Optimized Rendezvous of a Quadrotor

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Motivation

Source : Skycatch Inc.

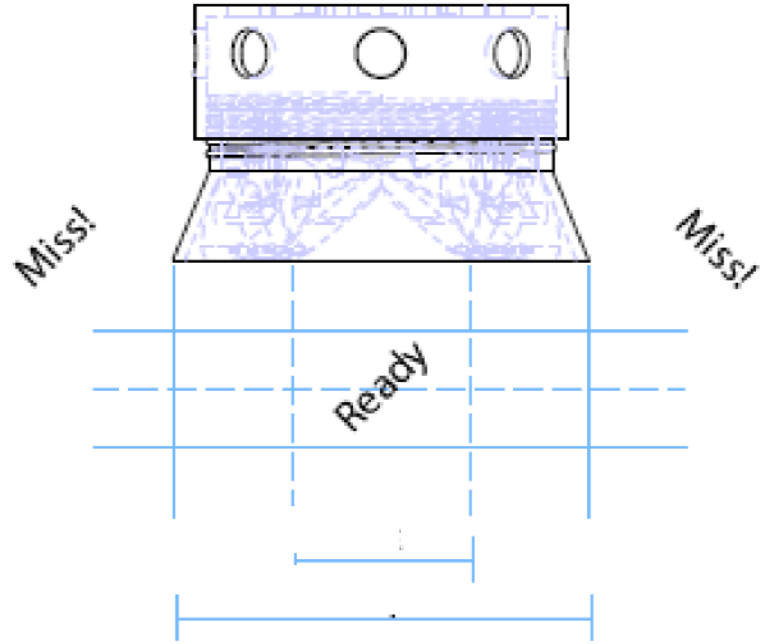
Source : GRASP lab

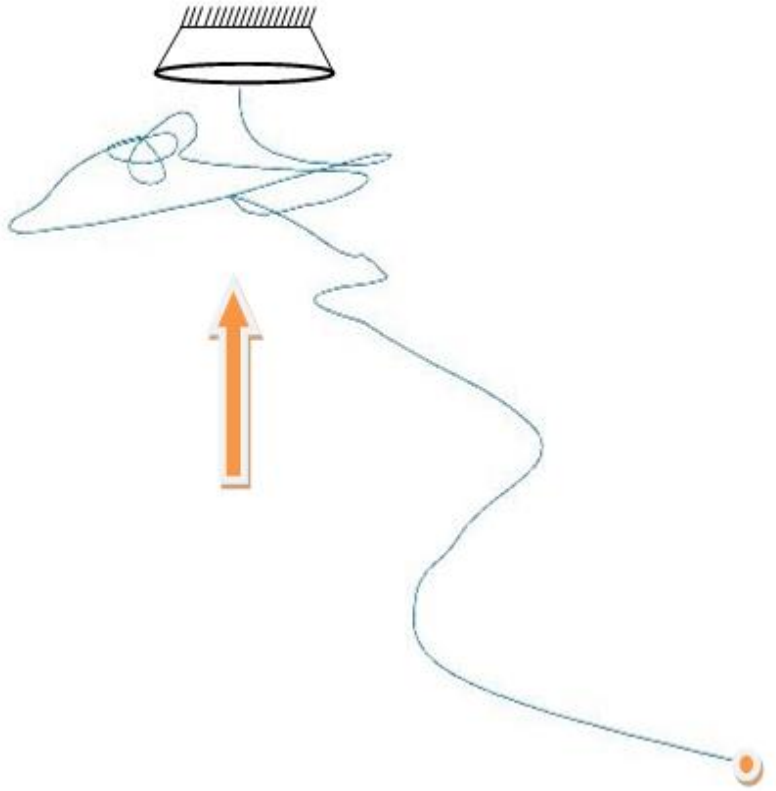
Source : ETH Zurich

Source : A passive gripper mechanism .. [DeGol et. al]

- Assume perfect position sensing
- Disturbances present due to wind
- Uncertainty in attaining the desired velocity vector
- Path planner is needed to find desired position

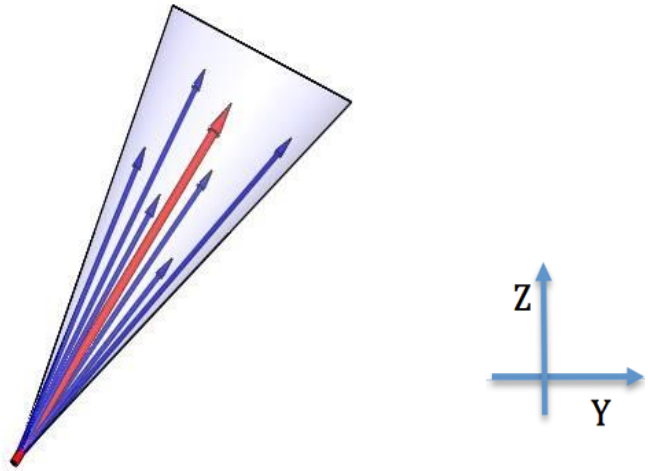
Related Work and New Approach



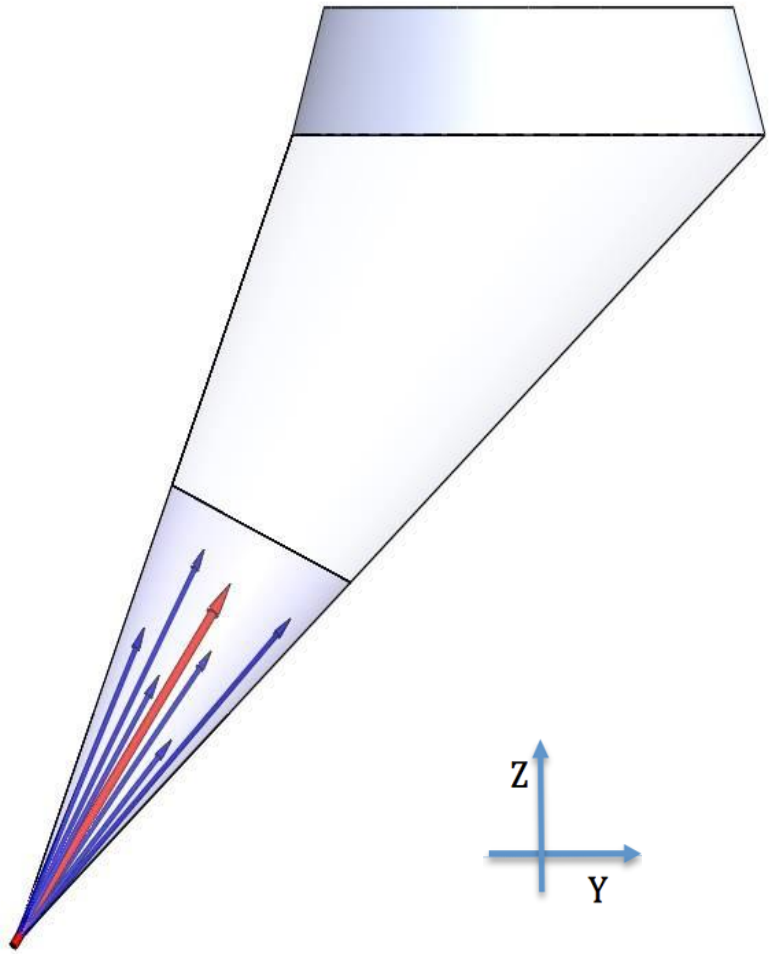


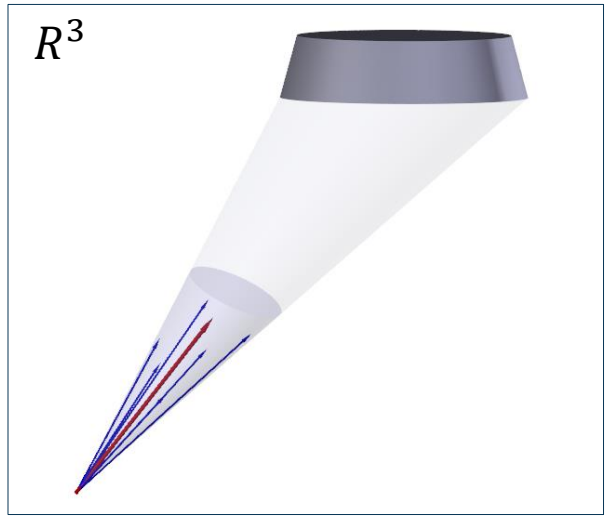
Method Intuition:

- Desired velocity vector
- Other possible velocity vectors

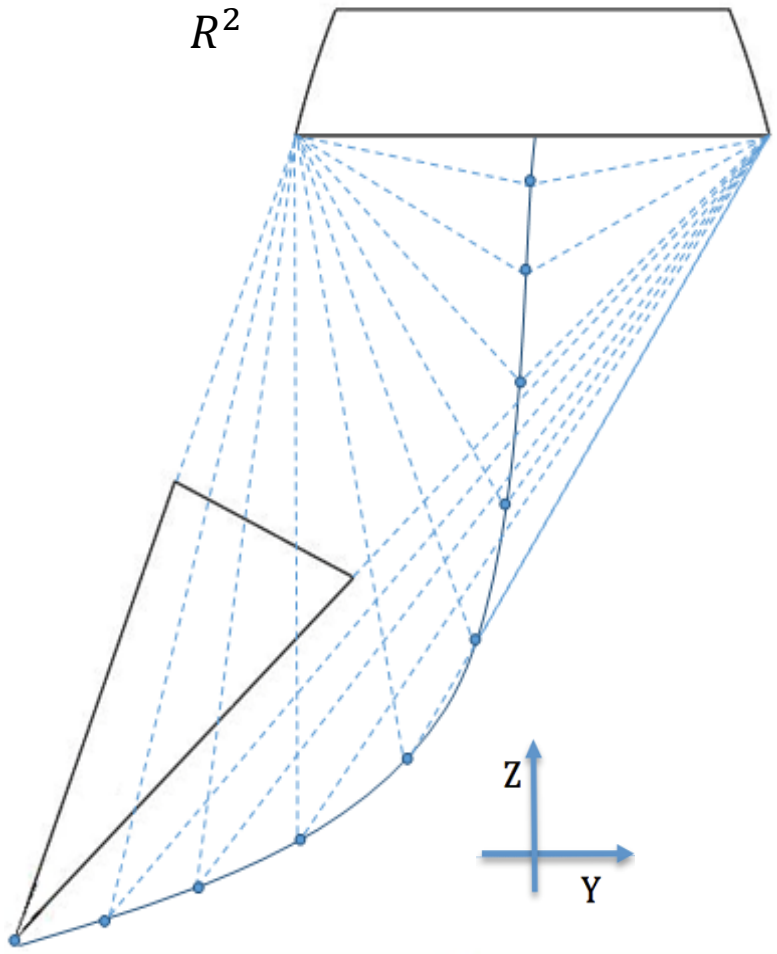


Method Intuition:



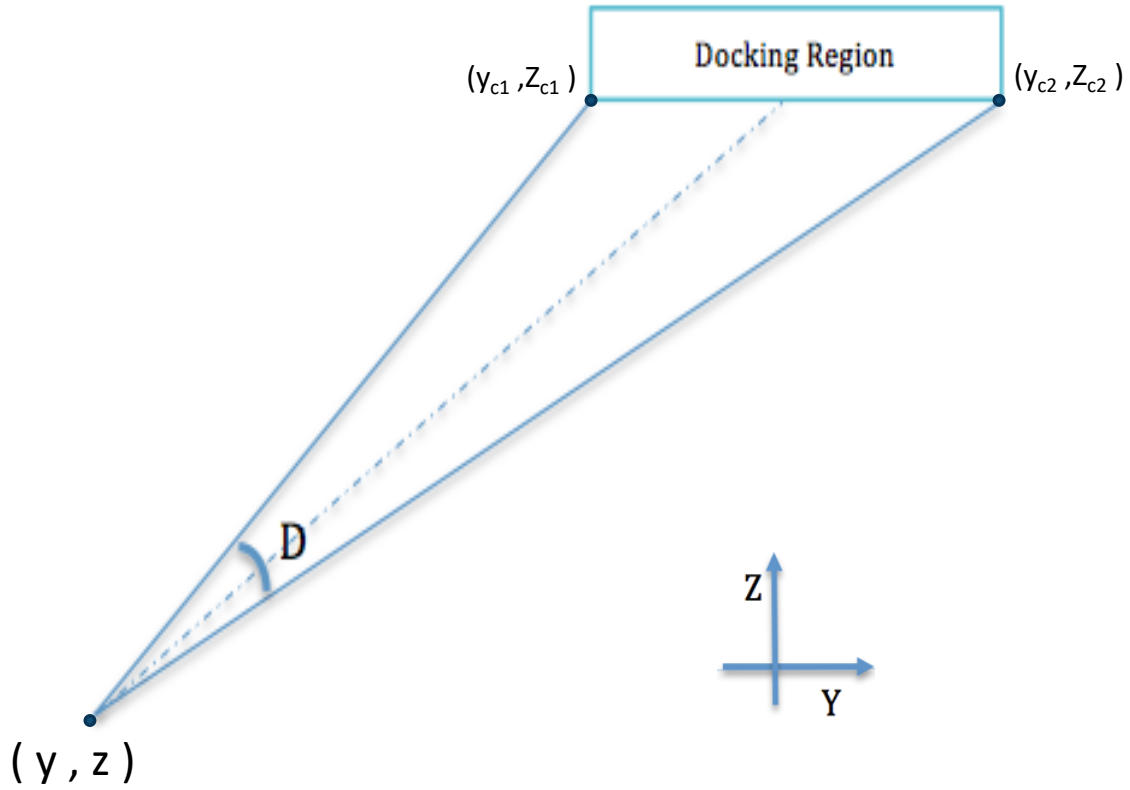


Method Intuition:



Method Intuition: The Difference function

- We define a "**D**ifference Angle" ,
  $D: \ R^2 \rightarrow [0,\pi]$



Method Intuition: Difference Space Properties

- Claim 1: $\forall\ Z_o,\ \theta \rightarrow 90°\ ,\ D_\theta = \max\ \{D(Z_o, \theta)\}$. [Figure 1]
- Claim 2: If pairs (Z_1, θ_1) and (Z_2, θ_2) are such that $\theta_1=\theta_2=90°$ and $Z_c > Z_2 > Z_1$, then, $D_2 > D_1$ where $D_1 = D\ (Z_1, \theta_1)$ and $D_2 = D\ (Z_1, \theta_1)$. [Figure 2]

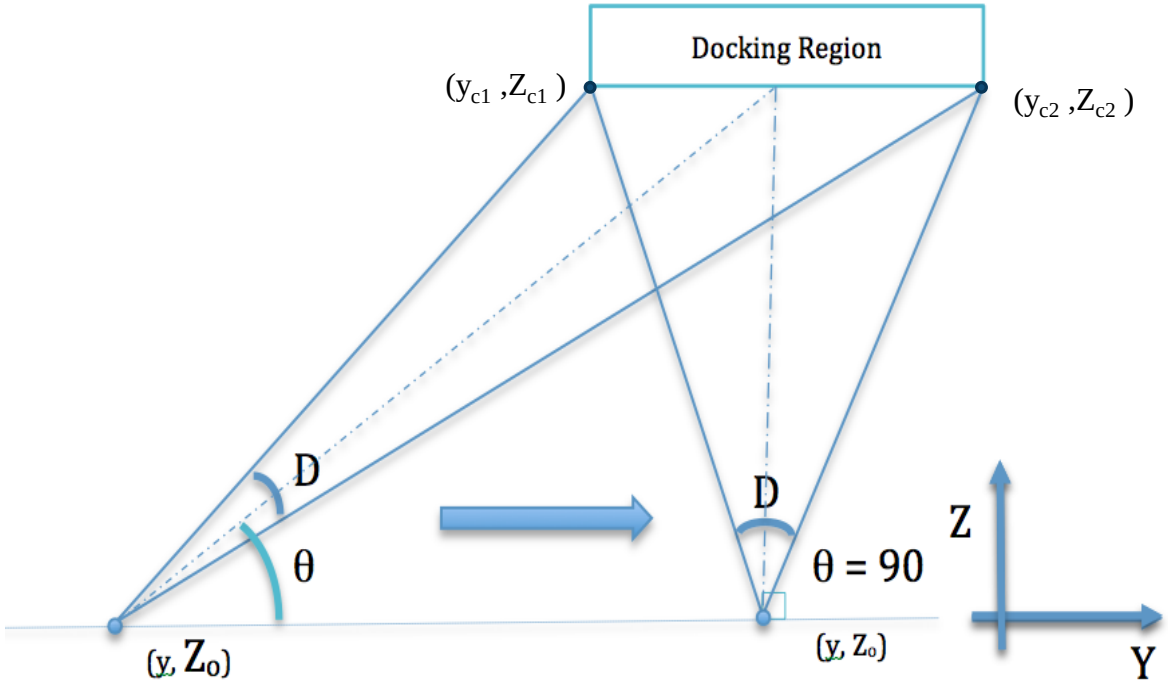


Figure 1. Comparison of D(y, Z_o, θ) as θ → 90°

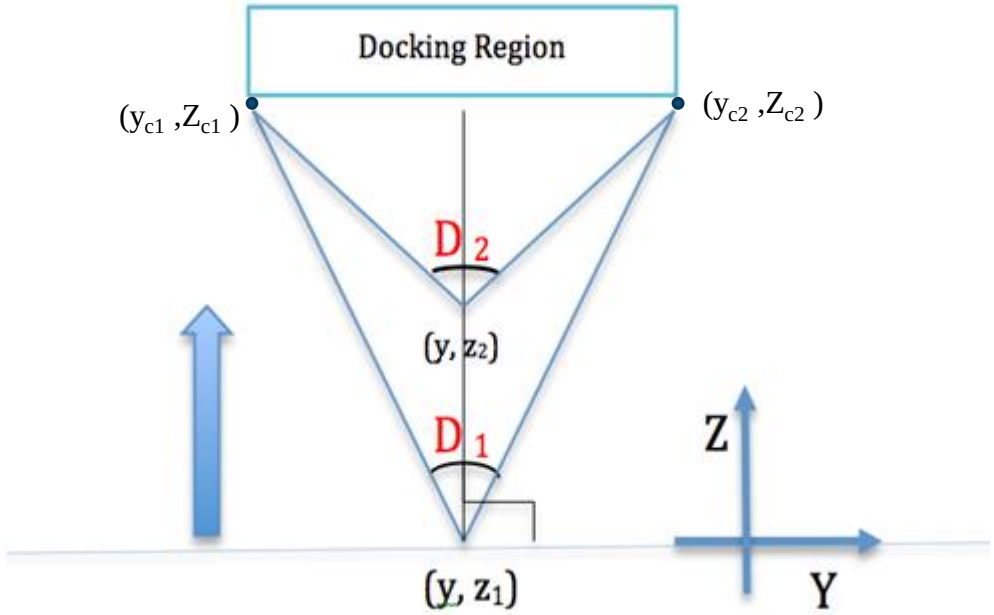


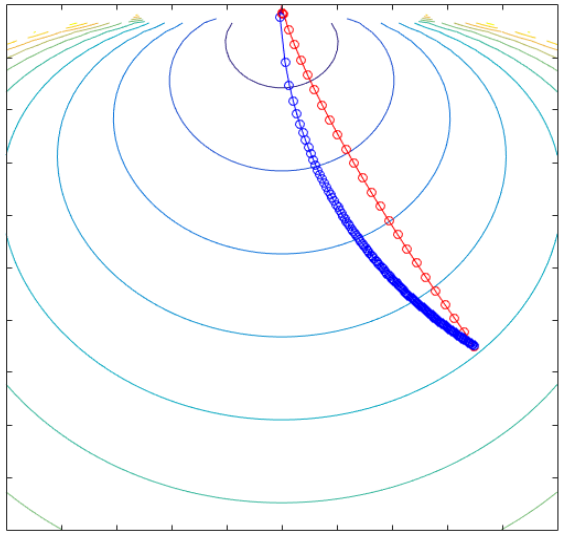
Figure 2. Comparison of D(y,z) as z increases when θ=90°

Objective Function

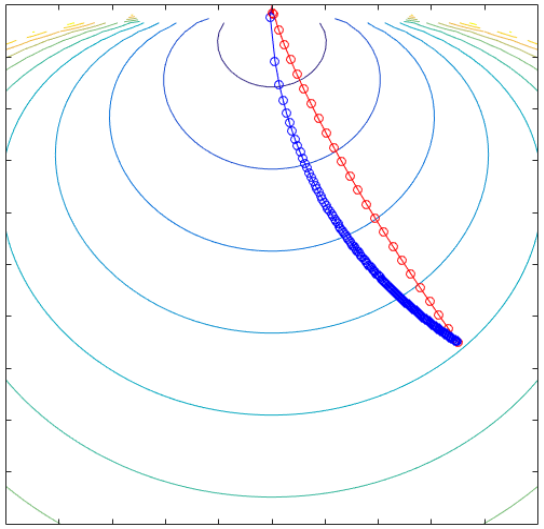
Difference angle increases the robustness, but in order to decrease the time to dock, we employ a new cost function assuming a constant velocity:

$$J = A\left(\frac{1}{D}\right) + B\left\|x_m - x_q\right\|$$

Method Intuition



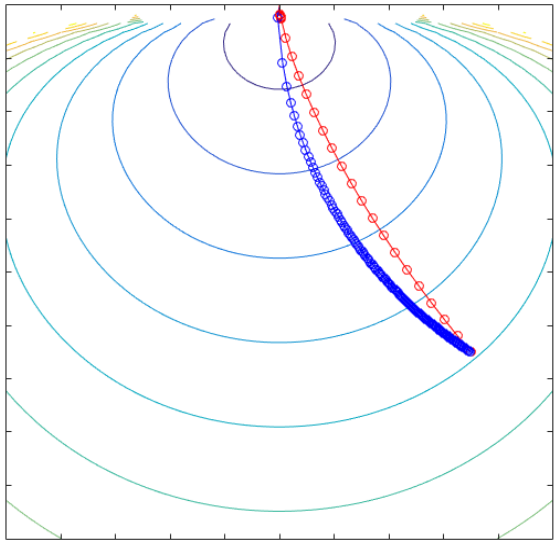
A = 0
B = 50



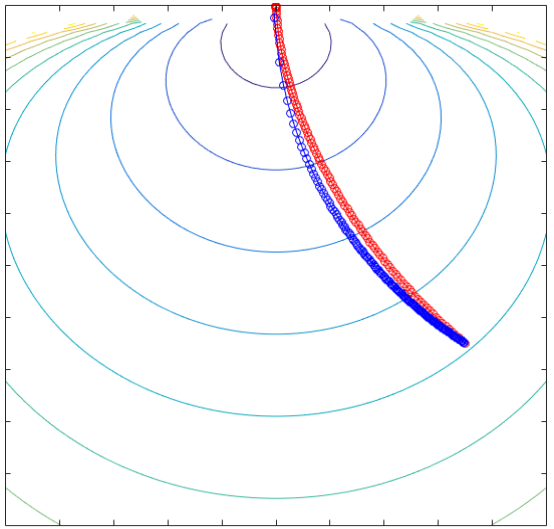
A = 1
B = 50

Proposed method

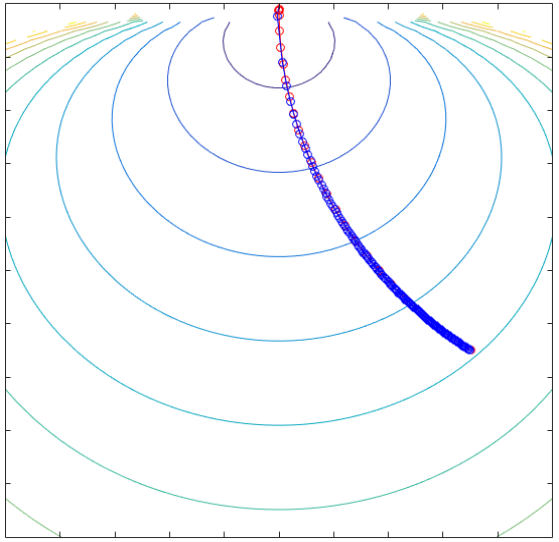
Diff. Angle method



A = 2
B = 50



A = 8
B = 50



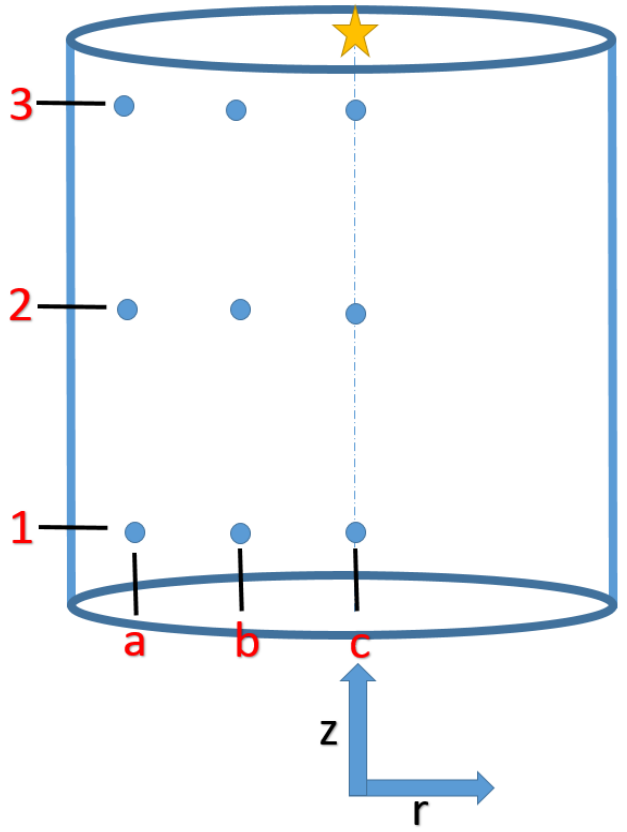
A = 50
B = 0

Monte Carlo Experiments

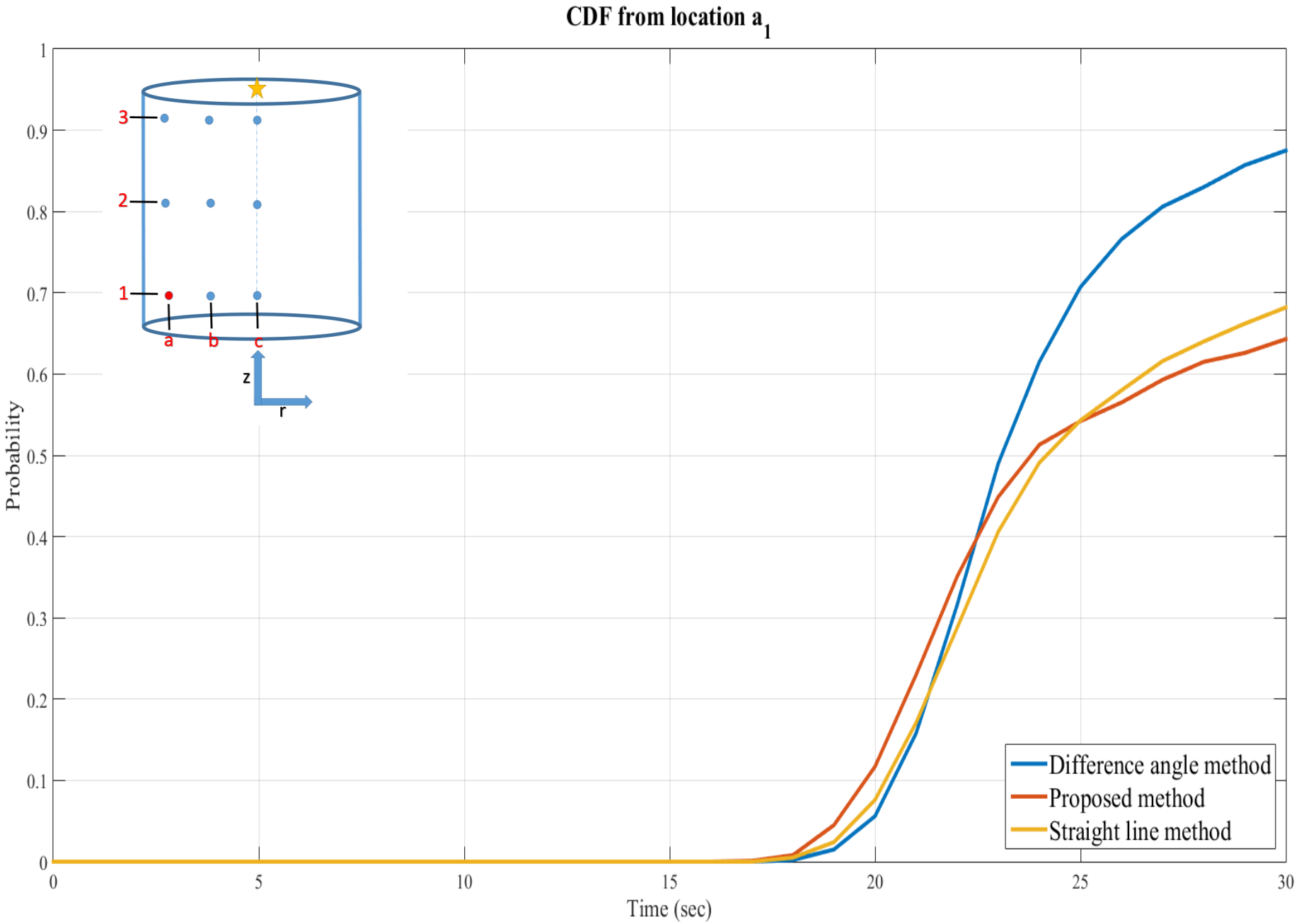
Experiment I Setup:

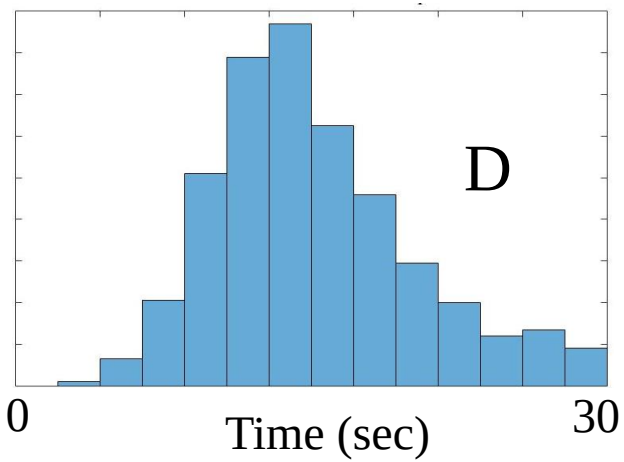
Experiment I
PD Controller (Constant Gains)
Disturbance: Mean=0, Variance=0.001
Constant Planner Gain
Docking region limit 0.01
Proposed method weights (A = 1, B =50)
Straight line method weights (A = 0, B =1)
Number of Monte Carlos runs : 1000

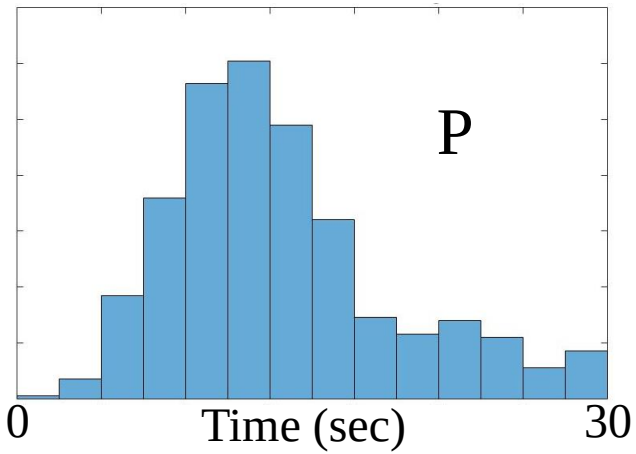
a_1 (0.95, 0.15)	a_2 (0.95, 1)	a_3 (0.95, 1.85)
b_1 (0.5, 0.15)	b_2 (0.5, 1)	b_3 (0.5, 1.85)
c_1 (0, 0.15)	c_2 (0, 1)	c_3 (0, 1.85)

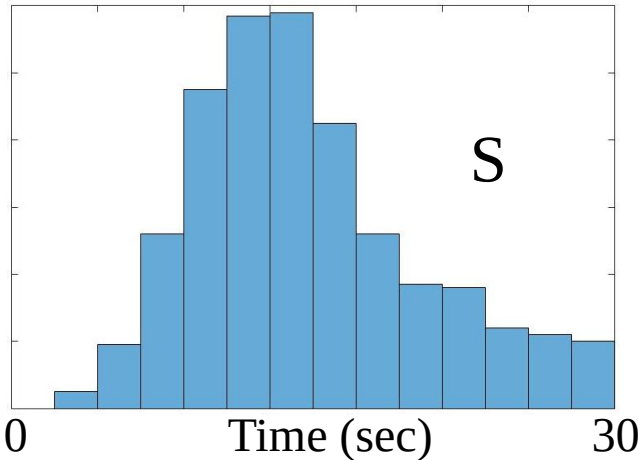


Experiment I – Results from location a_1

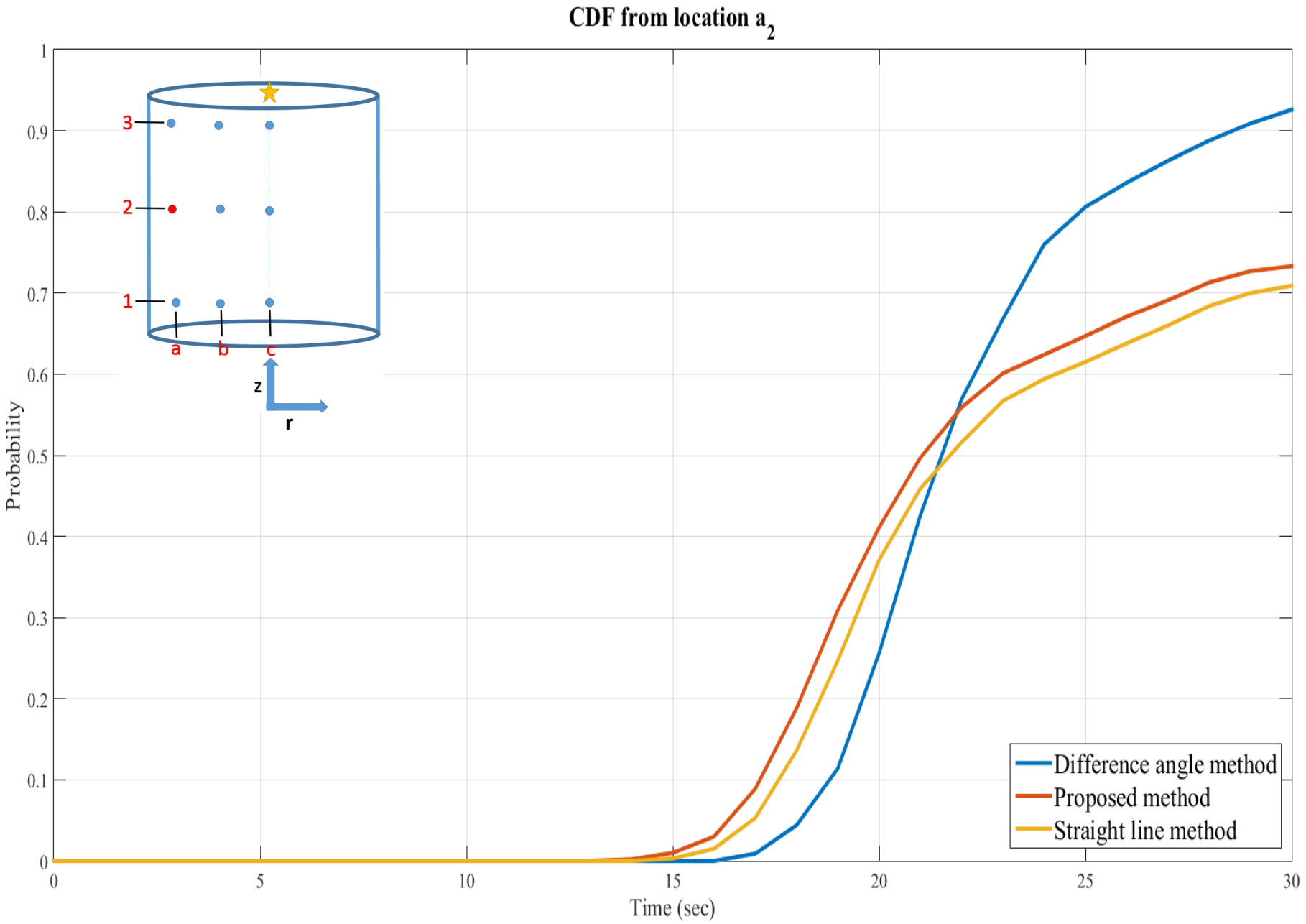


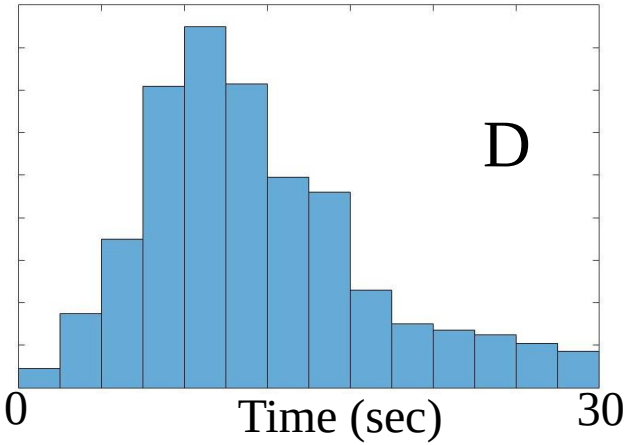


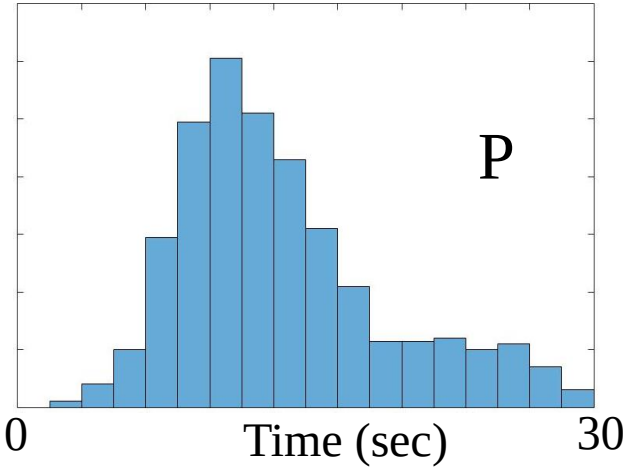


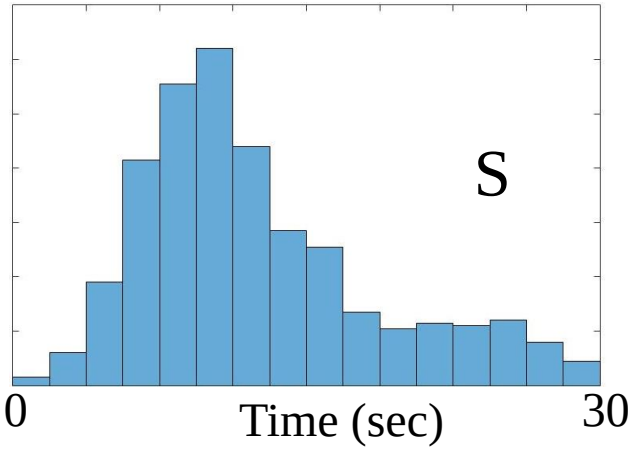


Experiment I – Results from location a_2

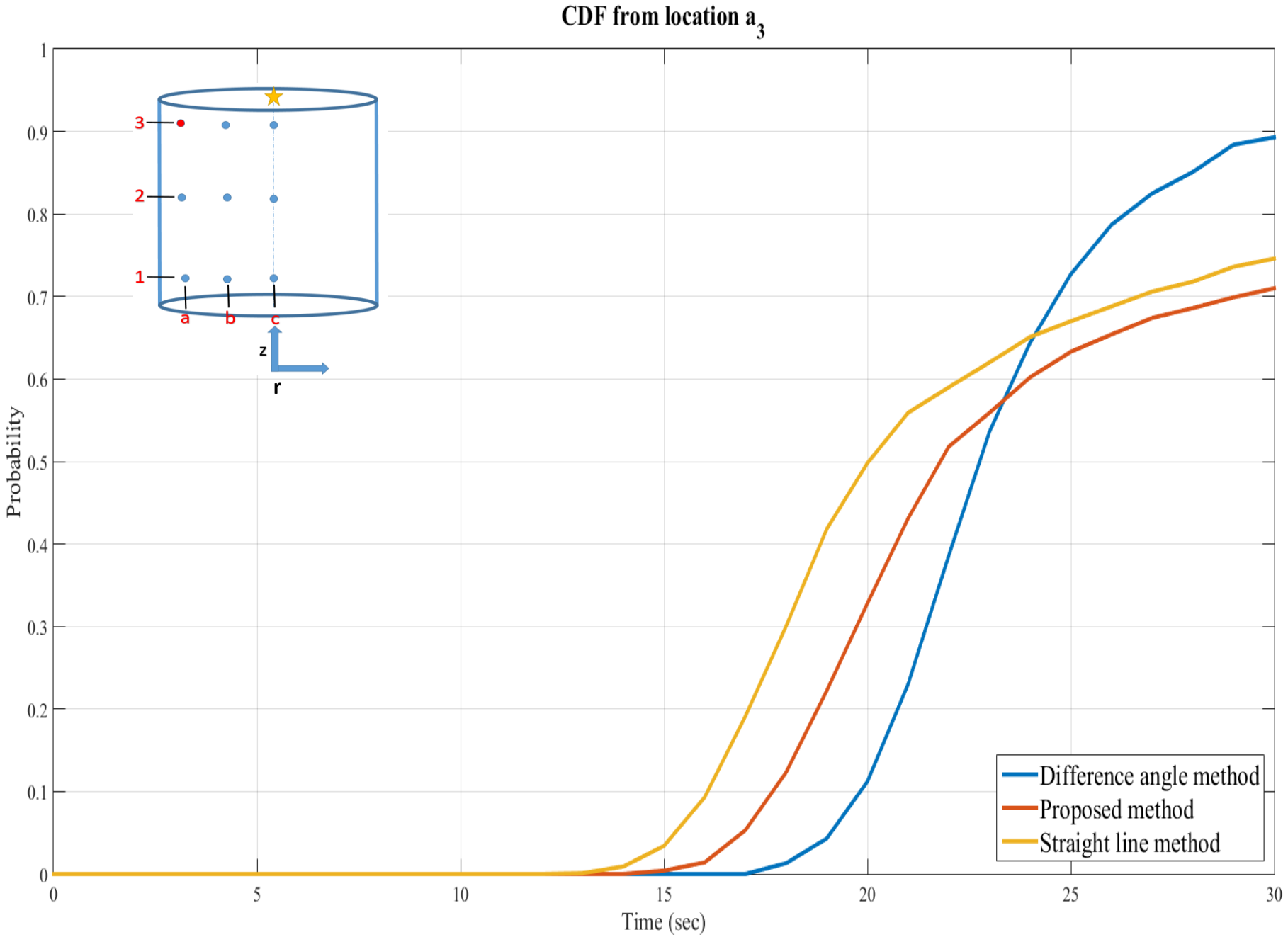


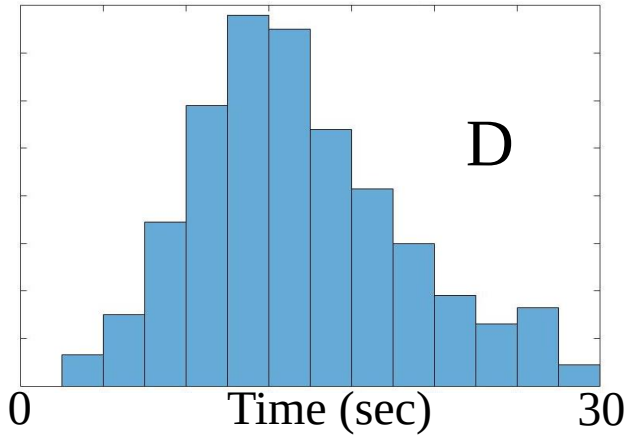


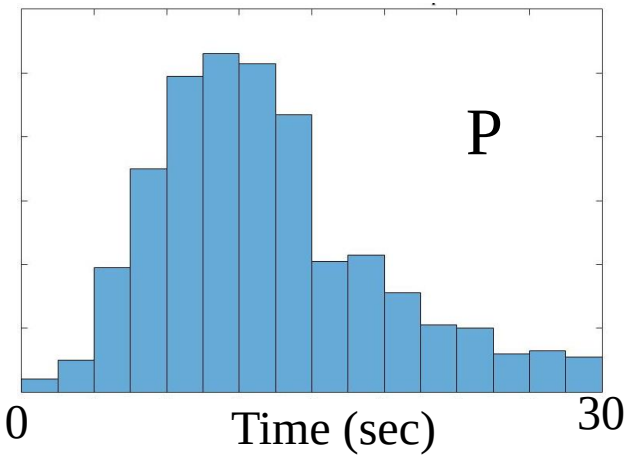


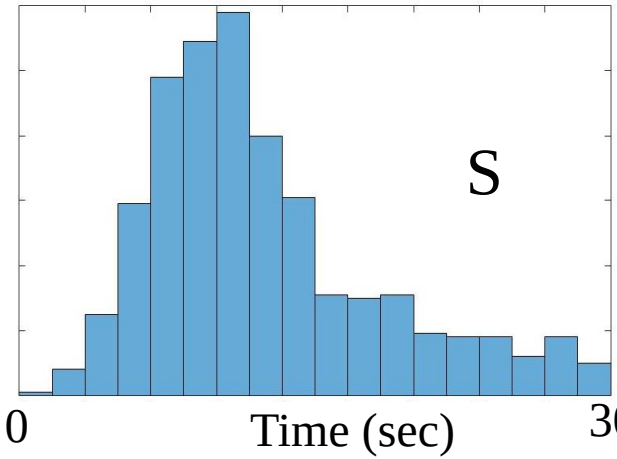


Experiment I – Results from location a_3

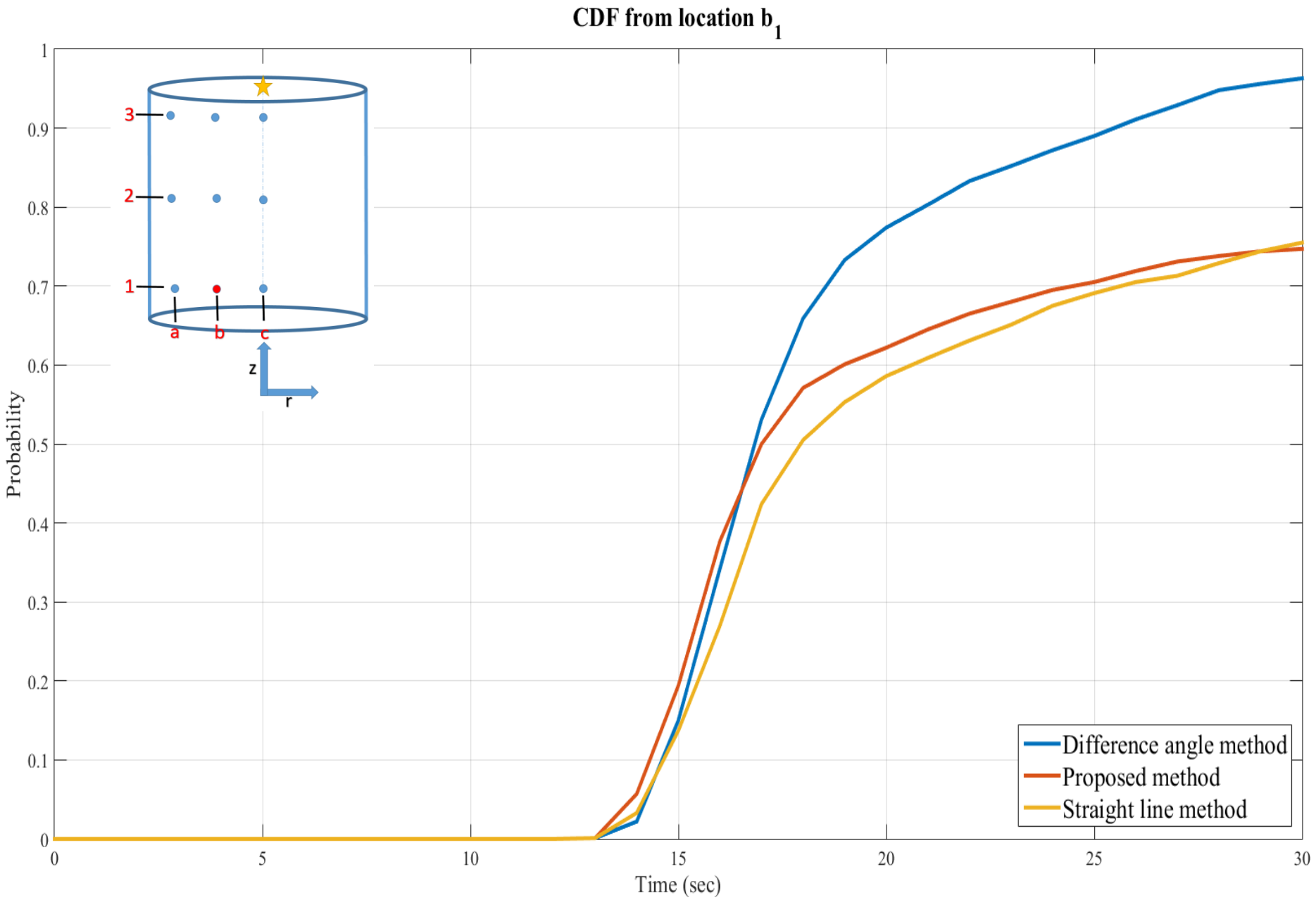


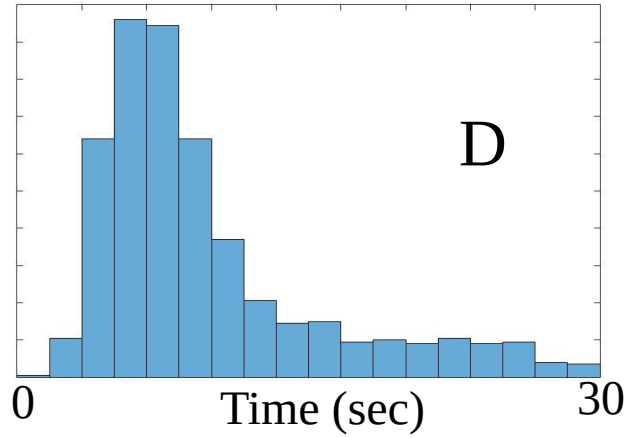


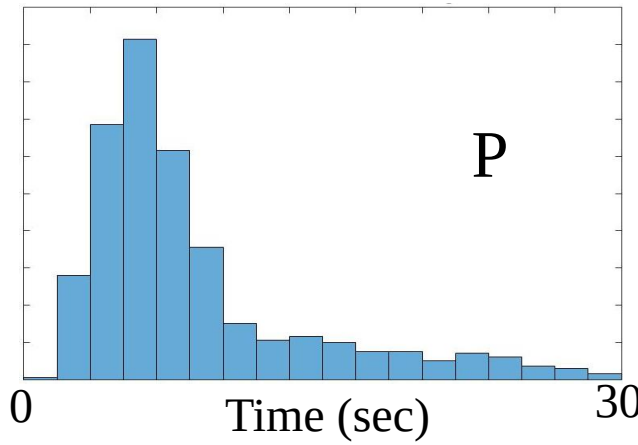


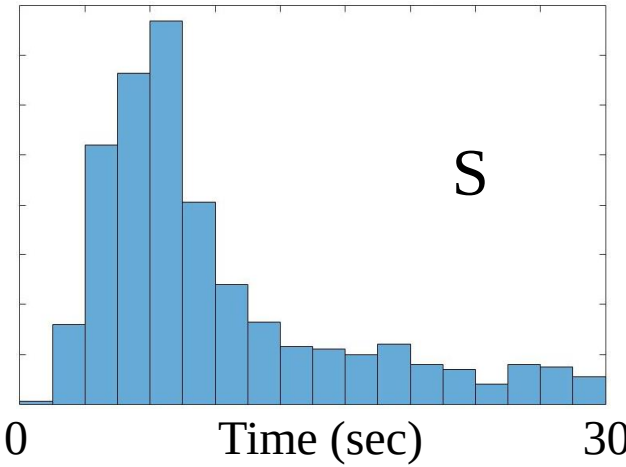


Experiment I – Results from location b_1

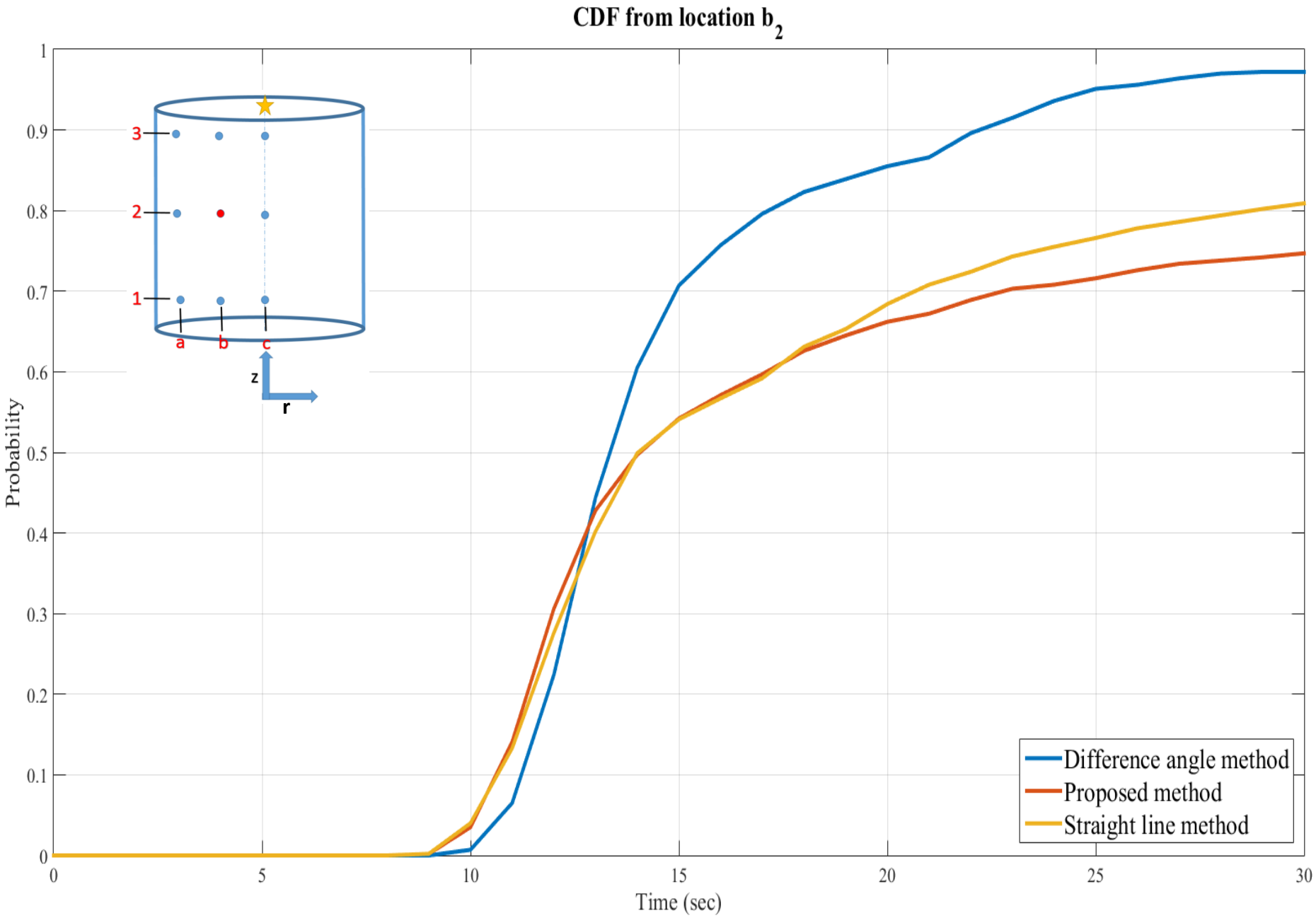


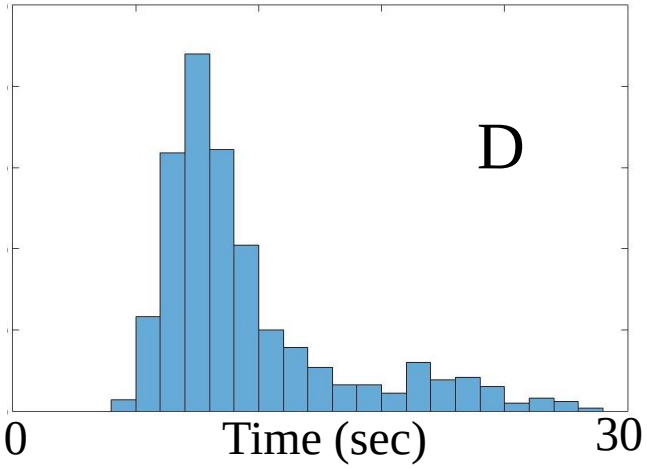


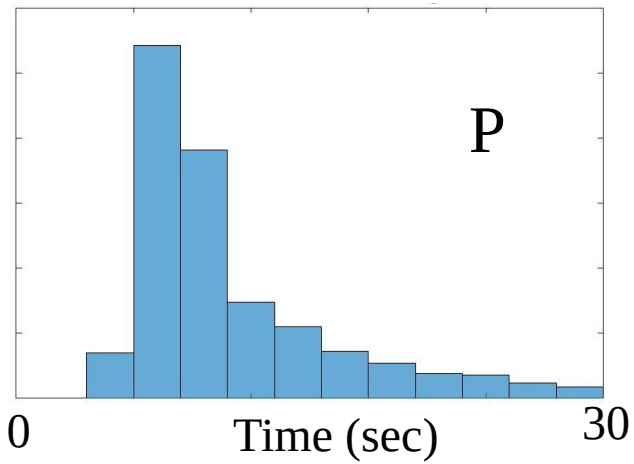


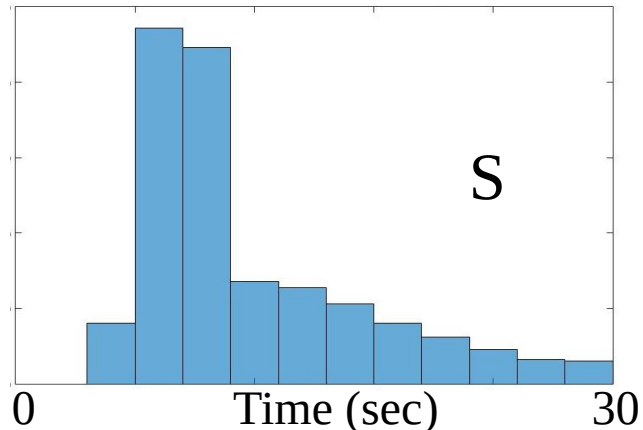


Experiment I – Results from location b_2

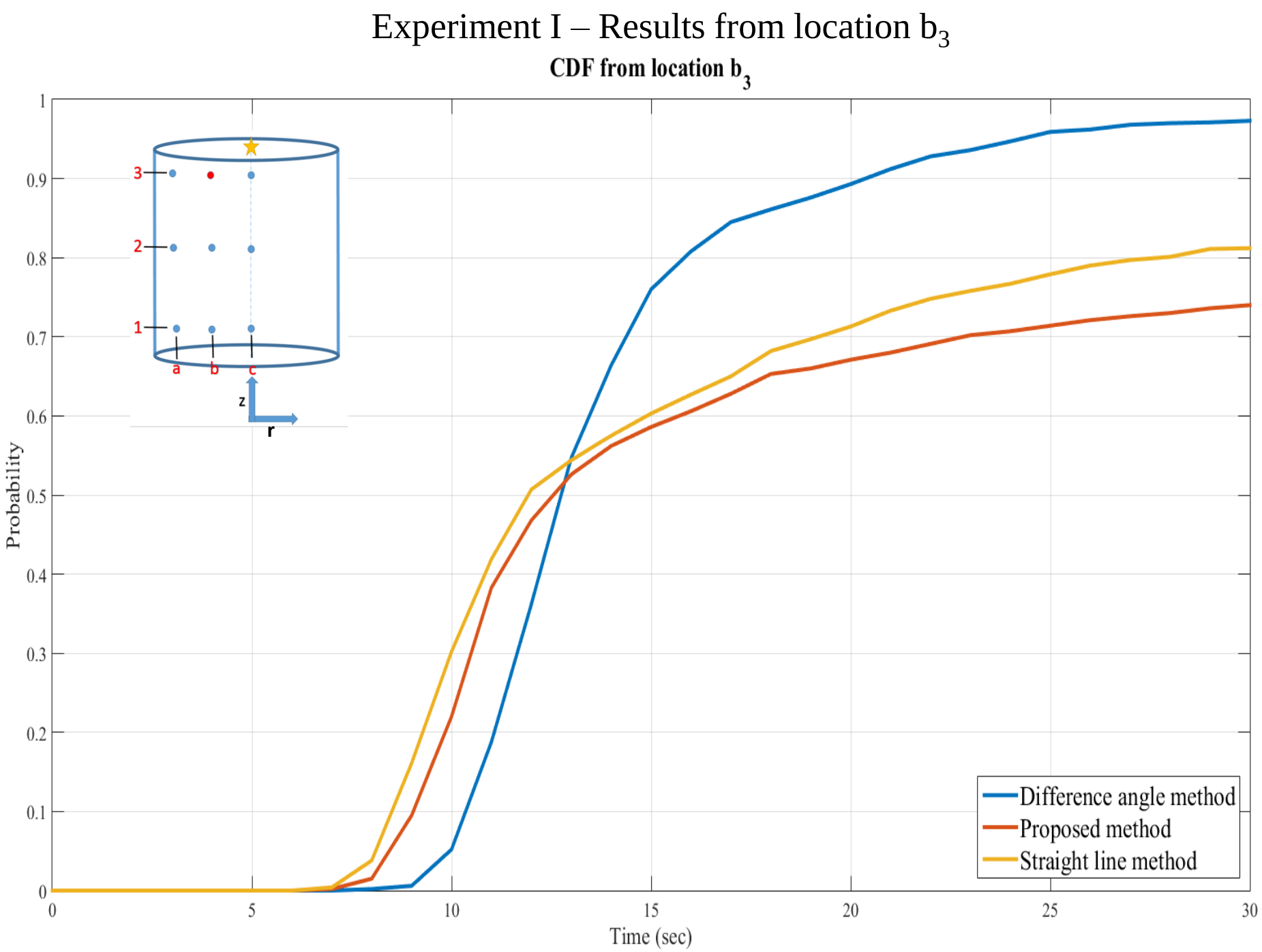


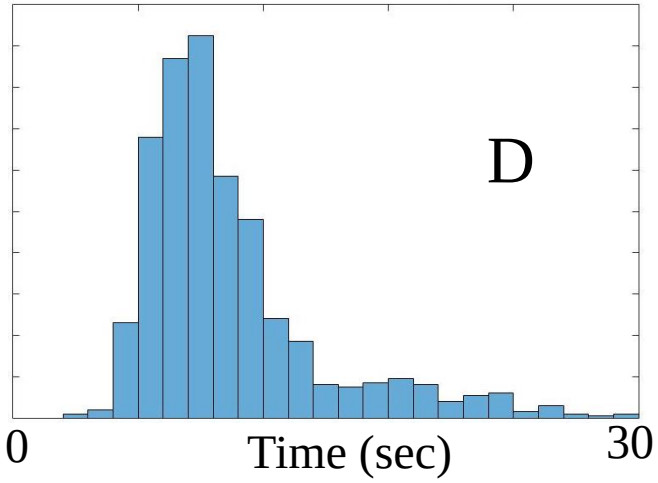


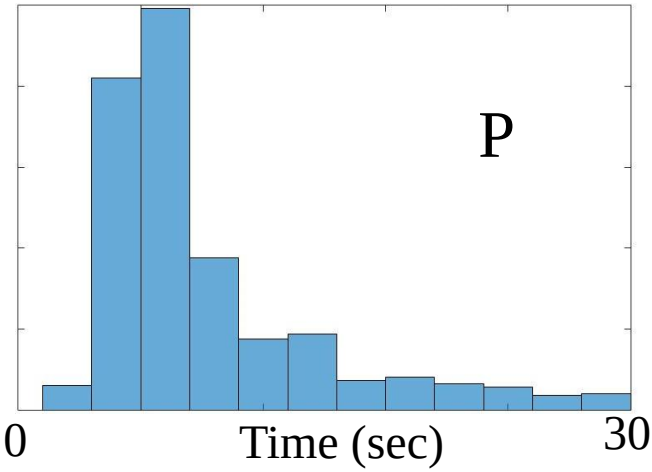


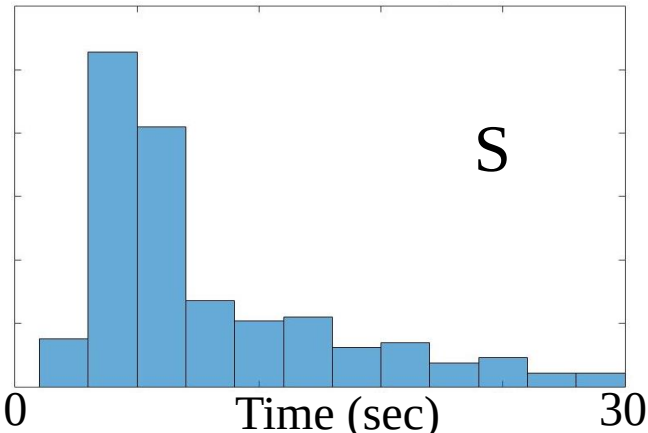


Experiment I – Results from location b_3







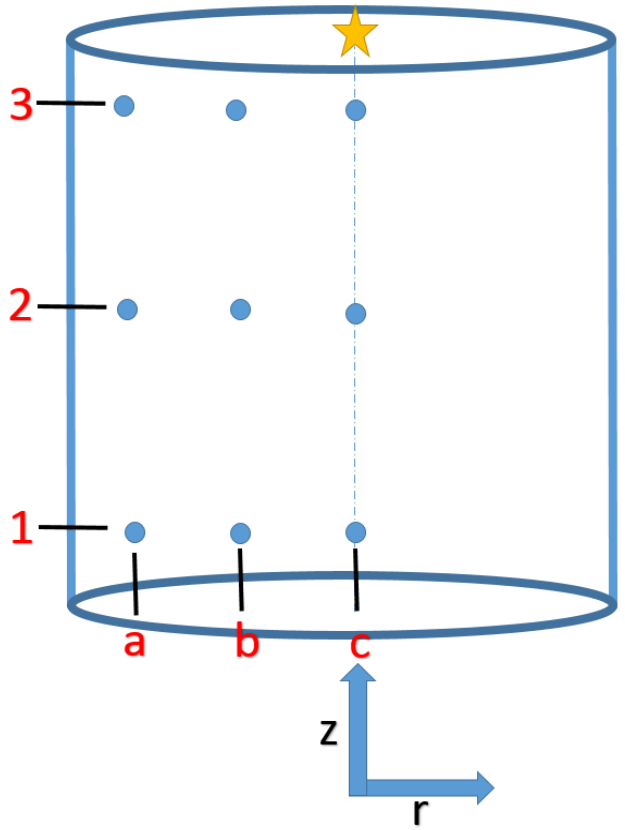


Monte Carlo Experiments

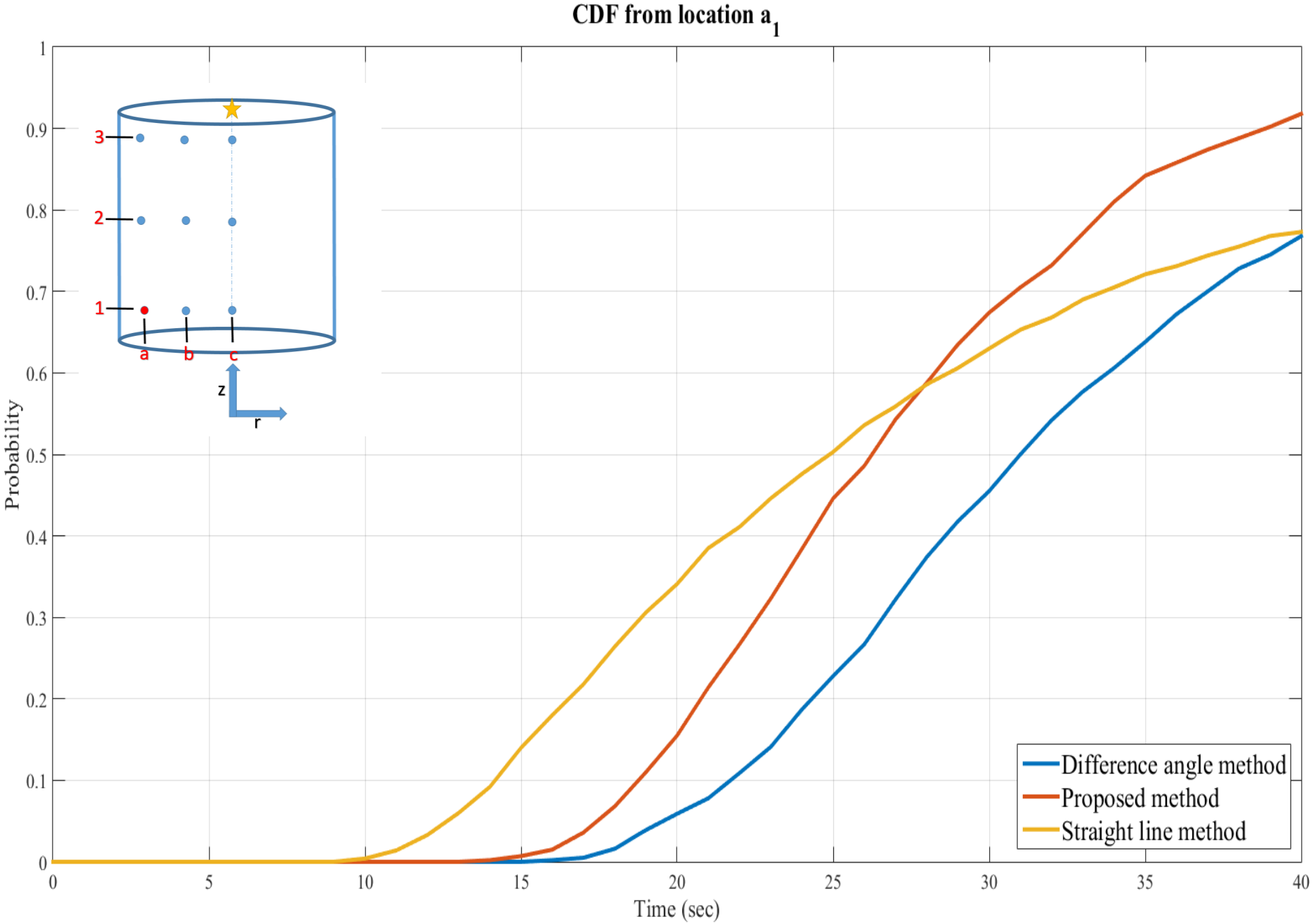
Experiment II Setup:

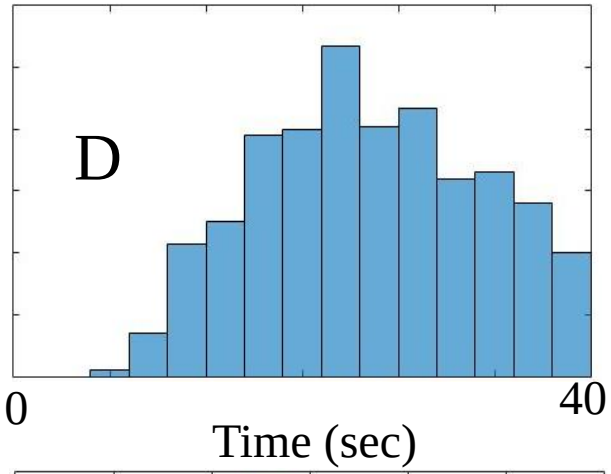
Experiment II
PD Controller (Constant Gains)
Disturbance: Mean=0, Variance=0.01
Scheduled Planner Gain
Docking region limit 0.043
Proposed method weights (A = 2, B =50)
Straight line method (A = 0, B =50)
Number of Monte Carlo runs : 1000

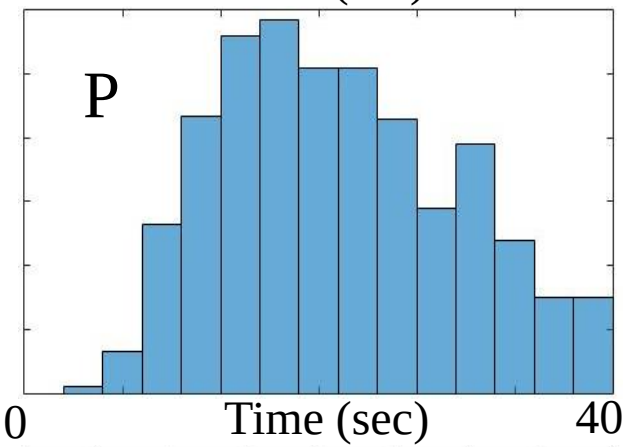
a_1 (0.95, 0.15)	a_2 (0.95, 1)	a_3 (0.95, 1.85)
b_1 (0.5, 0.15)	b_2 (0.5, 1)	b_3 (0.5, 1.85)
c_1 (0, 0.15)	c_2 (0, 1)	c_3 (0, 1.85)

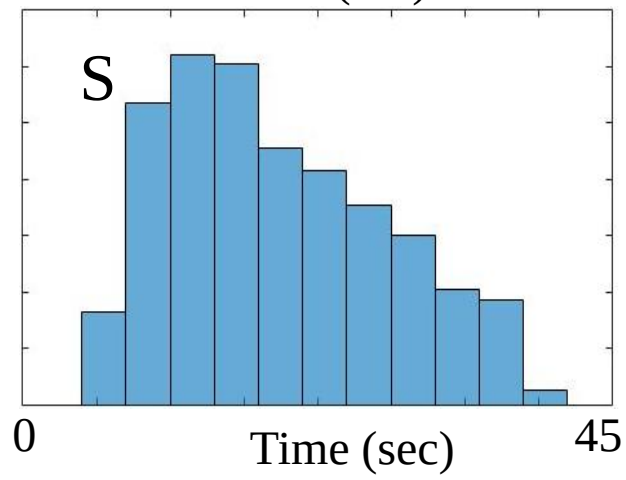


Experiment II – Results from location a_1

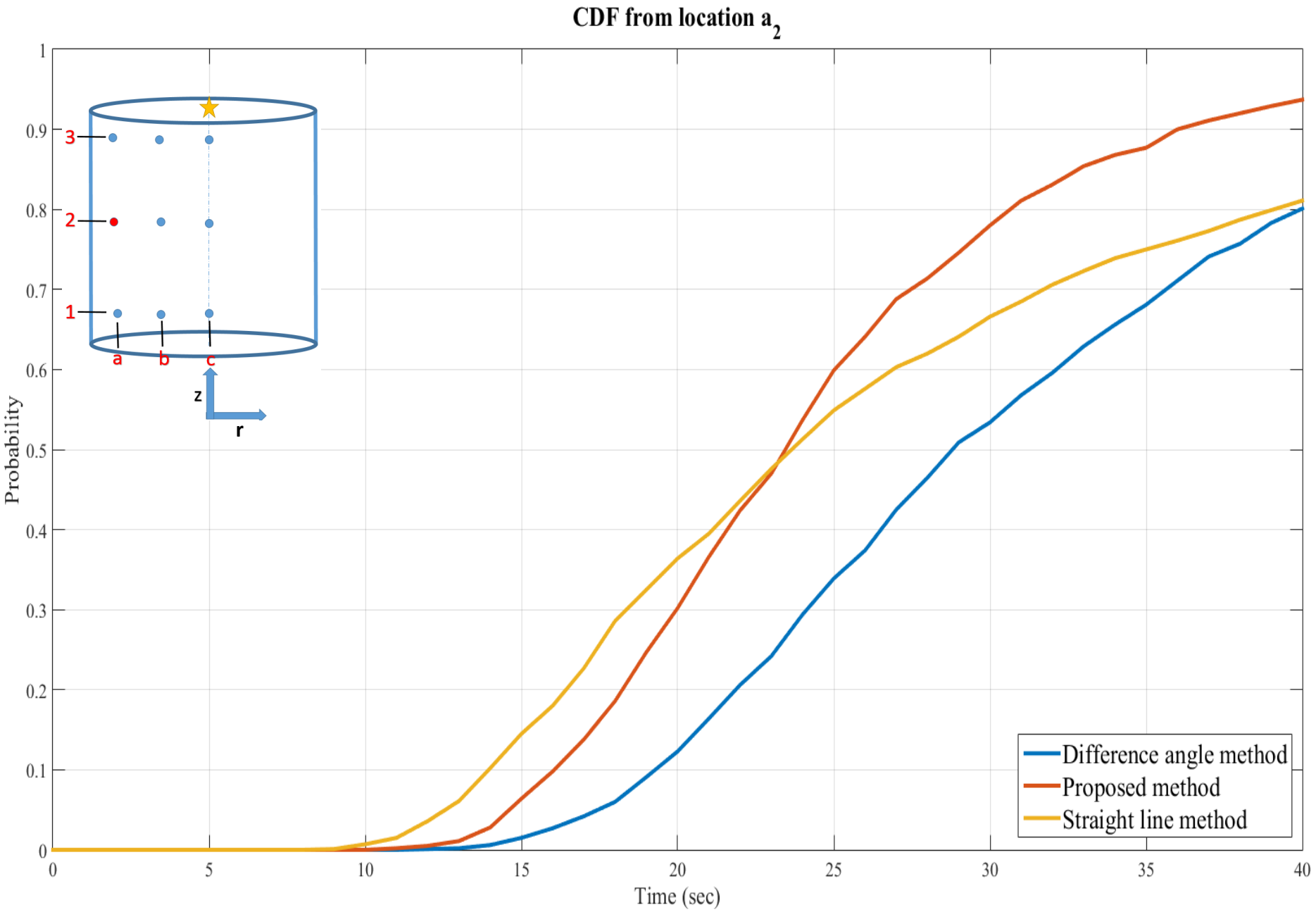


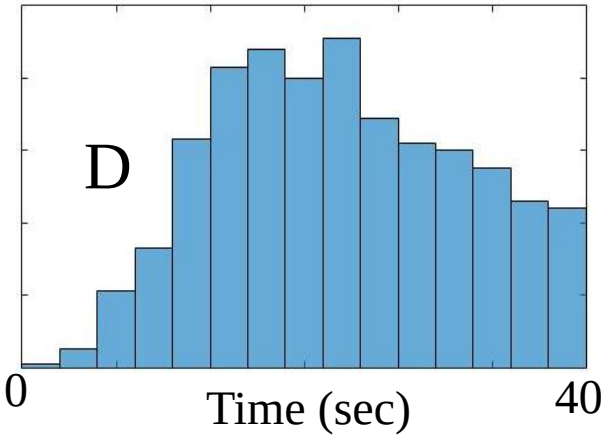


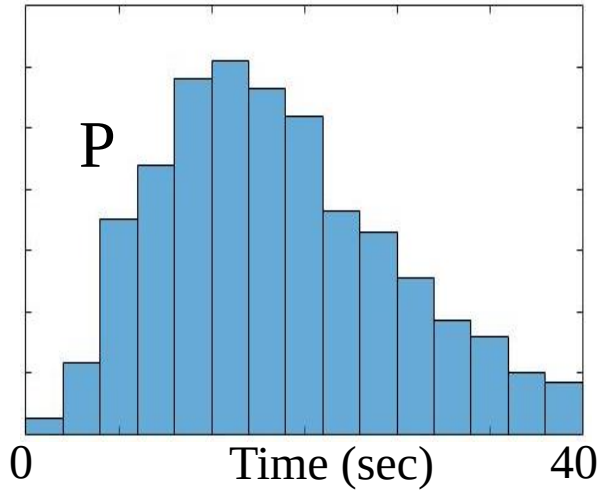


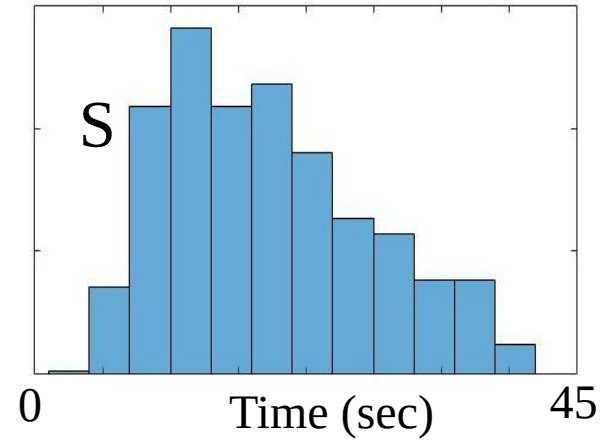


Experiment II – Results from location a_2

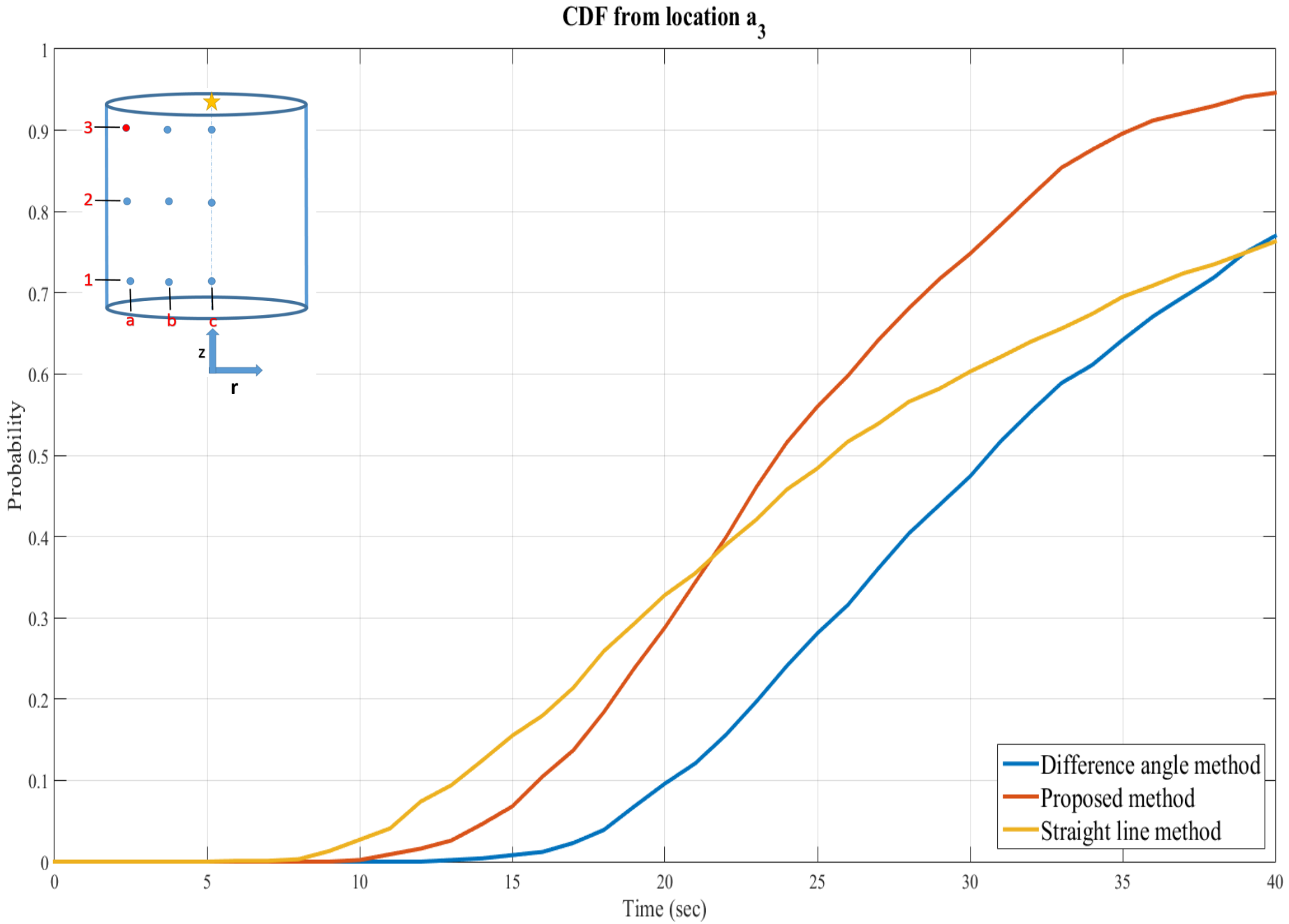


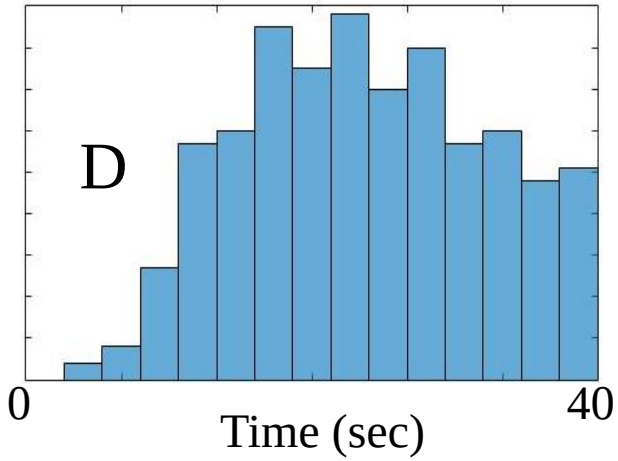


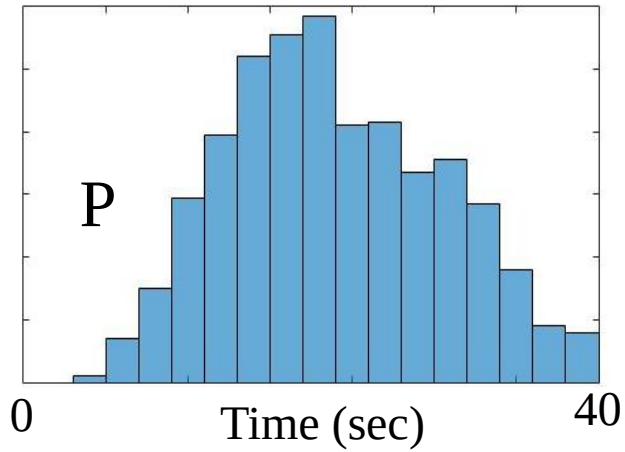


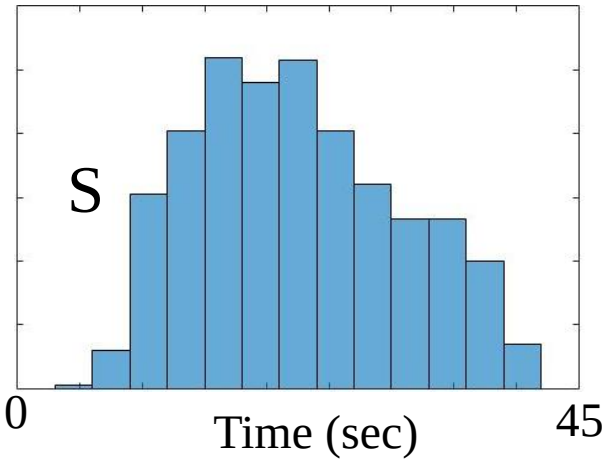


Experiment II – Results from location a_3

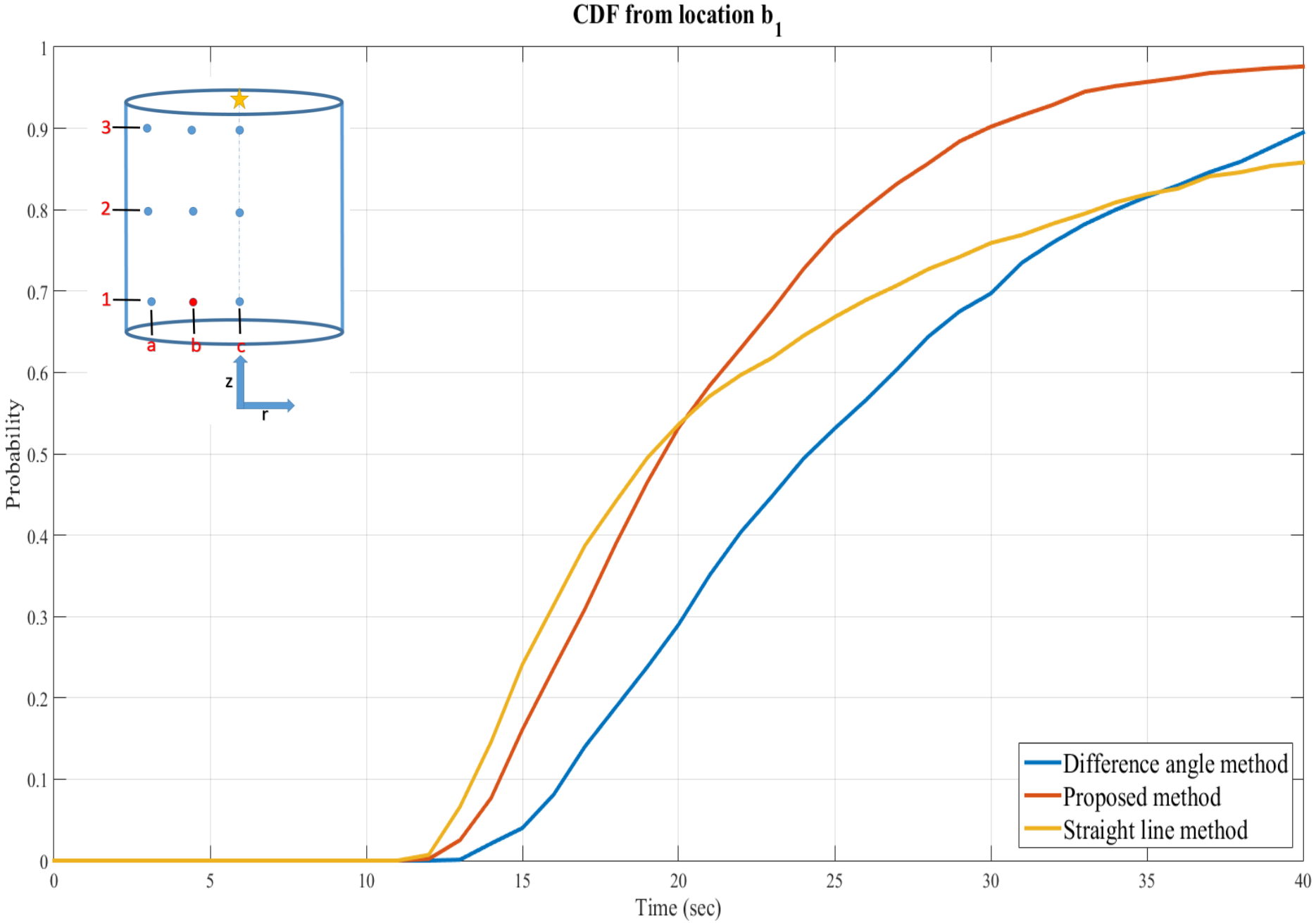


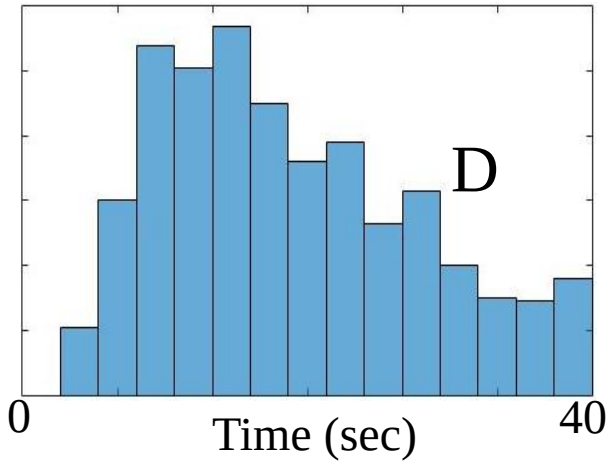


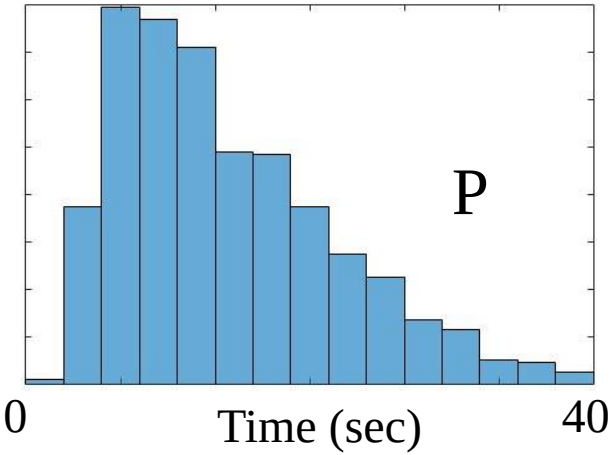


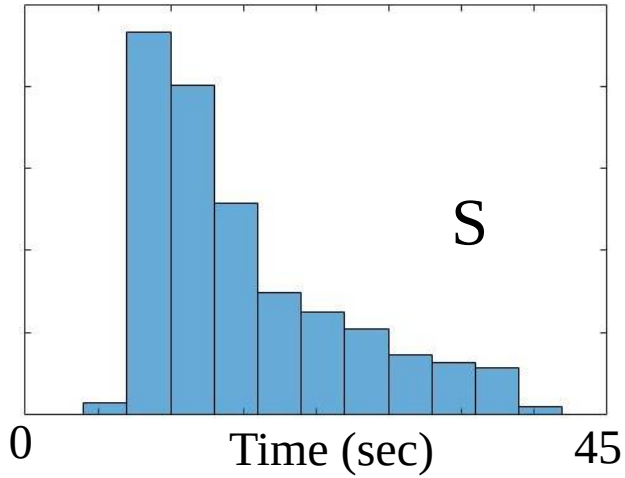


Experiment II – Results from location b_1

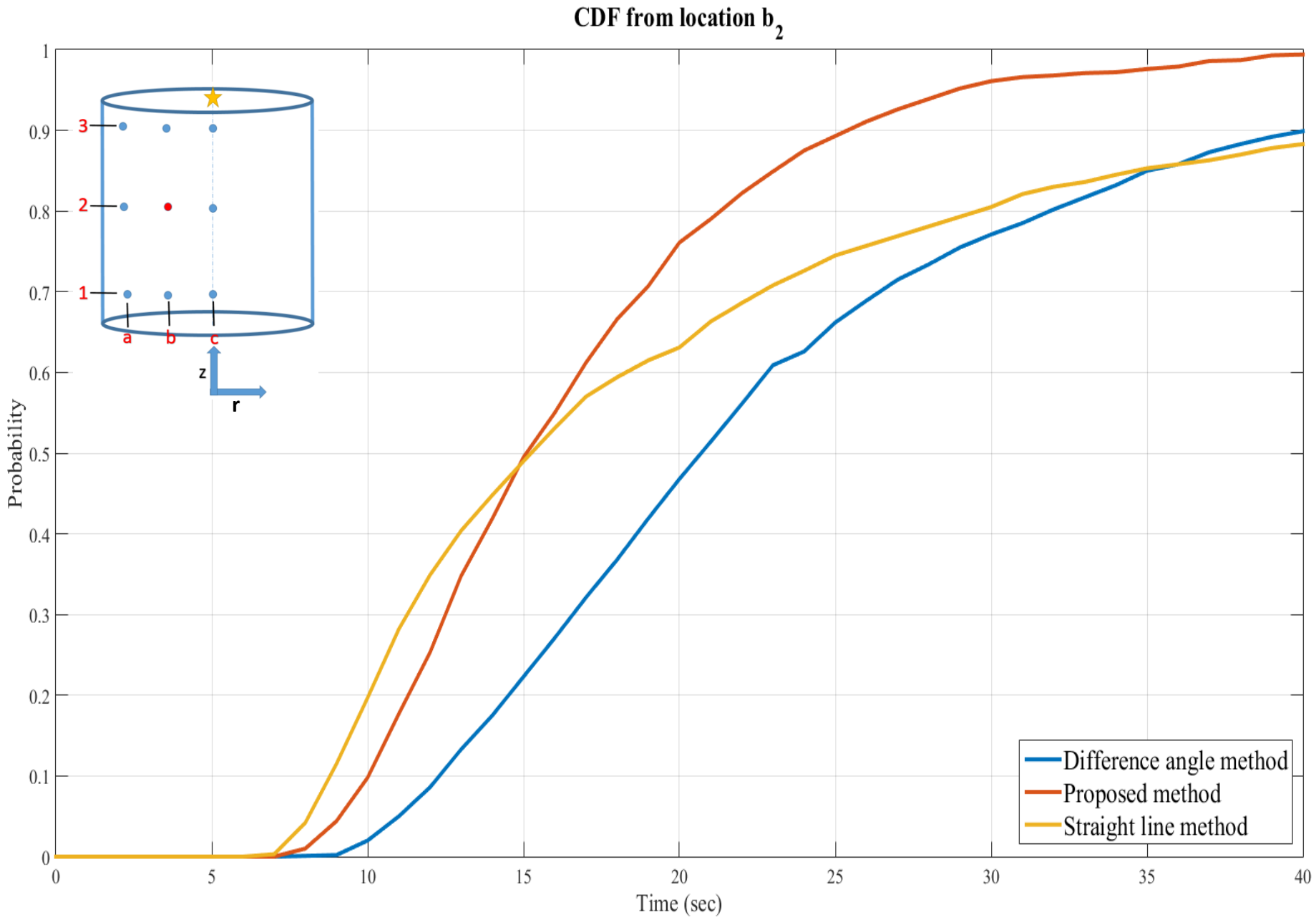


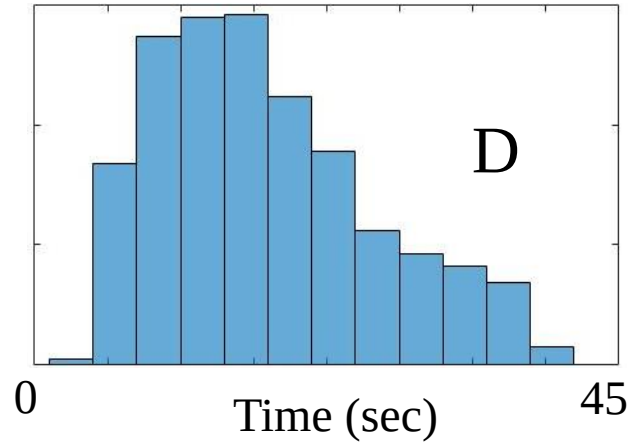


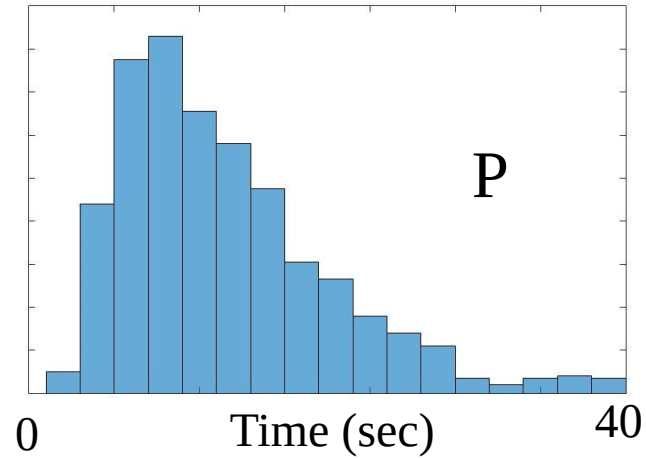


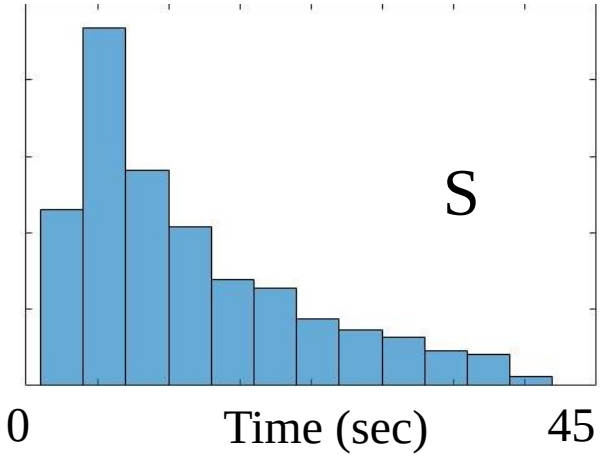


Experiment II – Results from location b_2

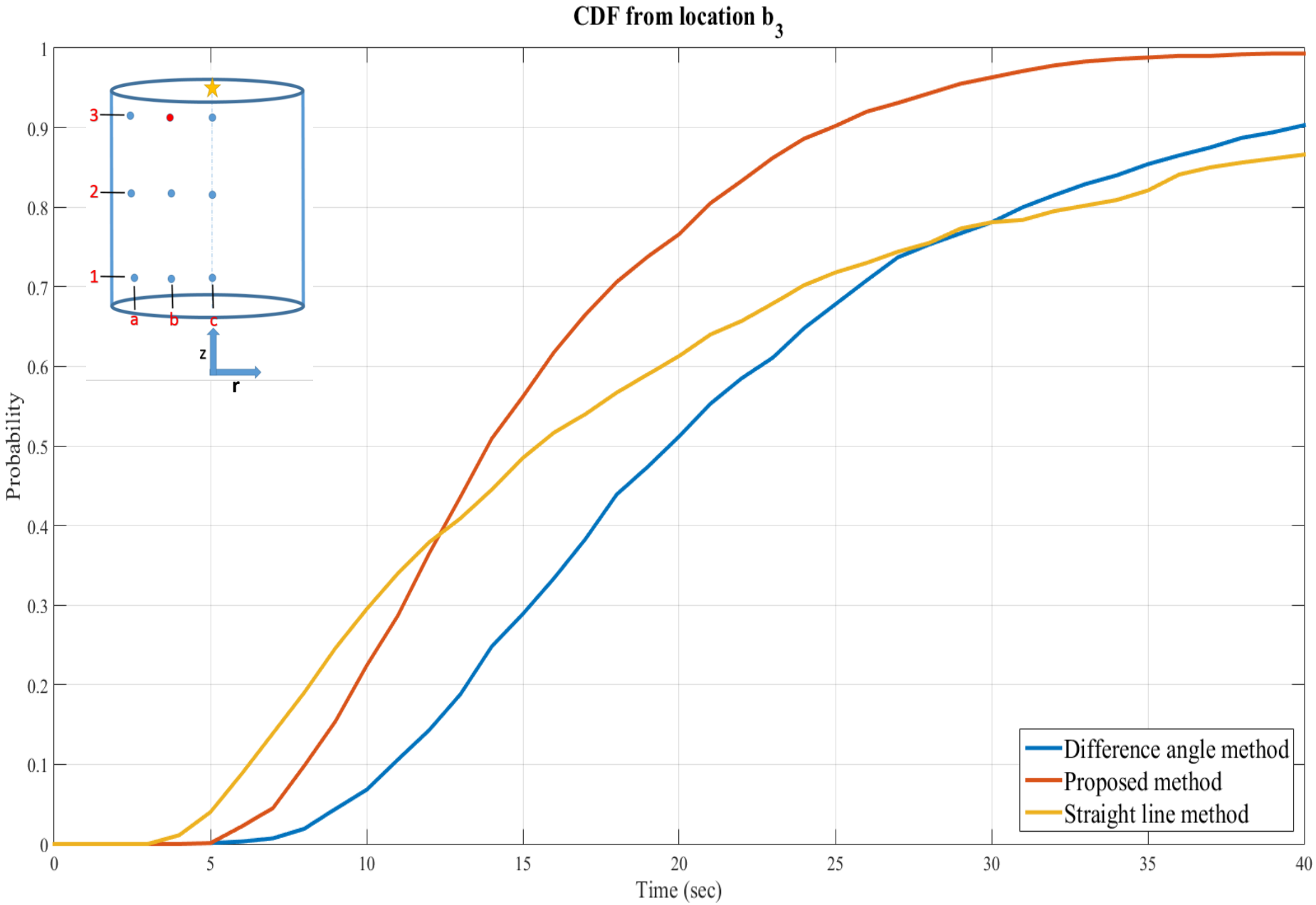


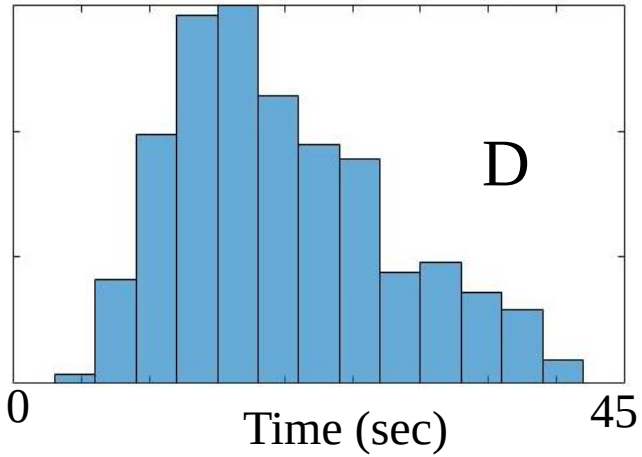


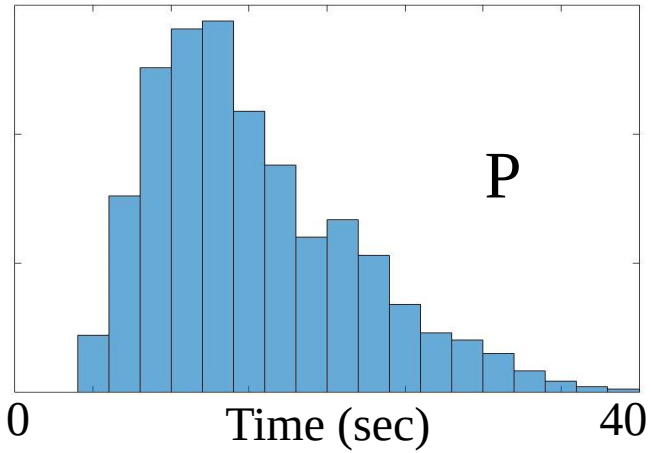


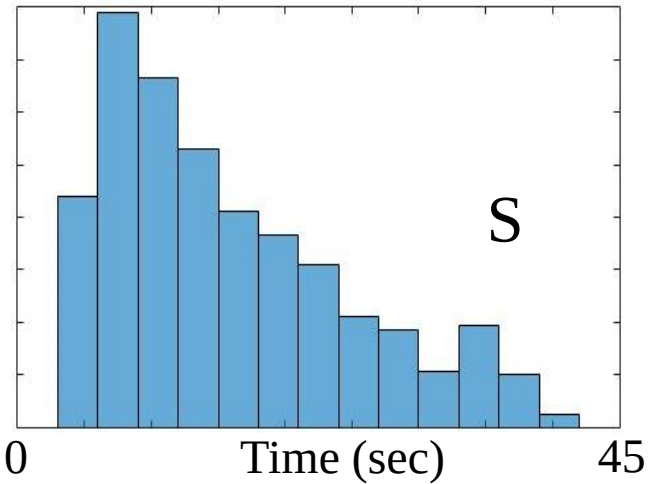


Experiment II – Results from location b_3









Future Work

- Simulations with other types of controllers
- Flight tests