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Design for Flexibility

A Human Systems Integration Approach

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Preface

The content of this book is strongly influenced by a compilation of presentations I have made over the past two decades, current results of the INCOSE[1] Human–System Integration Working Group, which I have the privilege of coordinating, and my current work within the FlexTech Program I lead at CentraleSupélec and ESTIA Institute of Technology. This work addresses the issue of flexibility in our current and future digital societies from the perspective of human systems integration (HSI).

Our increasing need for flexibility has emerged from the uses of new digital technologies, which are constantly expanding, and from the need to maintain the values of freedom and ethics. It should be noted that while these new digital technologies are of great service to us, they also introduce constraints, rigidity and a possible disconnection with reality. There is a risk of losing a certain "common sense."

"Common sense is nothing more than a deposit of prejudices laid down in the mind before age eighteen!" I have often thought of this statement by Albert Einstein,[2] remembering what some shepherds of the Pyrenees used to say to me when we were caring for the sheep on the mountainsides. They taught me proverbs to predict the weather the next day, such as, for example: "Red sky at night, shepherds delight," which means that when the sky becomes red at night, the weather will be good the day after.

I tried to apply these maxims myself, but very often to no avail. I would come back to the shepherds and tell them about my misadventures. They laughed with all their heart, saying: "But you haven't looked at the sky properly, my friend!" In the evening, they showed me the sky, explaining that if it was red, but this time the sun was reflecting on the clouds, then a different proverb had to be used: "The sun looks at itself, beware of the rain!" All this in Occitan of course! I was less than 18 years old! I actually found these shepherds full of "common sense" when the use of these heuristics worked.

[1] International Council on Systems Engineering (https://www.incose.org/).

[2] Barnett, L. (1948). The Universe and Dr. Einstein: Part II. *Harper's Magazine*, Volume 196 (microfilm). Harper & Brothers Publishers, New York. (retrieved 26-05-2020: https://quoteinvestigator.com/2014/04/29/common-sense).

Is this the "common sense" that my friends, the shepherds of the Pyrenees, taught me before I was 18 years old and which I still have today when I use my critical mind to make sense of calculations or experimental results of my research work? What really appeals to me is this combination of experiences, often accumulated and passed down through generations in the form of heuristics and rigorous rationalizations, often based on mathematics and logic, which seem to me to be deeply necessary to ensure results that "make sense." Meaning is more in the qualitative than in the quantitative, and every time we make "scholarly" calculations, we must always interpret them (i.e., give them meaning and therefore a good dose of subjectivity). This subjectivity is made up of profound experience acquired and compiled over time. I always found this kind of knowledge and knowhow, when constantly tested and carefully compiled, provides extensive flexibility in everyday activities. Of course, such tests and compilation are always very context-dependent (i.e., knowledge and associated knowhow are tested and compiled in specific contexts, which can or cannot be incrementally generalized)—this is one of the limitations of educated common sense.

It took me many years of studies and research to, one day, come across a book presenting the Arts of Memory of the ancient Greeks, the book by Frances Yates (Yates 2014, originally published in 1966). The ancient Greeks transmitted knowledge using mnemonic processes[3] that combined observable real objects with abstractions. This practice of transmitting knowledge continued practically until the 20th century, during which René Descartes' Discourse on Method, enunciated in 1610, gradually erased this part of ancestral practices. What is remarkable today is that the Internet, an external associative memory, but also a pure technological invention product of Descartes' Discourse of the Method, brings us back to the Arts of Memory through its use, because we need to associate "bookmarks," icons and other "reminders," to guide us in our searches on the Web, and thus associate concrete objects with abstractions. But how do we develop "common sense" in this context?

At this point, I'd like to share my NASA experience with you. I have had the good fortune and honor of working with some of the players in the Apollo program, long after their exploits of course. I learned humility. Beyond the extraordinary financial investment, why has a program like Apollo been such a global success? The first answer is preparation, flexibility and great commitment of the people involved.

It took about four days to fly to the moon. Twelve human beings walked on the moon between July 1969 and December 1972. Apollo teams were mainly made up of young pilots, engineers and scientists with experience in civil and/or military aviation who absorbed the training like sponges. Anytime I had the chance to discuss with some of them, I saw an extreme commitment, empathy and competence. The ground crew was always seen as an extension of the spacecraft crew; they had a deep respect for the flight crew and vice versa. The greatest strength of these men was their constant situational awareness and fear of making mistakes. Teamwork was

[3] A mnemonic process is a way to remember something using, for example, the method of loci of using a familiar physical location like a house and putting things to remember in locations of the house.

based on trust, discipline, and the slogan: "You must fly as you train,"[4] which meant a lot of hard work ahead. Debriefings were open, honest and complete. Feedback and corrective action for future flights were prompt (Griffin 2010).

An essential concept in the implementation of large projects and risky programs is trust between the human beings involved but also trust in the technologies used and the organizational set up. Without trust, there can be no effective collaboration, at least not in a free and accepted way. Overcoming failures requires resilience, and this is a quality required to bring any ambitious project to a successful conclusion. Needless to say, the Apollo 1 mission was a disaster in which the three astronauts perished in their burning capsule on launch pad 39 at Cape Canaveral, Florida, and there were 16 flights that followed, including Apollo 11, which, for the first time in human history, allowed two men, Neil Armstrong and Buzz Aldrin, to walk on the Moon in July 1969.

Where do we stand on this "common sense" made of accumulated, articulated, implemented and tested experiences? Going to the moon was a unique experience. In the beginning, of course, there was no common sense based on experience, because there was no experience at all in this field. They had to think, build concepts on assumptions and then act. The logical mechanism of abduction was in the forefront. Calculations, models and simulations were needed to build all the equipment necessary for the missions. Also, the setting up of flight management processes and the development of survival protocols, often carried out in real time in the event of abnormal situations, as was the case for Apollo 13. This "common sense" was built dynamically, in an agile manner, by chance and necessity, as Jacques Monod would have said, but also by the collaboration of competent and motivated teams.

How do we keep this "experience-based common sense" alive, changeable and evolving? Since Apollo, very few programs of this kind have been developed. On the contrary, we have experienced increasingly short-term projects, forcing the actors to be reactive to current situations based on short-term financial objectives, rather than being proactive based on humanistic goals.

Before the COVID-19 pandemic, we were still focused on a large automation replacement of humans by "autonomous" machines, such as autonomous vehicles. Today, we are thinking about rebuilding a world more oriented towards a balance between nature and more sustainable technology. This awareness is more tangible than ever. Are we going to design and develop aircraft that are more environmentally friendly? I think we have no choice, and aeronautics is not the only industrial sector affected by this issue. Future developments in sustainable technology will have to satisfy strong environmental, social and economic constraints.

It should be noted that although aeronautics was born and developed thanks to air and space enthusiasts, the last two decades have seen the financial management of aeronautical companies rise to the point of favoring sales at the expense of research. I hope COVID-19 crisis will contribute to change that. We're going to have to build greener aircraft, bringing the human and societal aspects to the forefront, and of

[4] You must do your task in earnest in the same way that you train to do it. This is what Jerry Griffin, a former NASA Flight Director, told us that they did all the time in the Apollo program.

course, balancing the economic side of things. We're going to have to move from techno-centric engineering to human-centered design. We're going to have to rethink the question of mobility in truly ecological and societal terms.

The FlexTech program is now in the running to participate in defining the founding principles of Human System Integration (HSI) in this new paradigm. HSI is indispensable in the century ahead, starting with societal technological integration. Let's stop making technology for engineers! Let's stop making money for money as the financial managers and shareholders of large commercial institutions continue to dictate! We will have to innovate. Despite all the precautions and anticipations, there always comes a time when we have to decide and take a risk in order to act; preparation is essential in taking a risk (Boy and Brachet 2010). The FlexTech program approach is centered on common sense based on experience, "a good sense of experience," which is itself based on preparation, trust and collaboration. This book proposes clues, concepts and approaches to make our sociotechnical systems more flexible and further develop this new sustainable paradigm.

There are many reasons to acknowledge and thank the people who helped in making this book a reality. This book is a primer for the first rationalization of the content of FlexTech program that includes a research and education program, as well as the ESTIA Concept Lab (CLE). The first people's names that come to my mind are Cynthia Lamothe, Helen Huard de la Marre, Patxi Elissalde, Bernard Yannou. Olivier Gicquel, Philippe Dufourq, and Jean-Patrick Gaviard. Thanks to Dassault Systèmes Foundation for their support in the initial setup of CLE.

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Paris, France
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Guy André Boy

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Acronyms

AAAI	Association for the Advancement of Artificial Intelligence
ADD	Active Design Documents
AI	Artificial Intelligence
AI4SE	Artificial Intelligence for Systems Engineering
AUTOS	Artifact, User, Task, Organization, Situation (pyramid model)
BPMN	Business Process Model Notation
CFA	Cognitive Function Analysis
CPSFA	Cognitive Physical Structure Function Analysis
CSCW	Computer Supported Cooperative Work
DC	Design Card
DTM	Design team Member
FMS	Flight Management System
FTP	File Transfer Protocol
GEM	Group Elicitation Method
GP	General Practitioner
GPS	Global Positioning System
HCD	Human-Centered Design
HCI	Human-Computer Interaction
HFE	Human Factors and Ergonomics
HITLS	Human-In-The-Loop Simulation
HSI	Human Systems Integration
HTTP	HyperText Transfer Protocol
IHU	Institut Hospitalo Universitaire (University Hospital Institute)
KBS	Knowledge-Based Systems
M2020	Mars 2020 rover, now called Perseverance
MAS	Multi Agent System
MBSE	Model Based Systems Engineering
NAIR	Natural-Artificial Intentional-Reactive Framework
ND	Navigation Display
PCR	Polymerase Chain Reaction
SE	Systems Engineering
SE4AI	Systems Engineering for Artificial Intelligence

SEIR	*Susceptible* → *Exposed* → *Infected* → *Recovered (model)*
SFAC	Structure-Function Abstract-Concrete Framework
SIM	Systemic Interaction Models
SimBSE	Simulation Based Systems Engineering
SoS	System of Systems
TOP	Technology, Organization and People (model)
UML	Unified Modeling Language

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