Study and design of a remote and virtual air traffic control center using a Human Systems Integration approach

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Alexandre Disdier [1,2,3,5], Dimitri Masson [4,5], Thomas Brethomé [3,5], Marija Jankovic [1,5], Guy André Boy [1,2,5]

Assistant advisor — Industrial advisor — Advisor — Co-advisor

(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

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Research objectives

- Study how virtualisation can help air traffic controllers in a remote center which replaces the traditional tower on the airfield
- Propose a design methodology consistent with the principles of Human Systems Integration (HSI) to support the acquisition of such a system

Remote and Virtual Towers (RVT)

RVTs have been studied since the late 90s as a new paradigm to Air Traffic Control (ATC). Most prototypes today aim to remove the physical tower and replace it with a remote center, potentially located hundreds of kilometers away, in which a screen wall is substituted for out-the-view windows. The screens display a video signal from cameras positioned around the target airfield (Fürstenau, 2016).

RVT advantages:

- Cost savings as construction and maintenance of the traditional tower is no longer required
- Pooling of resources from several low-traffic airfields into a single remote center
- Ease of deployment, particularly in military operations or isolated terrain

Problem:
RVTs as they are developed today require heavy equipment and infrastructures (wall of screens, camera sensors, broadband connections). Most of all, they only shift the controllers' difficulties into a remote location but do not reconsider the role of the human element (i.e. controllers, but also people like technicians, trainers, deployment personnel or pilots) within the system. In other words, issues regarding the controllers' trust in the system, focus, situation awareness, fatigue and comfort are not directly addressed.

Human Systems Integration (HSI)

HSI is an effort that strives to provide a set of methods, tools and processes as part of a wider systems engineering approach to ensure that humans are integrated in a cohesive manner into all stages of a system life cycle. In HSI, the human element is considered as being another component of a system along with traditional software and hardware components. The term "human" in HSI refers to all personnel involved with a given system, including not only end-users, but also owners, designers, test personnel, operators, maintenance personnel, support personnel, logistics suppliers and training personnel.

RVTs are complex, life-critical sociotechnical systems of systems. They are life-critical because an unanticipated or poorly managed event may result in severe injury and hazards. However, anticipating every potential event that may occur before a system is deployed is a difficult task. Human behavior during operation is also highly unpredictable. As such, an RVT system is likely to show emergent properties that may not have been expected during design time. This calls for measures to add flexibility: during operations so that the whole system should be able to restructure itself to cope with incidents and unusual events ; during system design, so that we want to detect these emergent properties as soon as possible, especially before any substantial financial commitment has been made.

When and how can we implement HSI?

We conducted a series of semi-structured interviews with engineers and designers involved in air traffic control programs for the French Airforce. We asked general questions about the systems engineering processes and practices currently in place. Following a grounded theory-based approach (Strauss, 1990), we identified 4 categories of critical points that appropriate HSI practices may improve.

Increase flexibility in design
High-level objectives
Circumvent rigidity of traditional SE models
Enablers
Consider several alternative designs
Develop supporting digital tools
Know when to reconsider decisions
Prioritize most needed features
Raise frequency of exchanges
Challenges
Late commitments from clients
Long-term requirement variability
Imposed SE contraints and standards
Ambiguity on V&V baseline

Engage the right stakeholders
High-level objectives
Involve operators
Enablers
Be transparent for customers
Ensure users are projected into the system
Ensure users trust system data
Highlight scenario-based design
Keep subject matter expert engaged
Make stakeholders interact with the system
Challenges
Out-of-scope client expectations
Subject matter expert varying availability
Intermediary stakeholder interference
Conflicting views

Consider post-deployment early
High-level objectives
Consider maintenance early
Consider training early
Ensure steady operational readiness
Ensure system performance in real conditions
Enablers
Keep documentation focused and short
Motivate stakeholders to use documentation

Grow an organization-wide culture
High-level objectives
Sensitize internal teams to SE challenges
Enablers
Make internal units cooperate
Challenges
Lack of trust on agility from collaborators

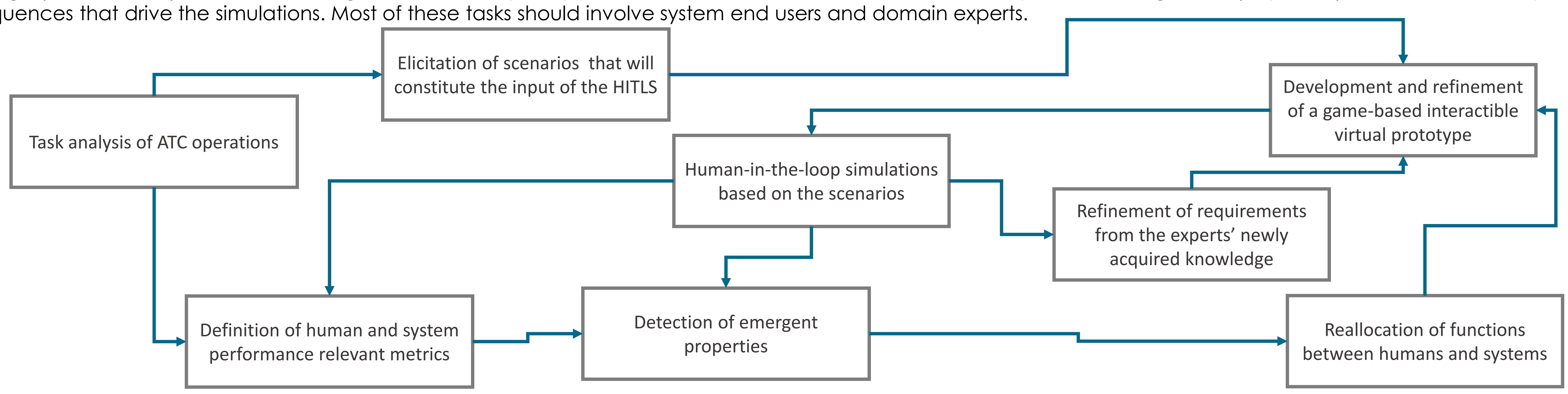
Our RVT desired characteristics

- Provide the same features than traditional towers
- Explore alternative interactions concepts (i.e. non-visual only)
- Not just be a heavy camera-based restitution of the airfield (most prototypes today)
- Reconsider roles of controllers, technicians, pilots, and non-human elements

Be designed as a complex sociotechnical system, following a Human Systems Integration approach based on early virtual human-in-the-loop simulations

Research methodology

We promote early user activity analysis, carried out through human-in the-loop simulations (HITLS) and virtual world storytelling (Madni, 2015), coupled with scenario-based design (Rosson, 2002). HITLS enable engineers to identify early patterns and behaviours that were not anticipated at design time (Boy, 2021). Scenarios are the procedural sequences that drive the simulations. Most of these tasks should involve system end users and domain experts.



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