

UTOPIA

UNCERTAINTY HANDLING AND TRAJECTORY SYNCHRONIZATION FOR THE AUTOMATED ARRIVAL MANAGEMENT

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Outline

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1. Status quo of the UTOPIA project
2. Simulation environment
3. Scenario setup
4. Implementation and simulation results
5. Outlook

The Team – The Goal

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Each UTOPIA member focuses on one of three innovative key elements:

- Study **uncertainty sources** and their propagation in the aircraft n-dimensional trajectories (nDT), considering also system disruptions
- Formal models of trajectory data and **trajectory synchronization** protocols for heterogeneous systems in an automated environment,
- Advanced **trajectory management algorithms** and ground synchronization functions based on the formal n-dimensional trajectory data and uncertainty models substituting today's HMI by **automated functions**



1. Status Quo - Concept Specification

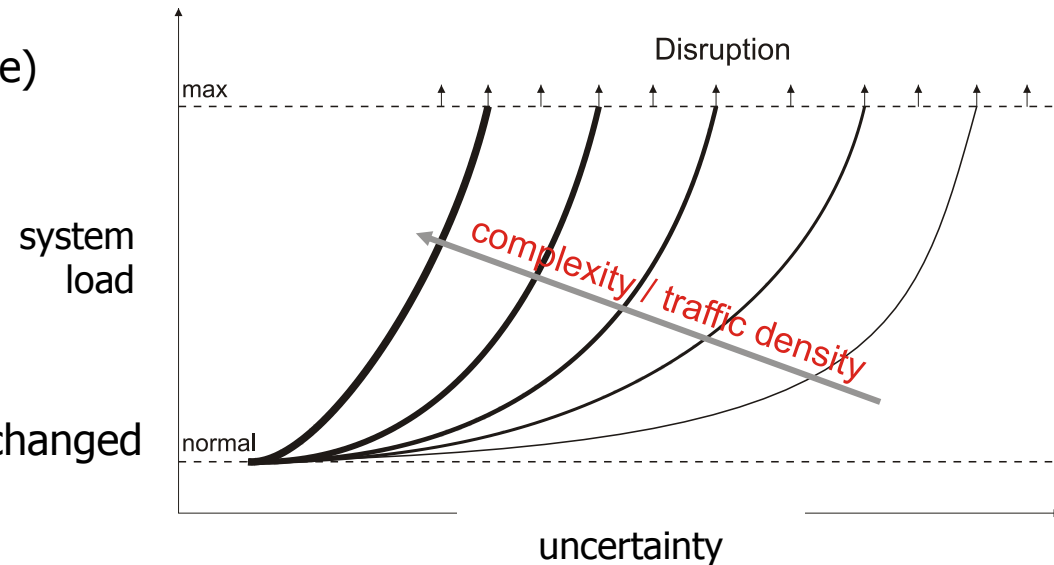
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- SESAR Milestone Deliverable 3 “The ATM Target Concept” and European ATM Master Plan as technological baseline of aircraft operations in the year 2020 (ConOps)
- Operational concept description (e.g. SESAR or NextGen) focusing on
 - aircraft and ground automation,
 - trajectory synchronization,
 - technical requirements for airspace users and ground-based systems
- UTOPIA specific ConOps
 - terminal maneuvering area (E-TMA) extended to 500+ NM imposing considerably larger look ahead times (LAT)
 - automated inbound sequencing
 - tailored to Frankfurt Airport (EDDF) environment in 3 RWY configuration

1. Status Quo - Stochastic Modeling, Definitions

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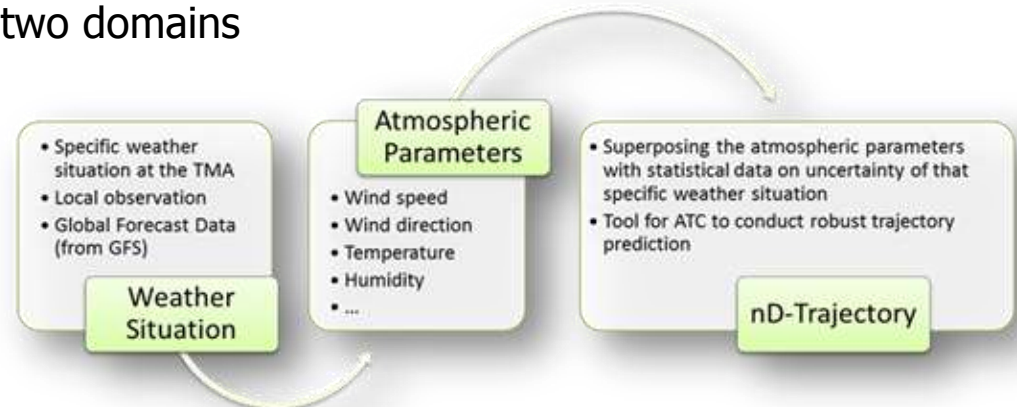
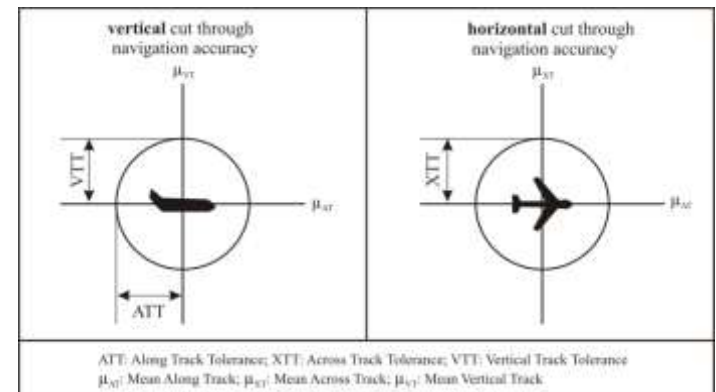
- Uncertainty triggered by
 - change of system states
 - availability of data (update rate)
 - (reliable) sources of data
- Disruption
 - uncertain states require high update rates inducing high amount of data to be exchanged to grant synchronization
 - system fails (disrupted) if it cannot satisfy the synchronization demand
- Synchronization (updates) required, if agents (represented by their trajectory) tend to violate pre-defined navigation tolerances



1. Status Quo - Stochastic Modeling, Basics

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- Following ICAO's RNP/RNAV concept:
 - uncertain input factors result into along, cross, and/or vertical track tolerances
 - along track tolerance (ATT) significant to target times (e.g. CTO, RTA) as generated through the UTOPIA AMAN
- Uncertainty factors classified into two domains
 - atmospheric conditions
 - navigation performance /operational factors
- Implementation
 - unsteady wind conditions result in increased ATT inducing uncertain target times (AMAN: over FAF)
 - Individual ATT additionally used to optimize the arrival sequence
 - convective weather scenarios covered by no-go-zones, leading to re-routing of individual flight plans

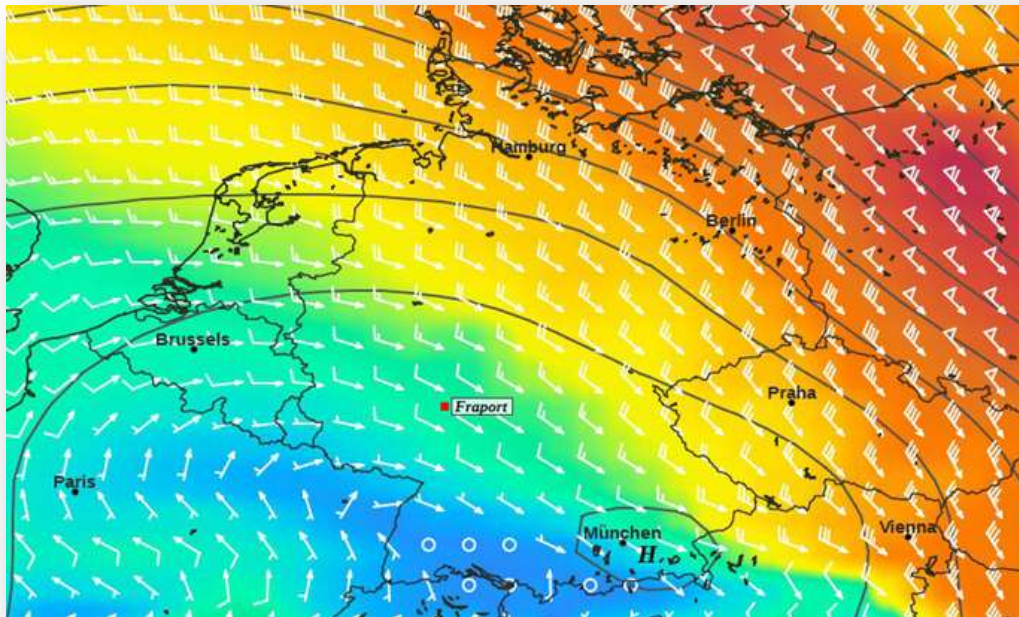


1. Status Quo - Stochastic Modeling, Data

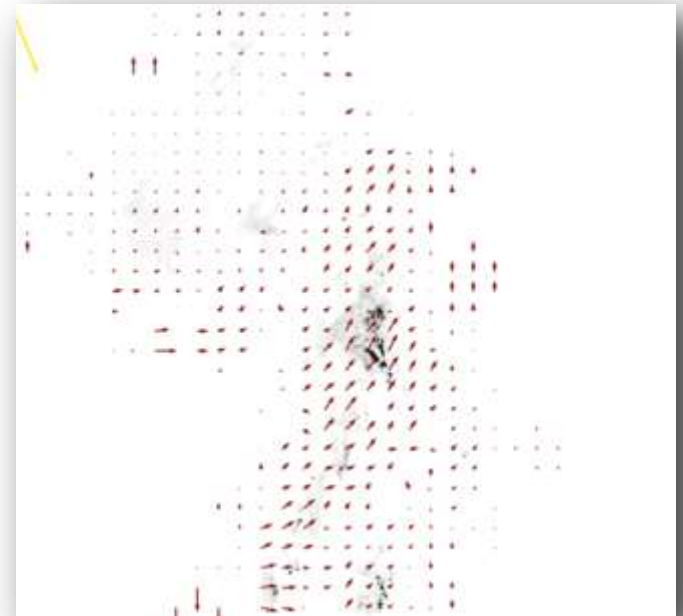
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- Atmospheric Conditions

Windfield



Convective Weather
(declared No-Go-Zones)



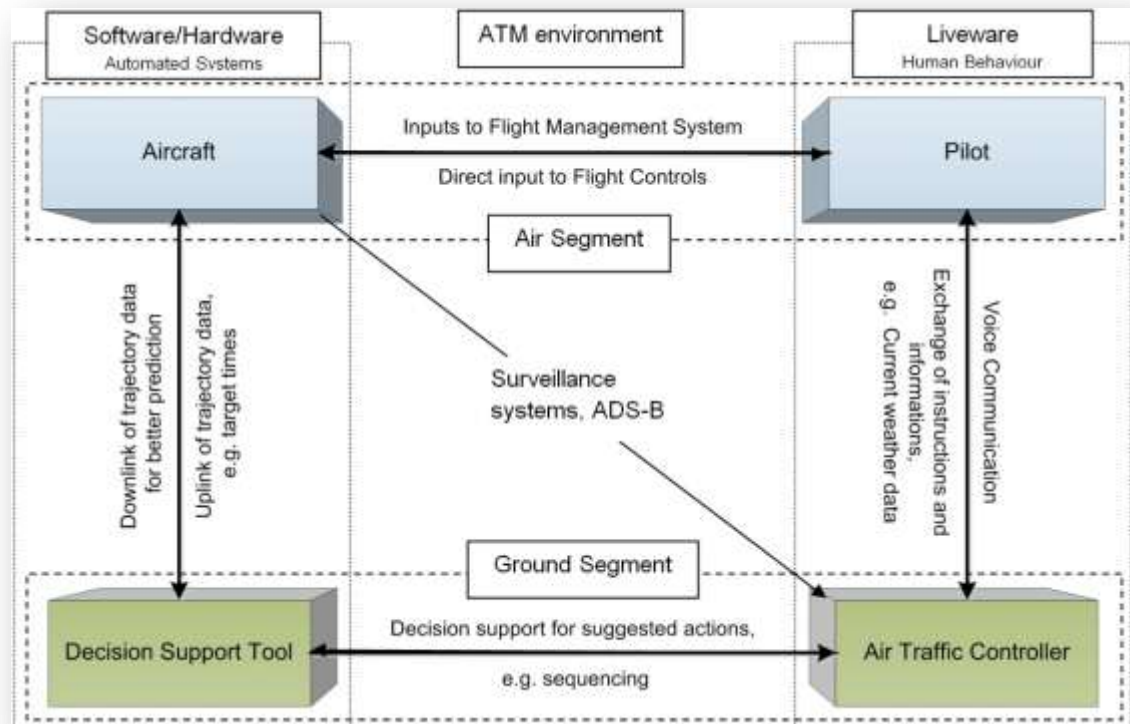
Meteox.com (DWD, KMI, KNMI, MetEireann, MeteoFrance, MetOffice)

1. Status Quo - Design Scheme for Virtual Environment

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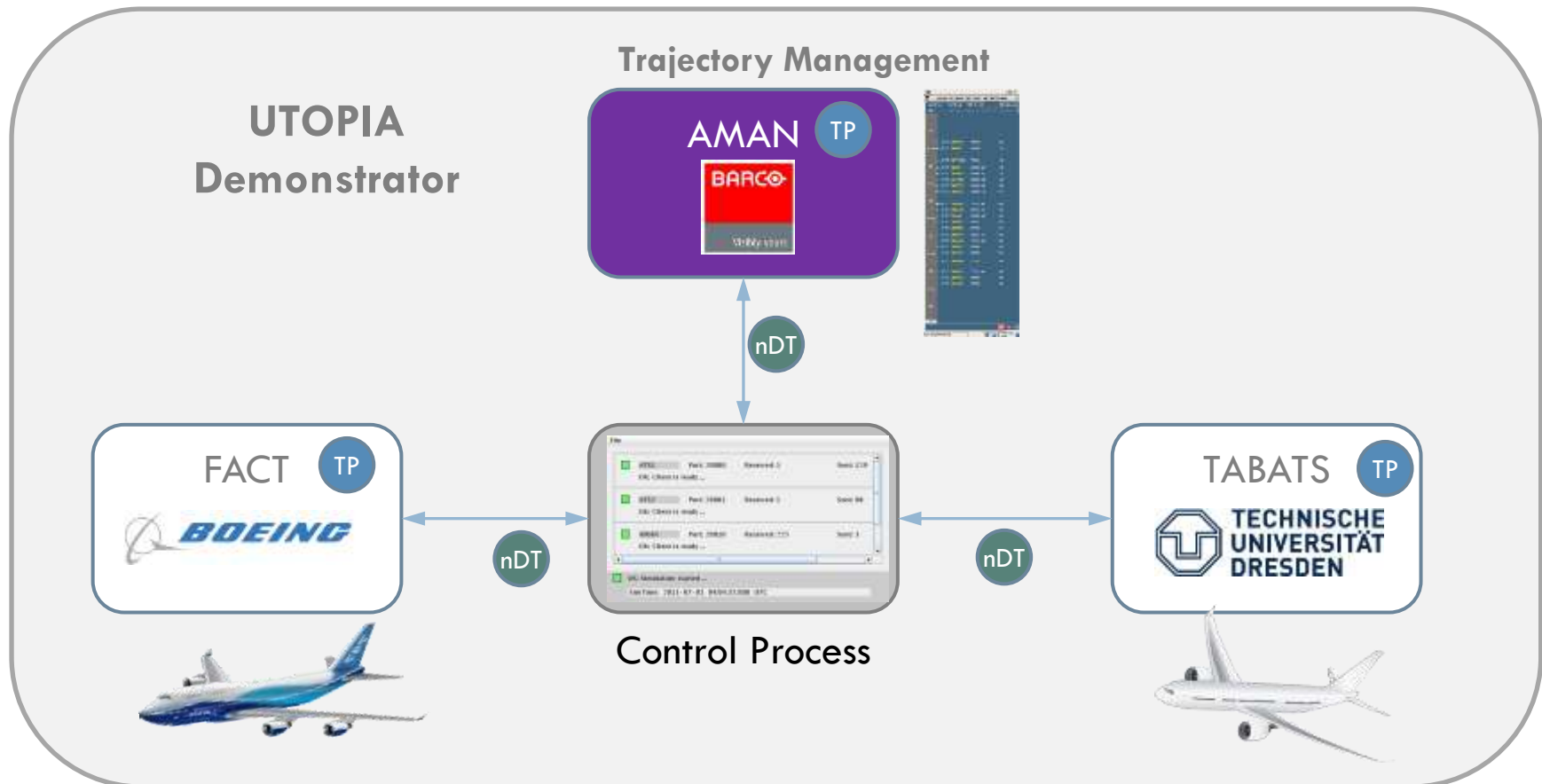
- Agent-based approach (capability of autonomous acting and decision making)
 - Agents individually plan their trajectory (through dedicated Boeing / Airbus FMS)
 - Agents individually react on AMAN advices
 - Agents communicate their decisions

- Modeling of
 - atmospheric conditions
 - weather patterns
 - corridor of uncertainty (COU)
- Mandatory set of messages for data exchange (AIDL) extended with uncertainty information



2. Simulation Environment

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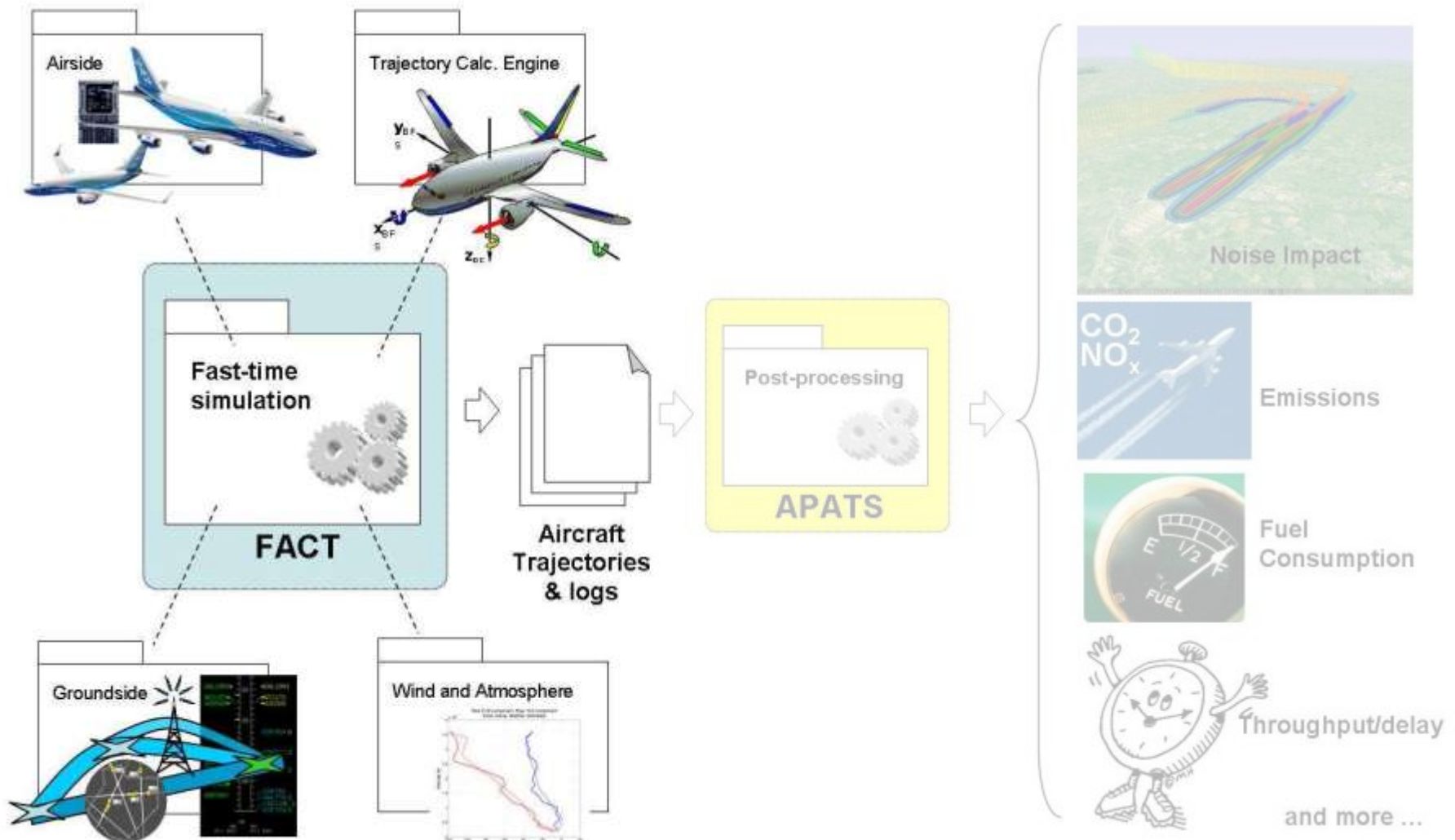


TP Trajectory Predictor

nDT n-dimensional trajectory description data

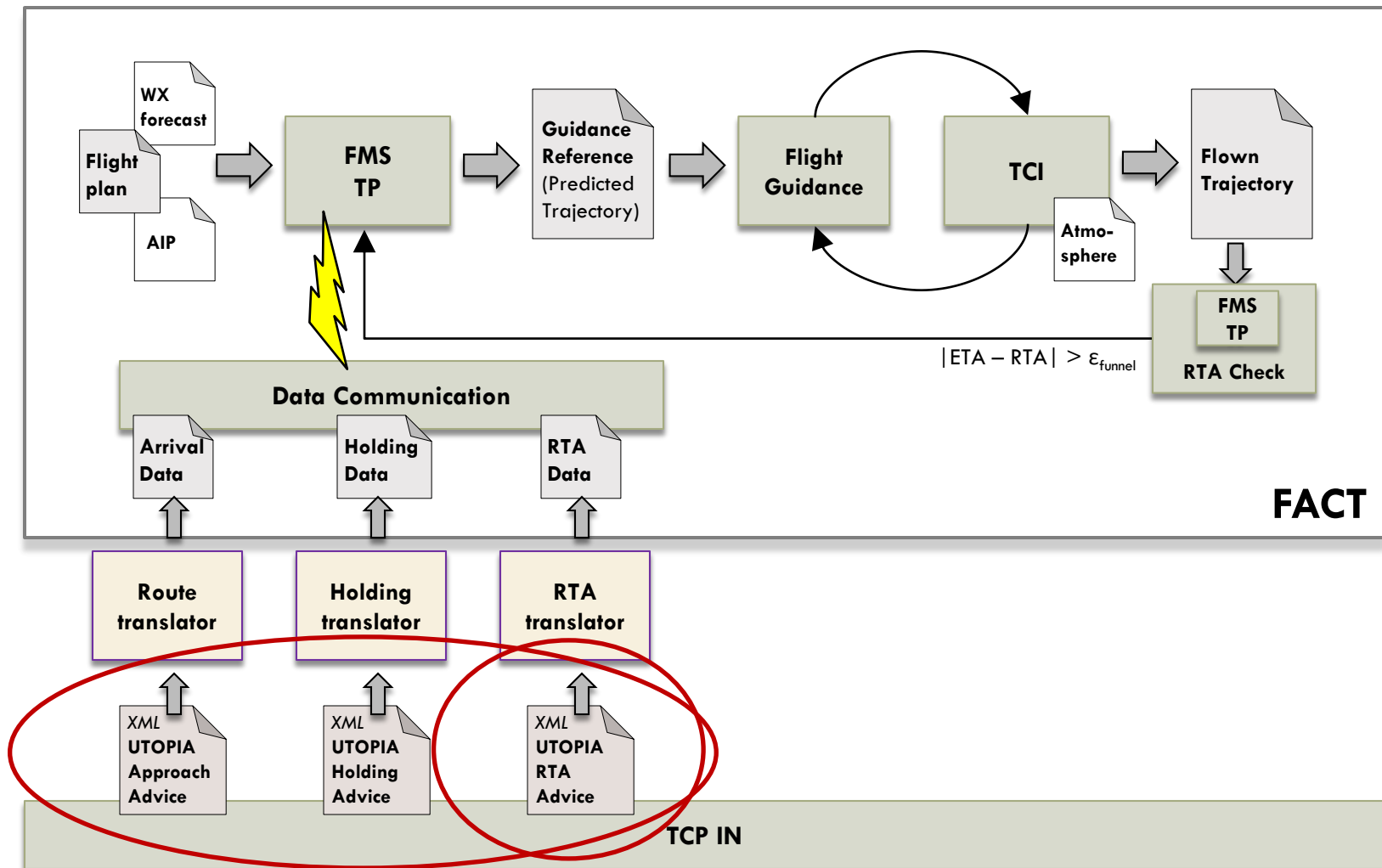
2. Simulation Environment - BR&TE Tools FACT & APATS

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2. Simulation Environment - Receiving UTOPIA Messages

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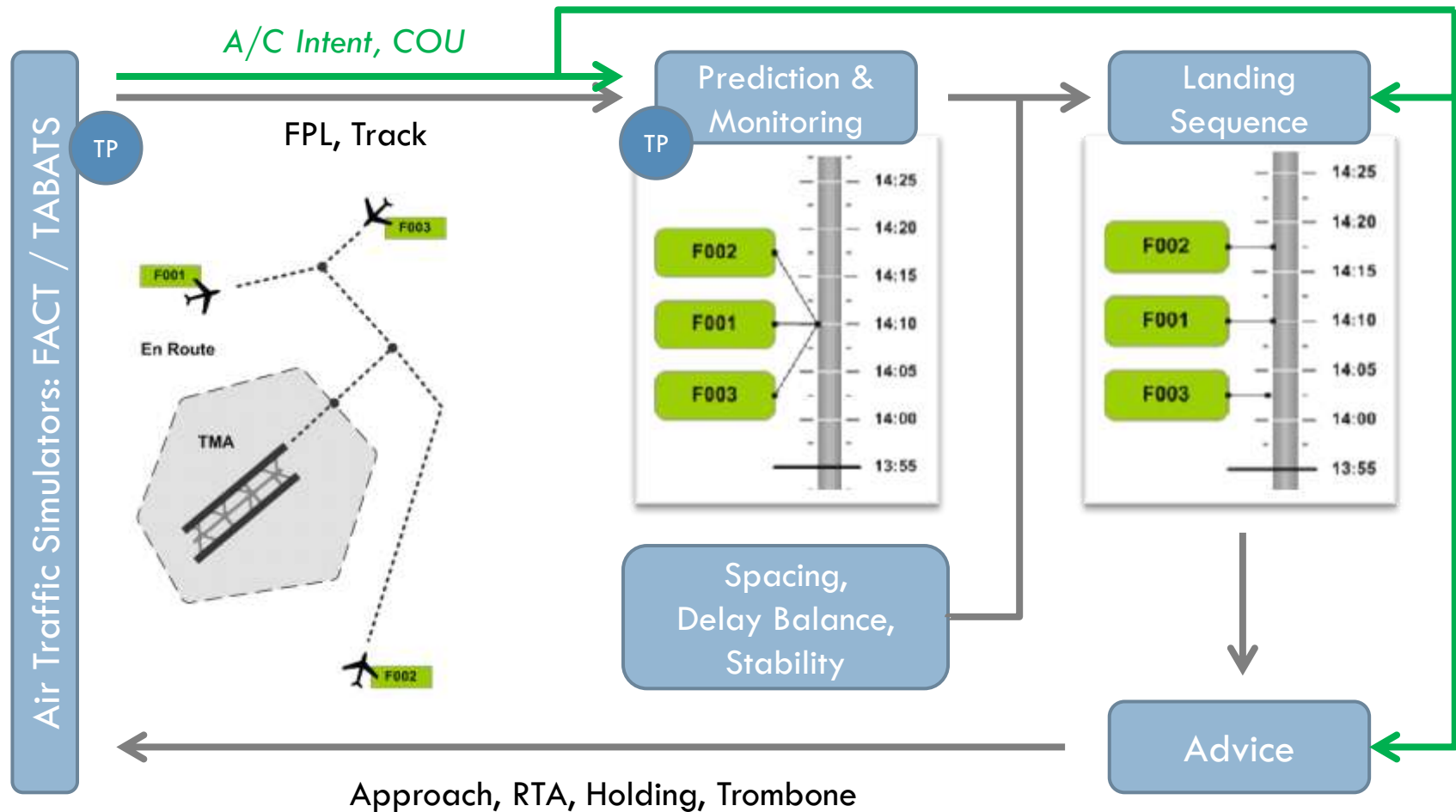
2. Simulation Environment - Trajectory Data Exchange

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- Exchange of trajectory information via **XML** messages
- **Currently** implemented UTOPIA message types
 - Aircraft → Ground (AMAN)
 - Flight Plan (later replaced by FIDL)
 - Track (pseudo message to simulate radar tracking)
 - 4D Trajectory (later replaced by AIDL)
 - Ground (AMAN) → Aircraft
 - administrative purposes (e.g. simulation time)
 - advisories
 - Required Time of Arrival (RTA) at Initial Approach Fix
 - approach transition
 - holding
 - trombone variant and fine tuning

3. Scenario Setup - Control Loop

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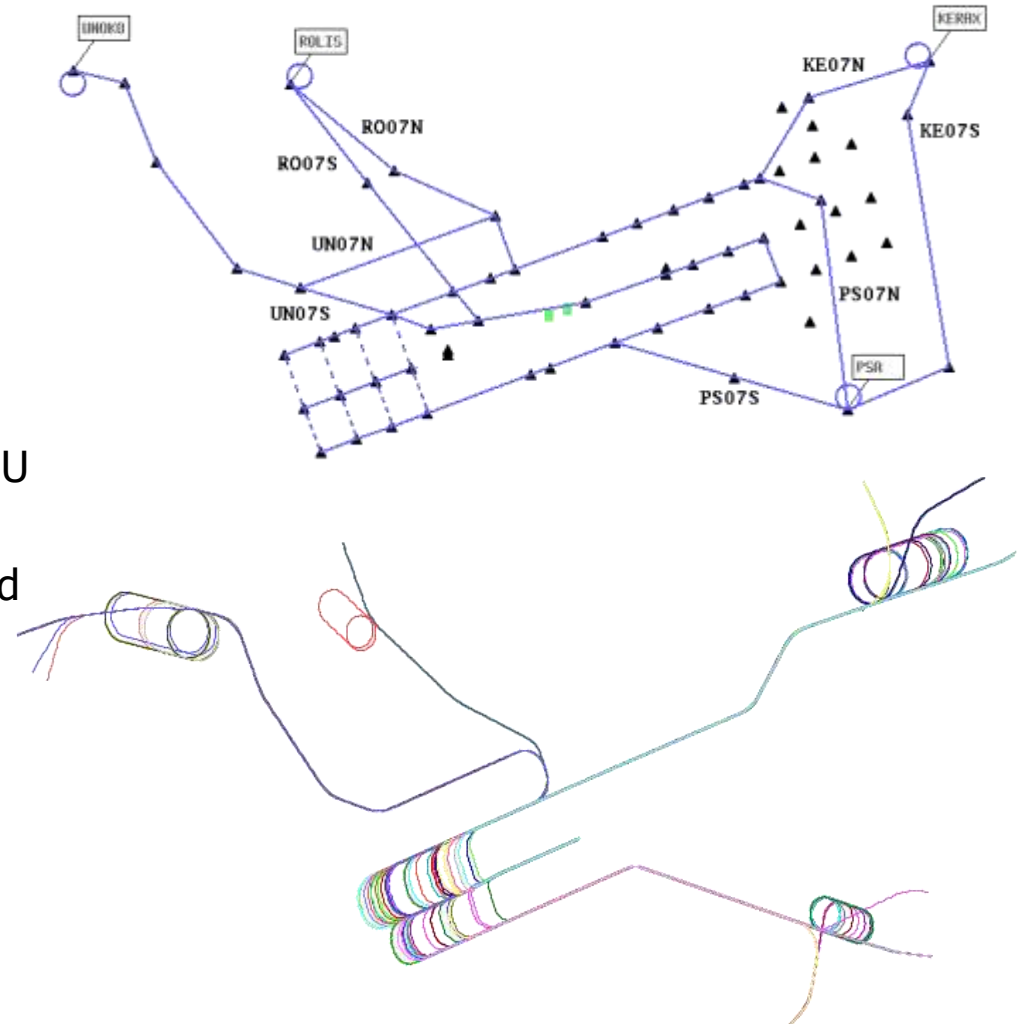


3. Scenario Setup - Airspace and Traffic

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- Frankfurt/Main EDDF
 - 'Old' 3 RWY configuration
 - RNAV-Z approaches with 'trombone' variations
 - Outer holdings

- Generated traffic is based on CFMU flight data set:
 - EDDF inbound traffic extracted
 - Variations of:
 - Traffic density
 - WTC mix
 - RTA capability



4. Implementation and Simulation Results - Advice Hierarchy

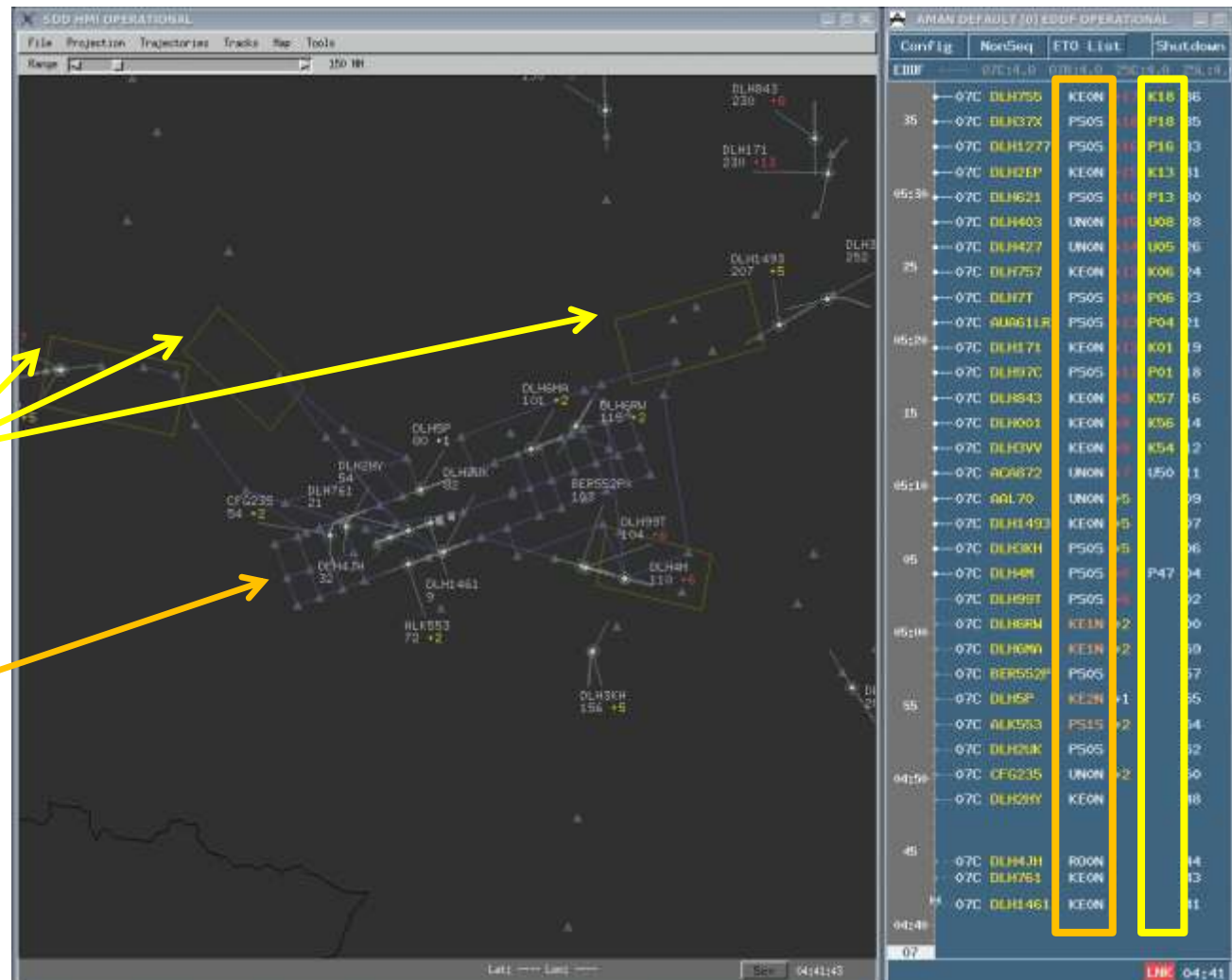
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1) Approach and
runway

2) RTA if possible

3) Delay
absorption in
holdings

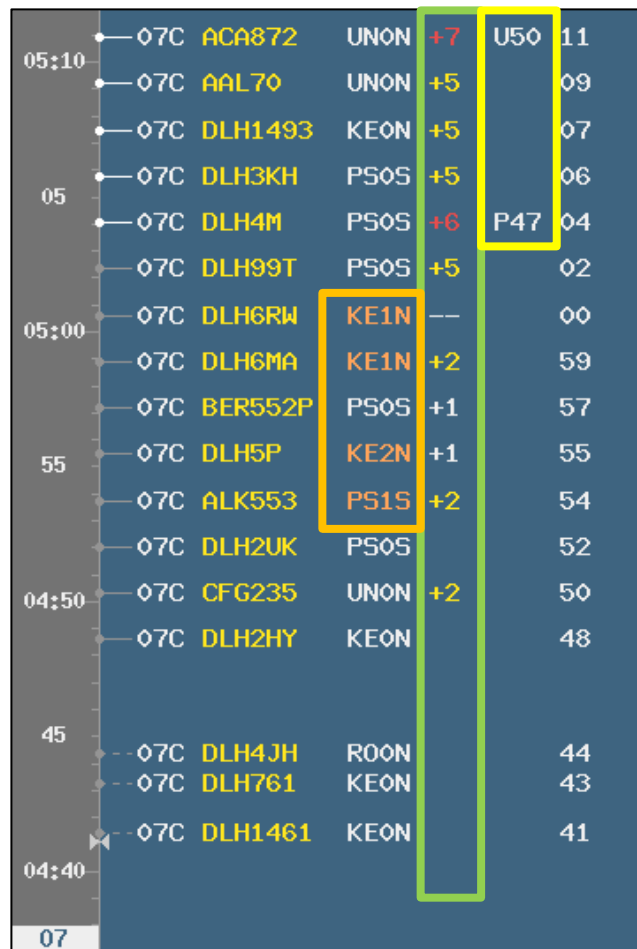
4) Path stretching
with 'trombones'
and 'trombone
fine tuning'



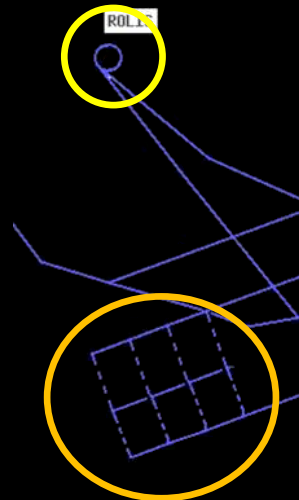
4. Implementation and Simulation Results - Advice Execution

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Without RTA Advice

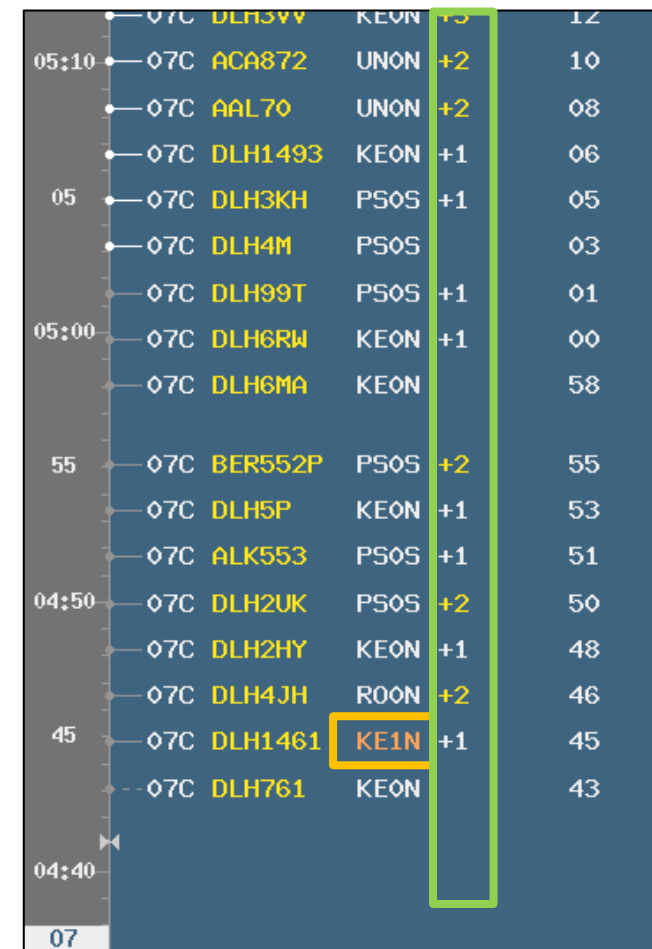


Trombones
& Holdings



Time To
Loose

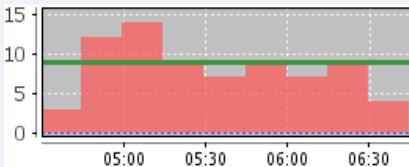
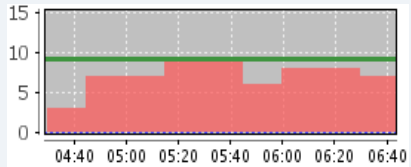
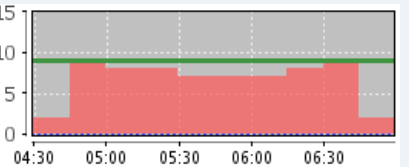
With RTA Advice



4. Implementation and Simulation Results - Example Metric

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- Scenario: 74 flights
- Flight horizon: 1 hour out
- Simulation time: 4 hours

Advice given / Metric	STAR & RWY (reference)	+ Holding & Trombones	+ RTA
# of Advice	74	360	426
Landings per 15 Minutes			
Average Fuel Usage per Flight	1,84 t	2,37 t	2,30 t

5. Outlook

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- Simulation test bed finished ... Debugging
- Full implementation of wind conditions and evaluation metrics
- **Uncertainty** handling:
 - Aircraft with reliable (certain) target times get a high priority in arrival sequence
 - Aircraft with uncertain target times get a higher degree of freedom in arrival sequence planning
 - Introduce flight path adaptations (re-routing) due to convective weather
- **Trajectory synchronization:**
 - Improve AMAN TP by using aircraft intent information from AIDL messages
- **Target:**
 - Evaluate effects of weather uncertainty and traffic mixes on the fully automated control loop

Thank you!

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