Agent-Based Modelling of Hazards in ATM

Tibor Bosse, Alexei Sharpanskykh, Jan Treur, Henk Blom, Sybert Stroeve

SESAR Innovation Days, Braunschweig, Germany, Nov 27-29, 2012

SUPPORTED BY SESAR JOINT UNDERTAKING

vrije Universiteit *amsterdam*

NLR

Contents

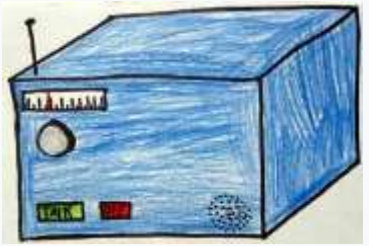
ATM: an Open Socio-Technical System

Complexity and performance variability in ATM

- Distributed human operators and technical systems
- Considerable interconnectivity between the agents
- Internal and external uncertainties and disturbances
- Human role is important to cope efficiently with uncertainties and disturbances






Resilience Engineering

"Design of socio-technical systems that are able to resist a wide variety of demands, variations, degradations and disruptions"

Human flexibility and system oversight are essential

- Away from error-thinking
- Towards a broad view on human performance in an overall system

Mathematical Approach towards Resilience Engineering in ATM (MAREA)

Aim

To develop a mathematical modelling and analysis approach that allows to bring Resilience Engineering at work for the complex ATM system

Focus on human performance

- Humans dealing with uncertainties and non-nominal conditions
- Psychological and organisational models

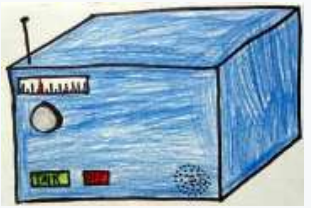
Identification of Hazards

Hazard = "Anything that may influence safety"

- Events / conditions / performance aspects
- Humans / systems / environment
- Interactions







NLR ATM Hazard Database

- ATM safety assessments
- Hazard brainstorm sessions
- 4000+ hazards

A Set of Generalised Hazards

4000+

Selection of unique hazards

Generalization of hazards

525

Development (Set I)

Validation (Set II)

Pilot mixes up ATC clearances

Flight plans of ATC system and FMS differ

Pilot validates without checking

Weather forecast is wrong

Alert causes attentional tunneling

Resolution of conflict leads to other conflicts

HMI

Risk of a conflict is underestimated

Animals on the runway

Controller has wrong SA about intent of aircraft

Contingency procedures have not been tested

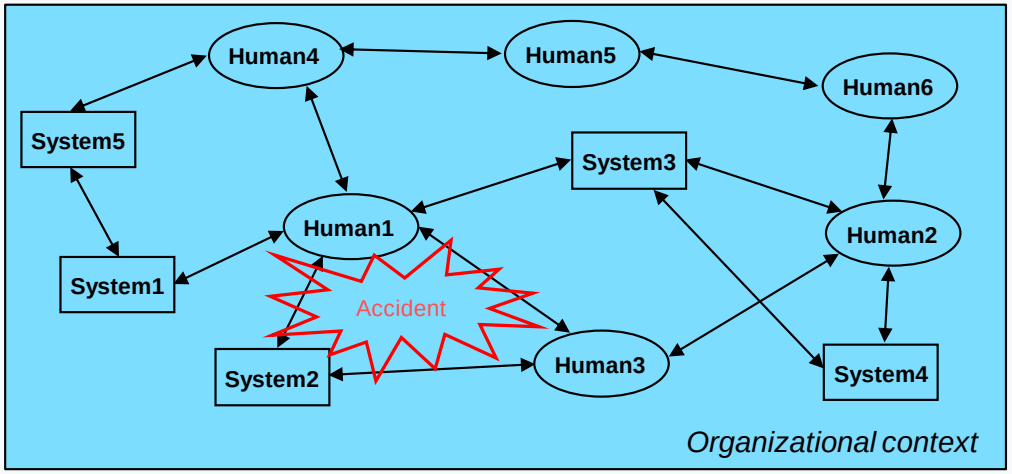
How to Model Hazards for Resilience Analysis?

Requirements

- Modelling at level of individual humans and technical systems
- Possibility to capture complex non-linear dynamics
- Availability of computational tools

Agent-based modelling

- 'Agent' = autonomous system interacting with environment
- Agents represent behaviour at local level
- Behaviour at global level 'emerges' in simulations



Main Research Goal

"To increase the percentage of potential hazards modelled by existing accident risk assessment methods for ATM"

More specifically:

- Model hazards from 'Set I' via ABM approaches

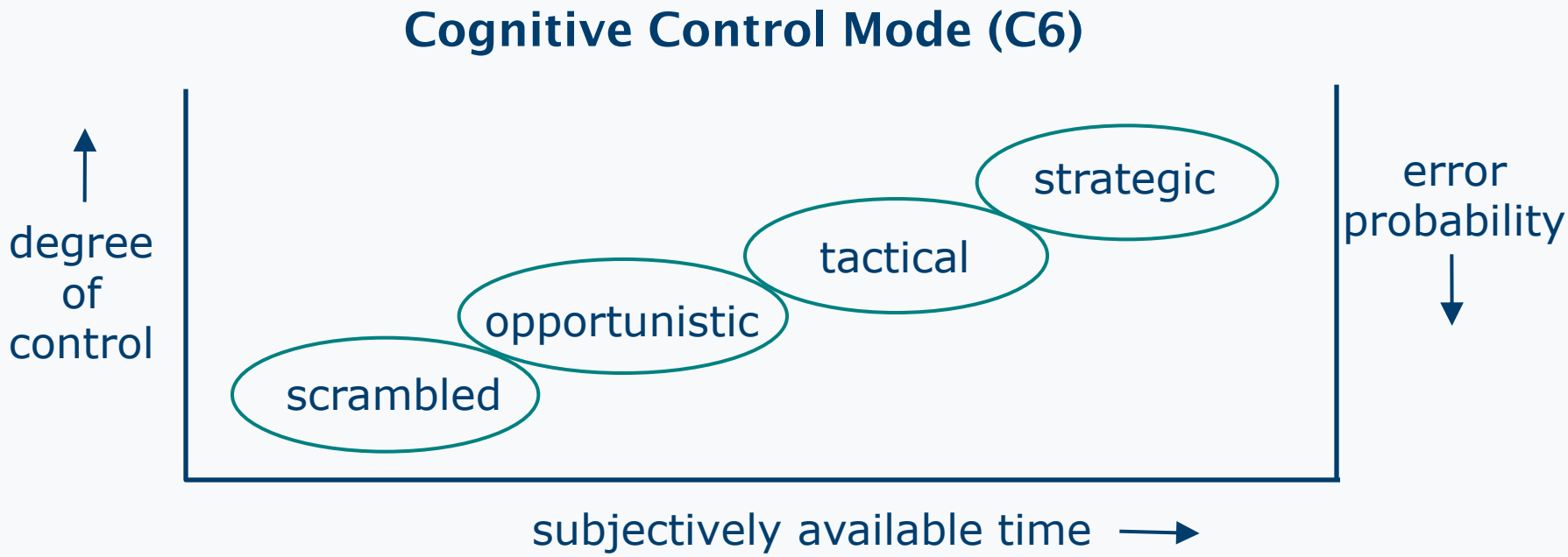
Three Phases:

1. TOPAZ model constructs (SID 2011)
2. VU model constructs (ATOS 2012)
3. New model constructs (SID 2012)

TOPAZ Model Constructs

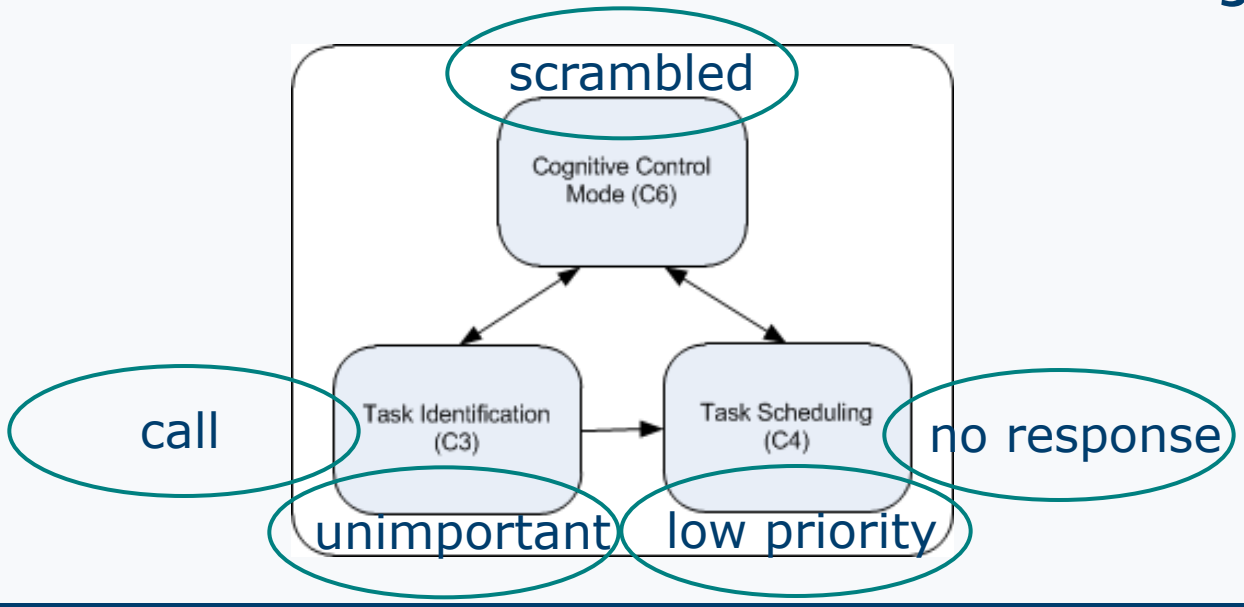
C1	Human Information Processing	C8	Human Error
C2	Multi-Agent Situation Awareness	C9	Decision Making
C3	Task Identification	C10	System Mode
C4	Task Scheduling	C11	Dynamic Variability
C5	Task Execution	C12	Stochastic Variability
C6	Cognitive Control Mode	C13	Contextual Condition
C7	Task Load		

TOPAZ Model Constructs - Example



Matching Model Constructs to Hazards

- Informal approach to assess ‘coverage’ of hazards
- For each hazard-model combination perform ‘mental simulation’
- Multiple analysts
- Example: ‘Pilots do not react to controller call due to high workload’



TOPAZ Model Constructs – Hazard Coverage

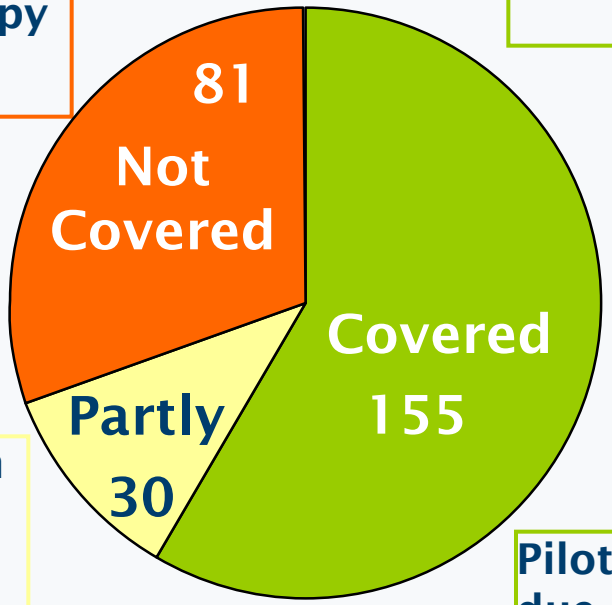
Cultural differences between airlines
- ...

Controller is fatigued and sleepy
- ...

Lack of experience in degraded modes
- ...

Procedure change → confusion
- Multi-agent SA
- Decision making
- ...

Controller ignores an alert
- Multi-agent SA
- ...



Controller makes a reading error
- Human error
- Multi-agent SA

Failure of GPS system
- System mode

Pilot reports wrong position
- Human error
- Multi-agent SA

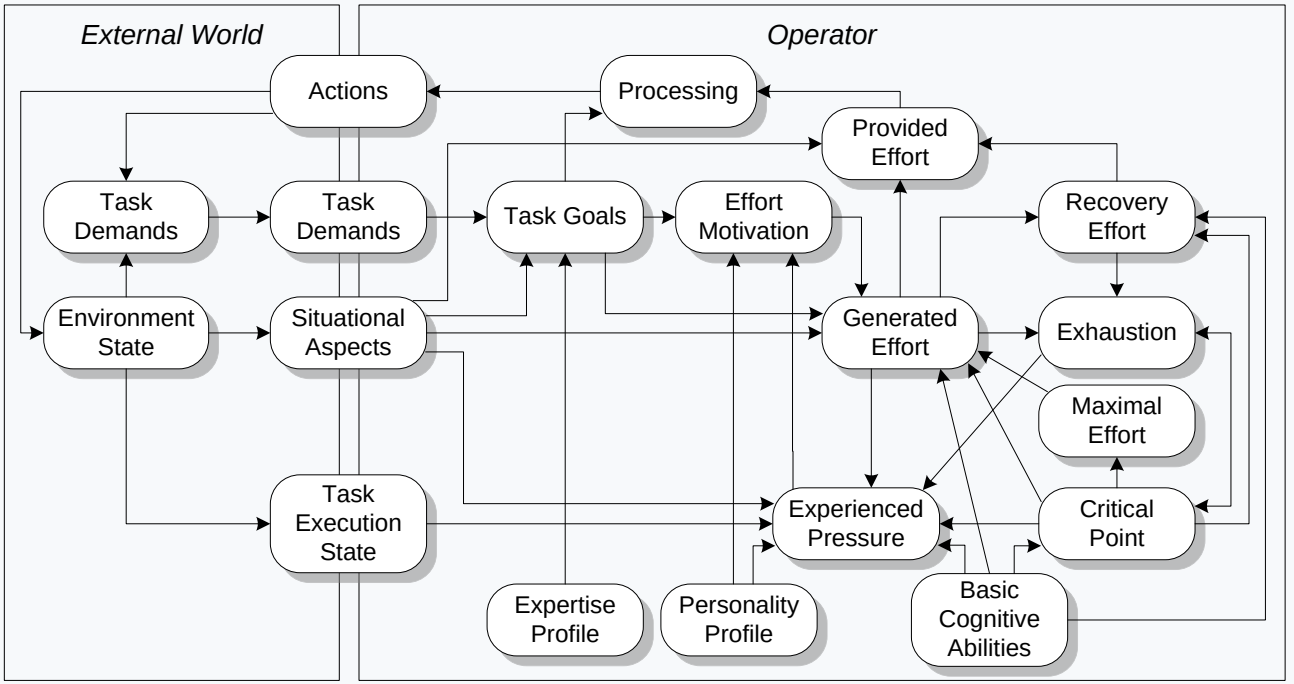
Pilots do not react to controller call due to high workload
- Task identification
- Task scheduling
- Cognitive control mode

VU Model Constructs

MC1	Bottom-up Attention	MC7	Trust
MC2	Experience-based Decision Making	MC8	Formal Organisations
MC3	Operator Functional State	MC9	Learning
MC4	Information Presentation	MC10	Goal-oriented Attention
MC5	Safety Culture	MC11	Extended Mind
MC6	Complex Beliefs in Situation Awareness		

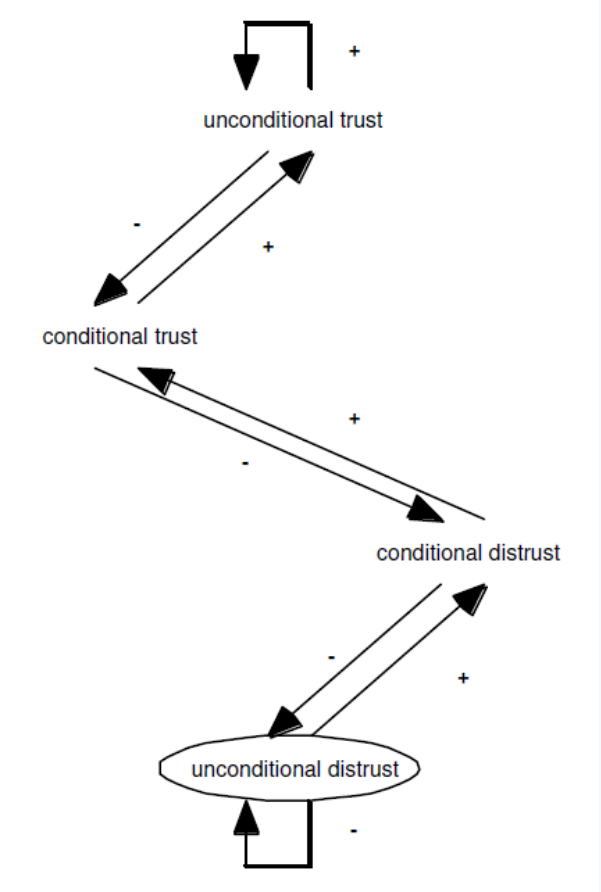
VU Model Constructs - Example

Operator Functional State (MC3)



VU Model Constructs - Example

Trust (MC7)



VU Model Constructs – Hazard Coverage

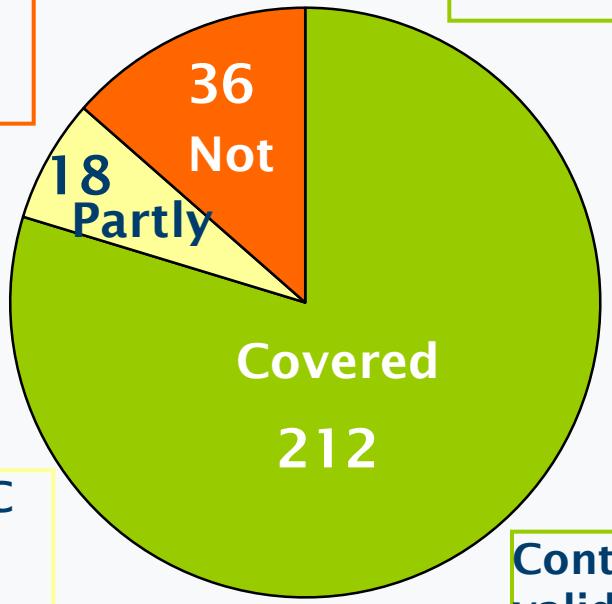
A jolly atmosphere on the frequency
- ...

Icing of the wings
- ...

Aircraft picks up beacons with similar frequencies
- ...

Negotiation problems Pilot-ATC
- Trust
- ...

Pilots falling asleep
- Operator Functional State
- ...



Complex procedure causes R/T overload
- Operator Functional State
- Formal Organisation

Controller is fatigued and sleepy
- Operator Functional State

Clutter of audio messages
- Information Presentation
- Situation Awareness

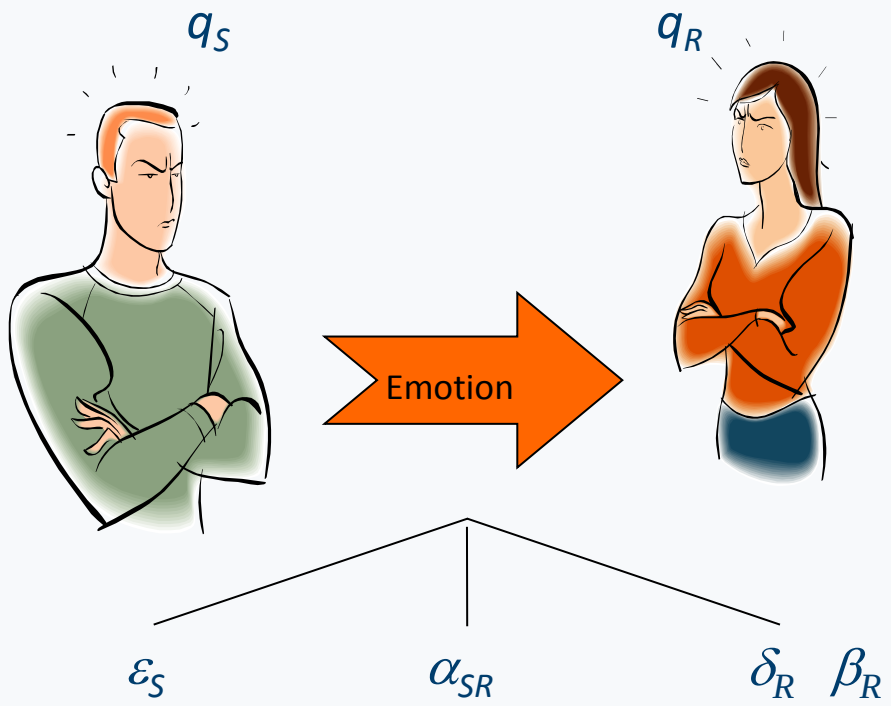
Controller has low confidence in validity of system alerts
- Trust

New Model Constructs

A	Unstabilised Approach	H	Merging or Splitting ATC Sectors
B	Handling of Inconsistent Information by a Technical System	I	Reduced Visibility
C	Sub-optimal Emotional Atmosphere	J	Weather Forecast Wrong
D	Complex or Unclear Procedures Leading to Confusion	K	Strong Turbulence
E	Changes in Procedures Leading to Confusion	L	Icing
F	Human Does Not Know When to Take Action	M	Influence of Many Agents on Flight Planning
G	Problems with Access Rights to an Information System	N	Uncontrolled Aircraft

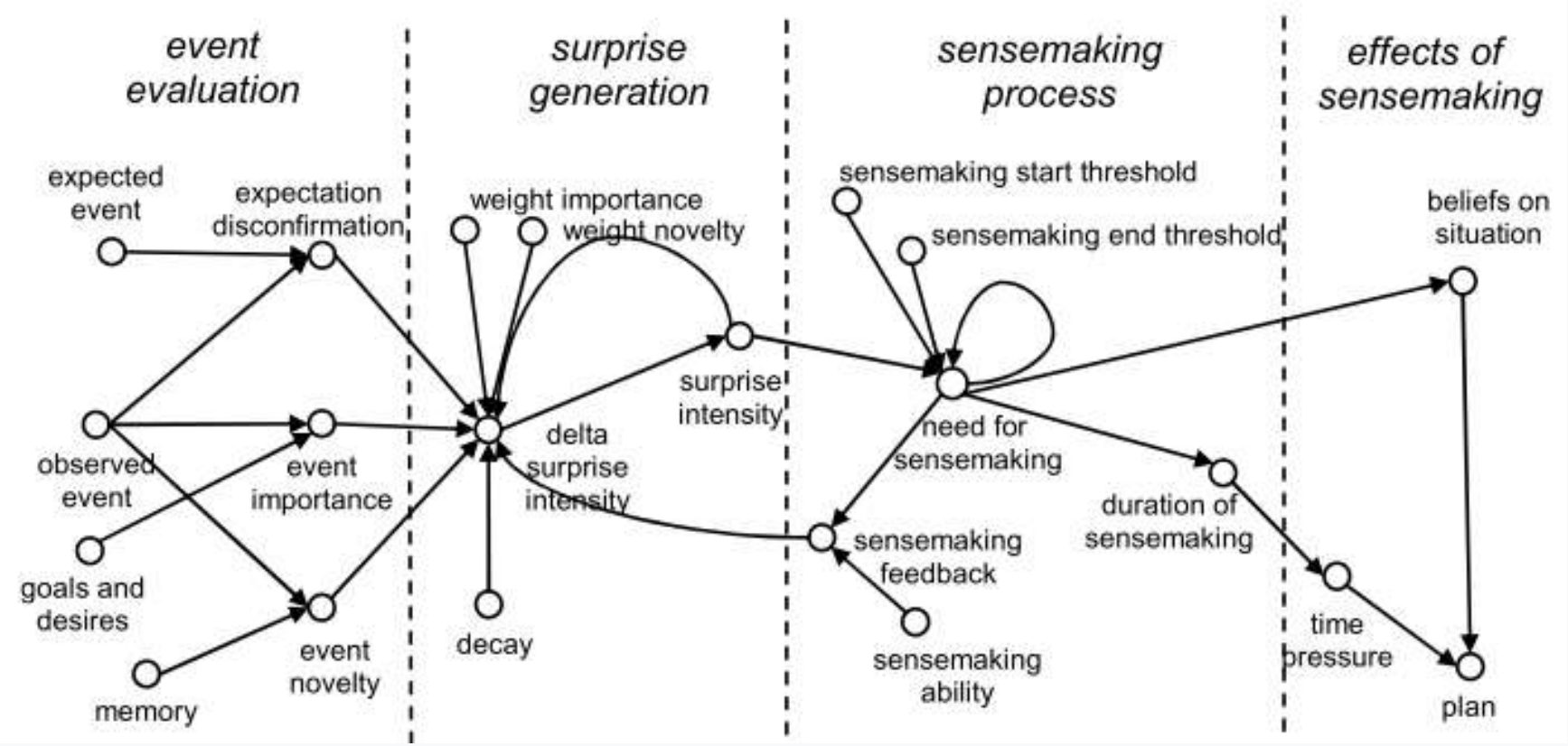
New Model Constructs - Example

Sub-optimal Emotional Atmosphere (C)



New Model Constructs - Example

Changes in Procedures Leading to Confusion (E)



New Model Constructs – Hazard Coverage

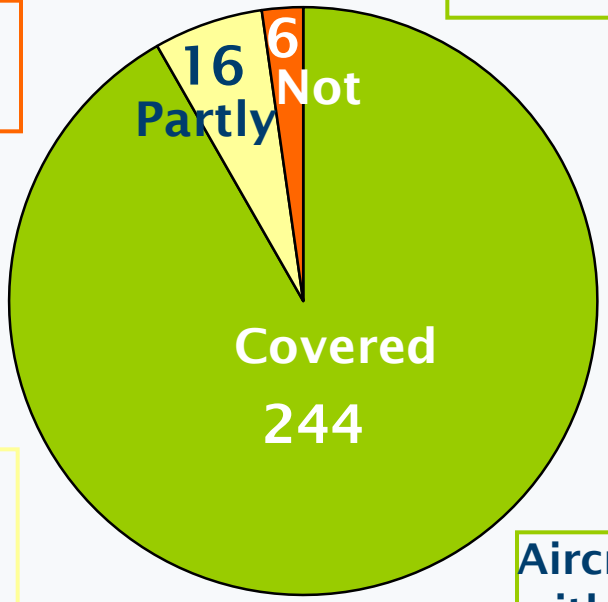
Security Intrusion
- ...

Unmanned Arial Vehicles
- ...

Military Aircraft Shoots a Civil Aircraft Down
- ...

Standard R/T not adhered to
- Confusion
- ...

Strong variation in view
- Weather
- ...



A jolly atmosphere on the frequency
- Operator Functional State
- Emotion Contagion

Icing of the Wings
- Icing

Unstabilised Approach
- Approach

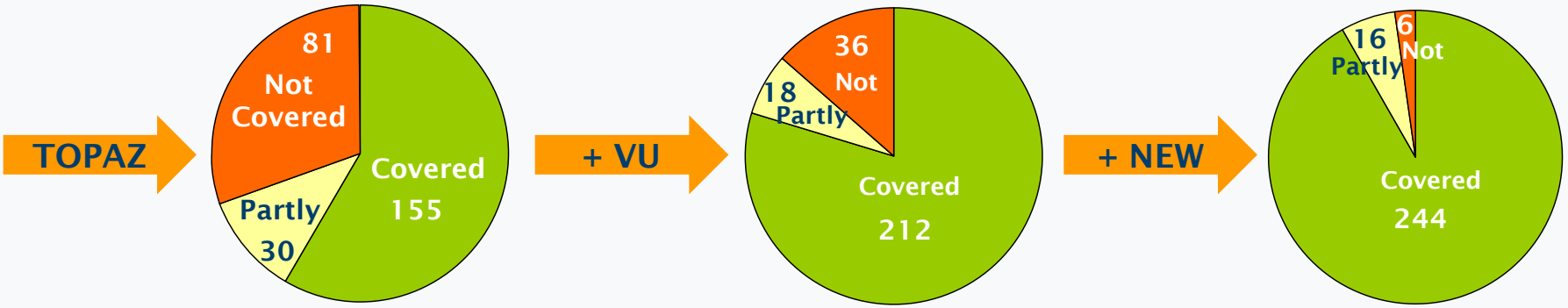
Aircraft picks up beacons with similar frequencies
- Handling of Inconsistent Info by a Technical System

Conclusion

38 agent-based model constructs have been identified

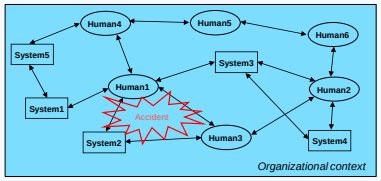
- 13 TOPAZ model constructs
- 11 VU model constructs
- 14 new model constructs

Result: considerable improvement of hazard coverage



Next Steps

- **Integration of model constructs**



- **Formalisation of integrated model constructs**
- **Preliminary 'validation' of model constructs**
  - *Test the coverage of Hazard Set II using 'mental simulation'*
  - *Apply model constructs to safety-relevant scenarios*
  - *Validate scenarios using interviews with operational experts*

Questions