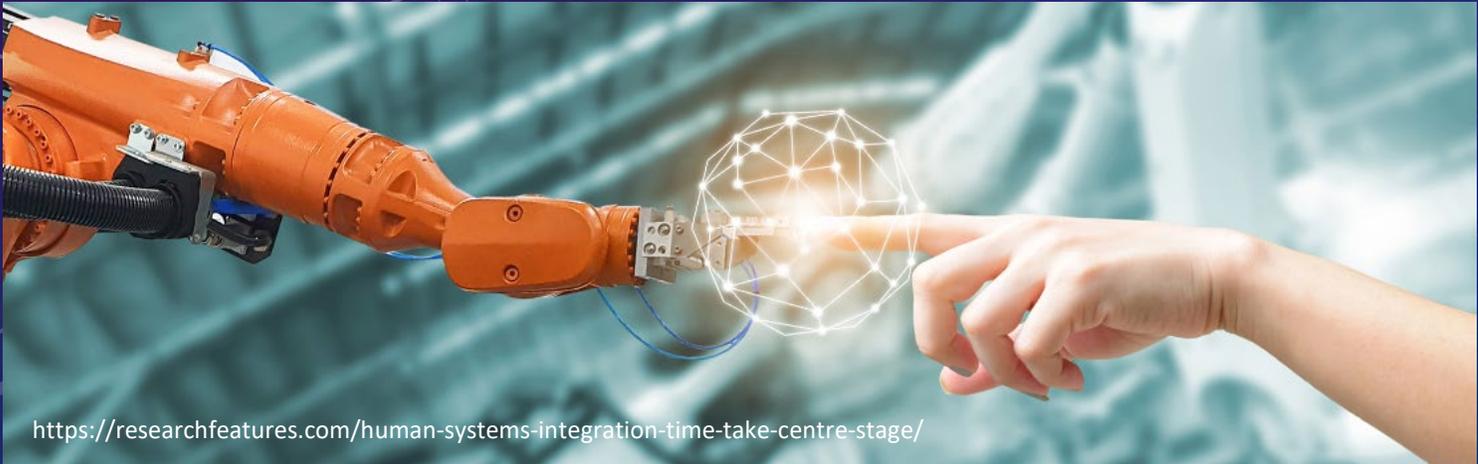AI4SE & SE4AI
RESEARCH AND APPLICATION WORKSHOP
SEPTEMBER 17-18, 2024 | Arlington, VA

PRODEC: A METHOD AND PLATFORM

FOR MODEL-BASED HUMAN SYSTEMS INTEGRATION OF HUMAN-AI TEAMS

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https://researchfeatures.com/human-systems-integration-time-take-centre-stage/

WHAT DO WE MEAN BY ARTIFICIAL INTELLIGENCE?

A Human Systems Integration (HSI) Approach
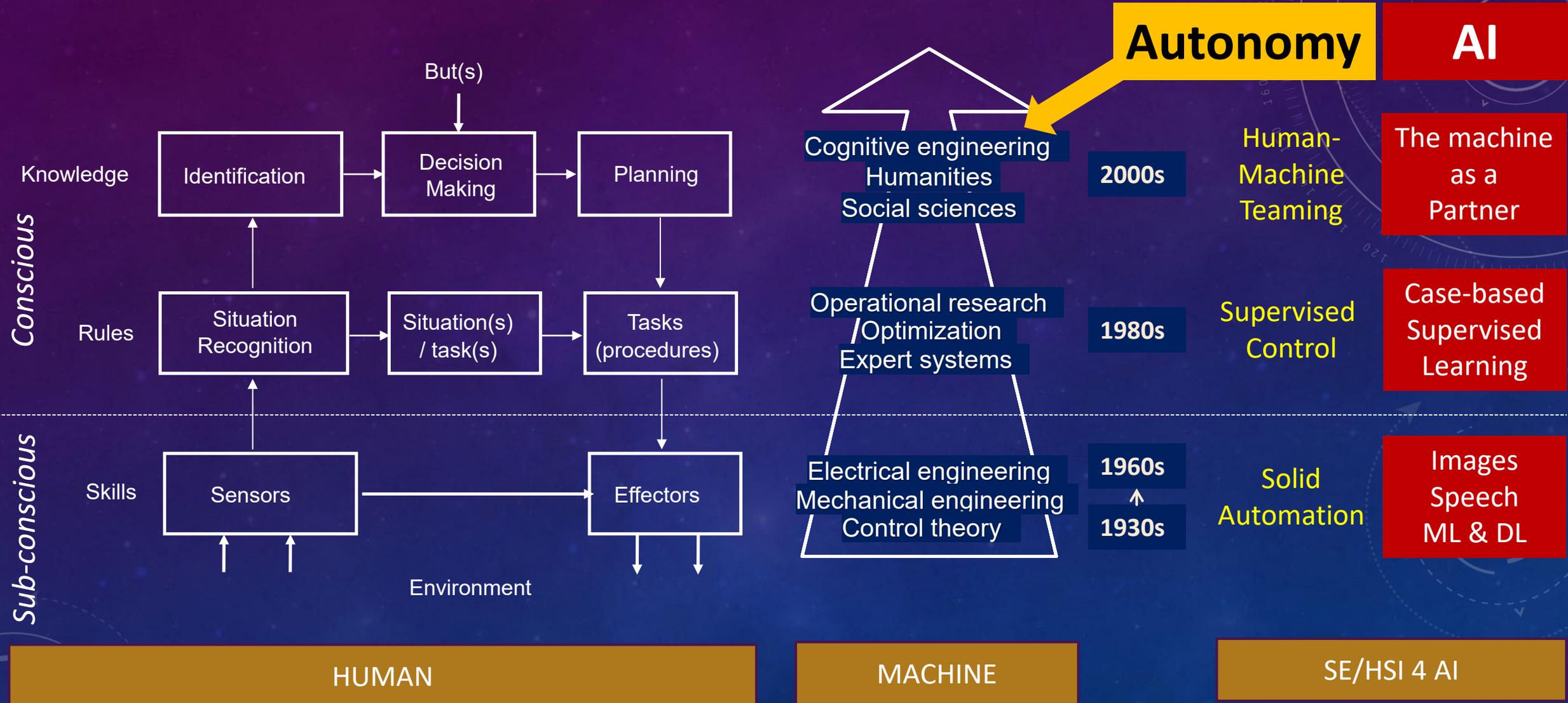
A REAL-WORLD RAILWAY OPERATIONAL SYSTEM
DESIGNED & DEVELOPED USING MODEL-BASED HUMAN SYSTEMS INTEGRATION (MB-HSI)

- RATP RER A in Paris
  - Largest urban train line in Europe (1.2M pax/day, more than 250 trains/day)
  - New system deployed in January 2024

- 64 systems orchestrated with Ingescape
  - Field equipment command & control, alerting, authentication, archiving, itineraries, trains parking, missions/trains/drivers management, etc.
  - 598 inputs/outputs
  - 438 services
  - 6664 monitored field equipment
  - 1580 messages/second

- 21 real-time gateways to external systems

- 9000+ applicable requirements

- 16 workstations and an 18-meters wide LED display (5 x UHD)

WHAT DO WE MEAN BY ARTIFICIAL INTELLIGENCE?

Autonomy

AI

	Conscious	Sub-conscious
Knowledge		
Rules		
Skills		

Human (diagram)

- Knowledge: Identification → Decision Making → Planning
- But(s) → Decision Making
- Rules: Situation Recognition → Situation(s) / task(s) → Tasks (procedures)
- Situation Recognition ↑ from Sensors
- Planning ↓ to Tasks (procedures) ↓ to Effectors
- Skills: Sensors → Effectors
- Environment

Machine (diagram)

- Cognitive engineering / Humanities / Social sciences — **2000s**
- Operational research / Optimization / Expert systems — **1980s**
- Electrical engineering / Mechanical engineering / Control theory — **1960s** ↑ **1930s**

		AI
Human-Machine Teaming	2000s	The machine as a Partner
Supervised Control	1980s	Case-based Supervised Learning
Solid Automation	1960s / 1930s	Images Speech ML & DL

HUMAN **MACHINE** **SE/HSI 4 AI**

SE4AI & AI4SE

- AGENT VS. SYSTEM
- MULTI-AGENT (AN AGENT AS A SOCIETY OF AGENTS) VS. SYSTEM OF SYSTEMS
- AGENT/SYSTEM → STRUCTURE & FUNCTION (ROLE, CONTEXT, RESOURCES (SUB-SYSTEMS))
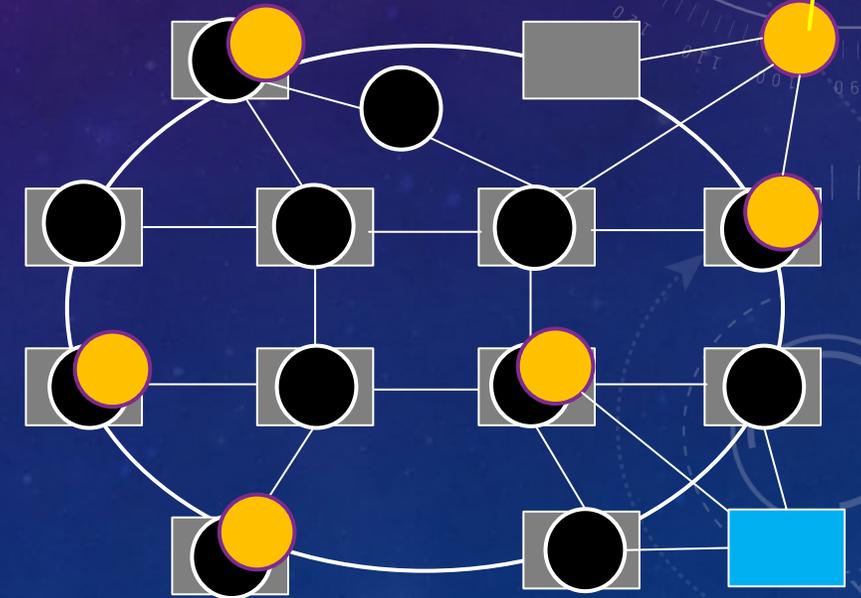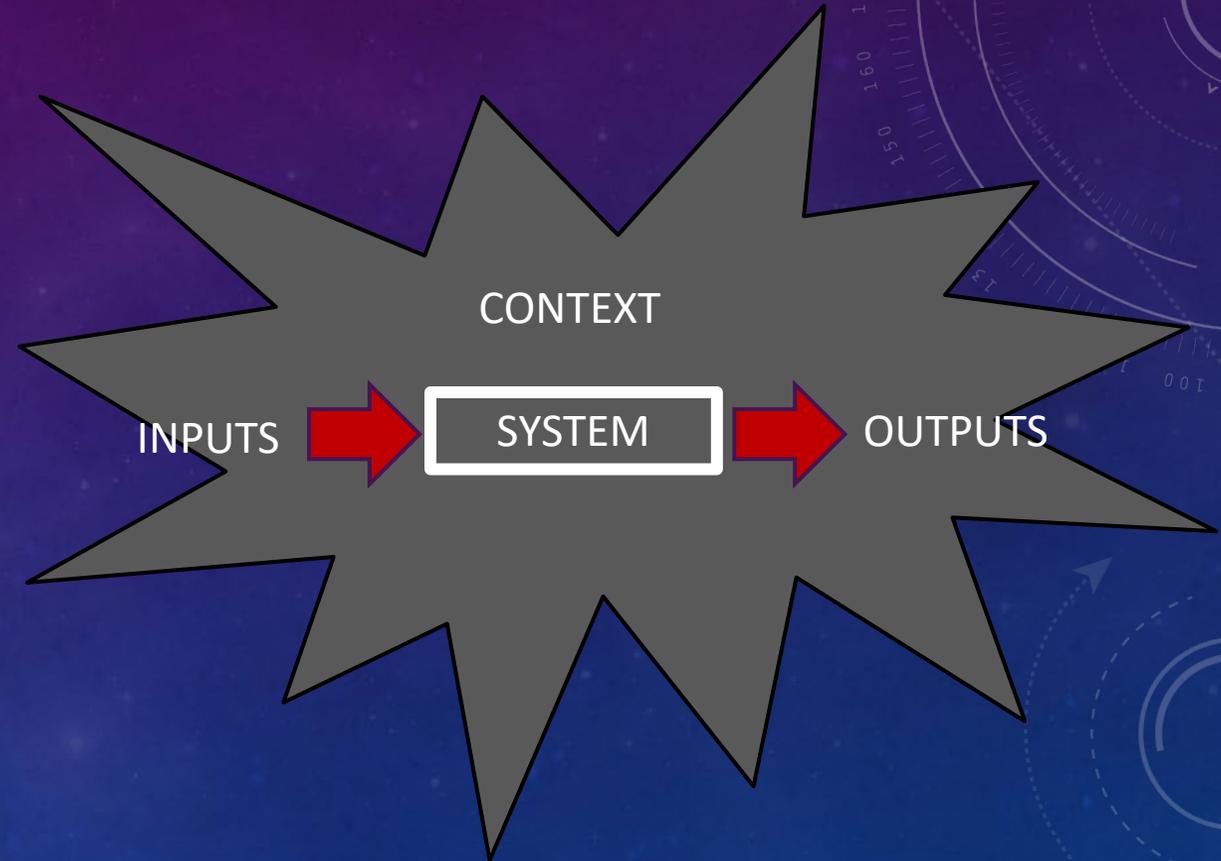- AGENT/SYSTEM CAN HUMAN AND/OR MACHINE (HARDWARE & SOFTWARE)

Input → **Isolated System** → Output

Cognitive ← can be ← **Function** → can be → **Physical**

Function has ↑ **System**

Human ← can be ← **System** → can be → **Machine**

Human → **System** (can include)

Machine → **System** (can include)

System has ↓ **Structure**

Physical ← can be ← **Structure** → can be → **Cognitive**

Systems represent Humans and Machines…
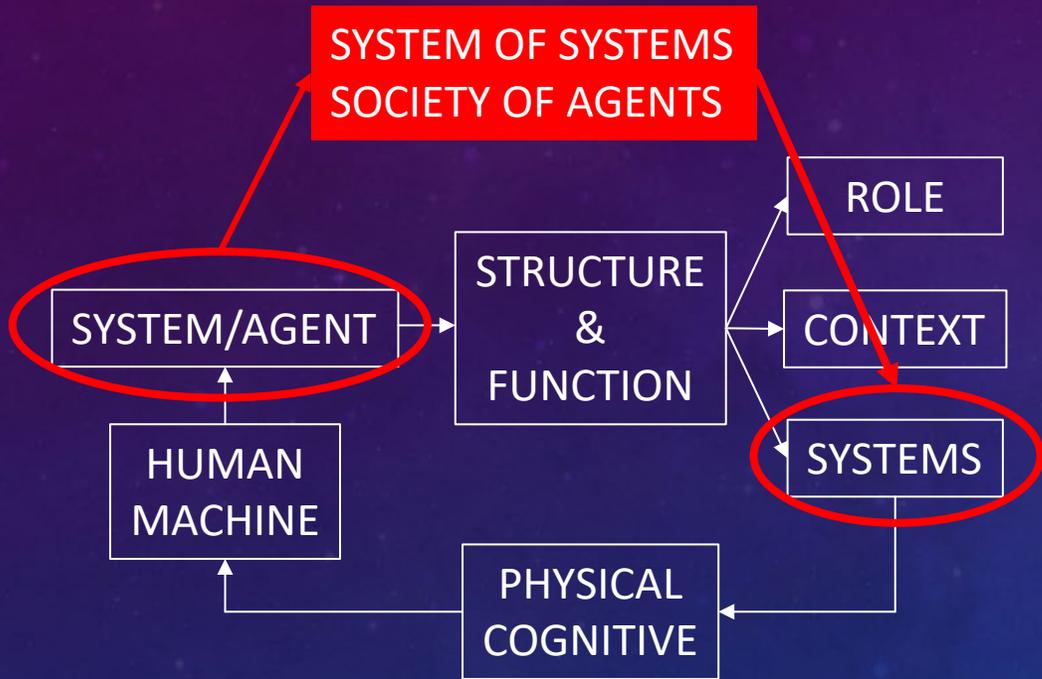
Interconnected System of Systems

SE4AI & AI4SE

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- AGENT/SYSTEM CAN HUMAN AND/OR MACHINE

Potentially, creating new people's jobs

Emergent Structures
Emergent Functions
Overlapping Functions of Functions

HSI principles:
- **Shared Situation Awareness**
- **Trust & Collaboration**
- **Speed & Precision**
- **Resilience**
- **...**

Interconnected Functions of Functions

Interconnected Structures of Structures

SE4AI & AI4SE

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Emergent Structures
Emergent Functions
Overlapping Functions of Functions

Interconnected Systems of Systems
Societies of agents

SE4AI & AI4SE

- AGENT VS. SYSTEM

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- AGENT/SYSTEM → STRUCTURE & FUNCTION (ROLE, CONTEXT, RESOURCES (SUB-SYSTEMS))

- AGENT/SYSTEM CAN HUMAN AND/OR MACHINE

SYSTEM OF SYSTEMS
SOCIETY OF AGENTS

SYSTEM/AGENT

STRUCTURE & FUNCTION

ROLE

CONTEXT

SYSTEMS

HUMAN MACHINE

PHYSICAL COGNITIVE

CONTEXT

INPUTS → SYSTEM → OUTPUTS

SYSTEMIC SPACE ← → CONTEXTUAL SPACE

OPERATIONS

PROCEDURAL SCENARIOS

CONTEXT ARCHITECTURE ...

... SYSTEMS ARCHITECTURE

DECLARATIVE CONFIGURATIONS

DESIGN ENGINEERING

PRODEC

INGESCAPE: A PLATFORM FOR **PRO**DEC PROCESSING

System architecture → Specification → Code generation → Iterative coding and integration → Verification & validation → Operational supervision
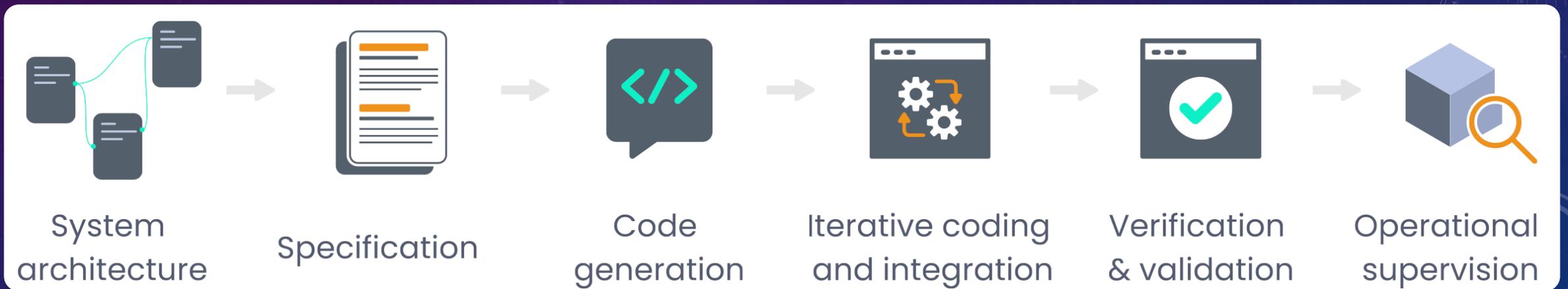
PRODEC: SCENARIO-BASED DESIGN & HUMAN-IN-THE-LOOP SIMULATION

TARGET AUDIENCE

ACTIVITY ANALYSIS

Emerging Functions & Structures

INTENT

OPERATIONS PEOPLE

PROTOTYPE HITLS

FUNCTION ANALYSIS

SUBJECT MATTER EXPERTS

STORY TELLING → TASK ANALYSIS

A MULTIDISCIPLINARY & ITERATIVE PROCESS

FOR SOCIOTECHNICAL SYSTEMS OF SYSTEMS ENGINEERING

1- Environment analysis & definition

2- Extended Model-Based System Engineering

code generation

environment instrumentation

3- Systems development, integration & verification

4- Assessments, validation and qualification
with humans and A.I. in the loop

5- Analysis, synthesis and decisions

- Target audience, intent, subject matter experts

- Seamlessly iterate on models for

  - Tasks, organizations & scenarios
  - Requirements & metrics
  - Systems structure, functions, behaviors and urbanization
  - Data formats & protocols

- Continuously use models & simulations to make systems

  - Human-in-the-loop simulations → emergent behaviors
  - Observable
  - Actionable — From task to activity analysis
  - Measurable
  - Verifiable

- Keep the models useful and up-to-date at all times

OFF-SHORE OIL & GAS MULTI-AGENT TELEROBOTIC SYSTEMS

Another example…

Situation awareness, Decision-making & Risk-taking → Human-AI Tangibility & Maturity
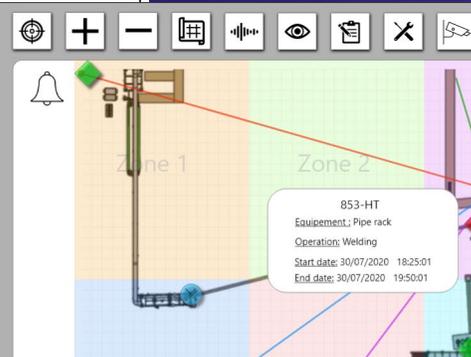
Using the PRODEC method (SBD & HITLS)

Tangibilization & Maturity
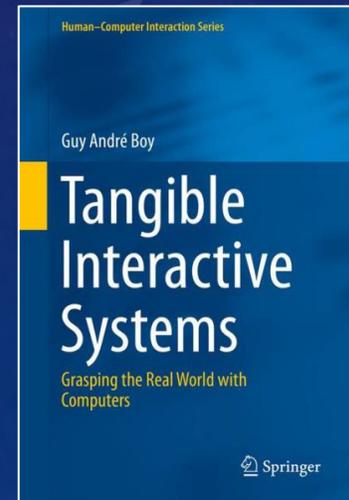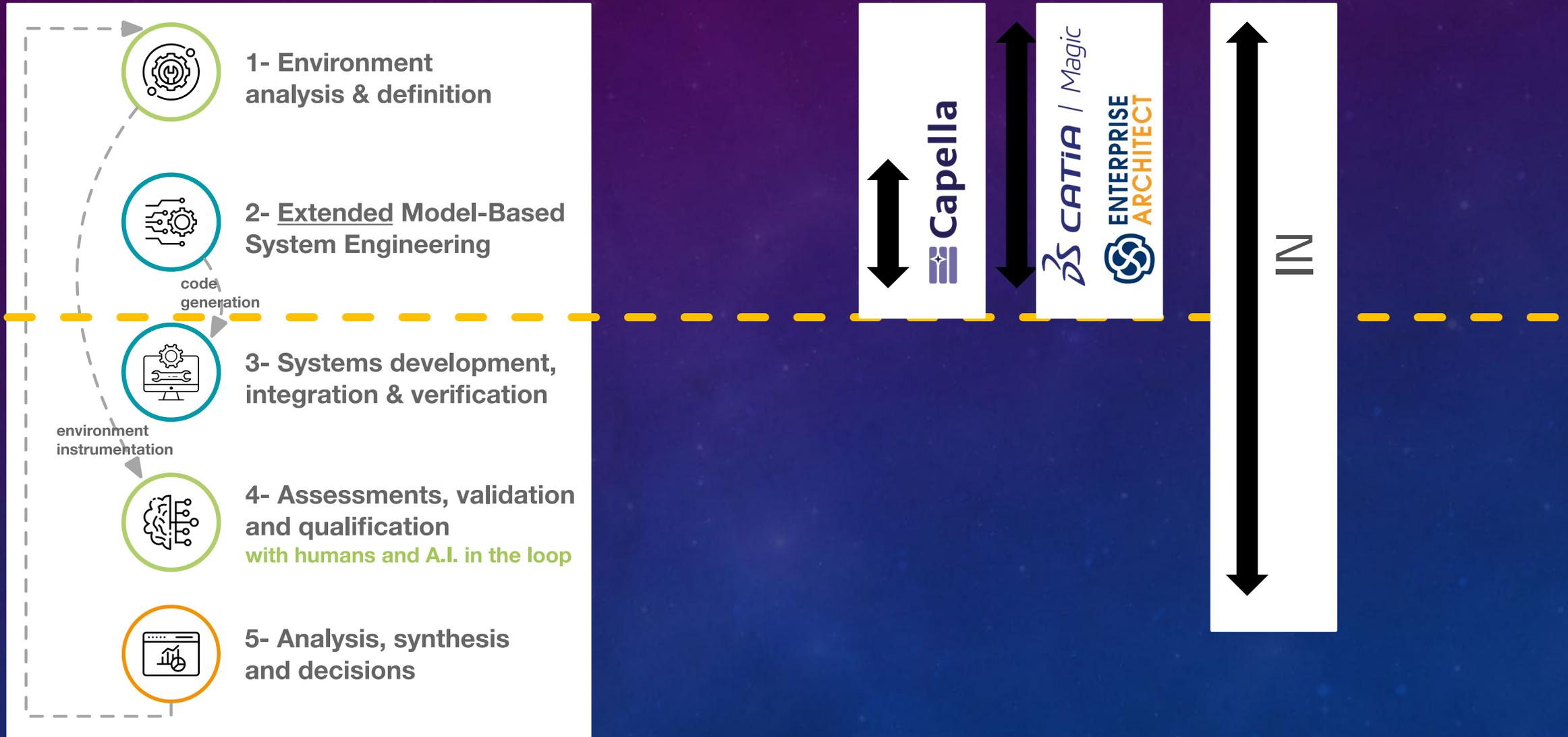
COLLABORATIVE WORK IN DESIGN TEAMS

- Graphical visualization → **Mediating tool for Collaborative Work**

- Linking Logical models (LM) & Operational models (OM) → improved **Tangibility/Maturity** assessment & design **Flexibility**

- Documenting the design process and its solutions → **Active Sociotechnical Documents for Design & Operations**

- Toward **Model-Based Human Systems Integration** (MB-HSI)

Boy, G.A. (2023). Model-Based Human Systems Integration.
In the Handbook of Model-Based Systems Engineering,
A.M. Madni & N. Augustine (Eds.). Springer, USA, pp. 471-499. DOI
https://doi.org/10.1007/978-3-030-27486-3_28-1.

A MULTIDISCIPLINARY & ITERATIVE PROCESS

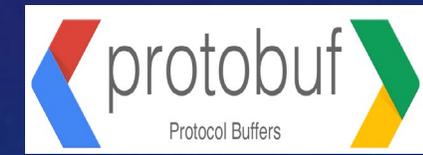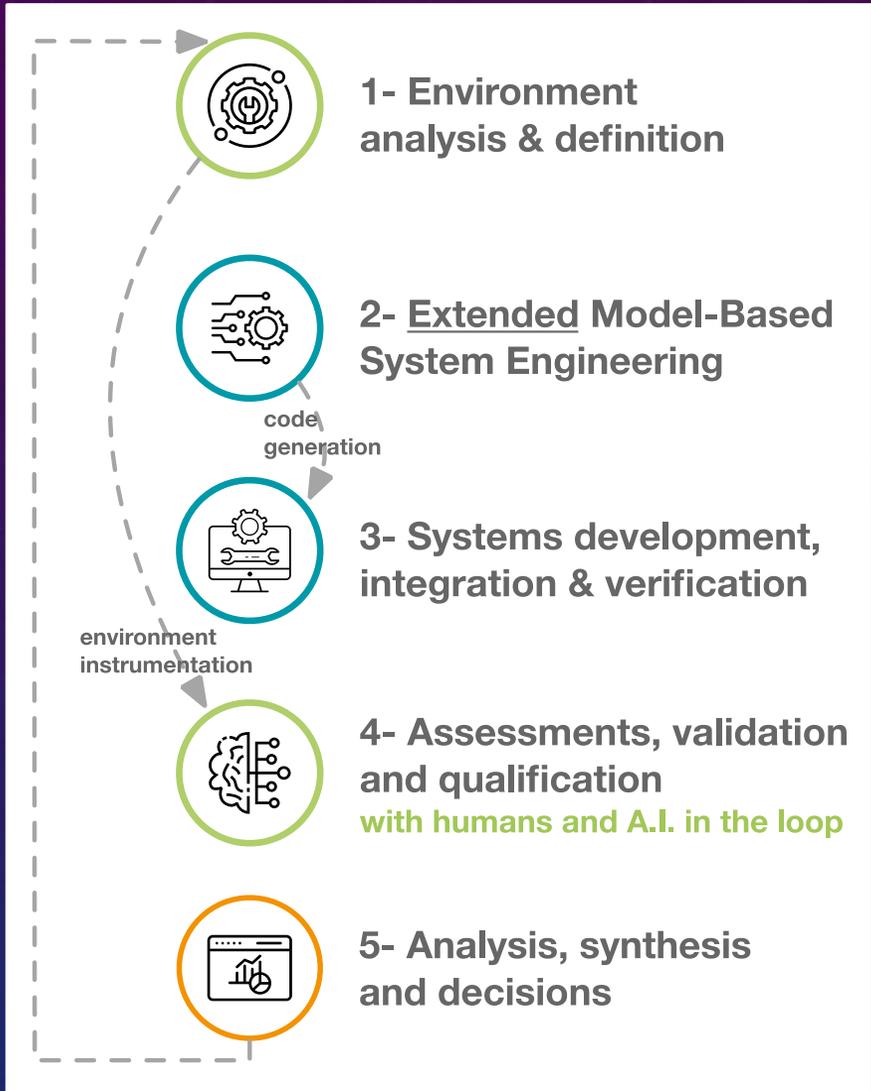FOR SOCIO-TECHNICAL SYSTEMS OF SYSTEMS ENGINEERING → MB-HSI

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Capella

CATIA / Magic
ENTERPRISE ARCHITECT

IN

1- Environment analysis & definition

2- <u>Extended</u> Model-Based System Engineering

code generation

3- Systems development, integration & verification

environment instrumentation

4- Assessments, validation and qualification
with humans and A.I. in the loop

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Etc.

The continuity principle…
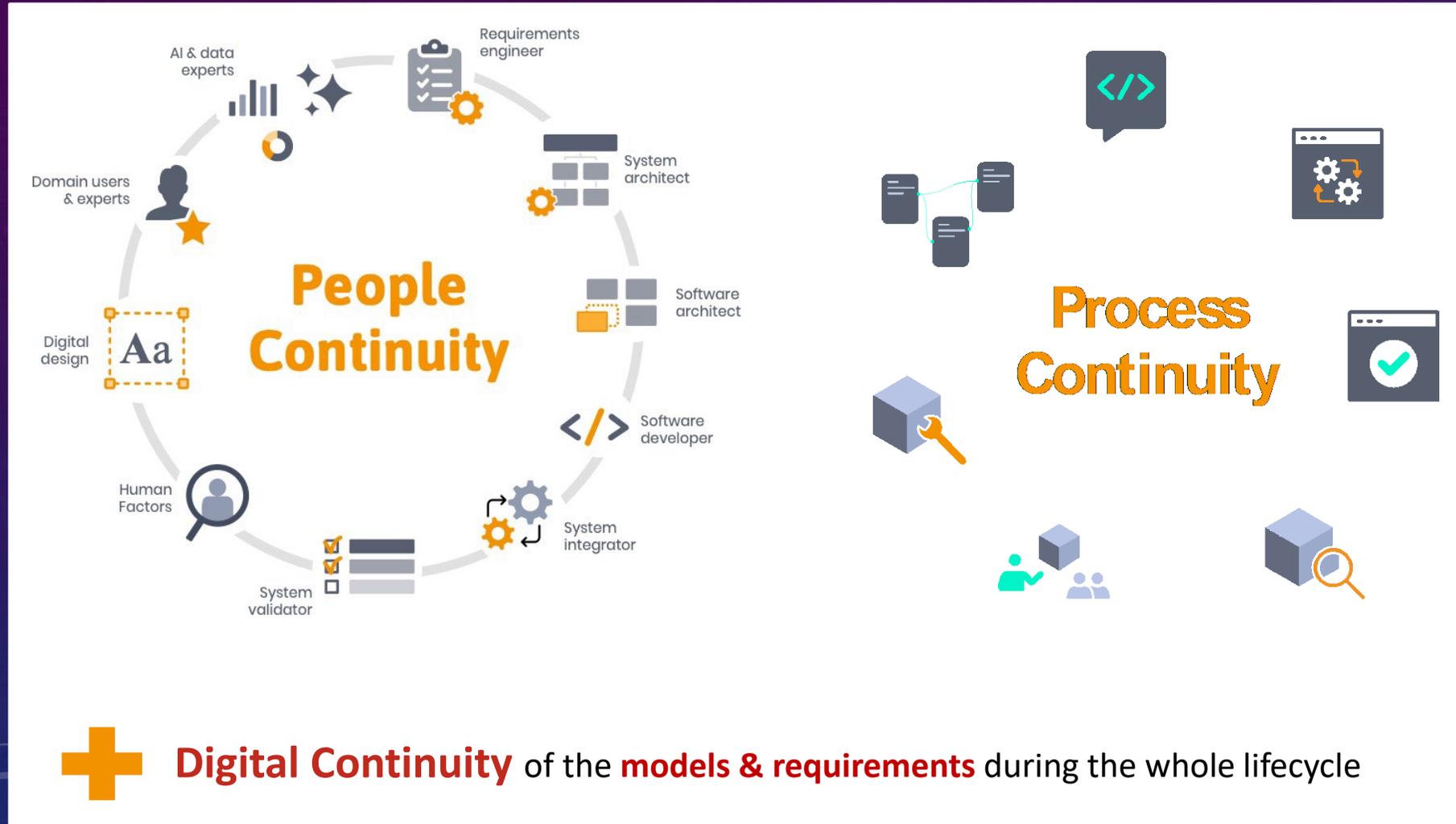
- People continuity
- Process continuity
- Digital continuity

Digital Continuity of the **models & requirements** during the whole lifecycle

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- Boy, G.A. (2022). Model-Based Human Systems Integration. In the Handbook of Model-Based Systems Engineering, A.M. Madni & N. Augustine (Eds.). Springer, USA. DOI: https://doi.org/10.1007/978-3-030-27486-3_28-1.

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- Boy, G.A. (2020). *Human Systems Integration: From Virtual to Tangible*. CRC Press – Taylor & Francis Group, USA (https://www.taylorfrancis.com/books/9780429351686).

… and others: https://www.flextechchair.org/publications.html

THANK YOU!

HUMAN–SYSTEMS
INTEGRATION
From Virtual to Tangible

Guy André Boy

CRC Press
Taylor & Francis Group