Human Factors Integration in ATM System Design

Basic Principles and Recommendations

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Outline

1. Introduction
2. Methodology
3. Nine Principles for an Advanced HF Integration
4. Recommendations for ANSPs and the HF Discipline

Introduction

Design

Safety

Human Factors

How do we understand safety?

November 28th 1979
Air-New-Zealand Flight 901

January 28th 1986
Challenger

July 1st 2002
Überlingen

February 1st 2003
Columbia

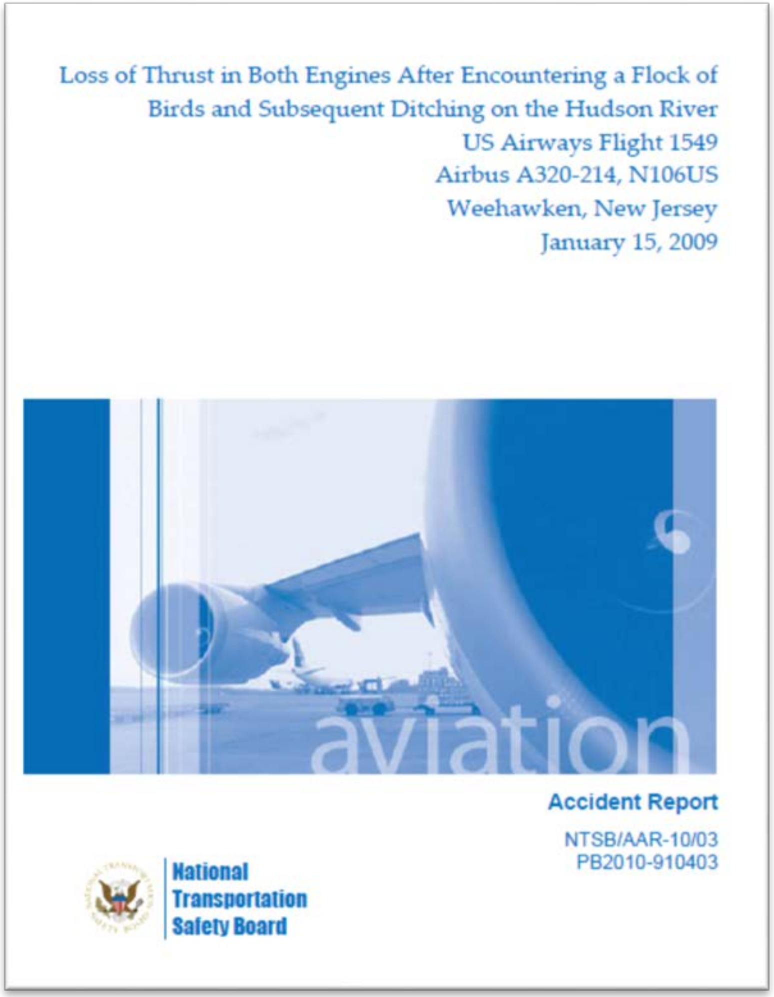
January 15th 2009
US-Airways Flight 1549

June 1st 2009
Air France 447

US-Airways Flight 1549

Contributing to the survivability of the accident was

- (1) the decision-making of the flight crewmembers and their **crew resource management** during the accident sequence;
- (2) the fortuitous use of an airplane that **was equipped for an extended overwater flight**, including the availability of the forward slide/rafts, even though it was not required to be so equipped;
- (3) the **performance of the cabin crewmembers** while expediting the evacuation of the airplane; and
- (4) the proximity of the emergency responders to the accident site and their **immediate and appropriate response** to the accident.



National Transportation Safety Board, 2010

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Safety and Design

Definition: Human Factors and Ergonomics

Definition from IEA (2012) and DIN EN ISO 6385 (2004):

Ergonomics (or human factors) is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance.

1. HF/E takes a systems approach
2. HF/E is design driven
3. HF/E focuses on system performance and human well-being

Dul et al. (2012)

Human Well-Being

Competence
"I'm good in what I do"

Autonomy
"I can do what I want the way I want it"

Popularity
"I have impact on what others do"

Physicality
"That my body was getting just what it needed"

Relatedness
"I feel close to the people I care about"

Security
"I'm safe from threats and uncertainties"

Stimulation
"I was experiencing new activities'

Hassenzahl (2019)

Methodology

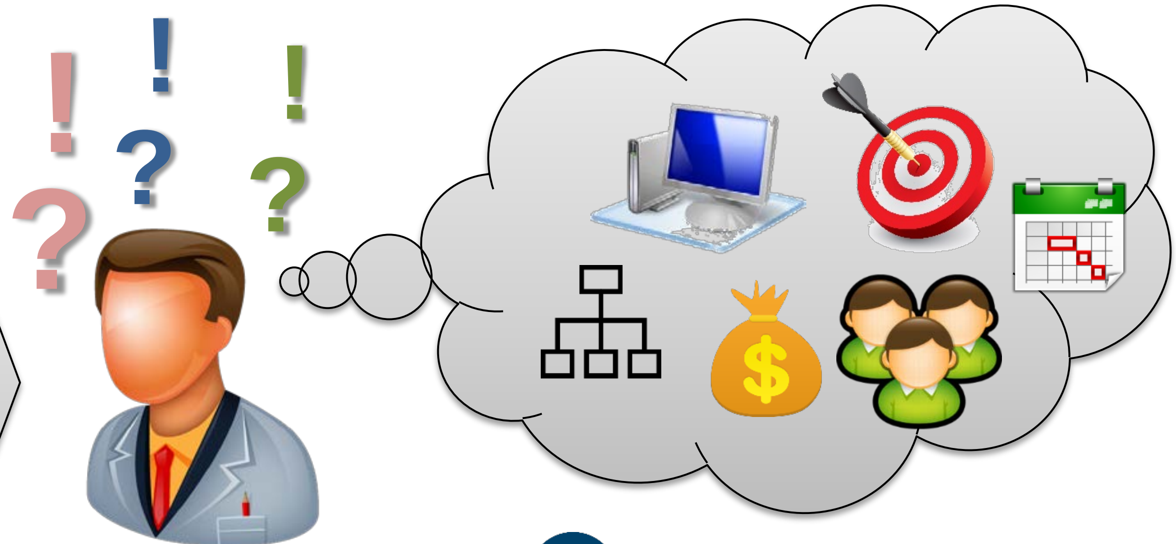
Abstract…

Specific…

Theories

Methods

Knowledge



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skyguide

1st Principle

Joint Design Teams

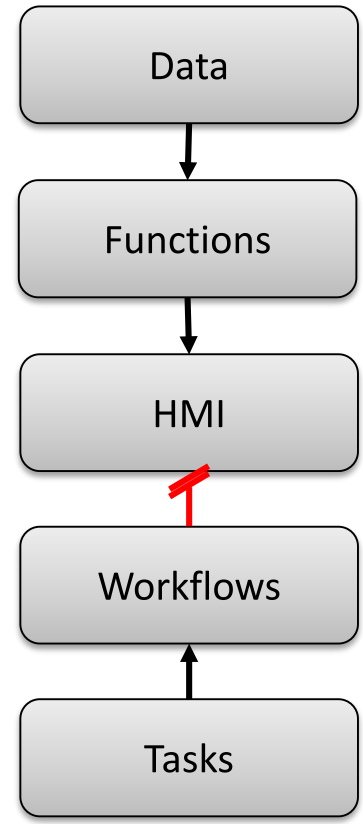
- HF/E is often seen as something separate and not as an active part of the development.
- HF/E is often reduced to the avoidance of the most important mistakes and “HF blessing” afterwards.
- Other industries typically don’t have separated HF departments. Why Aviation?
- Analysis vs. Design: What is the nature of HF/E and which process does it mainly support? Rather safety, risk and safety assurance or more requirements and systems engineering?
- Existing HF/E methods even facilitate the asymmetry between analysis and design. The implications are often implicit and vague from an engineering perspective.

> *Build joint design teams and incorporate HF/E into the development process: Not as a mandatory add-on, but as an integral part of the overall design process.*

2nd Principle

User-Centred Design Rationale

- It is often unclear why a CWP looks the way it does.
- It often makes sense from an engineering perspective (HMI is needed to provide the requested functions), but not necessarily from an user centered perspective (HMI is needed to carry out certain workflows in certain situations)
- What's needed is a coherent user centered rational from the very beginning.
- Today this is neither requested by the project managers nor provided by HF/E experts.

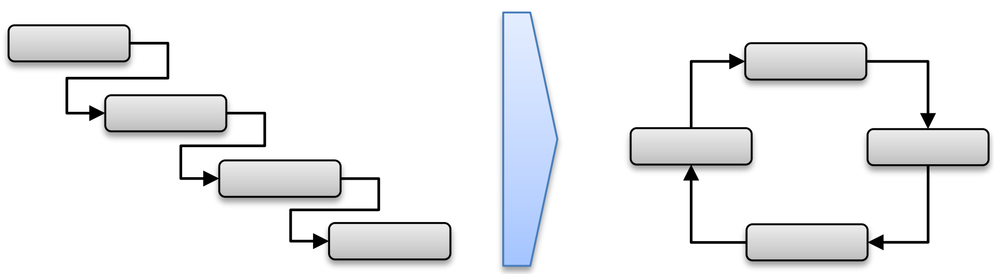


> *Today, system design mainly follows functional considerations. Make a coherent user-centred design rationale your HF/E product that can be seamlessly integrated into early phases of the engineering process.*

3rd Principle

User-Centred Design Process

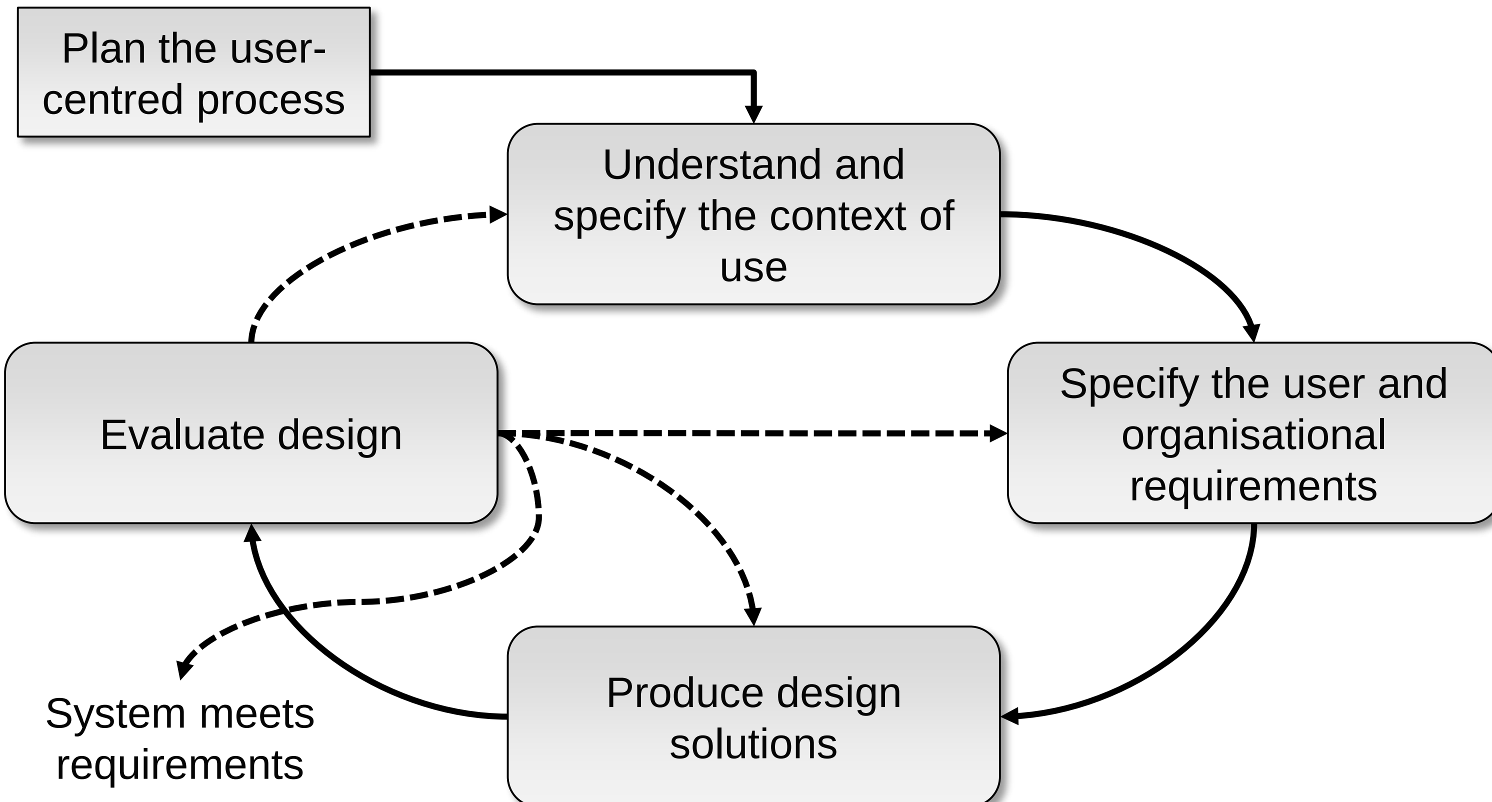
- Projects depend on certainty in terms of budget, schedule and quality. An incremental design approach is perceived to minimize project and safety risks.
- HF/E on the other hand needs a certain degree of flexibility to integrate identified HF/E aspects into ATM.
- Both objectives are not necessarily contradictory.
- Problems may arise, if the overall project management phase model does not reflect HF/E requirements.



> *Strive for a short, iterative user-centred design process and integrate it into existing processes, even though they are supposedly linear.*

3rd Principle

User-Centred Design Process



DIN EN ISO 9241-210

4th Principle

Objective HF/E Criteria

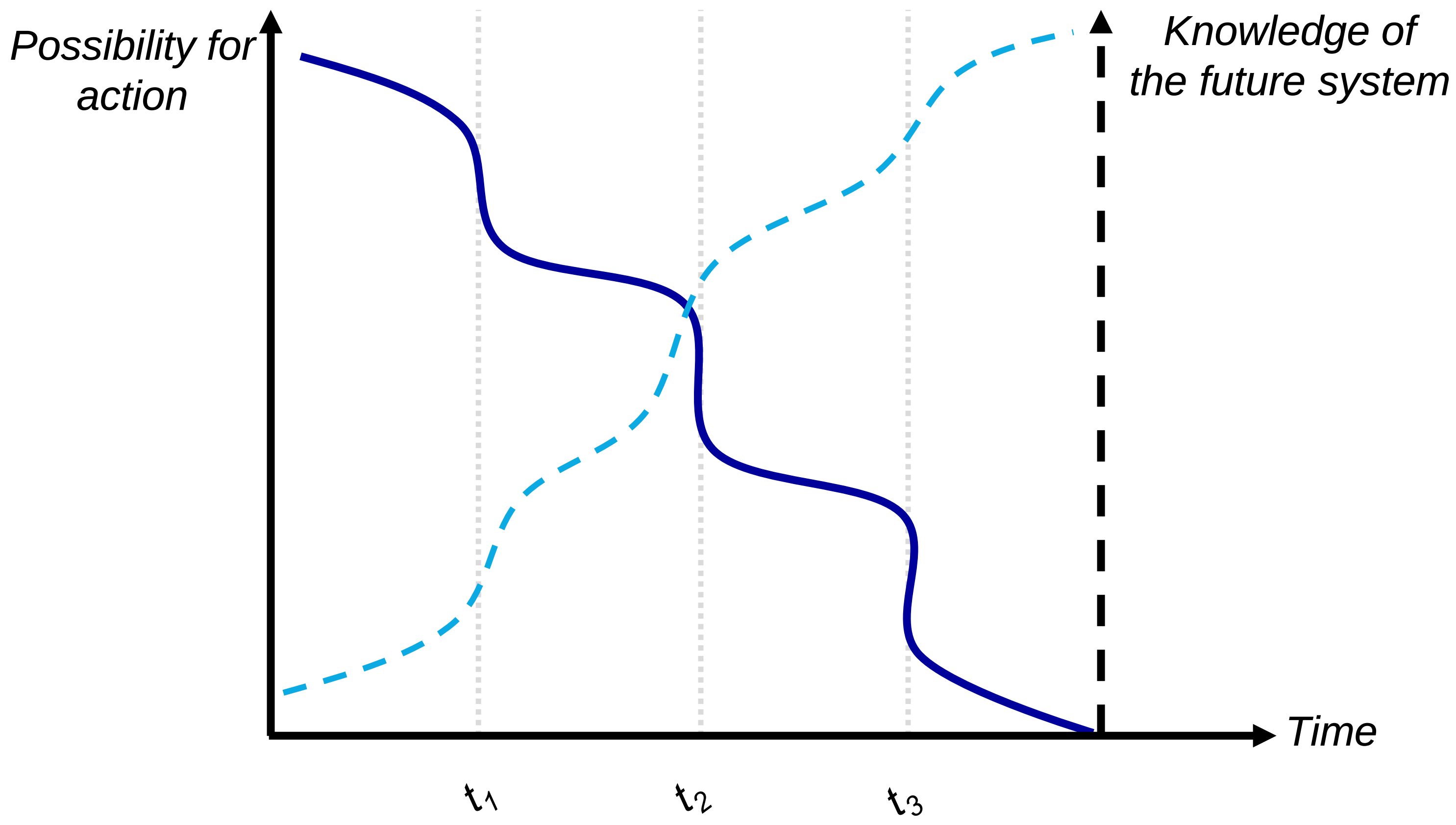
- One premise of user centered design is to include users as early as possible.
- It remains unclear how to integrate users in practice.
- User involvement is often opinion based and therefore highly subjective. Subjective criteria, however, are not suitable for a sustainable design rational.
- Danger of unstructured product reviews instead of discussing work related issues (procedures, adaptations, etc.).
- Other available methods are often restricted to a hazard oriented perspective (“what can go wrong”).

> *Opinions and anecdotes tell us little about underlying needs and mechanism. Translate user feedback into meaningful requirements and validate with the help of objective measures, which can be found within HF/E, but also other disciplines.*

5th Principle

Prototyping

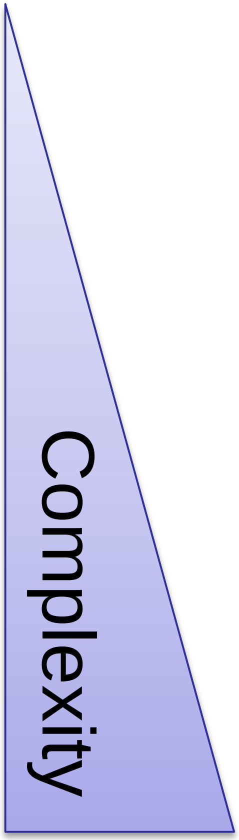
The dilemma of inverted knowledge acquisition



5th Principle

Prototyping

- ***Design Prototype :*** Early sketches and paper-based drafts to show the overall concept and the most important use cases.
- ***Laboratory Prototype:*** Analysis of specific issues under controlled conditions.
- ***Functional Prototype:*** Most features are already implemented and can be evaluated by the users (alpha version)
- ***Pilot System:*** Almost identicall with the final version (beta version)



> *Evaluate as early as possible with the help of prototypes, which range from pen & paper to beta versions to overcome the dilemma of inverted knowledge acquisition.*

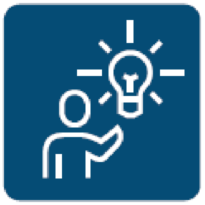
6th Principle

Conditions for Evaluating Prototypes

Normal operation	Abnormal operation / degraded mode
Normal amount of traffic Standard procedures apply All systems are working properly All positions are staffed	Working under extreme (high or low) workload Emergencies and exceptional situations Failure of primary and secondary systems Working under production pressure and short-staffed situations

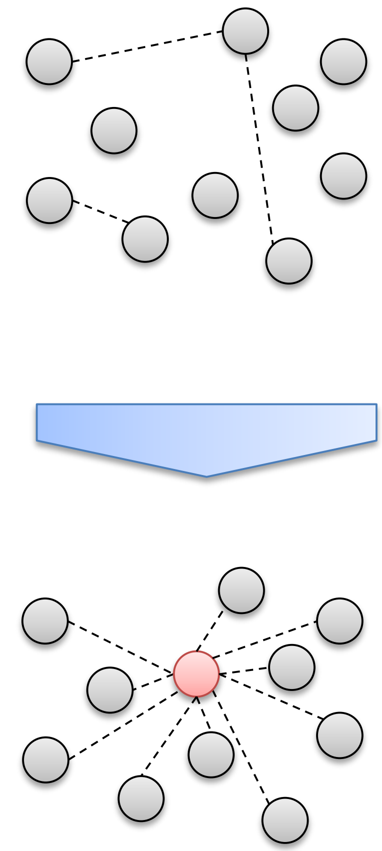
> *Select appropriate conditions for evaluation: Evaluate day-to-day scenarios as well as critical situations.*

7th Principle



Problem-solving

- Projects are complex and interdisciplinary undertakings. Responsibilities are scattered within the company.
- If single aspects are addressed in isolation, new problems are likely to occur.
- HF has the potential to resist the call for a quick fix by taking a holistic perspective.
- Balancing and weighting off different requirements from different disciplines and departments is a challenge in complex organizations.
- HF may act as mediator within an organization.



> “ *Support the problem-solving process during implementation by facilitating trade-off-decisions*

8th Principle

Problem-setting

Problem…

setting	solving
Task for a strategic HF/E	Task of an operational HF/E
Define desirable goals	Define achievable goals
Define a design strategies	Search the best solutions given the constraints (budget, time, human)
Decide on analysis and diagnosis	Coordinate interdependences
Coherence of requirements	Requires specific knowledge about HF/E in design
Project planning	HF/E as integral part of the project
Confrontation between required HF/E quality in ATM system and deadlines & cost criteria	

> *Do a proper problem-setting in the first place whenever possible to understand your actual problem and the underlying mechanism and needs.*

9th Principle

Purpose-Orientated View of New Technology

- Design projects are often technology driven.
- Technology is perceived to increase productivity without further investments.
- It is relative easy to demonstrate desirable benefits by laboratory studies and rapid prototyping, provided that conditions are made sufficiently idealized.
- However, the real world is far from being idealized. New behaviors emerge, cascades arise and unexpected conflicts occur that undermine the originally anticipated benefits.
- It is essential to close the gap between demonstration and the real thing so that the system has enough robustness for the complexity to come.

> *Confidence in technology does not make a strategy. It is task of HF/E to introduce a purpose-oriented view on new technology and to describe the mechanisms for an increase in system performance and human well-being.*

9th Principle

Purpose-Orientated View of New Technology

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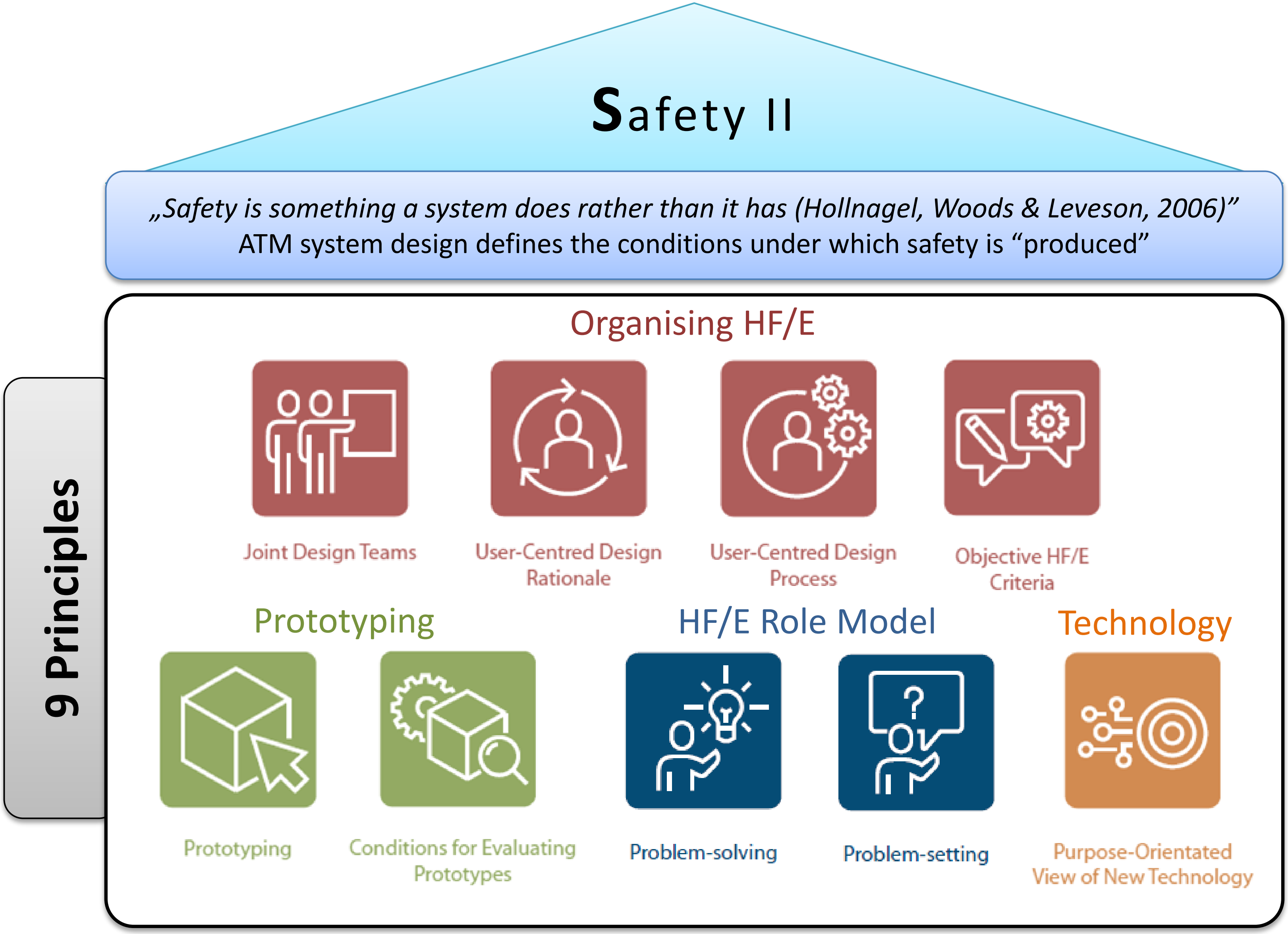
Human Factors in ATM Design



Suggestions for the scientific community

1. Even though HF/E claims to be design driven, there is a **lack of adequate design methods**.
2. Specific approaches are needed **how to integrate users**. General approaches like questionnaires, interviews or observations are still not structurally embedded in the user-centred design framework.
3. Air Traffic Control happens in a complex environment. HF/E acknowledges this complexity by following a systems approach. However, it still remains unclear **what makes a systems approach**.
4. The objective of HF/E is to optimize overall system performance and human well-being. While it is relatively easy to demonstrate a rise in performance, **human well-being** remains difficult to **operationalize**.
5. Design and **Safety II:** More effort needs to be spent on the question, how adaptability can be incorporated in the development of new systems
6. Multitude of **rival schools of thought**, such as psychology, engineering, computer science or economics. An integrated perspective is needed to prevent methodical fragmentation.

Suggestions for ANSPs

1. The ANSPs have to take the idea of **safety by design** seriously.
2. The **interface between HF/E and systems engineering needs to be defined** by elaborating ways of cooperation and the exact division of work.
3. Development processes need to change. **User-centred design** has to become the standard practice.
4. Technology itself is no good starting point. HF/E has to introduce a purpose-oriented perspective on technology for **strategic management decisions**. With the help of the systems approach, HF/E can contribute a deep understanding of current operations, bottlenecks, inefficiencies and latent potentials, which are a better starting point for improvements.

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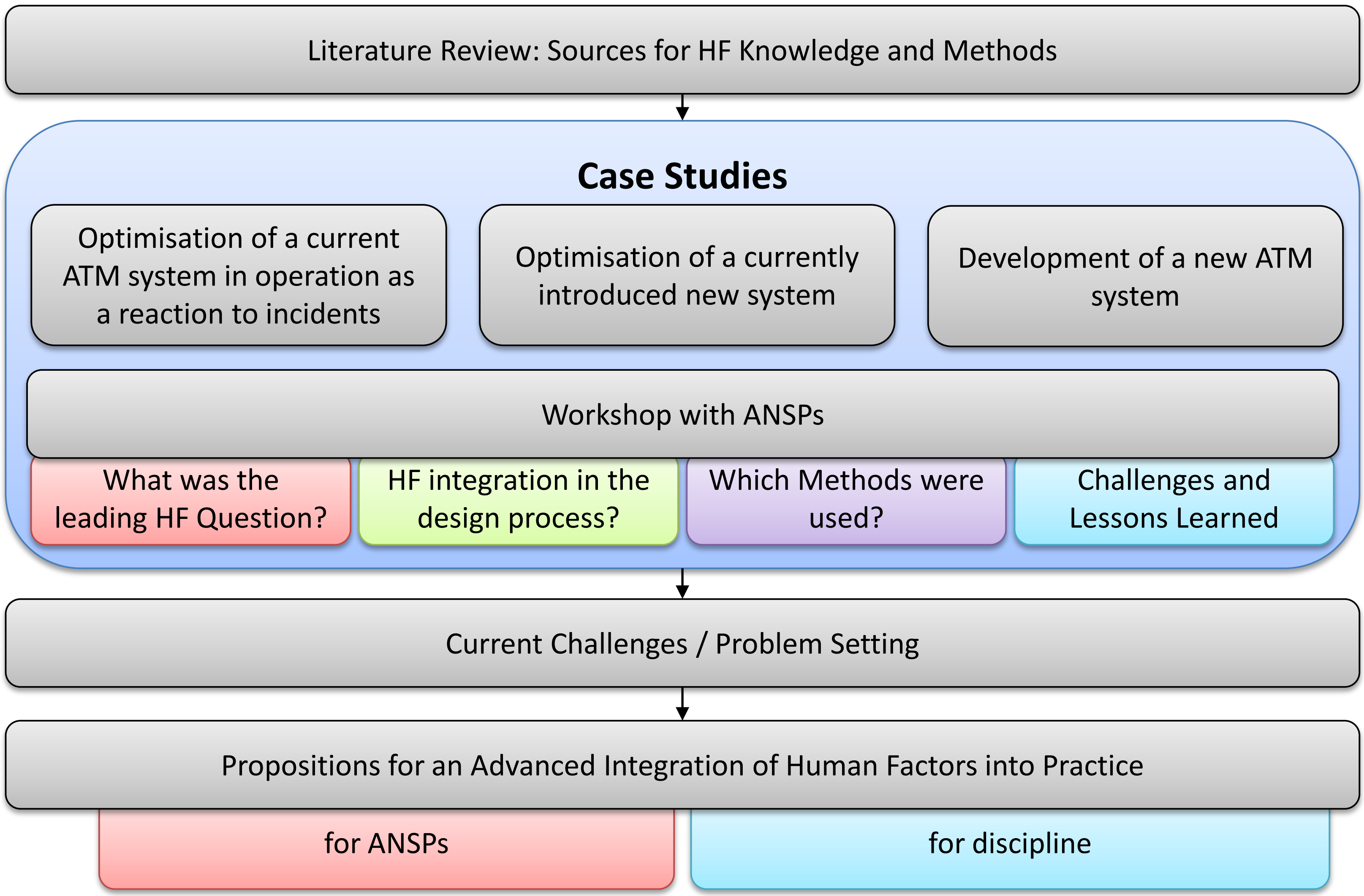
Methodology



Identification of Factors that Prevent and Promote the Integration of HF in Practice