SESAR WPE

STREAM – Strategic Trajectory de-confliction to Enable seamless Aircraft conflict Management

Toulouse, SESAR Innovation Days 2011

The STREAM project consortium

Advanced Logistics Group (ALG)

Boeing Research & Technology Europe (BR&TE)

Universitat Autònoma de Barcelona (UAB)

A project under

- Small project launched on *16th March 2011* , this presentation is limited to an **outline of the project objectives** augmented by some early findings.

Context and background

Problem statement

Conflict Detection and Resolution (CD/CR) tools currently used with limited look ahead time due to:

- Poor trajectory prediction by ground tools (limited information on trajectory intentions)
- Computational complexity of the pairwise algorithm: $O(n^2)$

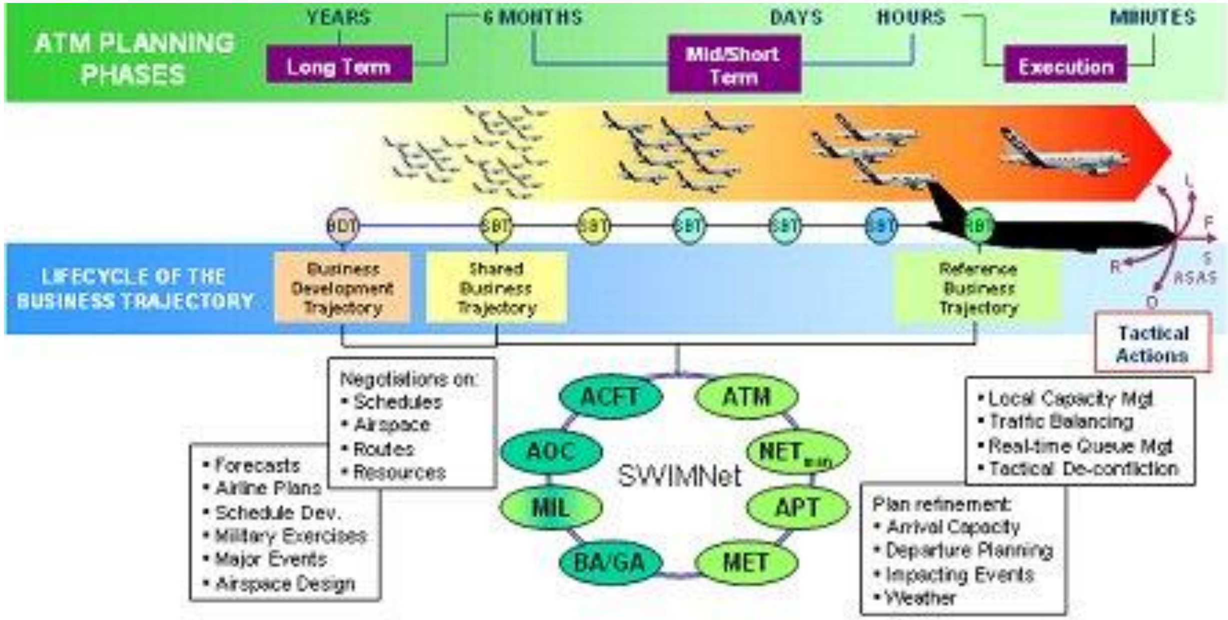
Consequences

- **A gap exists nowadays between the long-term predictive part of the ATM system and the short-term adaptive actions.**
- little or no automation support fro ATCOs, typically issuing tactical instructions via voice communications based mainly on surveillance information

Enablers for the change

SESAR introduces the concept of

- **4D Business Trajectory,** which evolves out of a collaborative layered planning through **3 main different phases: BDT, SBT and RBT**
- The **RBT constitutes the ultimate trajectory** that the airspace user agrees to fly and airports and ANSPs agrees to facilitate; **changes to the RBT must be kept to a minimum**
- NOP (Network Operations Plan): a system wide rolling plan for network planning



Consequences

- Shift from the current tactical reactive surveillance-based conflict resolution to strategic trajectory based separation assurance

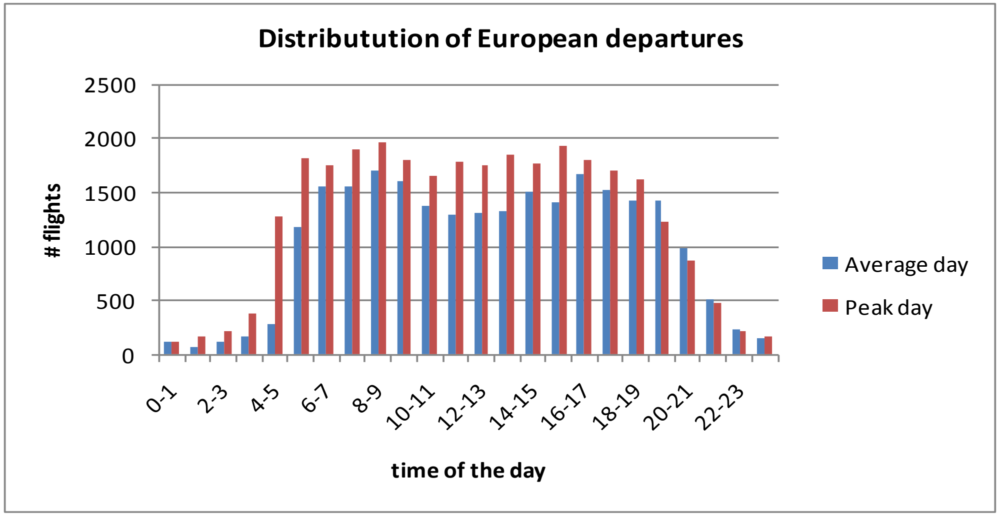
Project objectives

High level objective

- To perform **conflict detection at pre-departure phase,** thus allowing the integration of appropriate conflict resolution manoeuvres into the first RBT instantiation

Intermediate objectives (I)

1. To develop **time-efficient algorithms** O(n) for the strategic detection and resolution of traffic conflicts:
   - capable of adopting a combination of **different resolution strategies** (route, speed and flight level modifications);
   - that **run in linear time with respect to the number of trajectories** considered;
   - and manage a **high quantity of information describing 4D trajectories** and to ensure that resolutions maintain traffic complexity under control — at local(ACC), regional (FAB) and even global (ECAC) levels



Daily distribution of take offs in Europe (Average day: 09/11/2010, Peak day: 01/07/2010). Source: EUROCONTROL ALL_FT data.

Project objectives

Intermediate objectives (II)

2. To explore the **requirements on the reliability and robustness of traffic predictions** in order to allow the new strategic trajectory de-confliction algorithm that would efficiently modify SBTs

3. To define **metrics for assessing the fairness and equity** of the proposed algorithms towards an increase automation of the ATM system

4. To **perform simulations in a common environment** in order to validate the proposed algorithms and metrics

Description of the solution

Concept of operation

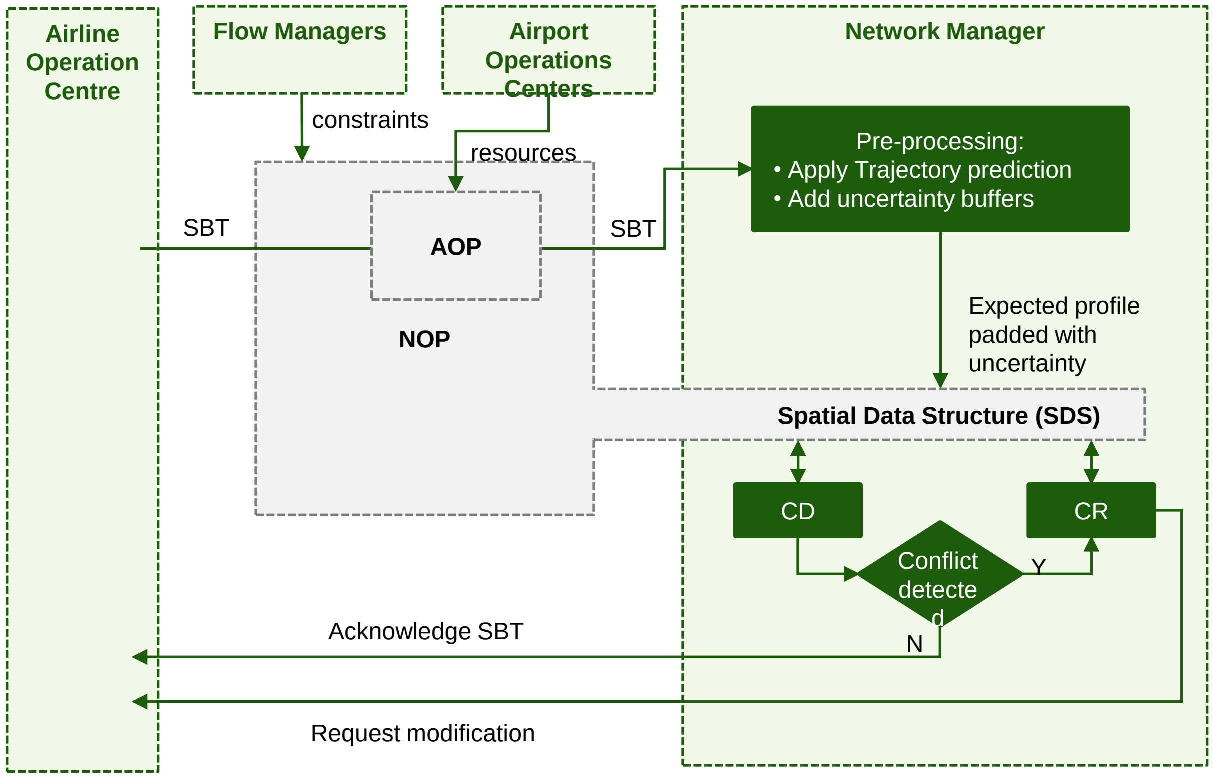
- STREAM solution is intended to be applied to **4D trajectories** that:
  - have already been subject to the **preliminary DCB** (airport slots, previous negotiations)
  - are still **published as SBT**, not already agreed as RBT
  - **prior to the take-off**, when forecasts are stable and estimates become reliable
  - are **independent** from the concepts of **airspace sector** and **sector capacity**

- Before reaching an agreement on the final RBT, the network manager assesses the interactions with the rest of the traffic and propose **appropriate modifications** (speed, time, path) to be included in the final RBT in order to:
  - **minimise the probability of conflicts** occurring during flight execution
  - **mitigate** the estimated **impact on the system**
  - ensure that **costs** derived from amendments are **fairly shared** among users

- Priority on the traffic headed to **congested airspaces**, with the aim of reducing traffic complexity where this eventually implies a reduction of **available capacity**

- The global traffic picture needs to be considered in order to:
  - Identify **critical situations** of high **congestion and workload**
  - Elaborate conflict resolutions that **avoid increasing complexity and conflict propagation** in other sectors
  - Consider the **user preferences** when constraining the trajectories in order to achieve **fairness**

STREAM logical architecture



- The STREAM algorithms will reside within the NM function.
- 4D flight position estimates with attached confidence intervals on specific hot-spots specified in the NOP.
- A series of 4D envelopes including the uncertainty bounds, conflict arise from their intersection
- 4D representation of traffic in the network at European level for the next 2-3 hours

STREAM logical architecture

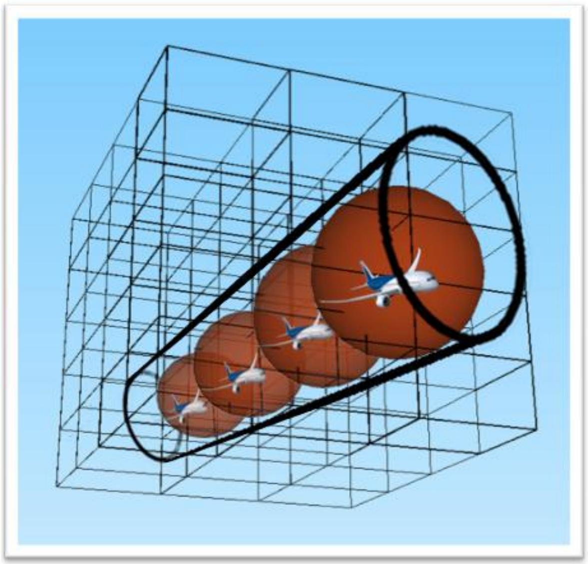
Advantages from the solution

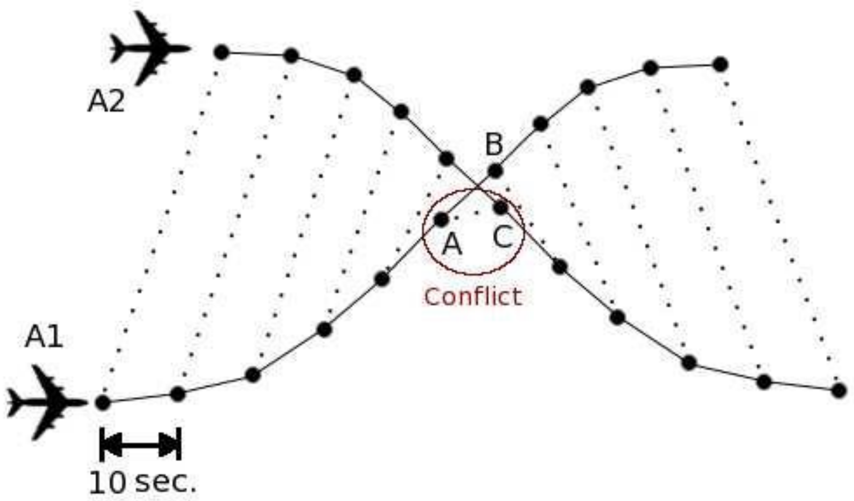
- The CR module works on the same SDS, adding visibility of the aircraft involved and of all the auxiliary information stored.
- The result of this process will be to have pre-synchronized traffic in the regions that are foreseen to be more congested.
- This synchronization will be agreed by involved actors (AUs, ANSPs and Airports) and formalized through the RBT, which will include the constraints in path and time derived by the strategic de-confliction measures.
- Main modalities for agreeing on a trajectory modification:
  1. The NM calculate and impose the best set of trajectory modifications according to pre-defined metrics (min total extension, min total delay, min sum of squared delays)
  2. The NM calculates several equivalent sets of options to the users and they in turn respond with the ranked order.
  3. The AUs are able to attach a specific priority coefficient to each trajectory, in order for the NM to assess and impose the best solution.

Tools Development Approach

Conflict Detection Module

- **Spatial Data Structure** (SDS), a mesh of discrete points representing the 3D airspace under analysis.
- It is possible to store a discrete representation for each of the 4D trajectories inserted (different 3D positions of aircraft in different discrete time steps).
- At the moment of storing a tube-point in the SDS, a conflict is detected:
  1. No other flight has reserved the space volume → no conflict
  2. Another flight has booked the space then comparison of time windows:
     a) time-windows are overlapping → conflict → CR module invoked.
     b) time windows are not overlapping → no conflict.

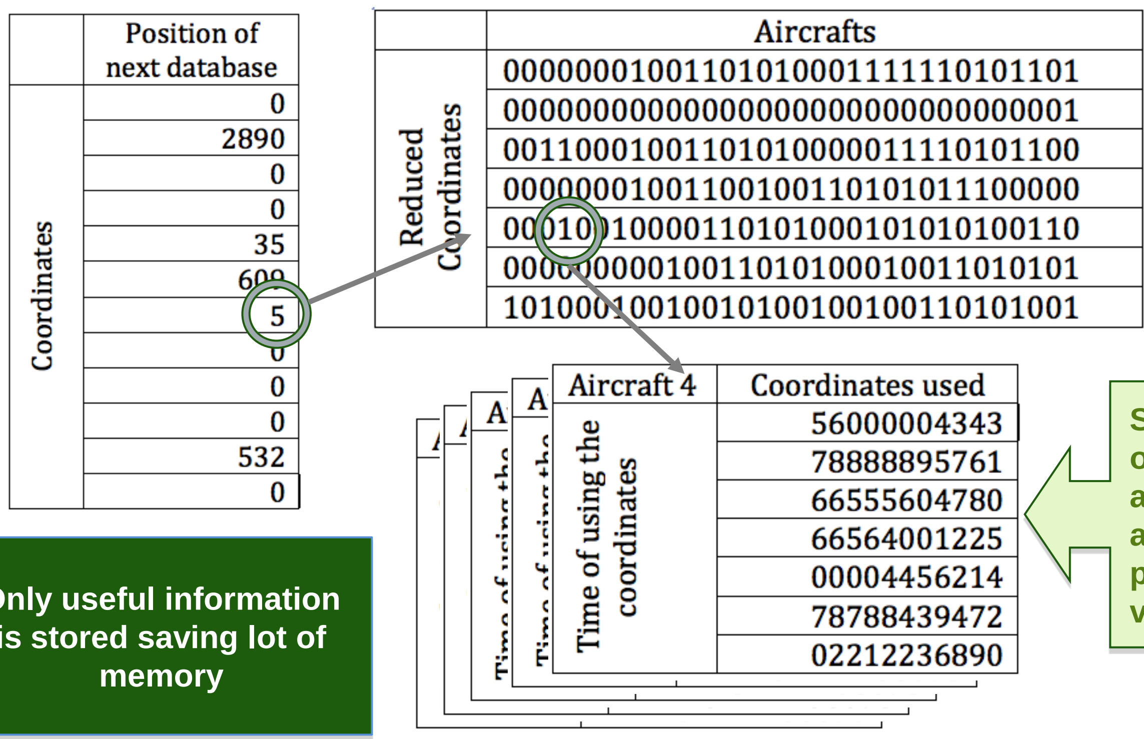




Tools Development Approach

Relational SDS

- A solution to reduce memory is the use of relational databases



Only useful information is stored saving lot of memory

Search by time or by coordinate and compare aircraft relative positions to verify conflicts

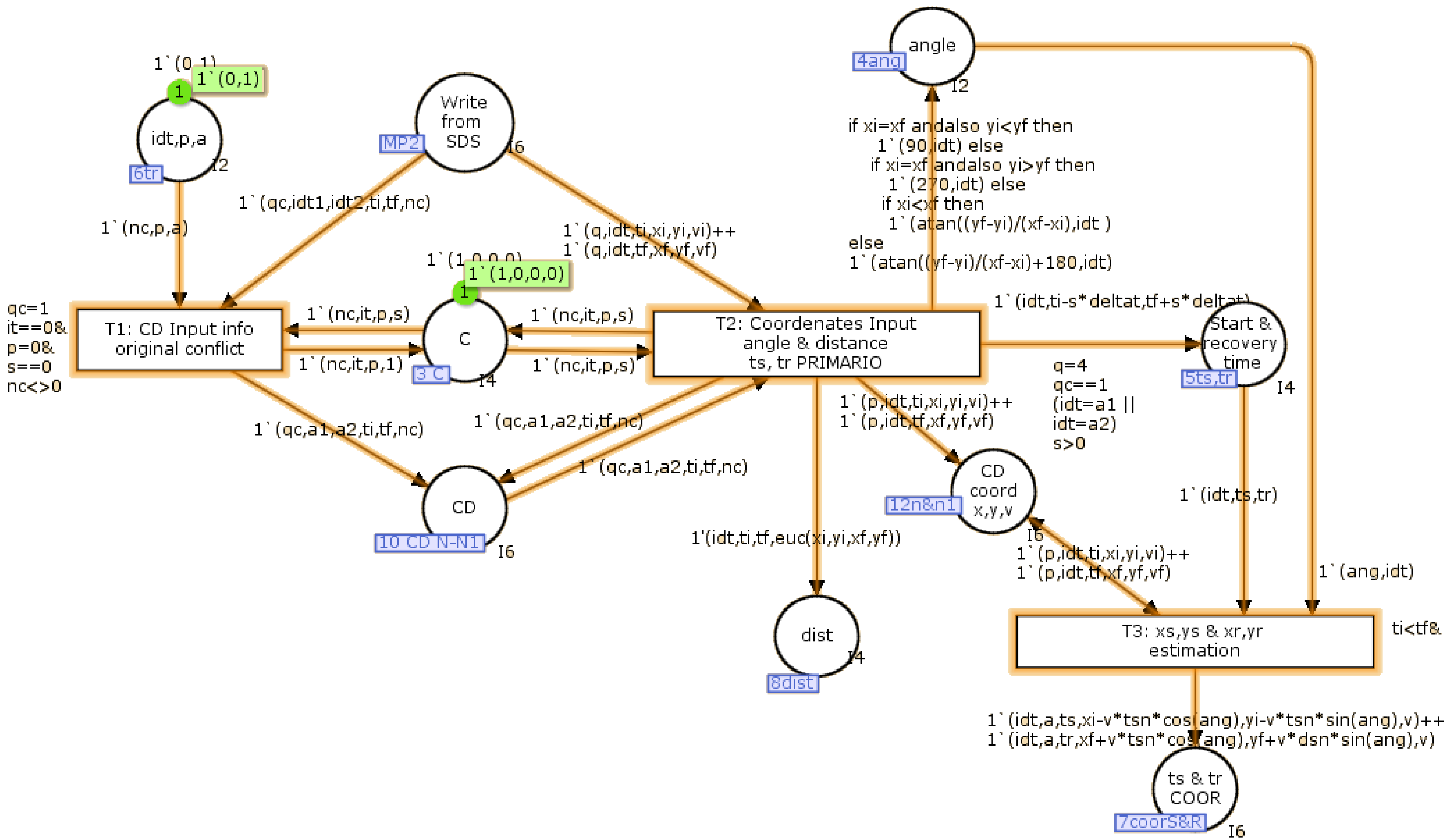
Tools Development Approach

Conflict Resolution Module

- A conflict can be detected either between different SBTs or between an SBT and an RBT already on execution. In this latter case there might be situations in which it could be more beneficial to modify an already agreed RBT than a number of different SBTs, even if this may imply a stronger coordination effort to be achieved.
- The Conflict Resolution Module will search the best trade-off between local impact and global impact imposed by the maneuver taking into account:
  1. Efficiency: time / fuel /flow stability
  2. Robustness: likelihood of amended trajectories to resolve the conflicts even in the presence of disturbances
  3. Fairness: taking into account the acceptance levels and individual satisfaction of users
  4. Equity: Treating all users equally without taking into account their specific identity, but rather their ability to facilitate trajectory management process.
- Solution 1: only one of the aircrafts performs the maneuvers to avoid conflicts (cooperative aircraft. CR approach based on the **heading angle change problem** (HAC).
- Solution 2: all involved aircraft in the conflict csn change their trajectory. CR approach based on **HAC problem with the velocity change (VC) problem.**

Tools Development Approach

Conflict Resolution Architecture: Solution 1



Expected Benefits

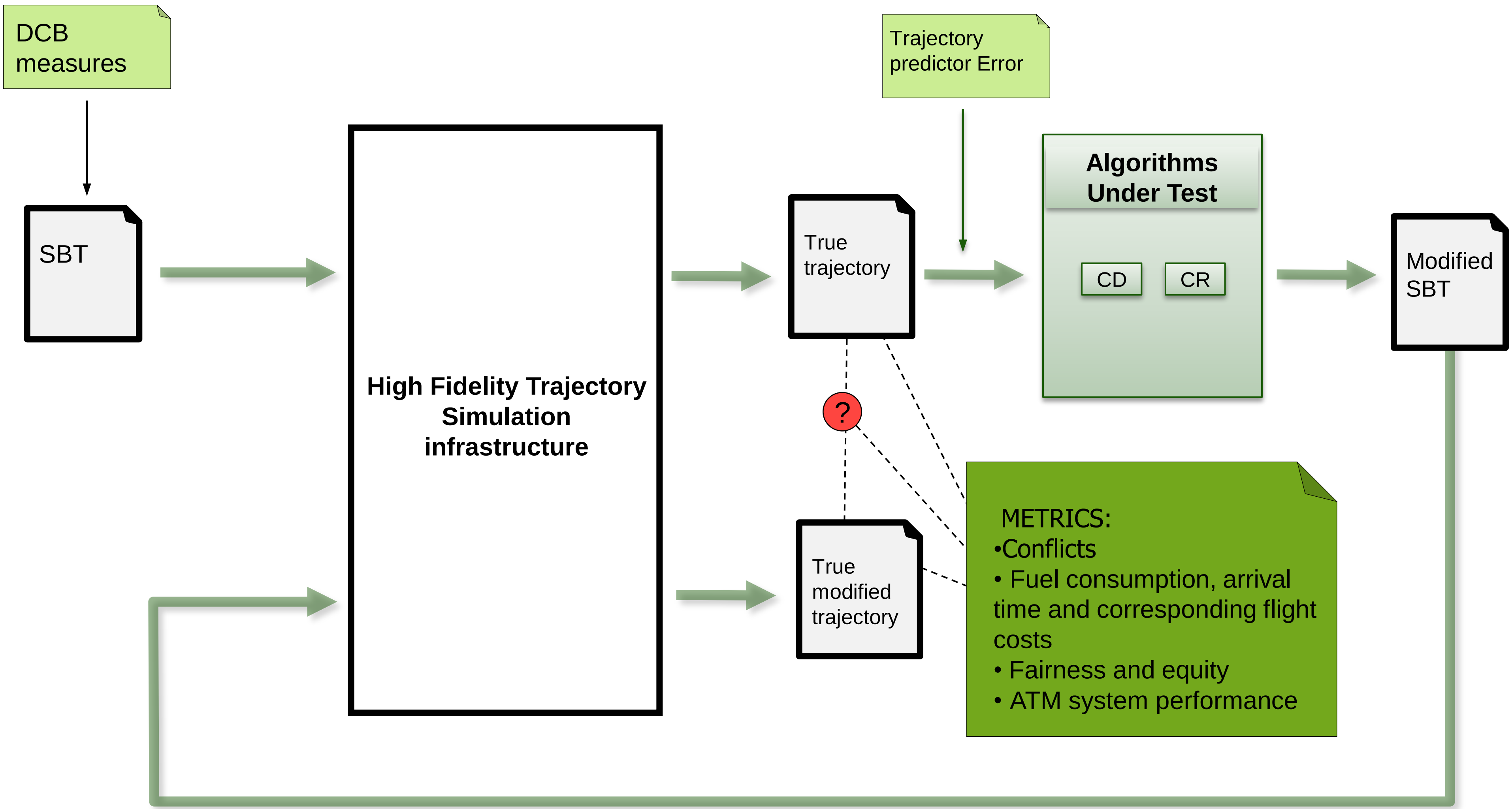
Key Performance Areas impacted

- Improved Predictability:
  - closer integration between predictive and reactive parts
  - Better visibility of the sensitivity of each trajectory to tactical modifications

- Capacity Increase
  - decrease of ATCOs workload inducing higher real capacity
  - Reduction of the “safety buffer” between true and declared capacity due to higher predictability

- Environmental Impact
  - Minimization of tactical interventions
  - Trajectories closer optimal ones

Simulations



Simulations

Scenario 1: No uncertainty

- Conflict free trajectories generated by the CR considering 4DT without uncertainties.
- Useful to understand:
  - Which uncertainty could be supported in each trajectory;
  - Time-space volumes sensitive to time uncertainties;
  - Trajectories crossing a higher amount of areas that can lead a conflict.

Scenario 2: Uncertainty only in the CR

- Conflict free trajectories generated by the CR considering a certain x% of uncertainty.
  - The trajectories generated will be more robust to uncertainty in the expected passing time.
  - This approach would avoid latent capacity in areas less sensitive to perturbations

Scenario 3: Uncertainty in the CD/CR

- Extra time window reserved in the SDS due to time uncertainty by both CD and CR
  - CF-Trajectories more robust to uncertainty,
  - Generation of latent capacity implied for safety buffers.

Andrea Ranieri

aranieri@alg-global.com

www.alg-global.com

BARCELONA
Tánger 98, 3ª planta
08018 Barcelona (España)
Tel: (+34) 93 430 4016
Fax: (+34) 93 363 0623
alg@alg-global.com