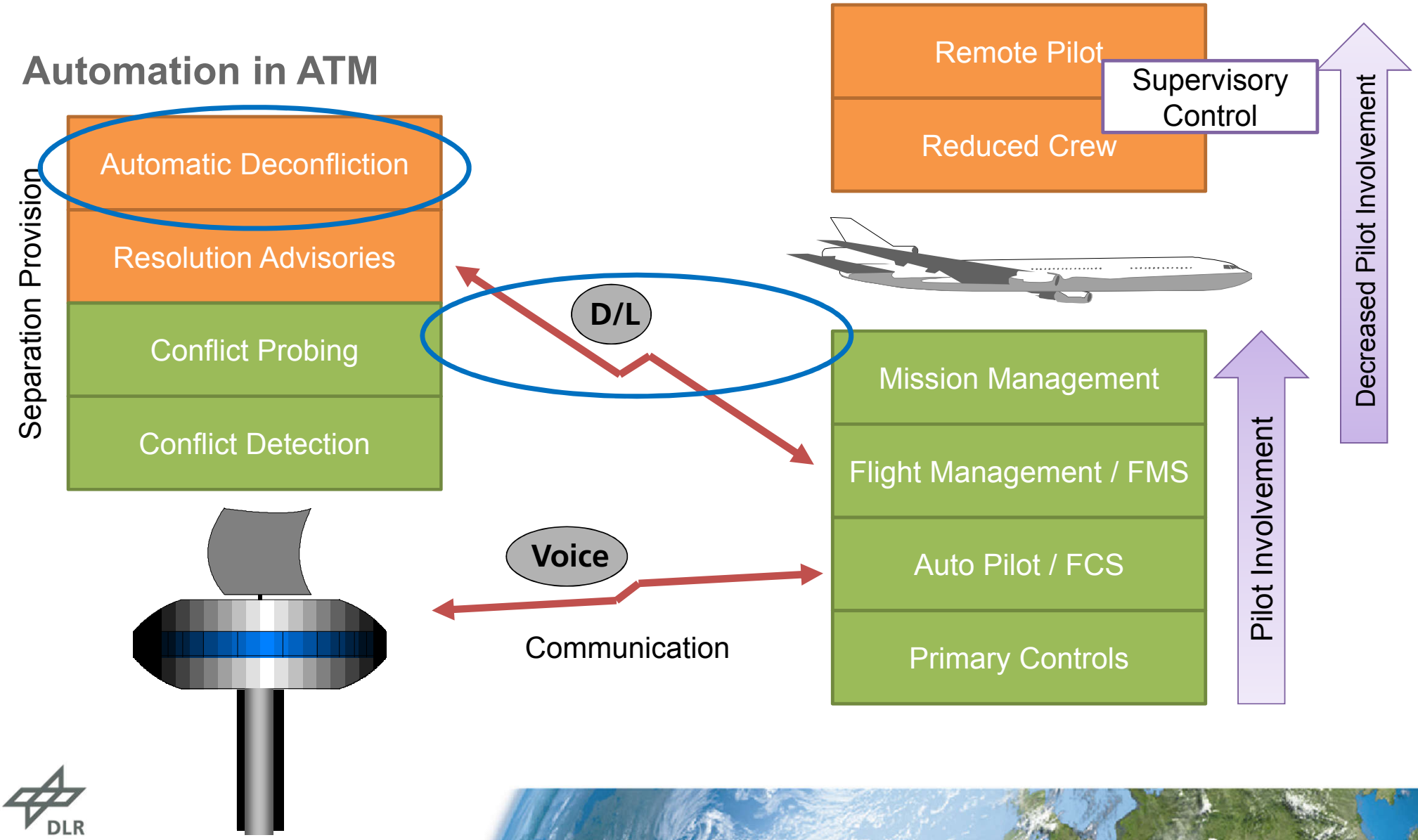
Panel on "Intelligent Automation and Autonomy for a safe and secure Air Transport System."

Concepts on how to introduce higher level of Automation in ATM

Dr. Bernd Korn
DLR – Institiute of Flight Guidance

Automation in ATM



Automation in ATM

Separation Provision

Automatic Deconfliction

Resolution Advisories

Conflict Probing

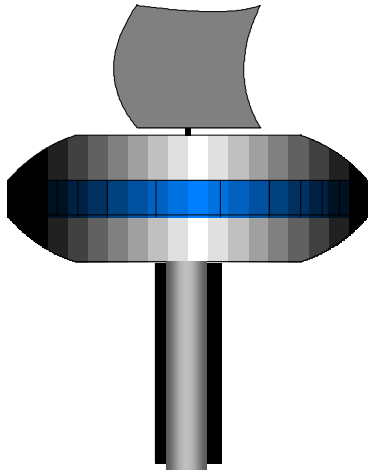
Conflict Detection

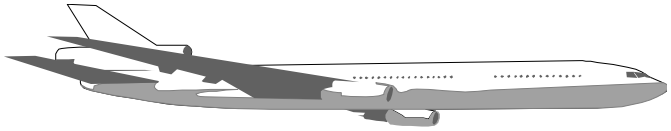
4D Contracts

D/L

Voice

Communication





Remote Pilot

Reduced Crew

Supervisory Control

Mission Management

Flight Management / FMS

Auto Pilot / FCS

Primary Controls

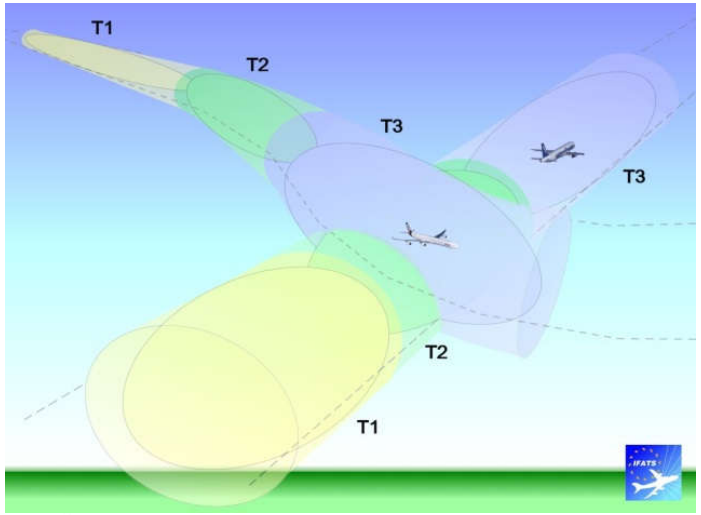
Pilot Involvement

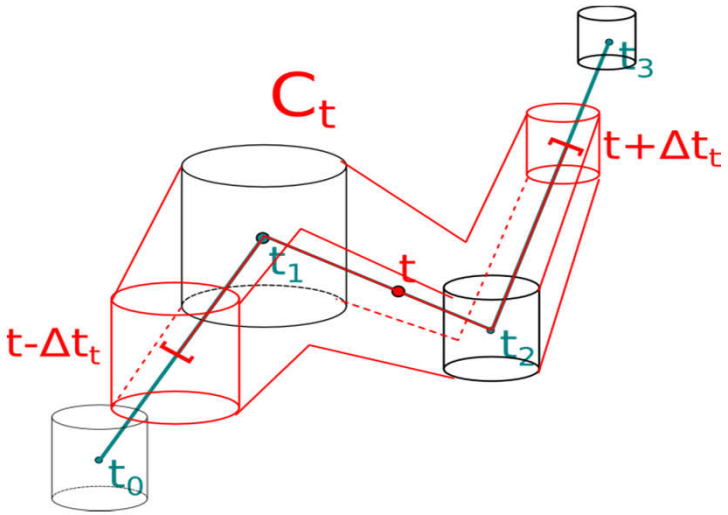
Decreased Pilot Involvement

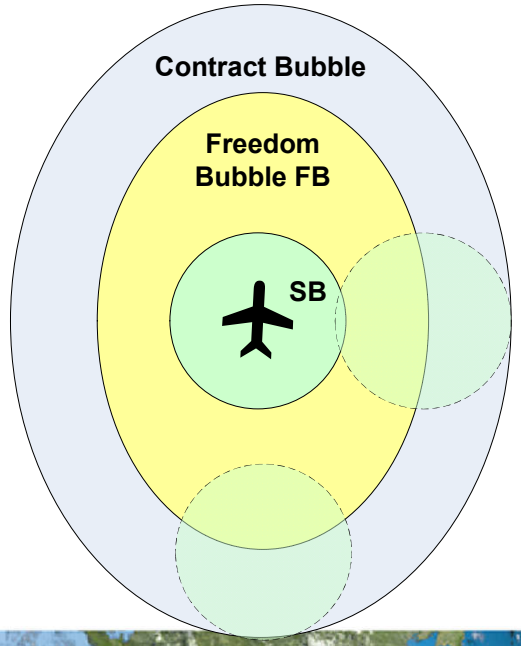
Separation Provision by Shared Responsibilities
Contract Based Control

4DCo-GC
4 Dimension Contract - Guidance and Control

Conflict free Contracts are assigned to A/C
A/C is responsible to stay within the contract
ATC monitors – is only active if contract is violated







DLR

Contract Definition

Trajectory bone

Safety Bubble

- ➢Margins around the aircraft
- ➢At any time, 2 SB must not intersect

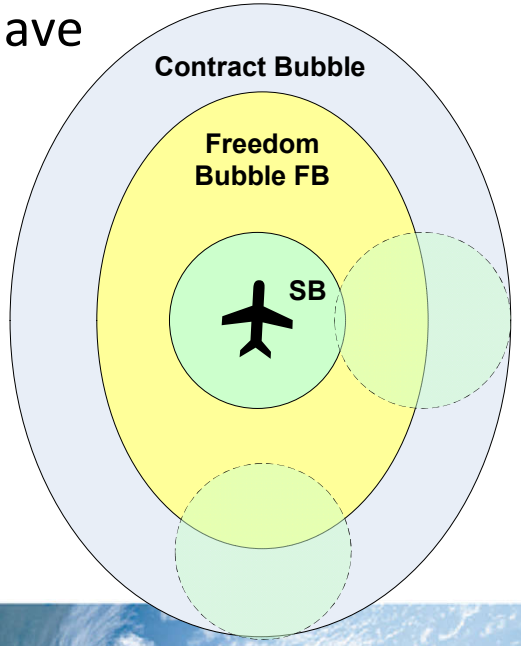
Contract Bubble:

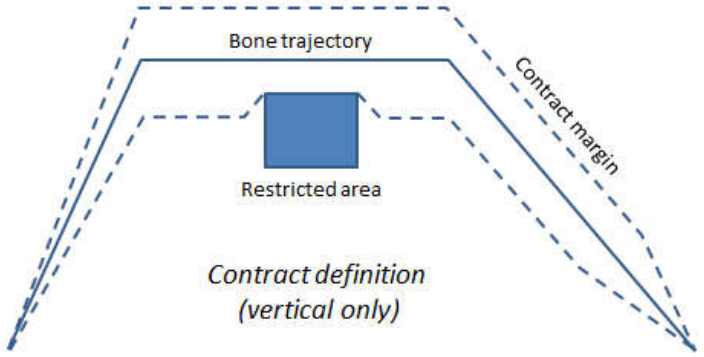
- ➢Calculated by the ground to have conflict-free 4D contracts
- ➢At any time, 2 CB should not intersect

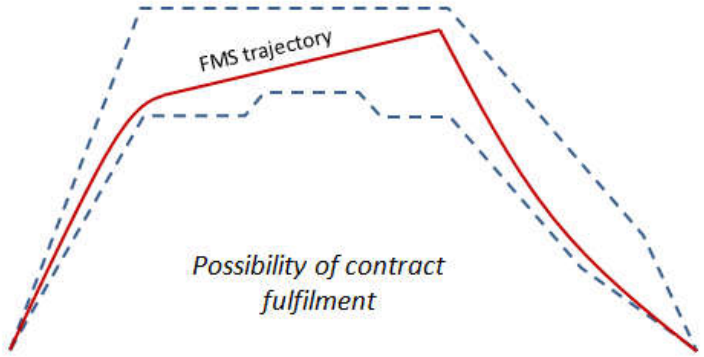
Freedom Bubble

- ➢Calculated by the FMS from CB and SB

4D contract = Bone + SB + CB





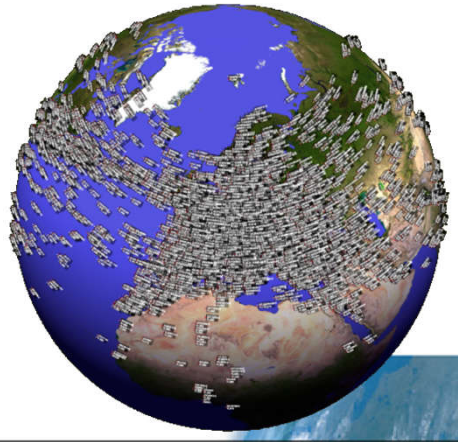


4D – Contracts: Simulations

4 Scenarios
Benelux - airspace
- Benelux 100% = 5297 flights
- Benelux 233% = 11925 flights

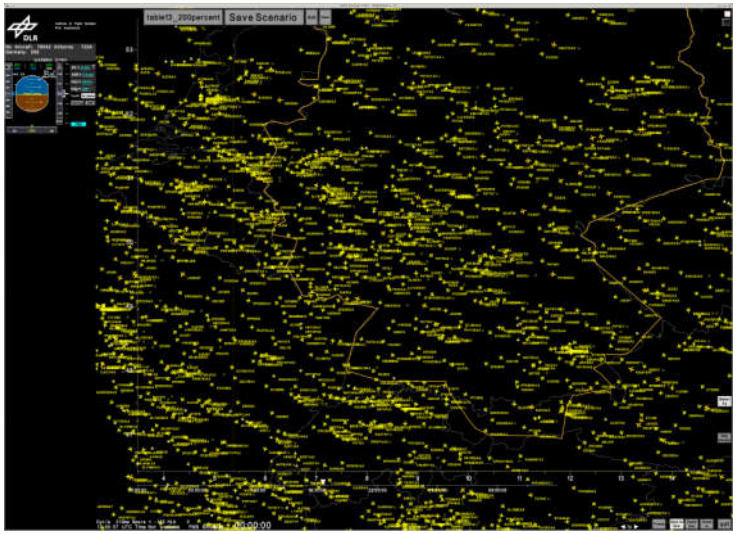
Separations:
6.0 NM/1000 ft above and in FL100
3.2 NM/1000 ft below FL100
3.0 NM safety

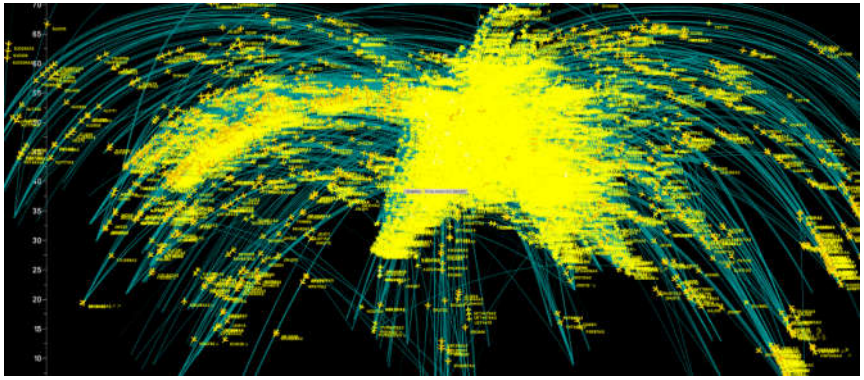
ECAC 233%



Scenario	Traffic	Event
S1	100% Benelux Traffic	~5 kts wind deviation between forecast and actual
S2	233% Benelux Traffic	~5 kts wind deviation between forecast and actual
S3	100% Benelux Traffic	Airport closure Luxembourg, replan to Brussels airport
S4	100% Benelux Traffic	Decompression, immediate decent, generating a conflict with another aircraft

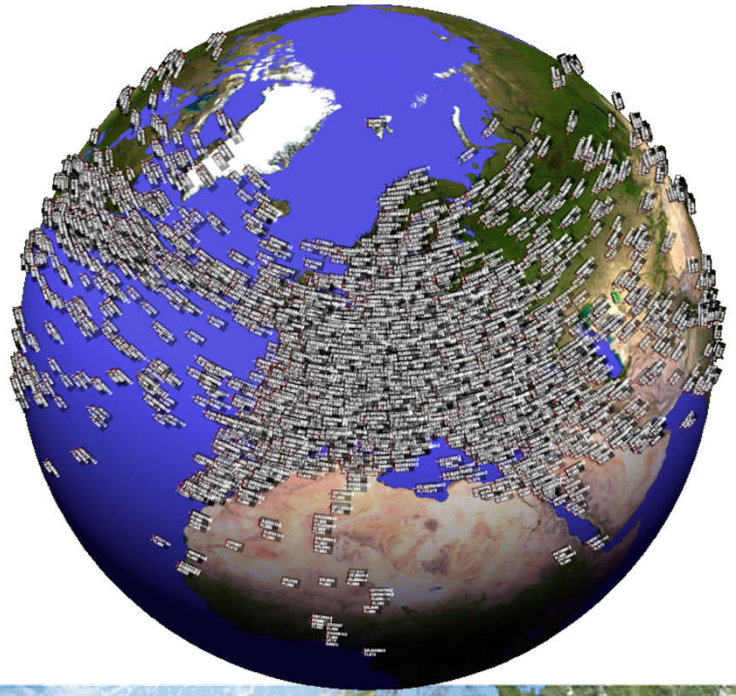
TrafficSimulation





DLR's TrafficSim

- Simulates a large number of AFMS-equipped (and unequipped) aircraft
- Supports scenarios with more than 100.000 aircraft in realtime



Analysis (100% Traffic)

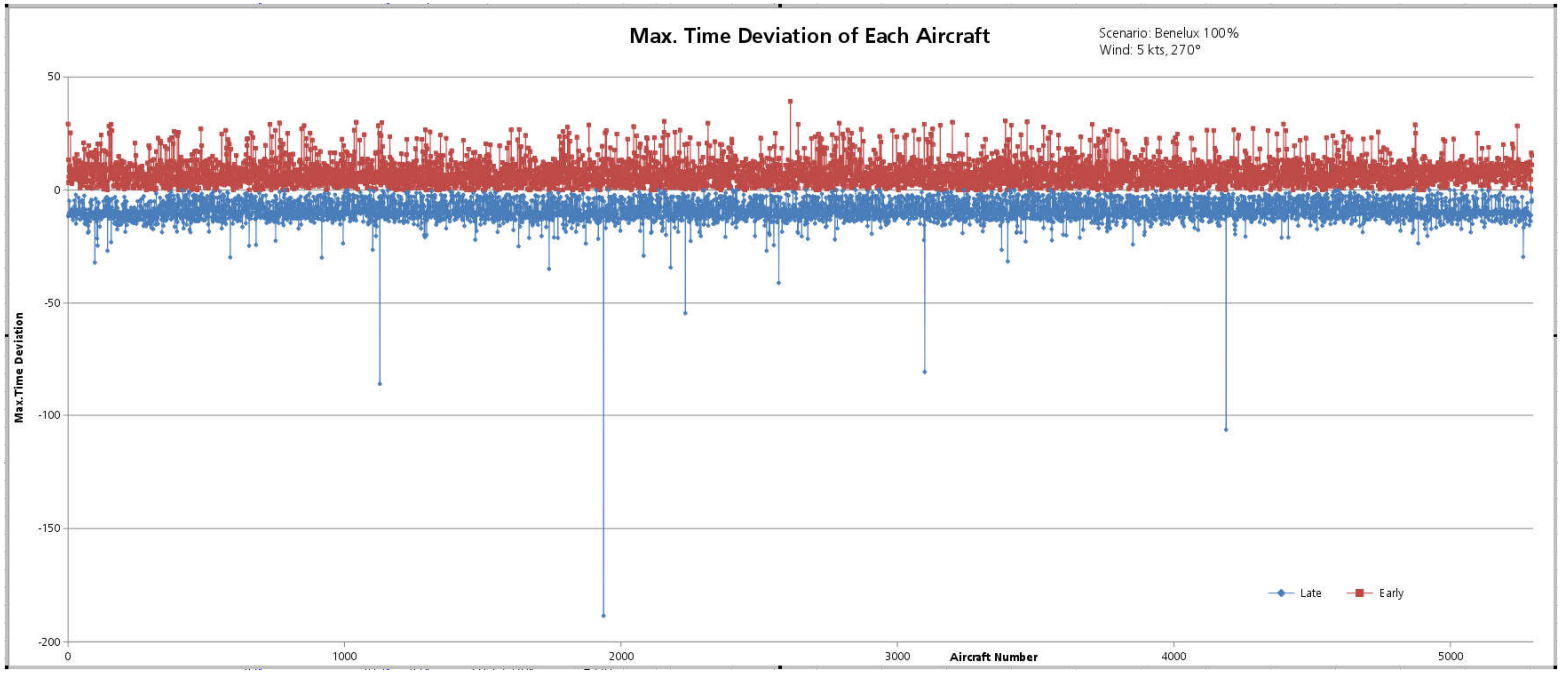
Scenario		Original	4DCoGC	Relative
Number of Flights		5297	5297	N/A
Heavy		876	876	16,5%
Medium		4209	4209	79,5%
Small		212	212	4,0%
Number of Conflicts		3170	3487-->0	0,0%
Number of Trajectory Points	μ±σ [min,max]	31.1±16.9 [3,94]	139.6±99 [19,666]	448,9%
Distance [NM]	μ±σ [min,max]	1194±1275 [17,5880]	1155±1249 [25,5917]	96,7%
Duration [s]	μ±σ [min,max]	10121±9390 [406,51174]	9837 ±9417 [529,45733]	97,2%
Beeline from Departure to Arrival [NM]	μ±σ [min,max]	1139±1250 [17,5880]		N/A

Analysis (233% Traffic)

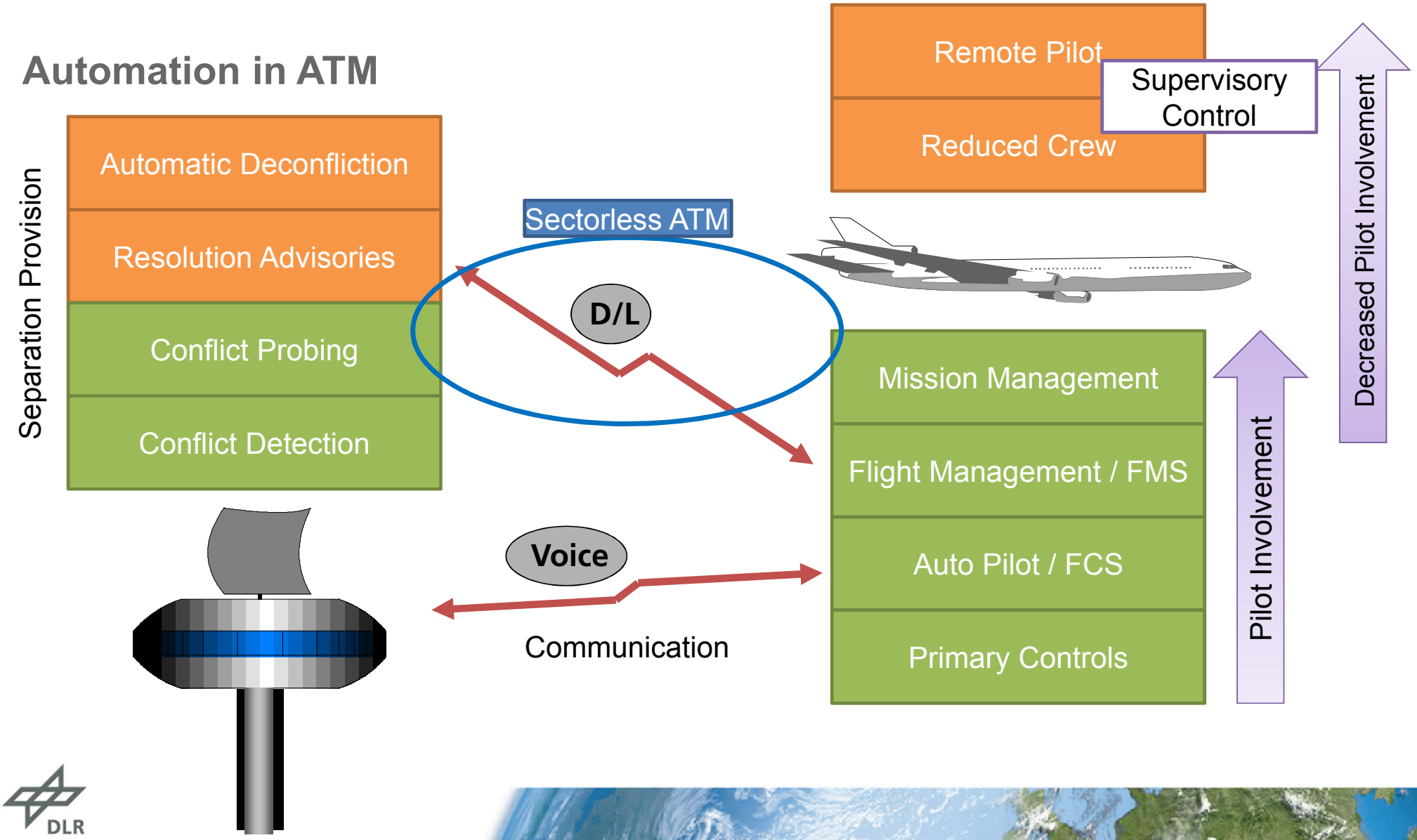
Scenario		Original	4DCoGC	Relative
Number of Flights		11925	11925	N/A
Heavy		2073	2073	17,4%
Medium		9225	9225	77,4%
Small		627	627	5,3%
Number of Conflicts		20303	17882-->0	0,0%
Number of Trajectory Points	μ±σ [min,max]	31.6±17 [3,90]	142.2±99.6 [19,666]	450,0%
Distance [NM]	μ±σ [min,max]	1229±1291 [23,6089]	1189±1264 [25,5917]	96,7%
Duration [s]	μ±σ [min,max]	10398±9520 [406,51174]	10112±9514 [529,45733]	97,3%
Beeline from Departure to Arrival [NM]	μ±σ [min,max]	1174±1265 [17,5880]		N/A

Analysis: Compliance to Contract

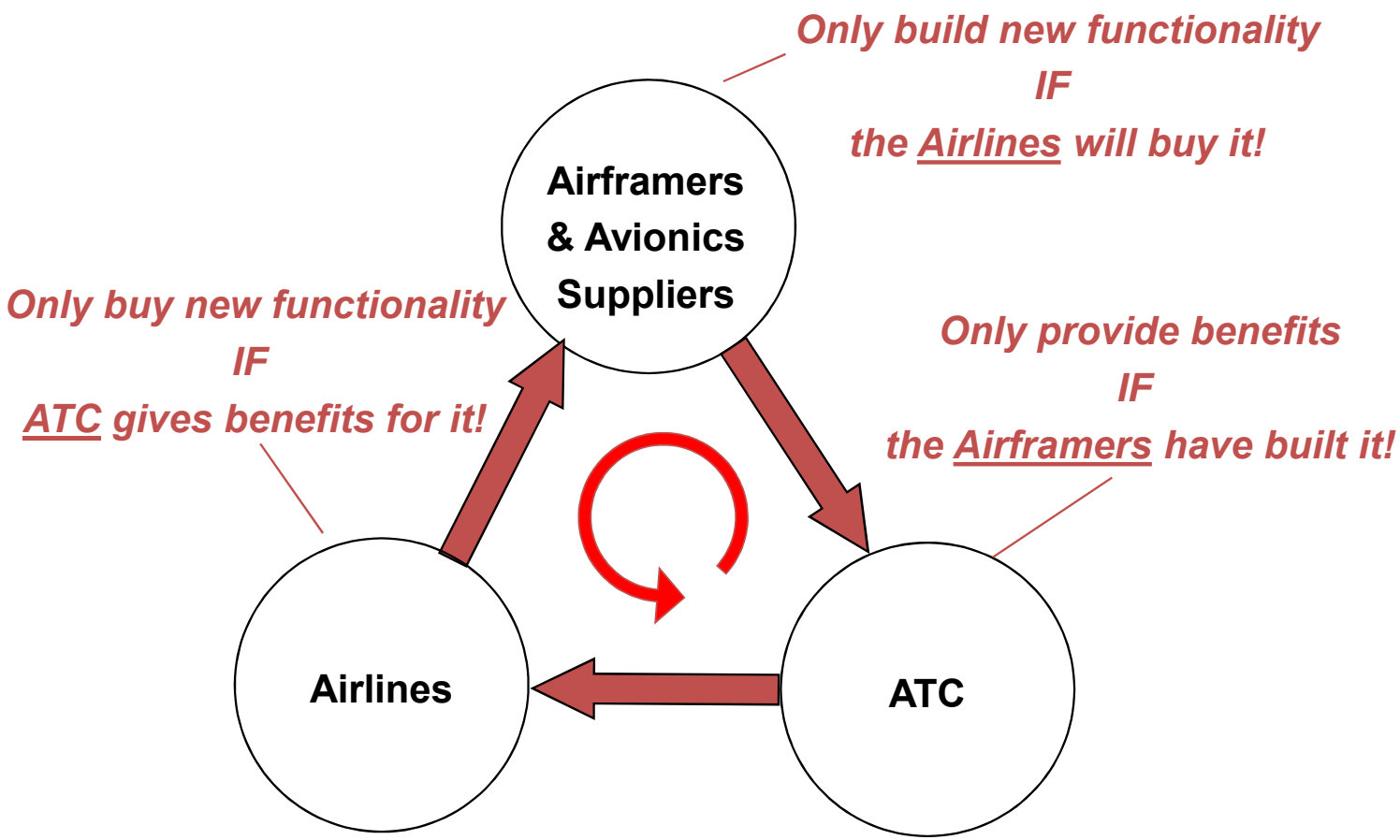
100% Traffic -> 99.66% fulfilled initial contract
233% Traffic -> 98.99% fulfilled initial contract
Regenerate reason: wind mismatch of ~5 kts



Automation in ATM

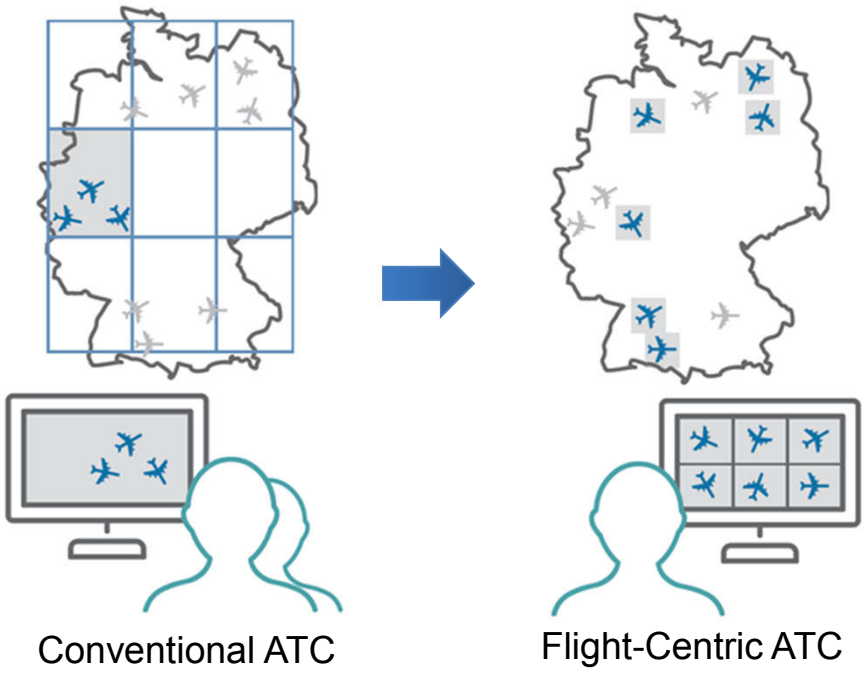


Automation in ATM: The Problem of Mixed Equippage



Sectorless Air Traffic Management (flight-centric ATC)

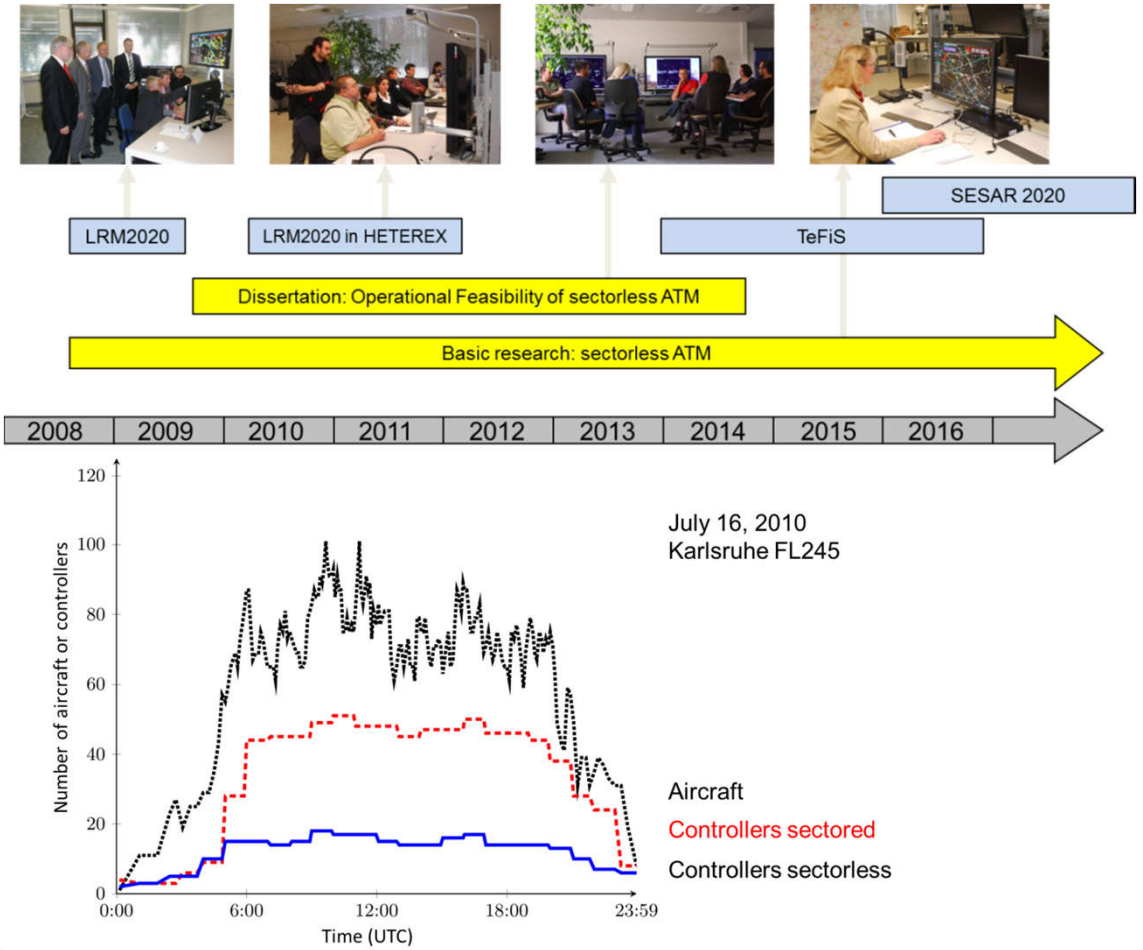
Robust and Efficient En-route Operations



Conventional ATC

Flight-Centric ATC

DFS Karlsruhe (UAC) 2021

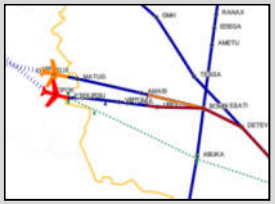


Sectorless ATM – Important Concept Components

Flight Phase	Priority
Level,Level, Overtaking Criteria = false	Right Aircraft
Level,Level Overtaking Criteria = true	Slower Aircraft
Level, Level but close to TOD	Aircraft in Level
Climb, Level	Aircraft in Level
Descent, Level	Aircraft in Level
Climb, Descent	Aircraft in Descent
Climb, Climb	Lower Aircraft
Descent, Descent	Upper Aircraft
Emergency	Aircraft in Emergency State
Efficency	*Aircraft with less Avoidance Manoeuvre*

Flight Rules

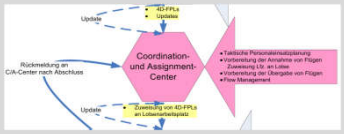
Controller WP



CD&R

Datalink

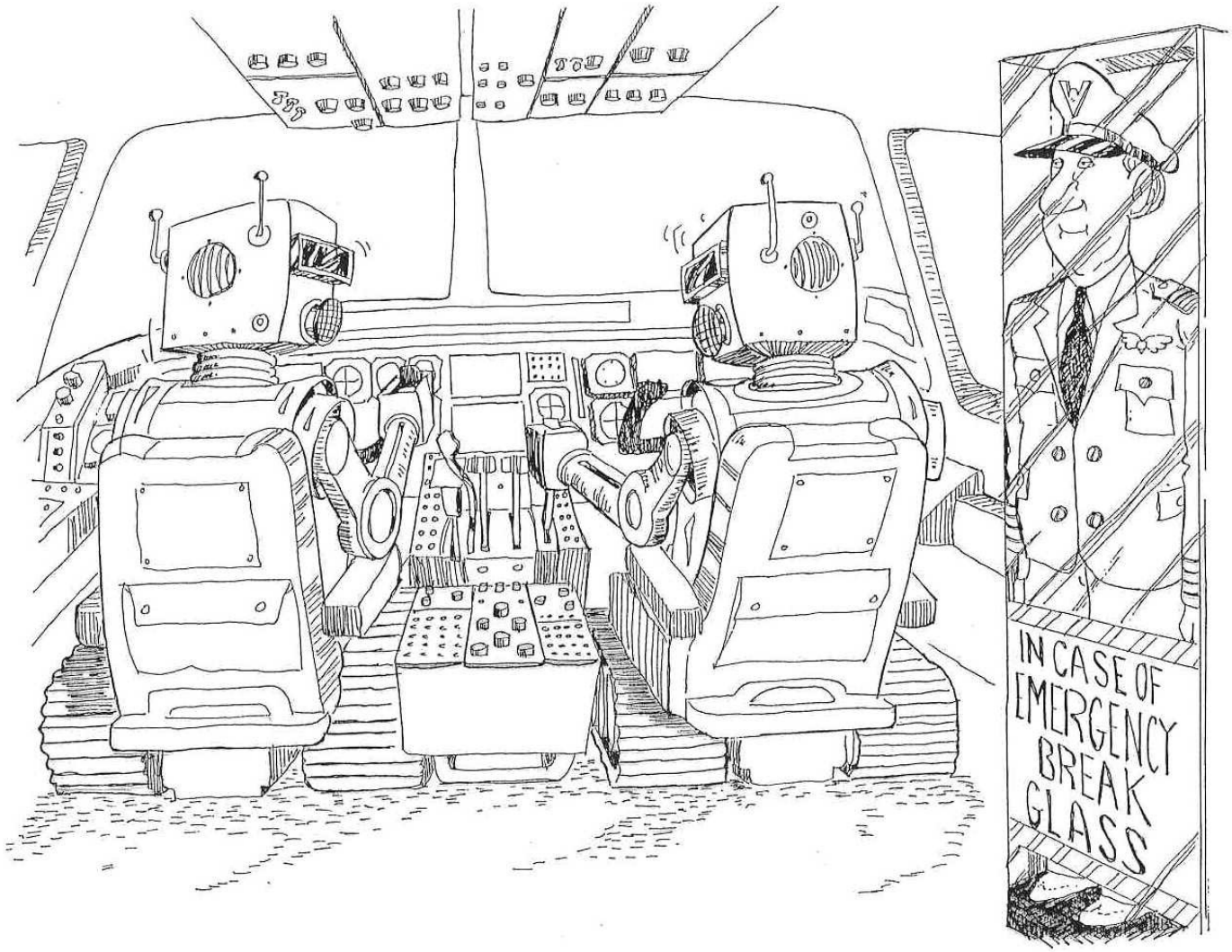
Voice Communication



Assignment Center

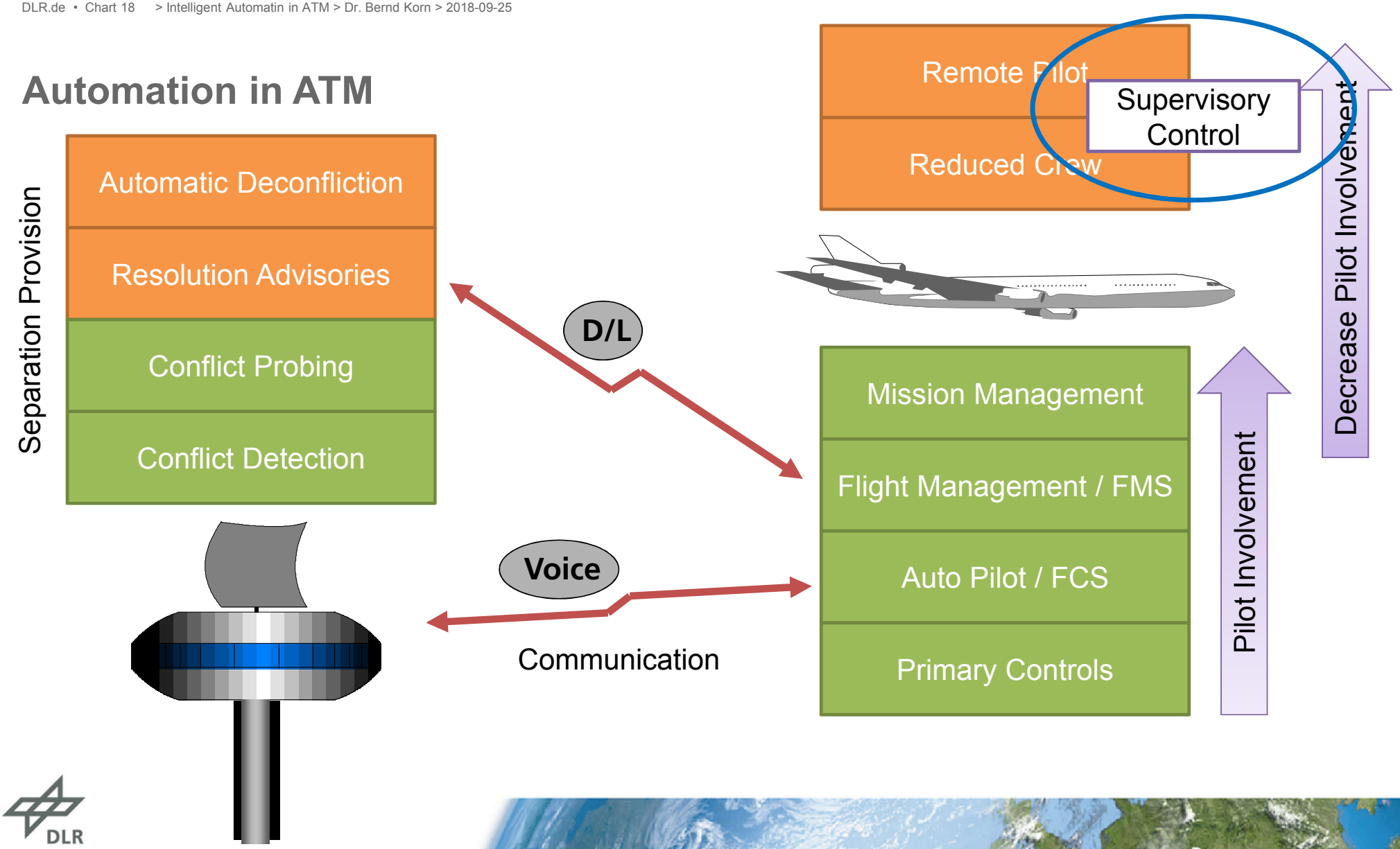
Sectorless ATM – HMI concept (here Tiled Display)

Questions?



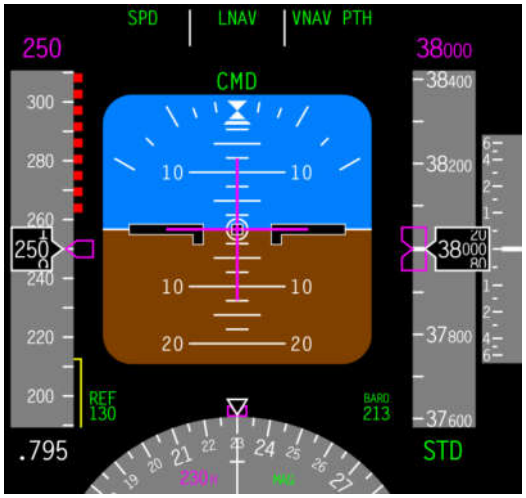
Backup Slides

Automation in ATM



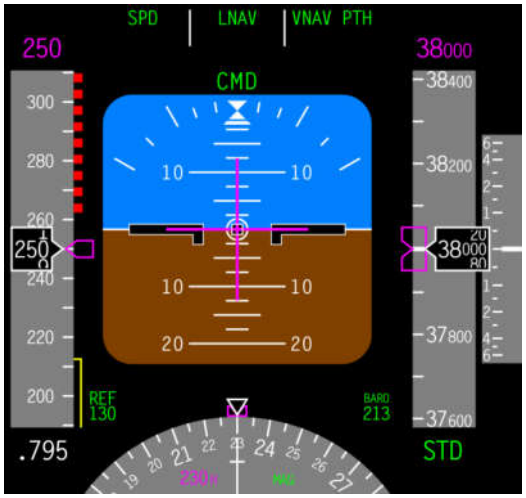
Supervisory Control: Information

1 aircraft



Supervisory Control: Information

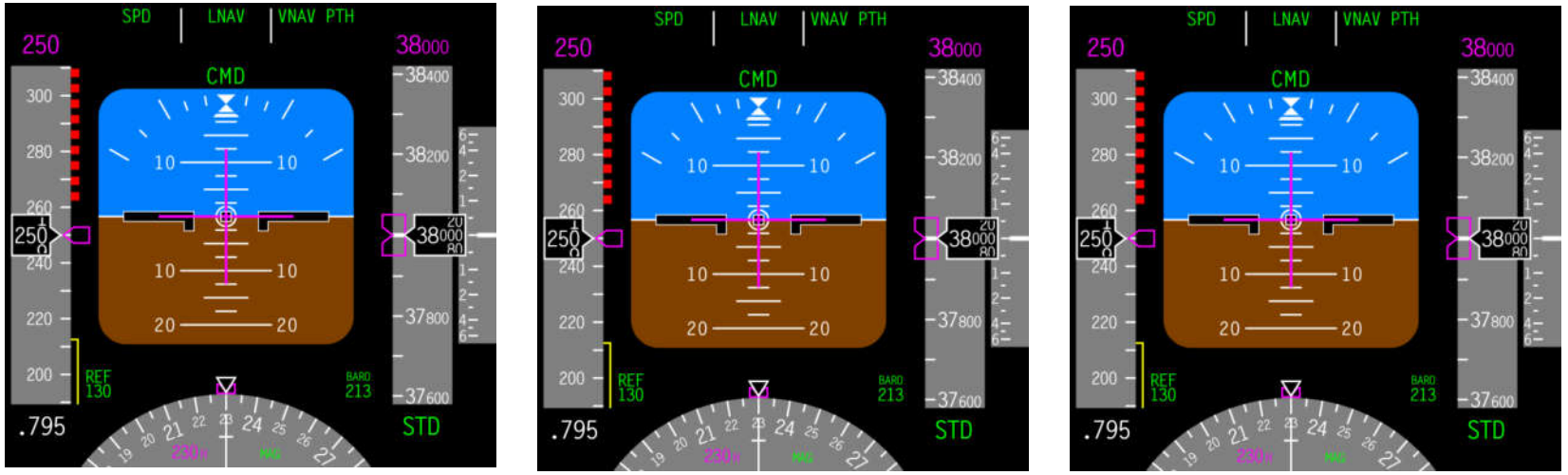
1 aircraft



Everthing ok?

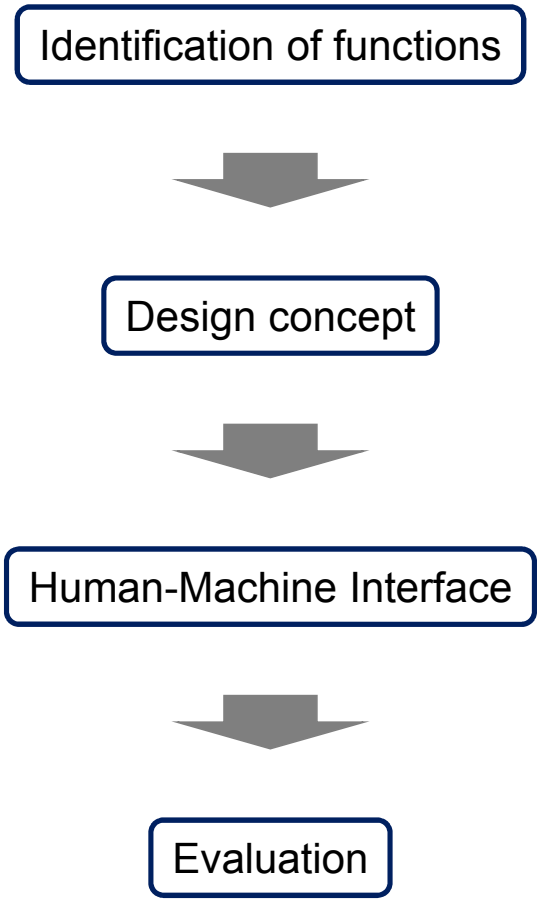
Supervisory Control: Information

3 aircraft



Everthing ok?

Supervisory Control: HMI Design Process



Identification of Functions
Abstraction Hierarchy

Functional Purposes
Reasons and purposes why the work system exists.

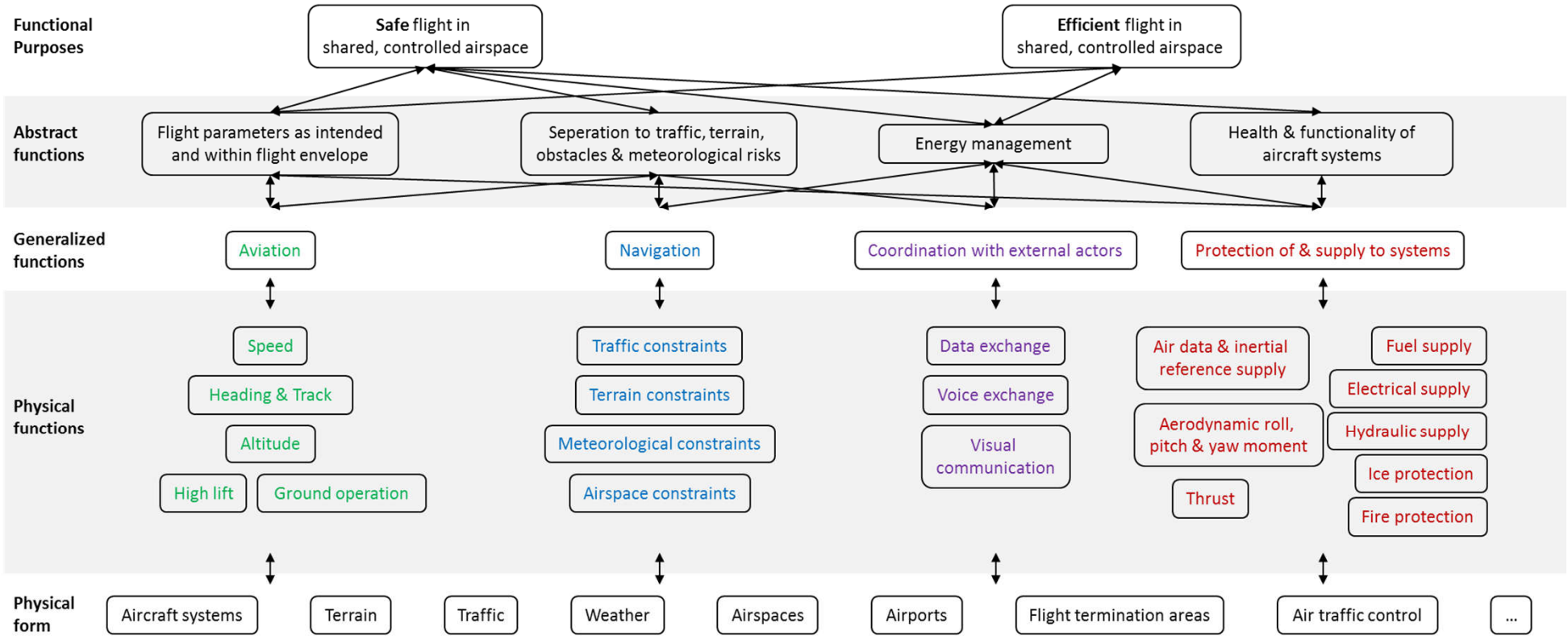
Abstract Function
Criteria by which the achievement of purposes can be judged.

Generalized Function
Functions that are necessary to achieve the purpose of the work system.

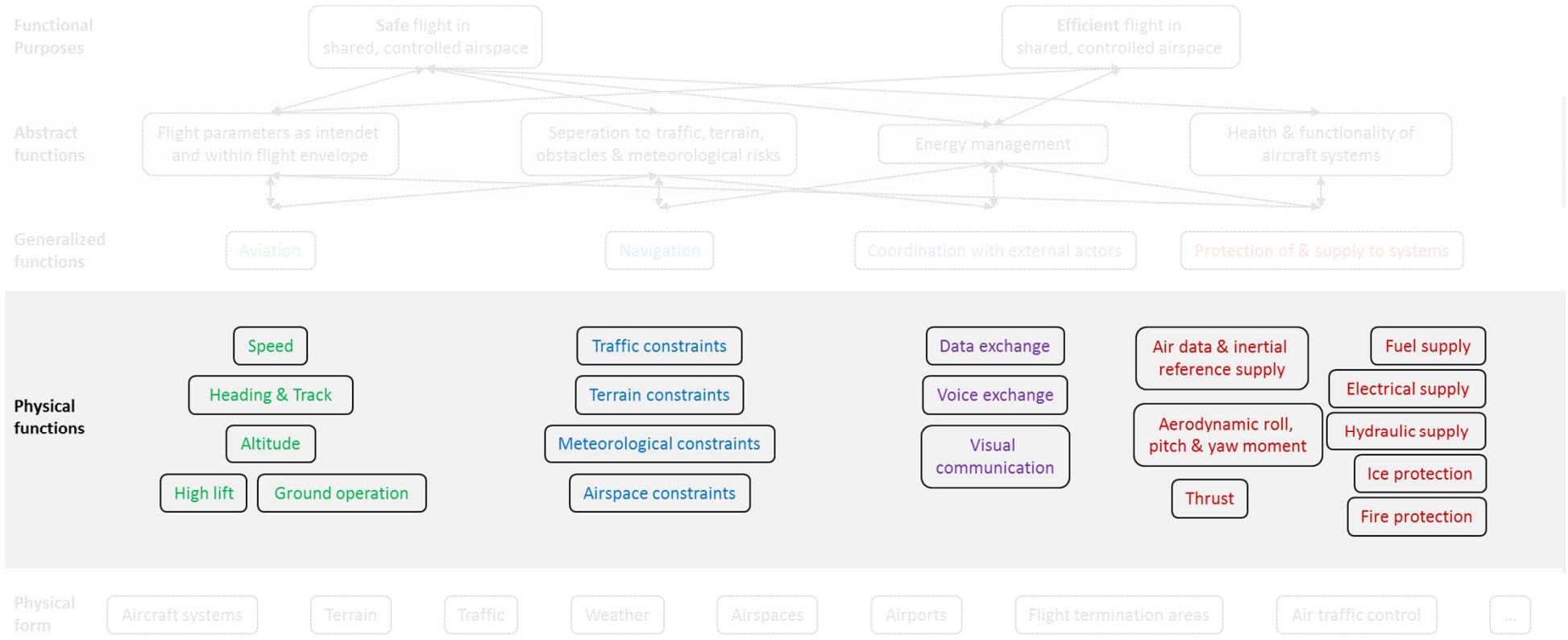
Physical Function
Physical processes that are necessary for execution of the generalized functions.

Physical Form
The actual physical objects of the work system.

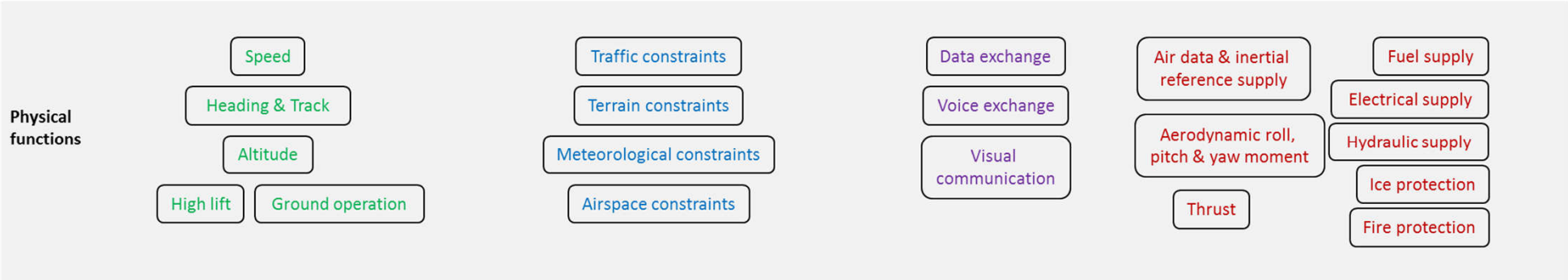
Identification of Functions
Abstraction Hierarchy



Design Concept



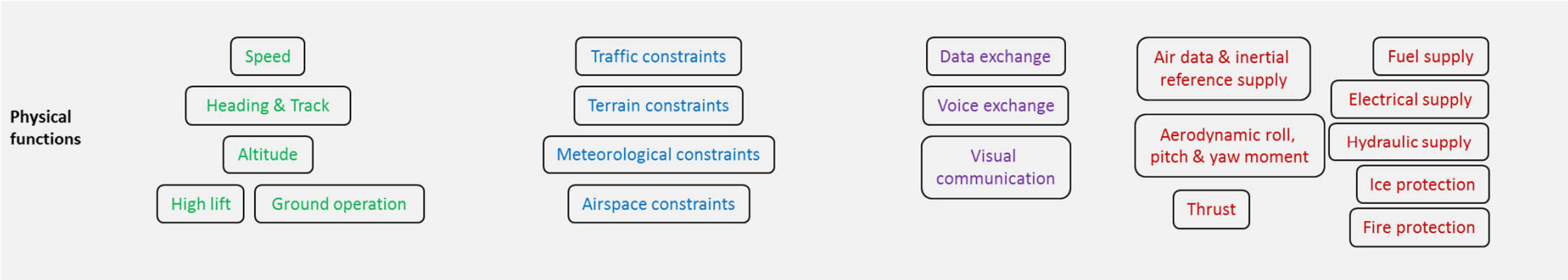
Design Concept



Visualization of functions as icons

Differentiation of system states by color

Design Concept

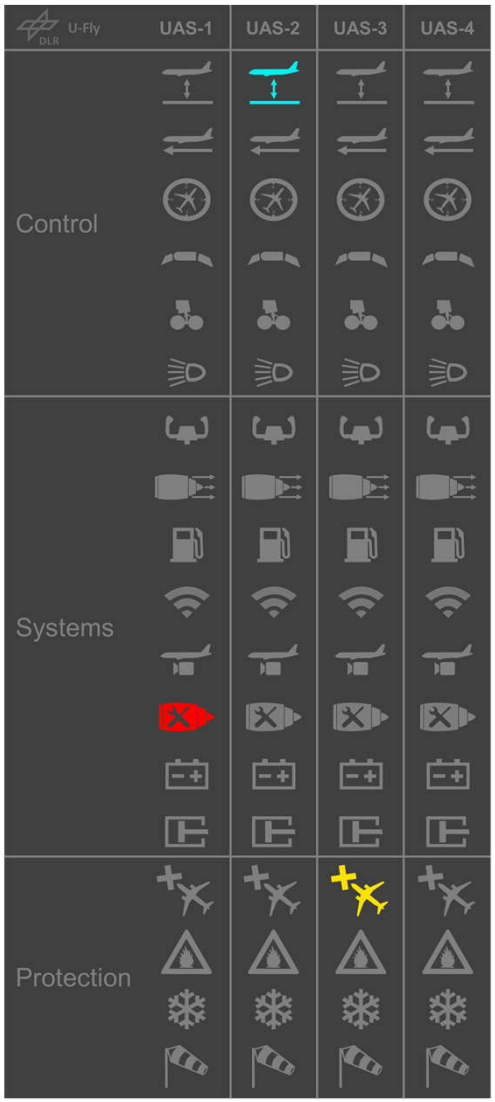


Visualization of functions as icons

Differentiation of system states by color

Visualization of function specific system parameters in a separate widget

Design Concept
Status Display

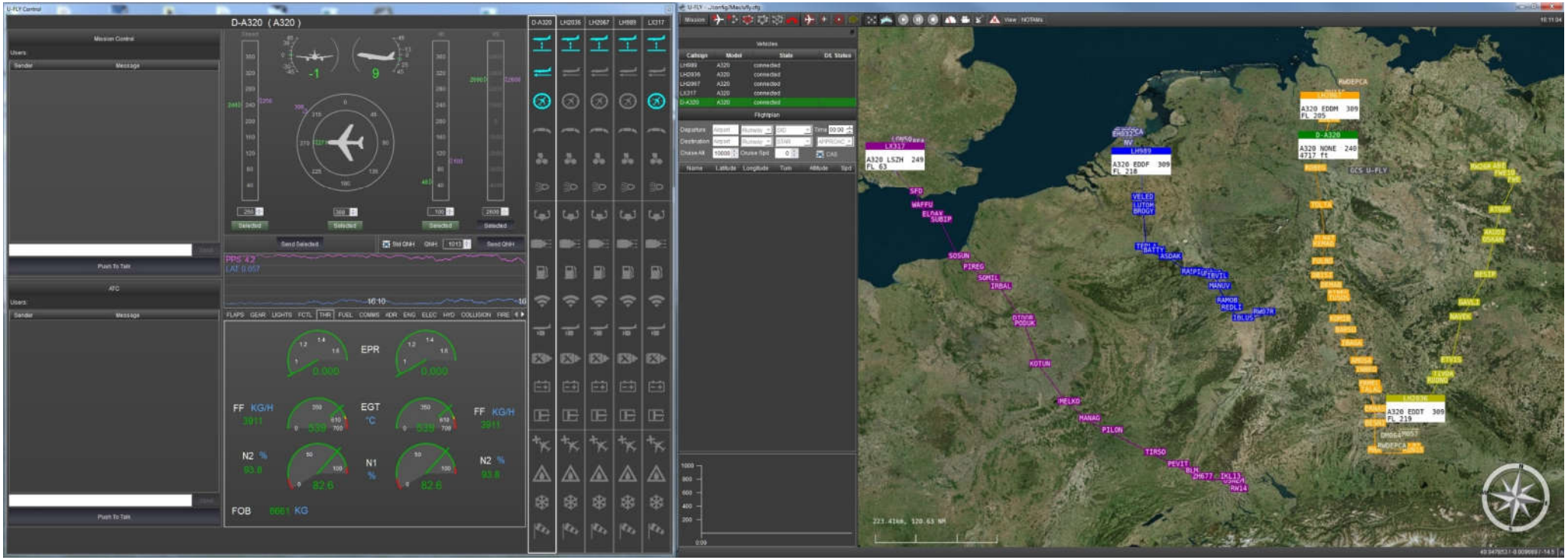


System Control

System Health

System Protection

Human-Machine Interface
DLR RPS Ufly

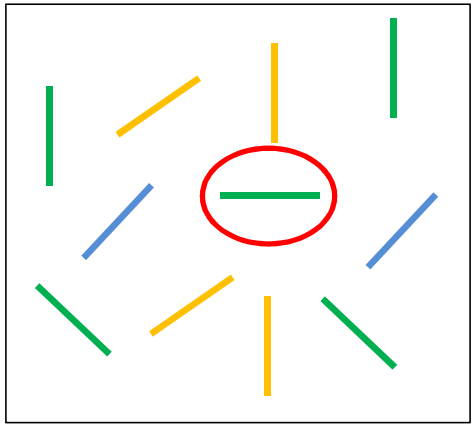


Feature Based Interface Design

Features (Treisman & Gelade, 1980)

Serial search (heterogeneous distractors):

Please find the unique object:



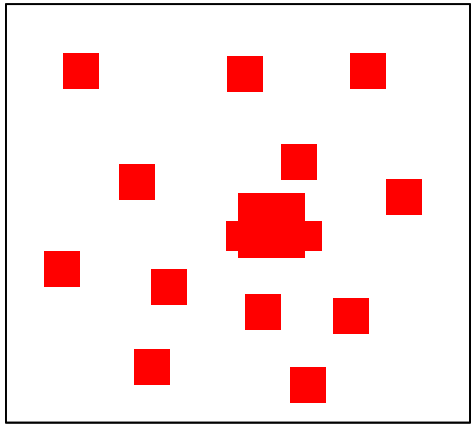
Linear increase in reaction time as a function of set size.

Feature Based Interface Design

Features (Treisman & Gelade, 1980)

Parallel search (homogeneous distractors):

Please find the unique object:



Reaction time is independent of set size.

Support parallel search!

Design Concept

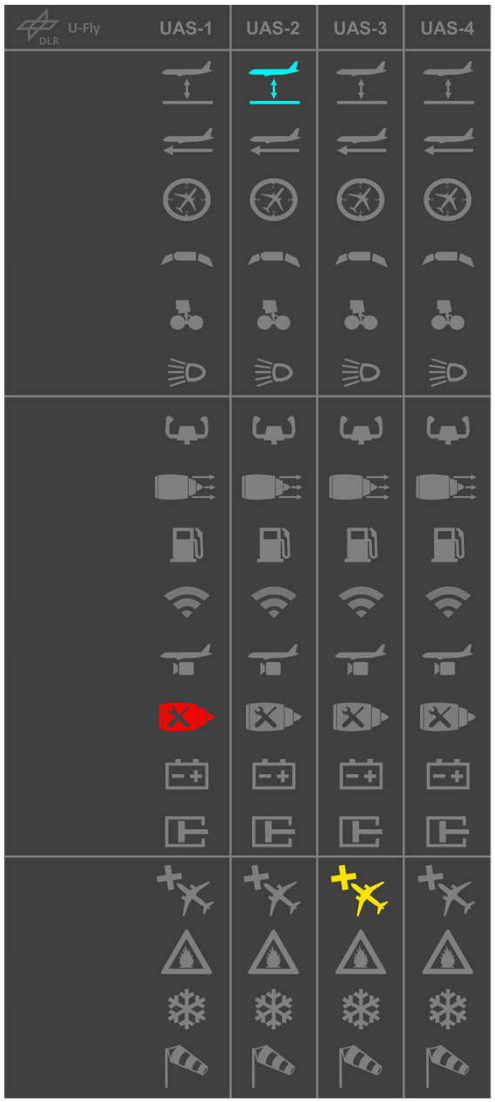
Icons

Function	Icon	Function	Icon
Altitude		Data & voice exchange – Radio communication	
Speed		Air data and inertial reference supply	
Heading & track		Thrust– Secondary engine parameters	
Aerodynamic lift & drag – Secondary flight controls		Electrical supply	
Ground operation – Landing gear		Hydraulic supply	
Visual communication – Lights		Traffic, terrain & airspace constraints	
Roll, pitch & yaw moment – Primary flight controls		Fire protection	
Thrust – Primary engine parameters		Ice protection	
Fuel supply		Meteorological constraints	

Design Concept
System States

System state	Color	Example
Normal		Altitude is within normal ranges
Transit		Aircraft is changing heading as expected
Caution		Potential hazard approaching (e.g. TCAS TA)
Warning		Engine parameter within critical ranges (e.g. oil temperature too high)

Design Concept
Status Display



Identification of functions

Design concept

Human-Machine Interface

Evaluation