BACHELOR OF GLOBAL ENGINEERING

CentraleSupélec | université PARIS-SACLAY | McGill

A FEW STORIES IN AERONAUTICS & SPACE
MY HUMAN SYSTEMS INTEGRATION EXPERIENCE

PROFESSOR GUY ANDRÉ BOY


FlexTech
CentraleSupélec-ESTIA Chair
Paris Saclay University, France

MY WORLD FOR ~45 YEARS…

From correction…

… to interaction

… to integration

… and other things

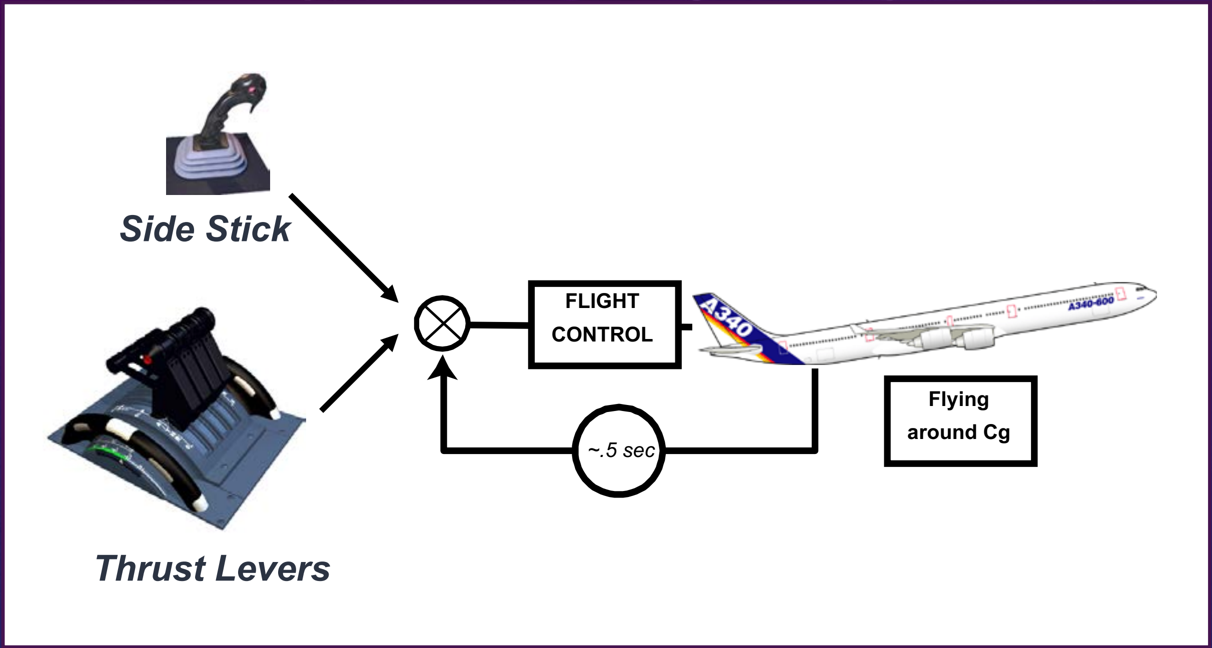
FLIGHT TESTS

FLIGHT CONTROLS:

FIRST LOOP OF AUTOMATION

1945 - 1987 : SLOW EVOLUTION, MECHANICAL FCTL

1987 onwards : A320, revolutionary step to FBW



Loop 1: Flight Control Loop

STEERING TASK AUTOMATION

AUTO-FLIGHT:

SECOND LOOP OF AUTOMATION

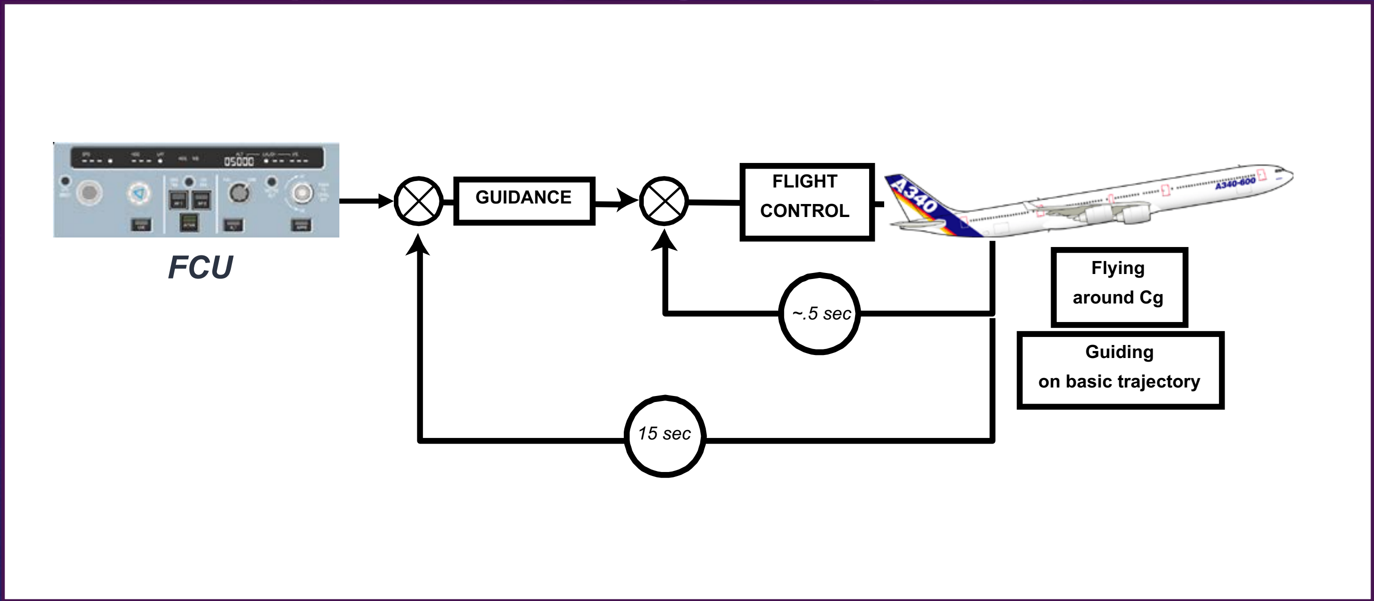
1970 - 1982: ANALOG AUTOFLIGHT SYSTEMS

1982 : A310,

FIRST REVOLUTION,

DIGITAL AUTOFLIGHT

GUIDANCE TASK AUTOMATION



Loop 2: Guidance Loop

NAVIGATION (FMS) & AUTOFLIGHT:
THIRD LOOP OF AUTOMATION

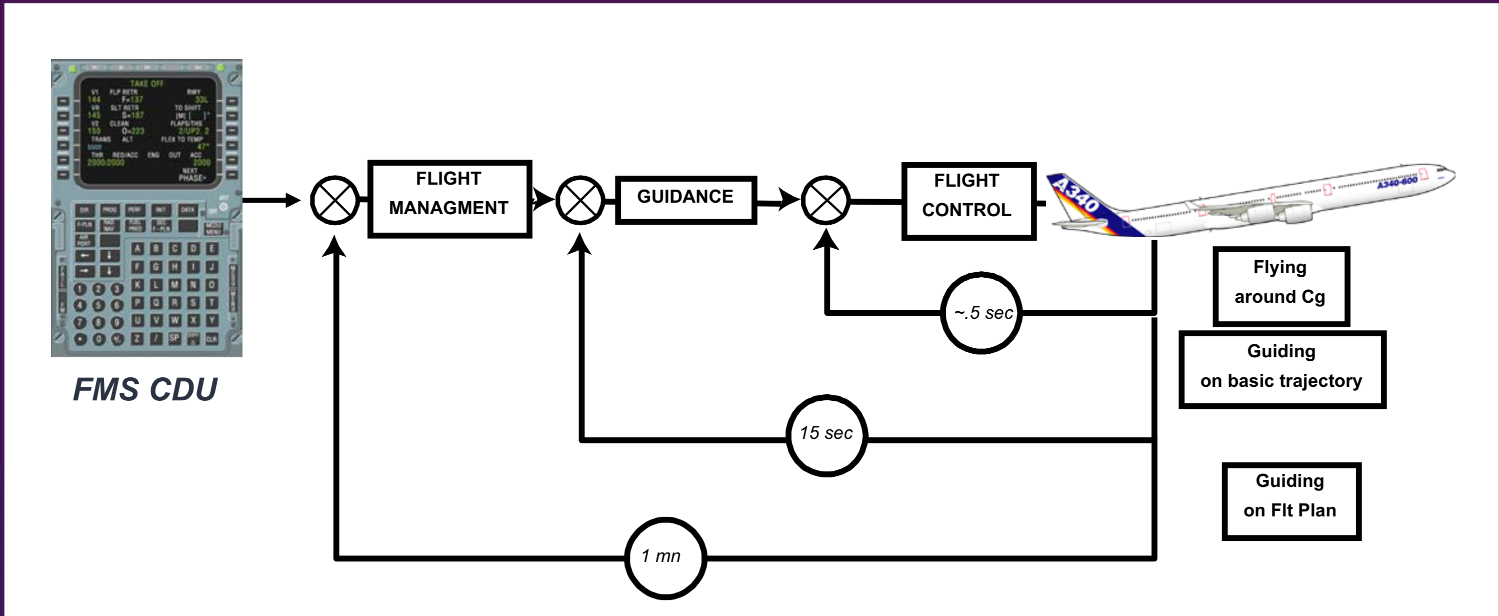
1945 - 1982: NAVIGATION RAW DATA & BASIC DISPLAYS

1982: A310, NAVIGATION FIRST REVOLUTION,

GLASS COCKPITS & FMS

1987: A320, NAVIGATION GPS SECOND REVOLUTION, AFS/FMS INTEGRATION

NAVIGATION TASK AUTOMATION

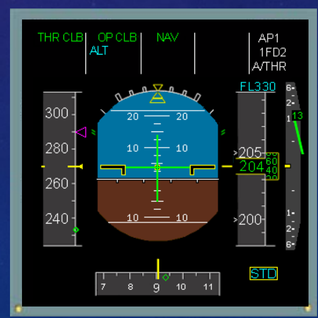


Loop 3: Navigation Loop

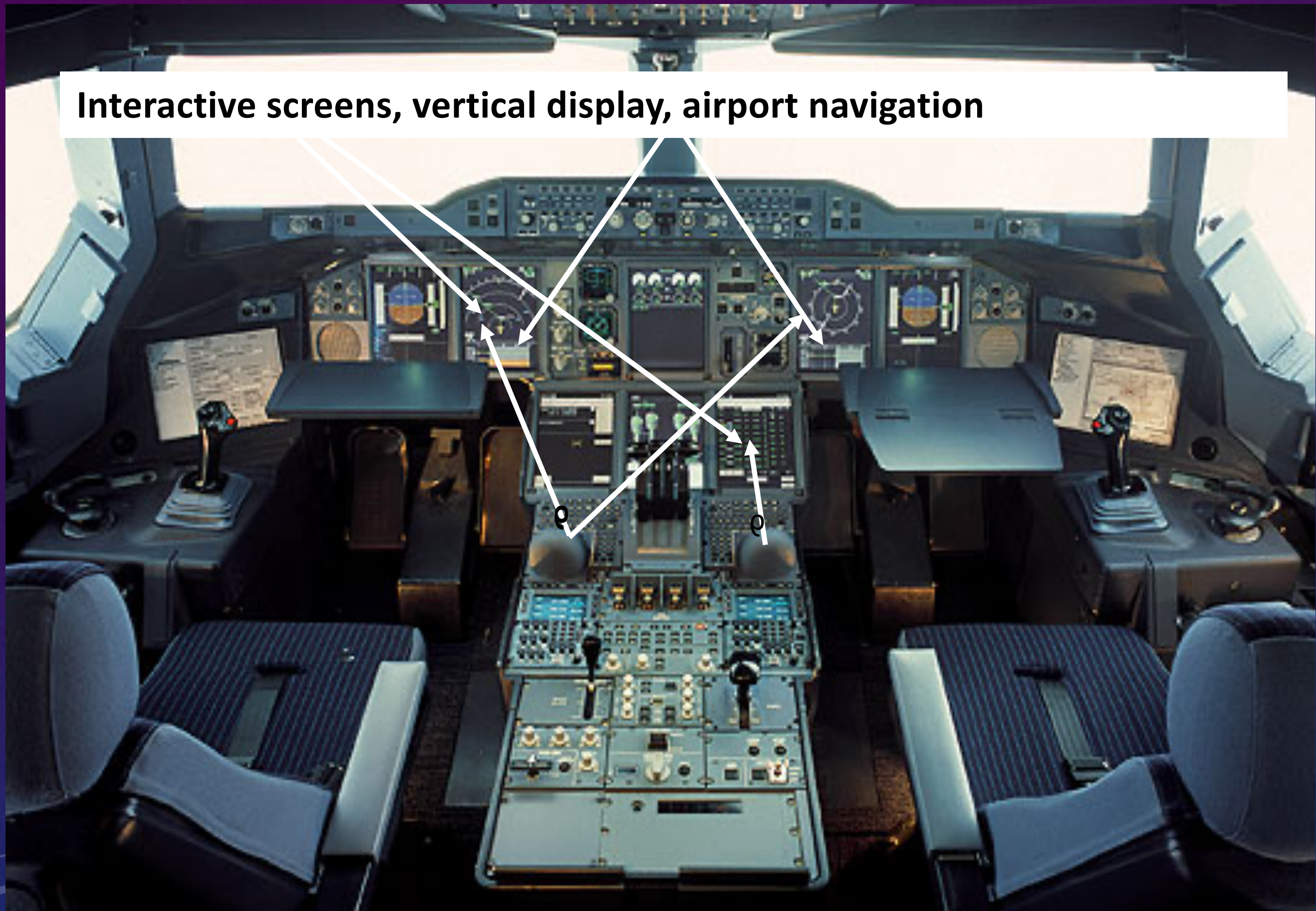
AUTOMATION CONSEQUENCES : EFFICIENT MONITORING

- Automation induced a new task for the pilot: **monitoring**
  - Evolution from Conventional Dials to Display Units (CRT then LCD)
  - Judiciously and realistically displayed information becomes necessary

    (e.g., “need to show” …)



FROM CONTROL TO MANAGEMENT…



2005: A380,

3RD LOOP OF AUTOMATION

IMPROVED HMI FOR

EFFICIENT MONITORING

COMMUNICATION
– ATM LATEST CONCEPTS:
FOURTH LOOP OF AUTOMATION

1990S : AIRSPACE SATURATION PROBLEMS

In the 90s, 2 types of saturation problems did arise:

- **Saturation of communications** between pilot and controller
- **Saturation of airspace** due to the management of air traffic and airspace by ATC

1945 - 1987: COMMUNICATE, VOICE COMMUNICATION

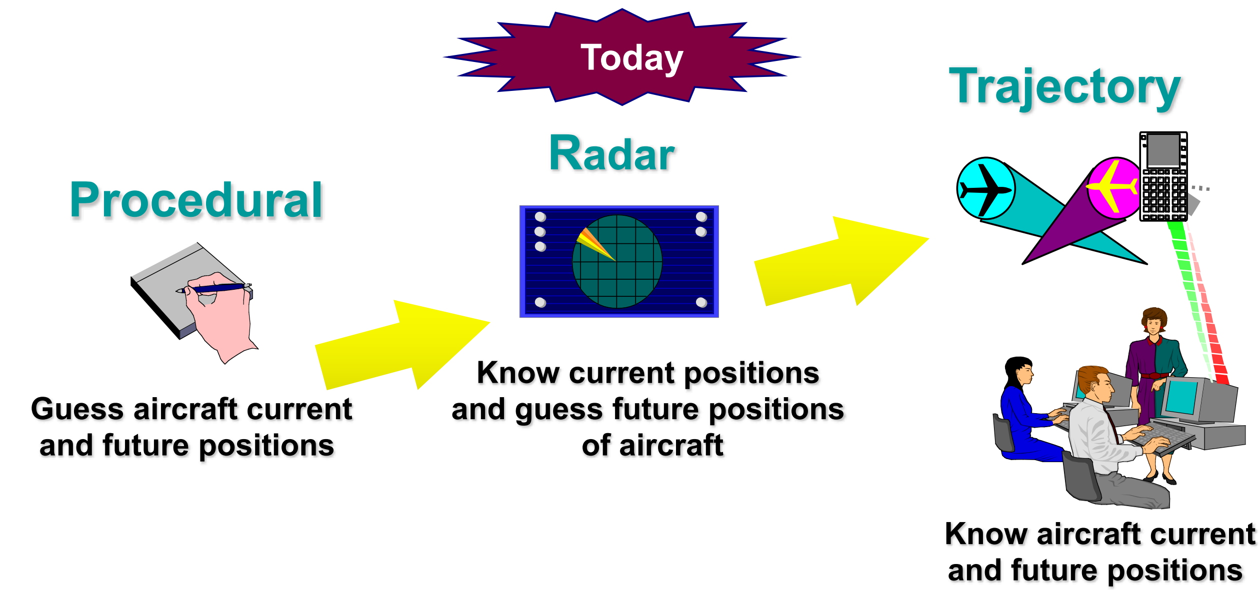
1987: COMMUNICATE, VOICE & AOC DATALINK

Aircraft Communication Addressing and Reporting System (ACARS)
Aeronautical operational control (AOC)

1995 ONWARDS: COMMUNICATE, DATALINK & FANS

Future Air Navigation Systems (FANS)

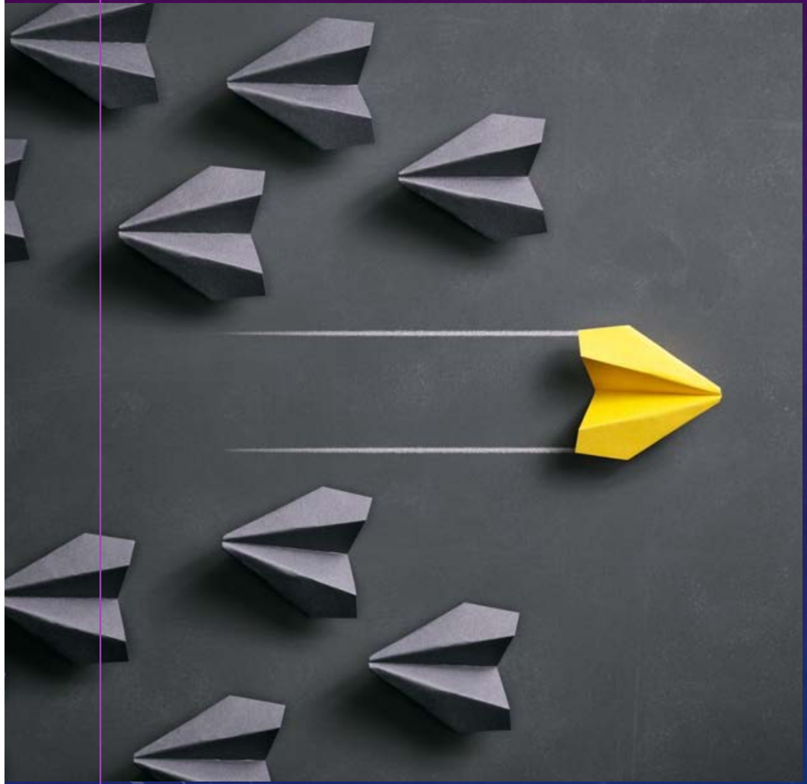
ATM evolution from a procedural control to a trajectory control



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

WHAT ANSWER TO AIR SPACE SATURATION PROBLEMS?

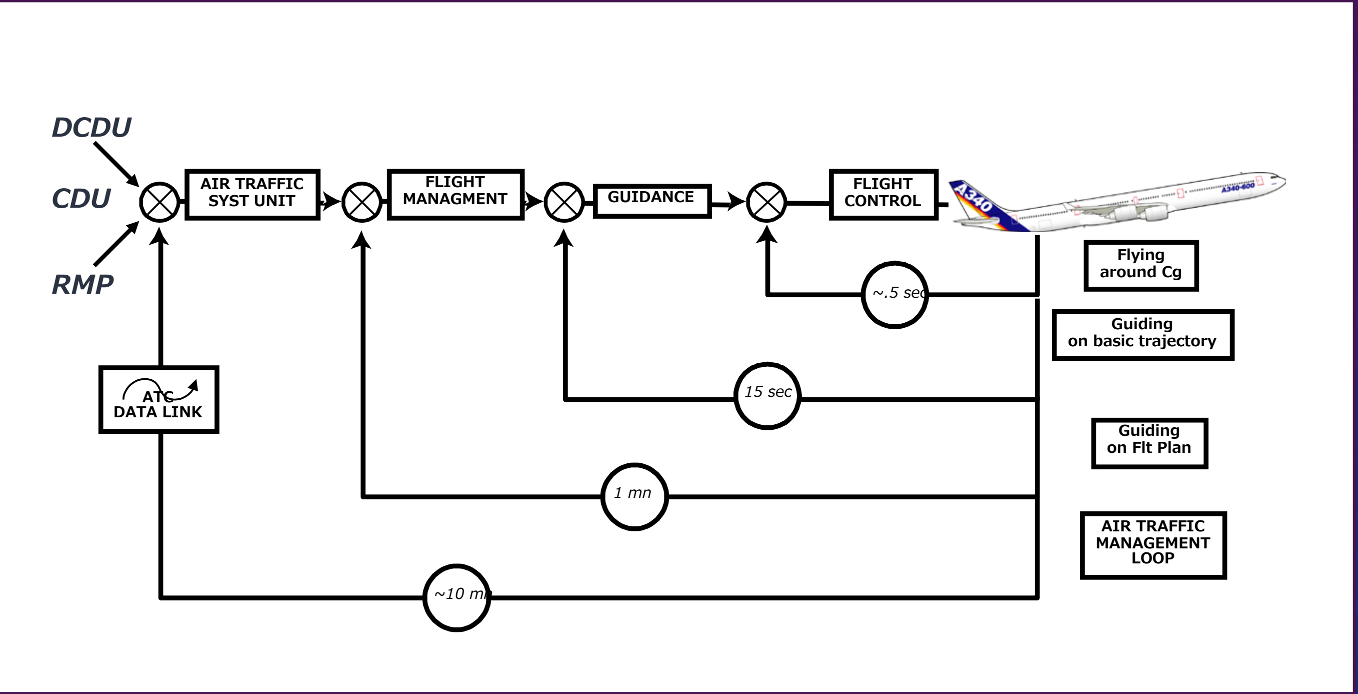
HISTORICAL PERSPECTIVE OF ATC



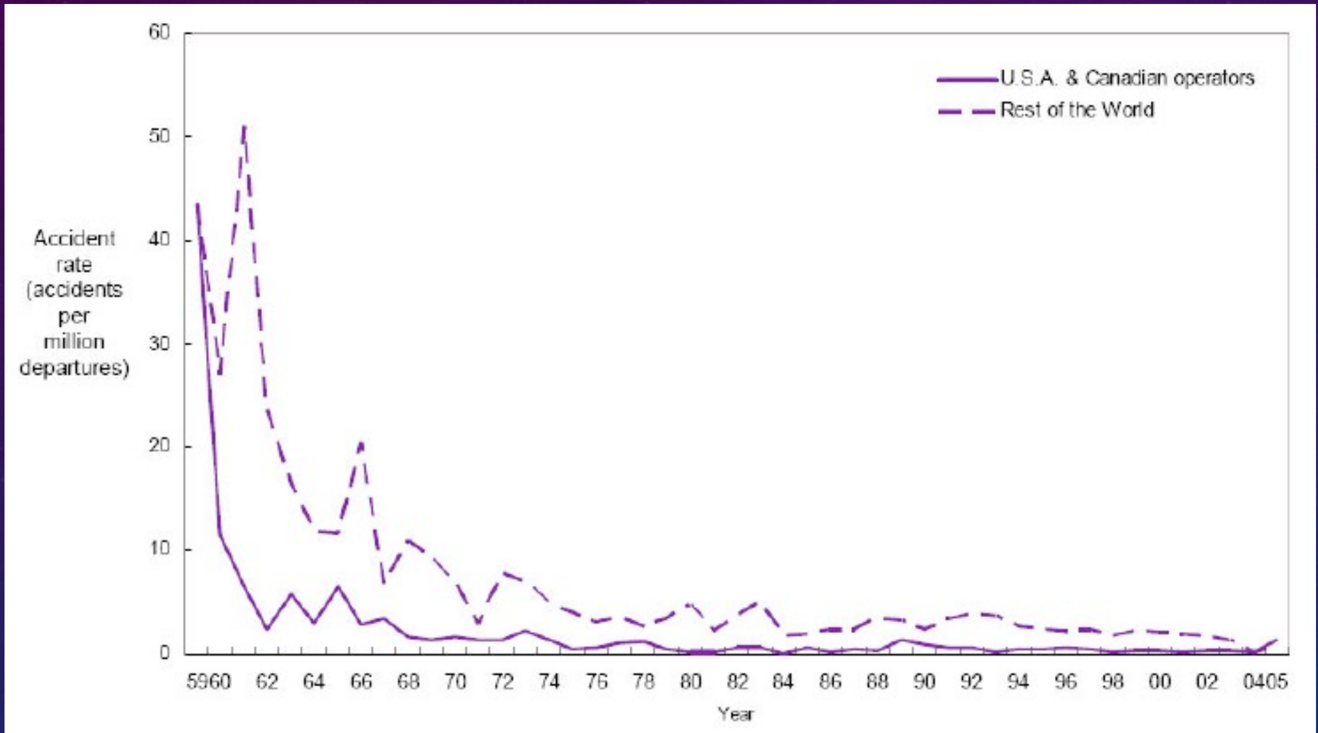
- Historical perspective of ATC
    - 1920/30s: radio beacons, ATC loosely coupled, manually operated, local *autonomy*
    - 1940s-60s: radar, VHF/VOR international standardization
    - 1960/70s: secondary surveillance *centralization, increasing complexity*
    - 1980s-2000: ACAS/TCAS semi-automated system, *decentralization*
    - 2000s: ADS-B global ATC system (Free-flight?)
- ADS-B - key element of new architecture of air transportation
    - From central control to decentralized self-coordination
    - New distribution of responsibility?
    - Aircraft: coordination, separation
    - Increased autonomy
    - Relying on automation
- ATM: supervision

Airborne Collision Avoidance Systems (ACAS)
Traffic alert & Collision Avoidance System (TCAS)
Automatic Dependent Surveillance–Broadcast (ADS–B)

AUTOMATION OF COMMUNICATION TASK : 4TH LOOP



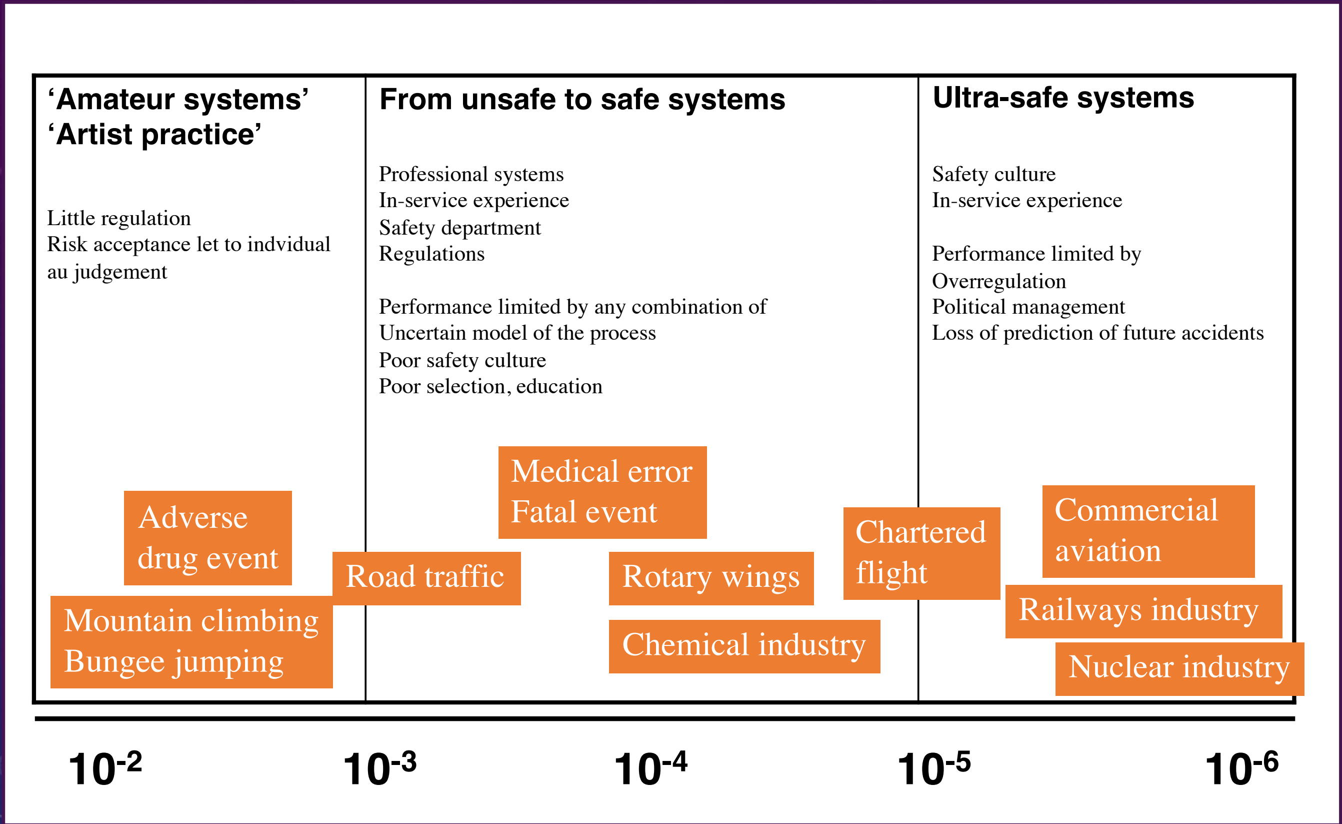
- Fourth automation loop called “ATM Loop”



ACCIDENT RATES (HULL LOSS AND FATAL ACCIDENTS)

2005 statistical summary,

May 2006, Source Boeing



SAFETY-CRITICAL SYSTEM CATEGORIES

(FROM AMALBERTI, 2001)

10 HIGH LEVEL DESIGN RULES

AIRBUS COCKPIT DESIGN CONCEPTS: 10 HIGH LEVEL RULES

1. The pilot is ultimately responsible for the safe operation of the aircraft. He has final authority with adequate information and means to exercise this authority

2. The full authority, when required, is obtained with simple intuitive actions, while aiming at eliminating the risks of overstress or over-control.

3. The design of a cockpit accommodates for a wide range of pilot skill levels and experience acquired on previous aircraft.

4. The design of a cockpit is dictated by safety, passenger comfort and efficiency in that order of priority.

5. The cockpit design aims at simplifying the crew's tasks, by enhancing situation and aircraft status awareness.

AIRBUS COCKPIT DESIGN CONCEPTS: 10 HIGH LEVEL RULES

6
- The automation is considered as a complement available to the pilot, who can decide when to delegate and what level of assistance is desirable, according to the situation

7
- Human machine interfaces are designed considering system features, together with pilot's strengths and weaknesses.

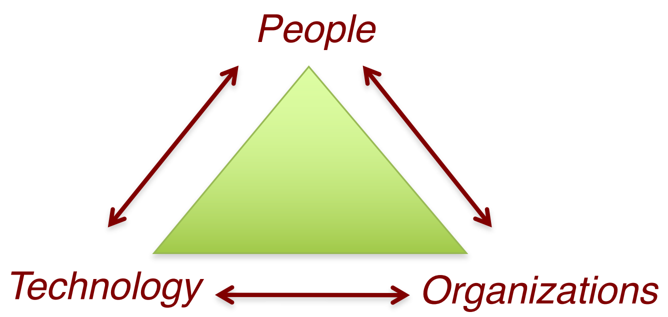
8
- The overall cockpit design facilitates crew communication.

9
- State of the art human factors considerations are applied in the system design process to manage the potential pilots' errors.

10
- The use of new technologies and implementation of new functionality's are dictated by:
    - **Significant safety benefits**
    - **Obvious operational advantages**
    - **A clear response to the pilot's needs**

INCREMENTAL ADAPTATION

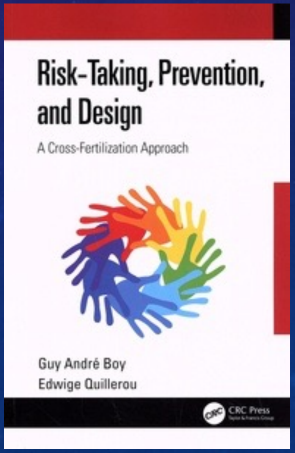
- Adaptation of Technology
- Adaptation of the Organization
- Adaptation of People



TOP Interaction !!!

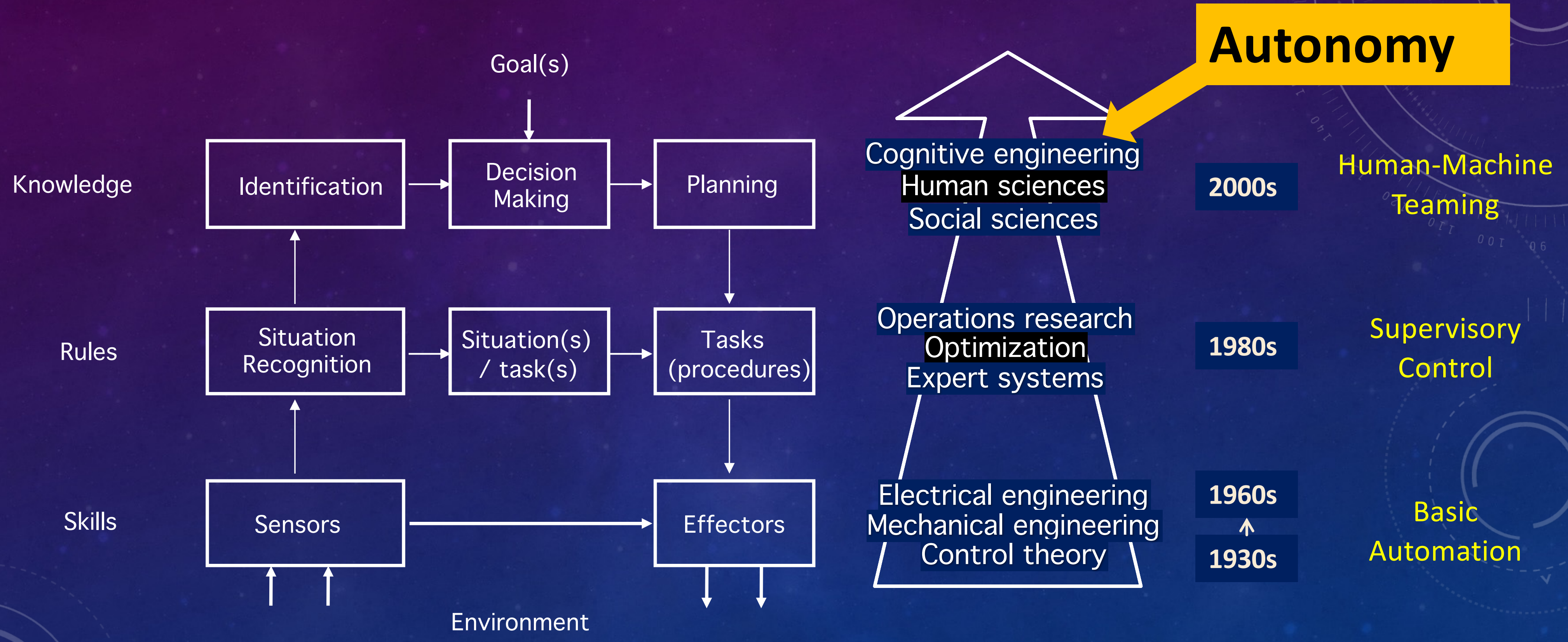
NO ADAPTATION WITHOUT RISK

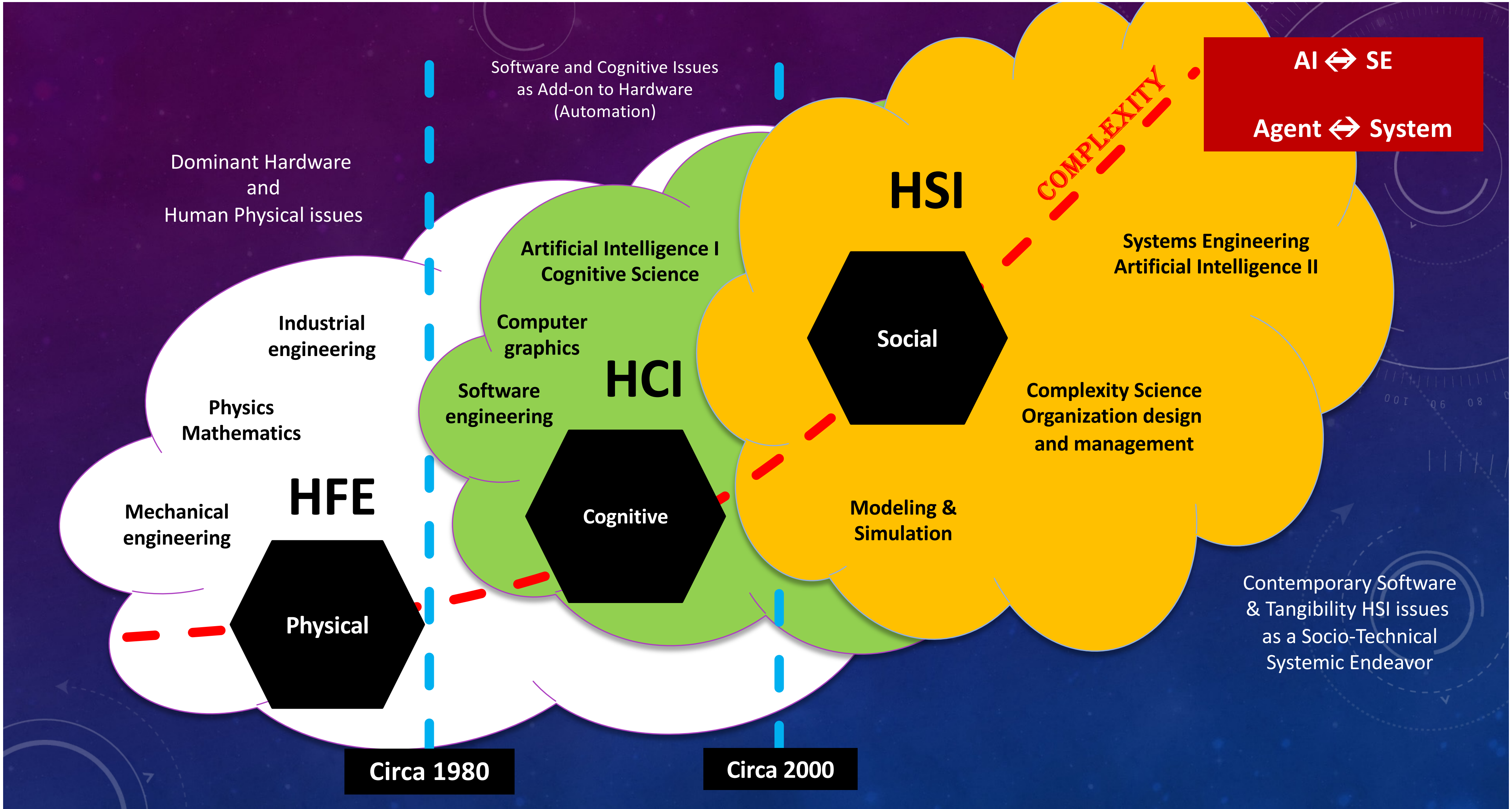
- Risk taking and management…
  - Legal and operational
  - Psychology and law
  - Preparation of risky operations
  - Responsibility
  - Individual and collective risks
  - Organizational risks



FROM AUTOMATION TO AUTONOMY…

… and emergence of contributing disciplines (Rasmussen's model)

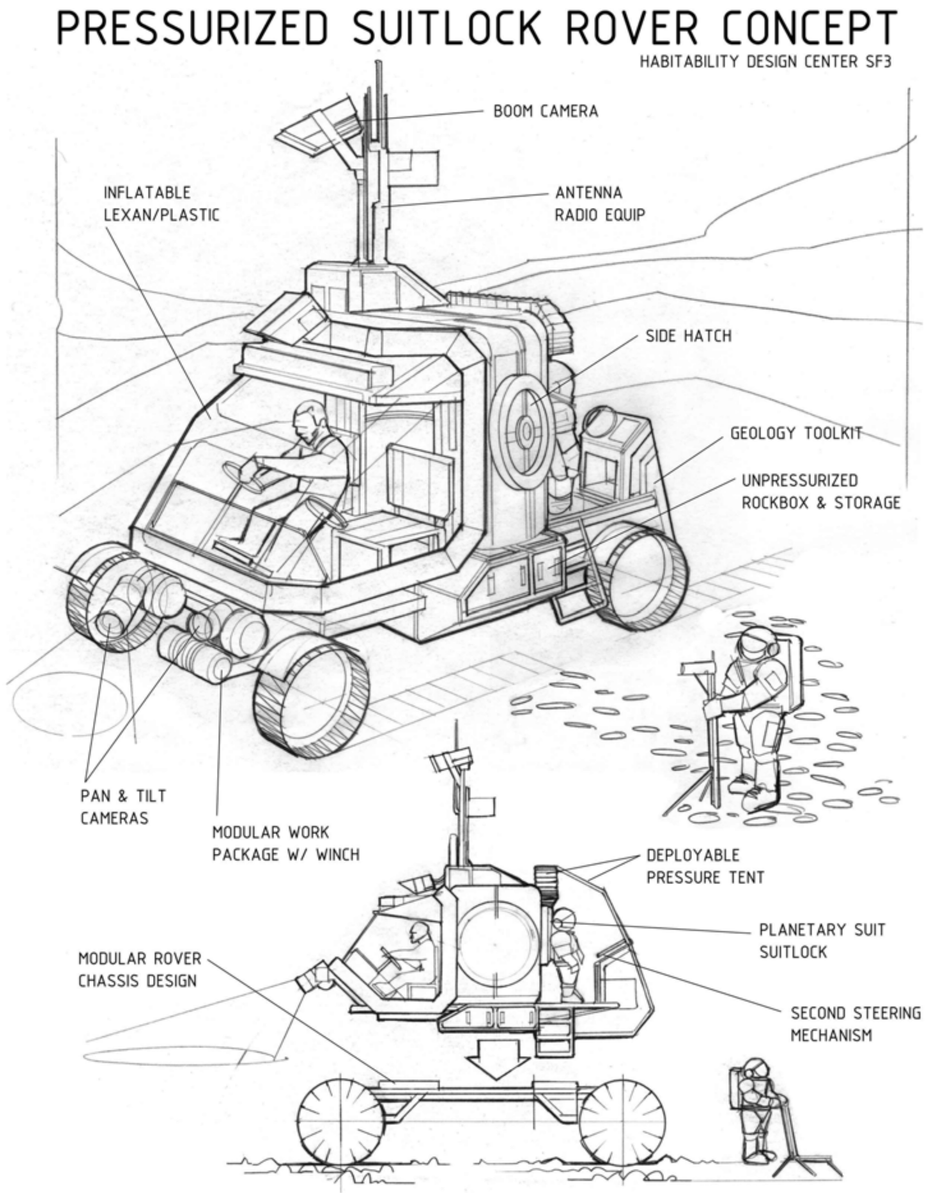



Software and Cognitive Issues
as Add-on to Hardware
(Automation)
Dominant Hardware
and
Human Physical issues
AI ⇔ SE
Agent ⇔ System
COMPLEXITY
HSI
Systems Engineering
Artificial Intelligence II
Social
Complexity Science
Organization design
and management
Modeling &
Simulation
Artificial Intelligence I
Cognitive Science
Computer
graphics
HCI
Software
engineering
Cognitive
Industrial
engineering
Physics
Mathematics
HFE
Mechanical
engineering
Physical
Contemporary Software
& Tangibility HSI issues
as a Socio-Technical
Systemic Endeavor
Circa 1980
Circa 2000

Creativity
as
Synthesis
and
Integration

LUNAR ELECTRIC ROVER & VIRTUAL CAMERA

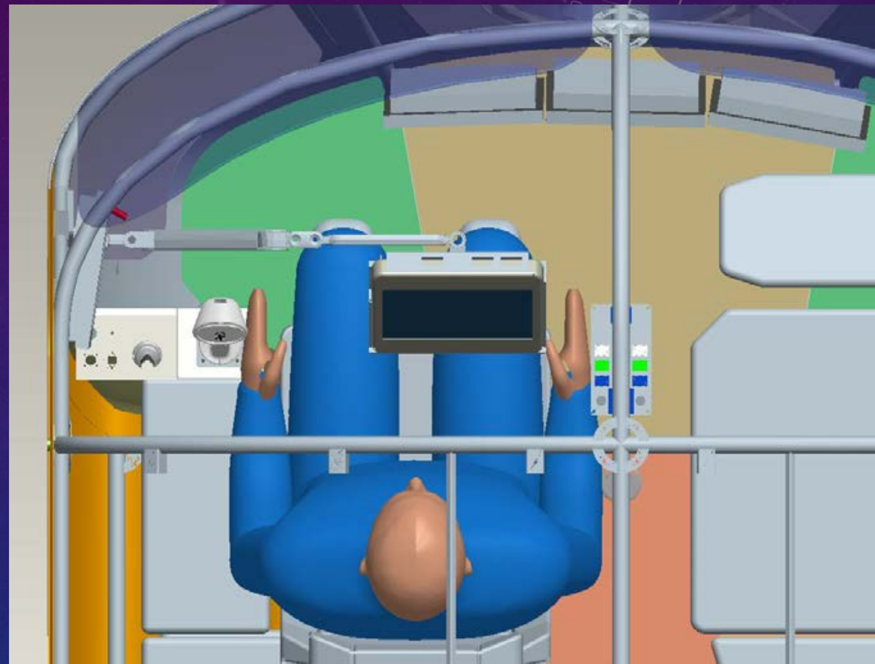

EVA Bluesky
Composing the Right Mix of Humans and Technology for Lunar Surface Exploration


PRESSURIZED SUITLOCK ROVER CONCEPT
HABITABILITY DESIGN CENTER SF3
BOOM CAMERA
INFLATABLE LEXAN/PLASTIC
ANTENNA RADIO EQUIP
SIDE HATCH
GEOLOGY TOOLKIT
UNPRESSURIZED ROCKBOX & STORAGE
PAN & TILT CAMERAS
MODULAR WORK PACKAGE W/ WINCH
DEPLOYABLE PRESSURE TENT
PLANETARY SUIT SUITLOCK
MODULAR ROVER CHASSIS DESIGN
SECOND STEERING MECHANISM

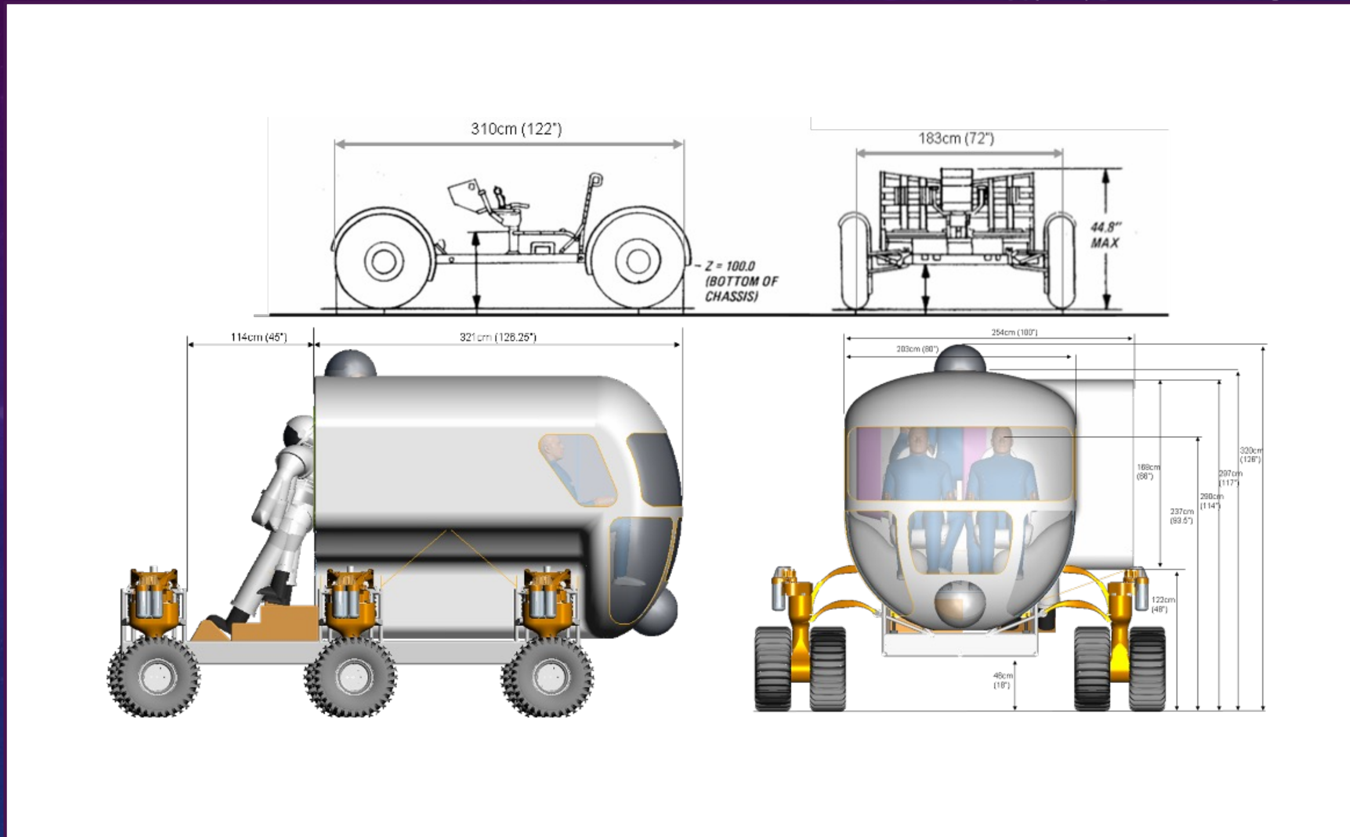
PARTICIPATORY DESIGN

STORYBOARDING

MODELING



MODELING


310cm (122")
183cm (72")
44.8" MAX
Z = 100.0 (BOTTOM OF CHASSIS)
114cm (45")
321cm (126.25")

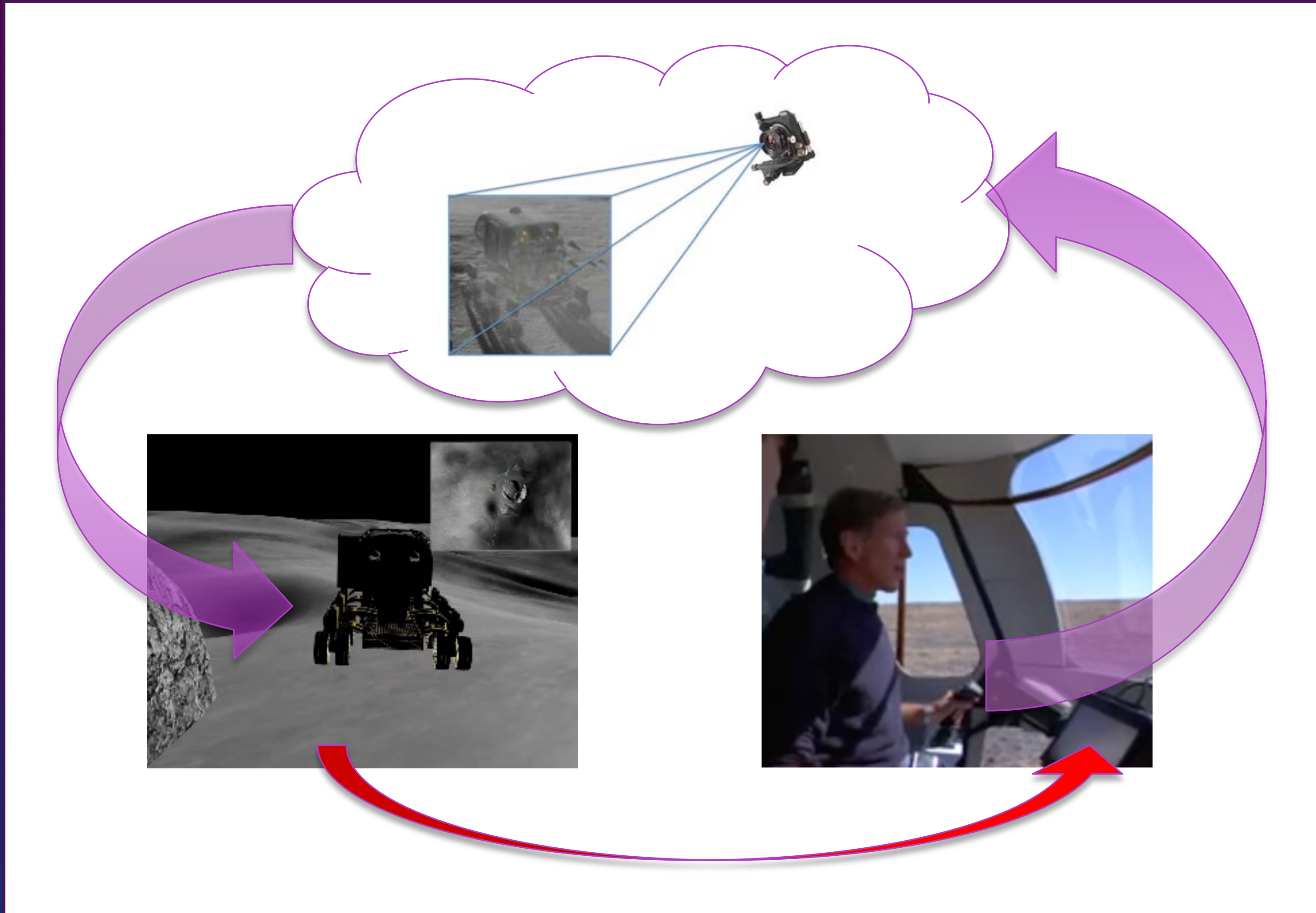
STORYTELLING

FIRST PROTOTYPE…

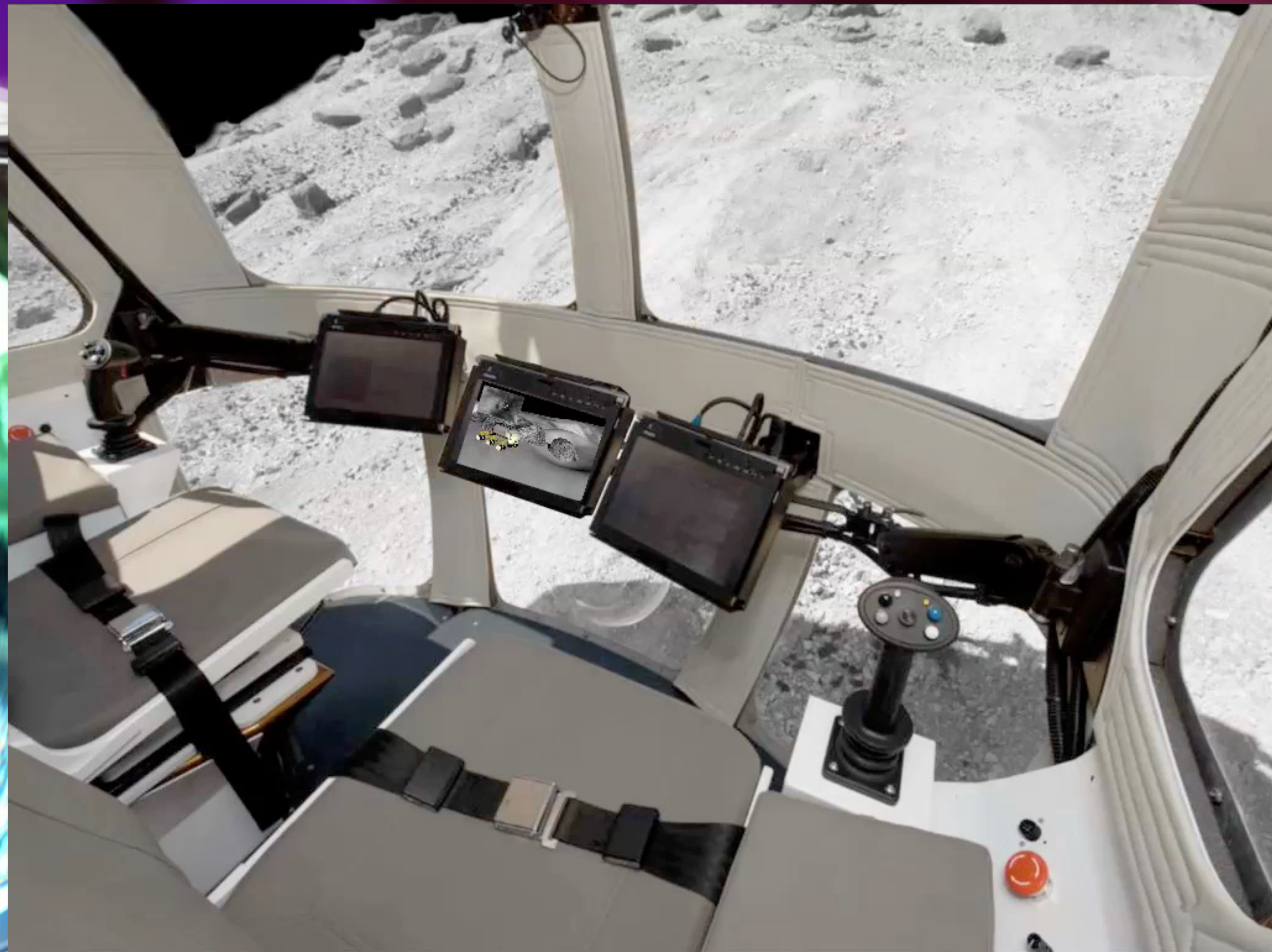
THE REAL THING…

ONCE IN FEBRUARY 2009…

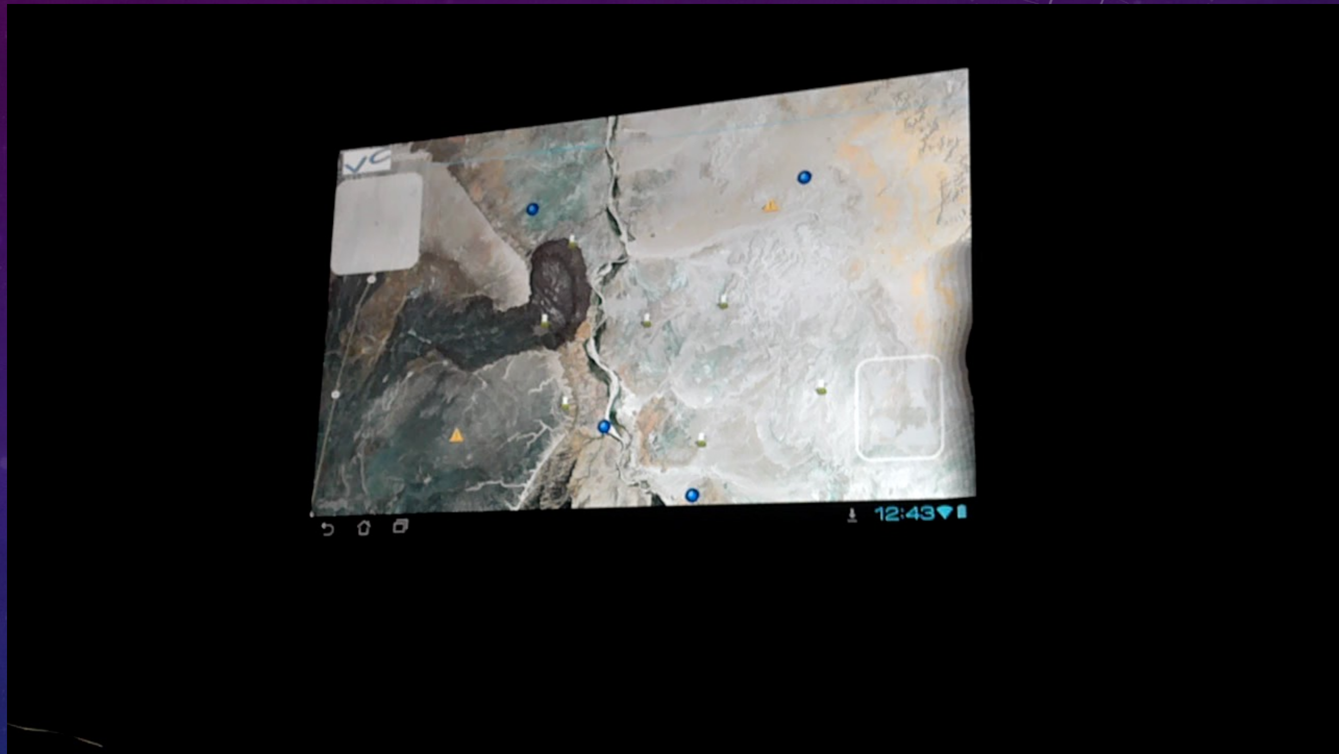
THE VIRTUAL CAMERA



THE VIRTUAL CAMERA



THE VIRTUAL CAMERA

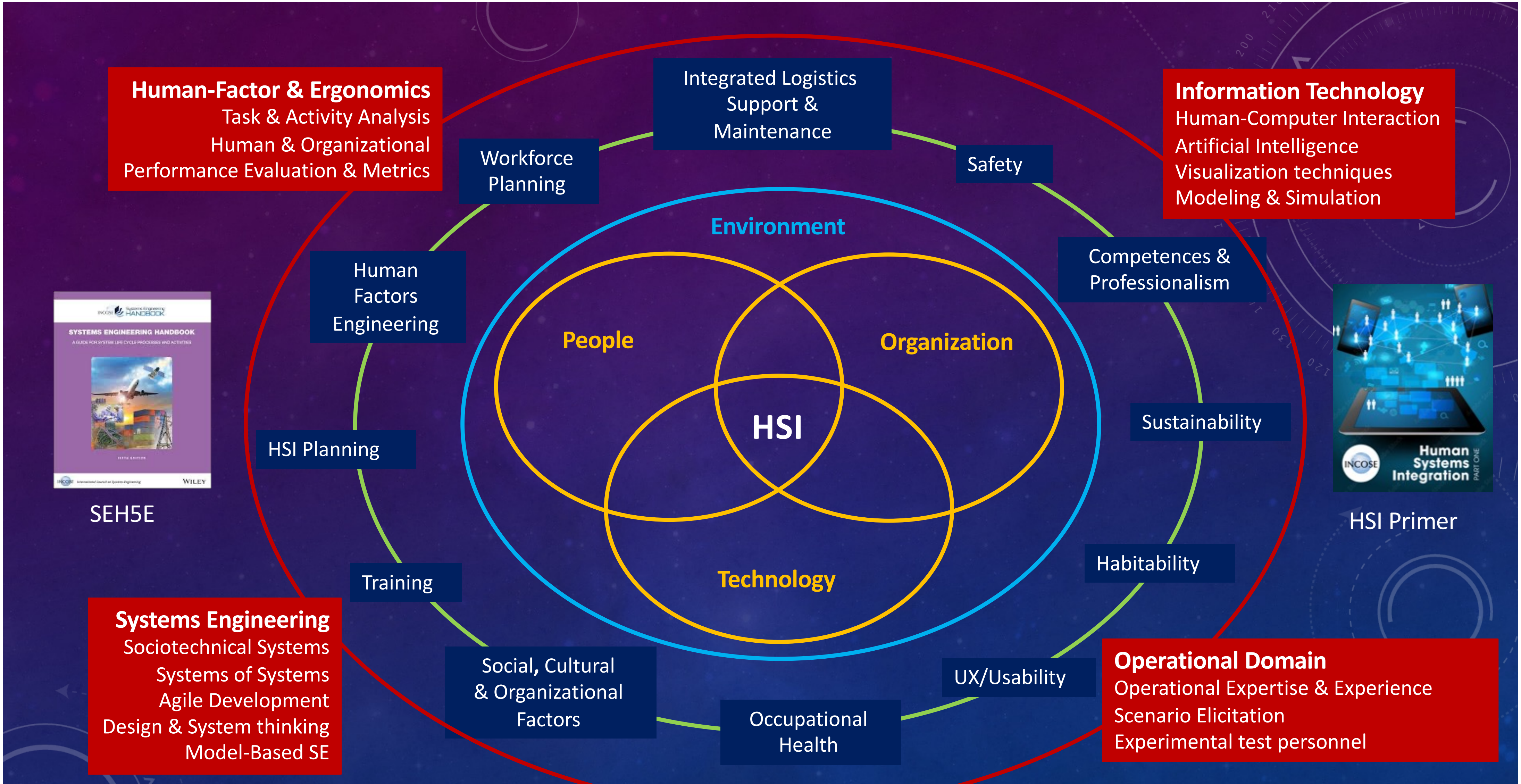


VIRTUAL CAMERA: OTHER POTENTIAL APPLICATIONS

- Disaster response personnel
- More field-based testing in more remote locations
- (longer, larger-scale field tests)
  - Train users and allow them to use device in the field for their own work
- Onboard Weather Situation Awareness System (OWSAS)
- Glass Wall for the next NASA KSC control room

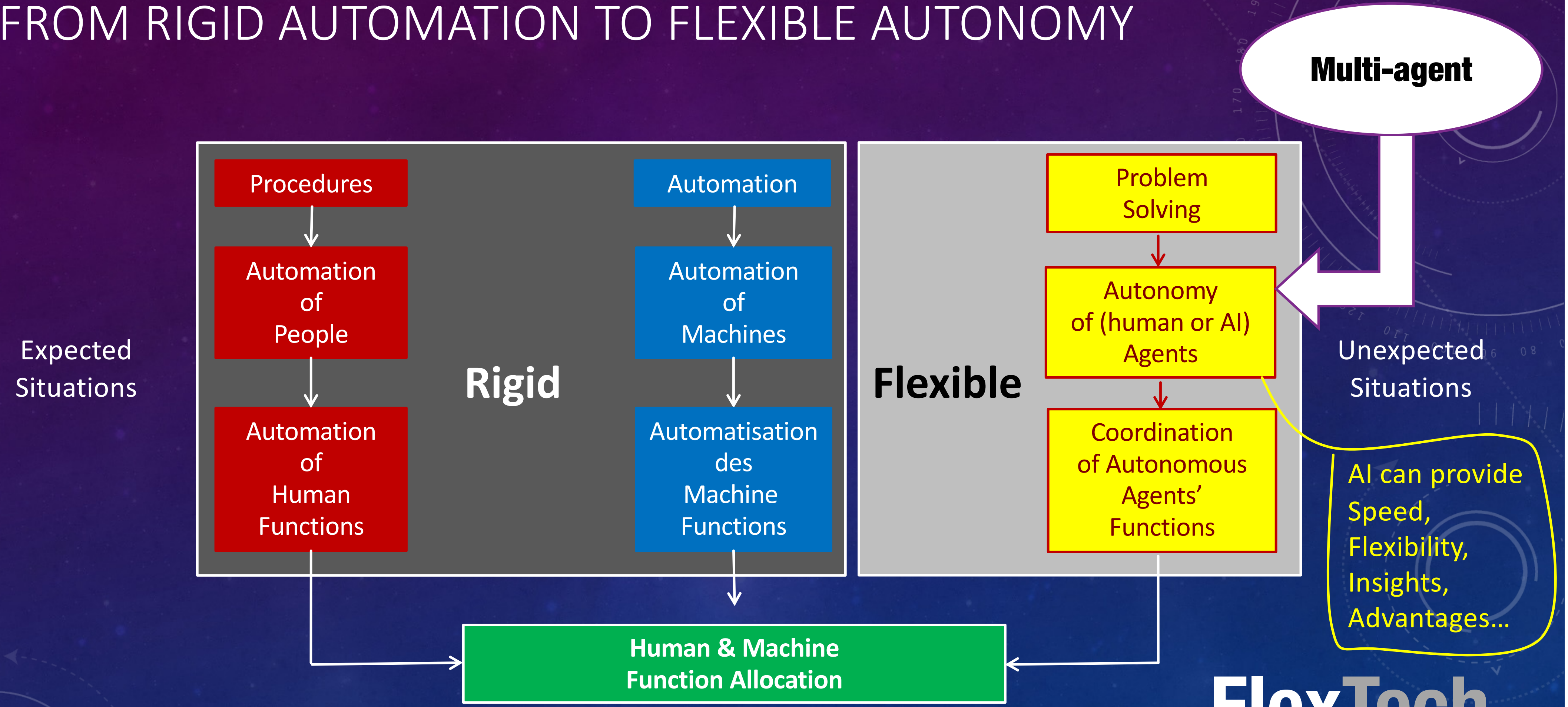
CURRENT EVOLUTION…

HUMAN SYSTEMS INTEGRATION…



https://www.incose.org/incose-member-resources/working-groups/analytic/human-systems-integration

FROM RIGID AUTOMATION TO FLEXIBLE AUTONOMY



FlexTech
CentraleSupélec-ESTIA Chair

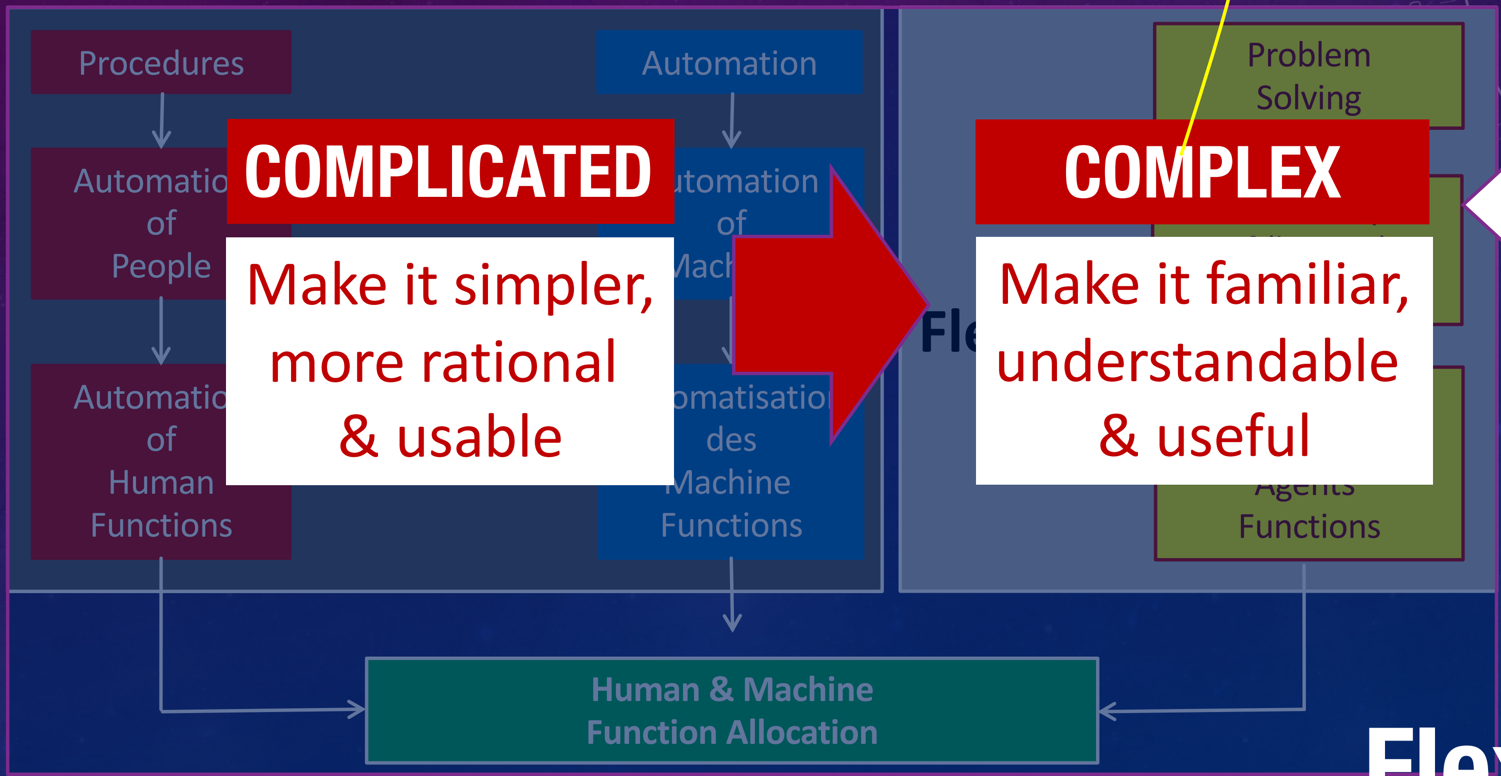
https://www.sciencedirect.com/science/article/pii/S0160791X23001033

FROM RIGID AUTOMATION TO FLEXIBLE AUTONOMY

Involves Maturity

Multi-agent

Expected Situations



Unexpected Situations

FlexTech

CentraleSupélec-ESTIA Chair

https://www.sciencedirect.com/science/article/pii/S0160791X23001033

READINESS LEVELS

Technology (TRL)

Human (HRL)

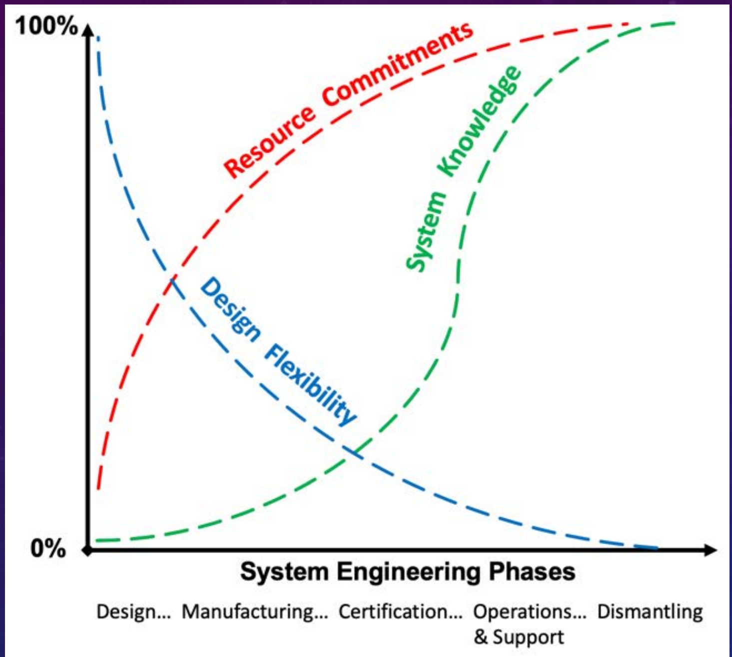
HRL	Description
1	Relevant human capabilities, limitations, and basic human performance issues and risks identified
2	Human-focused concept of operations defined and human performance design principles established
3	Analyses of human operational, environmental, functional, cognitive, and physical needs 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

Organization (ORL)

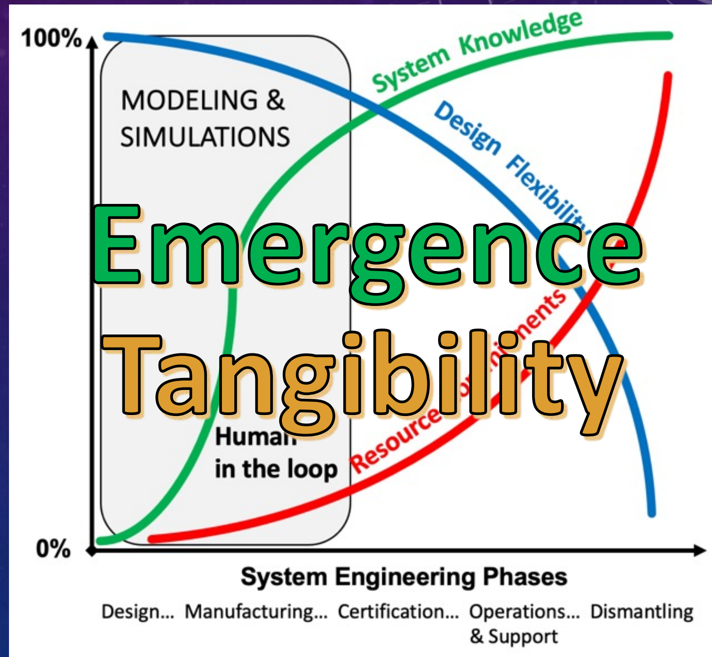
ORL-0	**First principles where potential organizational models are explored.**
ORL-1	Goal-oriented research that requires making choices from first principles to practical fully digital organizational setups
ORL-2	Proof of principle development, and active R&D is started in a virtual environment
ORL-3	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

https://www.sciencedirect.com/science/article/pii/S0160791X23001033

TECHNOLOGY-CENTERED ENGINEERING: LATE IN LIFE CYCLE



HUMAN-CENTERED DESIGN: WHAT WE REALLY WANT



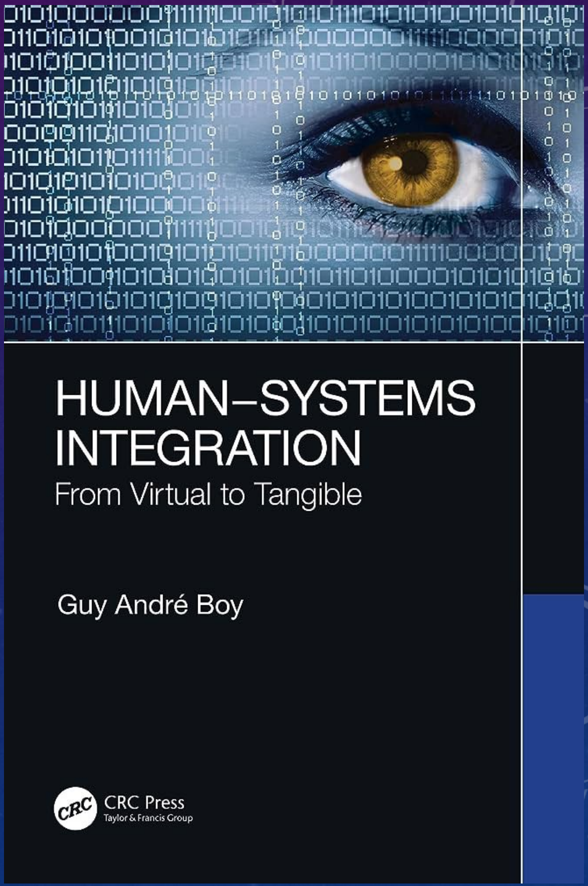
https://www.sciencedirect.com/science/article/pii/S0160791X23001033

FlexTech
CentraleSupélec-ESTIA Chair

REFERENCES

- Boy, G.A., Masson, D., Durnerin, E. & Morel C. (2024). PRODEC for Human Systems Integration of Increasingly Autonomous Systems. *Systems Engineering Journal*. Wiley, USA.
- Boy, G.A. (2023). An epistemological approach to human systems integration. *Technology in Society Journal*, 102298. https://doi.org/10.1016/j.techsoc.2023.102298.
- Boy, G.A. (2023). Uncertainty management in human systems integration of life-critical systems. In Griffin, Mark A., and Gudela Grote (eds). The Oxford Handbook of Uncertainty Management in Work Organizations (online edn, Oxford Academic, 20 Oct. 2022), Oxford University Press, UK, accessed 6 Dec. 2022.
- 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.
- Boy, G.A. (2021). Design for Flexibility - A Human Systems Integration Approach. Springer Nature, Switzerland. ISBN: 978-3-030-76391-6.
- Boy, G.A. (2021). Socioergonomics: A few clarifications on the Technology-Organizations-People Tryptic. Proceedings of INCOSE HSI2021 International Conference, Wiley Online Lib.
- Boy, G.A. (2020). *Human Systems Integration: From Virtual to Tangible*. CRC Press – Taylor & Francis Group, USA (https://www.taylorfrancis.com/books/9780429351686).

THANK YOU!



guy-andre.boy@centralesupelec.fr