APPENDIX

**Appendix A: Quad Rotor System**

**A1. State Vector**

[X Y Z Phi Theta Psi X’ Y’ Z’ Phi’ Theta’ Psi’]

**A2. Control Vector**

[U1 U2 U3 U4]

**A3. Quad Rotor Constants**

|  |  |
| --- | --- |
| Variable | Value |
| Moment of Inertia about the X axis | 2.297e-2 |
| Moment of Inertia about the Y axis | 2.297e-2 |
| Moment of Inertia about the Z axis | 4.935e-2 |
| Total Rotational Moment of Inertia around the propeller axis | 6.5e-5 |
| Mass in Kg | 1.89 |
| Thrust Factor | 1 |
| Drag Factor | 0.3048 |
| Length of Arms (Distance from Rotor to center) | 0.23 |

**Appendix B: Ducted Fan System**

**B1. The State Vector**

[Phi Theta Psi P Q R]

**B2. Control Vector**

[d1 d2 d3 d4 dt]

**B3. The A matrix**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 0 | 0 | 0 | 1 | -1.3103e-16 | 2.4495e-08 |
| 0 | 0 | 0 | 0 | 1 | 5.3493e-09 |
| 0 | 0 | 0 | 0 | -5.3493e-09 | 1 |
| 0 | 0 | 0 | 0 | 7.1782 | 0 |
| 0 | 0 | 0 | -6.7417 | 0 | 0 |
| 0 | 0 | 0 | 0 | 1.7951e-16 | 0 |

**B4. The B matrix**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 |
| -0.43279 | -0.43279 | -6.2763e-18 | 6.2763e-18 | -7.3552e-12 |
| 0 | 0 | -0.40647 | -0.40647 | -1.7118e-10 |
| 0.18763 | -0.18763 | -0.18763 | 0.18763 | -5.7012e-05 |

**B5. Sate and Input Values for Hover State**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Phi | Theta | Psi | P | Q | R | D1 | D2 | D3 | D4 | dt |
| 1.23e-7 | 1.95e-7 | -0.108 | 0 | 0 | 0 | 0.32 | 0.32 | 0.32 | 0.32 | 8301.46 |

**Appendix C: Control Matrices**

**C1. The Q Matrix**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 |

**C2. The R Matrix**

|  |  |  |  |
| --- | --- | --- | --- |
| 100000 | 0 | 0 | 0 |
| 0 | 100000 | 0 | 0 |
| 0 | 0 | 100000 | 0 |
| 0 | 0 | 0 | 100000 |

**C3. The A Matrix**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 0 | 0 | 0 | 0 | -9.81 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 9.81 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

**C4. The B Matrix**

|  |  |  |  |
| --- | --- | --- | --- |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |
| -0.5291 | -0.5291 | -0.5291 | -0.5291 |
| 0 | -13.269 | 0 | 13.269 |
| 13.269 | 0 | -13.269 | 0 |
| 0.0013171 | -0.0013171 | 0.0013171 | -0.0013171 |

**Appendix D: Graphs**