The Human Contribution to Resilience in Space Operations: System Characteristics & Tacit Operational Practice

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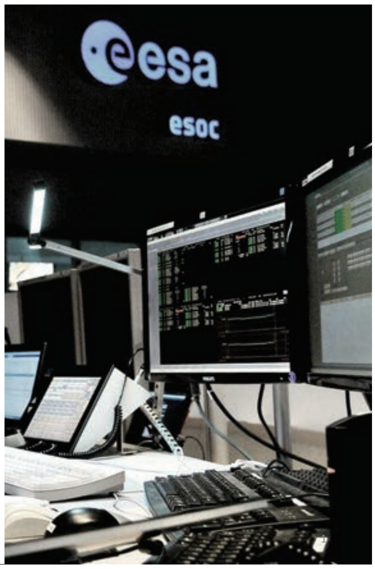
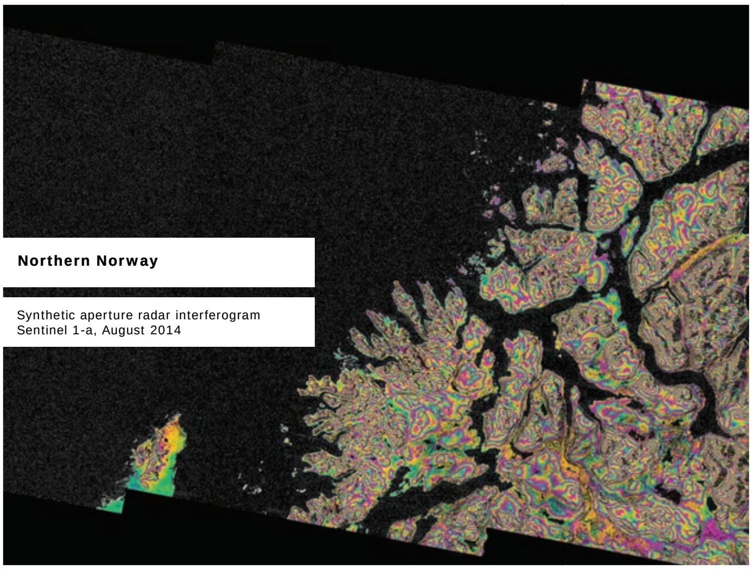
HFC Workshop “Human Factors in Control: 10 Years Enabling Safe & Efficient Operations”

Oslo, Norway, 15-16 October 2014

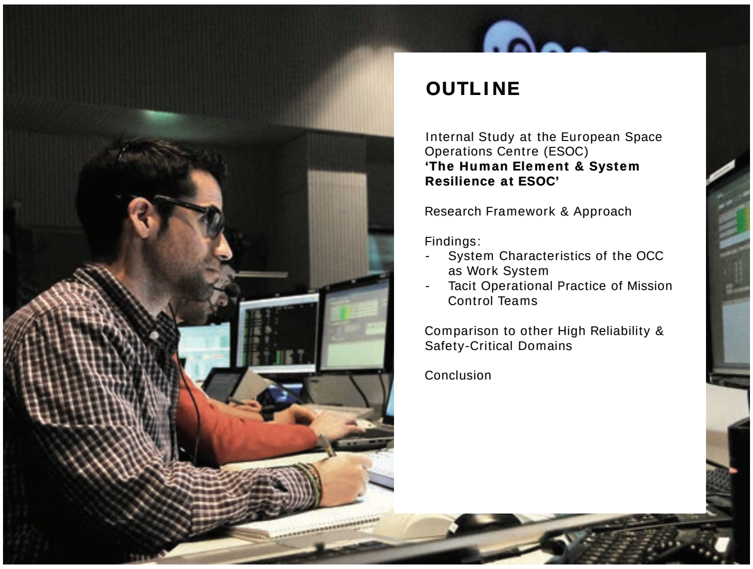


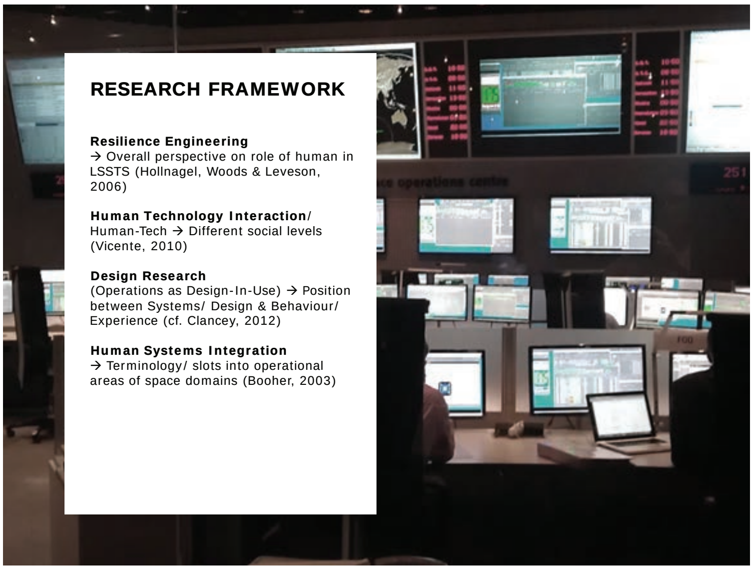


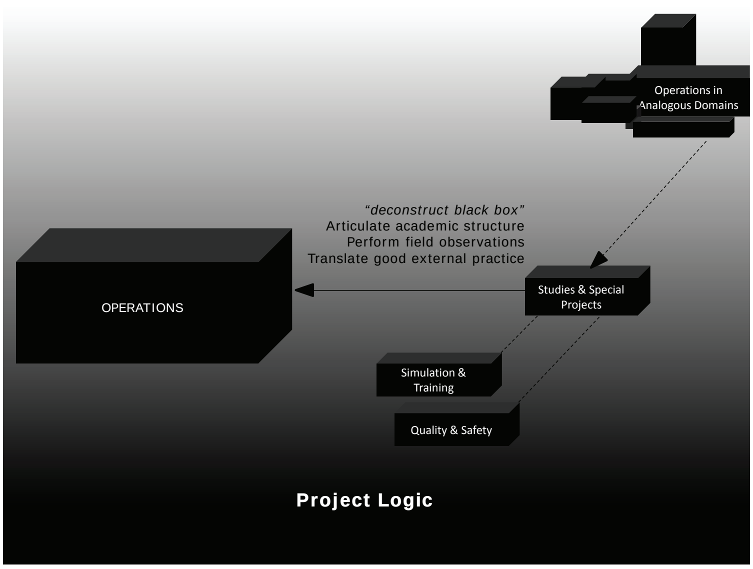
Northern Norway

Synthetic aperture radar interferogram
Sentinel 1-a, August 2014

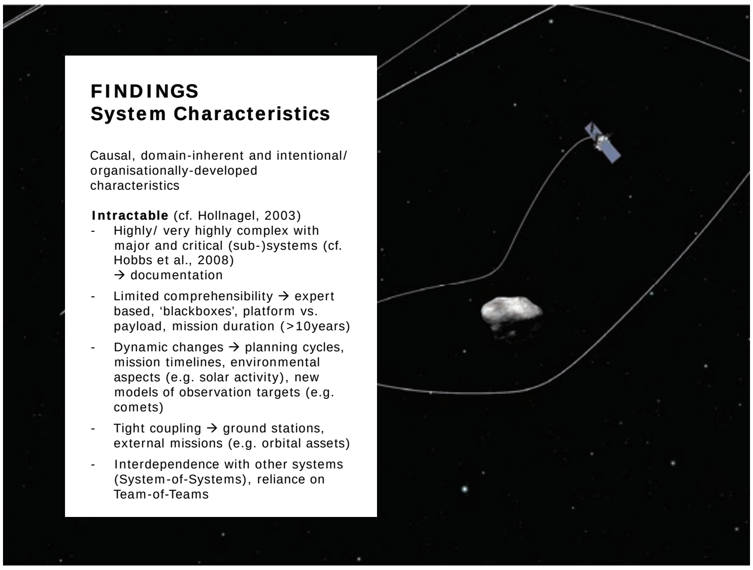
Oil Platforms off coast of Norway

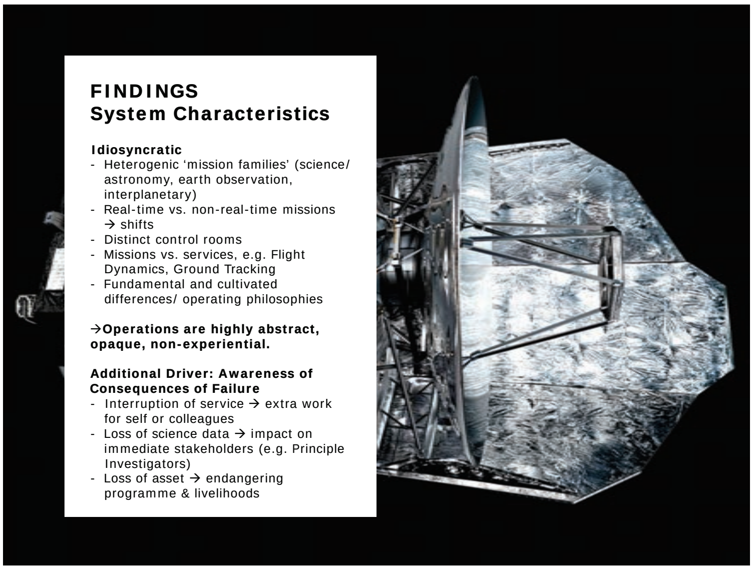

OUTLINE
Internal Study at the European Space Operations Centre (ESOC)
'The Human Element & System Resilience at ESOC'
Research Framework & Approach
Findings:
- System Characteristics of the OCC as Work System
- Tacit Operational Practice of Mission Control Teams
Comparison to other High Reliability & Safety-Critical Domains
Conclusion

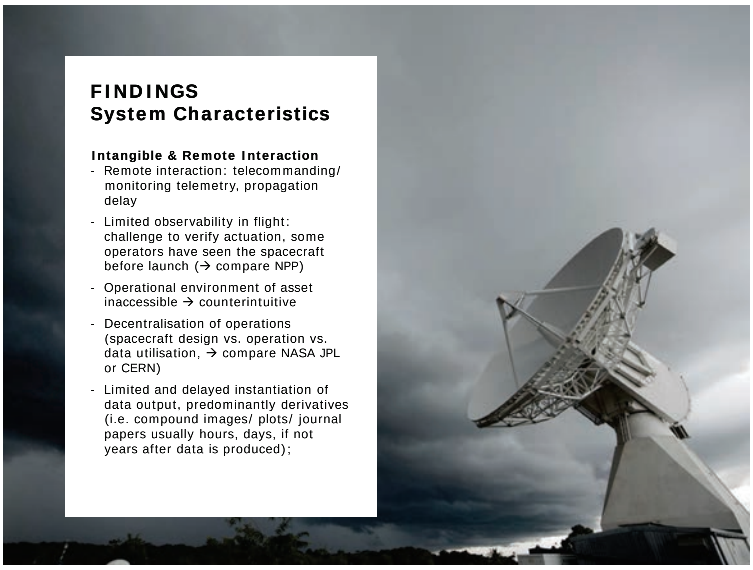

RESEARCH FRAMEWORK
Resilience Engineering
→ Overall perspective on role of human in LSSTS (Hollnagel, Woods & Leveson, 2006)
Human Technology Interaction/
Human-Tech → Different social levels (Vicente, 2010)
Design Research
(Operations as Design-In-Use) → Position between Systems/ Design & Behaviour/ Experience (cf. Clancey, 2012)
Human Systems Integration
→ Terminology/ slots into operational areas of space domains (Booher, 2003)

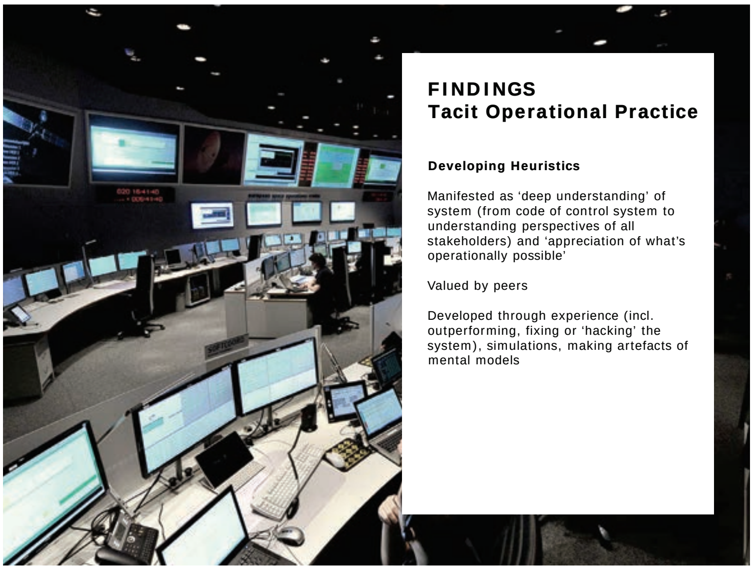

Operations in Analogous Domains
"deconstruct black box"
Articulate academic structure
Perform field observations
Translate good external practice
OPERATIONS
Studies & Special Projects
Simulation & Training
Quality & Safety
Project Logic


RESEARCH APPROACH
Work Domain Analysis
(cf. Vicente, 1999)
- Abstraction hierarchy, system decomposition (1 iteration)
- Structural perspective (theory on work systems/ complex sociotechnical systems) (cf. Perrow, 1984)
Field Work
(ethnographic/ contextual enquiry)
~260hrs of (non-)participant direct observations with elements of user conversations, walk-throughs
- Nominal, contingency operations
- LEOP Simulation Campaigns
- Operational Planning Meetings
- 9 missions/ Flight Control Teams and Services
Units of Analysis/ Discussion
- Functional Synthesis/ Patterns of Work-As-Done (cf. Woods & Hollnagel, 2006; Dekker, 2002)

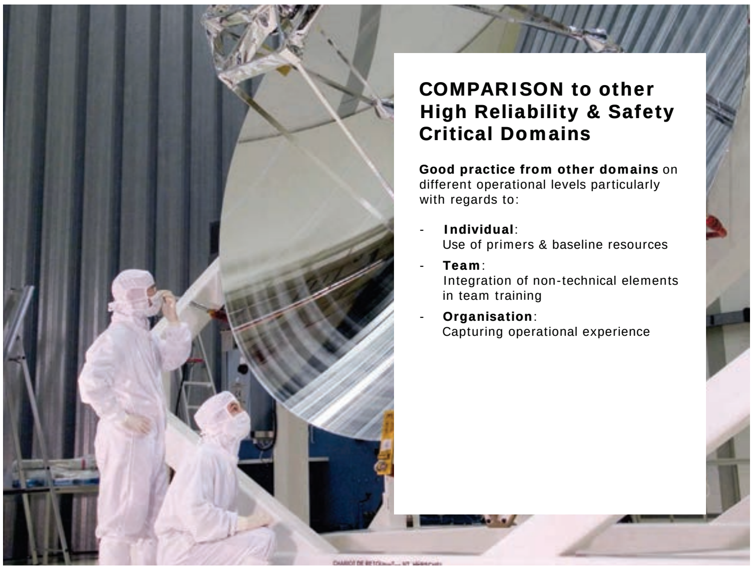

FINDINGS
System Characteristics
Causal, domain-inherent and intentional/ organisationally-developed characteristics
Intractable (cf. Hollnagel, 2003)
- Highly/ very highly complex with major and critical (sub-)systems (cf. Hobbs et al., 2008) → documentation
- Limited comprehensibility → expert based, 'blackboxes', platform vs. payload, mission duration (>10years)
- Dynamic changes → planning cycles, mission timelines, environmental aspects (e.g. solar activity), new models of observation targets (e.g. comets)
- Tight coupling → ground stations, external missions (e.g. orbital assets)
- Interdependence with other systems (System-of-Systems), reliance on Team-of-Teams


FINDINGS
System Characteristics
Idiosyncratic
- Heterogenic 'mission families' (science/ astronomy, earth observation, interplanetary)
- Real-time vs. non-real-time missions → shifts
- Distinct control rooms
- Missions vs. services, e.g. Flight Dynamics, Ground Tracking
- Fundamental and cultivated differences/ operating philosophies
→Operations are highly abstract, opaque, non-experiential.
Additional Driver: Awareness of Consequences of Failure
- Interruption of service → extra work for self or colleagues
- Loss of science data → impact on immediate stakeholders (e.g. Principle Investigators)
- Loss of asset → endangering programme & livelihoods


FINDINGS
System Characteristics
Intangible & Remote Interaction
- Remote interaction: telecommanding/ monitoring telemetry, propagation delay
- Limited observability in flight: challenge to verify actuation, some operators have seen the spacecraft before launch (→ compare NPP)
- Operational environment of asset inaccessible → counterintuitive
- Decentralisation of operations (spacecraft design vs. operation vs. data utilisation, → compare NASA JPL or CERN)
- Limited and delayed instantiation of data output, predominantly derivatives (i.e. compound images/ plots/ journal papers usually hours, days, if not years after data is produced);


FINDINGS
Tacit Operational Practice
Developing Heuristics
Manifested as 'deep understanding' of system (from code of control system to understanding perspectives of all stakeholders) and 'appreciation of what's operationally possible'
Valued by peers
Developed through experience (incl. outperforming, fixing or 'hacking' the system), simulations, making artefacts of mental models

Lowest vs. Highest Fidelity Spacecraft Models
(Representational Mock-Up/ Found object vs.
Functional Full-Scale Engineering Model)



COMPARISON to other High Reliability & Safety Critical Domains

Good practice from other domains on different operational levels particularly with regards to:

- **Individual**:
  Use of primers & baseline resources
- **Team**:
  Integration of non-technical elements in team training
- **Organisation**:
  Capturing operational experience

FINDINGS
Tacit Operational Practice

Developing Heuristics

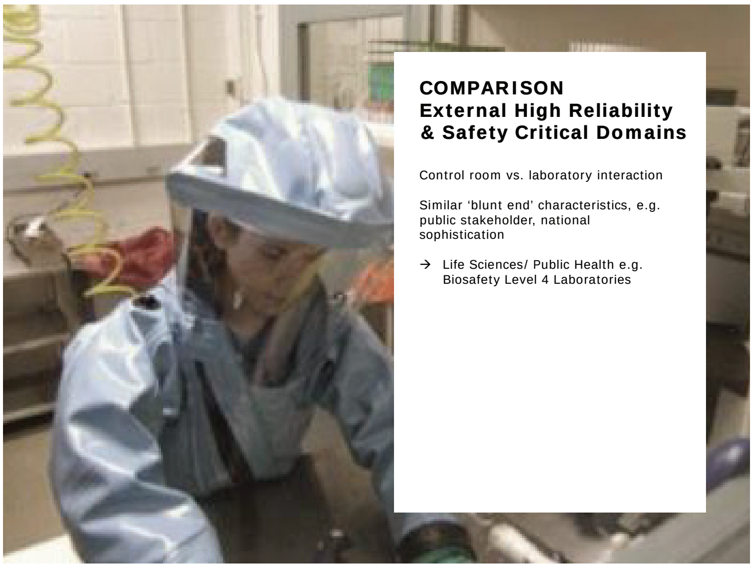
Expressed as hunch, hypothesis, gut feeling, instinct, inkling, analogy (e.g. anthropomorphised system)

Applies to plans, situations, parameters →esp. under time constraints: where to start investigation

Heuristics kick-start formal, highly structured investigation, diagnosis and problem-solving approaches

Uncrewed & Crewed Space	MOC	Launch sites	Fuelling	AIT	Ground Station s	Network Ctrl	HIT
Defense & Security	Aircraft Carrier	UAV	Nuclear Sub	Central Ops	CRNBC Research	Missile Silos	CCTV
Transport & Infrastructure	ATM	VTS	Rail Cargo	Mass Transit	Flight Deck	Controlled Demolition	Cran
Energy & Utilities	Petro/ CPP	NPP	Extraction/ Mining	Grid/ Power Distribution	Nuclear Fuel Cycle	Reservoirs/ Dams	Purifi
Physical Sci. & Engineering	Nuclear Res. Reactor	Particle Acc.	Tokamak/ Neutrino obs.	Ballistic Range Complex	Deep Sea Exploration	Wind Tunnel	Laser
Life Sciences & Biomedical	BSL-4 Labs/ Pathogen Unit	ICU	Telerobotic Surgery	Surgery	Pandemic Response	Anaesthesiolo gy	EMU
Other	Industrial Diving	Maritime Rescue	Robotic Assembly	Data Centres	Formula One	Facility Control	Finan

Excerpt Taxonomy of Analogous Domains


COMPARISON
External High Reliability
& Safety Critical Domains
Control room vs. laboratory interaction
Similar 'blunt end' characteristics, e.g. public stakeholder, national sophistication
→ Life Sciences/ Public Health e.g. Biosafety Level 4 Laboratories


MANY THANKS
QUESTIONS & COMMENTS
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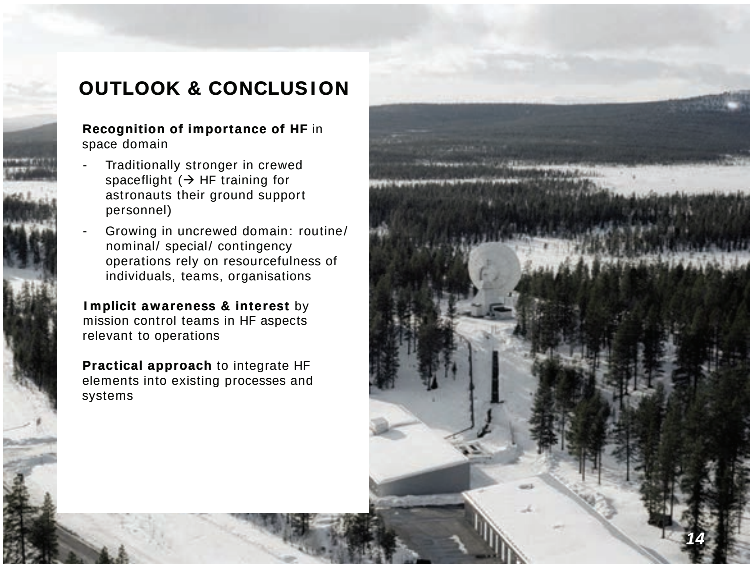
OUTLOOK & CONCLUSION
Recognition of importance of HF in space domain
- Traditionally stronger in crewed spaceflight (→ HF training for astronauts their ground support personnel)
- Growing in uncrewed domain: routine/ nominal/ special/ contingency operations rely on resourcefulness of individuals, teams, organisations
Implicit awareness & interest by mission control teams in HF aspects relevant to operations
Practical approach to integrate HF elements into existing processes and systems
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