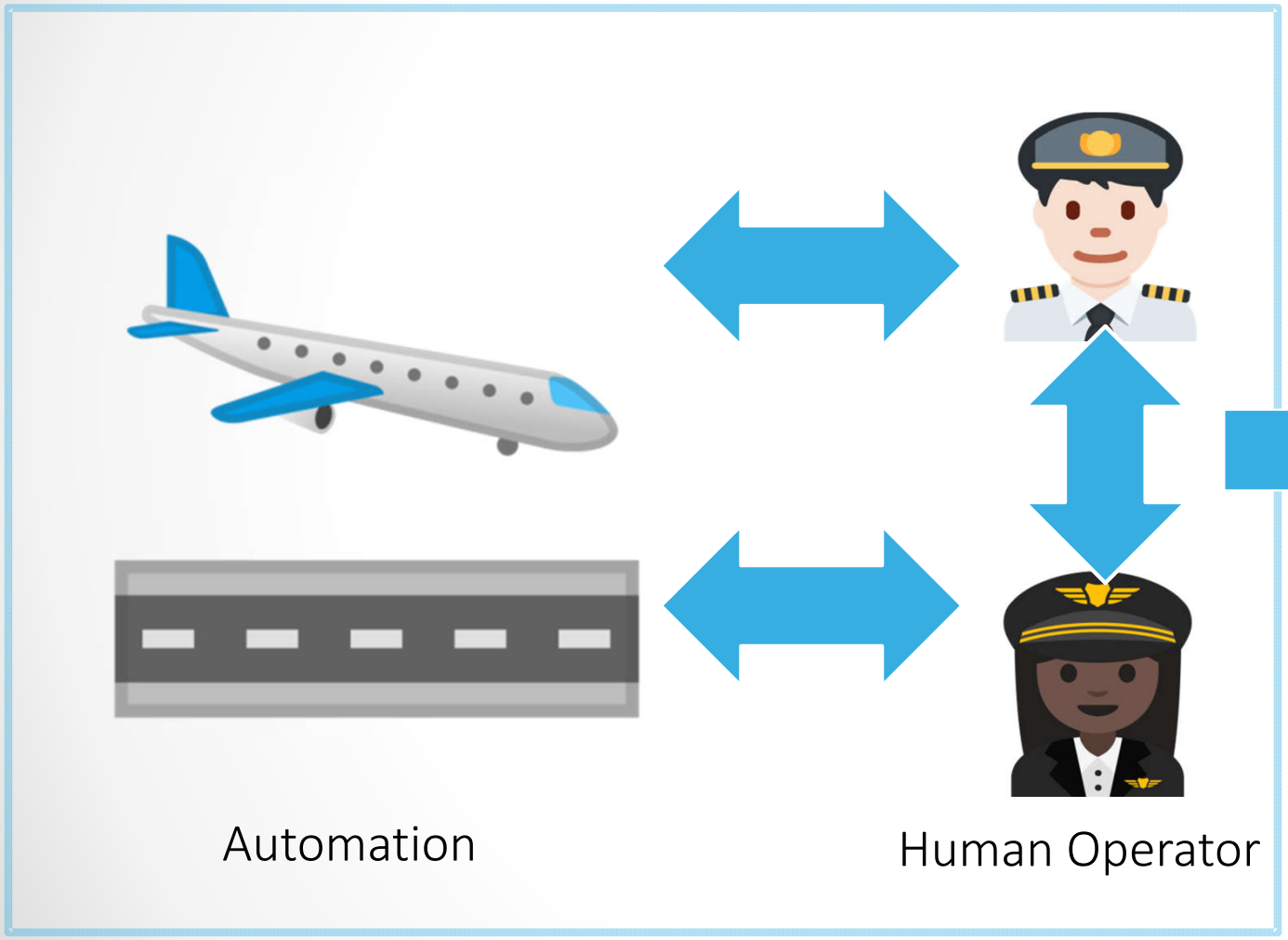
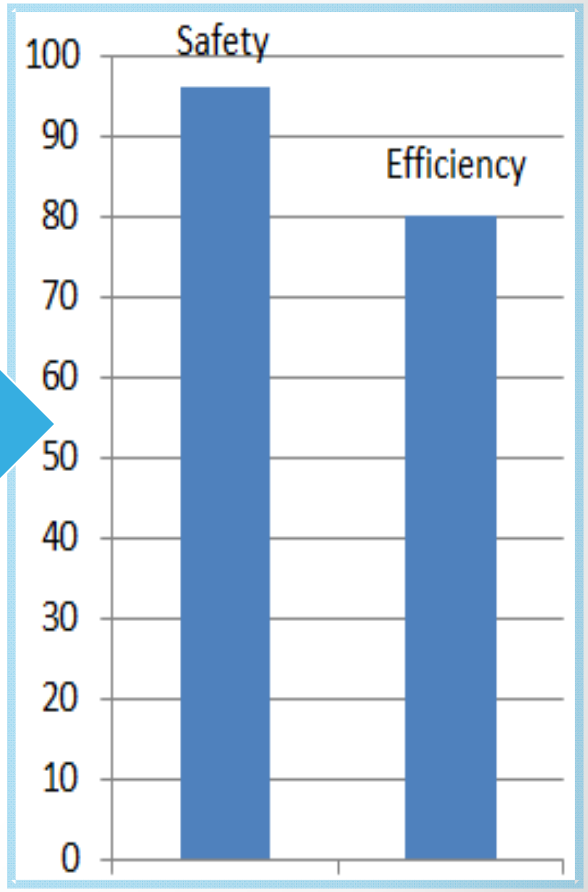
Human Performance Envelope:
Overview of the Project and Technical Results

Marcus Biella, DLR

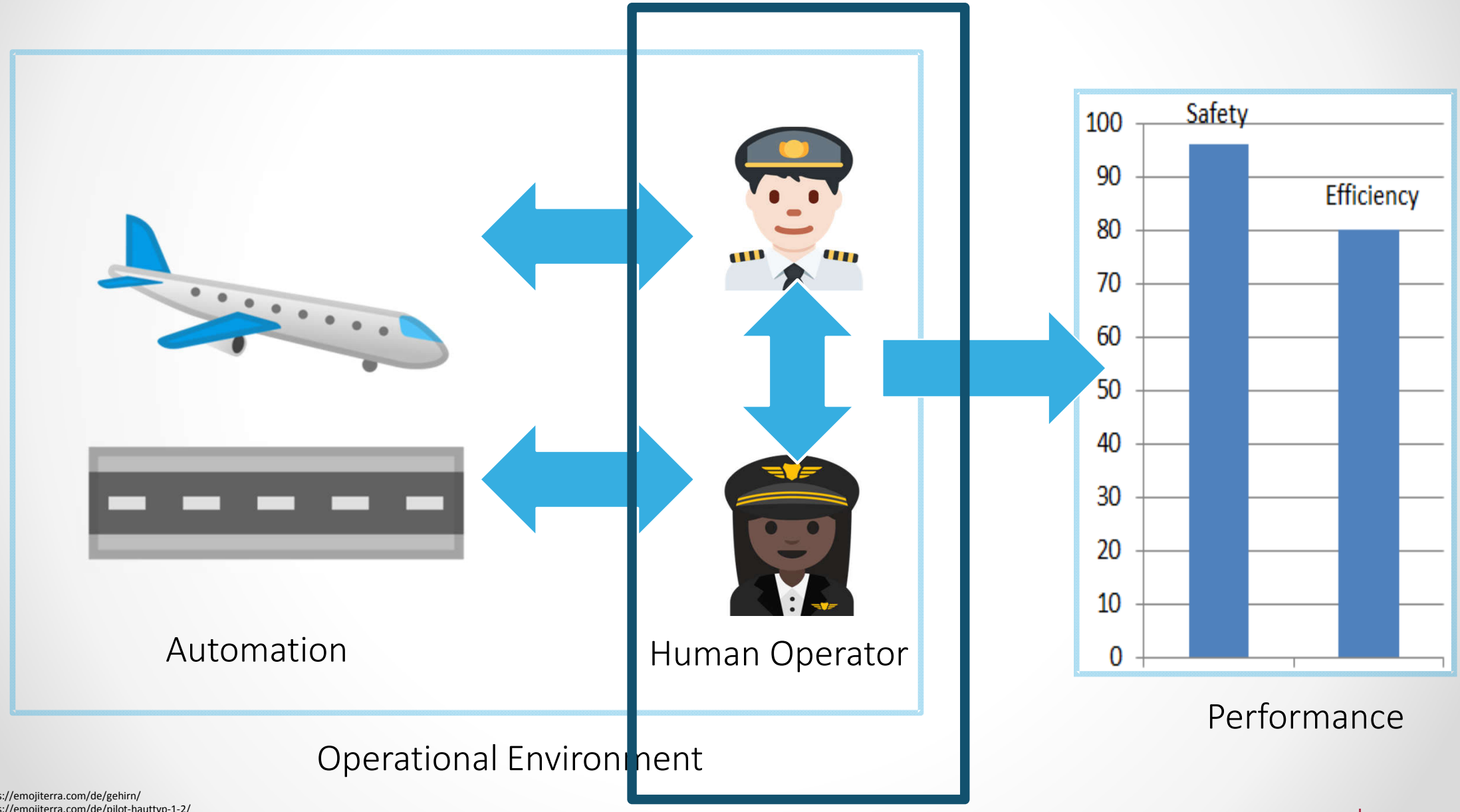
What are we aiming at?





https://emojiterra.com/de/gehirn/
https://emojiterra.com/de/pilot-hauttyp-1-2/
https://emojiterra.com/de/pilotin-hauttyp-6/
https://emojiterra.com/de/landung-eines-flugzeugs/

How to automate? Human Centered!



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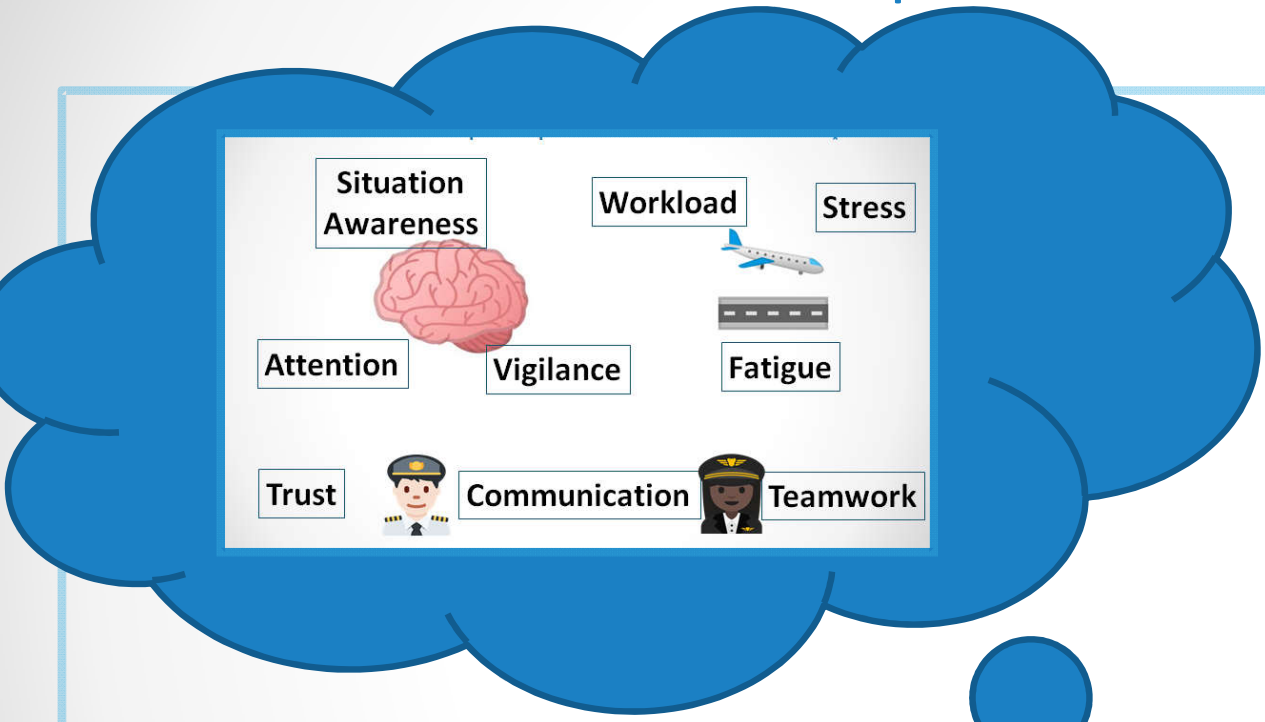
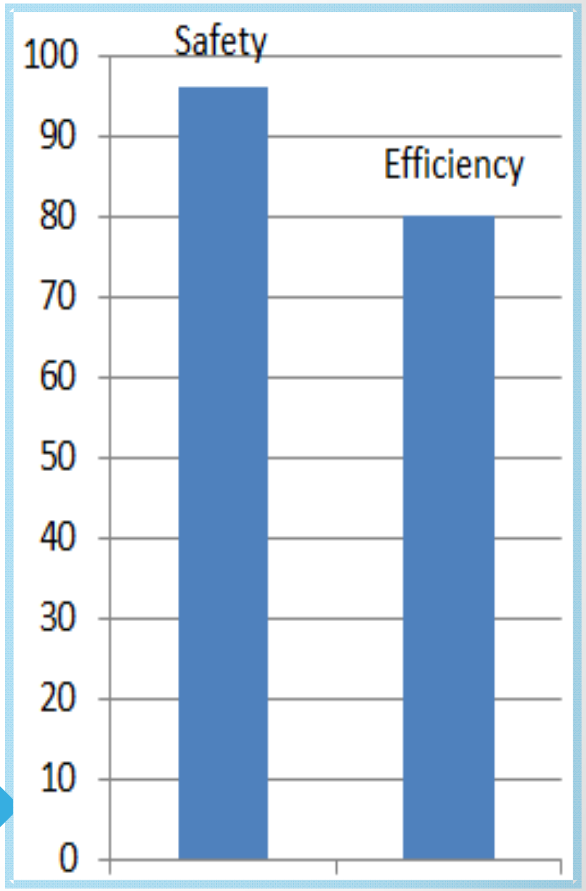
Performance is dependant on Human Factors



Human Factors

Human Operator



Performance

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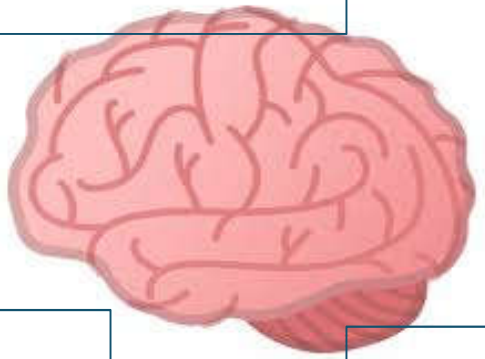
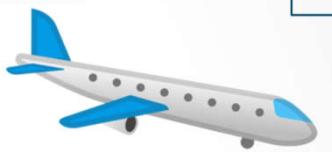
Situation Awareness

Workload

Stress



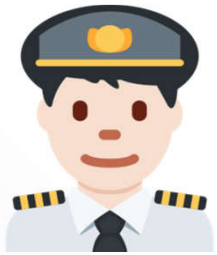


Attention

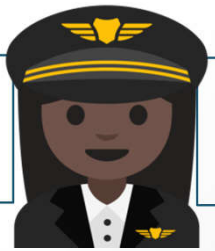
Vigilance

Fatigue

Trust



Communication



Teamwork

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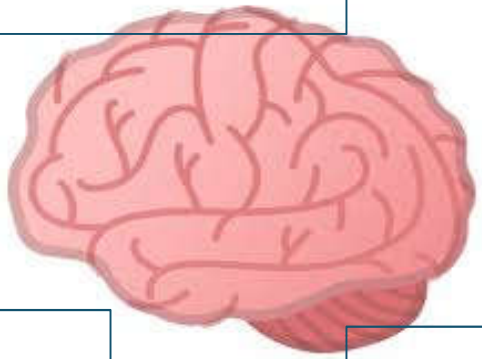
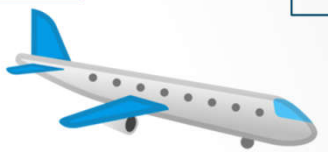
Situation Awareness

Workload

Stress





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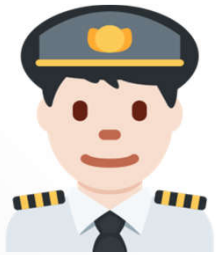

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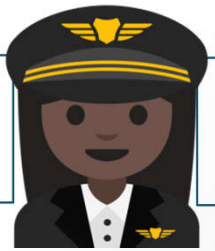

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Situation Awareness

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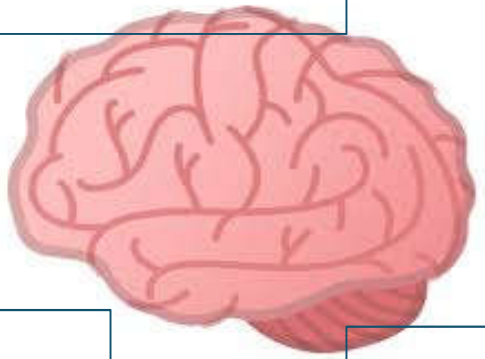

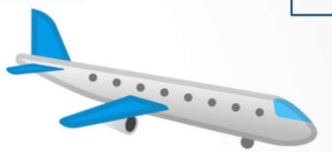

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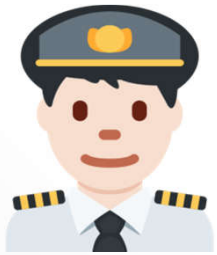

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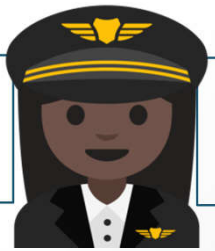

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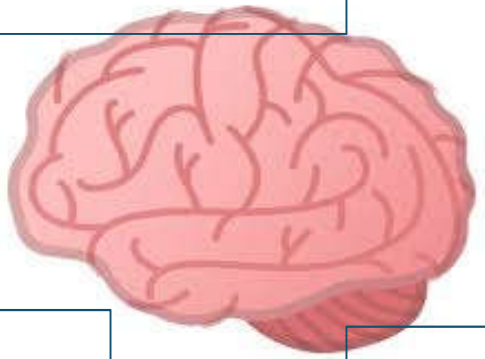
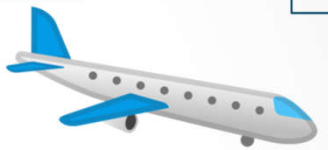
Decline in performance: is an interaction of Human Factors, even if these factors are only slightly impaired!

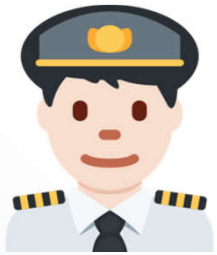
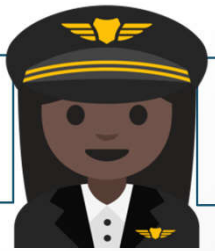
FUTURE SKY SAFETY

Situation Awareness ⟷ **Workload** ⟷ **Stress**





Attention **Vigilance** **Fatigue**

Trust  **Communication**  **Teamwork**

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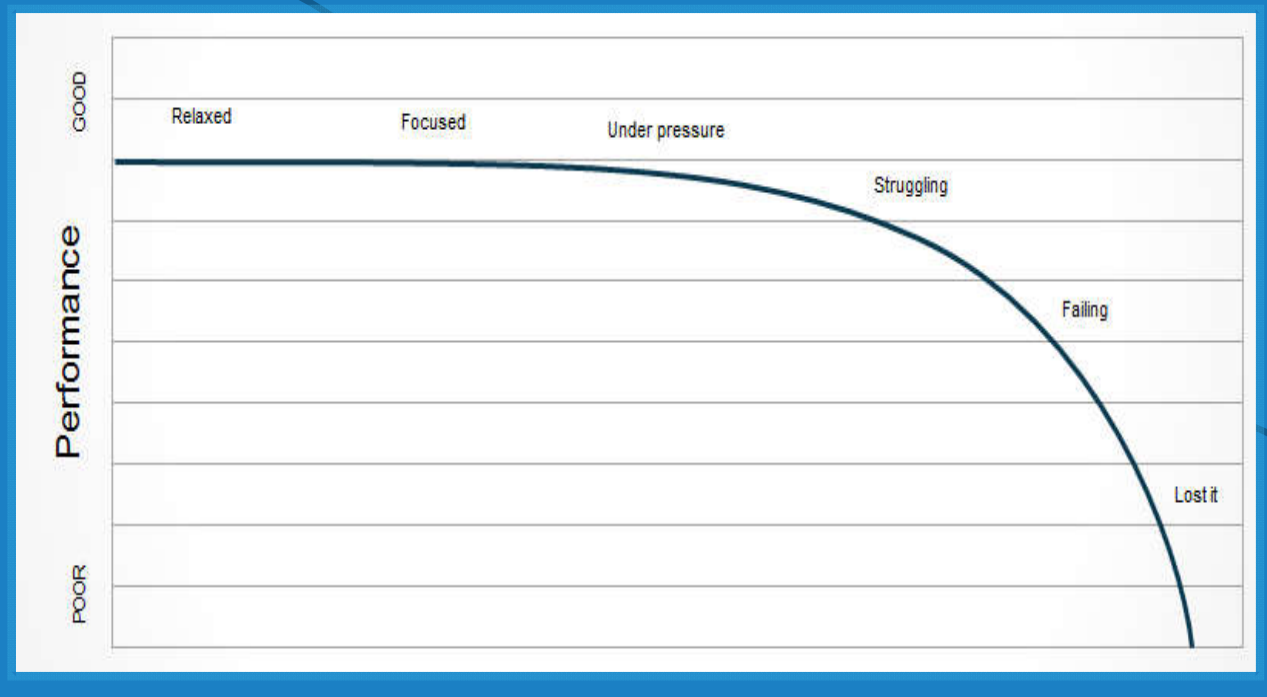
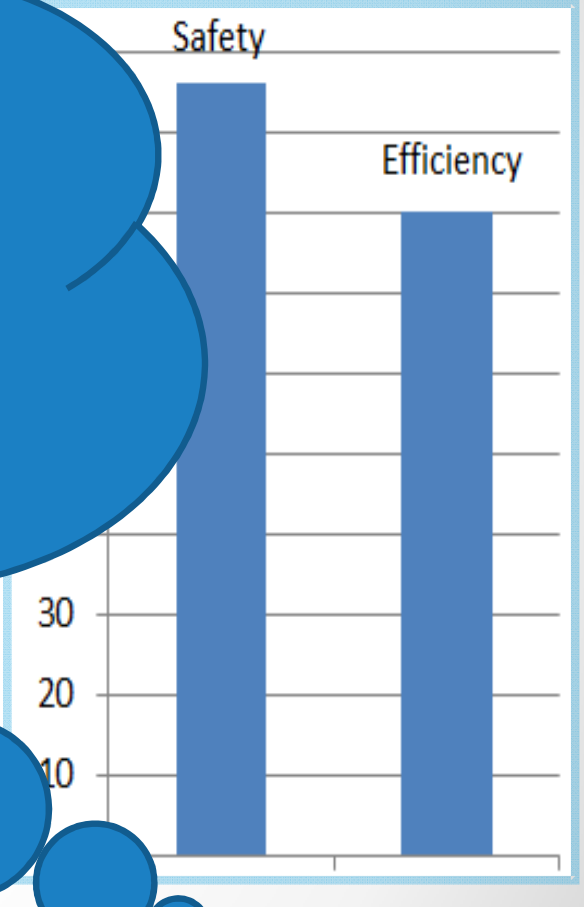
Decline in performance: it happens gracefully, not abrupt

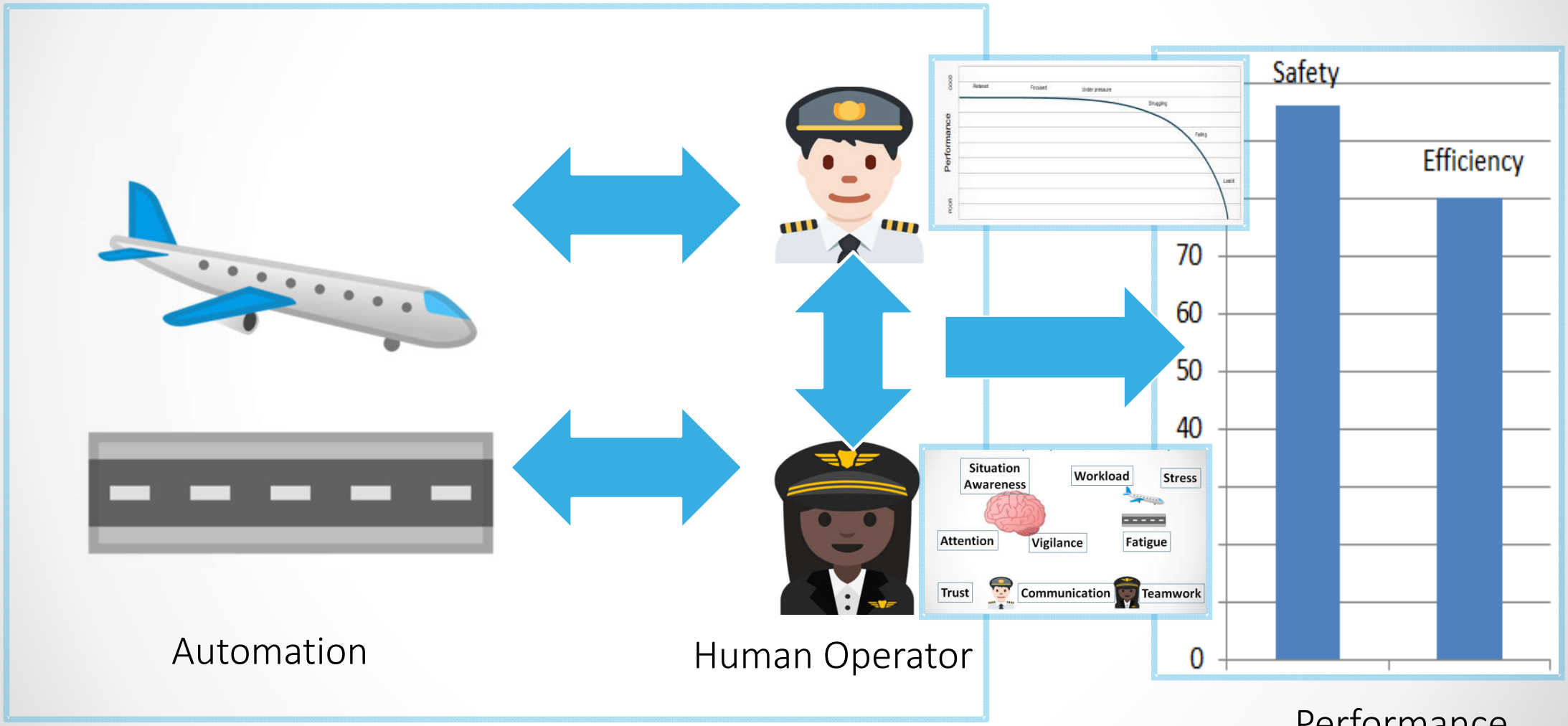




Performance

How to automate now? Human Centered!

… enabled by Human Performance Envelope



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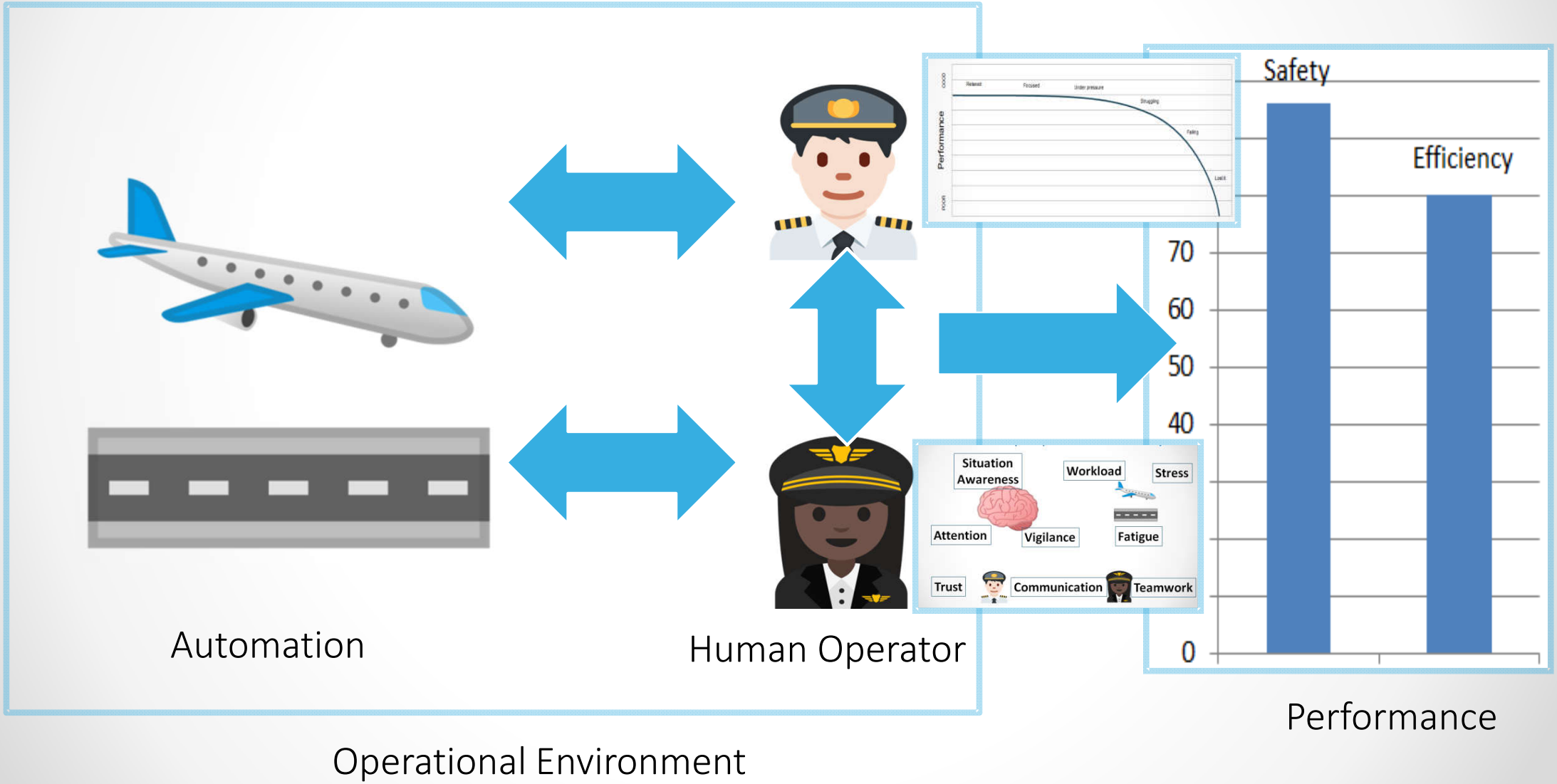
1. Detect operator‘s state on time



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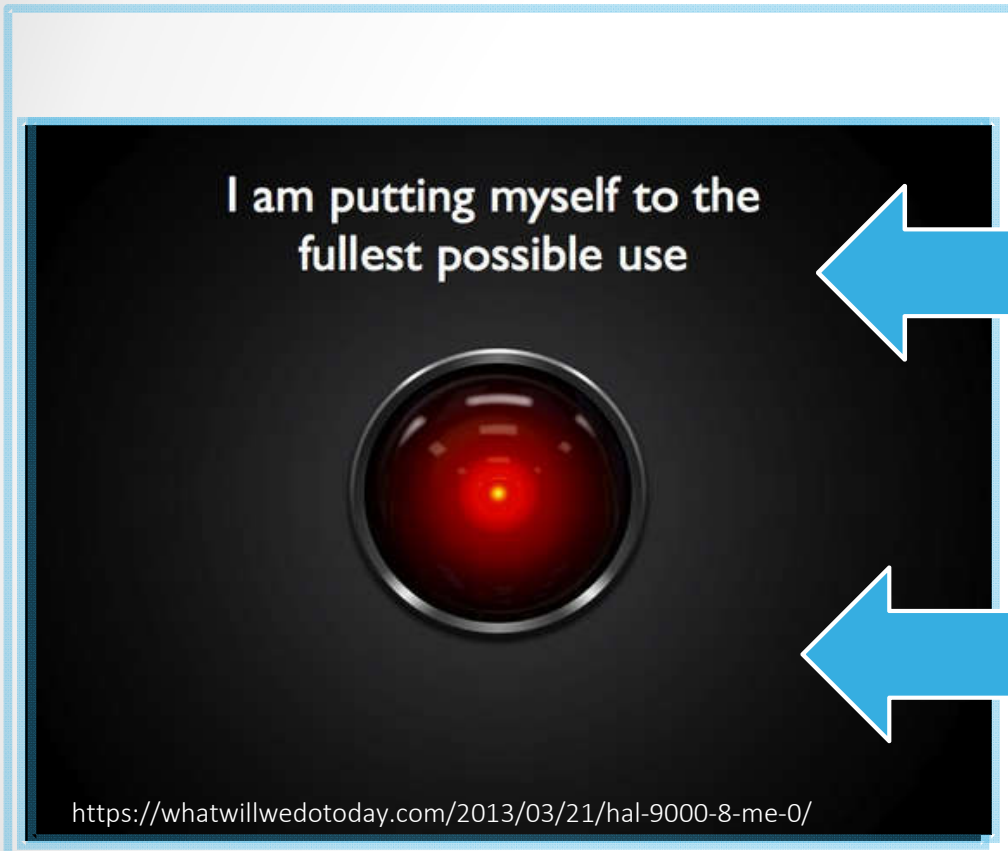
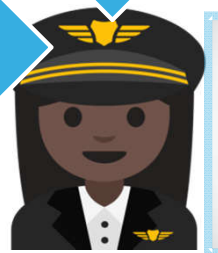
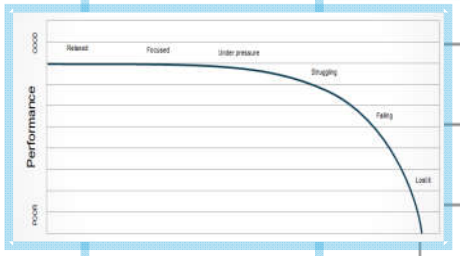
2. Develop automation which is capable to adapt to the state of the operator

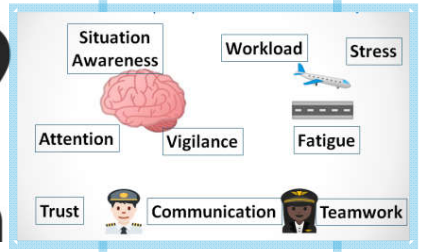


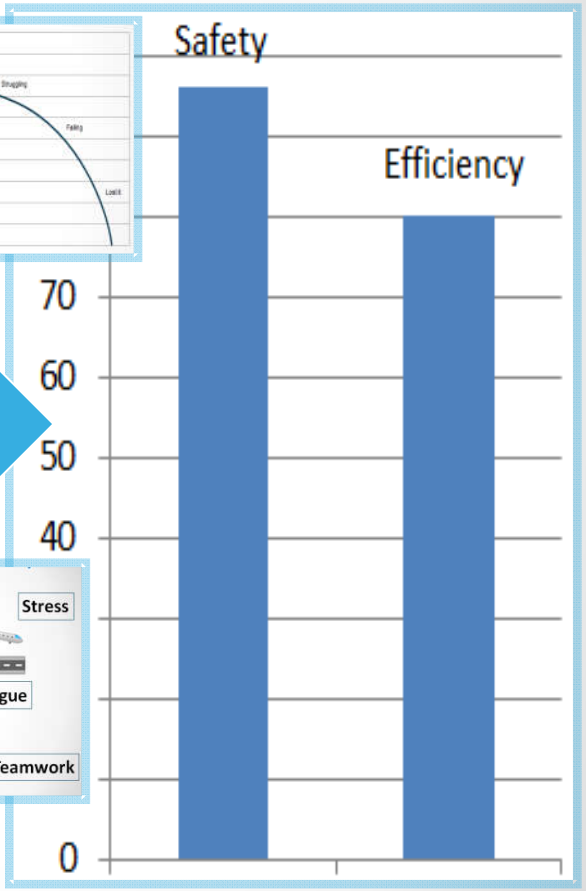
Automation



Human Operator







Performance

Operational Environment

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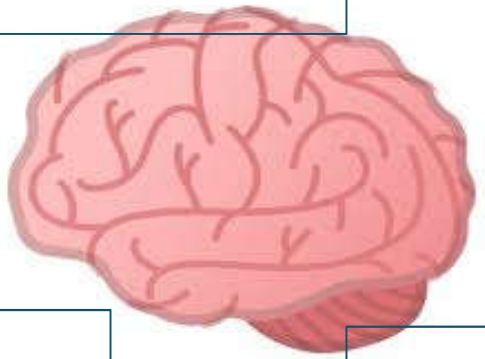
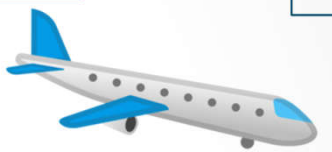
Situation Awareness

Workload

Stress





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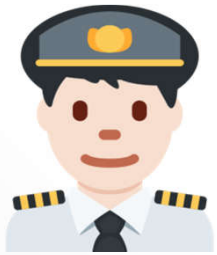
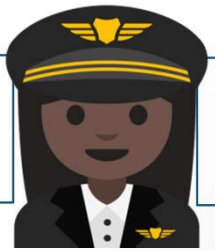


Communication



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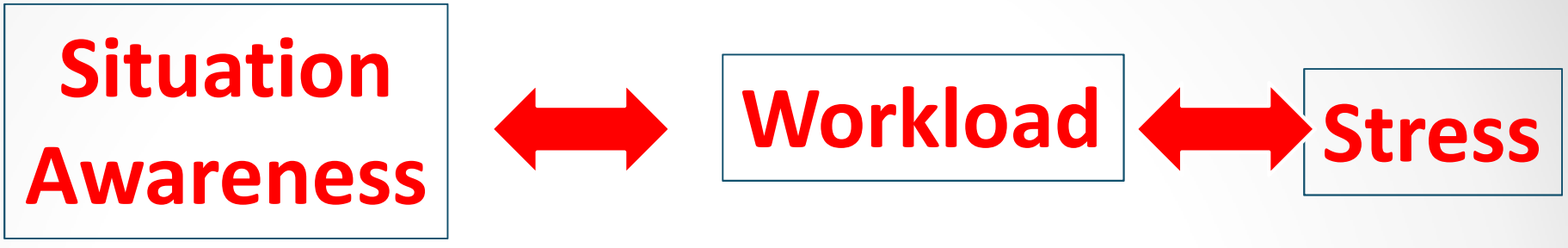
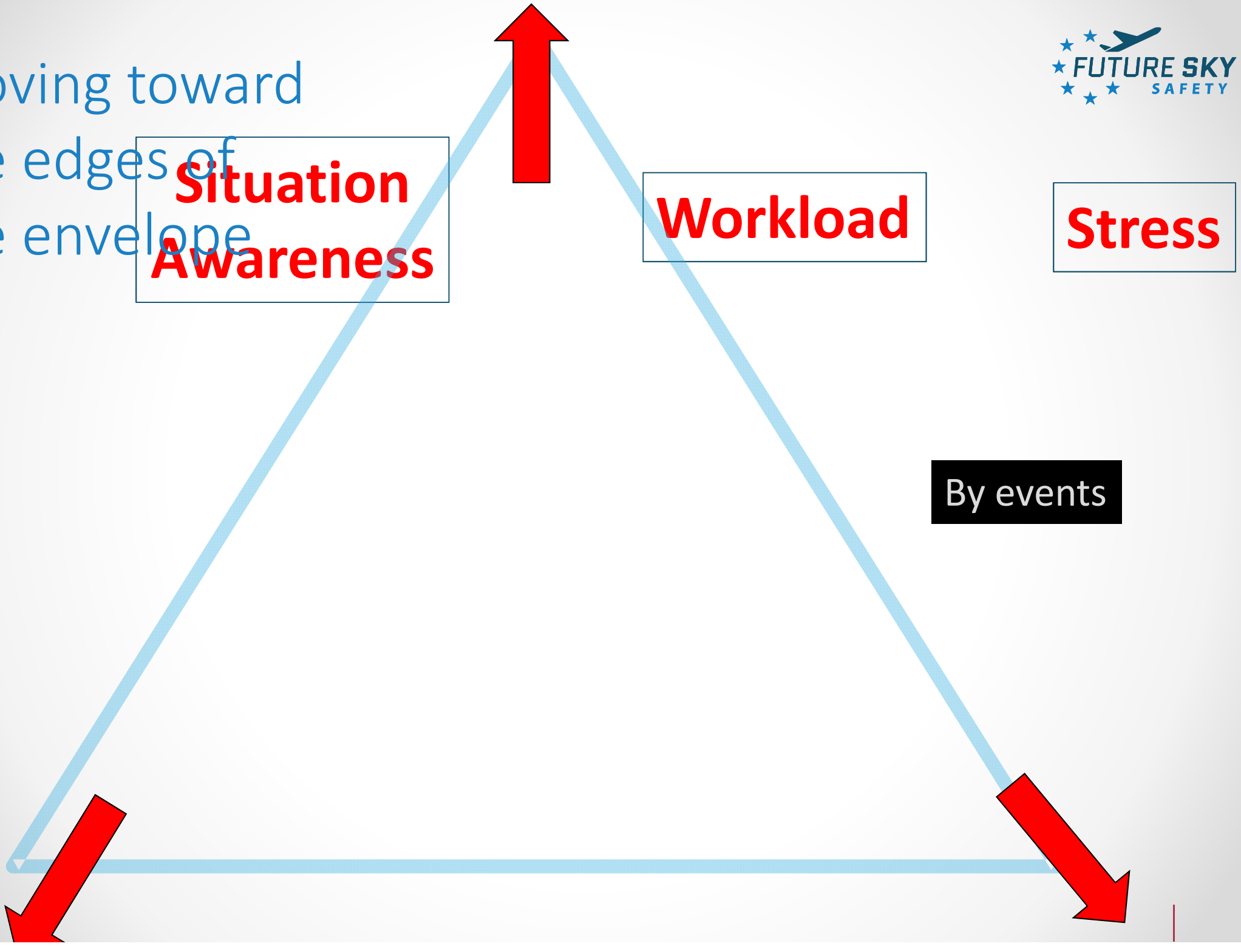
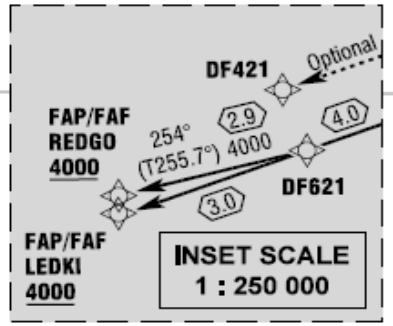

Situation Awareness
Workload
Stress

Moving toward the edges of the envelope



Frankfurt Approach



Task: manual approach

- **AP off**
- **A/THR off**
- **FD on**

Duration:
Approx. 15 - 20 min

① FOR ADDITIONAL INFORMATION SEE AD 2 EDDF 4-2-6 AND 4-2-8.

CLEARANCE LIMIT ⑤ KERAX
N 50° 28' 30"
E 009° 34' 55"

KERAX 25N
KERAX 25S
6000
13.3
252° (T253.6°)
5000
6.1
201° (T202.4°)
020°
200°
001°
181°

GEDERN
110.80 GED
CH 45 X
N 50° 24' 43"
E 009° 14' 57"

EBIPA
N 50° 22' 53"
E 009° 31' 18"
FL120

DF407
DF406
DF416
DF408
DF415
DF414
DF413
DF412
DF411
FL90
DF410
DF409
DF424
DF423
DF425
DF426
DF626
DF625
DF624
DF623
DF622
DF615
DF616
DF614
DF613
DF612
DF611
DF610
FL80
DF609
DF606
DF617
FL80

IF
DF422 ①
20.2 DME IFWR
20.2 DME IFNW

ROLIS 25N
SEE AD 2 EDDF 3-1-5
UNOKO 25N

ROLIS 25S
SEE AD 2 EDDF 3-1-5
UNOKO 25s

(See Inset)

FRANKFURT
114.20 FFM
CH 89 X
N 50° 03' 13"
E 008° 38' 14"

RIPKU
N 49° 59' 49"
E 009° 19' 27"

CHARLIE
115.50 CHA
N 49° 55' 16"
E 009° 02' 23"

CLEARANCE LIMIT
SPESSART
370.0 PSA
N 49° 51' 44"
E 009° 20' 54"
④

PSA 25N

② 249° (T250.1°) 5000

③ 249° (T250.3°)

④ PSA 25N: FL130
PSA 25S: FL110

⑤ KERAX 25N: FL110

Turn left HDG 280
cleared ILS APPR RWY 25L

Turn left HDG 340

Descent ALT 4000

Contact
DIRECTOR 127.275

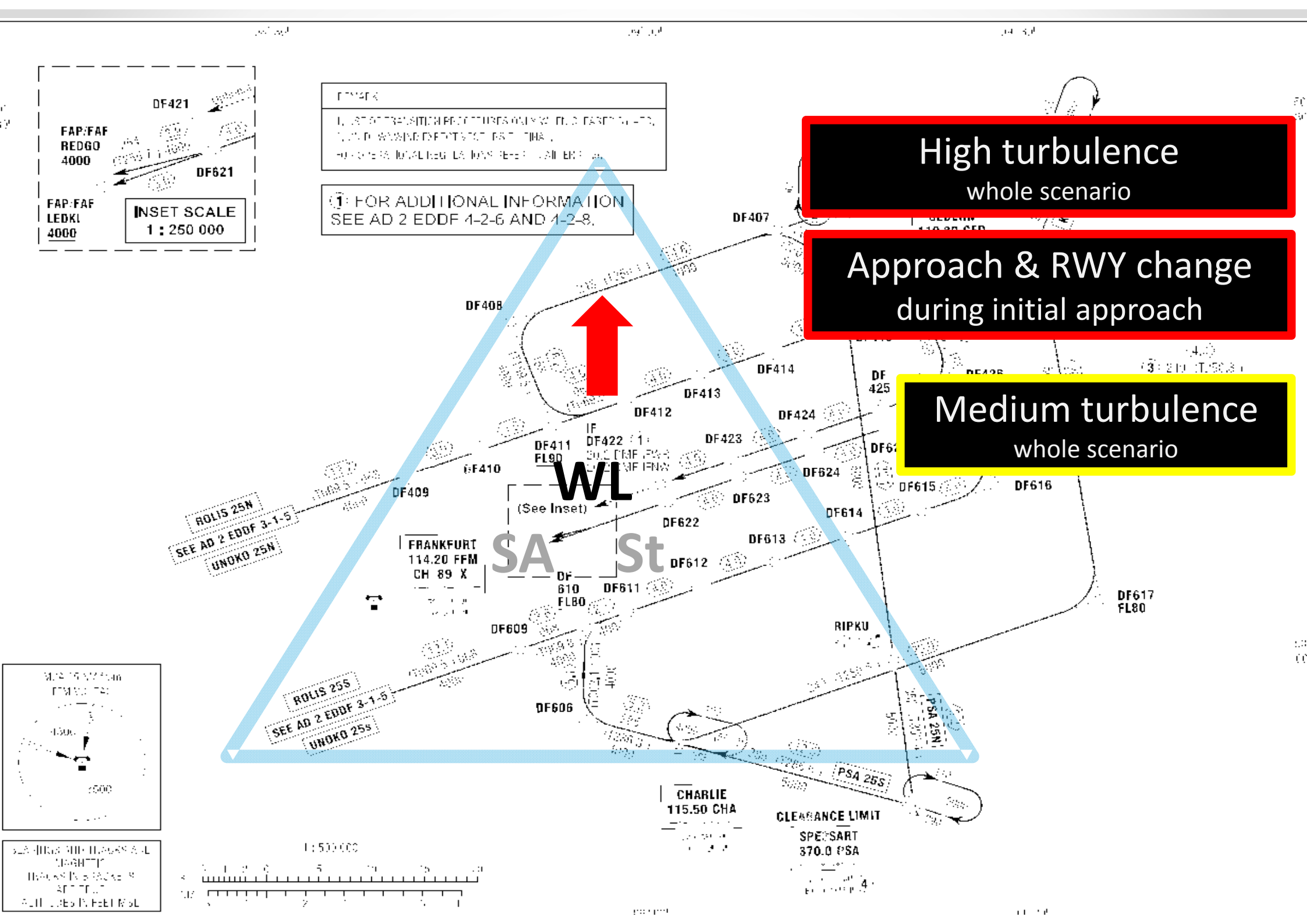
Descent ALT 6000

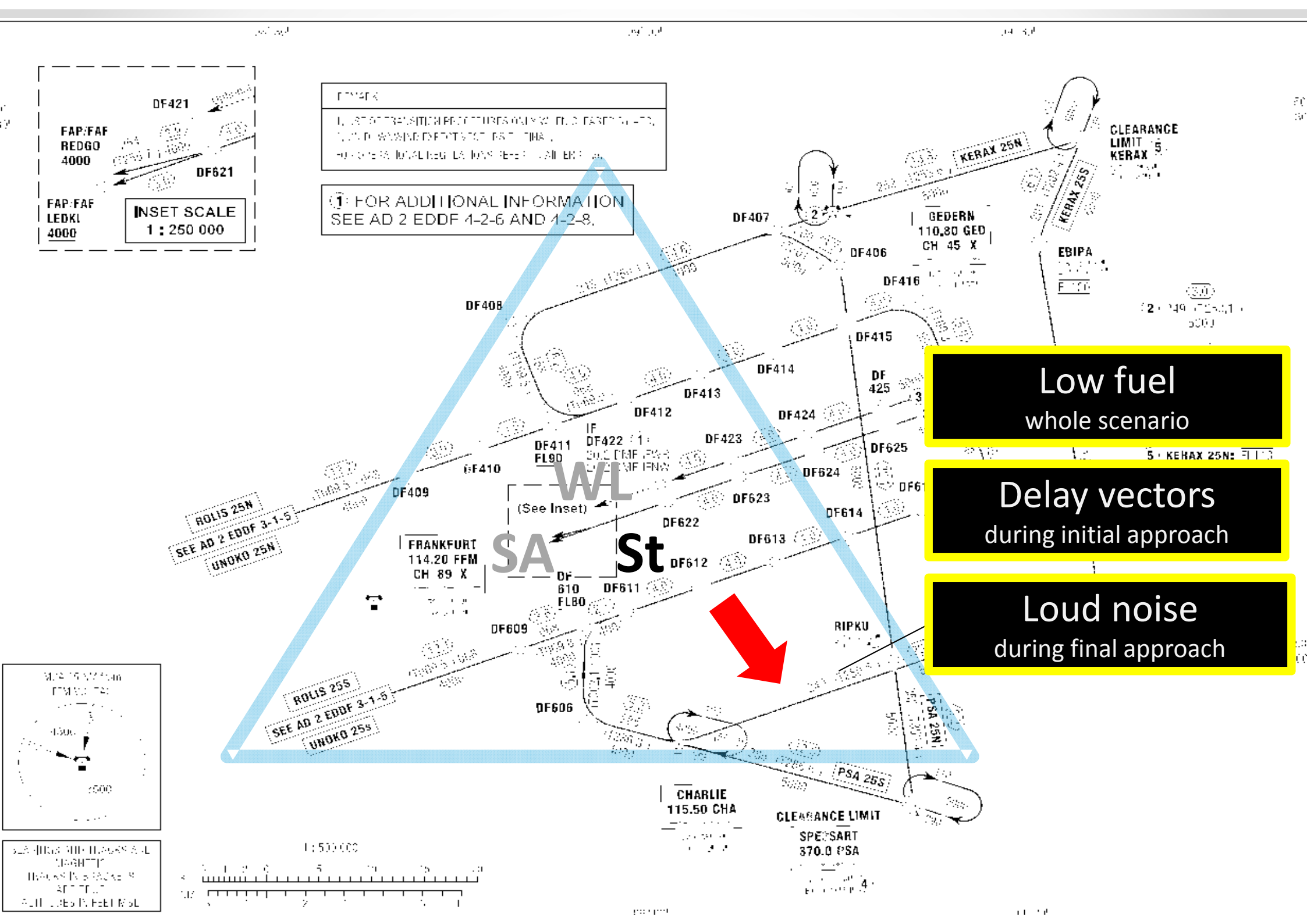
Initial Position

MSA 25 NM from
FFM VORTAC
4300
3500
190°
110°

BEARINGS AND TRACKS ARE
MAGNETIC
TRACKS IN BRACKETS
ARE TRUE
ALTITUDES IN FEET MSL

1 : 500 000
Km 6 4 2 0 5 10 15 20
NM 3 2 1 0 2 4 6 8 10


High turbulence
whole scenario
Approach & RWY change
during initial approach
Medium turbulence
whole scenario
WL
SA St
DF421
FAP/FAF
REDGO
4000
DF621
FAP/FAF
LEDKI
4000
INSET SCALE
1 : 250 000
1 FOR ADDITIONAL INFORMATION
SEE AD 2 EDDF 4-2-6 AND 4-2-8.
DF407
DF408
DF414
DF413
DF412
DF424
DF423
DF411
FL90
DF410
DF409
DF624
DF623
DF622
DF615
DF616
DF614
DF613
DF612
DF611
DF610
FL80
DF609
DF606
DF617
FL80
ROLIS 25N
SEE AD 2 EDDF 3-1-5
UNOKO 25N
ROLIS 25S
SEE AD 2 EDDF 3-1-5
UNOKO 25S
(See Inset)
FRANKFURT
114.20 FFM
CH 89 X
RIPKU
PSA 25N
PSA 25S
CHARLIE
115.50 CHA
CLEARANCE LIMIT
SPESSART
370.0 PSA


DF421
FAP/FAF
REDGO
4000
DF621
FAP/FAF
LEDKI
4000
INSET SCALE
1 : 250 000
1 FOR ADDITIONAL INFORMATION SEE AD 2 EDDF 1-2-6 AND 1-2-8.
DF407
DF406
DF416
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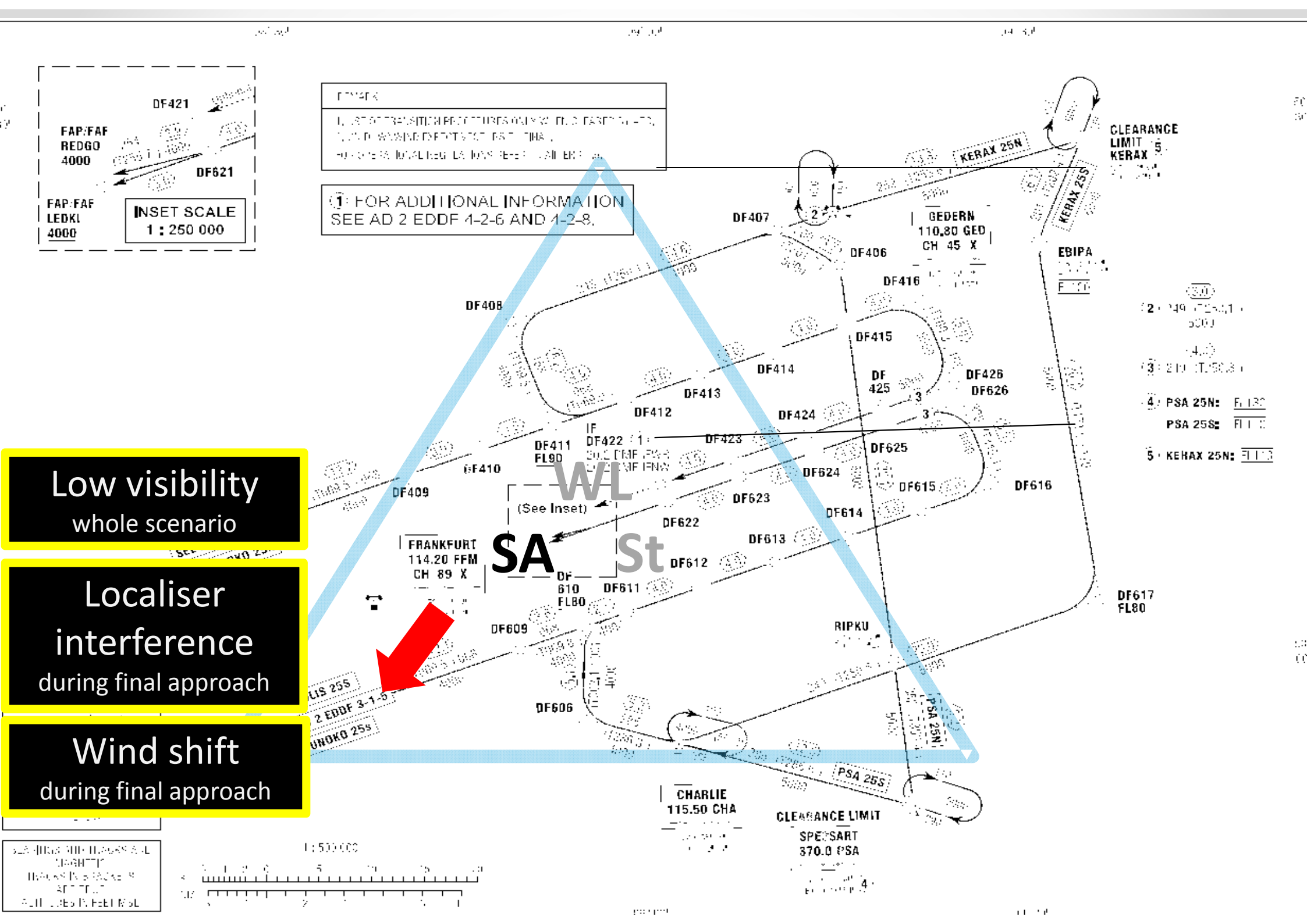
DF413
DF412
DF424
DF423
DF411
FL90
DF410
DF409
DF625
DF624
DF623
DF622
DF614
DF613
DF612
DF611
DF609
DF606
DF
610
FL80
DF
425
KERAX 25N
KERAX 25S
CLEARANCE
LIMIT
KERAX
GEDERN
110.80 GED
CH 45 X
EBIPA
ROLIS 25N
SEE AD 2 EDDF 3-1-5
UNOKO 25N
ROLIS 25S
SEE AD 2 EDDF 3-1-5
UNOKO 25S
FRANKFURT
114.20 FFM
CH 89 X
WL
(See Inset)
SA
St
RIPKU
PSA 25N
PSA 25S
CHARLIE
115.50 CHA
CLEARANCE LIMIT
SPESSART
370.0 PSA
Low fuel
whole scenario
Delay vectors
during initial approach
Loud noise
during final approach

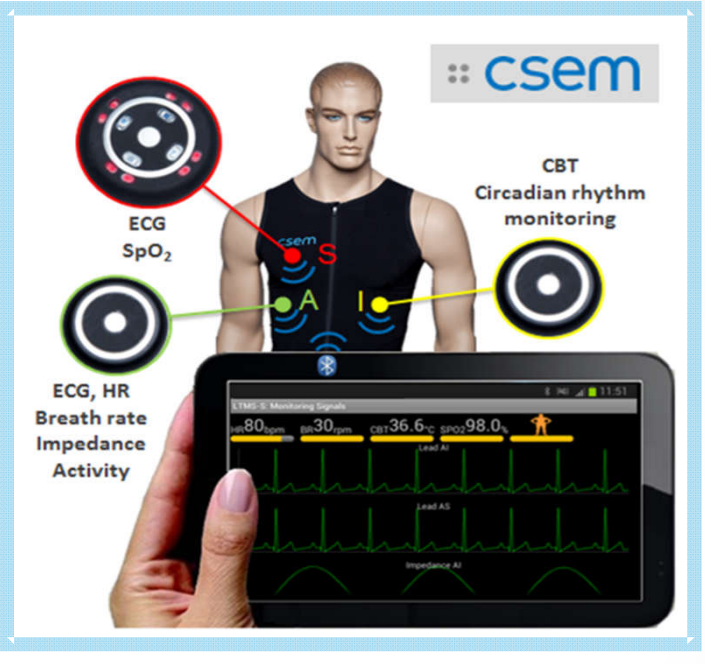


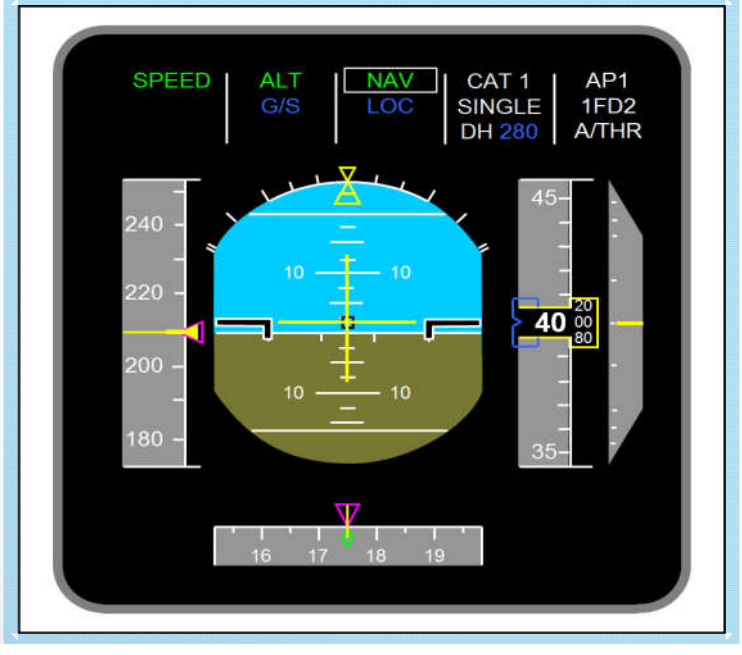
Low visibility
whole scenario

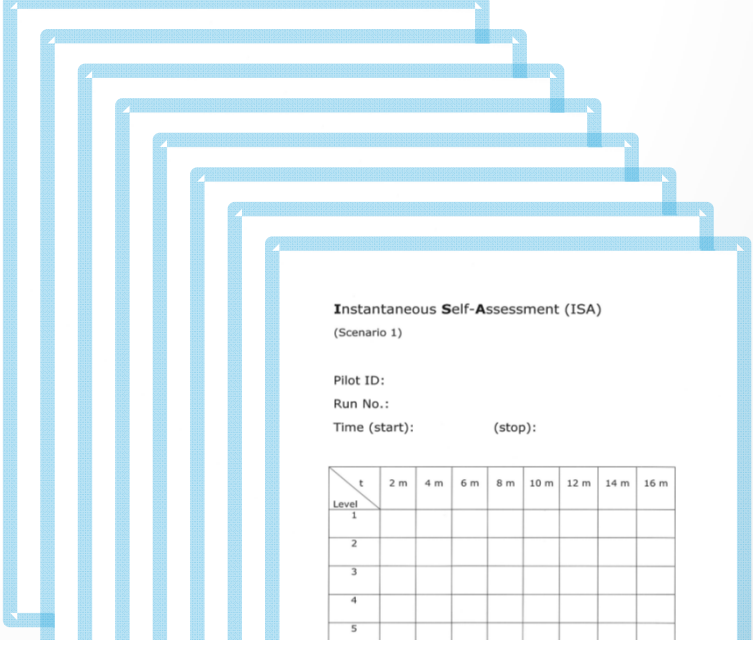
Localiser interference
during final approach

Wind shift
during final approach

Measurements







Instantaneous Self-Assessment (ISA)

(Scenario 1)

Pilot ID:

Run No.:

Time (start): (stop):

t / Level	2 m	4 m	6 m	8 m	10 m	12 m	14 m	16 m
1								
2								
3								
4								
5								

Measurements

Eye Tracking Data

- Point of Gaze
- Blink Rate
- Areas of Interest
- Pupil Diameter

Measurements

Physiological Data

- Heart Rate (HR)
- HR Variability (HRV)
  - RR Intervals
  - Breath Rate
- Perfusion Index

Measurements

Performance Data

- Speed
- Heading
- Altitude
- Vertical speed
- Localiser glideslope deviations
- Point of touchdown

Measurements

Subjective Data

- Self assessed performance
  - ISA
  - NASA-TLX
  - SACL
  - SART
- Samn-Perelli

Instantaneous **S**elf-**A**ssessment (ISA)

(Scenario 1)

Pilot ID:

Run No.:

Time (start): (stop):

Level \ t	2 m	4 m	6 m	8 m	10 m	12 m	14 m	16 m
1								
2								
3								
4								
5								

1 = Under-Utilised
2 = Relaxed
3 = Comfortable Busy
4 = High
5 = Excessive

Exploratory Simulations

A320 motion flight simulator

Pilots

Operational Environment

- **N=10 first officers**
  - major European airline
  - A320 type rated
- Age
  - M = 31
  - SD = 3.28
- Experience (total flight hours)
  - M = 4045
  - SD = 1569

- **Captain**
  - from same airline
  - complemented crew

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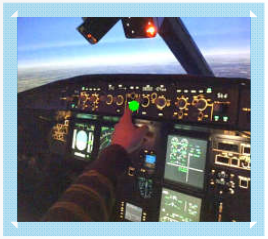
https://emojiterra.com/de/landung-eines-flugzeugs/

If workload increases…



Pupil Ø ⬆

Very high WL

⬆

High WL

⬆

Baseline WL

Heart Rate ⬆

Heart Rate Variability ⬇

Localiser / Glideslope Deviation ⬆

Self assessed Performance ⬇

⬆ NASA TLX / ISA

If stress increases

Pupil Ø ⬆

Heart Rate ⬆

Heart Rate Variability ⬆

Localiser / Glideslope Deviation (less compare to WL)

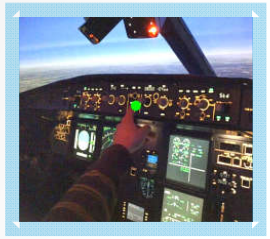
Baseline St

High St

Self assessed Performance ⬇

SACL ⬆

If situation awareness decreases…



Pupil Ø

Localiser / Glideslope deviation (higher compared to WL und St) ⬆

Heart Rate

Heart Rate Variability

Baseline SA

impaired SA

Self assessed Performance ⬇

SART ⬇

Results: combined factors

HPE more severely reduced by combined factors

Pupil Ø

Low Frequency HRV

Localiser / Glideslope Deviation

Design Philosophy

Pilots need to have information about:

- The status
- The limitations

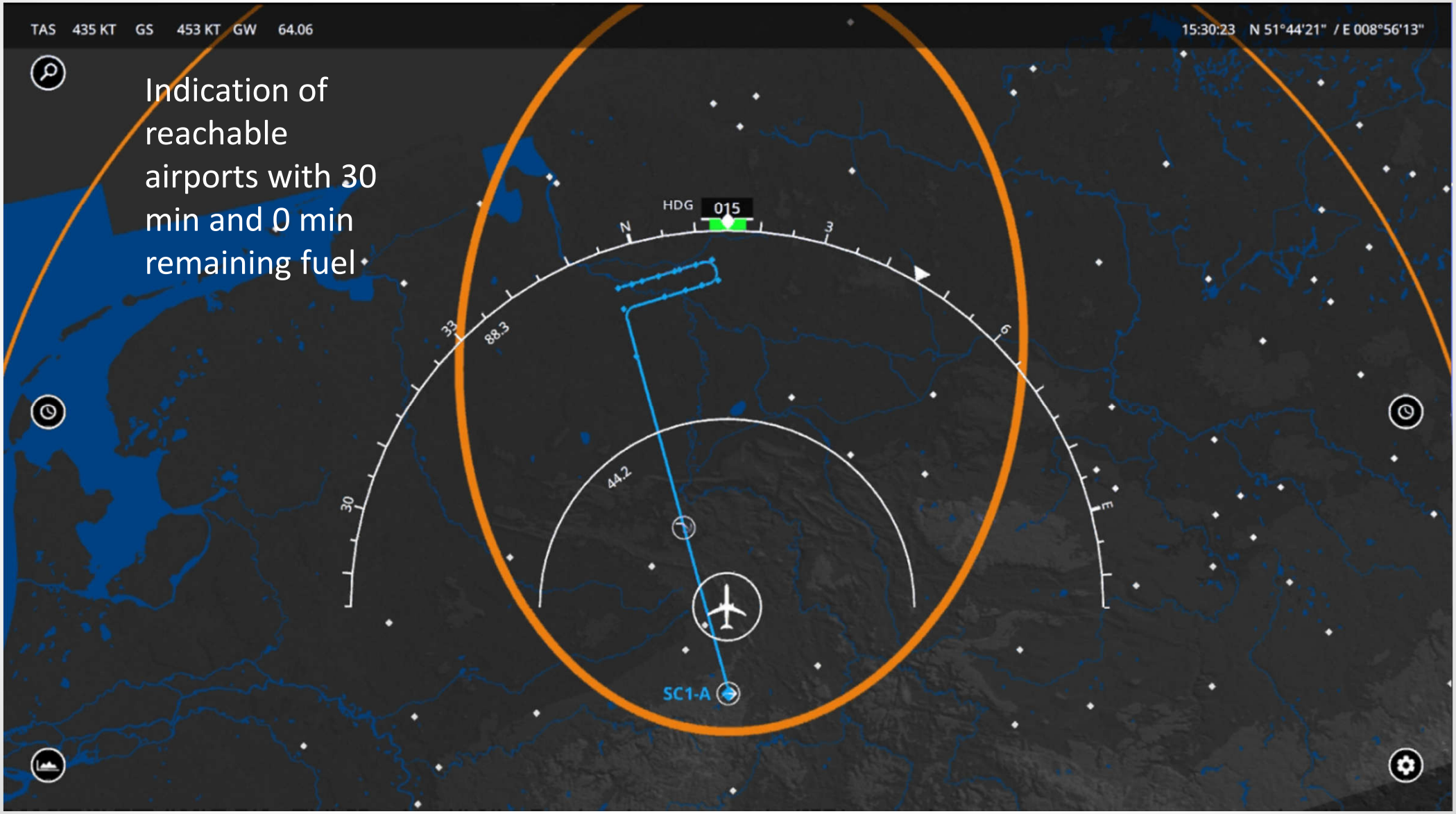
- The consequences of the limitations for operation and the impact of the limitations on safety
  - To be aware about the risks
  - To understand the risks
  - To understand the options
- The options
- The consequences of the options
- How to implement the options

Development of New HMI

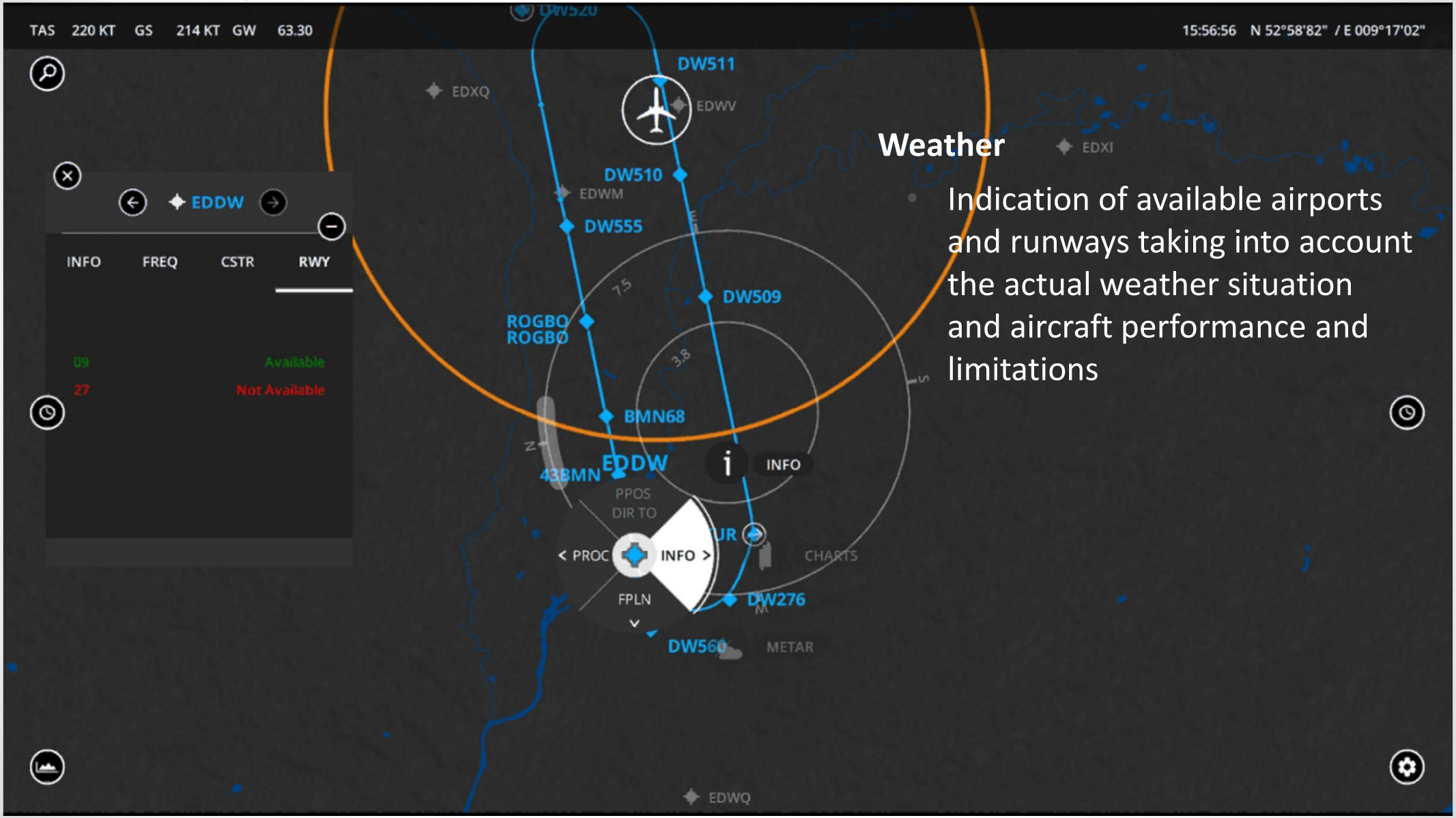
Fuel

- Pilots need a better understanding of the remaining flight time available

Development of New HMI



Development of New HMI



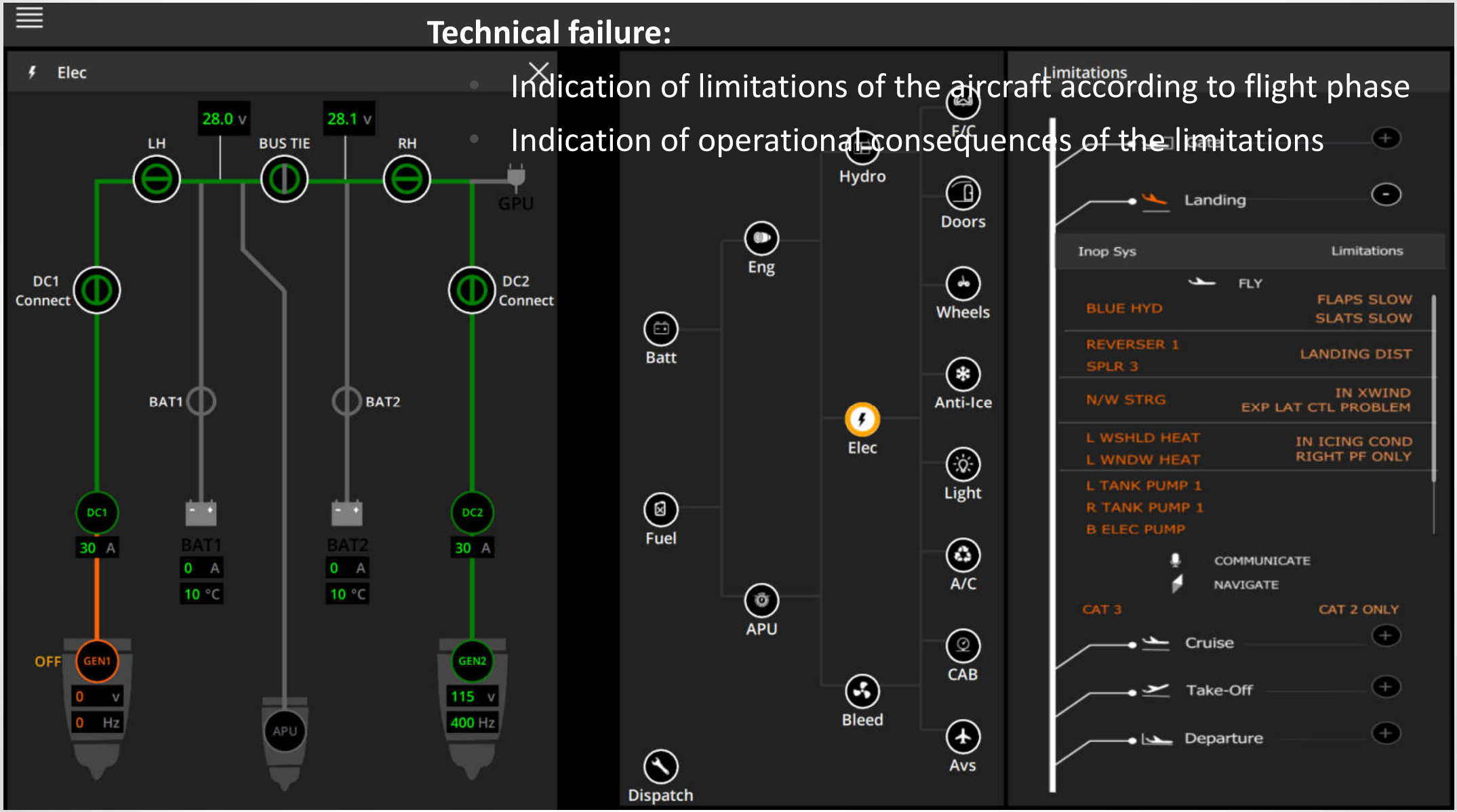
Weather

- Indication of available airports and runways taking into account the actual weather situation and aircraft performance and limitations

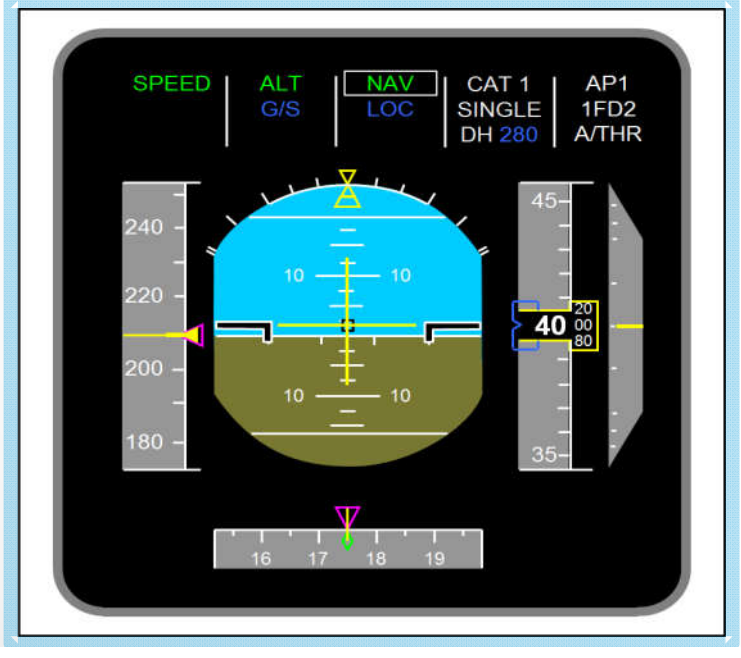
Development of New HMI

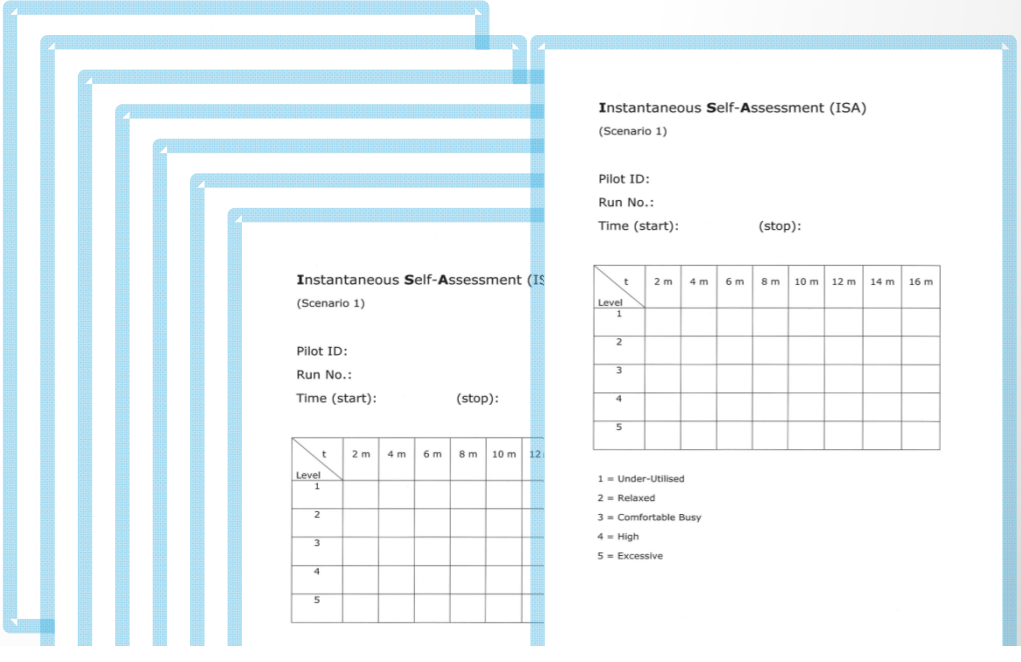
Technical failure:

- Indication of limitations of the aircraft according to flight phase
- Indication of operational consequences of the limitations



Measurements





Second Simulator Experiments

Avionics 2020 simulator

Pilots

Operational Environment

- **N=20 first officers**
  - major European airline
  - A320 type rated
- New HMI were integrated in Thales Avionics 2020 Cockpit Simulator
- Same aircraft model as in first simulator experiments (A320)
- Same scenario as in first simulator experiments

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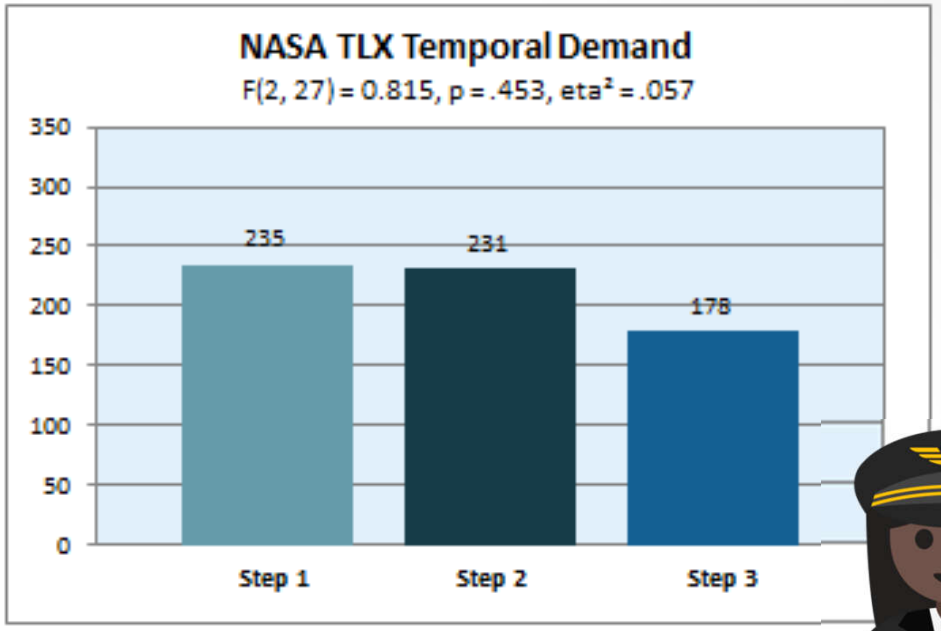
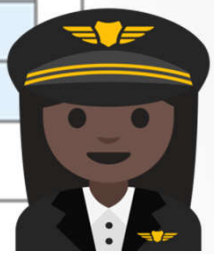
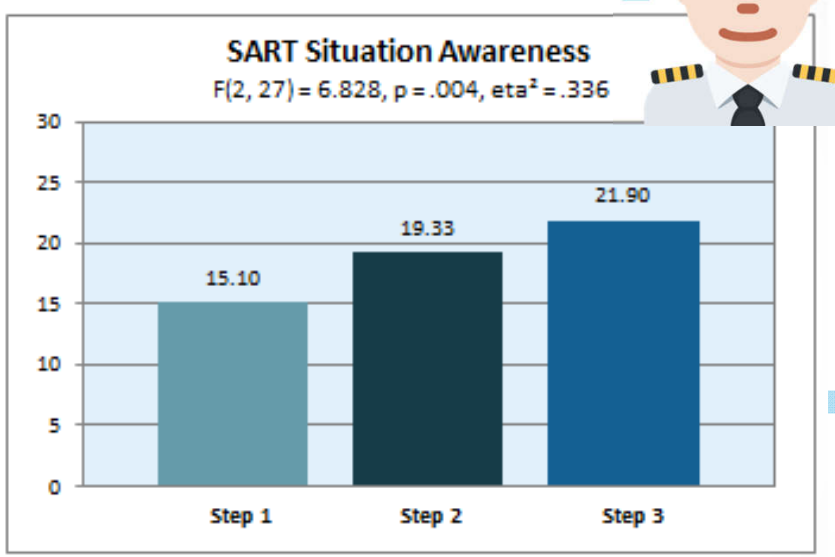




WL

SA St



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FUTURE SKY SAFETY

Consortium

Stichting Nationaal Lucht- en Ruimtevaartlaboratorium
Deutsches Zentrum für Luft- und Raumfahrt
Office national d'études et de recherches aérospatiales
Centro para a Excelência e Inovação na Indústria Automóvel
Centro Italiano Ricerche Aerospaziali
Centre Suisse d'Electronique et Microtechnique SA
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http://www.futuresky-safety.eu

Future Sky Safety has received funding from the European Union's Horizon 2020 research and innovation programme, under Grant Agreement No 640597.
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