EUROPEAN ORGANISATION
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The Human Error in ATM Technique (HERA-JANUS)

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Abstract

This report is the second in a series in Phase 1 of the ‘Human Error in ATM (HERA)’ Project, dealing with how human errors in Air Traffic Management (ATM) can be analysed to improve safety and efficiency in European ATM operations. The purpose of this work is to increase the effectiveness of error recording, analysis and prevention. This report describes the development and application of a framework and technique for analysing human error in ATM incidents. The HERA-JANUS taxonomy is presented for future use.

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Human error	Human performance	Classification system	Incident analysis
Incident Investigation	Model	Taxonomy	Techniques

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EXECUTIVE SUMMARY

This report is the second in a series in Phase 1 of the 'Human Error in ATM (HERA)' Project, dealing with how human errors in Air Traffic Management (ATM) can be analysed to improve safety and efficiency in European ATM operations. The purpose of this work is to increase the effectiveness of error recording, analysis and hopefully prevention. This work has arisen as a result of the increasing importance of the consequences of human error, error recovery and error reduction in ATM. This becomes more important as traffic levels increase, as European airspace becomes more harmonised, and as ATM operational centres make more use of computerised support and automation. Human error is a potential weak link in the ATM system and therefore measures must be taken to minimise errors and their impact, and to maximise other human qualities such as error detection and recovery.

Theories of human error, and practical approaches for analysing and managing error, have largely been developed in other industries such as chemical and nuclear power processing. In these industries the effects of human error have already resulted in numerous incidents and catastrophic accidents. These have resulted in a large body of knowledge regarding the errors which occur, how and why they occur, and how they can be prevented or guarded against. ATM can and should borrow from this knowledge to develop an ATM-specific approach.

This report develops a detailed methodology for analysing human errors in ATM, including all error forms and their causal, contributory and compounding factors. The methodology is based on the conceptual framework developed in the first report (written in two parts – see EATMP, 2002a & 2002b). This conceptual framework outlined a model of human performance, the types of taxonomies that would be required to classify errors and contextual factors relating to ATM incidents, and the format that these taxonomies should take.

The resultant approach for analysing human errors is called the 'Human Error in ATM Technique (HERA-JANUS)' and is fully described in this report.

The third technical report (EATMP, 2003) will summarise the results of a thorough validation of the technique, demonstrating its application in pan-European ATM incident analysis.

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1. INTRODUCTION

1.1 Overall Work Plan and Focus of this Report

This report forms part of the second of the three Work Packages (WPs) of the Human Error in ATM (HERA) Project, Phase 1 (HERA 1), which aim to develop and validate a conceptual framework and technique for analysing human errors in Air Traffic Management (ATM). The overall work plan for this project is summarised in Figure 1.

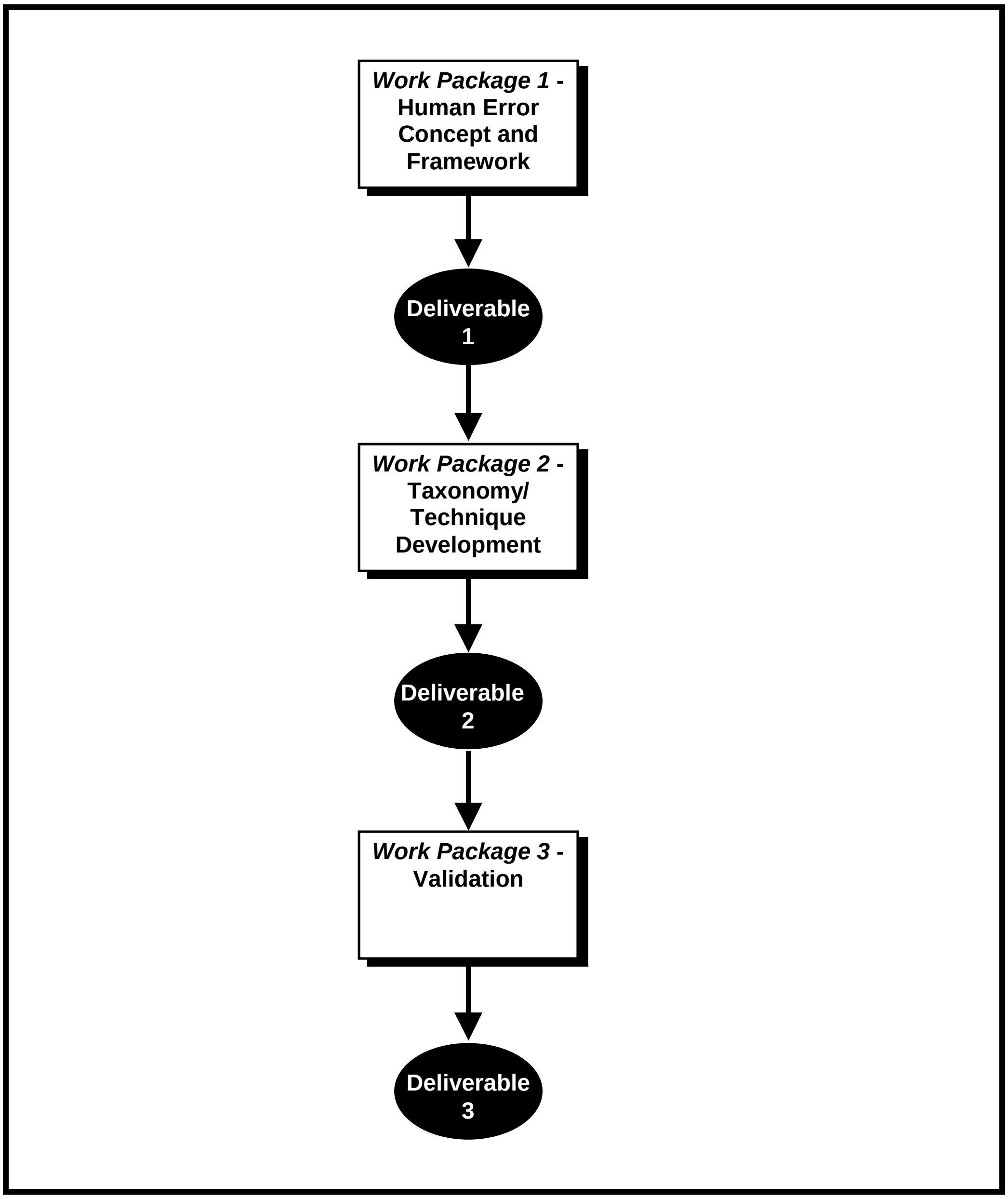

Figure 1: Overall work plan for Phase 1 of the HERA Project

This work plan covers Phase 1 of the project, namely the development of a methodology for analysing human errors in incidents in ATM. The present Work Package (WP2) derives a detailed methodology including all error forms and their causal, contributory and compounding factors, based on the conceptual framework developed in WP1. This was achieved by integrating different aspects from existing taxonomies, based on the literature review produced from WP1, into a comprehensive taxonomy and technique. The technique was then tailored to ATM using knowledge of the ATM tasks, such as required controller behaviours and functions, and specific factors which can affect controller performance.

1.2 Structure of the Report

The remainder of this report is concerned with the HERA-JANUS Technique, its use and development. Section 2 presents the rationale for the technique and Section 3 describes the technique itself. Finally, in the Appendix information can be found regarding the development of HERA-JANUS, from its inception through to the final adaptations and 'fine-tuning'. The Appendix also contains some examples from European and non-European ATM incident reports.

It should be noted that the development of the HERA-JANUS retrospective (incident analysis) technique has been iterated through three formal phases. Each of these phases has seen the adoption of changes in relation to the terminologies, the simplification of the structure, the reduction of the taxonomies for easier use and refined methodology to assist understanding. The changes were made from inputs given in the various meetings and group discussions during the lengthy development, and in all cases were the product of air traffic controllers, safety managers and incident investigators. This development also included the work which has been jointly developed with the Federal Aviation Administration (FAA) in the USA and the resultant twelve months of beta-testing with the HERA Technique in Europe. The technique was known as 'HERA-JANUS' once the harmonisation activities with the FAA were completed. This is why in this document the technique is systematically called 'HERA-JANUS' rather than just 'HERA'.

Throughout the report references will be made to the previous work packages and it should be noted that the terminologies and structure within this work package document are the most recent.

2. RATIONALE

Work Package 1 introduced a method for classifying human errors in ATM and associated contextual factors by selecting appropriate 'error types' from the literature, and shaping their usage within a conceptual framework. This conceptual framework included factors to describe the error, such as error modes and mechanisms and factors to describe the context, e.g. when did the error occur, who was involved, where did it occur, what tasks were being performed? This was achieved by employing a pre-defined taxonomic procedure, adapted from Shorrock (1997). This procedure is delineated in the Appendix of this report - Development of the HERA-JANUS Technique.

The resulting conceptual framework and taxonomy is called:

HERA (Human **E**rror in **A**TM Technique) **- JANUS**.

One of the most important issues in a development such as this, is the use of the technique for those in the ATM profession. Firstly, the question of who will be using such a technique and what materials will be used are addressed below.

2.1 The Users of HERA-JANUS

The HERA-JANUS Technique could be useful for a variety of disciplines. Some potential users include:

- decision-makers and managers with responsibility for safety,
- incident investigators and analysts,
- psychologists and human factors practitioners,
- reliability engineers,
- software developers.

Such users will have varying levels of knowledge in psychology, human factors and ATM. Therefore, it is important that the taxonomy and associated methods can be understood by all, and after initial training, used consistently and efficiently to yield useful results.

2.2 The Materials used with HERA-JANUS

The HERA-JANUS Technique should be usable with a variety of sources of information, since the types of materials which are obtainable and usable will vary depending on the purpose of classification, users (countries, centres, personnel, etc.), and situational factors. Table 1 below outlines the types of materials that could be classified, based on the applications described above.

Table 1: Applications of the HERA-JANUS Technique and potential source materials

Application	Materials
Incident investigation	Interviews, debriefs, reports, radar recordings, R/T, telephone and other voice recordings, Flight Progress Strips (FPS), simulation data.
Retrospective incident analysis	Formal compiled incident reports, Critical Incident Technique interviews, confidential (non-investigated) reports.
Error Prediction	Task analysis, Human-Machine Interface (HMI), documents (procedures, method of operation, operating instructions), simulation data.
Human error quantification	Expert judgement, observation.

3. THE HERA-JANUS TECHNIQUE

3.1 Defining the Classification System

In order to classify errors properly, two types of factors must be described:

- The **error** - what error occurred (type), how did the error occur (mechanisms).
- The **context** - when did the event occur, who was involved and what was their involvement (including the organisation factors), where did it occur, what tasks were being performed, how did the event occur and what information or topic did the error involve.

It is very important to ensure that the context is captured in classification, otherwise it will not be possible to specify plausible error reduction strategies. The types of taxonomy, both related to error and context, are shown in Table 2.

Table 2: Types of HERA-JANUS taxonomy and location within this report

Taxonomy	Description	Sub-section No.	Page No.
	Error		
Error Type	What keyword can be applied to the error (including rule breaking and violation), in terms of timing, selection or quality of performance or communication?	**3.4.1 & 3.4.2**	**12 & 14**
Error Detail (ED)	What cognitive process was implicated in the error?	**3.4.3**	**14**
Error Mechanism (EM)	What cognitive function failed, and in what way did it fail?	**3.4.3**	**14**
Information Processing Levels (IPs)	How did the error occur in terms of psychological mechanisms?	**3.4.3**	**14**
	Context		
Task	What task(s) was/were being performed by the controllers(s) at the time that the errors occurred?	**3.4.4**	**25**
Information & Equipment	What was the topic of the error, the equipment used in the error or the information involved? (e.g. what did the controller misperceive, forget, misjudge, etc.?) What HMI element was the controller using?	**3.4.5**	**26**
Contextual Conditions (CCs)	What other factors, either internal or external to the controller, affected the controller’s performance?	**3.4.6**	**30**

3.2 Forming a Method of Incident Analysis

HERA-JANUS incident analysis form

To ensure that the HERA-JANUS Technique is used as reliably as possible, it was necessary and desirable to create a method for analysing incidents. Several factors were therefore taken into account:

- *Details of the incident* - records details such as reference code, when and where the incident occurred, reported and recorded separation, and the analyst or HERA-JANUS user.
- *Description of the incident and depiction of the error chain* - describes the incident in approximately 300 to 800 words, with each error identified numerically.
- *Description of each error* - describes each error separately in a separate section of the form.
- *HERA-JANUS classifications* - the application of context and error classifications.
- *Assumptions and notes* - any assumptions that were made in the recording of classifications with any explanatory notes.

An example of the HERA-JANUS incident analysis form is shown in Table 3.

Definition of error

The following definition is given to an error which has been committed:

Human Error	***'Any action (or inaction) that potentially or actually results in negative system effects, where more than one possible course of action is available.'***

Thus, each erroneous action or inaction by each person involved should be classified separately. This ensures that a database can provide an accurate account of the numbers and types of errors in any incident. For example, if a controller failed to use the words 'avoiding action', as would be appropriate, when issuing avoiding actions instructions to two separate pilots, this would be counted as two errors. Following are two examples (note the bold numbers shown in brackets denote the position of the errors in the error chain).

> Two minutes later the controller erroneously instructed the B757 pilot to descend to FL100 instead of FL120 **[1]**. He did not detect his error from the readback and annotated the FPS with FL120 **[2]**. *(UK AIRPROX C 13/95)*

> 'The term "avoiding action" was not used to either crew **[4, 5]**.' *(UK AIRPROX C 46/96)*

Due to the safeguards in ATM (checks, STCA, TCAS, etc), there will usually be more than one error in any given incident.

Table 3: HERA-JANUS incident analysis form

HERA-JANUS INCIDENT ANALYSIS FORM			
DETAILS OF INCIDENT			
Reference:		**Date & Time:**	
Country:			
Aircraft:		**Operators:**	
Geographical position:			
ALT/HT/FL:		**Airspace type:**	
Reporter:			
Reported separation:			
Recorded separation:			
HERA-JANUS Analyst:			
BRIEF DESCRIPTION OF INCIDENT			
****Please record the individual errors in the sequence in which they occurred****			
DESCRIPTION OF ERROR # 1			
How detected:			
How recovered:			

Causal		**Contributory**		**Compounding**		**Non-contributory**	

HERA-JANUS CLASSIFICATIONS	
Error / Rule breaking / Violation Type (ET):	
Error Detail (ED):	
Error Mechanism (EM):	
Information Processing (IP):	
Task:	
Information/Equipment:	
Contextual Condition (CC):	
Reporter's assumptions:	
Analyst's assumptions:	

NOTES
DESCRIPTION OF ERROR # 2

Figure 2 below illustrates a chain of errors.

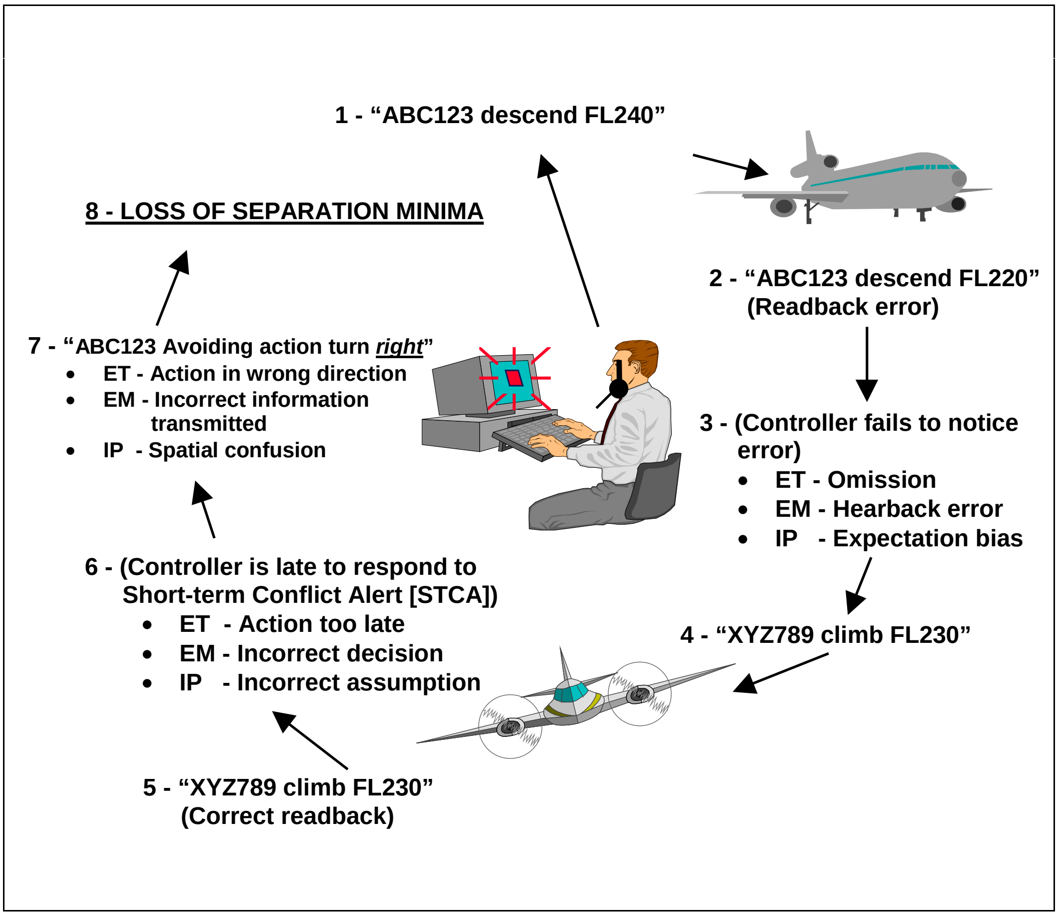

Figure 2: Example of an ATC incident with HERA-JANUS classifications

Error causality - types of error

The HERA-JANUS Incident Analysis Form shown as Table 3 contains four tick-boxes to denote the causality of each error. Below are the definitions for each category.

- **Causal error**: The ultimate cause of the incident, without which the incident would not have occurred.

> The B737 pilot read back, "Okay, when ready down to two two zero (FL220) and say the er fix".
>
> Also, the Bristol Sector controller did not detect the readback error, despite the transmission

- **Contributory error**: Errors that occurred in addition to the causal error(s) before loss of separation.

> After a routing instruction, the Bristol Sector controller cleared the B737 pilot to descend to FL240, but this was delivered in a distorted and somewhat rapid manner, with the level figure being indistinct.

- **Compounding error**: Errors that made the situation worse and that occurred after the controller realised that an incident was going to occur.

> The STCA triggered as the B737 was descending through FL256 and the Brasilia was climbing through FL209, at range 10nm. However, the Bristol Sector controller did not respond as he believed both aircraft would level off to maintain 1000 feet vertical separation.

- **Non-contributory error**: Other errors that occurred, but had no bearing on the incident (e.g. error due to panic on discovering the incident, but which did not make the situation worse).

3.3 Representation and Method of Use

The classification system was developed in two formats - a tabular format and a series of decision flowchart diagrams.

A tabular hierarchical format was used to represent the following:

- Errors,
- Task,
- Information and Equipment,
- Contextual Conditions (CCs) sub-categories.

This format allows for the quick identification of relatively clear categories.

A series of decision-flowchart diagrams were developed to enable the HERA-JANUS analyst to identify errors by answering a series of ‘Yes/No’ type questions. There are separate decision flow diagrams for:

- Error / Rule breaking / Violations,
- Error Detail (ED),
- Error Mechanism (EM) for each error detail,
- Information Processing levels (IPs) for each error detail,
- Contextual Conditions (CCs) main-categories.

The HERA-JANUS Technique is described in sub-section 3.4.

The analyst is guided through the analysis process by working systematically through the following formats:

1. Defining the error type.

2. Defining the error or rule breaking or violation behaviour through a flowchart.

3. Identifying the Error Detail through a flowchart.

4. Identifying the Error Mechanism and associated Information Processing failures through flowcharts.

5. Identifying the tasks from tables.

6. Identifying the Equipment and Information from tables.

7. Identifying all the Contextual Conditions through a flowchart and tables.

3.4 Error Tables and Flowcharts

3.4.1 Error Types (ETs) and definitions

Guidance for HERA-JANUS users

The Error Types and definitions can be found in Table 4. This describes how the action manifested itself externally. Note that:

- It may be difficult to decide what is the ‘right’ or wrong’ action. This should be determined from the incident investigation report which will have considered relevant procedures, expected actions and so on.

- An ‘object’ can be an aircraft on radar/TDB, a button or anything that the controller interacts with.

Table 4: Error Types (ETs) and definitions

Timing of action	***Examples***
The controller’s action was too fast	*The controller took over position too quickly after a break*
The controller’s action was too slow	*The OJTI spoke too slowly to the trainee*
The controller’s action was too early	*The controller transferred the aircraft too early*
The controller’s action was too late	*The supervisor waited too long to split the sectors*
The controller repeated the wrong	*The controller repeated a wrong data input*
The controller did the right action in the wrong order	*The controller arranged the aircraft strips in the wrong sequence*
Selection of action	
The controller forgot to	*The controller forgot to clear traffic to a higher FL*
The controller failed to	*The controller failed to separate two aircraft before transfer*
The controller gave too much / too little	*The controller instructed a greater speed control than was necessary*
The controller made the wrong action	*The controller dialled the wrong number into the communication panel*
The controller gave the wrong action to the right a/c	*The controller requested the correct aircraft to turn in the wrong direction*
The controller gave the wrong action to the wrong a/c	*The controller requested the wrong aircraft to turn in the wrong direction*
The controller gave the right action to the wrong a/c	*The controller requested the correct descent from the wrong aircraft*
The controller gave an unnecessary action	*The controller re-cleared an aircraft although there was no conflict*
Information transfer	
The controller transmitted/sent unclear, muffled or indistinct	*The controller gave a pushback clearance very unclearly*
The controller wrote/typed unclear, obscure or indistinct	*The controller wrote/typed the FPS amendment indistinctly*
The controller received unclear, muffled or indistinct	*The controller received a request from a foreign pilot which was not clear*
The controller failed to get the required	*The controller failed to get the readback from the pilot*
The controller failed to transmit/send the	*The controller did not transmit/send the airport information*
The controller failed to write/type the	*The controller failed to write/type the FPS amendment*
The controller transmitted/sent partial/incomplete	*The controller sent incomplete information regarding the latest NOTAMS*
The controller wrote/typed partial/incomplete	*The controller wrote/typed incomplete information regarding the weather*
The controller transmitted/sent incorrect	*The controller sent incorrect information regarding the taxiway closure*
The controller wrote/typed incorrect	*The controller prepared the FPS incorrectly*

3.4.2 Error / Rule breaking and Violation

Guidance for HERA-JANUS users

An analyst may need to know more clearly about the motivation behind some of the actions, or non-action, in an incident sequence. Typically, these rule breaking and violation behaviours can only be analysed to a certain behavioural level, if they do not include genuine cognitive failures.

Figure 3 illustrates how an analyst would identify an error which may be classified as rule breaking or violation behaviour.

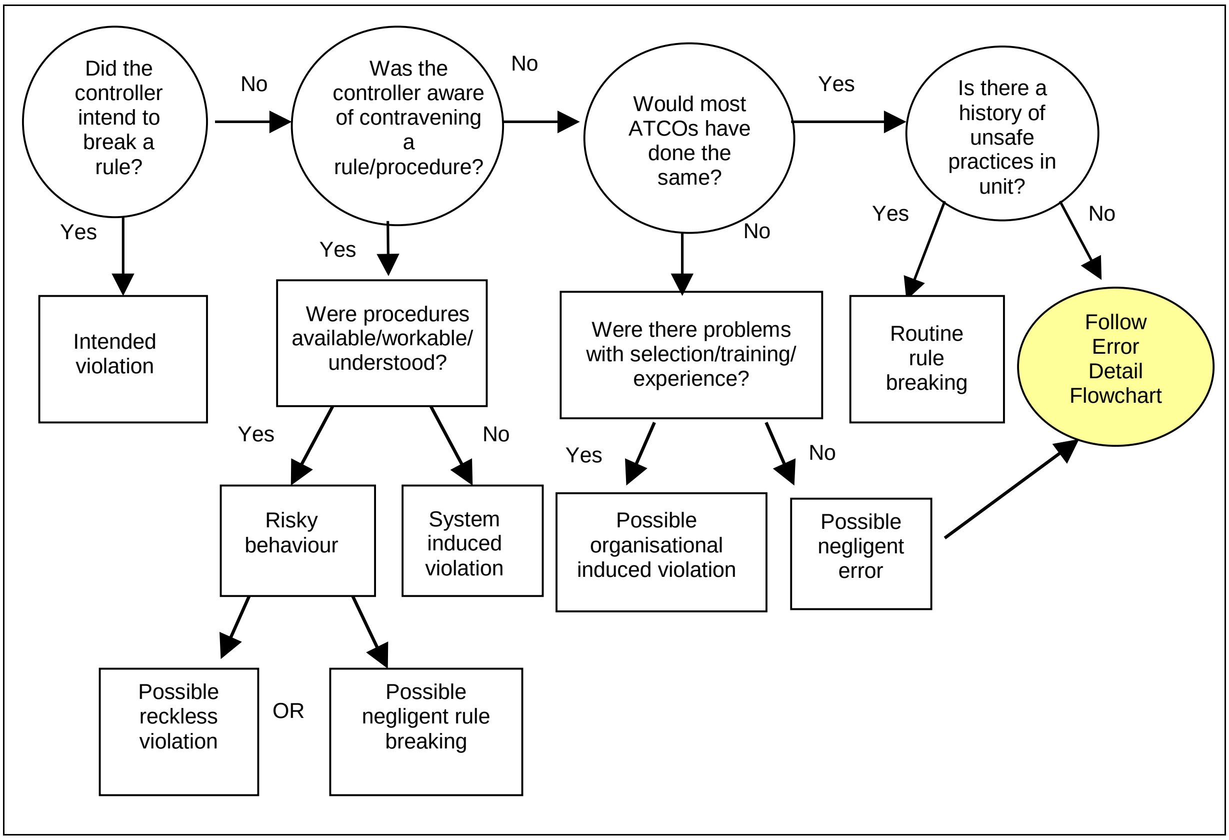

Figure 3: Rule breaking and violations

3.4.3 Error Detail, Error Mechanisms, Information Processing Levels

Guidance for HERA-JANUS users

The Error Detail (ED), Error Mechanisms (EMs) and Information Processing levels (IPs) describe the error from a psychological perspective.

There are four ED domains covering all the information processing activities.

These are:

– perception and vigilance,
– memory – working and long-term,
– planning and decision-making,
– response execution.

First, the EDs classify the error at a gross level (e.g. error of ‘working memory’ or ‘response execution’) and direct the user to a subset of errors within the relevant ED domain - the Error Mechanisms (EMs).

Error Mechanisms (EMs) describe the internal manifestation of the ED (e.g. misidentification, late detection, misjudgement).

The HERA-JANUS analyst then has to identify the psychological cause of the EMs involved in the error. The IPs within the ED (‘perception and vigilance’) include ‘expectation bias’ (i.e. seeing or hearing what one expects to hear), ‘information confusion’ (i.e. confusing two things that look or sound alike), and ‘distraction/preoccupation’ (i.e. temporary interruption by an external event or more prolonged loss of concentration due to internal thoughts).

Error Mechanisms (EMs) provide an interface between the errors and the Information Processing level (IPs), and thus give an intermediate level of detail. The Error Mechanisms are usually obtainable from incident reports and bring the analyst closer to error reduction measures than the errors alone.

HERA-JANUS’ internal structure of ETs, EMs and IPs therefore allows the analyst or incident investigator to classify errors at three levels of detail. There should almost always be sufficient information to classify the ET, and usually there will be enough information to classify the EMs. IPs add value to the analysis, but are the most difficult ‘level’ to classify, because there is sometimes insufficient information to determine them.

Note that each decision flow diagram starts at a different Error Detail (ED) domain. This allows the analyst to start at the applicable ED and makes the technique more resource-efficient. If the HERA-JANUS analyst is not confident of the applicable ED domain, it may be advisable to begin at ‘perception and vigilance’ and follow the decision flow diagrams through until the correct ED domain is found. In summary, the decision flow diagrams allow the analyst to begin at any ED domain. Also, the format allows the analyst to skip ED domains where they are confident that the error did not occur within that area, or where the analyst is directed to ‘jump’ to another ED domain.

Figure 4 indicates the Error Detail (ED) domains.

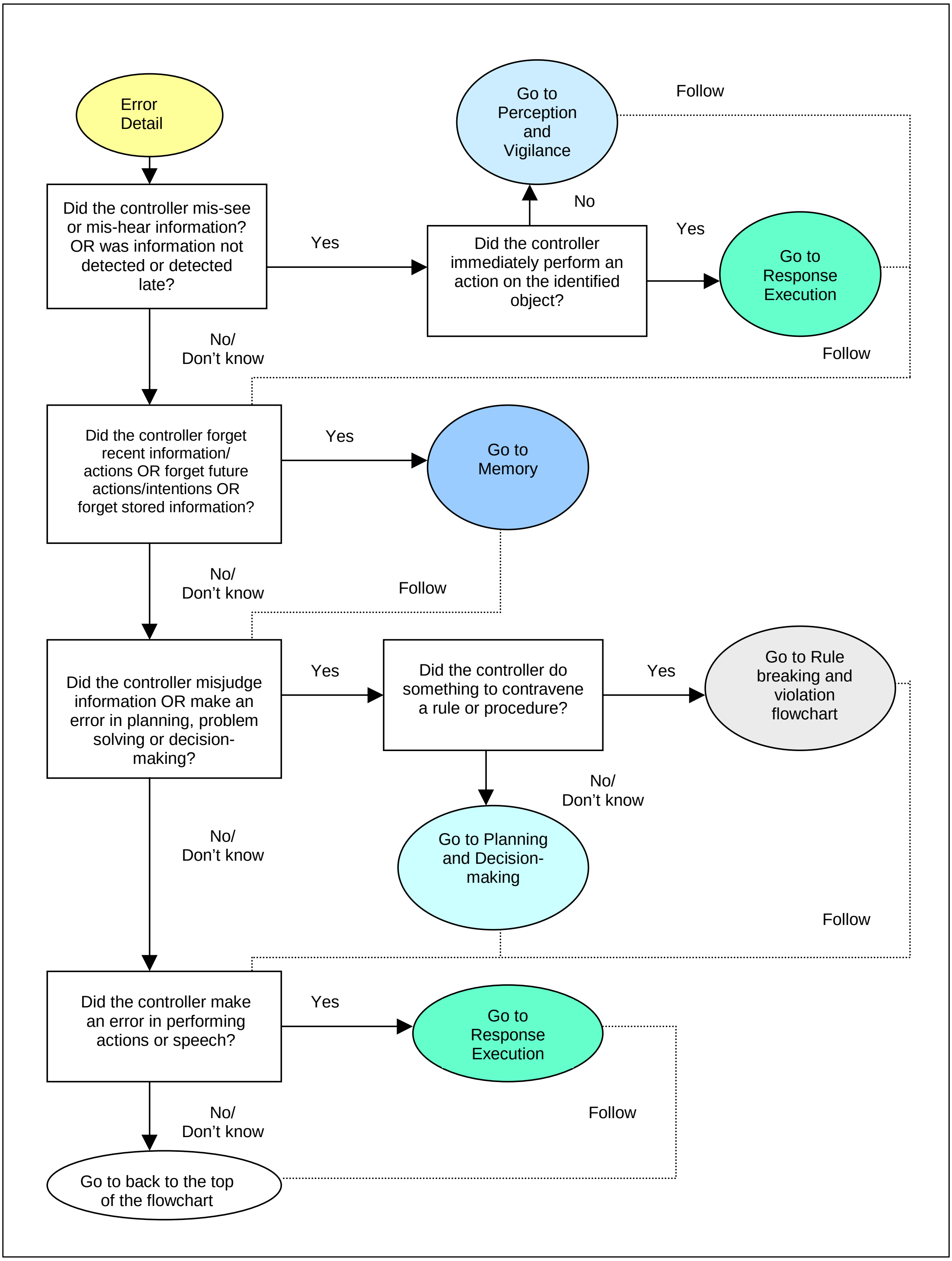

Figure 4: Error Detail (ED) domains

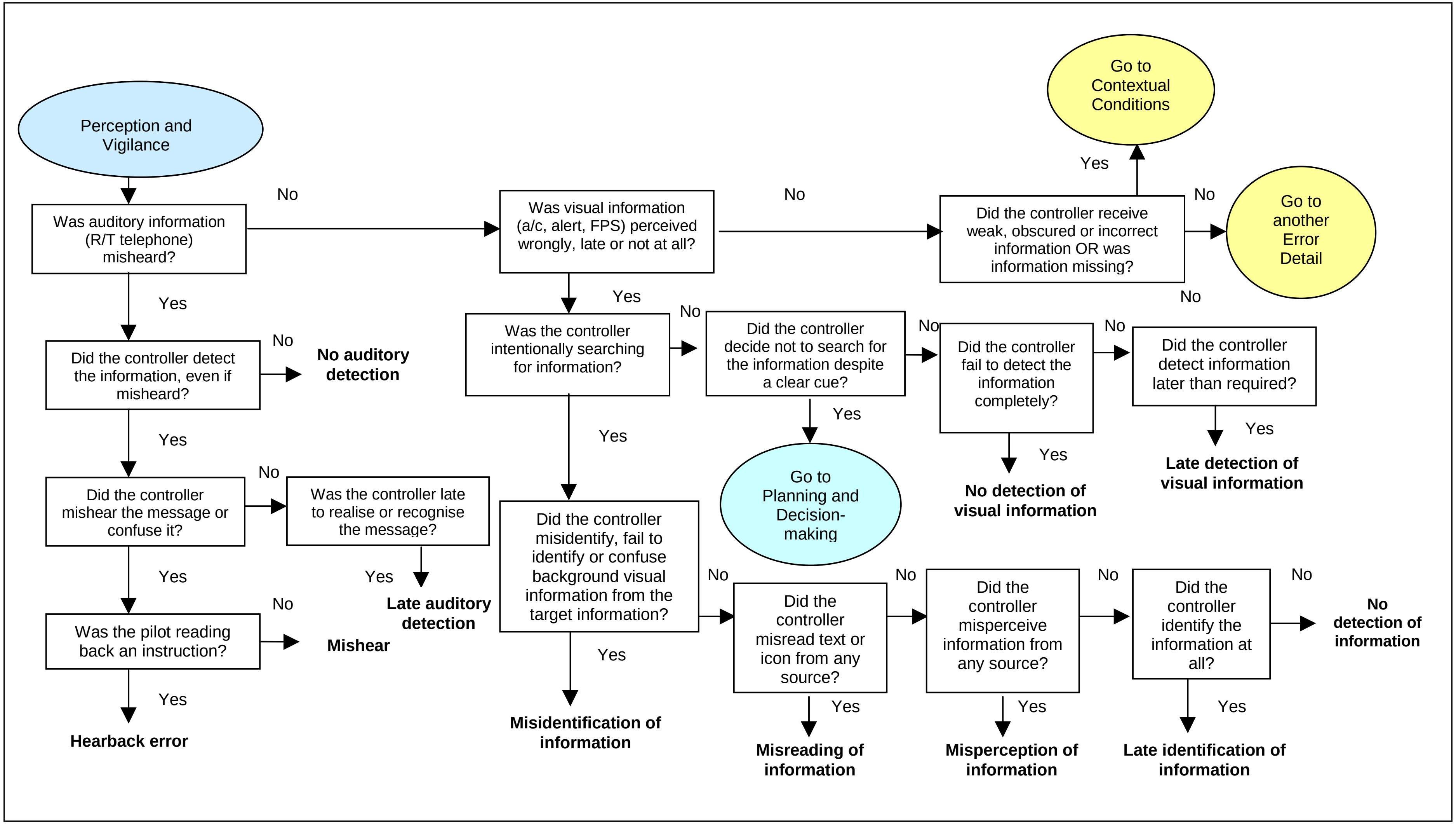

Figure 5: Perception and Vigilance (Error Mechanisms - EMs)

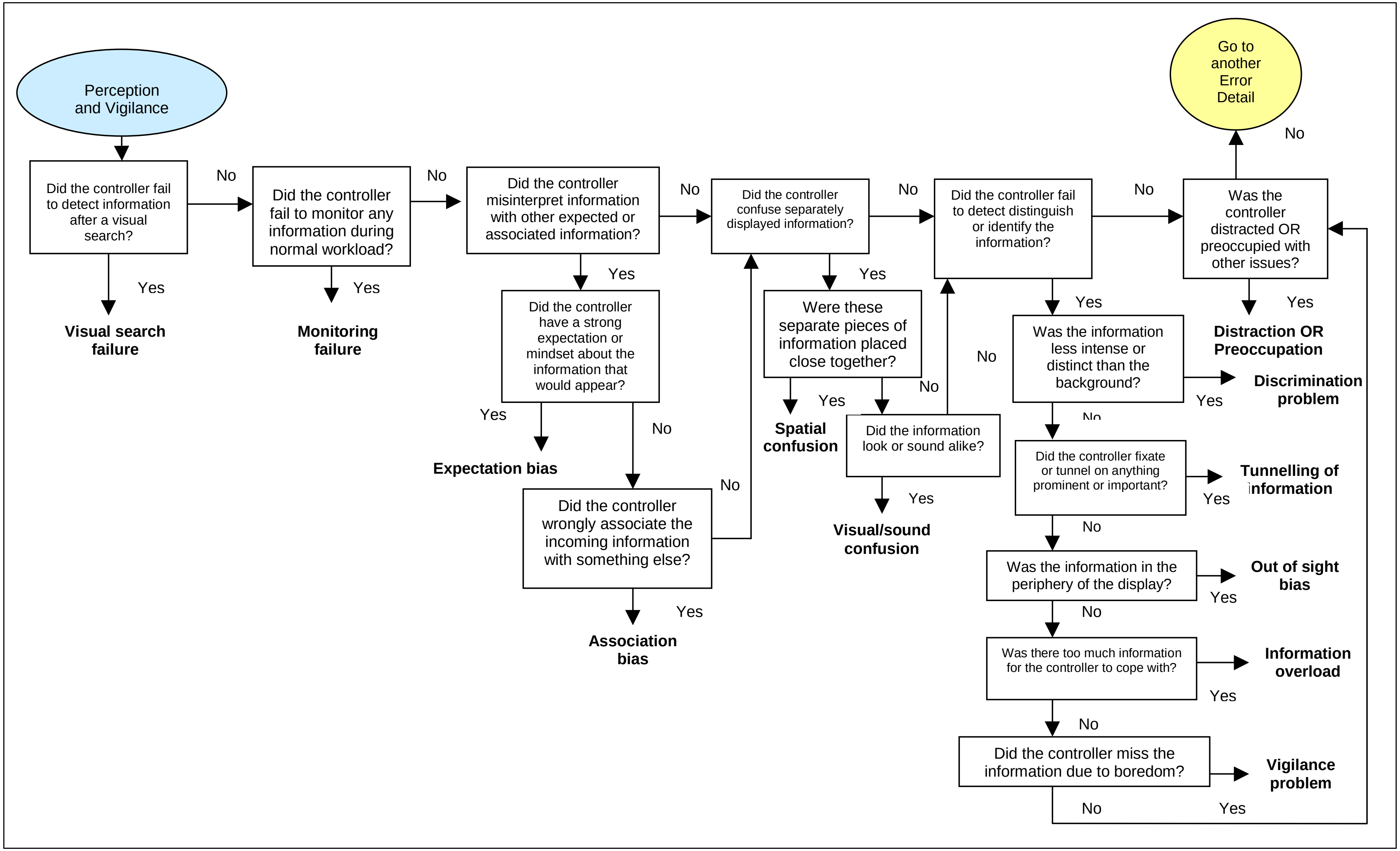

Figure 6: Perception and Vigilance (Information Processing levels - IPs)

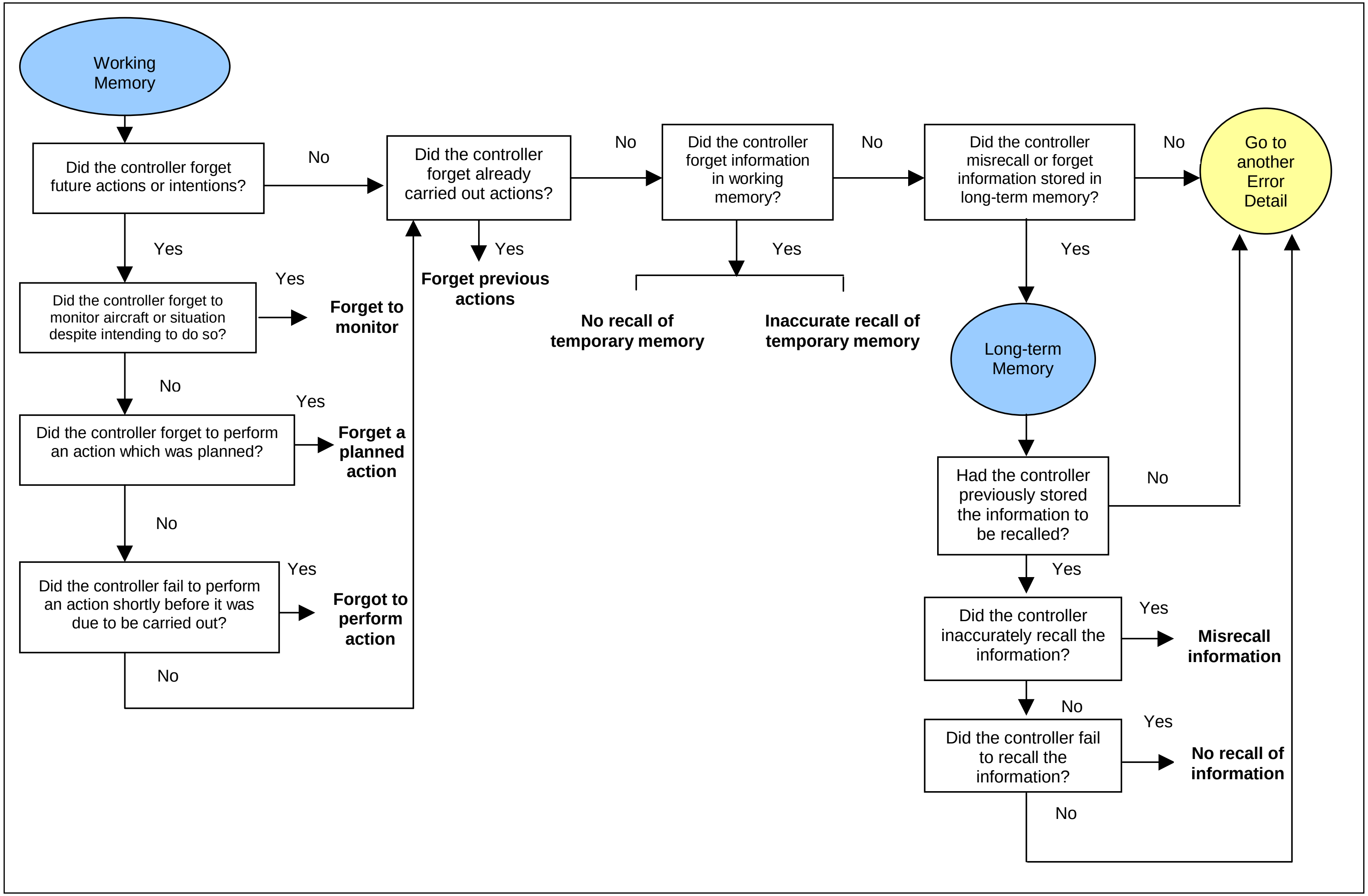

Figure 7: Memory (Error Mechanisms - EMs)

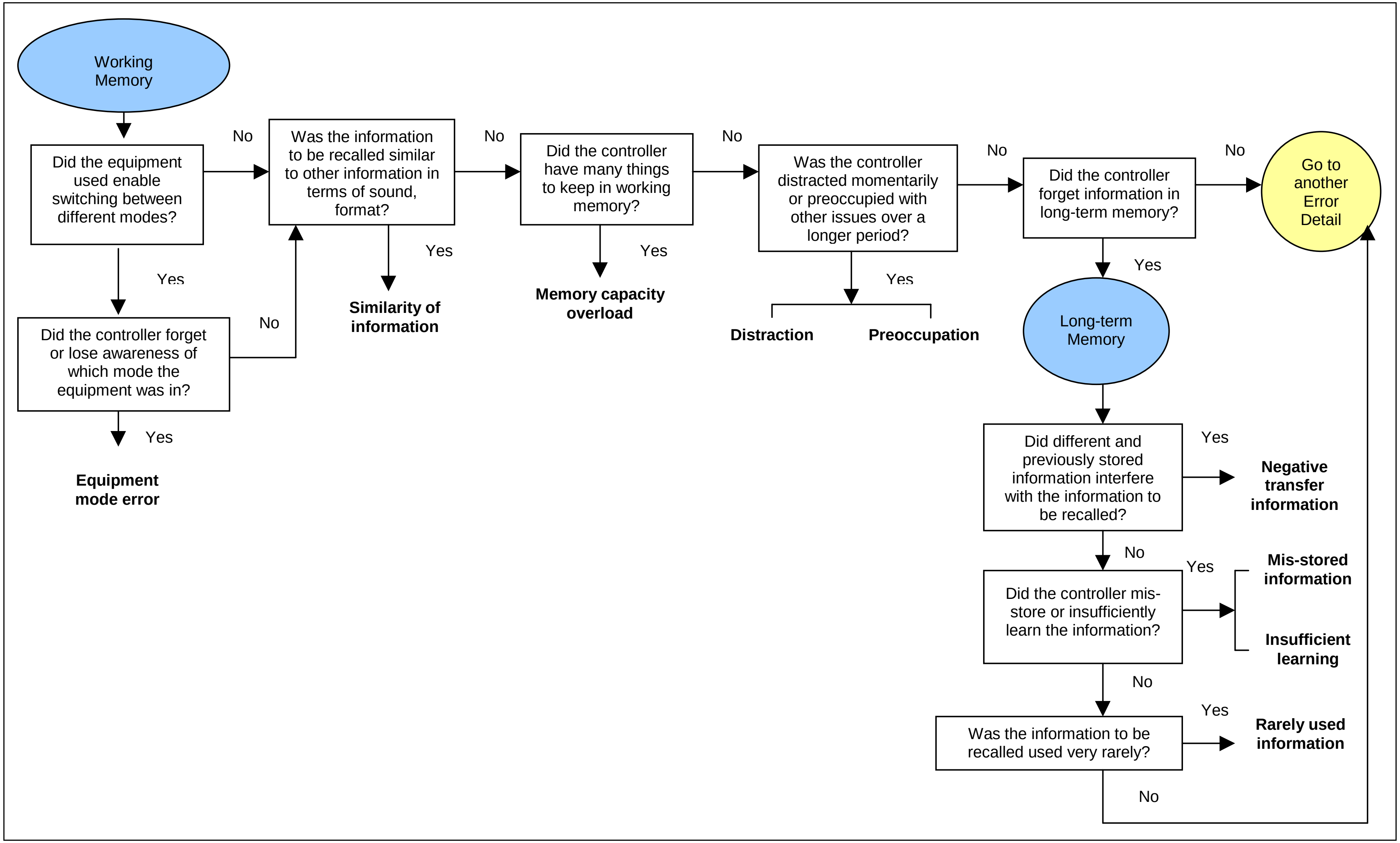

Figure 8: Memory (Information Processing levels - IPs)

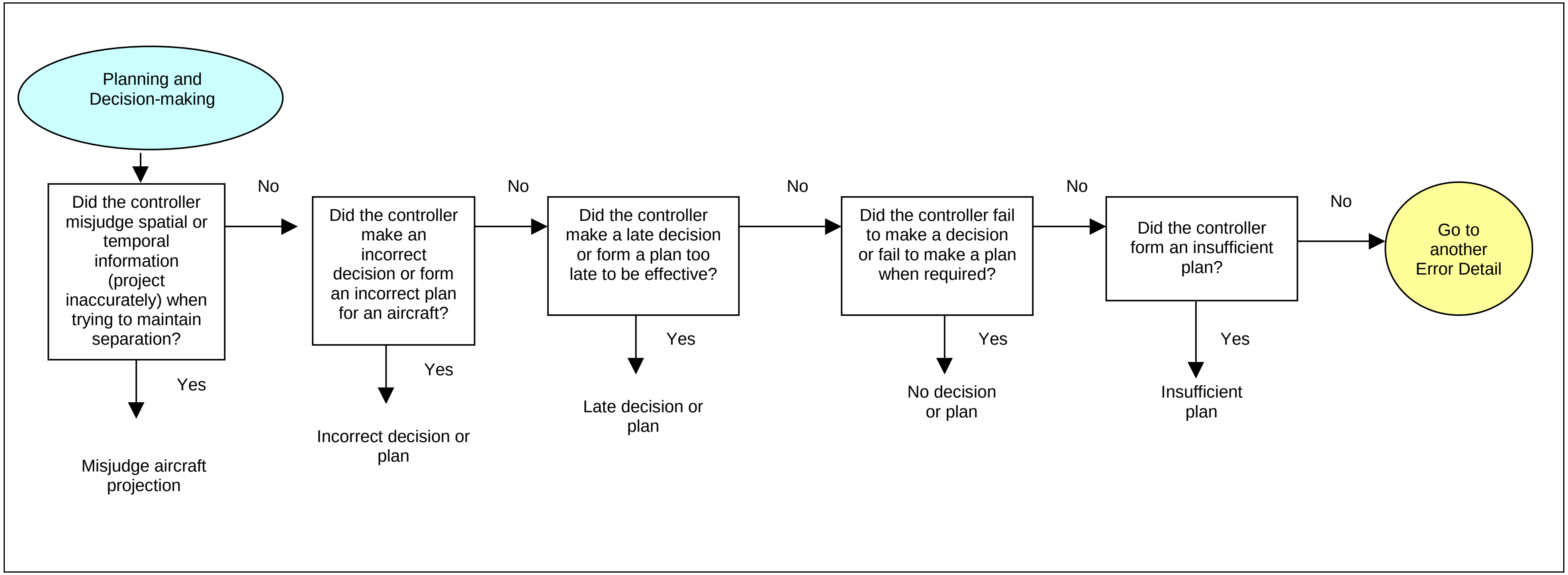

Figure 9: Planning and Decision-making (Error Mechanisms - EMs)

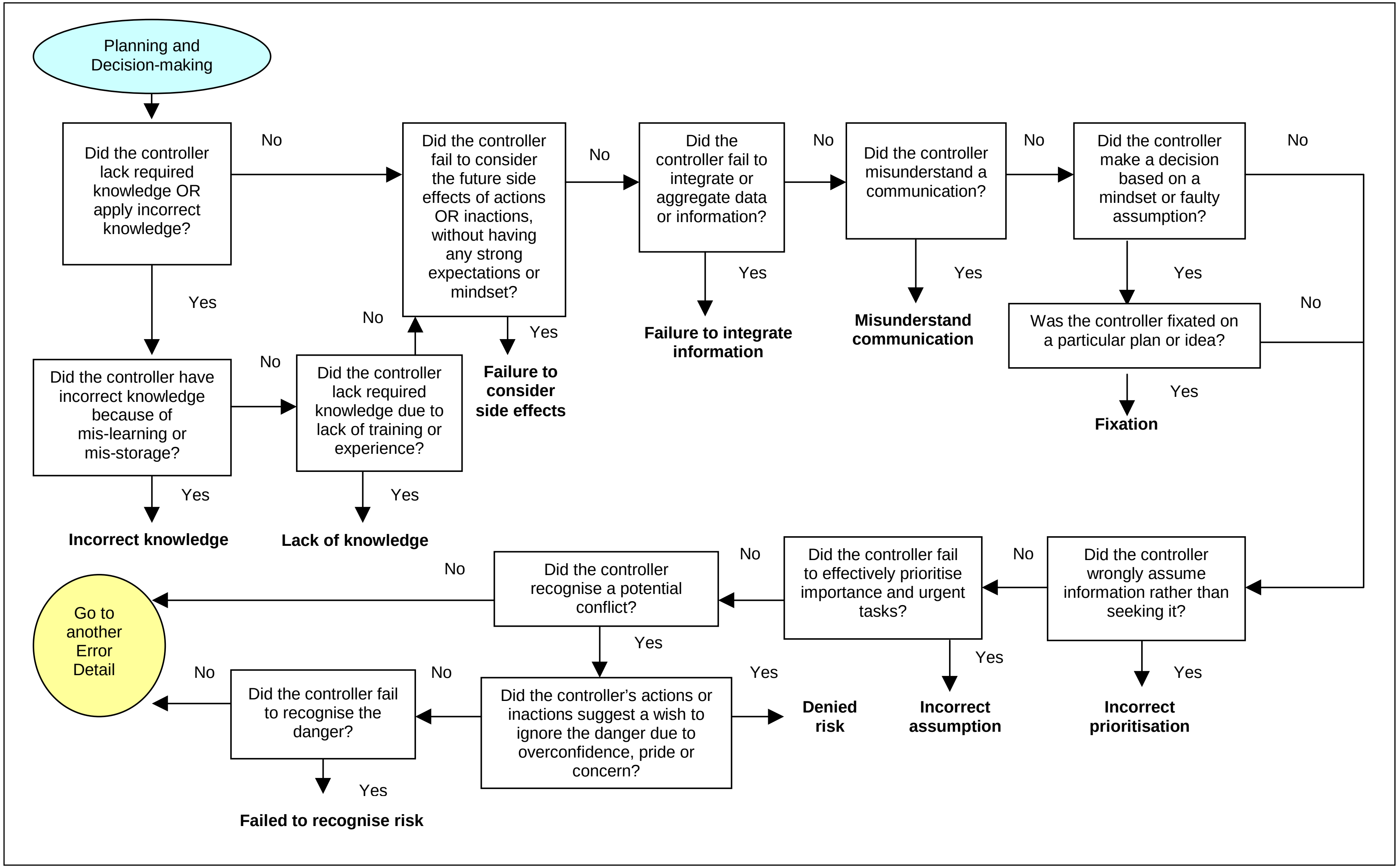

Figure 10: Planning and Decision-making (Information Processing levels - IPs)

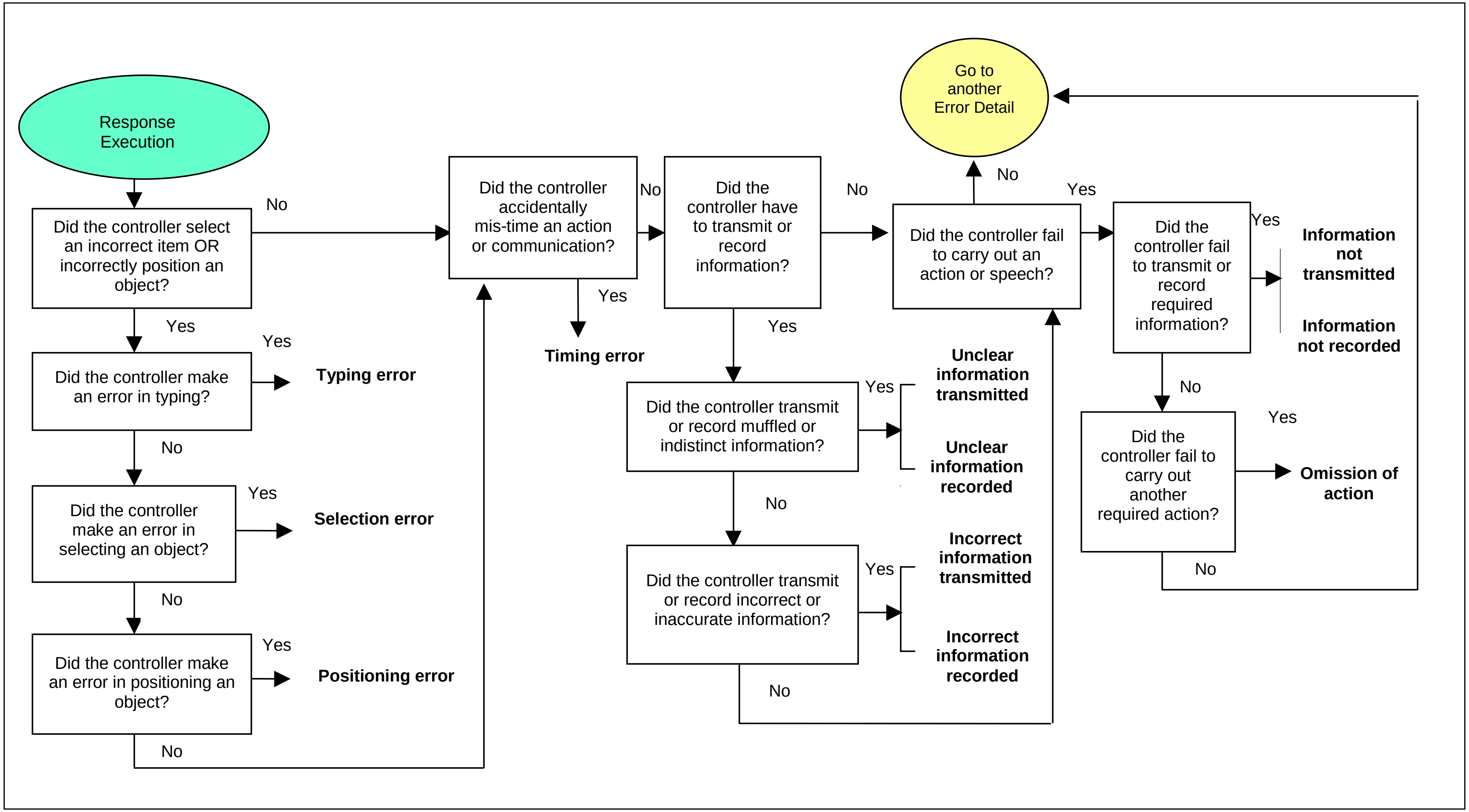

Figure 11: Response Execution (Error Mechanisms – EMs)

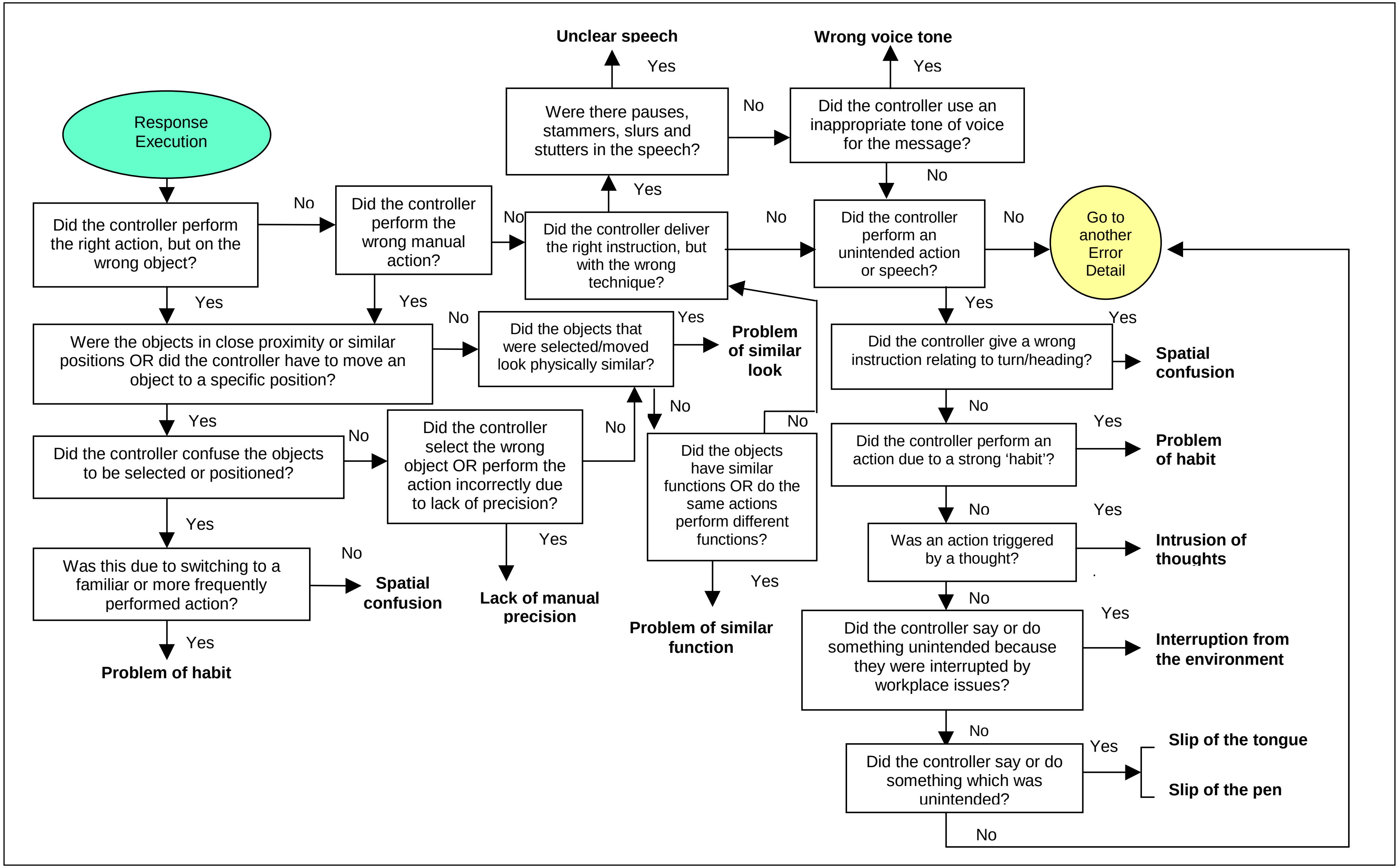

Figure 12: Response Execution (Information Processing levels - IPs)

3.4.4 Task Table

Guidance for HERA-JANUS users

In Table 5 the task table is used to classify the task that was performed incorrectly, or omitted. Note that:

- the controller(s) may have been performing more than one task – all of the tasks that the controller was performing at the time that the error occurred should be recorded;
- the category and, if appropriate, the sub-category, should be recorded (e.g. 'coordination – within sector').

Table 5: Task Taxonomy

TASK	DEFINITION
Coordination: ▪ within sector, ▪ between sector/position same facility, ▪ between sector/position different facility.	Working with (either verbally or sign) other controllers in the same or adjacent ATC units or centres to request and/or transfer traffic
Tower observation	Visually gathering information regarding traffic and/or weather
Planning	Thinking activity
R/T communications and instruction: ▪ instruction/clearance, ▪ acknowledgement, ▪ readback, ▪ advisory remark, ▪ request, ▪ courtesy, ▪ other / non-codable remarks.	Any verbal communication between pilots and controllers. (This may include a press of the transmitter as acknowledgement.)
Control room communications: ▪ within sector, ▪ between sector / same facility.	Exchanging (either verbally or by sign) information with other controllers in the same control room (excludes coordination)
Strip work: ▪ preparation, ▪ marking, ▪ handling, ▪ checking, ▪ handling.	Any activity which involves the use of paper/electronic flight progress strips and their holders

TASK	DEFINITION
Materials checking	Actively seeking or confirming information from documentation
Radar monitoring	Actively searching, checking or confirming information from radar
HMI input and functions	Any activity involving the inputting of information to, or interaction with, the available equipment
Handover briefing	Activity undertaken by the off-going controller with the aim of increasing the awareness and understanding of the ongoing controller with respect to the traffic situation. This may include pointing out information from the radar display, flight progress strips or documentation
Takeover	Activity undertaken by the relief controller in order to increase awareness and understand the traffic situation, including the gathering of information from the radar display, flight progress strips, documentation or other personnel
Training	Any activity in which the controller is under training or is providing training (mentoring)
Supervision	Any activity in which a designated supervisor(s) is working closely with the controller
Check / Examination	Any activity which is designated to be undertaken in a check or examination situation

3.4.5 Information and Equipment Table

Guidance for HERA-JANUS users

This table allows the HERA-JANUS analyst to record the specific information (or topic) which was the subject of the error (i.e. What did the controller misperceive, forget, misjudge, mis-communicate, etc.?) The categories can be found in Table 6.

One or more of the keywords below may be selected.

Table 6: Information and Equipment

INFORMATION & EQUIPMENT
ATC ACTIVITIES AND AIRCRAFT INFORMATION ***(includes detecting, searching, recognising, remembering, judging, deciding, instructing, etc.)***
Controller materials
Procedures
Briefing material
Flight Progress Strip (FPS)
Track Data Block (TDB)
Conflict alert
Restricted areas (weather, military, etc.)
ATS equipment – State
Controller activities
Aircraft sighting (tower)
Aircraft recognition (tower)
Point out
Handover
Separation
Transfer
Coordination
Type of air traffic service
Variable aircraft information
Climb
Descent
Flight Level (FL)
Altitude
Route
Heading
Direction of turn
Speed (incl. speed control)
Aircraft performance
Clearance
Frequency
Holding
Special instructions
Avoiding action
Emergency
Conversational R/T

Fixed aircraft information
Aircraft
Airline
Call sign
Aircraft type
Type of traffic
QNH/QFE (altimeter pressure settings)
TCAS
Other
(please specify)
AIRSPACE AND OTHER KEYWORDS
Time and location
Time
Distance
Geographical position
Airspace type
Airspace restrictions
Destination
Sector
Conflict
Weather
Airport
Airport
Airport monitoring and control equipment
Tower
Runway
Ground vehicles
Terrain
Personnel
Flight rules
Instrument Flight Rules (IFR)
Visual Flight Rules (VFR)
Other
(please specify)
EQUIPMENT*
Communication
Radiotelephone (R/T)
Telephone
Aeronautical Fixed Telecommunication Network (AFTN)
Datalink

Communication *(cont'd)*
Loudspeaker
Light signalling equipment
Other (please specify)
Navigation
Very high frequency Omni-directional Radio range (VOR)
Non-directional Beacon (NDB)
Distance Measuring Equipment (DME)
Global Navigation Satellite System (GNSS)
Other (please specify)
Surveillance
Primary radar
Secondary radar
Aircraft position display
Precision approach radar
Ground movement radar
Aerodrome surface movement indicator
Other (please specify)
Visual approach aids
Aerodrome equipment warning panels
Aerodrome auxiliary equipment controls
Flight information displays
Paper
Electronic
Other (please specify)
Input devices
Touch
Pad
Keyboard
Mouse
Rollerball
Other (please specify)
Other information displays
Auxiliary displays (runway details, weather)
Maps / charts / checklists
Notices
Other (please specify)

* Possible future tools/equipment can be added.

3.4.6 Contextual Conditions

Guidance for HERA-JANUS users

The Contextual Conditions (CCs) taxonomy allows the HERA-JANUS analyst to classify factors, internal or external to the controller, which influenced the controller's performance and 'provoked' the error. The taxonomy is represented first as a decision flow diagram to help the HERA-JANUS analyst to find the relevant main-categories of CCs. The HERA-JANUS analyst is then directed to the corresponding part of the CCs table, which lists the individual CCs (see Table 7). Note that:

- There may be more than one CC for an error.
- A CC may have provoked only one error within an incident, or more than one error. CC should therefore be recorded for **each** error that they influenced.
- CC should not be used to simply re-describe an error. Instead, they must have influenced the *occurrence* of that error. So, for example, a CC for poor communication ***pilot-controller communications*** should not be used to simply re-describe a communication error. However, if *prior* poor communication influenced the occurrence of a further error, then the CC should be used for that error.
- The actual CC type and identifier should be recorded. These can be found in the CC table, e.g. ***pilot-controller communications*** **- pilot language difficulties.**

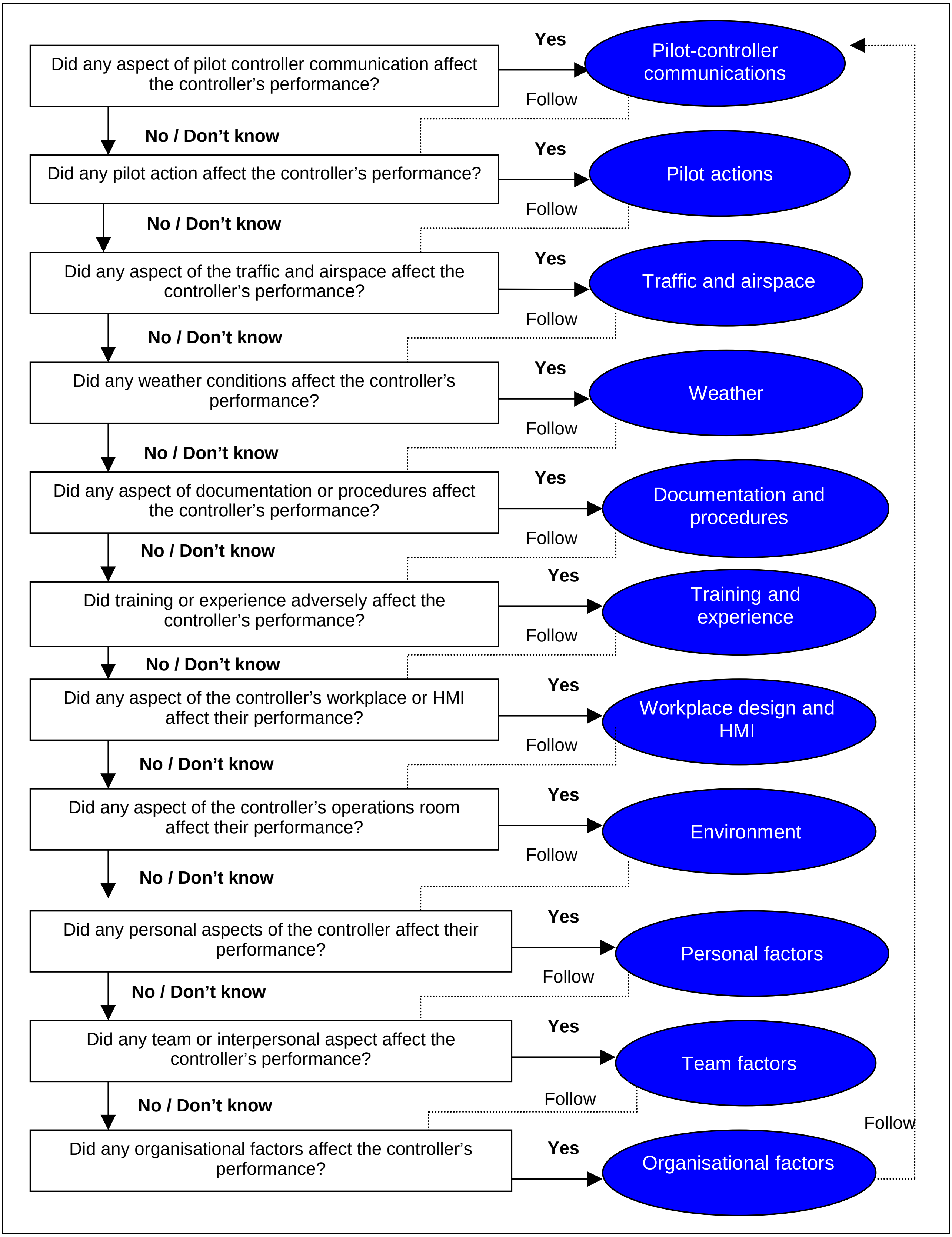

Figure 13: Contextual Conditions (CCs)

Table 7: Contextual Conditions (CCs)

CONTEXTUAL CONDITIONS (CCs)
Pilot-controller communications
Pilot language / accent difficulties
Similar confusable call signs
Pilot readback incorrect
Pilot experience
Situation not conveyed by pilots – urgency/party-line support
Pilot breach of R/T standards/phraseology
ATC breach of R/T standards/phraseology
Speech tone
Speech rate
Complexity of ATC transmission
Pilot high/excessive R/T workload
ATC high/excessive R/T workload
A/C struck transmitter
R/T interference
R/T cross-transmission
R/T blocked frequency
Other – State
Pilot actions
Responding to TCAS alert
Response time to ATC instructions
Correct pilot readback followed by incorrect action
Rate of turn
Rate of climb/descent
Speed changes
A/C navigational limitations not considered by pilot
Other – State
Traffic and airspace
Sector capacity limitations
Excessive traffic load
Complex traffic mix
Fluctuating traffic load with unexpected demands – off-route traffic
Holding patterns
Aircraft with similar/confusable call signs
Underload
Post peak traffic
Unusual situation – emergency or high risk
Flight in non-controlled and controlled airspace
IFR/VFR mix

CONTEXTUAL CONDITIONS (CCs)	
Traffic and airspace (cont'd)	
Flight in transitional airspace	
Airspace design characteristics - complexity, changes	
Traffic management initiatives - military, medical, parachuting, student pilot, State flight.	
Other – State:	
Weather	
TYPE	*CONSEQUENCE*
Snow / ice / slush	Taxi difficulties
Fog / low cloud	Vectoring problems/abilities
Thunderstorm	Route deviation
Extreme winds at high altitude	Difficulty tracking aircraft/vehicles
Extreme surface winds	Holding patterns
Down draft / windshear	Other – State:
Other – State:	
Documentation and procedures	
TYPE	*PROBLEM*
Orders	Unclear
Charts/notices	Contradictory
Temporary notices	Ambiguous
Advisory manuals/circulars	Incorrect
Checklists	Incomplete
Automated References	Inaccurate
Special information (NOTAMS, SIGMETS)	Too complex
	New/recent changes
Arrival	In revision
Landing	Outdated
Special arrival procedures	Not available
Landing and hold short	Unclear
Clearing runway	Contradictory
Simultaneous use of same runway	Ambiguous
Crossing runway	Incorrect
Taxi for position and hold	Incomplete
Departure	Inaccurate
Wake turbulence	Too complex
Visual separation	New/recent changes
En-route	In revision
Oceanic	Outdated
Noise abatement	Not available
Other – State:	Other – State:

CONTEXTUAL CONDITIONS (CCs)
Training and experience
Inadequate knowledge for position
Inadequate experience on position
Inadequate time on position
Unfamiliar task in routine operations
Novel situation
Over training
Inadequate mentoring
Inadequate On-the-Job Training (OJT)
Inadequate emergency training
Inadequate Team Resource Management (TRM) training
Inadequate recurrent/continuation training
Controller under training
Controller under examination/check
Other – State:

Workplace design and HMI	
TYPE	*PROBLEM*
Working position/console, i.e. HMI Surveillance, i.e. radar Communication, i.e. radio Navigation, i.e. approach aids Flight information display, i.e. Flight Progress Strips (FPS) / display Auxiliary equipment, i.e. generators Other Information display, i.e. weather Equipment warning devices, i.e. alarms and alerts Other – State:	Conflicting information Failed or broken equipment False information Feedback problem High false alarm rate Illegible information Inaccessible information Incorrect information Interference Lack of equipment/information Lack of coverage/range Lack of precision Lost information Mode confusion No equipment/information Nuisance information Poor design Poor display Poor positioning Recently introduced equipment/ information Equipment size problem Suppressed information Unavailable equipment/information Unclear equipment/information Unreliable equipment/information Untrustworthy equipment/information Visibility of equipment/information Other – State:

CONTEXTUAL CONDITIONS (CCs)
Environment
Noise from people – supervisors/colleagues/maintenance/visitors
Noise from equipment
Distraction - job related
Distraction - non-job related
Air quality - temperature/humidity
Lighting problems - illumination/glare
Pollution/fumes
Asbestos
Radiation
Other – State:
Personal factors
Distracted by personal thoughts
Incapacitation – illness/collapse
General health and fitness – nutrition/hydration/exercise
Impairment – alcohol/medication/drugs
Fatigue - tiredness
Fatigue - sleep loss
Fatigue - sleep deprivation
Pain
Abnormal stress symptoms - post incident/training/checking
High anxiety/panic
Domestic/lifestyle problems
Emotional stressors
Boredom
Complacency
Confidence in self
Trust in automation
Motivation/Morale
Other – State:
Team factors
Controllers on the floor assisting one another with the traffic
Currency and availability of all necessary equipment
Position relief briefing
Cooperative effort to accommodate the flow of traffic
Team relations – conflicts / personality problems
Late returns to the position after breaks
Positions left temporarily unstaffed
New or temporary team assignments
Lack of responsibility
Unclear working methods
Confidence in others
Team pressures

CONTEXTUAL CONDITIONS (CCs)
Team factors (cont'd)
Cooperation from supervisors from other areas in traffic flow initiatives
Support from others - flight data / maintenance
Management provision of resources and assistance as dictated by the traffic needs
Support from other units
Staffing for the traffic requirements
Confidence in supervisor's ability to manage the air traffic activity
Supervisory cooperation to manage the traffic during this shift
Management cooperation to assist and support the sectors/positions/ areas/facilities
Higher management cooperation to assist and support the sectors/positions/areas/facilities
Other – State:
Organisational factors
Work environment
Safety versus efficiency – for yourself / organisation
Numbers of qualified controllers
Job satisfaction
Roster/rest duty times
Work scheduling
Adherence to rules by ATCOs
Adherence to rules by supervisors
Terms and conditions of work
Supervisory decisions in staffing and facilities
Management decisions in staffing and facilities
Supervisory decisions in safety and efficiency policies
Management decisions in safety and efficiency policies
Other – State:

4. THE PRACTICAL APPLICATIONS OF THE HERA-JANUS TECHNIQUE

4.1 Introduction

Traditionally, the investigation of incidents and accidents in high-risk industries, such as ATM, has focussed on the manifestations of the errors, which equate to the Error Types (ETs) in the HERA-JANUS classification scheme. However, this level of investigation rarely helps those in the profession to learn from such errors. There are, in almost all cases, many contributing and underlying causes for such errors and it is this factor which demands a more 'in-depth' approach.

Figure 14 shows the spheres of influence of ETs, EMs, IPs and CCs.

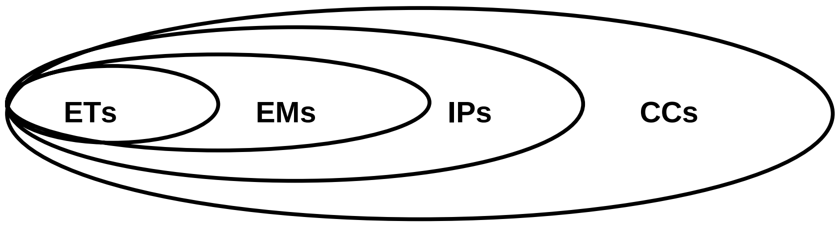

Figure 14: Spheres of influence of ETs, EMs, IPs and CCs

If we use the example given in Figure 14, it is clear that the focus of a traditional incident investigation would list as, for instance, ‘coordination not performed’, or ‘inadequate handover’, or something equivalent to the Error Type (ET) 'action omitted’, and perhaps stop at this level of detail. However, this does not give us any indication of how and why the omission occurred. In order to understand better the answers to these questions, the ET must be viewed within several spheres of influence.

Firstly, the Error Mechanism (EM) can be classified using HERA-JANUS by assigning the cognitive function which failed. In the example it was listed as *'late visual detection'.*

Secondly, the Information Processing level (IP) can be examined to elicit how the error occurred from a cognitive performance standpoint. From the information found in the example the error can be categorised as a problem of *'perceptual tunnelling'*.

Finally, to know the context in which the error occurred is essential and invaluable, particularly when these circumstances can be managed to prevent further errors. Other factors that contributed to the incident are known as

Contextual Conditions (CCs), e.g. *'other conflict on radar'.* Figure 15 illustrates the relationship between the HERA-JANUS taxonomies.

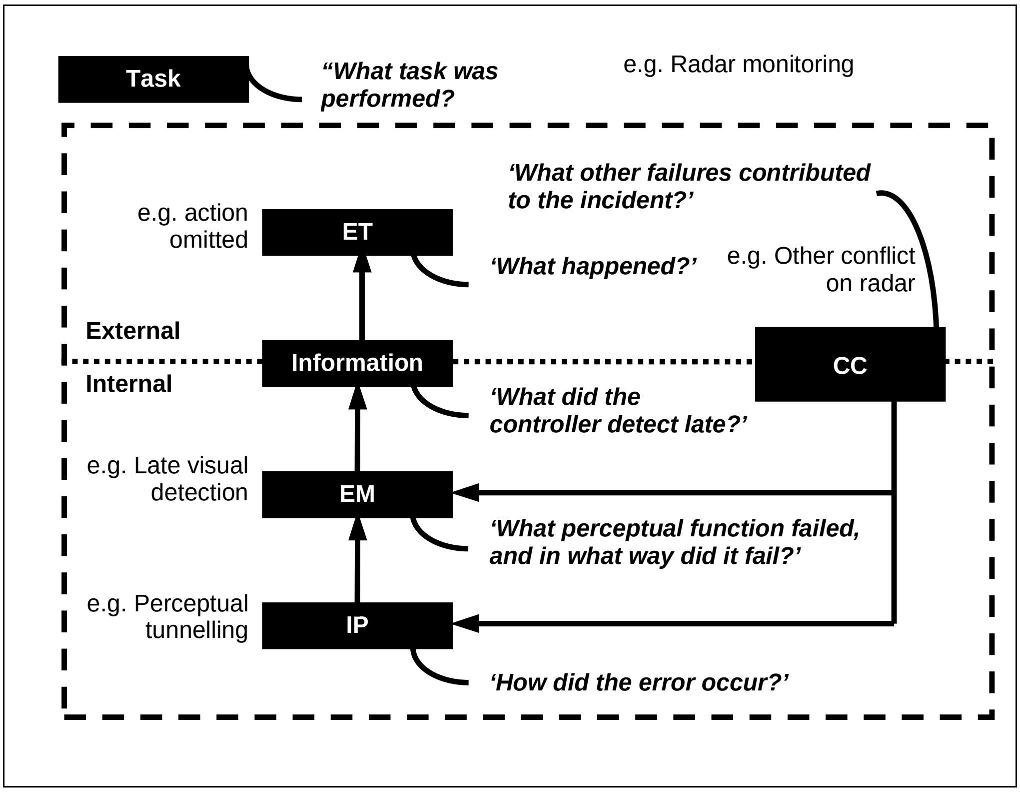

Figure 15: The relationship between error types within HERA-JANUS

4.2 Examples Using the HERA-JANUS Technique

The HERA-JANUS Technique was used in several incident analysis activities with occurrences from the UK, Sweden and other European and non-European countries.

4.2.1 Incident analysis

UK incident analysis

Twenty-five UK AIRPROX incidents were analysed using HERA-JANUS. Examples of the analysed incidents are shown in the Appendix. These incidents occurred during 1995-1996 and involved aircraft that were receiving a control service from London Area and Terminal Control Centre (LATCC), by various Area and Terminal Control Sectors (Civil Aviation Authority, 1996, 1997a & b, and 1998). The incidents implicated LATCC Air Traffic Service Personnel in the reported causal factors (i.e. reports that implicated only aircrews in the causal factors were omitted from the analysis).

The analysis captured all of the information shown on the HERA-JANUS incident Analysis form (Table 3). The HERA-JANUS Error Details Error Mechanisms and Information Processing levels which were used in the classification of events, are shown in Tables 8 and 9. Approximately 50% of errors, for which the error detail domain could be ascertained, fell into 'planning and decision-making' errors. The majority of these errors could be classed as 'incorrect decision'

Errors of 'misjudgement/misprojection' (i.e. incorrectly projecting spatial and temporal information, such as headings and flight levels) were relatively infrequent. Although such errors do occur it is likely that they are detected and recovered before they contribute to an incident.

The second largest category of errors was associated with perception and vigilance errors (approximately 35%). Hearback errors were the most common EM. Hearback errors could frequently be attributed to the IP 'expectation bias', where a strong expectation leads the controller to believe that the pilot has given a correct readback. Hearback errors were also sometimes associated with 'distraction'. The second largest category of errors was 'no detection (visual)', often due to 'distraction', 'stimulus overload' or general 'monitoring failure'.

Errors of response execution were less frequent, but all involved the controller transmitting incorrect or unclear information (e.g. incorrect FL), often due to a 'slip of the tongue'. Working memory errors included 'prospective memory failure' (forgetting to carry out planned actions or forgetting to monitor aircraft) and forgetting about the presence of aircraft.

Swedish incident analysis

Twenty incident reports from Swedish incident records were analysed using HERA-JANUS and entered into the HERA-JANUS incident analysis forms. The cases analysed occurred over a period of ten years from 1988 to 1998 from various functional control areas in Swedish airspace. By analysing incidents from a large time span it was the goal to ensure that HERA-JANUS was applicable to both 'new' and 'old' incidents. All of the analysed incident cases implicated one or several errors of air traffic controllers that had a causal effect on the course of events.

The distribution of Error Mechanisms (EMs) within the analysed Swedish reports was, in general terms, in good concordance with the UK and 'other' reports. A large majority (70%) of the identified errors involved 'planning and decision-making' and in this domain the errors in particular involved 'incorrect decision or plan' (EM) and 'incorrect assumption' (IP). The second largest amount of cognitive failures involved 'perception vigilance' (21%). The predominant groups of EM and IP were 'mishear' and 'expectation bias'. Only few errors were associated with 'working memory' (7%) and 'response execution' (2%) and no errors were associated with 'long-term memory'.

The Contextual Conditions (CCs) may be important in relation to understanding why errors occurred and also in identifying remedial or preventive strategies. In the Swedish cases the predominant group of CCs are 'workplace design and HMI factors'. However, 'team factors' and 'traffic and airspace' have also played an important role in many of the incidents. These factors also occur with a high frequency in the UK and 'other' reports.

Other incident analysis

Fifteen incidents from other European and non-European sources were analysed using HERA-JANUS. Examples of the analysed incidents are shown in the Appendix. These incidents occurred between 1995-1998, and involved aircraft that were receiving a control service from various countries and functional control areas. The incidents implicated ATS Personnel in the reported causal factors.

The analysis captured all of the information shown on the HERA-JANUS incident analysis form (see Table 3). The HERA-JANUS Error Details, Error Mechanisms and Information Processing levels, which were used in the classification of events, are shown in Tables 8 and 9. Approximately 70% of errors, for which the ED could be ascertained, fell into 'planning and decision-making' errors. The majority of these errors could be classed as 'misjudgement/misprojection' and 'incorrect decision' (EM) and 'integration failure' (IP).

The large number of errors in the 'incorrect decision' category was similar to those found in the UK incident analyses. Errors of 'misjudgement/ misprojection' (i.e. incorrectly projecting spatial and temporal information such as headings and flight levels) were also relatively high and may reflect the varied nature of the incidents. The incidents in this category were from a wide range of severity and represented incidents from all functional areas in ATC. The large number of 'integration failures' probably indicates the underlying cognitive problems related to the 'misjudgement/misprojection' errors and is therefore not surprising.

The remaining errors were approximately equally spread over other cognitive domains. Approximately 8% of the recorded errors were associated with the response execution error detail. 'information not transmitted' and omission were the most common EMs. One of these errors could be attributed to the IP 'spatial confusion'.

The two other categories, which accounted for approximately 10% of errors, were associated with perception and vigilance (5%) and working memory (5%). There was no dominant EMs in the perception and vigilance domain, but the leading IP was 'expectation bias'. In the working memory domain, there were no dominant EMs, but the majority of IPs were associated with 'memory capacity overload'.

Errors of long-term memory were less frequent, but one involved the controller not recalling stored information due to 'insufficient learning'. The full range of EMs and IPs can be seen in Tables 8 and 9. The identified CCs can be seen in Table 10.

Table 8: Distribution of Error Mechanisms (EMs) within analysed ATM incident reports

Error Mechanisms (EMs)			
	UK	**Swedish**	**Other**
Perception and vigilance			
Hearback error	8	5	0
Mishear	3	1	1
Late auditory recognition	1	0	0
No detection (visual)	9	3	1
Late detection (visual)	5	1	0
No identification	3	0	0
Misidentification	1	0	0
Misread	1	0	0
Working memory			
Forget to monitor	0	1	0
Forget to perform action	0	1	0
Forget planned action	4	0	1
Forget previous actions	2	0	0
Forget temporary information	2	0	1
Inaccurate recall of temporary information	1	1	0
Long-term memory			
No recall of temporary information	0	0	1
Planning and decision-making			
Misprojection of a/c	4	5	11
Incorrect decision or plan	31	25	11
No decision or plan	14	2	0
Late decision or plan	0	0	1
Insufficient plan	0	0	1
Response execution			
Selection error	0	0	1
Information not transmitted	0	0	2
Unclear information transmitted	1	0	0
Incorrect information transmitted	4	1	0
Omission	0	0	1
Total	**94**	**46**	**33**

Table 9: Distribution of Information Processing levels (IPs) within analysed ATM incident reports

Information Processing levels (IPs)			
	UK	**Swedish**	**Other**
Perception and vigilance			
Visual search failure	2	1	0
Monitoring failure	11	0	0
Expectation bias	5	8	2
Spatial confusion	1	0	0
Discrimination failure	0	1	0
Information overload	3	0	0
Distraction	5	0	0
Preoccupation	1	0	0
Working memory			
Memory capacity overload	0	2	2
Similarity of information	1	0	0
Distraction	2	1	0
Preoccupation	2	0	0
Long-term memory			
Insufficient learning	0	0	1
Planning and decision-making			
Incorrect knowledge	6	0	2
Lack of knowledge	6	0	4
Integration failure	2	1	11
Failure to consider side effects	10	3	3
Fixation	3	0	2
Incorrect assumption	17	11	4
Prioritisation error	0	3	0
Risk recognition failure	7	0	1
Response execution			
Spatial confusion	1	0	1
Unclear speech	1	0	0
Intrusion of thoughts	3	0	0
Environmental intrusion/distraction	2	0	0
Slip of the tongue	3	1	0
Total	**94**	**32**	**33**

Table 10: Occurrence of Contextual Conditions (CCs) within analysed ATM incident reports

Contextual Conditions (CCs)			
	UK	**Swedish**	**Other**
Traffic and airspace	50	9	14
Pilot-controller communications	2	0	0
Workplace design and HMI	19	15	11
Documentation and procedures	4	4	6
Training and experience	2	1	13
Environment	2	2	2
Personal factors	2	0	0
Team factors	39	10	7
Organisational factors	0	0	0
Total	**120**	**41**	**53**

4.2.2 Database Considerations

Ultimately, HERA-JANUS classifications could be used to create an incident and error database. Such a database should allow the entry, storage and retrieval of incident data such as date, time, sectors, aircraft, altitude/FL, separation, etc., as well as data describing the task and error. The aim of this would be to search for trends in error occurrence and allow specific database queries.

By searching for particular combinations of classifications, the analyst would be able to search for specific contextual errors. Figure 16 provides an example.

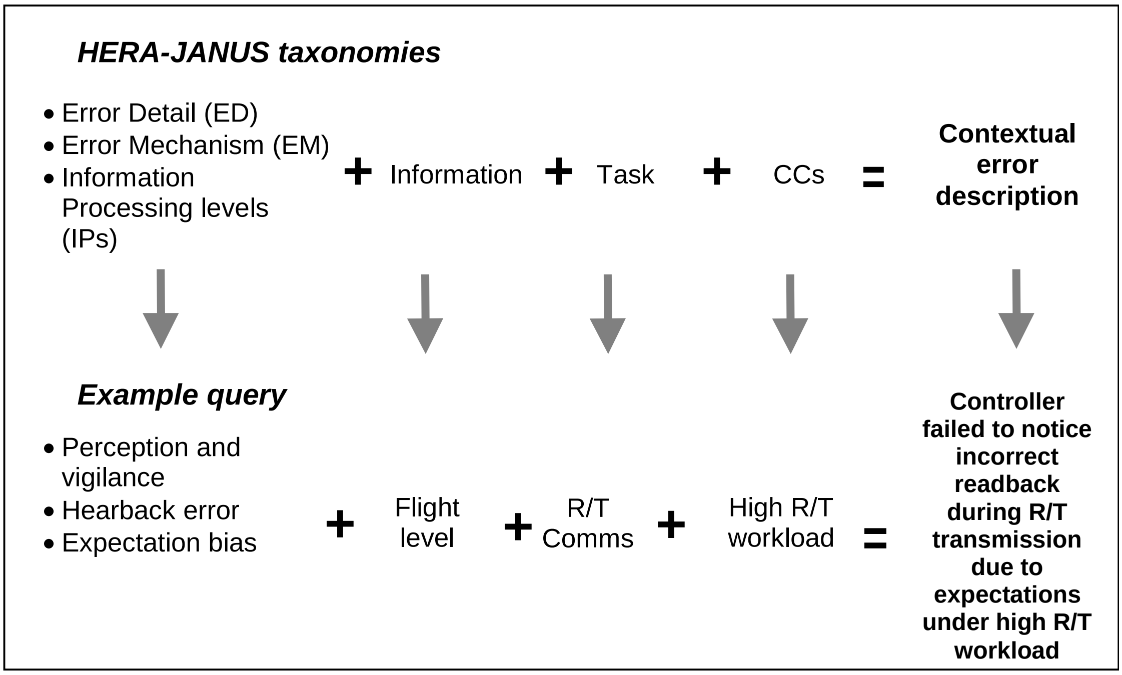

Figure 16: Derivation of contextual error descriptions

The issue of a human error database raises the importance of recording contextual information by using the task, information and CC taxonomies. It is little use to know that there were, *x* cases of 'incorrect decision' and *y* cases of ‘misperception’ during a given time period if it is not known *what* was the subject of the decisions, or what was misperceived, during what tasks, and with what external or internal influences. Such sophisticated database searches would, however, require electronic databases to ease the task.

5. CONCLUSION

This report has presented the Human Error in ATM Technique (HERA-JANUS). The report has introduced the rationale behind the development of HERA-JANUS and outlined the classification system and how the analyst should use the technique. The HERA-JANUS Technique is exemplified in this report through a review of several ATM incidents (retrospective analysis) and also through its application to a future ATM system (predictive analysis).

The lessons learnt from the application of HERA-JANUS to practical issues and projects will be used to refine the technique in order to make it more useful and usable for the population of potential HERA-JANUS analysts. The HERA-JANUS Technique will be validated in the next work package and some lessons learned during this process will be incorporated into the HERA-JANUS Technique for future use. The full report associated with this validation exercise will be presented in Work Package (WP) 3 (see EATMP, 2003).

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ABBREVIATIONS AND ACRONYMS

For the purposes of this document the following abbreviations and acronyms shall apply:

a/c or A/C	Aircraft
ADC	Aerodrome Control(ler)
AFTN	Aeronautical Fixed Telecommunication Network
ATC	Air Traffic Control
ATCA	ATC Assistant
ATCO	Air Traffic Controller / Air Traffic Control Officer *(US/UK)*
ATIS	Automatic Terminal Information Service
ATM	Air Traffic Management
ATS	Air Traffic Services
CAA	Civil Aviation Authority *(UK)*
CC	Contextual Condition
CENA	Centre d'Etudes de la Navigation Aérienne *(France)*
DFS	Deutsche Flugsicherung GmbH *(Germany)*
DGAC	Direction Générale de l'Aviation Civile *(France)*
DIS	Director(ate) Infrastructure, ATC Systems & Support *(EUROCONTROL Headquarters, SDE)*
DIS/HUM	See 'HUM (Unit)'
DME	Distance Measuring Equipment
EATCHIP	European Air Traffic Harmonisation and Integration Programme *(now EATMP)*
EATMP	European Air Traffic Management Programme *(formerly EATCHIP)*
ED	Error Detail
EM	Error Mechanism

ET	Error Type
EUROCONTROL	European Organisation for the Safety of Air Navigation
FAA	Federal Aviation Administration *(US)*
FIR	Flight Information Region
FL	Flight Level
FPS	Flight Progress Strip(s)
GNSS	Global Navigation Satellite System
HEI	Human Error Identification
HEP	Human Error Probability
HERA (Project)	Human Error in ATM (Project)
HFSG	Human Factors Sub-Group *(EATCHIP/EATMP, HUM, HRT)*
HMI	Human-Machine Interface
HRS	Human Resources Programme *(EATMP, HUM)*
HRT	Human Resources Team *(EATCHIP/EATMP, HUM)*
HSP	Human Factors Sub-Programme *(EATMP, HUM, HRS)*
HUM	Human Resources (Domain) *(EATCHIP/EATMP)*
HUM (Unit)	Human Factors and Manpower Unit *(EUROCONTROL Headquarters, SDE, DIS; also known as 'DIS/HUM')*
IFR	Instrument Flight Rules
IP	Information Processing level
LATCC	London Area and Terminal Control
LVNL	Luchtverkeersleiding Nederland *(ATC The Netherlands)*
NATS	National Air Traffic Services Ltd. *(UK)*
NDB	Non-Directional Beacon
NOTAMs	NOtices To AirMen
OJT	On-the-Job Training
OPS	Operations

PANS	Procedures for Air Navigation Services
QNH/QFE	*Altimeter pressure settings*
REP	Report *(EATCHIP/EATMP)*
RISØ	Risø National Laboratory *(Denmark)*
R/T	Radiotelephone/Radiotelephony
RTF	Radiotelephone/Radiotelephony
RWY	Runway
SDE	Senior Director, Principal EATMP Directorate *or, in short,* Senior Director(ate) EATMP *(EUROCONTROL Headquarters)*
SIGMET(s)	SIgnificant METeorological Information
SRK	Skill-Rule-Knowledge
STCA	Short-term Conflict Alert
TCAS	Traffic Alert and Collision Avoidance System *(US)*
TDB	Track Data Block
TRACEr	Technique for the Retrospective Analysis of Cognitive Errors in ATM
TRM	Team Resource Management
UAR	Upper Air Route
UTC	Universal Time Coordinated ⇨ Coordinated Universal Time
VFR	Visual Flight Rules
VOR	Very high frequency Omni-directional Radio range
WP	Work Package *(EATCHIP/EATMP)*

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APPENDIX

1. Development of the HERA-JANUS Technique

It is necessary in this report to explain what is needed for human error analysis and why, because to some extent every ECAC State will already have some means of recording, classifying and learning from human errors in ATM. The development of a new European system for analysing incidents may be seen as an implicit criticism of existing approaches. The question that should however be addressed, is why current approaches may not suffice, and therefore why a new approach is necessary. This section of the report therefore explains the process and outcome of the HERA-JANUS Technique development.

It is hoped that the new technique developed in this project will be seen as adding value to existing approaches. As already noted, concern over human error has not been the most important concern in ATM (although it has always been a major concern), and so many approaches will have evolved over time, adding new categories of error to existing systems as each new error arises. What this project has attempted to do is define all error types that can occur or could occur, whether with existing or future systems. The work then focussed on using more general human error frameworks and approaches based on tens of thousands of errors in many industries.

The approach developed in this project has attempted to carry out a ‘deeper’ analysis, in the psychological sense, than previous and existing error analysis systems. Other industries have realised the need to take this approach, for two fundamental reasons. The first is that such depth of analysis prevents ambiguities and aggregation of errors, which are fundamentally different. The second reason is that error prevention and reduction measures are never easy to achieve. The more precise the understanding of the causes, the more successful error prevention and reduction measures are likely to be.

In the development of a taxonomy and technique of error a model-based approach has been chosen. A model-based approach itself has some intrinsically desirable properties. Most importantly, a model allows causes and their inter-relations to be better understood. An error model provides an ‘organising principle’ to guide learning from errors. Trends and patterns tend to make more sense when seen against the background of a model, and more ‘strategic’ approaches to error reduction may arise, rather than short-term error reduction initiatives following each single error event. This will be particularly important as new tools and functions or procedures are introduced across Europe.

Models also need precise definition, so that the practitioners can agree a common set of terms and meanings. This is particularly important to learn lessons across Europe. This precision also has the advantage that different users will tend to classify the same events in the same way, thus ensuring a consistent and accurate picture of where problems originate. The consistency of the methodology (i.e. the technique and its associated method of use) which is being developed for this project will be tested in the validation stage, Work Package (WP) 3 (see EATMP, 2003).

Therefore, a model-based approach has certain advantages, in terms of understanding the errors and being able to learn from them, and in terms of increasing the effectiveness of error analysis. The development of a model-based approach that also incorporates the vast experience that has been accumulated by existing operationally based systems would represent a valuable tool that can significantly protect ATM from human error.

The following priorities should therefore be considered in the process of developing a classification system:

- The purpose of the classification - *why is the technique being developed?*
- The subject matter of classification - *what is being classified, what materials will be used for classification?*
- The method and criteria of classification - *how will the classification be achieved?*

The following sections describe each of these aspects of classification.

2. The Purpose of Classification

There are four primary purposes for classifying human error in ATM in the context of incidents that have occurred during operations:

(i) **Incident investigation** - To identify and classify what types of error have occurred when investigating specific ATM incidents (by interviewing people, analysing logs and voice recordings, etc.).

(ii) **Retrospective incident analysis** - To classify what types of error that have occurred within present ATM systems on the basis of incident reports; this will typically involve the collection of human error data to detect trends over time and differences in recorded error types between different systems and areas.

(iii) **Predictive error identification** - To identify errors that may affect present and future systems. This is termed Human Error Identification (HEI). Many of the classification systems in this review are derived from HEI tools.

(iv) **Human error quantification** - To use existing data and identified human errors for predictive quantification, i.e. determining how likely certain errors will be. Human error quantification can be used for risk assessment purposes.

Within these applications, retrospective incident analysis, above, is the main focus of HERA, although the resulting technique will also be usable for other purposes, in particular prediction of errors.

Human error classification can, and frequently does, play a vital part in ATM incident analysis. First, it allows monitoring of error occurrence over time to detect trends in serious errors. Incident recording systems allow incident investigators and analysts to organise, structure, and retrieve information on errors. Second, human error classification helps to generate research into errors, their causes and manifestations. Third, and most importantly, human error classification aids the development strategies to eliminate or reduce errors, or reduce their unwanted effects in systems. Despite this, however, error classification has been an under-developed part of the incident investigation process.

3. What is being classified?

The subject matter of classification includes both what is being classified, such as tasks, equipment, behaviours and errors, and what materials will be used for classification, such as investigated incidents, confidential (anonymous) reports, questionnaire data, interview data, observation and so on.

In deciding upon what is being classified in the human error taxonomy for ATM, the nature of the task must be considered. The Air Traffic Controller (ATCO) plays a very active role in ATM, and the controller's tasks are characterised by different 'cognitive skills' when compared to parallel roles in other domains, such as nuclear power plant operators. These cognitive skills include projection of aircraft movements in time and space, judgement, pattern recognition, maintaining situation awareness, planning, rapid decision-making, and rapid oral communication.

Many controller tasks are generally seen as 'cognitive', meaning the mental processes by which knowledge is acquired and tasks are performed. Such tasks are generally 'covert' and thus can be difficult to observe, and often cognitive tasks must be inferred from resulting behaviour. For example, whilst it is difficult to observe the mental process of planning, one can observe the subsequent execution of the plan. Alternatively, it is not possible to observe the cognitive processes involved in judgement of separation, but one can observe controller instructions, which attempt to maintain separation. However, it is rarely a straightforward task to infer cognitive processes from overt behaviours. For instance if a controller fails to perform a task - for instance, instructing a pilot to change Flight Level (FL) - this might be because the controller did not see or hear a cue to perform the task (e.g. the pilot's report of current FL). Alternatively, it may be because the controller forgot to perform the action or because the controller decided not to perform the action.

These considerations point to a 'behaviour descriptive approach' to classification (Fleishman and Quaintance, 1984). The approach is based upon observations and descriptions of what controllers actually did (and failed to do) in the events leading up to and during an incident, in terms of overt behaviours and covert psychological processes. Fleishman and Quaintance note that few descriptive systems are based exclusively on overt behaviours, as actions alone provide little information as to why the error occurred. Such systems would be of little use in attempting to ascertain causes and trends of human errors in ATM, or indeed in generating recommendations for the reduction of human errors or their effects. Hence, for human error analysis in complex systems such as ATM, it is both necessary and desirable to infer beyond actions.

This can be achieved by reference to the existing psychological and human factors research on human performance and human error, including both laboratory studies and applied field studies within various industrial domains, including ATM. It might also be useful to classify human errors on the basis of their effect on the system. However, basing the taxonomy on such relationships would be unwise given the rate of change of ATM systems, compared to the relative stability of human psychological processes and our understanding of them.

In summary, the subject matter for the present classification system can be summarised as:

- errors of omission - a required task is not performed;
- errors of commission - a required task is performed incorrectly or a non-required task is performed.

4. The Method and Criteria of Classification

The next step in the classification process involves seeking a method of classification. HERA-JANUS was adapted from the Technique for the Retrospective Analysis of Cognitive Errors in ATM (TRACEr).

The following procedural stages describe this development process.

4.1 Stage 1: Collection of Error Types

The first stage involves collecting the ‘taxa’, i.e. the terms that would be used to classify context and controller errors. A comprehensive search for human error types was conducted, and error types were identified from three main sources:

- errors that are included within present human error classification systems;
- errors that have been found in academic psychological research;
- errors that have been identified from operational experience in ATM (e.g. AIRPROX reports, simulations, interviews).

Some of the identified ‘error types’ were reported in the WP1 report: 'Technical Review of Human Performance Models and Taxonomies of Human Error in Air Traffic Management' (see EATMP, 2002a).

Error types were reviewed and recorded from the following sources:

- Baddeley and Hitch (1974),
- Danaher (1980),
- Embrey (1986),
- Fischhoff (1975),
- Fraser, Smith, and Smith (1992),
- Gerdes (1997),
- Hawkins (1993),
- Hollnagel (1993a & b),
- Kirwan (1994),
- Lourens (1990),
- Nagel (1988),
- Norman (1981),
- Rasmussen (1982),
- Reason (1979; 1987a, b & c; 1990),
- Rouse and Rouse (1983),
- Shafir and Tversky (1992, 1995),
- Slovic (1987), Stager and Hameluck (1990),
- Swain and Guttman, (1983),
- Taylor-Adams (1994),
- Tversky and Kahnemann (1974, 1981),
- Whalley (1988),
- Wickens (1992),
- Wilson (1997).

Some of these sources represent original experimental work whilst others represent uses and applications of the findings of other researchers. Some contextual error types were based on the analysis of AIRPROX (C) reports, and from ATM journals.

Each error type was named, usually based on the consensus of opinion in the literature. However, the descriptions of some errors have been tailored to the ATM environment. For instance, the error of mishearing an auditory signal such as a pilot's 'readback' of a clearance was named 'hearback error' as this term is ingrained in ATM. Other error types were renamed to render the title more intuitive. Each error type was also given a concise description, based on the explanations given in the literature.

4.2 Stage 2: Filtering of Error Types

As there are a large number of error types described in the literature, a procedure was adopted to ensure that the same error types were not represented more than once within the classification system. This procedure comprised three sub-stages, as explained below.

Screening

Error types, which had obviously already been recorded previously during the literature survey, were not recorded. For example, some error types had different names, but described the same phenomenon. These include errors such as ‘mis-ordering’ (Reason, 1979; Norman, 1981) and ‘steps out of sequence’ (Rouse and Rouse, 1983).

<u>Cross-checking</u>

Each combination of error types was cross-checked to curb violations of mutual exclusivity, for example, where one error type subsumed another. Where such ‘hierarchical’ relationships were evident, both ‘high level’ and ‘low level’ error types were retained if they added value to the taxonomy in terms of error-reduction utility or descriptive accuracy. For instance, one could argue all sequence errors can be reduced to timing errors, therefore sequence errors should be omitted. However, knowing that an error involves an incorrect sequence may suggest the need for physical constraints (i.e. interlocks) on controls, or a checklist approach. This may not be suggested by the term ‘timing error’.

Only clear violations of mutual exclusivity were omitted. Although at this stage the taxonomy aimed for some degree of mutual exclusivity, this was not permitted to constrain the usefulness of the taxonomy. Comprehensiveness was favoured and some degree of inter-rater reliability was therefore forfeited at the early stages of development.

<u>Applicability checking</u>

The error types were checked to ensure that they were applicable to ATM. This was achieved by (1) checking the incident for error types against the ATM literature and incident reports, (2) checking for the incidence of error types using controller interviews, and (3) presenting the developing taxonomy to air traffic controllers. This process resulted in the exclusion of error types that had been found in psychological research, but were not evident in ATM.

4.3 Stage 3: Model Development

Several authors have advocated the use of an underlying model of human performance for human error classification. Rouse and Rouse (1983) contend that the *internal consistency of a classification scheme is likely to be enhanced if the scheme is based on a model of the process within which errors occur* (p. 540). Such a model, they argue, can help to identify categories within the classification scheme and also illustrate the relationships among categories. Further support for this argument has come from Kirwan (1992), who argues that it is more desirable to have theoretically plausible models than approaches that are arbitrarily constructed, particularly for error reduction purposes.

<u>Choosing a model</u>

Many approaches to human error classification are loosely based on human information processing models such as that of Martiniuk (1976) and Wickens (1992). These models are well known within the human factors community, and concepts used within these models (e.g. perception, long-term memory) are also familiar to air traffic controllers and watch managers, and others with no formal training in human factors. Furthermore, these models are intuitive in that they enable the identification of errors (and to some extent the reduction of errors) based on their inferred origin within the information processing system. For these and other reasons outlined in the WP1 report the information processing model was considered appropriate.

Tailoring the model

These models are, on balance, considered the most appropriate for the present work, although various criticisms aimed at them must be resolved. Therefore, in order to make the present model more appropriate, a number of modifications were made. The enhanced model is therefore explained below and illustrated in Figure 17.

Reception and sensory processing

This stage involves the initial reception and sensory processing of external information (e.g. R/T call from a pilot) and internal information (e.g. the 'feel' of a foot switch). In ATM visual and auditory sensory data are of primary importance. Information from each sensory modality can be retained for a very short period of time (less than eight seconds) and without any attention in a 'short-term sensory store'.

Perception

Sensory information is detected, then identified or recognised, based on an association with long-term memory – a large store of relatively permanent information. Thus a controller may detect an aircraft 'blip' on the radar display and then identify the aircraft by using other information, such as call sign. Example errors of perception include misidentifying an aircraft on a radar display or a paper Flight Progress Strip (FPS), or failing to detect a pilot 'readback error', where a pilot fails to correctly read back a controller's instruction.

Working memory

Working memory refers to the temporary encoding, storage and retrieval of verbal and spatial information. For example, working memory is used to retain the contents of a pilot's transmission or a conversation with another controller, to perform mental arithmetic, or to remember to do something in the near future (called 'prospective memory').

In the enhanced model of human information processing used in HERA-JANUS working memory follows 'sequentially' from perception. This is a departure from Wickens' (1992) model which shows decision and response selection as following from perception. Wickens' rationale for this is that people decide to store information in working memory or to select a response. However, whilst people may have to decide to select a response, committing information to working memory is often automatic in the first instance. People may then decide how long to try to hold information in working memory for a specific time period or decide to try to recall something at a specific time in the future. Working memory is thought to contain part of what is traditionally referred to as 'the picture', (i.e. the controller's mental representation of the traffic situation) In the enhanced model this is termed '*ATM picture*'. However, controllers also have thoughts about themselves and their ability to cope with the traffic situation. This includes factors such as trust, confidence or perception of workload, and how situationally aware they feel. In the enhanced model this is termed '*self-picture*'.

Example errors of working memory include forgetting to transfer an aircraft to the next sector controller and forgetting the details of a coordination with another controller.

<u>Picture update process</u>

The 'picture update process' represents the flow of information used to update the controller's ATM picture. Information from perception and long-term memory, and from judgement, planning and decision-making is used to update the picture:

- information from *Perception*, e.g. current aircraft movements on the radar display, FPS markings, current pilot transmissions;
- information from *Long-term Memory*, e.g. recalled procedures, previous briefings;
- information from *Planning and Decision-making*, e.g. judgements regarding climbs, descents and turns; decisions about whether to split a sector or whether to act on a conflict alert.

<u>Long-term memory</u>

Long-term memory is a *storehouse of facts about the world and how to do things* (Wickens, 1992, p. 211). This 'storehouse' includes information derived from training, procedures and briefings. An error of long-term memory might occur following a change in procedures, where a controller could incorrectly revert to the previous and well-learned procedure.

<u>Mental model update process</u>

The 'mental model update process' is the flow of information from working memory to long-term memory. The controller's mental model is updated by new information from working memory, judgement, planning and decision-making.

<u>Judgement, planning and decision-making & response selection</u>

Previous models contain an information processing stage called 'decision and response selection'. This has been divided into two separate renamed processes:

- Planning and decision-making - This reflects more explicitly the processes of judgement, projection, prediction and planning used in ATM. ‘Judgement’ here refers to judging the required heading, climb, descend, or speed, etc., to achieve separation. A controller may, for example, misjudge a required climb. An example of an incorrect decision might be a decision to ignore a conflict alert, based on the assumption that it was a false alert.

- Response selection - Once the controller has made a decision a response is selected.

Response Execution

Response execution involves the physical actions or speech that are used to effect a decision. Hence errors of response execution include ‘slips’ such as writing or saying an unintended flight level.

Attention

Most of the processing that occurs following reception and sensory processing require attention to function efficiently. Attention is shown as the red shaded area in Figure 17. Wickens (1992) describes attention both as a ‘search light’ that selects information sources to process, and as a commodity of ‘limited availability'. Learning and practice reduce the demand for attention resources.

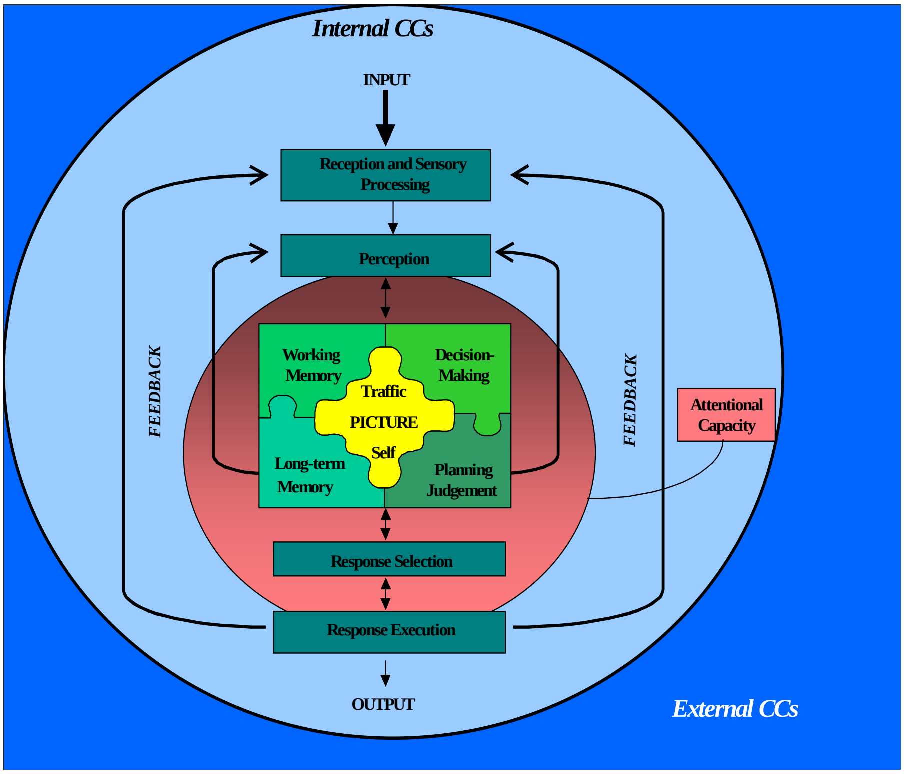

Figure 17: Enhanced model of human information processing

Applying the model

The model was used to organise error types directly, according to their inferred location within the cognitive architecture. This guided the task of allocating individual error types to high-level categories, and eases the user's task of finding the applicable category for an observed or reported error when using the classification system.

At this stage, each 'error type' was considered to find the appropriate cognitive domain. One guiding principle was the mapping of error types within high-level categories used by other authors to the present work. Table 11 shows a comparison of the cognitive domains utilised in the present work and the comparable stages of information processing or cognitive domains from other human error classification systems. Those error types, which were not included in previous models, could be located within a cognitive domain by considering the research context of the error type (e.g. perception, working memory, response execution). This could be achieved more readily with Wickens' stages than with those proposed by Rasmussen and other authors, as Wickens' model explicitly refers to the cognitive domains and structures.

Table 11: Comparison of 'Error Detail' (ED) levels and comparable stages of information processing from other human error classification systems

Developer	Comparable stage of information processing / error detail
Perception and vigilance	
Payne and Altman (1962) Berliner, et al. (1964) Andersch, et al. (1969) Pew, *et al.* (1981) based on Rasmussen (1986) Rouse and Rouse (1983) Norman (1986) Reason (1987a) Hollnagel (1993a) Kirwan (1994) based on Rasmussen (1986)	Input errors Perceptual processes Hears and reconstructs Activation/detection of system-state signal, observation and data collection, identification of system state Observation of system state Perception, interpretation Recognition failures, attentional failures Perception/observation, interpretation Activation/detection, observation and data collection
Working memory	
Payne and Altman (1962) Berliner, et al. (1964) Reason (1979) Norman (1981) Reason (1987a) Reason (1990) Hollnagel (1993a)	Mediation errors Mediational processes Storage failures Slips during the formation of an intention Memory lapses Skill-based lapses Memory
Long-term memory	
Payne and Altman (1962) Berliner, et al. (1964) Reason (1987a) Hollnagel (1993a)	Mediation errors Mediational processes Inaccurate and blocked recall Memory
Planning and decision-making	
Payne and Altman (1962) Berliner, et al. (1964) Andersch, et al. (1969) Pew, *et al.* (1981) based on Rasmussen (1986) Rasmussen (1982) Rouse and Rouse (1983) Rasmussen (1986) Norman (1986) Reason (1987a) Reason (1990) Hollnagel (1993a)	Mediation errors Mediational processes Structures, evaluates Identification of system state, interpretation of situation, evaluation of alternative strategies, definition of objectives, procedure selection Knowledge-based errors Choice of hypothesis, testing of hypothesis, choice of goal, choice of procedure Interpret, evaluate, define task, formulate procedure Evaluation, goals, intention Errors of judgement, reasoning errors Knowledge-based mistakes, violations Interpretation, planning/choice Identification of system state, interpretation, evaluation, goal selection and task definition, procedure selection

Developer	Comparable stage of information processing / error detail
Response execution	
Payne and Altman (1962)	Output errors
Berliner, et al. (1964)	Motor processes, communication processes
Andersch, et al. (1969)	Reacts, transmits
Reason (1979)	Discrimination failures, program assembly failures, test failures and sub-routine failures
Norman (1981)	Slips that result from faulty activation of schemas, slips that result from faulty triggering of schemas
Pew, *et al.* (1981) based on Rasmussen (1986)	Procedure execution
Rouse and Rouse (1983)	Execution of procedure
Rasmussen (1986)	Execute
Norman (1986)	Action specification, execution
Reason (1987a)	Unintended words and actions
Reason (1990)	Skill-based slips
Hollnagel (1993a)	Action execution
Kirwan (1994) based on Rasmussen (1986)	Procedure execution

On the whole, this procedure yielded a consistent mapping of error types from other human error / human performance models and taxonomies onto the error detail levels. However, categories within some systems based on Rasmussen's Skill-Rule-Knowledge (SRK) framework can map onto more than one error detail.

This classification effort resulted in a set of error types for each error detail level with the minimum of developer judgement. The classifications were predominantly based on distinctions within theories of human performance which have been heavily used, frequently cited and, to some extent, validated in the literature.

4.4 Stage 4: Developing an Internal Structure

The analysis at this stage revealed a tripartite distinction between the error - Error Types (ETs), Error Mechanisms (EMs) and Information Processing levels (IPs). These concepts are described below.

<u>Error Types (ETs)</u>

Error Types (ETs) describe what error occurred, in terms of the external and observable manifestation of the error. ETs are independent of their cognitive origins, and so do not imply anything about the cognitive origins of the error (e.g. intentionality).

ETs include errors of omission, timing, sequence, quality, selection and communication, including:

– omission,
– action too late,
– mis-ordering,

- extraneous act,
- right action on wrong object,
- incorrect information transmitted.

In addition, a flowchart to help identify the differences between errors, rule breaking and violation behaviours has been developed.

Error Mechanisms (EMs)

Error Mechanisms (EMs) describe the internal manifestation of the error within each Error Detail (ED) level (e.g. misidentification, late detection, misjudgement). EMs are linked specifically to the **functions** of the ED. For instance, the ED ‘perception and vigilance’ was divided into ‘visual’ and ‘auditory’, as well as ‘detection’, ‘identification’ and ‘comparison’. The cognitive functions within each ED level were then combined with a keyword. Example **keywords** include late, none and incorrect. EMs within ‘perception and vigilance’ include ‘late detection’, ‘misidentification’ and ‘hearback error’. EMs provide an interface between ETs, IPs and the model of information processing and thus give an intermediate level of detail. EMs are usually obtainable from incident reports and bring the analyst closer to error reduction measures than ETs alone. Table 12 shows how the EMs were generated for each ED.

Table 12: Generation of EMs within HERA-JANUS

Cognitive Function	Relevant Keywords	Example EM
Perception and vigilance *Hearing/vision*		
Detection	None, late, incorrect	Late detection
Identification	None, late, incorrect	Misidentification
Comparison	None, late, incorrect	Hearback error
Working memory		
Recall perceptual information	None, incorrect	Forget temporary information
Previous actions	None, incorrect	Forget previous actions
Immediate/current action	None, incorrect	Forget to perform action
Prospective memory	None, incorrect	Prospective memory failure
Long-term memory		
Stored information (procedural and declarative knowledge)	None, incorrect	Misrecall stored information

Cognitive Function	Relevant Keywords	Example EM
Planning and decision-making		
Judgement	Incorrect	Misprojection
Planning	None, too little, incorrect	Underplan
Decision-making	None, late, incorrect	Incorrect decision
Response execution		
Timing	Early, late, long, short	Action too early
Positioning	Too much, too little, incorrect, wrong direction	Positioning error: overshoot
Selection	Incorrect	Typing error
Writing	None, unclear, incorrect	Incorrect information recorded
Communication	None, unclear, incorrect	Unclear information transmitted

Information Processing levels (IPs)

Information Processing levels (IPs) describe how the psychological cause influences the EM within each Error Detail (ED) level. These ‘psychological causes’ refer to inherent human fallibility which influence behaviour, such as visual discrimination, expectations, working memory capacity, confusion, habit, etc. Many IPs are a by-product of normal human information processing. For instance, assumptions allow people to process information and make decisions when there is a lack of perfect information. Expectations allow people to make predictions based on experience and ‘overlearned’, ‘automatic’ or habitual tasks allow people to perform more than one task at a time. Many of these activities in normal circumstances spare mental resources, but, in other instances, can lead to error.

Example IPs within ‘perception and vigilance’ include ‘expectation bias’ (i.e. seeing or hearing what you expect to hear), ‘perceptual confusion’ (i.e. confusing two things that look or sound alike), and ‘preoccupation’. IPs are linked to mechanisms affecting cognitive functions, but also relate more generally to cognitive factors that affect people in various ways (e.g. expectation could affect both perception and decision-making; preoccupation could affect both perception and working memory).

HERA-JANUS’ internal structure of ETs, EMs and IPs allows the analyst or incident investigator to classify errors at three levels of detail. There will almost always be sufficient information to classify the ET, and usually there will be enough information to classify the EM. IPs add value to the analysis, but are the most difficult ‘level’ to classify, because there is sometimes insufficient information to determine them.

Table 13 shows examples of IPs, mapped against EMs within the error detail levels.

Table 13: Examples of the Error Detail (ED) level, EMs and IPs

Error Detail (ED)	Example Error Mechanism (EM)	Example Information Processing level (IP)
Perception and vigilance	Misperception	Expectation bias
Working memory	Forget temporary information	Memory capacity overload
Long-term memory	Forget learned information	Negative transfer
Planning and decision-making	Misprojection	False assumption
Response execution	Positioning error	Manual variability

Decision Flow Diagrams

Decision flow diagrams are used to enable the analyst to determine the correct categories already mentioned by means of a set of branch questions with yes/no responses.

The first decision flow diagram in the set asks a series of questions to help the analyst locate the relevant **Error Detail (ED)**. The analyst then selects the flow diagram containing the **Error Mechanisms (EMs)** for the selected error detail level, and finally the **Information Processing level** (IP). Each level contains a number of questions, of which there are three types:

- *Branch questions* - These lead the analyst down a particular 'branch' within the set of EMs or IPs. This reduces the possible number of EMs or IPs to a smaller subset, typically two to four, and so reduces the number of questions that the analyst must answer before arriving at the final choice of EM or IP. For instance, one branch question for perception and vigilance EMs concerns *auditory* errors, whilst another concerns *visual* errors.

- *Error type questions* - These usually ask a question which leads to one or two EMs or IPs.

- *Jump questions* - These direct the analyst to another error detail level when it is clear from previous responses to questions that a different error detail level applies.

In order to maintain consistency 'yes' answers always lead across the diagrams, either to an EM/IP or to an another question, or sometimes to a 'jump' question. 'No' answers generally lead to a response down the diagrams, usually to the next question, but sometimes to a 'jump' question or to an EM/IP.

The decision flow diagrams are structured to be as internally consistent as possible and their development required a detailed analysis of the relations between questions. In particular, questions which elicit a 'yes' response should not contradict preceding questions where a 'no' response was given. Also, branch questions that are answered 'no' (and thus lead down the diagram to the next question) should not allow the analyst to overlook an appropriate EM/IP. Hence, the phrasing of branch questions should be sufficiently broad to direct the analyst to EM/IP questions where there could be some doubt or uncertainty.

Each decision flow diagram starts at a different error detail level. This allows the analyst to start at the applicable error and makes the technique more resource-efficient. If the analyst is not confident of the applicable error detail level, they may choose to start at ‘perception and vigilance’ and follow the decision flow diagrams through to ‘response execution’.

This ‘start-point’ is compatible with many other human performance models and taxonomies of error. These include Rasmussen’s stepladder model for decision-making (Rasmussen, 1986), which begins with ‘activation’ (where the task performer is alerted to the need for information processing), and Rouse and Rouse’s (1983) model which begins with ‘observation of system state’. However, this is not to say that the root cause of errors will always be at this end of the model. For instance, a controller may transmit an unintended instruction to a pilot (a ‘slip of the tongue’). This might begin an error chain, i.e. a sequence of related errors. In summary, the decision flow diagrams allow the analyst to begin at any error detail level. Also, the format allows the analyst to skip levels where the analyst is confident that the error did not occur within that area, or where the analyst is directed to ‘jump’ to another error detail.

Task

The task lists describe the task(s) that the controller was performing at the time that the error was made. This was developed from a number of Hierarchical Tasks Analyses (Lamoureux, 1998). Example tasks include:

- coordination,
- tower observation,
- planning,
- R/T communications and instruction,
- control room communications,
- strip work,
- materials checking,
- radar monitoring,
- HMI input & functions,
- handover/relief briefing,
- takeover,
- training,
- supervision,
- examination.

Information/Equipment

The information/equipment lists describe the environment in which the error occurred. These lists were developed from a number of Hierarchical Tasks Analyses (Lamoureux, 1998) and from discussions with ATCOs. These are important lists since they highlight practical areas for error reduction. It is little use in knowing that a large number of memory failures occur if the analyst cannot pinpoint what information is being forgotten. A selection of the HERA-JANUS information/equipment elements are shown below:

- procedures,
- coordination,
- FL,
- aircraft type,
- geographical position,
- airport,
- flight rules,
- R/T,
- VOR,
- secondary radar,
- visual approach aids,
- aerodrome equipment,
- flight information displays,
- input devices.

Classifying contextual factors explicitly would, for example, allow the analyst to create a search on a database to find how many errors involved strip marking, radar monitoring or handover. More specifically, by combining error classifiers (e.g. no detection) with ‘information/equipment’ classifiers (e.g. conflict alert/ radar), the analyst could search a database to find instances where the controller failed to visually detect an STCA.

Contextual Conditions (CCs)

Contextual Conditions (CCs) can be defined as factors, internal or external to the controller, which influence the controller’s performance of ATM tasks. Contextual Conditions (CCs) can help to explain why the error occurred. An initial set of CCs for ATM was developed from an analysis of UK AIRPROX reports, discussions with ATCOs and the human factors literature.

The CCs include the following sub-categories:

- pilot-controller communications, e.g. pilot breach of R/T standards/phraseology;
- pilot actions, e.g. responding to TCAS alert;
- traffic and airspace, e.g. excessive traffic load / complex traffic mix;
- weather, e.g. extreme wind at high altitude;
- documentation and procedures, e.g. inappropriate regulations and standards;
- training and experience, e.g. controller under training;

- workplace design and HMI, e.g. R/T failure;
- environment, e.g. lighting - illumination, glare;
- personal factors, e.g. high anxiety / panic;
- team factors, e.g. poor/unclear coordination;
- organisational factors, e.g. problems in the work environment - administrative workload problems.

CCs should be applied individually to each error that is influenced by the factor, rather than just once for an incident. Furthermore, CCs should not be used to *redescribe* and error. CCs should only be used to classify *precursors* to errors.

5. Implications for the Development of the HERA-JANUS Technique

During the development of the HERA-JANUS Technique several different analyses helped to create, confirm and validate the iterative process. Section 4 of this report described the practical applications of the technique and below can be found the main lessons learned and information gained from such a process.

The analysis of incident reports

The majority of errors could be classified using the existing ET, EM and IP taxonomies. The form proved very useful. However, it was noted that a definition of error was needed in the technique itself and that there was a need to define more clearly causal, contributory and compounding factors within the technique.

In some cases the error detail level could not be ascertained, since there was insufficient information to determine the controller's intention. For instance, if a controller failed to pass traffic information, it is unclear whether the controller forgot or decided not to pass traffic information. This is an inherent limitation of incident reporting and investigation, unless clearly structured interviews are used.

Other amendments to HERA-JANUS have included:

- adding an error type listing with definitions to assist in identification of the errors;
- adding a flowchart concerned with the differences between error, rule breaking and violation behaviours;
- merging some EMs (e.g. combination of 'late decision' and 'late plan');
- renaming some EMs/IPs (e.g. 'misjudgement' was renamed 'misprojection');

- adding a small number of IPs (e.g. ‘Risk recognition’);
- making the task and equipment tables hierarchical and adding some tasks;
- adding, re-ordering and collapsing some CCs;
- renaming any element or psychological term to avoid misunderstanding.

6. Lessons from the Validation of the HERA-JANUS Technique

The aims of the validation will be to find the results of several issues with regard to robustness, usability and usefulness. The full results from the validation can be found in Work Package (WP) 3 (see EATMP, 2003).

7. Examples Using the HERA-JANUS Technique

7.1 UK Incident Example

This sub-section includes an example from the UK AIRPROX reports to illustrate the use of the HERA-JANUS Technique.

HERA-JANUS INCIDENT ANALYSIS FORM			
DETAILS OF INCIDENT			
Reference:	AIRPROX (C) 24/96	**Date & Time:**	21 September 1996 1225 UTC
Country:	UK		
Aircraft:	B767/B747	**Operators:**	Foreign airlines
Geographical position:	4nm South of Boulogne		
ALT/HT/FL:	FL310	**Airspace type:**	UAR – Class B
Reporter:	LATCC - London Upper Sector Controller		
Reported separation:	1.3nm horizontal / 300 feet vertical		
Recorded separation:	1.1nm horizontal / 400 feet vertical		
HERA-JANUS Analyst:	SS/RK		
BRIEF DESCRIPTION OF INCIDENT			

A B747 was en route from Zurich to New York, cruising at FL310 on UAR UB4 via Boulogne VOR to Brookmans Park. A B767 from Paris (Orly) to New York was routeing UB376, also via Boulogne VOR at FL180. Both aircraft were under the control of LUS. The traffic situation was described as busy, although the LUS was bandboxed. The CSC decided, in consultation with the off-going sector controller, that instead of splitting the sector into E and W, the off-going controller would be used as a support controller to the relief controller. Most of the traffic was on the East side, so it was thought that splitting the sector would be unproductive. The relief controller, who had little experience of this mode of operation, agreed to the plan. The B747 pilot reported level at FL310 on first contact, and was instructed to maintain FL310 and given a routeing of Boulogne, Brookmans Park and Trent. Shortly afterwards the B767 pilot established RTF contact with the LUS reporting approaching Boulogne at FL280 - the expected level as indicated on the FPS. However, the Sector controller erroneously instructed the B767 pilot to “Maintain FL310” **[1]**. The controller then turned her attention to other traffic and did not note the B767 pilot’s reply “up to 310” **[2]**. The support controller did not hear the sector controller’s call because he was concentrating his attention elsewhere (although there is no responsibility for a support controller to hear all the calls). However, the support controller noticed that the B767 was at FL283 Mode C, above FL280 as displayed on the FPS. When he drew this to the attention of the Sector controller, she replied initially that the aircraft was not on frequency. Still concerned, the support controller continued to prompt the Sector controller into taking action to resolve the problem. He was convinced that the B767 pilot was on frequency because the Sector controller had ticked the call sign on the FPS. Both he and the CSC tried to get the Sector controller’s attention to contact the B767 pilot but, because she was busy making calls, they found it difficult to make her aware of the circumstances. The Sector controller still did not believe that the B767 was on frequency, because she did not remember its first call. Hence, she did not take any action, but they continued to prompt her to call the aircraft **[3]**. About thirty seconds after the STCA activated, she called the B767 pilot who responded immediately and was told “...turn left now avoiding action a

<table>
<tr><th colspan="8">HERA-JANUS INCIDENT ANALYSIS FORM</th></tr>
<tr><td colspan="8">heading of 350 confirm your cleared level was FL280?" The B767 pilot replied "...I'm sorry (call sign) left 350 and broke you up". The Sector controller replied "...Roger (call sign) there is traffic on your right hand side a range of 3 miles your cleared level was 280". The support controller estimated that about 40 seconds passed between him warning the Sector controller of the situation and her making her first warning call, but this was 'off-mike' and so was not recorded. At the point of the transmission to the B767 pilot the aircraft was passing FL296, 5.5nm from the B747, with both aircraft on converging headings. The Sector controller admitted that the initial avoiding action heading was not a good one because it was very similar to, or to the right of, the aircraft's track [4]. Also, the Sector controller assumed that by stating the aircraft's cleared level the B767 pilot would probably stop the climb, but she admitted that she should have used a more positive instruction to instruct the pilot to descend to FL280 or FL290 [5]. She also intended to call the B747 pilot to issue a right turn but she was pre-empted by the pilot reporting traffic at 10 o'clock climbing through his level in a simultaneous transmission with the B767 pilot trying to confirm his cleared level. The Sector controller then instructed the B747 pilot to turn right heading 030° for avoiding action. The B767 continued to climb and when it was seen passing FL307 the Sector controller instructed the pilot to stop his climb and descend to FL290 and to turn left heading 030° for avoiding action.</td></tr>
<tr><th colspan="8">*Please record the individual errors in the sequence in which they occurred*</th></tr>
<tr><th colspan="8">DESCRIPTION OF ERROR # 1</th></tr>
<tr><td colspan="8">The LUS sector controller erroneously instructed the B767 pilot to "Maintain FL310"</td></tr>
<tr><td colspan="2">How detected:</td><td colspan="6">Error not detected by Sector controller or support controller. Support controller later pointed out problem and STCA alerted.</td></tr>
<tr><td colspan="2">How recovered:</td><td colspan="6">Left avoiding action turn</td></tr>
<tr><td>Causal</td><td>✔</td><td>Contributory</td><td></td><td>Compounding</td><td></td><td>Non-contributory</td><td></td></tr>
<tr><th colspan="8">HERA-JANUS CLASSIFICATIONS</th></tr>
<tr><td colspan="2"></td><td colspan="6"></td></tr>
<tr><td colspan="2"></td><td colspan="6"></td></tr>
<tr><td colspan="2">ET:</td><td colspan="6">Incorrect information transmitted. Extraneous act</td></tr>
<tr><td colspan="2">ED:</td><td colspan="6">Response execution</td></tr>
<tr><td colspan="2">EM:</td><td colspan="6">Incorrect information transmitted</td></tr>
<tr><td colspan="2">IP:</td><td colspan="6">Thoughts leading to actions</td></tr>
<tr><td colspan="2">Task:</td><td colspan="6">R/T communications/instructions</td></tr>
<tr><td colspan="2">Information/ Equipment:</td><td colspan="6">Flight Level /
Radar</td></tr>
<tr><td colspan="2">CC:</td><td colspan="6">N/A</td></tr>
<tr><td colspan="2">Reporter's assumptions:</td><td colspan="6">(i) "(The Panel) accepted that it was likely that this was a slip-of-the-tongue by the controller which was possibly because she had just instructed the B747 pilot to maintain FL310 and that this figure was still in her mind."</td></tr>
<tr><td colspan="2">Analyst's assumptions:</td><td colspan="6">N/A</td></tr>
</table>

<table>
<tr><th colspan="8">HERA-JANUS INCIDENT ANALYSIS FORM</th></tr>
<tr><th colspan="8">NOTES</th></tr>
<tr><td colspan="8">(ii) Alternatively, it could be that the sector controller misheard the B767 pilot’s call sign and believed it was the B747 calling a second time, or that the controller forgot that the B747’s first call, and expected the call to be from the B747 pilot.
(iii) Review by AIRPROX panel states that the scenario was not unusually busy for this sector or for the time of day.</td></tr>
<tr><th colspan="8">DESCRIPTION OF ERROR # 2</th></tr>
<tr><td colspan="8">The LUS sector controller turned her attention to other traffic and did not note the B767 pilot’s reply “up to 310”.</td></tr>
<tr><td colspan="2">How detected:</td><td colspan="6">Error not detected by Sector controller or support controller. Support controller later pointed out problem and STCA alerted.</td></tr>
<tr><td colspan="2">How recovered:</td><td colspan="6">Left avoiding action turn</td></tr>
<tr><td>Causal</td><td>✔</td><td>Contributory</td><td></td><td>Compounding</td><td></td><td>Non-contributory</td><td></td></tr>
<tr><th colspan="8">HERA-JANUS CLASSIFICATIONS</th></tr>
<tr><td colspan="2"></td><td colspan="6"></td></tr>
<tr><td colspan="2"></td><td colspan="6"></td></tr>
<tr><td colspan="2">ET:</td><td colspan="6">Omission</td></tr>
<tr><td colspan="2">ED:</td><td colspan="6">Perception and Vigilance</td></tr>
<tr><td colspan="2">EM:</td><td colspan="6">Hearback error</td></tr>
<tr><td colspan="2">IP:</td><td colspan="6">Unknown</td></tr>
<tr><td colspan="2">Task:</td><td colspan="6">R/T communications/instructions</td></tr>
<tr><td colspan="2">Information/ Equipment:</td><td colspan="6">Flight Level (FL) /
Radar</td></tr>
<tr><td colspan="2">CC:</td><td colspan="6">N/A</td></tr>
<tr><td colspan="2">Reporter’s assumptions:</td><td colspan="6">N/A</td></tr>
<tr><td colspan="2">Analyst’s assumptions:</td><td colspan="6">N/A</td></tr>
<tr><th colspan="8">NOTES</th></tr>
<tr><td colspan="8">(i) Possibly ‘expectation bias’ or ‘distraction’ (the AIRPROX Panel state that “The JAAP thought that the significance of the ‘up to three one zero’ escaped the controller’s notice because the pilot went on immediately ‘...er...say again the clearance’, i.e. his routeing; when the controller was already waiting to transmit to two other aircraft not involved in the AIRPROX”.</td></tr>
<tr><th colspan="8">DESCRIPTION OF ERROR # 3</th></tr>
<tr><td colspan="8">The LUS sector controller did not believe that the B767 was on frequency, because she did not remember its first call. Hence, she did not take any action.</td></tr>
<tr><td colspan="2">How detected:</td><td colspan="6">N/A</td></tr>
<tr><td colspan="2">How recovered:</td><td colspan="6">Left avoiding action turn</td></tr>
<tr><td>Causal</td><td></td><td>Contributory</td><td>✔</td><td>Compounding</td><td></td><td>Non-contributory</td><td></td></tr>
<tr><th colspan="8">HERA-JANUS CLASSIFICATIONS</th></tr>
<tr><td colspan="2"></td><td colspan="6"></td></tr>
<tr><td colspan="2"></td><td colspan="6"></td></tr>
</table>

<table>
<tr><th colspan="8">HERA-JANUS INCIDENT ANALYSIS FORM</th></tr>
<tr><td colspan="2">ET:</td><td colspan="6">Omission</td></tr>
<tr><td colspan="2">ED:</td><td colspan="6">Working memory</td></tr>
<tr><td colspan="2">EM:</td><td colspan="6">Forget previous actions</td></tr>
<tr><td colspan="2">IP:</td><td colspan="6">Unknown</td></tr>
<tr><td colspan="2">Task:</td><td colspan="6">Control room communications</td></tr>
<tr><td colspan="2">Information/ Equipment:</td><td colspan="6">Aircraft (on frequency) /
R/T</td></tr>
<tr><td colspan="2">CC:</td><td colspan="6">Cross-cultural R/T differences.
High/excessive R/T workload</td></tr>
<tr><td colspan="2">Reporter’s assumptions:</td><td colspan="6">N/A</td></tr>
<tr><td colspan="2">Analyst’s assumptions:</td><td colspan="6">N/A</td></tr>
<tr><th colspan="8">NOTES</th></tr>
<tr><td colspan="8">(i) The AIRPROX report states “The Sector controller, who was aware that the Support controller and the CSC were trying to bring the B767’s level to her attention, believed that the aircraft was not on frequency, having no recollection of its first call”. However, this led to an error of ‘Judgement, Planning and Decision-making’: IEM - Incorrect decision; PEM - Cognitive fixation.</td></tr>
<tr><th colspan="8">DESCRIPTION OF ERROR # 4</th></tr>
<tr><td colspan="8">The LUS sector controller’s initial avoiding action heading for the B767 was not a good one because it was very similar to, or to the right of, the aircraft’s track.</td></tr>
<tr><td colspan="2">How detected:</td><td colspan="6">Self, from radar display.</td></tr>
<tr><td colspan="2">How recovered:</td><td colspan="6">Instructed the B747 pilot to turn right, instructed the B767 pilot to descend and turn left.</td></tr>
<tr><td>Causal</td><td></td><td>Contributory</td><td></td><td>Compounding</td><td>✔</td><td>Non-contributory</td><td></td></tr>
<tr><th colspan="8">HERA-JANUS CLASSIFICATIONS</th></tr>
<tr><td colspan="2"></td><td colspan="6"></td></tr>
<tr><td colspan="2"></td><td colspan="6"></td></tr>
<tr><td colspan="2">ET:</td><td colspan="6">Action too little. Action too late</td></tr>
<tr><td colspan="2">ED:</td><td colspan="6">Planning and decision-making</td></tr>
<tr><td colspan="2">EM:</td><td colspan="6">Misjudgement</td></tr>
<tr><td colspan="2">IP:</td><td colspan="6">Unknown</td></tr>
<tr><td colspan="2">Task:</td><td colspan="6">R/T communications/instructions, planning, radar monitoring</td></tr>
<tr><td colspan="2">Information/ Equipment:</td><td colspan="6">Heading avoiding action /
Radar</td></tr>
<tr><td colspan="2">CC:</td><td colspan="6">N/A</td></tr>
<tr><td colspan="2">Reporter’s assumptions:</td><td colspan="6">N/A</td></tr>
<tr><td colspan="2">Analyst’s assumptions:</td><td colspan="6">N/A</td></tr>
<tr><th colspan="8">NOTES</th></tr>
<tr><td colspan="8">N/A</td></tr>
</table>

HERA-JANUS INCIDENT ANALYSIS FORM							
DESCRIPTION OF ERROR # 5							
The LUS sector controller assumed that by stating the aircraft's cleared level the B767 pilot would probably stop the climb, but she admitted that she should have used a more positive instruction to instruct the pilot to descend to FL280 or FL290							
How detected:	Self, from radar display.						
How recovered:	Instructed the B747 pilot to turn right, instructed the B767 pilot to descend and turn left.						
Causal		**Contributory**	✔	**Compounding**		**Non-contributory**	
HERA-JANUS CLASSIFICATIONS							
ET:	Unclear information transmitted						
ED:	Planning and decision-making						
EM:	Incorrect decision						
IP:	Incorrect assumption						
Task:	R/T communications/instructions						
Information/ Equipment:	Flight Level (FL) / Radar/strip						
CC:	N/A						
Reporter's assumptions:	N/A						
Analyst's assumptions:	N/A						
NOTES							
N/A							

7.2 Swedish Incident Example

This sub-section includes an example from Swedish incident reports to illustrate the use of the HERA-JANUS Technique.

HERA-JANUS INCIDENT ANALYSIS FORM			
DETAILS OF INCIDENT			
Reference:	S-941227	**Date & Time:**	27-12-94 07.33
Country:	Sweden		
Aircraft:	TWE732, Fokker 100, SCW 9000, Ba 46	**Operators:**	TWE SCW
Geographical position:	Tranås		
ALT/HT/FL:	FL280/290	**Airspace type:**	FIR- Class A
Reporter:	R1/Stockholm		
Reported separation:	5 miles horizontal / 1000 feet vertical		
Recorded separation:	5 miles horizontal / 1000 feet vertical		
HERA-JANUS Analyst:	TB / checked / corrected JB (AJ/LL)/HBA		
BRIEF DESCRIPTION OF INCIDENT			
Two aircraft, one in level flight, the other during climb, have been closer to each other than separation minima allow. The Controller initiated an avoiding action. The ATCA (Assistant Controller) in Stockholm (A1) calls and gives several estimates to A1 in Malmö who accepts these and the same time delivers an estimate to Stockholm on TWE 732 from Halmstad. In the estimate it is not mentioned that TWE 732 is climbing to the estimated level of FL 290. The ATCO in Stockholm involved in the incident has just started in position R1. At the same time another ATCO is starting to open sector 2 which has been configured together with sector 1. In connection with the opening of sector 2 the ATCO takes all the 'R2-strips' from the R1-position, among those the strip of TWE 732. R2 takes the strip for two reasons: TWE has destination Arlanda, which means it will be flying within sector 2 sector boundary, and R1 has already used the so called 'sector 2-strip'. SCW 9000 departed Arlanda cruising at FL 280. Heading for SHG (Shilling) VOR. TWE 732, has departed Halmstad (ESMT) and is climbing to FL 290 towards SHG. The ATCO (R1) has just taken over responsibility of the position. TWE 732 is calling R1 and reporting FL 235 climbing to FL 290. The ATCO (R1) answers with ”radar contact” and gives an inbound clearance. 3 minutes later Malmö R1 calls Stockholm R1 and comments on the conflict between TWE and SCW. R1 (Stockholm) initiates at once avoiding action for both aircraft and gives traffic advisory.			
Please record the individual errors in the sequence in which they occurred			

<table>
<tr><th colspan="8">HERA-JANUS INCIDENT ANALYSIS FORM</th></tr>
<tr><th colspan="8">DESCRIPTION OF ERROR# 1</th></tr>
<tr><td colspan="8">A1/ass. (Malmö) calls A1 (Stockholm) giving estimates of TWE732 from Halmstad, but he fails to include in his estimate that TWE will climb to the estimated FL 290</td></tr>
<tr><td colspan="2">How detected:</td><td colspan="6">N/A</td></tr>
<tr><td colspan="2">How recovered:</td><td colspan="6">N/A</td></tr>
<tr><td>Causal</td><td></td><td>Contributory</td><td>✔</td><td>Compounding</td><td></td><td>Non-contributory</td><td></td></tr>
<tr><th colspan="8">HERA-JANUS CLASSIFICATIONS</th></tr>
<tr><td colspan="2"></td><td colspan="6"></td></tr>
<tr><td colspan="2"></td><td colspan="6"></td></tr>
<tr><td colspan="2">ET:</td><td colspan="6">Omission</td></tr>
<tr><td colspan="2">ED:</td><td colspan="6">N/A</td></tr>
<tr><td colspan="2">EM:</td><td colspan="6">N/A</td></tr>
<tr><td colspan="2">IP:</td><td colspan="6">N/A</td></tr>
<tr><td colspan="2">Task:</td><td colspan="6">Coordination:area/area</td></tr>
<tr><td colspan="2">Information/ Equipment:</td><td colspan="6">Aircraft /
R/T</td></tr>
<tr><td colspan="2">CC:</td><td colspan="6">Procedures incomplete or not available</td></tr>
<tr><td colspan="2">Reporter’s assumptions:</td><td colspan="6">N/A</td></tr>
<tr><td colspan="2">Analyst’s assumptions:</td><td colspan="6">N/A</td></tr>
<tr><th colspan="8">NOTES</th></tr>
<tr><th colspan="8">DESCRIPTION OF ERROR# 2</th></tr>
<tr><td colspan="8">Shift leader should not have initiated opening of positions at the same time that relief of R1 was in progress.</td></tr>
<tr><td colspan="2">How detected:</td><td colspan="6">N/A</td></tr>
<tr><td colspan="2">How recovered:</td><td colspan="6">N/A</td></tr>
<tr><td>Causal</td><td></td><td>Contributory</td><td>✔</td><td>Compounding</td><td></td><td>Non-contributory</td><td></td></tr>
<tr><th colspan="8">HERA-JANUS CLASSIFICATIONS</th></tr>
<tr><td colspan="2"></td><td colspan="6"></td></tr>
<tr><td colspan="2"></td><td colspan="6"></td></tr>
<tr><td colspan="2">ET:</td><td colspan="6">Wrong action on right object</td></tr>
<tr><td colspan="2">ED:</td><td colspan="6">Planning and decision-making</td></tr>
<tr><td colspan="2">EM:</td><td colspan="6">Incorrect decision or plan</td></tr>
<tr><td colspan="2">IP:</td><td colspan="6">Prioritisation error</td></tr>
<tr><td colspan="2">Task:</td><td colspan="6">Planning</td></tr>
<tr><td colspan="2">Information/ Equipment:</td><td colspan="6">Sector</td></tr>
<tr><td colspan="2">CC:</td><td colspan="6">N/A</td></tr>
<tr><td colspan="2">Reporter’s assumptions:</td><td colspan="6">N/A</td></tr>
<tr><td colspan="2">Analyst’s assumptions:</td><td colspan="6">N/A</td></tr>
<tr><th colspan="8">NOTES</th></tr>
<tr><td colspan="8">There was some discussion with Swedish CAA investigators if this action was really an error; it was agreed that it might be a slightly risky action unless carefully supervised; but there was some reluctance to classifying the action as an error (rather than a CC). A good example of a 'grey area' case.</td></tr>
</table>

<table>
<tr><th colspan="8">HERA-JANUS INCIDENT ANALYSIS FORM</th></tr>
<tr><th colspan="8">DESCRIPTION OF ERROR# 3</th></tr>
<tr><td colspan="8">R1/ass. should have obtained a FPS for TWE 732 to ensure complete coverage of all aircraft in the sector.</td></tr>
<tr><td colspan="2">How detected:</td><td colspan="6">N/A</td></tr>
<tr><td colspan="2">How recovered:</td><td colspan="6">N/A</td></tr>
<tr><td>Causal</td><td></td><td>Contributory</td><td>✔</td><td>Compounding</td><td></td><td>Non-contributory</td><td></td></tr>
<tr><th colspan="8">HERA-JANUS CLASSIFICATIONS</th></tr>
<tr><td colspan="2"></td><td colspan="6"></td></tr>
<tr><td colspan="2"></td><td colspan="6"></td></tr>
<tr><td colspan="2">ET:</td><td colspan="6">Omission</td></tr>
<tr><td colspan="2">ED:</td><td colspan="6">Planning and decision-making</td></tr>
<tr><td colspan="2">EM:</td><td colspan="6">No decision or plan</td></tr>
<tr><td colspan="2">IP:</td><td colspan="6">N/A</td></tr>
<tr><td colspan="2">Task:</td><td colspan="6">Handover/relief briefing</td></tr>
<tr><td colspan="2">Information/ Equipment:</td><td colspan="6">Climb</td></tr>
<tr><td colspan="2">CC:</td><td colspan="6">Poor/unclear working methods</td></tr>
<tr><td colspan="2">Reporter's assumptions:</td><td colspan="6">N/A</td></tr>
<tr><td colspan="2">Analyst's assumptions:</td><td colspan="6">N/A</td></tr>
<tr><th colspan="8">NOTES</th></tr>
<tr><td colspan="8"></td></tr>
<tr><th colspan="8">DESCRIPTION OF ERROR# 4</th></tr>
<tr><td colspan="8">R1 overtook responsibility of position without an integrated understanding of the situation.</td></tr>
<tr><td colspan="2">How detected:</td><td colspan="6">N/A</td></tr>
<tr><td colspan="2">How recovered:</td><td colspan="6">N/A</td></tr>
<tr><td>Causal</td><td></td><td>Contributory</td><td>✔</td><td>Compounding</td><td></td><td>Non-contributory</td><td></td></tr>
<tr><th colspan="8">HERA-JANUS CLASSIFICATIONS</th></tr>
<tr><td colspan="2"></td><td colspan="6"></td></tr>
<tr><td colspan="2"></td><td colspan="6"></td></tr>
<tr><td colspan="2">ET:</td><td colspan="6">Action too early</td></tr>
<tr><td colspan="2">ED:</td><td colspan="6">Planning and decision-making</td></tr>
<tr><td colspan="2">EM:</td><td colspan="6">Incorrect decision or plan</td></tr>
<tr><td colspan="2">IP:</td><td colspan="6">N/A</td></tr>
<tr><td colspan="2">Task:</td><td colspan="6">Takeover</td></tr>
<tr><td colspan="2">Information/ Equipment:</td><td colspan="6">N/A</td></tr>
<tr><td colspan="2">CC:</td><td colspan="6">Poor handover/takeover</td></tr>
<tr><td colspan="2">Reporter's assumptions:</td><td colspan="6">N/A</td></tr>
<tr><td colspan="2">Analyst's assumptions:</td><td colspan="6">N/A</td></tr>
<tr><th colspan="8">NOTES</th></tr>
<tr><td colspan="8"></td></tr>
</table>

<table>
<tr><th colspan="8">HERA-JANUS INCIDENT ANALYSIS FORM</th></tr>
<tr><th colspan="8">DESCRIPTION OF ERROR# 5</th></tr>
<tr><td colspan="8">R1/Malmö, who still is responsible for TWE, does not react (i.e. inform Stockholm R1) to the fact that TWE has been estimated to be on FL 290, but is actually climbing to FL 290. R1 should have revised the height since its deviates from the ATS-estimate.</td></tr>
<tr><td colspan="2">How detected:</td><td colspan="6">N/A</td></tr>
<tr><td colspan="2">How recovered:</td><td colspan="6">N/A</td></tr>
<tr><td>Causal</td><td></td><td>Contributory</td><td>✔</td><td>Compounding</td><td></td><td>Non-contributory</td><td></td></tr>
<tr><th colspan="8">HERA-JANUS CLASSIFICATIONS</th></tr>
<tr><td colspan="2"></td><td colspan="6"></td></tr>
<tr><td colspan="2"></td><td colspan="6"></td></tr>
<tr><td colspan="2">ET:</td><td colspan="6">Omission. Information not transmitted</td></tr>
<tr><td colspan="2">ED:</td><td colspan="6">Planning and decision-making</td></tr>
<tr><td colspan="2">EM:</td><td colspan="6">No/incorrect decision or plan</td></tr>
<tr><td colspan="2">IP:</td><td colspan="6">N/A</td></tr>
<tr><td colspan="2">Task:</td><td colspan="6">Coordination: area-area. Radar monitoring. Strip work: checking</td></tr>
<tr><td colspan="2">Information/ Equipment:</td><td colspan="6">Flight level (FL). Climb /
Radar</td></tr>
<tr><td colspan="2">CC:</td><td colspan="6">N/A</td></tr>
<tr><td colspan="2">Reporter's assumptions:</td><td colspan="6">N/A</td></tr>
<tr><td colspan="2">Analyst's assumptions:</td><td colspan="6">N/A</td></tr>
<tr><th colspan="8">NOTES</th></tr>
<tr><td colspan="8"></td></tr>
<tr><th colspan="8">DESCRIPTION OF ERROR# 6</th></tr>
<tr><td colspan="8">R1 should have reacted when TWE said it was.</td></tr>
<tr><td colspan="2">How detected:</td><td colspan="6">Phone call from Malmö R1</td></tr>
<tr><td colspan="2">How recovered:</td><td colspan="6">Avoidance action</td></tr>
<tr><td>Causal</td><td>✔</td><td>Contributory</td><td></td><td>Compounding</td><td></td><td>Non-contributory</td><td></td></tr>
<tr><th colspan="8">HERA-JANUS CLASSIFICATIONS</th></tr>
<tr><td colspan="2"></td><td colspan="6"></td></tr>
<tr><td colspan="2"></td><td colspan="6"></td></tr>
<tr><td colspan="2">ET:</td><td colspan="6">Omission (general violation)</td></tr>
<tr><td colspan="2">ED:</td><td colspan="6">Perception and vigilance</td></tr>
<tr><td colspan="2">EM:</td><td colspan="6">No detection (visual)</td></tr>
<tr><td colspan="2">IP:</td><td colspan="6">N/A</td></tr>
<tr><td colspan="2">Task:</td><td colspan="6">R/T communication and instruction. Radar monitoring</td></tr>
<tr><td colspan="2">Information/ Equipment:</td><td colspan="6">Climb/
Radar</td></tr>
<tr><td colspan="2">CC:</td><td colspan="6">Poor/unclear working methods</td></tr>
<tr><td colspan="2">Reporter's assumptions:</td><td colspan="6">N/A</td></tr>
<tr><td colspan="2">Analyst's assumptions:</td><td colspan="6">Cognitive Domain is based on the assumption that he was looking at the display</td></tr>
<tr><th colspan="8">NOTES</th></tr>
<tr><td colspan="8"></td></tr>
</table>

7.3 Other Non-European Incident Example

This sub-section includes an example from other non-European incident reports to illustrate the use of the HERA-JANUS Technique.

HERA-JANUS INCIDENT ANALYSIS FORM			
DETAILS OF INCIDENT			
Reference:	BASI B/916/3032	**Date & Time:**	12th August, 1991
Country:	Australia		
Aircraft:	DC-10/A320	**Operators:**	Thai/Ansett
Geographical position:	Sydney airport (Kingsford Smith)		
ALT/HT/FL:	52 feet	**Airspace type:**	Airport
Reporter:	Chief Controller Sydney		
Reported separation:	33 meters horizontal / 11 meters vertical		
Recorded separation:	33 meters horizontal / 11 meters vertical		
HERA-JANUS Analyst:	AI/JR		
BRIEF DESCRIPTION OF INCIDENT			
A Thai Airways RPT flight DC-10 (call sign THA 458) was making an approach to RWY 34 after a scheduled flight from Bangkok. The flight plan for THA 485 originated from the ATS reporting office in Bangkok, at 21:33 EST on 11 August. The PANS/OPS category for this model DC-10 was ‘D’ (that is grater than 141kts) and was transmitted correctly. The ADSO in the Sydney AACC prepared the flight plan indicating the PANS/OPS category of the DC-10 as ‘C’ (that is less than 141 kts) **[1]**. However, the ADSO in the control tower prepared the FPS as a category ‘D’ aircraft. An Ansett Australia A320 aircraft (call sign VH-HYC) was making an approach to RWY 25 on completion of a scheduled flight form Bisbane. At the time of the incident, SIMOPS were in progress with aircraft’s landing on the intersecting RWY’s (SIMOPS procedures aircraft are cleared to land simultaneously on the crossing RWY’s without consideration being given to their relative positions. This procedure is based on the assumption that one aircraft will stop prior to the RWY intersection as required under SIMPOS instructions. The tower controller is required to give the landing clearance instruction ‘Expect traffic on crossing RWY’). Traffic at the time was reported as light. The relevant Automatic Terminal Information Service (ATIS) broadcast recording indicated that SIMOPS were in progress and that RWY 25 was nominated for departures, while RWY’s 25 and 34 were nominated for arrivals. The ATIS advised aircraft’s to ‘expect traffic on the crossing RWY’. Heavy jets were ‘to land on RWY 34 and international aircraft’s were to depart on RWY 34’. At the time of the incident the visibility was greater than 10kms, cloud 0/0, + 13, the surface wind was from the west at 10-15kts. Crosswind components on RWY’s 25 and 34 were 9kts and 12kts respectively.			

<table>
<tr><th colspan="8">HERA-JANUS INCIDENT ANALYSIS FORM</th></tr>
<tr><td colspan="8">At 10:23:39 THA 483 landed on RWY 34. The landing instructions given to the aircraft included a requirement to stop before the ‘flight strip’ of RWY 25, the intersecting RWY. With the expectation that THA 485 would hold short of the RWY intersection as required under SIMOPS procedures, the Aerodrome controller (ADC 1) cleared VH-HYC to land on RWY 25 [2]. At 10:23:57 VH-HYC initiated its landing flare. The progress of THA 485’s landing was being monitored by control tower personnel and by the captain of VH-HYC.
At 10:24:02, ADC 1 assessed that THA 485 was approaching the RWY intersection at an excessive speed. Believing that THA 485 would not stop before the intersection, the ADC 1 transmitted the instruction ‘Thai 485 stop immediately, stop immediately’. At that time the captain of the THA 485 applied heavy breaking.
At 10:24:04, the captain of VH-HYC, assessing that THA 485 might not stop before the intersection and that there was a possibility of a collision between the two aircraft, initiated a go-around form a height of 2 feet above the runway.</td></tr>
<tr><td colspan="8">*Please record the individual errors in the sequence in which they occurred*</td></tr>
<tr><td colspan="8">DESCRIPTION OF ERROR # 1</td></tr>
<tr><td colspan="8">The PANS/OPS category for this model DC-10 was ‘D’ (that is greater than 141kts) and was transmitted correctly. The ADSO in the Sydney AACC prepared the flight plan indicating the PANS/OPS category of the DC-10 as ‘C’ (that is less than 141 kts)</td></tr>
<tr><td colspan="2">How detected:</td><td colspan="6">By the ADSO in the control tower</td></tr>
<tr><td colspan="2">How recovered:</td><td colspan="6">The ADSO in the control tower prepared the FPS correctly as a category ‘D’ aircraft</td></tr>
<tr><td>Causal</td><td></td><td>Contributory</td><td>✔</td><td>Compounding</td><td></td><td>Non-contributory</td><td></td></tr>
<tr><td colspan="8">HERA-JANUS CLASSIFICATIONS</td></tr>
<tr><td colspan="2"></td><td colspan="6"></td></tr>
<tr><td colspan="2"></td><td colspan="6"></td></tr>
<tr><td colspan="2">ET:</td><td colspan="6">Incorrect information recorded</td></tr>
<tr><td colspan="2">ED:</td><td colspan="6">Unknown</td></tr>
<tr><td colspan="2">EM:</td><td colspan="6">Unknown</td></tr>
<tr><td colspan="2">IP:</td><td colspan="6">Unknown</td></tr>
<tr><td colspan="2">Task:</td><td colspan="6">Strip handling</td></tr>
<tr><td colspan="2">Information/ Equipment:</td><td colspan="6">Aircraft performance /
Strip</td></tr>
<tr><td colspan="2">CC:</td><td colspan="6">Illness and fatigue (ascertained from the full report)</td></tr>
<tr><td colspan="2">Reporter’s assumptions:</td><td colspan="6">N/A</td></tr>
<tr><td colspan="2">Analyst’s assumptions:</td><td colspan="6">N/A</td></tr>
<tr><td colspan="8">NOTES</td></tr>
<tr><td colspan="8">It is not possible to derive from the report the cognitive cause, why the ADSO prepared the FPS incorrectly.</td></tr>
</table>

<table>
<tr><th colspan="8">HERA-JANUS INCIDENT ANALYSIS FORM</th></tr>
<tr><th colspan="8">DESCRIPTION OF ERROR # 2</th></tr>
<tr><td colspan="8">With the expectation that THA 485 would hold short of the RWY intersection as required under SIMOPS procedures, the Aerodrome controller (ADC 1) cleared VH-HYC to land on RWY 25.</td></tr>
<tr><td colspan="2">How detected:</td><td colspan="6">By monitoring the approach of both aircraft</td></tr>
<tr><td colspan="2">How recovered:</td><td colspan="6">By emergency instruction to THA 485 and go-around of VH-HYC</td></tr>
<tr><td>Causal</td><td>✔</td><td>Contributory</td><td></td><td>Compounding</td><td></td><td>Non-contributory</td><td></td></tr>
<tr><th colspan="8">HERA-JANUS CLASSIFICATIONS</th></tr>
<tr><td colspan="2"></td><td colspan="6"></td></tr>
<tr><td colspan="2"></td><td colspan="6"></td></tr>
<tr><td colspan="2">ET:</td><td colspan="6">Wrong action on right object</td></tr>
<tr><td colspan="2">ED:</td><td colspan="6">Planning and decision-making</td></tr>
<tr><td colspan="2">EM:</td><td colspan="6">Misjudgement</td></tr>
<tr><td colspan="2">IP:</td><td colspan="6">Integration failure, risk recognition failure</td></tr>
<tr><td colspan="2">Task:</td><td colspan="6">R/T instruction and clearance</td></tr>
<tr><td colspan="2">Information/ Equipment:</td><td colspan="6">Clearance – landing /
Strip</td></tr>
<tr><td colspan="2">CC:</td><td colspan="6">Inappropriate procedures (SIMOPS)</td></tr>
<tr><td colspan="2">Reporter's assumptions:</td><td colspan="6">N/A</td></tr>
<tr><td colspan="2">Analyst's assumptions:</td><td colspan="6">N/A</td></tr>
<tr><th colspan="8">NOTES</th></tr>
<tr><td colspan="8">The design of the SIMOPS procedure at the time of the incident shows several weaknesses (in comparison to similar procedures used in the USA or Canada).</td></tr>
</table>

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