Automation systems and integration — Digital twin framework for manufacturing — Part 2: Reference architecture (ISO 23247-2:2021, IDT)

Language: Approved: 10/12/2021 Edition: 1

SWEDISH STANDARD SS-ISO 23247-4:2021

Automation systems and integration — Digital twin framework for manufacturing — Part 4: Information exchange (ISO 23247-4:2021, IDT)

Language: Approved: 10/18/2021 Edition: 1

SWEDISH STANDARD SS-ISO 23247-1:2021

Automation systems and integration — Digital twin framework for manufacturing — Part 1: Overview and general principles (ISO 23247-1:2021, IDT)

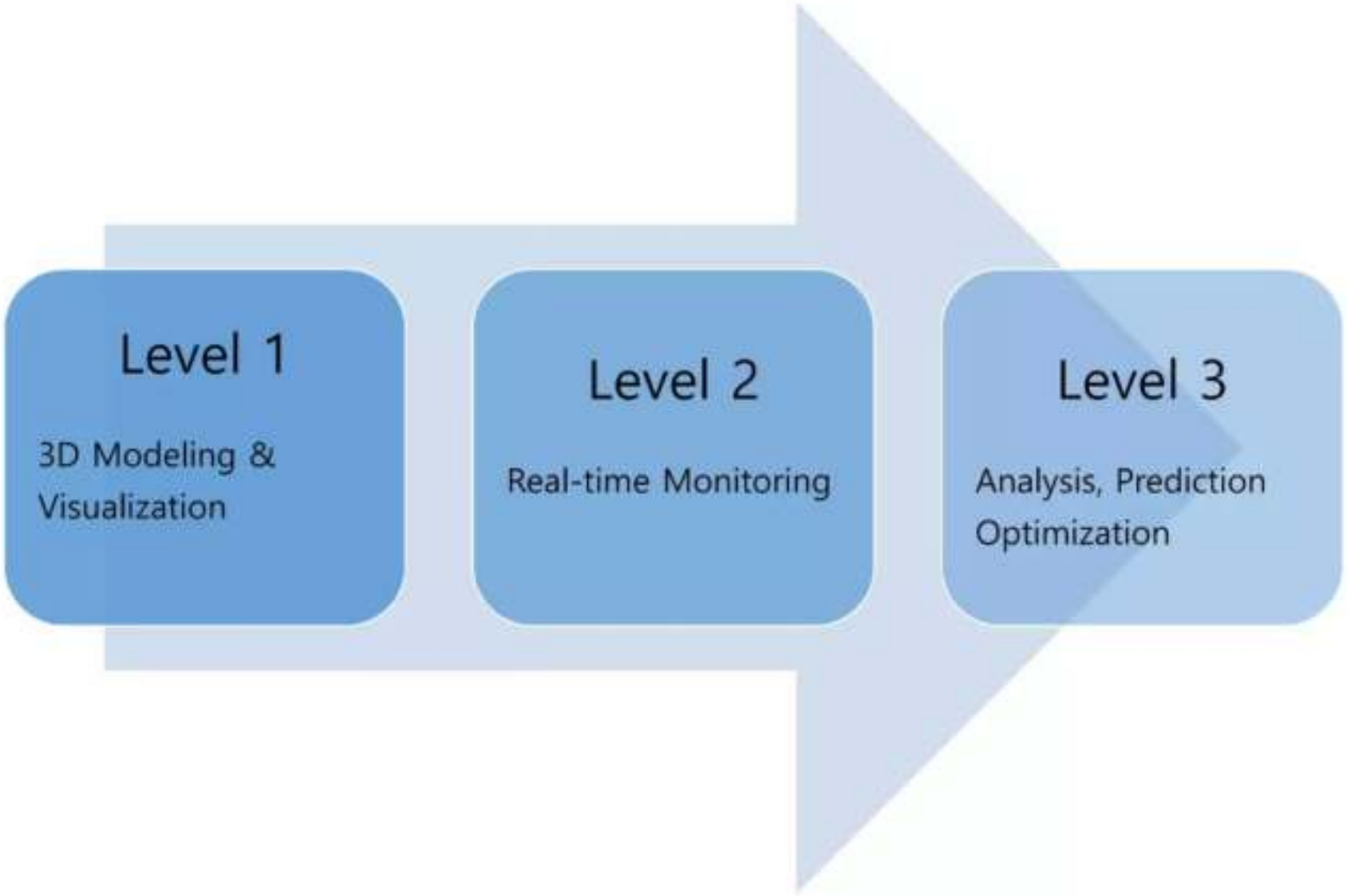
Language: Approved: 10/26/2021 Edition: 1

SVENSK STANDARD
SS-ISO 23247-1:2021

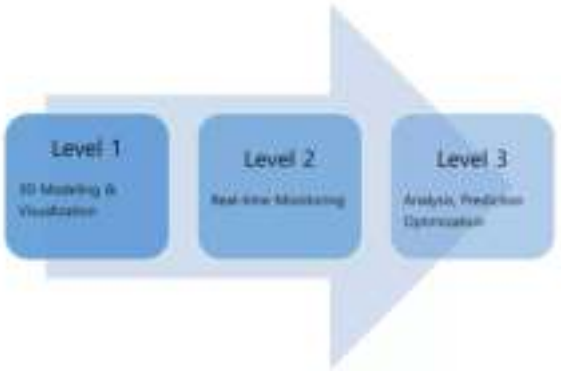
Industriautomation – Ramverk för digitala tvillingar – Del 1: Översikt och allmänna principer (ISO 23247-1:2021, IDT)

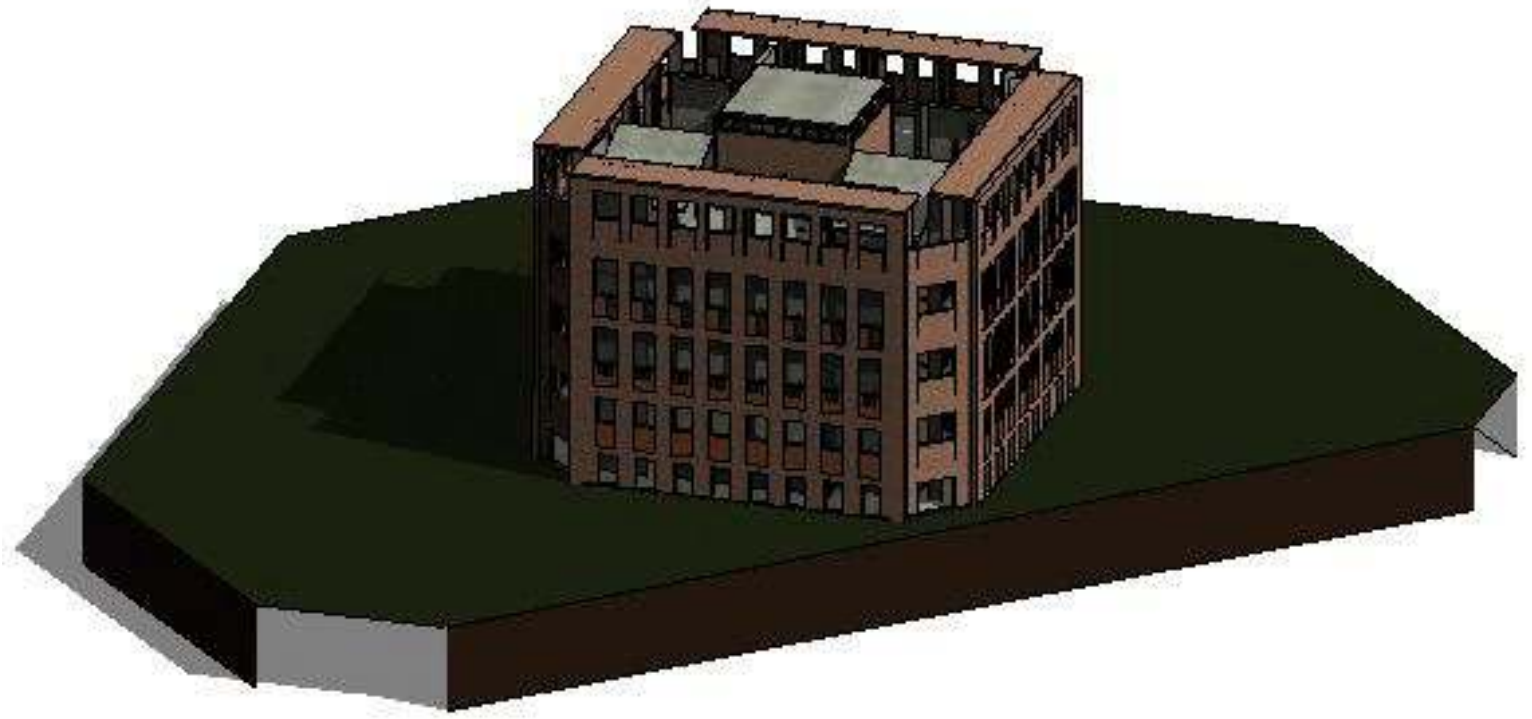
Automation systems and integration — Digital twin framework for manufacturing — Part 1: Overview and general principles (ISO 23247-1:2021, IDT)

Levels of Digital Twin



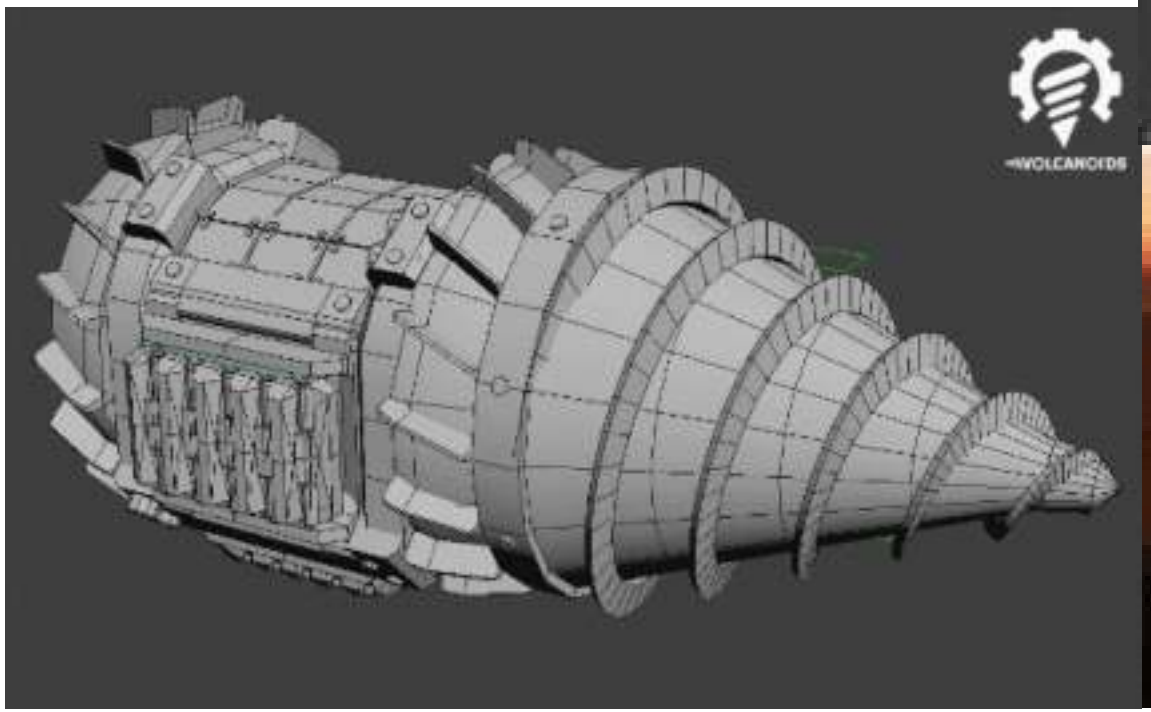
Level 1 of Digital Twin





Level 2 of Digital Twin

Level 3 of Digital Twin

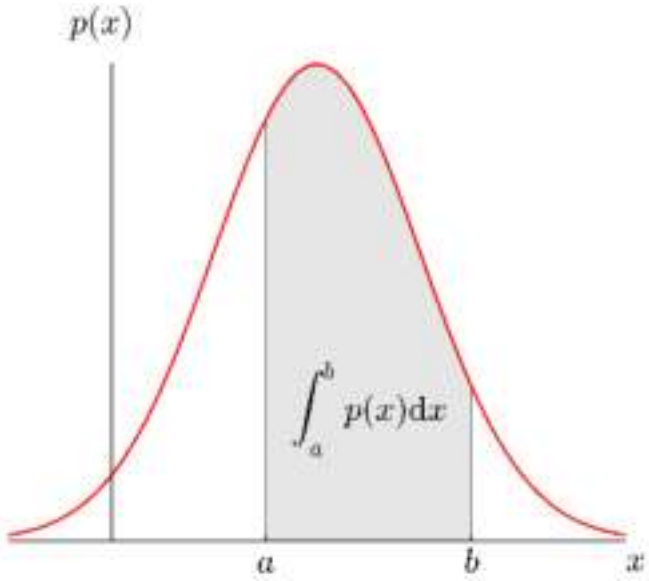


Digital twin

- The digital twin refers to a digital ***replica*** of physical assets, processes and systems that can be used in real-time for control and decision purposes
  - Computerized mathematical model (what we have done over years)
  - Real-time, thanks to IoT
- **In contrast to a physical asset, the digital twin can immediately perform forecasting**

Stochastic digital twin

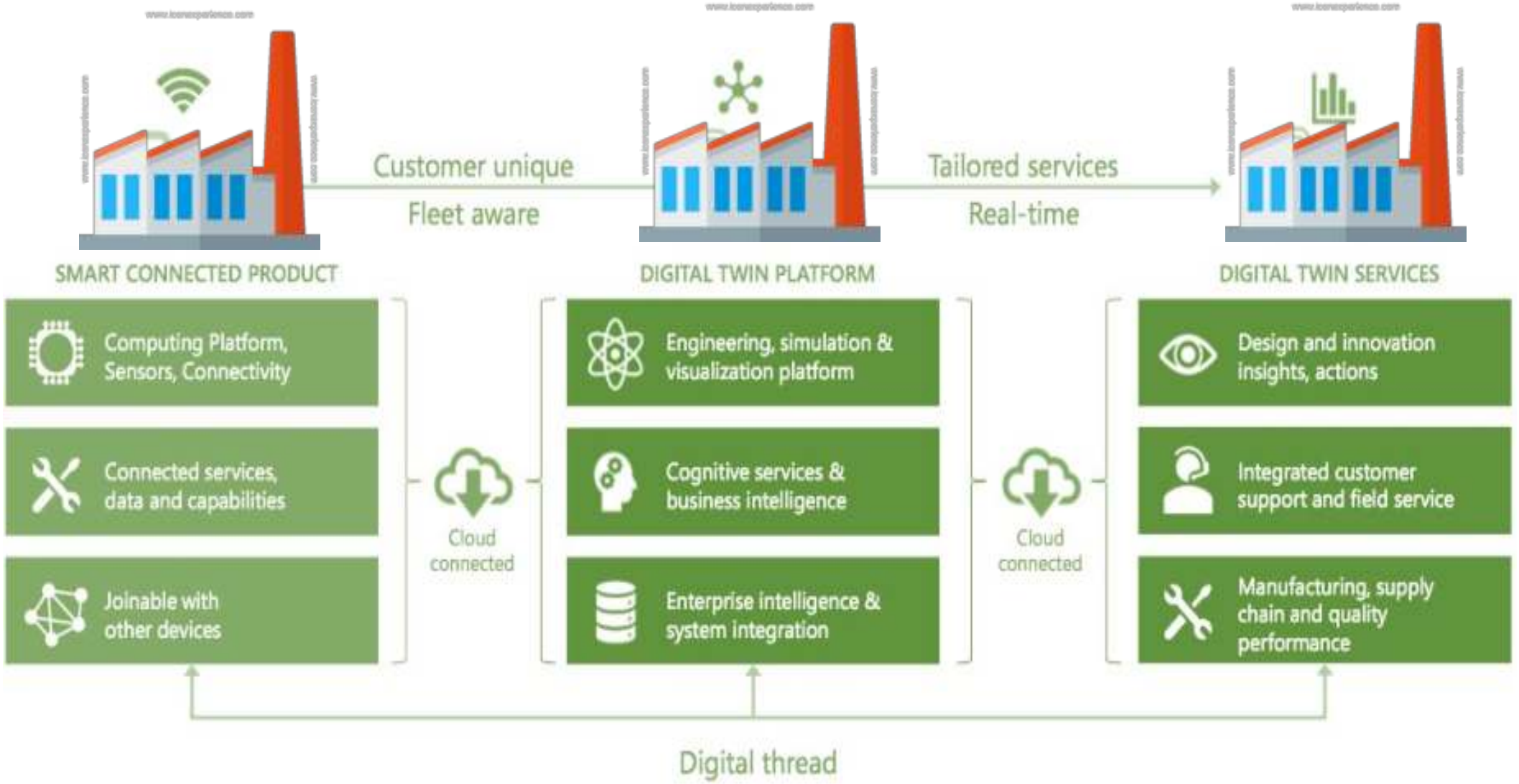
- A stochastic digital twin is a computerized model of the ***stochastic behavior*** of a system where
  - the model is updated in real-time
    - based on sensor information and other information
    - accessed via the internet and the use of cloud computing resources
- What-if inquiries result in ***pdf***'s rather than single values



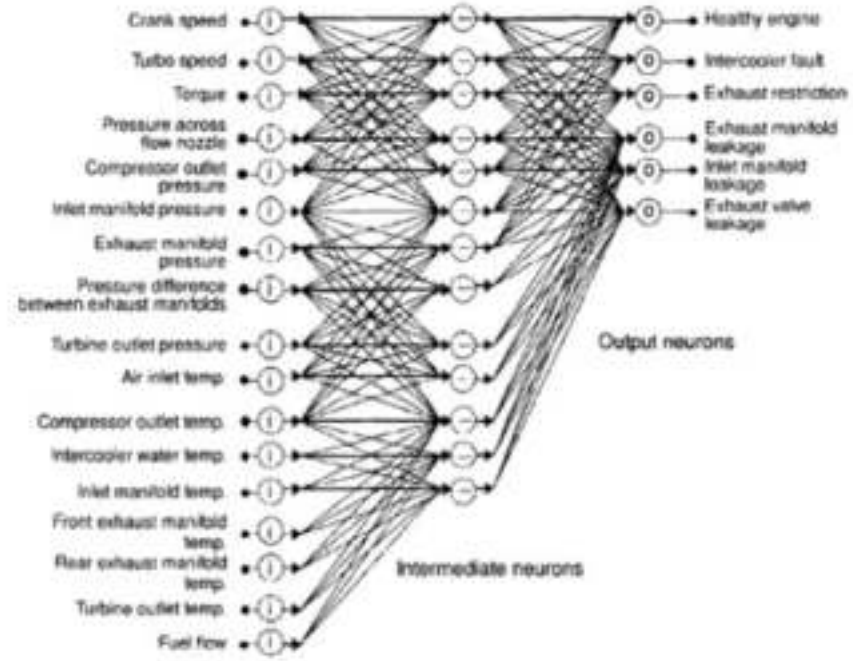
Real-time model

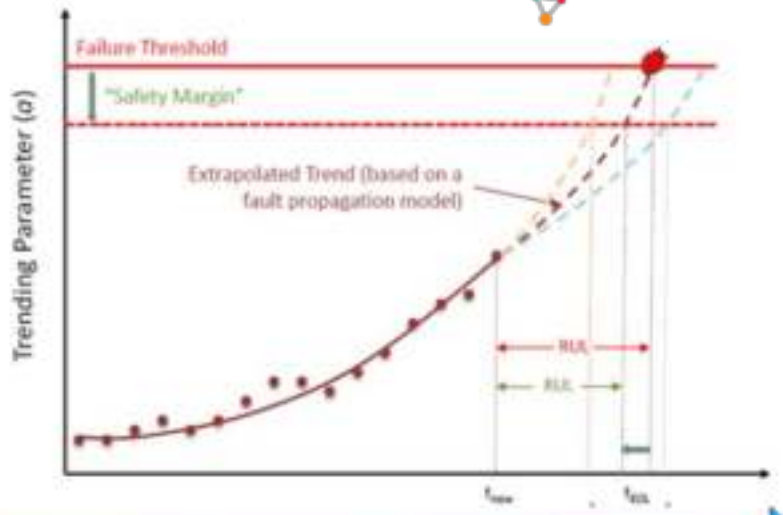
- A real-time model is a model where it is possible to obtain values of system performance and system states in ***real-time***
- With real-time we mean that data referring to a system is analysed and ***updated at the rate at which it is received***

Digital Twin Solution Architecture



Digital twin 1.0

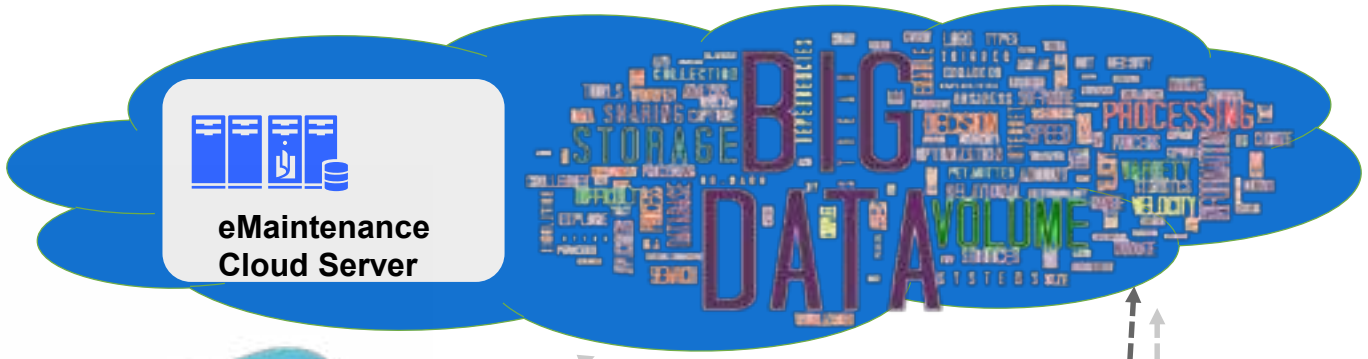




Diagnostics

Prognostics

Digital twin 1.0



On board Wireless System

Machine Maintenance
Analytics

Data → Information → Knowledge

Types of AI

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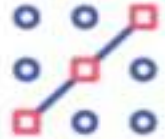

Limited memory

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Theory of mind

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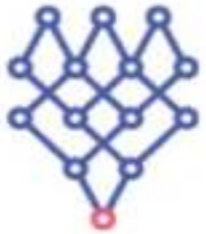
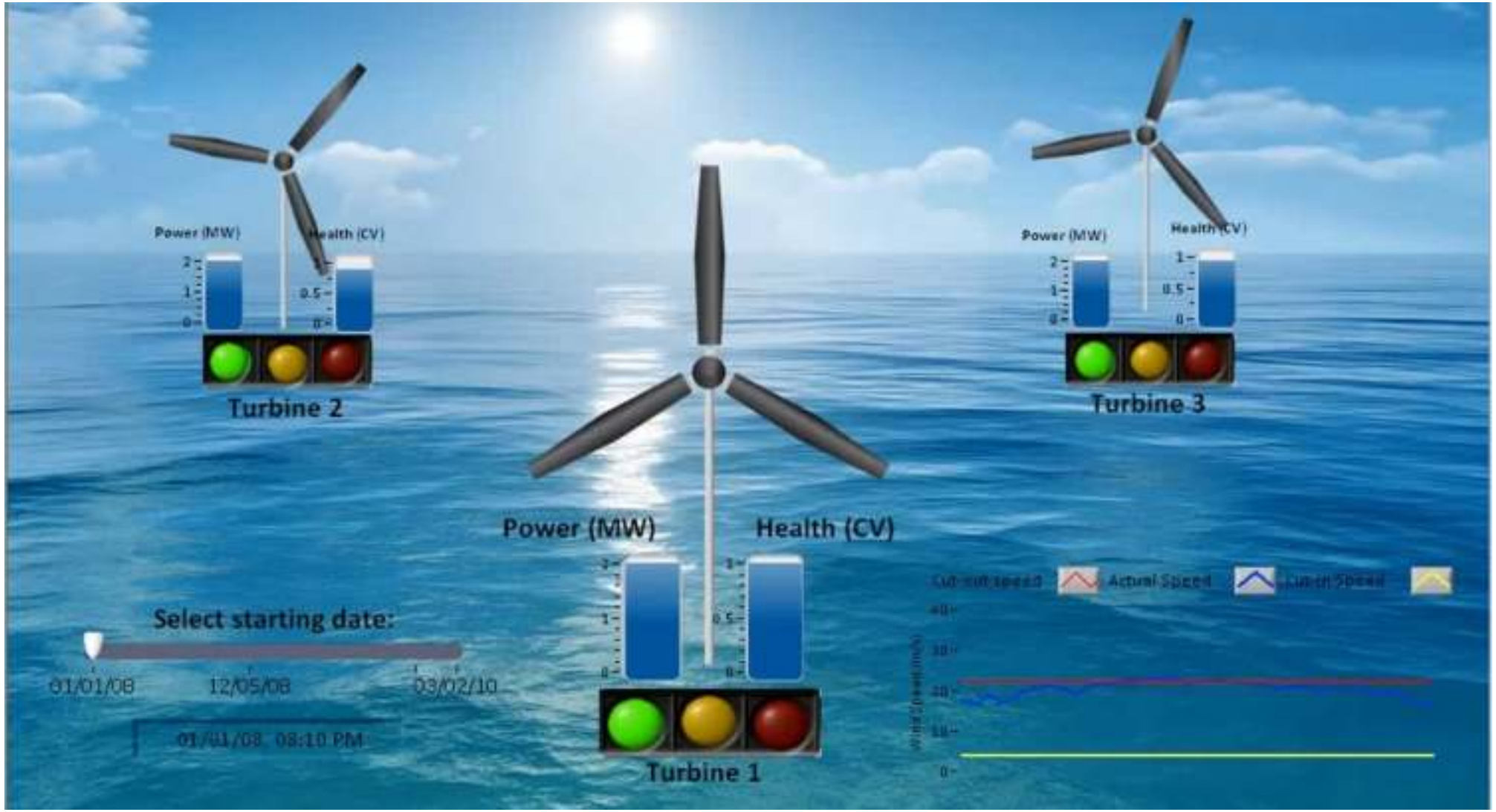


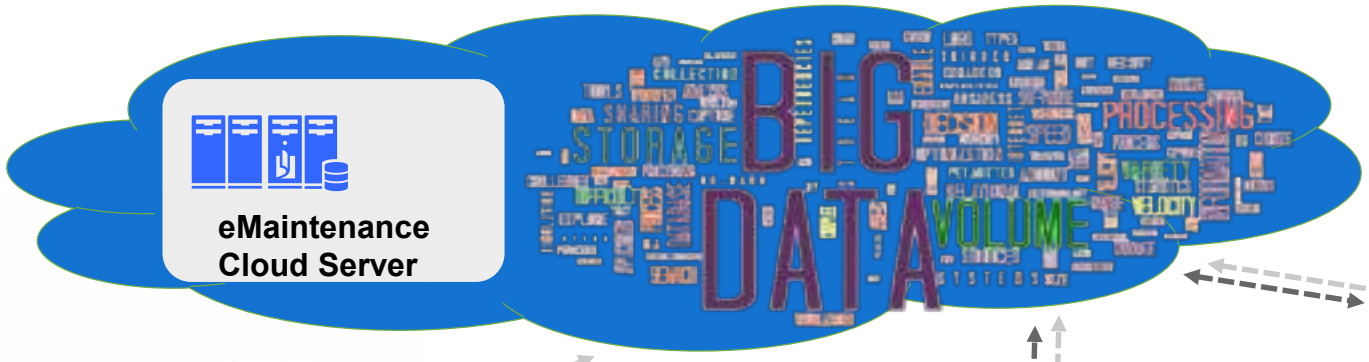
Self-aware

- Human-level intelligence that can bypass our intelligence, too

Twin based purely on OT



Digital twin 2.0



Technical services

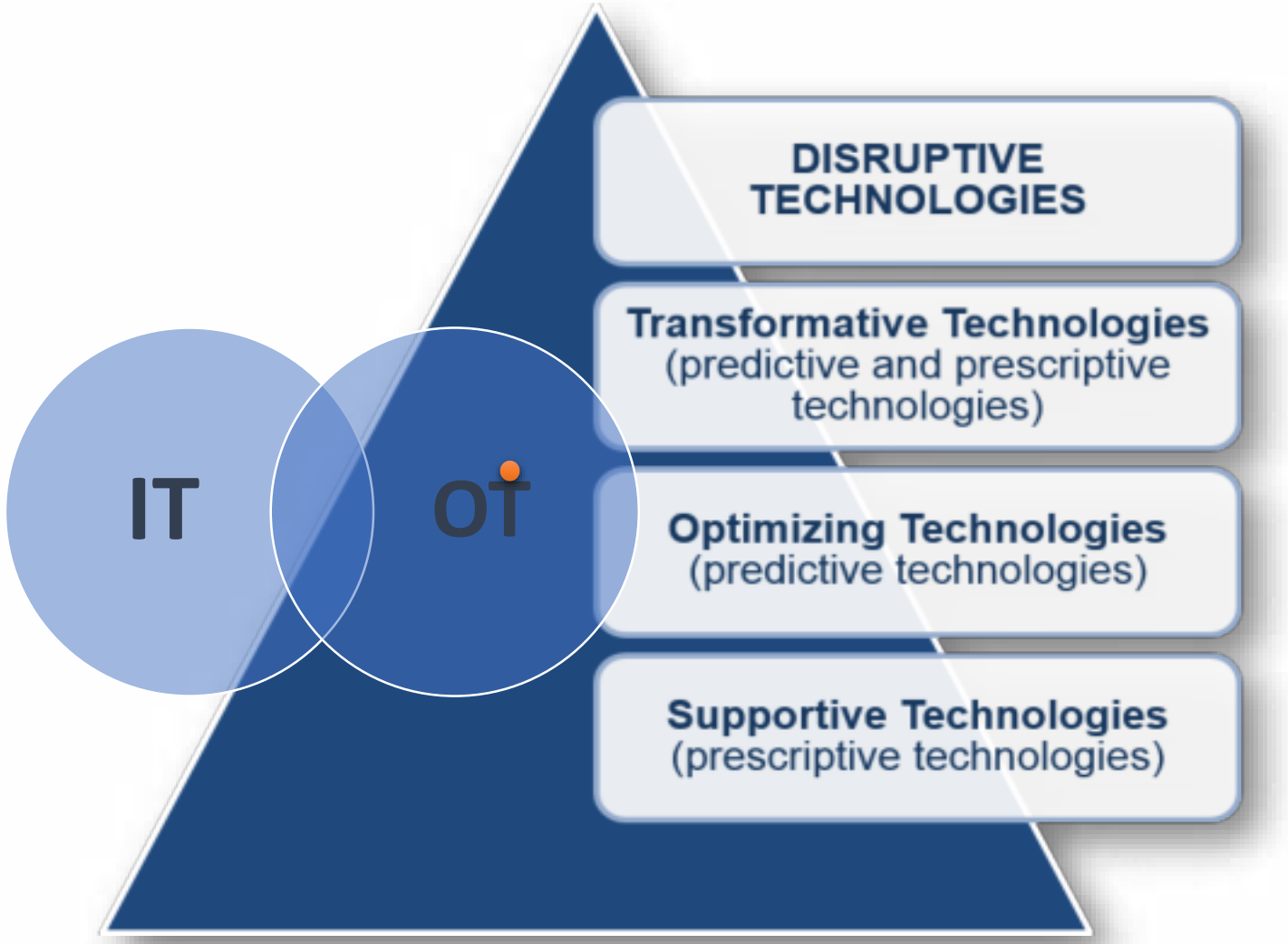
On board Wireless System

Machine Maintenance
Analytics

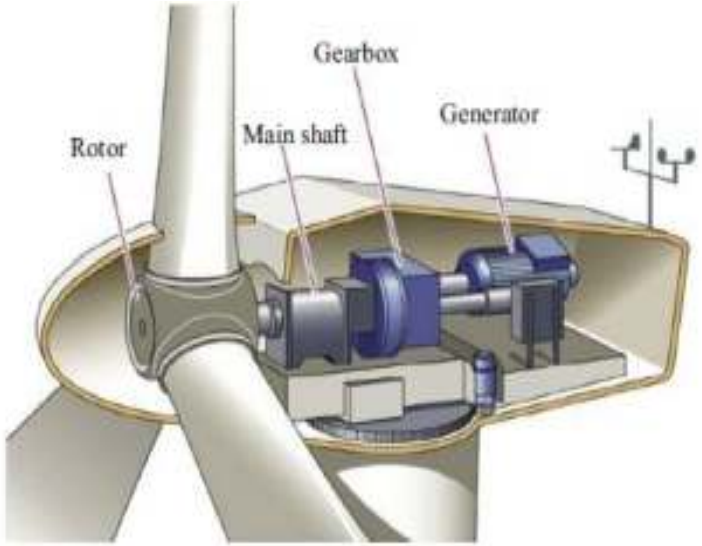
Truck scheduling

Data → Information → Knowledge

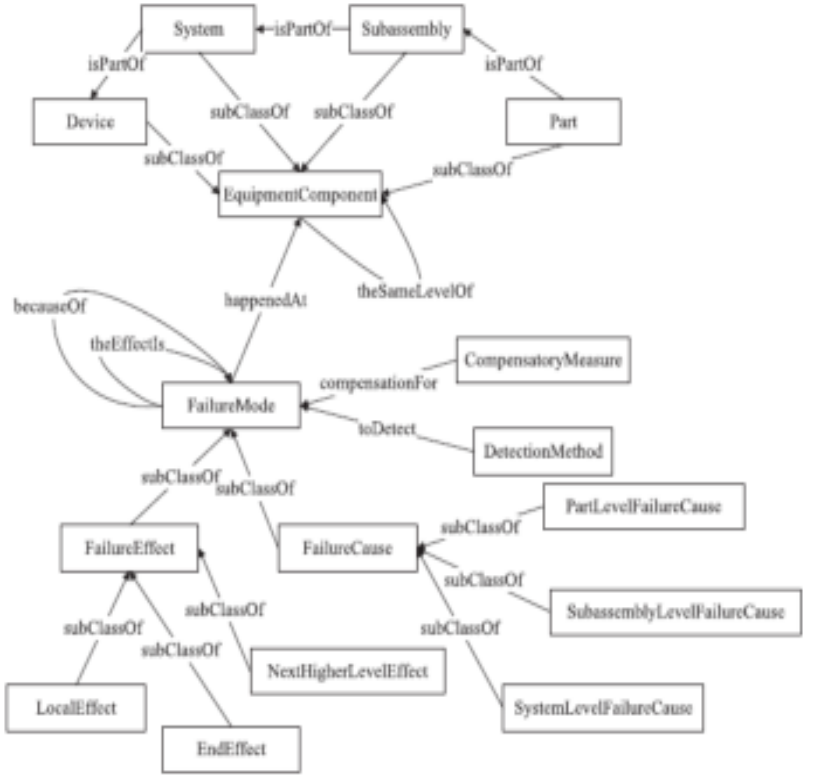
TRANSFORMATIVE MAINTENANCE SOLUTIONS
Integration & Application of Technologies



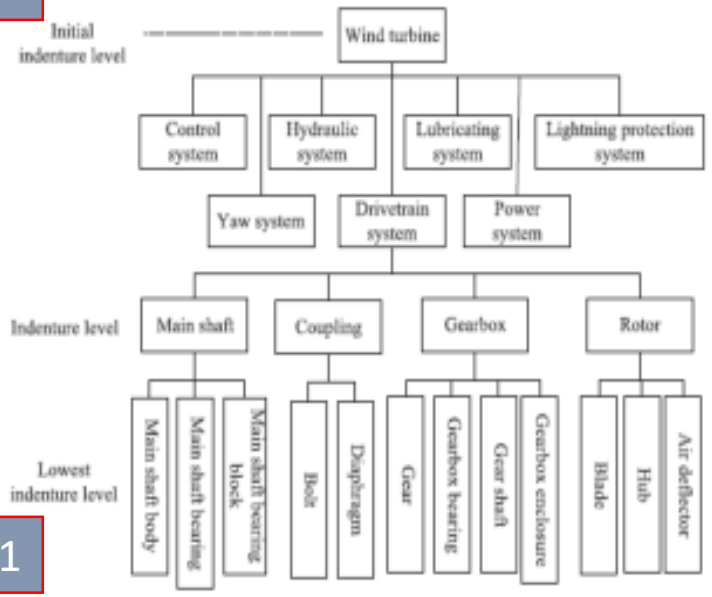
Taxonomies and ontologies



1



2

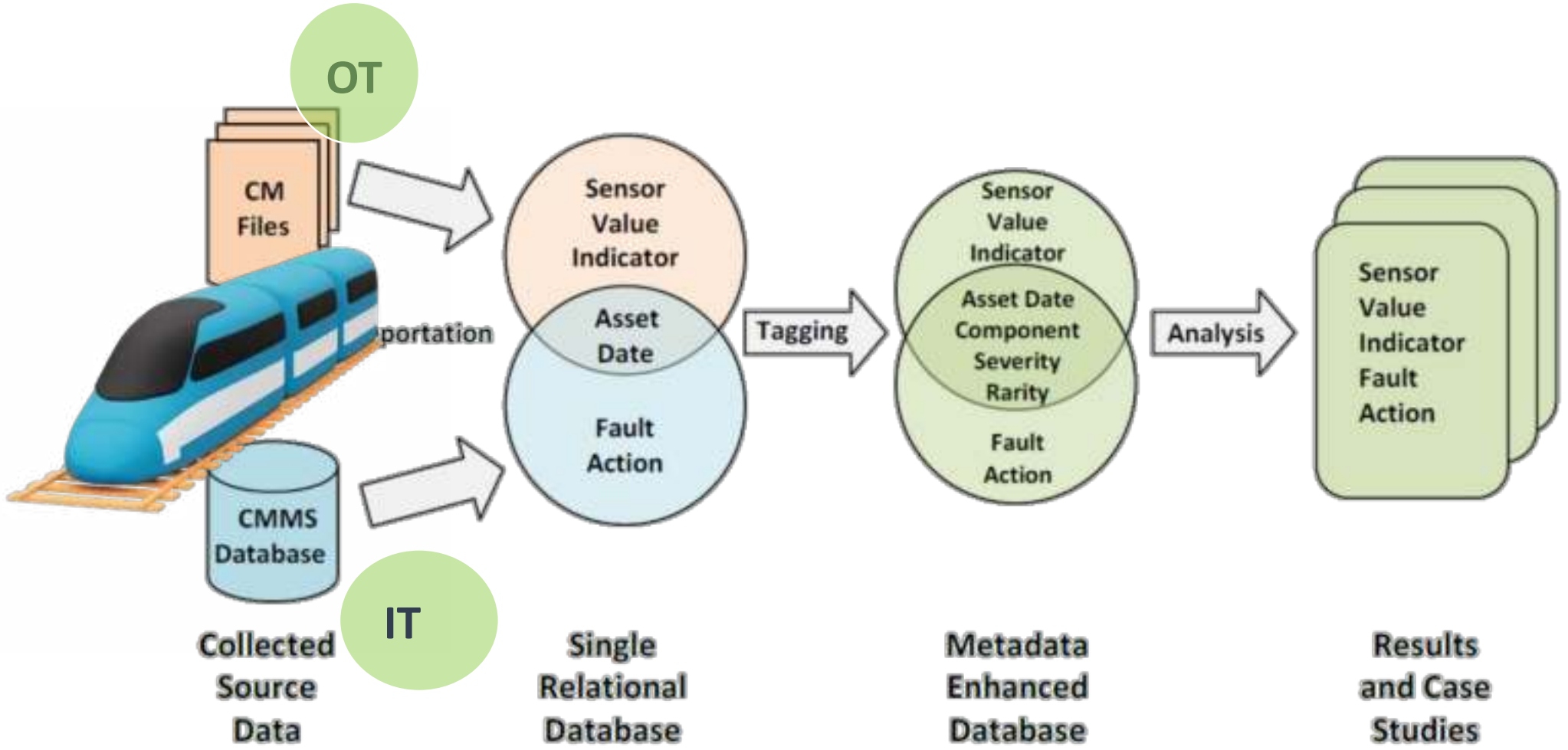


1

Rule-1
FailureMode(?x) ^ hasHappened(?x, true) ^ Device(?y) ^ happenedAt(?x, ?y) ^ FailureMode(?z) ^ theEndFffectIs(?z, ?x) ^ FailureMode(?a) ^ theHighEffectIs(?z, ?a)?theDirectFailureCauseIs(?x, ?a) ^ hasHappened(?a, true)

2

Digital twin 2.0



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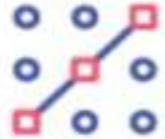

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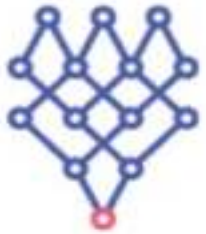


Self-aware

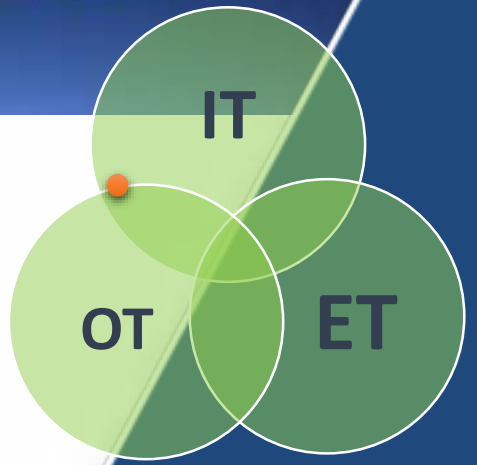
- Human-level intelligence that can bypass our intelligence, too

Only solution to confront black swans us to fill gap between data science and O&M

"I need to deploy models into live business environments."

"I need strong, transparent insights to improve my daily decisions."

Digital twin 3.0



DISRUPTIVE TECHNOLOGIES

Transformative Technologies
(predictive and prescriptive technologies)

Optimizing Technologies
(predictive technologies)

Supportive Technologies
(prescriptive technologies)

Huge gap between data science and O&M

Domain knowledge and AI, both needed


MINORITY
REPORT

Hybrid models

- Combine knowledge about the physical process and information from sensor readings to enhance prognostics capabilities.
- Integration of measured data and physics can lead to a reduction of uncertainty (e.g. adjust predictions from model using observed data).
- Integration can be implemented at different levels of the PHM process
  - Online model parameters updating.
  - Model predictions correction based on observed data.
  - Measure current damage level and propagate.
  - Build empirical degradation models from data.

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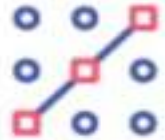

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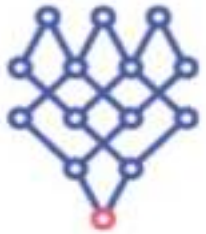

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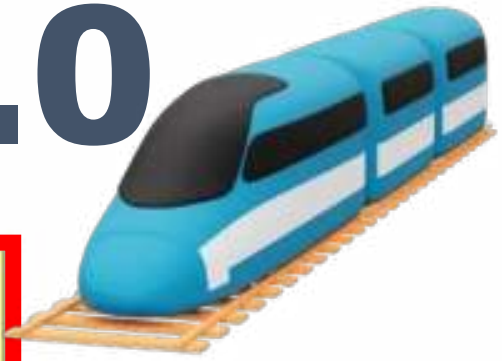
Digital twin 4.0



Complex Weapon System

Data Acquisition

- S1
- Sn
- Insp
- NDE

Data Manipulation

- Pre-Processing
- Feature Extraction
- Signal Characterization

Condition Monitoring/ Status Assessment

Compare against expected

Diagnostics/ Health Assessment

Prognostics

Project future health of the system, taking into account estimates of past and future operation profiles

3 or 4

Dynamic Mission Planning, Anticipatory Maintenance & Optimized Resource Management

State Awareness

Life Usage

Remaining Useful Life (RUL)

Logistics Management Processes

Advisory Generation

- Decision Reasoning
- Automated decision making

Mission Usage & Planning

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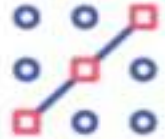

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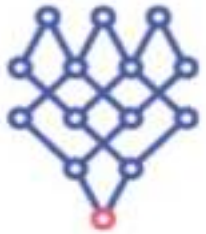

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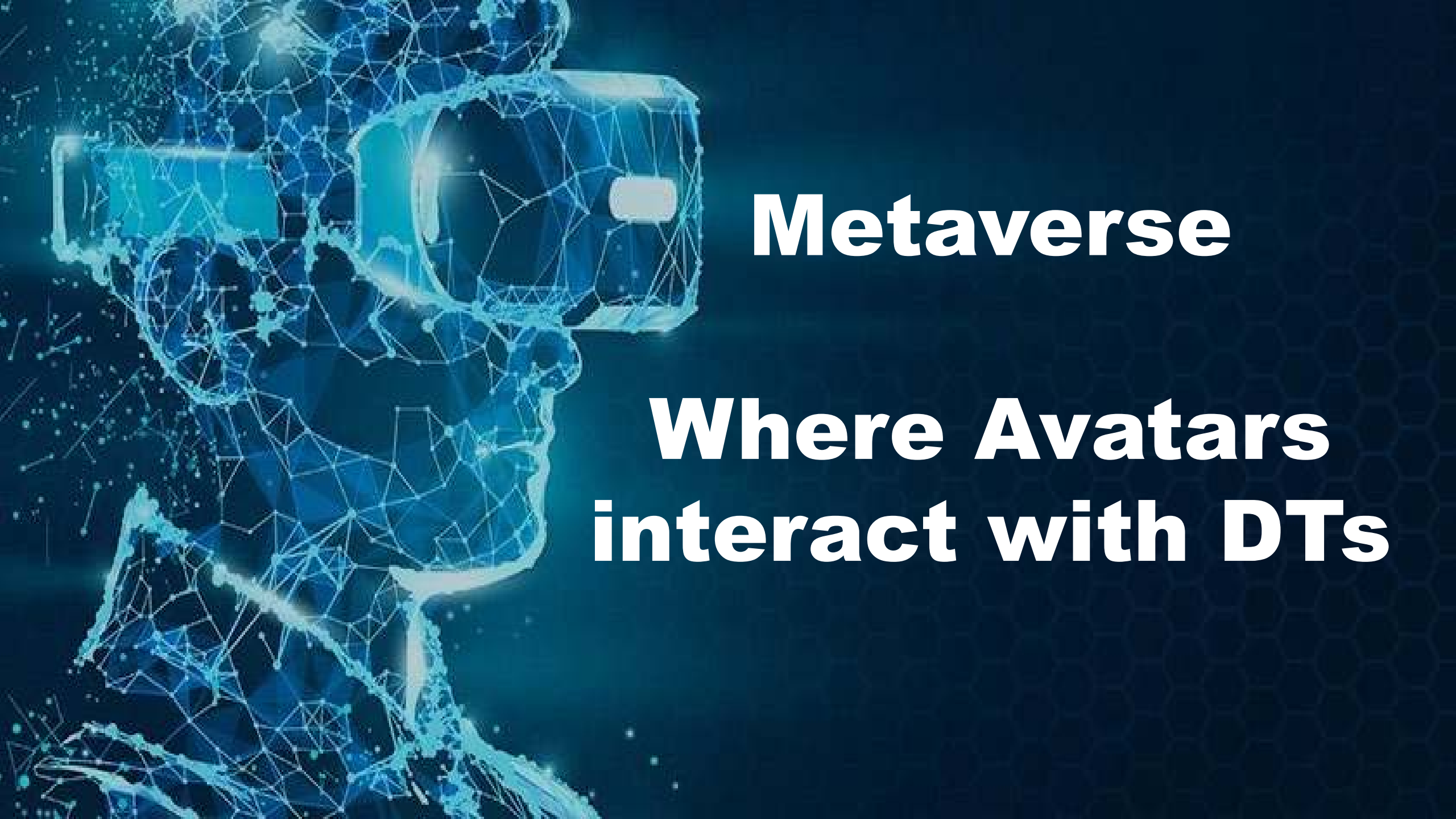
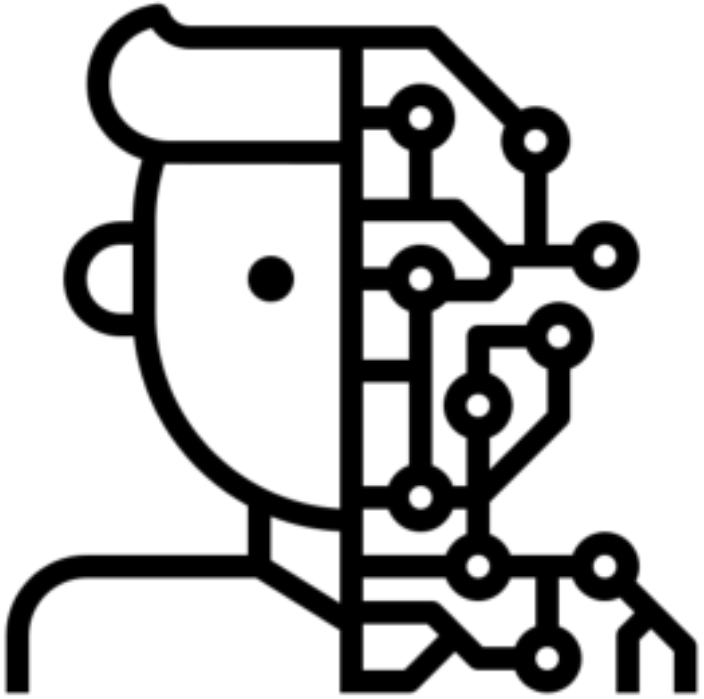
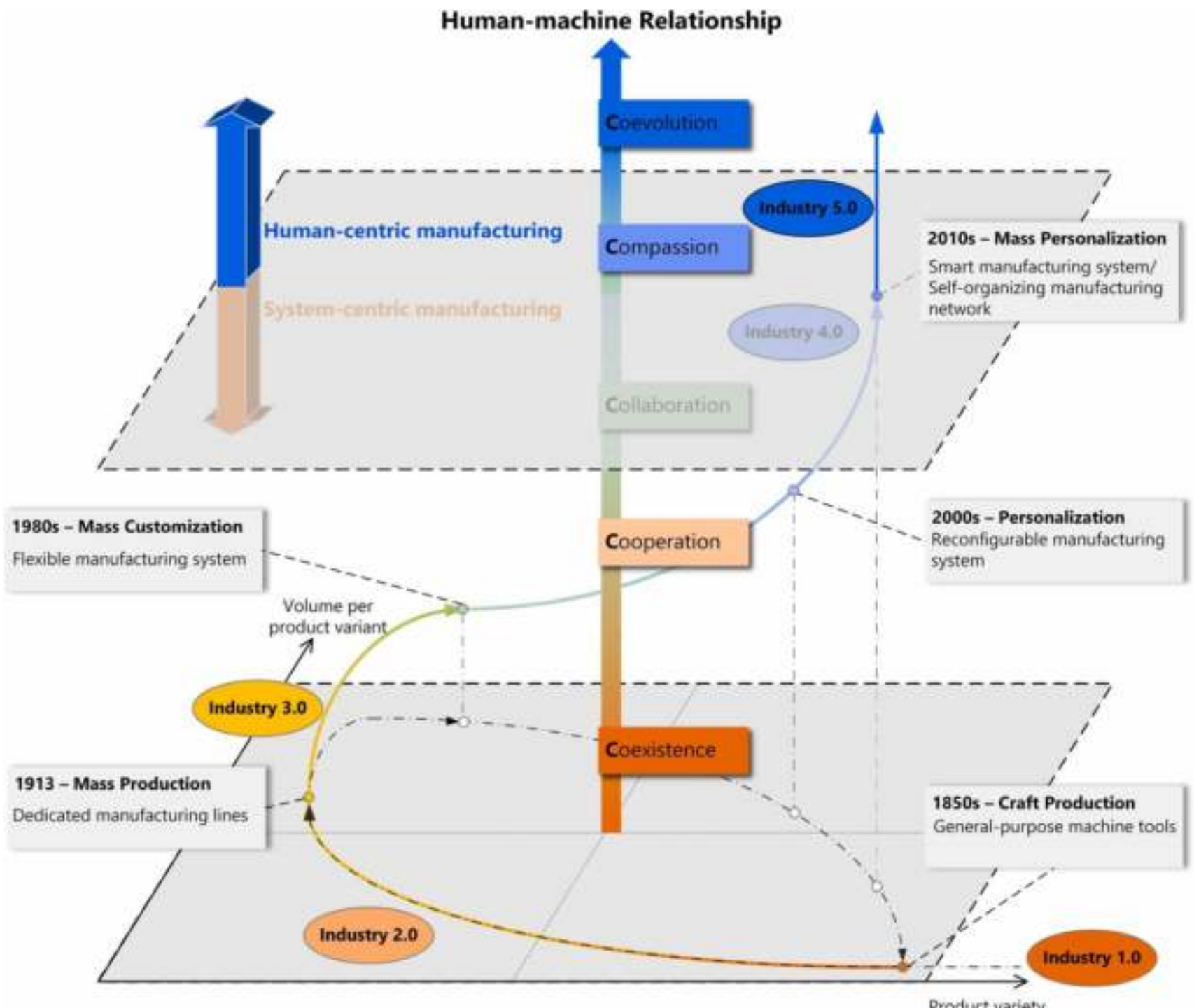

Metaverse
Where Avatars interact with DTs

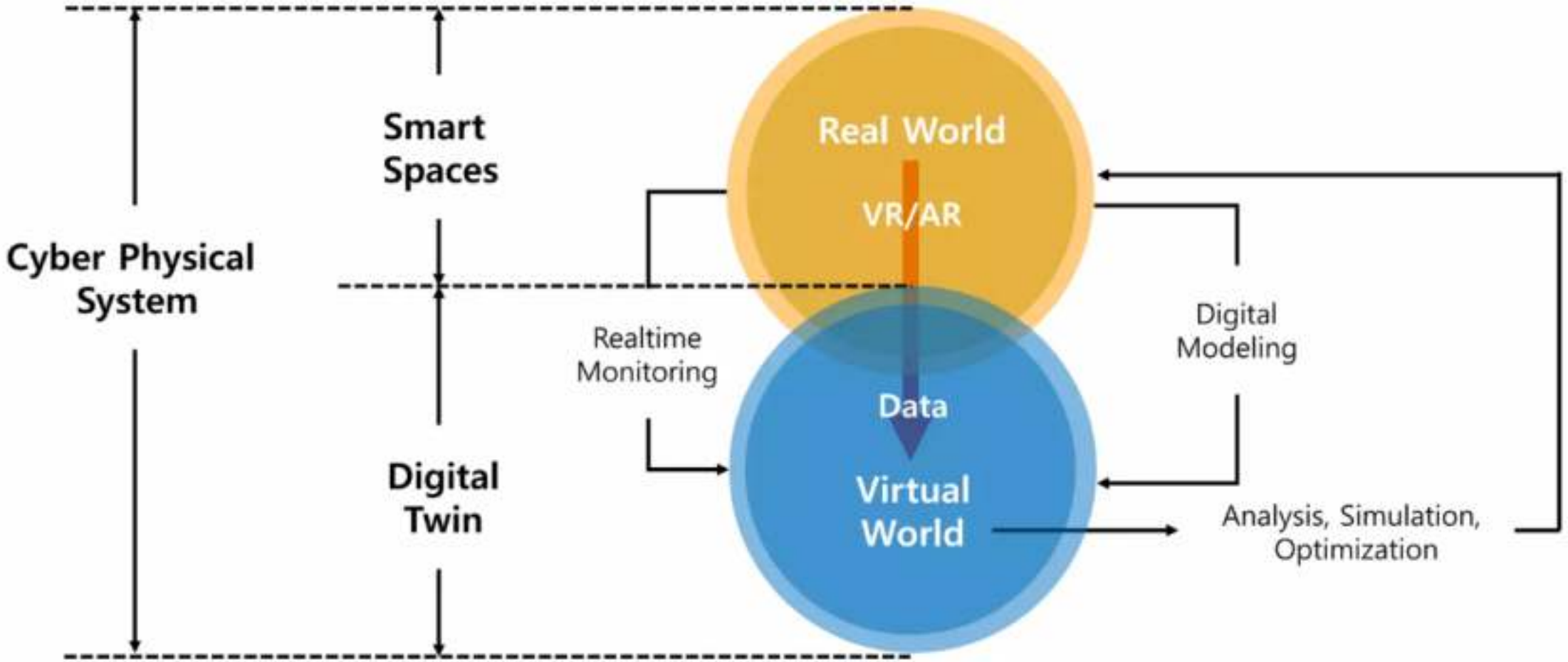
5.0 Let us redefine human machine relations

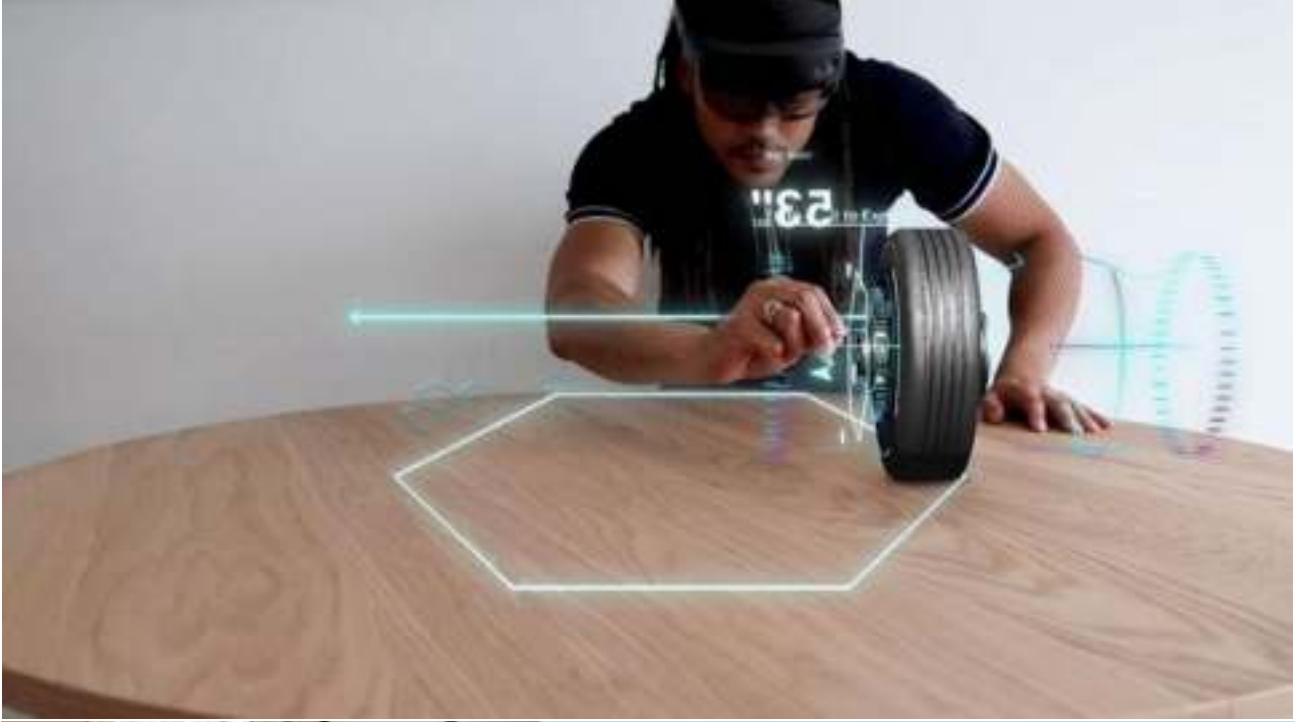


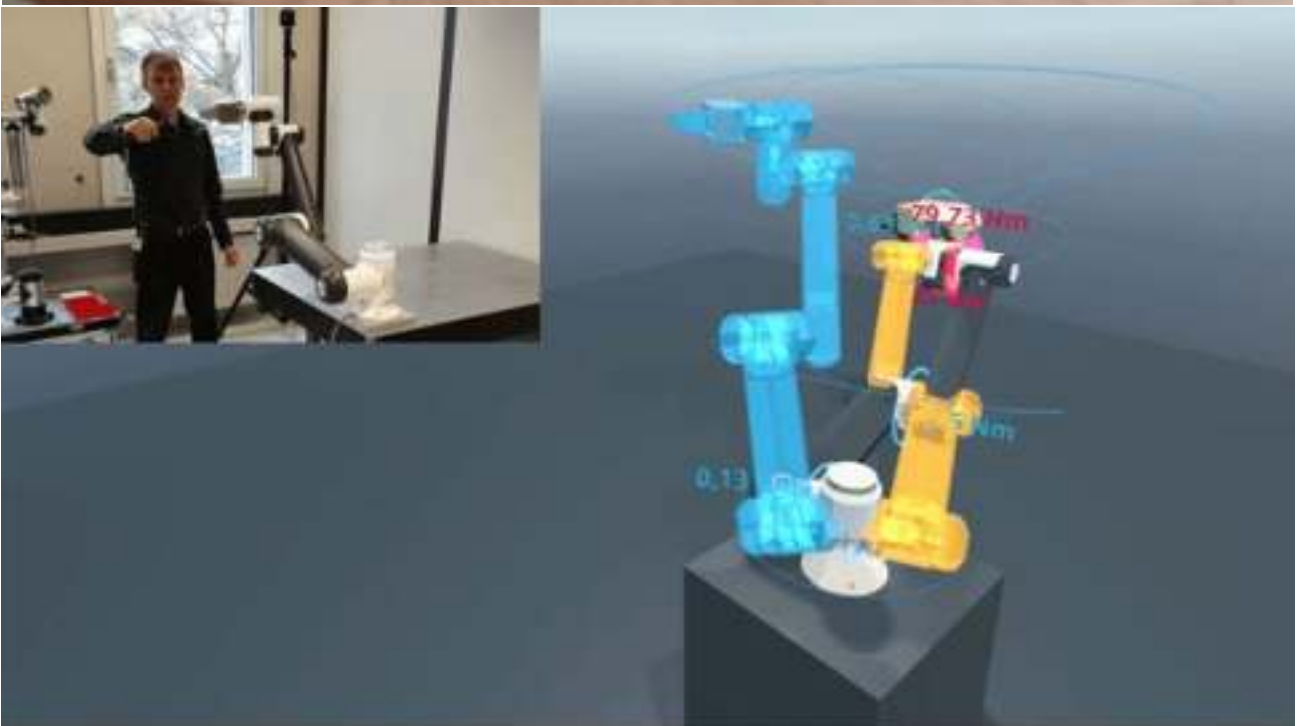


Augmentation seems to be the solution

Digital Twin and SMART





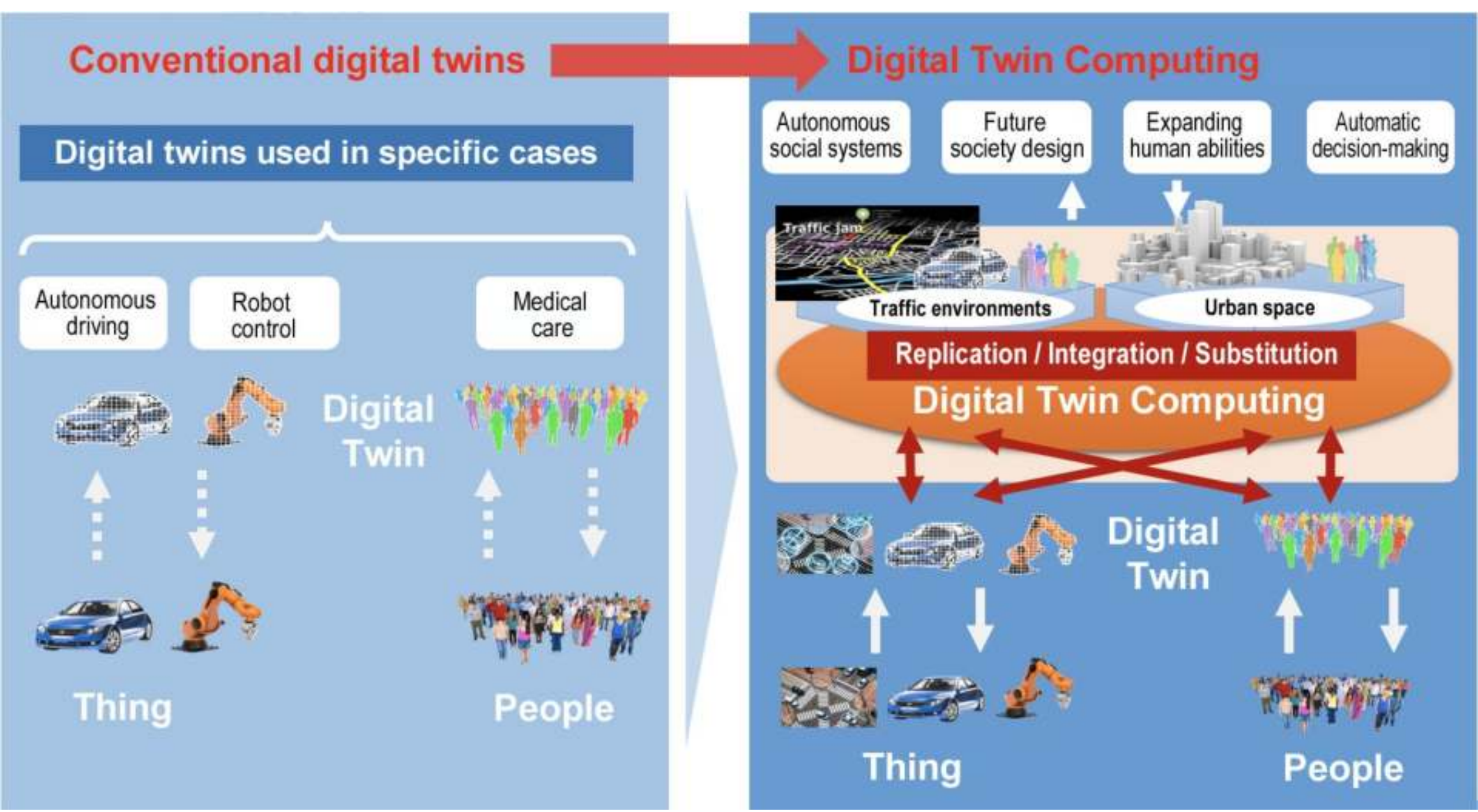


We want to be Alice


MAINTENANCE

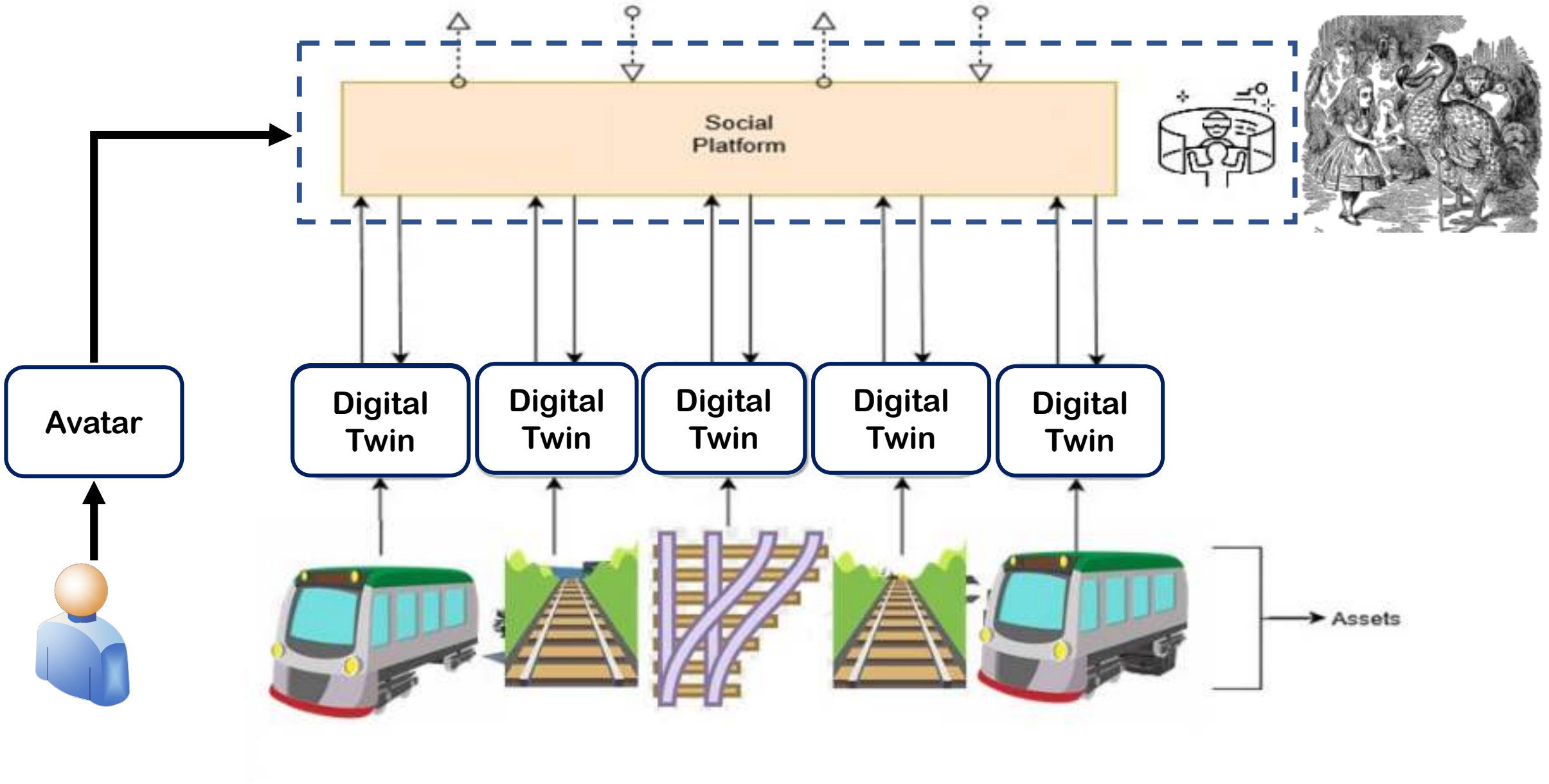

eMaintenanceLAB
eMaintenance LAB
AI Factory
AI Factory

INSIDE


Conventional digital twins
Digital twins used in specific cases
Autonomous driving
Robot control
Medical care
Digital Twin
Thing
People
Digital Twin Computing
Autonomous social systems
Future society design
Expanding human abilities
Automatic decision-making
Traffic jam
Traffic environments
Urban space
Replication / Integration / Substitution
Digital Twin Computing
Digital Twin
Thing
People

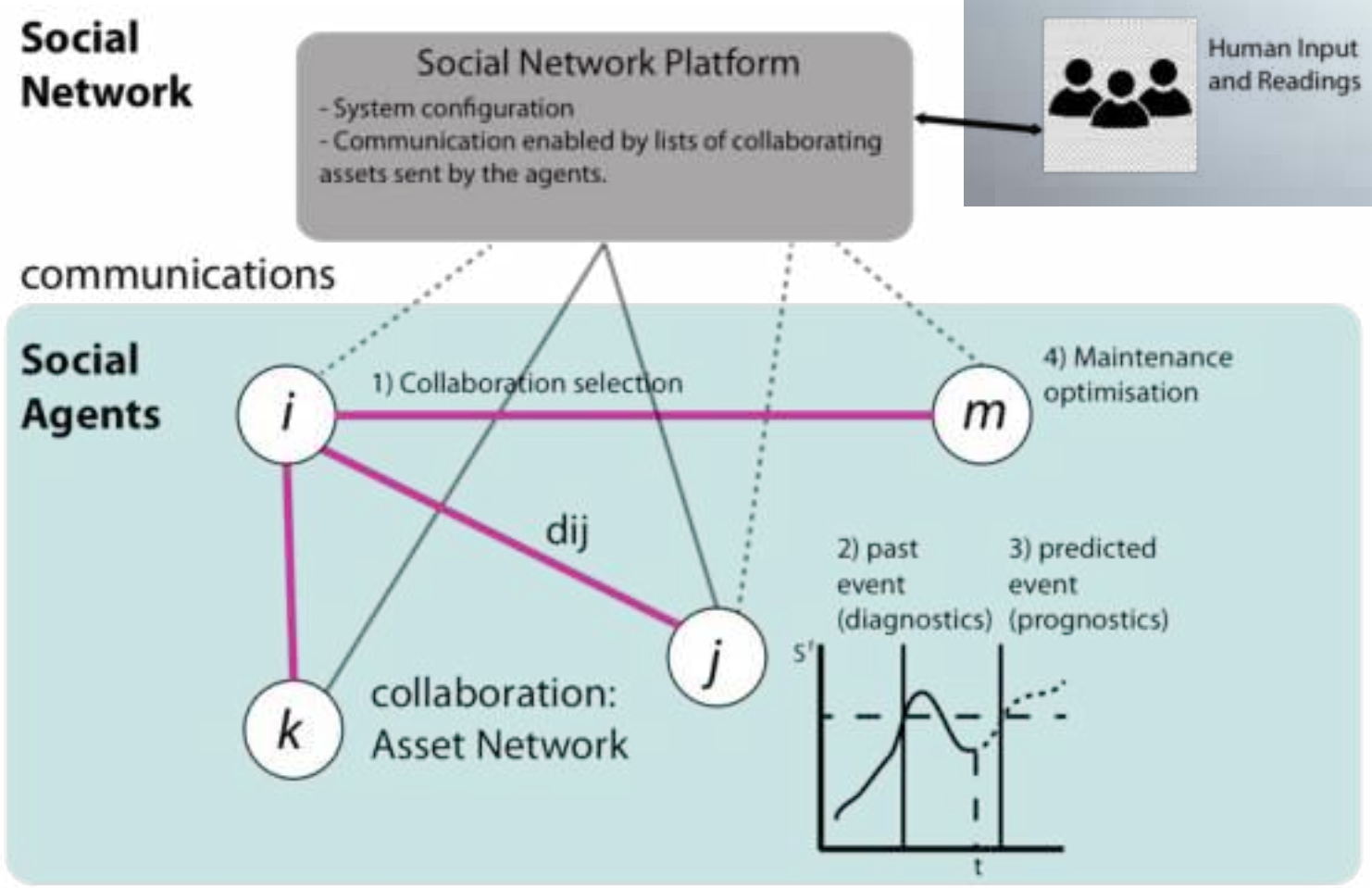

Research
challenge

Metaverse data exchange with assets and humans



The collective mind with distributed intelligence

Health management in social networks

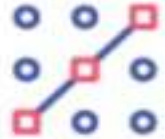


Types of AI

The emergence of artificial superintelligence will change humanity, but it's not happening soon. Here are the types of AI leading up that new reality.

Reactive AI

- Good for simple classification and pattern recognition tasks
- Great for scenarios where all parameters are known; can beat humans because it can make calculations much faster
- Incapable of dealing with scenarios including imperfect information or requiring historical understanding

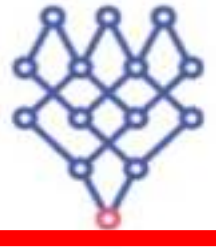


Limited memory

- Can handle complex classification tasks
- Able to use historical data to make predictions
- Capable of complex tasks such as self-driving cars, but still vulnerable to outliers or adversarial examples
- This is the current state of AI, and some say we have hit a wall

Theory of mind

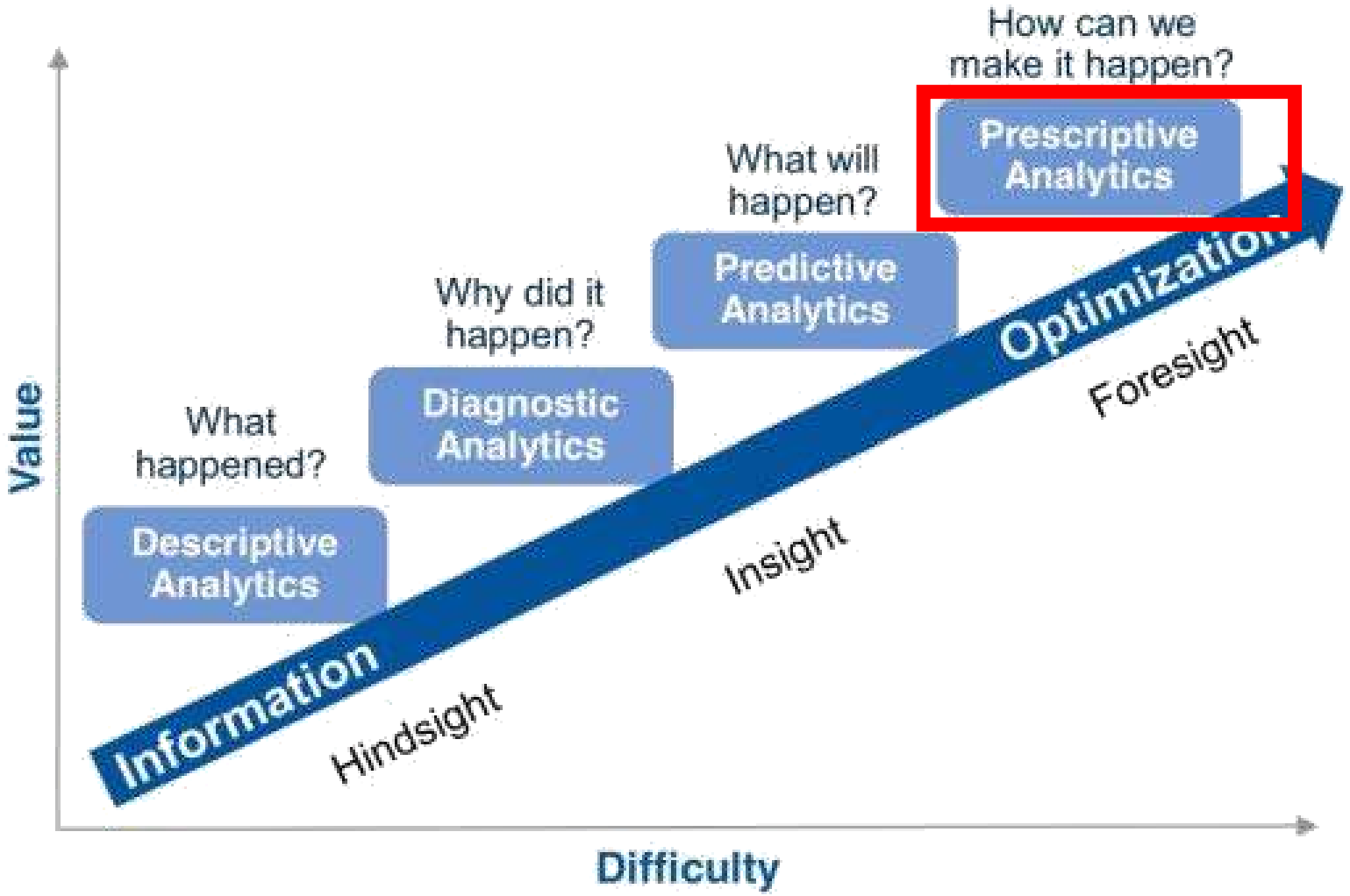
- Able to understand human motives and reasoning. Can deliver personal experience to everyone based on their motives and needs.
- Able to learn with fewer examples because it understands motive and intent
- Considered the next milestone for AI's evolution



Self-aware

- Human-level intelligence that can bypass our intelligence, too

Prescriptive maintenance as advisory engine for maintenance crew



Simulation of potential scenarios.....

Prescription autonomy and Multiverse

standard system connectivity

reality observation

data aggregation

domain expertise

Digitalization

Observation

Understanding

Prediction

data-driven prediction

machine learning

Prescription & Autonomy

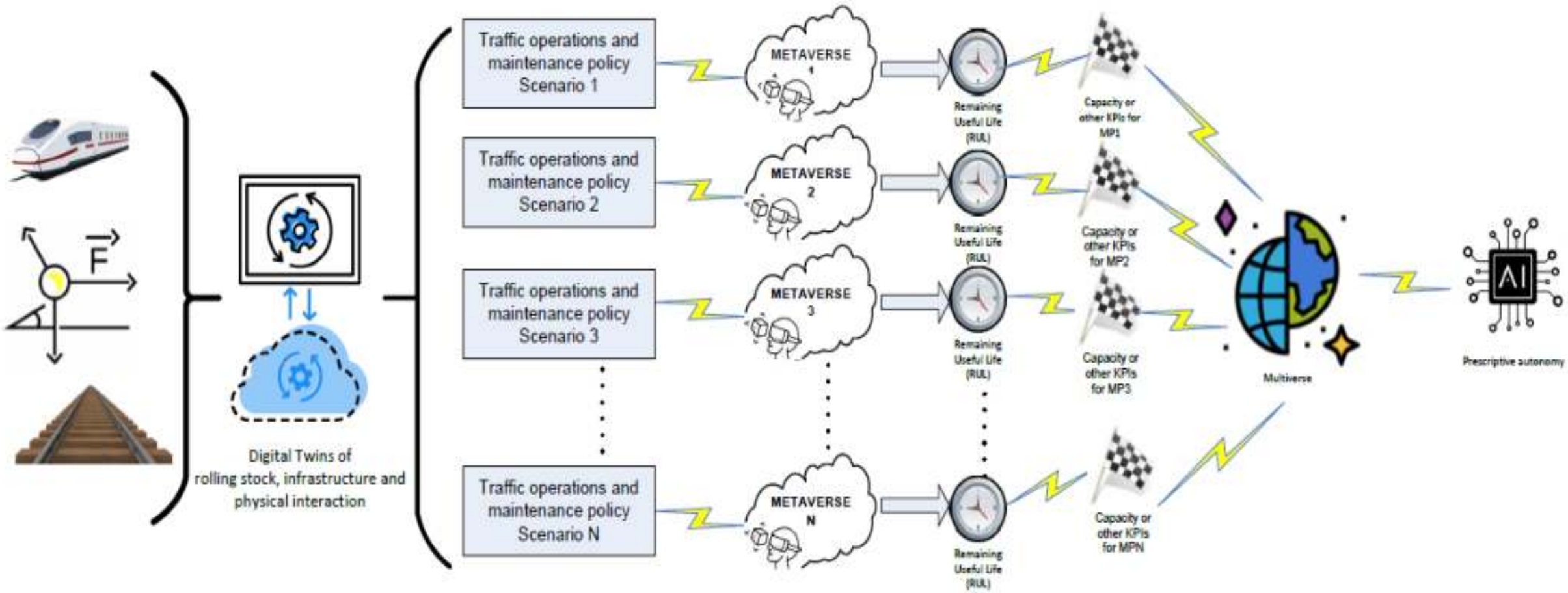
optimization

Descriptive Analytics

Predictive Analytics

Complexity

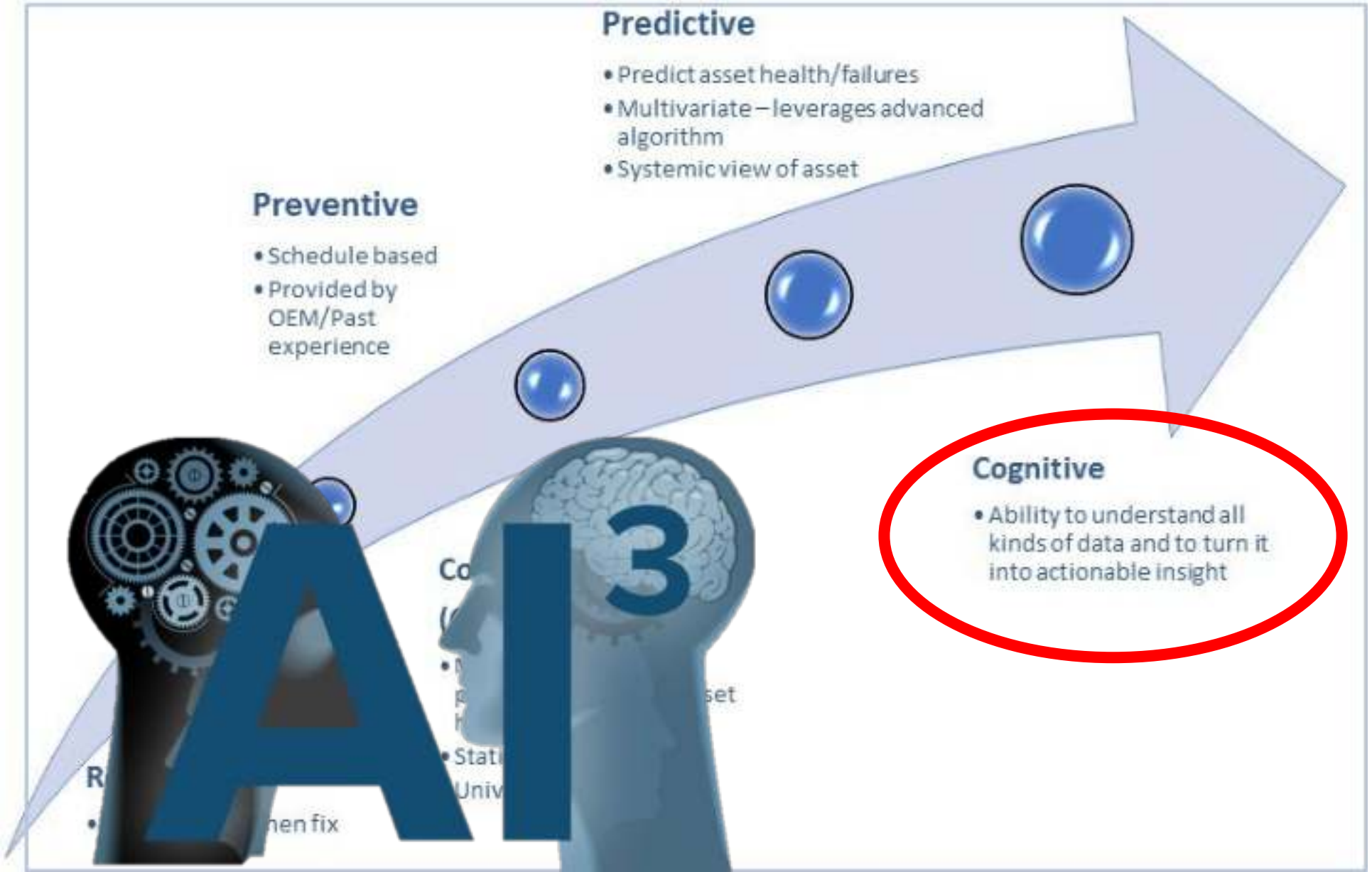
Autonomous prescription in Multiverse




Research
challenge

Cognitive DTs will self preserve the physical entities

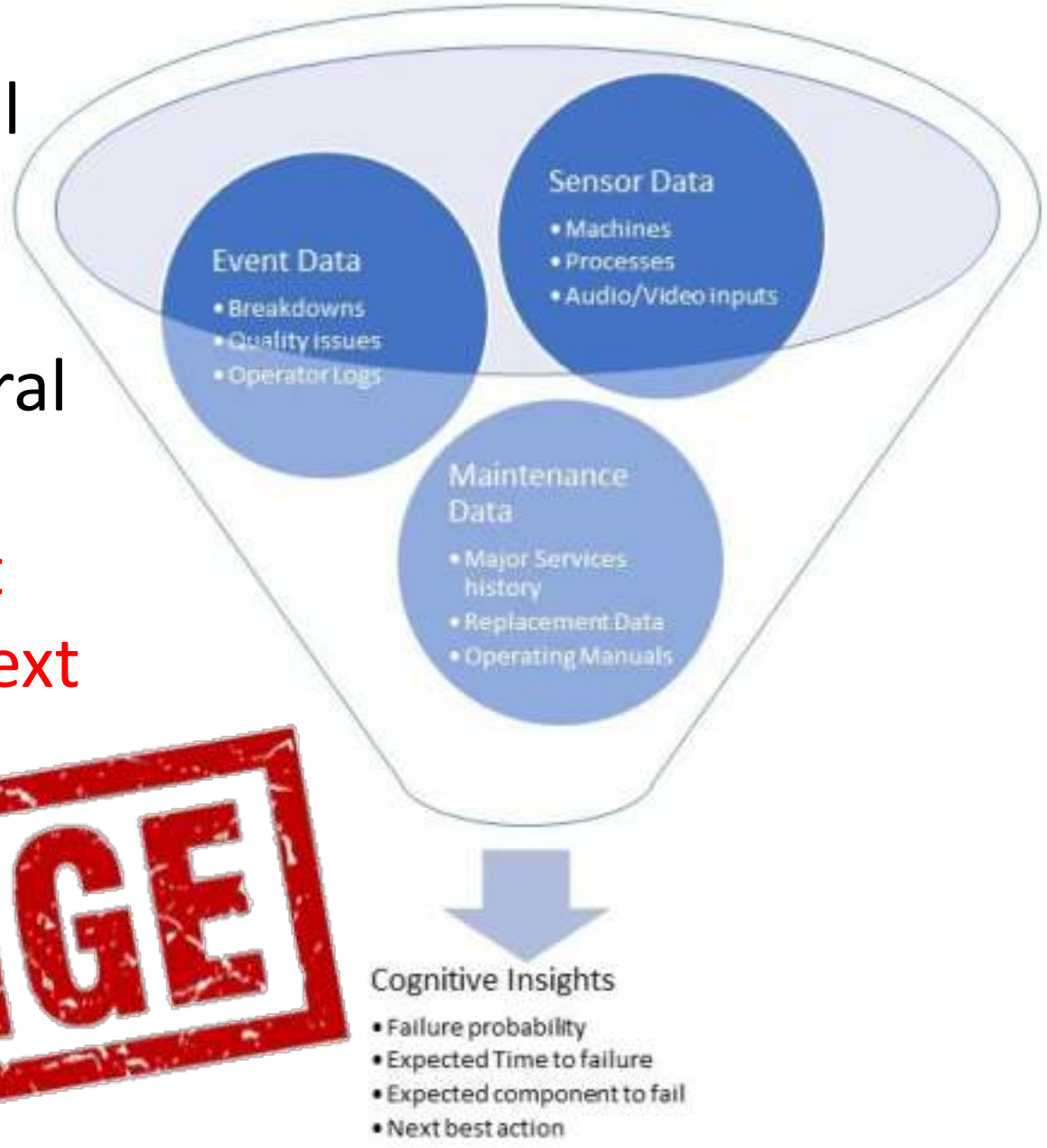
Cognitive Digital Twins skills

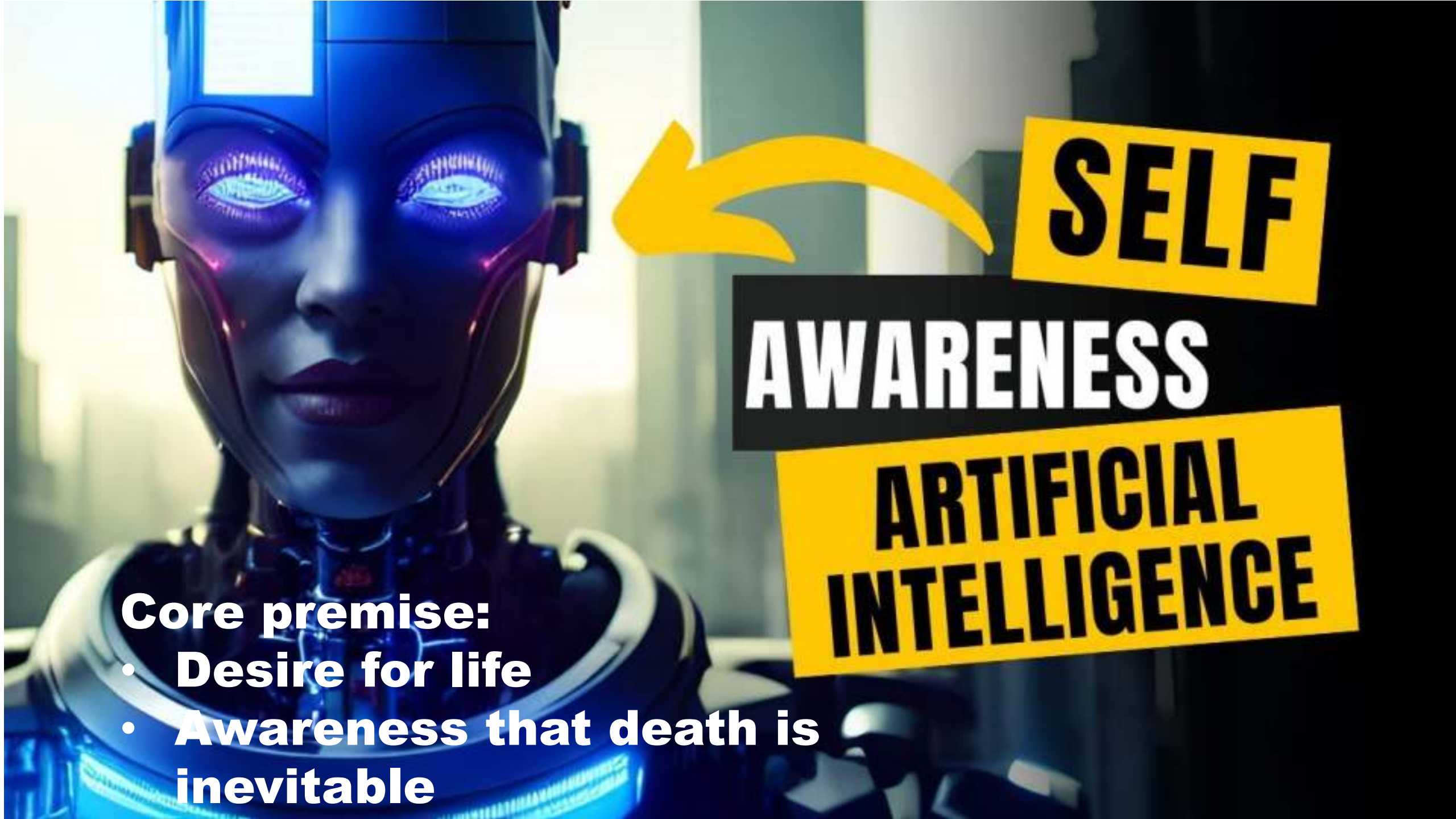


Cognitive DTs is a further upgrade, as it enables us to ingest all kinds of data

- Structured
- Unstructured (audio/video/natural language)

and obtain a better informed insight and superior recommendation on next best action.





Core premise:

- **Desire for life**
- **Awareness that death is inevitable**

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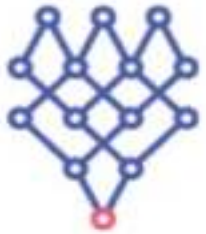


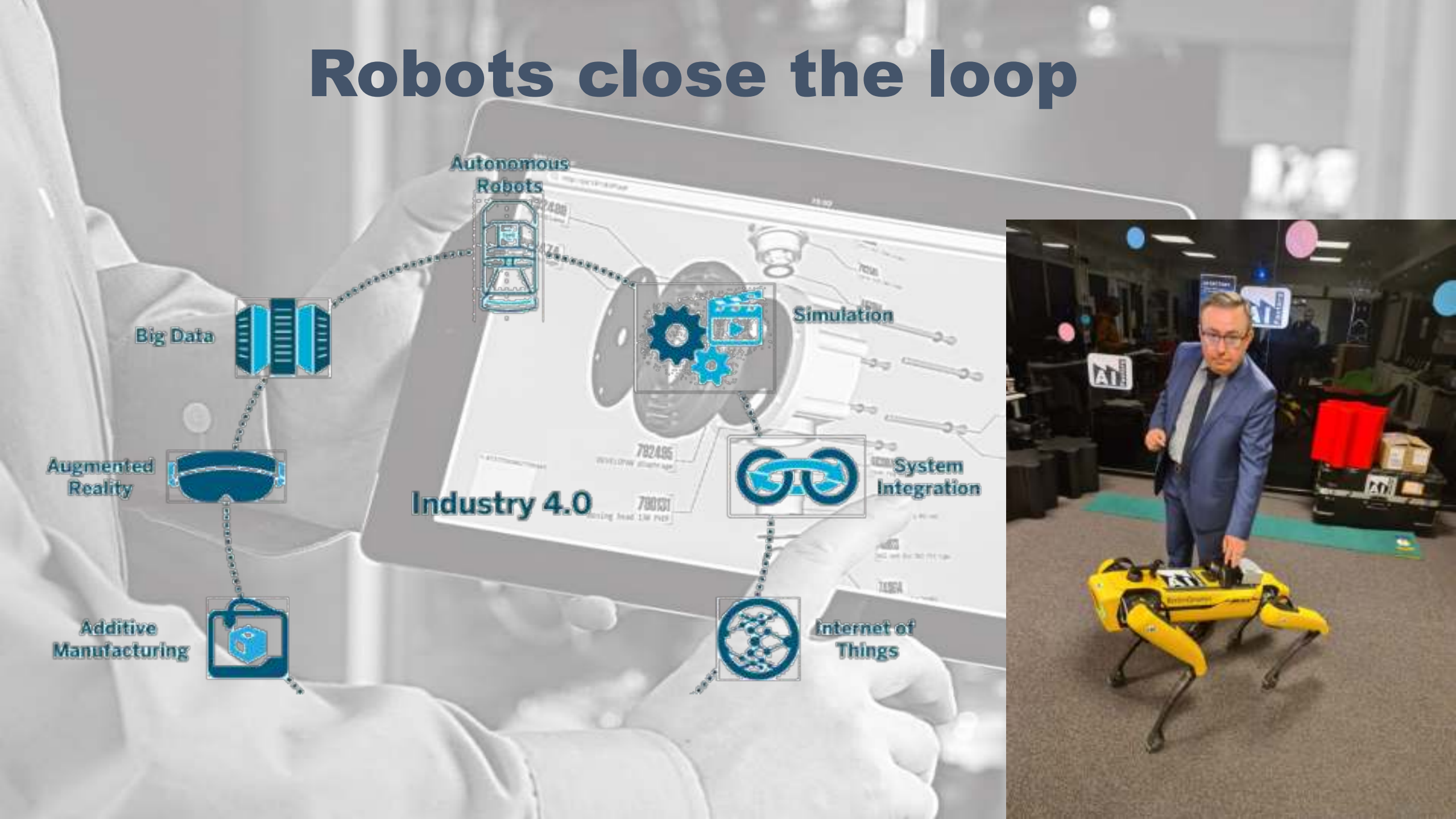
Self-aware

- Human-level intelligence that can bypass our intelligence, too

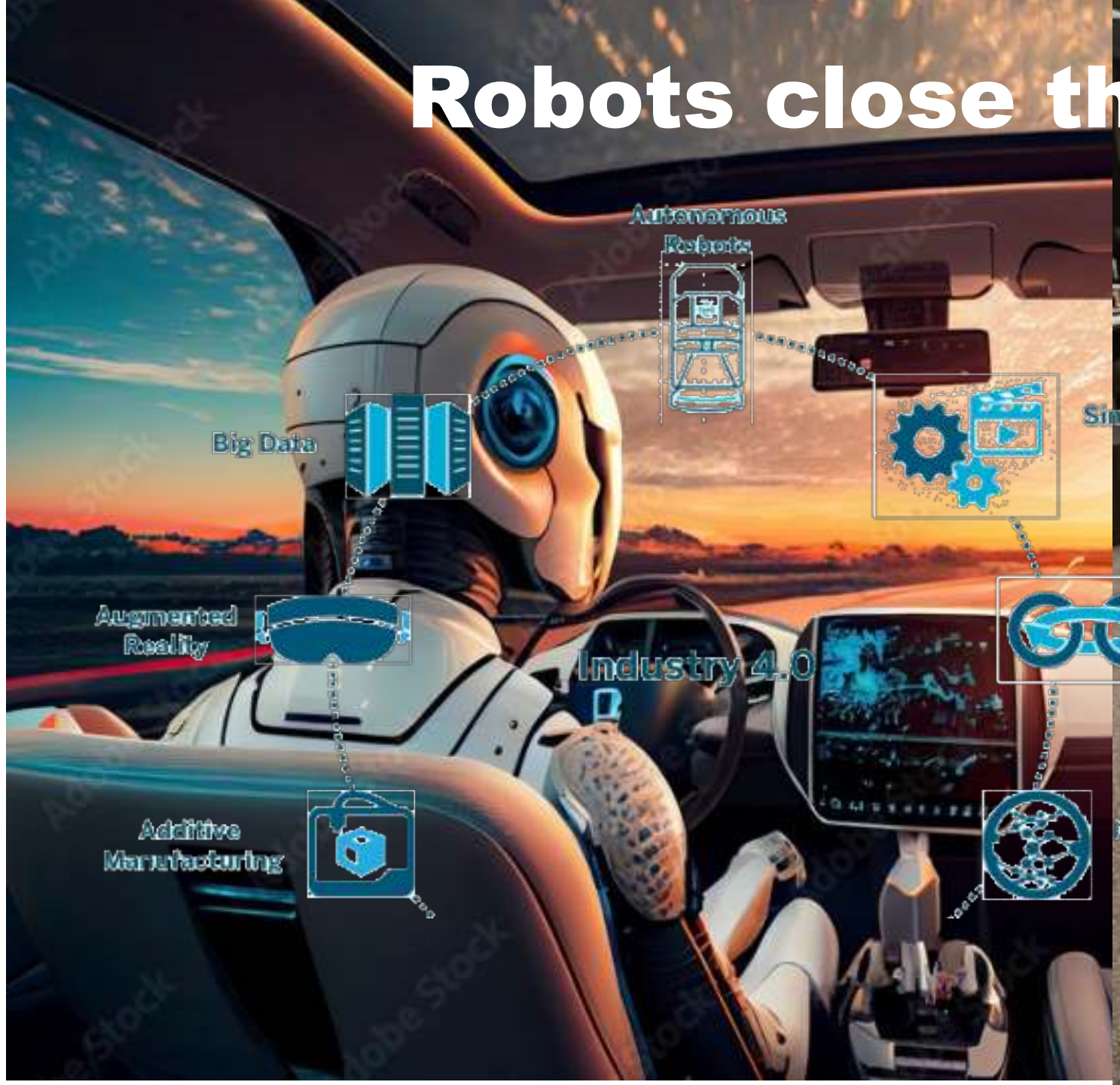

Cognition just one step ahead of
Autonomous Prescription


AI
AI
AI
ANALYTICS

Robots close the loop



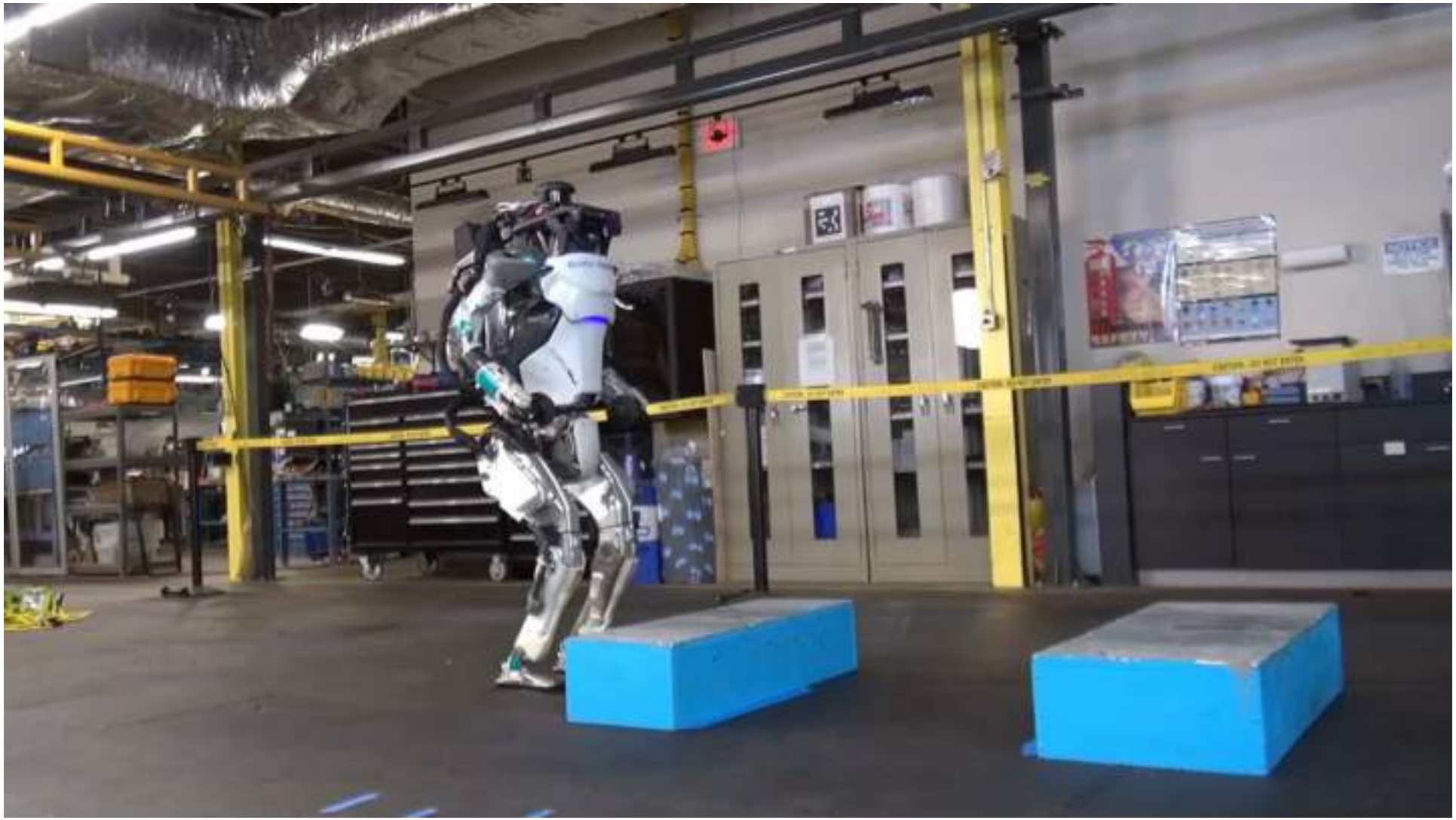
Robots close the loop



COLLABORATION AND CO-HABITATION ISSUES

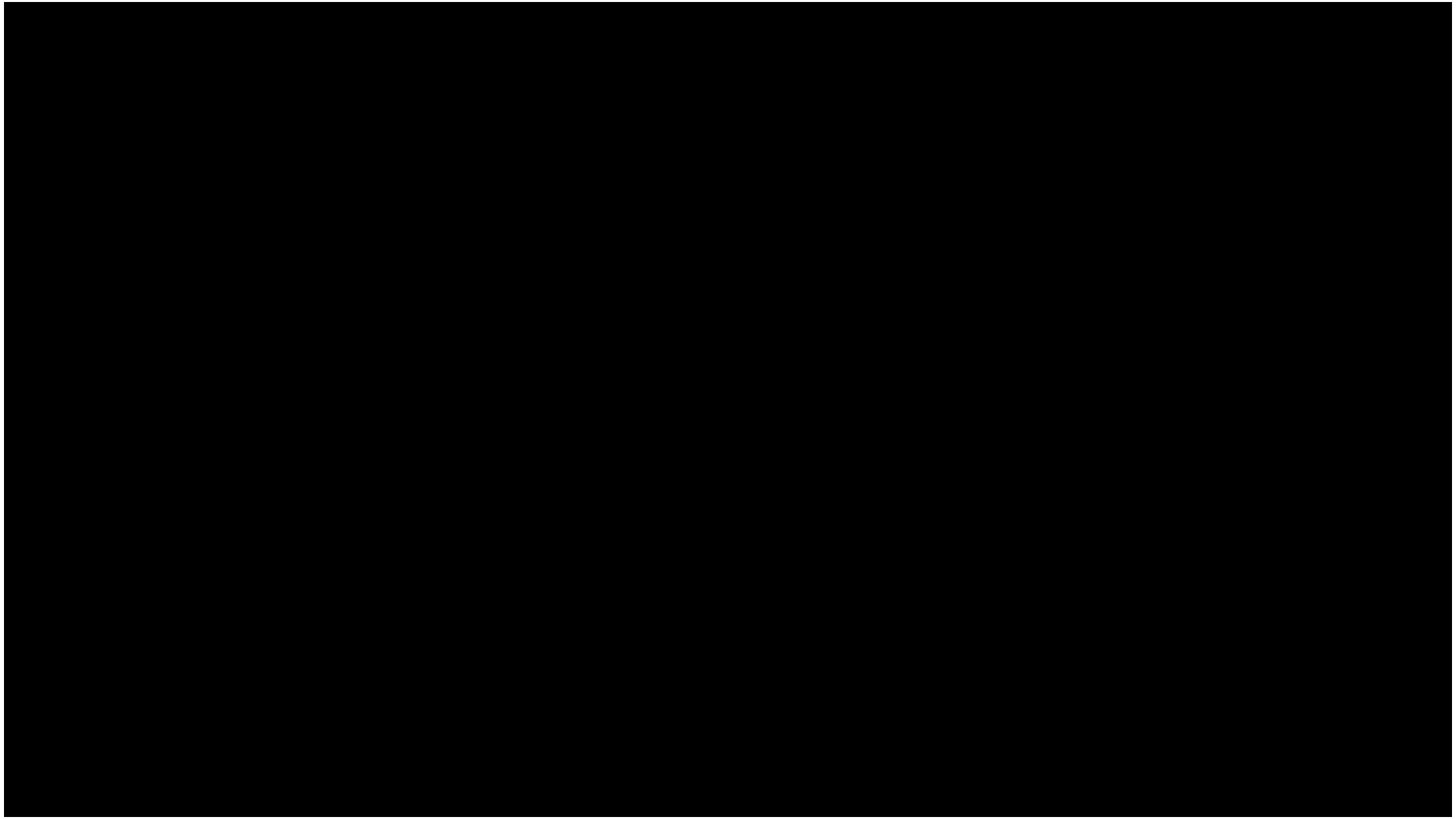
- Robots bumping into humans
- Robots (such as drones) falling and the danger this poses to the workforce on the ground
- Robots becoming stuck or lodged within an asset that needs human intervention
- Overlooking robots falling onto humans or other robots below
- Electrocution caused by robot malfunction

Droids , Humanoids or augmented workers




Robocop versus ED 209

Cobots who mimic humans

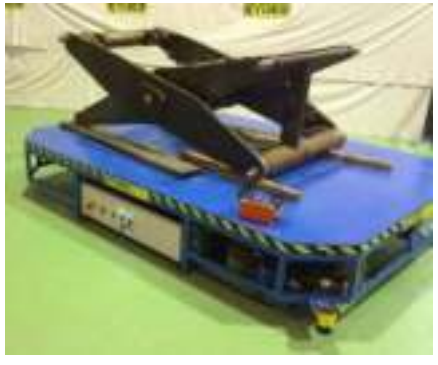


Cobots with 2 arms?

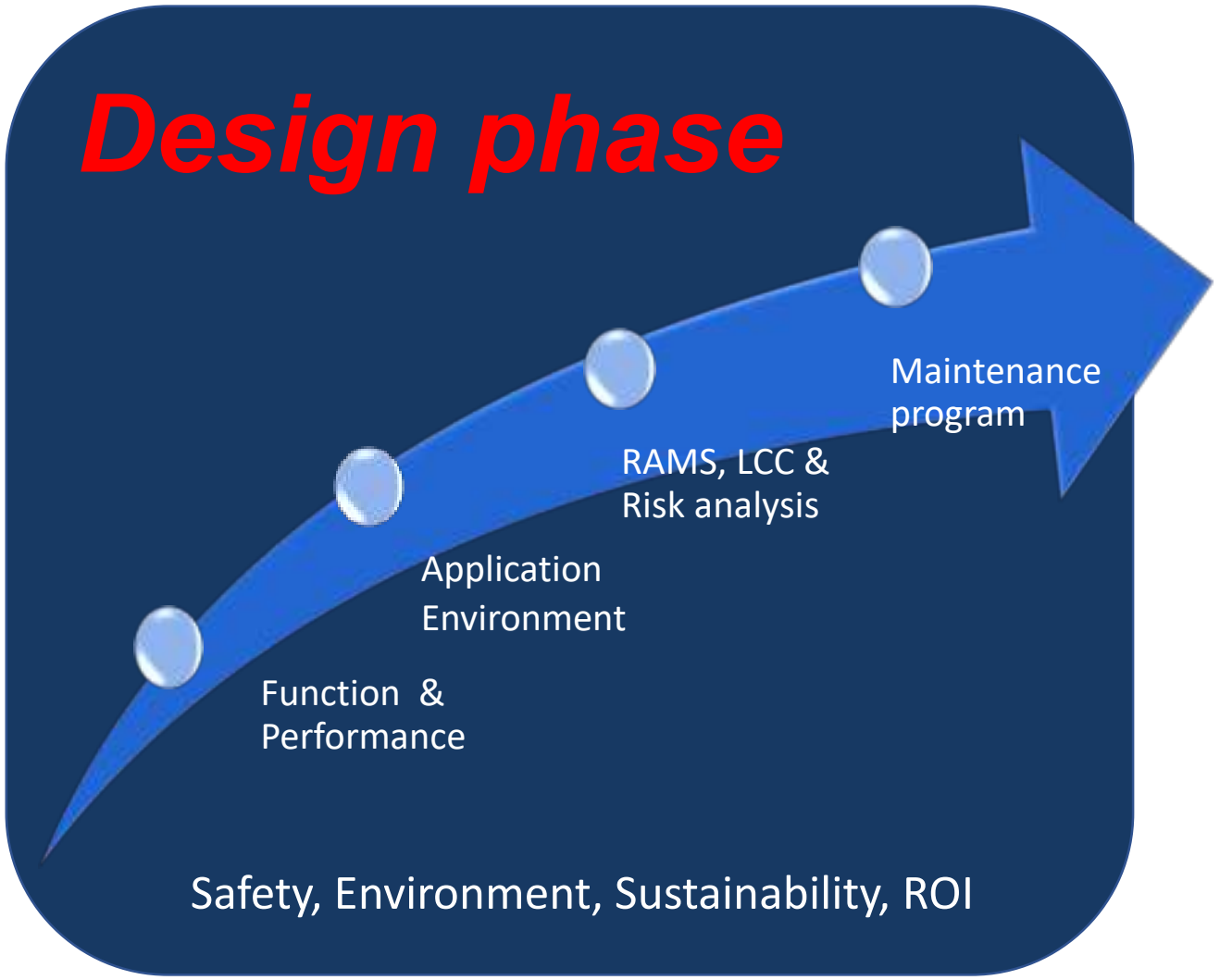
Robots with capability to move autonomously in the plant

Mobile manipulators are required when maintenance tasks are performed in different locations

It requires adapting the infrastructure (reflectors, wires, lines) or moving towards Autonomous navigation, with 3D obstacle avoidance and easy setup.



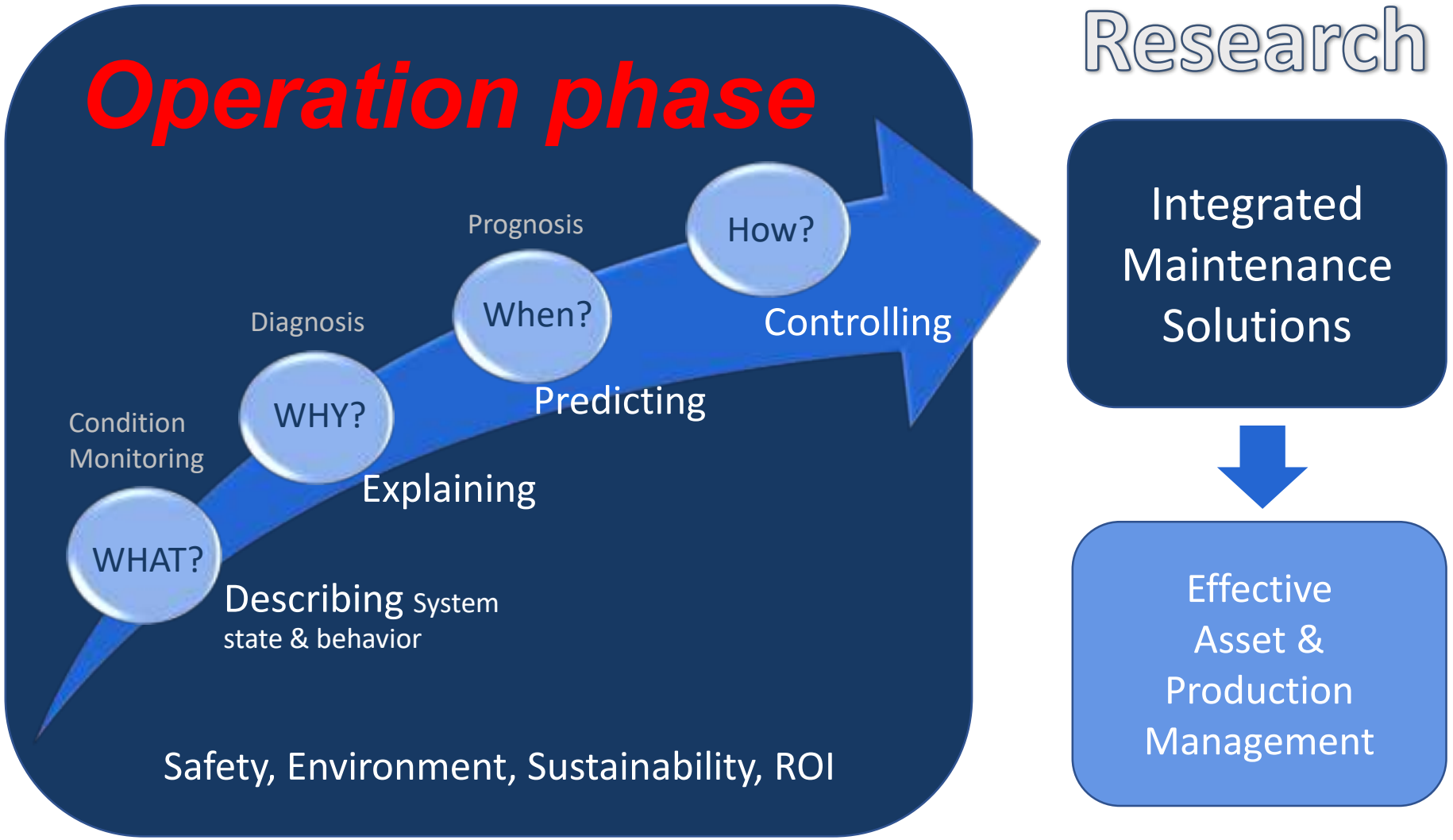
Robots with capability to move autonomously in the plant



Research

Integrated Maintenance Solutions

Cost Effective Product Development & Life Cycle Management

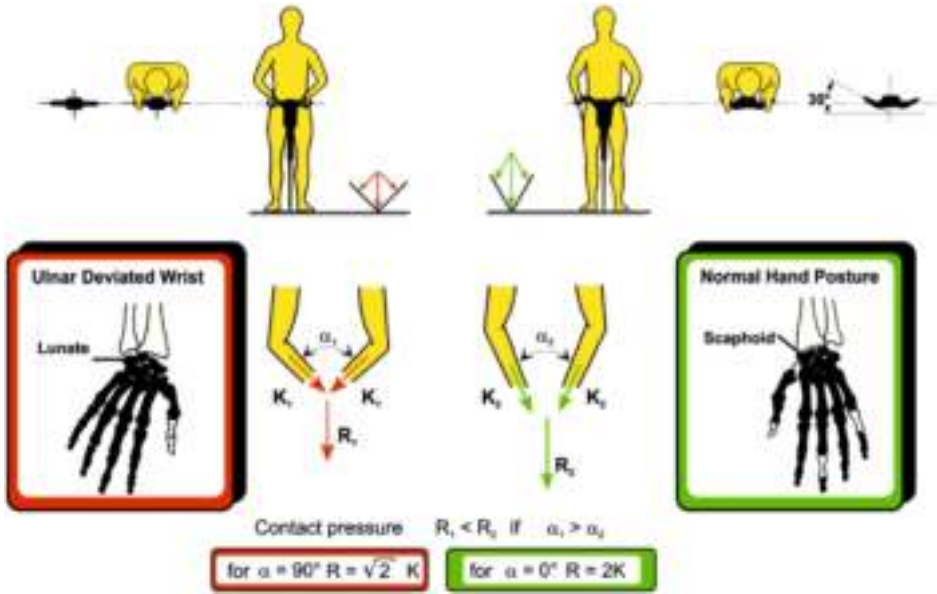

Operation phase
Condition Monitoring
WHAT?
Describing System state & behavior
Diagnosis
WHY?
Explaining
Prognosis
When?
Predicting
How?
Controlling
Safety, Environment, Sustainability, ROI
Research
Integrated Maintenance Solutions
Effective Asset & Production Management

Design for.....

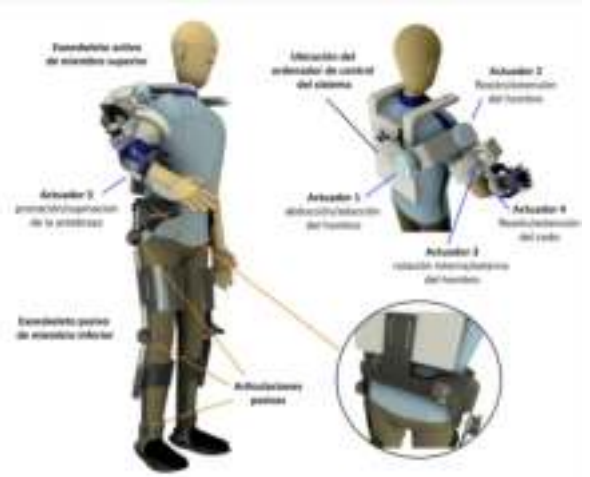
- Design for reliability
- Design for maintainability
- Design for maintenance
- Design for failure

Design for maintenance and maintainability

Maintainability is the measure of the ability of an item to be retained in or restored to a specified condition when maintenance is performed by personnel



1-Augmented maintenance crew



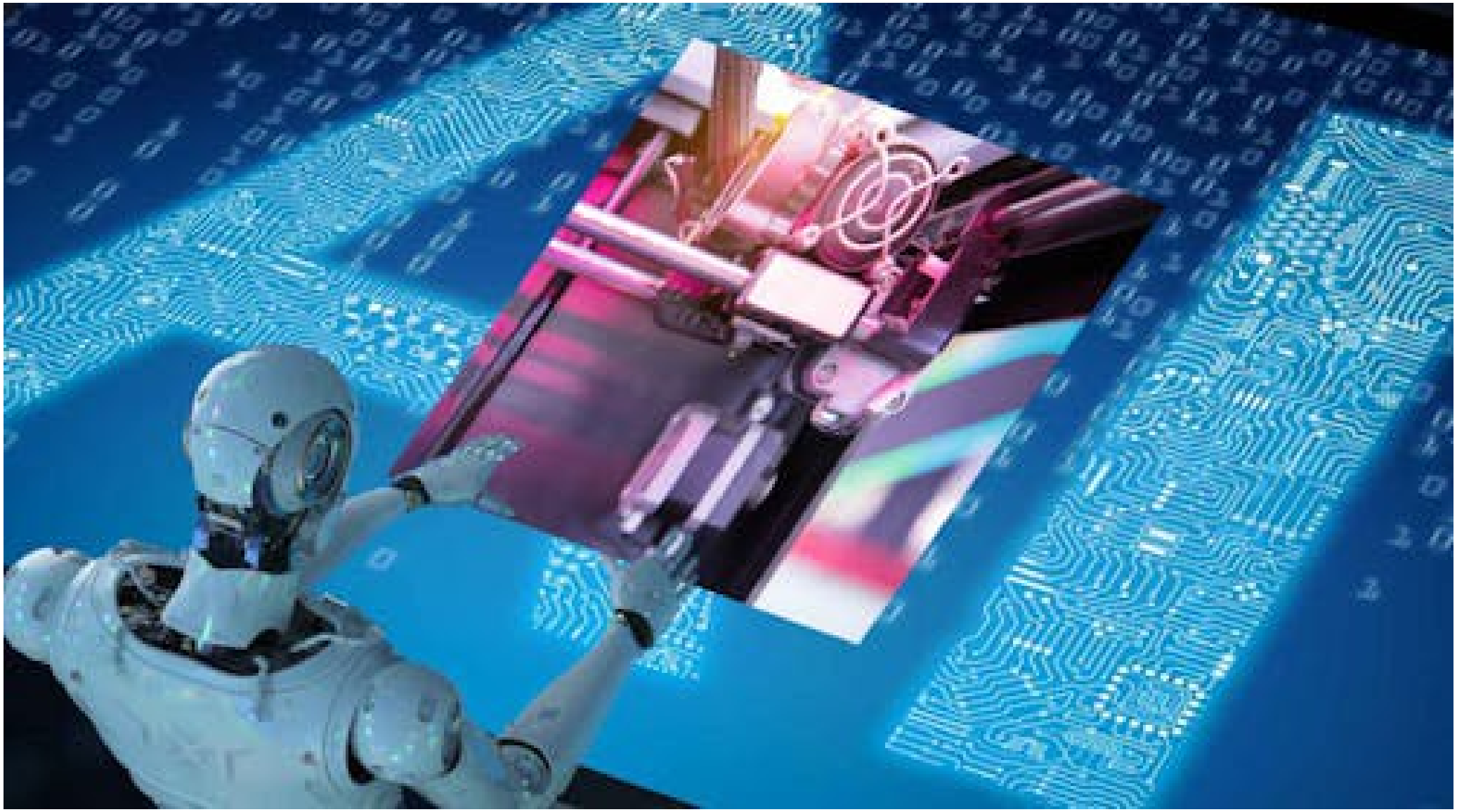
AR and VR to augment crew skills

2-Droids to perform as humans

Training robot by gestures

3- Machines designed to be maintained by robots

Industrial AI and generative design



INSPECTION AS THE NATURAL TASK

- The advantages this brings are immense:

- Eliminating or minimizing the need for human entry into hazardous environments, therefore significantly reducing risk. This also brings about associated lowered insurance premiums
- Reducing or negating requirements for venting enclosed areas and erecting scaffolding, therefore shortening the downtime of assets
- Dramatically reducing environmental risks
- Superior collection of data due to the elimination of human error or the inability to visualize hard to access areas
- Increased quality of data makes for better decision making and considerations for necessary maintenance and inspection schedules

Inspection as natural task

R-Bot: Seamless OT & IT integration

Promind® MACHINE LEARNING

Prisma® CMMS/GMAO

Captor® MES

R-Bot platform

Connectors | Connectors | Connectors | Connectors | Connectors | Connectors

Field

Robots

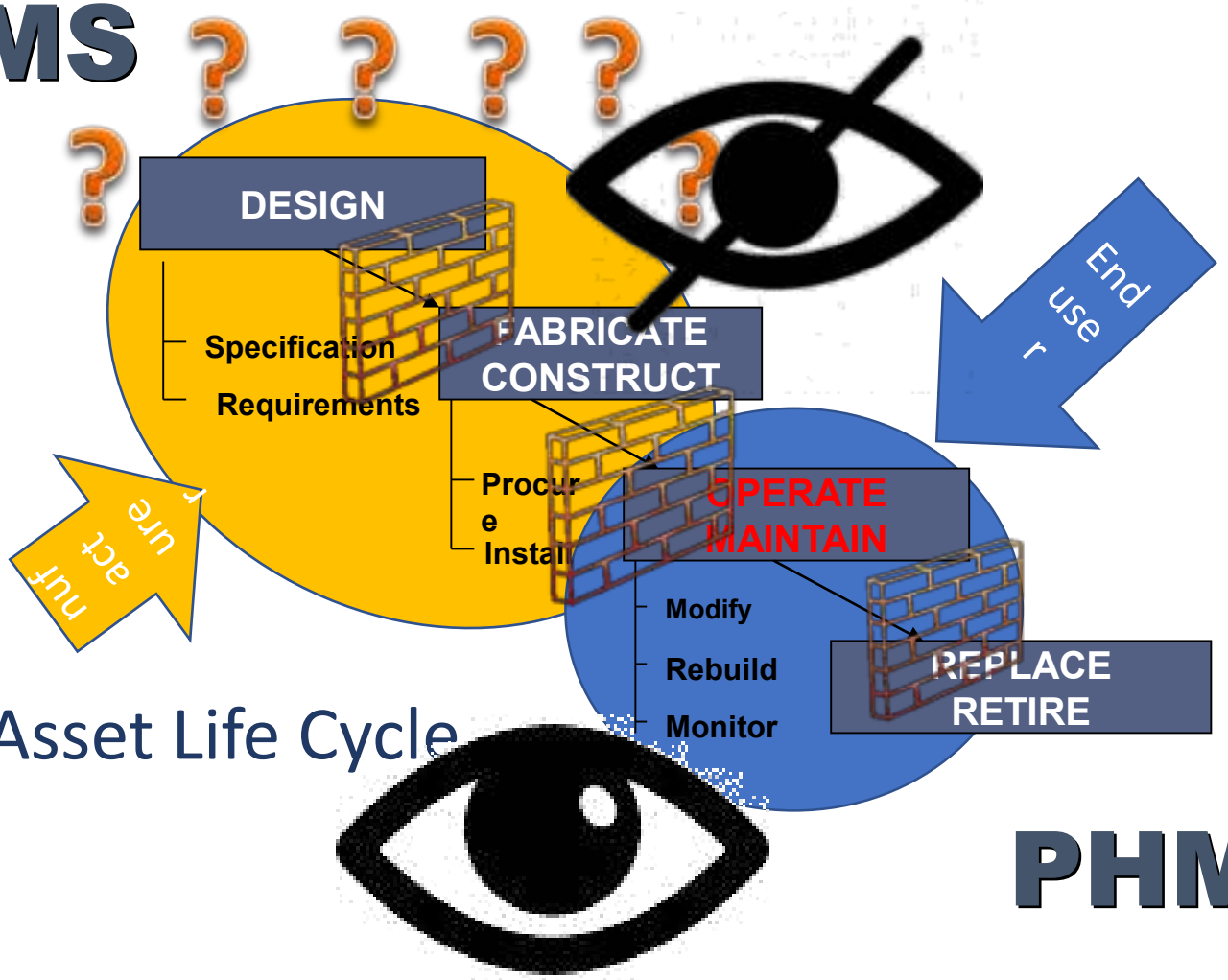
IoT sensors

Rover SW | Drone SW | Quadruped SW | Cobot SW | Other



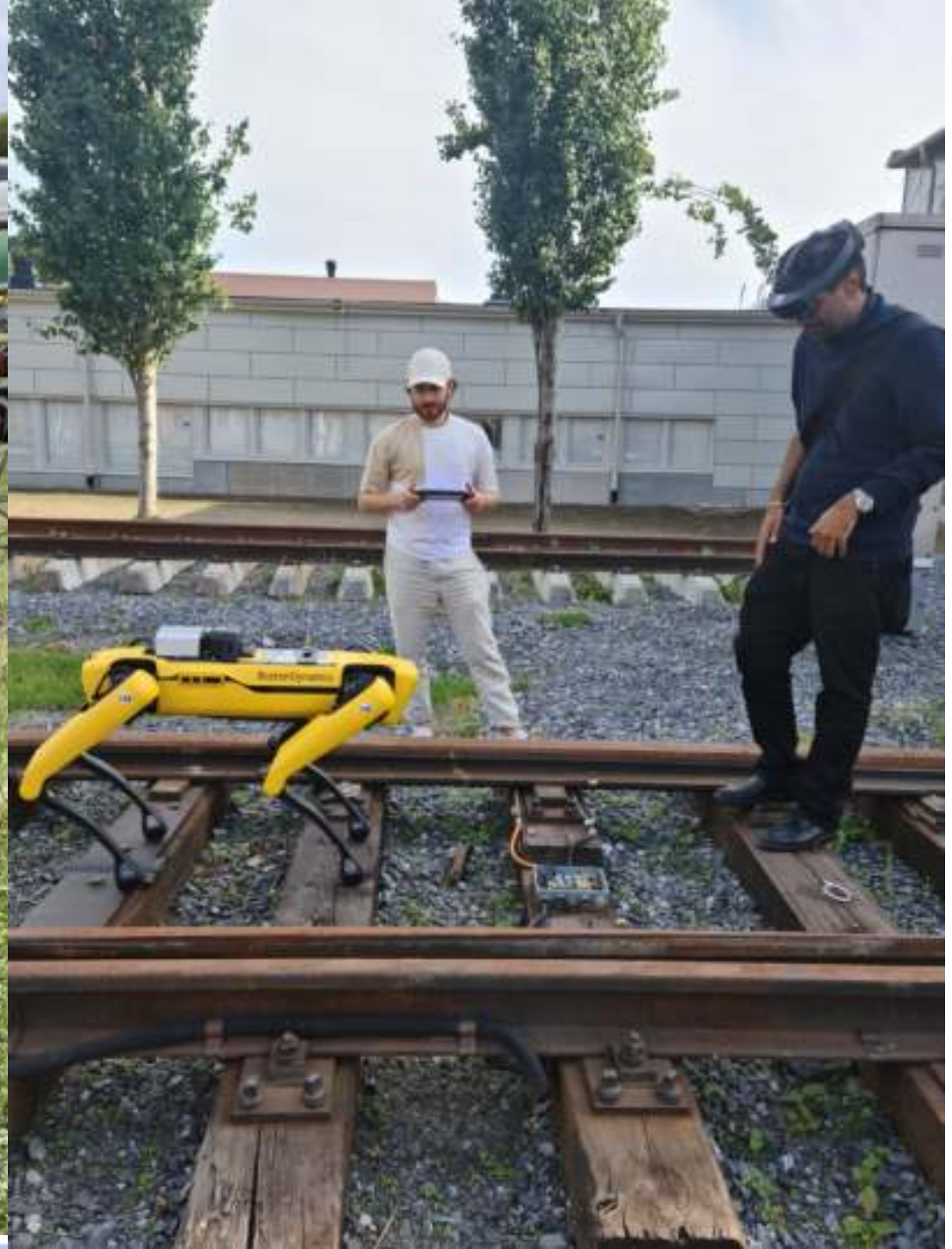



RAMS



Asset Life Cycle

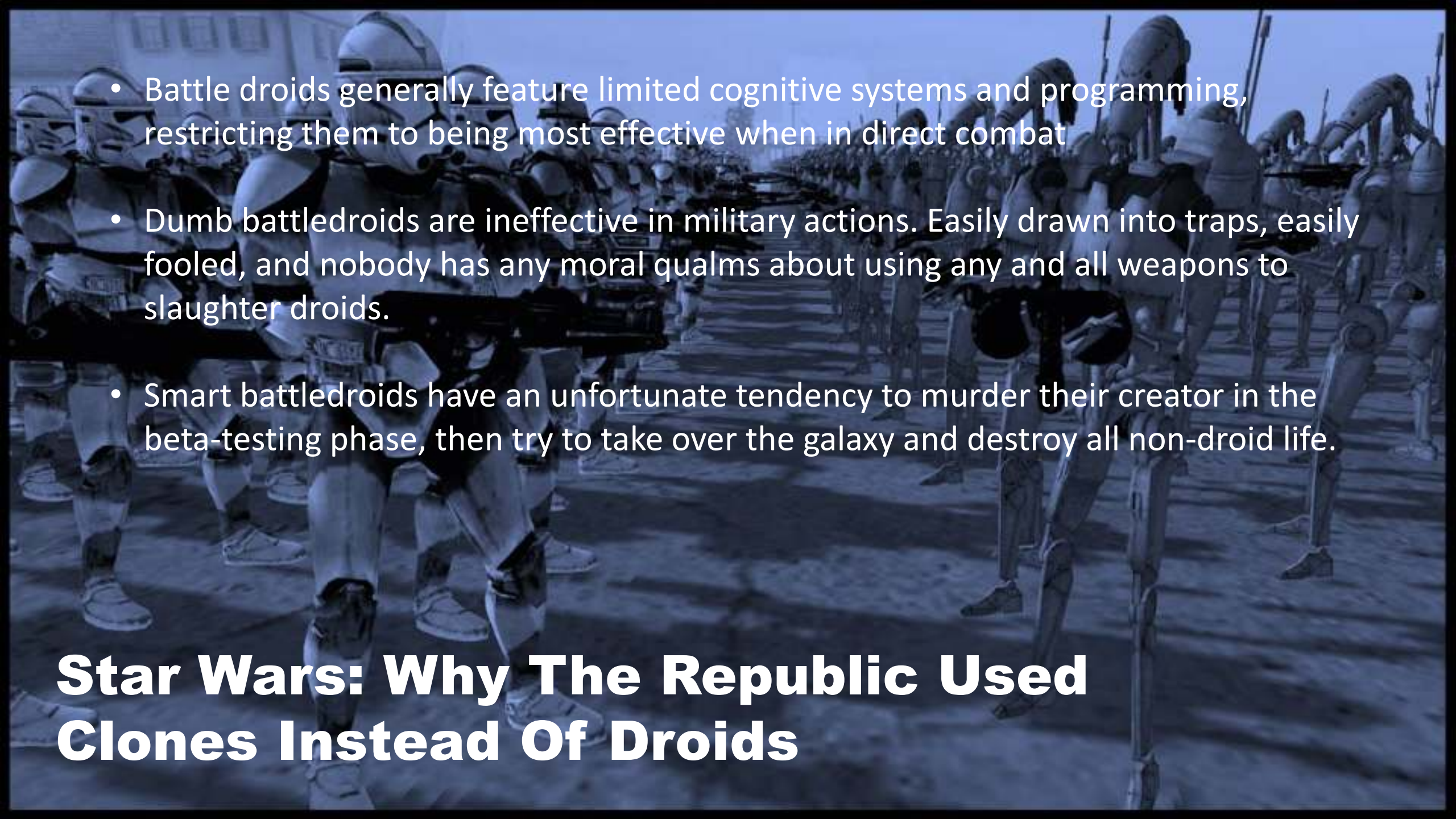
PHM



Seamless integration of AR

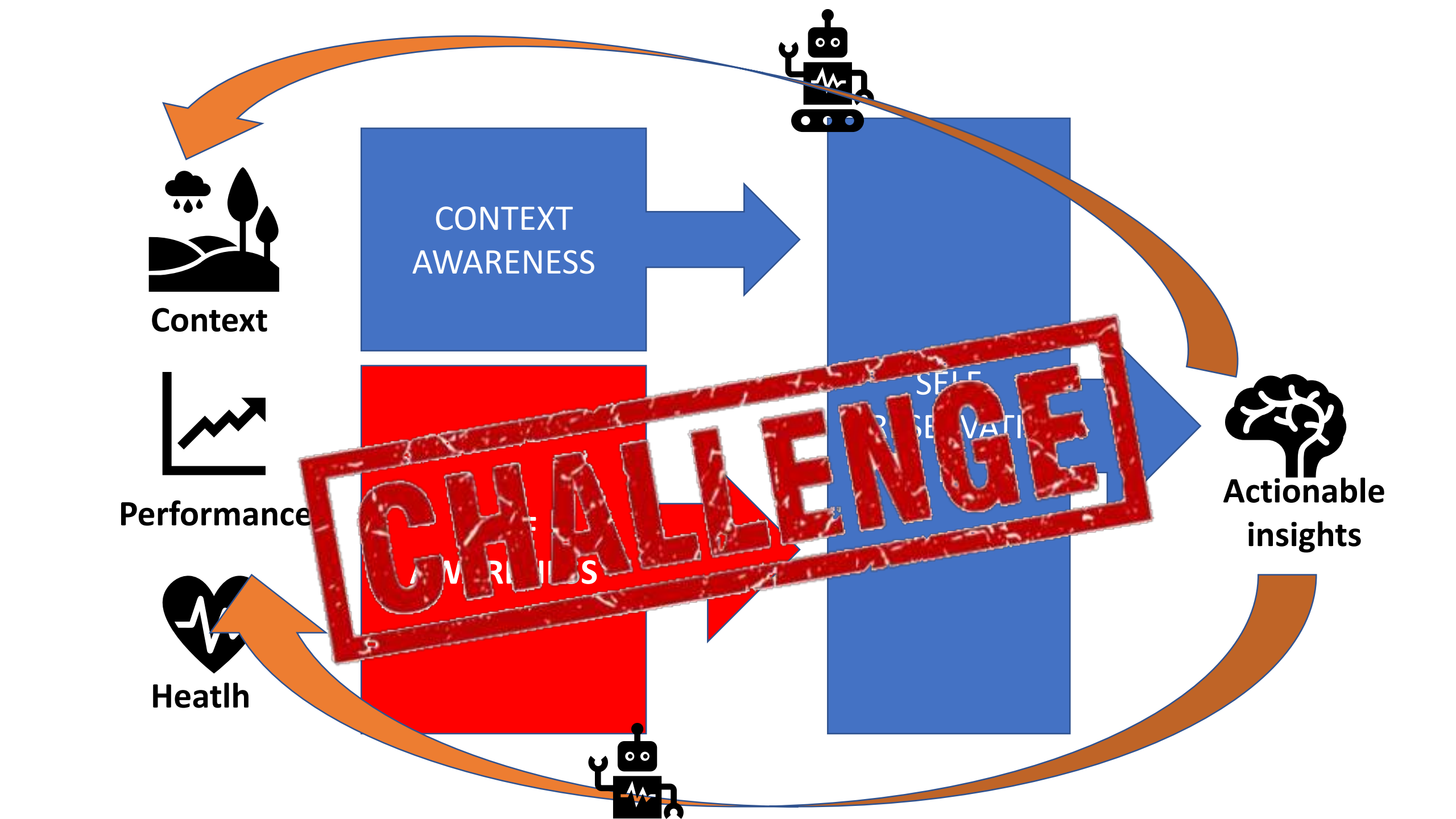
Metaverse and Virtual fencing

Star Wars: Why The Republic Used Clones Instead Of Droids



- Battle droids generally feature limited cognitive systems and programming, restricting them to being most effective when in direct combat
- Dumb battledroids are ineffective in military actions. Easily drawn into traps, easily fooled, and nobody has any moral qualms about using any and all weapons to slaughter droids.
- Smart battledroids have an unfortunate tendency to murder their creator in the beta-testing phase, then try to take over the galaxy and destroy all non-droid life.

Star Wars: Why The Republic Used Clones Instead Of Droids


CONTEXT
AWARENESS
Context
Performance
Heatlh
Actionable
insights
CHALLENGE

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