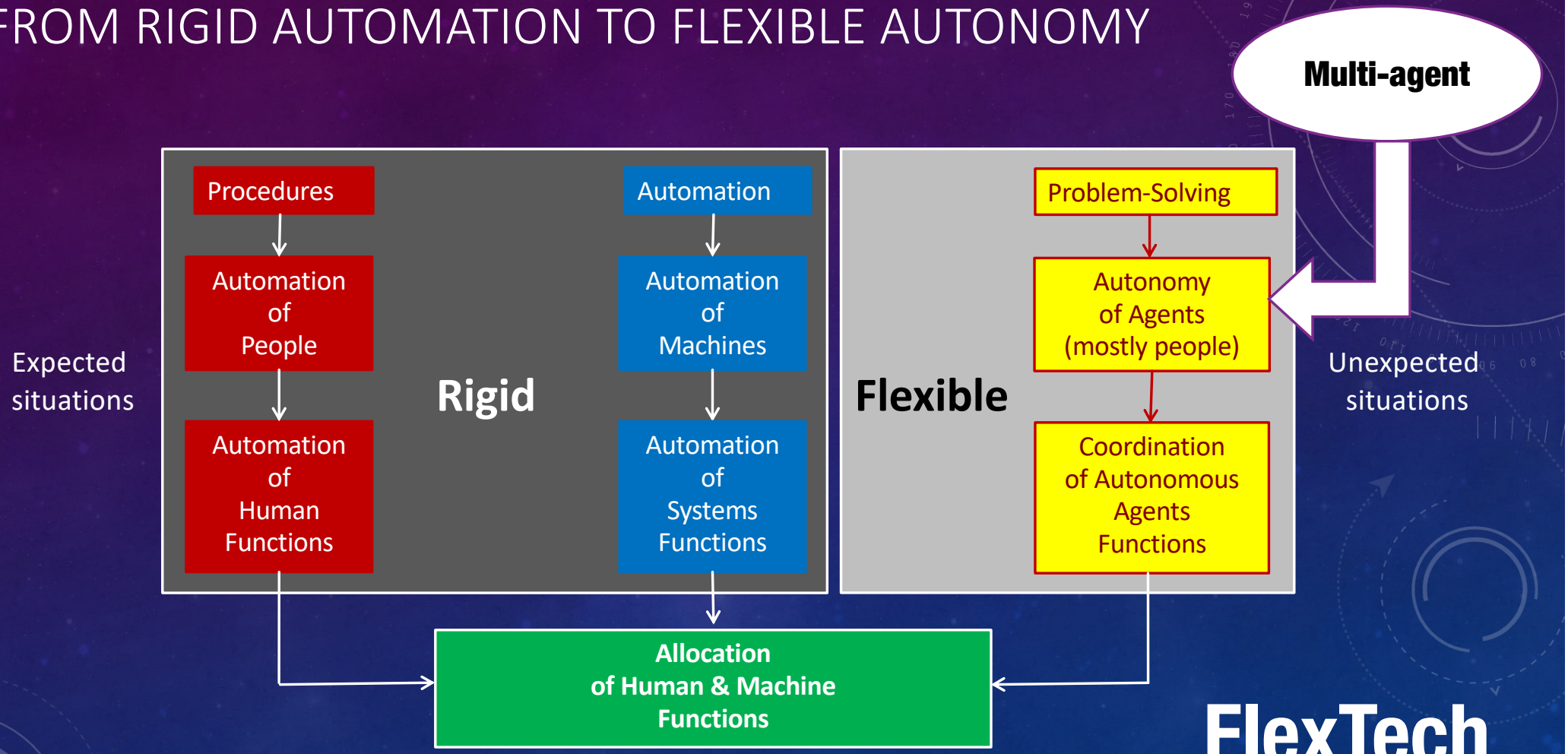
# PROBLEM-SOLVING & PROCEDURES:
## HOW PEOPLE HANDLE UNEXPECTED SITUATIONS

PROF. GUY ANDRÉ BOY

# OUTLINE

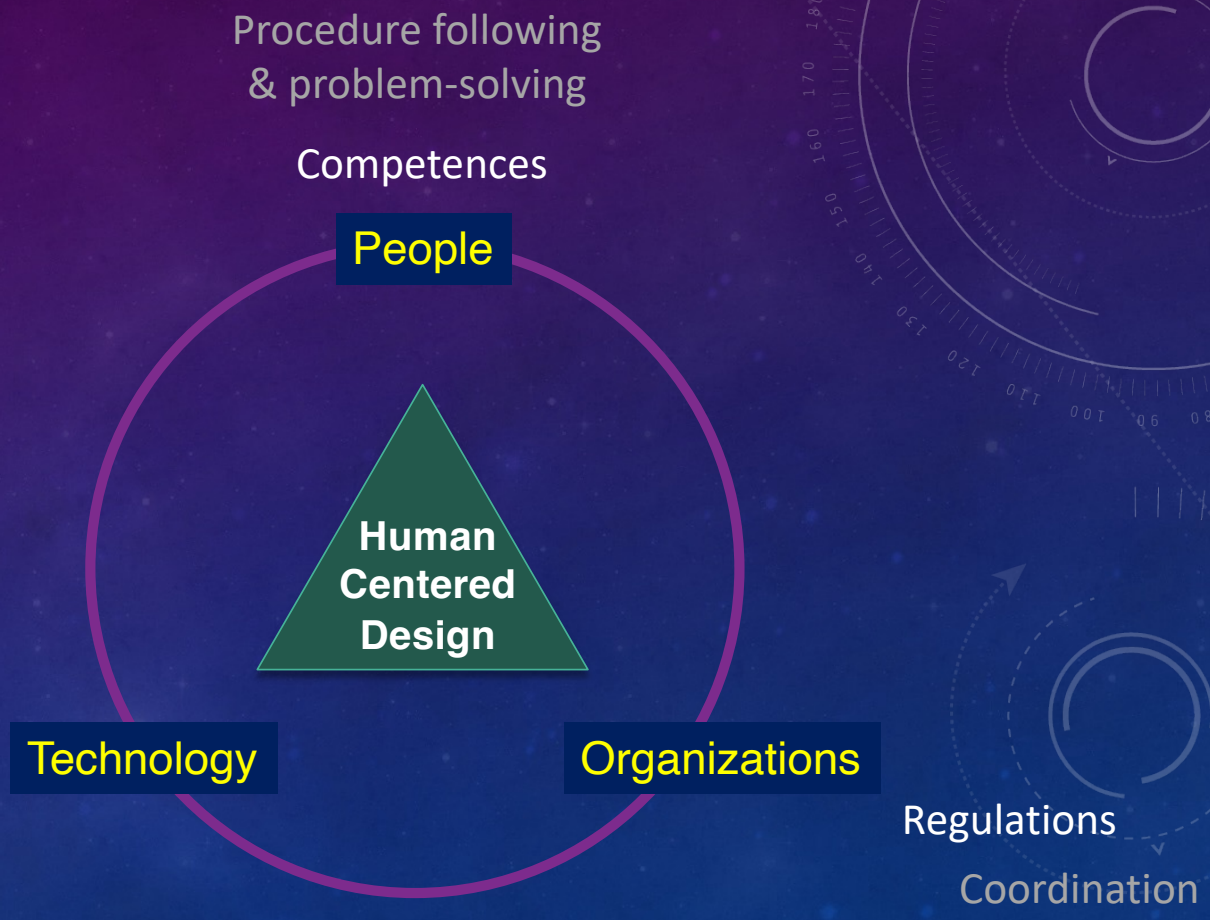
- The lecture is about procedures, automation and problem solving in life-critical systems
- What are human factors that matter?
- Talking about competence: combining creativity, knowledge and experience
- Dealing with uncertainty and unexpected events
- How could human and artificial intelligence complement each other?
- The complexity of human machine teaming: the maturity issue
- Constructing a vision: from short-term prediction to longer-term possible futures
- Starting a discussion: Risk taking, prevention and design

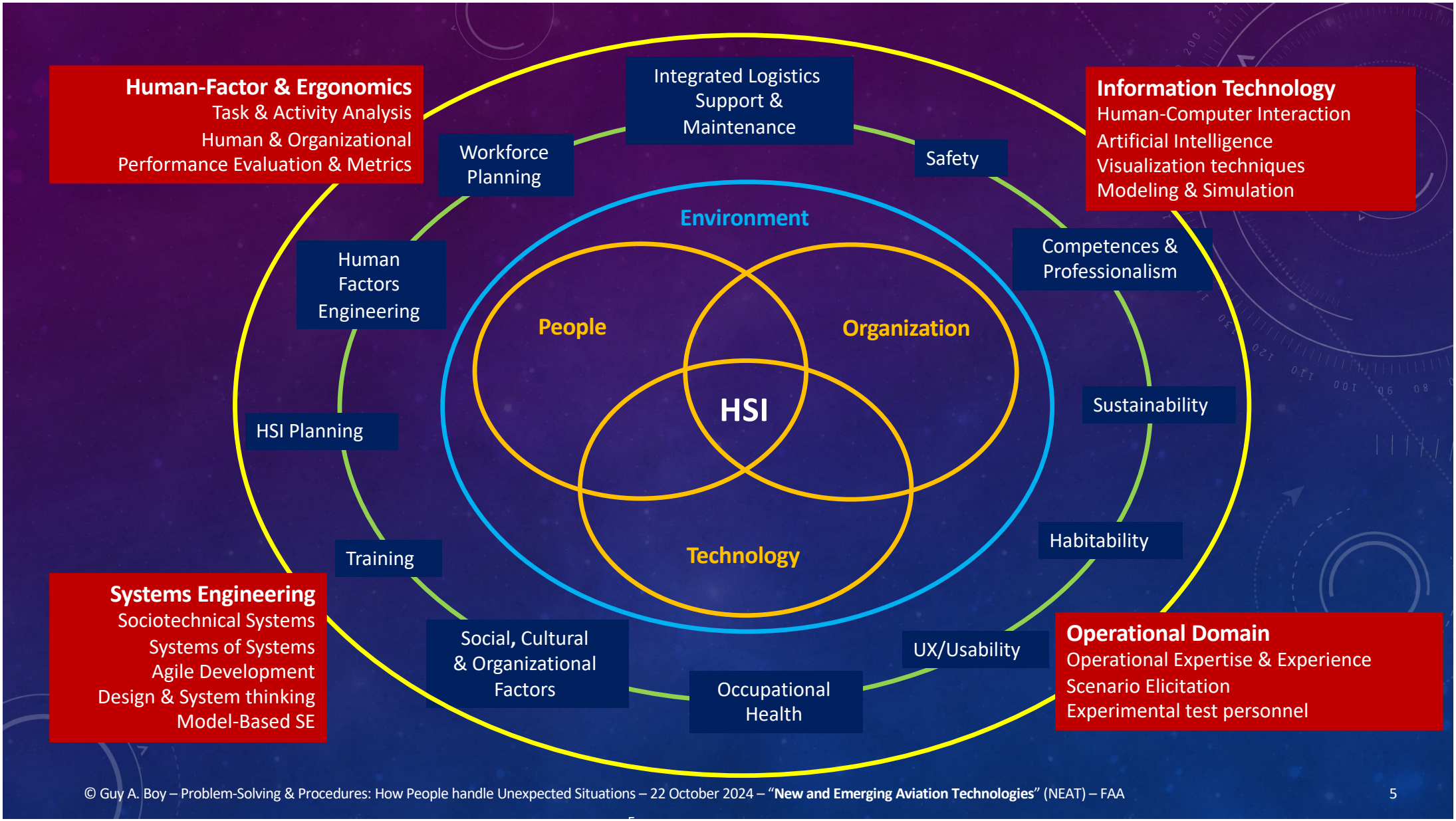
# FROM RIGID AUTOMATION TO FLEXIBLE AUTONOMY




FlexTech

# THE T.O.P. MODEL…



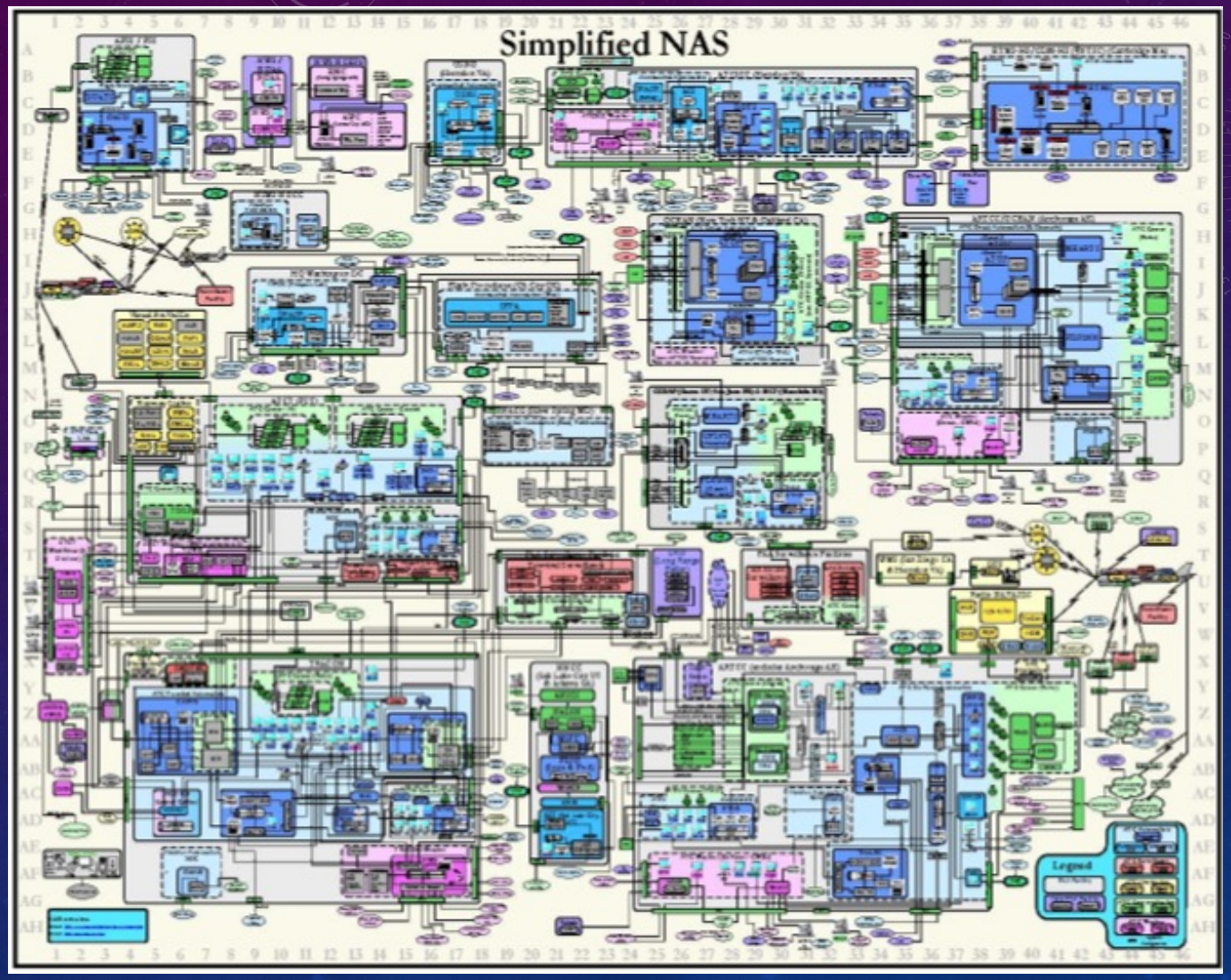

Human-Factor & Ergonomics
Task & Activity Analysis
Human & Organizational
Performance Evaluation & Metrics
Integrated Logistics Support & Maintenance
Workforce Planning
Safety
Information Technology
Human-Computer Interaction
Artificial Intelligence
Visualization techniques
Modeling & Simulation
Environment
Human Factors Engineering
Competences & Professionalism
People
Organization
HSI
Sustainability
HSI Planning
Training
Habitability
Technology
Systems Engineering
Sociotechnical Systems
Systems of Systems
Agile Development
Design & System thinking
Model-Based SE
Social, Cultural & Organizational Factors
UX/Usability
Occupational Health
Operational Domain
Operational Expertise & Experience
Scenario Elicitation
Experimental test personnel

# COMPETENCE EVOLUTION…

- from flight quality control to management of embedded systems
- teaming up with machines increasingly equipped with artificial intelligence (human-machine teaming)
- integration of software concepts with physical concepts (adaptation to digital, keeping physical skills)
- articulation of physical tangibility [grasping a physical object, touching, physically feeling] and figurative (or cognitive) tangibility [grasping an abstract object, understanding, situation awareness]
- moving from rigid automation (especially in unexpected situations, where procedures and automata are out of context which creates dangerous rigidity) to flexible autonomy (solving problems in action)

# COMPLEXITY MANAGEMENT

- Simplify (use separability property)
- Familiarize
- Categorize
- Collaborative problem solving
- Develop a complexity culture based on experience/knowledge/skills management
- Develop and maintain experience feedback
- Use digital twin technology to support situation awareness, decision making and action taking

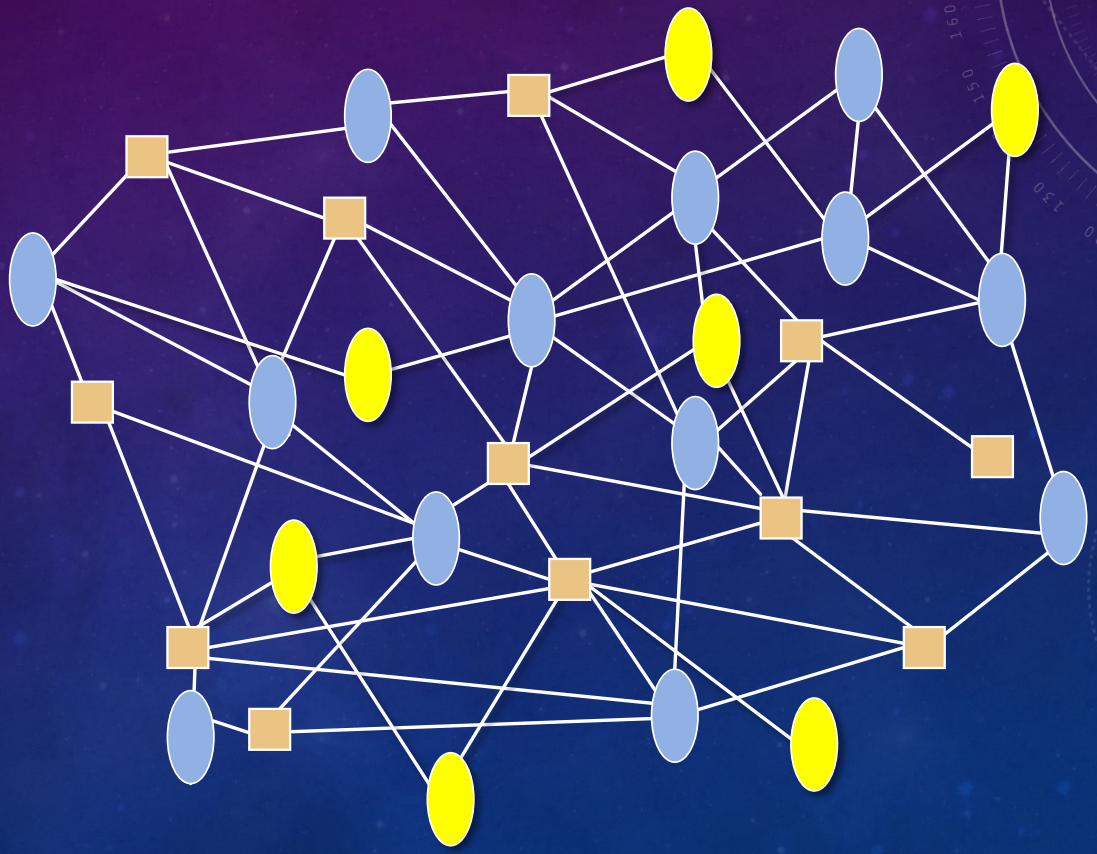

Simplified NAS
Legend

# A COMPLEX SYSTEM AS A LIVING ORGANISM

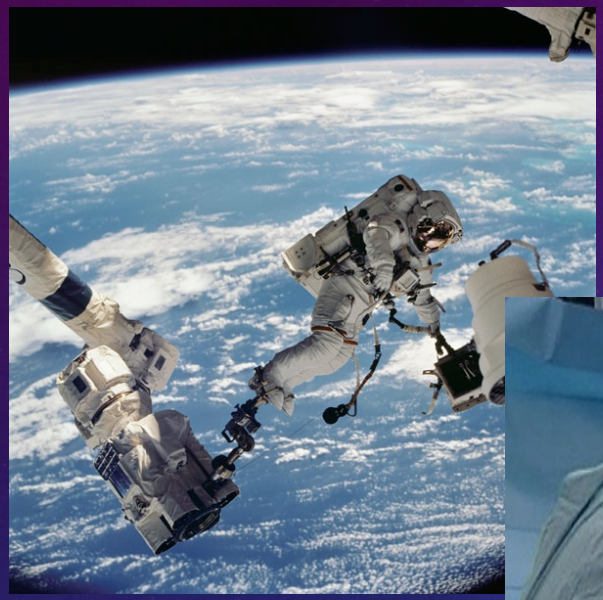
**Separability**
a crucial issue

**Complexity**
in the connections
as well as
in the agents themselves

**Emergents Functions**
&
the **maturity** issue



# LIFE-CRITICAL SYSTEMS…



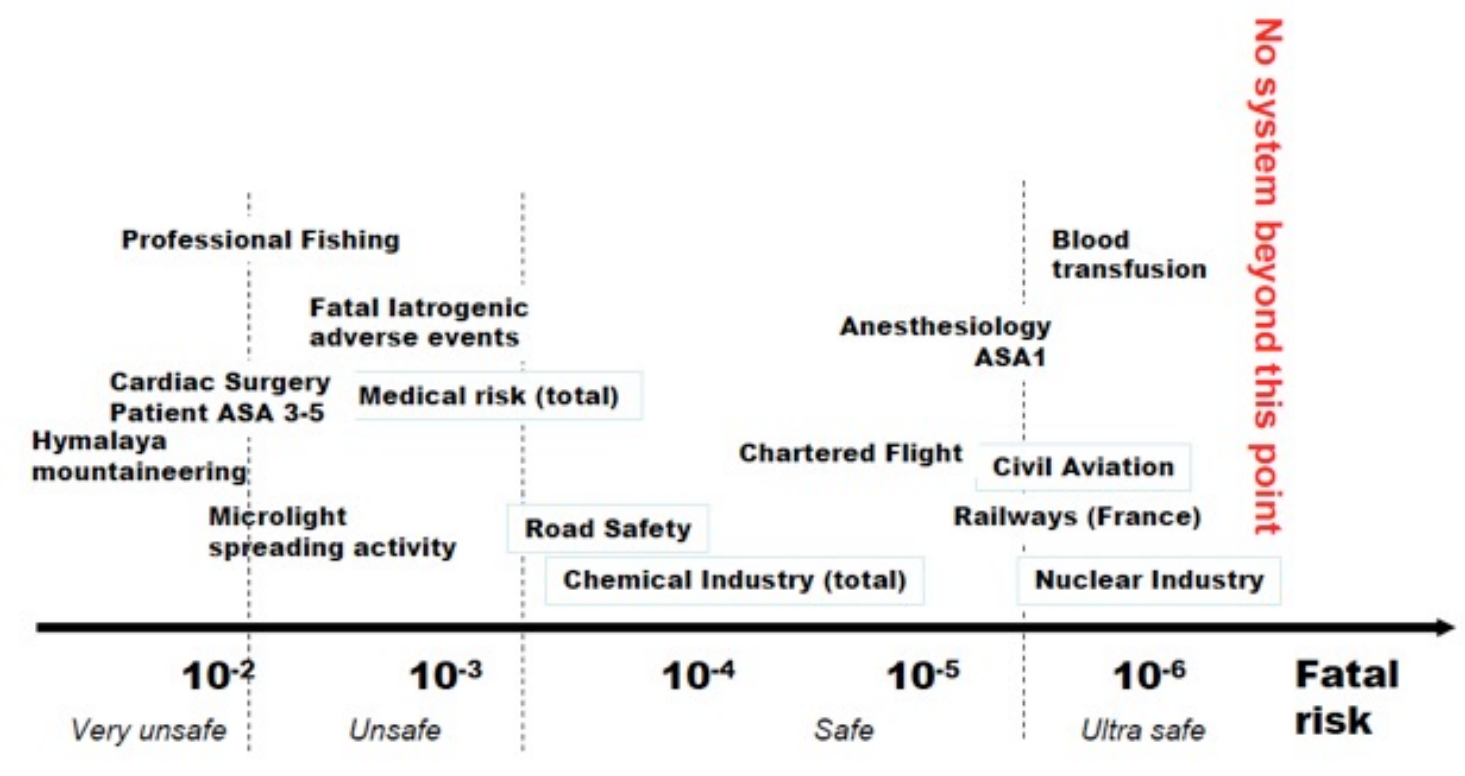
Safety

Efficiency

Comfort

# LIFE-CRITICAL SYSTEM CATEGORIES

(AMALBERTI, 2001)



# LIFE-CRITICAL SYSTEMS

Aerospace, nuclear energy, medicine …

- safety cultures
- *acceptable domains of risk*
- systems engineering
  - *regulations, operational procedures and training programs*
- *system reliability*
- *human reliability*
- …

Despite this heavy framing work,
we still have to face **unexpected situations**
that people have to manage
in order to *minimize consequences*.

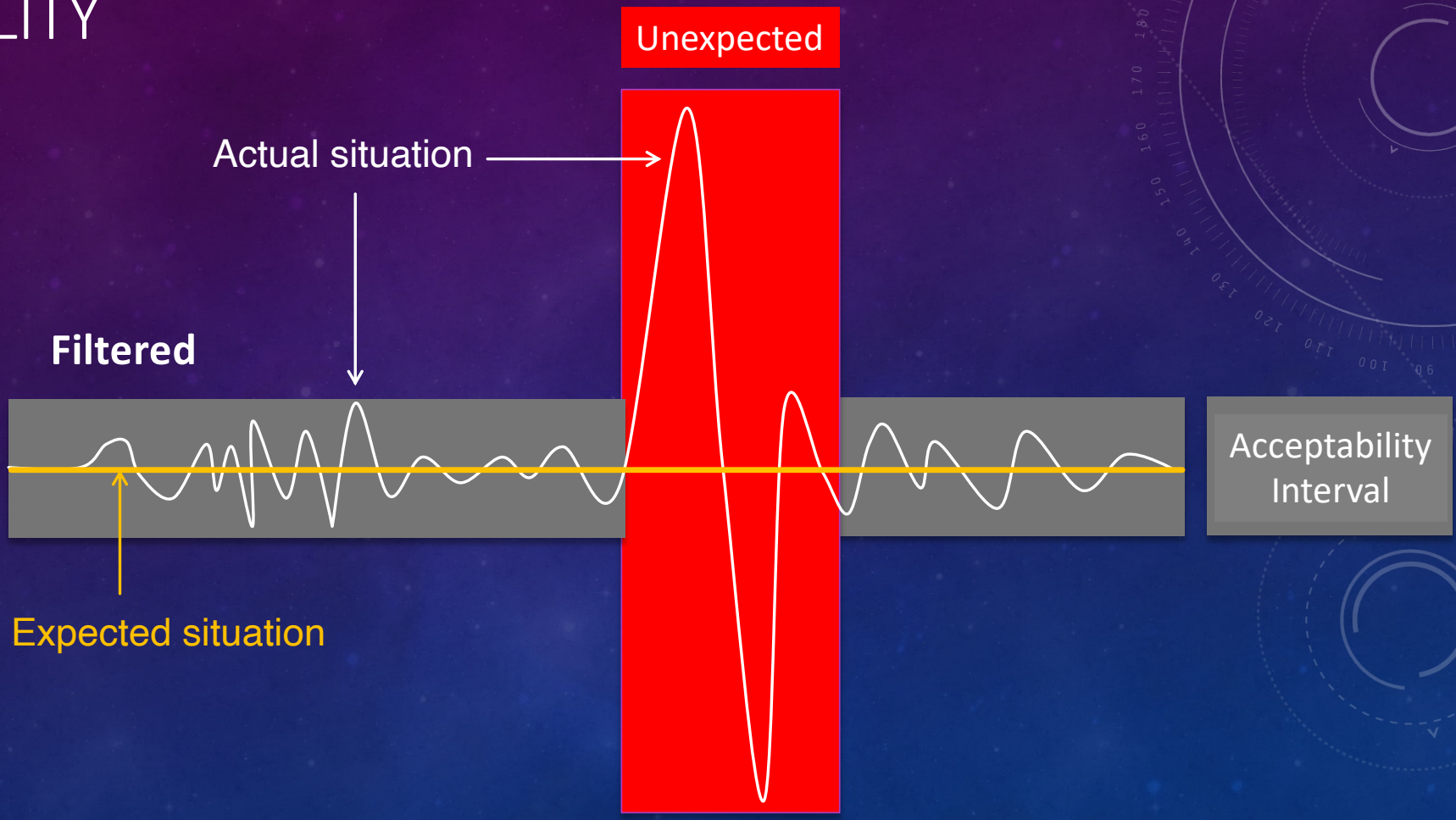
# WHAT IS A LIFE-CRITICAL SYSTEM (LCS)?

# VARIABILITY

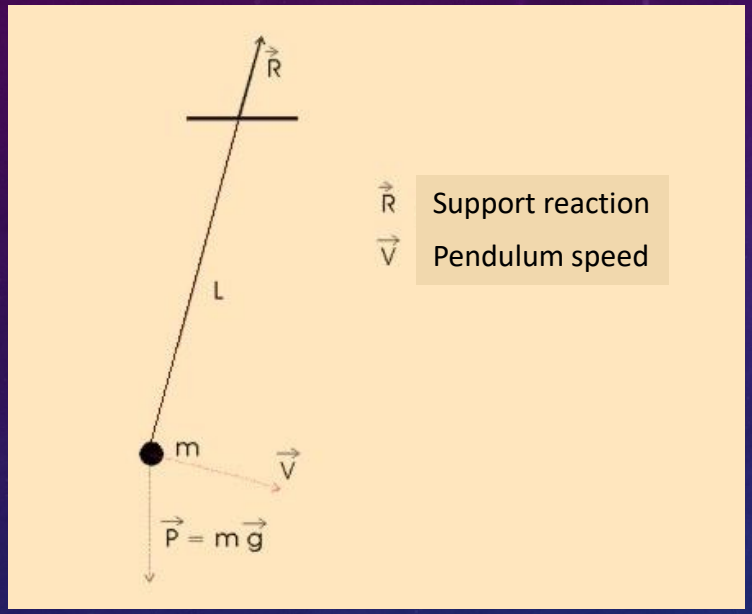
# VARIABILITY

# VARIABILITY

# VARIABILITY



# STABILITY




… stable
… passive stability

… instable
… active stability

# SIMPLIFICATION ➔ REDUCTIONIST LIMITATIONS

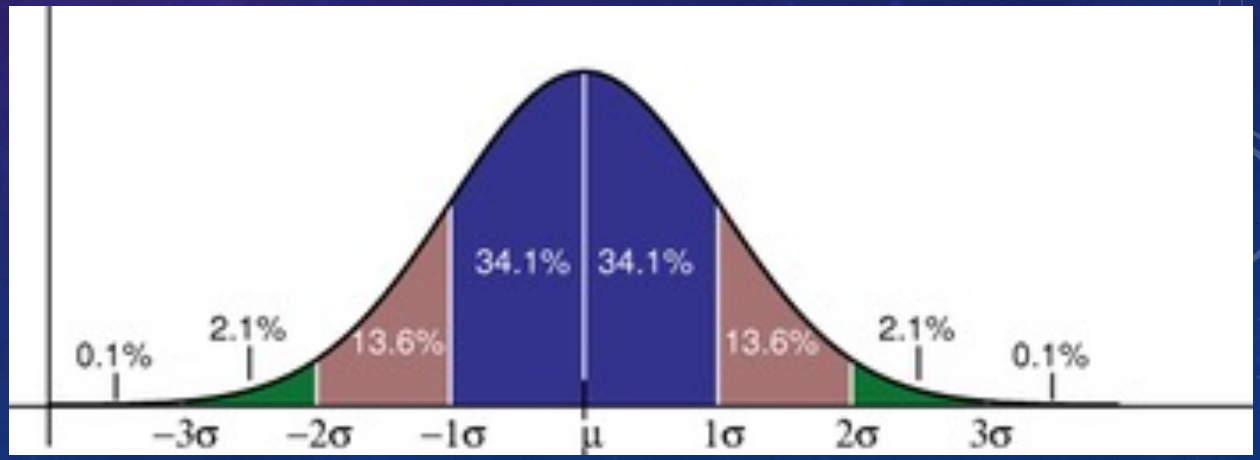
*linear* approach

user *interfaces and operational procedures based on experience feedback*

deviation from the (linear) norm = noise

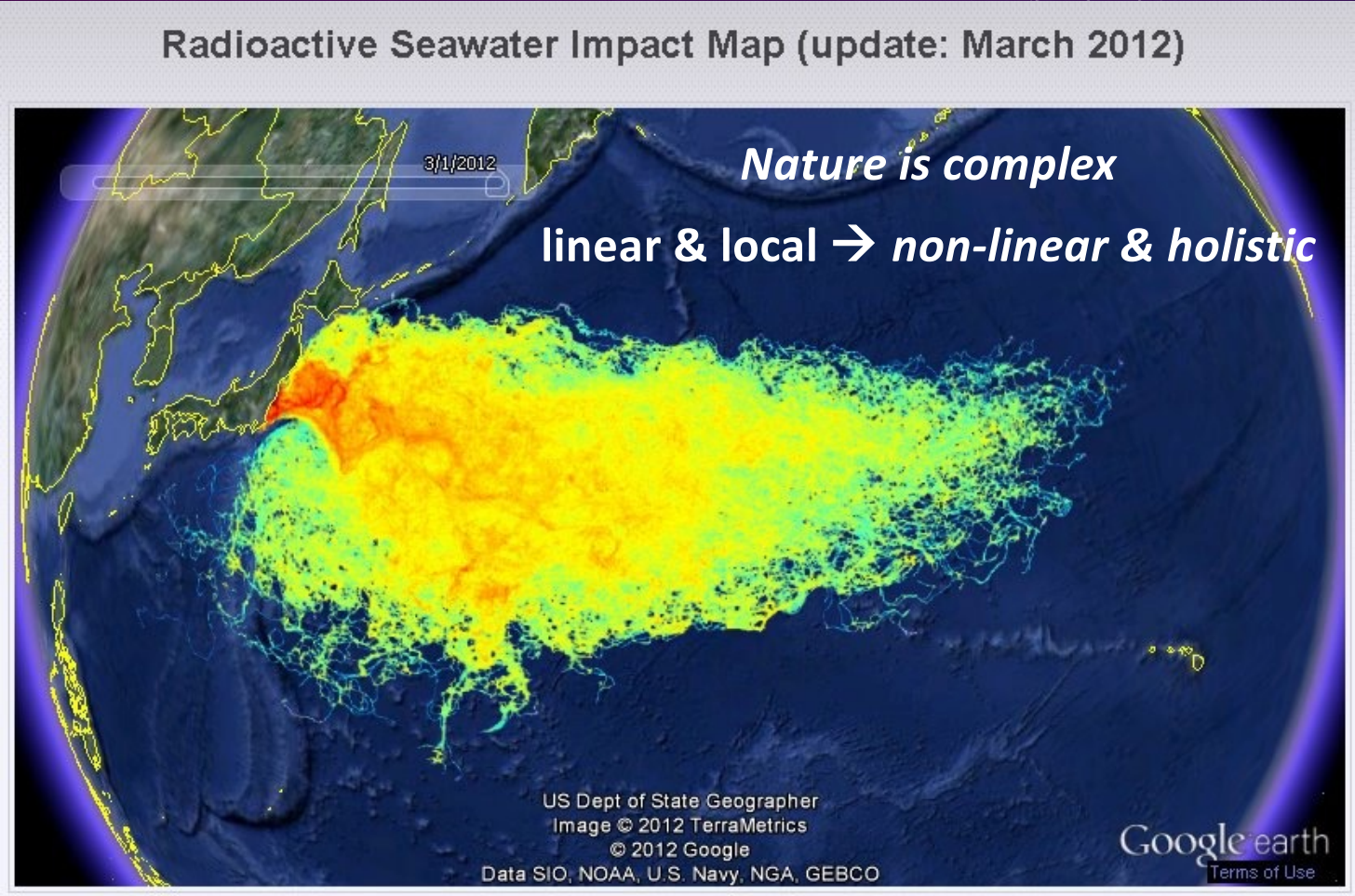
➢ ***unexpected as an exception***

**Context ?!**



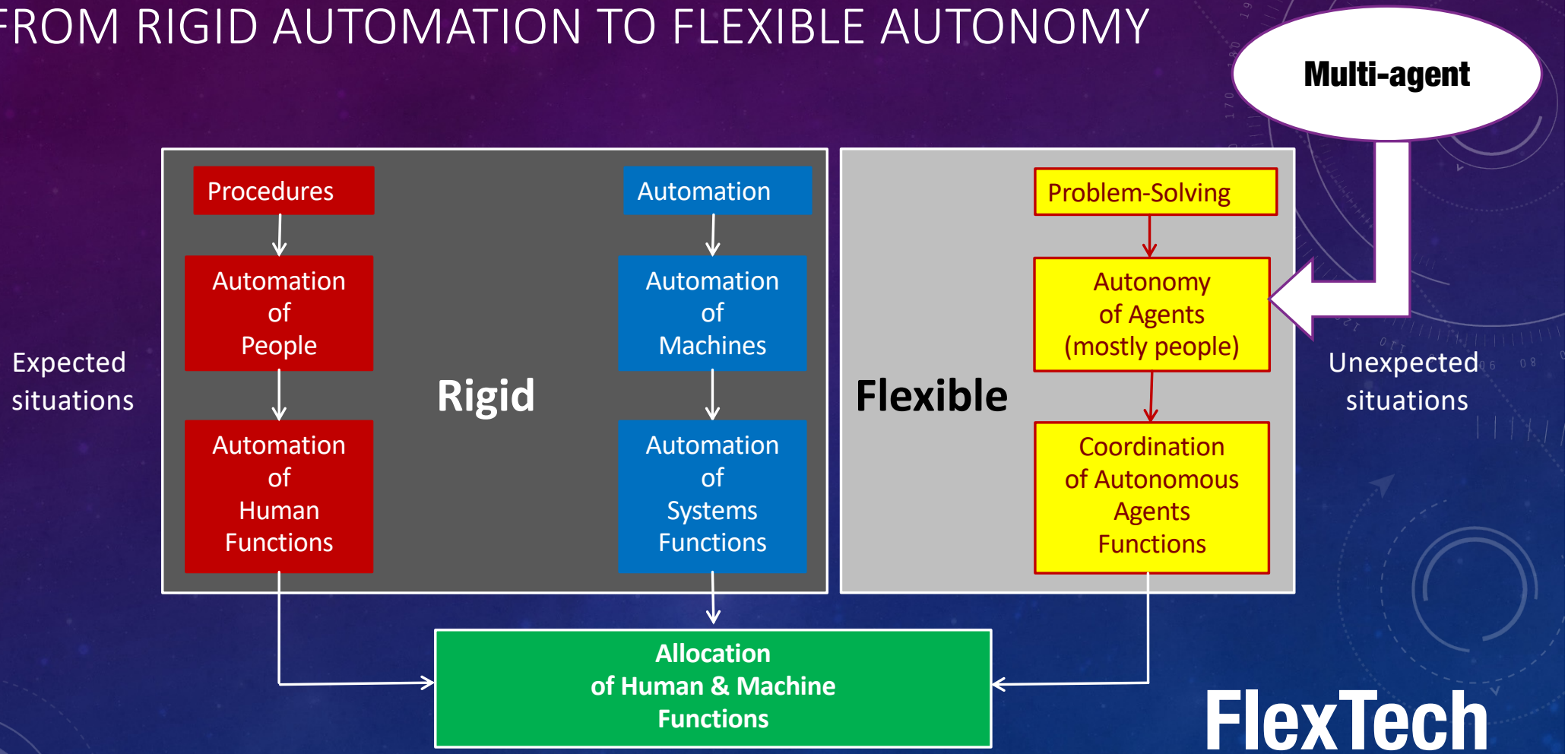
# Risk = Probability x Consequence

# FUKUSHIMA…




2011

# FROM RIGID AUTOMATION TO FLEXIBLE AUTONOMY




FlexTech
CentraleSupélec-ESTIA Chair

# DHL A300 CARGO TERRORIST SHOT…

Problem-solving competence

2003

# QANTAS A380 FLIGHT 32 ENGINE

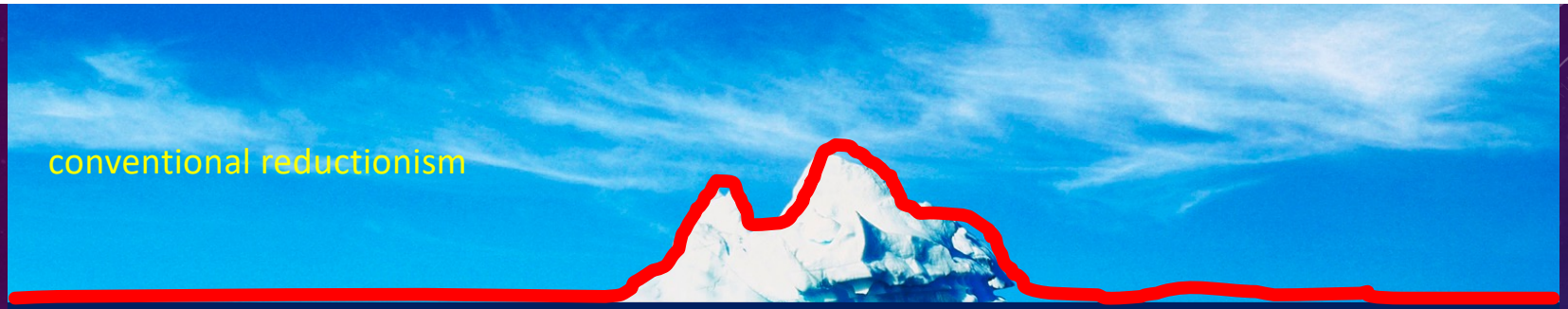
Problem-solving competence


2010

# US AIRWAYS FLIGHT 1549

Problem-solving competence

2009




*complexity science*

catastrophe theory
bifurcation theory
chaos theory

sudden “qualitative” or topological change

# MANAGING THE UNEXPECTED

Understand deeper knowledge (the whole iceberg)

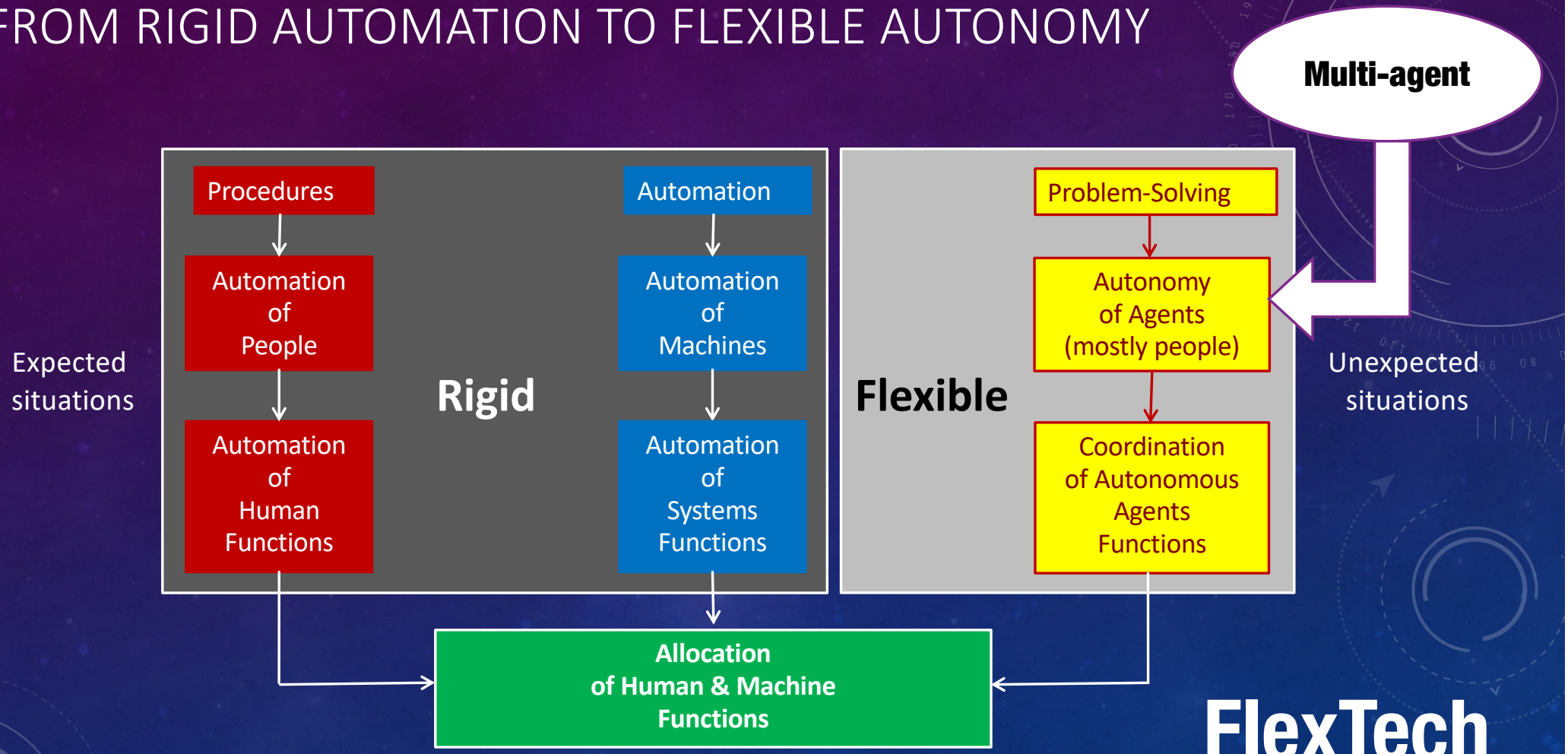
→ extensive training over a long period of time

***Creativity*** **is key**

"creativity" and "procedure following" are contradictory but complementary concepts

fallacious expectation of zero risk

# FROM RIGID AUTOMATION TO FLEXIBLE AUTONOMY



# RISK TAKING

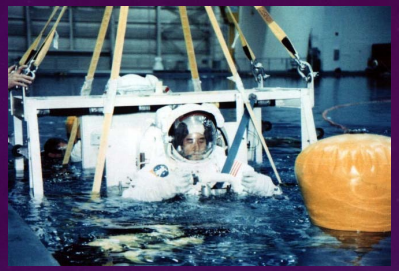
Preparation
Routine
Abduction
Understanding
Experience
Discipline (safety margins)
Availability
Action

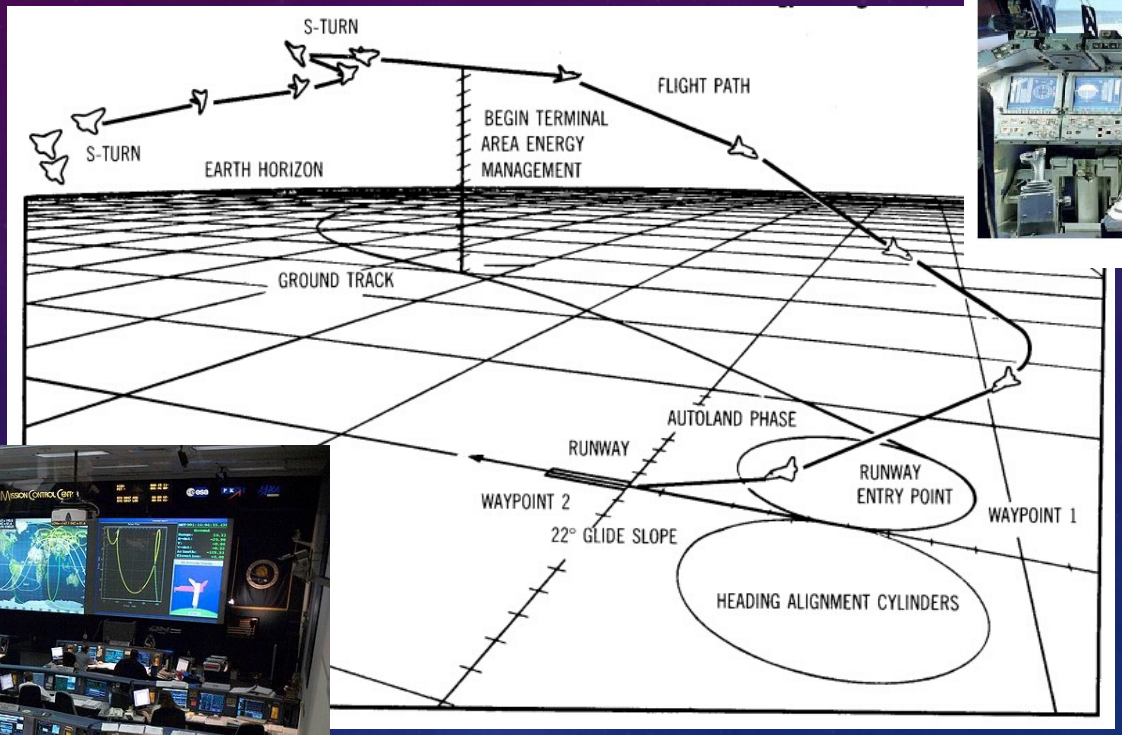

2010

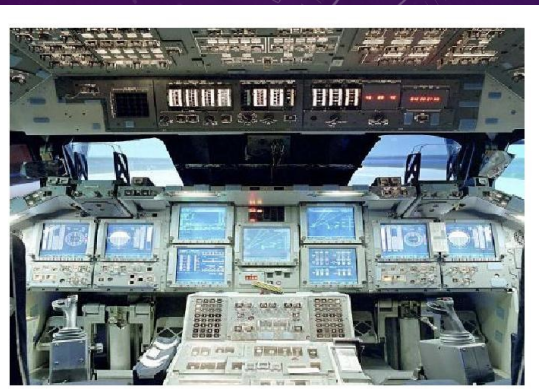
# APOLLO 13 $CO_2$ …

Organizational problem solving

# HUMAN SYSTEMS INTEGRATION (HSI)…

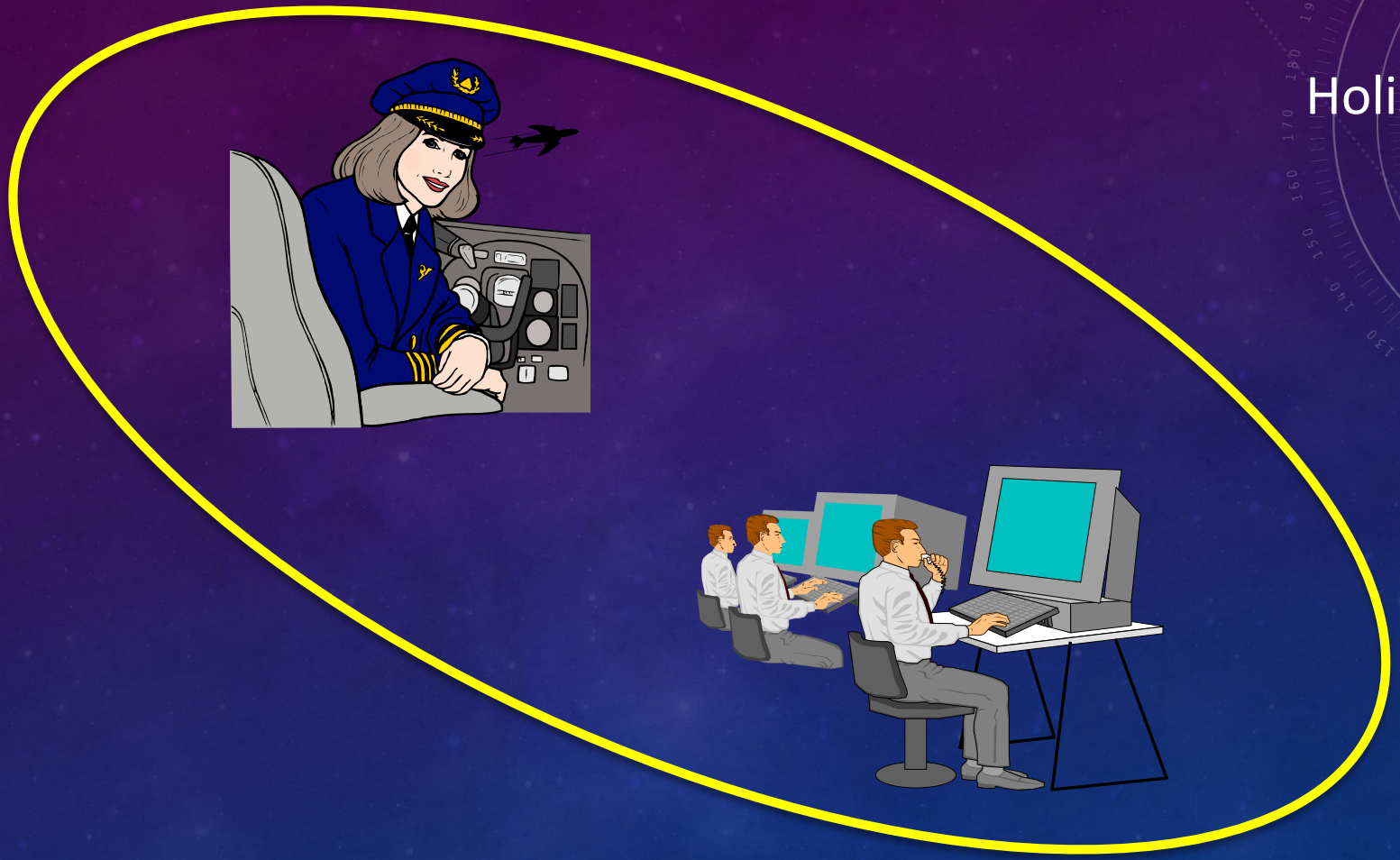




# Holistic HSI

# Holistic HSI



# THE ORCHESTRA MODEL

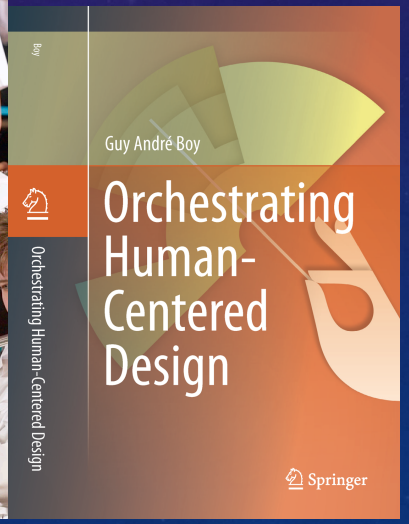
Music theory

Scores and composer(s)

Conductor(s)

Musicians

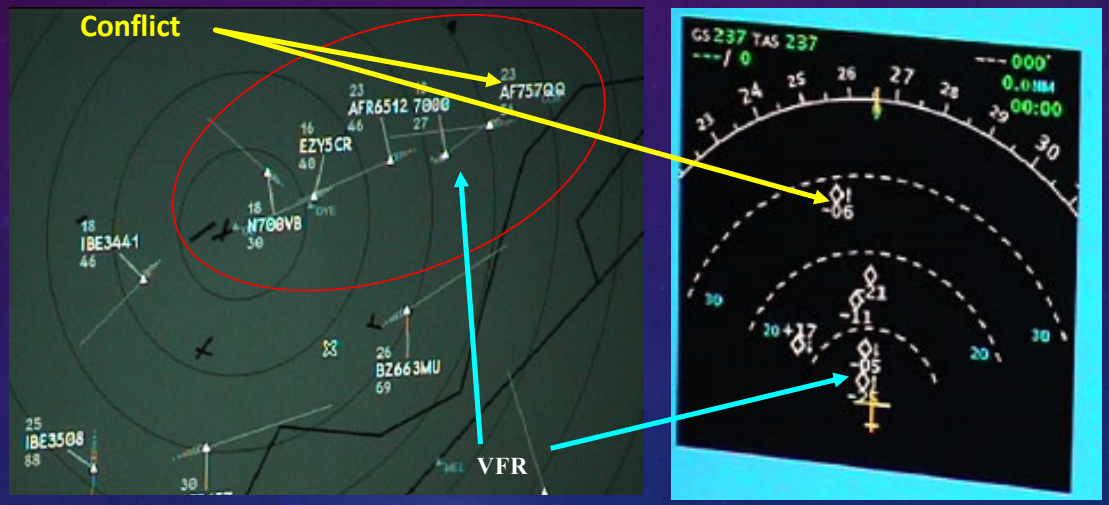
Audience



# AN EXAMPLE OF SITUATION AWARENESS SHARING…

Ground View

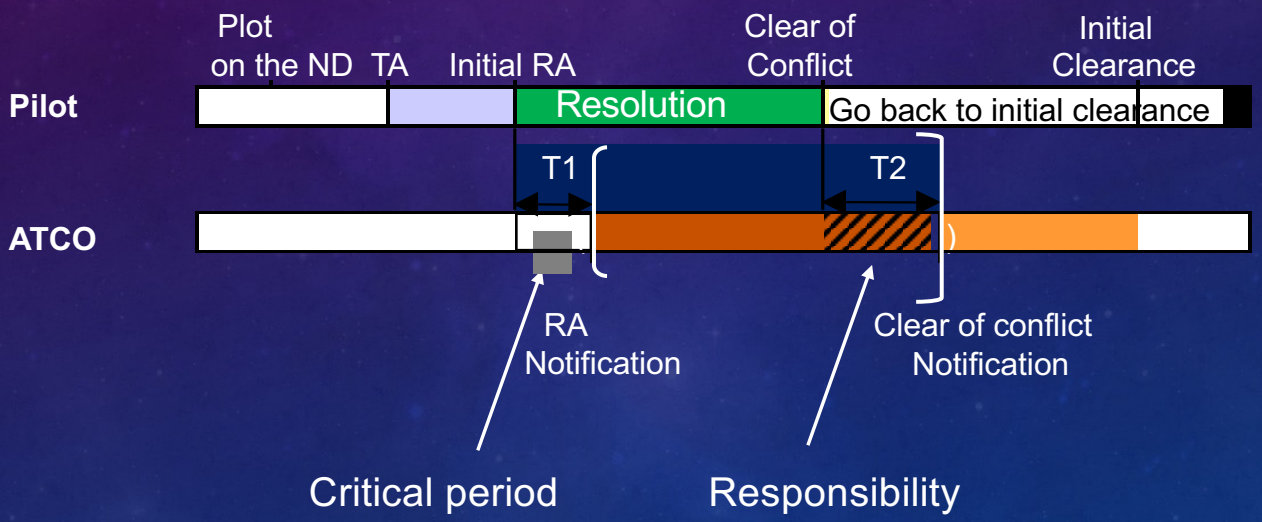
Aircraft View




**Same Situation → 2 Viewpoints**
**Intersubjectivity**
**Coordination**

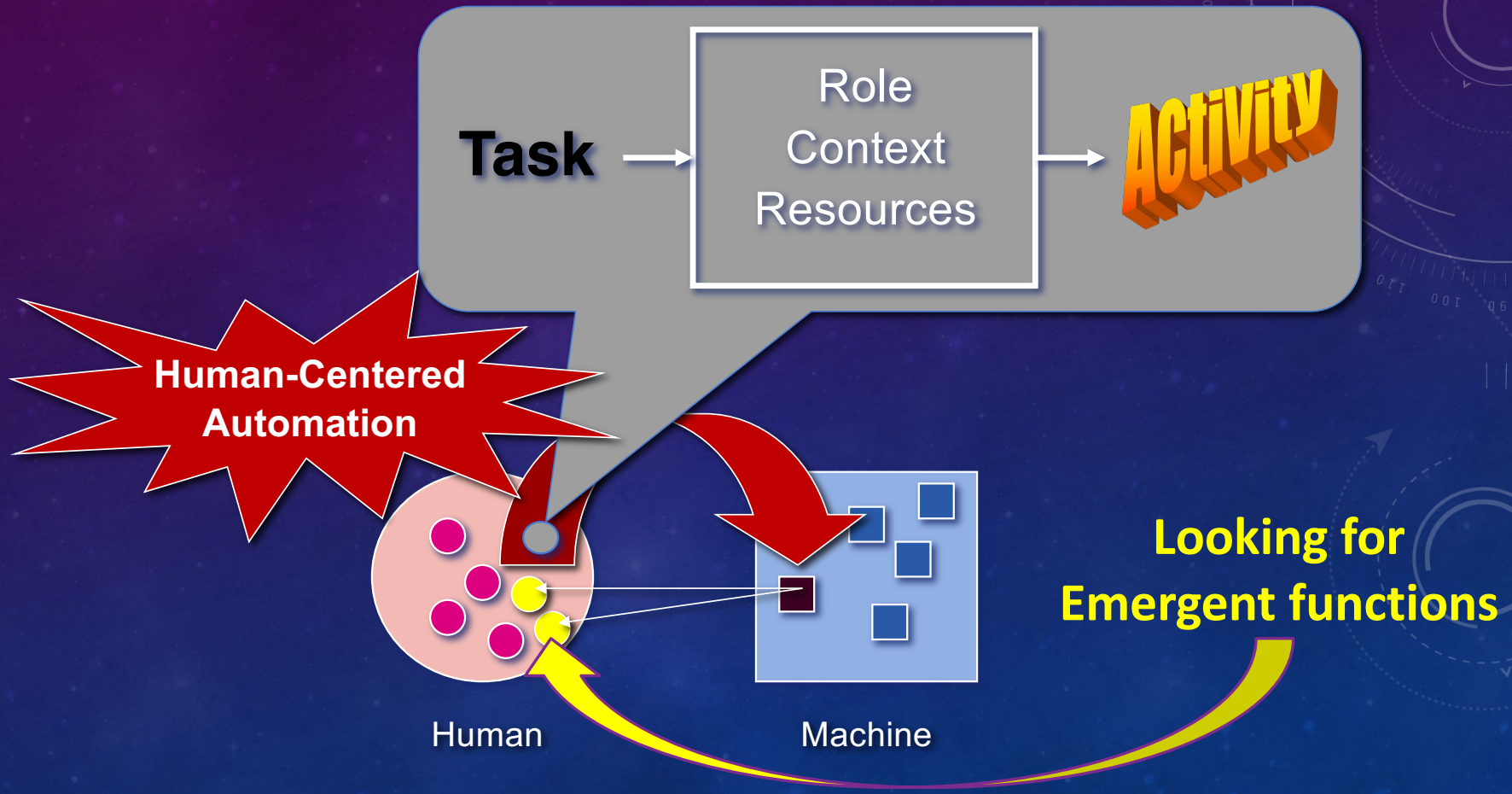
# DISCUSSION: TCAS TIME ISSUES

**Traffic-alert & Collision Avoidance System (TCAS) resolution : an interlude in the air-ground dialogue**

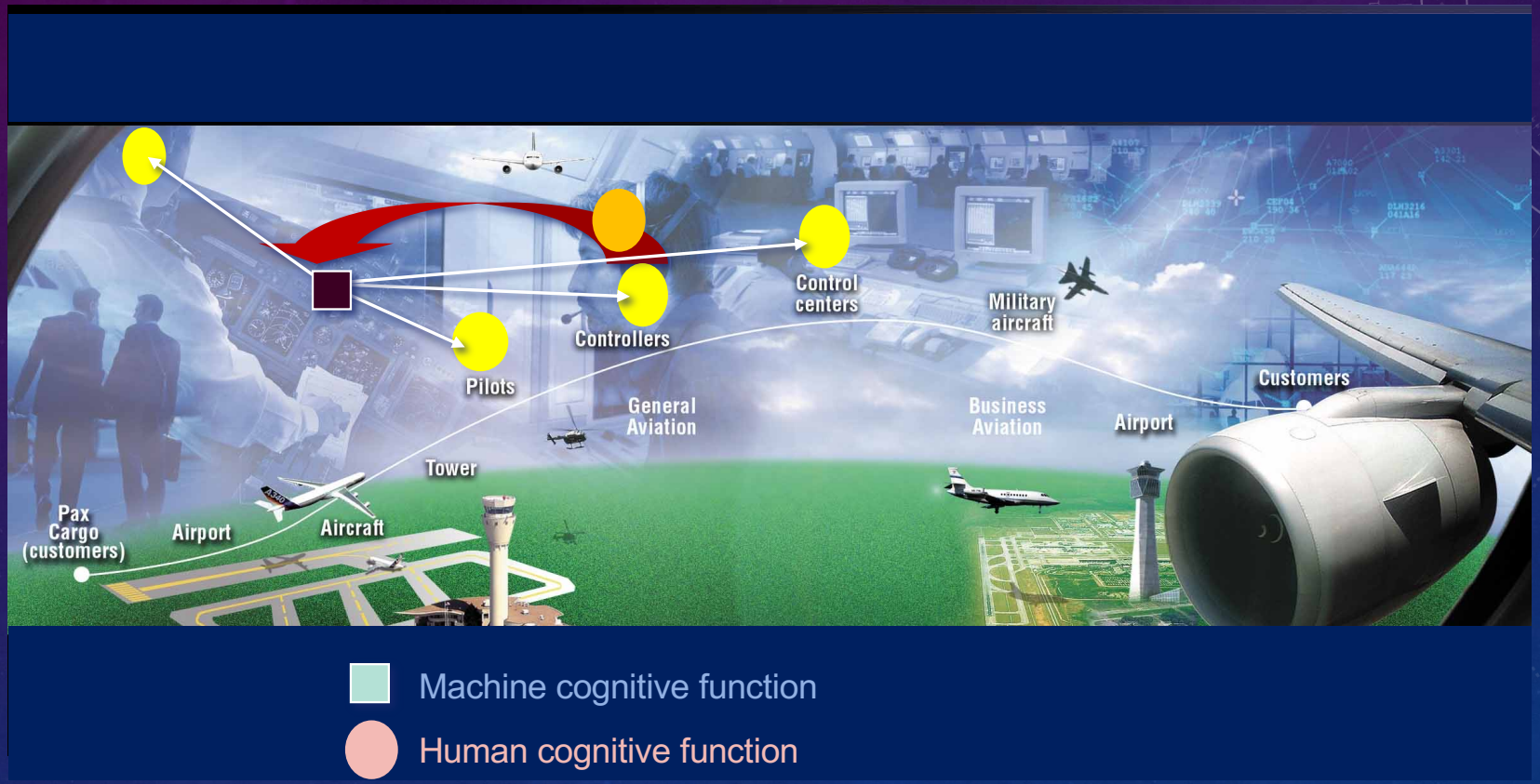



Stress study, DSNA-LAA, 2006

# THE COGNITIVE FUNCTION PARADIGM

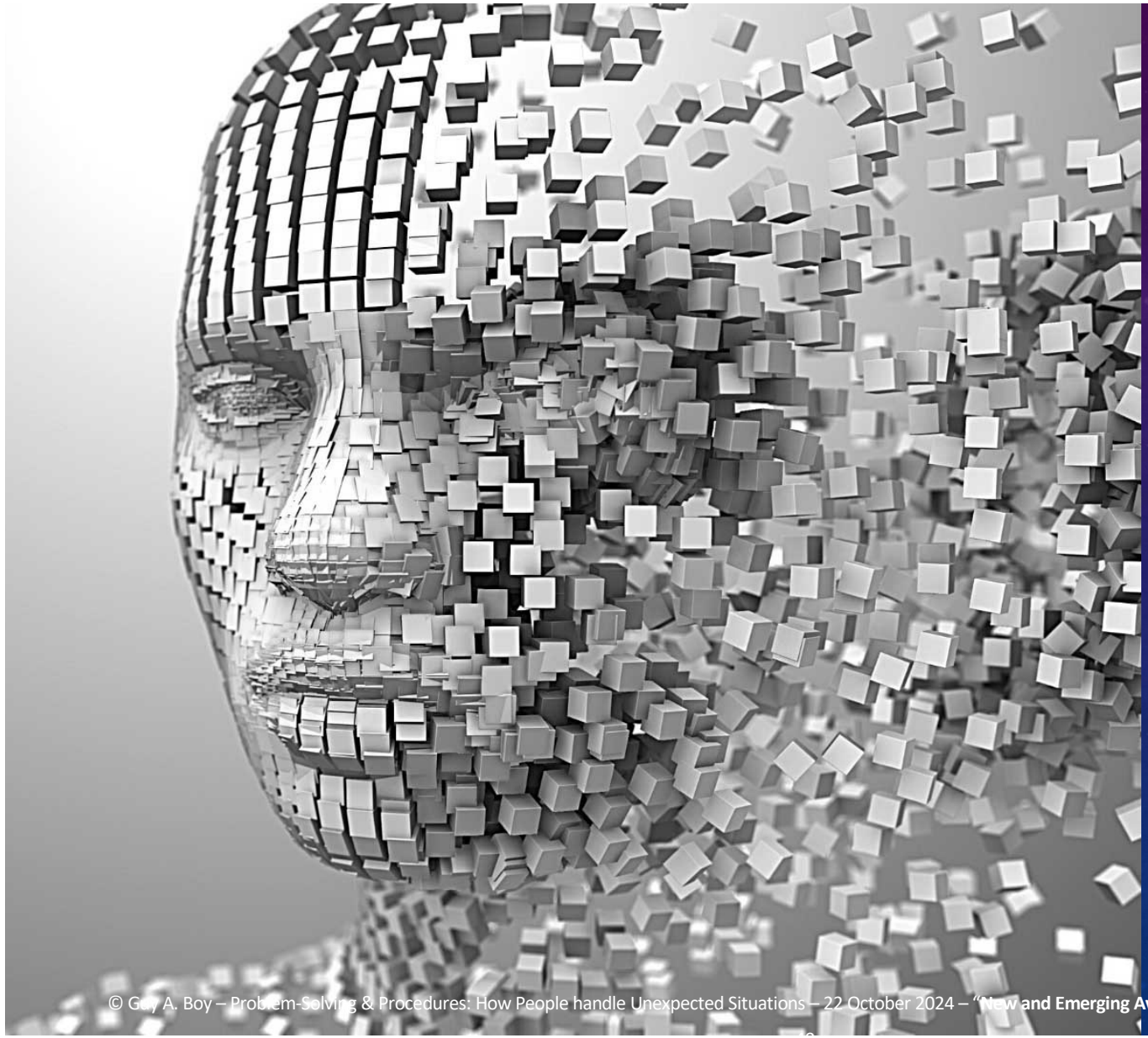


# ATM AGENTS AND INTERCONNECTIVITY…



# HUMAN-ARTIFICIAL INTELLIGENCE (AI) INTEGRATION

- AI may make decisions in limited contexts (we talk about **machine autonomy**)
- AI affords to assist people in making decisions (we talk about **intelligent assistance**)
- AI affords people to do things that they could not do before
- People's behavior and activities change when they use AI



# IS ARTIFICIAL INTELLIGENCE MATURE ENOUGH TO BE USED SAFELY, EFFICIENTLY AND COMFORTABLY?

# T.O.P. READINESS LEVELS

## Technology (TRL)


## Organizations (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 |

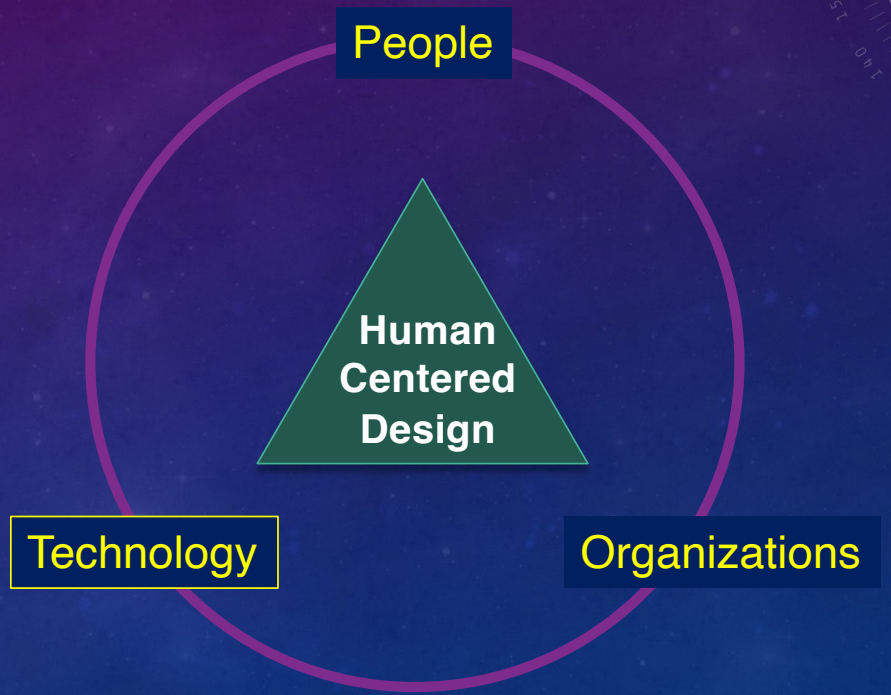
## People (HRL)

| 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 |

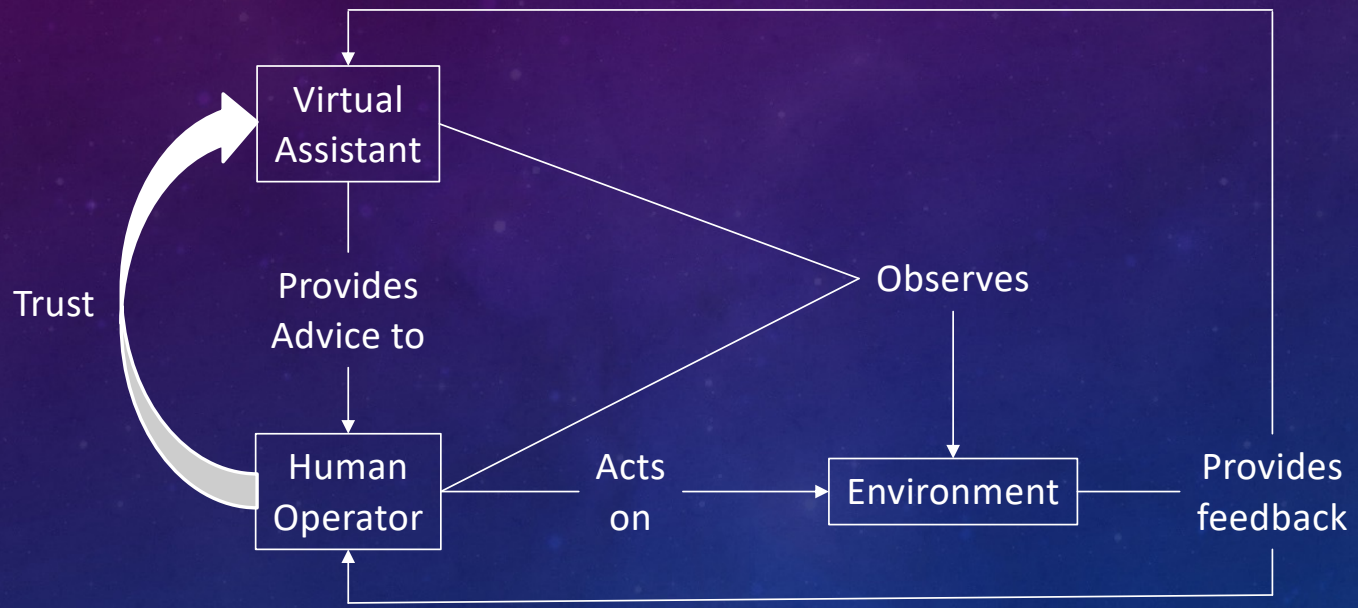
# WHAT ARE THE T.O.P. FACTORS THAT MATTER?

## Technological factors

- Consistency
- Easy access to appropriate information
- Context-sensitive information
- Affordances
- Interruption support
- Physical and cognitive ergonomics



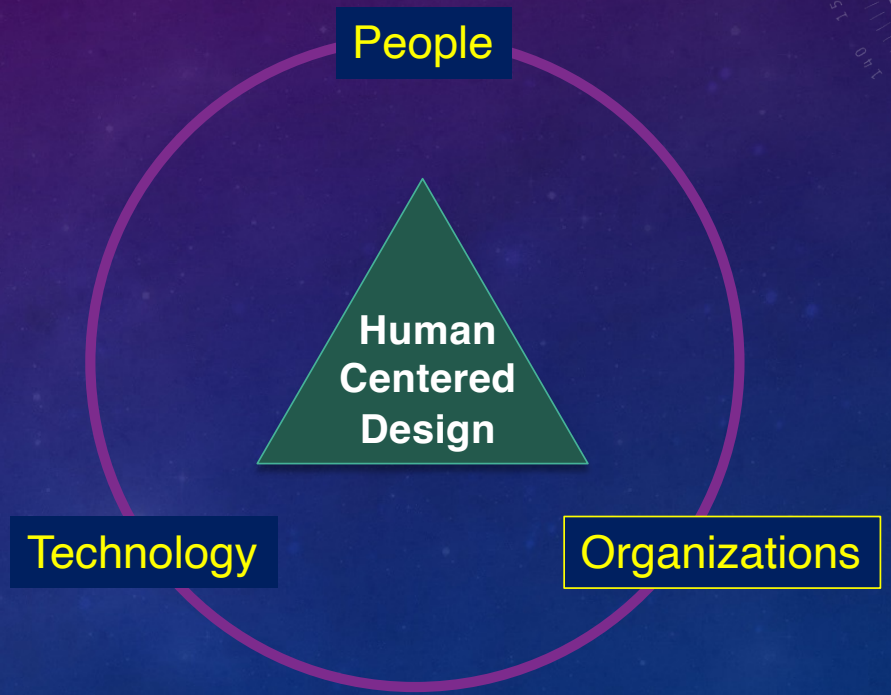
# THIS REQUIRES A FEEDBACK LOOP PROCESS…



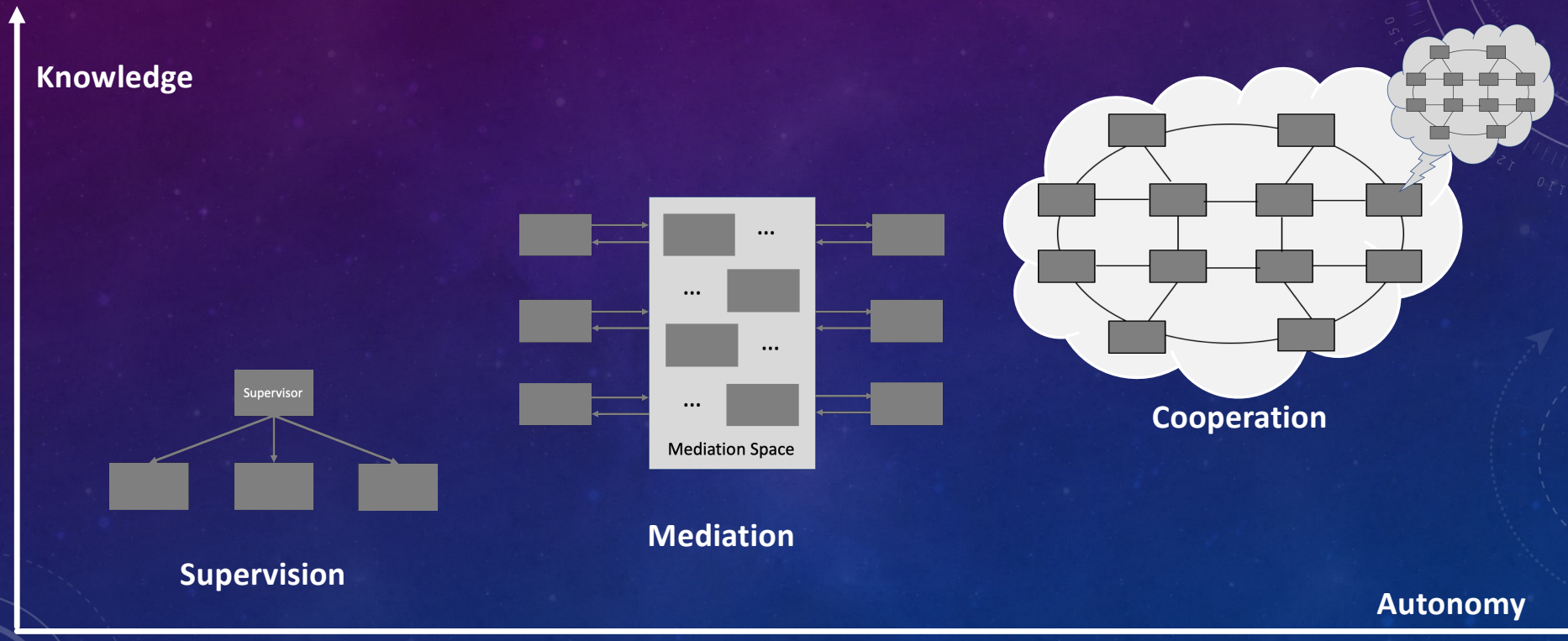
# WHAT ARE THE T.O.P. FACTORS THAT MATTER?

## Organizational factors

- Communication
- Supervision
- Mediation
- Cooperation
- Coordination
- Conflict and priority management



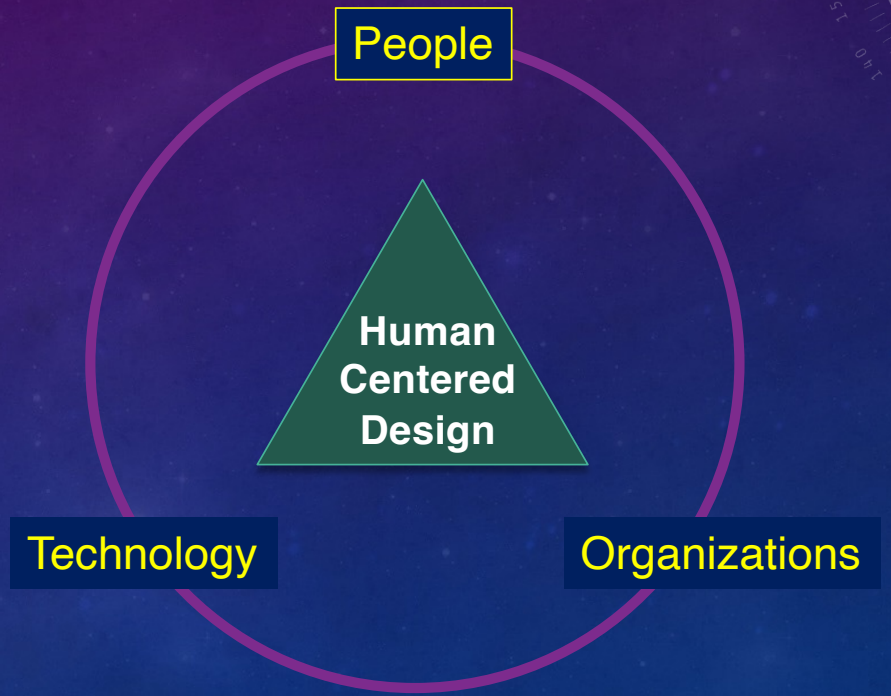
# SYSTEMIC INTERACTION MODELS…
# … AND AUTHORITY SHARING

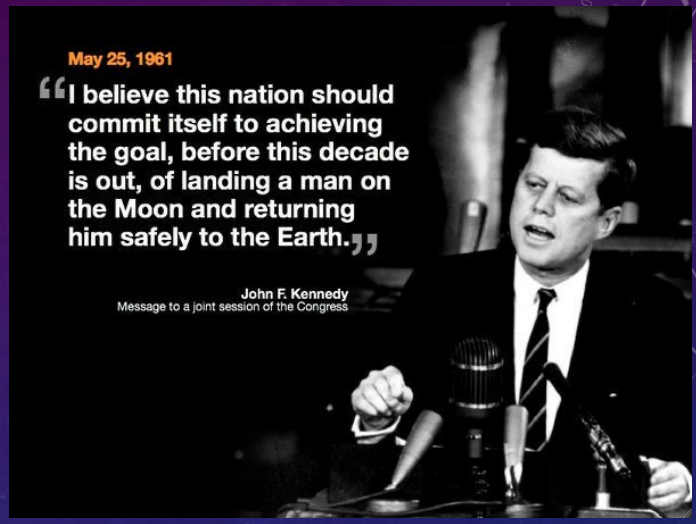


# WHAT ARE THE T.O.P. FACTORS THAT MATTER?

## Human factors

- Situation awareness
- Decision making
- Risk taking
- Workload
- Performance
- Trust
- Collaboration






Technology-Centered Engineering

Human-Centered Design

From Means to Purpose → From Purpose to Means

Reactive (Event-driven)

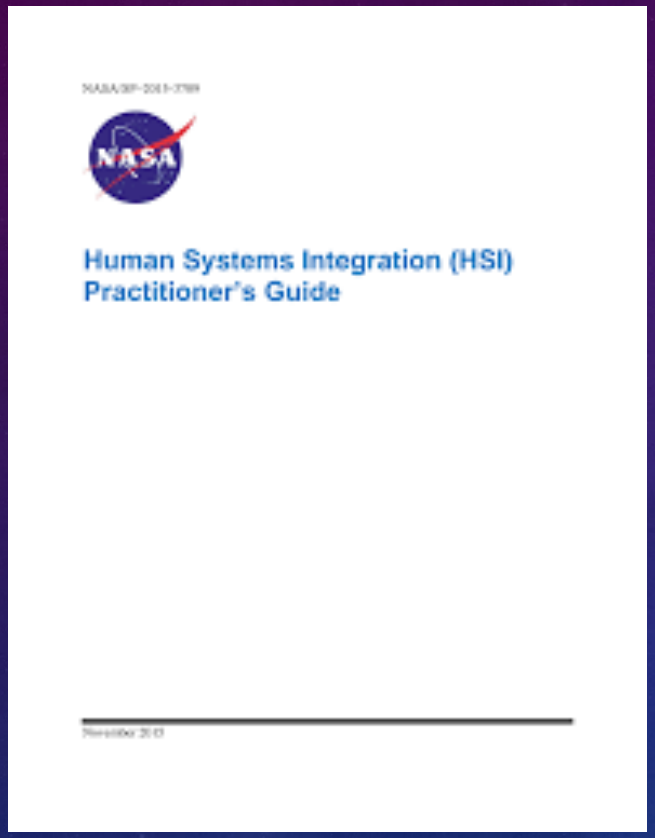
Proactive (Goal-driven)

Prediction

Possible Futures

**Short Term**

**Longer Term**


NASA
Human Systems Integration (HSI)
Practitioner's Guide


INCOSE
Human
Systems
Integration
PART ONE

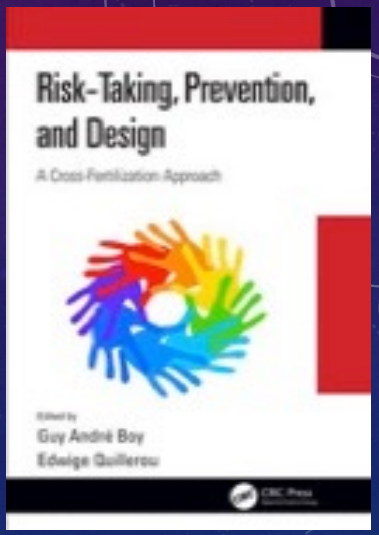
# SOURCES

***Air Transport Pilots facing the Unexpected***
Air and Space Academy International Conference
November 29, 2011

HCI-Aero Conferences (1998-2016)
→ HSI Conferences (2019-Present)

Aircraft accident investigations…


2010




2022

Boy, G.A. (2013). Dealing with the Unexpected in our Complex Socio-Technical World. Proceedings of the 12th IFAC/IFIP/IFORS/IEA Symposium on Analysis, Design, and Evaluation of Human-Machine Systems. Las Vegas, Nevada, USA.

# Future Integrated Automation in Aviation

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# TANK YOU…

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