

# AMIT K. SANYAL

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## Home

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## Research Interests and Applications

Navigation and Control of Spacecraft, Unmanned Vehicles and their Formations, Geometric Mechanics, Nonlinear and Geometric Control, Discrete Variational Mechanics, Optimal Control and Estimation, Robotics, Adaptive Control, Geometric/Algebraic methods in Nonlinear Systems, Dynamics of Multi-Body Systems.

## Education

**2001-2004** Ph.D. in Aerospace Engineering, University of Michigan, Ann Arbor, MI. Date of completion: August 2004.

Dissertation title: *Dynamics and Control of Multibody Systems in the Presence of Gravity*.

Co-Chairs: N. Harris McClamroch (Aerospace Engineering), Anthony M. Bloch (Mathematics).

**2001-2004** Master of Science in Mathematics, University of Michigan, Ann Arbor, MI. Date of completion: December 2004.

Advisor: Anthony M. Bloch, Mathematics.

**1999-2001** Master of Science in Aerospace Engineering, Texas A & M University, College Station, TX. Date of completion: May 2001.

Thesis title: *Geometrical Transformations in Higher Dimensional Euclidean Spaces*.

Chair: John L. Junkins, Aerospace Engineering.

**1995-1999** Bachelor of Technology in Aerospace Engineering, Indian Institute of Technology, Kanpur, India. Project title: *Input Shaping Control of Flexible Spacecraft*, supervised by: Ashish Tewari.

## Research and Teaching Experience

**2015-** *Associate Professor, Mechanical and Aerospace Engineering, Syracuse University, Syracuse, NY.* Joint appointment with Electrical Engineering and Computer Science.

Nonlinear control and estimation of unmanned vehicles and aerospace systems, geometric mechanics, geometric control, optimal control and estimation.

Courses taught: *AEE 577, Spaceflight mechanics; MEE 725, Advanced Engineering Dynamics; MAE 312, Engineering Analysis; MAE 700, Nonlinear and Optimal Control.*

**2010-2015** *Assistant Professor, Mechanical and Aerospace Engineering, New Mexico State University, Las Cruces, NM.*

Nonlinear control and estimation of spacecraft and unmanned vehicles, spacecraft rendezvous and proximity operations, coupled translational and rotational motion control for asteroid/comet proximity operations.

Courses taught: *AE 362, Orbital Mechanics; ME 452, Control System Design; AE 561/ME 405, Spacecraft Dynamics and Control; AE/ME 527, Control of Mechanical Systems, AE/ME 529, Nonlinear and Optimal Control, ME 580 Numerical Analysis II.*

**2007-2010** *Assistant Professor, Mechanical Engineering, University of Hawaii, Honolulu, HI.*

Nonlinear and optimal control and estimation of spacecraft, underwater vehicles, aircraft and mobile robots. Designed spacecraft attitude determination and control subsystem (ADCS) in the Hawaii Space Flight Laboratory.

Courses taught: *ME 451, Feedback Control Systems; ME 691, Graduate Seminar; ME 402, Dynamical Systems Laboratory; ME 651, Automatic Control; ME 696, Rigid Body Dynamics and Control.*

**2004-2006** *Post-doctoral research associate, Arizona State University, Tempe, AZ.*

Discrete and continuous variational problems, optimal control and estimation for mechanical systems. Co-organizer of *Geometry, Control and Dynamical Systems Seminar*. Taught courses in control systems, linear algebra, and attitude determination and control.

**2003-2004** *Research Assistant, Aerospace Engineering, University of Michigan, Ann Arbor, MI.*

Control, dynamics, and numerical integration of nonlinear under-actuated mechanical systems, applying ideas from modern geometry and algebra. Emphasis on applications to the control of underactuated multibody spacecraft.

**2002-2003** *Teaching Assistant, Aerospace Engineering, University of Michigan, Ann Arbor, MI.*

Held some classes and office hours (6 hours/week) for junior year flight dynamics and control course. Developed solutions and formulated some problems for graded assignments.

**2001-2002** *Research Fellow, Aerospace Engineering, University of Michigan, Ann Arbor, MI.*

Adaptive control and identification techniques applied to a tri-axial attitude control testbed. Used MATLAB/Simulink Real-time Workshop and WinCon control software (Quanser Consulting, Inc.), to interface between remote terminal and onboard PC104.

**1999-2001** *Research Assistant, Aerospace Engineering, Texas A & M University, College Station, TX.*

Star pattern recognition for attitude determination using a CCD camera as star tracker, as part of StarNav experiment on space shuttle mission STS-107.

### **Honors and Awards**

**2001** Distinguished Graduate Student Masters Research Award, Texas A & M University.

**2002** College of Engineering Fellowship, University of Michigan.

**2003** Engineering Academic Scholar Certificate, College of Engineering, University of Michigan.

**2012** Summer Faculty Fellow, Air Force Research Laboratory.

**2015** Senior Member, AIAA and IEEE.

### **Professional Service**

**2004** Chair of session on Spacecraft Control, American Control Conference.

**2008-2011** Member of AIAA Technical Committee on Guidance, Navigation and Control (GNC TC).

**2009-2015** Reviewer for National Science Foundation, NASA.

**2009-** Member of IEEE technical committees on Aerospace Control and Nonlinear Systems.

**2009** AIAA Guidance, Navigation and Control Conference: Chair of session titled "Spacecraft GN&C: Rendezvous and Proximity Operations."

**2010** AIAA Guidance, Navigation and Control Conference: Technical area co-chair for Sensor Systems; chair of session titled "Sensor Systems 1."

**2012** Co-chair of session on Estimation and Fault Detection, ASME Dynamic Systems and Control Conference.

**2012** Organizer and co-chair of session on Geometric Control, IEEE Conference on Decision and Control.

**2014** Organizer and chair of industry/applications tutorial session on Rendezvous, Proximity Operations and Capture of Space Objects, American Control Conference.

**2014, 2015** International Program Committee, Indian Control Conference.

**2015** Organizer and chair of session on Attitude and Pose Estimation, IEEE Conference on Decision and Control.

**2010, 2016** Program Committee, IEEE Conference on Decision and Control.

**2017** Co-chair of session “Control Applications II”, American Control Conference.

### **Professional Society Memberships**

**AIAA, ASME, IEEE, SIAM.**

### **Research Projects (Past and Current)**

- *Enabling Multimodal Sensing, Real-time Onboard Detection and Adaptive Control for Fully Autonomous Unmanned Aerial Systems*, NSF Cyber-Physical Systems, 8/15/2017 to 8/14/2019, Co-PI, \$400,000.
- *Towards Full Onboard Autonomy for Unmanned Vehicles in GPS-denied Environments*, Gryphon Sensors and Syracuse University, 1/11/2016 to 31/10/2017, PI, \$74,826.
- *Guidance and Control of Low-Altitude Small Unmanned Aerial Vehicles in GPS-Denied Environments*, Syracuse University Center for Advanced Systems and Engineering, 2/1/2016 to 7/31/2017, \$50,000.
- *Adaptive Singularity-Free Control Moment Gyroscope Cluster*, NMSU Arrowhead Launch program, 2/1/2015 to 1/31/2016, \$30,000.
- *High Control Authority Variable Speed Control Moment Gyroscope*, AFRL Young Entrepreneurs Program, AFRL, 3/1/2015-12/31/2015, \$50,000.
- *Spacecraft Autonomous Rendezvous and Proximity Operations*, AFRL Summer Faculty Fellowship Program, July-August 2012 (8 weeks), \$12,400.
- *Robust State and Uncertainty Estimation for Unmanned Systems in the Presence of External Uncertainties*, NSF, 9/1/2011-8/31/2014, PI, \$278,158.
- *Proximity Operations for Near-Earth Asteroid Exploration*, NASA, 9/1/2011-8/31/2015, Co-PI, \$749,980 (multi-institution, \$459,318 was NMSU share).
- *Inclusion of Spacecraft Dynamics and Control in Aerospace Engineering Curriculum at NMSU*, NASA NM Space Grant Consortium, 9/1/2010-7/31/2012, PI, \$24,481.
- *Robust Estimation and Control of Small Spacecraft with Reconfigurable Sensors and Actuators*, NASA NM Space Grant Consortium, 9/1/2010-7/31/2012, PI, \$24,902.
- *Enhanced Advanced Intelligent Reconnaissance System (E-AIRS): Identification and tracking of targets from a UAV platform using visible range COTS cameras*, Hawaii Technology Development Venture (HTDV), 1/1/2010 to 12/31/2010, PI, \$35,000.

## Research Papers

### Research papers in journals or books

1. S. P. Viswanathan, A. K. Sanyal and E. Samiei, "Integrated Guidance and Feedback Control of Underactuated Robotics System in SE(3)," *Journal of Intelligent & Robotic Systems*, vol. 89, pp. 251-263, 2018, doi: 10.1007/s10846-017-0547-0.
2. A. Siravuru, S. P. Viswanathan, K. Sreenath and A. K. Sanyal, "The Reaction Mass Biped: Geometric Mechanics and Control," *Journal of Intelligent & Robotic Systems*, vol. 89, pp. 155-173, 2018.
3. A. K. Sanyal and M. Izadi, "Stable Estimation of Rigid Body Motion Based on the Lagrange-d'Alembert Principle," in *Multisensor Attitude Estimation: Fundamental Concepts and Applications*, pp. 57-76, 2016, ed.: H. Fourati, CRC Press (Taylor and Francis), FL.
4. M. Izadi and A. K. Sanyal, "Rigid Body Pose Estimation based on the Lagrange-d'Alembert Principle," *Automatica*, vol. 71(9), pp. 78-88, 2016, doi: 10.1016/j.automatica.2016.04.028.
5. S. Brás, M. Izadi, C. Silvestre, A. Sanyal and P. Oliveira, "Nonlinear Observer for 3D Rigid Body Motion Estimation using Doppler Measurements", *IEEE Transactions on Automatic Control*, vol. 61(11), pp. 3580-3585, 2016, doi: 10.1109/TAC.2016.2526671.
6. M. Nazari, E. Butcher, T. Yucelen and A. K. Sanyal, "Decentralized Consensus Control of a Rigid Body Spacecraft Formation in Orbit with Communication Delay," *AIAA Journal of Guidance, Control and Dynamics*, vol. 39, pp. 838-851, 2016, doi: 10.2514/1.G001396.
7. G. Misra, M. Izadi, A. Sanyal and D. Scheeres, "Coupled Orbit-Attitude Dynamics of Spacecraft and Relative State Estimation During Exploration of Small Solar System Bodies," *Advances in Space Research*, vol. 57(8), pp. 1747-1761, 2016, doi: 10.1016/j.asr.2015.05.023.
8. J. Bohn and A. K. Sanyal, "Almost global finite-time stabilization of rigid body attitude dynamics using rotation matrices," *International Journal of Robust and Nonlinear Control*, 2016, vol. 26(9), pp. 2008-2022, doi: 10.1002/rnc.3399.
9. E. Samiei, E. A. Butcher, A. K. Sanyal and R. Paz, "Attitude Stabilization of Rigid Spacecraft with Minimal Attitude Coordinates and Unknown Time-varying Delay," *Aerospace Science and Technology*, vol. 46, pp. 412-421, 2015, doi: 10.1016/j.ast.2015.08.007.
10. S. P. Viswanathan, A. K. Sanyal, F. Leve and N. H. McClamroch, "Dynamics and Control of Spacecraft with a Generalized Model of Variable Speed Control Moment Gyroscopes," *ASME Journal of Dynamic Systems, Measurement and Control*, vol. 137(7), paper 071003, 2015, doi: 10.1115/1.4029626.
11. A. K. Sanyal and J. Bohn, "Finite Time Stabilization of Simple Mechanical Systems using Continuous Feedback," *International Journal of Control*, vol. 88(4), pp. 783-791, 2015.
12. D. Lee, A. Sanyal, E. Butcher and D. Scheeres, "Finite-Time Control for Spacecraft Body-Fixed Hovering over an Asteroid", *IEEE Transactions in Aerospace and Electronic Systems*, vol. 51(1), pp. 506-520, 2015, doi: 10.1109/TAES.2014.140197.
13. D. Lee, A. Sanyal and E. Butcher, "Asymptotic Tracking Control for Spacecraft Formation Flying with Decentralized Collision Avoidance," *AIAA Journal of Guidance, Control and Dynamics*, vol. 38(4), pp. 587-600, 2015.
14. D. Lee, E. A. Butcher and A. K. Sanyal, "Optimal interior Earth-Moon Lagrange point transfer trajectories using mixed impulsive and continuous thrust," *Aerospace Science and Technology*, vol. 39, pp. 281-292, 2014.

15. D. Lee, A. Sanyal, E. Butcher and D. Scheeres, "Almost Global Asymptotic Tracking Control for Spacecraft Body-Fixed Hovering near an Asteroid," *Aerospace Science and Technology*, vol. 38, pp. 105-115, 2014.
16. D. Lee, H. Bang, E. A. Butcher and A. K. Sanyal, "Kinematically Coupled Relative Spacecraft Motion Control using the State-Dependent Riccati Equation Method," *ASCE Journal of Aerospace Engineering*, 2014, doi: 10.1061/(ASCE)AS.1943-5525.0000436.
17. M. Izadi and A. K. Sanyal, "Rigid Body Attitude Estimation Based on the Lagrange-d'Alembert Principle," *Automatica*, vol. 50(10), pp. 2570-2577, 2014.
18. D. Lee, H. Bang, A. Sanyal and E. Butcher, "Nonlinear Output Tracking and Disturbance Rejection for Autonomous Close Range Rendezvous and Docking of Spacecraft," *Transactions of Japan Society for Aeronautical and Space Sciences*, vol. 57(4), pp. 225-237, 2014.
19. A. K. Sanyal and A. Goswami, "Dynamics and Balance Control of the Reaction Mass Pendulum (RMP): A 3D Multibody Pendulum with Variable Body Inertia," *ASME Journal of Dynamic Systems, Measurement and Control*, vol. 136(2), paper 021002, 2014.
20. D. Lee, E. Butcher and A. Sanyal, "Optimal mixed impulsive and continuous thrust trajectories to the interior Earth-Moon L1 Lagrange point," *Advances in the Astronautical Sciences*, vol. 148, pp. 3963-3982, 2013.
21. A. Weiss, I. Kolmanovsky, D. S. Bernstein, and A. Sanyal, "Inertia-Free Spacecraft Attitude Control Using Reaction Wheels," *AIAA Journal of Guidance, Control and Dynamics*, vol. 36(5), pp. 1425-1439, 2013.
22. M. C. Sorgenfrei, S. S. Joshi, and A. K. Sanyal, "Controller Gain-Tuning for a Small Spacecraft Attitude Tracking Maneuver Using a Genetic Algorithm," *Journal of Small Satellites*, vol. 2(1), pp. 105-118, 2013.
23. A. K. Sanyal and N. Nordkvist, "Attitude State Estimation with Multi-Rate Measurements for Almost Global Attitude Feedback Tracking," *AIAA Journal of Guidance, Control and Dynamics*, vol. 35(3), pp. 868-880, 2012.
24. A. M. Bloch, P. E. Crouch, N. Nordkvist and A. K. Sanyal, "Embedded geodesic problems and optimal control for matrix Lie groups," *Journal of Geometric Mechanics*, vol. 3(2), pp. 197-223, 2011.
25. N. A. Chaturvedi, A. K. Sanyal, and N. H. McClamroch, "Rigid Body Attitude Control: Using rotation matrices for continuous, singularity-free control laws", *IEEE Control Systems Magazine*, vol. 31(3), pp. 30-51, 2011.
26. A. K. Sanyal, N. Nordkvist and M. Chyba, "An Almost Global Tracking Control Scheme for Maneuverable Autonomous Vehicles and its Discretization," *IEEE Transactions on Automatic Control*, vol. 56(2), pp. 457-462, 2011.
27. A. K. Sanyal, A. Fosbury, N. A. Chaturvedi, and D. S. Bernstein, "Inertia-Free Spacecraft Attitude Tracking with Disturbance Rejection and Almost Global Stabilization," *AIAA Journal of Guidance, Control and Dynamics*, vol 32(4), pp. 1167-1178, 2009.
28. A. K. Sanyal, C. Moseley, and A. M. Bloch, "Analytical and Numerical Solution of a Sub-Riemannian Optimal Control Problem with Applications to Quantum Spin Systems," *Comm. Information and Systems*, special issue dedicated to Roger Brockett on his 70th birthday, vol 9(1), pp. 59-76, 2009.

29. A. M. Bloch, I. I. Hussein, M. Leok, and A. K. Sanyal, "Geometric structure-preserving Optimal Control of the Rigid Body," *Journal of Dynamical and Control Systems*, vol. 15, no. 3, pp. 307-330, 2009.
30. A. K. Sanyal, A. M. Bloch, P. E. Crouch, and J. E. Marsden, "Optimal Control and Geodesics on Quadratic Matrix Lie Groups," *Foundations of Computational Mathematics*, vol 8(4), pp. 469-500, 2008.
31. A. K. Sanyal, T. Lee, M. Leok, and N. H. McClamroch, "Global Optimal Attitude Estimation using Uncertainty Ellipsoids," *Systems and Control Letters*, vol 57(3), pp. 236-245, 2008.
32. A. M. Bloch, P. E. Crouch, and A. K. Sanyal, "A Variational Problem on Stiefel Manifolds," *Nonlinearity*, vol 19(10), pp. 2247-2276, 2006.
33. N. A. Chaturvedi, A. K. Sanyal, M. Chellapa, Jean L. Valk, N. H. McClamroch, and D. Bernstein, "Adaptive Tracking of Angular Velocity for a Planar Rigid Body with Unknown Models for Inertia and Input Nonlinearity," *IEEE Transactions on Control Systems Technology*, vol 14(4), pp. 613-627, 2006.
34. A. K. Sanyal, J. Shen, A. M. Bloch, and N. H. McClamroch, "Stability and Stabilization of Relative Equilibria of Dumbbell Bodies in Central Gravity," *AIAA Journal of Guidance, Control and Dynamics*, vol 28(5), pp. 833-842, 2005.
35. A. K. Sanyal, A. M. Bloch, and N. H. McClamroch, "Dynamics of multibody systems in planar motion in a central gravitational field," *Dynamical Systems*, vol. 19(4), pp. 303-343, 2004.
36. J. Shen, A. K. Sanyal, and N. H. McClamroch, "Asymptotic Stability of Multibody Attitude Systems," *Stability and Control of Dynamical Systems with Applications*, D. Liu and P. J. Antsaklis, Eds., Birkhäuser, Boston, 2003.
37. A. K. Sanyal, A. Verma, and J. L. Junkins, "Adaptation and Cooperation in Control of Multiple Robot Manipulators," *Journal of Astronautical Sciences*, Vol. 48(2,3), pp. 305-336, 2000.

### Refereed conference papers

1. M. H. Dhulliplalla, R. Hamrah and A. K. Sanyal, "Trajectory Generation on SE(3) with Applications to a Class of Underactuated Aerial Vehicles", *IEEE Conference on Decision and Control*, Melbourne, Australia, pp. 2557-2562, December 2017.
2. S.P. Viswanathan, A. K. Sanyal and R. R. Warier, "Finite-Time Stable Tracking Control for a Class of Underactuated Aerial Vehicles in SE(3)", *American Control Conference*, Seattle, WA, pp. 3926-3931, May 2017.
3. R. R. Warier, A. K. Sanyal, S. Sukumar, and S.P. Viswanathan, "Feedback Tracking Control Schemes for a Class of Underactuated Aerial Vehicles in SE(3)", *American Control Conference*, Seattle, WA, pp. 899-904, May 2017.
4. S. P. Viswanathan, A. K. Sanyal and M. Izadi, "Integrated Guidance and Nonlinear Feedback Control of Underactuated Vehicles in SE(3)", *AIAA Guidance, Navigation, and Control Conference, AIAA SciTech Forum*, AIAA 2017-1044, January 2017.
5. J. Bohn, A. K. Sanyal, and E. A. Butcher, "Unscented State Estimation for Rigid Body Attitude Motion with a Finite-time Stable Observer," *IEEE Conference on Decision and Control*, Las Vegas, NV, pp. 4698-4703, December 2016.

6. S. P. Viswanathan, A. K. Sanyal, and G. Misra, "Controllability Analysis of Spacecraft with Only Attitude Actuation Near Small Solar System Bodies," *IFAC Symposium on Nonlinear Control Systems*, Monterey, CA, August 2016.
7. M. Izadi, S. P. Viswanathan, A. K. Sanyal, C. Silvestre and P. Oliveira, "The Variational Attitude Estimator in the Presence of Bias in Angular Velocity Measurements," *American Control Conference*, Boston, MA, pp. 4065-4070, July 2016.
8. S. P. Viswanathan and A. K. Sanyal, "Design of an Adaptive Singularity-free Control Moment Gyroscope Cluster for Spacecraft Attitude Control," *Indian Control Conference*, Hyderabad, India, January 2016.
9. M. Izadi, A. K. Sanyal, S. P. Viswanathan, E. J. Barany, "Rigid Body Motion Estimation Based on the Lagrange-d'Alembert Principle," *IEEE Conference on Decision and Control*, Osaka, Japan, pp. 3699-3704, December 2015.
10. M. Izadi, A. K. Sanyal, R. W. Beard, H. Bai, "GPS-Denied Relative Motion Estimation for Fixed-Wing UAV Using the Variational Pose Estimator," *IEEE Conference on Decision and Control*, Osaka, Japan, pp. 2152-2157, December 2015.
11. S. P. Viswanathan and A. K. Sanyal, "Design of an Adaptive Singularity-free Control Moment Gyroscope (ASCMG) Cluster for Spacecraft Attitude Control", *ASME Dynamic Systems and Control Conference*, Columbus, OH, p. DSCC2015-9818, October 2015.
12. M. Izadi, A. K. Sanyal, E. Samiei and S. P. Viswanathan, "Discrete-time Rigid Body Attitude State Estimation based on the Discrete Lagrange-d'Alembert Principle", *American Control Conference*, Chicago, IL, pp. 3392-3397, July 2015.
13. K. Sreenath and A. K. Sanyal, "The Reaction Mass Biped: Equations of Motion, Hybrid Model for Walking and Trajectory Tracking Control," *IEEE International Conference on Robotics and Automation*, Seattle, WA, pp. 5741-5746, May 2015.
14. M. Izadi, E. Samiei, A. K. Sanyal and V. Kumar, "Comparison of an Attitude Estimator based on the Lagrange-d'Alembert Principle with some State-of-the-Art Filters," *IEEE International Conference on Robotics and Automation*, Seattle, WA, pp. 2848-2853, May 2015.
15. E. Samiei, M. Izadi, S. P. Viswanathan, A. K. Sanyal, and E. A. Butcher, "Robust Stabilization of Rigid Body Attitude Motion in the Presence of a Stochastic Input Torque," *IEEE International Conference on Robotics and Automation*, Seattle, WA, pp. 428-433, May 2015.
16. G. Misra, A. Sanyal and E. Samiei, "Asteroid Landing Guidance Design in the Framework of Coupled Orbit-Attitude Spacecraft Dynamics," *AIAA/AAS Space Flight Mechanics Meeting*, Williamsburg, VA, January 2015.
17. E. Samiei, A. K. Sanyal, and E. A. Butcher, "Asymptotic Stabilization of Rigid Body Attitude Motion in the Presence of Unknown Time Delay in Feedback", *Indian Control Conference*, Chennai, India, pp. 209-214, January 2015.
18. S. P. Viswanathan, A. Sanyal and M. Izadi, "Mechatronics Architecture of Smartphone-Based Spacecraft ADCS using VSCMG Actuators", *Indian Control Conference*, Chennai, India, pp. 310-315, January 2015.
19. G. Misra and A. Sanyal, "Analysis of Orbit-Attitude Coupling of Spacecraft Near Small Solar System Bodies", *AIAA Guidance, Navigation and Control Conference*, Kissimmee, FL, January 2015.

20. A. K. Sanyal, M. Izadi and J. Bohn, "An Observer for Rigid Body Motion with Almost Global Finite-time Convergence", *ASME Dynamic Systems and Control Conference*, San Antonio, TX, October 2014.
21. A. Sanyal, M. Izadi, G. Misra, E. Samiei and D. Scheeres, "Estimation of Dynamics of Space Objects from Visual Feedback during Proximity Operations", *SPACE 2014*, San Diego, CA, August 2014.
22. A. Sanyal, E. Butcher and M. Izadi, "Determination of Relative Motion of a Space Object from Simultaneous Measurements of Range and Range Rate," *American Control Conference*, Portland, OR, pp. 1607-1612, June 2014.
23. J. Bohn and A. Sanyal, "Almost Global Finite-Time Stable Observer for Rigid Body Attitude Dynamics," *American Control Conference*, Portland, OR, pp. 4949-4954, June 2014.
24. D. Lee, A. K. Sanyal, E. A. Butcher, and D. J. Scheeres, "Finite-time Control for Body-fixed Hovering of Rigid Spacecraft over an Asteroid," *AIAA/AAS Space Flight Mechanics Meeting*, Santa Fe, NM, Jan 2014.
25. D. Lee, A. K. Sanyal, E. A. Butcher, and D. J. Scheeres, "Finite-time Observer for Rigid Spacecraft Motion over an Asteroid," *AIAA/AAS Space Flight Mechanics Meeting*, Santa Fe, NM, Jan 2014.
26. S. P. Viswanathan, A. K. Sanyal and F. Leve, "A General Dynamics Model for Spacecraft with Variable Speed Control Moment Gyroscopes," *AIAA/AAS Space Flight Mechanics Meeting*, Santa Fe, NM, Jan 2014.
27. A. K. Sanyal, J. Bohn and A. M. Bloch, "Almost Global Finite-time Stabilization of Rigid Body Attitude Dynamics," *IEEE Conference on Decision and Control*, Florence, Italy, pp. 3261-3266, Dec 2013.
28. S. Bras, M. Izadi, C. Silvestre, A. Sanyal and P. Oliveira, "Nonlinear Observer for 3D Rigid Body Motion," *IEEE Conference on Decision and Control*, Florence, Italy, pp. 2588-2593, Dec 2013.
29. M. Izadi, J. Bohn, D. Lee, A. K. Sanyal, E. Butcher and D. J. Scheeres, "A Nonlinear Observer Design for a Rigid Body in the Proximity of a Spherical Asteroid," *ASME Dynamic Systems and Control Conference*, Stanford, CA, Oct 2013, DSCC2013-4085.
30. S. P. Viswanathan, A. K. Sanyal, F. Leve, and N. H. McClamroch, "Geometric Approach to Attitude Dynamics and Control of Spacecraft with Variable Speed Control Moment Gyroscopes," *IEEE Multi-Conference on Systems and Control*, Hyderabad, India, pp. 556-561, Aug 2013.
31. M. Sorgenfrei, A. K. Sanyal and S. Joshi, "On the Performance of a Genetic Algorithm for Spacecraft Controller Gain Optimization," *AIAA Guidance, Navigation and Control Conference*, Boston, MA, Aug 2013, AIAA-2013-5029.
32. D. Lee, S. P. Viswanathan, L. Holguin, A. K. Sanyal and E. A. Butcher, "Decentralized Guidance and Control for Spacecraft Formation Flying Using Virtual Leader Configuration," *American Control Conference*, Washington DC, pp. 4833-4838, June 2013.
33. J. Bohn and A. Sanyal, "Unscented State Estimation for Rigid Body Motion on  $SE(3)$ ," *IEEE Conference on Decision and Control*, Maui, HI, pp. 7498-7503, Dec 2012.
34. E. Gregory and A. K. Sanyal, "A Comparison Study of State Estimators for Dynamics on the Sphere," *ASME Dynamic Systems and Control Conference*, Ft. Lauderdale, FL, Oct 2012.
35. S. P. Vishwanathan, A. Sanyal and L. Holguin, "Dynamics and Control of a Six Degrees of Freedom Ground Simulator for Autonomous Rendezvous and Proximity Operation of Spacecraft," *AIAA Guidance, Navigation and Control Conference*, Minneapolis, MN, Aug 2012, AIAA-2012-4926.



36. M. Sorgenfrei, A. K. Sanyal and S. Joshi, "Preliminary Optimization Results for an Almost Globally Stable Control Law Using a Genetic Algorithm", *AIAA Guidance, Navigation and Control Conference*, Minneapolis, MN, Aug 2012, AIAA-2012-4558.
37. A. Sanyal, L. Holguin and S. P. Vishwanathan, "Guidance and Control for Spacecraft Autonomous Chasing and Close Proximity Maneuvers," *IFAC Symposium on Robust Control Design*, Aalborg, Denmark, Jun 2012.
38. N. Nordkvist, P. E. Crouch, A. M. Bloch, and A. K. Sanyal, "Embedded Optimal Control Problems," *Proc. of IEEE Conference on Decision and Control*, Orlando, FL, pp. 7311-7316, Dec 2011.
39. A. K. Sanyal and A. Goswami, "Dynamics and Control of the Reaction Mass Pendulum (RMP) as a 3D Multibody System: Application to Humanoid Modeling", *ASME Dynamic Systems and Control Conference*, Arlington, VA, pp. 589-596, Oct 2011.
40. N. Nordkvist and A. Sanyal, "A Lie Group Variational Integrator for Rigid Body Motion in SE(3) with Applications to Underwater Vehicle Dynamics," *IEEE Conference on Decision and Control*, Atlanta, GA, pp. 5414-5419, Dec 2010.
41. A. K. Sanyal and N. Nordkvist, "A Robust Estimator for Almost Global Attitude Feedback Tracking," *AIAA Guidance, Navigation and Control Conference*, Toronto, ON, Aug 2010, AIAA-2010-8344.
42. N. Nordkvist and A. K. Sanyal, "Attitude Feedback Tracking with Optimal Attitude State Estimation," *Proc. of American Control Conference*, Baltimore, MD, pp. 2861-2866, Jun 2010.
43. A. K. Sanyal and Z. Lee-Ho, "Attitude Tracking Control of a Small Satellite in Low Earth Orbit," *AIAA Guidance, Navigation and Control Conference*, Chicago, IL, Aug 2009, AIAA-2009-5902.
44. A. K. Sanyal and M. Chyba, "Robust Feedback Tracking of Autonomous Underwater Vehicles with Disturbance Rejection," *Proc. of American Control Conference*, St. Louis, MO, pp. 3585-3590, Jun 2009.
45. A. K. Sanyal and R. Baghaei, "Realistic Ground Simulation of Spacecraft Motion using Spacecraft Simulators," *Proc. of the 2008 IEEE Multiconference on Systems and Control*, San Antonio, TX, Sept 2008.
46. A. K. Sanyal and N. A. Chaturvedi, "Almost Global Robust Attitude Tracking Control of Spacecraft in Gravity," *AIAA Guidance, Navigation and Control Conference*, Honolulu, HI, Aug 2008, AIAA-2008-6979.
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#### **Conference and Workshop Presentations (without Proceedings)**

1. A. M. Bloch, P. E. Crouch, and A. K. Sanyal, "A Variational Problem on Stiefel Manifolds," SIAM Conference on Applications of Dynamical Systems, Snowbird, UT, 2005.
2. A. K. Sanyal, "Sub-Riemannian Optimal Control of a Three-Spin Quantum System," 44th Annual Technical Meeting of the Society of Engineering Science, College Station, TX, 2007.

3. A. K. Sanyal, T. Lee, M. Leok, and N. H. McClamroch, "A Geometric Method for Global Optimal Attitude Estimation," 44th Annual Technical Meeting of the Society of Engineering Science, College Station, TX, 2007.
4. A. K. Sanyal, S. B. Singh, and N. Nordkvist, "Numerical Simulation of an Almost Global Attitude Tracking Control Scheme Using a Lie Group Variational Integrator," SIAM Conference on Control and Applications, Denver, CO, 2009.
5. A. K. Sanyal, "Riccati Equation, Flexible Spacecraft and Variational Integrators: The trajectory of N. Harris McClamroch in Nonlinear Dynamics and Control," *HarrisFest: on the retirement occasion of N. Harris McClamroch*, University of Michigan, May 2010 (also reported on IEEE Control Systems Magazine, July 2010).
6. A. K. Sanyal, "Robust State Estimation and Control for Small Spacecraft Using Geometric Mechanics," research presentation at NASA Ames Research Center, Mountain View, CA, May 2013.
7. A. K. Sanyal, "Navigation and Control of Spacecraft in Proximity Operations: How Good Theory can Lead to Good Practice," research presentation at NASA Langley Research Center, Hampton, VA, July 2014.
8. A. K. Sanyal, "Dynamics, Control and Estimation of Robotic Spacecraft: How Good Theory Can Lead to Good Practice," research presentation at University of Arizona, Tucson, AZ, January 2015.

## Intellectual Property and Entrepreneurship

- *High Control Authority Variable Speed Control Moment Gyroscope*, patent application filed January 2015.
- *Robustly Stable Autonomous Vision-Inertial Navigation System (ROSAVINS) for Unmanned Vehicles*, provisional patent application filed September 2016.
- *Co-founder and owner of Akrobotix LLC*, one of six winners of Genius NY business accelerator program, January 2017.

## Reviewer for

- *AIAA Journal of Guidance, Control and Dynamics*
- *Aerospace Science and Technology*
- *ASME Journal of Dynamic Systems, Measurement and Control*
- *Automatica*
- *IEEE Transactions on Automatic Control*
- *IEEE Transactions on Control Systems Technology*
- *IET Control Theory and Applications*
- *Journal of Geometric Mechanics*
- *Journal of Vibration and Control*
- *Journal of Small Satellites (online)*
- *SIAM Journal on Control and Optimization*
- *Systems and Control Letters*

- *Royal Society Proceedings-A*
- Conference reviewer for: *AIAA Guidance Navigation and Control Conference, American Control Conference, IEEE Conference on Decision and Control, ASME Dynamic Systems and Control Conference, Int. Symp. on Mathematical Theory of Networks and Systems, International Conference on Robotics and Automation, IFAC conferences*

### **Associate Editor**

- *Aerospace Science and Technology*
- *Journal of Small Satellites*

### **Students**

- *Current:* PhD students: H. Eslamiat, R. Hamrah, A. Butkus and M. H. Dhullipalla.
- *Past:* PhD students: J. Bohn, S. P. Viswanathan, M. Izadi, and E. Samiei (co-advised with E. Butcher); MS students: G. Misra, S. P. Vishwanathan, J. Bohn, L. Holguin, E. Gregory, Z. Lee-Ho and S. B. Singh (co-advised with M. Chyba); BS students: W. Jones, A. Duran and J. Bohn (honors student).
- *Past Visiting:* S. Bras (Institute for Systems and Robotics, IST, Lisbon, Portugal); R. Warier (Indian Institute of Technology, Bombay, India).

### **Post-docs**

- *2015-2016:* Sashi P. Viswanathan (PhD, New Mexico State University, Las Cruces, NM).
- *2012-2013:* Daero Lee (PhD, Missouri University of Science and Technology, Rolla, MO).
- *2008-2010:* Nikolaj Nordkvist (PhD, Technical University of Denmark, Kongens Lyngby, Denmark).

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