BRUSSELS | JUNE 7-8, 2023

SAFETY FORUM
KNOWLEDGE, SKILLS AND EXPERIENCE
FOR SAFE OPERATIONS
Powered by SKYbrary

HUMAN-MACHINE TEAMING ISSUES

IMPACTING CONTEMPORARY AIRSPACE SAFETY
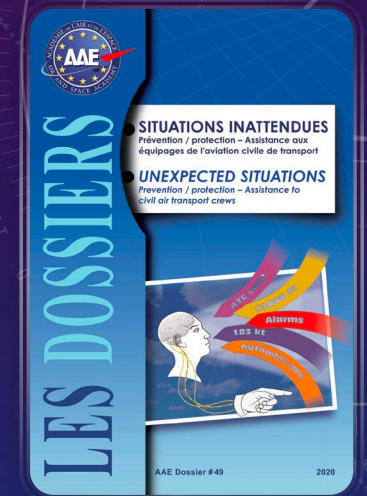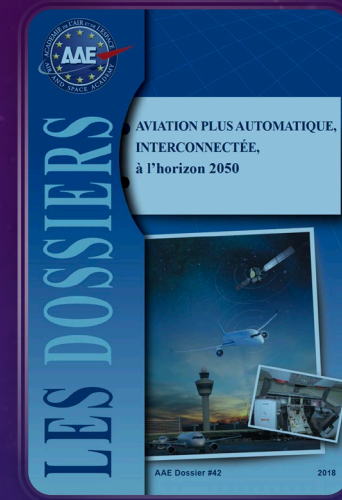
PROFESSOR GUY ANDRÉ BOY

FlexTech Chair

CentraleSupélec | université PARIS-SACLAY | ESTIA INSTITUTE OF TECHNOLOGY
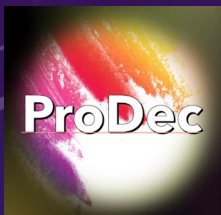
AAE

BACKGROUND

- Work done at the **Air & Space Academy** on aircraft and airspace automation, as well competences in the aviation world (2018-2023)

- Work performed within the **FlexTech Chair** (Paris Saclay University – CentraleSupélec & ESTIA Institute of Technology) on human systems integration in increasingly autonomous systems (2019-2023)

- A series of five HSI lectures given within "System Thinking, Safety and Human Factors" Webinars and scheduled by **EUROCONTROL** from September 2022 to June 2023

- INCOSE **Human Systems Integration** Working Group (2015-2023) and Systems Engineering Vision 2035

- PAUSA project (2006-2008) with **DGAC**

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OUTLINE

Holistic, Flexible & Systemic Approach

ProDec

- digital, interconnectivity & autonomy
- aircraft, ATC & coordination between the two
- what it means to fly in the cloud era
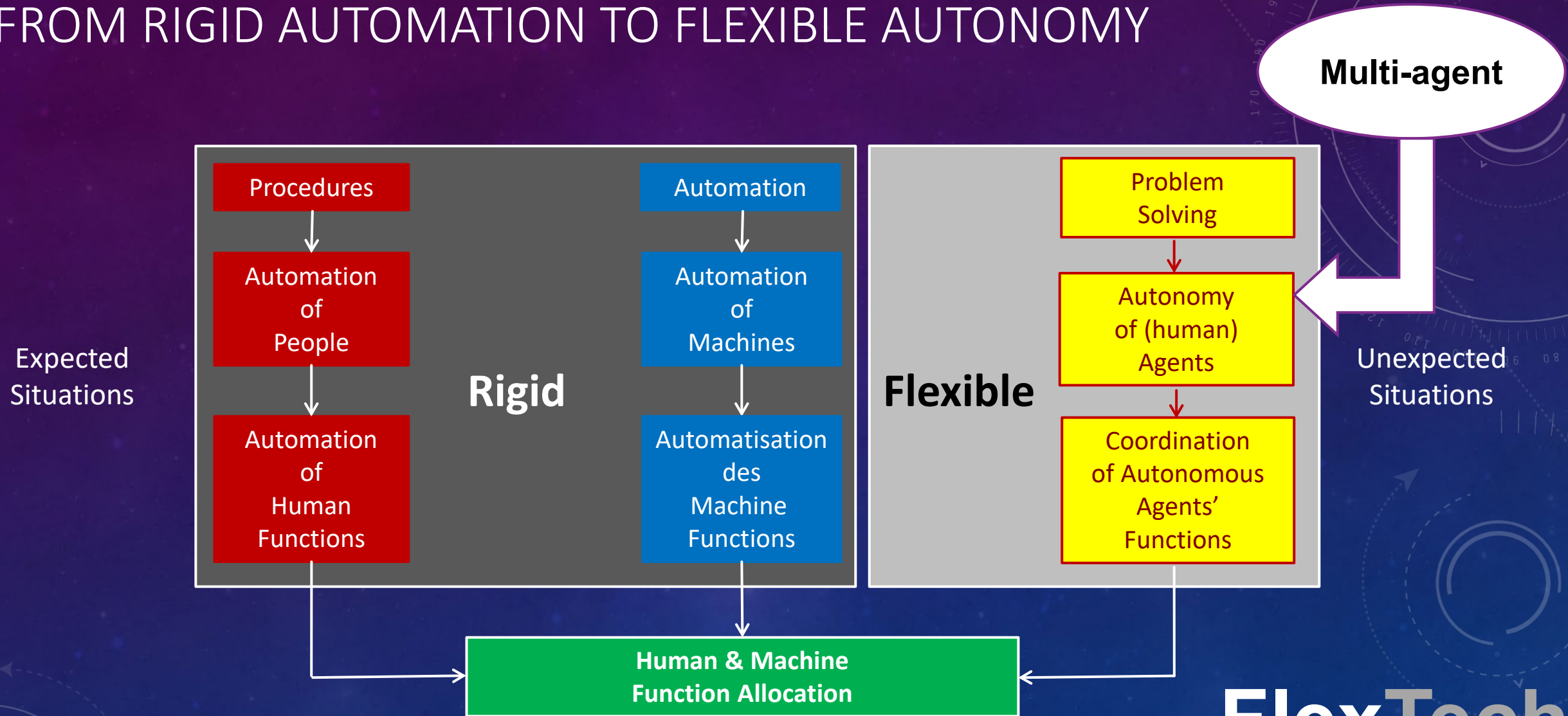- model-based systems engineering & digital twins
- human-in-the-loop simulations
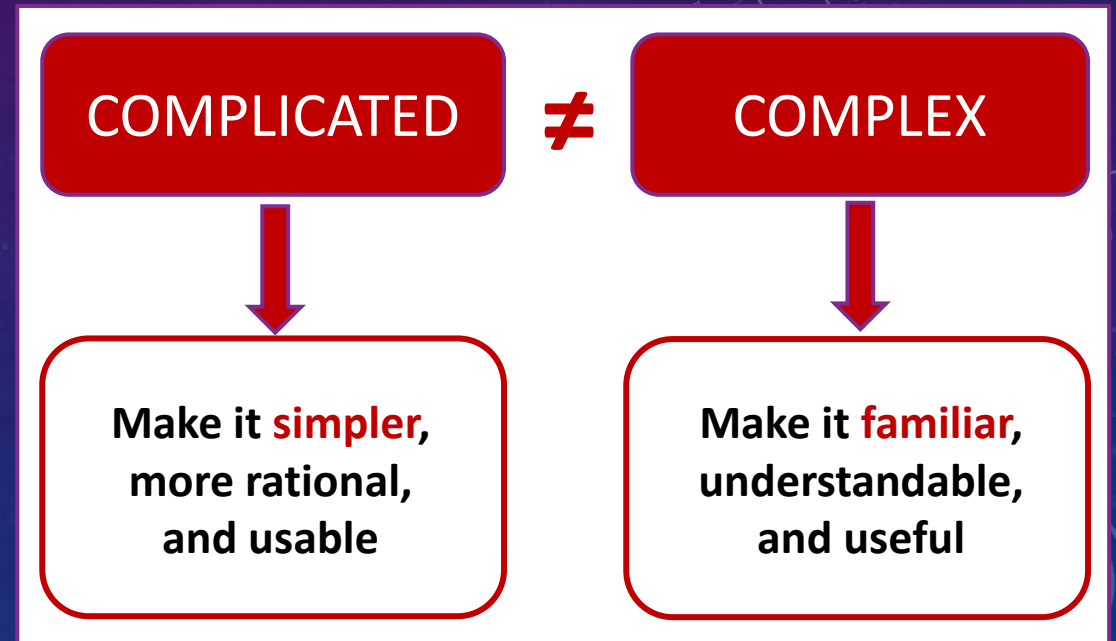- metrics for assessing human systems integration

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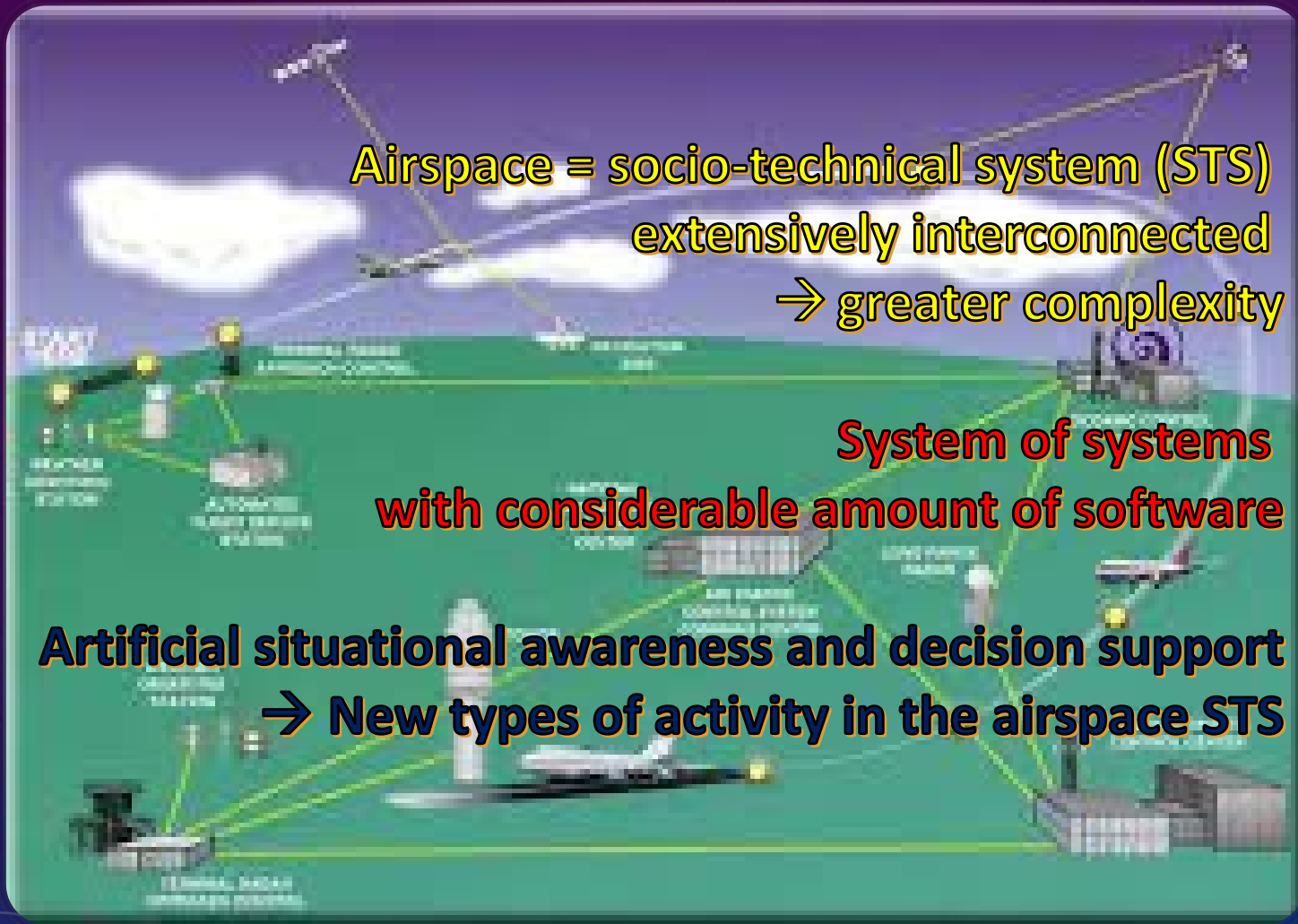
FROM RIGID AUTOMATION TO FLEXIBLE AUTONOMY

Multi-agent

Rigid

Expected Situations		
Procedures	Automation	
Automation of People	Automation of Machines	
Automation of Human Functions	Automatisation des Machine Functions	

Flexible

Problem Solving
Autonomy of (human) Agents
Coordination of Autonomous Agents' Functions

Unexpected Situations

Human & Machine Function Allocation

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COMPLEXITY & UNCERTAINTY ANXIETY OR OPPORTUNITY

COMPLICATED	≠	COMPLEX
↓		↓
Make it **simpler**, more rational, and usable		Make it **familiar**, understandable, and useful

Risk Taking → Abduction (Heuristics)
Control → Uncertainty Reduction
Accountability → Uncertainty Management

NEW SAFETY ISSUES IN SYSTEMS OF SYSTEMS

Airspace = socio-technical system (STS)
extensively interconnected
→ greater complexity

System of systems
with considerable amount of software

Artificial situational awareness and decision support
→ New types of activity in the airspace STS

Connected airspace systems …

→ **System of Systems**

Today's airspace **socio-technical system** (STS) is very *different* from what we knew only thirty years ago, and future systems will be even more *different*.

What does "different" mean?

SMART
v
HUMAN - MACHINES
~~INTERACTION~~
INTEGRATION

Technology becomes a partner...

... rather than a tool

Context matters

Multi-agent nature of problems:

→ **reduction or amplification of danger?**

Organizational Automation

Trust

Collaboration

Single Agent System VS Multi Agent System

THE T.O.P. MODEL...
... IN HUMAN SYSTEMS INTEGRATION (HSI)

Procedure following
& problem solving

Skills & Knowledge

People

Human Systems Integration

Technology

Organizations

Automation

Regulations

AI & Data Science

Coordination

CREW-GROUND INTEGRATION

Systems currently developed in isolation

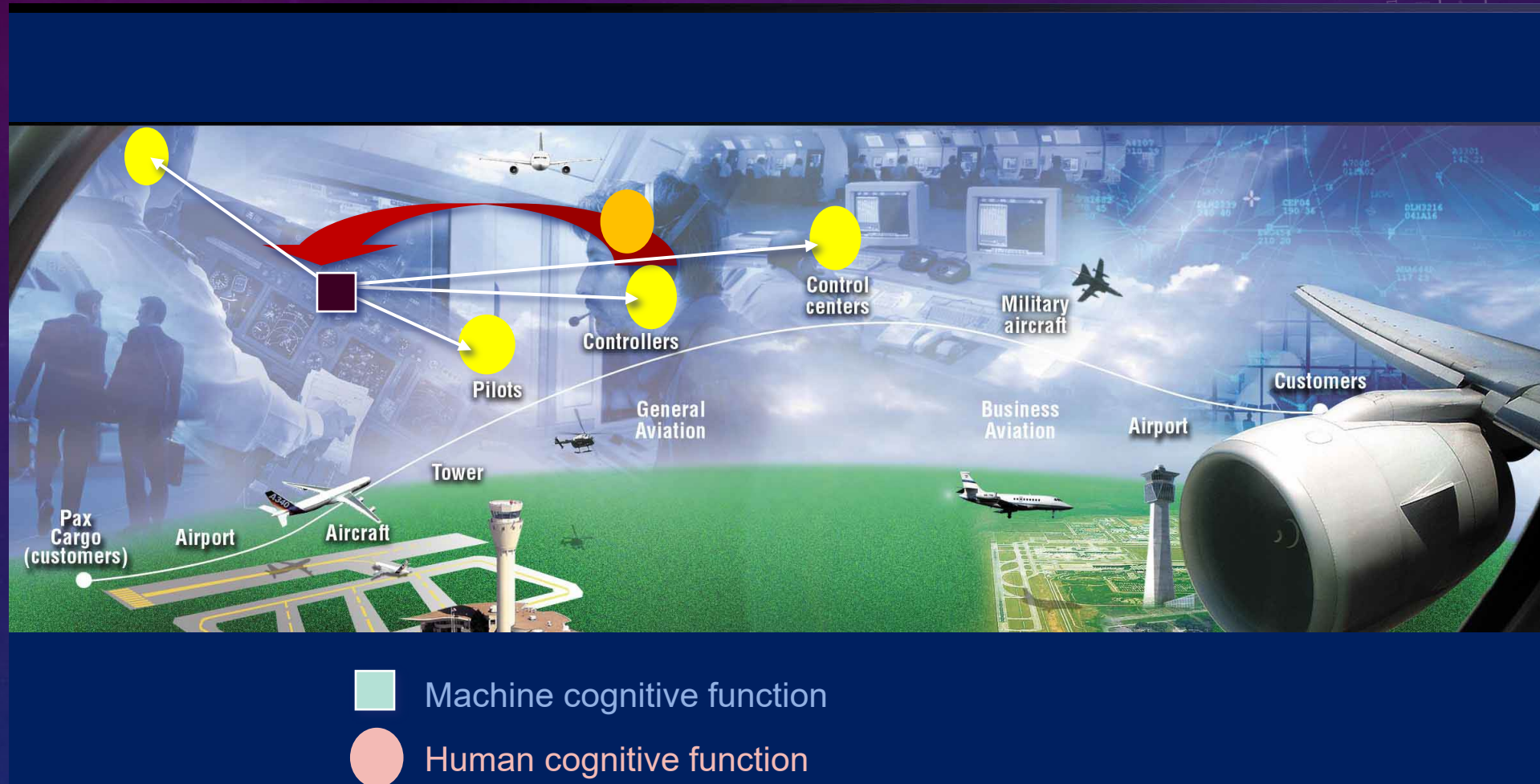**Human Systems INTEGRATION should be part of high-level requirements**
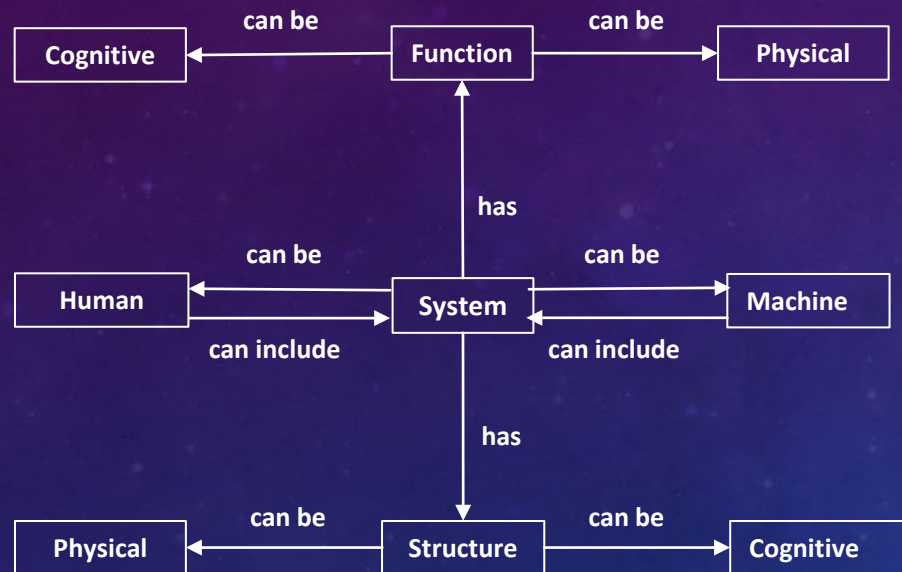
Articulate Operations & Systems Engineering

Emergent properties

➤ Scenarios
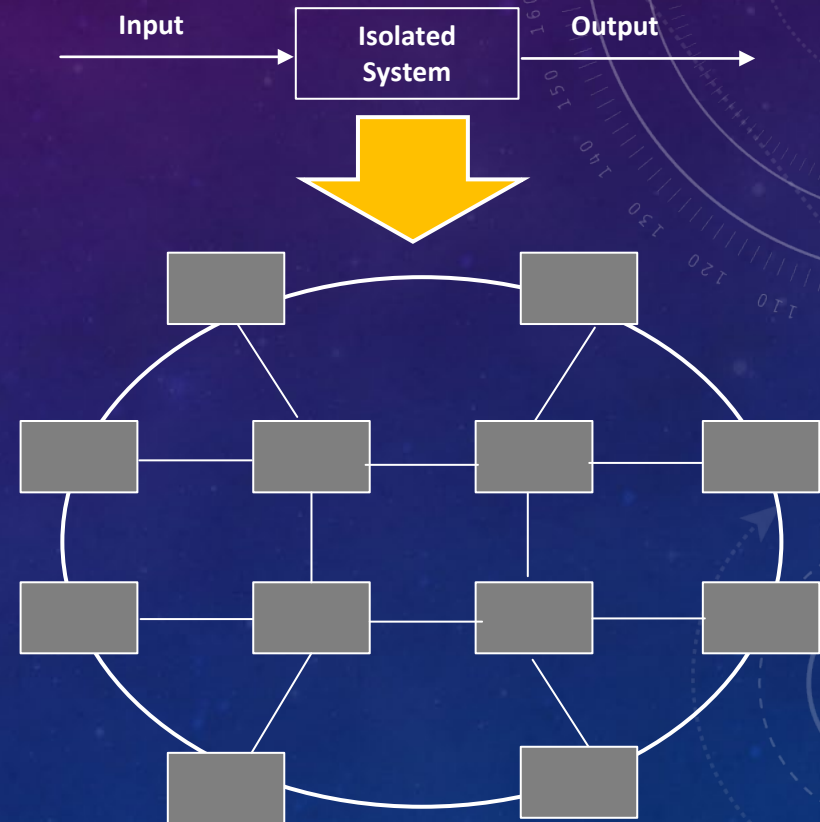➤ Principles and criteria
➤ Human-in-the-loop simulations (HITLS)

AIRSPACE SYSTEMS / AGENTS AND INTERCONNECTIVITY…

Machine cognitive function

Human cognitive function
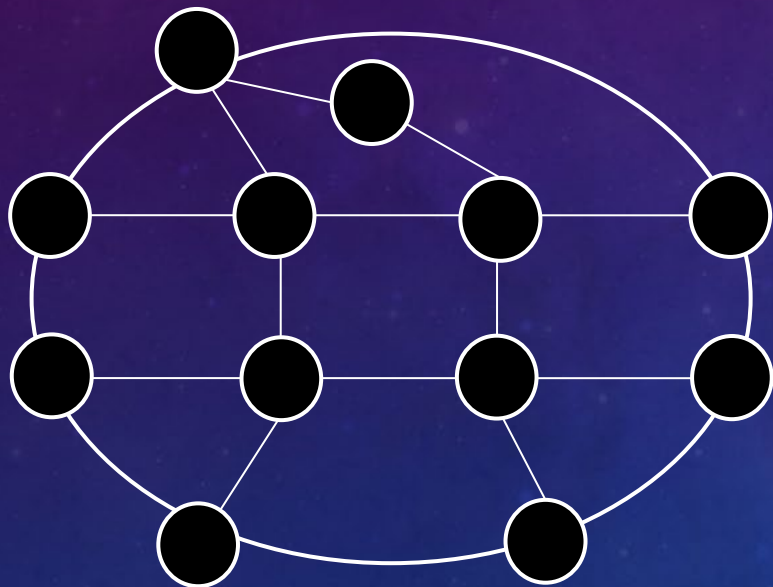
WHAT IS A SYSTEM/AGENT?
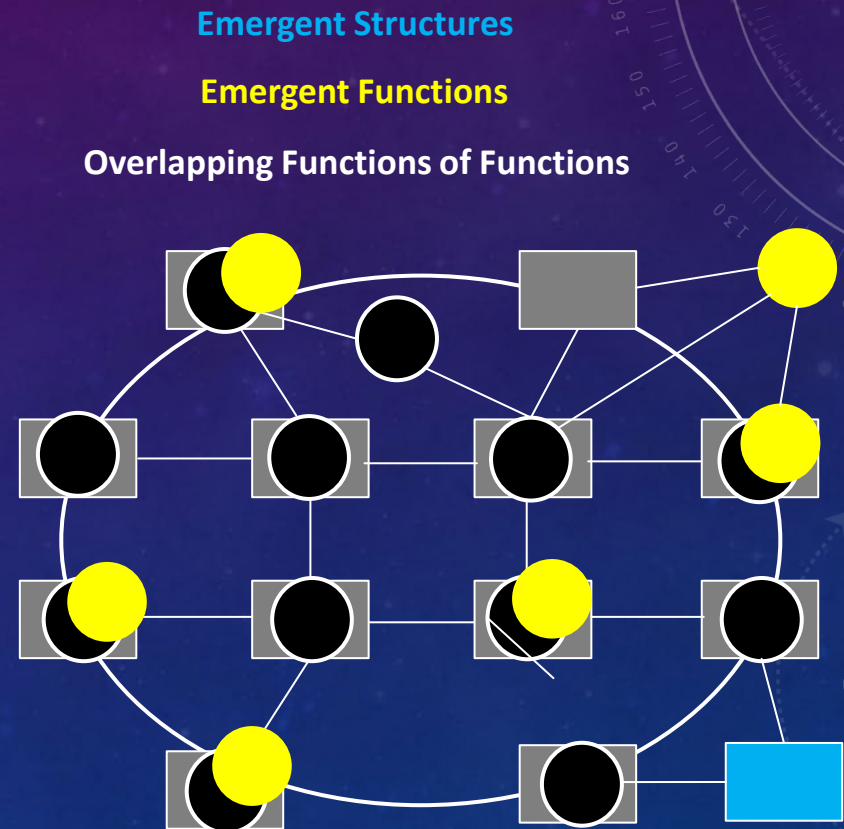

Systems represents Humans and Machines...

Interconnected System of Systems

SYSTEM = STRUCTURE + FUNCTION

Emergent Structures

Emergent Functions
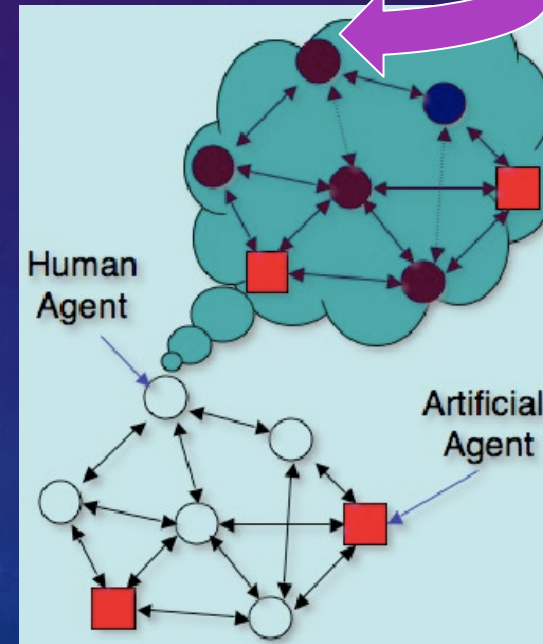
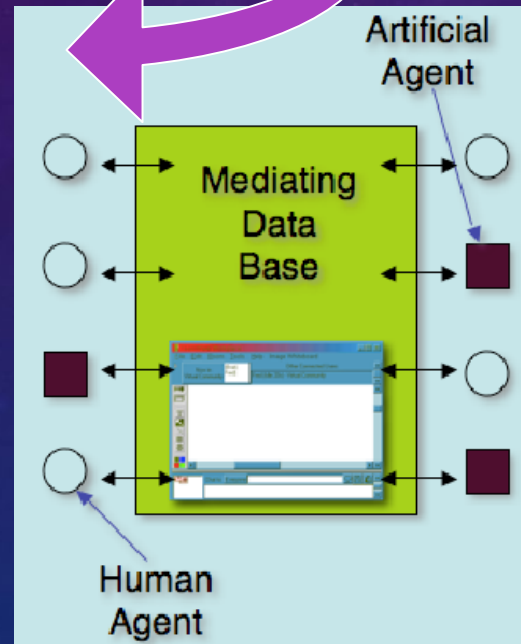**Overlapping Functions of Functions**

Interconnected Functions of Functions

Interconnected Structures of Structures

THREE SYSTEMIC INTERACTION MODELS

- ❑ Supervision
- ❑ Mediation
- ❑ Cooperation by common understanding

Boy, G.A. (2020). Human Systems Integration: From Virtual to Tangible, CRC, Taylor & Francis, Florida, USA.

OPERATIONS

PROCEDURAL SCENARIOS

Systems engineering

CONTEXT ARCHITECTURE…

… SYSTEM ARCHITECTURE

Data analytics

DECLARATIVE CONFIGURATIONS

ENGINEERING DESIGN

Maturity Readiness Levels

MATURITY READINESS LEVELS
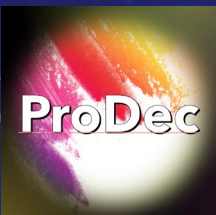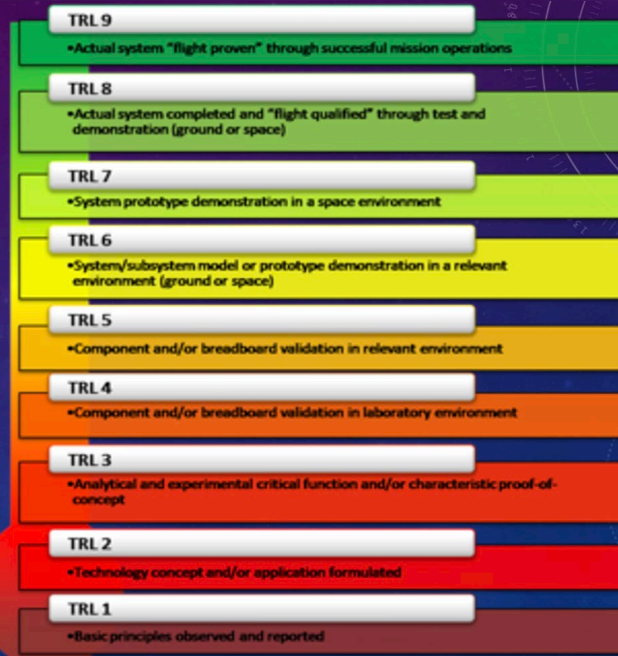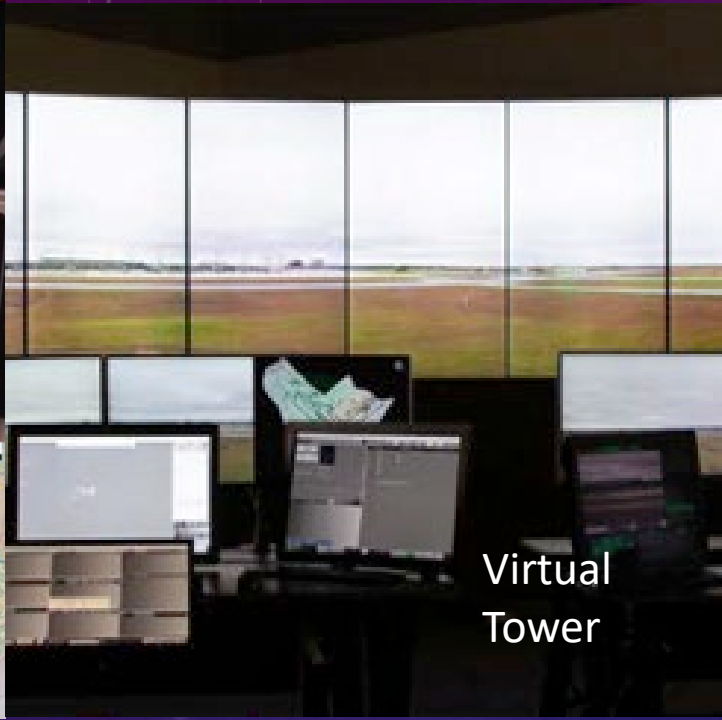
Organization: ORL

Human: HRL

Technology: TRL

TRL 9
• Actual system "flight proven" through successful mission operations

TRL 8
• Actual system completed and "flight qualified" through test and demonstration (ground or space)

TRL 7
• System prototype demonstration in a space environment

TRL 6
• System/subsystem model or prototype demonstration in a relevant environment (ground or space)

TRL 5
• Component and/or breadboard validation in relevant environment

TRL 4
• Component and/or breadboard validation in laboratory environment

TRL 3
• Analytical and experimental critical function and/or characteristic proof-of-concept

TRL 2
• Technology concept and/or application formulated

TRL 1
• Basic principles observed and reported

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

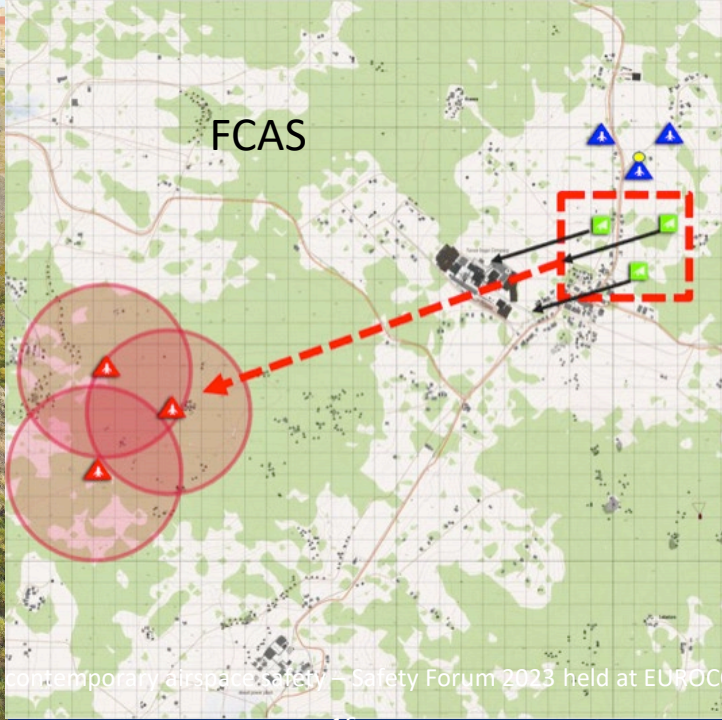| ORL-0	First principles where potential organizational models are explored.
ORL-1	Goal-oriented research that requires making choices from first principles to practical fully digital organizational setups
ORL-2	Proof of principle development, and active R&D is started in a virtual environment
ORL-3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

MOHICAN

Virtual Tower
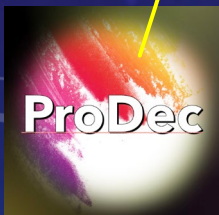
ProDec

RESEARCH EFFORTS

SNCF Autonomous Train

FCAS

Off-shore telerobotics

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NOW, LET'S USE PRODEC
IN CIVIL AIRSPACE DESIGN FOR SAFETY...

Human Systems Integration

ProDec

FlexTech Chai

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THANK YOU...