THE EVOLUTION OF AUTOMATION

PROF. GUY ANDRÉ BOY

FlexTech

GROUPE ISAE ESTIA INSTITUTE OF TECHNOLOGY CentraleSupélec

THIS LECTURE IS THE FIRST OF A SERIES OF FOUR…

- In this first lecture, **automation** will be described as departing from a single-agent perspective

  This will be historical… showing how we automated and further designed aircraft during the last half century…
- My second lecture will be devoted to **the human role in large complex systems**

  Automation will then be described from a multi-agent perspective
- My third lecture will be focusing on problem-solving support (**FlexTech**)

  How to shift from rigid automation to flexible autonomy in unexpected situations?
- In the fourth lecture, I will illustrate the various ways of automating systems using industrial projects

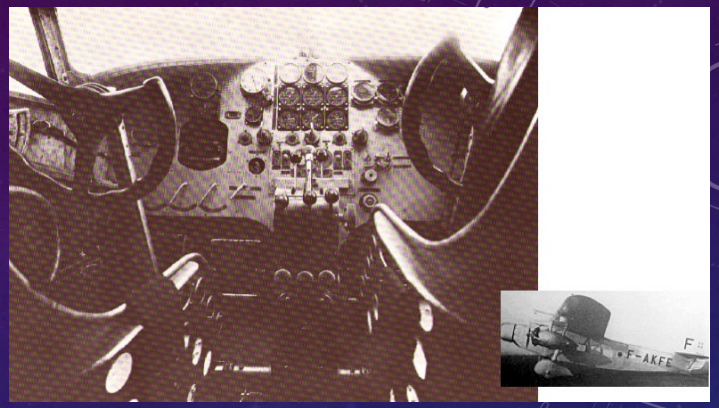
- This evolutionary series of lectures will try to explain the genesis of **Human Systems Integration (HSI)**

OUTLINE

- Cockpit automation evolution
- Analysis of a few accidents
- Cognitive function analysis
- Human factors associated with automation: human error issues
- Regulatory solutions…
- Human-centered design and automation

AERONAUTICAL EVOLUTION

Farman F60 Goliath (1919)



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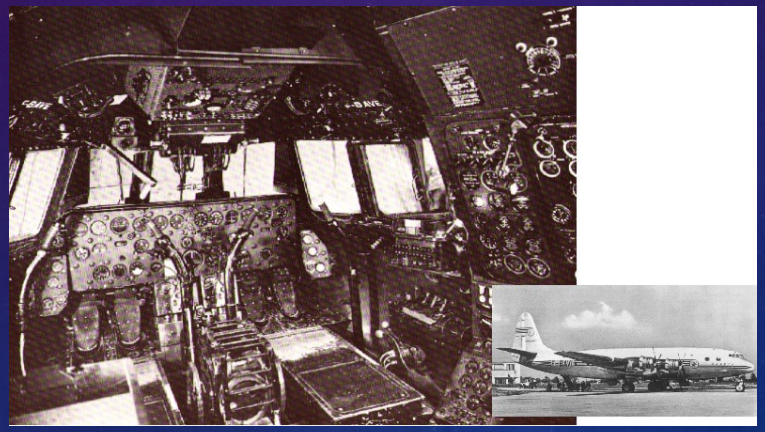


Armagnac SE 2010 (1949)

The number of instruments increased…

Three main criteria…

- Safety
- Performance
- Comfort

AERONAUTICAL EVOLUTION

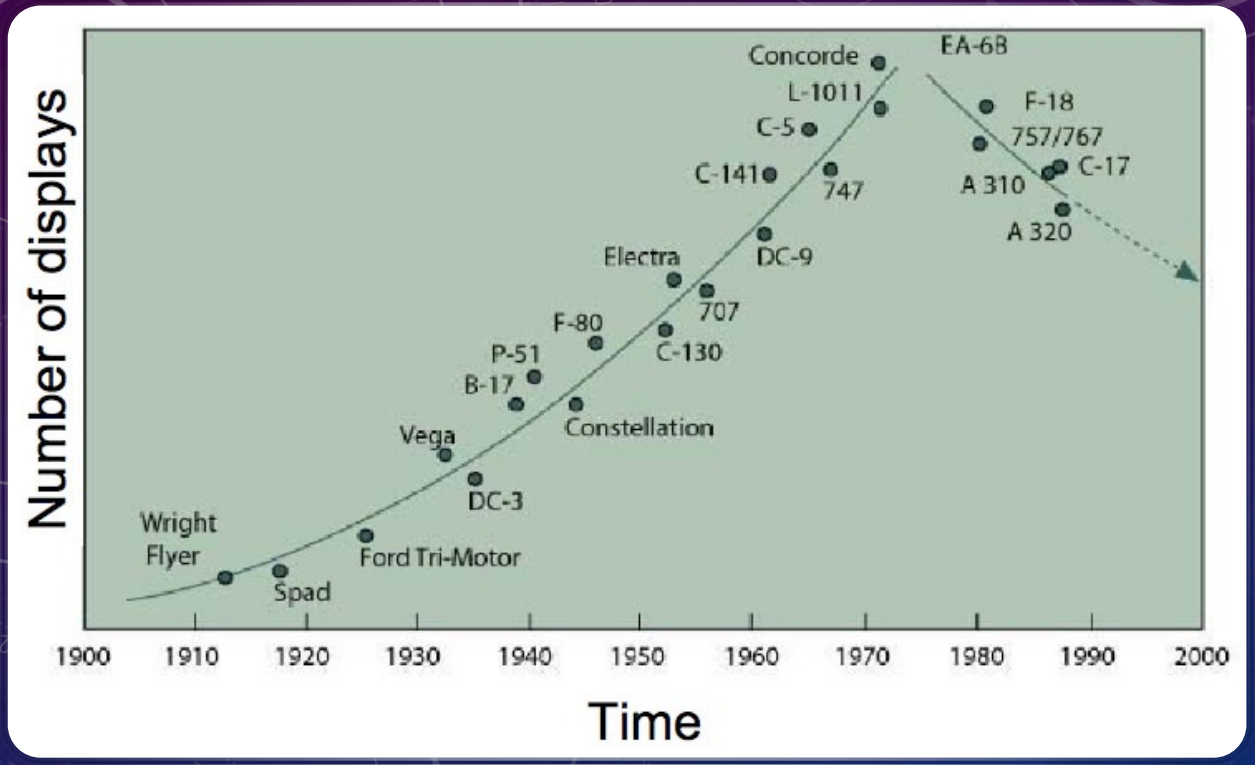
Caravelle (1955)

Concorde (1969)

Airbus 320, 330, 340

Airbus 380

NUMBER OF DISPLAYS IN COCKPITS



Courtesy of J. Hansman, MIT

WE HAVE INCREMENTALLY INCREASED INFORMATION PROCESSING…

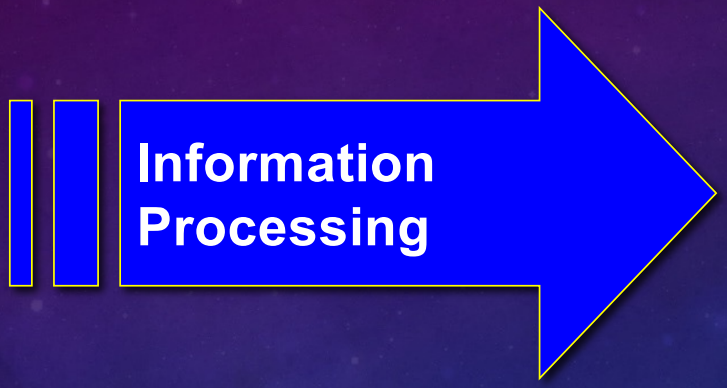
- To decrease workload, in particularly demanding flight phases
- To provide the right understandable information at the right time
- To enable pilots to react safer and more efficiently to situations
- To enable pilots to delegate tasks to automation (human-machine teaming)

→ The pilot remains the master of the operations

However, there are various ways to proceed with automation…

A SOCIO-TECHNICAL SHIFT…

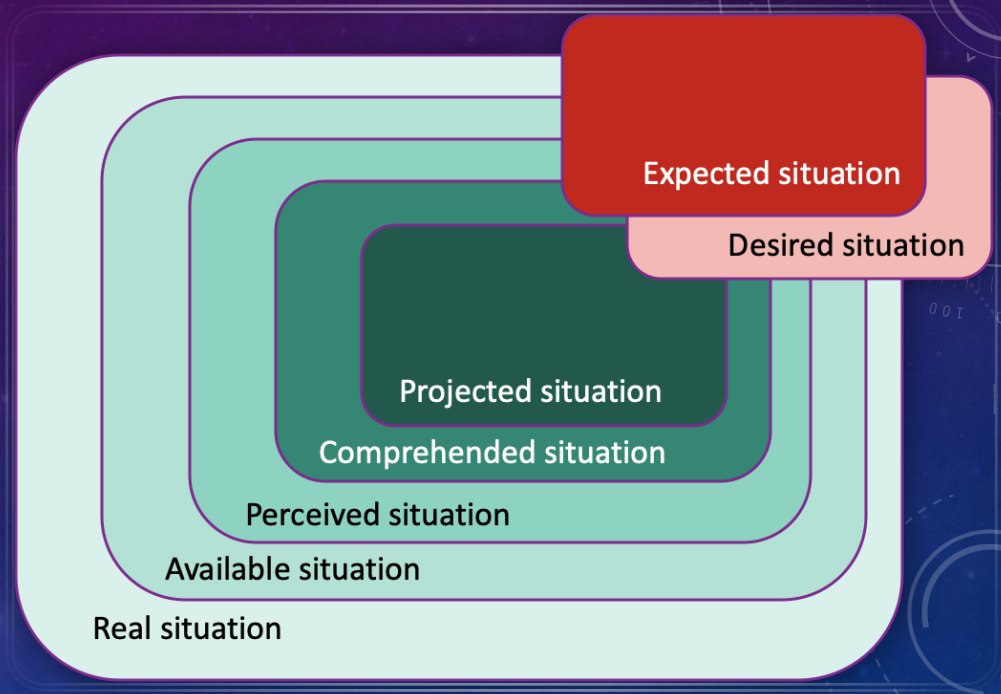
Signals
Information
Knowledge



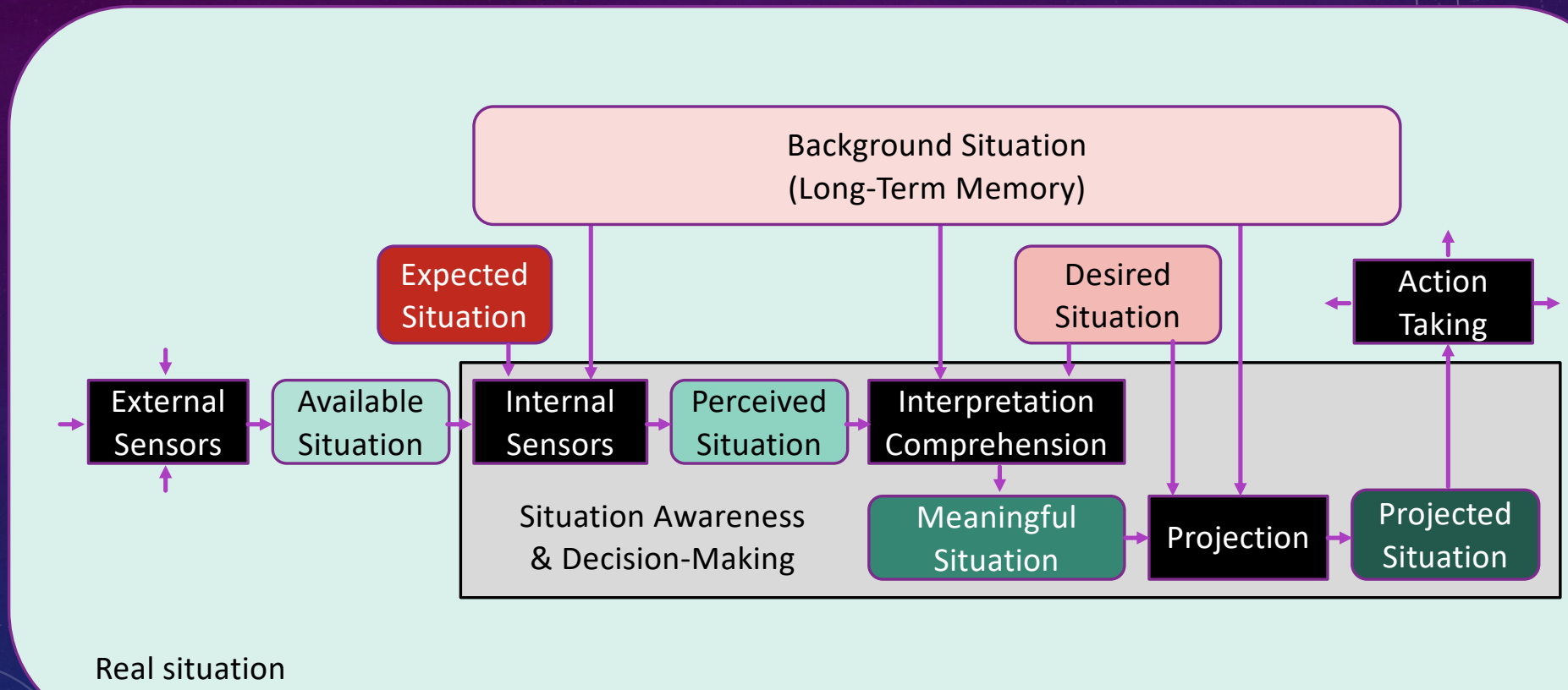
Multi-agent
Delegation
Cooperation
Coordination

Situation Awareness

WHAT DO WE MEAN BY A SITUATION?

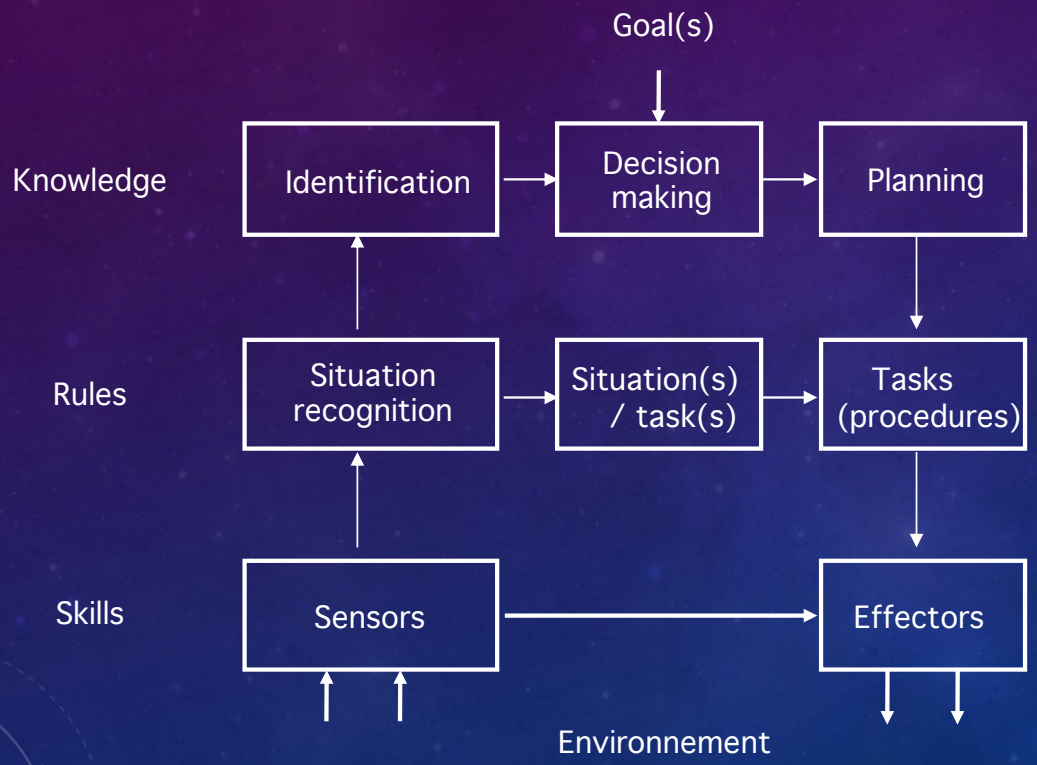


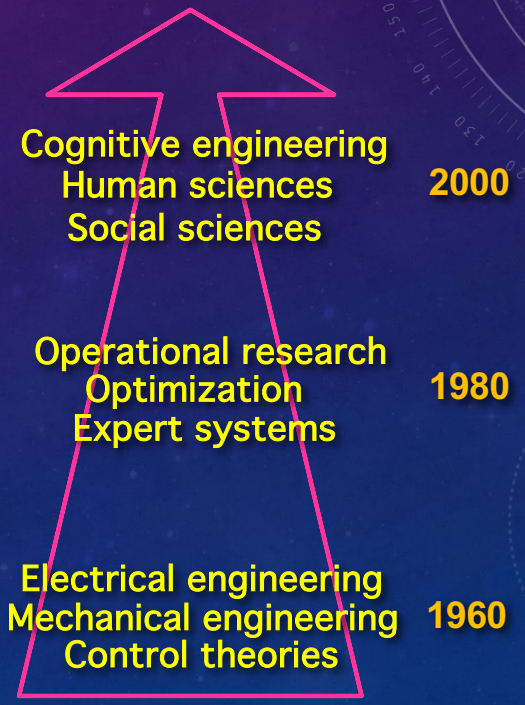
HOW THE VARIOUS SITUATIONS CAN BE LINKED?



AUTOMATION EVOLUTION: AN INTERPRETATION

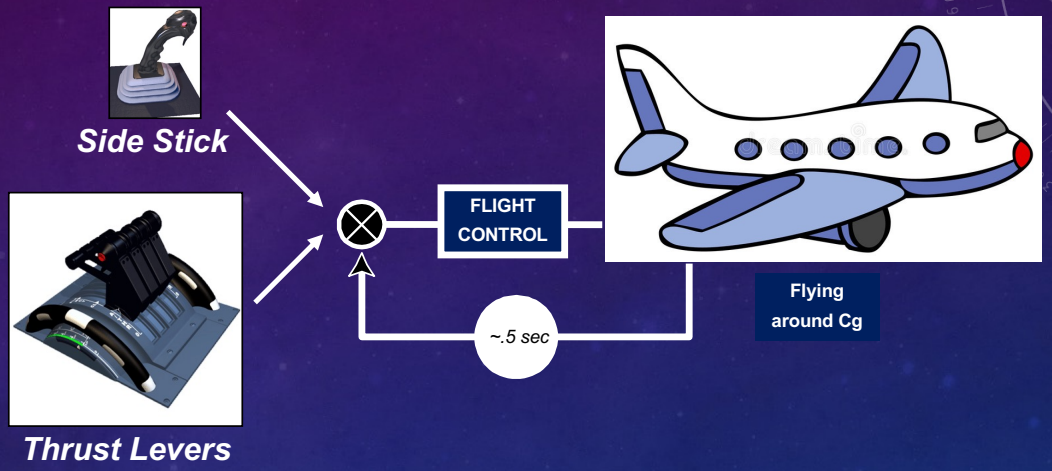
Automation evolution and **emergence of contributing disciplines**
(Rasmussen's model)





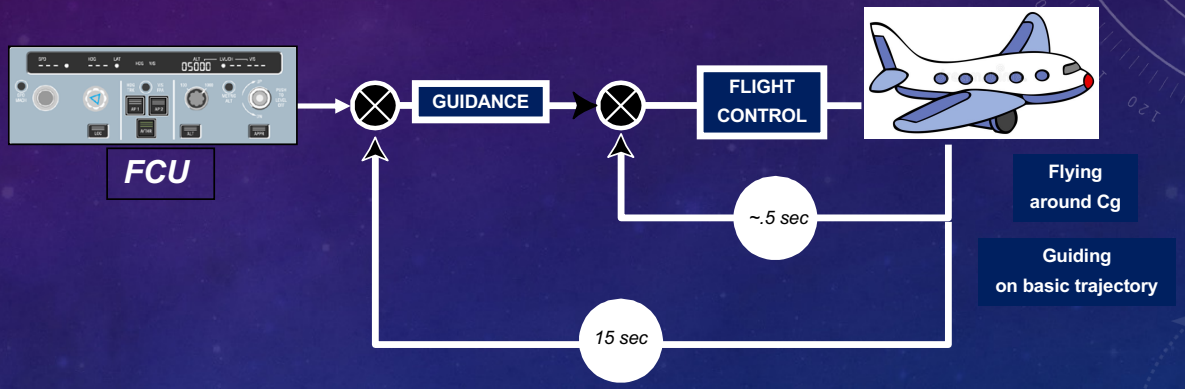
LOOP 1

Trajectory control automation



The 4-loop approach to ATM was first provided by Etienne Tarnowski at HCI-Aero'06, Seattle, USA

LOOP 2



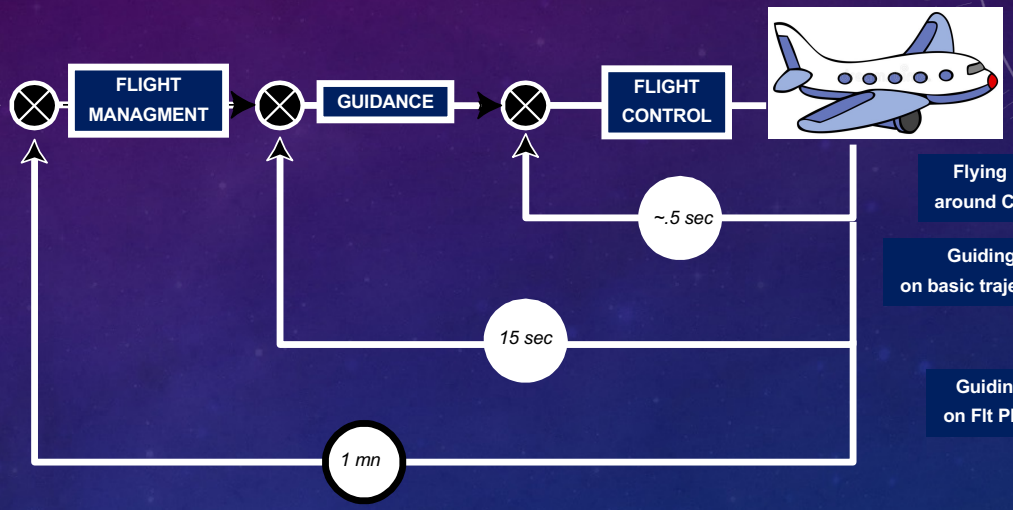
Guidance automation

- Integrated and digital autopilot and autothrottle
- High level modes

The 4-loop approach to ATM was first provided by Etienne Tarnowski at HCI-Aero'06, Seattle, USA

LOOP 3

FMS CDU

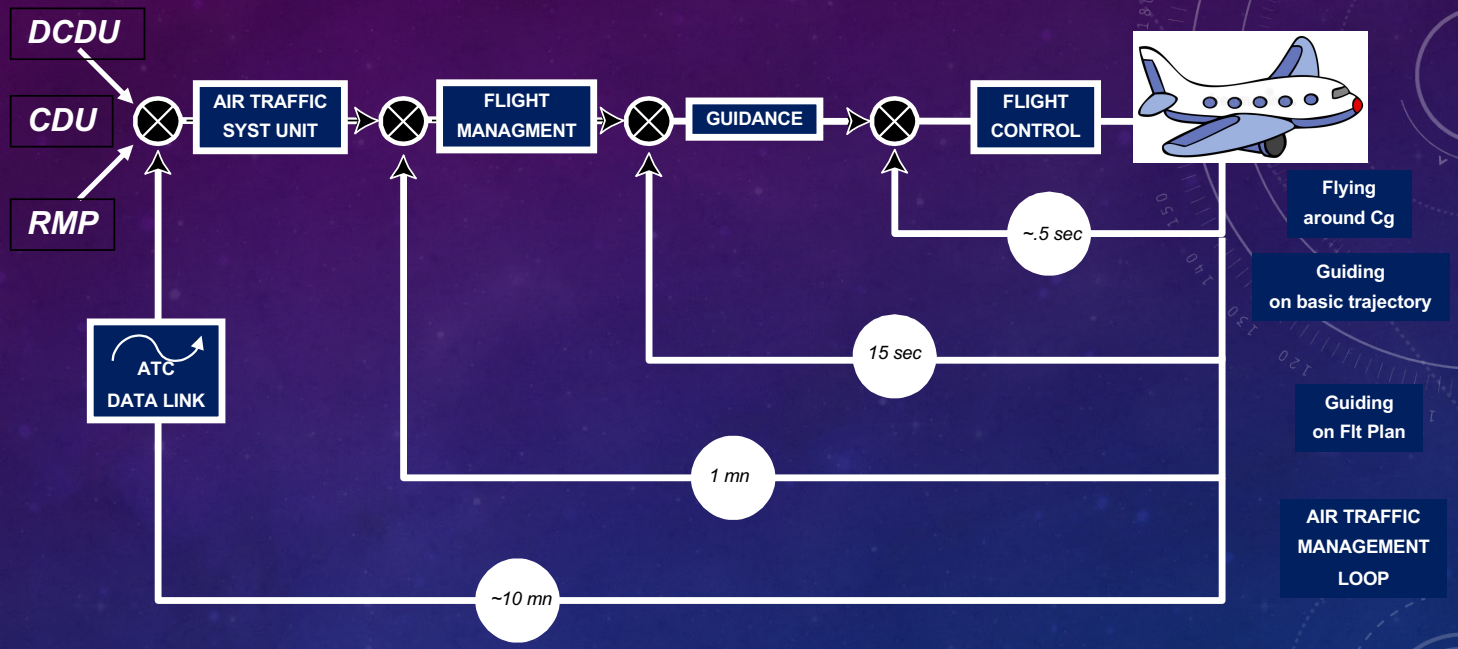


- Navigation automation
  - Integration of guidance and flight management

Glass cockpits

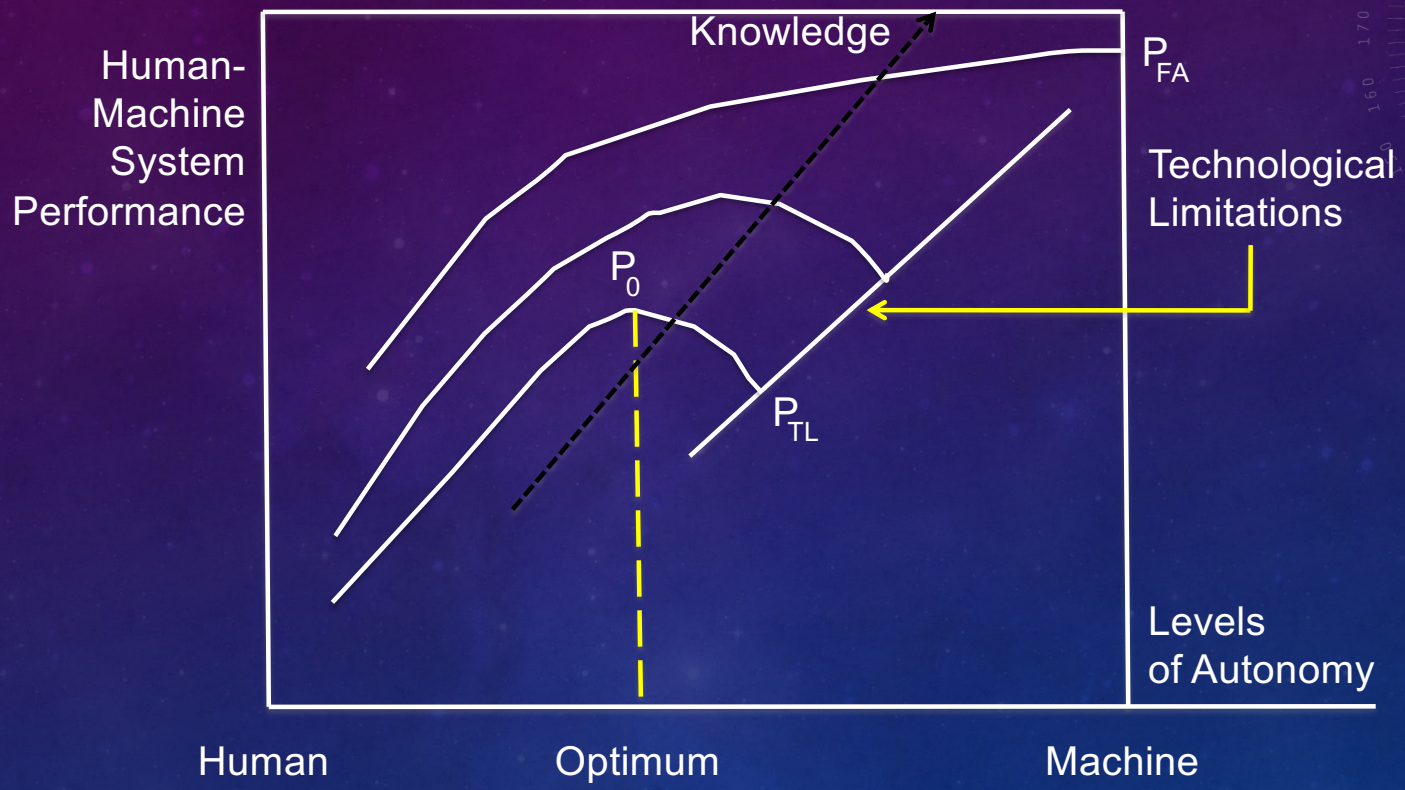
The 4-loop approach to ATM was first provided by Etienne Tarnowski at HCI-Aero'06, Seattle, USA

LOOP 4



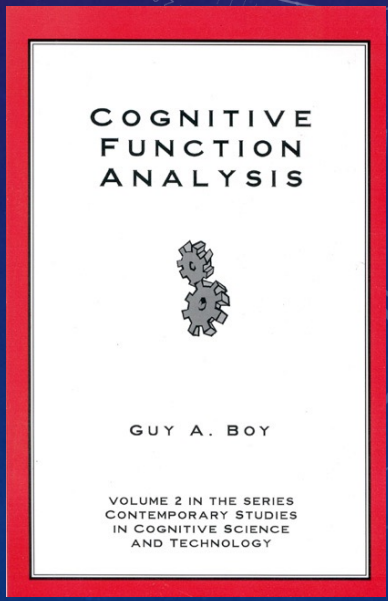
- Automation of the ATM

The 4-loop approach to ATM was first provided by Etienne Tarnowski at HCI-Aero'06, Seattle, USA

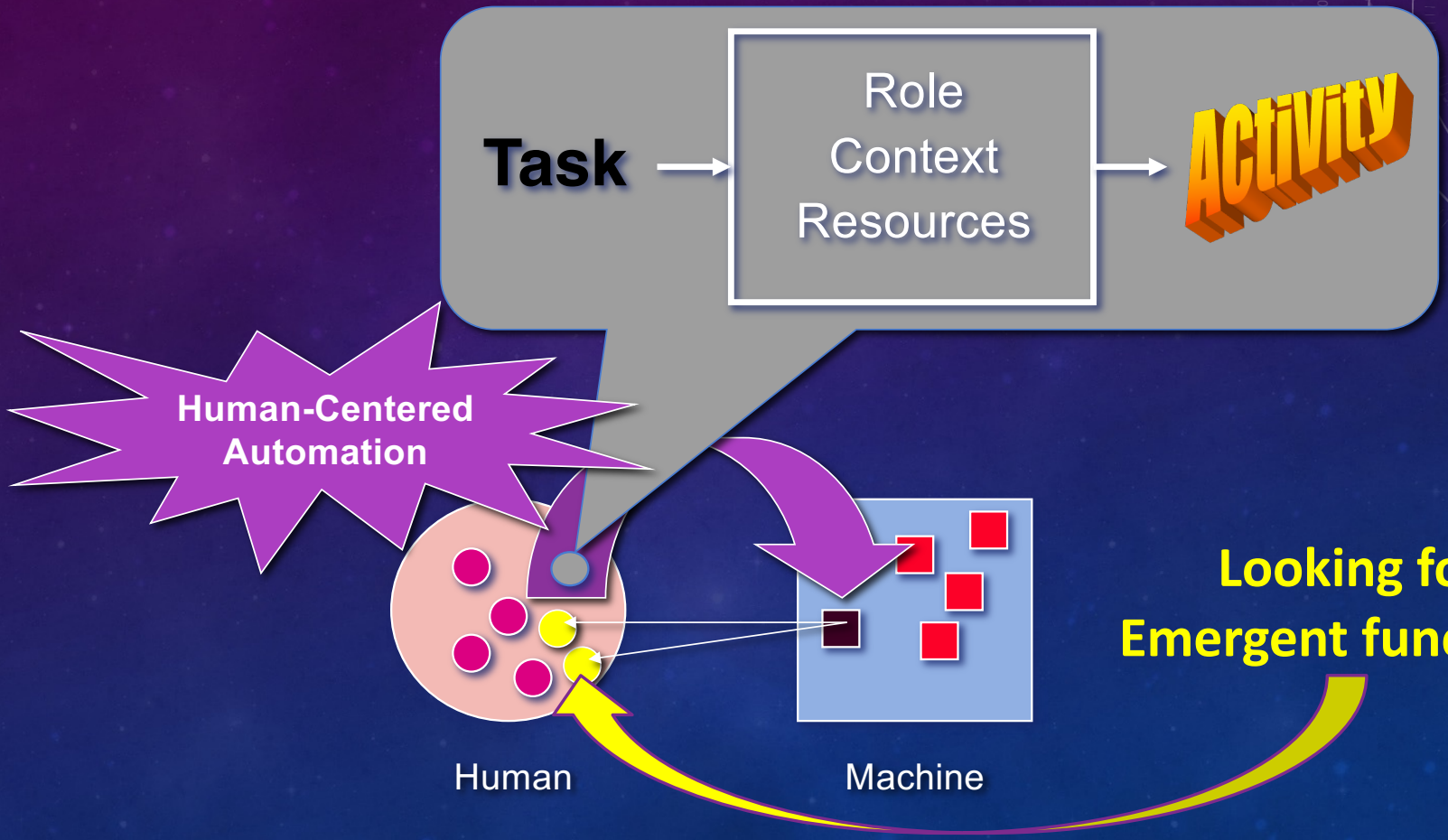

Human-
Machine
System
Performance
Knowledge
P_{FA}
Technological
Limitations
P_0
P_{TL}
Levels
of Autonomy
Human
Optimum
Machine

WHERE IS THE HUMAN THERE?

- We needed a representation that supports function allocation…
- Functions can be cognitive and physical… (cyber-physical systems and people)
- Functions can be logical [y=f(x)] and theleological [a function of an agent in an agency]
  - A function transforms a task into activity
  - A function has a role, a context of validity, and resources



THE COGNITIVE FUNCTION PARADIGM



AN EXAMPLE OF SHARED SITUATION AWARENESS…

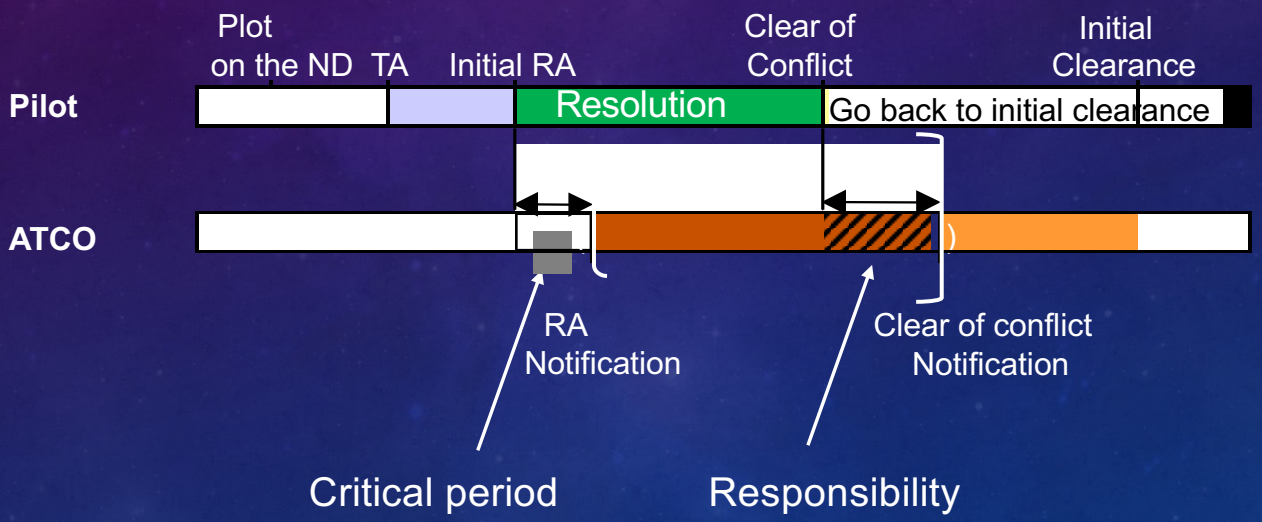
Ground

Aircraft

Same situation → 2 points of view
Intersubjectivity
Coordination

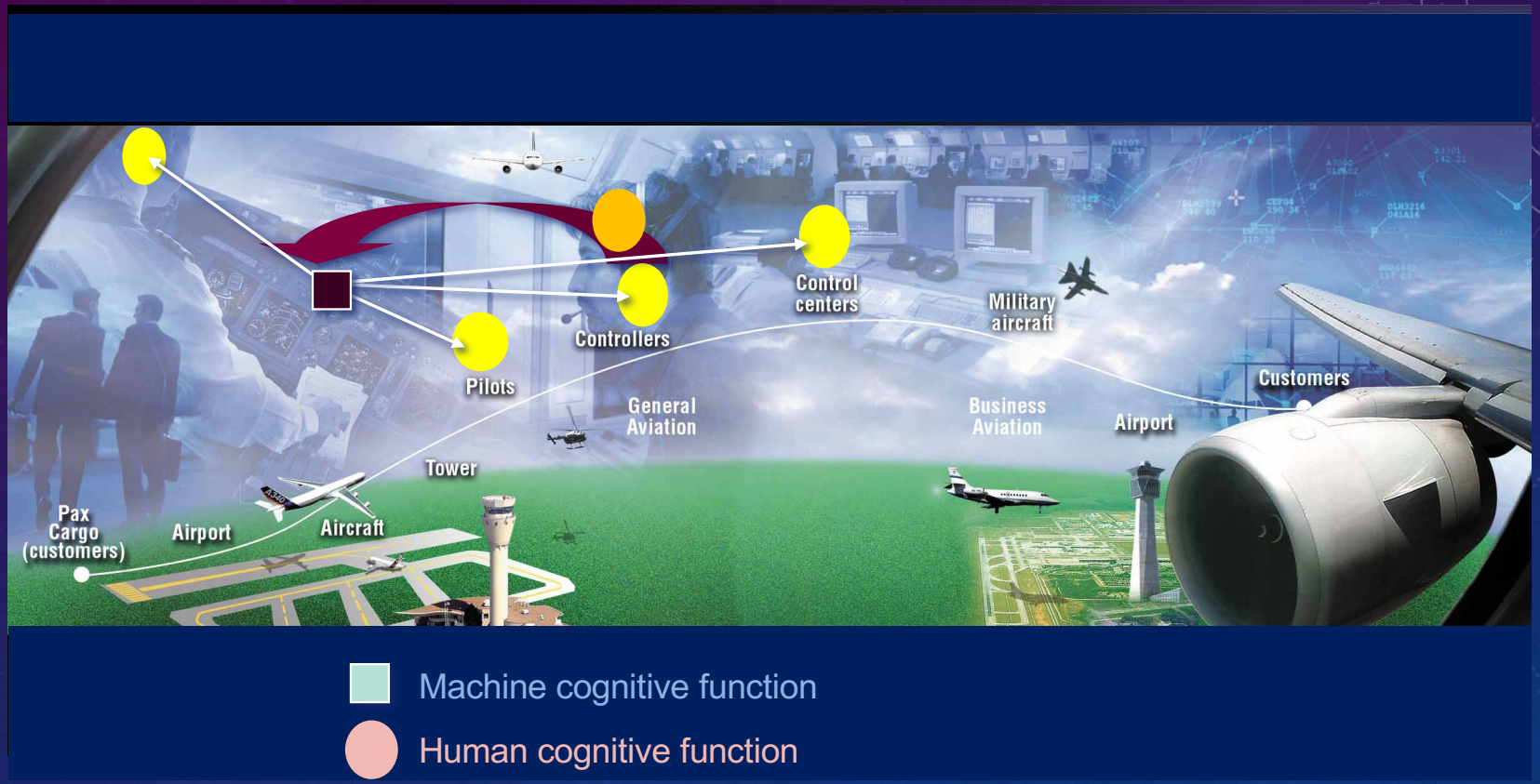
DISCUSSION: TCAS INTERLUDE

TCAS resolution :
an interlude in the air-ground dialogue



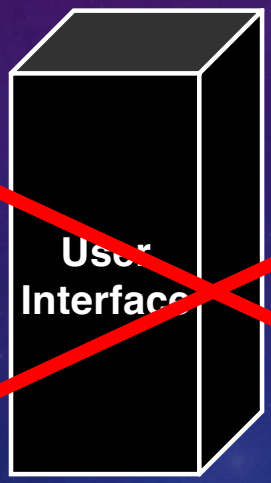
Stress study, DSNA-LAA, 2006

ATM AGENTS AND INTERCONNECTIVITY…



THE USER INTERFACE: A CONCEPT OF 20TH CENTURY…

Human Factors



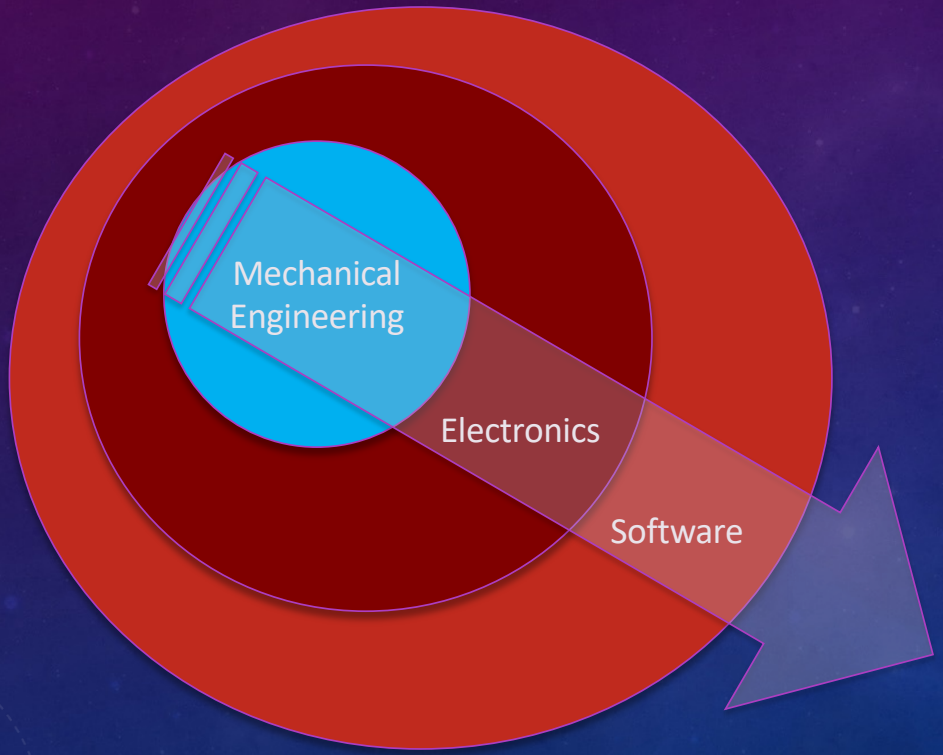
Ergonomics & Automation

Engineering

MY CAR WHEN I WAS A STUDENT

A CAR TODAY

ENGINEERING OF THE 20TH CENTURY

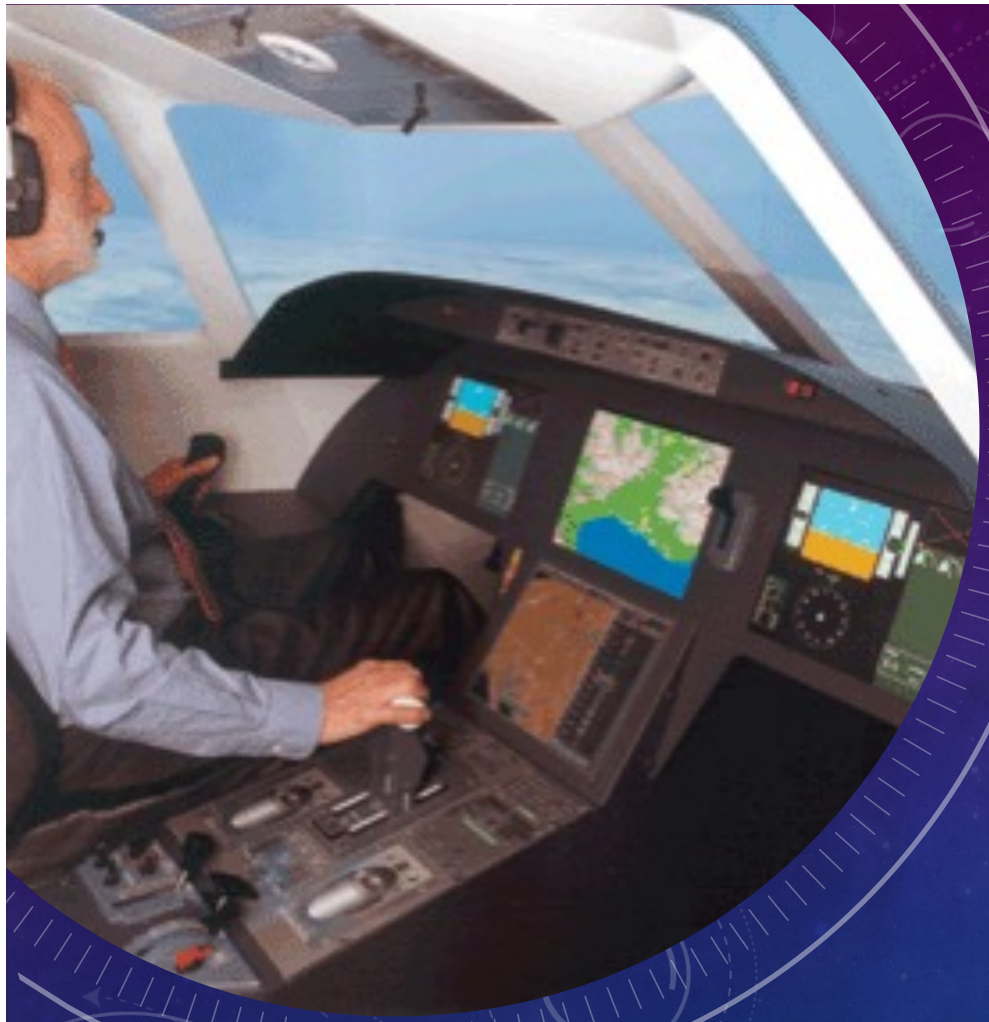


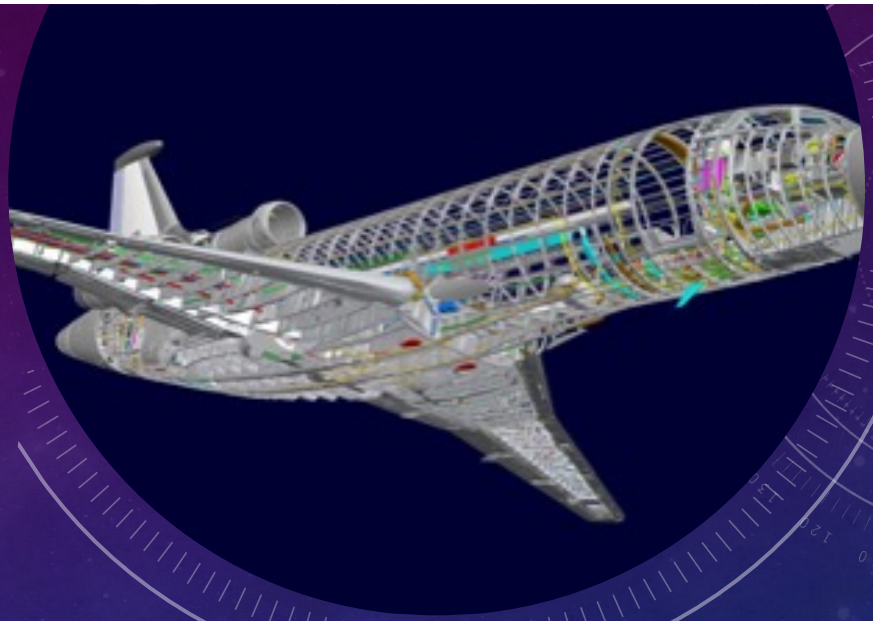
Automation
&
AI-1 & HCI

Incremental accumulation of software **functions** into hardware **structures**

…

From Hardware to Software

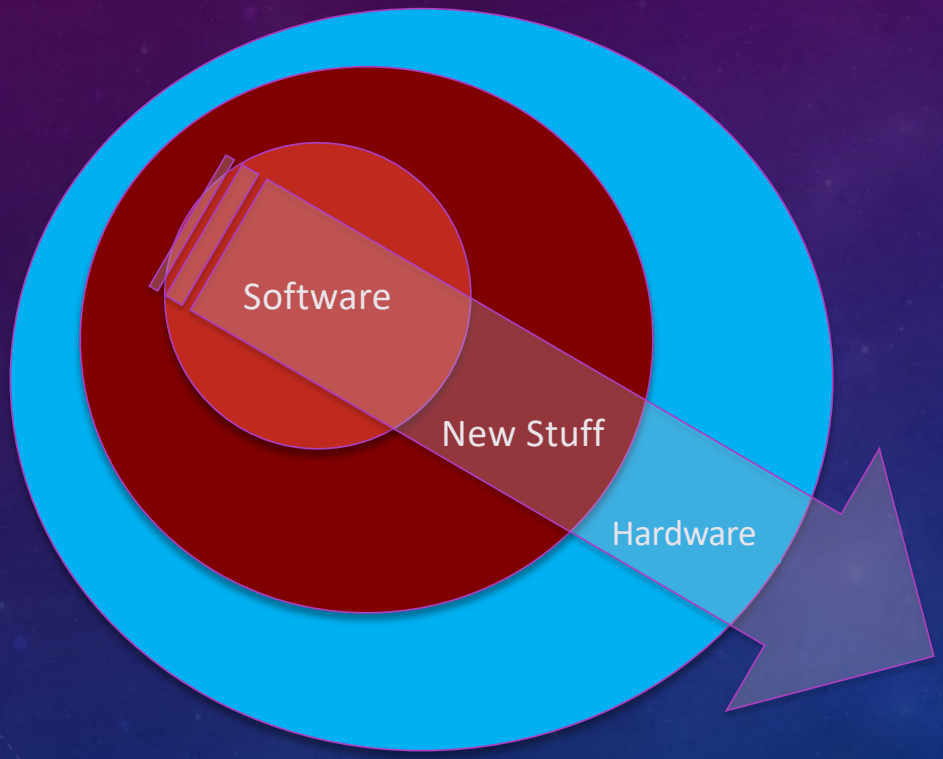




WHY IS HCD POSSIBLE TODAY?

HCD: Human Centered Design
VHCD: Virtual HCD

ENGINEERING OF THE 21ST CENTURY



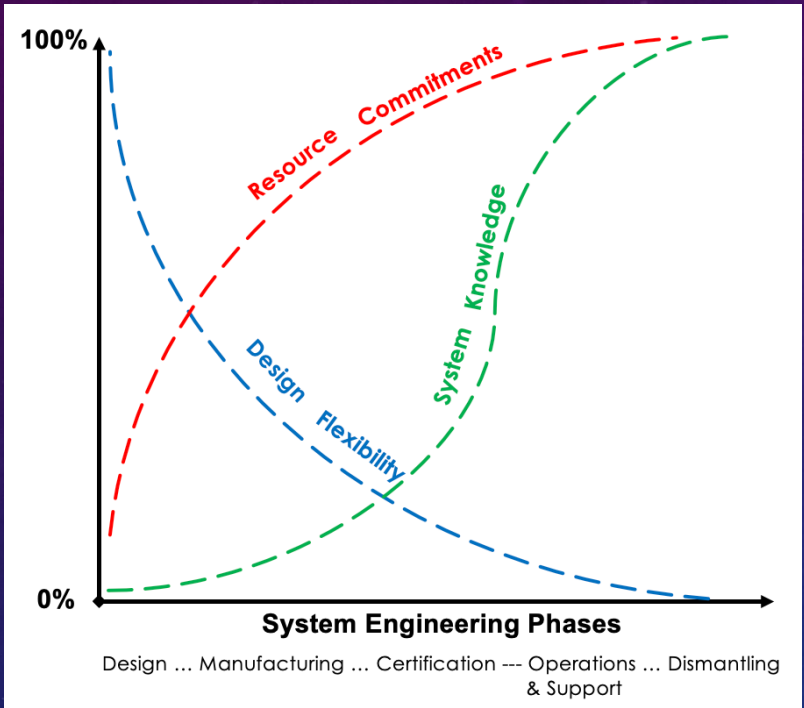
AI-2 & HCI & VHCD
& Tangible Interactive Systems

Modeling & Simulation
Connectivity
Orchestration
Data & Cognitive Science
3D Printing
…

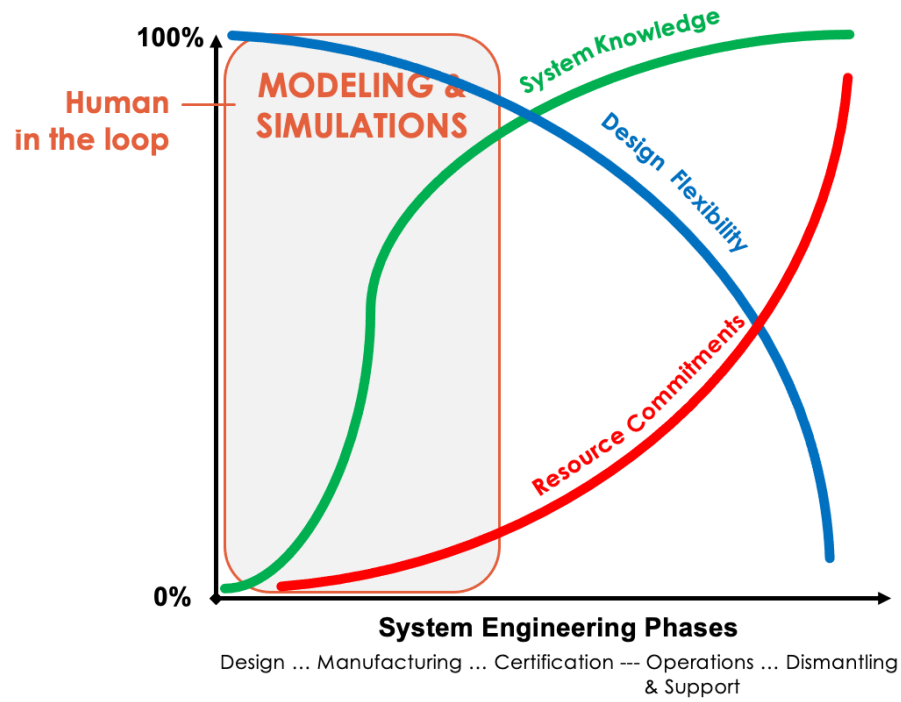
From Software to Hardware

LIFE-CYCLED HUMAN SYSTEMS INTEGRATION

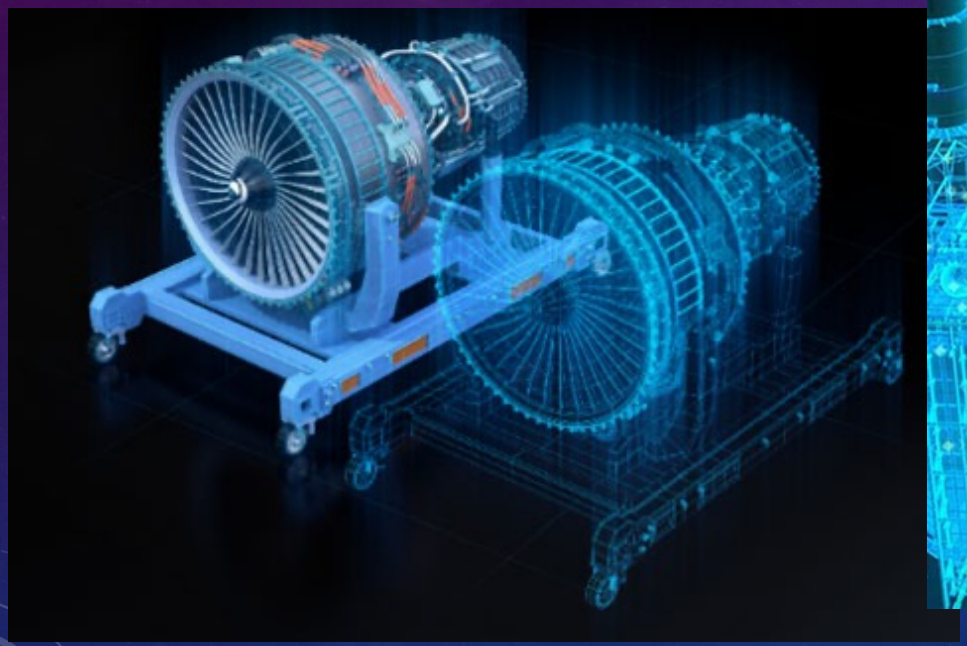
Technology-centered

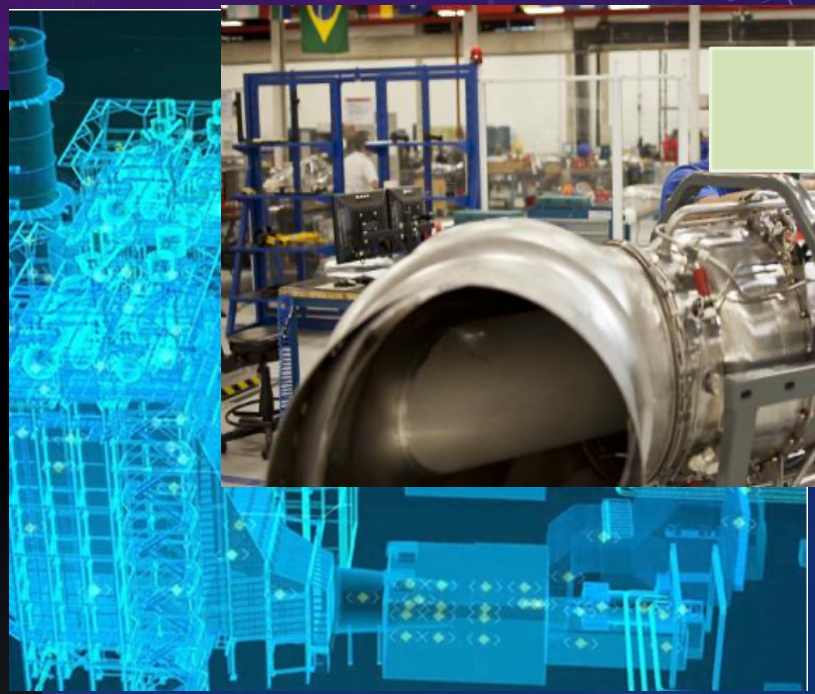


Human-centered



HUMAN-CENTERED DESIGN OF A DIGITAL TWIN FOR HELICOPTER ENGINE MAINTENANCE





DIGITAL TWINS

Expanding HITLS

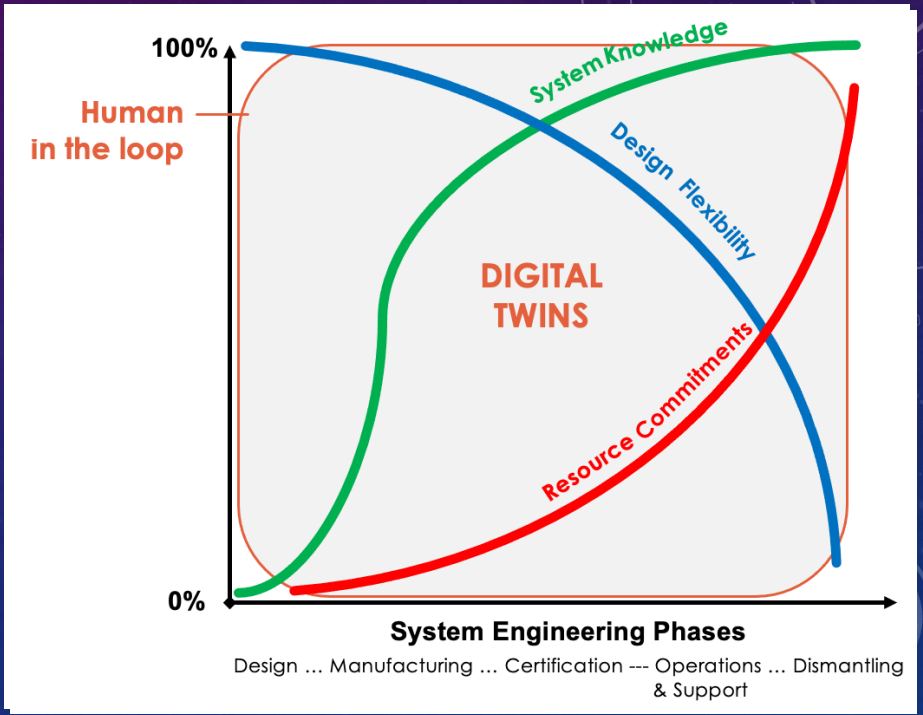
- During the whole life cycle
- “what if?”

Vivid documentation → MBSE

- Integration of experience feedback
- Organizational memory

DTs as virtual assistants → HMT

- Multi-agent collaboration
- Mediators for collaborative work



MBSE: Model-Based Systems Engineering
HMT: Human Machine Teaming
(where the machine is increasingly autonomous)

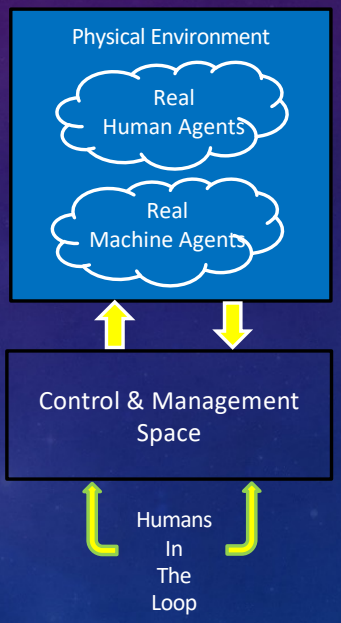
FROM MEANS TO PURPOSE

Engineering

Ergonomics & Automation

Human Factors

Tangible
Human-Centered Engineering

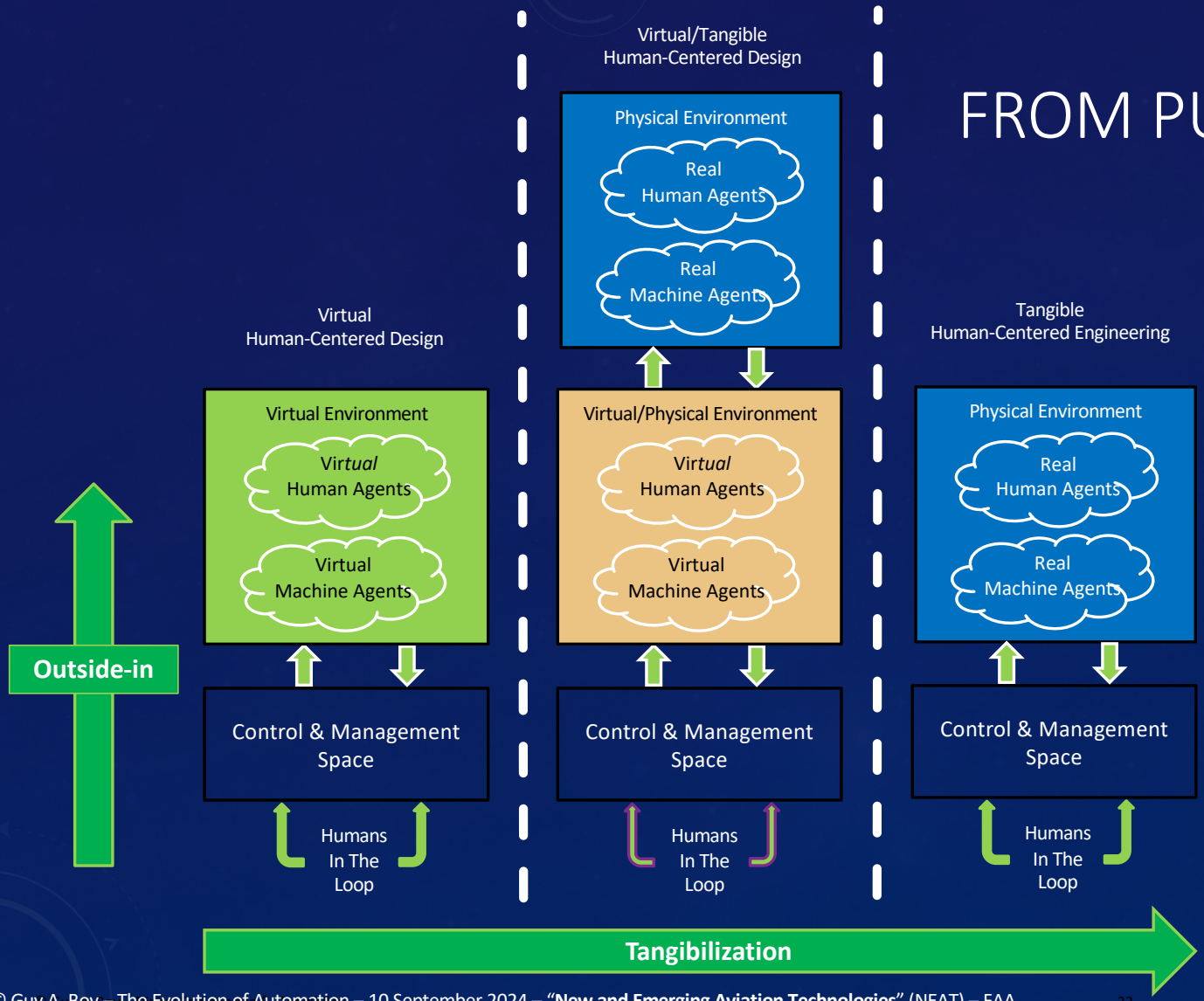


Inside-out

20th century approach

Engineering, Ergonomics, HCI & Automation

FROM PURPOSE TO MEANS



21ST CENTURY APPROACH

HSI

TANGIBILITY

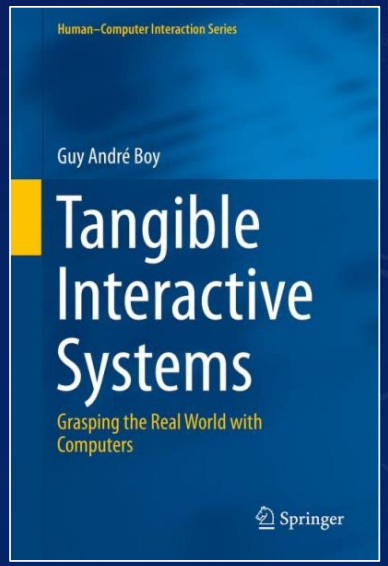
- Physical vs. Figurative Tangibility
  - Grasping virtual things both physically and cognitively
  - Situation awareness at the center of Industry 4.0
- Virtual Prototyping and Human-In-The-Loop Simulation (HITLS)
  - Enabling Human-Centered Design (HCD)
  - Activity-based development
- From Purpose to Means instead of the usual opposite
  - The User Interface is a component of complex systems to be designed
  - Approach: Outside-In instead of Inside-Out
  - TOP Model (Technology-Organizations-People based concurrent design)

TANGIBILITY: SYSTEMIC ATTRIBUTES

- Complexity → separability, interconnectivity, collaboration, trust, …
- Maturity → TRLs & HRLs & ORLs
- Flexibility (design & operations) → safety nodes, reversibility, FlexTech, …
- Stability/Resilience → passive vs. active, resilience, crisis management, …
- Sustainability → design rationale, knowledge management, …

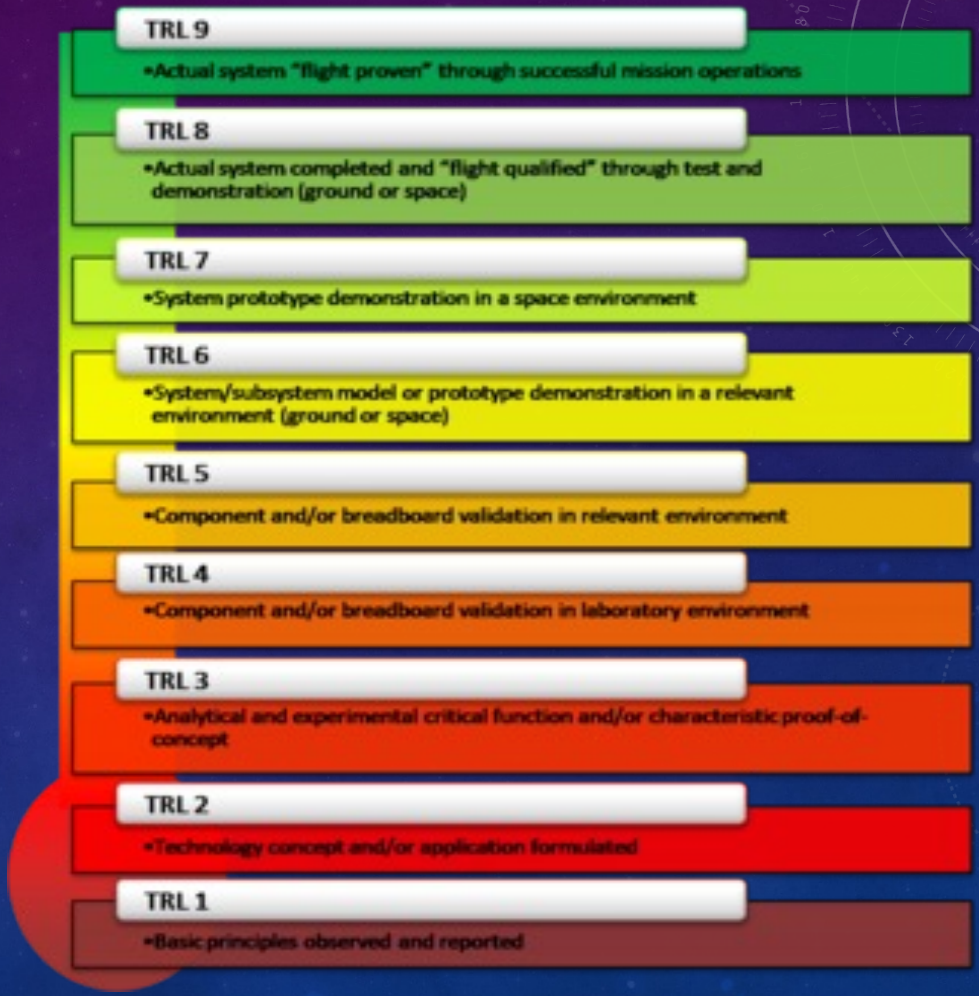
+ Social Factors

Shared situation awareness
Cooperative decision-making
Harmonized risk taking
Trust and collaboration



MATURITY = READINESS LEVELS

TRL: Technology



MATURITY = READINESS LEVELS

HRL: Human

HRL	Description
1	Relevant human capabilities, limitations, and basic human performance issues and risks identified
2	Human-focused concept of operations defined and human performance design principles established
3	Analyses of human operational, environmental, functional, cognitive, and physical needs completed, based on proof of concept
4	Modeling, part-task testing, and trade studies of user interface design concepts completed
5	User evaluation of prototypes in mission-relevant simulations completed to inform design
6	Human-system interfaces fully matured as influenced by human performance analyses, metrics, prototyping, and high-fidelity simulations
7	Human-system interfaces fully tested and verified in operational environment with system hardware and software and representative users
8	Total human-system performance fully tested, validated, and approved in mission operations, using completed system hardware and software and representative users
9	System successfully used in operations across the operational envelope with systematic monitoring of human-system performance

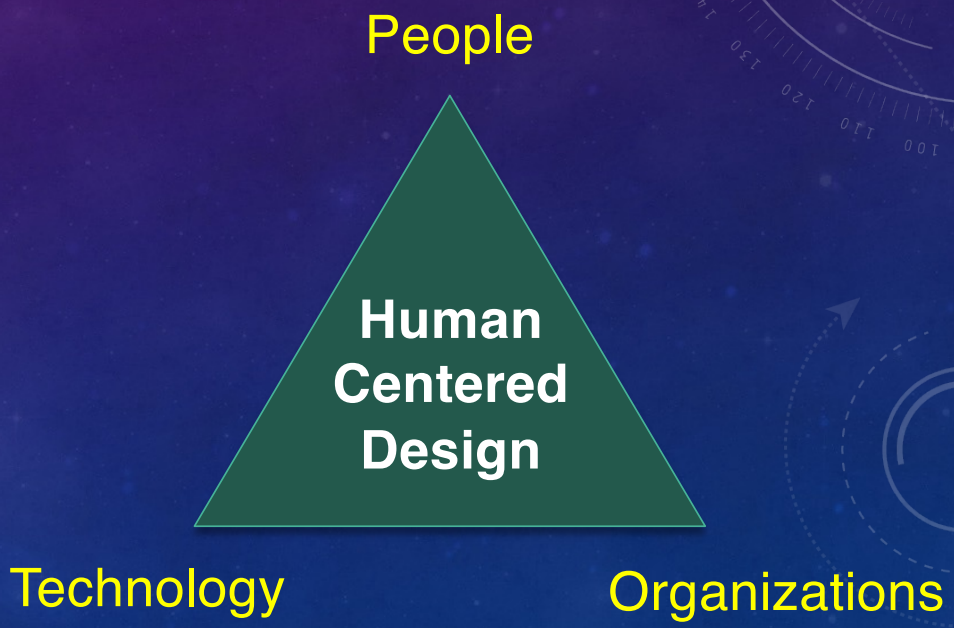
MATURITY = READINESS LEVELS

ORL: Organization

ORL-0	**First principles where potential organizational models are explored.**
ORL-1	Goal-oriented research that requires making choices from first principles to practical fully digital organizational setups
ORL-2	Proof of principle development, and active R&D is started in a virtual environment
ORL-3	Virtual agile organizational prototype development and first HITLS (virtual HCD)
ORL-4	Proof of organizational concept development using concrete scenario-based design from fully virtual to more tangible environments
ORL-5	Assessing organization capability in terms of authority sharing (responsibility, accountability and control), trust, collaboration and coordination, for example
ORL-6	Real-world use-case tests in a wider variety of situations - tangibilization continues
ORL-7	Practical integration with respect to criteria such as safety, efficiency and comfort, at various levels of granularity of the organization – tangibilization continues
ORL-8	Readiness for effective implementation on a real site (fully tangible) based on personnel feedback for deployment approval
ORL-9	Deployment involving both personnel and real machines

MATURITY = INCREMENTAL ADAPTATION

- Adaptation of Technology
- Adaptation of the Organization
- Adaptation of People



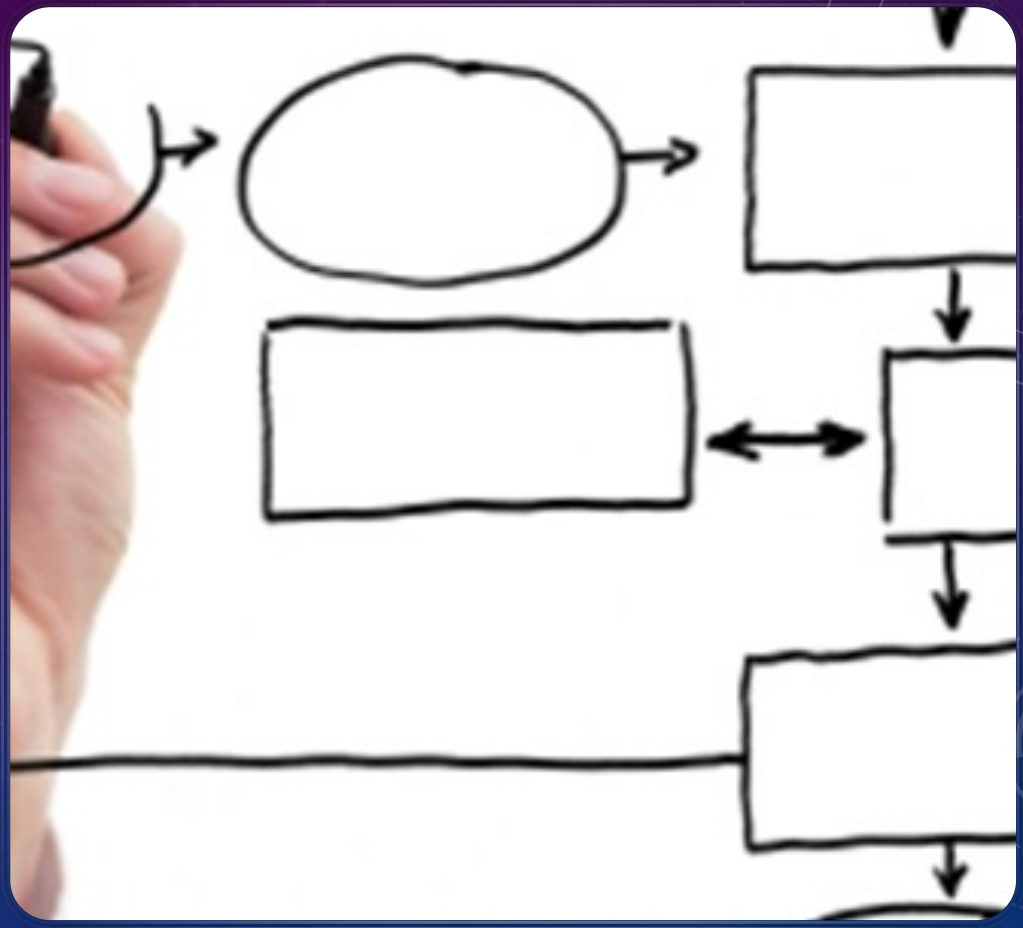
NO ADAPTATION WITHOUT RISK

Risk taking and management…

- Legal and operational
- Psychology and law
- Preparation of risky operations
- Responsibility
- Individual and collective risks
- Organizational risks

NOW, WE NEED A METHOD…

- The next two lectures will be devoted to methods
- Next time, I will present the PRODEC method that supports Human Systems Integration (HSI)
- This method cannot be used without a deeper understanding of what HSI is about!
- HSI will then be further presented and discussed during the next lectures…



REFERENCES FOR THIS LECTURE

- Cognitive Function Analysis
- The Handbook of Human-Machine Interaction
- Orchestrating Human Centered Design
- Human Systems Integration

- … be curious!

THANK YOU FOR YOUR ATTENTION…

I am open to questions…