4DCo-GC

4 Dimension Contract - Guidance and Control

Project achievements and first findings

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Project requirements

- 4D contracts guidance and control study requires…
  - Aircraft models
    - Performance
    - Guidance and control system
  - 4D contracts!
    - Definition
    - Modeling
    - Generation
    - Tools for their execution
      - Nominal and degraded situations
  - Simulation infrastructure and tools
  - Validation goals and criteria

Project achievements
Aircraft

- Aircraft performance model for global traffic simulation based on BADA

- Ability to follow a 4D contract: 4DCAE
  - Individual trajectory generation for staying inside the contract bubble
  - Trajectory update during the flight in case of difference with the initial conditions

- Optimization of the trajectory
  - Trajectory “greening”, in order to optimize fuel consumption

Project achievements
4D contracts

- Refinement of the 4D contract concept developed in IFATS
  - Bone trajectory + “bubbles”
    - Safety bubble
    - Freedom bubble
    - Contract bubble
  - 4D contract execution and non nominal situation management

- Modeling of the 4D contracts
  - Definition of the size and shape of the “bubbles”
  - Interpolation of these bubbles along the bone trajectory
    - Size vary with the local traffic density

Project achievements
4D contracts

- Creation of a traffic sample to be used as an initial airlines demand

- Algorithms for 4D contracts generation
  - Conflict-free trajectories generation, based on the traffic sample
  - Transformation into 4D contracts
  - Arrival-Departure Optimization Tool
  - Ground movement planning

- Algorithms linked to 4D contracts execution
  - Contract compliance monitoring
  - Local replanning
  - Emergency management
  - Data link

Project achievements
Simulation infrastructure and tools

- Creation of a simulation infrastructure based on
  - DLR's Datapool
  - Onera's HLA
  - Gateway between both, available via Internet
    - For on site online testing
- Development of modules for all the required functions
- Integration of all the modules in a single simulator
  - Interactions between the modules
- Several simulation runs

Project first findings
Aircraft guidance and control

- It is possible for aircraft to follow 4D contract with a satisfactory efficiency
  - 93% of flights of the global simulation stay within their assigned contracts
  - According to the wind hypotheses
  - Individual aircraft simulation show excellent results
- Ability to recover from technical problem
  - Aircraft can self-generate an alternative trajectory
  - Used as input by the replanning function
- Optimization of trajectory within the 4D contracts
  - Theoretically feasible, with significant fuel savings (several %)
  - Practically difficult to perform, due to the size of the freedom bubbles

Project first findings
4D contracts - planning

- It is possible to generate 4D contracts at the European level, for one entire day
  - Even for more than twice the current traffic
  - Simulation of traffic over the whole Europe is difficult due to required computation resources
    - Use of Benelux area for demo, in order to keep traffic density

- It is possible to optimize the arrival and departure sequences, to a certain extent
  - Integration of optimal arrival/departure sequences with the “air picture” would require additional research
  - An iterative process is necessary

Project first findings
4D contracts - execution

- Size of the bubbles has an impact on the number of necessary replanning
  - Increase of “thickness” (z axis) enables to reduce the number of replanning more effectively than the other axes
- Replanning involves a maximum of 2 aircraft
  - Most of the time, only ownship contract modification is enough
  - Algorithm works with more, but situation never happens
- “One of the biggest problems for all scenarios was to find/create a conflict”!
  - Provided simplified wind assumptions

Project first findings
4D contracts - execution

- Contract potential non compliance can be forecasted
  - In nominal situation – no emergency – in all cases
  - Maximum time horizon of 10 minutes
- Network centric architecture
  - All the aircraft constantly connected to the ground segment
    - Directly via the global network
    - Or using the local networks
- Degraded / emergency situations can be managed
  - Use of local networks
  - Adapted embedded algorithms
  - Need to combine several failures to trigger the 4DLC

SESAR CONOPS at a glance

- Automation support to conflict/interaction detection, situation monitoring and conflict resolution

Generation of conflict free 4D Contracts

- A significant reduction in the need for controller tactical intervention, by
  - (a) reducing the number of potential conflicts using a range of de-confliction methods, and
  - (b) redistributing the tactical interventions to the pilot

Make aircraft comply with 4D Contracts

Current results vs project objectives

Objective To address the aircraft 4D contract guidance and control principle	**Results**	**Achieved**
Defining and modeling 4D contracts	- 4D contract definition refinement (compared to IFATS) and modeling	✓
Assessing the 4D contract concept of operation viability and performance (simulations based on a distributed architecture), especially from a guidance & control of aircraft perspective	- Distributed simulator available to simulate the 4D contract ConOps - Possibility to generate 4D contracts at the ECAC level - Assessment of the possibility and number of replanning - Assessment of the feasibility by the FMS to follow 4D contracts	✓ ✓ ✓ ✓
Deriving recommendations for future 4D trajectory system development and performance standards	- Use of the bubble thickness to decrease the number of replanning	▭

Current results vs project objectives

Objectives To go deeper in the definition of the "4D contract concept"	**Results**	**Achieved**
Recommendations for future 4D trajectories (4DT) guidance and control aircraft systems and for 4D trajectory ground system development	First findings	
Recommendations for overall system performance standards	First findings	

Next phase activities

- Take into account C2 audience comments and remarks
- Summarize the 4D contracts characteristics from the simulation results
- Summarize the advantages and limitations of the 4D contract concept
  - At the global level
  - At the aircraft level
- Derive recommendations
  - For future (SESAR) 4D trajectory/contract concept of operations
  - For future related aircraft systems
  - For future related ground systems