COGNITIVE SYSTEMS ENGINEERING LABORATORY

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Functional Resonance Accident Model Method and examples

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Premises for FRAM analysis

Model type	Sequential model	Epidemiological model	Systemic model
Model structure	Structurally decomposable	Structurally decomposable	Functionally decomposable
Model dynamics	Linear independence	Linear dependence	Non-linear dependencies
Typical representation	Event tree, fault tree	Barriers (Swiss cheese)	Functional modules (resonance)
Risk assessment method	THERP, HAZOP, FMEA	Swiss cheese, TRIPOD	FRAM

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FRAM analysis steps

1. Identify essential system functions; characterise each function by six basic parameters.*
2. Characterise the (context dependent) potential variability using a checklist.
3. Define functional resonance based on possible dependencies (couplings) among functions.
4. Identify barriers for variability (damping factors) and specify required performance monitoring.

* Based on the principles of SADT ("Structured Analysis and Design Technique")

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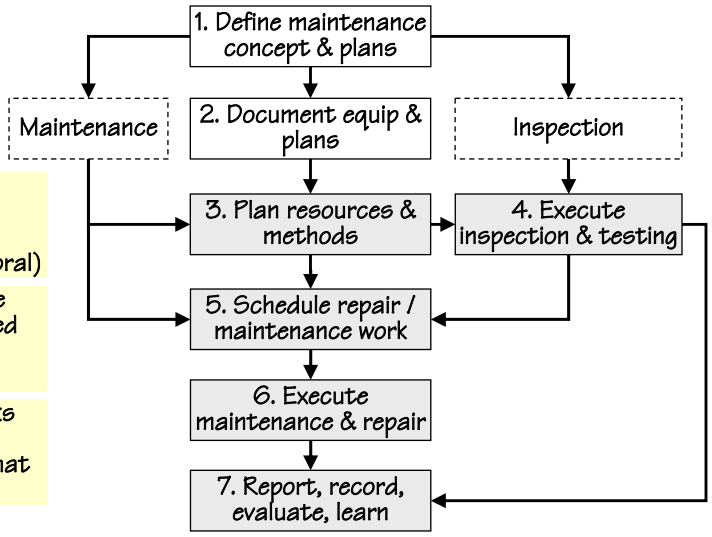
"Maintenance, repair and modification"

The common flow-chart describes pre-defined relations among component actions.

The nature of the relations is usually unspecified (but assumed to be temporal)

The relations describe the normal or expected case = what should happen

Risk assessment looks for the unusual or unexpected case = what could happen



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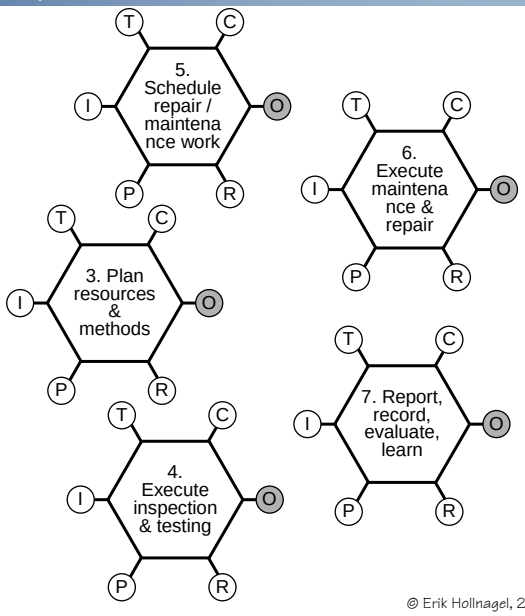
"Maintenance, repair and modification"

A FRAM analysis begins by identifying the functions needed to achieve an objective.

Some methods:
Goals-means analysis,
Flow modelling,
Functional analysis.

Each function is described in terms of six fundamental parameters ...

... but relations or dependencies among functions are not described at the start.



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Functional unit parameters

Inputs (I)	What is needed to perform function. Constitute the links to previous functions; can be either transformed or used in order to produce outputs.
Outputs (O)	What is produced by function. Constitute links to subsequent functions.
Resources (R)	What is needed by function to process input (e.g., hardware, procedures, software, energy, manpower).
Controls / constraints (C)	Serve to supervise or restrict function (monitor, adjust it when it goes astray). Can be active functions or just plans, procedures and guidelines.
Preconditions (P)	System conditions that must be fulfilled before a function can be carried out, e.g., that another step or process has been completed or that a specific system condition has been established.
Time (T)	Everything takes place in time and is governed by time. Can also be a constraint in the sense of a time window for an activity (a duration), Can be considered as a special kind of resource. .

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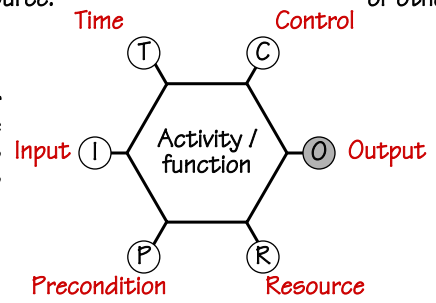
FRAM functional unit (module)

Time available: This can be a constraint but can also be considered as a special kind of resource.

That which supervises or adjusts a function. Can be plans, procedures, guidelines or other functions.



That which is used or transformed to produce the output. Constitutes the link to previous functions.

That which is produced by function. Constitute links to subsequent functions.

System conditions that must be fulfilled before a function can be carried out.

That which is needed or consumed by function to process input (e.g., matter, energy, hardware, software, manpower).

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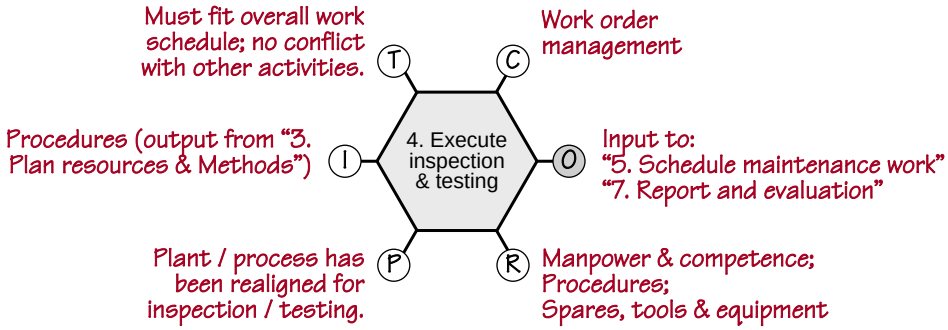
FRAM description of a function



QUESTION 1: Which conditions can lead to increased performance variability?

QUESTION 2: Which functions are affected and how can the variability express itself?

QUESTION 3: How may this affect / be affected by other functions? (Functional resonance)

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Finding likely variability

Rating of common performance conditions → Determine which functions may be affected → Possible expressions of variability ("failure modes")

Each common performance condition rated as: adequate, inadequate, unpredictable.

Dependency on M, T, O function types on common performance conditions

If high variability is likely, then determine possible "failure modes", i.e., how actions may be affected by variability.

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Effect of common performance conditions

Common Performance Conditions	Rating category			M	T	O
	Adequate	In-adequate	Unpre-dictable	Functions affected		
Availability of resources	(x)	(x)	(x)	X	X	
Training and experience (competence)	(x)	(x)	(x)	X		
Quality of communication	(x)	(x)	(x)	X		X
HMI and operational support	(x)	(x)	(x)	X		
Access to procedures and methods	(x)	(x)	(x)	X		
Conditions of work	(x)	(x)	(x)	X	X	
Number of goals and conflict resolution	(x)	(x)	(x)	X		X
Available time / time pressure	(x)	(x)	(x)	X		X
Circadian rhythm, stress	(x)	(x)	(x)	X		
Crew collaboration quality	(x)	(x)	(x)	X		
Quality and support of organisation	(x)	(x)	(x)			X

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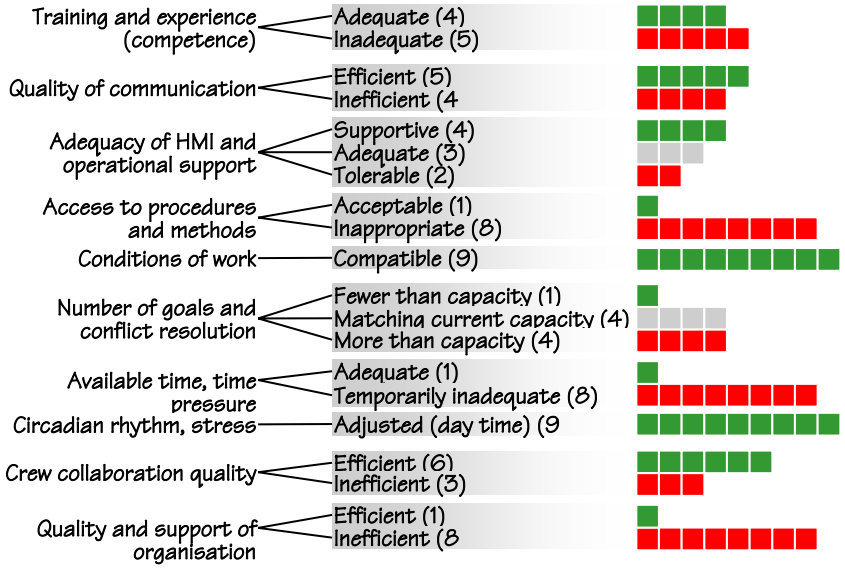

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Available time / time pressure	(x)	(x)		X		X
Circadian rhythm, stress	(x)		(x)	X		
Crew collaboration quality		(x)	(x)	X		
Quality and support of organisation		(x)	(x)			X

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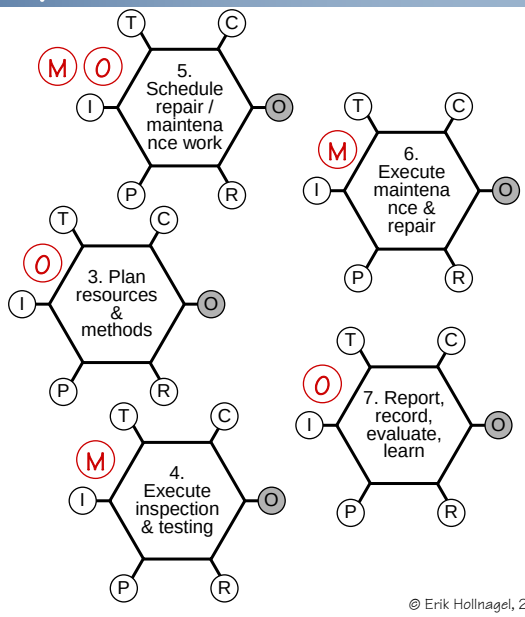
"Maintenance, repair and modification"

M – a function that primarily involves or depends on (hu)man activity.

T – a function that primarily involves or depends on technology.

O – a function that primarily involves or depends on the organisation.



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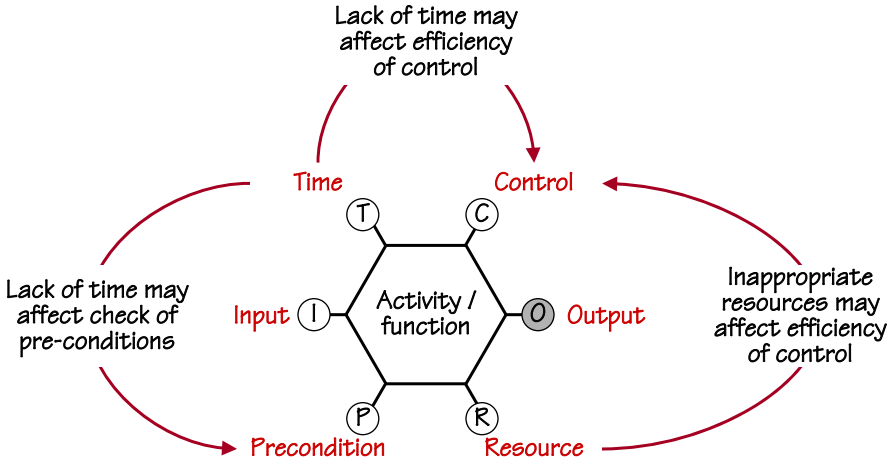
Conditions that may affect performance



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How conditions may affect each other

A deficit or lack of this …	… may have the following consequences for this: Time	Control	Pre-conditions	Resources
Time	-	Shortcuts	Reduced checks	Insufficient use
Control	Time savings	-	Reduced checks	Inappropriate use
Pre-conditions	Time savings	Missing	-	Unavailable
Resources	Possible lack of time	Shortcuts	Reduced checks	-
Input	Time savings	Improvisations	Improvisations	Increased demands
Input	Possible lack of time	Shortcuts	Reduced checks	Increased demands

… and all affect the quality and regularity of process, hence output

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Effects of ETTO thinking

Problems here …		… may lead to adjustments …	… with consequences.	
Time	Resources	ETTO rules	Control	Pre-conditions
✘	-	Looks fine	✘	✘
✘	✘	Not really necessary	-	✘
✘	-	Normally OK, no need to check	-	✘
✘	-	Will be checked by someone else	✘	-
✘	-	Has been checked by someone else	-	✘
✘	✘	No time - no resources - do it later	✘	-
-	✘	Can't remember how to do it	✘	-
-	✘	Worked last time	-	✘
✘	✘	This is good enough for now	✘	-

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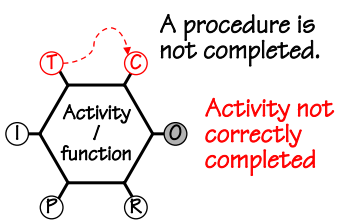
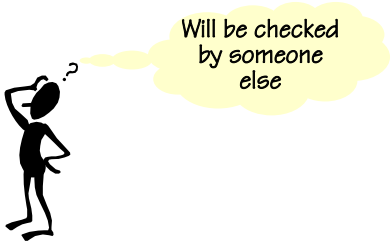
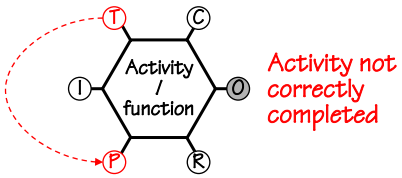
Unexpected combination of variability



A procedure is not completed.

Activity not correctly completed





Activity not correctly completed

A pre-condition not checked

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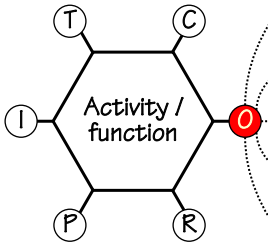
How can functions affect each other?

If a function is likely to have increased variability, then establish the dependencies by the following questions:



- Which other functions uses this as input?
- Which other functions depends on this as a pre-condition?
- Which other functions depend on this for timing? (synchronisation, start, finish)
- Which other functions uses this as a resource?
- Which other functions depend on this to control what they do?

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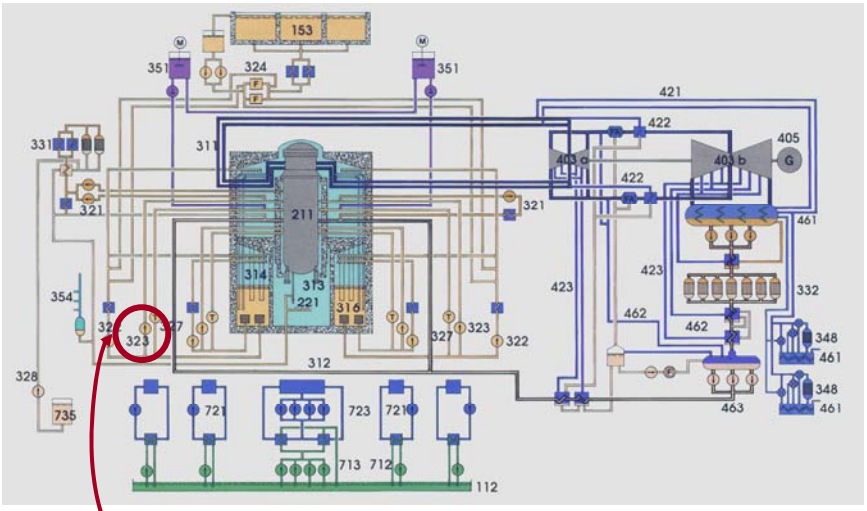
Oskarshamn Unit 2 (Sweden)

LPCS: Low Pressure Core Spray



Disconnecting switch erroneously left open

Detected NOV 13, 1996 – one week after completion of outage

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Event report

EVENT

On November 13, 1996 at the O2 NPP, a monthly surveillance test revealed that both Low Pressure Core Spray (LPCS) pumps were inoperable.
The Disconnecting Switches to the two pumps were erroneously left open after the annual refueling outage that had ended November 5.

Details

In this case the LPCS had already been aligned for operation when the leak rate test of the containment required the LPCS to be blocked by opening the Disconnecting Switches of the two pumps.
When the LPCS pumps then should be realigned the realignment was postponed due to ongoing work in the wetwell and concerns about personal safety of the workers involved.
The realignment step in the procedure was signed off as performed.
The operators were convinced that the startup procedure included a check of the Disconnecting Switches of the LPCS pumps, however this was not the case.

ROOT CAUSE

The decision not to restore the LPCS system based on personal safety aspects was correct. But as a consequence the last barrier in preventing the LPCS to be inoperable was broken due to the violation of how to handle such a situation.
The operators anticipated that the closing of the disconnecting switches for the LPCS pumps were included in the startup procedure, but never checked this assumption.

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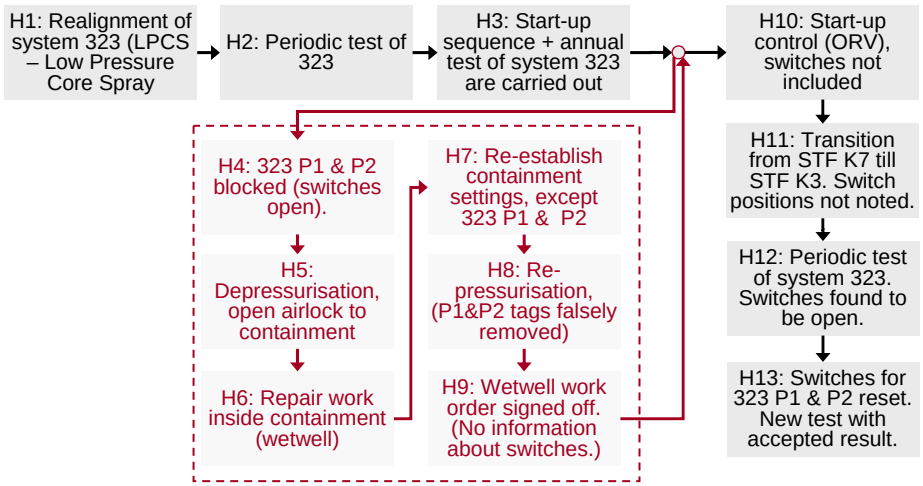
System 323 – actual development



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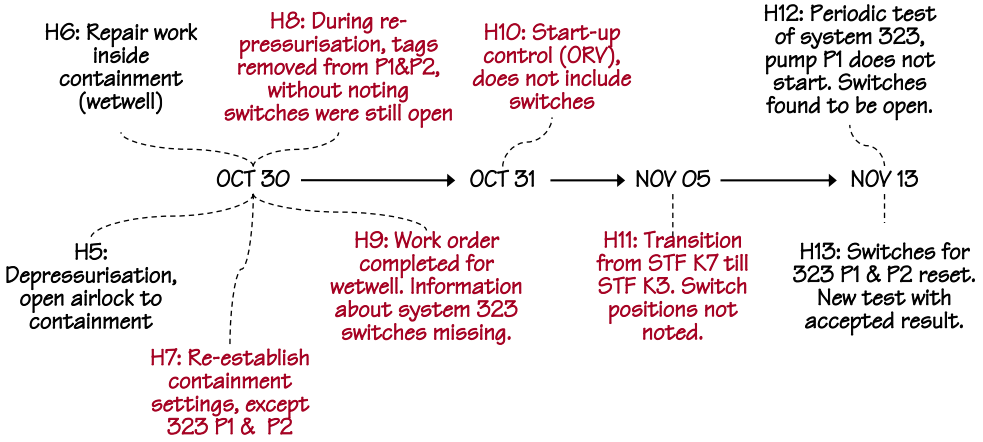
System 323 – sequential analysis



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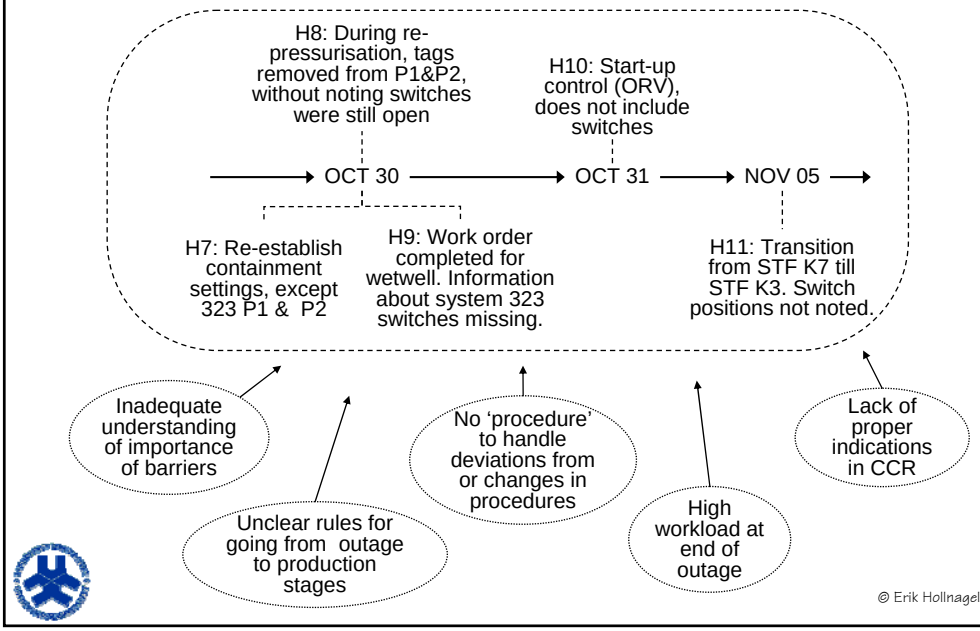
System 323 – epidemiological analysis



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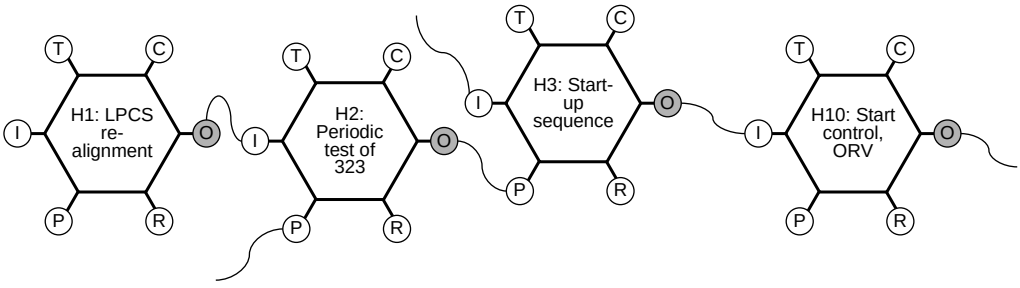
System 323 – normal procedure



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System 323 – potential variability

Common Performance Conditions	Rating category			M	T	O
	Adequate	In-adequate	Unpre-dictable	Functions affected		
Availability of resources	(x)		(x)	X	X	
Training and experience (competence)		(x)	(x)	X		
Quality of communication		(x)	(x)	X		X
HMI and operational support		(x)	(x)	X		
Access to procedures and methods	(x)		(x)	X		
Conditions of work		(x)	(x)	X	X	
Number of goals and conflict resolution	(x)	(x)		X		X
Available time / time pressure	(x)	(x)		X		X
Circadian rhythm, stress		(x)	(x)	X		
Crew collaboration quality	(x)		(x)	X		
Quality and support of organisation	(x)		(x)			X

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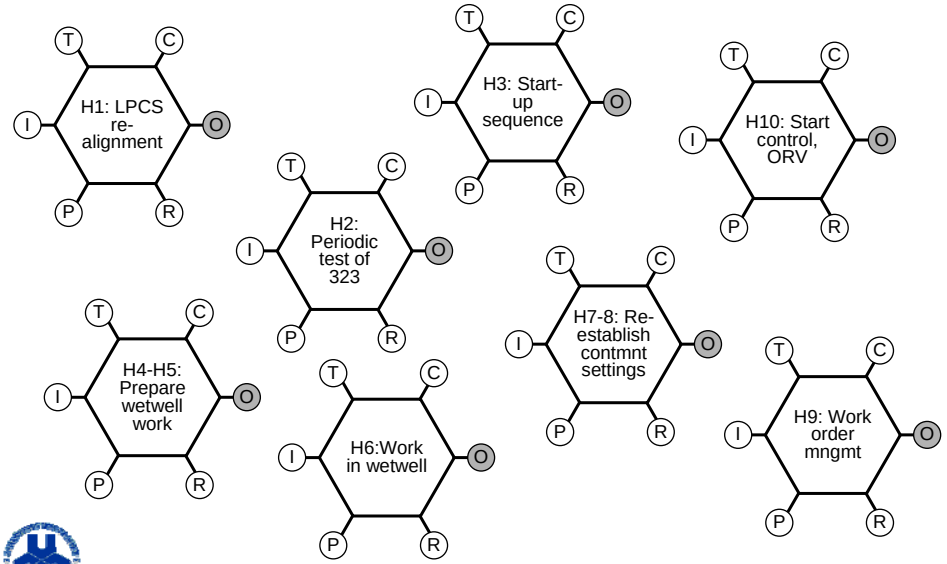
System 323 – actual development



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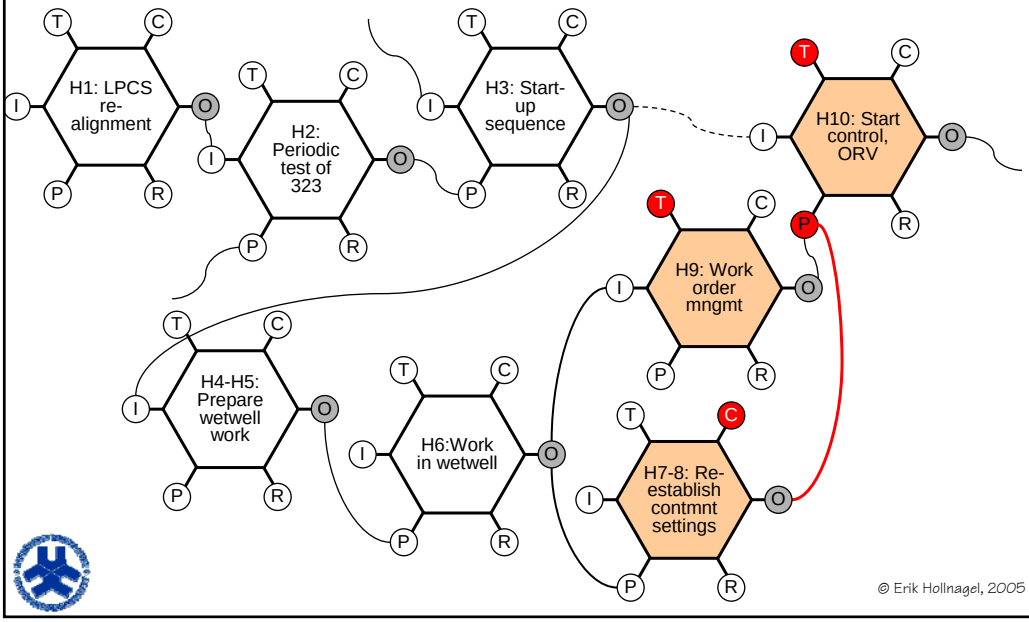
System 323 – actual development



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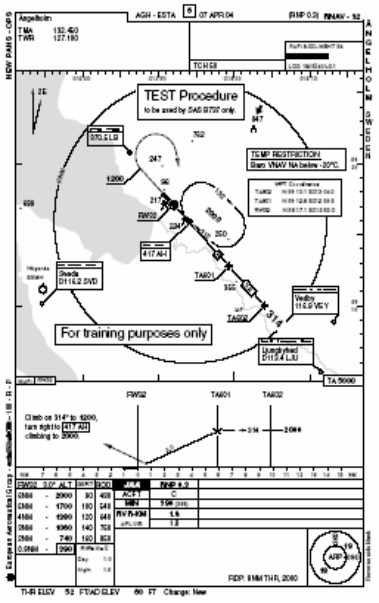
Area navigation



RNAV (area navigation) operations is a method of navigation, which permits aircraft operation on any desired flight path within the coverage of station-referenced navigation aids or within the limits of the capability of self-contained aids, or a combination of these.

The purpose of RNAV approach operations is to fly the aircraft on a pre-defined lateral and vertical track down to the decision height.

This track is defined without the use of land-based navigational aids.

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RNAV steps

1. Code procedure from paper into a digital navigation database
2. Load navigation database in A/C
3. Insert RNAV procedure in FMC flight plan
4. Check correct procedure inserted
5. Engage Autopilot (AP) and/or Flight Director (FD) in LNAV and VNAV modes
6. Monitor navigation performance
7. Control Flight Technical Error (FTE)
8. Manage speed to be appropriate for landing latest at Decision Height
9. Land the aircraft with the use of visual cues from DH

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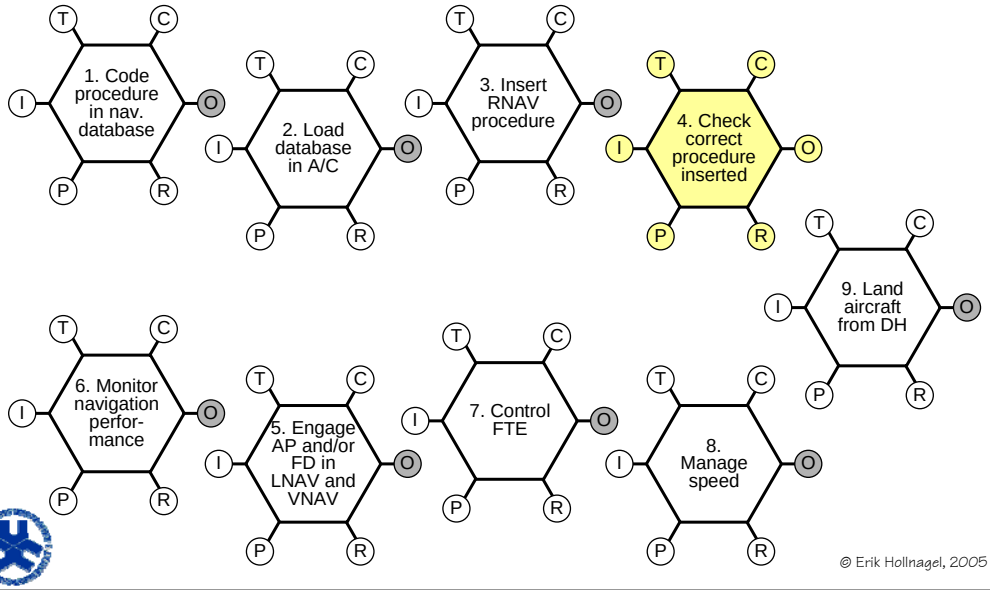
RNAV approach



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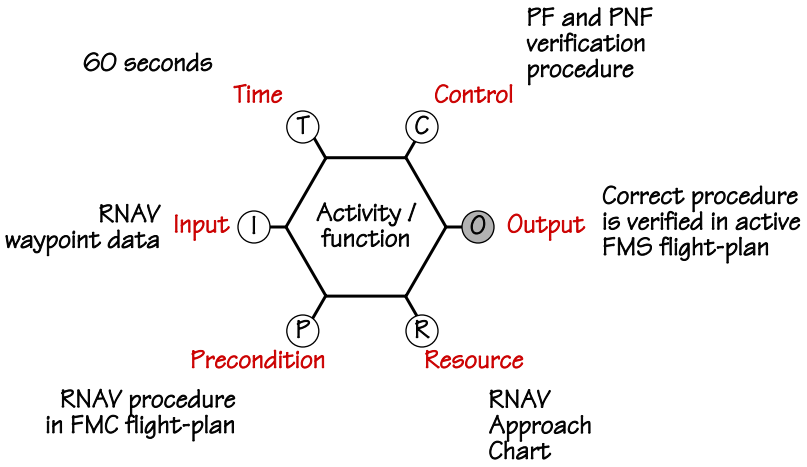
RNAV Approach



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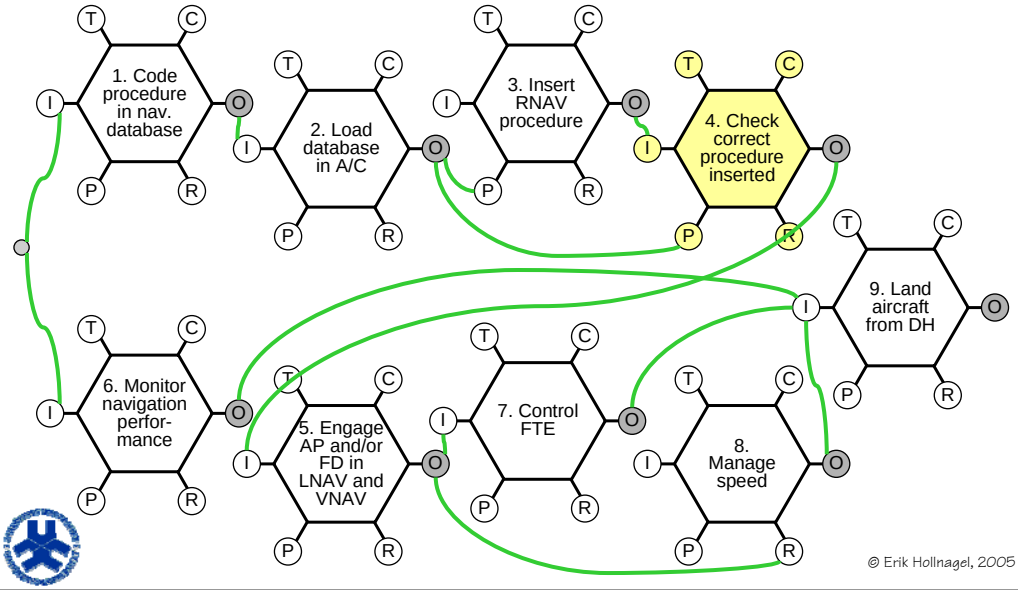
RNAV approach



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Effect of common performance conditions

Common Performance Conditions	Rating category: Adequate	Rating category: In-adequate	Rating category: Unpre-dictable	M	T	O
				Functions affected		
Availability of resources		(x)	(x)	X	X	
Training and experience (competence)		(x)	(x)	X		
Quality of communication	(x)	(x)		X		X
HMI and operational support		(x)	(x)	X		
Access to procedures and methods		(x)	(x)	X		
Conditions of work		(x)	(x)	X	X	
Number of goals and conflict resolution	(x)	(x)		X		X
Available time / time pressure	(x)	(x)		X		X
Circadian rhythm, stress	(x)		(x)	X		
Crew collaboration quality		(x)	(x)	X		
Quality and support of organisation		(x)	(x)			X

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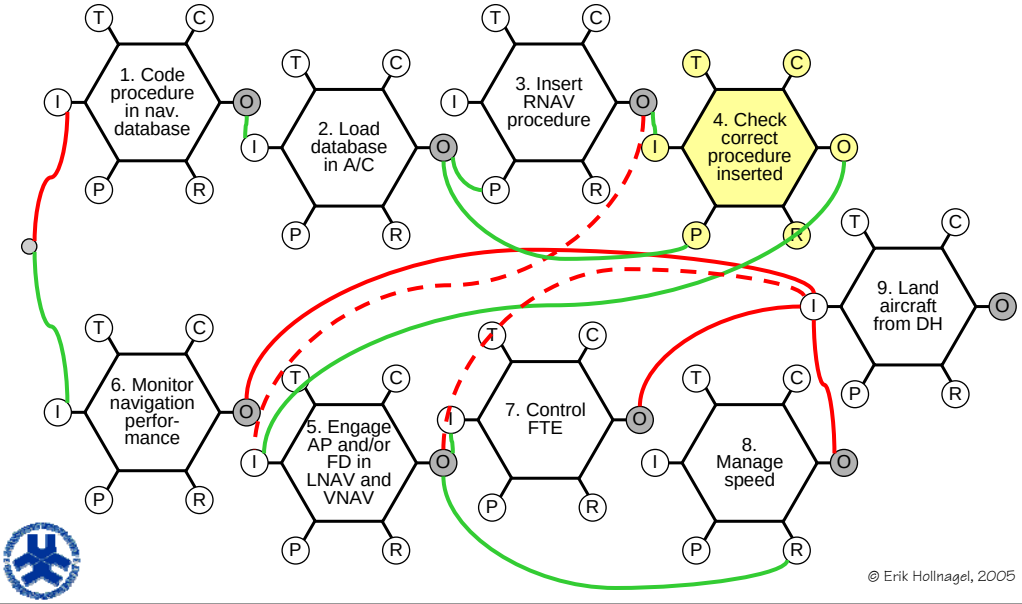
RNAV approach - variations



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Performance monitoring

- Generic performance measurements
  - TRIPOD-DELTA
  - WANO
  - …
- Specific performance measurements
  - ETTO-conditions
  - Typical / frequent adjustment types
  - …
- Barriers
  - Insisting on procedure compliance is an inefficient solution
  - Instead focus on the reasons why short-cuts are made
- Damping (variability) instead of eliminating (failures)
  - Improve the conditions that require trade-offs to be made
  - E.g., additional resources, reduced pressures, better information

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Performance indicators

WANO (World Association of Nuclear Operators):
Collective doses,
fuel index,
unavailability of safety systems,
unplanned scrams,
availability,
unplanned losses of production

Generic (from survey of about 80 models of organisational effectiveness):
top-level commitment
awareness (of safety problems)
Preparedness
Flexibility
just culture
organisational learning
visibility (of safety margins)

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Conclusions

Risk assessment based on principle of functional resonance

→ Not constrained by pre-defined links and relations (event trees)

Accidents seen as a result of concurrencies

→ Analysis: find concurrencies present in the situation

No assumptions about individual failures

→ Prediction: find potential concurrencies for the task/activity

Determine when performance variability is likely

Determine how variability may express itself

Determine how other functions may be affected by variability (resonance).

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Exercise

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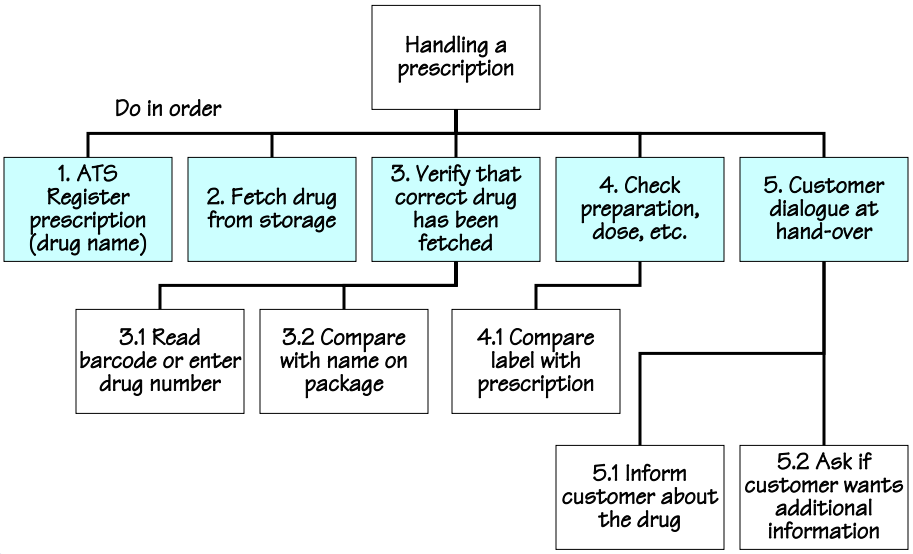
Handling drug prescriptions (HTA)



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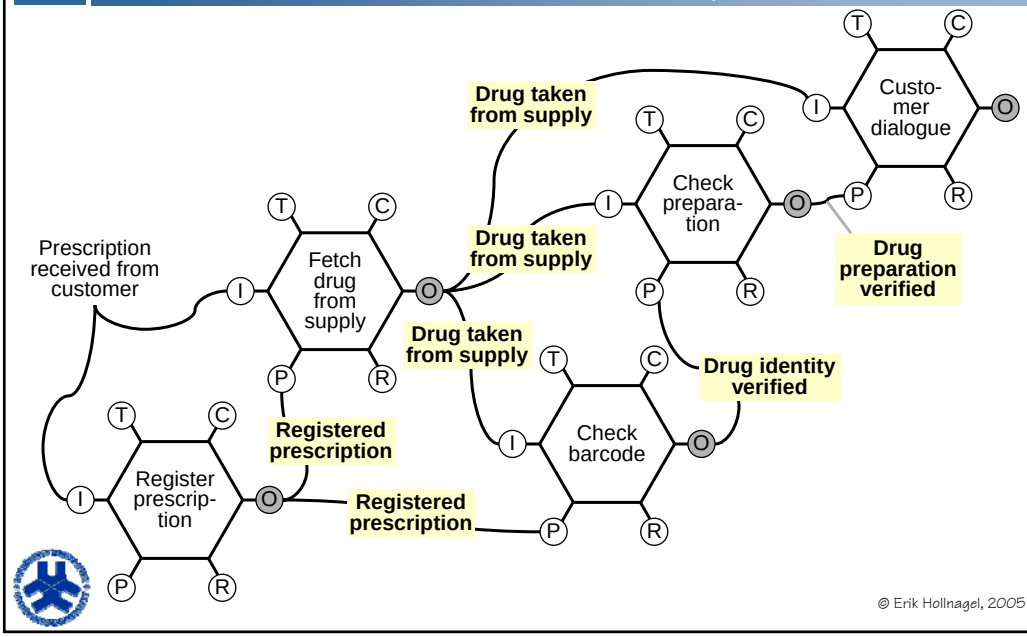
Drug handling – normal procedure



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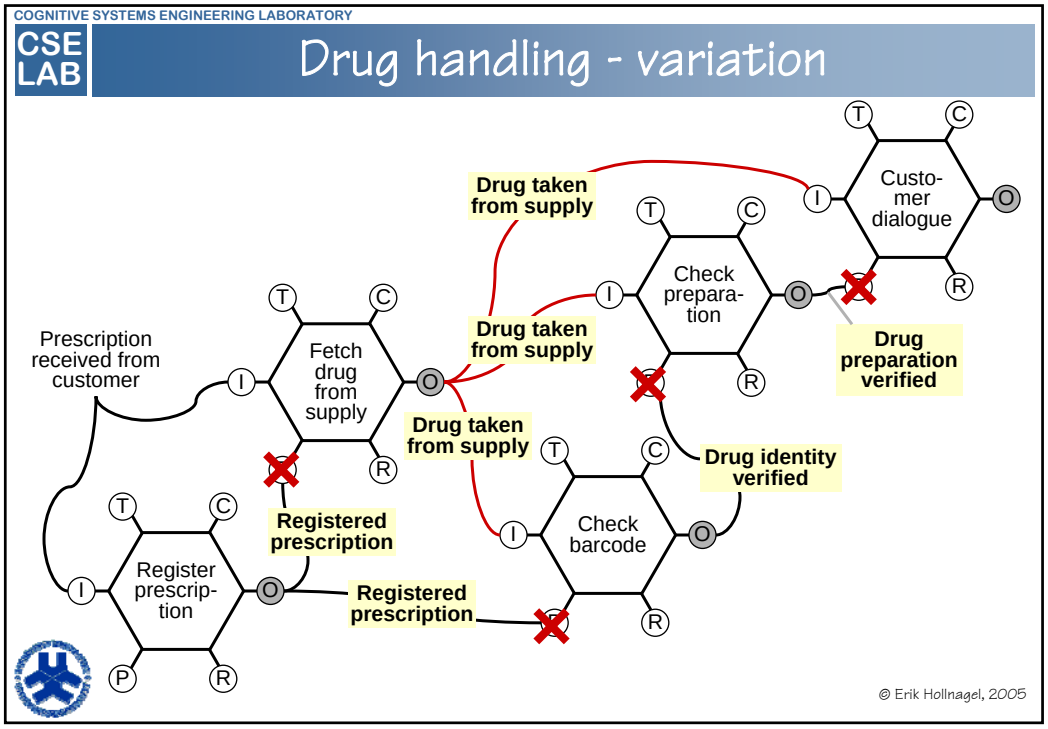
Number of goals and conflict resolution	(x)		(x)	X		X
Available time / time pressure	(x)		(x)	X		X
Circadian rhythm, stress		(x)	(x)	X		
Crew collaboration quality		(x)	(x)	X		
Quality and support of organisation	(x)		(x)			X


COGNITIVE SYSTEMS ENGINEERING LABORATORY
CSE LAB
Drug handling - variation
Prescription received from customer
Fetch drug from supply
Register prescrip-tion
Check prepara-tion
Check barcode
Custo-mer dialogue
Drug taken from supply
Drug taken from supply
Drug taken from supply
Registered prescription
Registered prescription
Drug preparation verified
Drug identity verified
T
C
I
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R
P
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