Human error analysis and reliability assessment

Michael Harrison

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Purpose of Human Error Assessment

- explore difficulties of use early in design with the aim of improving design
  - hence comparable with other usability and walkthrough techniques
- assessing likelihood of human error of a developed design as part of an assessment process
  - hence comparable with other reliability assessment techniques
  - Method for focus here will be qualitative or descriptive rather than a quantitative but will discuss role of quantitative techniques

CAA Draft Requirements and Advisory Material

"It must be shown by analysis, substantiated where necessary by test, that as far as reasonably practicable all design precautions have been taken to prevent human errors in production, maintenance and operation causing hazardous or catastrophic effect"

Assessing Dependability

- Analysing and measuring dependability without assessing human reliability is at best incomplete and at worst misleading

- Human dependability not just at the sharp end, also maintenance crew, operator support, management teams, organisational personnel

- However still not part of core standards such as 61508 (i.e. tends to be in ancillary documentation)

The human in the loop?

- Treat those aspects of the system as totally unreliable?
  - (or to ignore it - which has been the approach in some sectors)
    - problem: either fails to recognise safety issues or produces an absolute worst case design.

- Provide probabilistic safety arguments at the same level as for the rest of the system
  - plugging in to a failure modes and effects analysis.

- Provide a structured qualitative assessment
  - systematic consideration of the design of the system.

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Problem with probabilities

- validity
  - probabilities either collected in the laboratory, simulator or the field
    - data rarely available for the same system and the same circumstances, particularly when a new design.
- feasibility
  - failure rates of 10**-9 required for catastrophic events - trials could never produce data at these levels where humans are involved, and certainly not on a new design.
- range
  - 5 x 10 -5 to 5 x 10-3 for ‘automatic’ acts
  - 5 x 10-4 to 5 x 10-2 for ‘rule-based’ acts
  - 5 x 10-3 to 5 x 10-1 for ‘knowledge-based’ acts
- However there are good reasons for taking a numerical approach
  - “numbers is better than no numbers all of the time”

Difficulties with probabilities

“Engineering” approach

Quantitative ‘decomposition’

- **Human treated as a “component” in a complex system**
- **The mechanistic assumption: “The human / mind as a fallible machine”**
- **The atomistic assumption: Human performance can be adequately described by considering individual elements of the performance. *Total* performance is an aggregate of the individual performance elements (dominant approach to HRA)**

“Cognitive” approach

Explicit use of models and theories of cognitive functions which underlie human behaviour

Cognitive psychology still immature

Problem: human cognition is not *directly* observable

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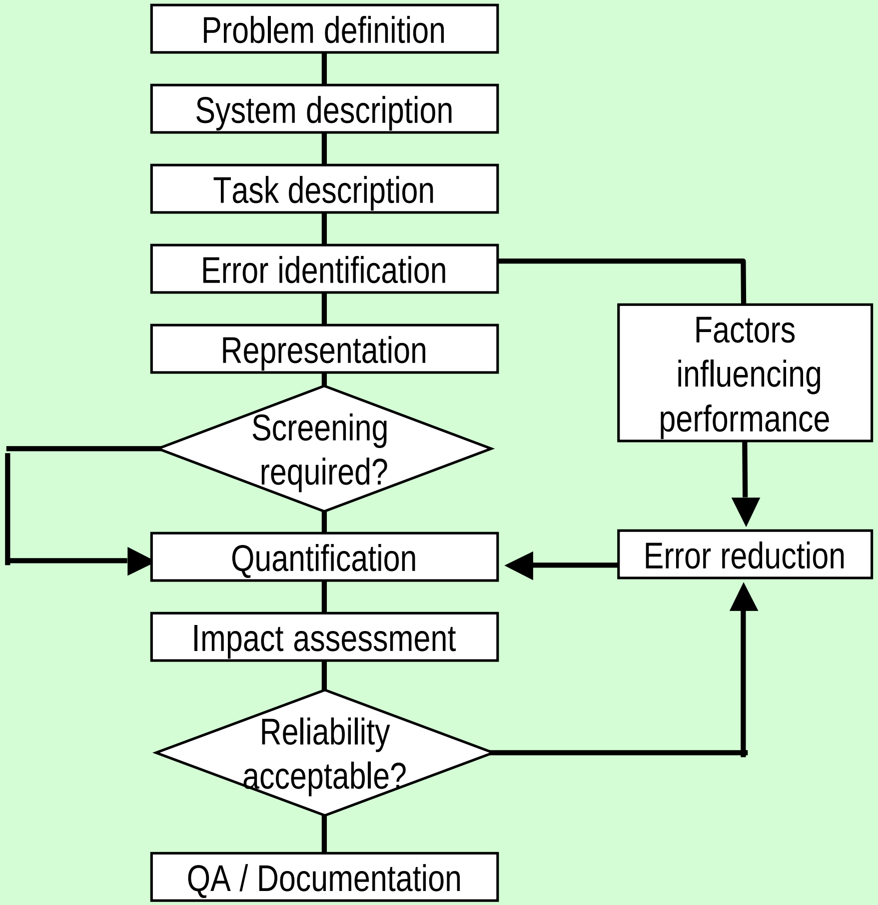
Human reliability assessment

- Generic process covering many methods
- Used extensively in the nuclear power industry
- Usually a back-end assessment exercise
- Adapted from Kirwan (1994)
- Will discuss some issues of system description



HRA History

- 35 years, pace accelerated after "Three Mile Island";
- Interdisciplinary - based on, and copies approaches used in, reliability engineering. Attempts to provide same level of quantification;
- 1st generation HRA: Simple manifestations (omissions, commissions, extraneous actions) + Behavioural categories (detection/diagnosis/execution) ==> less complexity in determining associated probabilities; not ideal, but no clear alternatives;
- Increasing recognition today of the fundamental role and importance of human cognition.

Human error identification

- Behavioural and/or causal guide words systematically applied to what people do (using tasks or scenarios as a starting point)
  - imaginatively finding situations where there are problems
- Human hazard identification
  - identifying areas in the design where problems might arise

- Behavioural guide words
  - traditional approach of HRA, for example THERP and HAZOP.

- Causal guide words
  - based on some model of what causes error, approach used by THEA.

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Behavioural guide words

- ‘Traditional’ HRA guidewords for error analysis: (Swain & Guttman,1983)
- Take a so called phenotypical perspective as a starting point

Errors of *Omission*	Omit actions / sub-goals
Commission	Substitute actions / sub-goals
	Carry out action incorrectly
	Insert extraneous action
Errors of *Sequence*	Actions in wrong order
Repetition	Actions repeated unnecessarily
Qualitative error	*Too much / too little*
Time error	*Too early / too late / too long*

Examples

- Omission: operator fails to close the valve.
- Commission: operator turns the valve clockwise thereby opening it wider rather than closing it.
- Commission (extraneous): instead of closing the isolation valve, operator switches off the pump because pump on-off switch is close to isolation valve ("doing the wrong thing")

Some problems of definition

- e.g. task: Entering an altitude (ALT) value into the altitude alert (ALT ALERT) window:
- "Substitution error" could be
  - Doing something other than entering data;
  - Entering data into a different device;
  - Entering a distance value instead of the altitude.
- "Commission error" is not very constraining as a guide due to the large number of substitutions possible;
- What is needed is more cognitive analysis for attributing error causes.

Error analysis method

- Start at a goal (task or scenario)
- Apply guide words to goal and corresponding plan
- Record the guide word and error generated in a table
- Risks associated with errors significant?
- If so, consider sub-goals and repeat process
- Issues: what questions applied to what

Guide word

ActionAction TypeHuman ErrorL FIREAlert acknowledge- not read (pilot unaware of warning)- misread (pi

Error

Extract of pilot procedure for a left engine failure during takeoff (pilot task: deal with the fire)

Error analysis

ActionAction TypeHuman ErrorL FIREAlert acknowledge- not read (pilot unaware of warning- misread (pil

Human ErrorApplicable design featuresNot reading L FIRE- Highlight (flashing red caption head-down)

Assign HEPs from lookup tables:

1 x 10^{-4} per action

1 x 10^{-3} per action

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Further developments

- How might we make the questions richer and more easy to apply by non-experts?
- Use a questionnaire based on human causes of error
- Focus questions around some classification of aspects of system use where error might occur
- Take account of contextual factors when asking questions.

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Requirements for THEA

- Make it possible for system engineers to use without specific human factors expertise
- Easy and efficient to apply and sensible to use iteratively to refine design
- Relevant to display and action as well as goals and plans
- Not goal and plan focussed - takes account of context
- Descriptive rather than quantitative - however possible to indicate significance or severity
- Traceable technique

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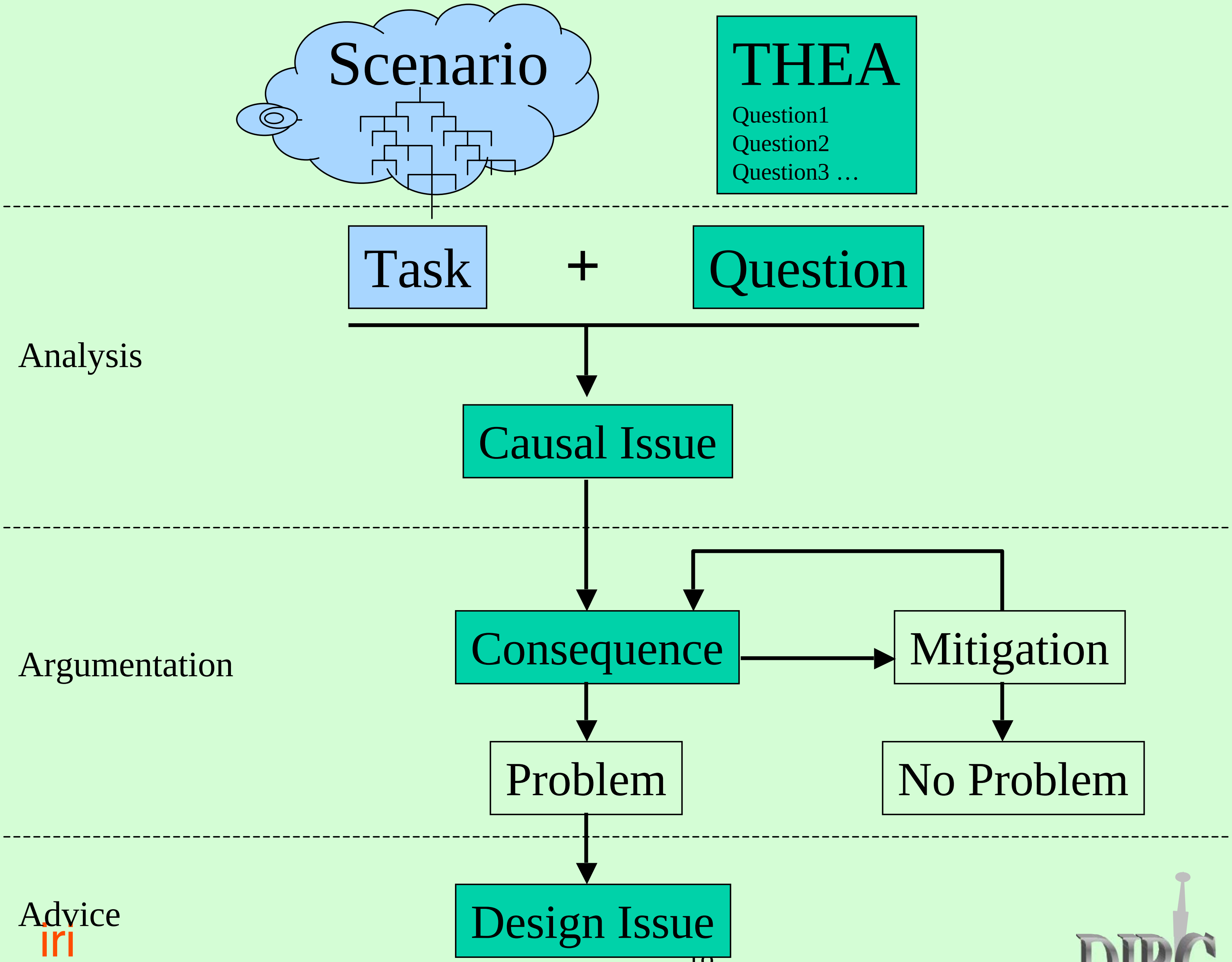
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THEA
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Question2
Question3 …
Task
+
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Causal Issue
Argumentation
Consequence
Mitigation
Problem
No Problem
Advice
Design Issue

Representing the work context

- Usage scenarios represent the system in context;
- Focussing questions about the design through the way the artefact functions in the scenario;
- Take the specific and concrete rather than the abstract and general – bottom up analysis rather than top down;
- *scenarios describe*: agents, rationale, situation and environment, task context, system context, action and exceptional circumstances.

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What is in a scenario?

Agents

flown by two flight deck crew (in contrast to the three currently present on the flight deck); ECAM is the agent being analysed.

Rationale

involves activities in which, in the old system, the flight engineer heavily involved

Situation and Environment

aircraft at low level (200 feet) during daytime, over water, photographing a fishing vessel

Task Context

crew must take immediate action to keep aircraft flying
then commence the drills in response to the engine fire/failure and any secondary warnings

System Context

- This scenario is particularly concerned with the way recovery procedures are displayed by the ECAM.
- Here the ECAM displays a selected recovery procedure one at a time.

Action

- How are the tasks carried out *in context*?
- How do the activities overlap?
- Which goals do actions correspond to?

Exceptional circumstances

- How might the scenario evolve differently, either as a result of uncertainty in the environment or because of variations in agents, situation, design options, system and task context?

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What is in a scenario? (continued)

- **Agents**
  - flown by two flight deck crew (in contrast to the three currently present on the flight deck); ECAM is the agent being analysed.
- **Rationale**
  - involves activities in which, in the old system, the flight engineer heavily involved
- **Situation and Environment**
  - Aircraft at low level (200 feet) during daytime, over water, photographing a fishing vessel
- **Task Context**
  - crew must take immediate action to keep aircraft flying then commence the drills in response to the engine fire/failure and any secondary warnings
- **System Context**
  - This scenario is particularly concerned with the way recovery procedures are displayed by the ECAM.
  - Here the ECAM displays a selected recovery procedure one at a time.

What is in a scenario?(continued)

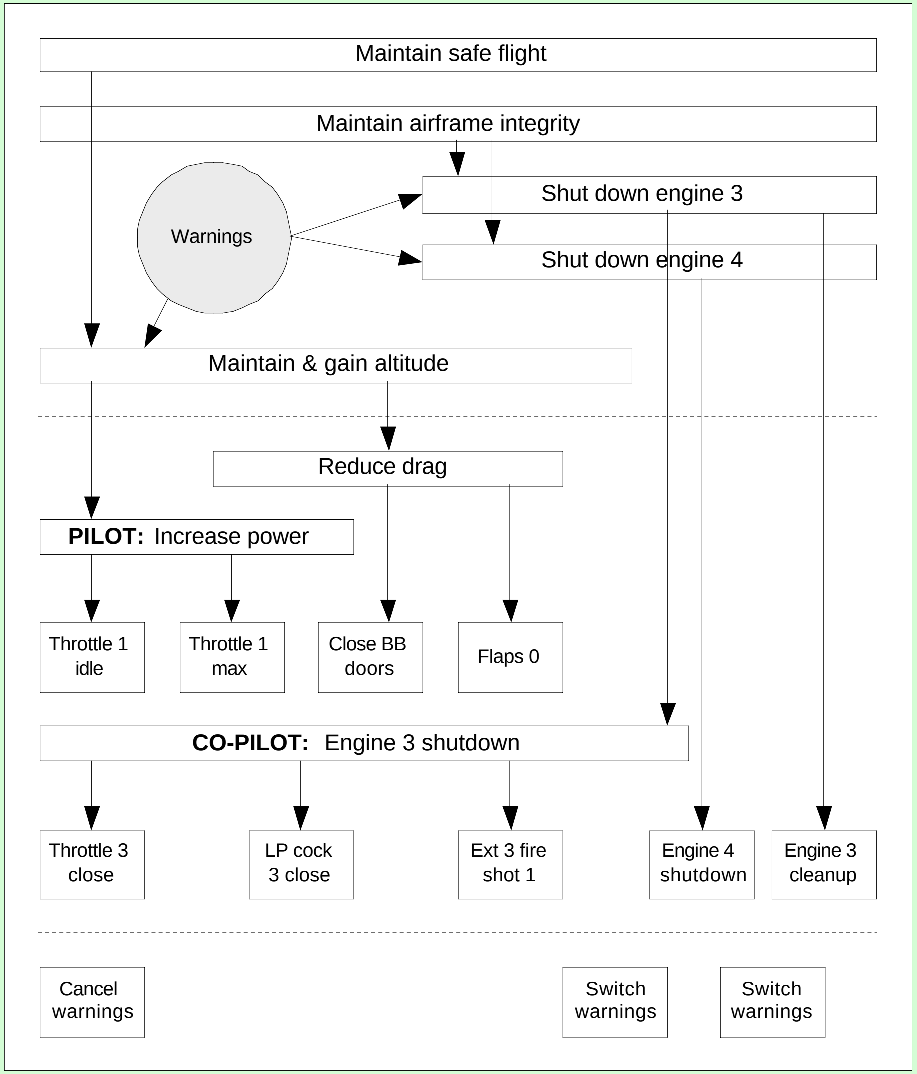
– **Action**
  - How are the tasks carried out *in context*?
  - How do the activities overlap?
  - Which goals do actions correspond to?

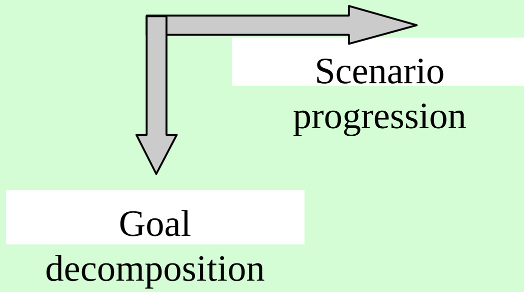
– **Exceptional circumstances**
  - How might the scenario evolve differently, either as a result of uncertainty in the environment or because of variations in agents, situation, design options, system and task context?

HTA task description in THEA format

- 160: Maintain Airframe Integrity[NO EA]
  - Plan 71: In any order
    - 161: Shut Down Engine 3[NO EA]
      - Plan 72: 1,2,3 in order. Then 4
        - 163: Throttle 3 Close[NO EA]
        - 164: LP Cock 3 Close[NO EA]
        - 165: Ext 3 Fire Shot 1[NO EA]
        - 166: Engine 3 Cleanup[NO EA]
    - 162: Shut Down Engine 4[NO EA]
      - Plan 72: 1,2,3 in order. Then 4
        - 167: Throttle 4 Close[NO EA]
        - 168: LP Cock 4 Close[NO EA]
        - 169: Ext 4 Fire Shot 1[NO EA]
        - 170: Engine 4 Cleanup[NO EA]

Hierarchical goal structuring of scenario actions





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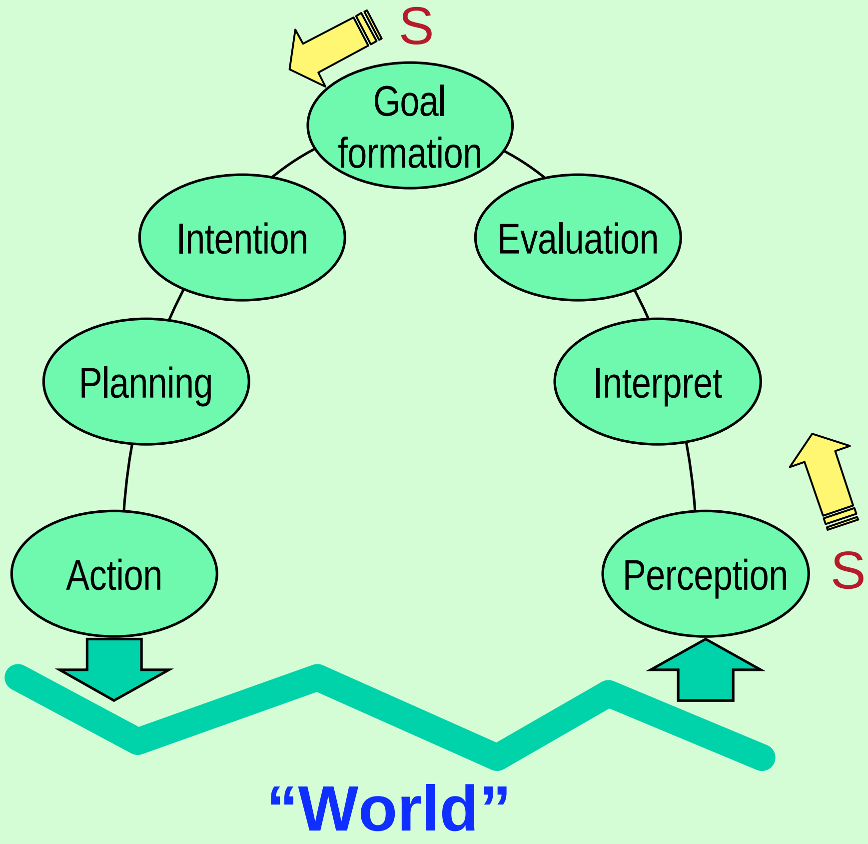
Causal guidewords

A more cognitive approach to error analysis using *Normanís cyclic model of human information processing*



- The cycle may start with goal formation or perception
- Processes in the model may be more or less significant as a result of different styles of interaction (for example, direct manipulation or plan following)

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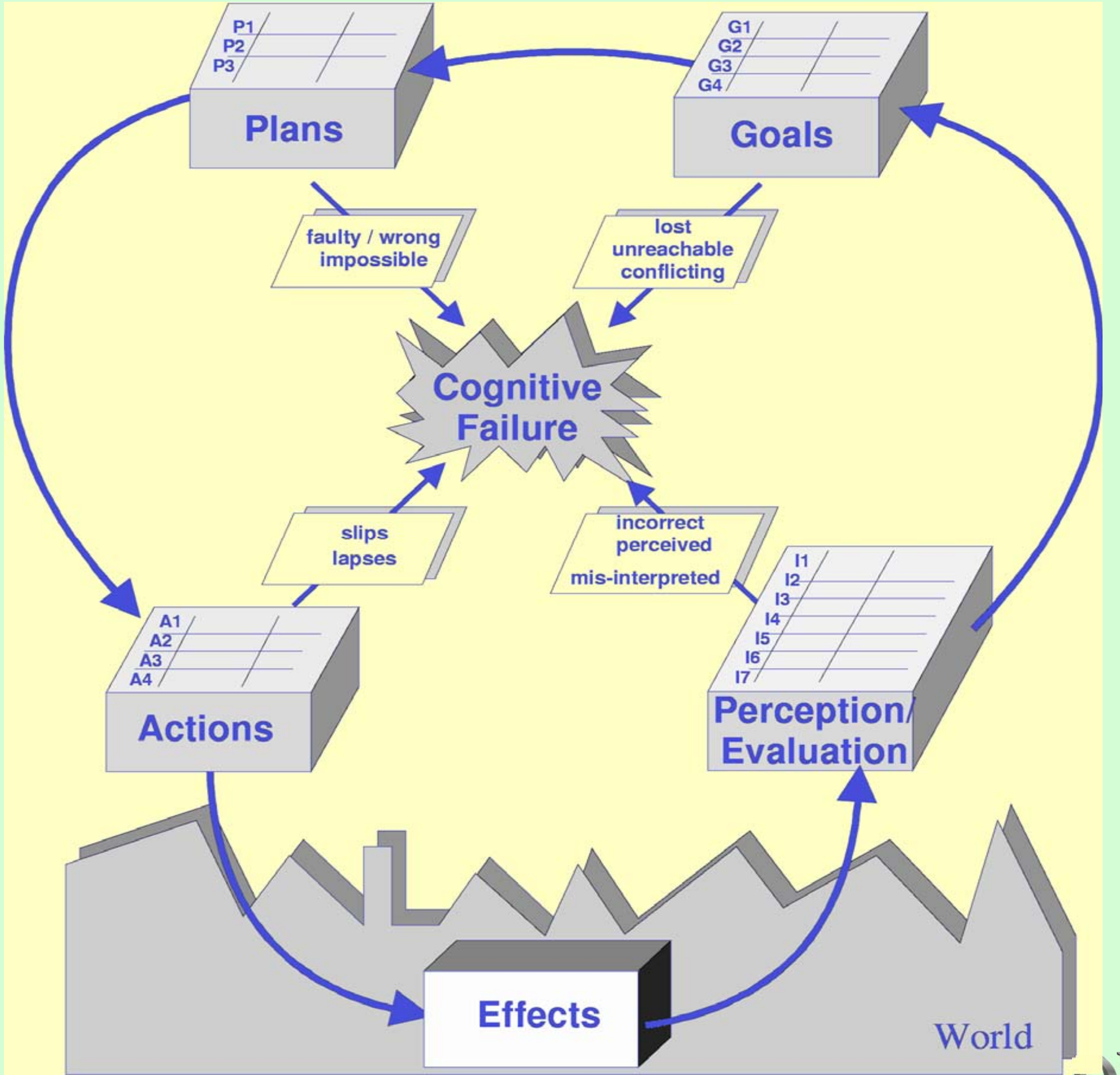
P1
P2
P3
Plans
G1
G2
G3
G4
Goals
faulty / wrong
impossible
lost
unreachable
conflicting
Cognitive
Failure
slips
lapses
incorrect
perceived
mis-interpreted
A1
A2
A3
A4
Actions
I1
I2
I3
I4
I5
I6
I7
Perception/
Evaluation
Effects
World

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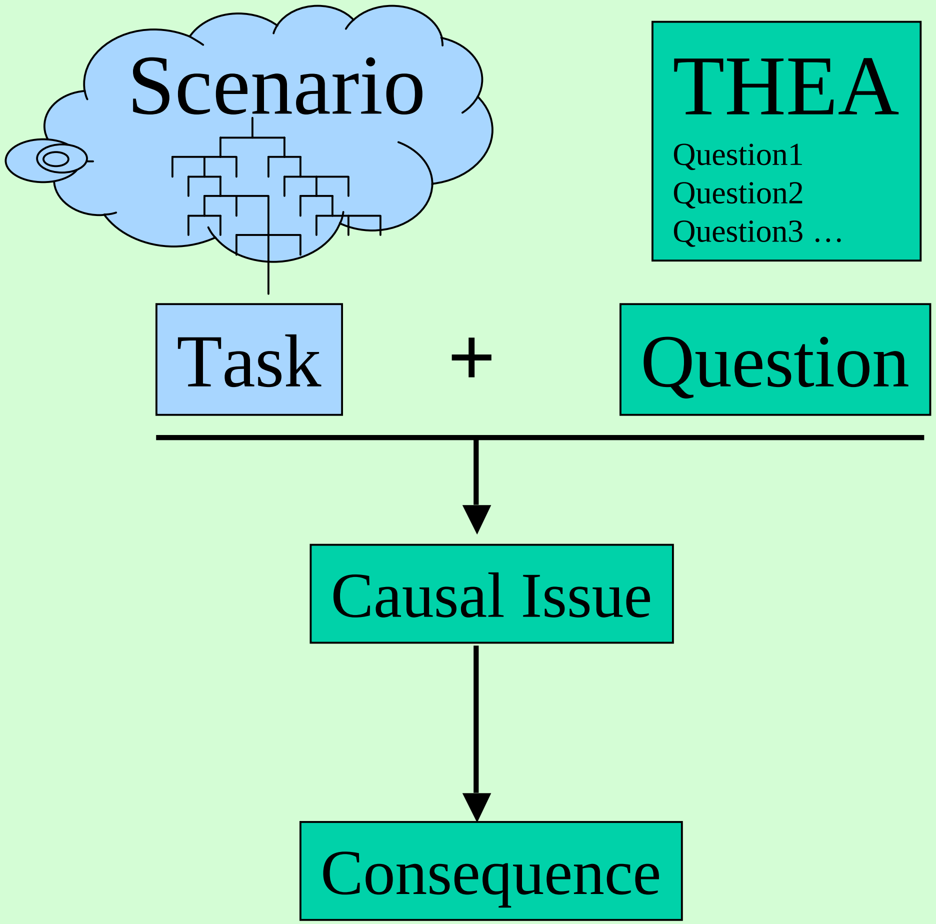
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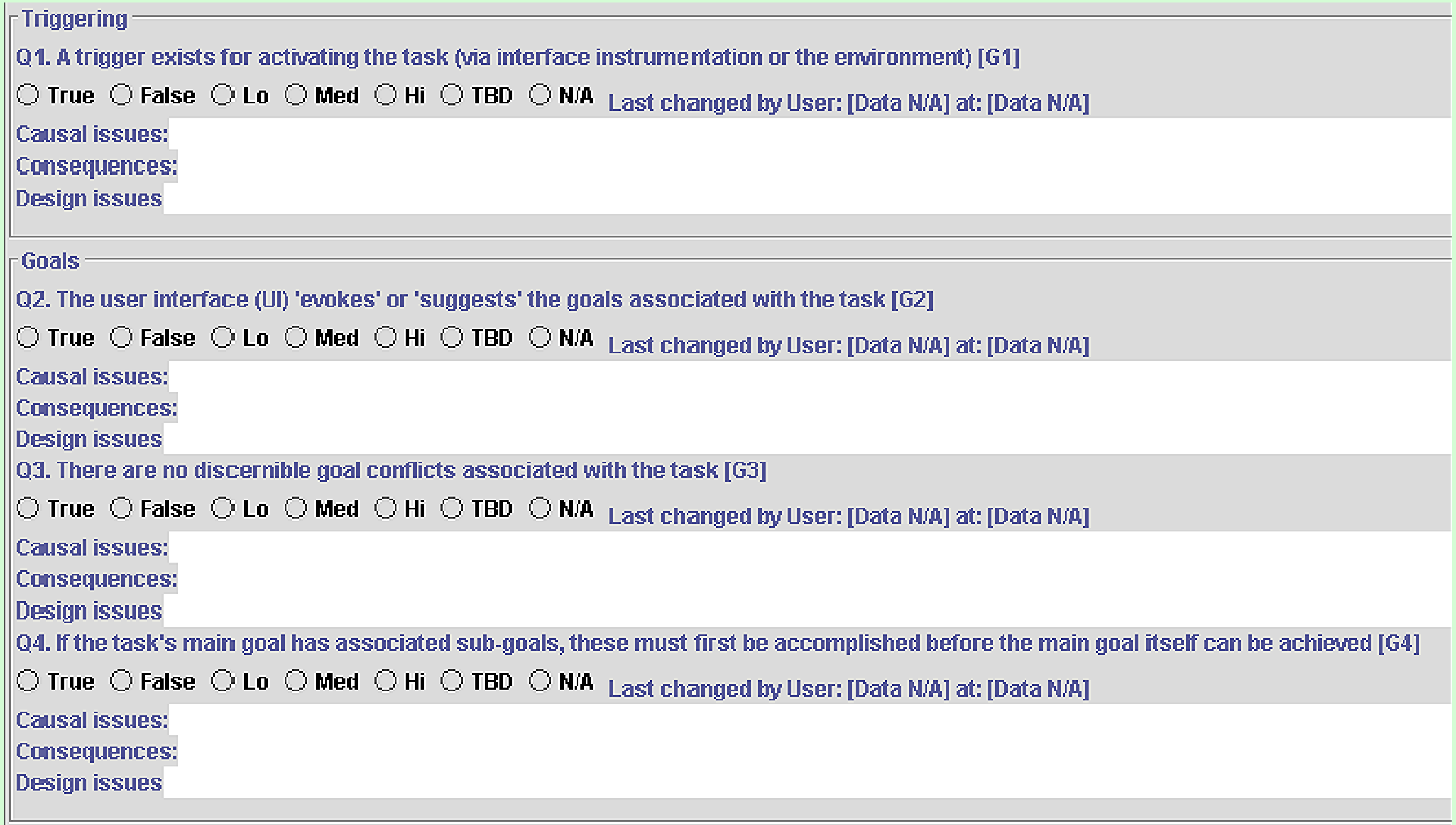
THEA Error Analysis questions 1 - 4



THEA Questionnaire

Triggering

Q1. A trigger exists for activating the task (via interface instrumentation or the environment) [G1]

○ True ◉ False ○ Lo ◉ Med ○ Hi ○ TBD ○ N/A Last changed by User: Anon at: 10:42 5/7/2001

Causal issues: Some goals are poorly triggered, especially if there are several goals with only a single trigger on the display e.g. "Engine 4 shutdown" or "Engine 3 cleanup"

Consequences: It is also possible that "Engine 4 shutdown" or "Engine 3 cleanup" might be omitted or delayed

Design issues

Goals

Q2. The user interface (UI) 'evokes' or 'suggests' the goals associated with the task [G2]

○ True ○ False ○ Lo ○ Med ○ Hi ○ TBD ○ N/A Last changed by User: [Data N/A] at: [Data N/A]

Causal issues:

Consequences:

Design issues

Q3. There are no discernible goal conflicts associated with the task [G3]

○ True ◉ False ○ Lo ◉ Med ○ Hi ○ TBD ○ N/A Last changed by User: Anon at: 10:42 5/7/2001

Causal issues: Goals to increase power and Engine 3 shutdown are in conflict (although inevitable here)

Consequences: Resolving the conflict satisfactorily requires negotiation between pilot and co-pilot. The time required for this may lead to a non-optimal (too late) decision.

Design issues

THEA Error questionnaire completion example

THEA Question	Causal Issues	Consequences
G1: Triggers, task initiation	Some goals are poorly triggered, especially if there are several goals with only a single trigger on the display e.g. “Engine 4 shutdown” or “Engine 3 cleanup”	It is also possible that “Engine 4 shutdown” or “Engine 3 cleanup” might be omitted or delayed
G3: Goal conflicts	Goals to increase power and Engine 3 shutdown are in conflict (although inevitable here)	Resolving the conflict satisfactorily requires negotiation between pilot and co-pilot. The time required for this may lead to a non-optimal (too late) decision

THEA Error Analysis questions 5 - 9

Plans

Q5. The task can be performed without any advance planning (I.e. it can be done "on-the-fly") [P2]

○ True ○ False ○ Lo ○ Med ○ Hi ○ TBD ○ N/A Last changed by User: [Data N/A] at: [Data N/A]

Causal issues:

Consequences:

Design issues

Q6. There is a pre determined and well practised plan associated with this task [P1]

○ True ○ False ○ Lo ○ Med ○ Hi ○ TBD ○ N/A Last changed by User: [Data N/A] at: [Data N/A]

Causal issues:

Consequences:

Design issues

Q7. This plan could be confused with another (similar) plan [P3]

○ True ○ False ○ Lo ○ Med ○ Hi ○ TBD ○ N/A Last changed by User: [Data N/A] at: [Data N/A]

Causal issues:

Consequences:

Design issues

Q8. There exists a similar plan which is performed more frequently than the task's intended one [P4]

○ True ○ False ○ Lo ○ Med ○ Hi ○ TBD ○ N/A Last changed by User: [Data N/A] at: [Data N/A]

Causal issues:

Consequences:

Design issues

Q9. Feedback allows user to determine that task is proceeding successfully towards goal, and according to plan (if there is one) [P5, ex I5]

○ True ○ False ○ Lo ○ Med ○ Hi ○ TBD ○ N/A Last changed by User: [Data N/A] at: [Data N/A]

Causal issues:

Consequences:

Design issues

THEA Error Analysis questions 10 - 13

Actions

Q10. There is no mental (or physical) difficulty in carrying out this task [A1]

○ True ○ False ○ Lo ○ Med ○ Hi ○ TBD ○ N/A Last changed by User: [Data N/A] at: [Data N/A]

Causal issues:
Consequences:
Design issues

Q11. There are no actions required for this task which are (or become) unavailable to the operator [A2]

○ True ○ False ○ Lo ○ Med ○ Hi ○ TBD ○ N/A Last changed by User: [Data N/A] at: [Data N/A]

Causal issues:
Consequences:
Design issues

Q12. If interaction with a moded system is involved in the task, performing the action correctly is not dependent on the current mode [A3]

○ True ○ False ○ Lo ○ Med ○ Hi ○ TBD ○ N/A Last changed by User: [Data N/A] at: [Data N/A]

Causal issues:
Consequences:
Design issues

Q13. The operator does not need to perform additional actions in order to make the right controls and information available at the right time [A4]

○ True ○ False ○ Lo ○ Med ○ Hi ○ TBD ○ N/A Last changed by User: [Data N/A] at: [Data N/A]

Causal issues:
Consequences:
Design issues

THEA Error Analysis questions 14 - 17

Perception

Q14. Changes to the system arising from user action(s) are clearly perceivable by the user(s) [I1]

○ True ○ False ○ Lo ○ Med ○ Hi ○ TBD ○ N/A Last changed by User: [Data N/A] at: [Data N/A]

Causal issues:

Consequences:

Design issues

Q15. The effects of any changes on the system arising from user action(s) are perceivable immediately [I2]

○ True ○ False ○ Lo ○ Med ○ Hi ○ TBD ○ N/A Last changed by User: [Data N/A] at: [Data N/A]

Causal issues:

Consequences:

Design issues

Q16. Changes to the system arising from autonomous system action(s) are clearly perceivable by the user(s) [I1_1]

○ True ○ False ○ Lo ○ Med ○ Hi ○ TBD ○ N/A Last changed by User: [Data N/A] at: [Data N/A]

Causal issues:

Consequences:

Design issues

Q17. The effects of any changes on the system resulting from autonomous system action(s) are perceivable immediately [I2_1]

○ True ○ False ○ Lo ○ Med ○ Hi ○ TBD ○ N/A Last changed by User: [Data N/A] at: [Data N/A]

Causal issues:

Consequences:

Design issues

THEA Error Analysis questions 18 - 21

Q18. This task does not involve significant amounts of monitoring, vigilance, or continuous attention [I3]

○ True ○ False ○ Lo ○ Med ○ Hi ○ TBD ○ N/A Last changed by User: [Data N/A] at: [Data N/A]

Causal issues:

Consequences:

Design issues

Q19. The user can easily determine the relevant system information needed to perform this task (from the total information provided) [I4]

○ True ○ False ○ Lo ○ Med ○ Hi ○ TBD ○ N/A Last changed by User: [Data N/A] at: [Data N/A]

Causal issues:

Consequences:

Design issues

Q20. There is no complex reasoning, calculation, or decision making associated with this task [I6]

○ True ○ False ○ Lo ○ Med ○ Hi ○ TBD ○ N/A Last changed by User: [Data N/A] at: [Data N/A]

Causal issues:

Consequences:

Design issues

Q21. If interaction with a moded system(s) is involved in the task, interpreting the information provided is not dependent on the current mode [I7]

○ True ○ False ○ Lo ○ Med ○ Hi ○ TBD ○ N/A Last changed by User: [Data N/A] at: [Data N/A]

Causal issues:

Consequences:

Design issues

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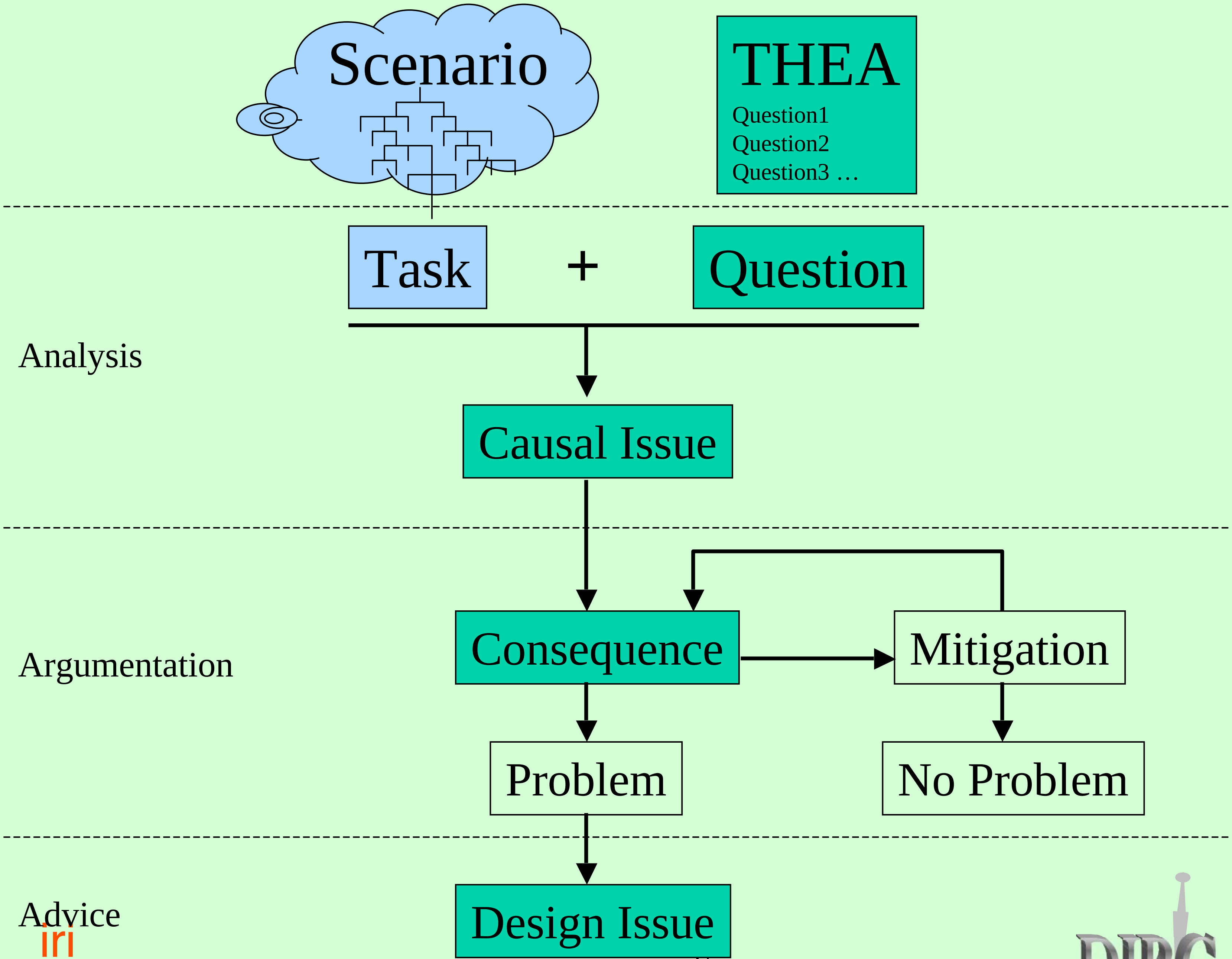
Using the checklist

- Not all items on the checklist are applicable in all situations;
- Style of interaction will vary and is influenced by:
  - type of user;
  - type of interface;
  - type of task.
- The checklist is meant to raise questions, not provide definitive answers. Guides analyst in a structured way to consider areas of design for potential interaction difficulties.

Consequences and design issues

- Consequences of failure may be in terms of:
  - performance and successful outcome of the scenario
  - workload of participants;
  - state of the systems involved including hazardous states.

- Design issues
  - analyst provided with a space for documenting ideas about design changes that could ameliorate/avoid the problems identified.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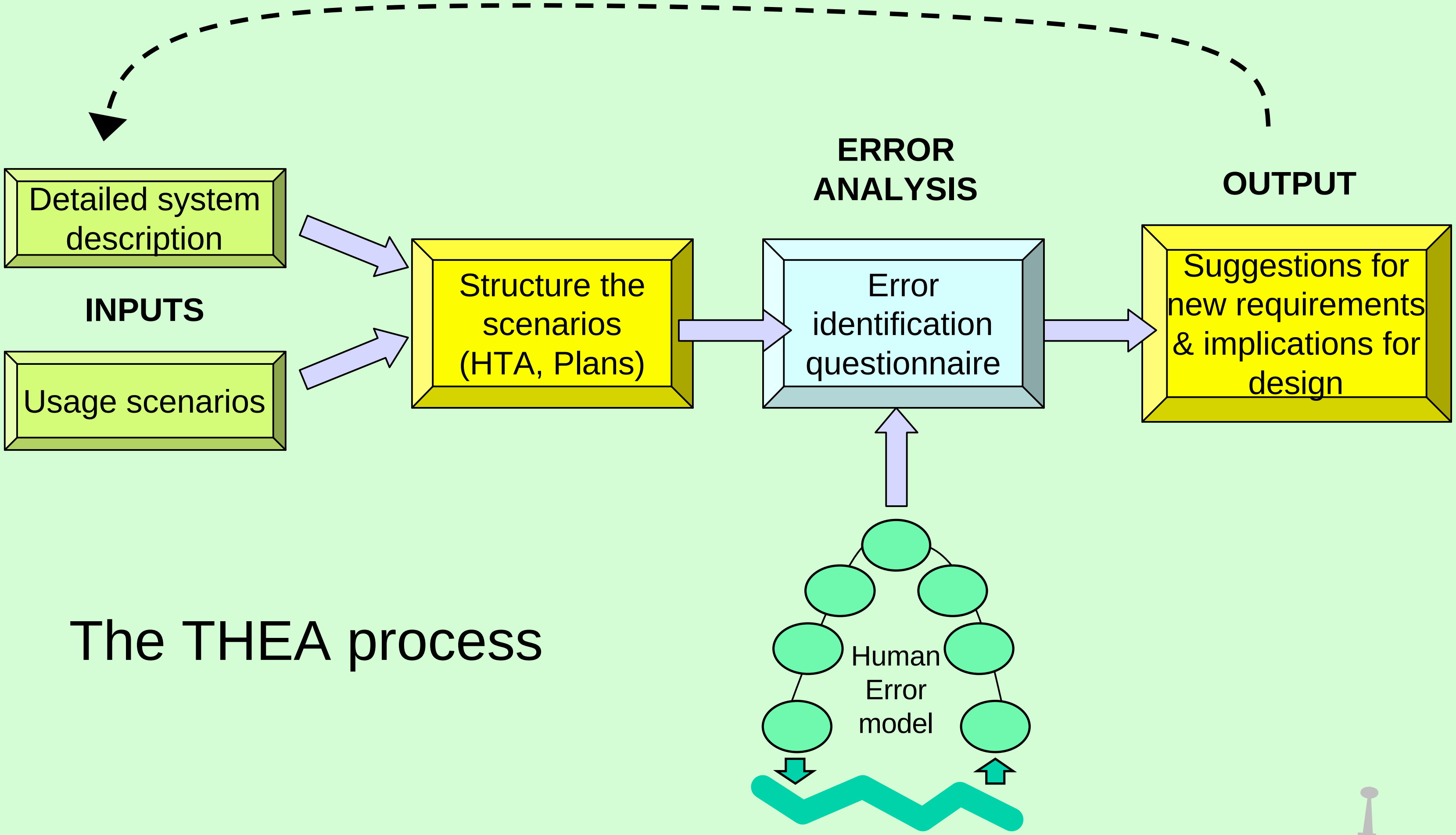
Bringing it all together



The THEA process

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ProtoTHEA

- A tool is available that supports the use of THEA.
- Generates an appropriate database and provides triggers for the questionnaire
- Summaries include information about coverage of questions against HTA and where concentrations of errors are.
- Available as informally supported system.

Where has THEA been applied?

- NATS: software maintenance and configuration
  - method used without our help
- BAE SYSTEMS companies: Operating and maintenance procedures
  - case studies but some independent analysis
  - some quantitative analysis for difficult situations
- BAE SYSTEMS companies: Flight deck assessment
  - case studies
  - used in preliminary hazard assessment

Where is THEA deficient?

- THEA only deals with single-user computer interaction
- Most work is actually performed in groups/teams
- Susceptible to a different type of error
- No error analysis technique that deals with the specific problems associated with collaborative work
- Other EA methods – don't help lead to design improvements

Type of Work CHLOE Analyses (work done by Angela Miguel and Peter Wright)

- 2 types of collaboration under consideration:
  - Social Collaborative – Human agents collaborate directly between themselves to achieve joint goals
  - ‘Technology-mediated’ Collaborative – Human agents,as before, collaborate to achieve mutual goals, but either by means of, or through, the technology medium itself
- Different types of collaborative system: ATC, Hospital work
- Involve: Collaboration - coordination, communication, cooperation
- Error/failures caused by: e.g. lack of awareness, misunderstandings between participants, conflicts, failures of coordination

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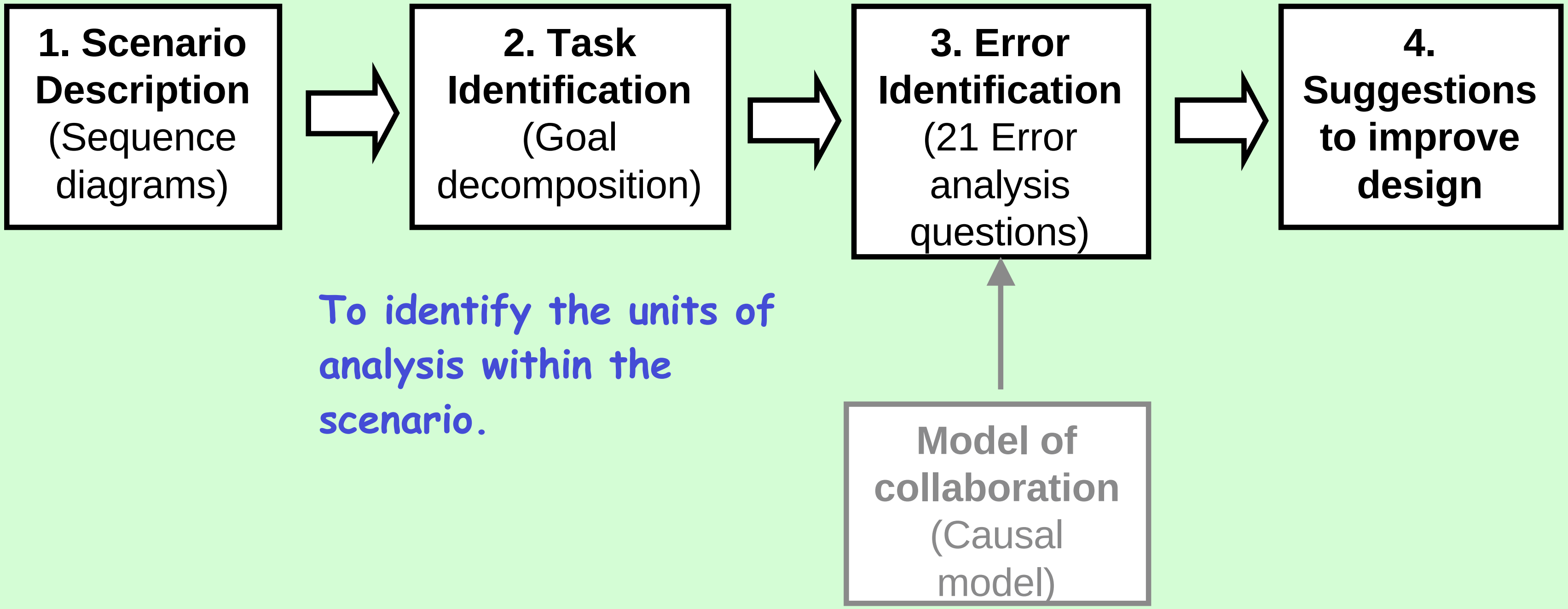
Aims of CHLOE

- Analysis technique specifically for collaborative errors
- Take an HCI/CSCW evaluation approach to analysis
  - Based on failures within a cognitive model of collaboration
- Usable by non-Human Factors experts
- Analysis that helps lead to re-design
- Applied to quite mature systems to check vulnerability to failure (consistent with HEA process)

The CHLOE Process



Quantification

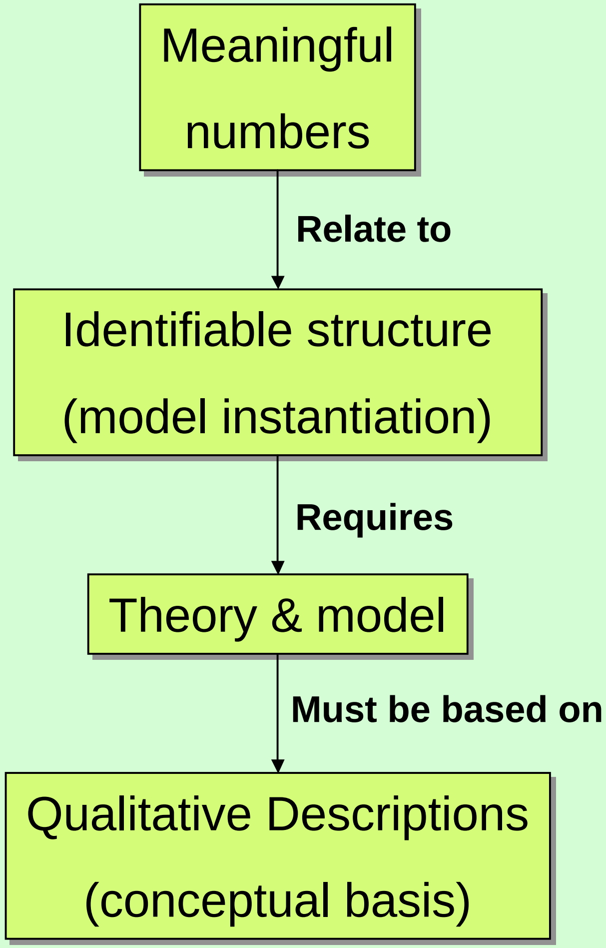
- selecting some actions, or subtasks that have been identified during human error identification.
- attaching numbers to the action or subtask.
- smaller the unit of analysis the more time consuming the process
  - THERP uses actions
  - HEART uses generic tasks.
- ISSUE about how the numbers should be used.

Atomistic assumption appropriate?

- Assigning numbers to events identified in the human error identification phase
- Safety engineering issues:
  - can clearly separable actions be seen as unique causes with no interaction between events (could be at a goal level or an action level)?
  - can human reliability really be viewed as an aggregation of parts?
  - Failures usually result from a cascade of actions. Probability assessments view each action in isolation;
  - No account of cognitive functions - person treated unrealistically as ‘black box’.

Quantitative or Qualitative?

- Reliability analyses often neglect the importance of qualitative aspects
- *Qualitative* and *Quantitative* predictions are really two aspects of the same thing
- *Quantitative* descriptions (e.g. a probability measure) are based on qualitative descriptions - quantities must be quantities of something previously described
- Purpose is to identify potential for human erroneous actions, especially where they're likely
- Numbers work best when serving as 'tokens' for negotiation of concerns



(Adapted from Hollnagel, 1993)

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Numbers and context

- Data which does exist derived from military and nuclear industries, known as Human Error Probabilities (HEPs). Represent the probability estimates of general or universal (failure) characteristics of human performance
- To modify these from nominal to actual situations, Performance Shaping Factors (PSFs) devised. Represent specific context or task characteristics, and serve to:
    - Compensate for lack of appropriate empirical data
    - Compensate for lack of context in a decomposition-based analysis
    - BUT: Often treated in a very simplistic way
    - An artefact derived from the decomposition principle in HRA

Quantification techniques

- HEART: a human performance model-based technique utilising some standard probabilities
  - A data-based method for assessing and reducing human error to improve operational performance.

  J.C. Williams (1988) IEEE Fourth Conference on Human Factors and Power Plants (pp.436-450)
- SLIM: a utility-based technique using team based judgements
- THERP: earliest method
- (Many more, mostly based on engineering models)

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Example approach: HEART

- HEART employed to assess significant sequences within a scenario;

- A 'pre-processed' HRA technique, assisting with:
  - identification of Error Producing Conditions (EPCs)
  - assessment of their importance
  - calculation of the predicted probabilities of task failure

- Based on long-term sizeable human reliability database; weighting factors based on HF literature. Assumes human performance usually deteriorates when EPCs interact (eg a conflict of objectives + shortage of time);

HEART generic categories (after Williams, 1986)

Generic Task	Nominal human unreliability	
(A) Totally unfamiliar, performed at speed with no real idea of likely consequences	0.55	(0.35-0.97)*
(B) Shift or restore system to a new or original state on a single attempt without supervision or procedures	0.26	(0.14-0.42)
(C) Complex task requiring high level of comprehension and skill	0.16	(0.12 - 0.28)
(D) Fairly simple task performed rapidly or given scant attention	0.09	(0.06 - 0.13)
(E) Routine, highly practised, rapid task involving relatively low level of skill	0.02	(0.007 - 0.045)
(F) Restore or shift a system to original or new state following procedures, with some checking	0.003	(0.0008 - 0.007)
(G) Completely familiar, well-designed, highly practised, routine task occurring several times per hour, performed to highest possible standards by highly motivated, highly-trained and experienced personnel, with time to correct potential error, but without the benefit of significant job aids	0.0004	(0.00008 - 0.009)
(H) (H) Respond correctly to system command even when there is an augmented or automated supervisory system providing accurate interpretation of system state	0.00002	(0.000006 - 0.0009)

(*5th-95th percentile bounds)

Error producing Conditions (EPCs) [1]

1	*Unfamiliarity with a situation which is potentially important but which only occurs infrequently or which is novel*	17
2	*A shortage of time available for error detection and correction*	11
3	*A low signal-noise ratio*	10
4	*A means of suppressing or over-riding information or features which is too easily accessible*	9
5	*No means of conveying spatial and functional information to operators in a form which they can readily assimilate*	8
6	*A mismatch between an operator's model of the world and that imagined by the designer*	8
7	*No obvious means of reversing an unintended action*	8
8	*A channel capacity overload, particularly one caused by simultaneous presentation of non-redundant information*	6

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Error producing Conditions (EPCs) [2]

9	*A need to unlearn a technique and apply one which requires the application of an opposing philosophy*	6
10	*The need to transfer specific knowledge from task to task without loss*	5.5
11	*Ambiguity in the required performance standards*	5
12	*A means of suppressing or over-riding information or features which is too easily accessible*	4
13	*A mismatch between perceived and real risk.*	4
14	*No clear, direct and timely confirmation of an intended action from the portion of the system over which control is exerted.*	4
15	*Operator inexperience (e.g., a newly qualified tradesman but not an expert)*	3
16	*An impoverished quality of information conveyed by procedures and person-person interaction*	3

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Error producing Conditions (EPCs) [3]

17	*Little or no independent checking or testing of output*	3
18	*A conflict between immediate and long term objectives*	2.5
19	*Ambiguity in the required performance standards*	2.5
20	*A mismatch between the educational achievement level of an individual and the requirements of the task*	2
21	*An incentive to use other more dangerous procedures*	2
22	*Little opportunity to exercise mind and body outside the immediate confines of a job*	1.8
23	*Unreliable instrumentation (enough that it is noticed)*	1.6
24	*A need for absolute judgements which are beyond the capabilities or experience of an operator*	1.6

Error producing Conditions (EPCs) [4]

25	*Unclear allocation of function and responsibility*	1.6
26	*No obvious way to keep track of progress during an activity*	1.4
27	*A danger that finite physical capabilities will be exceeded.*	1.4
28	*Little or no intrinsic meaning in a task*	1.4
29	*High level emotional stress*	1.3
30	*Evidence of ill-health amongst operatives especially fever.*	1.2
31	*Low workforce morale*	1.2
32	*Inconsistency of meaning of displays and procedures*	1.2

Error producing Conditions (EPCs) [5]

33	*A poor or hostile environment*	1.15
34	*Prolonged inactivity or highly repetitious cycling of low mental workload tasks (1st half hour)*	1.1
34	*(thereafter)*	1.05
35	*Disruption of normal work sleep cycles*	1.1
36	*Task pacing caused by the intervention of others*	1.06
37	*Additional team members over and above those necessary to perform task normally and satisfactorily. (per additional team member)*	1.03
38	*Age of personnel performing perceptual tasks*	1.02

Application of HEART to case study

Generic Task (F): **Shift system to new state using procedures:** **0.003**

Task 1: **Operator removes lifeboat tarpaulin and safety anchoring bolts**

Error Producing Conditions	Total HEART effect **(E)**	Assessed proportion **(P)**	Assessed Effect
		$(\Sigma \neq 1)$	= ((E-1)*P)+1
2. Shortage of time	11.00	0.10	2.00
13. Poor feedback	4.00	0.10	1.30
17. No independent check	3.00	0.20	1.40
27. Physical capabilities exceeded	1.40	0.05	1.02
29. Emotional stress	1.30	0.40	1.12
33. Hostile environment	1.15	0.50	1.08
35. Disruption of sleep	1.10	0.10	1.01

Application of HEART to case study (cont)

- Assessed probability of failure = 0.003 * 2.00 * 1.30 * 1.40 * 1.02 * 1.12 * 1.08 * 1.01 = 0.014
- Task 2: Stow bolts in pre-designated central location; Assessed probability of failure = 0.378
- Task 3: Check bolts are stowed prior to pressing detonator button; Assessed probability of failure = 0.397

Error-producing conditions (EPCs)

	ERROR PRODUCING CONDITION	MAXIMUM PREDICTED MULTIPLIER OF NOMINAL PROBABILITY
(17)	Little or no independent checking or testing of output	**x3**
(33)	Hostile environment	**x1.15**

Identify task EPCs considered to have a negative influence on human performance...

…then, add amount by which the EPC modifies the unreliability

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Case study example

- Operator deckside tasks for a ‘quick-release’ lifeboat:

1. Remove lifeboat tarpaulin and two safety anchoring bolts
2. Physically stow bolts in a pre-designated central location
3. Check that bolts are indeed stowed
4. Pressing the ‘release lifeboat’ detonator button

CONCERN: What is the probability that the operator will attempt to launch the lifeboat without first removing the safety anchoring bolts?

Application of HEART to case study

Generic Task (F): **Shift system to new state using procedures**: **0.003**

Task 1: **Operator removes lifeboat tarpaulin and safety anchoring bolts**

Error Producing Conditions	Total HEART effect **(E)**	Assessed proportion **(P)** ($\Sigma \neq 1$)	Assessed Effect = ((E-1)*P)+1
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Assessed probability of failure = 0.003 * 2.00 * 1.30 * 1.40 * 1.02 * 1.12 * 1.08 * 1.01 = **0.014**

Task 2: Stow bolts in pre-designated central location; **Assessed probability of failure = 0.378**

Task 3: Check bolts are stowed prior to pressing detonator button; **Assessed probability of failure = 0.397**

SLIM: Success Likelihood Index Method

- Problem with HEART:
  - Small database of numbers, highly susceptible to expert judgement – the proportions tend to dominate.
  - Therefore discuss it to indicate how the number issue might be dealt with.
  - No suggestion that you should use it.
  - However, the process of generating the numbers might be valuable.
- SLIM addresses the numerical but is probably more susceptible to expert judgement.
- Based on meeting involving expert panel (for example, two operators with "minimum 10 years experience"; one human factors analyst; one reliability analyst).
- Calculates success likelihood index from performance shaping factors ratings.
- Converts SLIs into probabilities.

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SLIM: Success Likelihood Index Method

- not based on tables of human performance data rather based on similarity with similar situations.
- based on meeting involving expert panel (for example, two operators with “minimum 10 years experience”; one human factors analyst; one reliability analyst);
- calculates success likelihood index from performance shaping factors ratings
- converts SLIs into probabilities

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Summary

- Introduced a technique for human error identification based on a cognitive model of human behaviour, including a checklist for assessing the complexity of the interface of the system
- Brief introduction to issues of quantification
  – quantification should be considered with extreme caution
  – HEART based on data which is highly dependent on contextual factors
- CREAM combining attributes of THEA and HEART, but has an initial phase in which the control mode and generic reliability characteristics are derived.