PIU4TP

Probabilistic information **I**ntegration in **U**ncertain data processing for **T**rajectory **P**rediction

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Engage TC2 Workshop – Data Driven Trajectory Prediction

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Probabilistic information Integration in Uncertain data processing for Trajectory Prediction

- Funder: **SESAR Engage KTN – second Call for catalyst funding**
- Thematic challenge 2: **Data-driven trajectory prediction**

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Development of a data-driven methodology for the prediction of the flight path in the pre-tactical phases starting weeks before the flight execution with the declared flight intention of the airspace users and ending few hours before the estimated off blocks time.

- It proposes the use of state of the art Machine Learning/Data Mining algorithms, which are able to learn from past experience how to obtain behavioral models based on complex but statistically reliable rules.
- It provides results that show the abilities of the developed methodology at the pre-tactical stage of operations.
- It is intended to support the planning activities in terms of demand-capacity balance and pre-tactical identification of conflicts.

Proof of concept able to provide a "map" of likely flight paths with the relative confidence on the basis of two input variables: **initial take-off weight** and **weather forecasts**

Weather Forecast

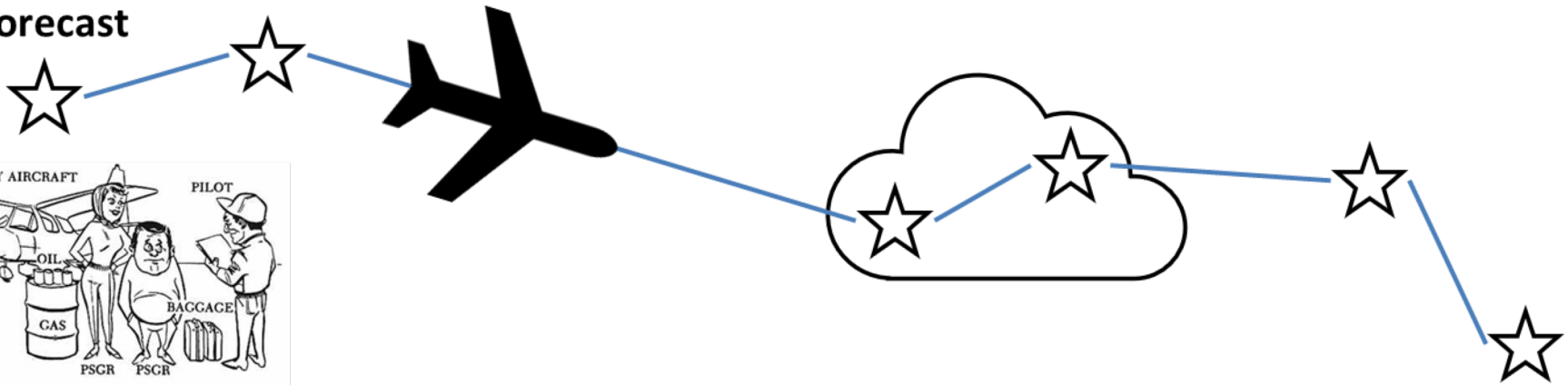


FIGURE 30. Empty weight . ...ul load = takeoff weight.

Take-Off Weight Forecast

What is outside the scope of this project?

Other causes of uncertainties such as the pilot intent, FMS performance, ATC tactical intervention, **are excluded** from this project.

Development and test of a methodology for trajectories prediction able to support final strategic and pre-tactical phases of the air traffic flow management process

*The **first** phase (completed) concerned the definition of relevant reference scenario, including the investigation of the structure of available data, the identification and tuning of models to generate data, and the realization of needed databases.*

*The **second** project phase (on going) will deal with the methodology development. The state-of-the-art of applied and applicable techniques will be analysed, the methodology implemented and possible lack of relevant data in current historical database identified.*

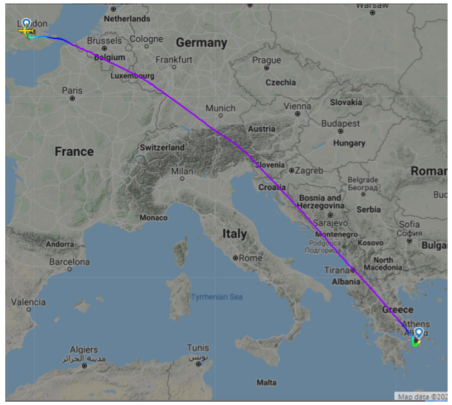
*In the **third** phase, the proposed methodology will be tested.*

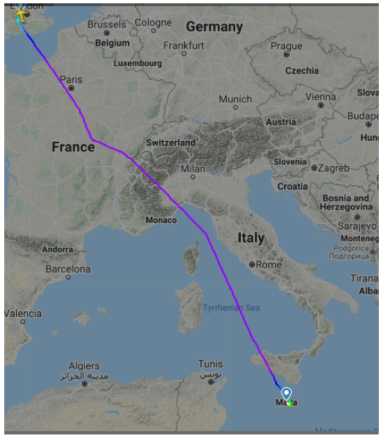
Key scenario elements:

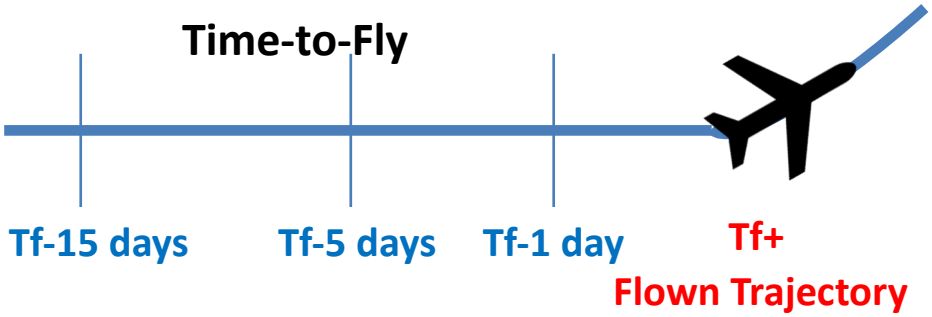
Airspace

The European airspace is considered and two routes selected:

- London Heathrow (EGLL) - Athens Eleftherios Venizelos (LGAV)
- London Gatwick (EGKK) - Malta International Airport (LMML)

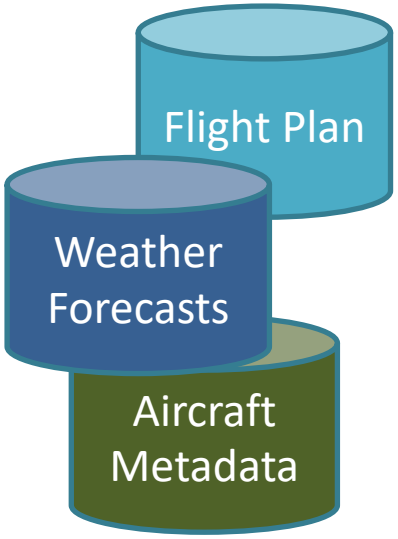






Time window

- The trajectory prediction is performed 15 days, 5 days, and 1 day before the flight.
- Input data and related uncertainties required for trajectory prediction are provided on these dates.
- Actual data experienced during the flight are also available.



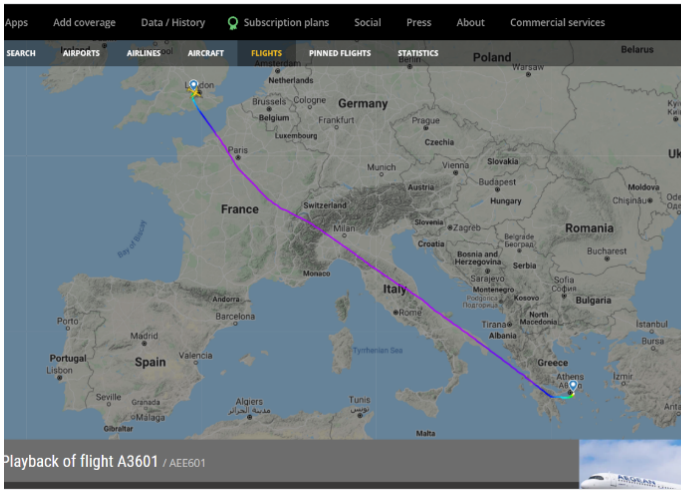
Data sources identification and selection

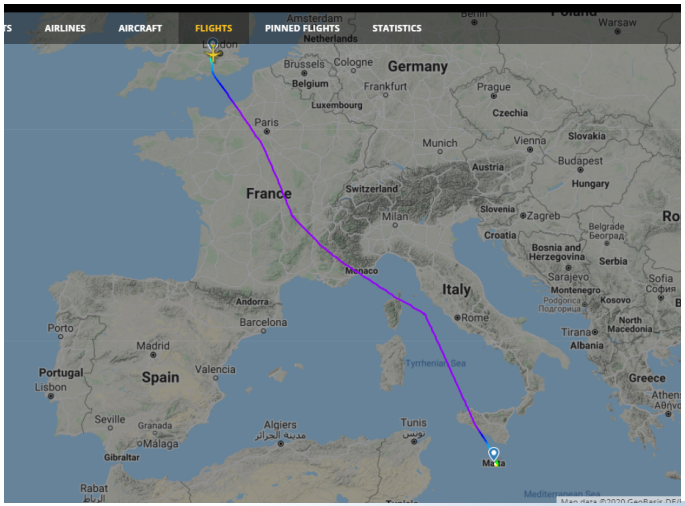
- List of possible flight plans for each route.
- Weather forecasts along the flight routes as above identified and their probabilistic uncertainties.
- Take-off weights for the flights considered and their probabilistic uncertainties.

- All these data were collected exploiting the information available in the literature and in the open databases.
- They are provided as input to a **simulation environment for flight plan selection and trajectory generation**.

FlightRadar24

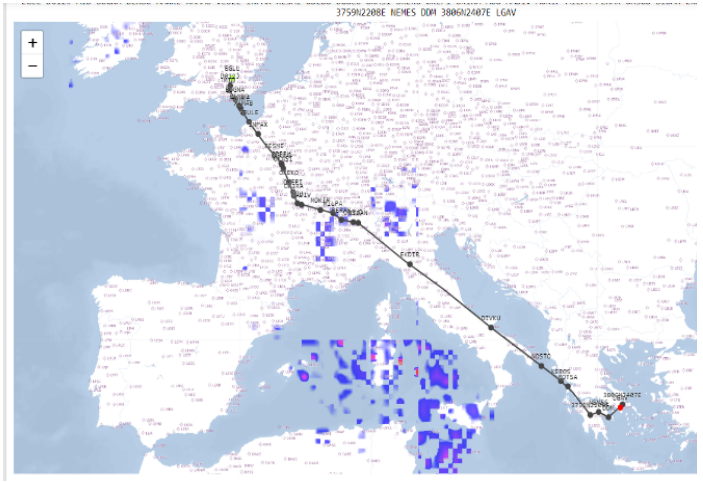
- Flown trajectories in a defined period of time





Flight Plan Database

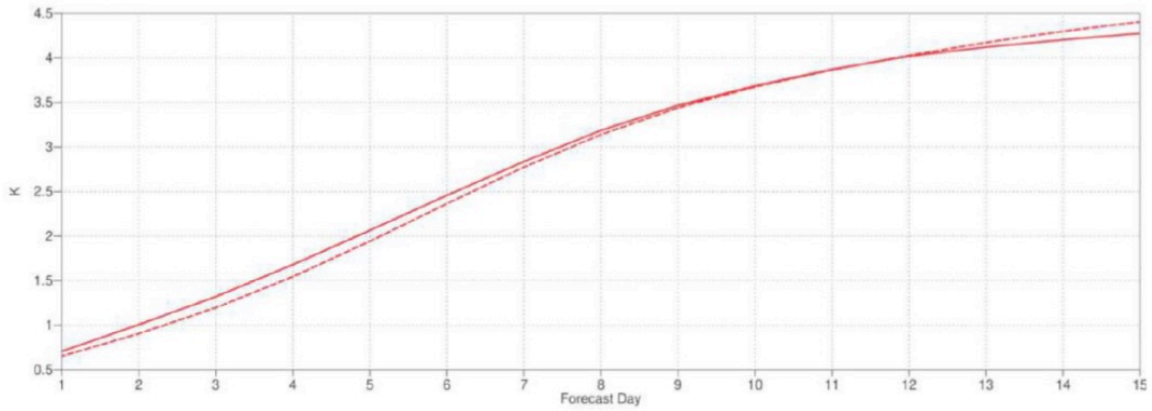
- Flight plan



ERA5 database of the European Centre of Medium-range Weather Forecast - ECMWF
https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysis-era5-pressure-levels?tab=overview

ERA5

- Latest generation climatic re-analysis data produced by the ECMWF
- Used data of days of October and November at 2pm hours from 1979 to 2013
- Included information about uncertainties on the exploited variables:
  - Air temperature
  - Wind direction and intensity



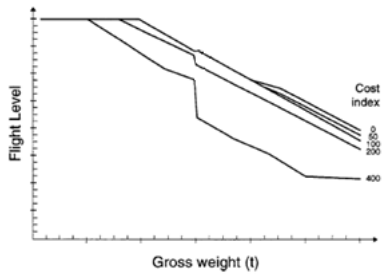
Temperature uncertainty vs forecast day (Std and RMS)

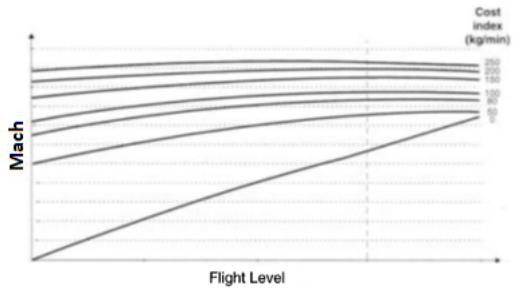
- The take-off weight (TOW) is included in the range between Minimum Take-Off and Maximum Take-Off Weight of the considered aircraft.

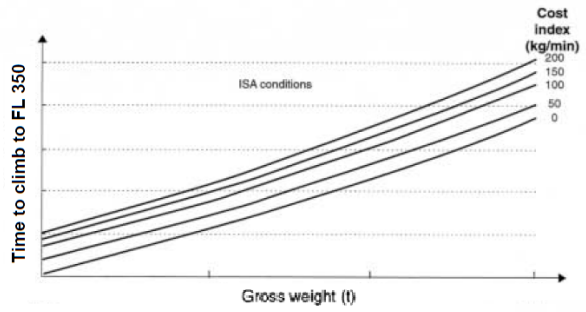
- Uncertainties are associated to the TOW when it is estimated in advance with respect to the scheduled day of flight.

- The uncertainties are assumed as a percentage of the whole TOW range variation and they reduce while approaching the day of the flight.

- Weather data and TOW are pre-processed and exploited to select the best 4D flight plan for the considered route and date of the flight
- Wind direction and intensity is used to identify the no-fly zones (due to hazardous or dis-comfortable flight conditions) that shall be avoided during the flight.
- Given the cost index applied by the airline, air temperature and TOW allow selecting the 4D flight plan by identifying:
  - The optimal flight level
  - The optimal Mach number and True Air Speed in cruise
  - The climb performance of the aircraft
- Compute the aircraft ground speed from the True Air Speed, and consequently the time of arrival to each waypoint of the flight plan (4D flight plan) considering the wind direction and speed.





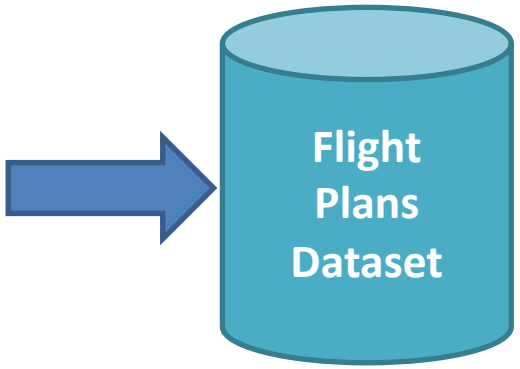


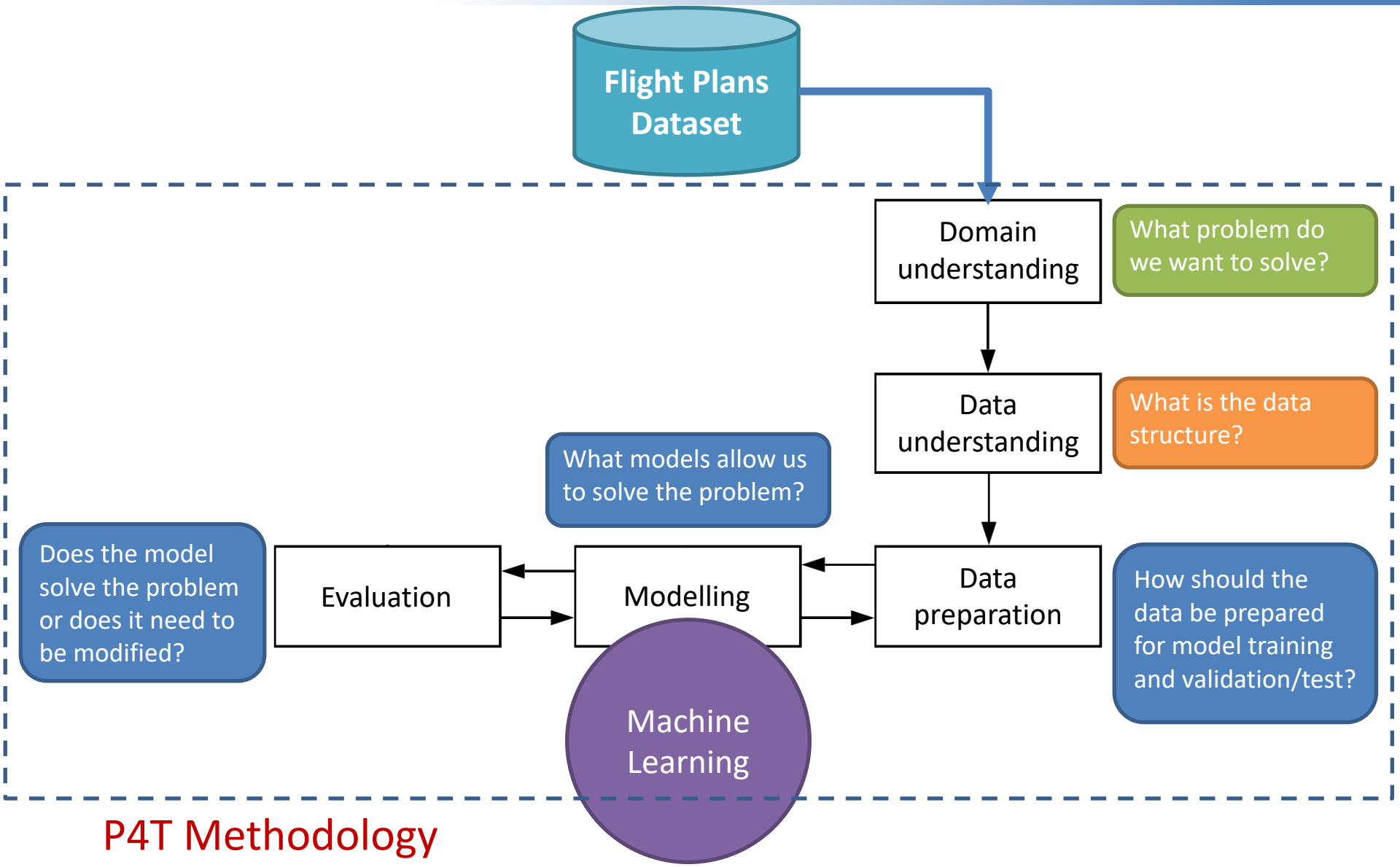
The simulation data to be generated are the following:

- Flight plans including input variables uncertainties at Tf-15;
- Flight plans including input variables uncertainties at Tf-5;
- Flight plans including input variables uncertainties at Tf-1;
- Flight plans at Tf+ (actually, the flown flight trajectory with full knowledge of actual weather condition and TOW)

Iterative procedure for each Tf

a. at a selected day/time, for each flight route, all the available flight plans will be identified, in terms of waypoints position both on the horizontal (LON-LAT) and on the vertical plan (light level);
b. the weather data for the selected day/time is extracted from the ERA5 database, and the related uncertainties characterization identified;
c. the take-off weight information data are selected (randomly) from the available ranges of weights, and related uncertainties characterization identified;
d. The sample represented by the flight plan, together its probabilistic information, is generated.





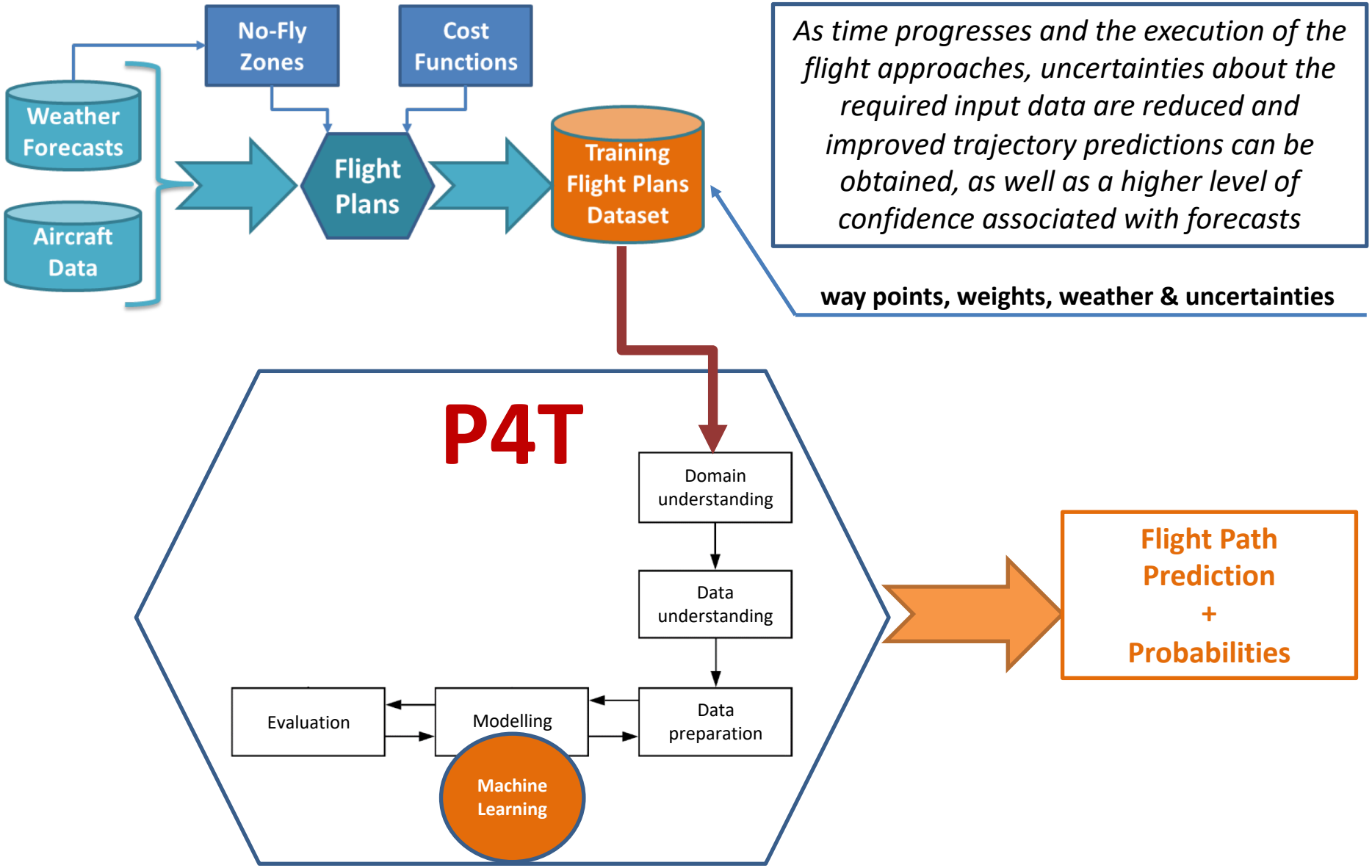
P4T Methodology

- As a result of the domain understanding phase, in the P4T methodology the domain objective has been translated into a data analysis objective which consists of a multiclass classification:
  - Predict which, among N possible flight plans, will be selected for the flight execution.
  - Input variables for the predictive model are:
    - Forecast temperature and wind speed and direction (east, north and down components) for each waypoint of the flight plan with relative uncertainties.
    - Forecast take-off weight with uncertainty.
- **Data understanding** is still in progress, we are characterising the statistical properties of the raw simulated data to gain insights for the subsequent predictive modelling steps.

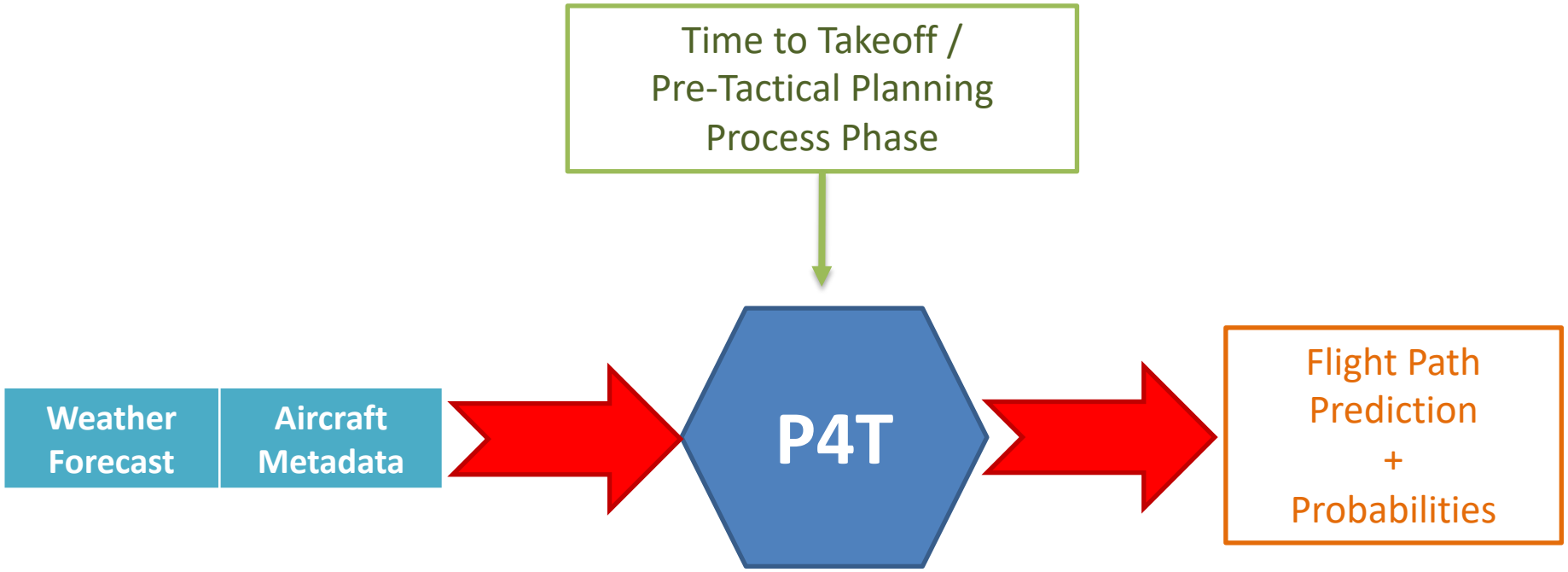
- **Data preparation.** Identify and solve potential problems within the data, preprocess the data (normalize, filter, define and extract useful features) to report them in a format usable by modelling algorithms.

- **Modelling.** Apply one or more classification algorithms to the prepared data and validate them in order to select the best one for the project objectives from a statistical point of view. To get a better understanding of the data, it cannot be excluded that also other type of algorithms could be used in this phase. Above all, the model should be able to handle the uncertainties in the input data.

- **Evaluation.** This phase includes the interpretation of data analysis results within the domain context. All results are evaluated by a joint work of data analysis experts and domain experts.



After the training phase the methodology is tested according to the following flow



- First stakeholders consultation exercise (October, 2020).
- Operational scenario definition (December, 2020).
- Presentation for SESAR Innovation Days 2020 (December, 2020).
- Intermediate progress report (January, 2021).

QUESTION TIME