Fe^3 – An evaluation tool for low-altitude air traffic operations

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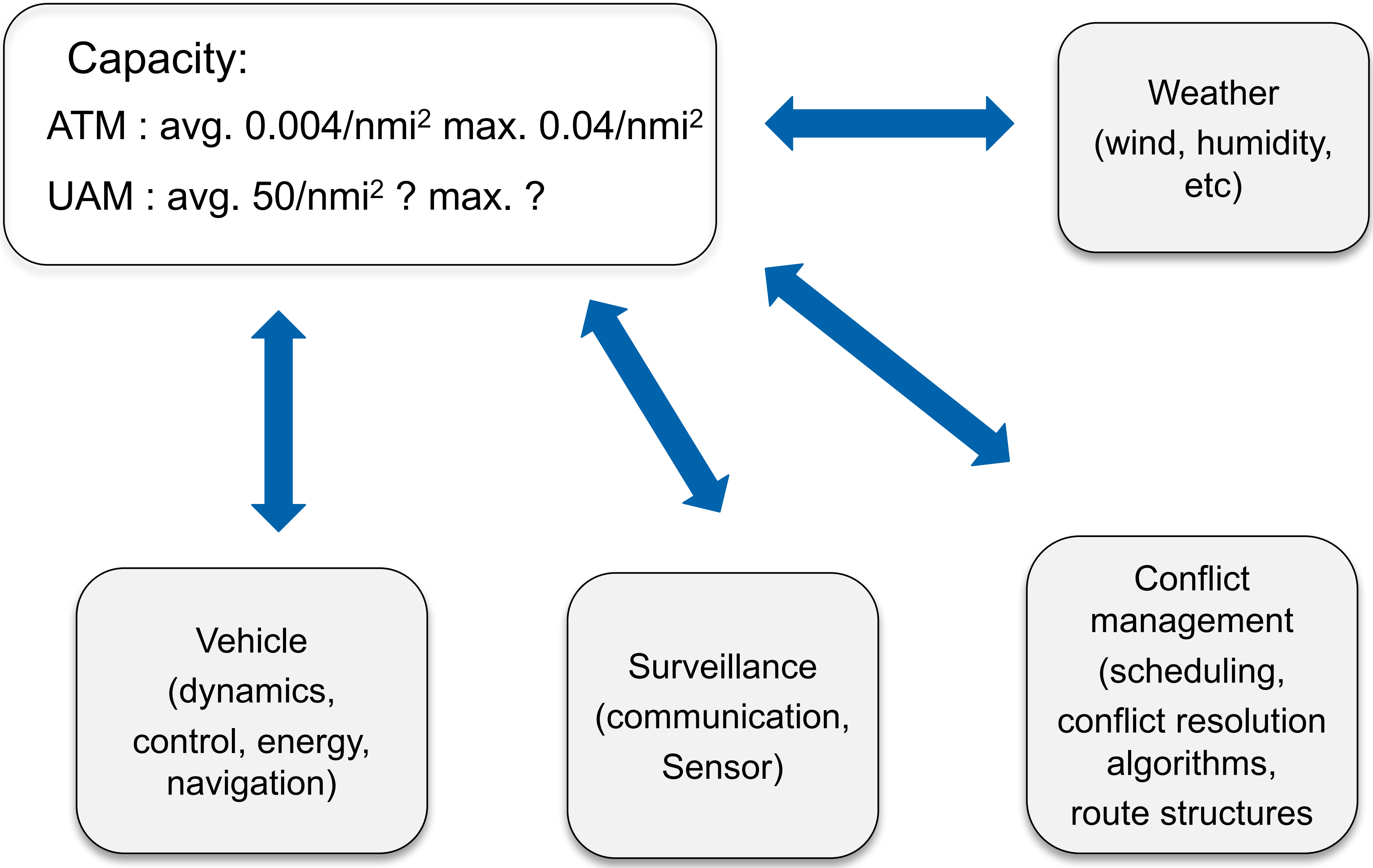

Capacity:
ATM : avg. 0.004/nmi^2 max. 0.04/nmi^2
UAM : avg. 50/nmi^2 ? max. ?
Weather
(wind, humidity, etc)
Vehicle
(dynamics, control, energy, navigation)
Surveillance
(communication, Sensor)
Conflict management
(scheduling, conflict resolution algorithms, route structures

Motivation

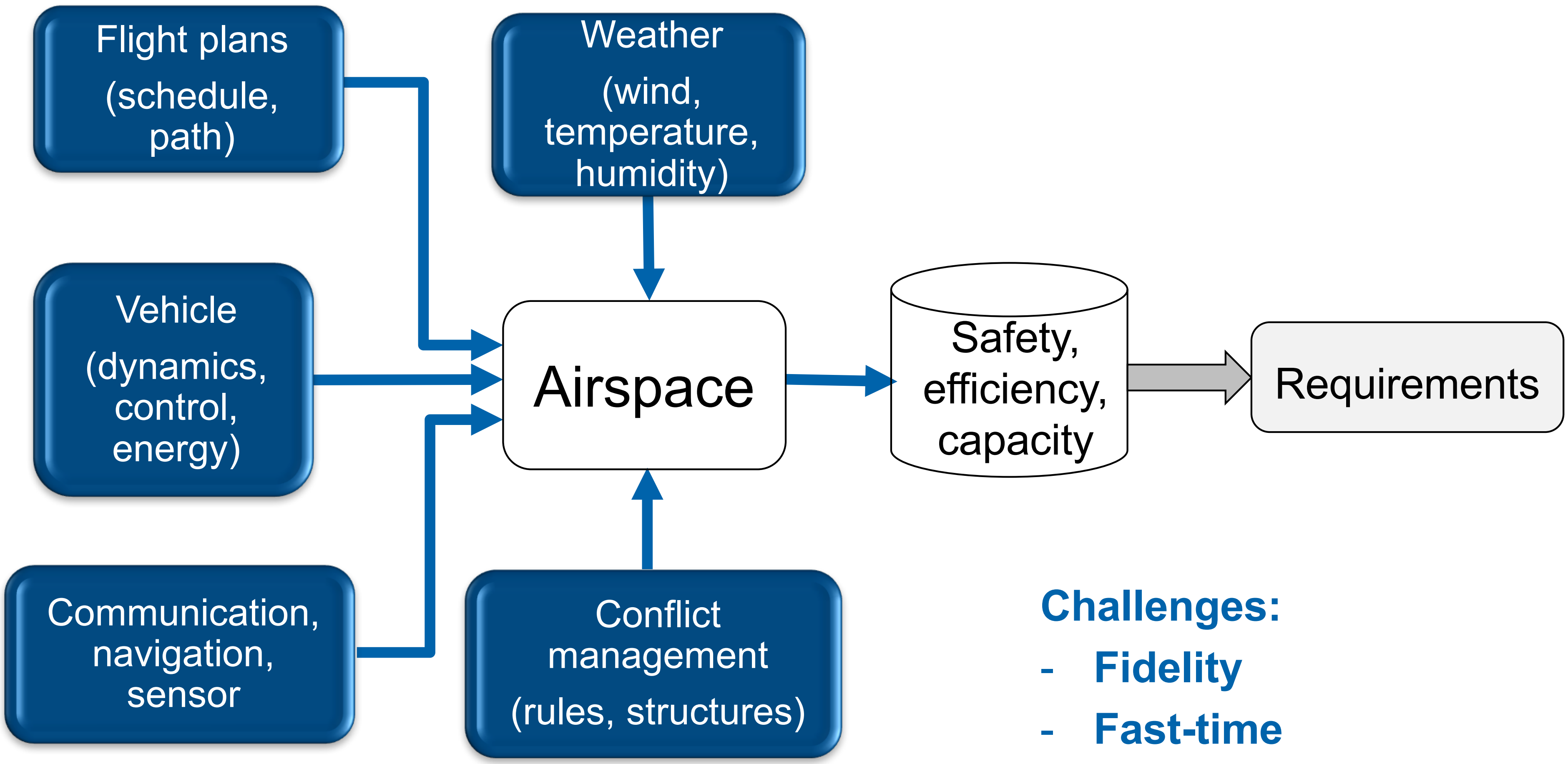
Develop a flexible and fast-time evaluation tool to study key factors contributing airspace safe operational capacity:

- Derive requirements to support a given capacity
- Provide capacity guidance with given conditions

Outline

- Approach
- Fe^3 Architecture and Models
- Cloud Implementation
- Example Case Studies
- Summary

Approach

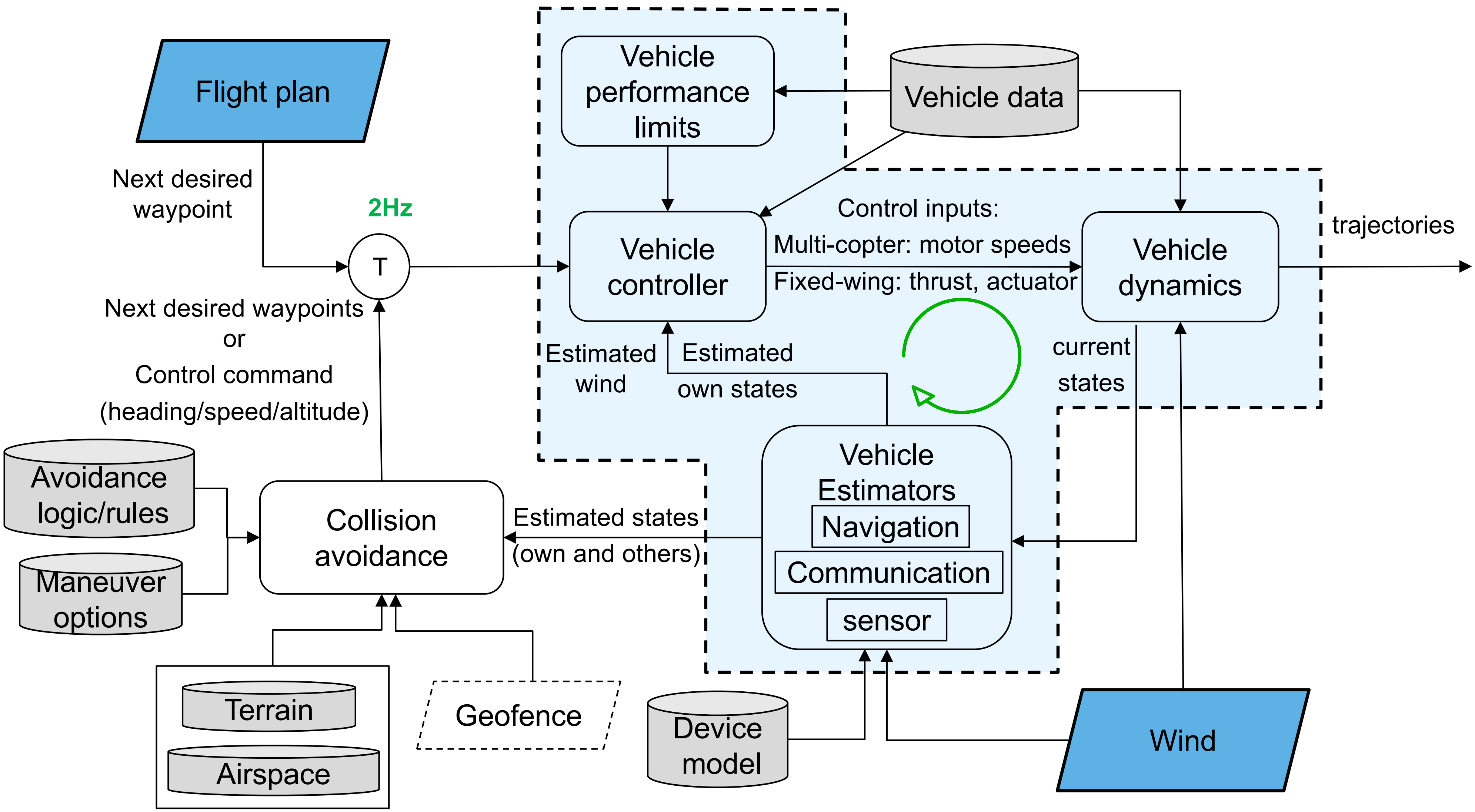


Challenges:

- **Fidelity**
- **Fast-time**
- **Flexibility**

Fe^3 Architecture and Models

Fe3 Core Architecture



Vehicle model

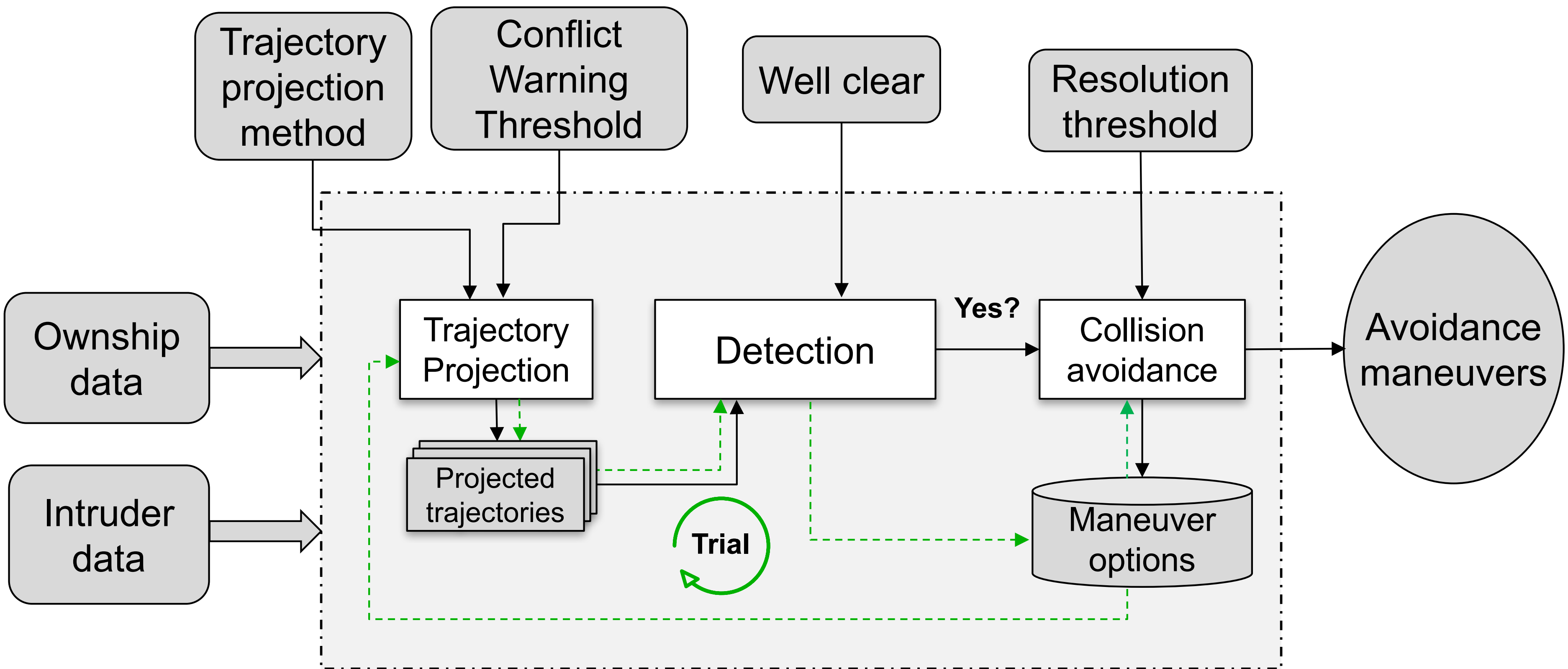
- Trajectory model
  - 6DOF, Dynamics, Controller
  - Multi-copter, Fixed-wing
  - Generalized model with various parameters

- Motor thrust:
  - Low-fidelity model: simple function of rotating speed
  - High-fidelity model: based on blade momentum theory

- Power:
  - Low-fidelity model: simple function of rotating speed
  - High-fidelity model: using various motor parameters

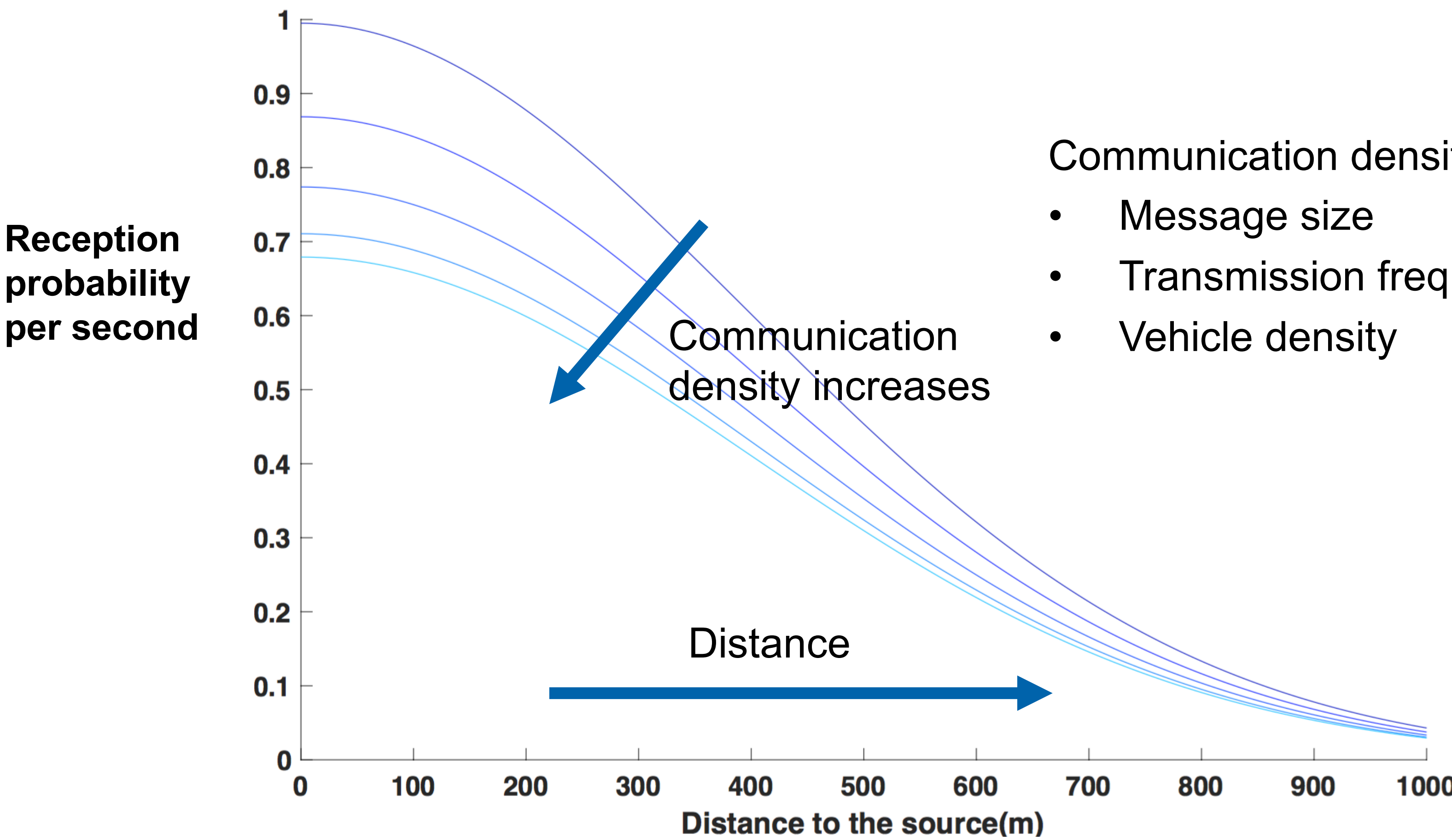
Conflict resolution algorithms

1. Trajectory Projection based algorithms
2. Offline Table based algorithms
3. Force field based algorithms



Communication device models

- Horizontal position: e.g. Gauss-Markov model (ADS-B)
- Vertical position: e.g. Gaussian (ADS-B)
- Reception probability: a function of **transmission power** and **communication density**



Communication density:

- Message size
- Transmission frequency
- Vehicle density

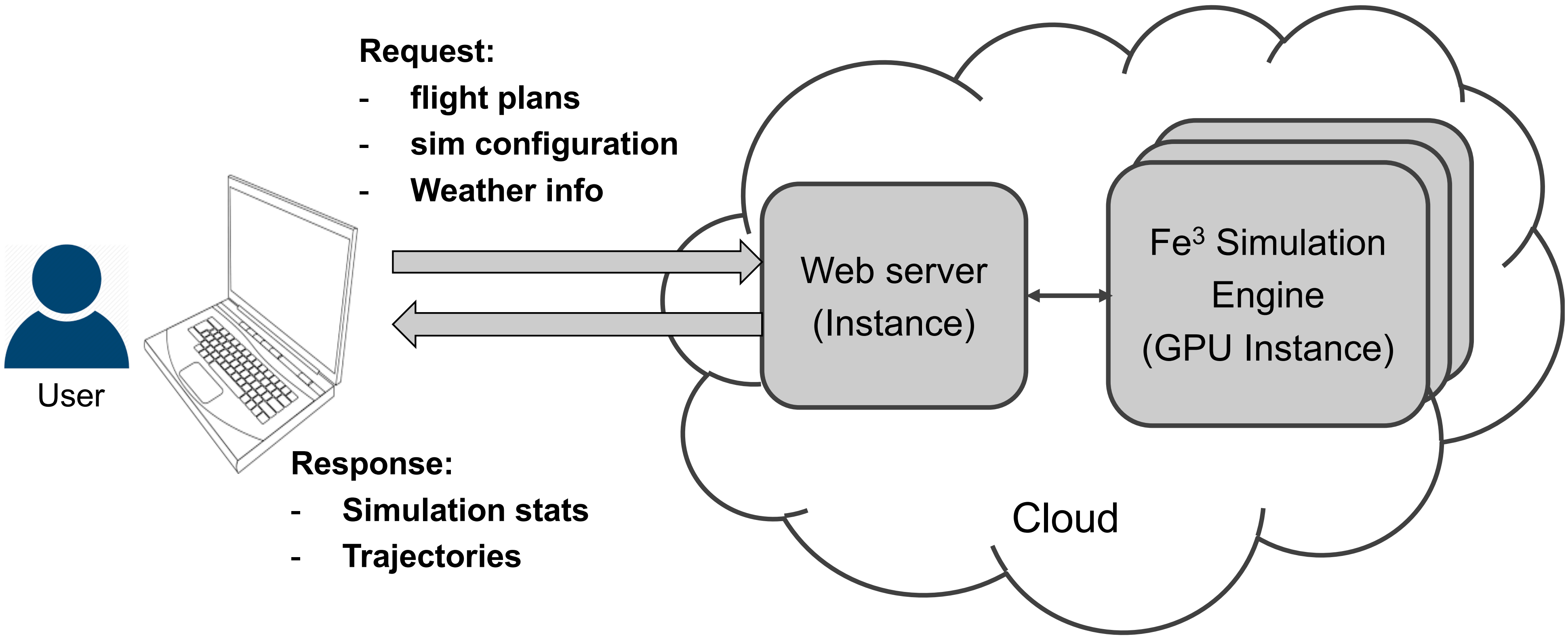
Other Models

- Onboard sensor model and parameters:
  - Detection ranges (constant): distance, azimuth, elevation
  - Resolutions (Gaussian): Azimuth, elevation, velocity, distance

- Wind model:
  - Four dimensional grids
  - Gaussian with variance (turbulence intensity) at each grid

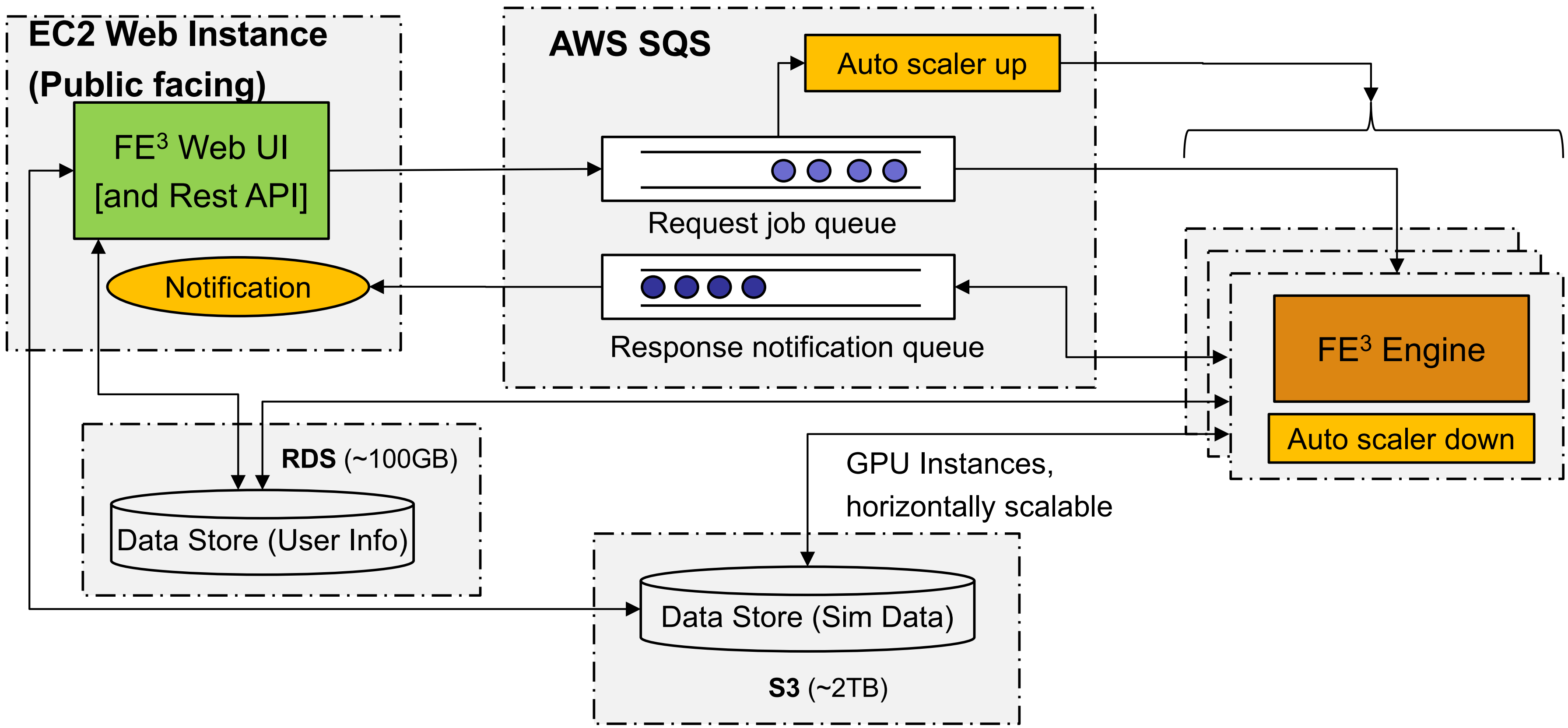
Cloud Implementation

Cloud-based platform

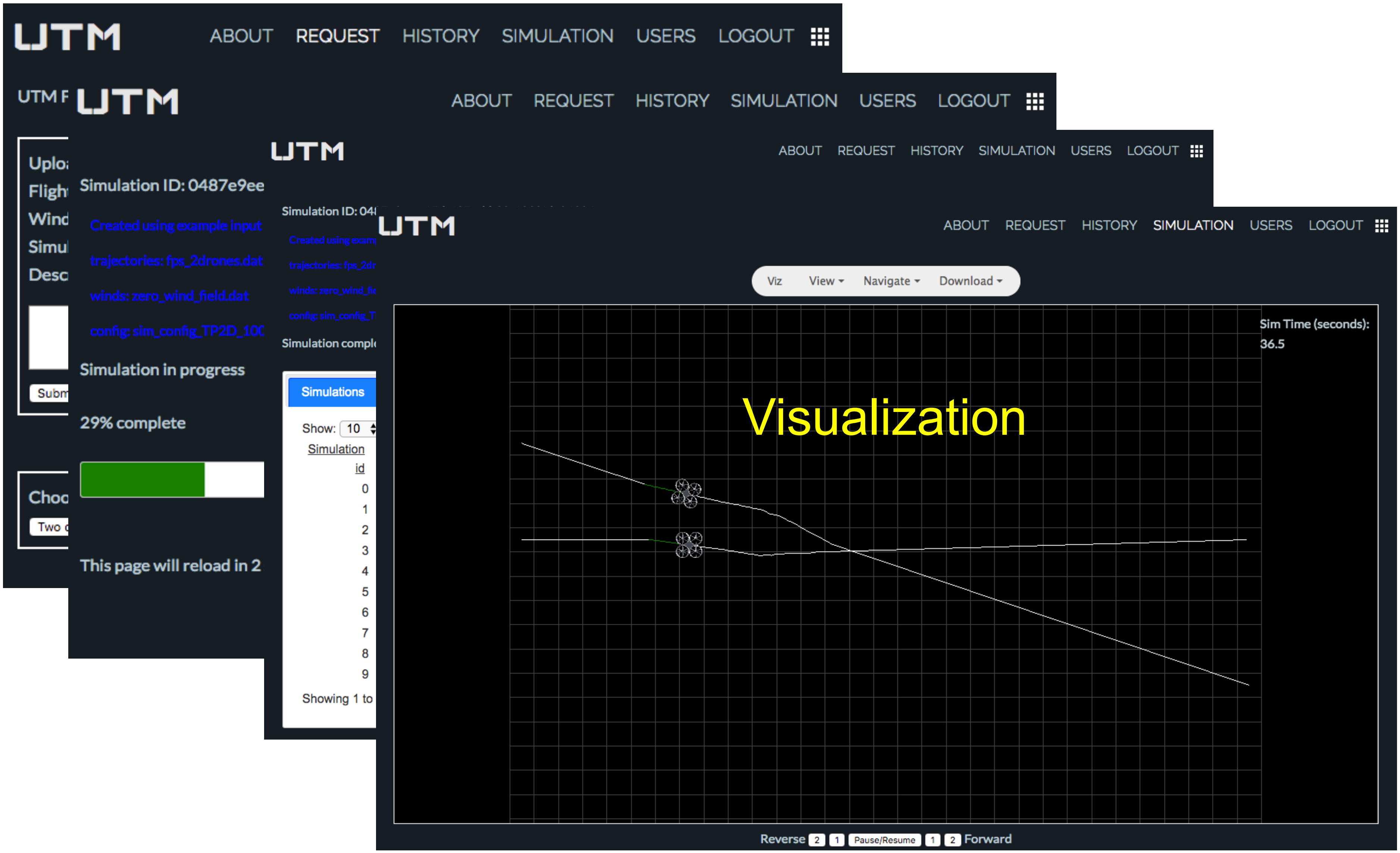


- Graphic Process Units(GPU) – fast
- Cloud GPU instances –faster
- Web portal I/O – easy to use

Cloud Architecture



Fe^3 Interface



Computational Performance

1 AWS GPU instance

(0.5 Tesla K80 GPU with12 GB memory)

# of Monte Carlo sims	# of sUAVs	Traffic density (per nmi^2)	Flight time (minute)	Running time (second)
1,000	10	3.8	7.7	10
1,000	50	19.0	8.7	55
1,000	100	38.1	9.8	118
40	500	190.5	13.6	366
40	800	304.9	13.5	904
40	1,000	381.1	14.0	1,379

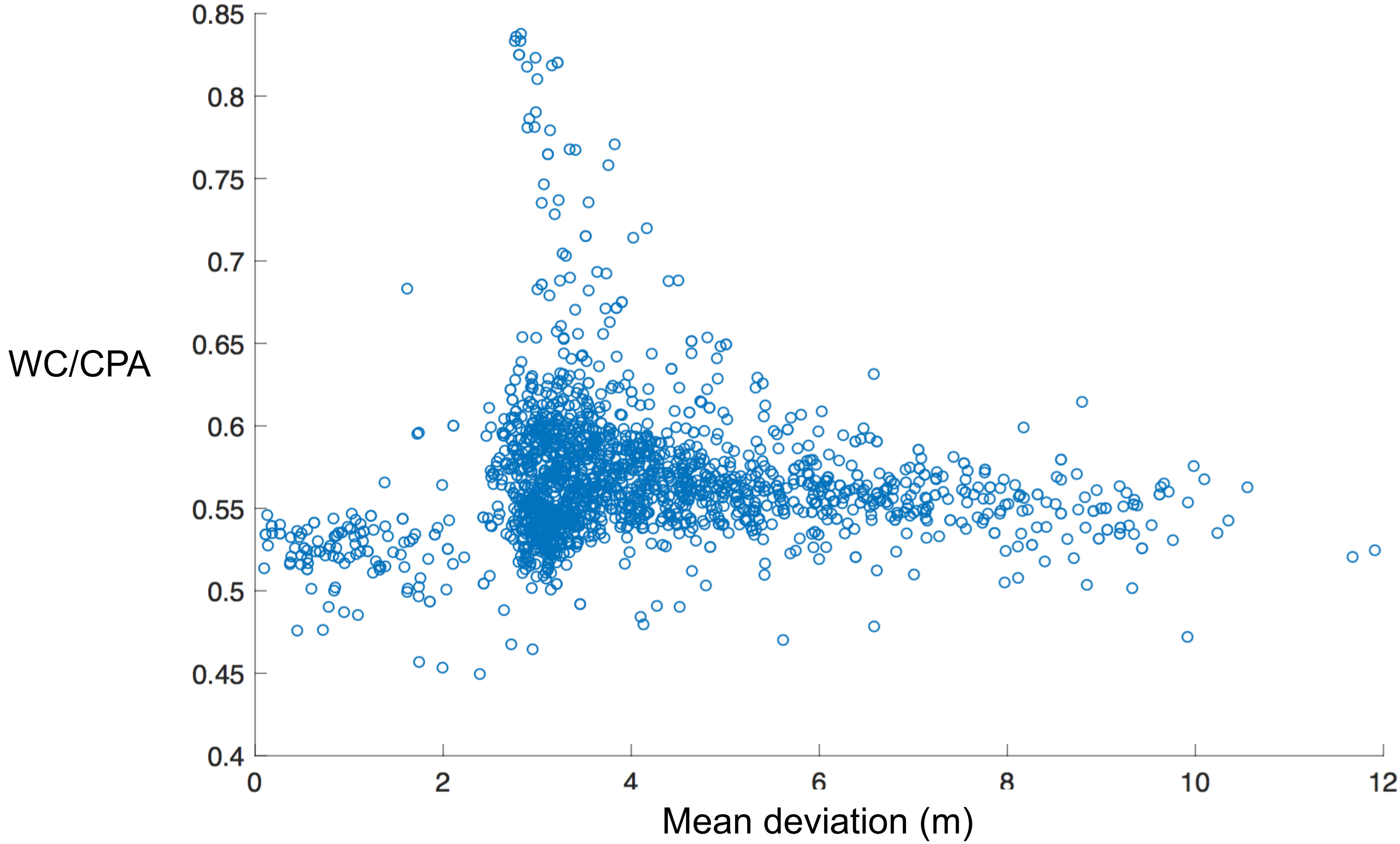
Example Case Studies

Experiment Setup

- Vehicle model: Quad-rotor
- Conflict resolution algorithm:
  - Trajectory projection based
  - Heading change only
- Well clear definition:
  - sUAV to sUAV: horizontal separation distance = 30 ft
  - sUAV to manned: horizontal separation distance = 200 ft
- Communication: V2V

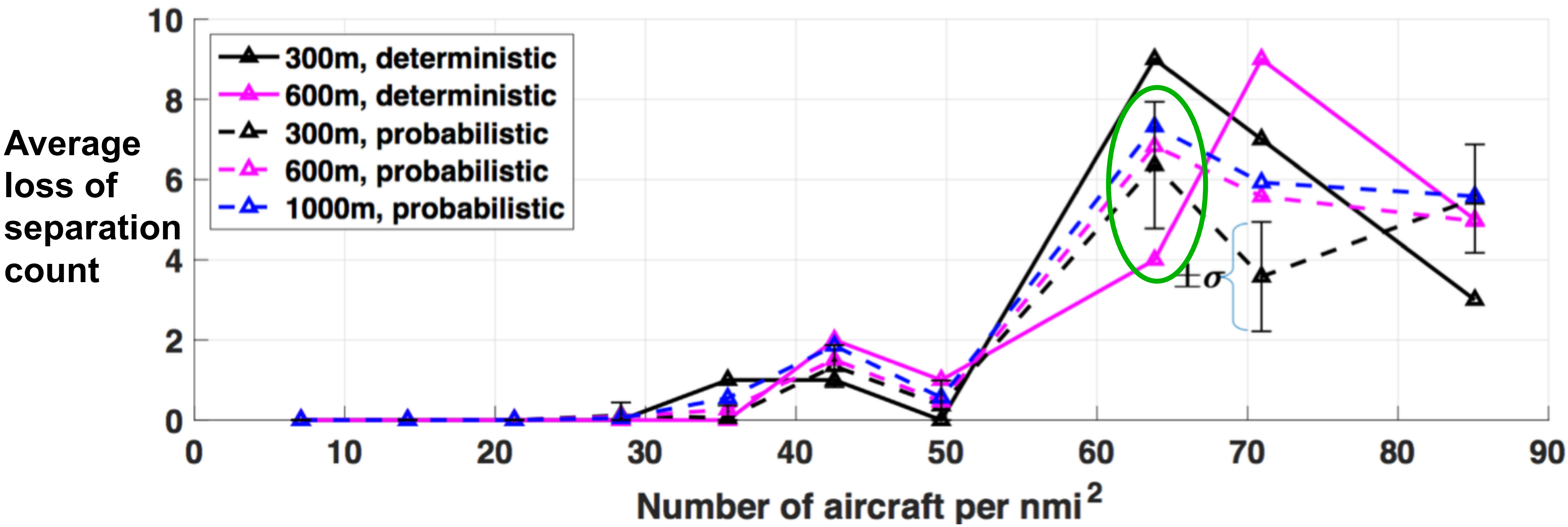
Pairwise encounters

2,000 scenarios, combinations of relative encounter angles and speeds



Conflict resolution algorithm perform well in pairwise encounters

Communication



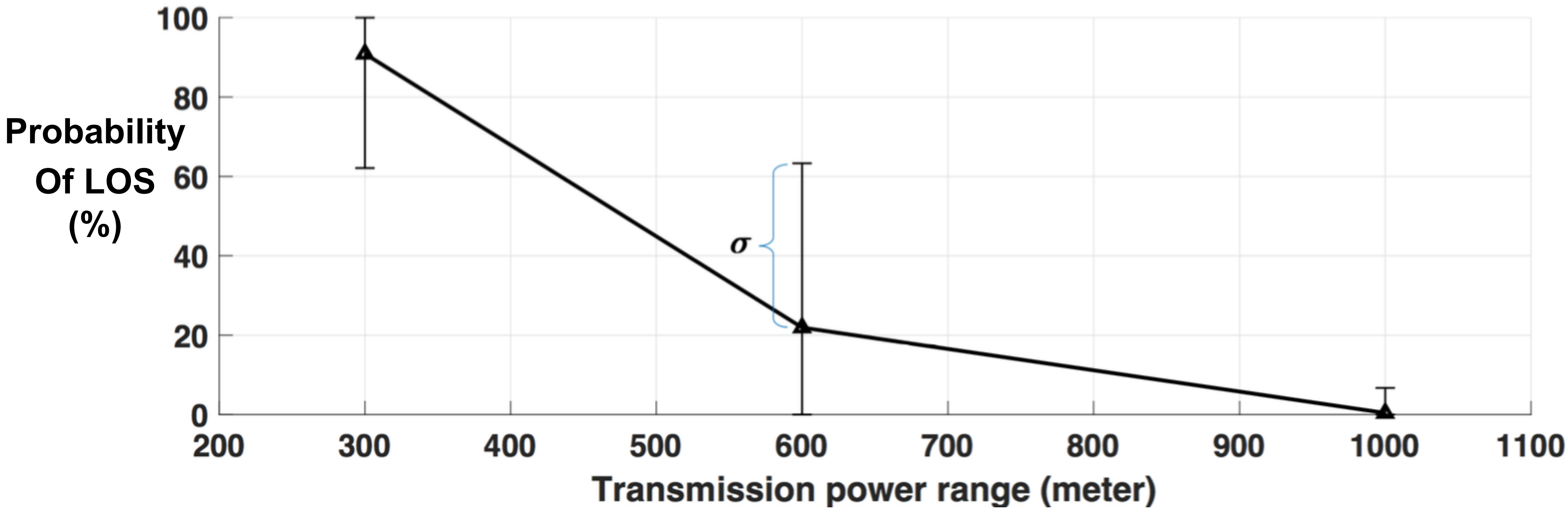
Loss of separation (LOS) happens after ~27 vehicles per square nmi

LOS doesn't monotonically increase with traffic density

Increasing communication density results in **more** LOS counts

Mixed operations with manned aircraft

- 20 Quad-rotors and 2 manned aircraft
- Manned aircraft has the right of the way



When mixed with high speed and large WC, communication range does help reduce the probability of LOS and it variations.

Summary

- Developed the Fe^3 simulator with:
  - Generalized models
  - GPU and Cloud implementation
  - Web based UI
- Able to conduct a wide range of studies:
  - Impact of communication
  - Impact of wind uncertainty
  - Mixed operations with manned aircraft

Future work

- Incorporate more generalize models:
  - Vehicle models
  - Communication & sensor models
  - Conflict resolution algorithms
  - Urban terrain & wind models

- Sensitivity studies of key factors in high density operations
  - Surveillance
  - Wind
  - Well clear definition
  - Conflict resolution algorithms
  - Airspace designs/structures

Questions?

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