USE CASE GROUP 1: Studying the operational context of remote air traffic control center

Spring School: "Human-AI teaming: A Human Systems Integration Approach"

Alexandre Disdier [1,2,3,5]
Justine Limoges [5,6]

29th May 2024

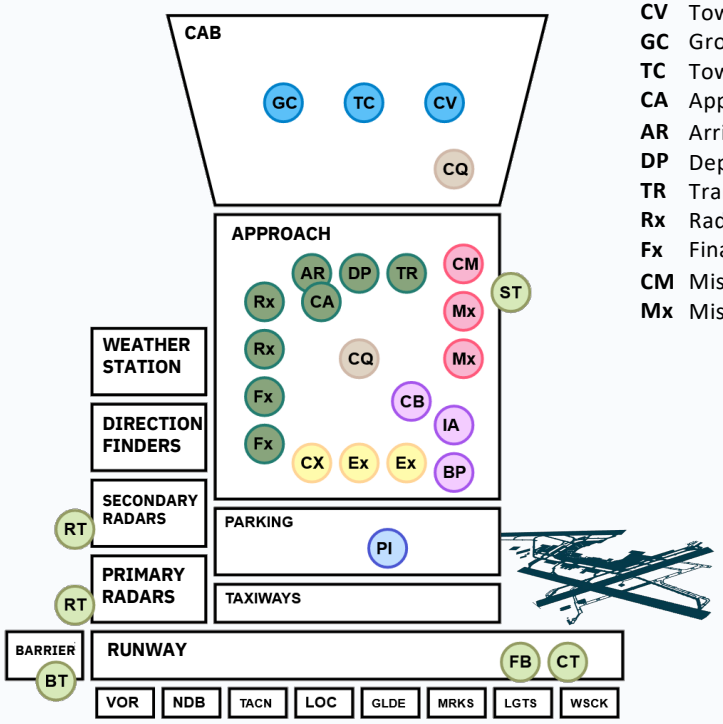
Pr. Marija Jankovic [1,5]
Pr. Guy André Boy [1,2,5]
Dr. Dimitri Masson [4,5]
Dr. Anne-Laure Jousselme [3]

Research project from from 10th January 2022 to 30th June 2025

(1) Paris Saclay University, CentraleSupélec, LGI, 9 rue Joliot Curie, 91190 Gif-sur-Yvette, France
(2) ESTIA Institute of Technology, 90 allée Fauste d'Elhuyar, F-64210 Bidart, France
(3) CS Group, 22 Avenue Galilée, 92350 Le Plessis-Robinson, France
(4) Bordeaux University, ESTIA Institute of Technology, 90 allée Fauste d'Elhuyar, F-64210 Bidart, France
(5) FlexTech Chair, CentraleSupélec and ESTIA
(6) Ingenuity io, 3 avenue de l'Europe, Bât B, 31400 Toulouse, France

The air traffic control tower: a complex sociotechnical system

TRADITIONAL TOWER

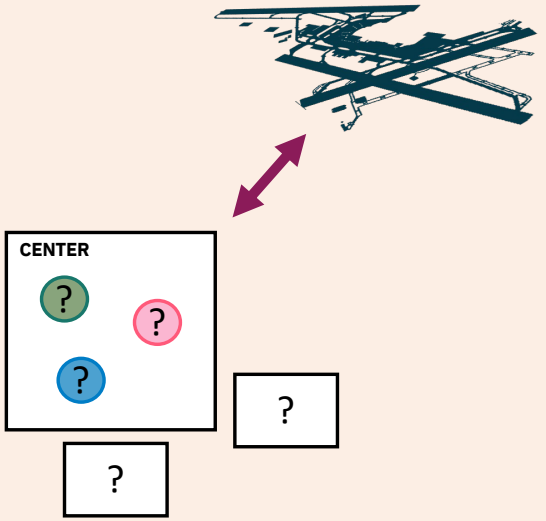


CQ Officer
CV Tower Officer
GC Ground Controller
TC Tower Controller
CA Approach Officer
AR Arrival Controller
DP Departure Controller
TR Transfer Controller
Rx Radar Controller
Fx Final Controller
CM Mission Officer
Mx Mission Controller

CX Flight Test Officer
Ex Flight Test Controller
CB Information Officer
IA Information Operator
BP Track Controller
ST Server Technician
RT Radar Technician
BT Barrier Technician
FB Fire Brigades
CT Crash Team
ER En Route Controller

- **MILITARY DETECTION CENTERS**
- **MILITARY EN ROUTE CENTERS** ER
- **CIVIL EN ROUTE CENTERS** ER
- **OTHER TOWERS**
- **COMMAND AND CONTROL**

REMOTE CENTER

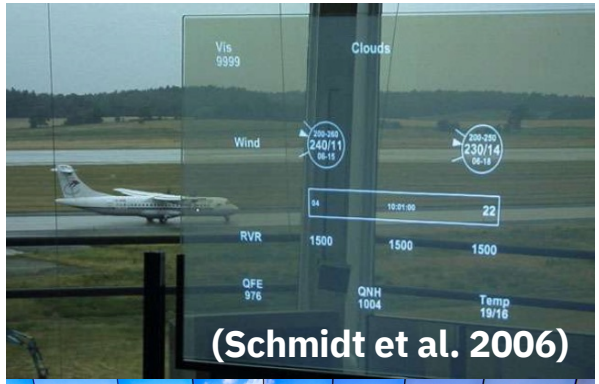


Motivation :

Cost savings
Monitoring of isolated airfields
Less exposure to enemy forces

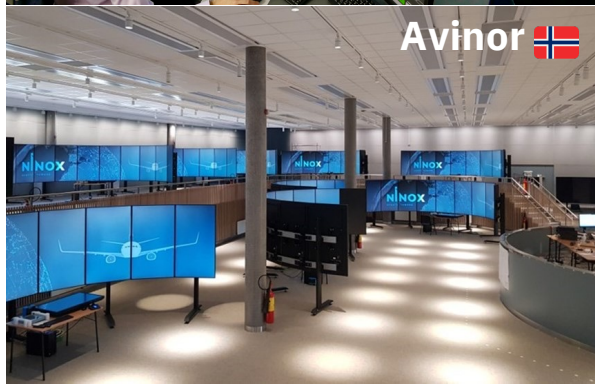
Remote and Virtual Towers (RVTs): a brief history

First studies: augment the window view with optronic devices (Fürstenau et al., 2004)
Goal: keep controller's focus outside the tower

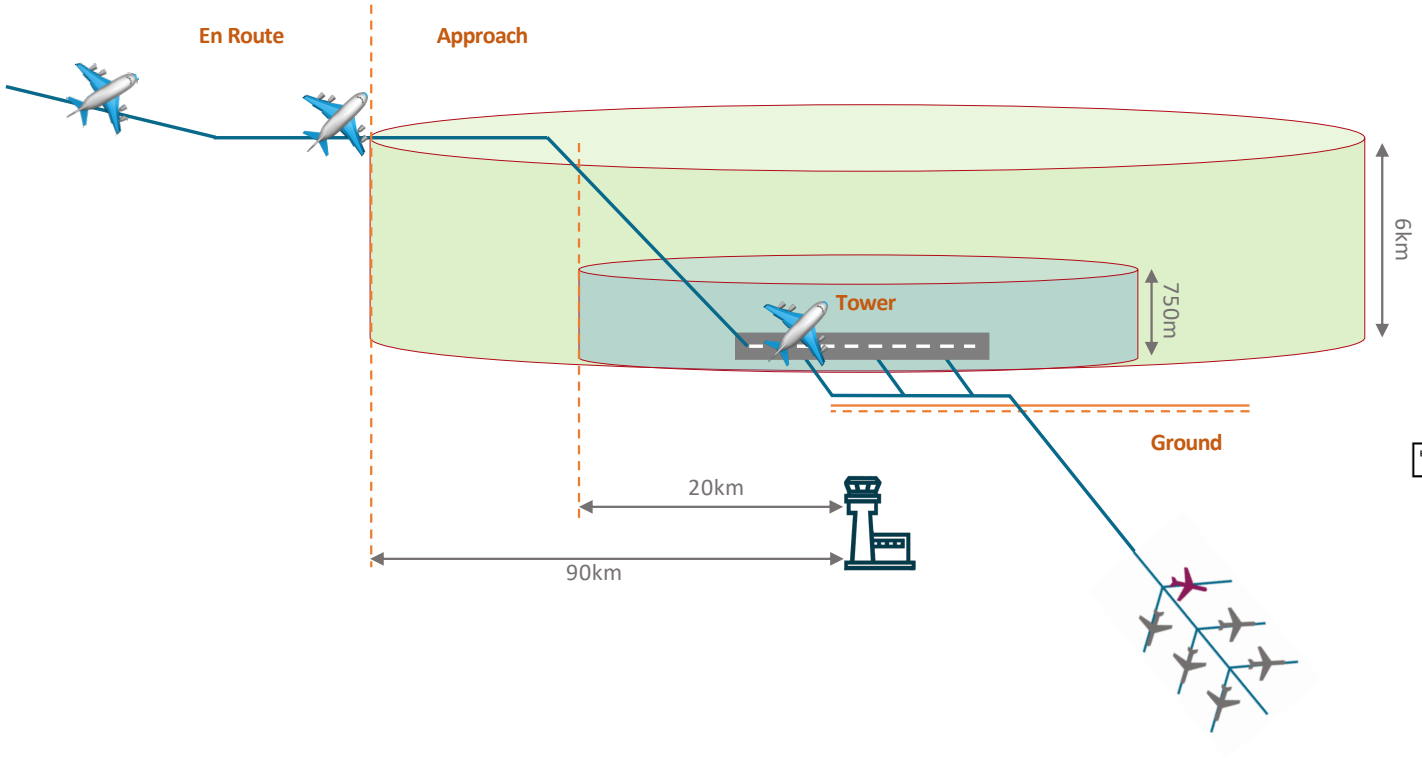


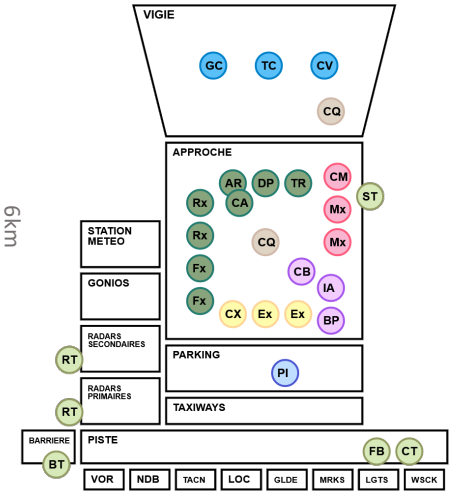
Then: remove the physical tower and replace it with a remote center (Schaik et al., 2016)
Potentially located hundreds of kilometers away
A screen wall has been substituted for out-the-view windows

Now: one center for multiple airfields (Papenfuss and Friedrich, 2016)
We talk about Multiple Remote Tower Operations (MRTO)

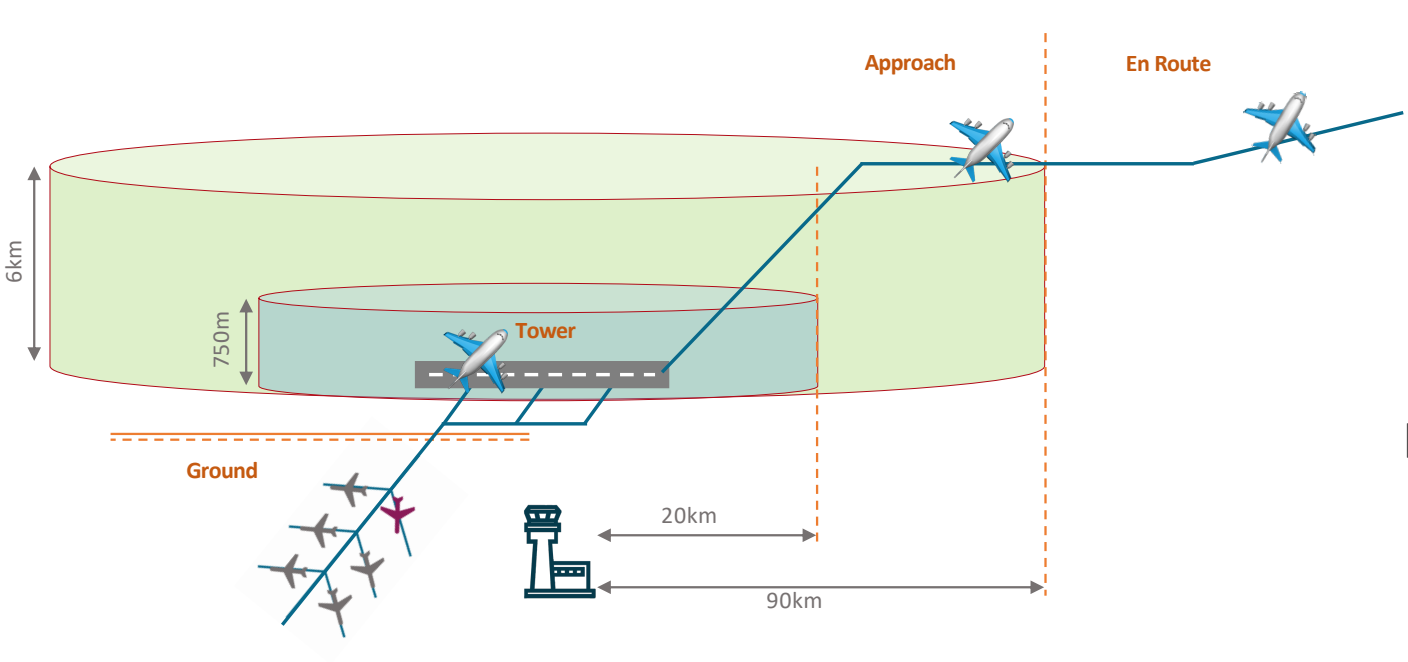


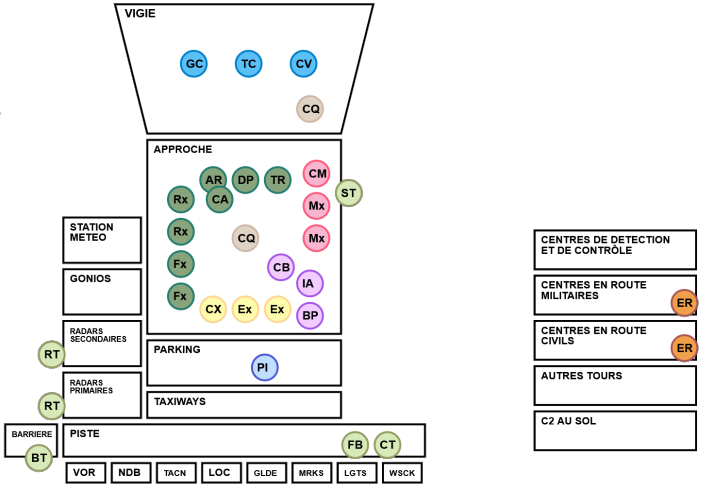
How Air Traffic Control (ATC) works: arrivals





How Air Traffic Control (ATC) works: departures





Need for an HSI approach to the remote ATC center problem

Operational people

Controllers, radar technicians, barrier technicians, maintenance personnel, ground personnel, pilots, weather forecast personnel, fire brigades, emergency service, crash team, security personnel, services de secours, crash team, security personnel, passengers

Non operational people

Designers, developers, testing team, engineers, managers, supervisors, training personnel, manufacturers, suppliers, qualifiers, regulators

A Human Systems Integration (HSI) approach to design must consider the need of everyone throughout the whole lifecycle (Booher, 2003; US Air Force, 2009; NASA, 2021)

EXAMPLES OF HUMAN SYSTEMS INTEGRATION (HSI) METHODS (Booher, 2003; USAF, 2009; NASA, 2021)

User-Centered Design (UCD)

"Design process in which end-users influence how a design takes shape"

(Abras, 2004)

Scenario-Based Design (SBD)

"*The **use** of a future system is concretely described at an early point in the development process*"

(Rosson and Carroll, 2002)

Human-In-The-Loop Simulations (HITLS)

"*Generating a better understanding of human behavior under complex situations*"

(Rothrock and Narayanan, 2011)

An example: procedural model of a precision approach and landing

The *context* component in complex sociotechnical systems

Case study from CS GROUP's French Airforce ATC program

Grounded Theory analysis of collaborators interviews to identify the gaps in CS GROUP's engineering processes
Publication in ICED23 proceedings (Disdier, 2023)

The focus of this project is on the notion of *operational context*

Context complexity is what make systems of systems behavior emergent (Shah, 2007)

MAIN RESEARCH QUESTION

How could the context of complex sociotechnical systems be integrated in the modeling of operational scenarios during design?

Our review process for studying context in the literature

1. Look for Systems Engineering and HSI-related papers

TABLE 1 Database exploration of SE context-related papers

Database	# output results	# relevant sources
IEEE Xplore	437	14
Web of Science	224	3
Scopus	248	20
ScienceDirect	118	3
Systems Engineering Journal (Wiley)	41	3
INCOSE Papers & Presentations Library	20	2

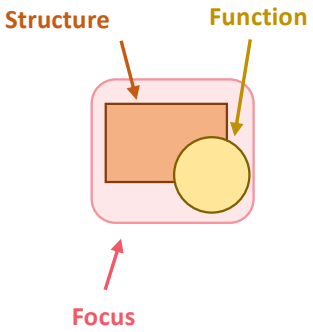
2. Extend our corpus to some other engineering and non-engineering papers

TABLE 2 Selected sources statistics per domain

Research domain	# sources	# definitions
Context-Aware Computing	8	4
Computer Science	7	5
Design Processes	6	3
Systems Engineering	7	1
Complex Systems	5	4
Cognitive Sciences	5	4
Business Processes	5	1
Artificial Intelligence	4	1
Requirements Engineering	4	2
Ubiquitous Computing	4	2
Systems of Systems	4	2
Human-Computer Interaction	3	2
Cyber-Physical Systems	3	3
Social Sciences	2	1
Information Systems	2	0
Intelligent Systems	2	2
Miscellaneous	10	7
Total	**81**	**44**

There is no consensual definition of context

Our operational context model for complex sociotechnical systems (1/6)



Examples

Structure : Ground Controller

Function: Give clearance for takeoff

Our operational context model for complex sociotechnical systems (2/6)

Examples

Weather ∈ {Clear Skies, Few Clouds, Scattered Clouds, Broken Clouds, High Level Clouds, Overcast, Rain, Snow, Storm}

Hour ∈ [[0;23]]

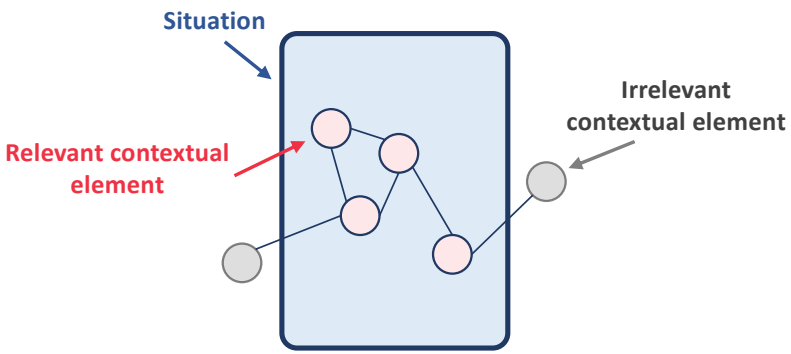
Minute ∈ [[0;59]]

Air Traffic ∈ {Low, Medium, High}

Primary Radar State ∈ {On, Off}

…

Our operational context model for complex sociotechnical systems (3/6)



Example

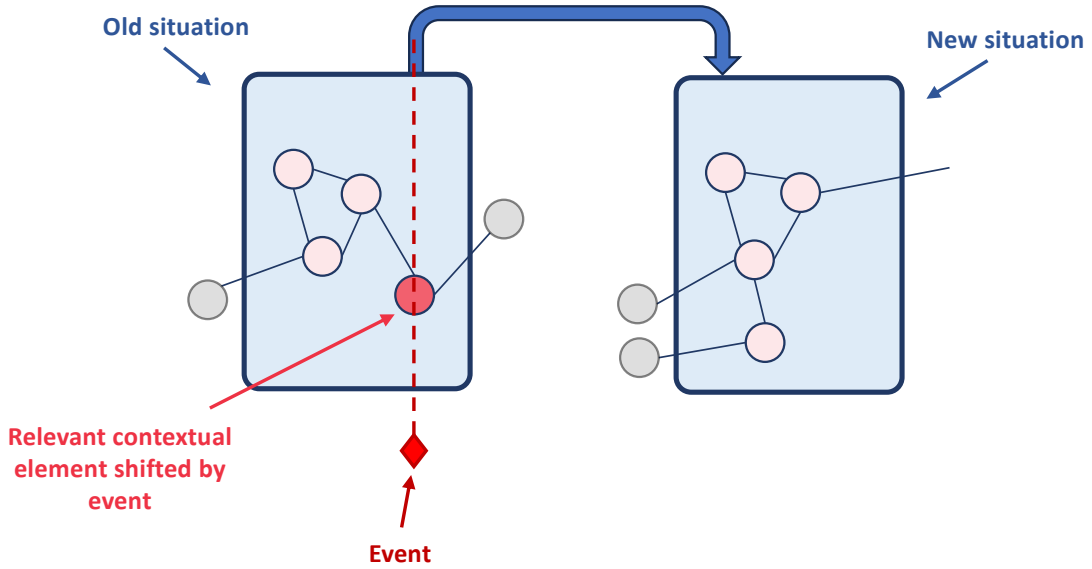
Weather: Clear Skies
Ground Trafic: Low
Flight Plan: Found
Flight Type: Visual(VFR)

Relevant

Radar state: maintenance
Track: Cleared
Barrier: Working
Aera Access Status: Restricted
Place: Mont-de-Marsan
Hour: 10h50
Controllers on duty: 2
...

Irrelevant

Our operational context model for complex sociotechnical systems (4/6)

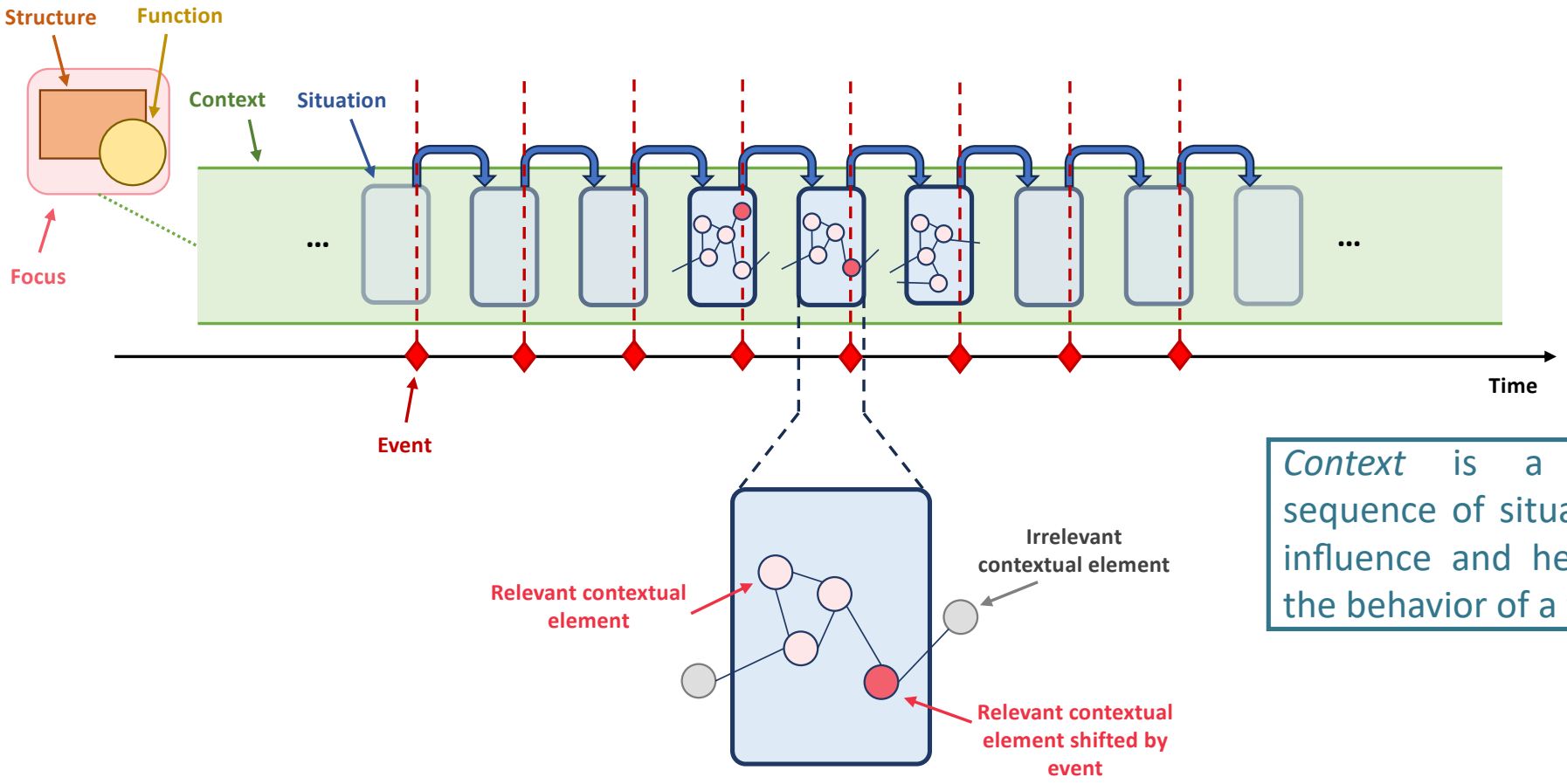


Example

Weather: ~~Clear Skies~~ => High Level Clouds

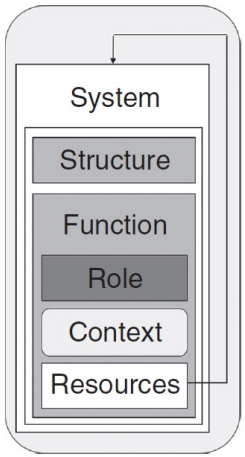
Storm Event

Our operational context model for complex sociotechnical systems (5/6)

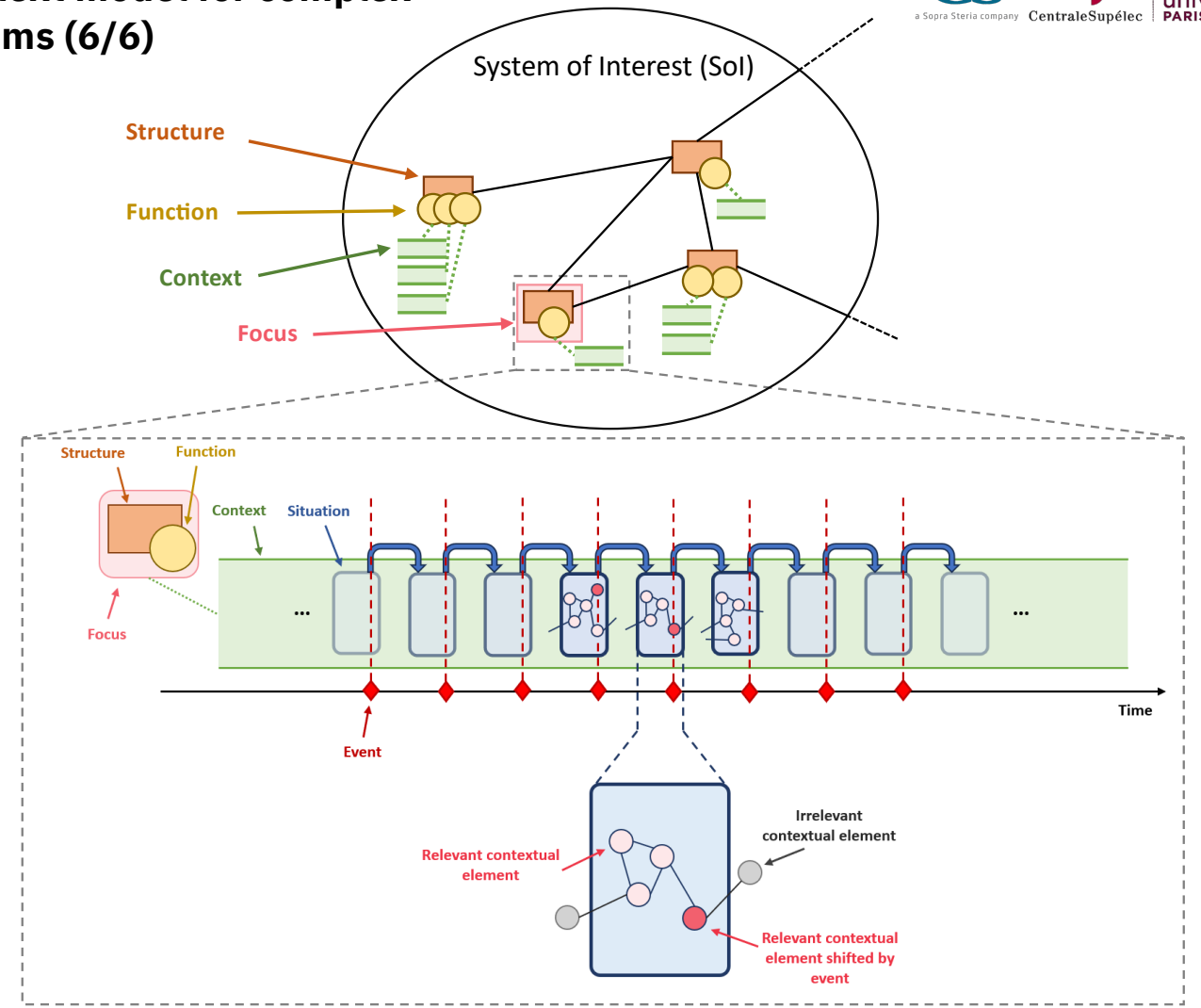


Context is a historical sequence of situations that influence and help explain the behavior of a focus.

Our operational context model for complex sociotechnical systems (6/6)

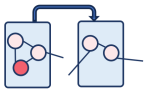


(Boy, 2022)



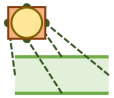
The 6 properties of operational context

Transient



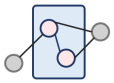
Context is not static, it is a dynamic thing that changes through time

Specific



Context is always relative to some focus object and cannot be discussed in an absolute manner

Curated

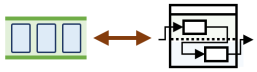


Only a few contextual elements have a real relevance to the system and its behavior

Holistic

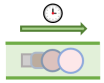
Multiple agents can share contextual elements, so some contexts are agregations of others

Entangled



Context and systems affect each other's resources and behavior

Persistent



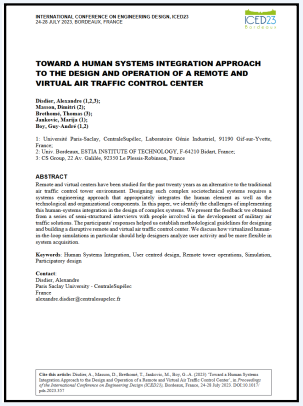
Former values of a contextual element can still have a relevance to the current situation

Going further

ICED23

"Toward a Human System Integration Approach to the Design and Operation of a Remote and Virtual Air Traffic Control Center"

- Identify the gaps in SE within French Airforce's ATC program from CS Group
- Semi-structured interviews with CS Group collaborators
- Grounded theory analysis of interviews


INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, ICED23
24-28 JULY 2023, BORDEAUX, FRANCE

TOWARD A HUMAN SYSTEMS INTEGRATION APPROACH TO THE DESIGN AND OPERATION OF A REMOTE AND VIRTUAL AIR TRAFFIC CONTROL CENTER

Didier, Alexandre (1,2,3);
Masson, Dimitri (2);
Brethomé, Thomas (3);
Jankovic, Marija (1);
Boy, Guy-André (1,2)

ABSTRACT

Keywords: Human Systems Integration, Users centred design, Remote tower operations, Simulation, Participatory design

Contact:
Didier, Alexandre
Paris Saclay University - CentraleSupélec
France
alexandre.didier@centralesupelec.fr

Cite this article: Didier, A., Masson, D., Brethomé, T., Jankovic, M., Boy, G.-A. (2023) 'Toward a Human Systems Integration Approach to the Design and Operation of a Remote and Virtual Air Traffic Control Center', in *Proceedings of the International Conference on Engineering Design (ICED23)*, Bordeaux, France, 24-28 July 2023. DOI:10.1017/pds.2023.337

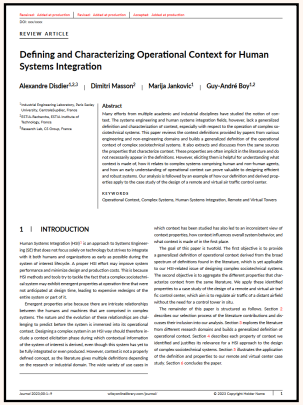
Completion

Accepted & Published

INCOSE's Systems Engineering Journal (HSI Special Issue)

"Defining and Characterizing Operational Context for Human Systems Integration"

- Literature review article
- Elicitation of context definition and properties
- Focus on the *operational context* of complex sociotechnical systems


REVIEW ARTICLE

Defining and Characterizing Operational Context for Human Systems Integration

Alexandre Didier[1,2,3] | Dimitri Masson[2] | Marija Jankovic[1] | Guy-André Boy[1,2]

Abstract

KEYWORDS
Operational Context, Complex Systems, Human Systems Integration, Remote and Virtual Towers

1 | INTRODUCTION

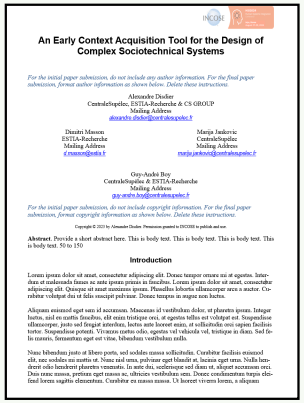
10-15 published pages, double-column
Deadline: unknown

Accepted

INCOSE's HSI 2024 Conference

"An Early Context Acquisition Tool for the Design of Complex Sociotechnical Systems"

- Presentation of the tool
- Description of the scenario contextualization process
- Application to the remote control center case study


An Early Context Acquisition Tool for the Design of Complex Sociotechnical Systems

Alexandre Didier
CentraleSupélec, ESTIA-Recherche & CS GROUP
Mailing Address
alexandre.didier@centralesupelec.fr

Dimitri Masson
ESTIA-Recherche
Mailing Address
d.masson@estia.fr

Marija Jankovic
CentraleSupélec
Mailing Address
marija.jankovic@centralesupelec.fr

Guy-André Boy
CentraleSupélec & ESTIA-Recherche
Mailing Address
guy-andre.boy@centralesupelec.fr

Abstract. Provide a short abstract here. This is body text. This is body text. This is body text. This is body text. 50 to 150

Introduction

8 published pages, single-column
Deadline: 20th december 2023

Accepted

Brainstorm

Which contextual elements matter to our landing scenario?

Guiding questions (for TO-BE solution and report)

- Identify other visual, audio or non-visual/non-audio features that may be relevant to the Ground and Tower Controller

- Try to classify the provided features (and any additional feature you may have thought of) according to the basic ATC cognitive functions: DETECT, RECOGNIZE, IDENTIFY, JUDGE

- Consider how the transition from a local to a remote context may affect these features. Which resources may keep the controller aware of the situation in a remote context?

- Does the first half of the scenario from Sheet #1 (i.e. during the "Before transfer" and "Approach" stages) need to be modified to cope with the new remote context?

- How would you classify/order contextual elements (political, cognitive, disponibility of equipment, visual, sounds, physical...)?

- What is context to you? Would you model context for complex sociotechnical systems differently?

Key references

Furstenau, N., Rudolph, M., Schmidt, M., Lorenz, B. and Albrecht, T. (2004), "On the use of transparent rear projection screens to reduce head-down time in the air-traffic control tower", in: HPSAA, Vol. 1, Psychology Press, Daytona Beach, pp. 195–200.

Schaik, F.J., Roessingh, J.J.M., Lindqvist, G. and Fält, K. (2016), Detection and Recognition for Remote Tower Operations, in: Fürstenau (2014), pp. 53–65, http://doi.org/10.1007/978-3-319-28719-5_3.

Disdier, A., Masson, D., Brethomé, T., Jankovic, M. & Boy, G.A. (2023). Toward a Human Systems Integration approach to the design and operation of a remote and virtual air traffic control center. Proceedings of ICED 2023, Bordeaux, France.

Mankins, J.C. (1995). Technology Readiness Levels-A White Paper.

Salazar, George & See, Judi & Handley, Holly & Craft, Richard. (2020). Understanding Human Readiness Levels. Proceedings of the Human Factors and Ergonomics Society Annual Meeting. 64. 1765-1769. 10.1177/1071181320641427.

Booher, H.R. (2003), Handbook of human systems integration, John Wiley & Sons. http://doi.org/10.1002/0471721174.

US Air Force (2009), Air Force Human Systems Integration Handbook, US Air Force.

NASA (2021), Human Systems Integration Handbook, NASA.

Strauss, A. and Corbin, J. (1990), Basics of qualitative research, Sage publications.

Rosson, M.B., & Carroll, J.M. (2002). Scenario-based design.

Rothrock, L., & Narayanan, S. (2011). Human-in-the-Loop Simulations: Methods and Practice.

Boy GA, Morel C. The machine as a partner: Human-machine teaming design using the PRODEC method. Work. 2022;73(s1):S15-S30. doi: 10.3233/WOR-220268. PMID: 36214030.

Camara Dit Pinto, Stélian & Masson, Dimitri & Villeneuve, Éric & Boy, Guy & Urfels, Laetitia. (2021). From Requirements to Prototyping: Application of Human-Systems Integration Methodology to Digital Twin Design. Proceedings of the Design Society. 1. 1617-1626. 10.1017/pds.2021.423.

Abowd, G.D., Dey, A.K., Brown, P.J., Davies, N., Smith, M.T., & Steggles, P. (1999). Towards a Better Understanding of Context and Context-Awareness. HUC.

Winograd, Terry. (2001). Architectures for Context. Human-Computer Interaction. 16. 10.1207/S15327051HCI16234_18.

Brézillon, P., & Pomerol, J. C. (1999). Contextual knowledge sharing and cooperation in intelligent assistant systems. Le travail humain, 223-246.

Brézillon, Patrick. (2007). Context Modeling: Task Model and Practice Model. 4635. 122-135. 10.1007/978-3-540-74255-5_10.

Azad M. Madni, 2015. "Expanding Stakeholder Participation in Upfront System Engineering through Storytelling in Virtual Worlds," Systems Engineering, John Wiley & Sons, vol. 18(1), pages 16-27, January.

a Sopra Steria company

CentraleSupélec

université PARIS-SACLAY

LGi Laboratoire Génie Industriel

ESTIA INSTITUTE OF TECHNOLOGY RECHERCHE

FlexTech CentraleSupélec-ESTIA Chair

Thank you for your attention

✉ alexandre.disdier@csgroup.eu