



# CONTRACT-BASED AIR TRANSPORTATION SYSTEM (CATS)

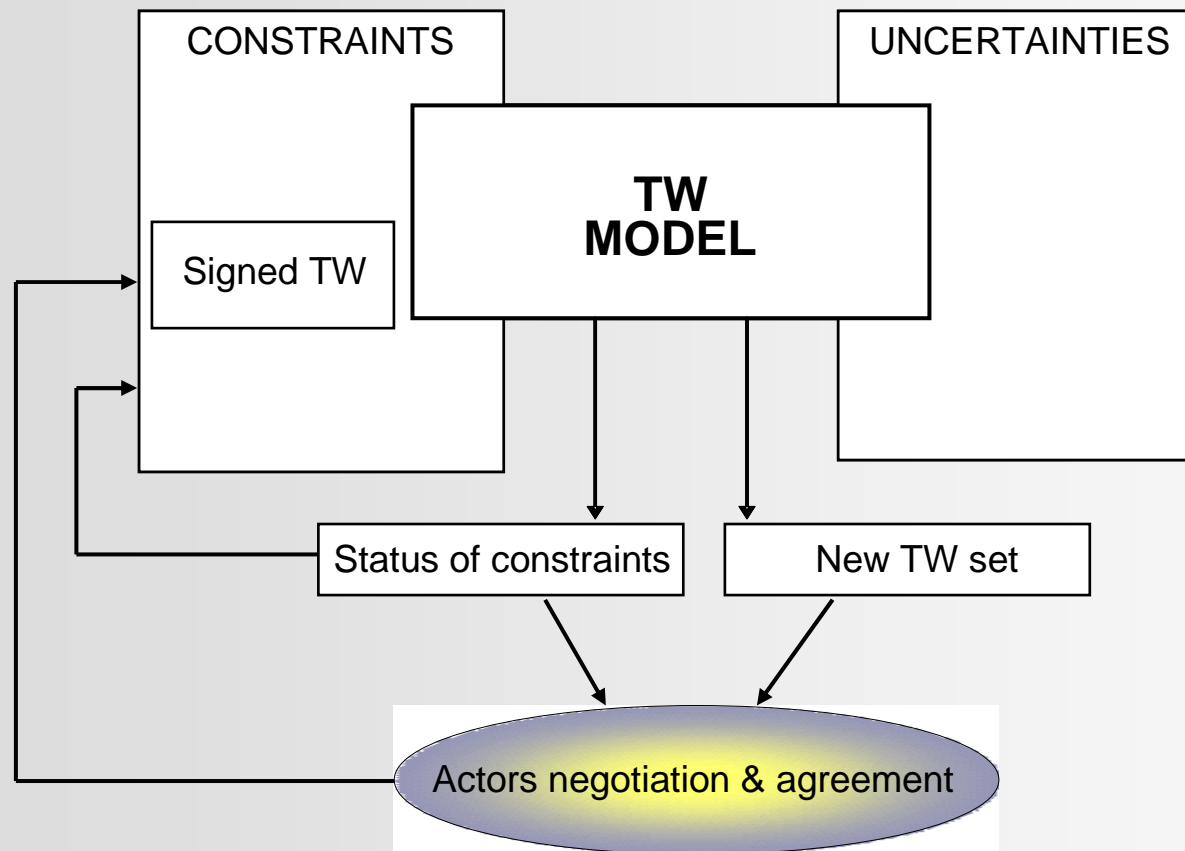
Target Windows modelling

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## Goal of WP2.2.4

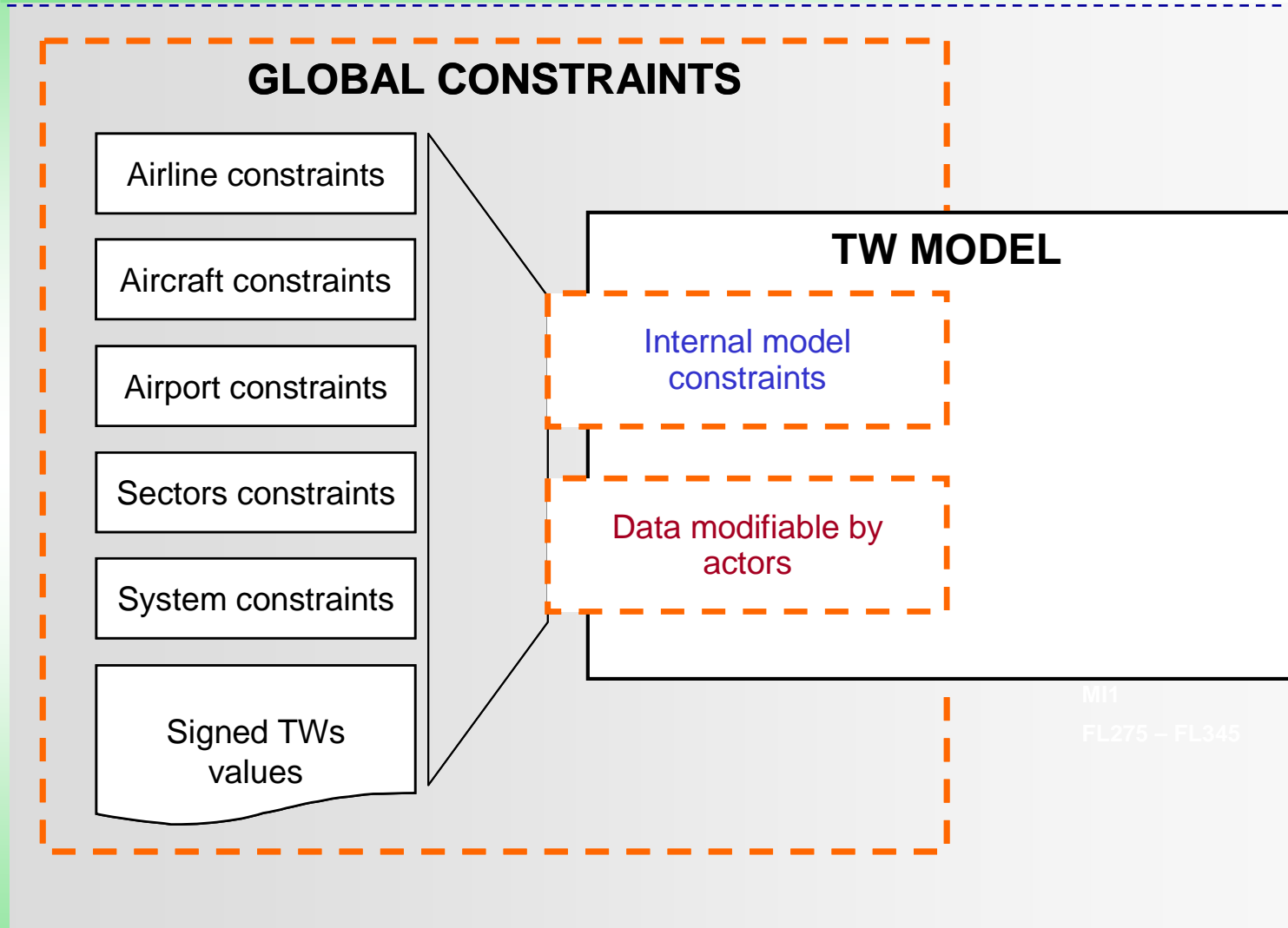
- To develop mathematical models of TW generation by integration actors and system constraints and capable to give margins of manoeuvre to limit the uncertainties of system.
  
- The deliverables of WP2.2.4 are:
  - D2.2.4.1 Initial evaluation of the Target Windows for experimentations
  - D2.2.4.2 Developed tools
  - D2.2.4.3 Report on Target Windows modelling.

# Global approach for TW modelling



Target Windows model gives margins of manoeuvre to limit the uncertainties

# Global constraints and TW modelling



# Airline and Airport constraints



## ■ Airline constraints

- Departure and Arrival times
- List of waypoints from Aircraft route
- Speed and Flight level values at some waypoints
- Destination airport
- TTA (for SESAR, out of AMAN horizon) according to Airport

## ■ Airport constraints

- Departure and arrival capacity
  - reduced capacity imposed by meteorological constraints
  - reduced capacity imposed by infrastructure constraints

# Aircraft constraints

- Aircraft envelop data in normal conditions
  - MinOperational speeds /FL
  - MaxOperational speeds /FL
- Aircraft Performance data in normal conditions
  - maximum altitude
  - rate of climb (ROC)
  - rate of descent (ROD)
- Aircraft failure
  - max speed of the aircraft
  - max FL of the aircraft

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# ANSP constraints (1)

## ■ Sector constraints

- Capacity
- Environmental constraints
  - meteorological constraints □ interval time restriction / area
  - military area constraints □ interval time restriction / area
- Sector boundary constraints / TW
  - No SUP TW near X nm from boundary sector (proposed X = 10 nm)
  - No SUP TW near X nm of crossing points
- Paired level constraint
  - Odd FL constraint
  - Even FL constraint
- Altitude limits
  - lower altitude of sector in feet
  - upper altitude of sector in feet
- Boundary points geo position (lat/long)

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## ANSP constraints (2)

- Network constraints
  - Route network constraints
- Military area
- Environnement constraints
  - Meteo

# System constraints

- The safety issues (D2.2.1 Risk and Safety Assessment), regarding the number of TW's overlapping at the same time, same area, same FL...
  - Minimum Separation TW's constraints
- Signed TW's values for other flights

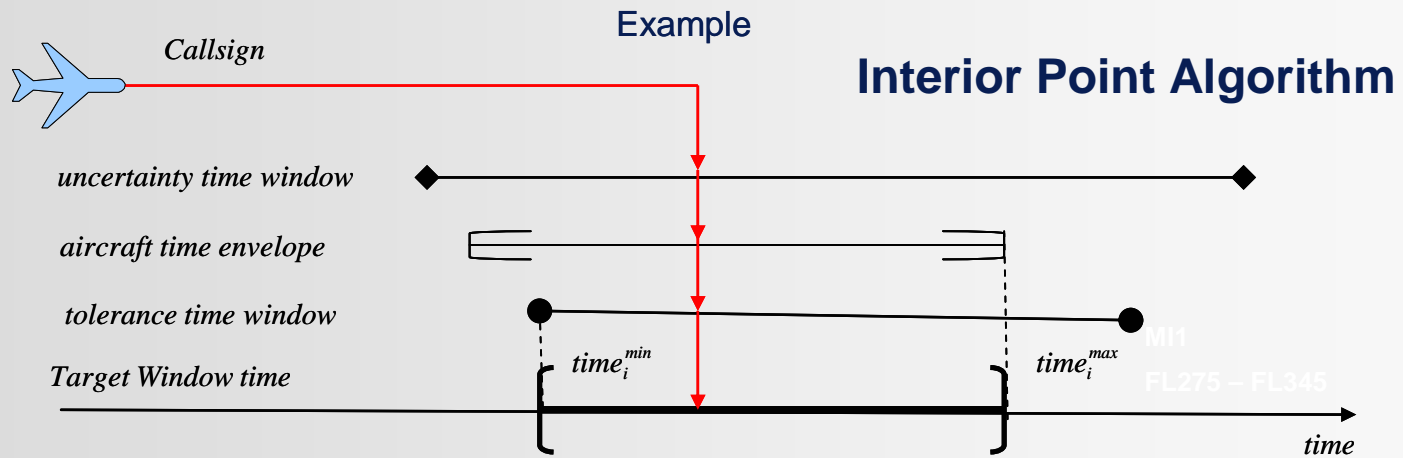
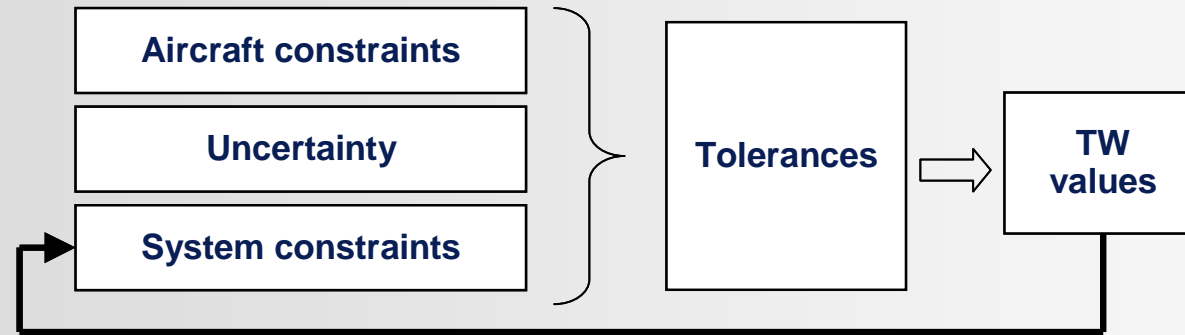
# Uncertainties

- Target Windows model gives margins of manoeuvre to limit the uncertainties
  - **Ad hoc events occurrences**
    - ▶ Logistical delays at airport
    - ▶ Reduced runway capacities
    - ▶ Meteorological phenomena
    - ▶ Occurrences on board aircraft
  - **Permanent uncertainty**
    - ▶ Current aircraft position
    - ▶ Aircraft performance
    - ▶ Air mass properties
    - ▶ Measurement noise, noise model accuracy
  - **ATC-flight crew communications**
  - **Separation function** (conflict resolution,.....)

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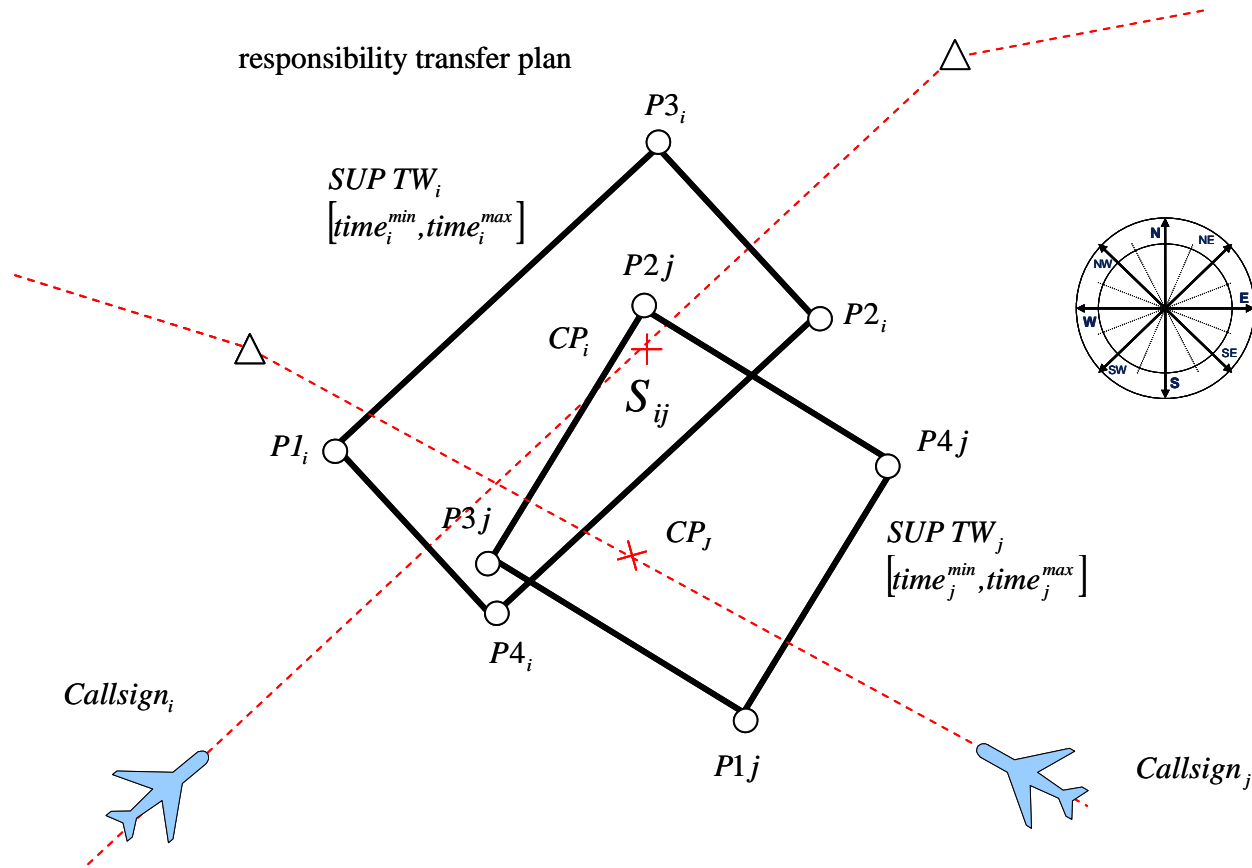
# Illustration of TW calculation



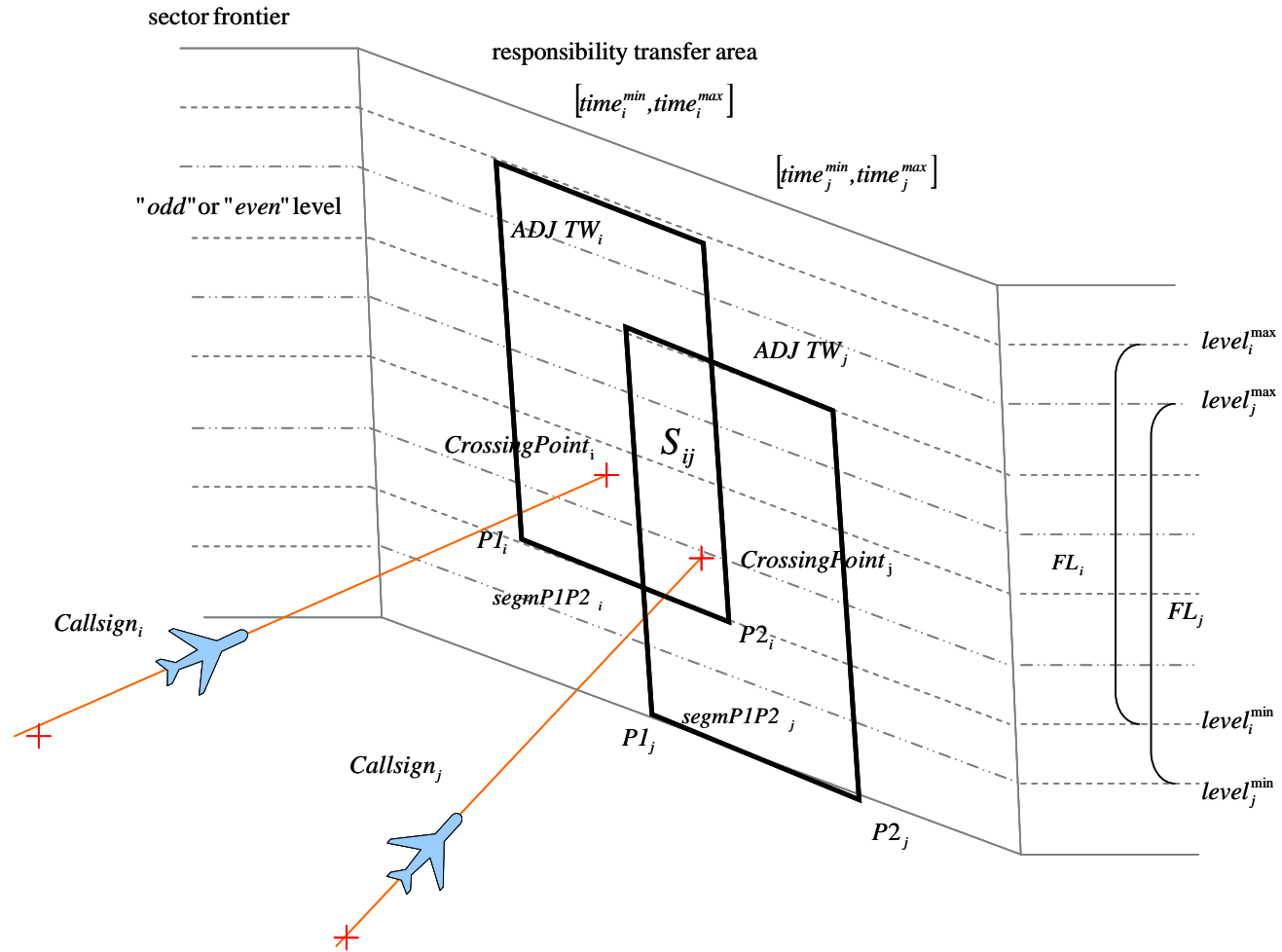
$$\text{min\_time Target Window} = \max\{\min(\text{time\_acceptance}, \text{time}_i^{\text{min}}), \min(\text{aircraft\_time\_envelope})\}$$

$$\text{max\_time Target Window} = \min\{\max(\text{time\_acceptance}, \text{time}_i^{\text{max}}), \max(\text{aircraft\_time\_envelope})\}$$

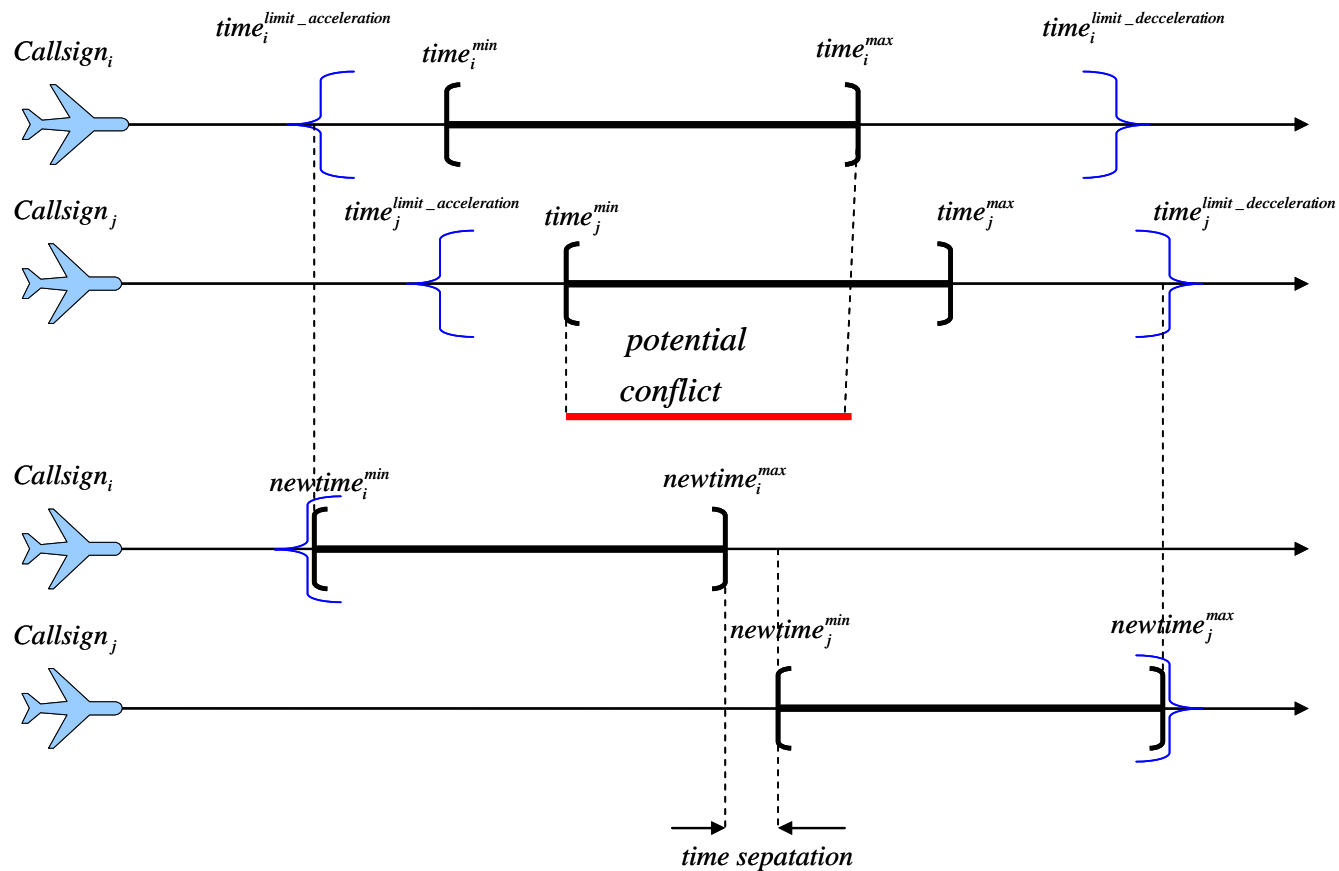
# Example of SUP TW overlapping



# Example of ADJ TW's overlapping



# Illustration of TWs de-confliction by time separation



**Just for overlapping**

# Summary

- Two kinds of TWGenerators were developed:
  - For planning phase
    - TWG use an external Trajectory Predictor
  - For execution phase
    - TWG use an internal Trajectory Predictor
- The TWGs were converted in executable using Converter MATLAB tools (TheMathWorks)
- These tools have been used during the execution of the HIL experiments to calculate initial values of the Target Windows (HIL1 and HIL2) and also to renegotiate them during HIL3



# Example of generated TW file for HIL experiments



[AFR1504]

1=ADJ;17:53:53;18:01:13;290;330;;FD;KL1;MOKIP+;46.4371/5.1557;46.5935/5.2155;46.2808/5.0958  
2=ADJ;18:11:08;18:17:50;290;330;;KL1;MI1;LAPRI+;44.9796/7.1720;45.1235/7.1922;44.8358/7.1518  
3=ADJ;18:33:31;18:38:07;280;340;D;MI1;FD;SIPLO-;43.9294/10.3703;43.9345/10.4900;43.9244/10.2507  
4=APT;18:58:09;19:01:09;;;;;LIRF;;;;;

[SWR342Z]

1=SUP;17:39:06;17:46:28;275;275;C;FD;MI1;LUKIM-44.0641/9.3694;43.7616/9.2996;44.3666/9.4393;44.1339/9.0669  
2=ADJ;17:54:21;18:01:11;280;340;C;MI1;KL1;PIMOT+;45.5048/7.7189;45.4233/7.5926;45.5864/7.8451  
3=SUP;17:56:53;18:03:39;345;345;C;KL1;FD;AOSTA;45.7378/7.4207;45.4673/7.4113;46.0083/7.4302;45.7472/7.1502  
4=APT;18:47:00;18:50:00;;;;;EBBR;;;;;

[VEX55N]

1=ADJ;17:59:08;18:06:02;280;340;;FD;MI1;BELEL+;43.5645/9.7607;43.5063/9.6205;43.6227/9.9009  
2=ADJ;18:19:24;18:25:48;300;340;;MI1;KL1;PIMOT+;45.5048/7.7189;45.4320/7.6060;45.5777/7.8317  
3=ADJ;18:34:56;18:40:56;320;340;;KL1;FD;GILIR-;47.0542/6.2447;47.0156/6.1301;47.0929/6.3594  
4=APT;19:12:33;19:15:33;;;;;EBBR;;;;;

[TSO9121]

1=ADJ;17:06:33;17:12:29;290;330;;FD;MI1;LUSIL-;46.0494/10.1308;45.9538/10.2010;46.1450/10.0606  
2=ADJ;17:26:52;17:32:34;290;330;;MI1;FD;VAMTU-;44.1532/7.6319;44.1057/7.7305;44.2007/7.5332  
3=APT;18:10:02;18:13:02;;;;;LEBL;;;;;

[EZS1118]

1=ADJ;17:55:50;18:03:06;280;340;;FD;MI1;BELEL+;43.5645/9.7607;43.5012/9.6081;43.6278/9.9133  
2=ADJ;18:18:00;18:24:04;320;340;;MI1;FD;ABESI+;46.1670/9.0410;46.1591/8.9183;46.1748/9.1637  
3=APT;18:40:20;18:43:20;;;;;LFSB;;;;;