

## Shankar Kulumani

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CONTACT INFORMATION	2800 Woodley Rd NW Washington, DC 20008 USA	<i>Mobile:</i> 630-336-6257 <i>E-mail:</i> <a href="mailto:skulumani@gwu.edu">skulumani@gwu.edu</a> <i>Web:</i> <a href="https://shankarkulumani.com">https://shankarkulumani.com</a>
RESEARCH INTERESTS	<b>Dynamics and Control of Aerospace Systems</b> Application of geometric mechanics and control to systems evolving on nonlinear manifolds.	
EDUCATION	<b>George Washington University</b> , Washington, DC Aug 2014-Present PhD, <b>Mechanical and Aerospace Engineering</b> Area of Study: Geometric Mechanics and Control of Aerospace Systems Advisor: Taeyoung Lee <b>Purdue University</b> , West Lafayette, IN Jan 2011-Dec 2013 M.S., <b>Aeronautical and Astronautical Engineering</b> Area of Study: Astrodynamics, Analytical Mechanics <b>United States Air Force Academy</b> , Colorado Springs, CO Jun 2005-May 2009 B.S., <b>Astronautical Engineering</b>	
QUALIFICATIONS AND SKILLS	Programming: MATLAB, L <sup>A</sup> T <sub>E</sub> X, Python, C++, ROS, JPL/SPICE, Satellite Toolkit (STK) Design: AutoCAD, SolidWorks Hardware: Vicon/PhaseSpace motion capture systems	
PROFESSIONAL EXPERIENCE	<b>George Washington University</b> , Washington DC <i>Instructor, MAE3134 - Linear System Dynamics</i> Spring 2017 <i>Graduate Research/Teaching Assistant</i> Aug 2014-Present <ul style="list-style-type: none"><li>• Grader for MAE6246 - Linear Control Systems. Responsible for grading graduate student homework assignments relating to linear dynamic analysis, linear control system design, and linear algebra.</li><li>• Graduate teaching assistant for Engineering Drawing and Computer graphics course. Responsible for teaching the fundamentals of sound engineering design and use of technical design software. Developed assignments and examinations to test students ability in applying principles in technical drawing.</li><li>• Performing research in the Flight Dynamics and Control laboratory with applications in geometric mechanics and control. Developing methods of continuous low thrust orbital transfers by leveraging the nonlinear manifolds of the three body problem.</li><li>• Applying computational geometric mechanics to develop algorithms which preserve the geometric properties of mechanical systems to obtain accurate numerical results and long term stability.</li><li>• Designing constrained geometric control for the coupled translation and rotational dynamics of spacecraft. This allows for globally defined control systems that track a desired trajectory while simultaneously avoiding obstacles or path constraints.</li></ul> <i>Aerospace Research Intern, Applied Defense Solutions</i> Jun 2016 <ul style="list-style-type: none"><li>• Developed several techniques for extracting useful information theoretic quantities from particle clouds. Created Python software tools for performing <math>k</math> nearest-neighbor estimation and Monte Carlo estimation for the analysis and tracking of space objects.</li></ul>	

- Investigated the conservation of probabilistic properties of Hamiltonian systems.
- Implemented parallel processing software on the [Maui High Performance Computing Center \(MHPCC\)](#) to track and categorize space objects. Developed software and tutorials for the implementation of Java based software on parallel computing clusters.

*Space Scholar, AFRL Scholar Program*

Jun 2015-Jul 2015

- Investigated combined translational and rotational control techniques for spacecraft rendezvous and proximity operations in the presence of constraints. Developed a geometric nonlinear controller which allows for global attitude tracking.
- The control system is developed directly on the nonlinear manifold and defined globally without the need of local parameterizations. Attitude constraints are incorporated directly on the nonlinear manifold through the use of barrier functions and allow for excellent convergence properties in the presence of constraints.

### **United States Air Force, Captain**

*Threat Systems Engineer, Missile and Space Intelligence Center  
Defense Intelligence Agency (MSIC/DIA)*

Sep 2014-Present

- Supported 2016 Sensor Week training exercise at Eglin Air Force Base, FL. A wide variety of air and ground vehicles are tested against realistic sensor systems. Directly supported the implementation and deployment of several radar tracking systems and enabled effective air defense against operational flight missions. Developed software tools to analyze and display geospatial data from several sensor platforms.
- Responsible for the development of computational tools for the analysis of rocket and missile systems. Developed software to accurately model the aerodynamic forces and effects on rocket systems through all phases of flight. Accurate modeling of the aerodynamics allows for improved simulation accuracy and performance predictions.
- Developed software to accurately interface operational sensor systems. Implemented an extensive MATLAB/ Python library to simulate and analyze missile systems and sensors.
- Contributed to ETA Graphical User Interface (GUI) development using [Qt Creator](#). GUI serves as graphical software tool used to interface with a variety of missile and aerodynamic simulation tools.

*Lead Test Engineer, Guidance, Navigation, & Control Group  
Air Force Research Laboratory (AFRL/RVSVC)*

Aug 2011-Sep 2014

- Directed a 6 member team in developing orbit determination software and designing an observation campaign for the ANGELS flight experiment. An Unscented Kalman Filter (UKF) was developed to verify and validate the performance of a GPS receiver in geostationary orbit. Additionally, a ground based collection strategy, incorporating AFSSN sensors, was developed and tested on operational satellites. The AFRL ANGELS vehicle launched in 2014 to advance autonomous rendezvous and proximity operation control algorithms. The UKF and ground based observation campaign was critical for accurate navigation and allowed for more aggressive maneuvers.
- Designed custom astrodynamics force model for the ANGLES flight experiment. Incorporated the effects of solar radiation pressure, attitude control actuators and sensors, Earth gravitational models, and thruster uncertainties to predict the expected performance of the spacecraft. Analysis predicted a coupling between rotational and translational motion during angular momentum desaturation burns. A orientation profile was developed which minimized the accumulation of undesired angular momentum and allowed for extended quiescent periods in support of orbit determination activities.

- Led \$5M lab development program to develop an in situ attitude dynamics and control simulator. Responsible for procurement, design, and integration of the largest spherical air-bearing platform in the world. Developed software to interface with inertial measurement units, motion capture systems, and control hardware to allow for hardware in the loop system testing. The facility is currently being used to validate future flight attitude control actuators and algorithms.
- Developed a method for space based geolocation via time difference of arrival signals. Implemented geometric techniques to develop a closed form analytical solution to locate a noncooperative electromagnetic signal based on the time of arrival to a formation of satellites.
- Led the development of a satellite relative motion simulator using embedded ground based robotic systems. Designed the software to allow for accurate scaling and simulation of spacecraft motion. Directly implemented a motion capture system on embedded hardware to allow for accurate positioning and control.
- Managed \$4M DARPA space situational awareness contract by leading diverse team of academia, industry, and government in an effort to develop integrated orbit determination software.

*Deputy Space Vehicles Lead, Responsive Space Squadron*

*Space Development and Test Directorate (SDTD/SDDR)*

May 2009-Aug 2011

- Responsible for development, integration, test, & launch of ORS-1 (Operationally Responsive Space) satellite. ORS-1 was the first operational satellite developed under the ORS office and supports US Central Command Battlespace Awareness. An accelerated development cycle allowed for the integration and launch in under 2 years.
- Extensive experience with technical management of diverse contractor/government teams leading to successful ORS-1 launch and orbit operation. Managed a team of 5 to ensure the correct integration and testing of the space vehicle. Ensured mission requirements were being met during the integration period.
- Resolved a \$600K satellite flight sensor failure. Directly managed the repair analysis team to prevent launch delays and ensure the system capability. Monitored the hardware repair process and verified they were completed correctly.
- Firsthand experience monitoring 100+ days of integration and testing of ORS-1. Sole space vehicles lead during launch site operations at Wallops Island, VA. Ensured correct procedures and standards leading to on-time launch on 29 June 2011
- Assessed and served as on-site government inspector of 200+ satellite test plans. Verified technical analysis and testing procedures on all flight hardware of ORS-1. Test plans were critical in ensuring correct performance of both ground and space hardware and critical to mission success.

## PUBLICATIONS

### Journal Publications

- Shankar Kulumani and Taeyoung Lee. “Constrained Geometric Attitude Control on  $SO(3)$ ”. In: *International Journal of Control, Automation, and Systems* (under review)

### Conference Publications

- Shankar Kulumani and Taeyoung Lee. “Bayesian Attitude Estimation on  $SO(3)$  with Matrix Fisher Mixtures”. In: *Proceedings of the AAS/AIAA Astrodynamics Specialists Conference, San Antonio, TX*. 2017
- Shankar Kulumani and Taeyoung Lee. “Low-Thrust Trajectory Design Using Reachability Sets near Asteroid 4769 Castalia”. In: *Proceedings of the AIAA/AAS Astrodynamics Specialists Conference, Long Beach, California*. Sept. 2016. DOI: 10.2514/6.2016-5376. arXiv: 1608.05601 [[math.OC](#)]

	<ul style="list-style-type: none"> <li>• Shankar Kulumani et al. “Estimation of Information-Theoretic Quantities for Particle Clouds”. In: <i>Proceedings of the AIAA/AAS Astrodynamics Specialists Conference, Long Beach, California</i>. Sept. 2016. DOI: <a href="#">10.2514/6.2016-5629</a></li> <li>• Shankar Kulumani, Christopher Poole, and Taeyoung Lee. “Geometric Adaptive Control of Attitude Dynamics on SO(3) with State Inequality Constraints”. In: <i>2016 American Control Conference (ACC)</i>. July 2016, pp. 4936–4941. DOI: <a href="#">10.1109/ACC.2016.7526135</a>. arXiv: <a href="#">1602.04286 [math.OC]</a></li> <li>• Shankar Kulumani and Taeyoung Lee. “Systematic Design of Optimal Low-Thrust Transfers for the Three-Body Problem”. In: <i>Proceedings of the AAS/AIAA Astrodynamics Specialist Conference, Vail, Colorado</i>. 757. Aug. 2015. arXiv: <a href="#">1510.02695 [math.OC]</a></li> <li>• Shankar Kulumani. “Space Based TDOA Geo-Location”. In: <i>Proceedings of the Space Control Conference, MIT/Lincoln Laboratories</i>. May 2013</li> </ul>	
PROFESSIONAL MEMBERSHIPS	Institute of Electrical and Electronics Engineers (IEEE), Member American Astronautical Society (AAS), Member American Institute of Aeronautics and Astronautics (AIAA), Member Sigma Gamma Tau, Member	2016-present 2015-present 2012-present 2008-present
	Technical Training <ul style="list-style-type: none"> <li>• First aid training including Self Aid Buddy Care (SABC), CPR Heartsaver</li> </ul>	
PROFESSIONAL SERVICE	Reviewer for <a href="#">Advances in Space Research</a>	
AWARDS	George Washington University <ul style="list-style-type: none"> <li>• Graduate Research Fellowship, George Washington University</li> <li>• Best session presentation award, American Control Conference (ACC)</li> <li>• Student Travel Award, American Control Conference (ACC)</li> <li>• Hetherington Family Scholarship, George Washington University</li> <li>• 1st Place Experimental Research Award, R&amp;D Showcase</li> </ul> George Washington University <ul style="list-style-type: none"> <li>• Most Innovative/Creative Project Award, 5th Annual Student Competition</li> </ul> Society of Satellite Professionals International (SSPI)	2014-2016 2016 2016 2016 2016 2016 2015
	Responsive Space Squadron <ul style="list-style-type: none"> <li>• Rotary National Award for Space Achievement Foundation Stellar Award nomination for successful ORS-1 mission accomplishments</li> <li>• ORS-1 named by C4ISR Journal as one of the top 25 most important intelligence, surveillance and reconnaissance concepts of the year</li> </ul>	2011 2011
	United States Air Force Academy <ul style="list-style-type: none"> <li>• Commandant/Dean pin for high military/academic performance</li> <li>• Top Academic Performer - Astrodynamics 321</li> </ul>	2005-2009 2007
SECURITY CLEARANCE	Cleared for Top Secret information and granted access to sensitive compartmented information based on a single scope background investigation completed on 21 June 2010. Please contact SSO AF Reserve Command for additional clearance information.	