Spacecraft Dynamics Lecture - UUM571 - Project Part 2

Name and Surname: Resul Dagdanov

Student ID: 511211135

- Istanbul Technical University
- ITU Aeronautical and Astronautical Engineering

Project Part 2 Overview

- Detecting Mars eclipse.
- Kalman filter for estimating sensor measurements
- **Stages**:
  - 1) General information about Kalman Filter
  - 2) Detect Mars eclipse or shadow in parking orbit
  - 3) Construction of the EKF algorithm
  - 4) Apply two experimental cases with/out Rate-Gyro
  - 5) Calculate RMS Errors

Extended Kalman Filter Introduction

- Applied for both non-linear and linear systems.

$$x_k = f(x_{k-1}, u_k) + w_k$$

$$y_k = h(x_k) + v_k$$

$$K(k) = P(k|k-1) * H(k)^T * (H(k) * P(k|k-1) * H(k)^T + R(k))^{-1}$$

$$x(k|k) = x(k|k-1) + K(k) * y(k)$$

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F: state transition matrix
H: observation matrix
Q: process noise covariance
R: measurement noise covariance
x: initial state estimate
P: initial covariance estimate
z: measurement vector
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Detect Mars Eclipse

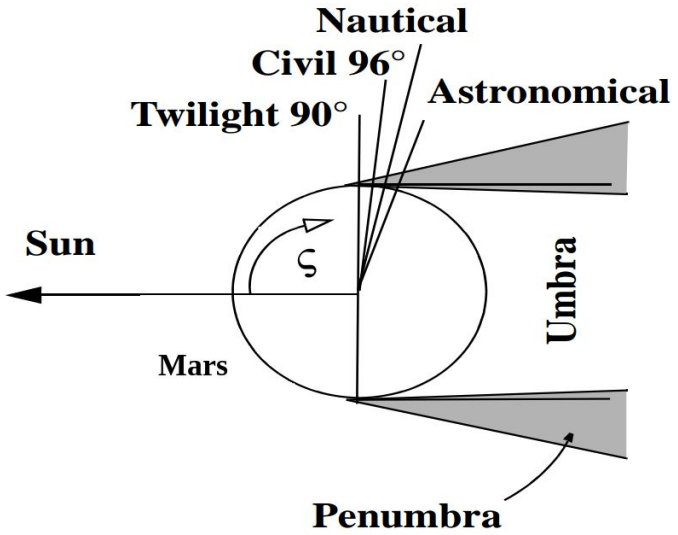
- From Project Part 1, the spacecraft will be on a 300 km parking orbit of Mars on the date 2024 year, January month, 24th day, hour 10 a.m., 59 minutes, and 59 Seconds.

Julian Date $J_D = 2.4603339 \text{ x } 10^6$

$$L = mod(280.459^o + (n \text{ x } 0.98564736^o),\ 360^o)$$

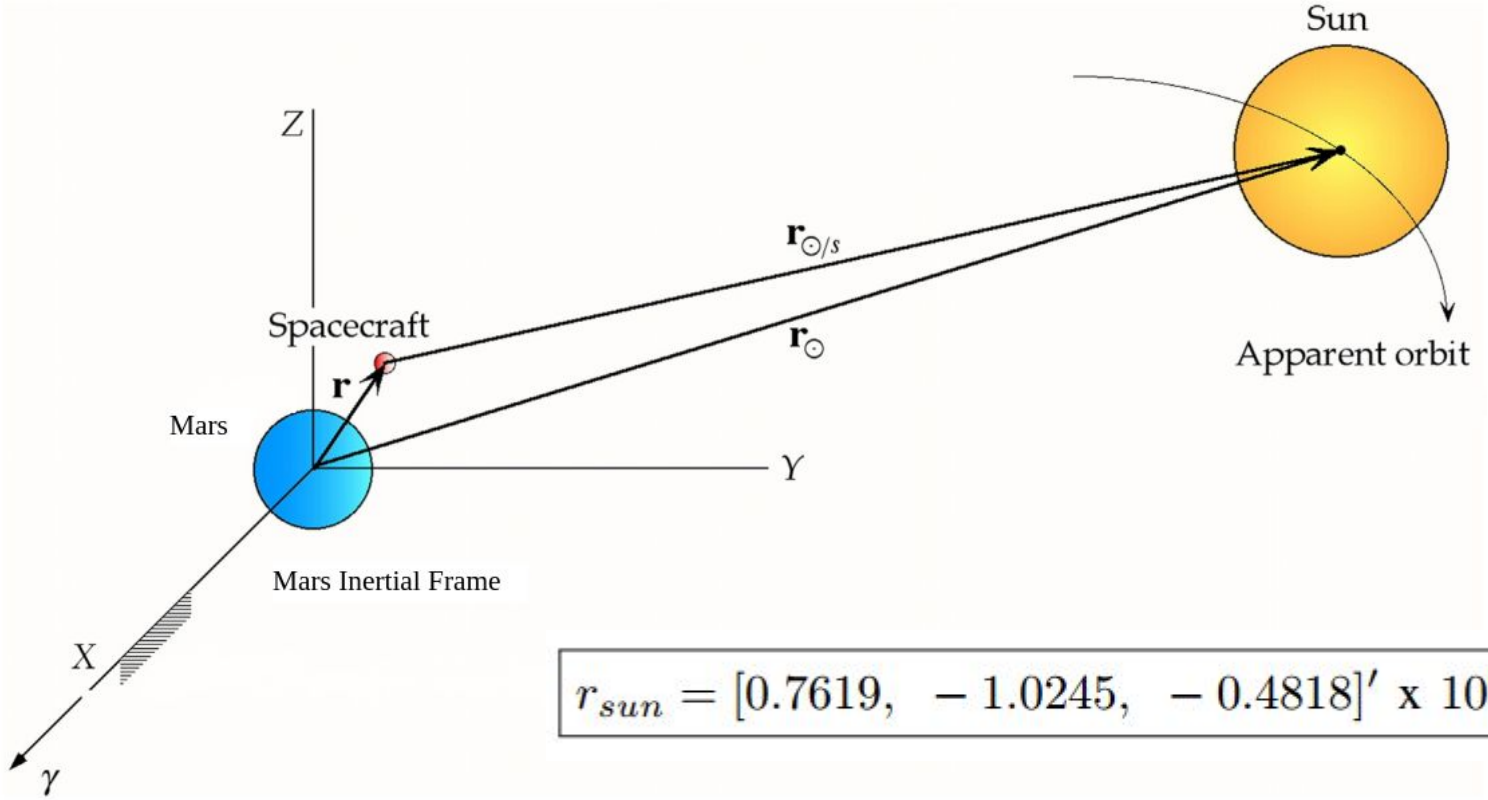
Longitude and Mean Anomaly of Mars $L = 303.2726^o$

$M = 19.9280^o$



$T_{eclipse} = 1145sec$

Sun Position Vector



$$r_{sun} = [0.7619, \ -1.0245, \ -0.4818]' \text{ x } 10^8 km$$

EKF Approach

- Zero mean gaussian noise for both dynamic and measurement functions

$$E[w(k)] = E[v(k)] = 0, \quad \forall k$$

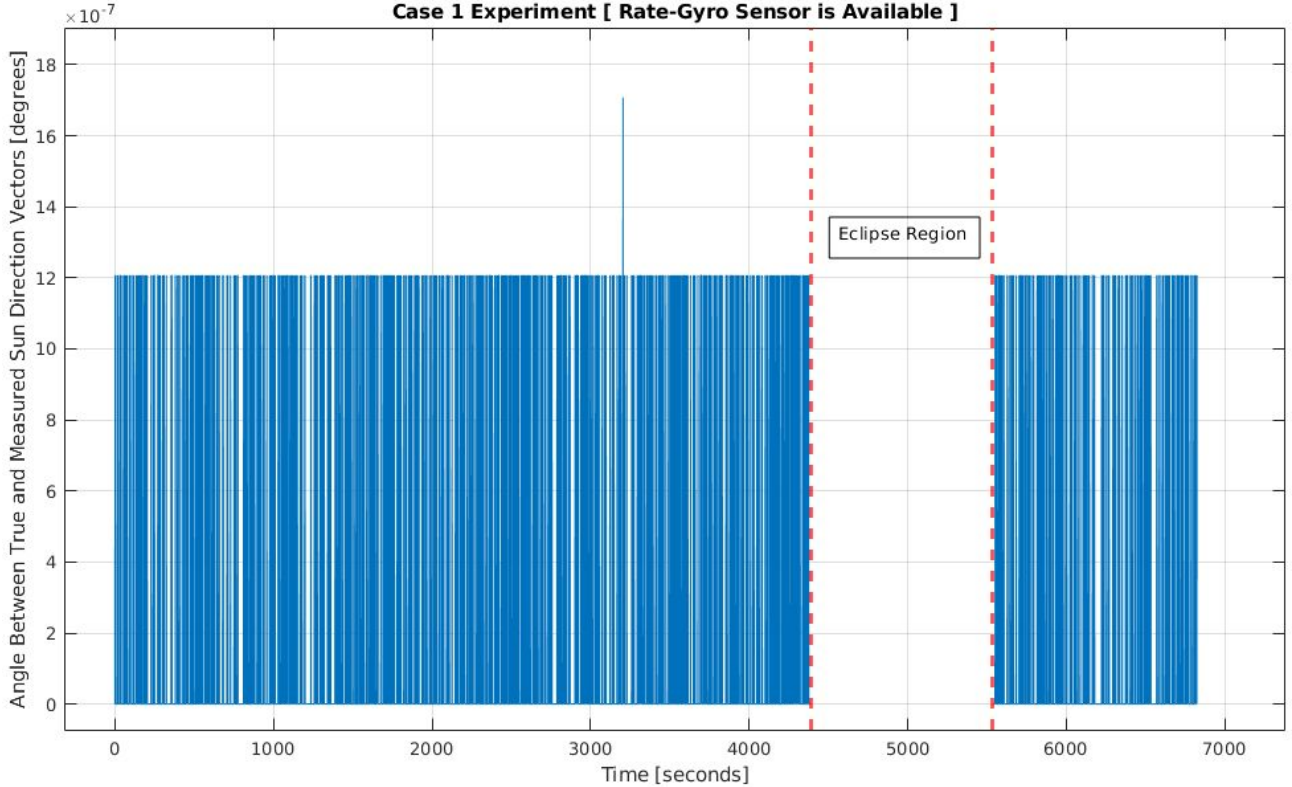
$$h_i(x) = n_i * d$$

$$H(x) = [n_1^T, n_2^T, ..., n_i^T]^T$$

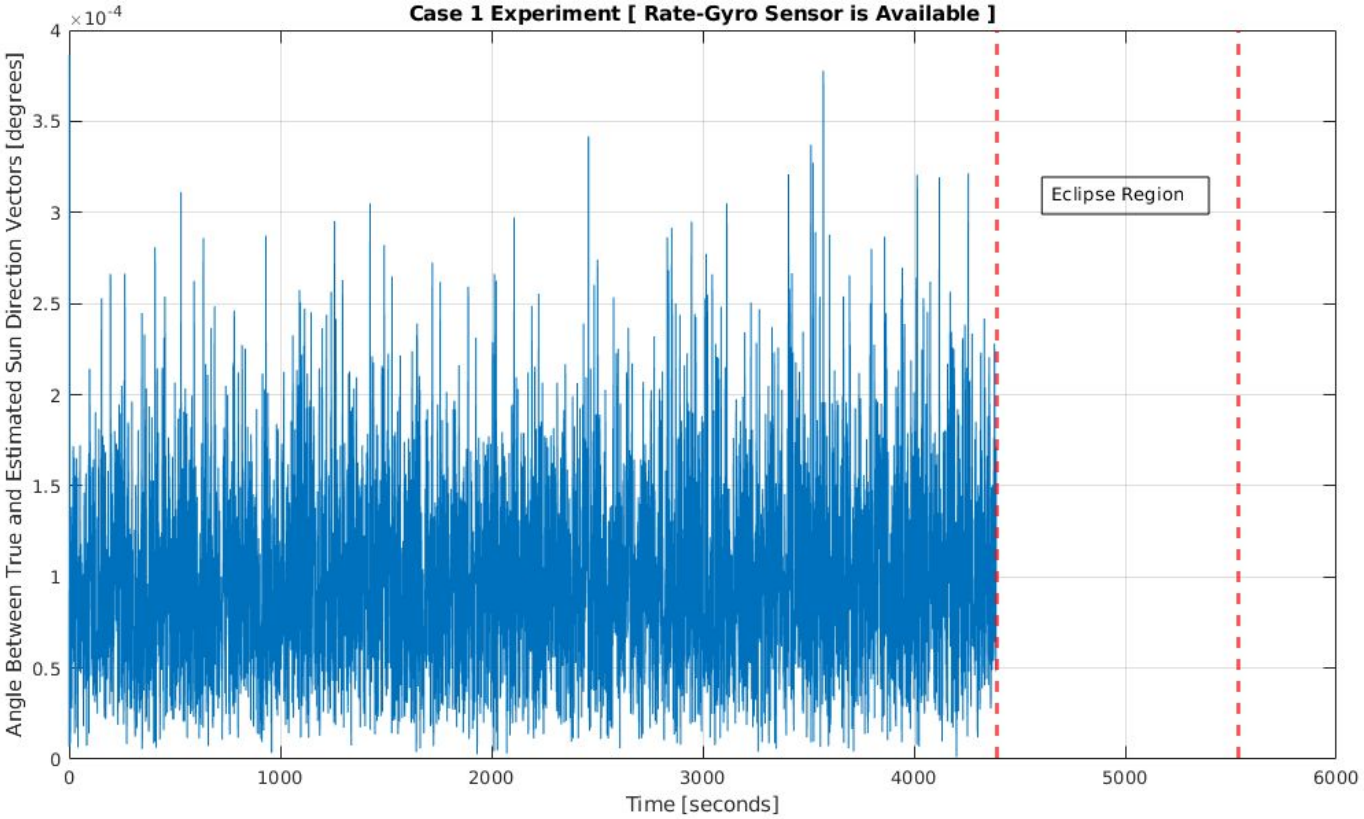
$$H = \begin{Bmatrix} n_1 \\ n_2 \\ n_3 \\ n_4 \\ n_5 \\ n_6 \\ n_7 \\ n_8 \end{Bmatrix} = \begin{bmatrix} a & -b & b \\ a & -b & -b \\ a & b & -b \\ a & b & b \\ -a & -b & b \\ -a & -b & -b \\ -a & b & -b \\ -a & b & b \end{bmatrix}$$

$$\boxed{a = \frac{\sqrt{2}}{2}} \text{ and } \boxed{b = 0.5}$$

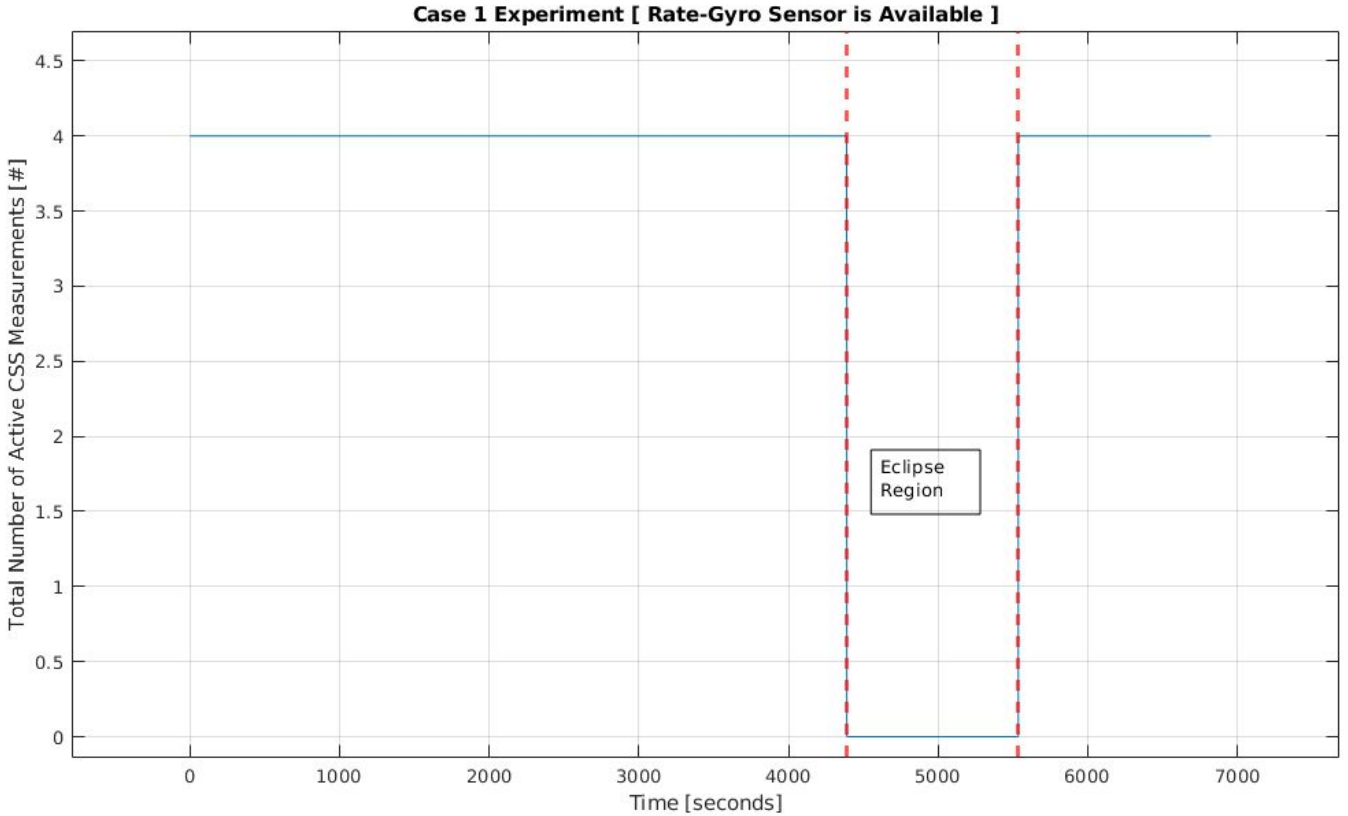
Experiments Case 1



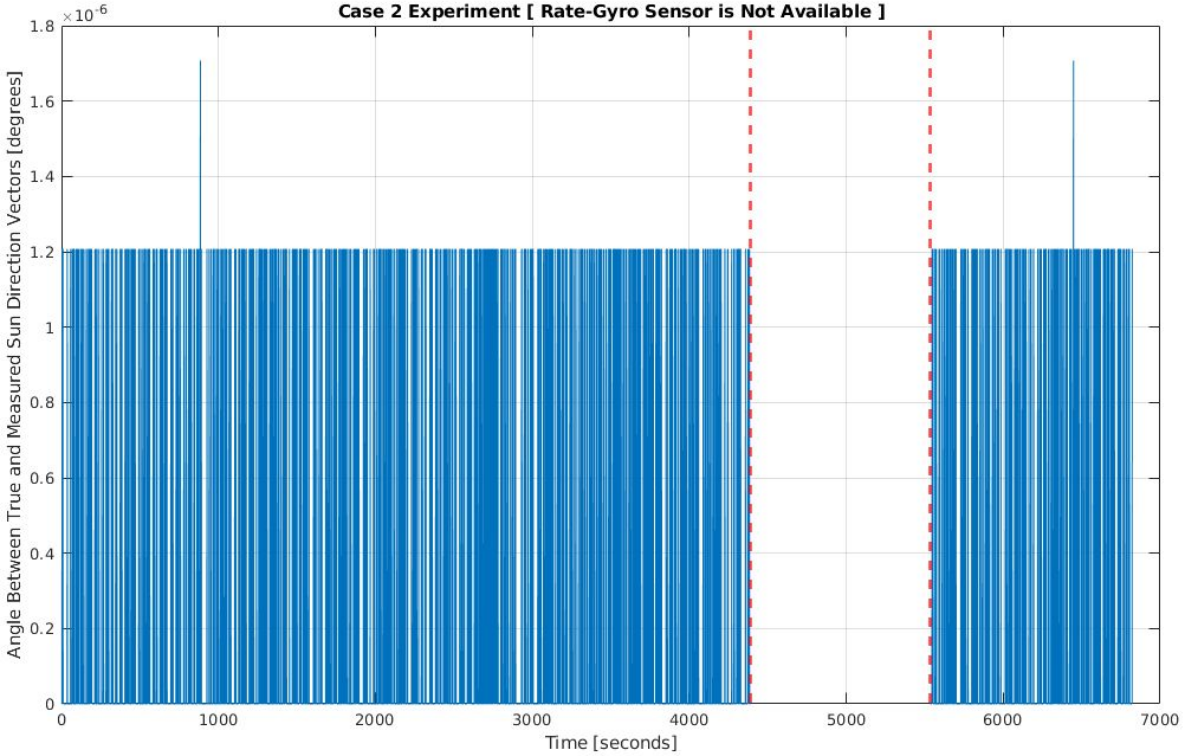
Experiments Case 1



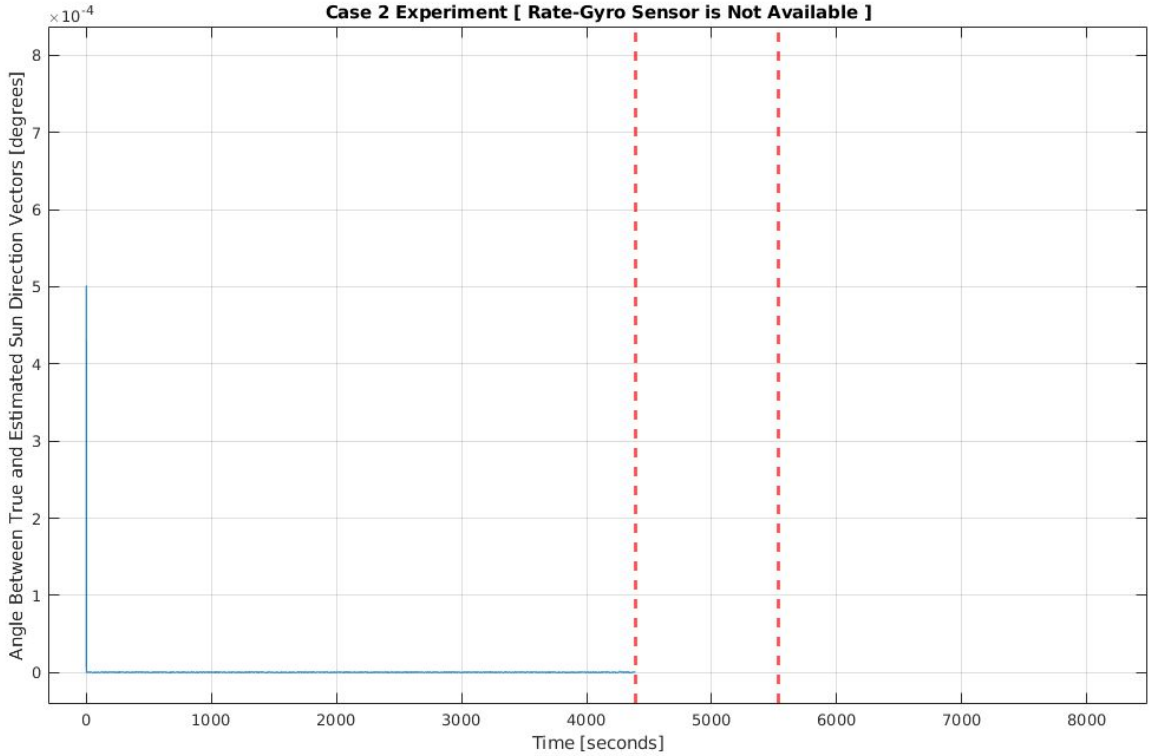
Experiments Case 1



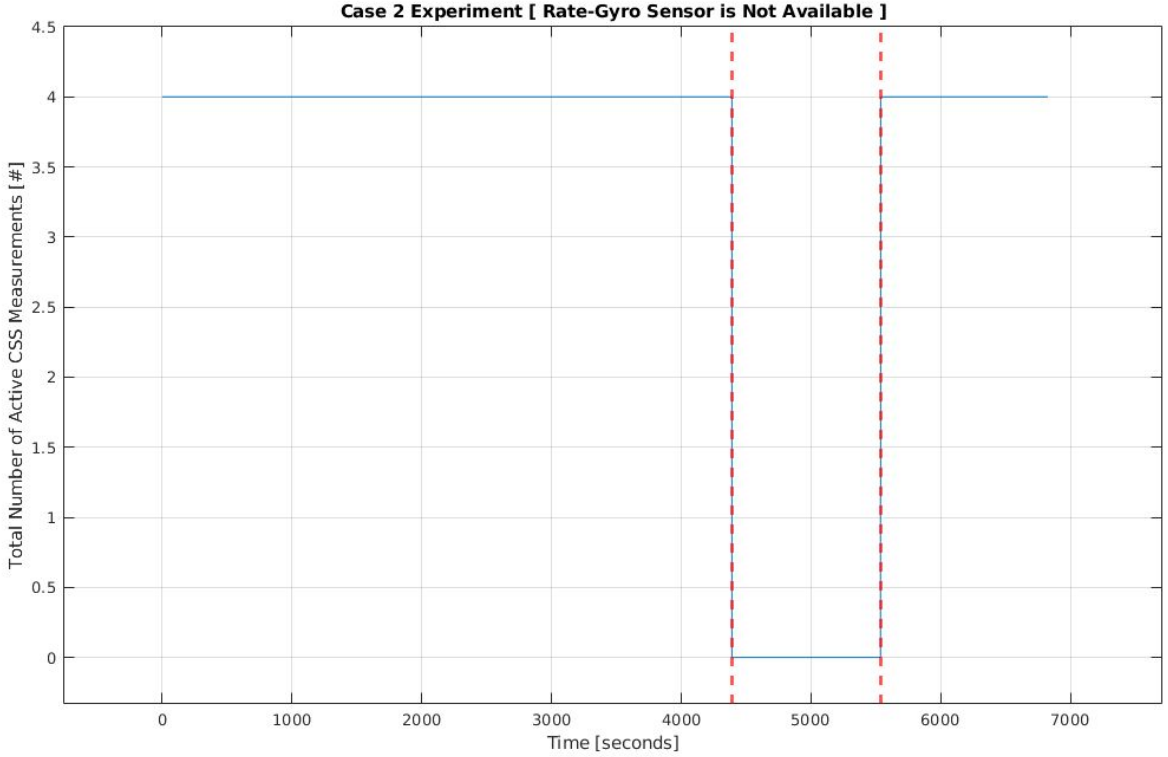
Experiments Case 2



Experiments Case 2



Experiments Case 2



RMS Errors in Sun Direction Estimation

Case 1: (Rate-Gyro available)

RMS Error Angle Between True and Estimated: **217.2029 km**

Case 2: (Rate-Gyro not available)

RMS Error Angle Between True and Estimated: **16.1830 km**

Conclusion

- Codes and simulation are conducted in MATLAB.
- Detailed report is submitted to the Ninova system with all codes and simulations, including LaTEX file.