Association-Free Multilateration Based on Times of Arrival

Daniel Frisch and Uwe D. Hanebeck

ICRA 2020 Conference Presentation

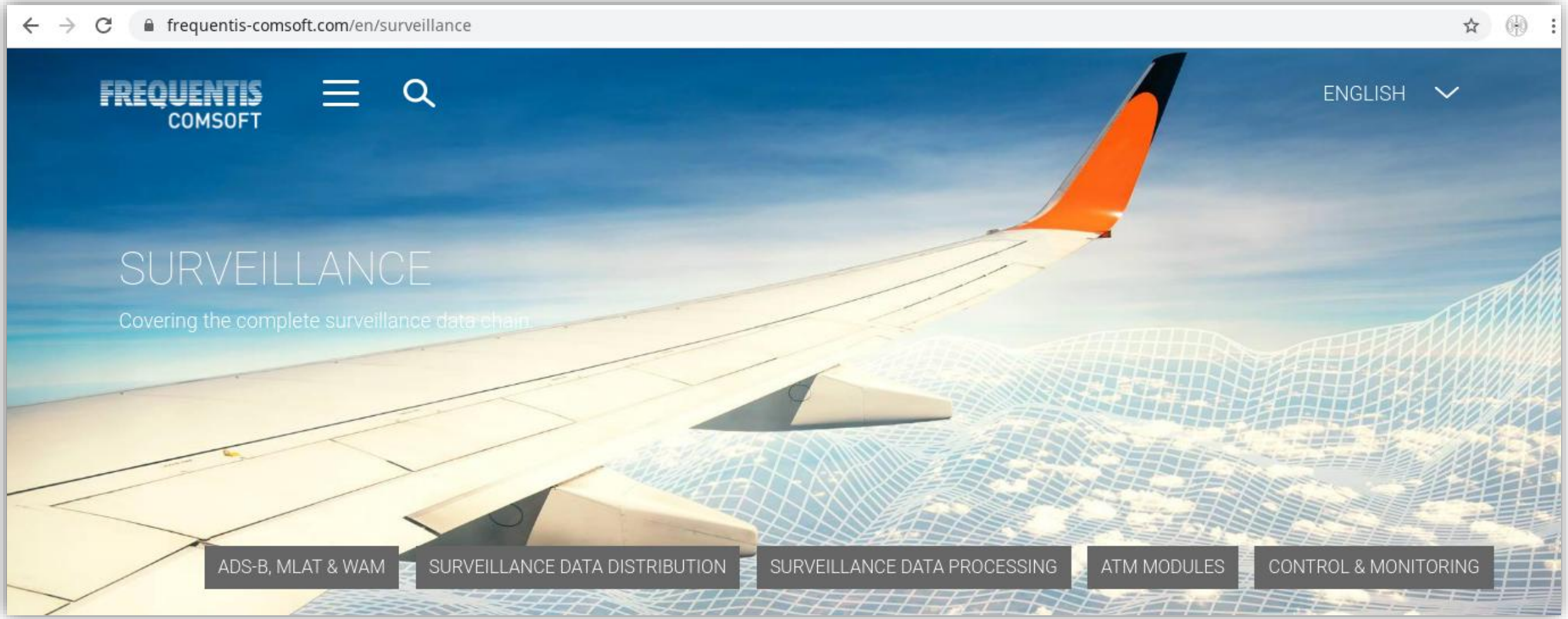
Intelligent Sensor-Actuator-Systems Laboratory (ISAS)
Institute for Anthropomatics and Robotics
Karlsruhe Institute of Technology (KIT)
Karlsruhe, Germany

https://isas.iar.kit.edu

Karlsruhe Institute of Technology

Intelligent Sensor-Actuator-Systems

Cooperation Partner: Frequentis Comsoft



Karlsruhe Institute of Technology

FREQUENTIS COMSOFT

Intelligent iSAS Sensor-Actuator-Systems

Overview

Receivers

- Passive
- Known locations
- Synchronized

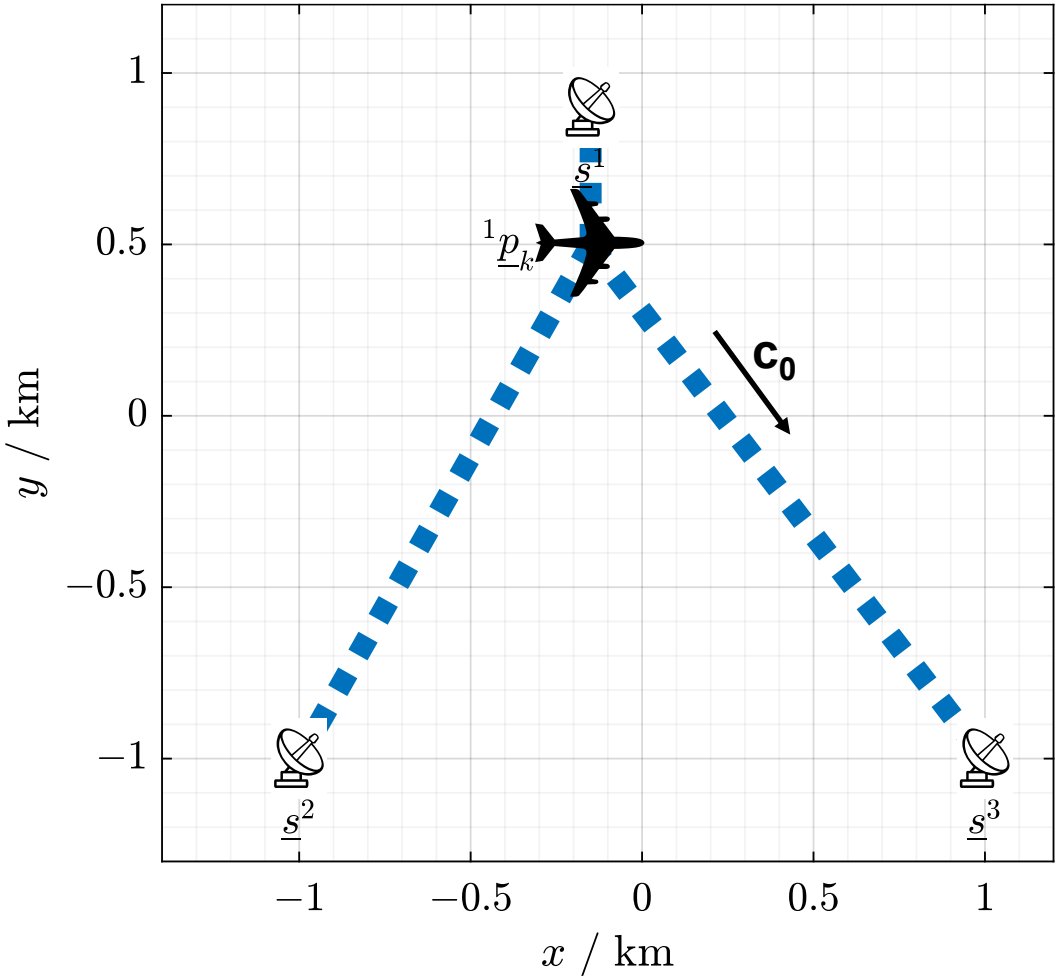
Methods

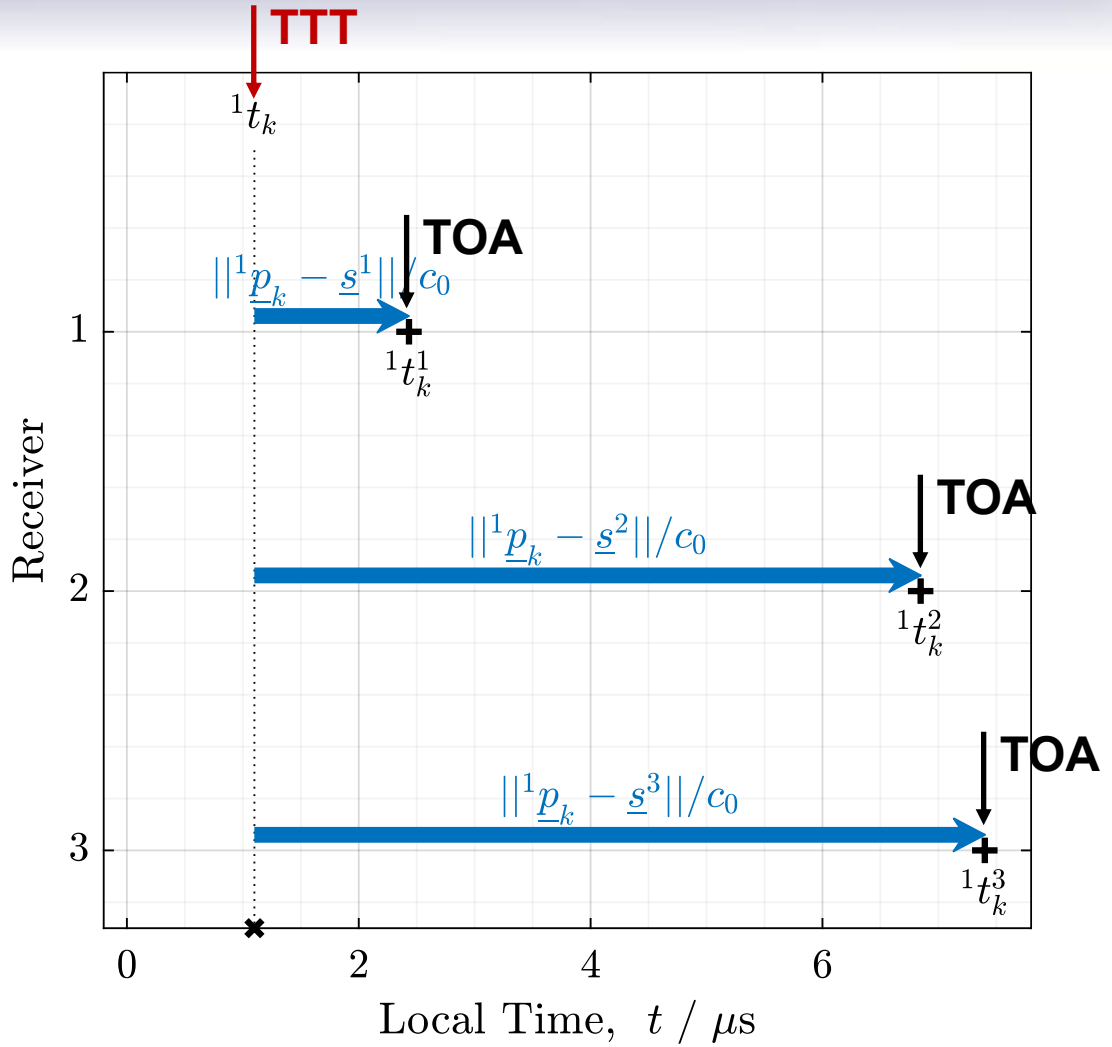
- Maximum likelihood
- Wasserstein distance
- Hungarian Algorithm
- Nonlinear optimization

Estimation

- Independent,
  no prior knowledge
- No Tracking involved

Multilateration

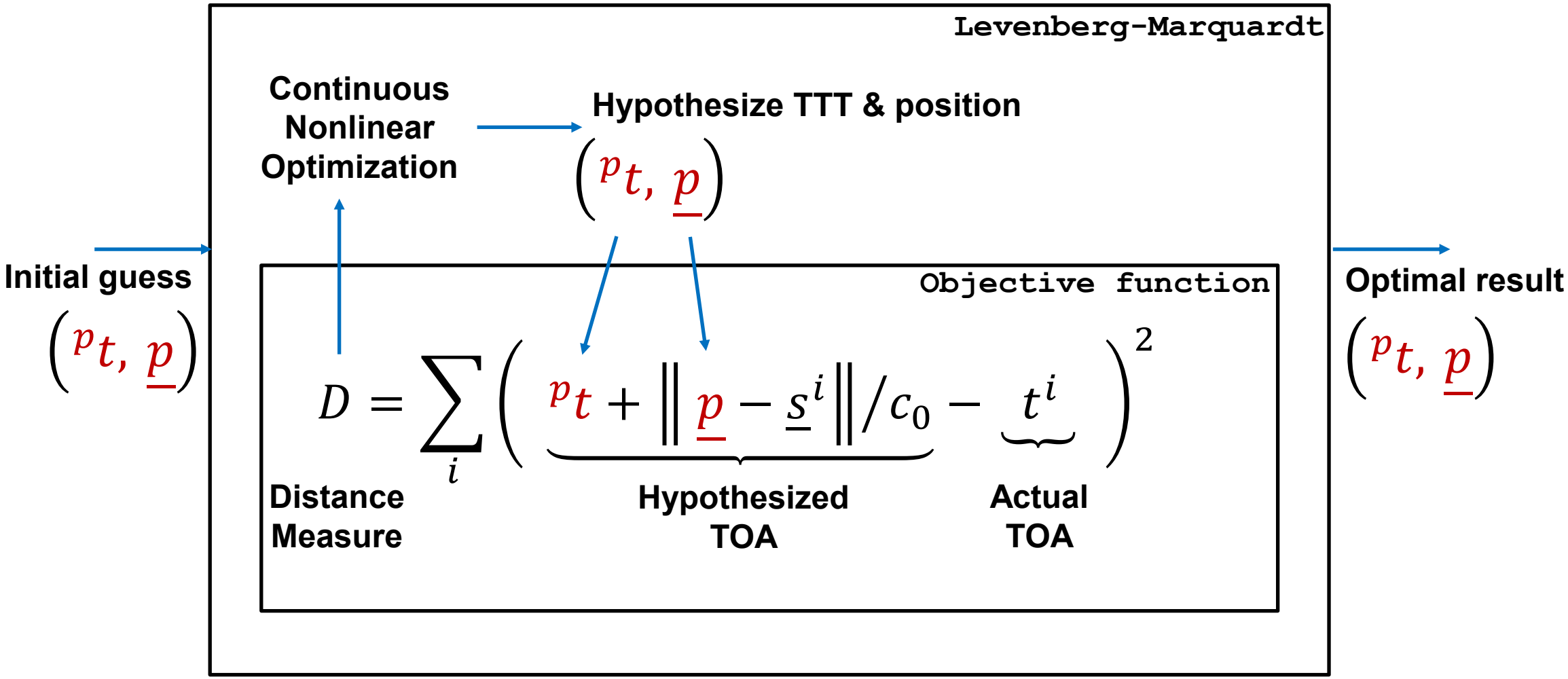




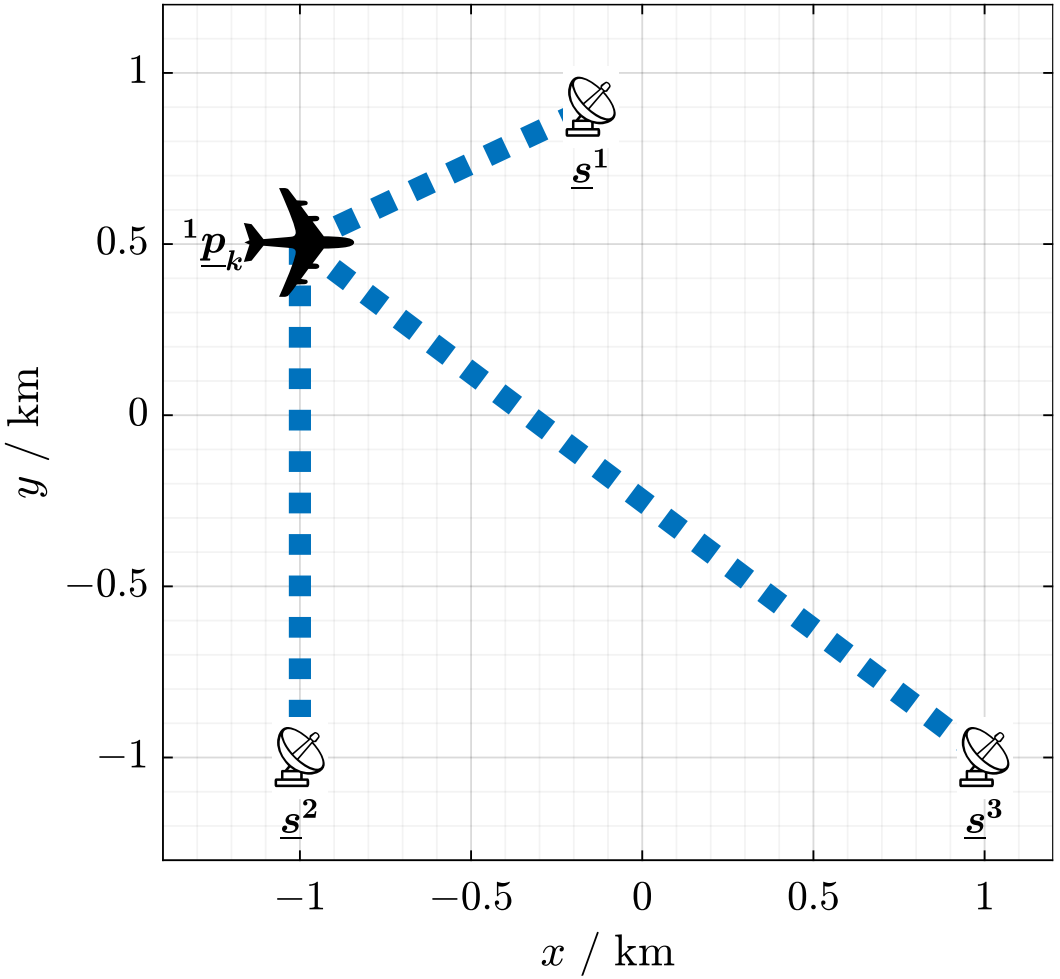
$$t^i = {}^p t + \left\| \underline{p} - \underline{s}^i \right\| / c_0 \ , \qquad i \in \{1, 2, 3\}$$

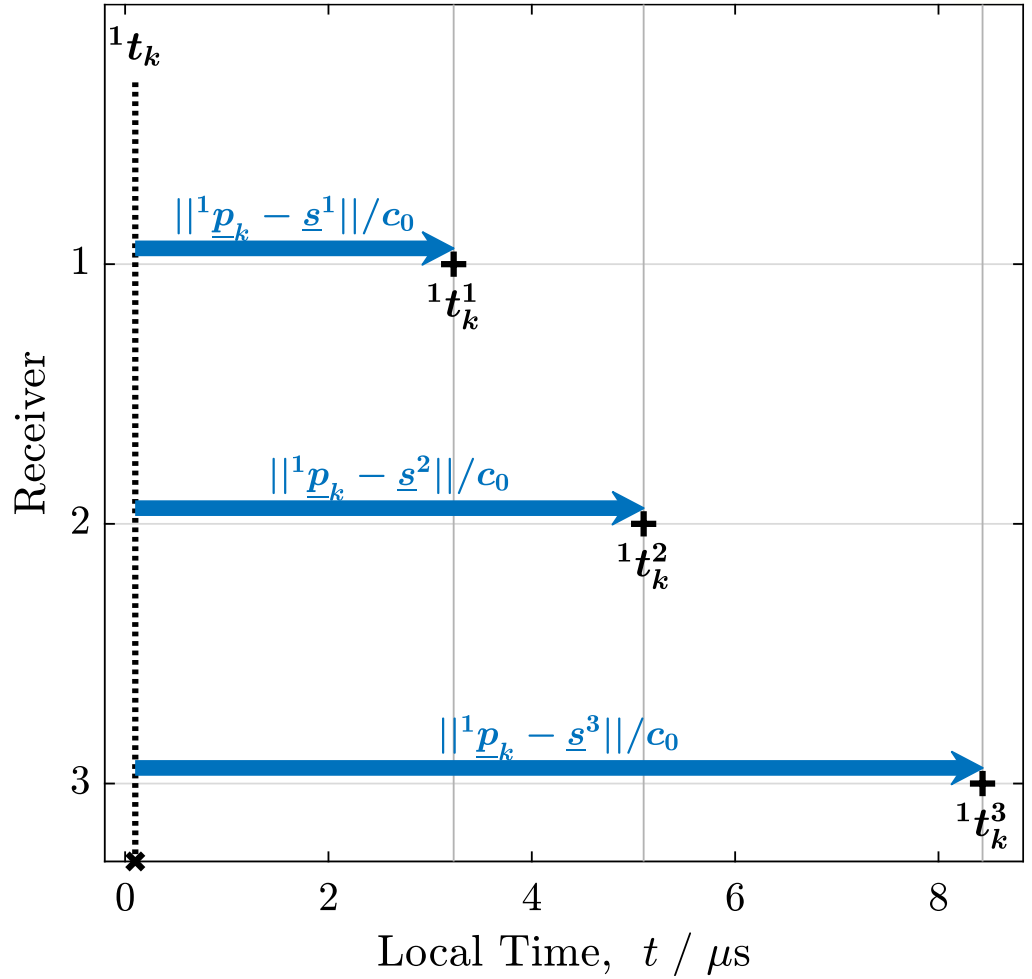
+ Single Target +
+ Nonlinear Equation System +

Solve Single Target



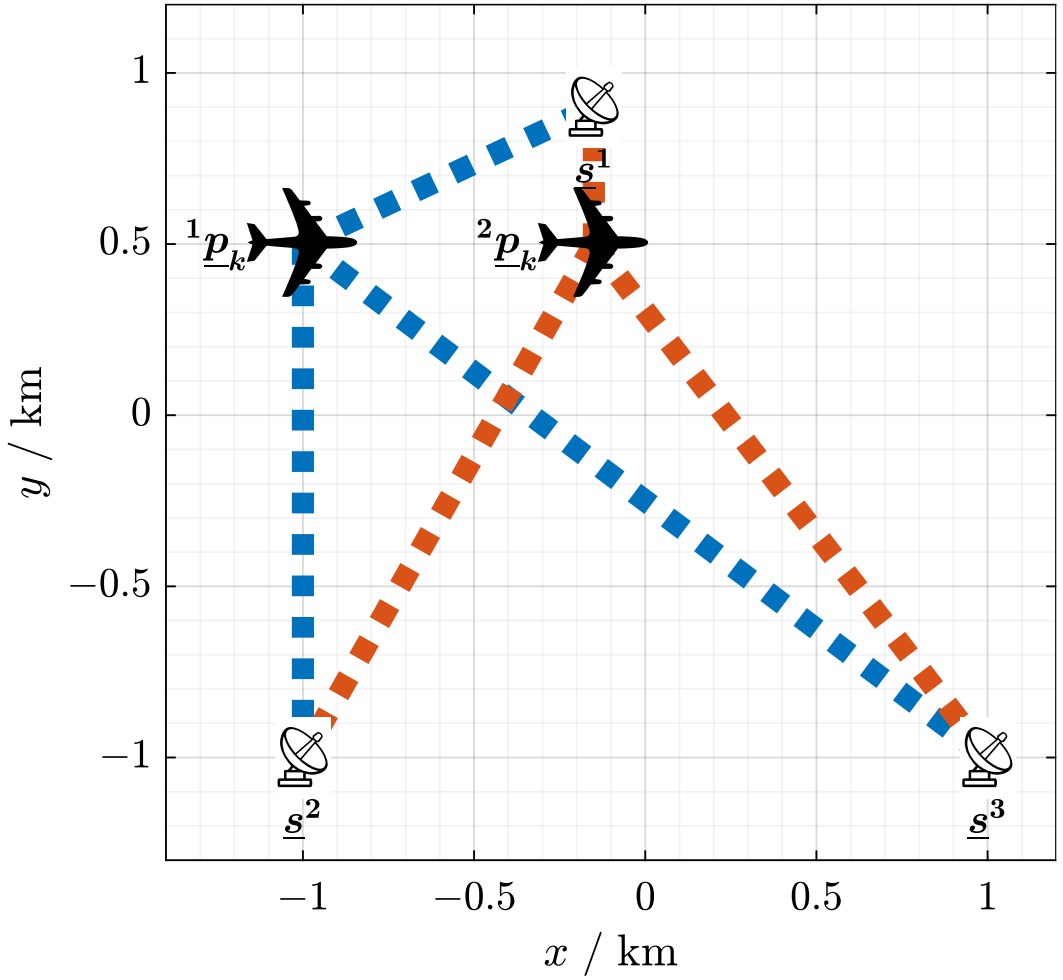
Multi Target Multilateration

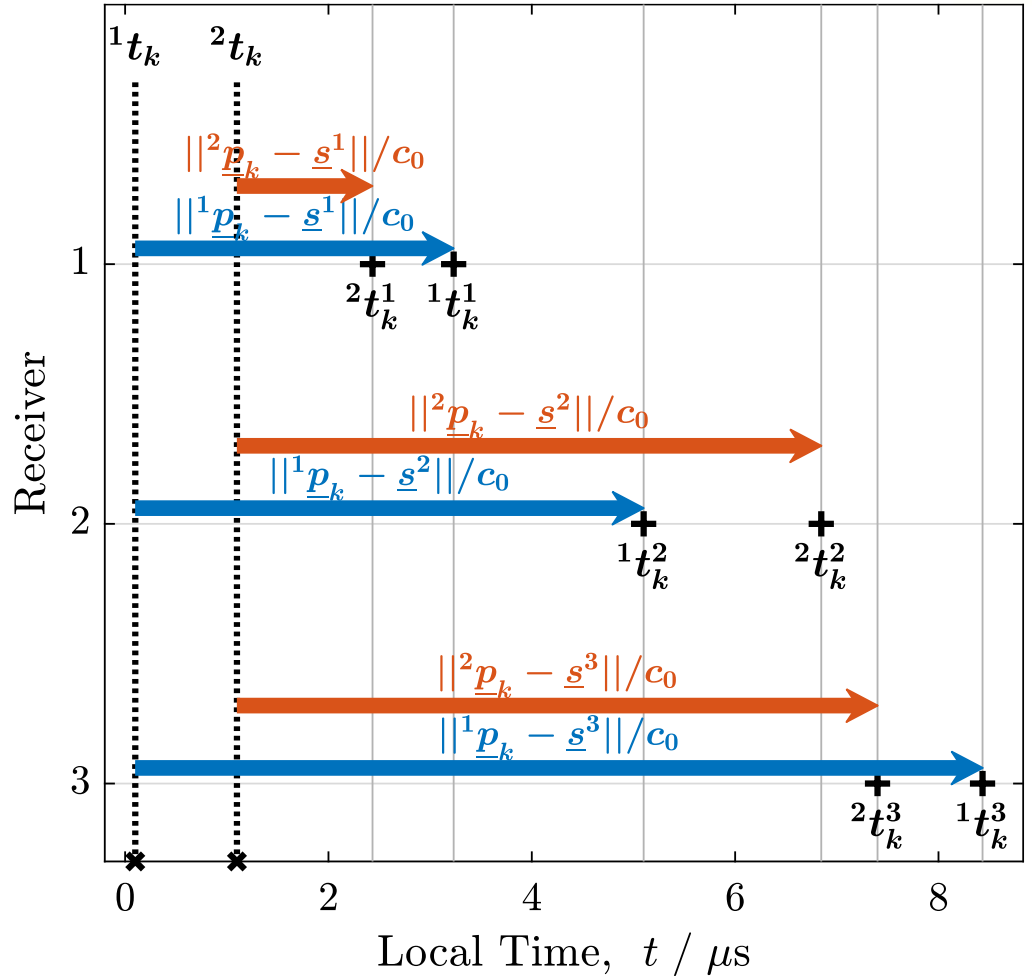




$$^jt^i = {}^jt + \left\| {}^j\underline{p} - \underline{s}^i \right\| / c_0 \ , \qquad i, j \in \{1, 2, 3\}$$

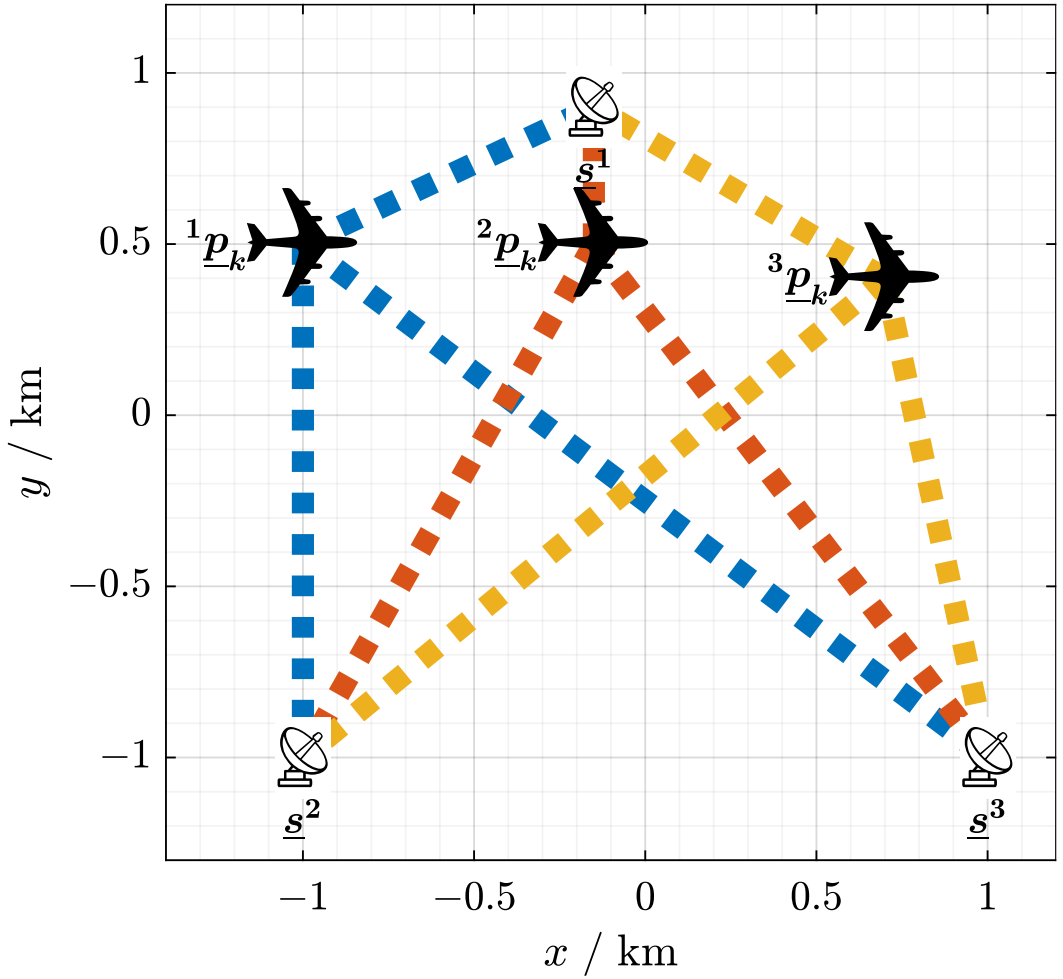
Multi Target Multilateration

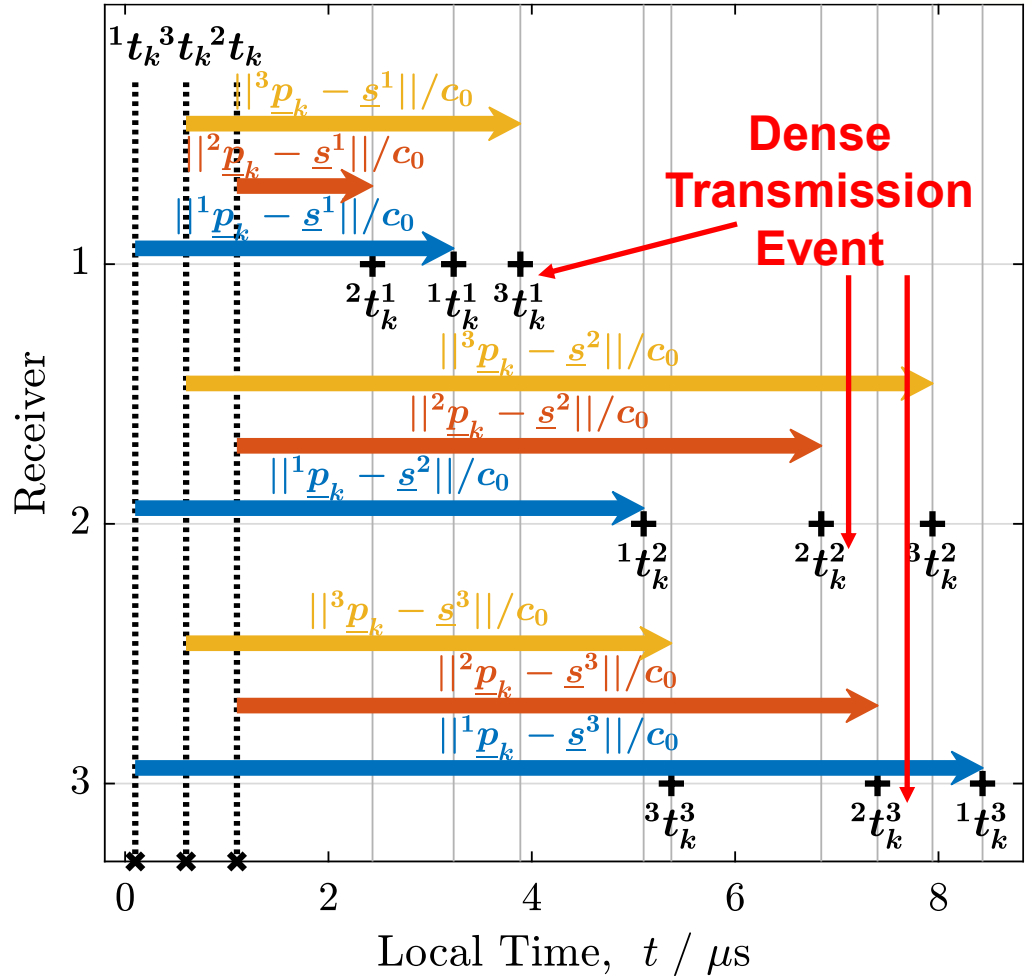




$$^jt^i = {}^jt + \left\| {}^j\underline{p} - \underline{s}^i \right\| / c_0 \ , \qquad i, j \in \{1, 2, 3\}$$

Multi Target Multilateration

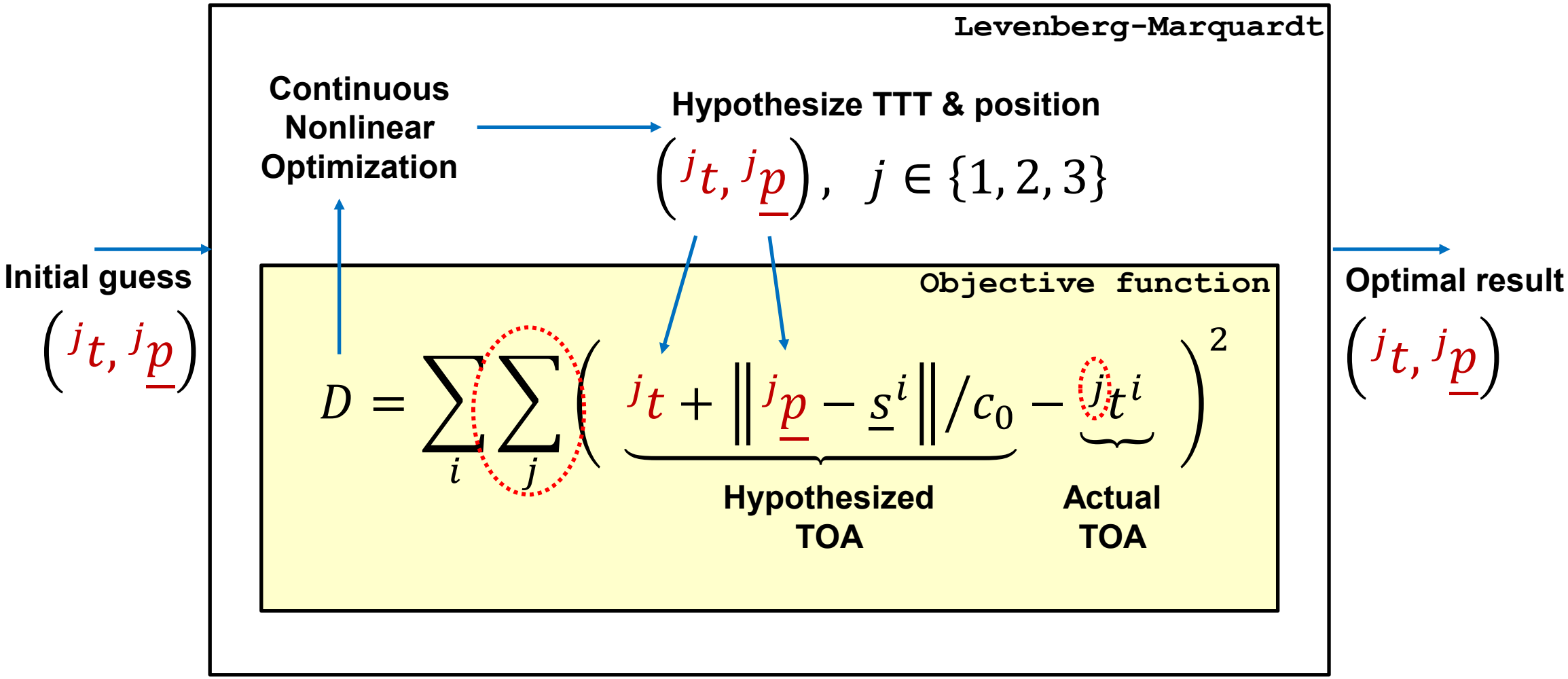




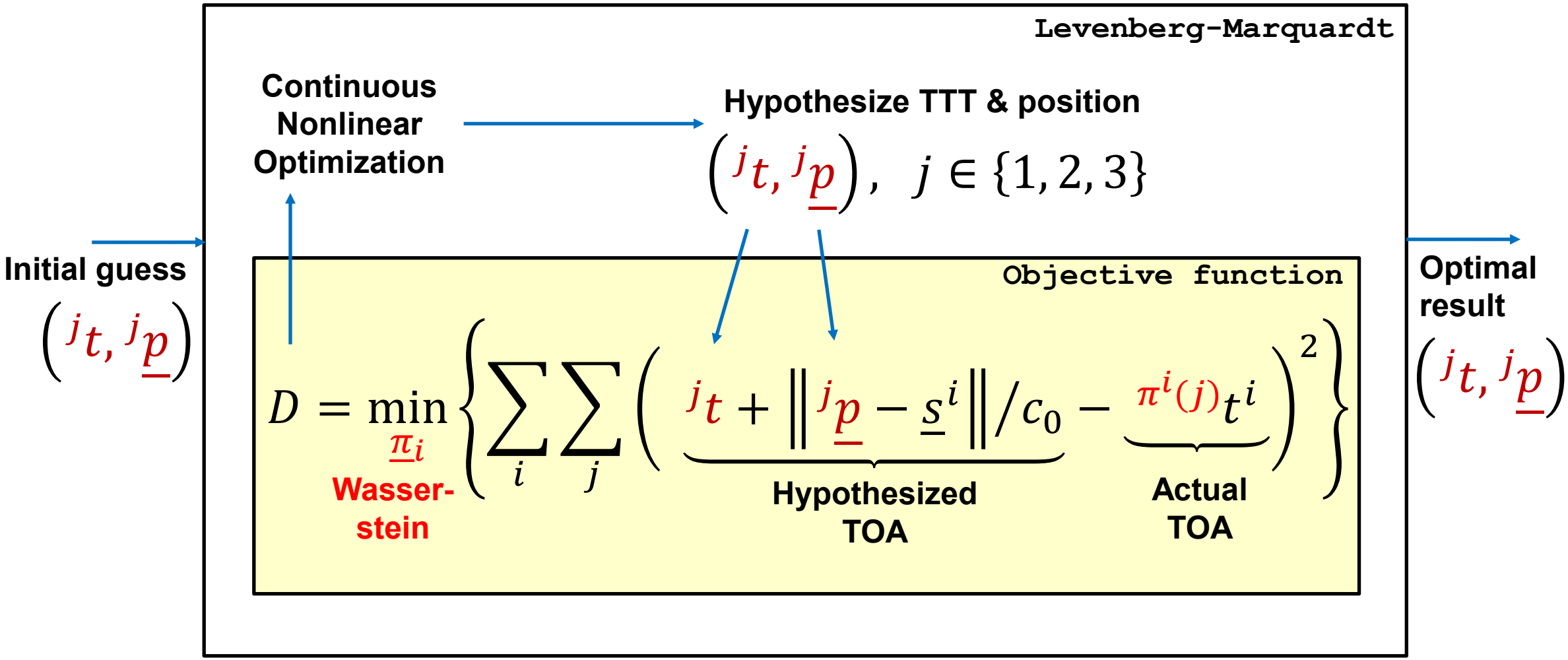
$$^jt^i = {}^jt + \left\| {}^j\underline{p} - \underline{s}^i \right\| / c_0 \ , \qquad i,j \in \{1,2,3\}$$

+ Multiple Targets +
! Mixed Combinatorical Problem !

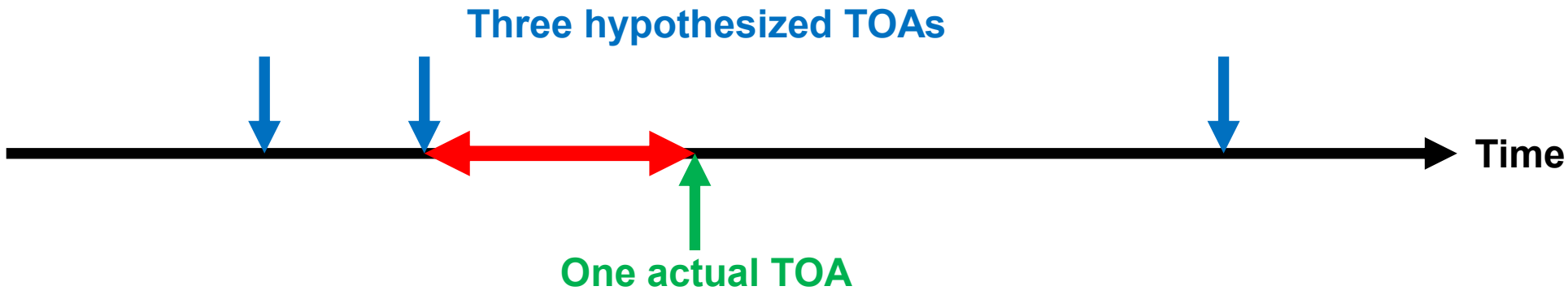
Solve Multiple Targets



Solve Multiple Targets



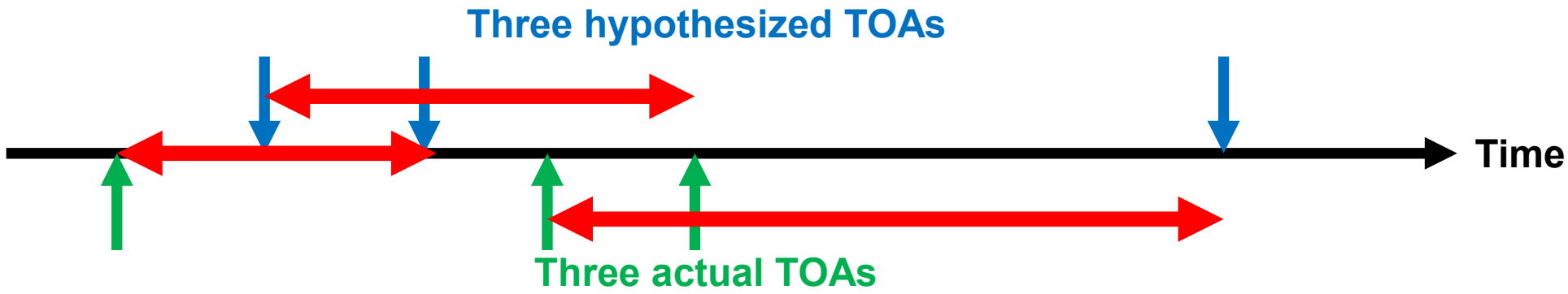
Wasserstein Distance I



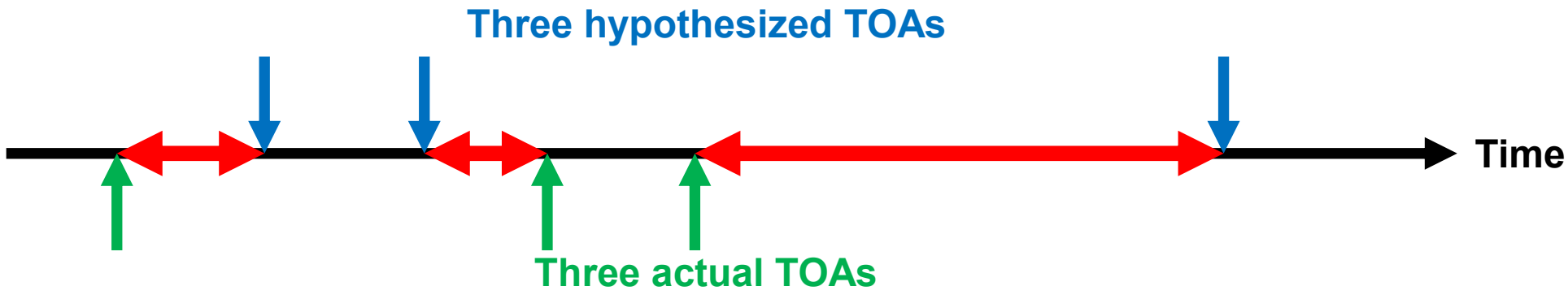
Single measurement

- Nearest neighbor
- Minimum of vector

Wasserstein Distance II



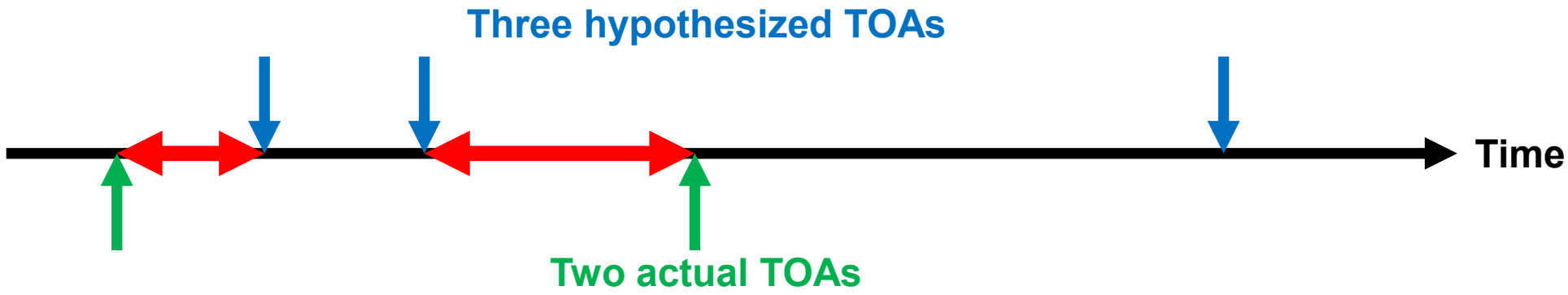
Wasserstein Distance II



Equal number of TOAs

- Associate earliest with earliest etc.
- Sort the TOA vectors

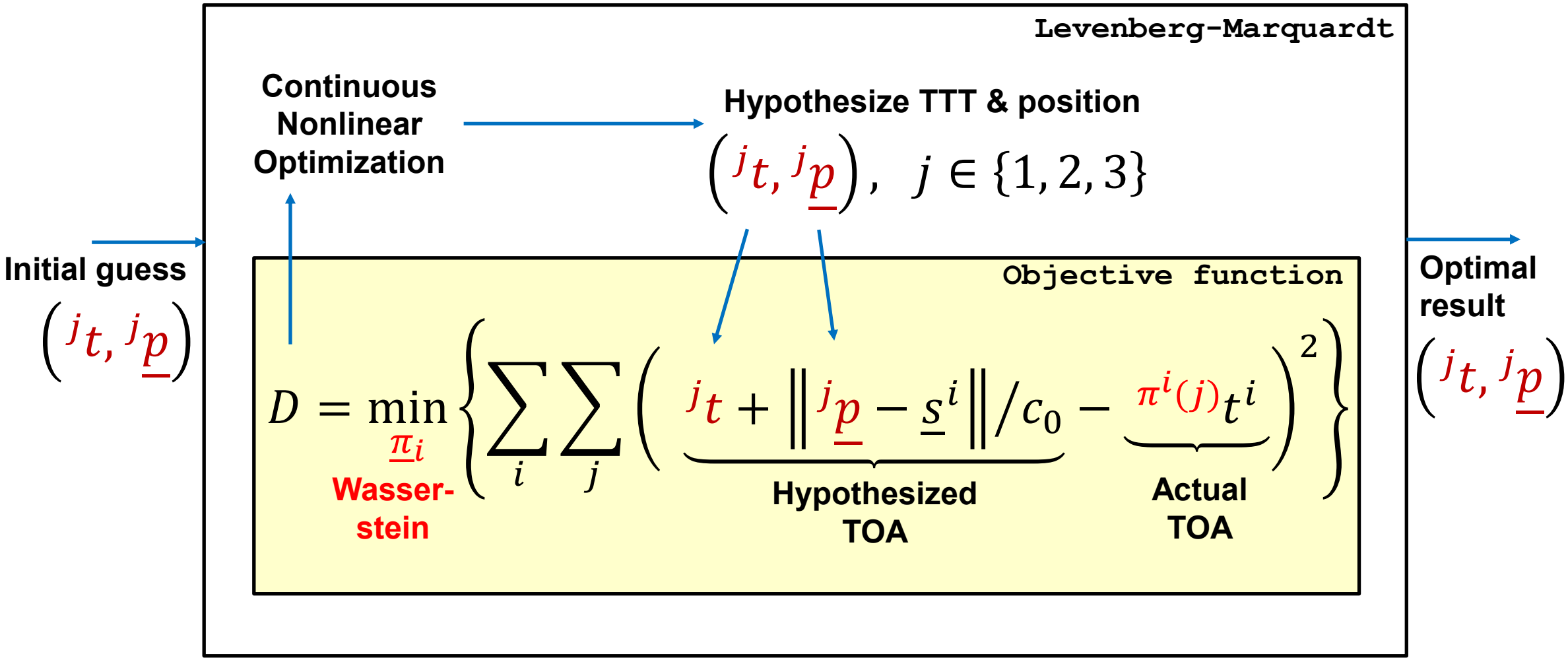
Wasserstein Distance III



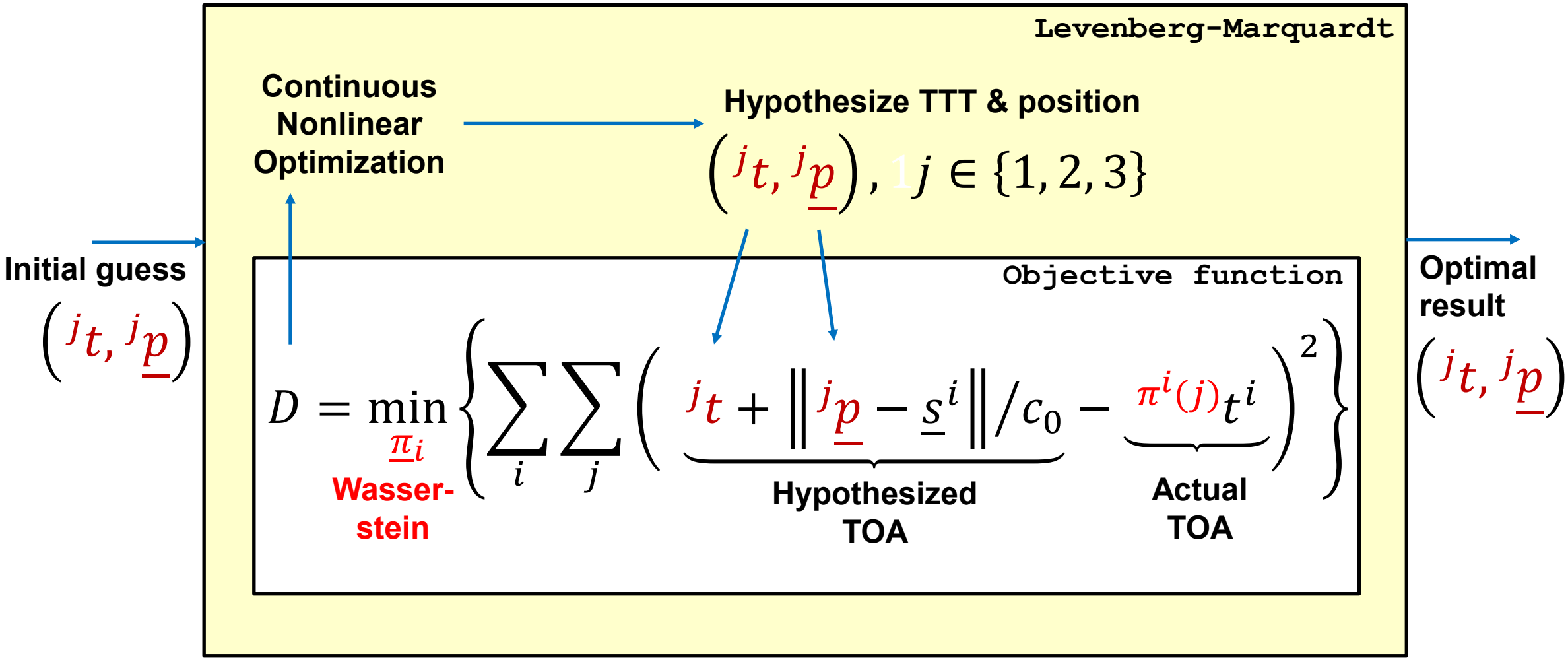
Different numbers of TOA

- Linear assignment problem
- Hungarian algorithm

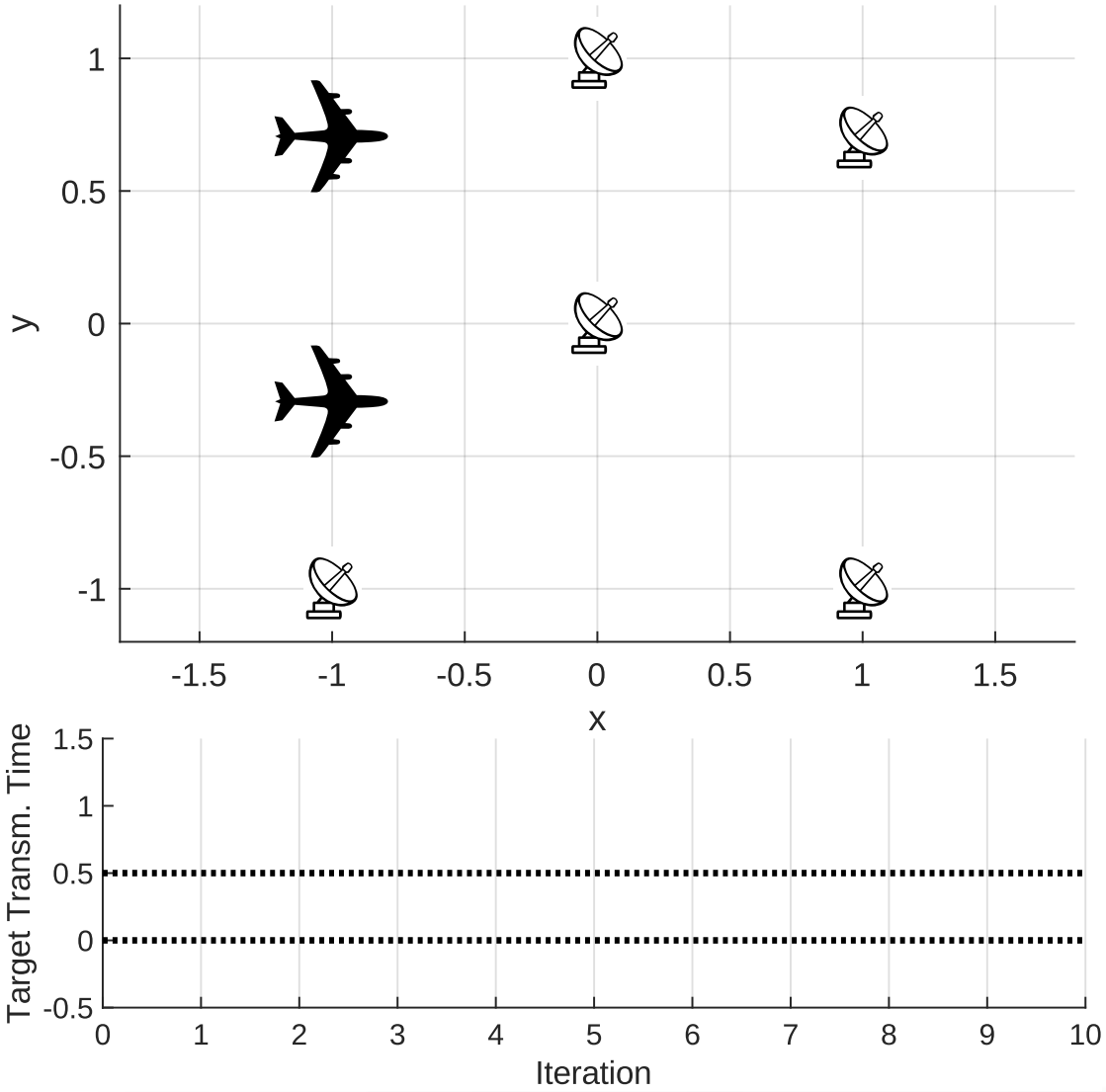
Solve Multiple Targets



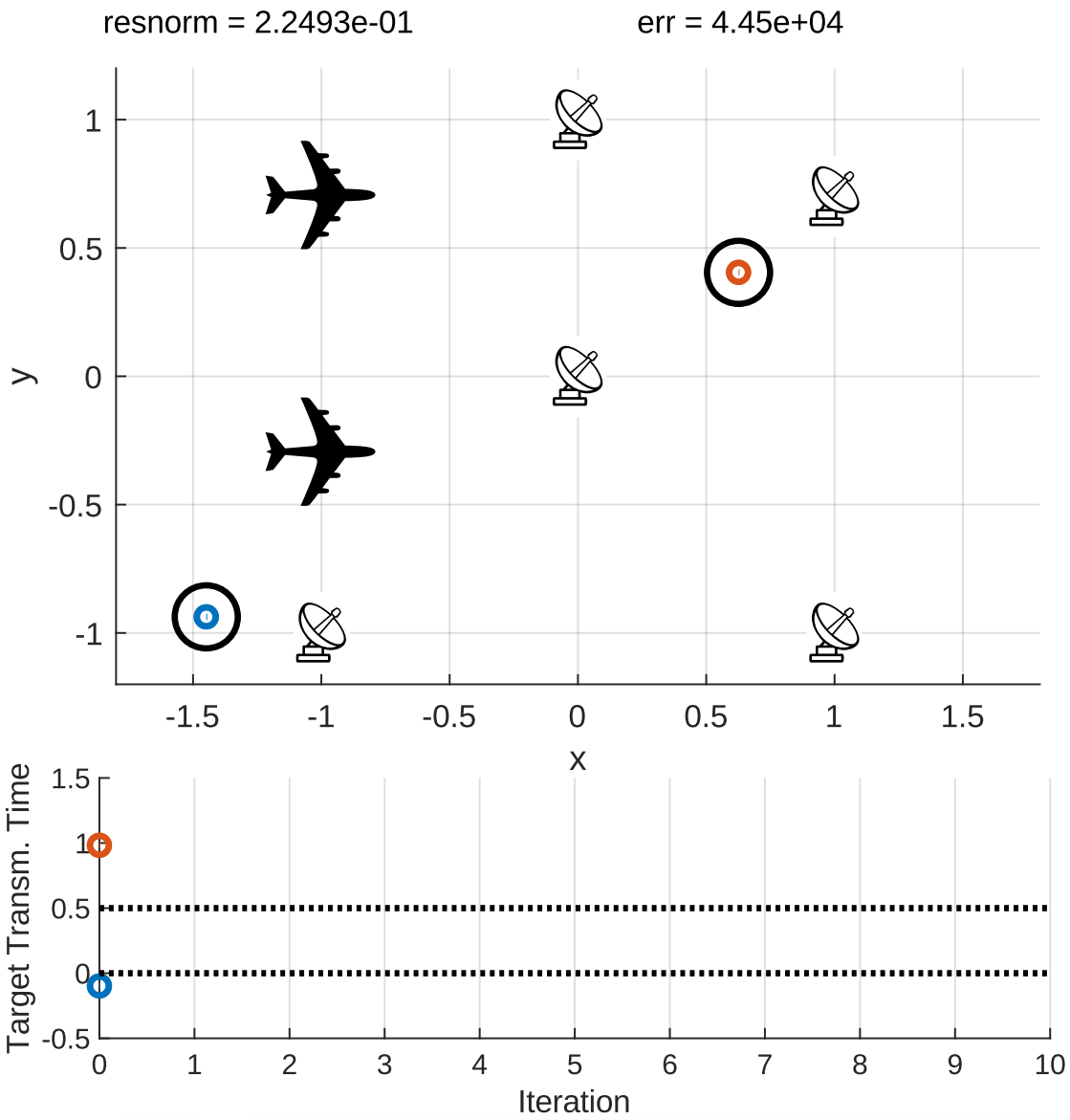
Solve Multiple Targets

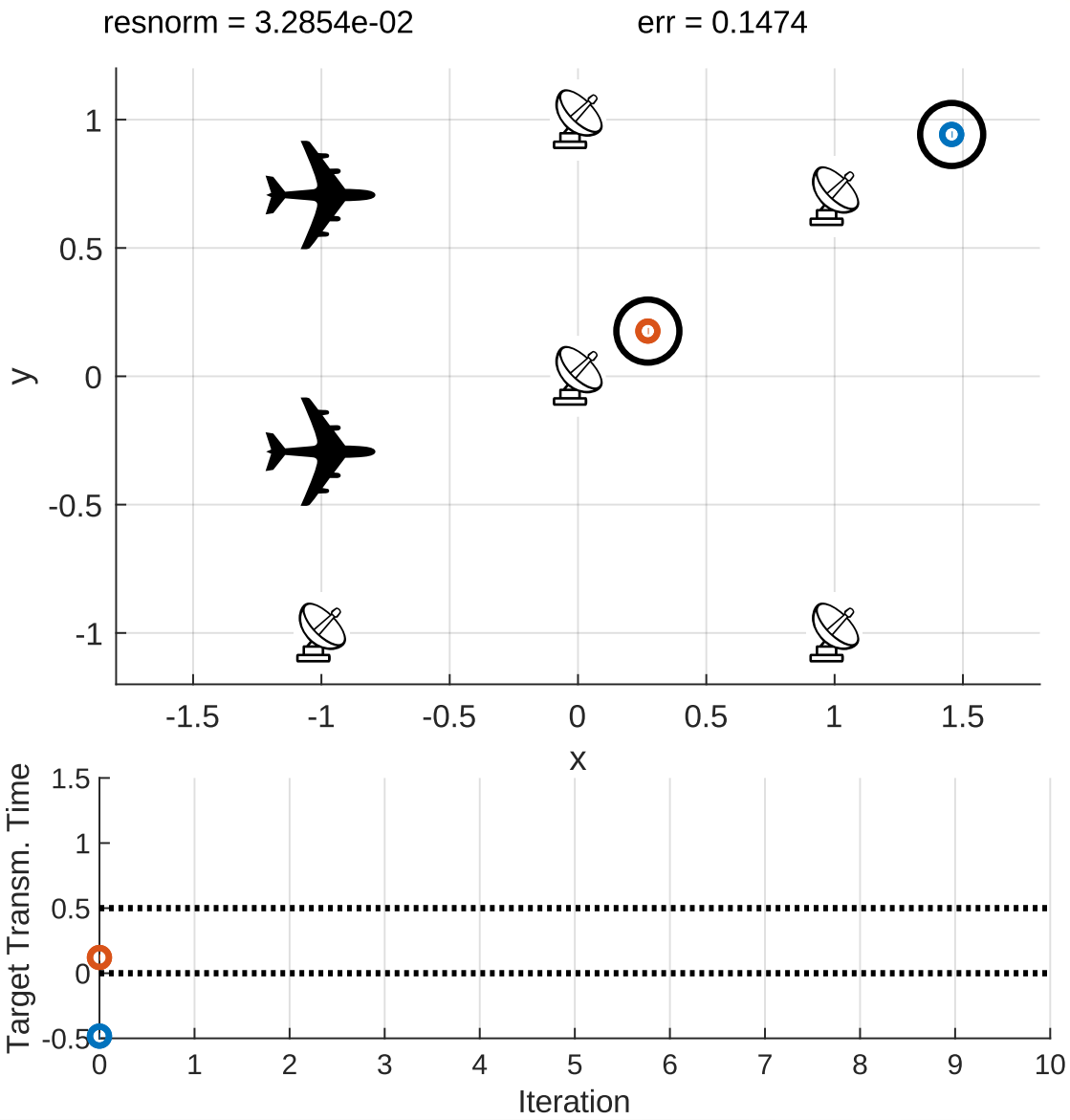


Evaluation

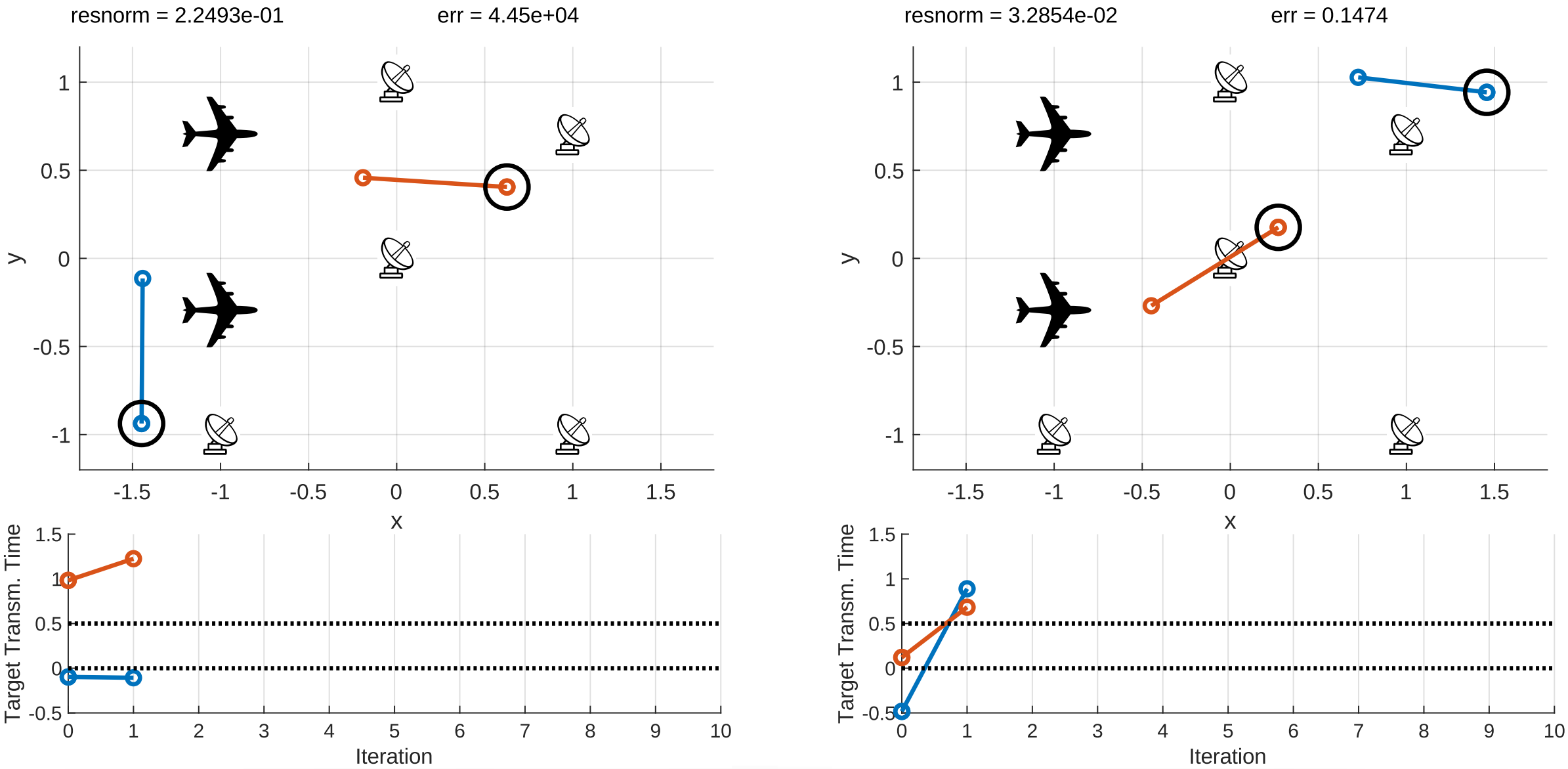

1
0.5
0
-0.5
-1
y
-1.5
-1
-0.5
0
0.5
1
1.5
x
Target Transm. Time
1.5
1
0.5
0
-0.5
0
1
2
3
4
5
6
7
8
9
10
Iteration

Evaluation

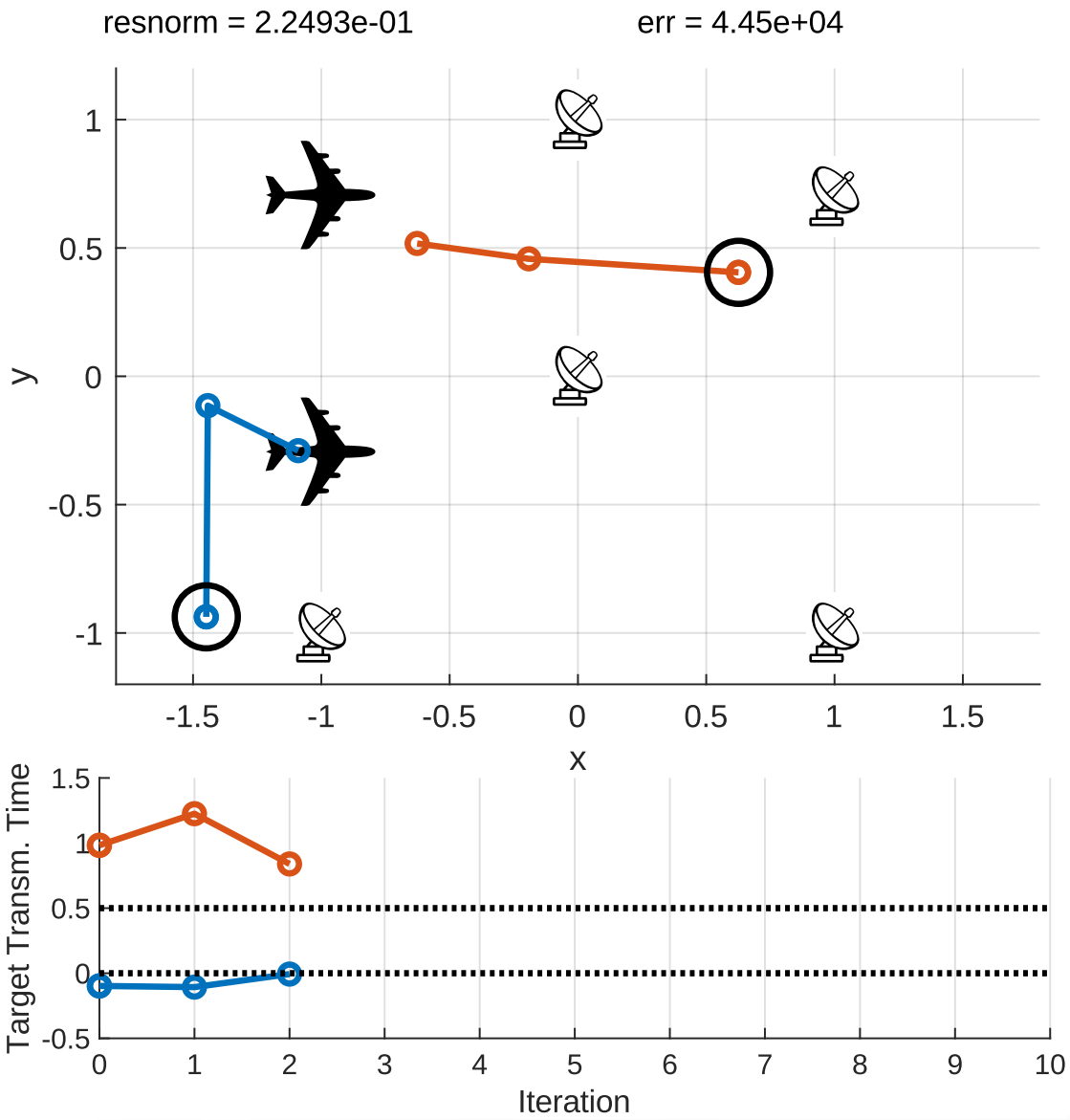

resnorm = 2.2493e-01
err = 4.45e+04
y
x
Target Transm. Time
Iteration

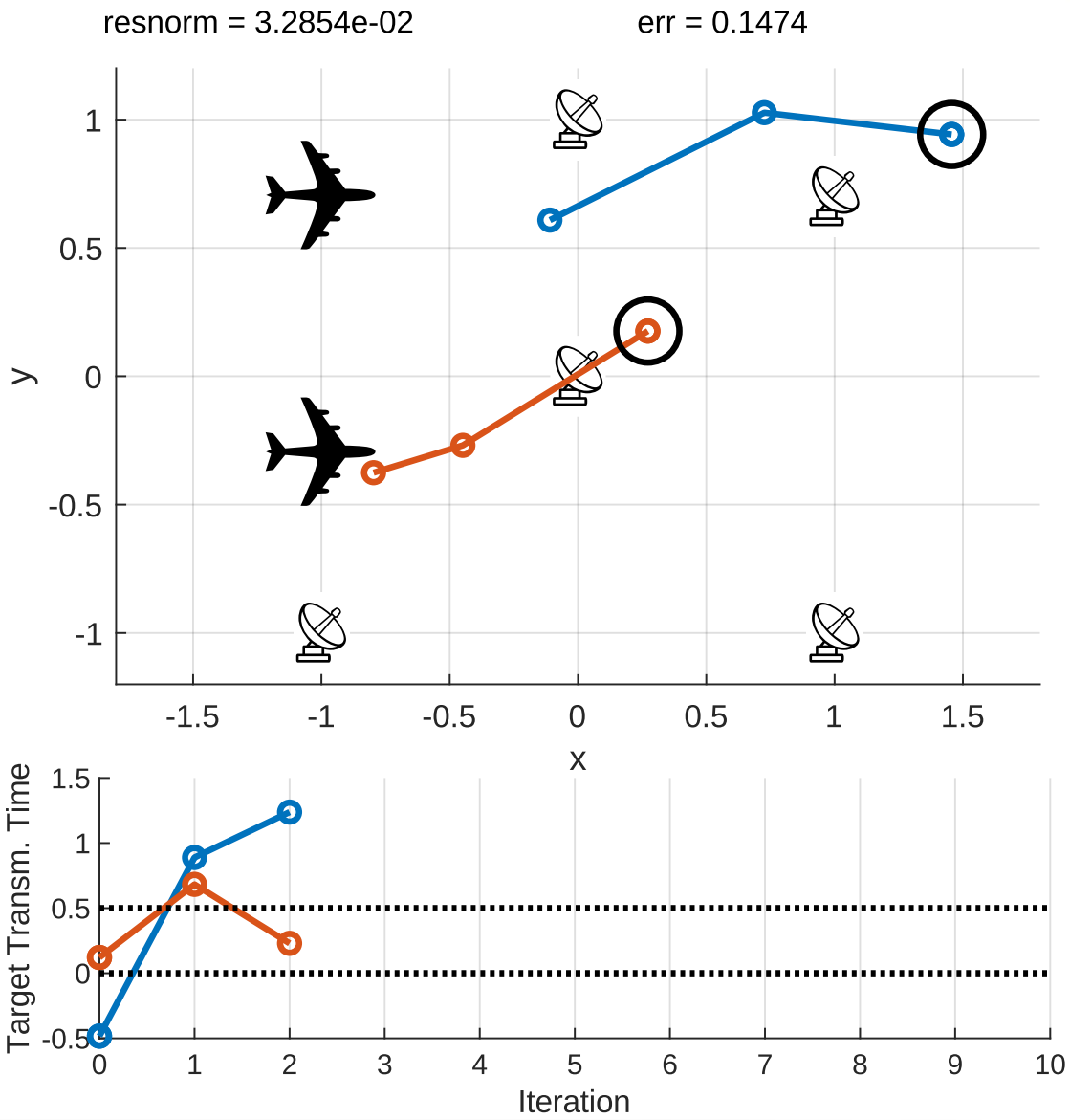

resnorm = 3.2854e-02
err = 0.1474
y
x
Target Transm. Time
Iteration

Evaluation

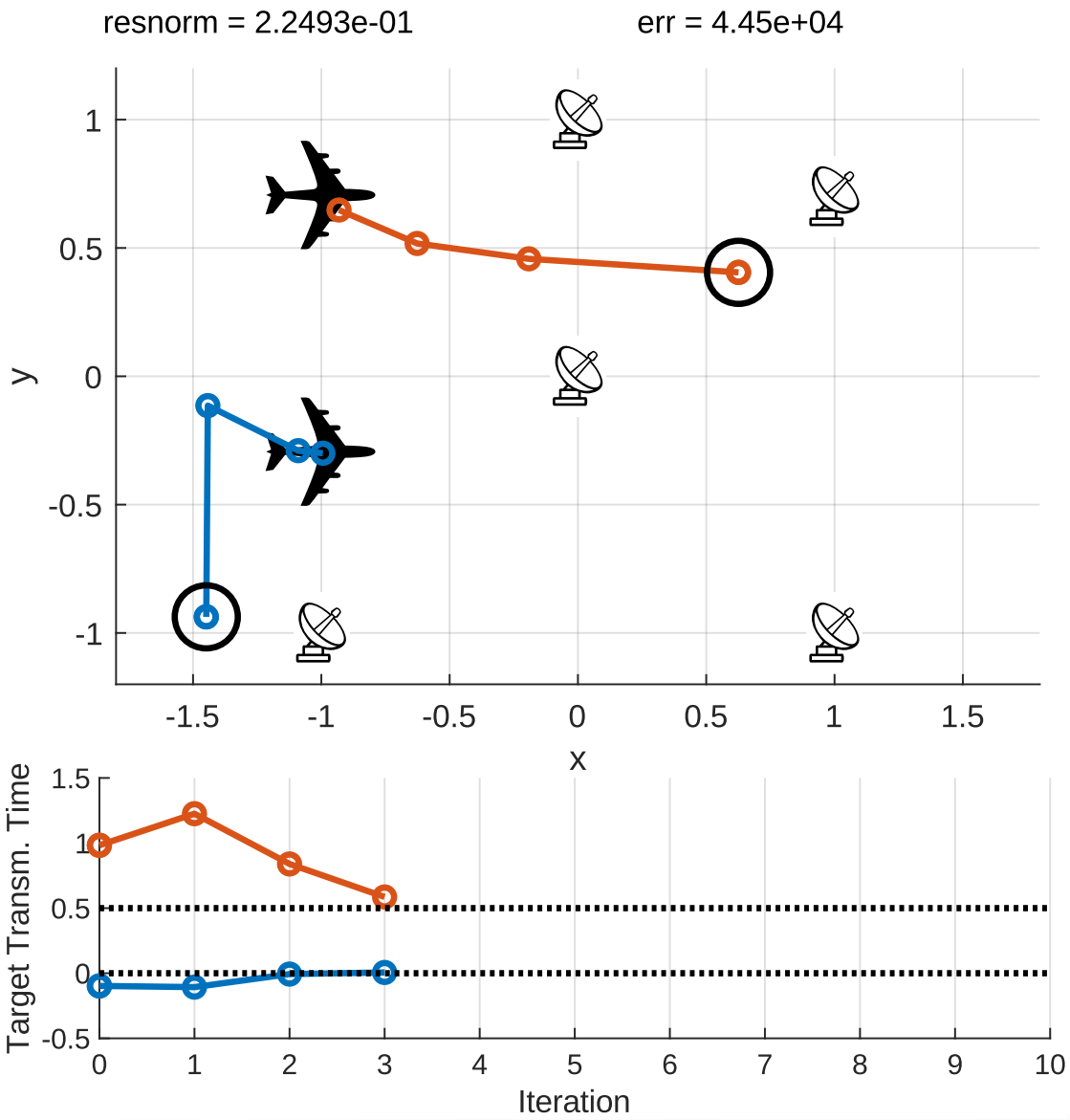

resnorm = 2.2493e-01
err = 4.45e+04
resnorm = 3.2854e-02
err = 0.1474
y
x
Target Transm. Time
Iteration

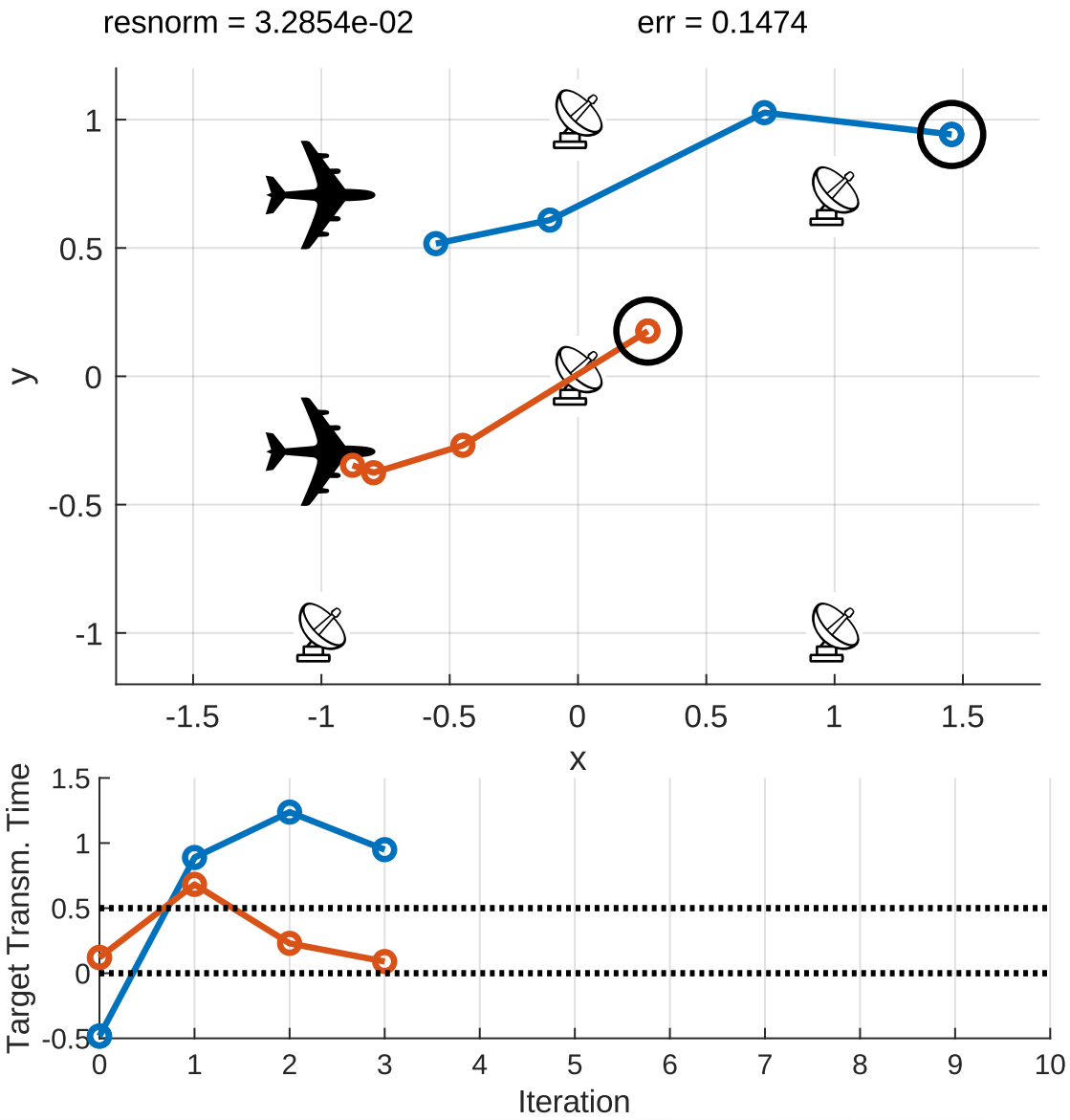
Evaluation


resnorm = 2.2493e-01
err = 4.45e+04
y
x
Target Transm. Time
Iteration

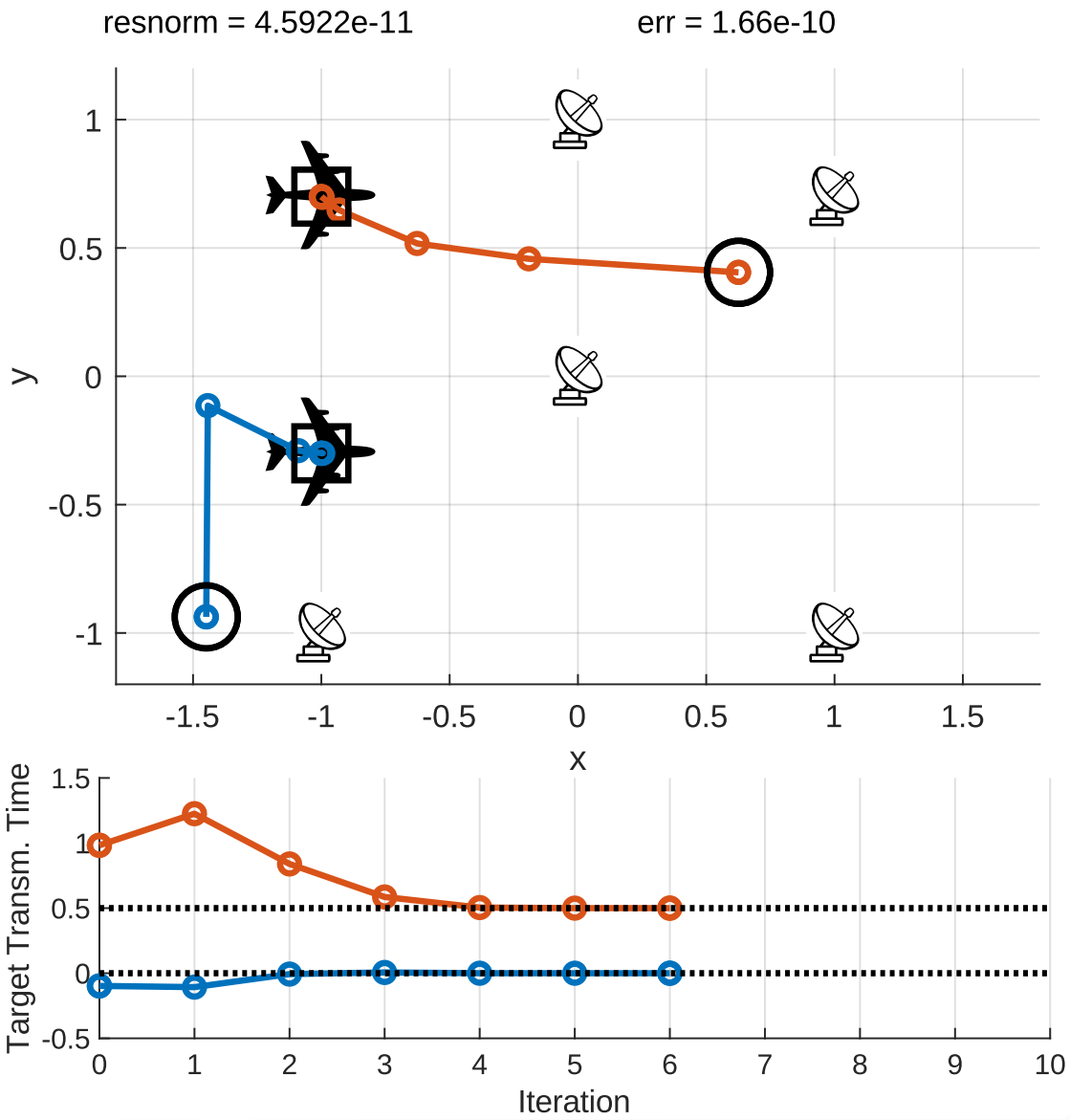

resnorm = 3.2854e-02
err = 0.1474
y
x
Target Transm. Time
Iteration

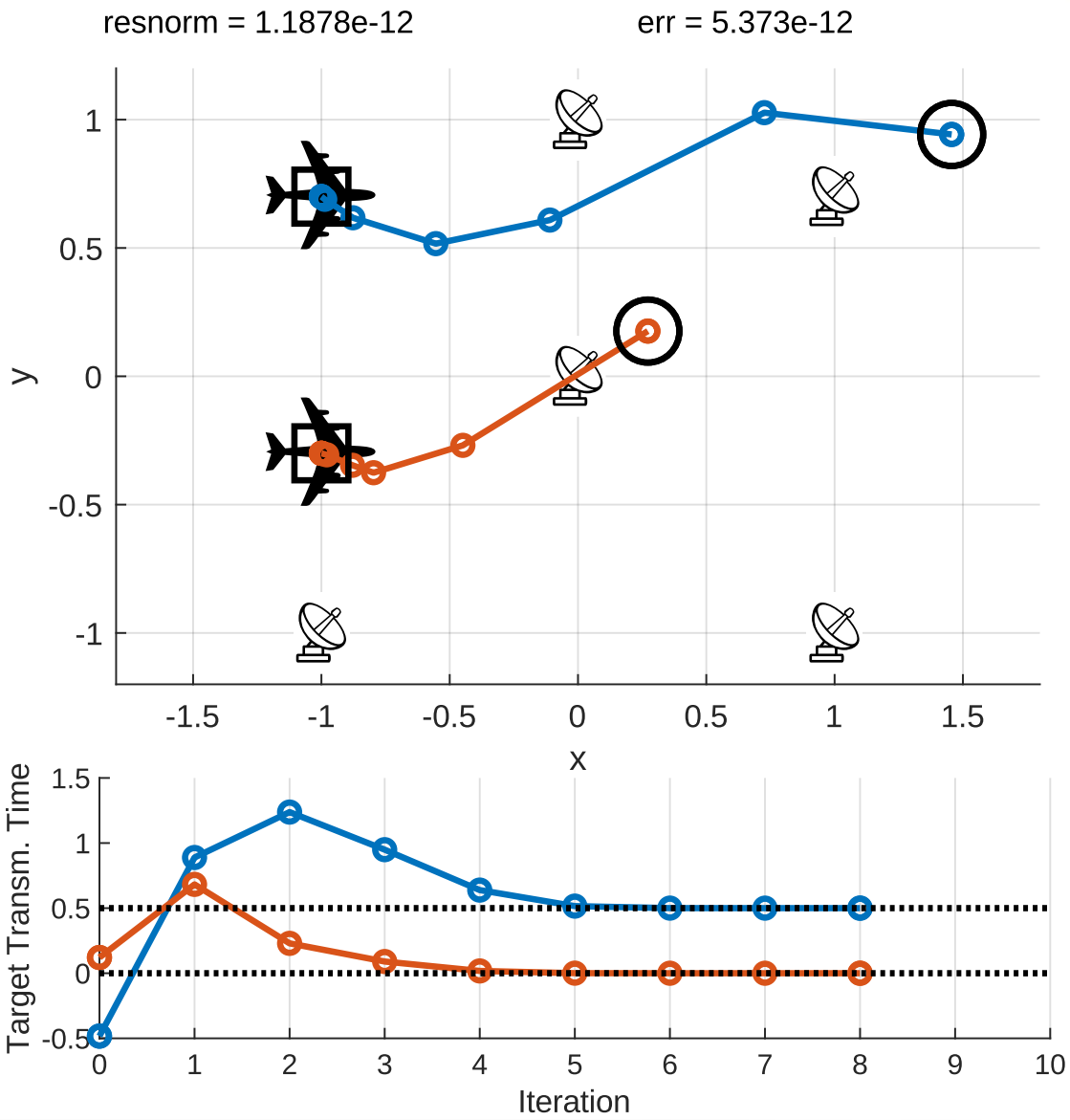
Evaluation


resnorm = 2.2493e-01
err = 4.45e+04
y
x
Target Transm. Time
Iteration

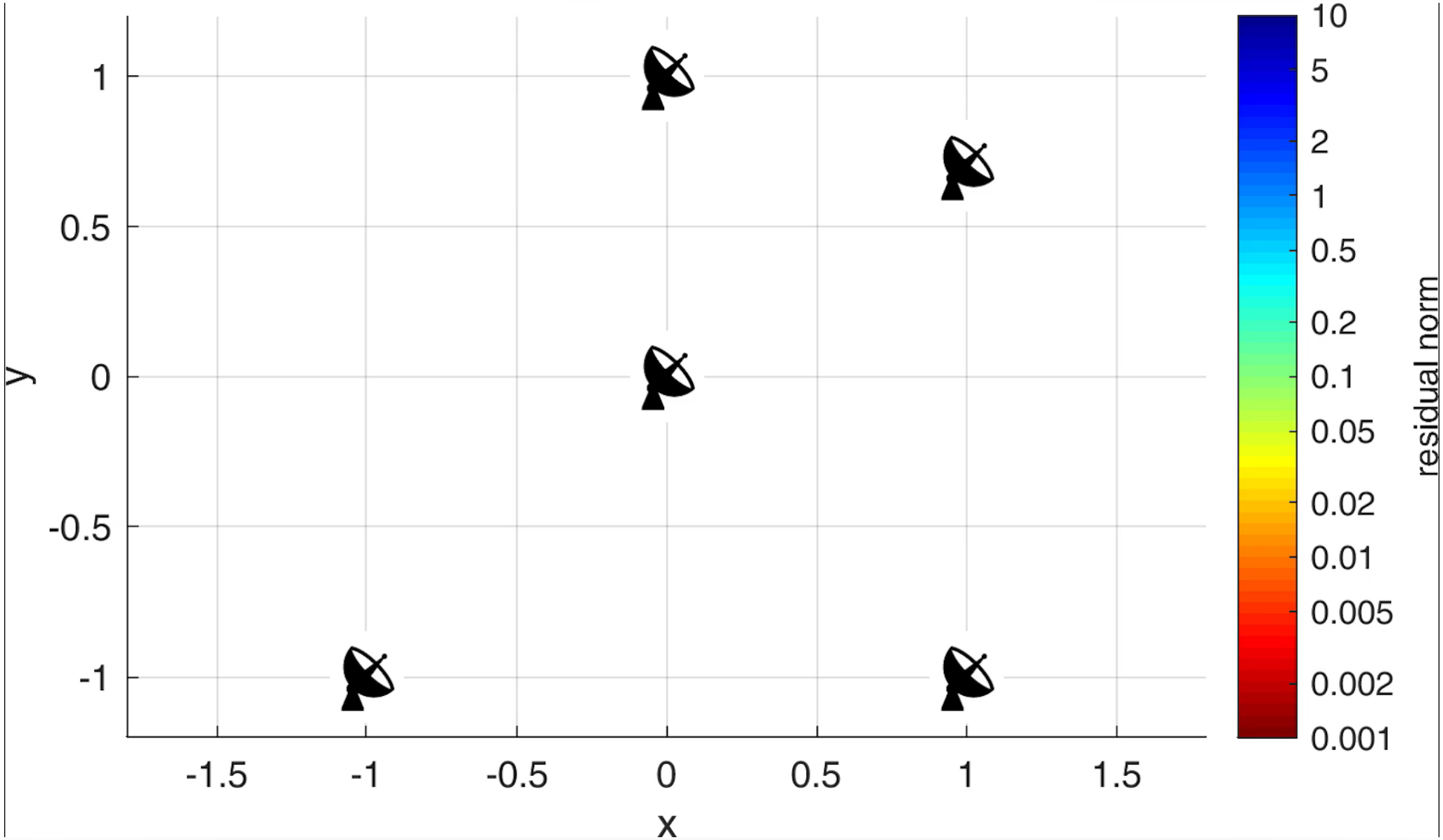

resnorm = 3.2854e-02
err = 0.1474
y
x
Target Transm. Time
Iteration

Evaluation

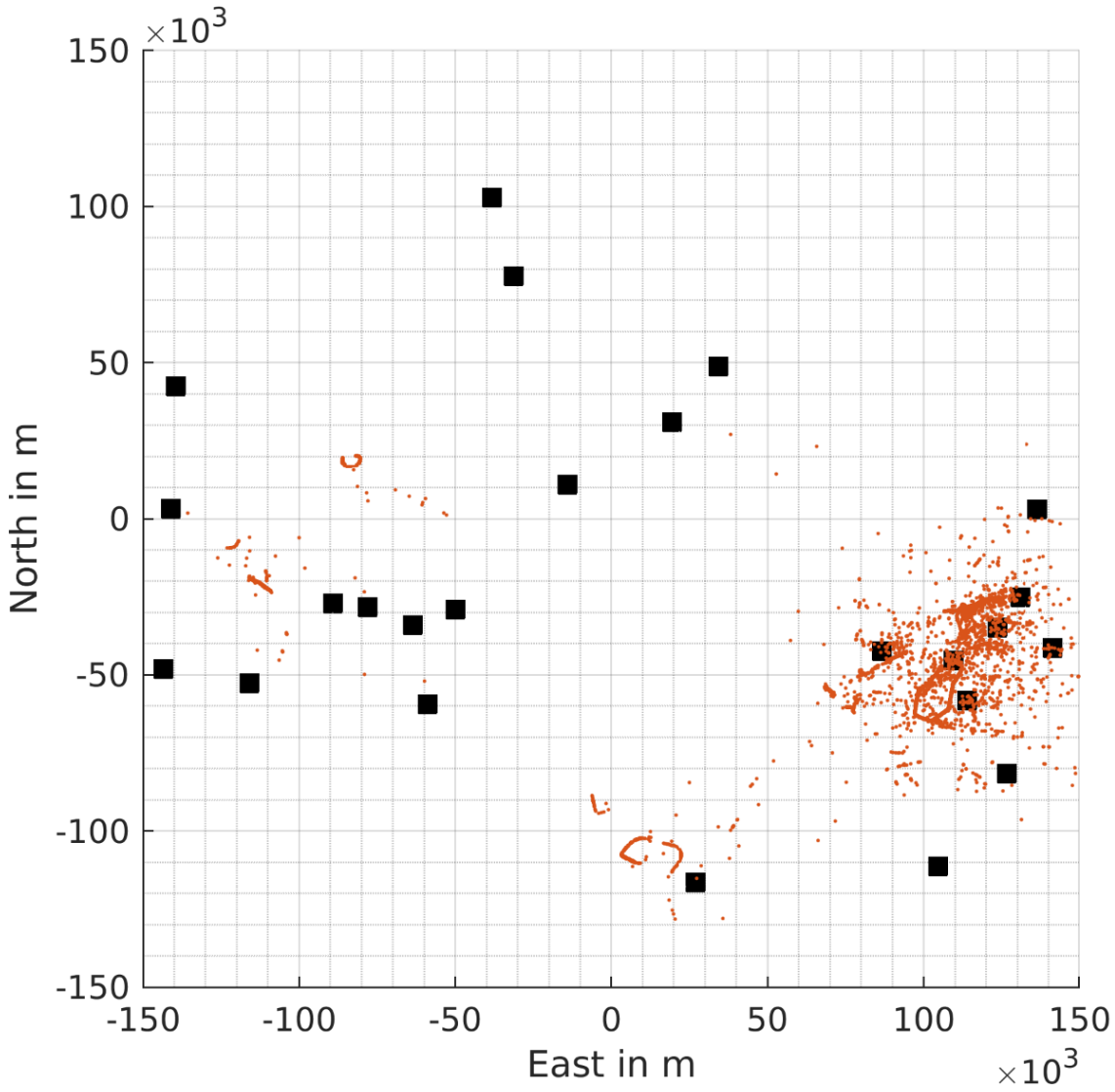

resnorm = 4.5922e-11
err = 1.66e-10
y
x
Target Transm. Time
Iteration

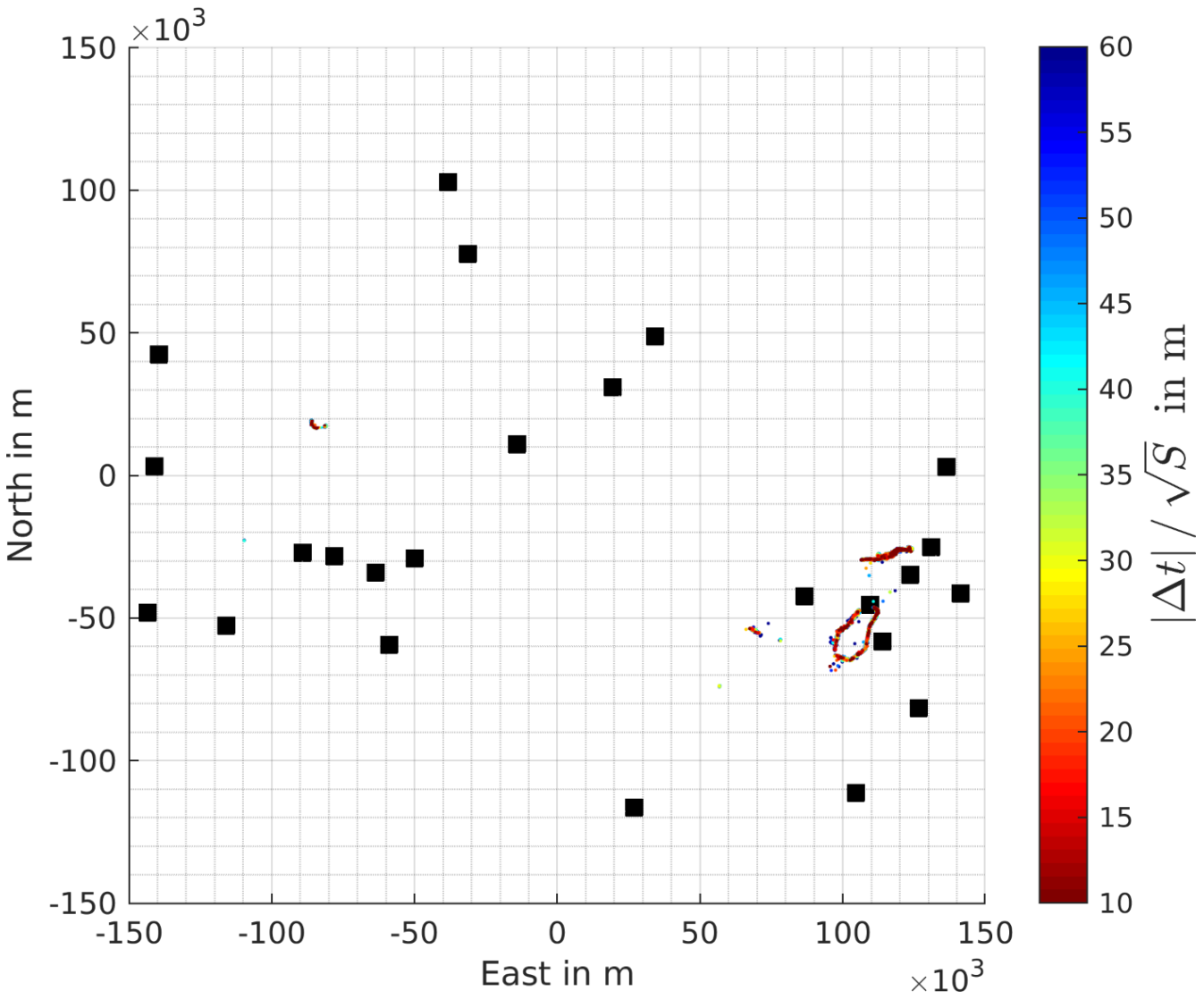

resnorm = 1.1878e-12
err = 5.373e-12
y
x
Target Transm. Time
Iteration

Video: Simulation and Real Data Examples



Example Before vs After

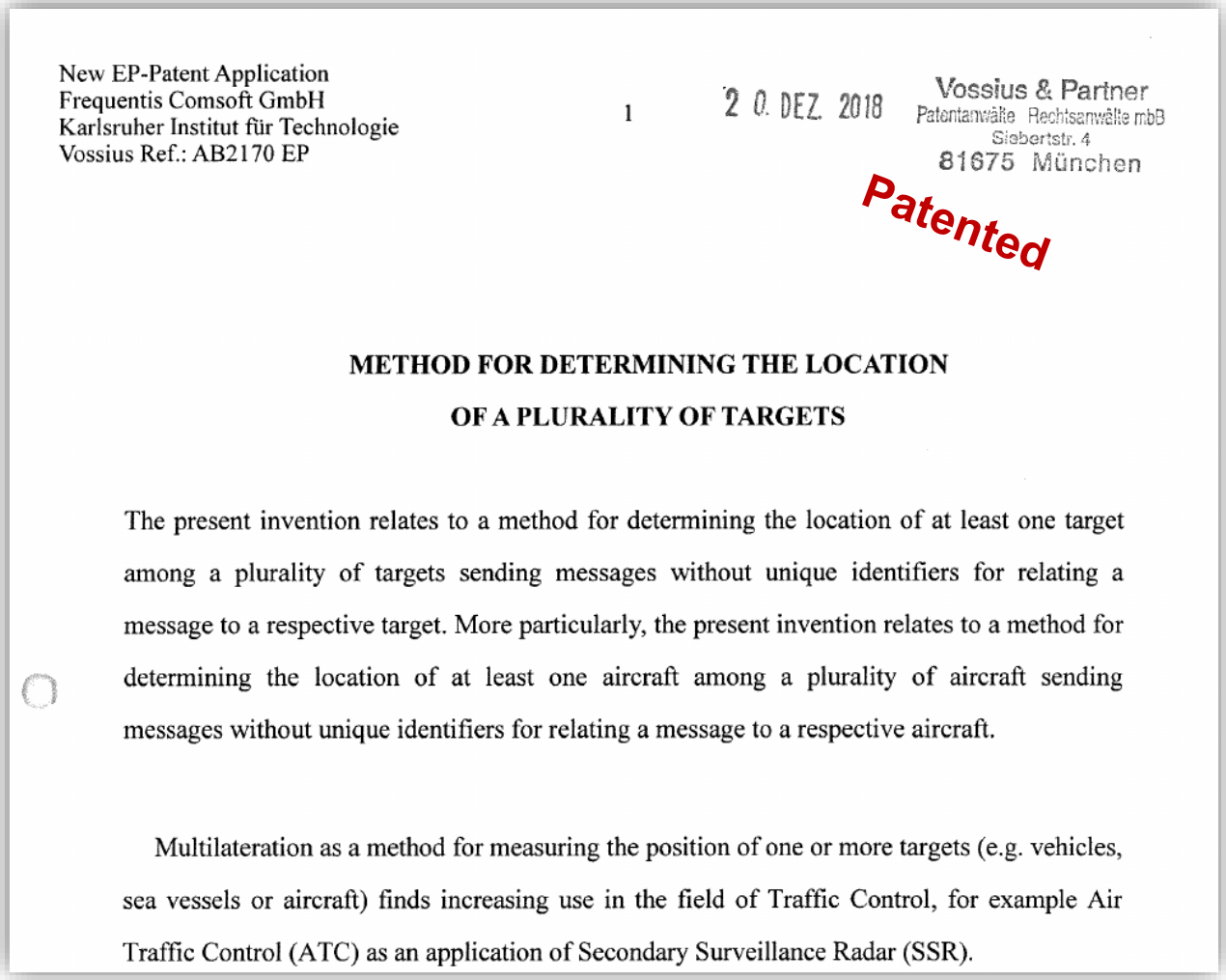




Conclusions

Multi Target Multilateration Features

- Unknown Associations (TOA to target)
- Passive Sensors
- Reliability
- Independent Estimates



New EP-Patent Application
Frequentis Comsoft GmbH
Karlsruher Institut für Technologie
Vossius Ref.: AB2170 EP

1

2 0. DEZ. 2018

Vossius & Partner
Patentanwälte Rechtsanwälte mbB
Siebertstr. 4
81675 München

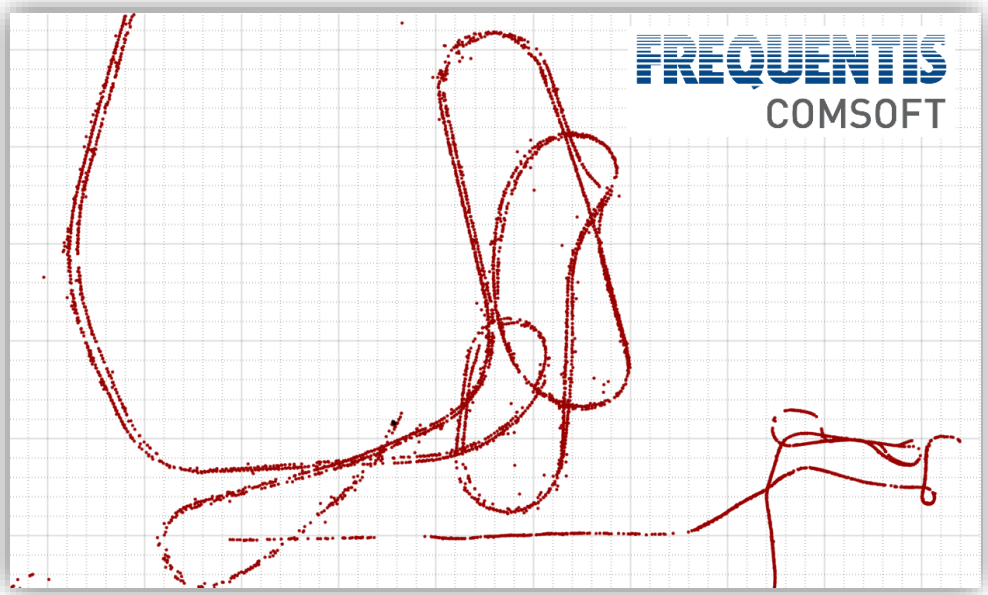
Patented

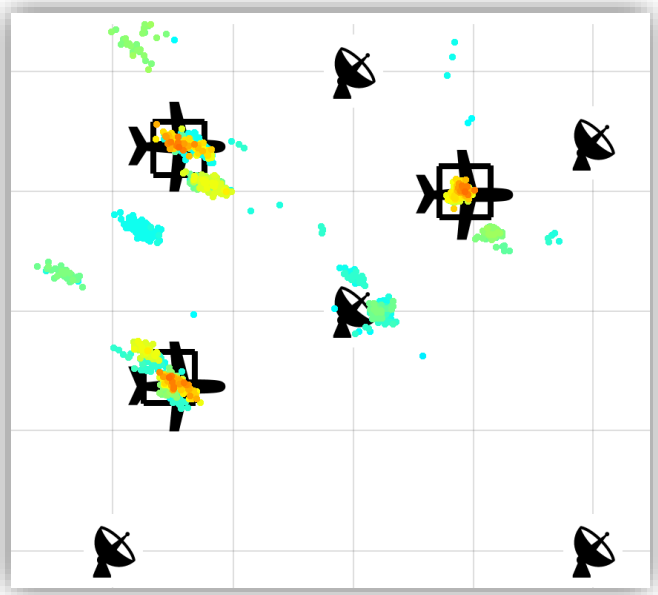
METHOD FOR DETERMINING THE LOCATION OF A PLURALITY OF TARGETS

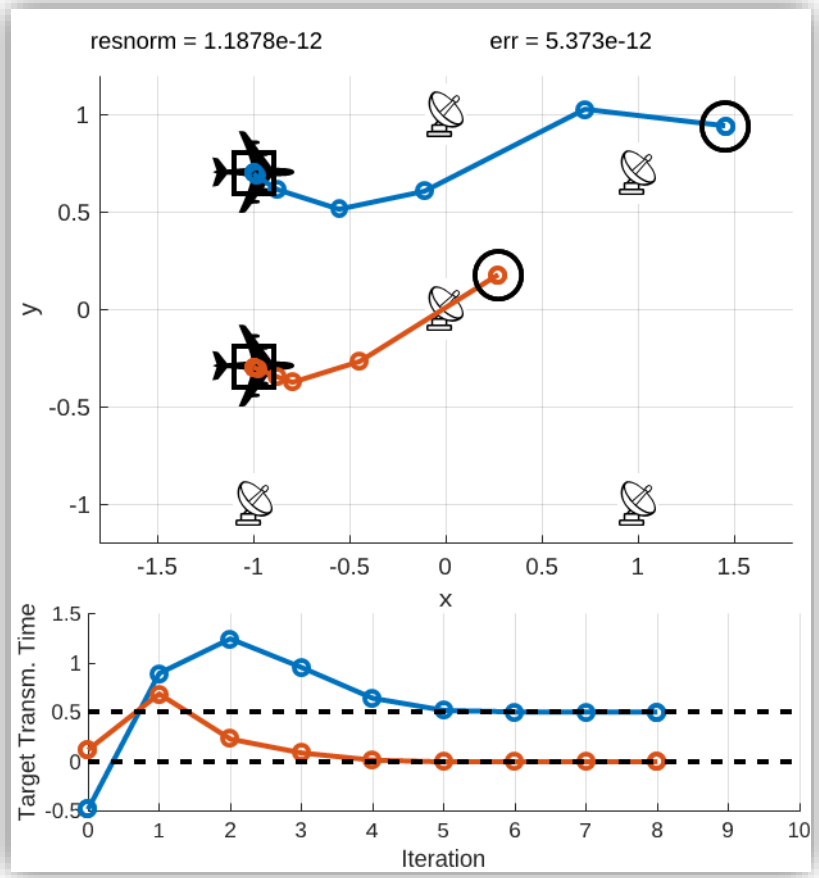
The present invention relates to a method for determining the location of at least one target among a plurality of targets sending messages without unique identifiers for relating a message to a respective target. More particularly, the present invention relates to a method for determining the location of at least one aircraft among a plurality of aircraft sending messages without unique identifiers for relating a message to a respective aircraft.

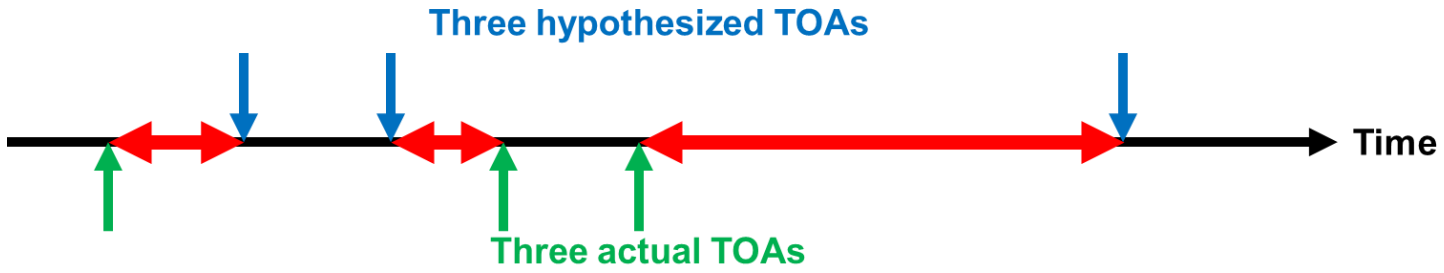
Multilateration as a method for measuring the position of one or more targets (e.g. vehicles, sea vessels or aircraft) finds increasing use in the field of Traffic Control, for example Air Traffic Control (ATC) as an application of Secondary Surveillance Radar (SSR).

END


FREQUENTIS
COMSOFT




resnorm = 1.1878e-12
err = 5.373e-12
y
x
Target Transm. Time
Iteration


Three hypothesized TOAs
Time
Three actual TOAs