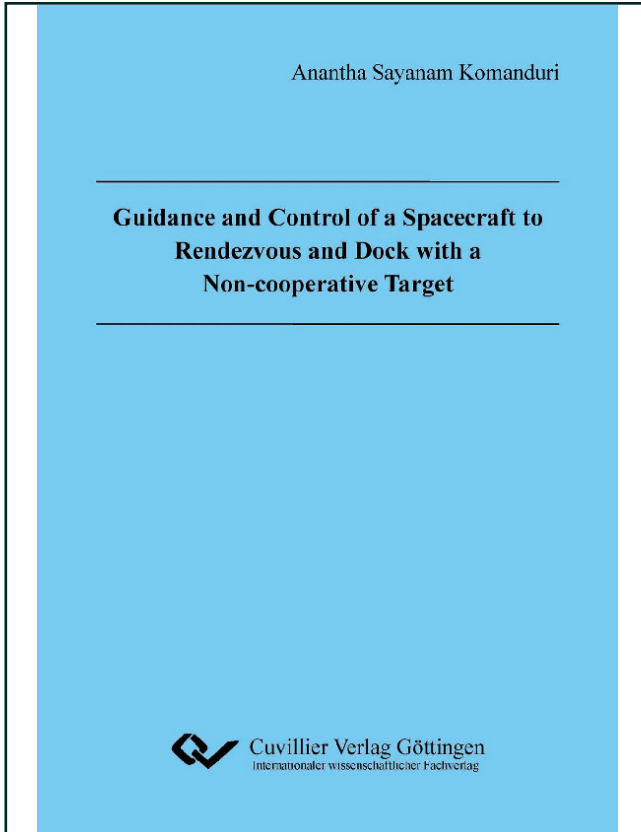




Anantha Sayanam Komanduri (Autor)  
**Guidance and Control of a Spacecraft to Rendezvous and Dock  
with a Non-cooperative Target**



<https://cuvillier.de/de/shop/publications/180>

Copyright:

Cuvillier Verlag, Inhaberin Annette Jentzsch-Cuvillier, Nonnenstieg 8, 37075 Göttingen, Germany  
Telefon: +49 (0)551 54724-0, E-Mail: [info@cuvillier.de](mailto:info@cuvillier.de), Website: <https://cuvillier.de>

# Contents

<b>Contents</b>	<b>11</b>
<b>List of Figures</b>	<b>15</b>
<b>List of Tables</b>	<b>19</b>
<b>Acronyms</b>	<b>21</b>
<b>Nomenclature</b>	<b>25</b>
<b>1. Introduction</b>	<b>29</b>
1.1. Space Rendezvous and Docking . . . . .	29
1.2. Cooperative vs Non-cooperative targets . . . . .	29
1.3. Motivation . . . . .	33
1.3.1. OOS with autonomous Rendezvous and Dock(ing) (RVD) technology . . . . .	34
1.4. Historical review . . . . .	35
1.4.1. Brief survey on RVD missions . . . . .	35
1.4.2. Survey on On-Orbit Servicing . . . . .	37
1.4.3. Survey on RVD with non-cooperative targets: current state of art . . . . .	41
1.5. Thesis outline . . . . .	45
1.6. Summary . . . . .	46
<b>2. Problem Statement</b>	<b>47</b>
2.1. Introduction . . . . .	47
2.2. Docking vs berthing . . . . .	47
2.3. Problem description . . . . .	48
2.4. Solution approach . . . . .	51
2.4.1. Assumptions . . . . .	54
2.4.2. Guidance Navigation and Control (GNC) architecture for RVD mission . . . . .	54
2.5. Preliminaries and notations . . . . .	57
2.6. Coordinate frames . . . . .	57
2.6.1. Earth Centered Inertial Frame (ECI) frame . . . . .	57

2.6.2.	Hill frame . . . . .	57
2.6.3.	Spacecraft attitude or body fixed frame . . . . .	58
2.6.4.	Coordinate transformation . . . . .	58
2.7.	Behavior of the non-cooperative target . . . . .	59
<b>3.</b>	<b>Rendezvous Dynamics</b>	<b>63</b>
3.1.	Relative translational dynamics . . . . .	63
3.1.1.	Hill equations . . . . .	66
3.1.2.	State space model . . . . .	67
3.1.3.	Hill Clohessy Wiltshire equations . . . . .	68
3.2.	Chaser attitude kinematics and dynamics . . . . .	71
3.3.	Perturbations and disturbance torques . . . . .	74
3.3.1.	Gravitational torque . . . . .	76
3.3.2.	Aerodynamic torque . . . . .	76
<b>4.</b>	<b>Guidance Strategies</b>	<b>81</b>
4.1.	Previous guidance algorithms proposed for RVD . . . . .	81
4.1.1.	Guidance algorithms proposed for RVD with non-cooperative targets . . . . .	82
4.2.	Path planning algorithms . . . . .	83
4.2.1.	In-plane maneuver: Lambert transfer . . . . .	85
4.2.2.	Any plane inspection maneuver: Elliptical fly around . . . . .	86
4.2.3.	Glideslope algorithm . . . . .	89
4.3.	Proximity approaching phases: guidance options . . . . .	93
4.3.1.	Far range maneuvers . . . . .	95
4.3.2.	Inspection maneuvers . . . . .	96
4.3.3.	Close approach maneuvers . . . . .	99
4.3.4.	Station keeping . . . . .	101
4.3.5.	Solution classification . . . . .	101
4.4.	Guidance solutions for simple cases . . . . .	102
<b>5.</b>	<b>Tracking Controllers</b>	<b>105</b>
5.1.	Issues specific for RVD with a non-cooperative target . . . . .	106
5.1.1.	Navigation issues . . . . .	106
5.1.2.	Control issues . . . . .	108
5.2.	Control algorithms proposed for RVD with non-cooperative targets . . . . .	109
5.3.	Linear Quadratic Regulator (LQR) problem statement and solution . . . . .	110
5.3.1.	Linear tracker . . . . .	111
5.3.2.	LQ regulator design for the rendezvous problem . . . . .	112
5.4.	Chaser attitude control . . . . .	113
5.4.1.	Attitude tracking control law . . . . .	115
5.5.	Summary . . . . .	115

<b>6. Simulation and Results</b>	<b>117</b>
6.1. Safety issues . . . . .	118
6.1.1. Safety analysis . . . . .	118
6.2. Results for important algorithms . . . . .	121
6.2.1. Impulsive maneuvers . . . . .	121
6.2.2. Glideslope . . . . .	122
6.2.3. Lambertian transfer . . . . .	125
6.2.4. Elliptical fly around out-of-plane . . . . .	126
6.3. Comparative study on algorithms . . . . .	129
6.3.1. Far approaches . . . . .	130
6.3.2. Fly around approaches . . . . .	132
6.4. Controller performance . . . . .	136
6.4.1. LQ tracking performance . . . . .	137
6.4.2. LQ control performance during injection at H2: regulation and set point tracking . . . . .	139
6.4.3. Attitude tracking performance . . . . .	140
6.5. Case studies . . . . .	145
6.5.1. GEO target . . . . .	145
6.5.2. LEO target . . . . .	158
6.6. Summary . . . . .	174
<b>7. Conclusion and Future recommendations</b>	<b>177</b>
7.1. Conclusions . . . . .	177
7.2. Future recommendations . . . . .	181
<b>Bibliography</b>	<b>183</b>
<b>A. Kinematics and Dynamics</b>	<b>191</b>
A.1. Direction Cosine (Direction Cosine (DC)) matrix . . . . .	191
A.1.1. Relationship between direction cosines and quaternions . . . . .	192
A.2. Quaternion kinematics . . . . .	192
A.3. Euler equations for rotational motion . . . . .	195
<b>B. Elaborations for Hill Equations</b>	<b>197</b>
B.1. Jacobian matrix . . . . .	197
<b>C. LQR Theory</b>	<b>199</b>
C.1. LQR problem statement and solution . . . . .	199
<b>D. Virtual Reality Simulation</b>	<b>203</b>