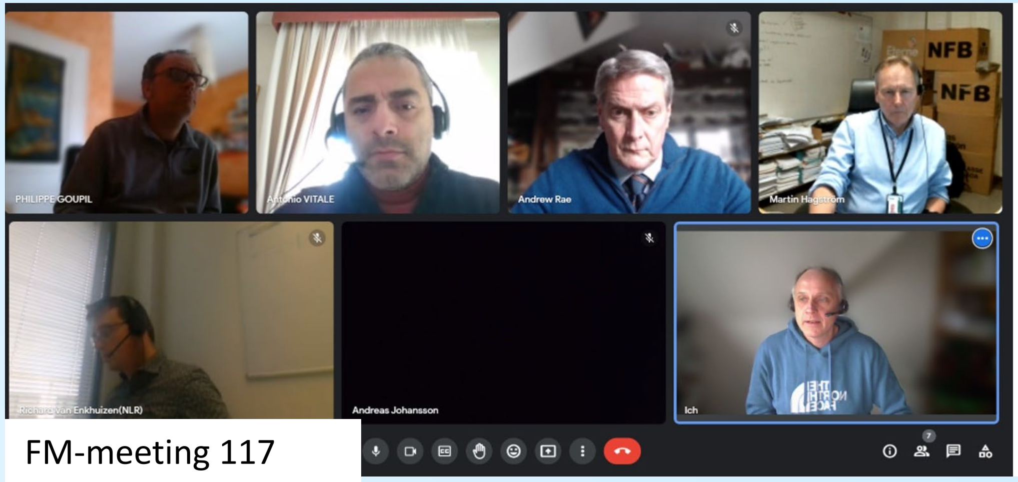
"Flight Mechanics, Systems and Integration (GoR FM)": key themes and impact highlights

Dr. Bernd Korn
Chairman GoR FM

"Flight Mechanics, Systems and Integration (GoR FM)": key themes and impact highlights

- GoR FM – General Overview
- Some examples of GoR FM projects

GoR FM: Who we are!



FM-meeting 117

Current members

Airbus (F): Philippe Goupil

Airbus (G): Martin Hanel

Dassault: Laurent Goerig

Saab: Andreas Johansson

CIRA: Antonio Vitale

DLR: **Bernd Korn (Chairman)**

FOI: Martin Hagström

NLR: Marinus Johannus (Richard) van Enkhuizen

ONERA: ***Carsten Doll (Vice Chairman)***

University of the Highlands and Islands in Scotland & Ampaire: Andrew Rae

GoR FM: How do we work

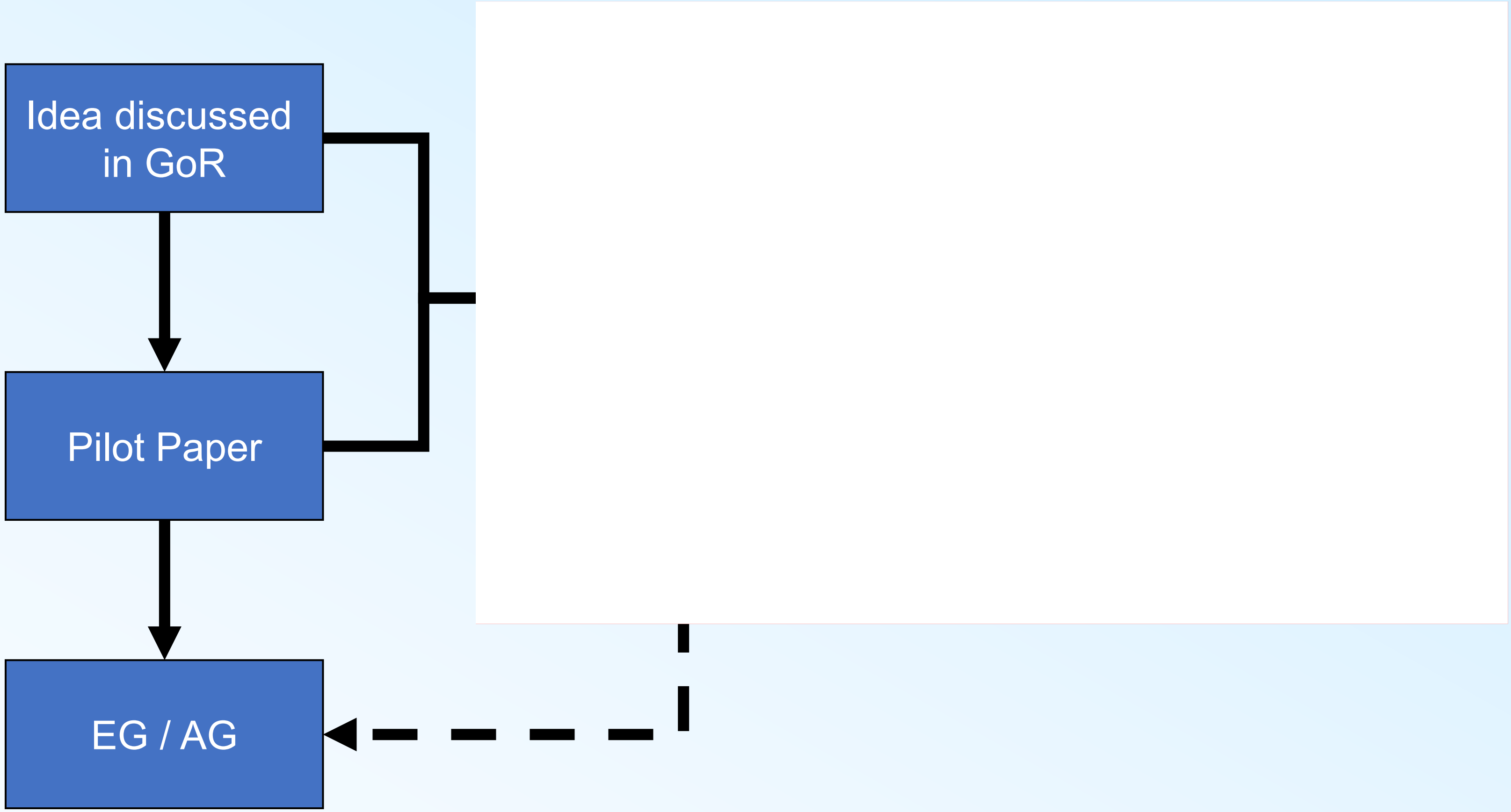
Pilot Paper → Enough interest among partners → **EG: Exploratory Group** → Commitment by partners (own funding) → **AG: Action Group**

Pilot Paper ↑ One or two pages describing the idea of a project

EG: Exploratory Group ↓ The project plan

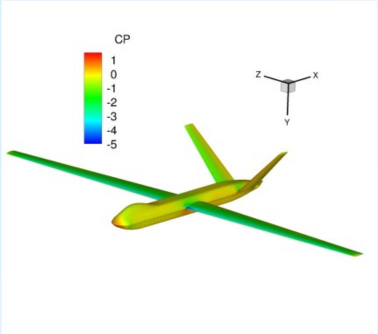
AG: Action Group ↓ Typical Results:
- Visionary concepts
- Models / benchmarks
- Handbooks
- …

Lack of funding: GARTEUR activity or European Project?

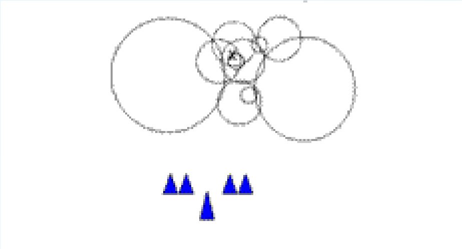


GoR FM: Research Objectives

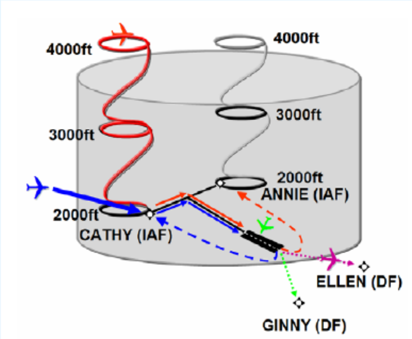
A *Development and benefit assessment of advanced methods for analysis and synthesis of flight control systems for aircraft with both conventional and non conventional aero structural configurations.*



B *Development of advanced methods for UAV mission automation*

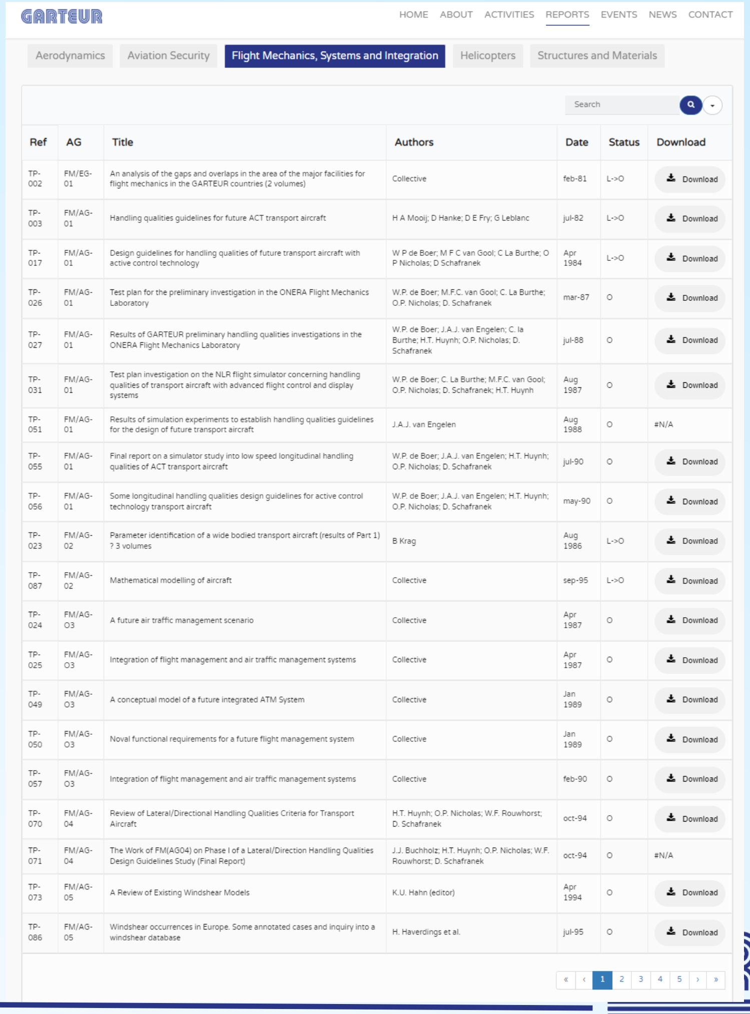


C *Development and benefit assessment of advanced aircraft capabilities into ATM/ATC related applications*

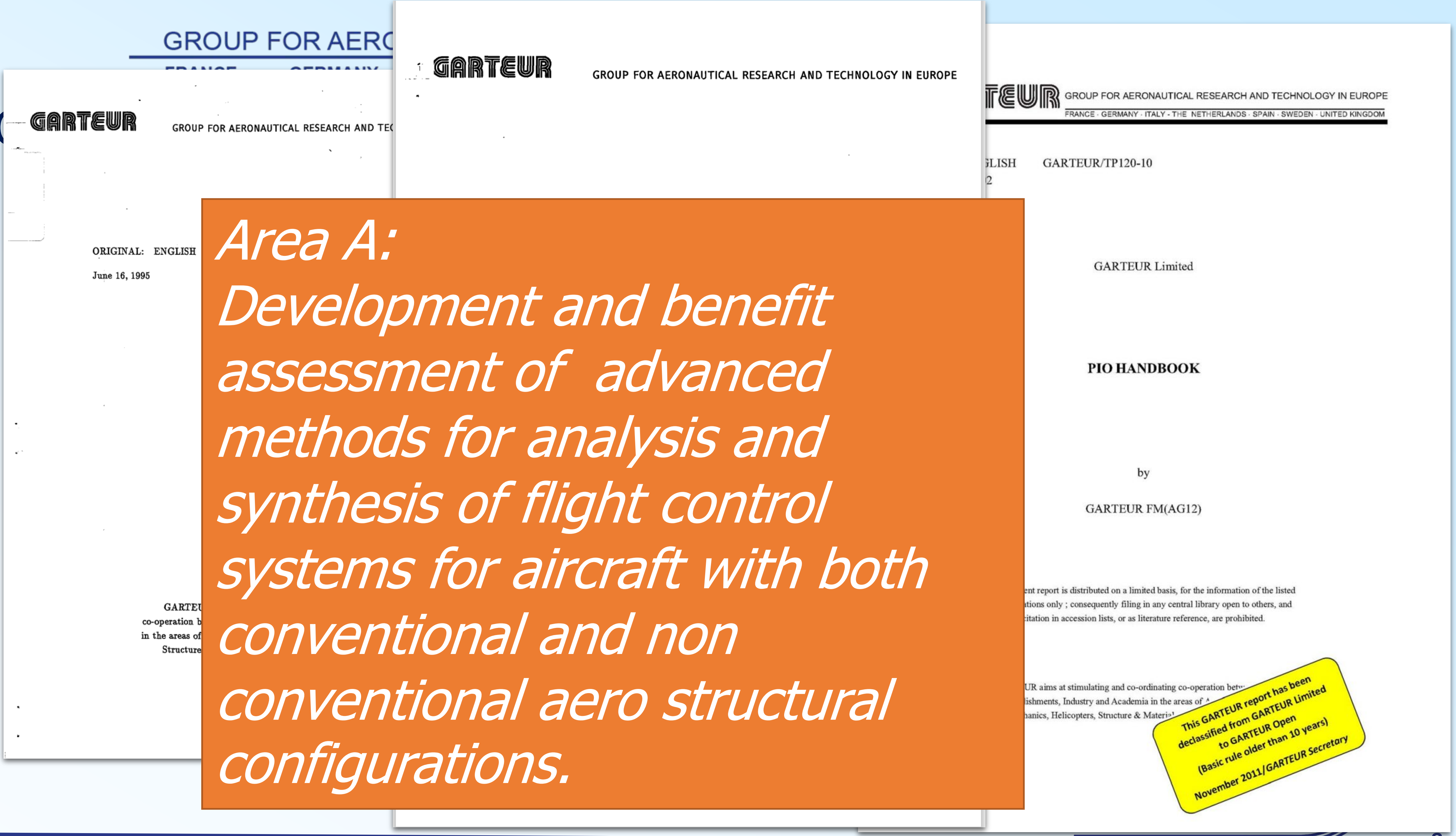


GoR FM: Research Activities

- More than 80 reports on Garteur website (https://garteur.org)



Ref	AG	Title	Authors	Date	Status	Download
TP-002	FM/EG-01	An analysis of the gaps and overlaps in the area of the major facilities for flight mechanics in the GARTEUR countries (2 volumes)	Collective	feb-81	L->O	Download
TP-003	FM/AG-01	Handling qualities guidelines for future ACT transport aircraft	H A Mooij; D Hanke; D E Fry; G Leblanc	jul-82	L->O	Download
TP-017	FM/AG-01	Design guidelines for handling qualities of future transport aircraft with active control technology	W P de Boer; M F C van Gool; C La Burthe; O P Nicholas; D Schafranek	Apr 1984	L->O	Download
TP-026	FM/AG-01	Test plan for the preliminary investigation in the ONERA Flight Mechanics Laboratory	W.P. de Boer; M.F.C. van Gool; C. La Burthe; O.P. Nicholas; D. Schafranek	mar-87	O	Download
TP-027	FM/AG-01	Results of GARTEUR preliminary handling qualities investigations in the ONERA Flight Mechanics Laboratory	W.P. de Boer; J.A.J. van Engelen; C. la Burthe; H.T. Huynh; O.P. Nicholas; D. Schafranek	jul-88	O	Download
TP-031	FM/AG-01	Test plan investigation on the NLR flight simulator concerning handling qualities of transport aircraft with advanced flight control and display systems	W.P. de Boer; C. La Burthe; M.F.C. van Gool; O.P. Nicholas; D. Schafranek; H.T. Huynh	Aug 1987	O	Download
TP-051	FM/AG-01	Results of simulation experiments to establish handling qualities guidelines for the design of future transport aircraft	J.A.J. van Engelen	Aug 1988	O	#N/A
TP-055	FM/AG-01	Final report on a simulator study into low speed longitudinal handling qualities of ACT transport aircraft	W.P. de Boer; J.A.J. van Engelen; H.T. Huynh; O.P. Nicholas; D. Schafranek	jul-90	O	Download
TP-056	FM/AG-01	Some longitudinal handling qualities design guidelines for active control technology transport aircraft	W.P. de Boer; J.A.J. van Engelen; H.T. Huynh; O.P. Nicholas; D. Schafranek	may-90	O	Download
TP-023	FM/AG-02	Parameter identification of a wide bodied transport aircraft (results of Part 1) ? 3 volumes	B Krag	Aug 1986	L->O	Download
TP-087	FM/AG-02	Mathematical modelling of aircraft	Collective	sep-95	L->O	Download
TP-024	FM/AG-03	A future air traffic management scenario	Collective	Apr 1987	O	Download
TP-025	FM/AG-03	Integration of flight management and air traffic management systems	Collective	Apr 1987	O	Download
TP-049	FM/AG-03	A conceptual model of a future integrated ATM System	Collective	Jan 1989	O	Download
TP-050	FM/AG-03	Noval functional requirements for a future flight management system	Collective	Jan 1989	O	Download
TP-057	FM/AG-03	Integration of flight management and air traffic management systems	Collective	feb-90	O	Download
TP-070	FM/AG-04	Review of Lateral/Directional Handling Qualities Criteria for Transport Aircraft	H.T. Huynh; O.P. Nicholas; W.F. Rouwhorst; D. Schafranek	oct-94	O	Download
TP-071	FM/AG-04	The Work of FM(AG04) on Phase I of a Lateral/Direction Handling Qualities Design Guidelines Study (Final Report)	J.J. Buchholz; H.T. Huynh; O.P. Nicholas; W.F. Rouwhorst; D. Schafranek	oct-94	O	#N/A
TP-073	FM/AG-05	A Review of Existing Windshear Models	K.U. Hahn (editor)	Apr 1994	O	Download
TP-086	FM/AG-05	Windshear occurrences in Europe. Some annotated cases and inquiry into a windshear database	H. Haverdings et al.	jul-95	O	Download



Area A:
Development and benefit assessment of advanced methods for analysis and synthesis of flight control systems for aircraft with both conventional and non conventional aero structural configurations.

GoR FM: Research Activities

(iii) Resolution of conflicts more strategically, over longer time horizons.

(iv) Improved en-route capacity through exploitation of more accurate three-dimensional (3-D) navigation, and use of longitudinal (ie time) navigation and control to increase capacity of junctions and terminal areas.

(v) Improved acco ... of flight, based on com ...

7 CONSTRAINTS AN ...

These guidelin ...

(i) Must maintain ...

...dimensional
...th respect to:
...s would be
... tubes would
meteorological
...ft would not
... implies that
...hould be built
... the clearance unaided. Poorly equipped aircraft might require assistance, particularly in terminal areas where the constraints would be more stringent.

Area C:
Development and benefit assessment of advanced aircraft capabilities into ATM/ATC related applications

From AG3 – Report on „A Future Air Traffic Management Scenario“

GoR FM: Research Activities

(a) The best model of the aircraft's performance, its costs and capabilities will reside in the aircraft's computers. One may deduce that the aircraft should propose a trajectory and possibly bid for a time slot.

(b) The only viable model of the overall ATC situation is in the ATC system and its computers, therefore the ground based system should retain the overall adjudication, safety and optimisation functions. It must allocate slot times and trajectories and arbitrate between conflicting requirements.

(c) Air and ground system should agree on the description of a partial or complete trajectory to ensure that it is practical and safe, which the aircraft must then execute.

(d) The ground system should provide a monitoring function against significant deviations from these agreed trajectories.

(e) Provision must be made for modification of this trajectory to cope with unexpected events.

see
SESAR activity on
initial 4D…

From AG3 – Report on „Integration of Flight Management and ATM Systems“

S

3.2.3 Description of Trajectories as Tubes in Space

In essence a 4D trajectory could be described as a line through 4D space. For practical reasons tolerances must be introduced and so the line becomes a tube. It can be imagined as a bubble moving through a tube such that its position as a function of time is known. It could also be regarded as an extension of today's separation standards which are defined in vertical, horizontal and longitudinal directions.

The bubble would have internal structure composed of three concentric regions. From the inside, these regions reflect the performance of aircraft navigation, ATC surveillance and any correction manoeuvre should an aircraft stray outside its agreed trajectory.

The three regions are defined as follows :

- manoeuvre space is the inner region. The aircraft is authorised to optimise its own trajectory within this space, subject only to remaining within this space. The minimum dimensions of manoeuvre space are determined by the aircraft's navigation accuracy.

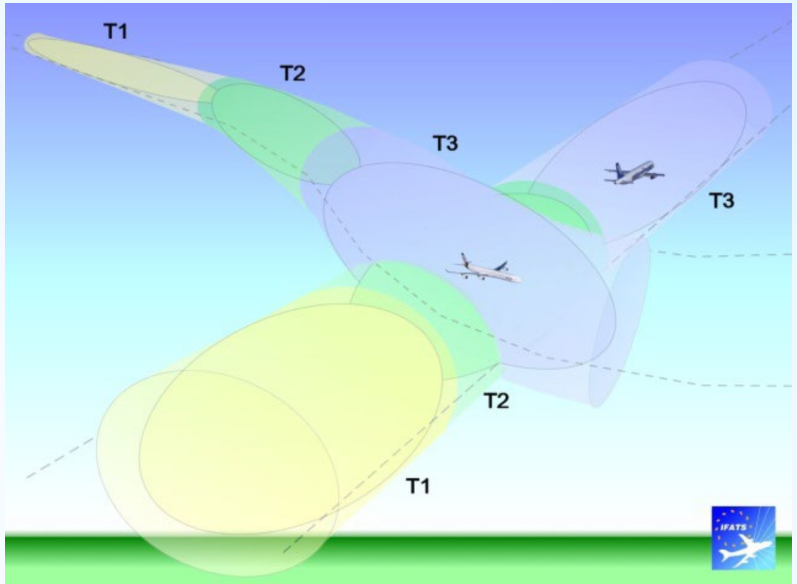
- detection space, which surrounds manoeuvre space. It is there to allow the ATC surveillance process to detect that an aircraft has left its manoeuvre space. The minimum dimensions of detection space are determined by the accuracy of the surveillance system.

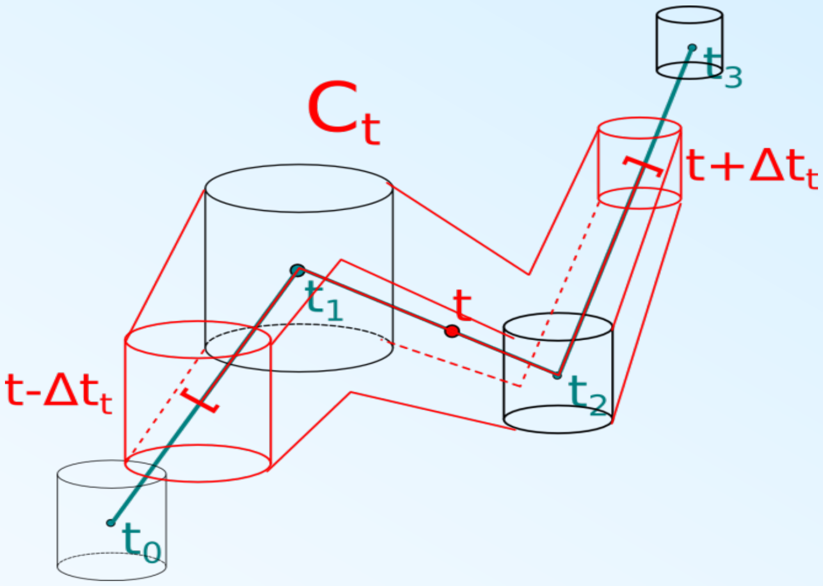
From AG3 – Report on „A Conceptual Model of a Future Integrated ATM system“

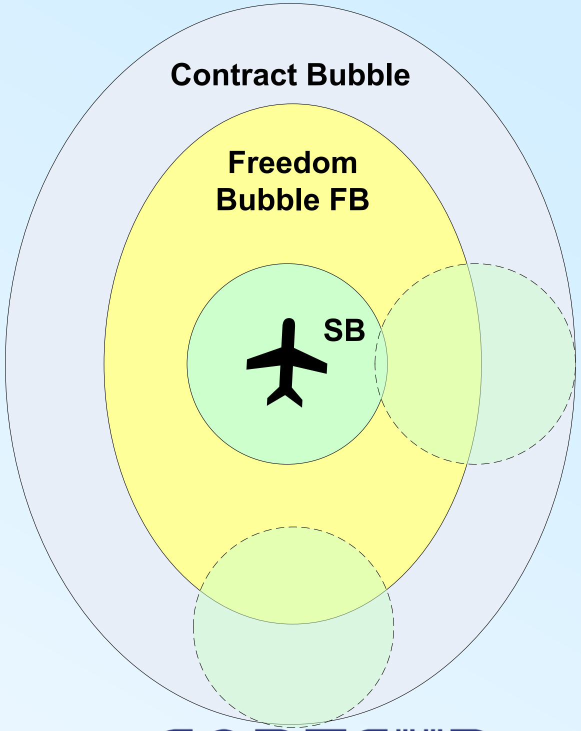
European Project 4DCo-GC

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







European Project 4DCo-GC

4 Scenarios

Benelux - airspace

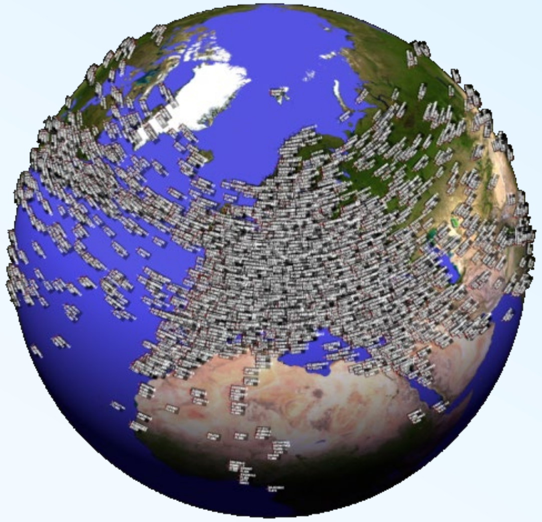
- Benelux 100% = 5297 flights
- Benelux 233% = 11925 flights

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

AG17 "Non Linear Analysis and Synthesis Techniques for Aircraft Control"

Chairman: M. Hagström, FOI

Objectives:

- Application of modern non-linear methods for system analysis and control synthesis to aircraft control in an industrial setting. The goal is to identify and evaluate methods that are easy to use, accurate, reliable and time saving that can replace the traditional tools used in the aircraft industry for control synthesis and analysis today.

Achievements:

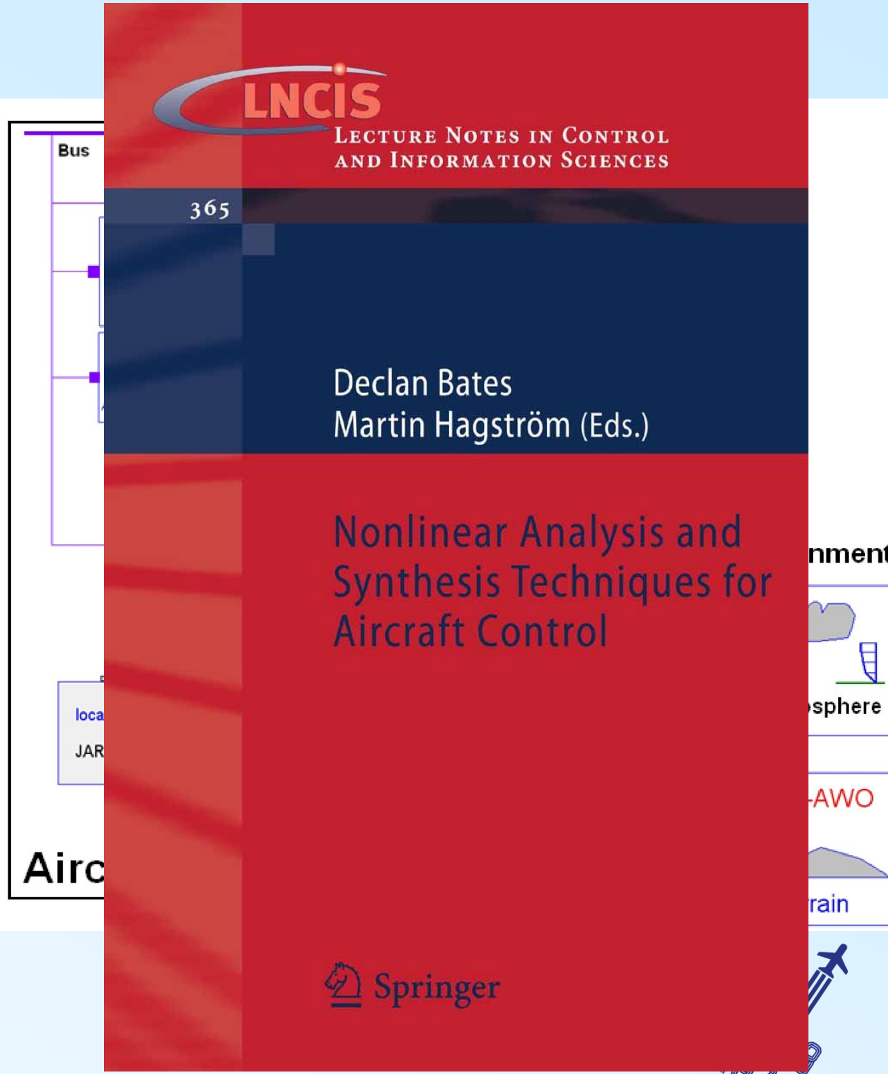
- ✓ The AG17 produce the first exhaustive set of results of advanced nonlinear control methods for complex models of aircrafts both civil and military
- ✓ Results published as book by Springer

AG17: Some more details

Developement of an on-ground transport aircraft benchmark (simulation model + design challanges)

Application of nine different approaches and techniques to the benchmark problems:

- Nonlinear symbolic LFT tools for modelling, analysis and design
- Nonlinear LFT modelling for on-ground transport aircraft
- On-ground aircraft control design using an LPV anti-windup approach
- Rapid prototyping using inversion-based control and object-oriented modelling
- Robustness analysis versus mixed LTI/LTV uncertainties for on-ground aircraft
- An LPV Control Law Design and Evaluation for the ADMIRE Model
- Block Backstepping For Nonlinear Flight Control Law Design
- Optimisation-based flight control law clearance
- Investigation of the ADMIRE Manoeuvring Capabilities Using Qualitative Methods



FM/AG-18 'Towards greater Autonomy in Multiple Unmanned Air Vehicles'

Chairman: Dr Jon Platts, QinetiQ, UK

Objectives

- Use of machine based reasoning and artificial cognition
- To facilitate co-operation between UAV and other assets
- Reduced human intervention

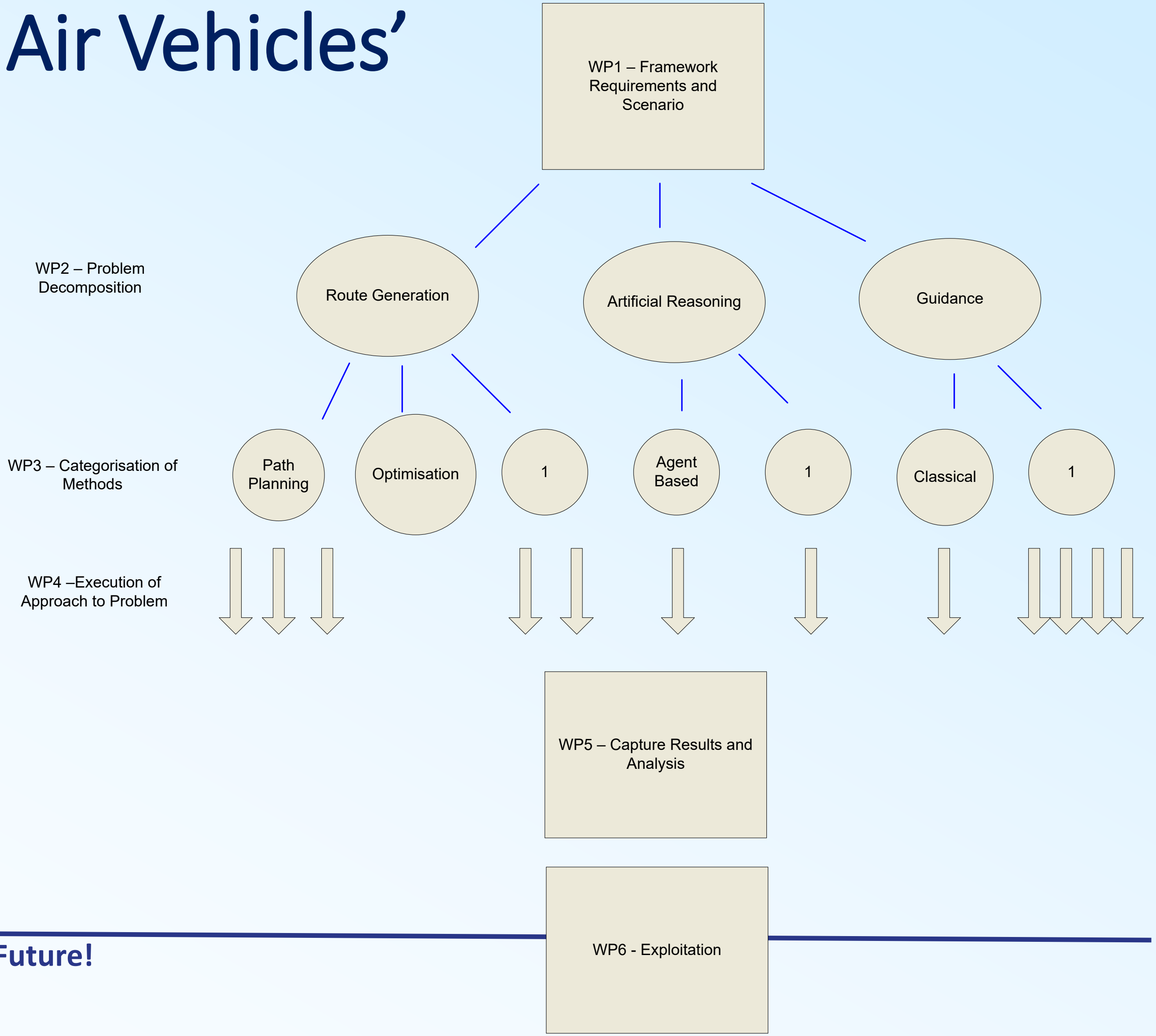
Participation

✓ QinetiQ, ONERA, NLR, DLR, CIRA, INTA,

✓ University of Bristol, Universität der Bundeswehr München, Universidade Compultense Madrid, University of Leicester, University of Cranfield, University of Bristol

✓ Dassault Aviation, EADS Cassidian, EADS CASA, Thales NL

FM/AG-18 'Towards greater Autonomy in Multiple Unmanned Air Vehicles'

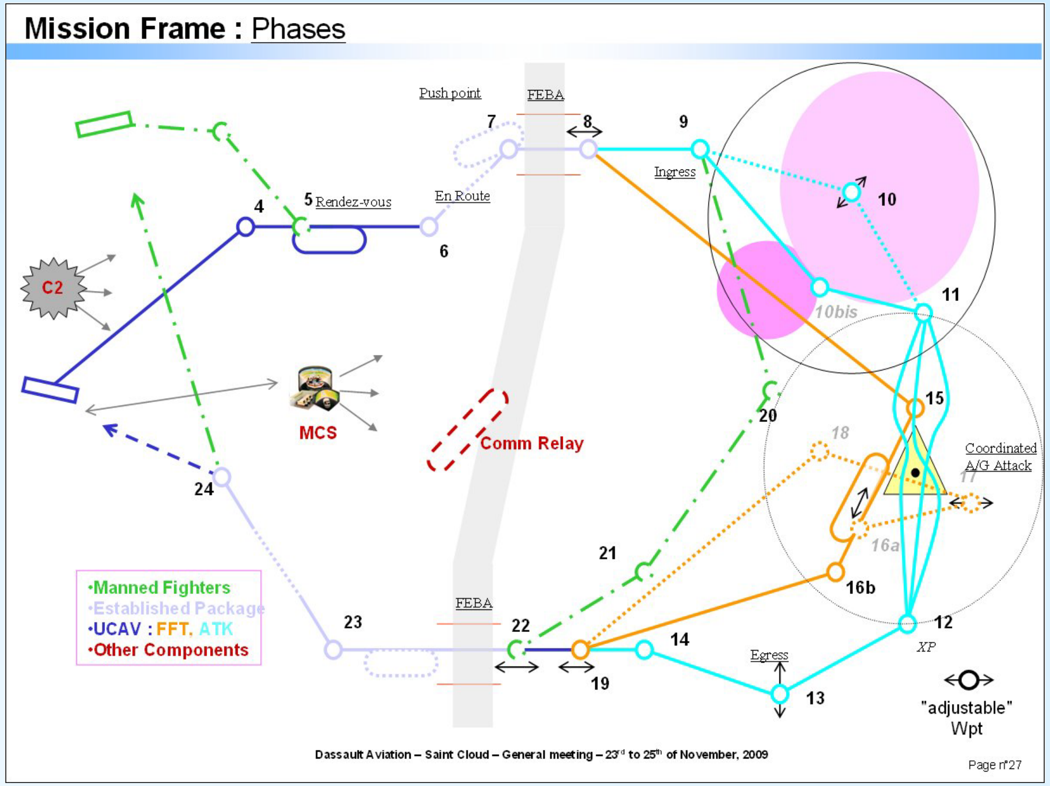


FM/AG-18 ‘Towards greater Autonomy in Multiple Unmanned Air Vehicles’

Candidate Methods:

- Real time trajectory generation and tracking algorithm for 4D autonomous navigation (CIRA)
- Nonlinear Branch and Bound for path planning with avoidance (Univ. Bristol)
- Dual-mode cognitive automation for guidance (BWh Univ. Munich)
- Evolutionary path planner for multiple UAV in realistic environments (Univ. Madrid + CASA)
- Trajectory generation and mission planning and optimization for multiple UAV (NLR)
- Dubins and PH curve path planning + behavior recognition and tracking by non-linear model predictive control on a receding horizon (Univ. Cranfield)
- Reactive and deliberative architecture with planning based on constraint satisfaction (ONERA + Dassault)
- Non Linear robust flitering and SLAM (Univ. Leicester)

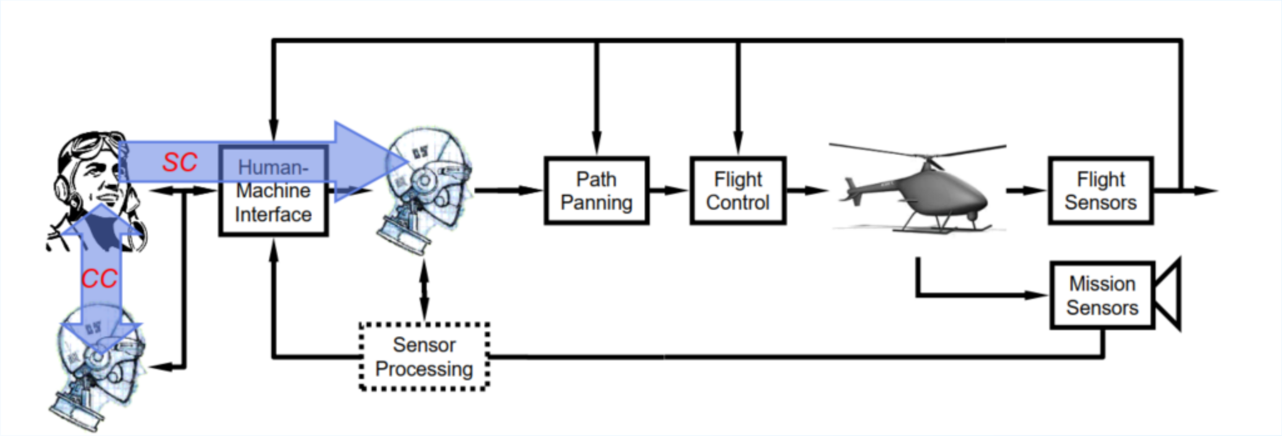
Global mission benchmark



FM/AG-18 ‘Towards greater Autonomy in Multiple Unmanned Air Vehicles’

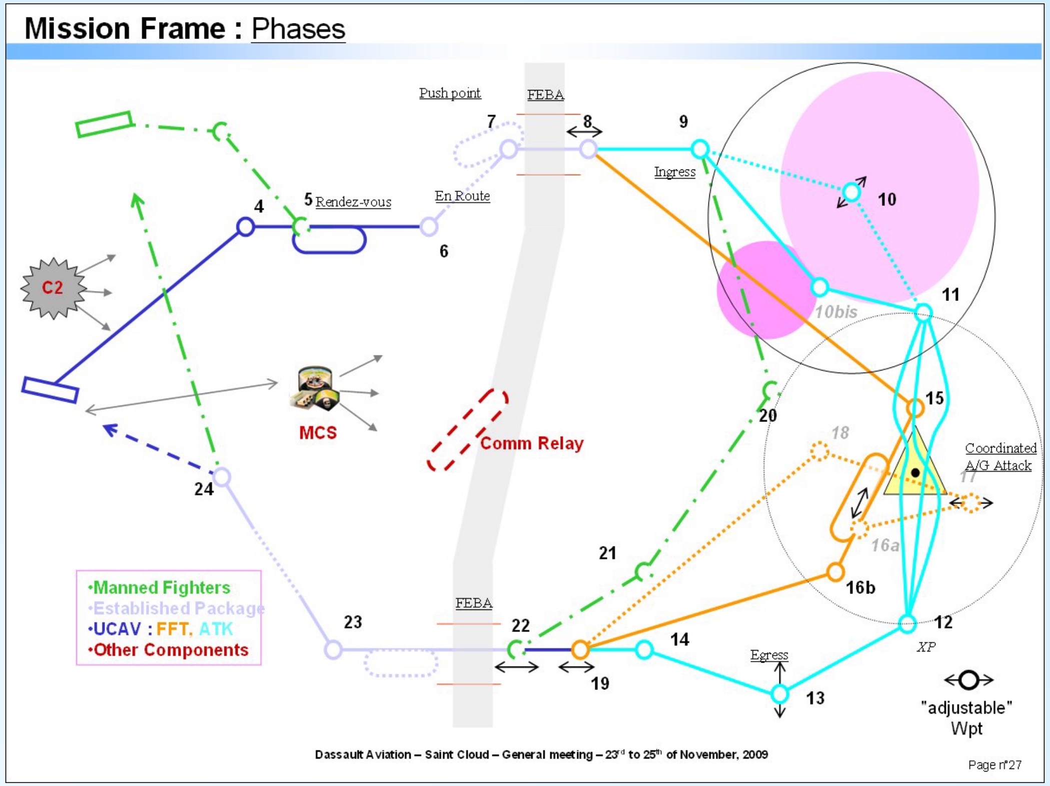
Example:

Universität der Bundeswehr München - Cognitive automation approaches to multi-UAV mission management

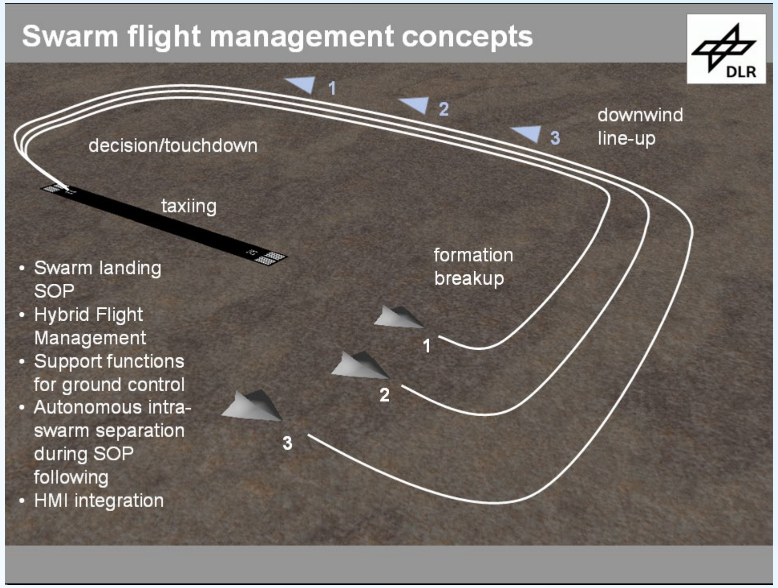


Integration of “Artificial Cognitive Units” allowing the human to switch between Supervisory Control (SC) of highly automated vehicle and Cooperative Control (CC) in which the human and the artificial cognitive agent work together like a cockpit crew

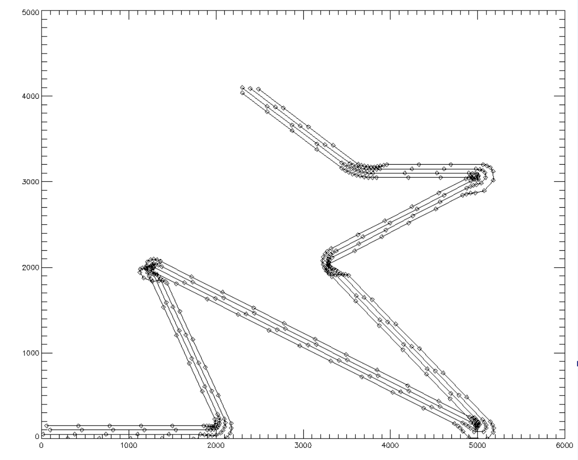
Global mission benchmark

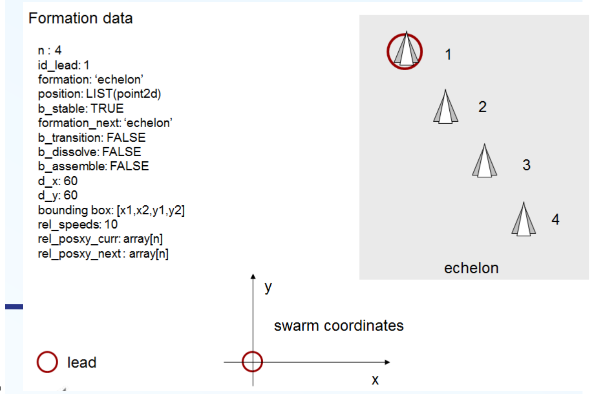


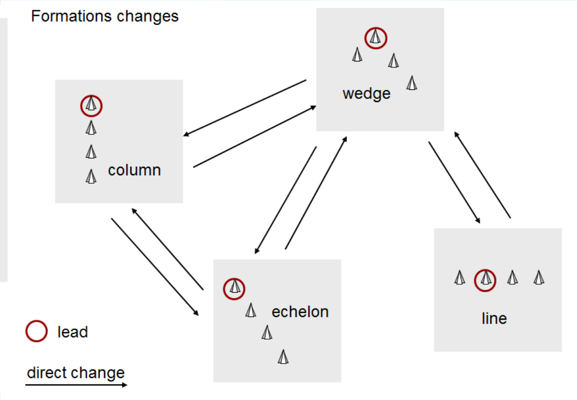
FM/AG-18 ‘Towards greater Autonomy in Multiple Unmanned Air Vehicles’



FM/AG-18 Example:
DLR – formation management







Thank you for your attention