

## Curriculum Vitae of Dr. Anil V. Rao

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### EDUCATION

<b>Princeton University</b> Ph.D., Mechanical and Aerospace Engineering	Princeton, NJ June 1996
<b>Princeton University</b> M.A., Mechanical and Aerospace Engineering	Princeton, NJ June 1992
<b>University of Michigan</b> M.S.E., Aerospace Engineering	Ann Arbor, MI December 1989
<b>Cornell University</b> B.S., Mechanical Engineering (with Distinction); A.B., Mathematics	Ithaca, NY May 1988

### ACADEMIC APPOINTMENTS

<b>University of Florida</b> Department of Mechanical and Aerospace Engineering <i>Associate Professor</i> - University of Florida Term Professorship (August 2017 - August 2020) - Erich Farber Faculty Fellow (November 2016 - November 2019)	Gainesville, FL August 2012 - Present
<i>Assistant Professor</i>	July 2006 - August 2012
<b>Boston University</b> Department of Mechanical Engineering <i>Lecturer/Senior Lecturer</i>	Boston, MA September 2001 - May 2006

### INDUSTRY APPOINTMENTS

<b>The Charles Stark Draper Laboratory, Inc</b> Guidance, Navigation, and Control Systems Division <i>Senior Member of the Technical Staff</i>	Cambridge, MA August 2000 - June 2006
<b>The Aerospace Corporation</b> Flight Mechanics Department <i>Senior Member of the Technical Staff</i> <i>Member of the Technical Staff</i>	El Segundo, CA February 1998 - August 2000 March 1996 - February 1998

### CITATION STATISTICS

<b>Web of Science Citation Count</b> 1625 Total Citations	22 October 2017 h-Index = 15
<b>Google Scholar Citation Count</b> 3865 Total Citations	22 October 2017 h-Index = 27

### JOURNAL PUBLICATIONS

1. Hager, W. W., Hou, H., Mohapatra, S., and Rao, A. V., "Convergence Rate for a Radau hp Collocation Method Applied to Unconstrained Optimal Control," *SIAM Journal on Control and Optimization*, Submitted for Publication, October 2017.

- Hager, W. W., Hou, H., Mohapatra, S., and **Rao, A. V.**, "Convergence Rate for a Gauss Collocation Method Applied to Constrained Optimal Control," *SIAM Journal on Numerical Analysis*, Submitted for Publication, July 2016.

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—Above This Line: Publications In Review—

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- Liu, F., Hager, W. W., and **Rao, A. V.**, "Adaptive Mesh Refinement Method for Optimal Control Using Decay Rates of Legendre Polynomial Coefficients," *IEEE Transactions on Control Systems Technology*, Published Online in Early View, 6 June 2017. DOI: 10.1109/TCST.2017.2702122.
- Weinstein, M. J. and **Rao, A. V.**, "Algorithm 984: ADiGator, a Toolbox for the Algorithmic Differentiation of Mathematical Functions in MATLAB Using Source Transformation via Operator Overloading," *ACM Transactions on Mathematical Software*, Vol. 44, No. 2, Article 21, September 2017, pp. 21:1–21:25.
- Hager, W. W., Hou, H., and **Rao, A. V.**, "Lebesgue Constants Arising in a Class of Collocation Methods," *IMA Journal of Numerical Analysis*, Vol. 37, No. 4, October 2017, pp. 1884–1901.
- Meyer, A. J., Eskinazi, I., Jackson, J. N., **Rao, A. V.**, Patten, C., and Fregly, B. J., "Muscle Synergies Facilitate Computational Prediction of Subject-Specific Walking Motions," *Frontiers in Bioengineering and Biotechnology*, Vol. 4, Article 77, October 2016, 26 pages.
- De Groote, F., Kinney, A. L., **Rao, A. V.**, and Fregly, B. J. "Evaluation of Direct Collocation Optimal Control Problem Formulations for Solving the Muscle Redundancy Problem," *Annals of Biomedical Engineering*, Vol. 44, No. 10, October 2016, pp. 2922–2936.
- Weinstein, M. J. and **Rao, A. V.**, "A Source Transformation via Operator Overloading Method for the Automatic Differentiation of Mathematical Functions in MATLAB," *ACM Transactions on Mathematical Software*, Vol. 42, No. 2, June 2016, pp. 11:1–11:44.
- Hager, W. W., Hou, H., and **Rao, A. V.**, "Convergence Rate for a Gauss Collocation Method Applied to Unconstrained Optimal Control," *Journal of Optimization Theory and Applications*, Vol. 169, No. 3, June 2016, pp. 801–824.
- Graham, K. F. and **Rao, A. V.**, "Minimum-Time Trajectory Optimization of Low-Thrust Earth-Orbit Transfers with Eclipsing," *Journal of Spacecraft and Rockets*, Vol. 53, No. 2, March–April 2016, pp. 289–303. DOI: 10.2514/1.A33416.
- Cannataro, B., Davis, T. A., and **Rao, A. V.**, "State-Defect Constraint Pairing Graph Coarsening Method for Karush-Kuhn-Tucker Matrices Arising in Orthogonal Collocation Methods for Optimal Control Problems," *Computational Optimization and Applications*, Vol. 64, No. 3, July 2016, pp. 793–819.
- Liu, F., Hager, W. W., and **Rao, A. V.**, "Mesh Refinement for Optimal Control Using Nonsmoothness Detection and Mesh Size Reduction," *Journal of the Franklin Institute*, Vol. 352, No. 10, October 2015, pp. 4081–4106. DOI: 10.1016/j.franklin.2015.05.028.
- Graham, K. F. and **Rao, A. V.**, "Minimum-Time Trajectory Optimization of Many Revolution Low-Thrust Earth-Orbit Transfers," *Journal of Spacecraft and Rockets*, Vol. 52, No. 3, May–June 2015, pp. 711–727. DOI: 10.2514/1.A33187.
- Limebeer, D. J. N. and **Rao, A. V.**, "Faster, Higher, and Greener: Vehicular Optimal Control," *IEEE Control Systems Magazine*, Vol. 35, No. 2, April 2015, pp. 36–56. DOI 10.1109/MCS.2014.2384951
- Limebeer, D. J. N., Perantoni, G., and **Rao, A. V.**, "Optimal Control of Formula One Car Energy Recovery Systems," *International Journal of Control*, Vol. 87, No. 10, October 2014, pp. 2065–2080.
- Françolin, C. C. and **Rao, A. V.**, "Costate Estimation in Optimal Control Using a Integral Gaussian Quadrature Orthogonal Collocation Methods," *Optimal Control Applications and Methods*, Vol. 36, No. 4, July - August 2015, pp. 381–397. DOI: 10.1002/oca2112.
- Patterson, M. A., Hager, W. W., and **Rao, A. V.**, "A  $p_h$  Mesh Refinement Method for Optimal Control," *Optimal Control Applications and Methods*, Vol. 36, No. 4, July - August 2015, pp. 398–421. DOI: 10.1002/oca2114.

18. Patterson, M. A. and **Rao, A. V.**, "GPOPS-II: A MATLAB Software for Solving Multiple-Phase Optimal Control Problems Using *hp*-Adaptive Gaussian Quadrature Collocation Methods and Sparse Nonlinear Programming," *ACM Transactions on Mathematical Software*, Vol. 41, No. 1, October–December 2014, pp. 1:1–1:37.
19. Patterson, M. A., Weinstein, M., and **Rao, A. V.**, "An Efficient Overloaded Method for Computing Analytic Derivatives of Mathematical Functions in MATLAB," *ACM Transactions on Mathematical Software*, Vol. 39, No. 3, April 2013, pp. 17:1–17:36.
20. Şenses, B. and **Rao, A. V.**, "Minimum-Fuel Finite-Thrust Low-Earth Orbit Aeroassisted Orbital Transfer of Small Spacecraft," *Journal of Guidance, Control, and Dynamics*, Vol. 36, No. 6, November–December 2013, pp. 1802–1810.
21. Françolin, C. C., **Rao, A. V.**, Duarte, C., and Martel, G., "Optimal Control of an Autonomous Surface Vehicle to Improve Connectivity in an Underwater Vehicle Network," *Journal of Aerospace Computing, Information, and Communication*, Vol. 9, No. 1, September 2012, pp. 1–13.
22. Patterson, M. A. and **A. V. Rao**, "Exploiting Sparsity in Direct Collocation Pseudospectral Methods for Solving Optimal Control Problems," *Journal of Spacecraft and Rockets*, Vol. 49, No. 2, March–April 2012, pp. 364–377.
23. Darby, C. L., Garg, D., and **Rao, A. V.**, "Costate Estimation Using Multiple-Interval Pseudospectral Methods," *Journal of Spacecraft and Rockets*, Vol. 49, No. 5, September–October 2011, pp. 618–628.
24. Darby, C. L., Hager, W. W., and **Rao, A. V.**, "An *hp*-Adaptive Pseudospectral Method for Solving Optimal Control Problems," *Optimal Control Applications and Methods*, Vol. 32, No. 4, July–August 2011, pp. 476–502.
25. Darby, C. L. and **Rao, A. V.**, "Minimum-Fuel Low-Earth Orbit Aeroassisted Orbital Transfer of Small Spacecraft," *Journal of Spacecraft and Rockets*, Vol. 48, No. 4, July–August 2011, pp. 618–628.
26. Garg, D., Patterson, M. A., Françolin, C., Darby, C. L., Huntington, G. T., Hager, W. W., and **Rao, A. V.**, "Direct Trajectory Optimization of Finite-Horizon and Infinite-Horizon Optimal Control Problems Using a Radau Pseudospectral Method," *Computational Optimization and Applications*, Vol. 49, No. 2, June 2011, pp. 335–358.
27. Darby, C. L., Hager, W. W., **Rao, A. V.**, "Direct Trajectory Optimization Using a Variable Low-Order Pseudospectral Method," *Journal of Spacecraft and Rockets*, Vol. 48, No. 3, May–June 2011, pp. 433–445.
28. Garg, D., Hager, W. W., and **Rao, A. V.**, "Pseudospectral Methods for Solving Infinite-Horizon Optimal Control Problems," *Automatica*, Vol. 47, No. 4, April 2011, pp. 829–837.
29. Garg, D., Patterson, M. A., Hager, W. W., **Rao, A. V.**, Benson, D. A., and Huntington, G. T., "A Unified Framework for the Numerical Solution of Optimal Control Problems Using Pseudospectral Methods," *Automatica*, Vol. 46, No. 11, November 2010, pp. 1843–1851.
30. **Rao, A. V.**, Benson, D. A., Darby, C. L., Patterson, M. A., Françolin, C., Sanders, I., and Huntington, G. T., "Algorithm 902: GPOPS, A MATLAB Software for Solving Multiple-Phase Optimal Control Problems Using Gauss Pseudospectral Method," *ACM Transactions on Mathematical Software*, Vol. 37, No. 2, April–June 2010, pp. 22:1–22:39.
31. Baumgartner, K. A. C., Ferrari, S., and **Rao, A. V.**, "Optimal Control of an Underwater Sensor Network for Cooperative Target Tracking," *IEEE Journal of Oceanic Engineering*, Vol. 34, No. 4, October 2009, pp. 678–697.
32. Matsumura, T., Gogu, C., Haftka, R., and **A. V. Rao**, "Aeroassisted Orbital Transfer Considering Thermal Protection System Mass," *Journal of Guidance, Control, and Dynamics*, Vol. 32, No. 3, May–June 2009, pp. 927–938.
33. Huntington, G. T. and **Rao, A. V.**, "Comparison of Global and Local Collocation Methods for Optimal Control," *Journal of Guidance, Control, and Dynamics*, Vol. 31, No. 2, March–April 2008, pp. 432–436.
34. Huntington, G. T. and **Rao, A. V.**, "Optimal Reconfiguration of Spacecraft Formations Using the Gauss Pseudospectral Method," *Journal of Guidance, Control, and Dynamics*, Vol. 31, No. 3, May–June 2008, pp. 689–698.

35. Huntington, G. T., Benson, D. A., and **Rao, A. V.**, "Design of Optimal Tetrahedral Spacecraft Formations," *The Journal of the Astronautical Sciences*, Vol. 55, No. 2, April–June 2007, pp. 141–169.
36. Benson, D. A., Huntington, G. T., Thorvaldsen, T. P., and **Rao, A. V.**, "Direct Trajectory Optimization and Costate Estimation via an Orthogonal Collocation Method," *Journal of Guidance, Control, and Dynamics*, Vol. 29, No. 6, November–December, 2006, pp. 1435–1440.

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—Above This Line: Publications Since Joining University of Florida—

37. **Rao, A. V.**, "Riccati Dichotomic Basis Method for Solving Hyper-Sensitive Optimal Control Problems," *Journal of Guidance, Control, and Dynamics*, Vol. 26, No. 1, January–February, 2003, pp. 185–189.
38. **Rao, A. V.**, Tang, S., Hallman, W. P., "Numerical Optimization Study of Multiple-Pass Aeroassisted Orbital Transfer," *Optimal Control Applications and Methods*, Vol. 23, No. 4, July–August, 2002, pp. 215–238.
39. **Rao, A. V.**, "Application of a Dichotomic Basis Method to Performance Optimization of Supersonic Aircraft," *Journal of Guidance, Control, and Dynamics*, Vol. 23, No. 4, July–August, 2002, pp. 570–573.
40. **Rao, A. V.**, "Minimum-Variance Estimation of Reentry Debris Trajectories," *Journal of Spacecraft and Rockets*, Vol. 37, No. 3, May–June, 2000, pp. 366–373.
41. **Rao, A. V.** and Mease, K. D., "Eigenvector Approximate Dichotomic Basis Method for Solving Hyper-Sensitive Optimal Control Problems," *Optimal Control Applications and Methods*, Vol. 21, No. 1, January–February, 2000, pp. 1–17 (republished from original version in Vol. 20, No. 2, 1999, due to publisher error).
42. **Rao, A. V.** Mease, K. D., "Dichotomic Basis Approach to Solving Hyper-Sensitive Optimal Control Problems," *Automatica*, Vol. 35, No. 4, April 1999, pp. 633–642.
43. Bharadwaj, S, **Rao, A. V.**, and Mease, K. D., "Entry Trajectory Tracking Law via Feedback Linearization," *Journal of Guidance, Control, and Dynamics*, Vol. 21, No. 5, September–October, 1998, pp. 726–732.

### CONFERENCE PUBLICATIONS

1. Agamawi, Y. and **Rao, A. V.**, "Exploiting Sparsity in Direct Collocation Pseudospectral Methods for Solving Multiple-Phase Optimal Control Problems," *2018 AIAA/AAS Space Flight Mechanics Meeting*, Kissimmee, Florida, 8 - 12 January 2018. Submitted for Publication, June 2017.
2. Miller, A. T., Hager, W. W., and **Rao, A. V.**, "A Preliminary Analysis of Mesh Refinement for Optimal Control Using Discontinuity Detection via Jump Function Approximations," *2018 AIAA Guidance, Navigation, and Control Conference*, Kissimmee, Florida, 8 - 12 January 2018. Submitted for Publication, June 2017.
3. Hager W. W. and **Rao, A. V.**, "Mesh-Generation Method for Real-Time Optimal Control Using Adaptive Gaussian Quadrature Collocation," *2018 AIAA Guidance, Navigation, and Control Conference*, Kissimmee, Florida, 8 - 12 January 2018. Submitted for Publication, June 2017.
4. Fuhr, R. and **Rao, A. V.**, "Minimum-Impulse Low-Earth Orbit Aeroassisted Orbital Transfer with Heating Constraints," *2018 AIAA/AAS Space Flight Mechanics Meeting*, Kissimmee, Florida, 8 - 12 January 2018. Submitted for Publication, June 2017.

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—Above This Line: Conference Publications In Review—

5. Agamawi, Y., Hager, W. W., and **Rao, A. V.**, "Mesh Refinement Method for Optimal Control Problems with Discontinuous Control Profiles," *2017 AIAA Guidance, Navigation, and Control Conference*, AIAA Paper 2017-1506, 9–13 January 2017, Grapevine, Texas.
6. Miller, A. T. and **Rao, A. V.**, "Rapid Ascent-Entry Vehicle Mission Optimization Using hp-Adaptive Gaussian Quadrature Collocation," *2017 AIAA Atmospheric Flight Mechanics Conference*, AIAA Paper 2017-0249, 9 – 13 January 2017, Grapevine, Texas.
7. Eide, J. and **Rao, A. V.**, "Lavrentiev Phenomenon in *hp* Gaussian Quadrature Collocation Methods for Optimal Control," *2016 AIAA/AAS Astrodynamics Specialist Conference*, AIAA Paper 2016-5575, 13–16 September 2016, Long Beach, California, .

8. Zhao, Z., Liu, F., Kumar, M., and **Rao, A. V.**, "A Novel Approach to Chance Constrained Optimal Control Problems," *2015 American Control Conference*, Chicago Illinois, 1–3 July 2015.
9. Graham, K. F. and **Rao, A. V.**, "Mesh Refinement for Low-Thrust Trajectory Optimization of Earth-Orbit Transfers," *2015 AAS/AIAA Space Flight Mechanics Meeting*, AAS Paper 15-434, Williamsburg, Virginia, 11 - 15 January 2015.
10. Graham, K. F. and **Rao, A. V.**, "Low-Thrust Trajectory Optimization of Earth-Orbit Transfers with Eclipsing Constraints," *2015 AAS/AIAA Space Flight Mechanics Meeting*, AAS Paper 15-438, Williamsburg, Virginia, 11 - 15 January 2015.
11. Weinstein, M. A., Patterson, M. A., and **Rao, A. V.**, "Utilizing the Algorithmic Differentiation Package ADiGator for Solving Optimal Control Problems Using Direct Collocation," *2015 AIAA Guidance, Navigation, and Control Conference*, Kissimmee, FL, January 2015.
12. Senses, B., Davis, T. A., and **Rao, A. V.**, "Graph Coarsening Method for Solving KKT Systems Arising in Orthogonal Collocation of Optimal Control Problems," *2015 AIAA Modeling and Simulation Technologies Conference*, Kissimmee, FL, 4 - 7 January 2015.
13. Liu, F., Hager, W. W., and **Rao, A. V.**, "An  $hp$  Mesh Refinement Method for Optimal Control Using Discontinuity Detection and Mesh Size Reduction," *2014 IEEE Conference on Decision and Control*, Los Angeles, California, 15 – 17 December 2014.
14. Françolin, C. C., Hou, H., Hager, W. W., and **Rao, A. V.**, "Costate Estimation of State-Inequality Path Constrained Optimal Control Problems Using Collocation at Legendre-Gauss-Radau Points," *2013 Conference on Decision and Control*, Florence, Italy, 10–13, pp. 6469–6474.
15. Rexius, S. L., Rexius, T. E., Jorris, T. R., and **Rao, A. V.**, "Advances in Highly Constrained Multi-Phase Trajectory Generation Using the General Pseudospectral Optimization Software GPOPS," *2013 AIAA Guidance, Navigation, and Control Conference*, AIAA Paper 2013–4950, 19–22 August 2013, Boston, Massachusetts.
16. Schubert, K. F. and **Rao, A. V.**, "Minimum-Time Low-Earth Orbit to High-Earth Orbit Low Thrust Trajectory Optimization," *2013 AAS/AIAA Astrodynamics Specialist Conference*, AAS Paper 13-926, Hilton Head, South Carolina, 12–15 August 2013. (**Paper Chosen for American Astronautical Society John V. Breakwell Student Travel Award**)
17. Françolin, C. and **Rao, A. V.**, "Direct Trajectory Optimization and Costate Estimation of State Inequality Path-Constrained Optimal Control Problems Using a Radau Pseudospectral Method," *2012 AIAA Guidance, Navigation, and Control Conference*, AIAA Paper 2012–4528, Minneapolis, Minnesota, August 13–16, 2012.
18. Hou, H., Hager, W. W., and **Rao, A. V.**, "Convergence of a Gauss Pseudospectral Method for Optimal Control," *2012 AIAA Guidance, Navigation, and Control Conference*, AIAA Paper 2012–4452, Minneapolis, Minnesota, August 13–16, 2012.
19. Şenses, B. and **Rao, A. V.**, "A Preliminary Analysis of Small Spacecraft Finite-Thrust Aeroassisted Orbital Transfer," *2012 AIAA/AAS Astrodynamics Specialist Conference*, AIAA Paper 2012–4812, Minneapolis, Minnesota, August 13–16, 2012.
20. Weinstein, M., Patterson, M. A., and **Rao, A. V.**, "A Method for Computing Derivatives in MATLAB," *2012 AIAA/AAS Astrodynamics Specialist Conference*, AIAA Paper 2012–4521, Minneapolis, Minnesota, August 13–16, 2012.
21. Mohan, K., Patterson, M. A., and **Rao, A. V.**, "Optimal Trajectory and Control Generation for Landing of Multiple Aircraft in the Presence of Obstacles," *2012 AIAA Guidance, Navigation, and Control Conference*, AIAA Paper 2012–4826, Minneapolis, Minnesota, August 13–16, 2012.
22. Darby, C. L., Garg, D., and **Rao, A. V.**, "Costate Estimation Using Multiple-Interval Pseudospectral Methods," *2011 AIAA Guidance, Navigation, and Control Conference*, AIAA Paper 2011–6571, Portland, Oregon, August 8–11, 2011.
23. Darby, C. L., Hager, W. W., and **Rao, A. V.**, "A Preliminary Analysis of a Variable-Order Approach to Solving Optimal Control Problems Using Pseudospectral Methods," *2011 AIAA/AAS Astrodynamics Specialist Conference*, AIAA Paper 2010–8272, Toronto, Ontario, Canada, August 2–5, 2010.

24. Françolin, C., **Rao, A. V.**, Duarte, C., and Martel, G., "Optimization of the Motion of a Mobile Gateway to Improve Connectivity in a Network of Autonomous Underwater Vehicles," *AIAA Guidance, Navigation, and Control Conference*, AIAA Paper 2010-7572, Toronto, Ontario, Canada, August 2-5, 2010.
25. Patterson, M. A. and **Rao, A. V.**, "An Object-Oriented Method for Computation of Analytic Derivatives," *AIAA Modeling and Simulation Technologies Conference*, AIAA Paper 2010-7783, Toronto, Ontario, Canada, August 2-5, 2010.
26. Garg, D., Hager, W. W., and **Rao, A. V.**, "Gauss Pseudospectral Method for Solving Infinite-Horizon Optimal Control Problems," *AIAA Guidance, Navigation, and Control Conference*, AIAA Paper 2010-7890, Toronto, Ontario, Canada, August 2-5, 2010.
27. Jorris, T. R. and **Rao, A. V.**, "Bang-Bang Trajectory Optimization Using Autonomous Phase Placement and Mesh Refinement Satisfying Waypoint and No-Fly Zone Constraints," *AAS/AIAA Space Flight Mechanics Meeting*, AAS Paper Number 10-115, San Diego, California, February 15-17, 2010.
28. Darby, C. L. and **Rao, A. V.**, "Optimal Impulsive LEO to LEO Aeroassisted Orbital Transfer of Small Satellites," *AAS/AIAA Space Flight Mechanics Meeting*, AAS Paper Number 10-102, San Diego, California, February 15-17, 2010.
29. **Rao, A. V.**, "A Survey of Numerical Methods for Optimal Control," *AAS/AIAA Astrodynamics Specialist Conference*, AAS Paper 09-334, Pittsburgh, PA, August 10-13, 2009.
30. Garg, D., Patterson, M. A., Hager, W. W., **Rao, A. V.**, Benson, D. A., and Huntington, G. T., "An Overview of Three Pseudospectral Methods for The Numerical Solution of Optimal Control Problems," *AAS/AIAA Astrodynamics Specialist Conference*, Pittsburgh, PA, August 10-13, 2009.
31. Garg, D., Patterson, M. A., Darby, C. L. Françolin, C., Huntington, G. T., Hager, W. W. and **Rao, A. V.**, "Direct Trajectory Optimization and Costate Estimation of General Optimal Control Problems Using a Radau Pseudospectral Method," *AIAA Guidance, Navigation, and Control Conference*, AIAA Paper 2009-5989, Chicago, IL, August 10-13, 2009.
32. Darby, C. L. and **Rao, A. V.**, "A State Approximation-Based Mesh Refinement Algorithm for Solving Optimal Control Problems Using Pseudospectral Methods," *AIAA Guidance, Navigation, and Control Conference*, AIAA Paper 2009-5791, Chicago, IL, August 10-13, 2009.
33. Darby, C. L. and **Rao, A. V.**, "An Initial Examination of Using Pseudospectral Methods for Time-Scale and Differential Geometric Analysis of Nonlinear Optimal Control Problems," *AIAA/AAS Astrodynamics Specialist Conference*, AIAA Paper 2008-6449, Honolulu, Hawaii, August 18-21, 2008.
34. **Rao, A. V.**, Scherich, A. W., Cox, S., and Mosher, T., "A Concept for Operationally Responsive Space Mission Planning Using Aeroassisted Orbital Transfer," *AIAA Responsive Space Conference*, AIAA Paper RS6-2008-1001, Los Angeles, California, 28 April-1 May, 2008.
35. Matsumura, T., Gogu, C., Haftka, R., and **Rao, A. V.**, "Aeroassisted Orbital Transfer Trajectory Optimization Considering Thermal Protection System Mass," *AIAA Aerospace Sciences Meeting*, AIAA Paper 2008-898, Reno, Nevada, January 7-10, 2008.
36. Huntington, G. T., Benson, D. A., How, J. P., Kanizay, N., Darby, C. L., and **Rao, A. V.**, "Computation of Boundary Controls Using a Gauss Pseudospectral Method," *AAS/AIAA Astrodynamics Specialist Conference*, AAS Paper 07-381, Mackinac Island, Michigan, August 20-23, 2007.
37. Huntington, G. T., Benson, D. A., and **Rao, A. V.**, "A Comparison of Accuracy and Computational Efficiency of Three Pseudospectral Methods," *AIAA Guidance, Navigation, and Control Conference*, AIAA Paper 2007-6405, Hilton Head, SC, August 20-23, 2007.
38. Huntington, G. T. and **Rao, A. V.**, "A Comparison of Local and Global Orthogonal Collocation Methods for Solving Optimal Control Problems," *American Control Conference*, New York, July 11-13, 2007.
39. Huntington, G. T., Benson, D. A., and **Rao, A. V.**, "Post-Optimality Analysis and Evaluation of a Formation Flying Problem via a Gauss Pseudospectral Method," *AAS/AIAA Astrodynamics Specialist Conference*, Lake Tahoe, California, August 7-11 2005.

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—Above This Line: Publications Since Joining University of Florida—

40. Huntington, G. T. and **Rao, A. V.**, "Optimal Reconfiguration of Tetrahedral Spacecraft Formations via a Gauss Pseudospectral Method," *AAS/AIAA Astrodynamics Specialist Conference*, Lake Tahoe, California, August 7–11 2005.
41. Huntington, G. T. and **Rao, A. V.**, "Optimal Configuration of Tetrahedral Spacecraft Formations via a Gauss Pseudospectral Method," *AAS/AIAA Space Flight Mechanics Meeting*, Copper Mountain, Colorado, January 23–27 2005.
42. **Rao, A. V.**, "Extension of a Pseudospectral Legendre Method to Non-Sequential Multiple-Phase Optimal Control Problems," *AIAA Guidance, Navigation, and Control Conference*, AIAA Paper 2003–5634, Austin, TX, August 11–14, 2003.
43. **Rao, A. V.** and Clarke, K. A., "Performance Optimization of a Maneuvering Re-entry Vehicle via a Legendre Pseudospectral Method," *AIAA Atmospheric Flight Mechanics Conference*, AIAA Paper 2002–4885, Monterey, CA, August 6–9, 2002.
44. **Rao, A. V.**, "Riccati Dichotomic Basis Method for Solving Hyper-Sensitive Optimal Control Problems," *AIAA Guidance, Navigation, and Control Conference*, Montreal, Quebec, August 6–9, 2001.
45. **Rao, A. V.**, "Numerical Optimization Study of Multiple-Pass Aeroassisted Orbital Transfer," *AIAA Guidance, Navigation, and Control Conference*, Denver, Colorado, August 5–8, 2000.

#### arXiv Articles

1. Hager, W. W., Mohapatra, S., and **Rao, A. V.**, "Convergence Rate for a Gauss Collocation Method Applied to Constrained Optimal Control," July 10, 2016. Revised September 30, 2016. Cite as arXiv:1607.02798.
2. Hager, W. W., Hou, H., Mohapatra, S., and **Rao, A. V.**, "Convergence Rate for an *hp* Collocation Method Applied to Unconstrained Optimal Control," May 6, 2016. Cite as arXiv:1605.02121.
3. Hager, W. W., Hou, H., and **Rao, A. V.**, "Convergence Rate for a Radau Collocation Method Applied to Unconstrained Optimal Control," August 17, 2015. Revised September 12, 2015. Cite as arXiv:1508.03783.

#### BOOKS

**Rao, A. V.**, *Dynamics of Particles and Rigid Bodies: A Systematic Approach*, Cambridge University Press, 2006, 528 pages.

#### ENCYCLOPEDIA ARTICLES

**Rao, A. V.**, "Trajectory Optimization," *Encyclopedia of Aerospace Engineering*, John Wiley and Sons, 2010.

#### EDITED VOLUMES

**Rao, A. V.**, Lovell, T. A., Chan, F. K., and Cangahuala, L. A., Eds., *Advances in the Astronautical Sciences*, Vol. 135, Univelt Publishers, San Diego, August 2009, 2446 pages.

#### SOFTWARE

1. Patterson, M. A., and **Rao, A. V.**, GPOPS – III: A MATLAB Software for Solving Multiple-Phase Optimal Control Problems Using Sparse Nonlinear Programming and *hp*-Adaptive Pseudospectral Methods. <http://www.gpops2.com>.
2. Weinstein, M. J. and **Rao, A. V.**, ADiGator, a MATLAB Software for Algorithmic Differentiation of Mathematical Functions Using Source Transformation via Operator Overloading, <http://sourceforge.net/projects/adigator>.
3. **Rao, A. V.**, Benson, D. A., Patterson, M. A., Françolin, C. C., Sanders, I., and Huntington, G. T., GPOPS: A MATLAB Software for Solving Optimal Control Problems Using Gauss Quadrature Collocation. Algorithm 902 Collected Algorithms of the Association of Computing Machinery. <http://calgo.acm.org>.

### GRADUATED Ph.D. STUDENTS

Student Name	Institution	Date Awarded	Current Employer
Dr. Fengjin Liu	University of Florida	December 2015	—
Dr. Kathryn F. Graham	University of Florida	December 2015	Shafer Corporation
Dr. Begum Cannataro	University of Florida	August 2015	<a href="#">Draper Laboratory</a>
Dr. Matthew J. Weinstein	University of Florida	May 2015	<a href="#">Draper Laboratory</a>
Dr. Camila C. Françolin	University of Florida	August 2013	<a href="#">Draper Laboratory</a>
Dr. Michael A. Patterson	University of Florida	May 2013	<a href="#">Johns Hopkins Applied Physics Laboratory</a>
Dr. Divya Garg	University of Florida	August 2011	<a href="#">Intel Corporation</a>
Dr. Christopher L. Darby	University of Florida	April 2011	<a href="#">Intel Corporation</a>
Dr. Geoffrey T. Huntington	MIT	May 2007	<a href="#">Blue Origin, LLC</a>

### CURRENT Ph.D. STUDENTS

Student Name	Institution	Expected Completion Date
Rachel Keil	University of Florida	May 2021
Miriam Dennis	University of Florida	May 2021
Yunus Agamawi	University of Florida	May 2020
Alexander Miller	University of Florida	May 2020
Joseph Eide	University of Florida	December 2017

### TEACHING EVALUATIONS (UNIVERSITY OF FLORIDA)

Course Number	Course Name	Semester Taught	Rao Overall Evaluation	Department Mean	College Mean
EML 4220	Mechanical Vibrations	Fall 2006	4.54	3.99	4.13
EML 4220	Mechanical Vibrations	Spring 2009	4.57	4.10	4.19
EML 4220	Mechanical Vibrations	Fall 2012	4.48	4.17	4.19
EGM 3400	Elements of Dynamics	Spring 2007	4.60	4.00	4.17
EGM 3400	Elements of Dynamics	Fall 2008	4.75	4.10	4.19
EGM 3400	Elements of Dynamics	Fall 2010	4.64	4.14	4.21
EGM 3401	Engineering Dynamics	Spring 2007	4.70	4.00	4.17
EGM 3401	Engineering Dynamics	Fall 2008	4.79	4.10	4.19
EGM 3401	Engineering Dynamics	Fall 2010	4.66	4.14	4.21
EGM 3401	Engineering Dynamics	Spring 2011	4.76	4.12	4.11
EGM 3401	Engineering Dynamics	Spring 2013	4.57	4.16	4.15
EGM 3401	Engineering Dynamics	Fall 2014	4.62	4.07	4.13
EGM 3401	Engineering Dynamics	Spring 2015	4.90	4.13	4.14
EGM 3401	Engineering Dynamics	Fall 2016	4.85	4.18	4.15
EGM 3401	Engineering Dynamics	Spring 2017	4.93	4.21	4.16
EML 5215	Analytical Dynamics	Fall 2007	4.54	3.99	4.14
EML 5215	Analytical Dynamics	Fall 2009	4.75	4.14	4.18
EML 5215	Analytical Dynamics	Fall 2011	4.67	4.11	4.17
EML 5215	Analytical Dynamics	Fall 2013	4.14	4.05	4.17
EML 6934	Optimal Control	Spring 2008	4.53	4.08	4.20
EML 6934	Optimal Control	Spring 2010	4.35	4.10	4.17
EML 6934	Optimal Control	Spring 2012	4.50	4.20	4.17
EML 6934	Optimal Control	Spring 2014	4.56	4.09	4.14



**EXTERNAL RESEARCH FUNDING**

<b>Total Funding as PI or Co-PI</b>	\$5,148,110
<b>Agency</b> <b>Role</b> <b>Title</b> <b>Period of Performance</b> <b>Amount</b>	National Science Foundation Principal Investigator (Co-PI: M. Kumar) A Computational Framework for Chance-Constrained Optimal Control July 2016 to June 2019 \$400,000
<b>Agency</b> <b>Role</b> <b>Title</b> <b>Period of Performance</b> <b>Amount</b>	U.S. Naval Air Systems Command (via Systems Technology, Inc) Principal Investigator (Co-PI: W. W. Hager) Phase II: Pseudospectral Optimal Control for Flight Trajectory Optimization January 2017 to January 2019 \$295,580
<b>Agency</b> <b>Role</b> <b>Title</b> <b>Period of Performance</b> <b>Amount</b>	U.S. Naval Air Systems Command (via Systems Technology, Inc) Principal Investigator (Co-PI: W. W. Hager) Phase I: Pseudospectral Optimal Control for Flight Trajectory Optimization July 2015 to October 2016 \$72,500
<b>Agency</b> <b>Role</b> <b>Title</b> <b>Period of Performance</b> <b>Amount</b>	U.S. Air Force Research Laboratory Principal Investigator (Co-PI: W. W. Hager) Solutions to Optimal Control Problems for Boost Glide High-Speed Applications September 2015 to September 2017 \$358,842
<b>Agency</b> <b>Role</b> <b>Title</b> <b>Period of Performance</b> <b>Amount</b>	NASA Florida Space Grant Consortium Principal Investigator A Novel Computational Approach to Solving Optimal Control Problems Whose Solutions Lie on Singular Arcs August 2015 to August 2016 \$25,000
<b>Agency</b> <b>Role</b> <b>Title</b> <b>Period of Performance</b> <b>Amount</b>	National Science Foundation Co-Principal Investigator (PI: W. W. Hager) Fast Sparse Nonlinear Optimization and Its Application to Optimal Control July 2015 to July 2018 \$299,793
<b>Agency</b> <b>Role</b> <b>Title</b> <b>Period of Performance</b> <b>Amount</b>	U.S. Office of Naval Research Co-Principal Investigator (PI: W. W. Hager) New Innovations in Large-Scale Sparse Optimization and Applications March 2015 to February 2018 \$479,870
<b>Agency</b> <b>Role</b> <b>Title</b> <b>Period of Performance</b> <b>Amount</b>	National Science Foundation Co-Principal Investigator (PI: B. J. Fregly) A Next-Generation Computation Framework for Predicting Optimal Walking Motion August 2014 to August 2017 \$499,994
<b>Agency</b> <b>Role</b> <b>Title</b> <b>Period of Performance</b> <b>Amount</b>	National Aeronautics and Space Administration Principal Investigator A Computational Approach for the Efficient and Accurate Solutions of Low-Thrust Trajectory Optimization Problems August 2014 to August 2015 \$30,657
<b>Agency</b> <b>Role</b> <b>Title</b> <b>Period of Performance</b>	U. S. Space and Naval Warfare Systems Command Principal Investigator (Co-PI: M. Kumar) A Computational Approach for Probabilistically Constrained Design Optimization Using Generalized Polynomial Chaos and Pseudospectral Methods (Phase 1: gPC Modeling and Sparse Symmetric Linear Solver) September 2013 to December 2014

<b>Amount</b>	\$247,083
<b>Agency</b>	NASA Florida Space Grant Consortium
<b>Role</b>	Principal Investigator
<b>Title</b>	A Novel Computational Framework for Efficient and Accurate Low-Thrust Optimal Mission Planning
<b>Period of Performance</b>	August 2013 to February 2015
<b>Amount</b>	\$25,000
<b>Agency</b>	National Aeronautics and Space Administration
<b>Role</b>	Principal Investigator
<b>Title</b>	Low-Thrust Trajectory Optimization Using Pseudospectral Methods
<b>Period of Performance</b>	January 2012 to December 2012
<b>Amount</b>	\$25,000
<b>Agency</b>	U. S. Defense Advanced Research Projects Agency
<b>Role</b>	Principal Investigator (Co-PI: W. W. Hager)
<b>Title</b>	A Computational Framework for the Rapid, Reliable, & Robust Solutions to Complex Constrained Optimal Control Problems
<b>Period of Performance</b>	October 2011 to October 2014
<b>Amount</b>	\$986,684
<b>Agency</b>	U. S. Office of Naval Research
<b>Role</b>	Principal Investigator (Co-PI: W. W. Hager)
<b>Title</b>	A Computational Framework for the Real-Time Solution of Optimal Control Problems
<b>Period of Performance</b>	November 2010 to October 2013
<b>Amount</b>	\$551,728
<b>Agency</b>	Advatech Pacific/U. S. Air Force Research Laboratory
<b>Role</b>	Principal Investigator
<b>Title</b>	Advancement in Computational Methods for Optimal Control Using Pseudospectral Methods
<b>Period of Performance</b>	September 2010 to May 2011
<b>Amount</b>	\$75,000
<b>Agency</b>	U. S. Air Force Research Laboratory
<b>Role</b>	Principal Investigator
<b>Title</b>	A Pseudospectral Mission Planning Tool for Prompt Global Strike
<b>Period of Performance</b>	September 2009 to August 2010
<b>Amount</b>	\$75,000
<b>Agency</b>	NASA Florida Space Grant Consortium
<b>Role</b>	Principal Investigator
<b>Title</b>	A Multi-Disciplinary Design Optimization Approach to Rapid Space Planning for Operationally Responsive Space
<b>Period of Performance</b>	August 2009 to August 2010
<b>Amount</b>	\$16,000
<b>Agency</b>	Lockheed-Martin Corporation
<b>Role</b>	Co-Principal Investigator (PI: G. Wiens)
<b>Title</b>	Multi-Disciplinary Design Optimization of Aeroassisted Orbital Transfer
<b>Period of Performance</b>	January 2009 to December 2009
<b>Amount</b>	\$95,000
<b>Agency</b>	U. S. Office of Naval Research
<b>Role</b>	Principal Investigator
<b>Title</b>	A Computational Approach for Autonomous Undersea Vehicle Near-Optimal Path Planning and Guidance
<b>Period of Performance</b>	September 2008 to August 2012
<b>Amount</b>	\$224,379
<b>Agency</b>	U. S. Army Research Office
<b>Role</b>	Principal Investigator (Co-PI: W. W. Hager)
<b>Title</b>	A Computational Framework for Path Planning and Guidance for Dynamical Systems with Nonholonomic Constraints

<b>Period of Performance</b>	September 2008 to June 2009
<b>Amount</b>	\$50,000
<b>Agency</b>	NASA Florida Space Grant Consortium
<b>Role</b>	Principal Investigator
<b>Title</b>	Student Award for Trajectory Optimization
<b>Period of Performance</b>	August 2008 to August 2009
<b>Amount</b>	\$10,000
<b>Agency</b>	NASA Florida Space Grant Consortium
<b>Role</b>	Principal Investigator
<b>Title</b>	A Computational Approach for Rapid Space Mission Planning
<b>Period of Performance</b>	August 2007 to August 2008
<b>Amount</b>	\$25,000
<b>Agency</b>	ATK Launch Systems
<b>Role</b>	Principal Investigator
<b>Title</b>	Launch Vehicle Ascent Guidance Using Pseudospectral Methods
<b>Period of Performance</b>	July 2007 to August 2008
<b>Amount</b>	\$65,000
<b>Agency</b>	ATK Launch Systems
<b>Role</b>	Principal Investigator
<b>Title</b>	Launch Vehicle Ascent Guidance Using Pseudospectral Methods
<b>Period of Performance</b>	January 2007 to June 2007
<b>Amount</b>	\$60,000
<b>Agency</b>	National Aeronautics and Space Administration
<b>Role</b>	Principal Investigator
<b>Title</b>	Legendre Pseudospectral Method for Multiple Spacecraft Formation Flying
<b>Period of Performance</b>	July 2003 to June 2006
<b>Amount</b>	\$180,000

#### INVITED TALKS

<b>Institution</b>	<b>Topic</b>	<b>Dates</b>
Pennsylvania State University	Next-Generation Computational Framework for Rapid and Reliable Solutions to Optimal Control Problems	March 2017
University of Cincinnati	Next-Generation Computational Framework for Rapid and Reliable Solutions to Optimal Control Problems	November 2016
University of Texas at Arlington	Next-Generation Computational Framework for Rapid and Reliable Solutions to Optimal Control Problems	September 2016
International Conference on Continuous Optimization (ICCOPT 2016)	Novel Computational Framework for the Numerical Solution of Constrained Optimal Control Problems	August 2016
Georgia Institute of Technology	Next-Generation Computational Framework for Rapid and Reliable Solutions to Optimal Control Problems	March 2016
University of Edinburgh – International Symposium for Computer Simulation in Biomechanics	Numerical Methods for Optimal Control	July 2015
Imperial College of Science & Technology – 2015 British-French-German Conference on Optimization	Graph Coarsening of KKT Systems Arising in Orthogonal Collocation Methods for Optimal Control	June 2015
Clemson University	Next-Generation Computational Framework for Rapid and Reliable Solutions to Optimal Control Problems	April 2015

Oxford University	Pseudospectral Methods: Theory and Practice	March 2014
Embry-Riddle Aeronautical University	Next-Generation Computational Framework for Rapid and Reliable Solutions to Optimal Control Problems	January 2014
Johannes Kepler University – Workshop on Optimization and Optimal Control in Automotive Systems	Survey of Numerical Methods for Optimal Control	July 2013
Oxford University	Pseudospectral Methods: Theory and Practice	December 2012
McGill University – 2012 Bellairs Workshop on Computer Graphics & Animation	Pseudospectral Methods: for Optimal Control for Computer Animation	March 2012
University of Toronto	Next-Generation Computational Framework for Rapid and Reliable Solutions to Optimal Control Problems	March 2012
George Washington University	Next-Generation Computational Framework for Rapid and Reliable Solutions to Optimal Control Problems	April 2010
Georgia Institute of Technology	Next-Generation Computational Framework for Rapid and Reliable Solutions to Optimal Control Problems	March 2010
University of Illinois at Urbana – Champaign	Next-Generation Computational Framework for Rapid and Reliable Solutions to Optimal Control Problems	March 2010

#### CONSULTING AND SHORT COURSES

Institution	Work Performed	Dates
NASA Goddard Space Flight Center	Short Course on Optimal Control	July 2016
Doolittle Institute (Eglin Air Force Base)	Short Course on Optimal Control	December 2015
Edwards Air Force Base	Short Course on Optimal Control	August 2015
MITRE Corporation	Optimal Control Consulting	July 2015 – Present
Doolittle Institute (Eglin Air Force Base)	Short Course on Optimal Control	October 2014
Edwards Air Force Base	Short Course on Optimal Control	September 2014
Kirtland Air Force Base	Short Course on Optimal Control	July 2014
Doolittle Institute (Eglin Air Force Base)	Short Course on Optimal Control	May 2014
Edwards Air Force Base	Short Course on Optimal Control	March 2013
Advatech Pacific	Optimal Control Consulting	Throughout 2010 – 2011
Analytical Graphics, Inc.	Short Course on Optimal Control	May 2010

#### PROFESSIONAL SERVICE

Role	Service	Dates of Service
Member, Space Flight Mechanics Technical Committee	American Astronautical Society	September 2016 to Present
General Chair	2012 AIAA/AAS Astrodynamics Specialist Conference	August 2012
Technical Chair	2009 AAS/AIAA Astrodynamics Specialist Conference	August 2009
Associate Editor	Journal of the Astronautical Sciences	November 2006 to Date
Associate Editor	Journal of Optimization Theory and Applications	June 2011 to Date
Associate Editor	Journal of Spacecraft and Rockets	January 2015 to Date

Member, Space Flight Mechanics Technical Committee	American Astronautical Society	January 2007 to August 2013
Member, Publications Committee Technical Committee	American Institute of Aeronautics and Astronautics	January 2009 to December 2011

### HONORS AND AWARDS

<b>Award</b>	<b>Institution Conferring Award</b>	<b>Date of Award</b>
University of Florida Term Professorship	College of Engineering University of Florida	August 2017
Erich Farber Faculty Fellow	Department of Mechanical & Aerospace Engineering University of Florida	November 2016
Pramod P. Kargonekar Junior Faculty Award	College of Engineering University of Florida	July 2012
Associate Fellow	American Institute of Aeronautics and Astronautics	January 2011
Teacher of the Year	Department of Mechanical & Aerospace Engineering University of Florida	April 2007
Faculty of the Year	Department of Mechanical Engineering Boston University	May 2006
Book of the Year	The Charles Stark Draper Laboratory, Inc.	April 2006
Outstanding Faculty of the Year	College of Engineering Boston University	May 2004
Faculty of the Year	Department of Mechanical Engineering Boston University	May 2002

### REFERENCES

Available Upon Request