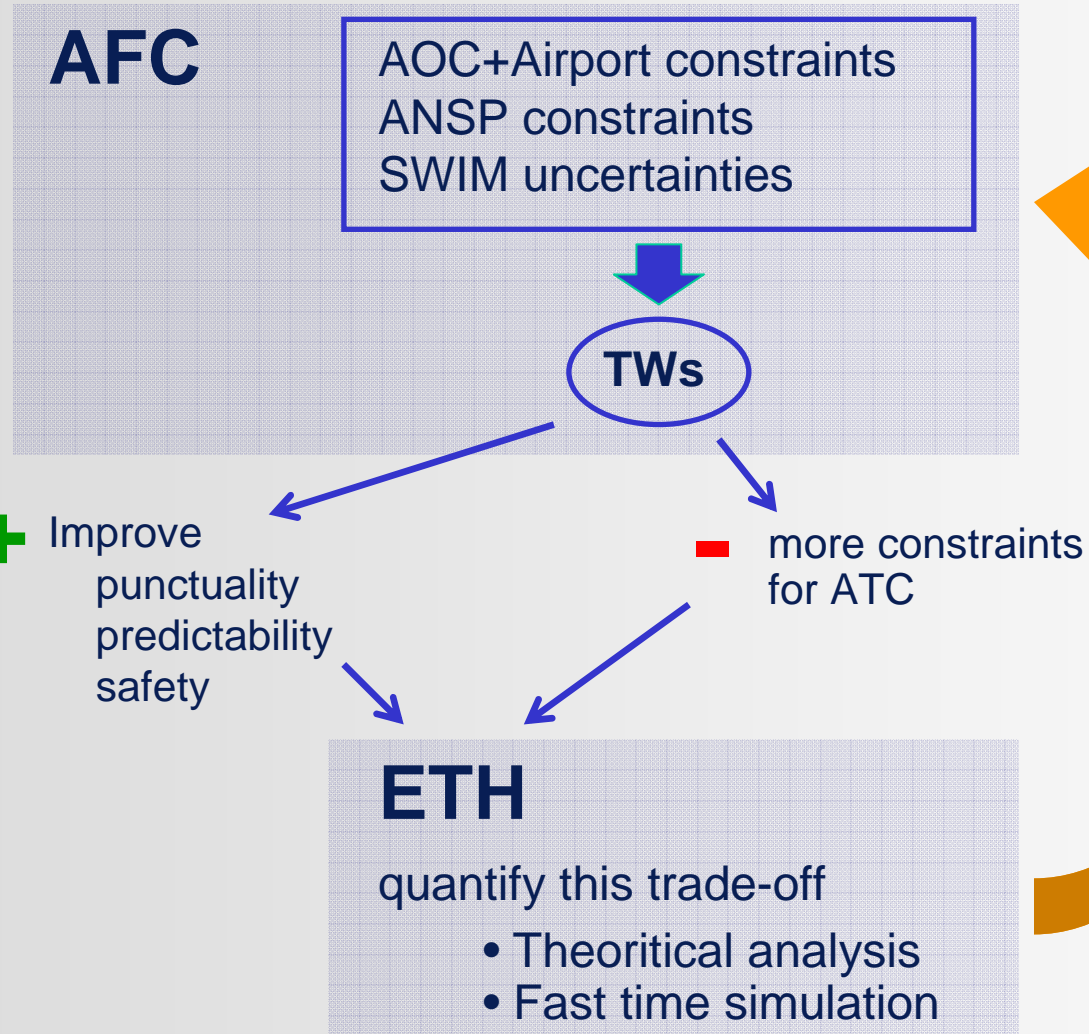




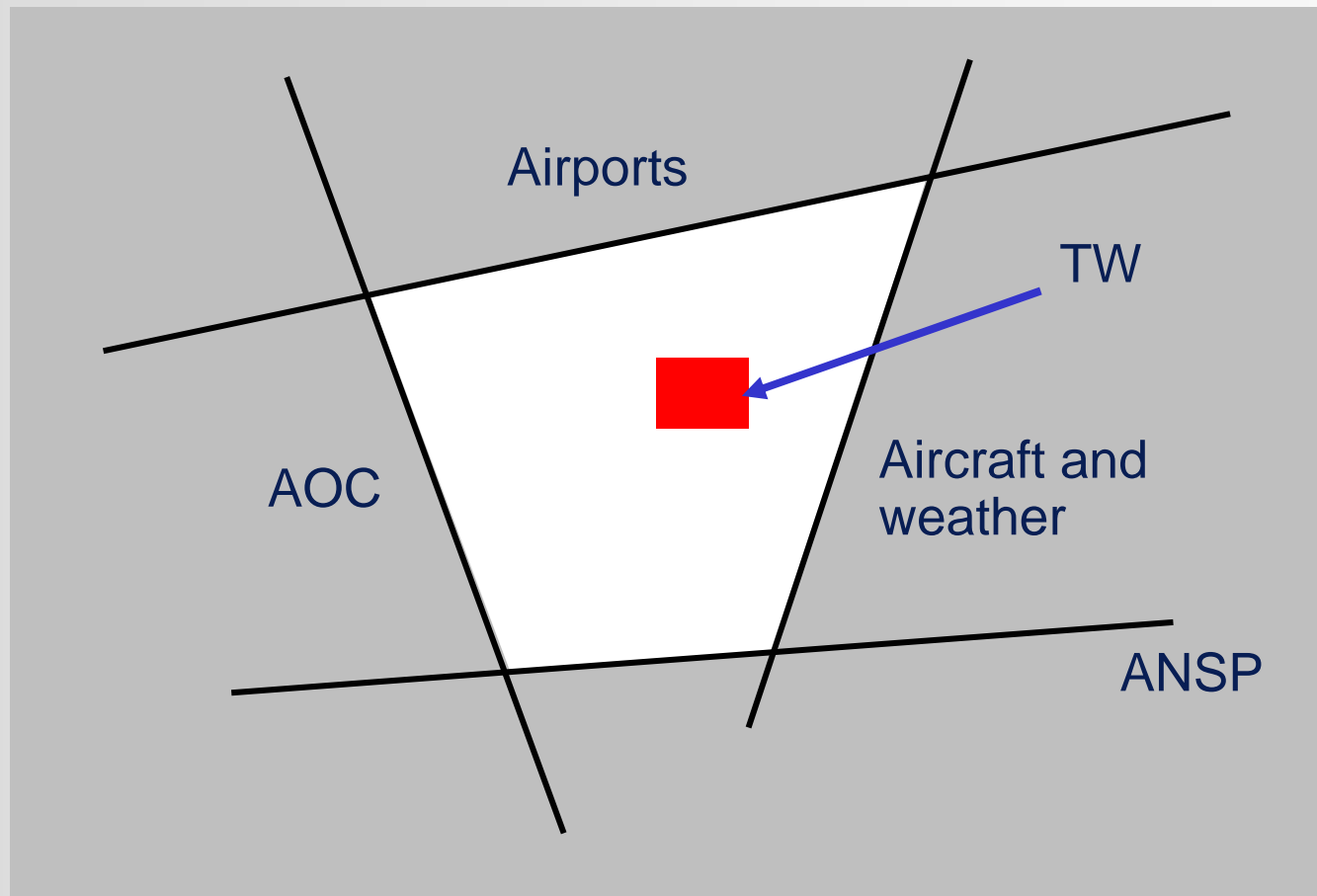
# Safety and TW Modelling

John Lygeros  
ETH Zurich

# Role in the project



# Intersection of constraints



# What is our objective?

- Complement HIL safety studies
  - HIL sample too small to reliably assess safety
  - Fast time simulation can check more scenarios
  - Conflicts, freedom allowed by TW to resolve them, ...
- Insight regarding TW size → Feedback to TW modeling
  - Determine probability of missing TW
  - Determine maneuvering freedom afforded by TW
  - Conflict resolution under TW
- Enabling technology for fast time simulation
  - Unlike HIL, human controller not available
  - Develop algorithms for
    - Meeting TW requirements (Time of Arrival controller)
    - Conflict resolution under TW (reachability methods)

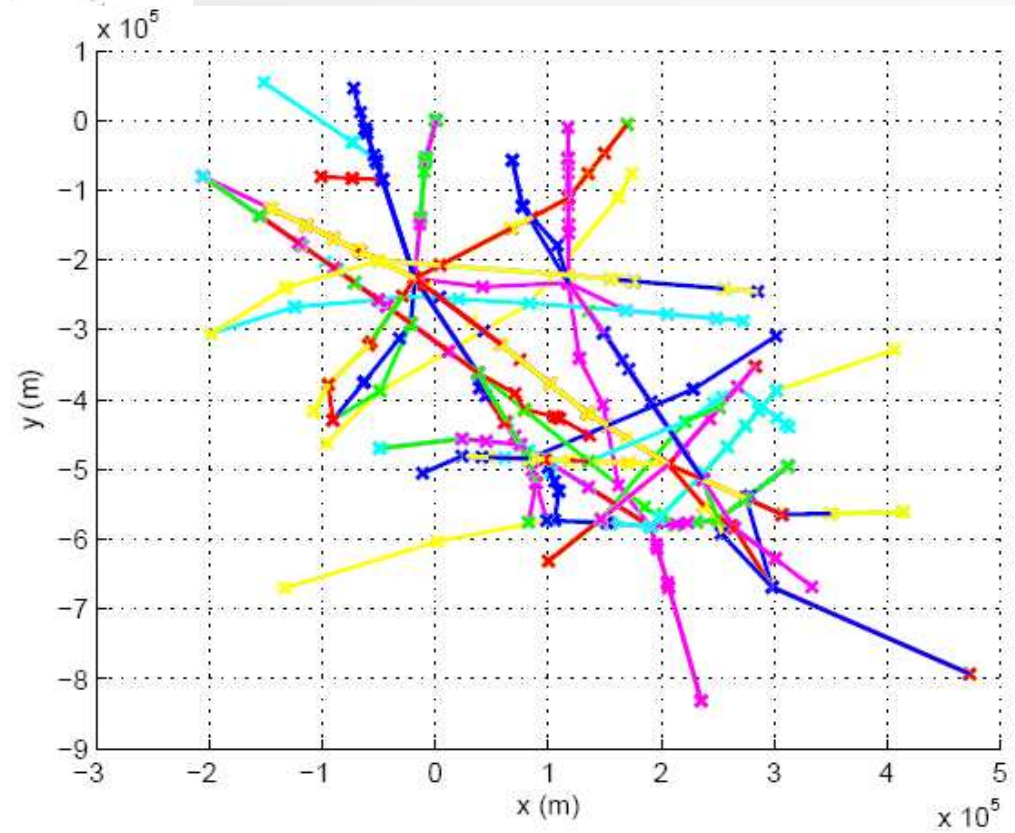
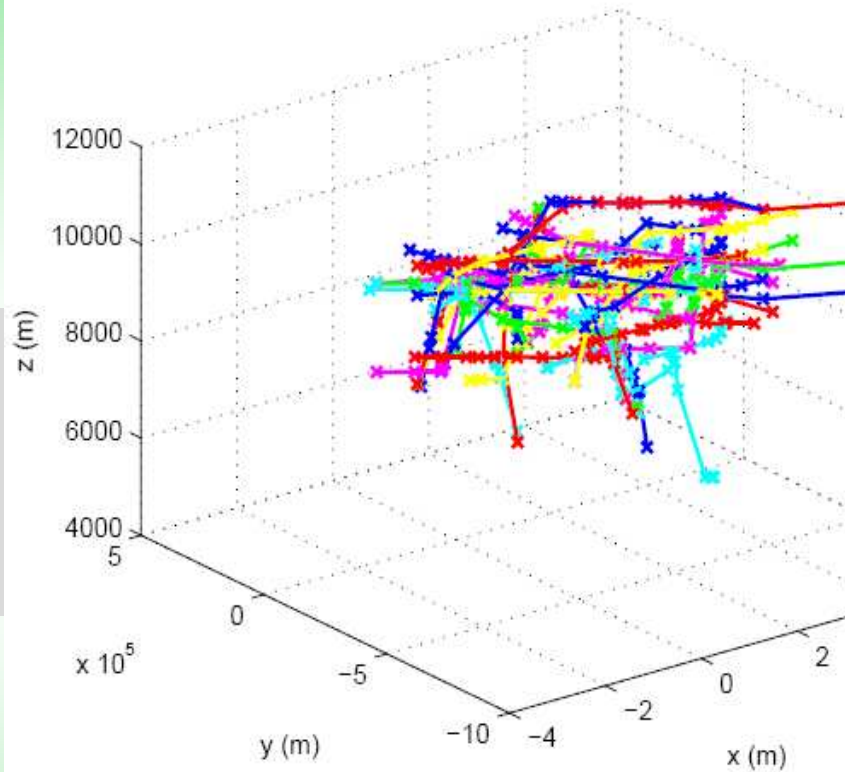
# Fast time simulation set up

- HIL 2 set up in fast time simulator
  - Point mass aircraft model
  - FMS for flight plan tracking, cruise climb, descent, etc.
  - BADA parameters
  - Wind forecast uncertainty (stochastic, realistic statistics)
- Implementation issues
  - Java simulator
  - Fast, object oriented → better for dynamic setup
- Uncertainty sources
  - In this talk: Only wind
  - Also: Mass, airspeed, entry point



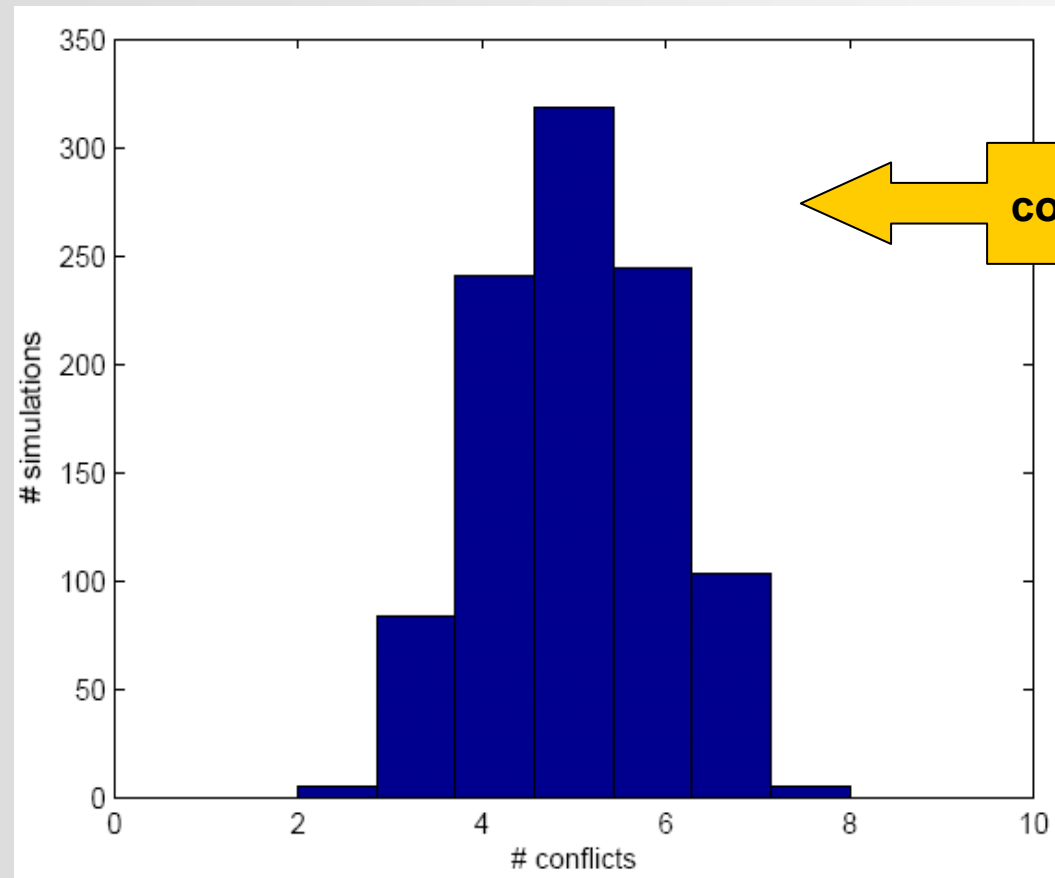
# Simulation results

## 45 flights from HIL2

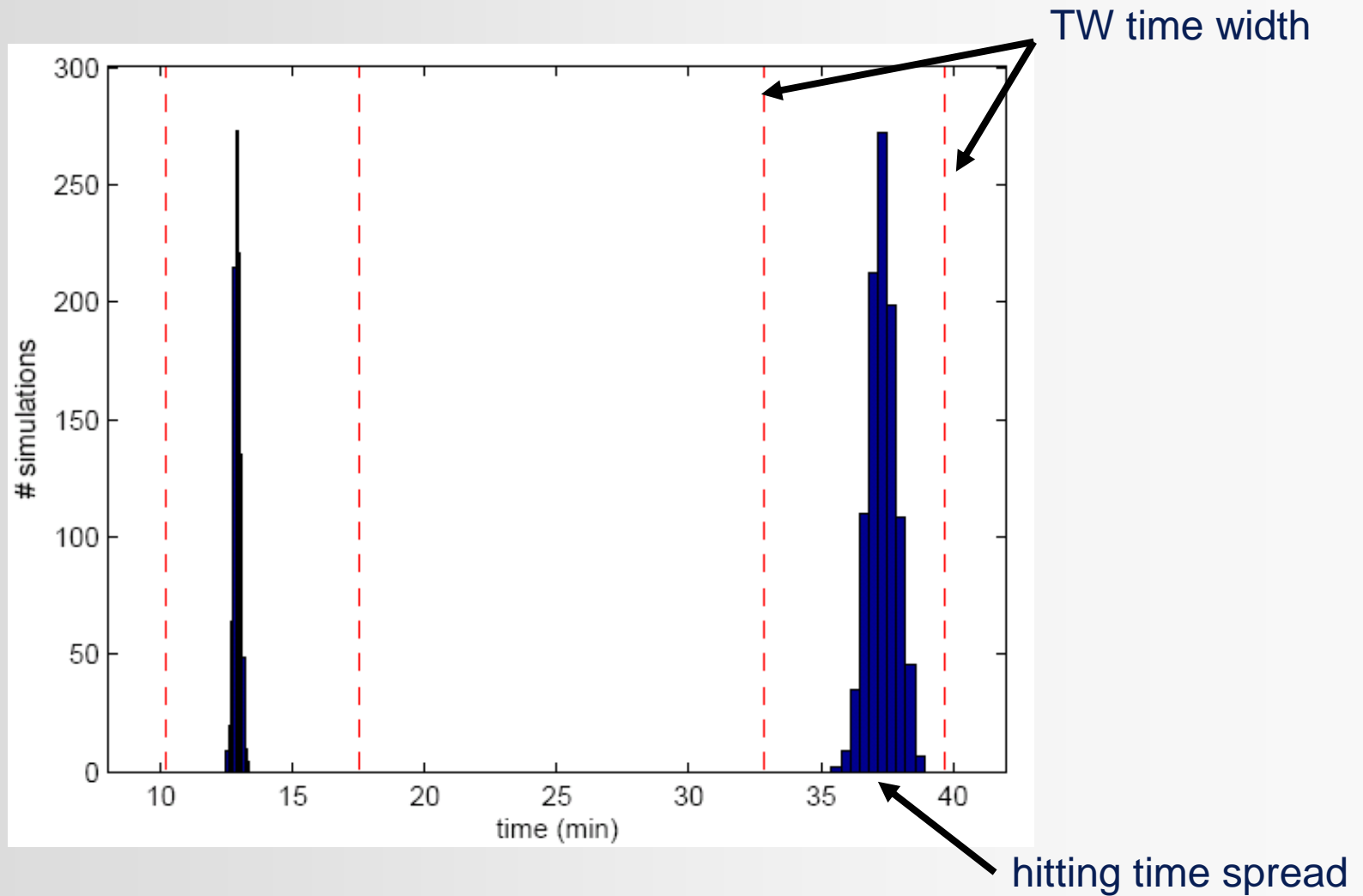


# Simulation results

- Monte Carlo
  - 1000 simulations

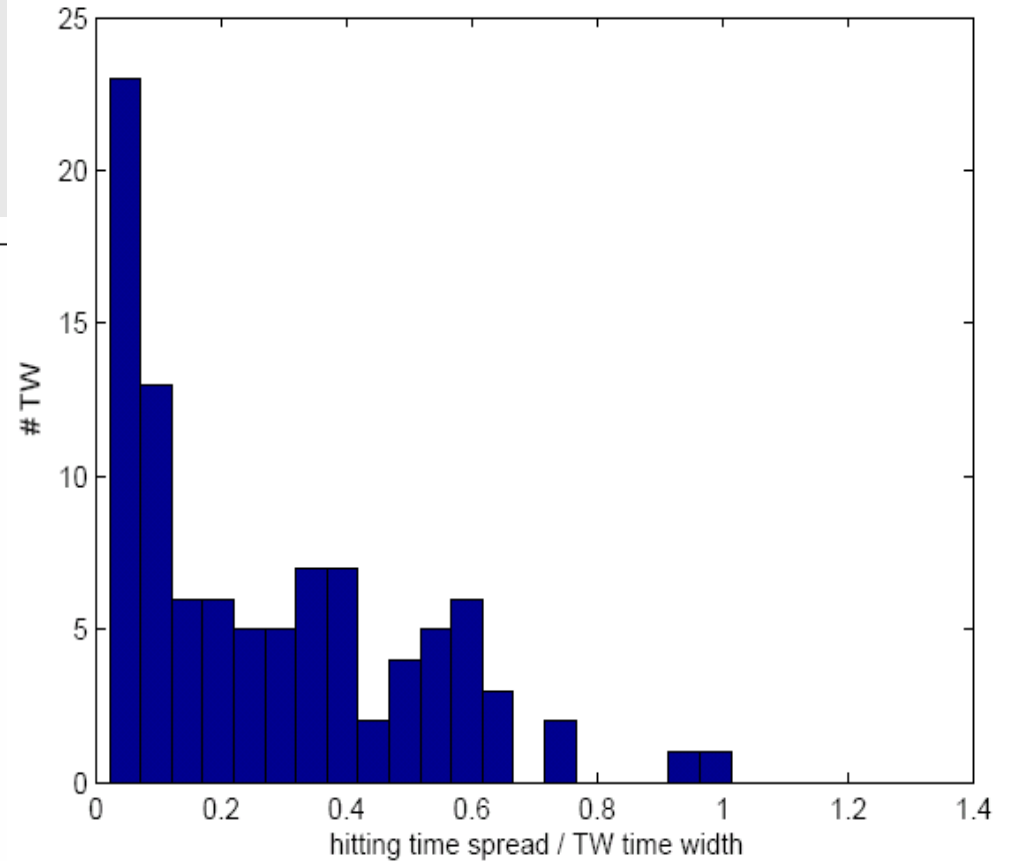
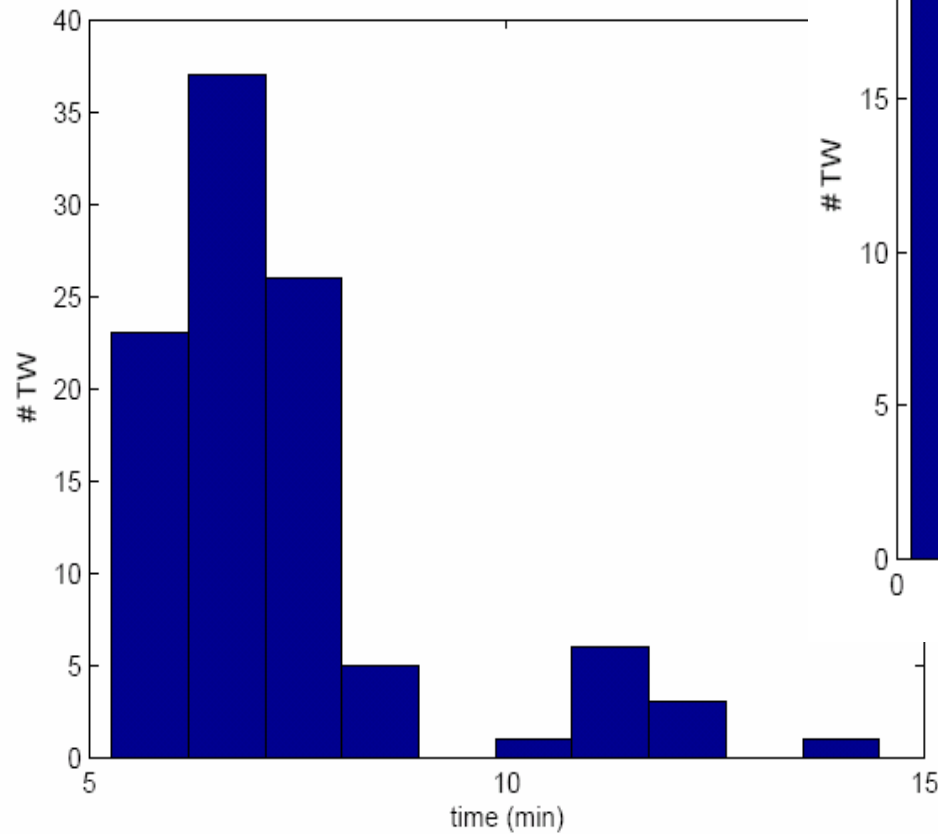


# Simulation results



# Simulation results

**TW's size indicator**

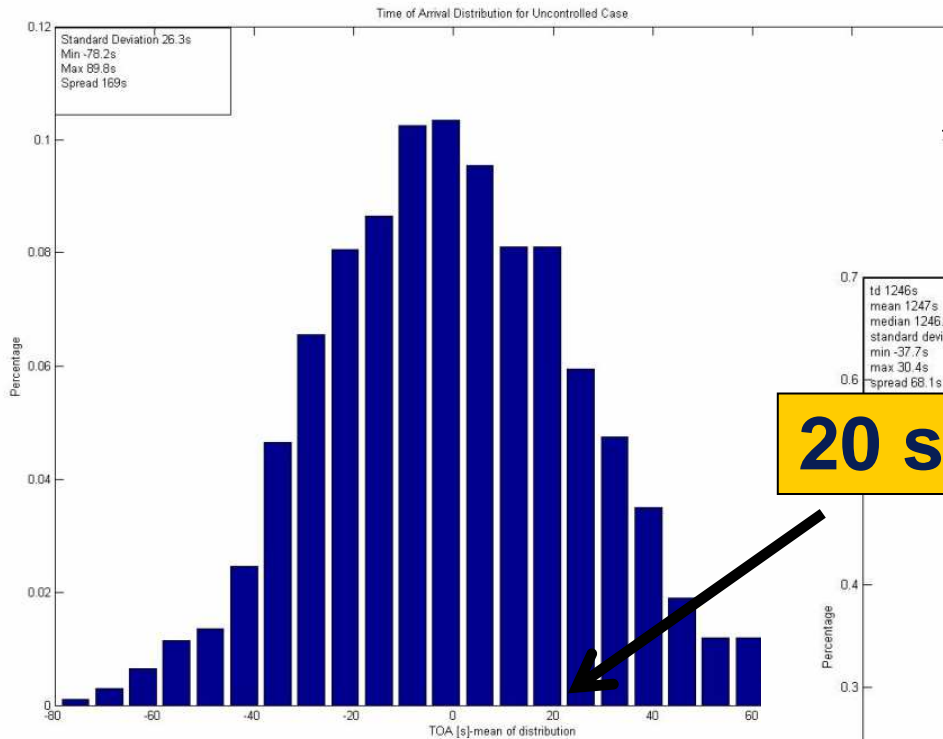


**TW time width**

# Can we do better?

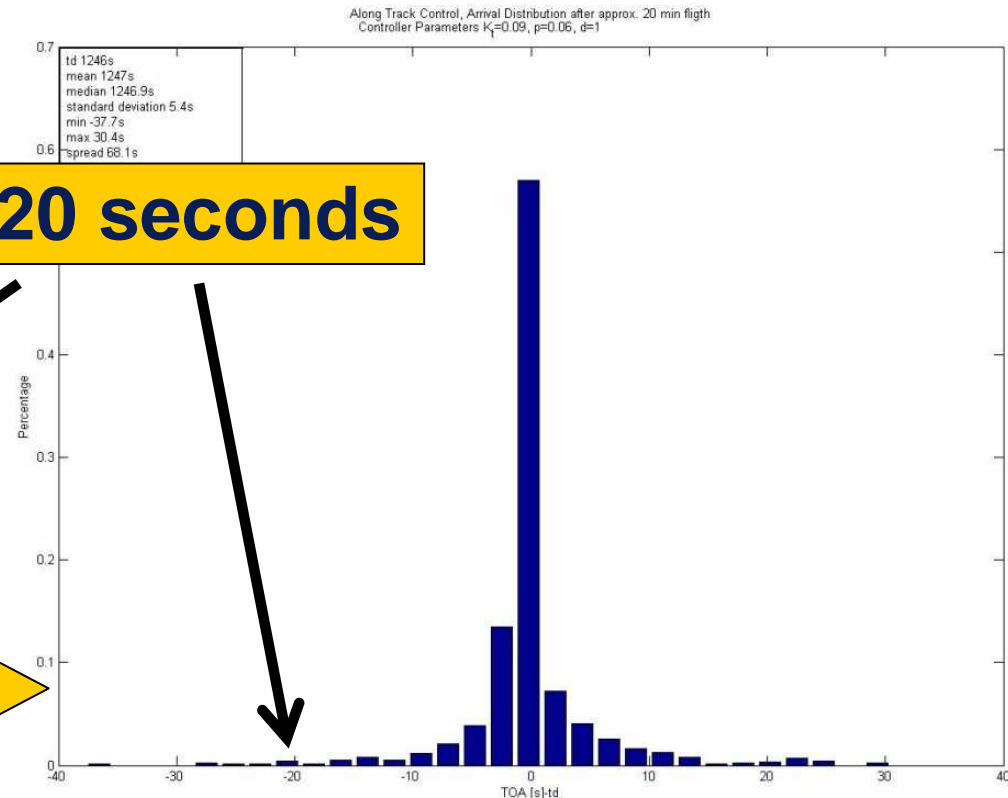
- Somewhat conservative
  - Aircraft make no effort to meet TW (temporal component)
  - In reality ATC/pilot/FMS will be providing corrections
- Time of arrival controller
  - Add a correction term to the nominal speed
  - Simulate effect of air traffic controller/pilot in HIL
- Current implementation
  - More like 4D FMS
  - Continuous corrections, aim for the center of TW
  - Parameters can be tuned to mimic human corrections
  - Indicate feasible time intervals for the TW
    - Feedback to the TW modeling phase

# Time of Arrival Control



**Without TOA control:  
Broad distribution**

**20 seconds**



**With TOA control:  
Narrow distribution  
Indication of how  
narrow TW can be**

# Remarks and future plan

- Fast time simulation results suggest ...
  - TW easy to hit in space
    - Thanks to FMS
    - Room to maneuver in case of conflicts
  - TW not always easy to hit in time
    - Most TW generous, but some already in the limit
    - Improvement with time of arrival control
    - Size can be reduced substantially
- Current work
  - Uncertainty in mass, airspeed, entry point etc.
  - Conflict resolution by adding “artificial” TW
  - Parametric study in TW size
  - Statistical analysis → Feedback to TW modeling

**Thank you for your attention!**

