FRAM strongest vessel in the world and has **advanced further** south and north than any other

2nd FRAM WORKSHOP

20-22 February, 2008

Ecole des Mines de Paris, Sophia Antipolis, France

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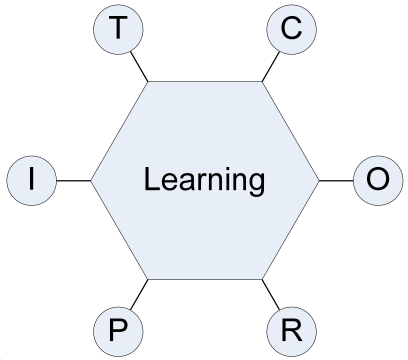

FRAM: New insight in accident investigation?

Comparing
Sequentially Timed Events Plotting method
(STEP, Hendrick & Benner, 1986) and
Functional Resonance Accident Model
(FRAM, Hollnagel, 2004)

Ivonne Herrera
Rogier Woltjer

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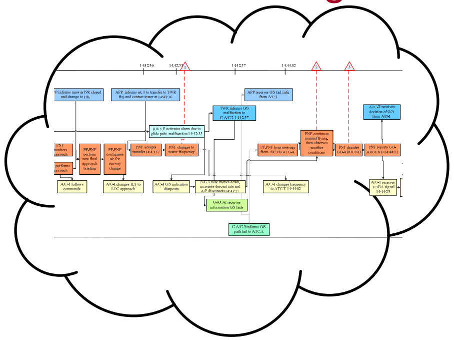
Purpose

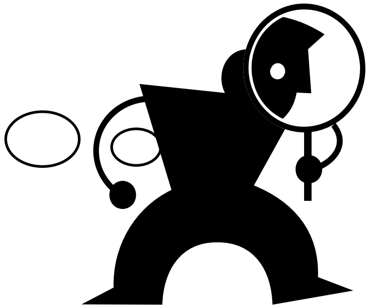
- What we can learn from both methods, how, when, and why to apply them, and which aspects of these methods may need improvement

Multi-sequential accident model

Assumption: An accident is a special class of process where a perturbation transforms a dynamically stable activity into unintended interacting changes of states with a harmful outcome.



Sequential Time Event Plotting



Consequence: Accidents are prevented by identifying, classifying and eliminating safety hazards.
Safety requires constant ability to detect uncontrolled changes and counteract their effects.

Hazards-risks: Are disruptive changes (perturbations) that persons or things introduce, which trigger undesired interactions

Adapted based on © Erik Hollnagel, 2004

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STEP in short

- Multilinear sequences in a worksheet
  - Basis for the investigation
  - Establishes recommendations from the accident sequence
- Worksheet structure
  - Rows actors
  - Columns follows time frame
  - The description of the accident is performed by universal events building blocks. Events flows in a process linked with arrows
- Three tests to check completeness of the sequence

FRAM steps

0 Define the purpose of modelling (accident investigation/risk assessment) and describe the target situation or scenario to be analysed.

1 Identify essential system functions; characterise each function by six basic aspects.

2 Characterise the (context dependent) potential variability using a checklist. Consider both normal and worst case variability.

3 Define functional resonance based on possible dependencies (couplings) among functions.

4 Identify barriers for variability (damping factors) and specify required performance monitoring.

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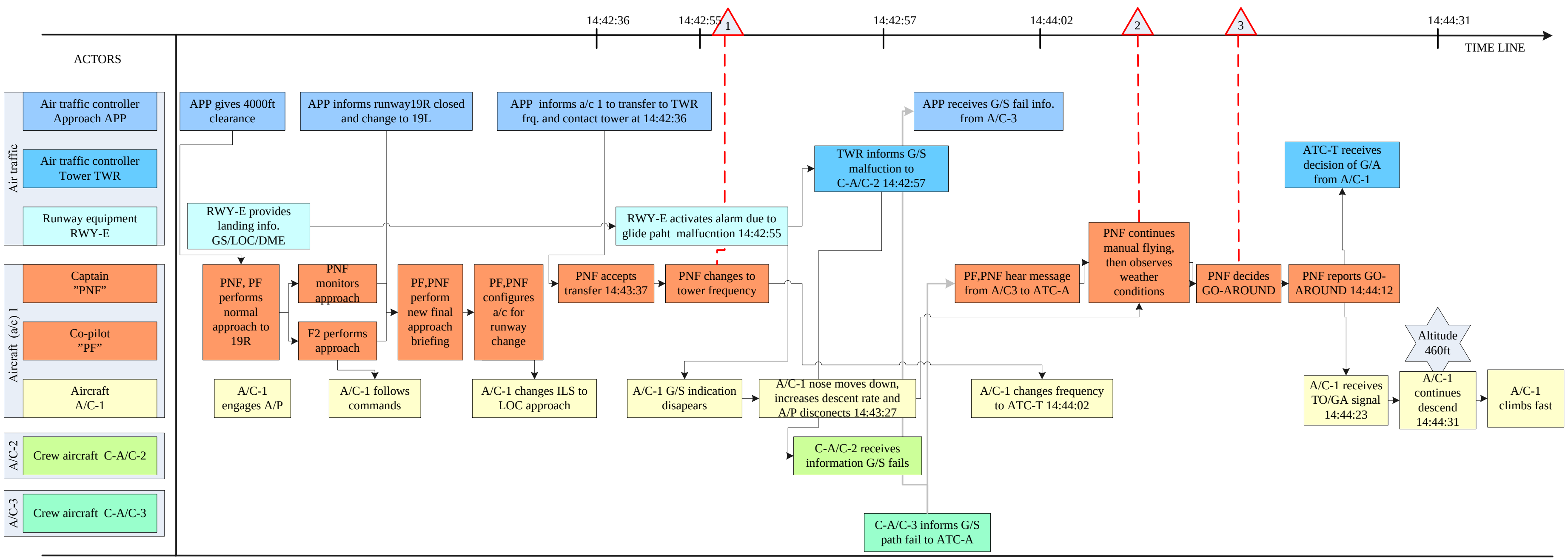
The LN-KKL case

” *Boeing B737-36N from Norwegian Air Shuttle was enroute from Stavanger lufthavn Sola to Oslo lufthavn Gardermoen (OSL). Under the last part of the flight, at this time the aircraft has established localizer (LLZ) and* ***glidepath (GP) for runway 19L, the glidepath signal was off****. Immediately after the glide path signal disappears the aircraft increases descend rate to 2200ft/min while the aircraft is flown manually towards LLZ-minima. The* ***aircraft came into a significant lower approach than expected and was at the lowest at 460ft*** *over ground at DME 4,8. The distance at this point from the runway terminal* ***should be 1100ft higher****. The approach was cancelled due to the aircraft was still in dense clouds and the aircraft drifted a little bit from the LLZ at OSL. The* ***crew did not notice*** *that the* ***aircraft movements were not normal****.”*

Norwegian Accident Investigation Board SL RAP.: 20/2004

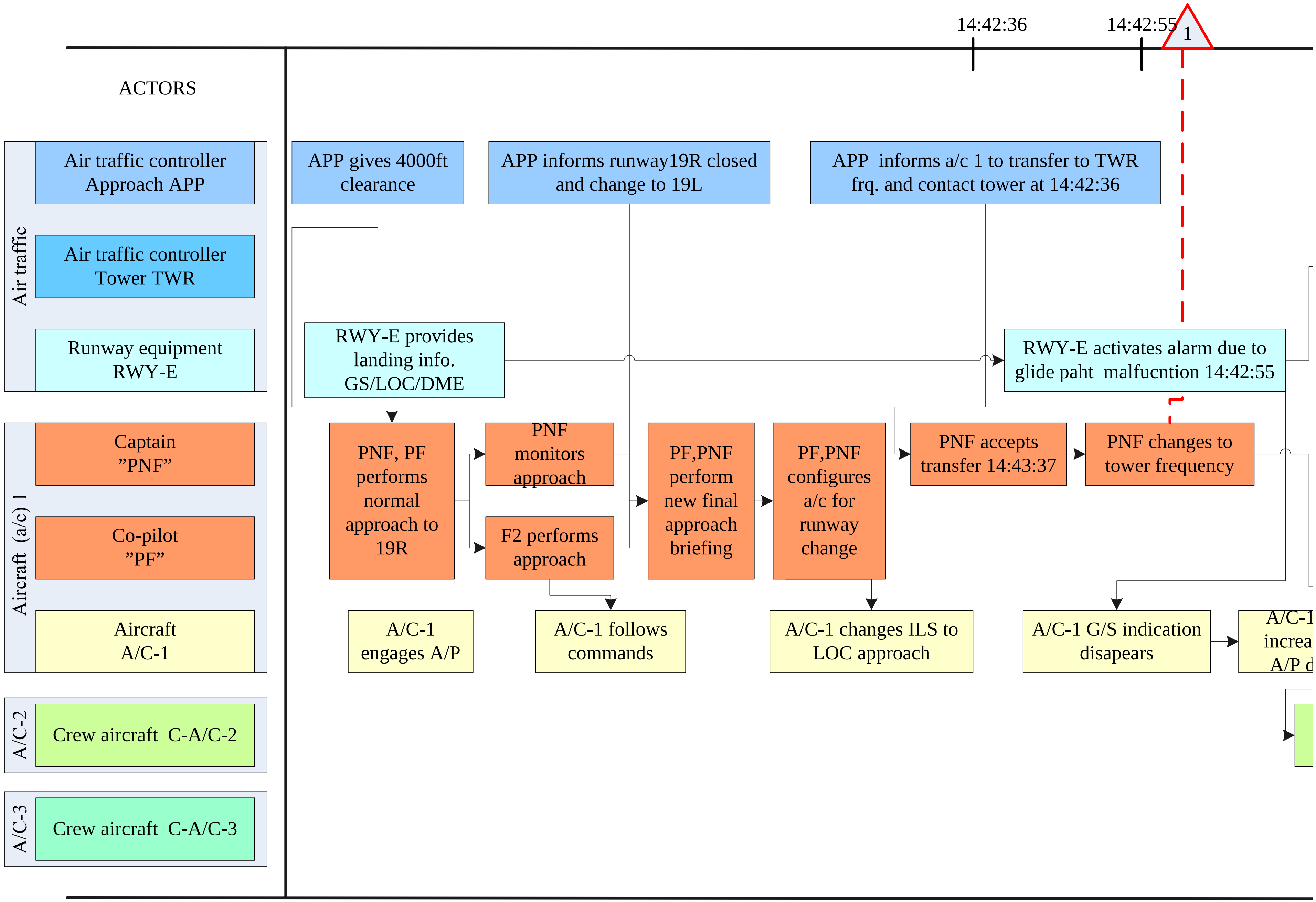
STEP worksheet



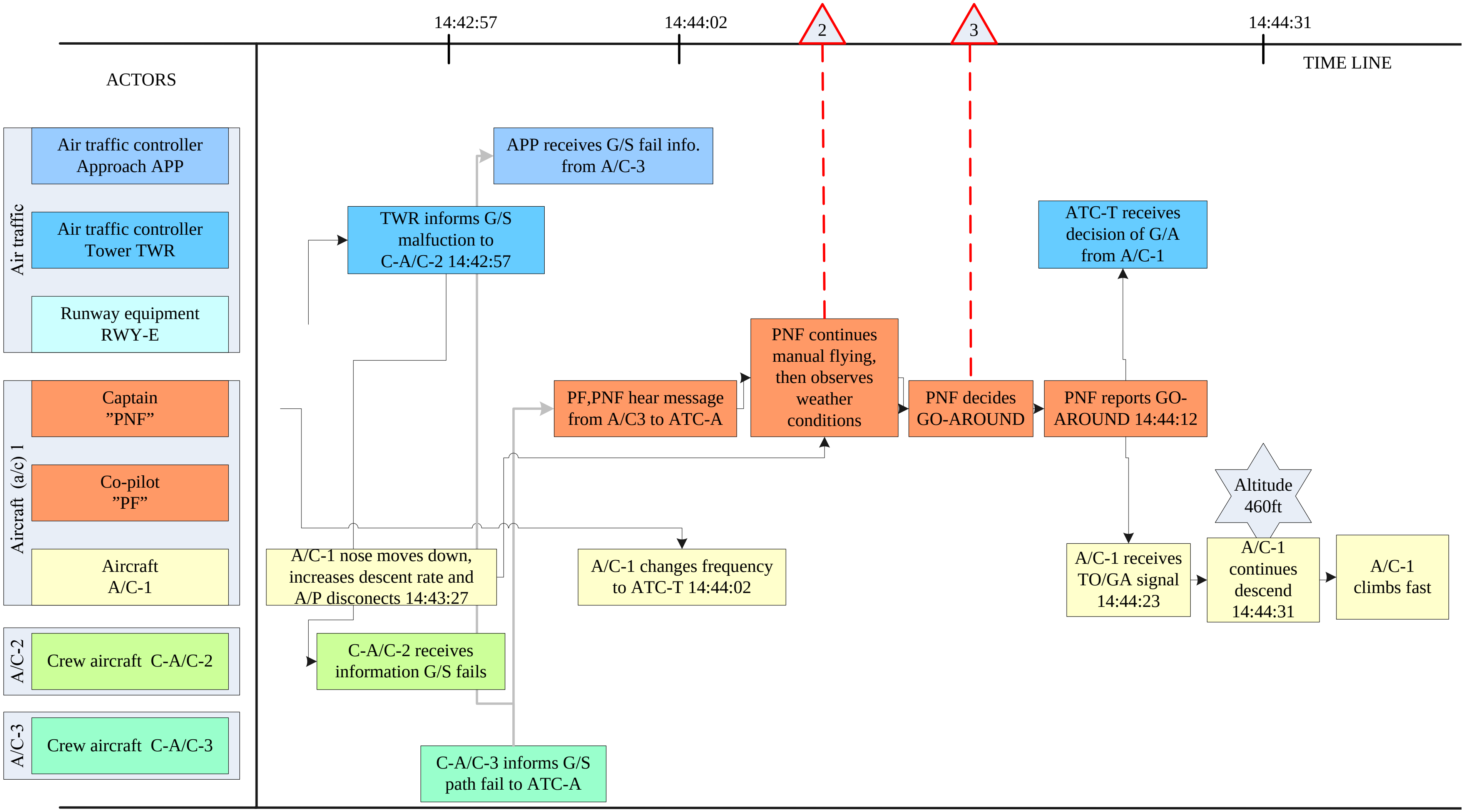
1 There is no communication between tower and aircraft 1

2 Not coordinated change roles between flying pilot and non flying pilot

3 Pilots not aware of low altitude



There is no communication between tower and aircraft 1


14:42:57
14:44:02
2
3
14:44:31
TIME LINE
ACTORS
Air traffic
Air traffic controller Approach APP
Air traffic controller Tower TWR
Runway equipment RWY-E
Aircraft (a/c) 1
Captain "PNF"
Co-pilot "PF"
Aircraft A/C-1
A/C-2
Crew aircraft C-A/C-2
A/C-3
Crew aircraft C-A/C-3
APP receives G/S fail info. from A/C-3
TWR informs G/S malfuction to C-A/C-2 14:42:57
ATC-T receives decision of G/A from A/C-1
PNF continues manual flying, then observes weather conditions
PF,PNF hear message from A/C3 to ATC-A
PNF decides GO-AROUND
PNF reports GO-AROUND 14:44:12
Altitude 460ft
A/C-1 nose moves down, increases descent rate and A/P disconects 14:43:27
A/C-1 changes frequency to ATC-T 14:44:02
A/C-1 receives TO/GA signal 14:44:23
A/C-1 continues descend 14:44:31
A/C-1 climbs fast
C-A/C-2 receives information G/S fails
C-A/C-3 informs G/S path fail to ATC-A

FRAM steps

0 Define the purpose of modelling (accident investigation/risk assessment) and describe the target situation or scenario to be analysed.

1 Identify essential system functions; characterise each function by six basic parameters.

2 Characterise the (context dependent) potential variability using a checklist. Consider both normal and worst case variability.

3 Define functional resonance based on possible dependencies (couplings) among functions.

4 Identify barriers for variability (damping factors) and specify required performance monitoring.

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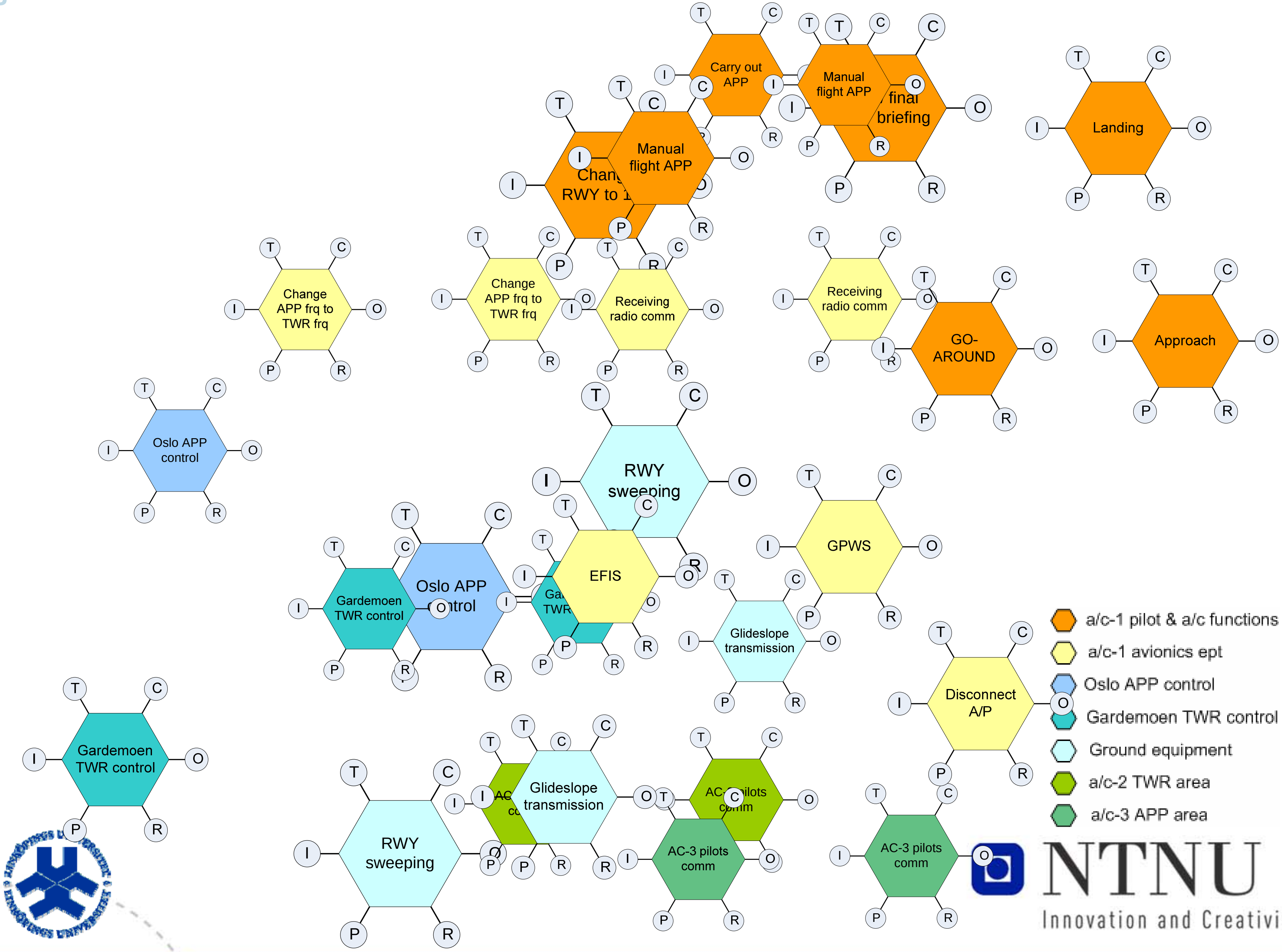
Applying FRAM

0 Define the purpose of modelling (accident investigation) and describe the target situation or scenario to be analysed

Result: Purpose of the analysis and context

1 Identify essential system functions; characterise each function by six basic parameters

Result: List of functions



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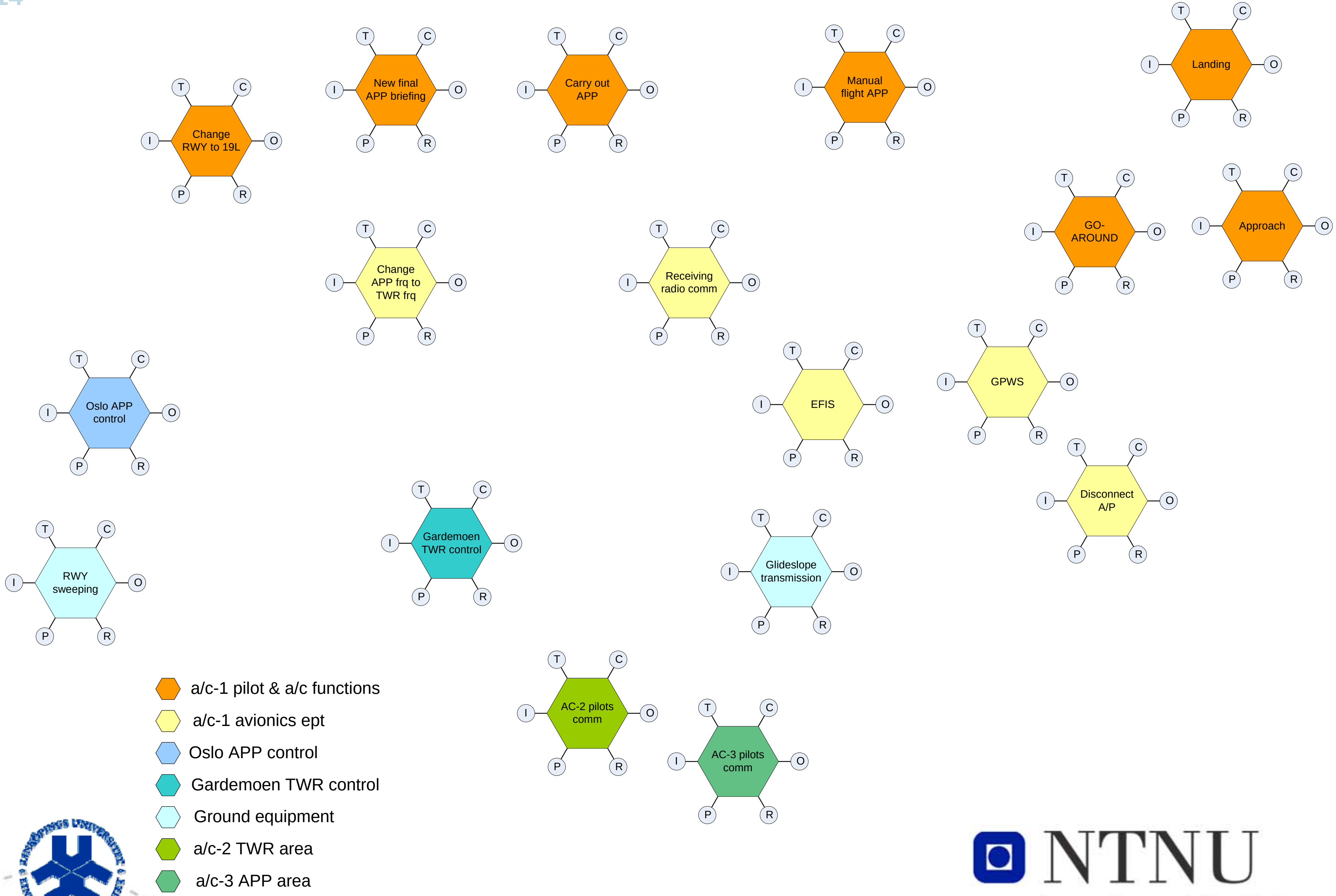
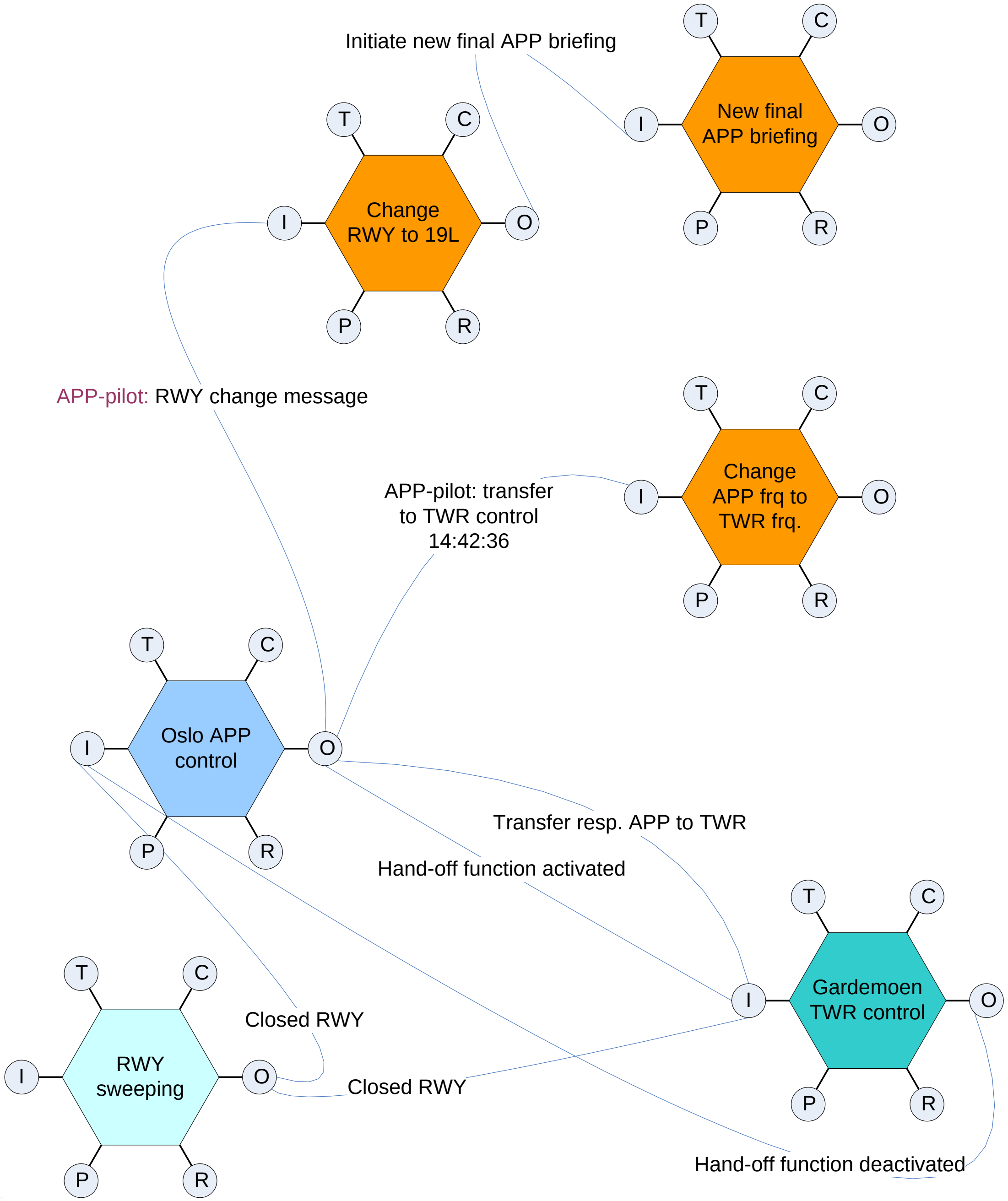
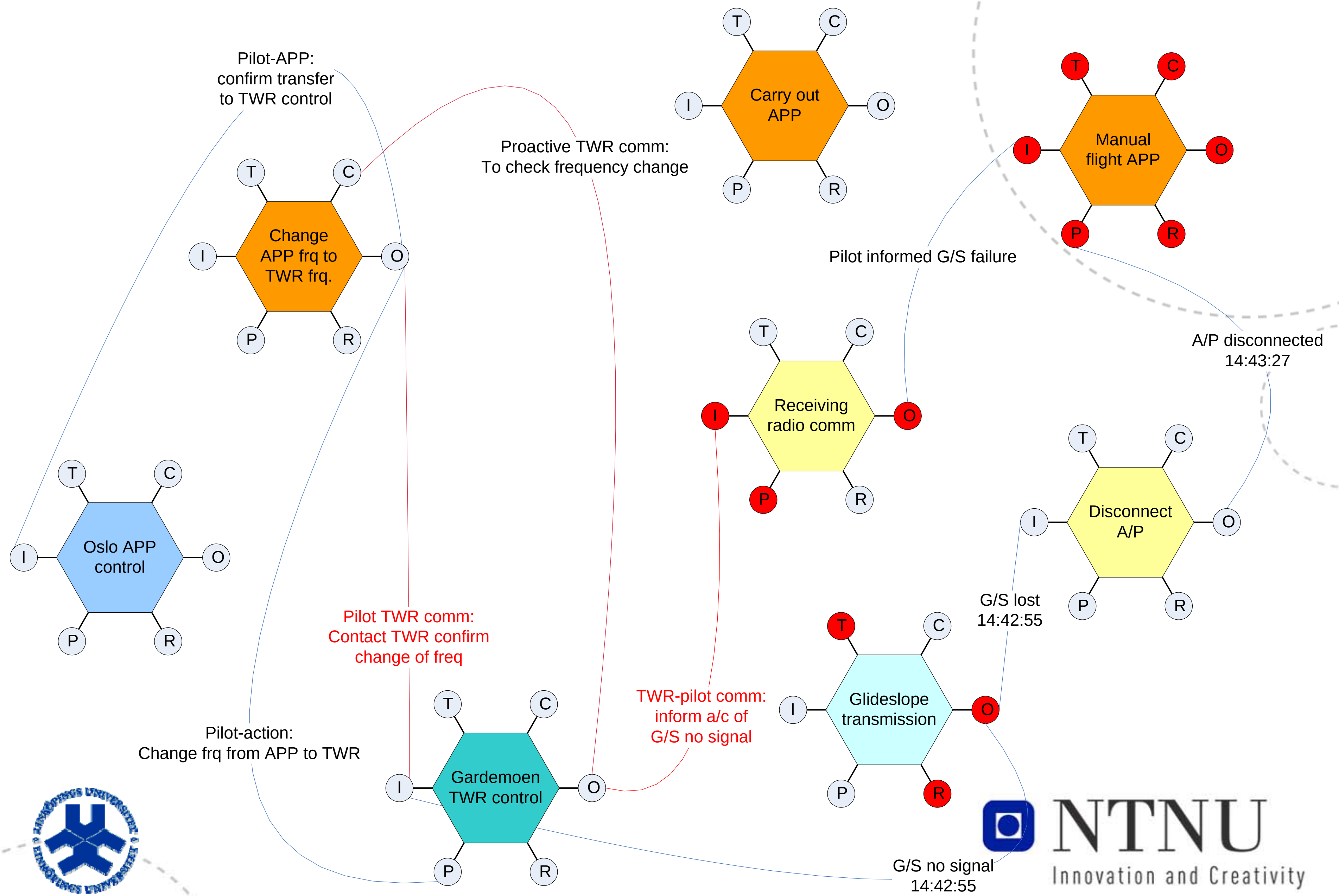

Change RWY to 19L
New final APP briefing
Carry out APP
Manual flight APP
Landing
GO-AROUND
Approach
Change APP frq to TWR frq
Receiving radio comm
EFIS
GPWS
Disconnect A/P
Oslo APP control
RWY sweeping
Gardemoen TWR control
Glideslope transmission
AC-2 pilots comm
AC-3 pilots comm
T
C
I
O
P
R
a/c-1 pilot & a/c functions
a/c-1 avionics ept
Oslo APP control
Gardemoen TWR control
Ground equipment
a/c-2 TWR area
a/c-3 APP area



Instantiation, connections before 14:42:36

Instantiation, connections 14:42:37-14:43:27



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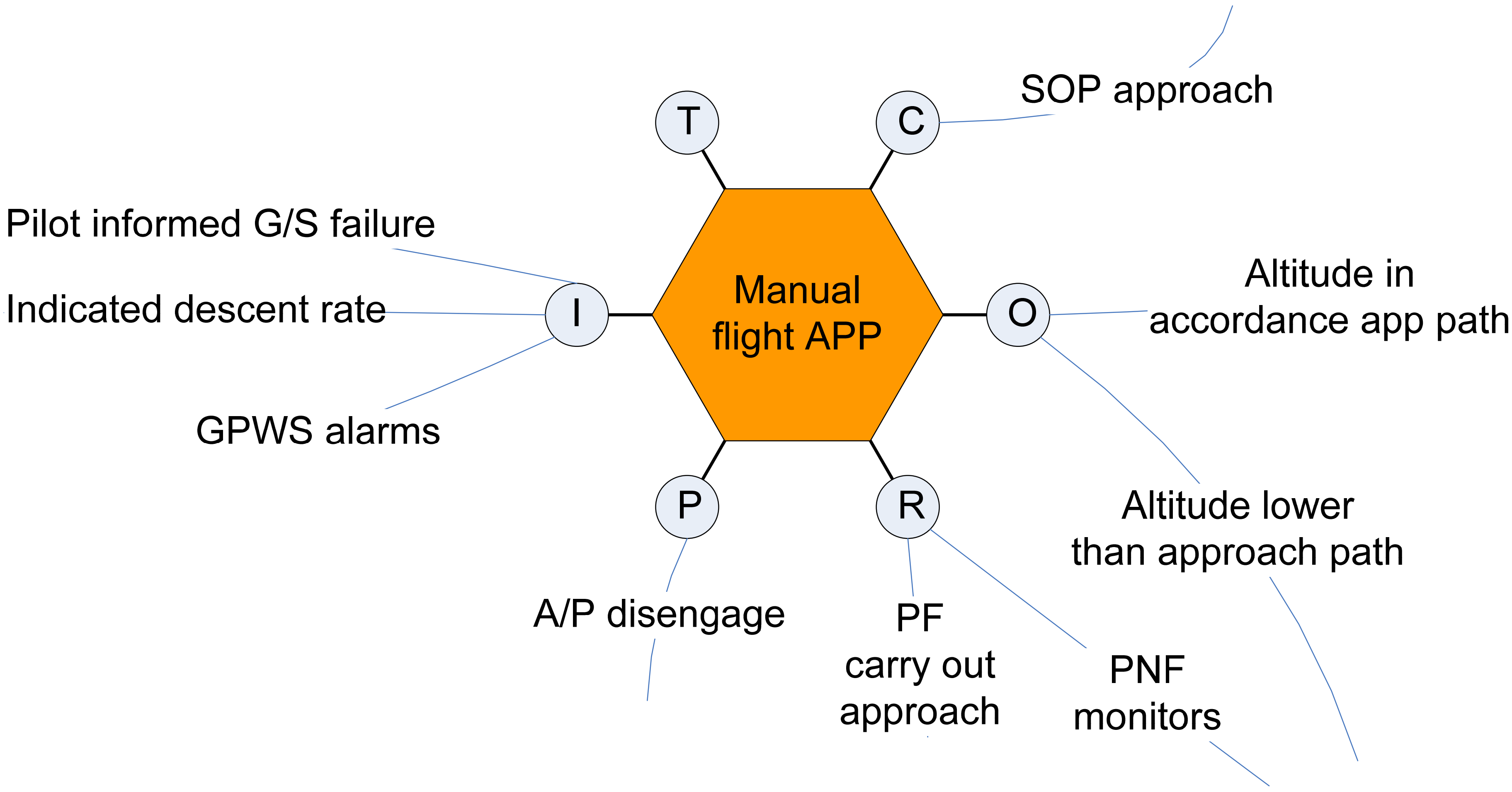
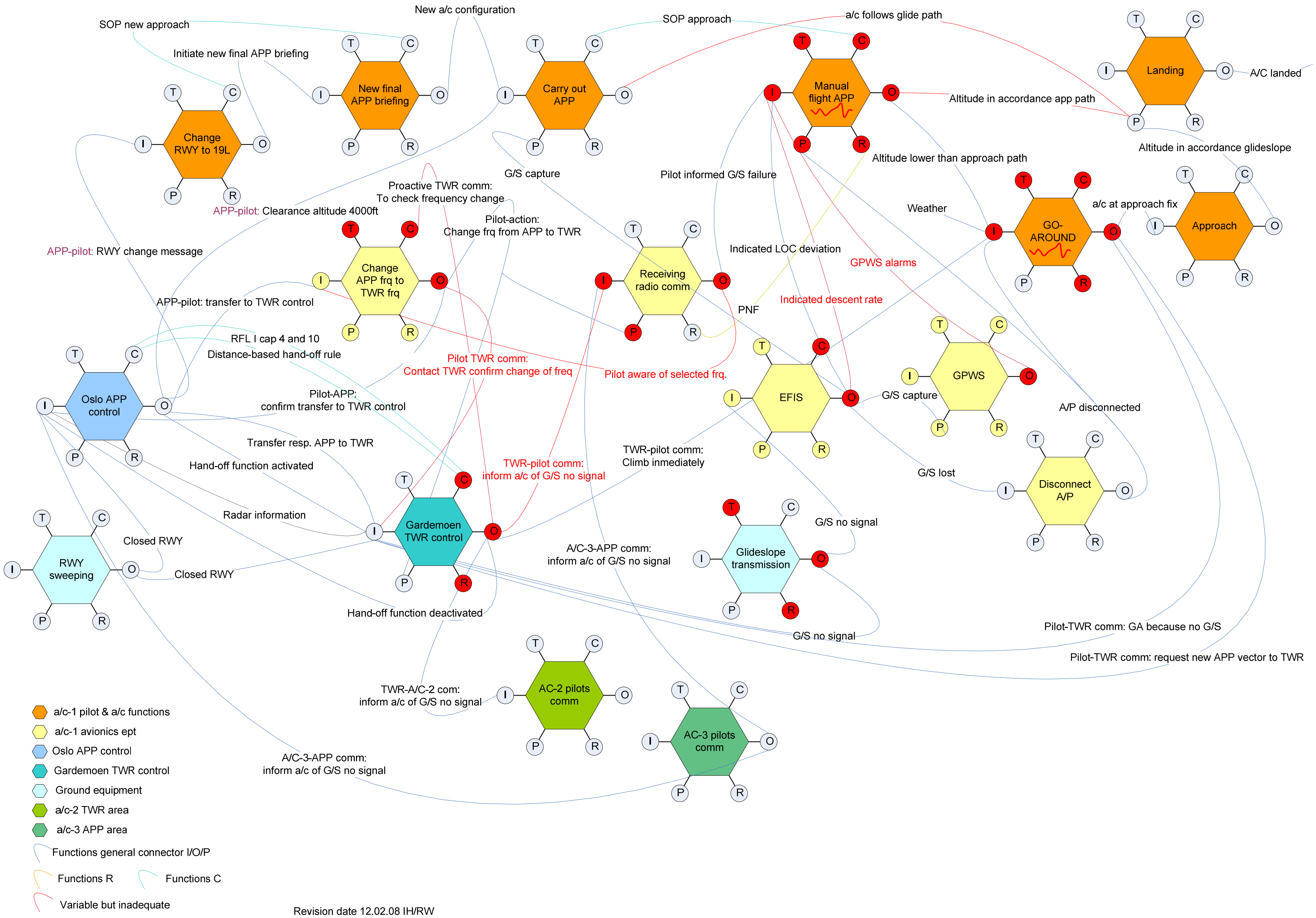


SOP approach
T
C
Pilot informed G/S failure
Indicated descent rate
I
Manual
flight APP
O
Altitude in
accordance app path
GPWS alarms
P
R
Altitude lower
than approach path
A/P disengage
PF
carry out
approach
PNF
monitors



SOP new approach
Initiate new final APP briefing
New a/c configuration
SOP approach
a/c follows glide path
New final APP briefing
Change RWY to 19L
Carry out APP
Manual flight APP
Landing
A/C landed
Altitude in accordance app path
Altitude in accordance glideslope
Altitude lower than approach path
G/S capture
Pilot informed G/S failure
Proactive TWR comm: To check frequency change
APP-pilot: Clearance altitude 4000ft
Pilot-action: Change frq from APP to TWR
APP-pilot: RWY change message
Change APP frq to TWR frq
Receiving radio comm
Weather
a/c at approach fix
GO-AROUND
Approach
Indicated LOC deviation
GPWS alarms
Indicated descent rate
PNF
APP-pilot: transfer to TWR control
RFL I cap 4 and 10
Distance-based hand-off rule
Pilot TWR comm: Contact TWR confirm change of freq
Pilot aware of selected frq.
Oslo APP control
EFIS
GPWS
G/S capture
A/P disconnected
Pilot-APP: confirm transfer to TWR control
Transfer resp. APP to TWR
Hand-off function activated
TWR-pilot comm: inform a/c of G/S no signal
TWR-pilot comm: Climb immediately
G/S lost
Disconnect A/P
Radar information
Gardemoen TWR control
Closed RWY
RWY sweeping
Closed RWY
A/C-3-APP comm: inform a/c of G/S no signal
Glideslope transmission
G/S no signal
Hand-off function deactivated
G/S no signal
Pilot-TWR comm: GA because no G/S
Pilot-TWR comm: request new APP vector to TWR
TWR-A/C-2 com: inform a/c of G/S no signal
AC-2 pilots comm
AC-3 pilots comm
A/C-3-APP comm: inform a/c of G/S no signal
a/c-1 pilot & a/c functions
a/c-1 avionics ept
Oslo APP control
Gardemoen TWR control
Ground equipment
a/c-2 TWR area
a/c-3 APP area
Functions general connector I/O/P
Functions R
Functions C
Variable but inadequate
Revision date 12.02.08 IH/RW

2 Potential for variability

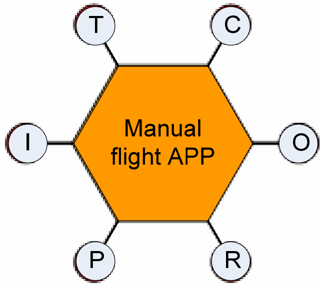
11 Common Performance Conditions (CPCs):

- Availability of personnel and equipment,
- Training, preparation, competence,
- Communication quality,
- Human-machine interaction, operational support,
- Availability of procedures,
- Work conditions,
- Goals, number and conflicts,
- Available time,
- Circadian rhythm, stress,
- Team collaboration,
- Organizational quality

Result: Characterization of variability

After identifying the CPCs, the variability needs to be determined in a qualitative way in terms of stability, predictability, sufficiency, and boundaries of performance

2 Potential for variability example



11 Common Performance Conditions (CPCs):

- Availability of personnel and equipment,
- Training, preparation, competence, *PF 64 hrs on type*
- Communication quality, *crew did not contact TWR (delay)*
- Human-machine interaction, operational support, *EFIS & GPWS alerts unclear*
- Availability of procedures,
- Work conditions,
- Goals, number and conflicts, *overloaded*
- Available time,
- Circadian rhythm, stress,
- Team collaboration, *switched roles*
- Organizational quality

FRAM Normal variability

- Change runway to 19L - Time available not inadequate for 15miles.
  - Briefings over 10000ft SOP but changes are not out of the ordinary.
- Change APP frq to TWR frq - Quality of communication -
  - It is not abnormal delay, but it does not happen very often.
- Change APP frq to TWR frq - Concurrent goals - CRM
  - Different types of captains from supportive CRM to a situation where pilots do not “share” responsibilities.
- Receiving radio communication - Quality of communication
  - Pilots “overload” to step back and analyse the situation to recognise that APP freq still selected

How to support the management of variability?

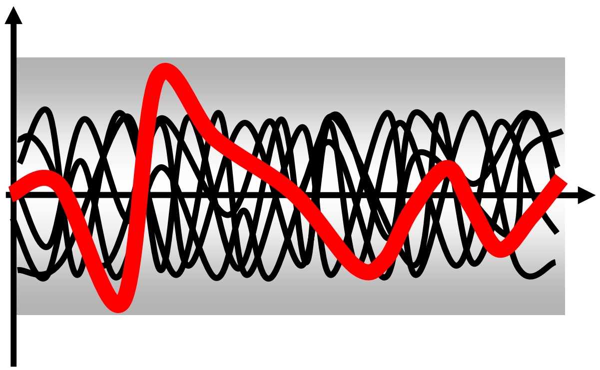
3 Functional resonance

- Based on interdependencies among the functions i.e. couplings

- Network connections
- Network problems

Result: Stochastic resonance

Determination of how "stochastic resonance" results from variability propagation



Hollnagel, 2007

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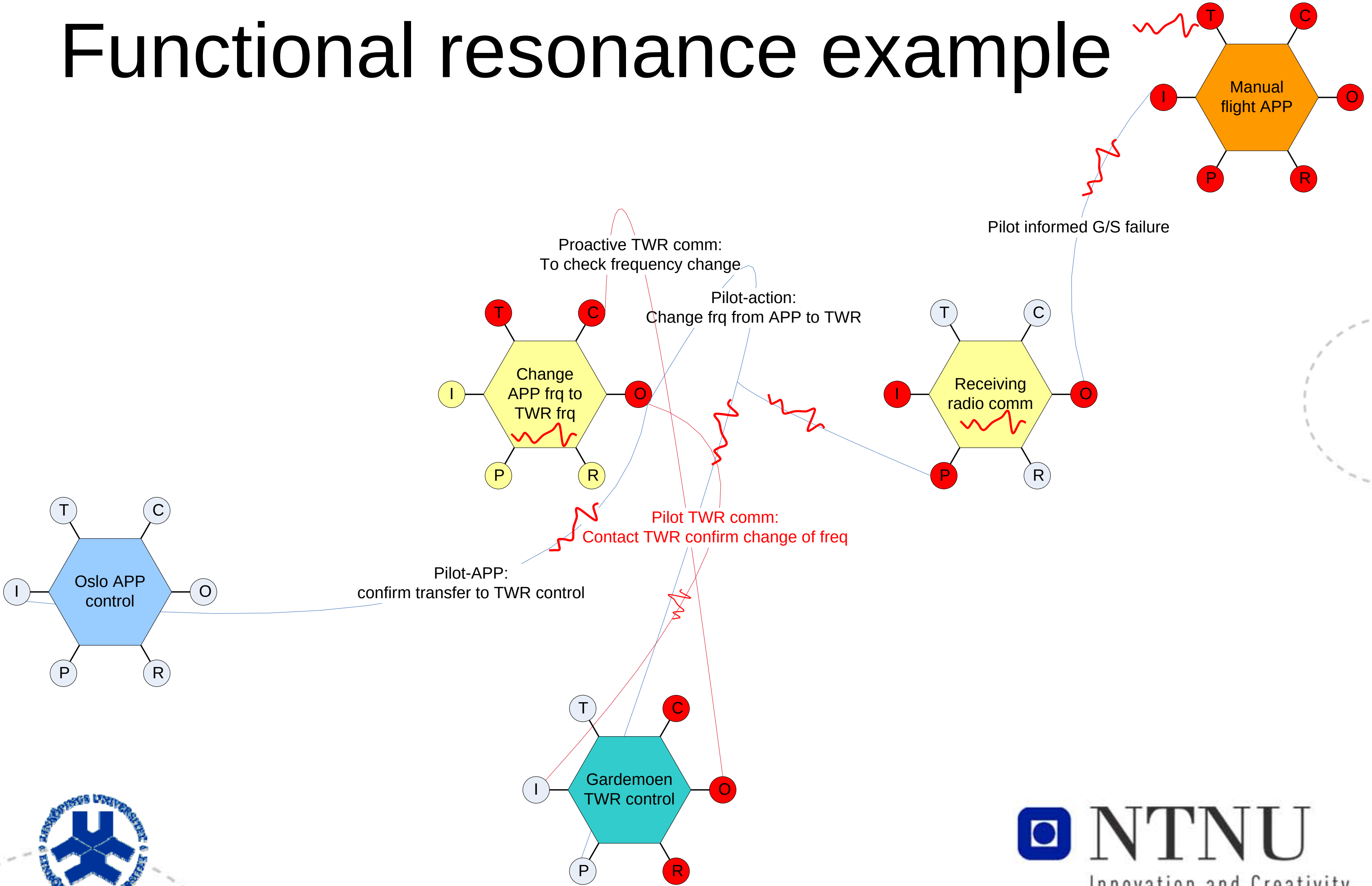
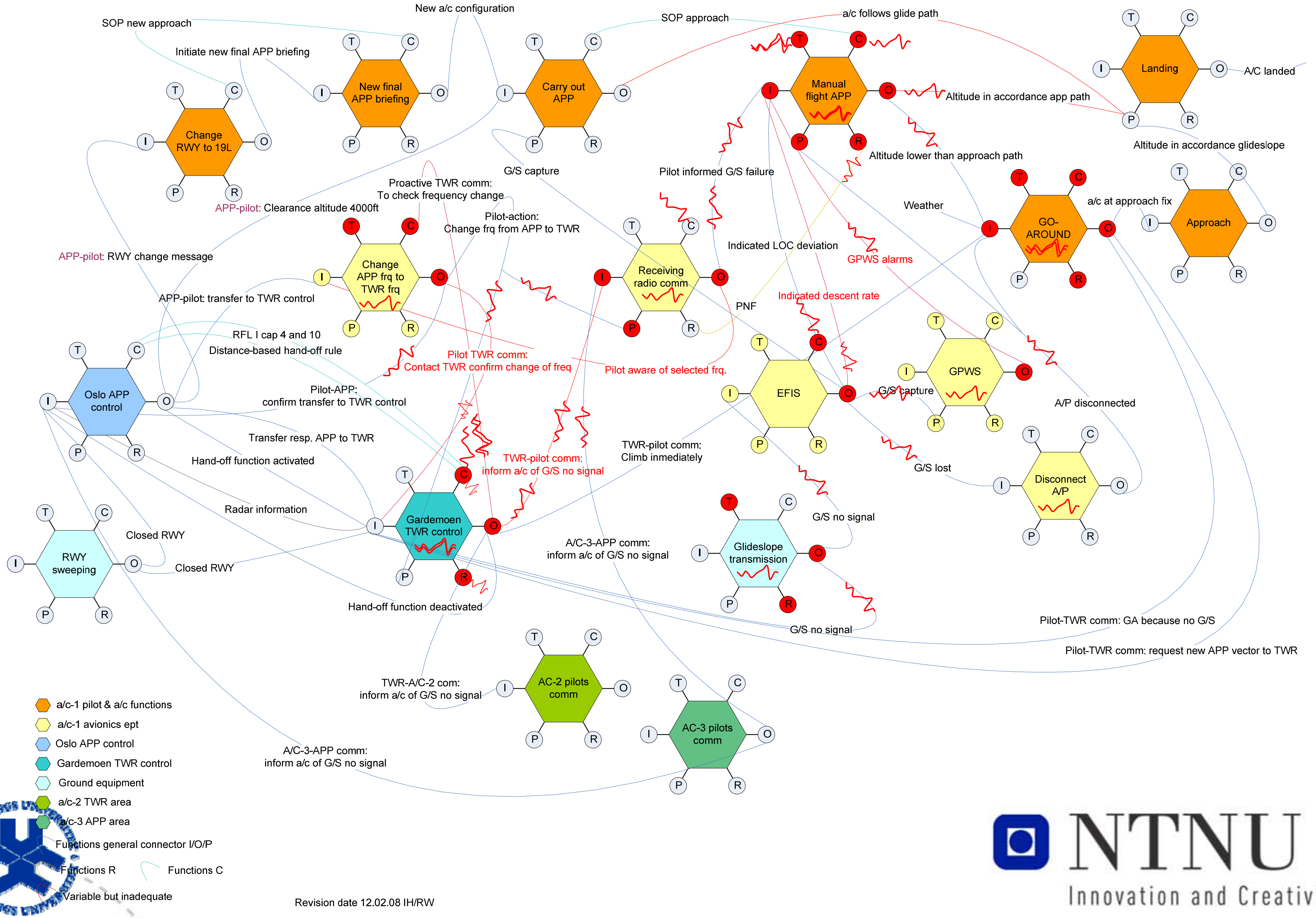
Functional resonance example



Functional resonance - incident



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4 Identify barriers for variability and…

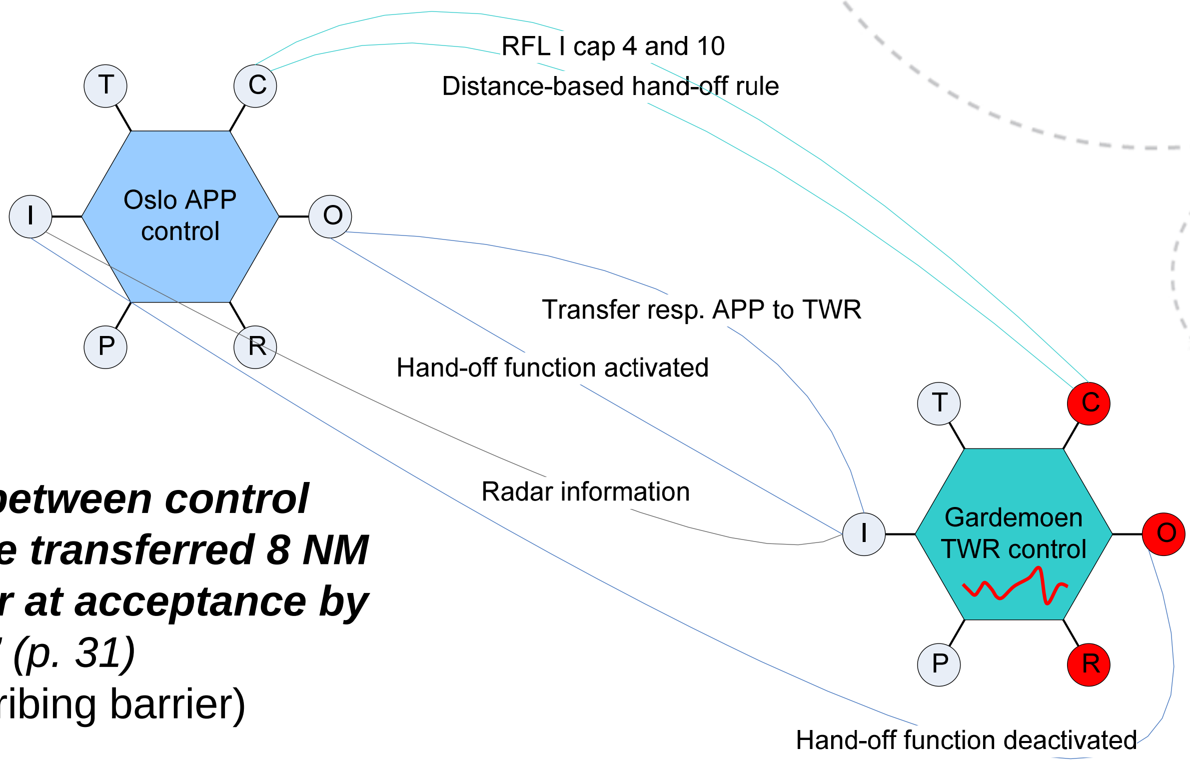
(1) Physical barrier systems block the movement or transportation of mass, energy, or information. Examples include fuel tanks, safety belts, and filters.

(2) Functional barrier systems set up pre-conditions that need to be met before an action (by human and/or machine) can be undertaken. Examples include locks, passwords, and sprinklers.

(3) Symbolic barrier systems are indications of constraints on action that are physically present. Examples include signs, checklists, alarms, and clearances. Potential functions encompass preventing, regulating, and authorizing actions.

(4) Incorporeal barrier systems are indications of constraints on action that are not physically present. Examples include ethical norms, group pressure, rules, and laws.

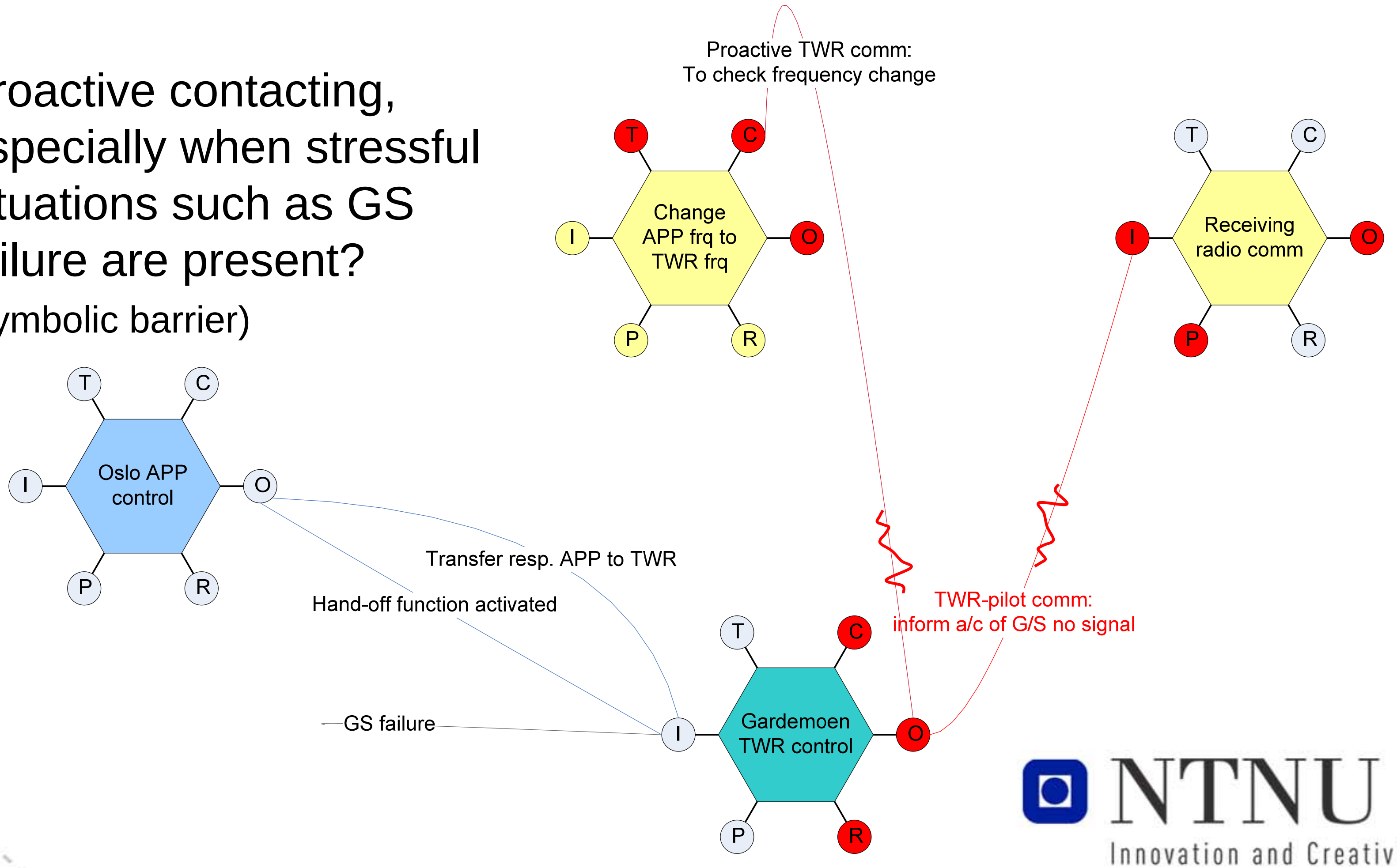
Barriers analysis – HSLB Recommendations



"Responsability between control centers should be transferred 8 NM before landing, or at acceptance by radar hand over." *(p. 31)*
(incorporeal prescribing barrier)

FRAM Recommendations

- Proactive contacting, especially when stressful situations such as GS failure are present?
  (symbolic barrier)

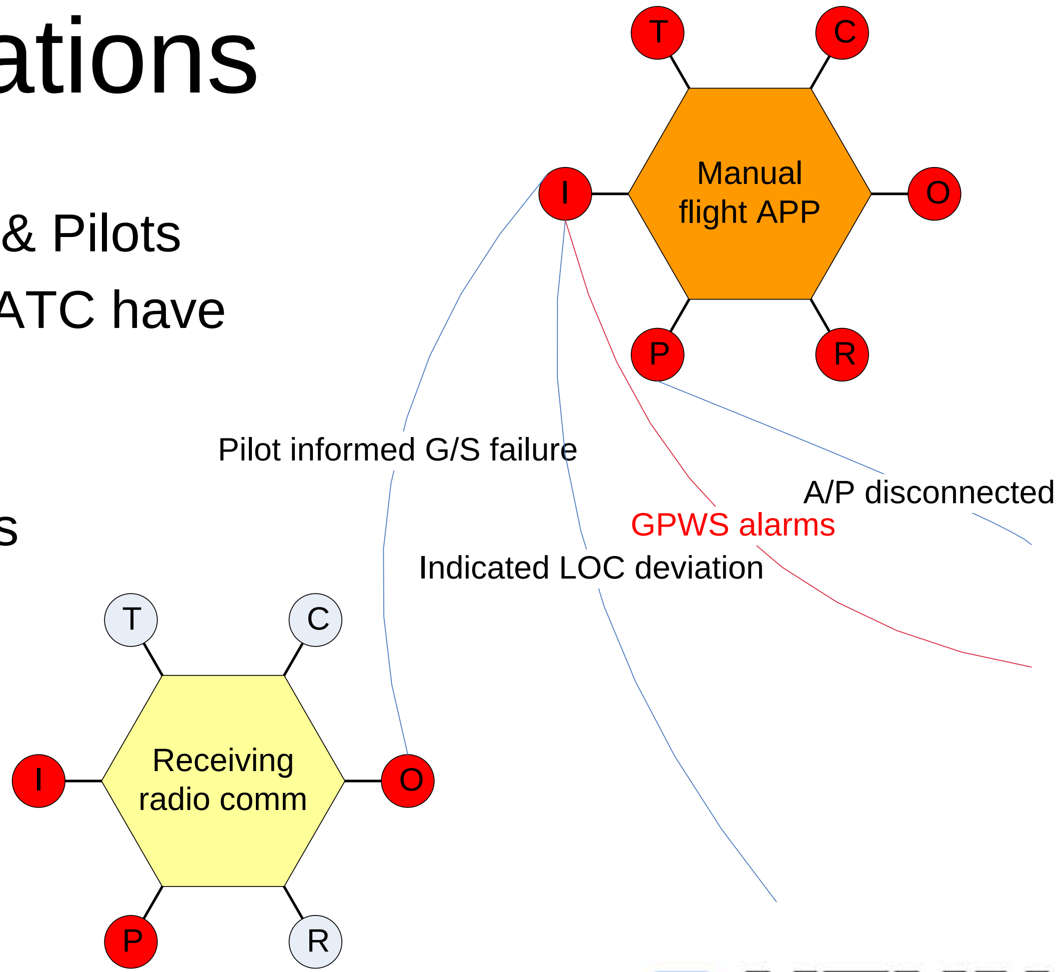


FRAM Recommendations

Training including for ATC & Pilots

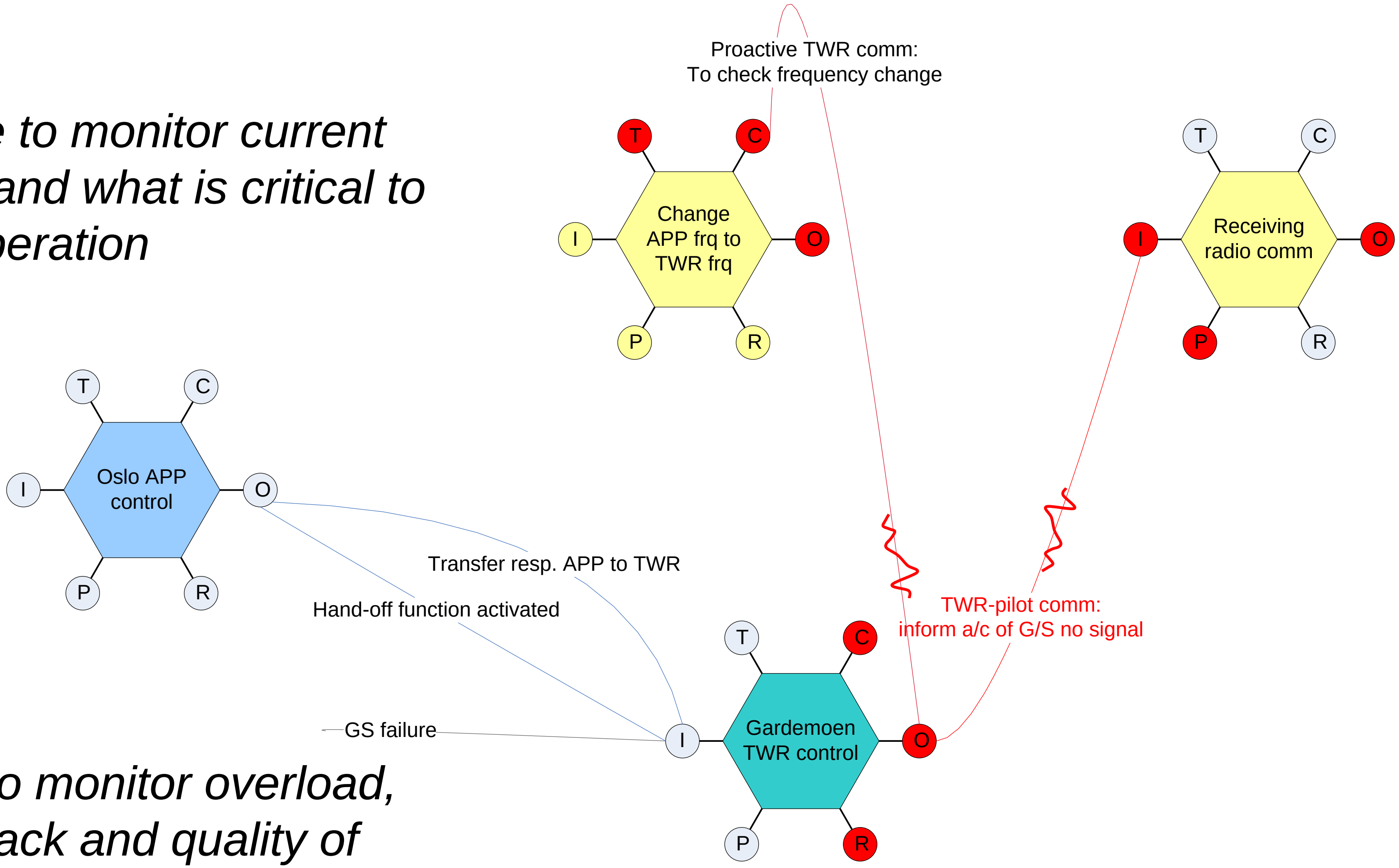
- Situations where pilots/ATC have different experience
- Changing conditions
- Communication analysis

(symbolic barrier)



FRAM Performance Monitoring

…flexible to monitor current state and what is critical to the operation



- *How to monitor overload, feedback and quality of communication?*

Discussion

- what we can learn from both methods, how, when, and why to apply them, and which aspects of these methods may need improvement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