

S. N. Balakrishnan**S N Balakrishnan**

TITLE: Curators' Professor, Aerospace Engineering
Missouri University of Science and Technology, Dept. of Mechanical and Aerospace Engineering, 1870 Miner Circle, Rolla, MO 65409-1350

TELEPHONE: (573) 341-4675 **FAX:** (573) 341-4607 **E-mail:** bala@mst.edu
E-mail: bala@snu.edu.in

EDUCATION: Ph.D. (Aerospace Engineering), University of Texas at Austin, Texas, December 1983
Dissertation: Development of Two Maximum Likelihood Estimation Methods and Their Applications to Tracking Problems
Advisor: Dr. J. L. Speyer

ACADEMIC EXPERIENCE:**New Courses Introduced:**

1. Estimation: Theory and Applications (graduates only)
2. Modern Control I (senior undergraduates and graduates)
3. Linear Systems Theory (undergraduates)
4. Robust Control (graduates only)
5. Nonlinear Control (graduates only)

Courses Taught:**Missouri University of Science and Technology, UMR**

1. Robust Control (new, graduate)
2. Estimation: Theory and Applications (new, graduate)
3. Nonlinear Control (new, Graduate)
4. Modern Control I (new, senior undergraduate, graduate)
5. Flight Dynamics: Stability and Control II (senior undergraduate, graduate)
6. Flight Dynamics: Stability and Control I (undergraduate)
7. Aerospace Mechanics (Orbital Mechanics, undergraduate)
8. Aircraft Structures (undergraduate)
9. Control of Mechanical and Aerospace Systems (senior undergraduate, ME course)

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10. Control Labs(ME senior level, coordinator)

University of Texas at Austin, Texas

1. Statics (undergraduate)
2. Dynamics (undergraduate)
3. Intermediate Dynamics of Particles and Rigid Bodies (undergraduate)
4. Flight Mechanics (undergraduate)
5. Flight Mechanics Laboratory (undergraduate)
6. Flight Control Systems (undergraduate)

Research Interests:

Guidance, Stability, Control and Estimation, Pattern Recognition, Stochastic Processes, Optimization, Neural Networks, Autonomous Vehicles

Research Summary:

Dr. Balakrishnan's major technical contributions include the development of a new closed form suboptimal control for nonlinear systems called the **theta-D control** which approximates solutions to the Hamilton-Jacobi-Bellman equations. He has a strong research record in **intelligent control** and was the first to develop optimal neurocontrollers for systems modeled by partial differential equations and for systems driven by impulse inputs. He has developed optimal control and filters solutions to spacecraft, helicopter, missile, aircraft, manufacturing, and MEMS problems using neural networks. He has also developed and **implemented** optimal temperature profile control, vibration control and aircraft control using neural networks. Dr. Balakrishnan has also formulated a new approach to guidance and control called the **Integrated Guidance and Control (IGC)** and has shown its success in missile interception problems.

Research Supervision:

Number of students graduated: 43

Number of Undergraduate students advised: 9

Titles of M.S. and Ph.D. Theses:

1. "Dynamic Control and Parameter Estimation of a Robotics Manipulator," Alan Lewis (MS), 1987.
2. "Energy Method for Data-Track Correlation in Multitarget-Multiple Sensor Problems," H. Park (MS), 1989.
3. "Estimation of the Process Noise Covariance in Homing Guidance," Y. C. Hsu (MS), 1989.
4. "Moving Object Recognition and Guidance Robots Using Neural Networks," A. Neogy (MS), 1992.
5. "Self-Tuning Control Applied to Aeroassisted Orbit Transfer Problems," G. Kamarsu

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- (MS), 1993.
6. "Approximate Analytical Guidance and Estimation Schemes for Homing Missiles," D. Stansbery (MS), 1994.
 7. "Genetic Algorithms for Aeroassisted Trajectory Optimization and Time-Optimal Spacecraft Reorientation Controller Design," Y. F. Cheng (MS), 1994.
 8. "Adaptive Critic Based Neural Networks for Control," V. L. Biega (MS), 1994.
 9. "A Critic Based System for Neural Guidance and Control," Jeffrey S. Dalton (PhD), 1994.
 10. "A New Approach to Automatic Target Recognition Using Wavelet Transforms," Anitha Panapakkam (MS), 1994.
 11. "Fuzzy Logic in Reconfigurable Flight Control Systems," Howard Ho (MS), 1995.
 12. "Adaptive Critic Based Neurocontroller for Autolandings of Aircrafts," Gaurav Saini (MS), May 1996.
 13. "Critical Characteristic Capture Model Reduction," Michael Sharp (MS), May 1997.
 14. "Modifications to Adaptive Critic Based Controllers for Uncertain Plant Dynamics," Mayank Pant (MS), November 1997.
 15. "Design, Stability and Robustness Analysis of Two Neural Networks with Control Applications," Jie Shen, (PhD), Dec. 1997.
 16. "System Identification Using a Batch Processing Filter and Haar Function Wavelets," William Bockman (MS), 1999.
 17. "Fuzzy Logic and Tolerance Design," Kannan Srikanth (MS), 1999.
 18. "Hopfield and Modified Hopfield Neural Network Based Parameter Estimation and Control," Zhenning Hu (MS), 1999.
 19. "Hypersonic Vehicle Trajectory Optimization Using Neural Networks," Jonathan Richard Grohs (MS), 2000.
 20. "Development and Implementation of Adaptive Critic Based Optimal Neurocontroller on a Cantilevered Plate," Abhishek Gupta (MS), 2000.
 21. "Optimal Control of Distributed Parameter Systems Using Adaptive Critic Neural Networks," Radhakant Padhi (PhD), 2001.
 22. "Implementation and Validation of Adaptive Critic based Optimal Neurocontroller on a Multi-input Multi-output System," Vijaykumar Janardhan (MS), 2002.
 23. "Modeling and Experimental Control of a Distributed Parameter Heat Diffusion System Using Adaptive Critic Neural Networks," Prashant Prabhat (MS), 2002.
 24. "Hierarchical Multi-resolutional Optimal Control Systems," Anand Dasgupta (MS), 2002.
 25. "Nonlinear Flight Control Using Adaptive Critic based Neural Networks," Sergio Esteban Roncero (MS), 2002.
 26. "A New Method for Suboptimal Control of a Class of Nonlinear Systems," Ming Xin (PhD), 2002.
 27. "Lyapunov Function based Neurocontrollers for a Class of Deterministic and Stochastic problems," Zhongwu Huang (PhD), 2002.
 28. "Nonlinear Control of a Robotic Manipulator Using Neural Networks," Akhil Koul (MS), 2003.

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29. "Suboptimal Analytic Guidance Laws for Reusable Launch Vehicles," Katie Grantham (MS), 2003.
30. "Nonlinear Suboptimal Control for Reusable Launch Vehicles," David Drake (MS), 2004.
31. "Design and Implementation of Controllers for a Class of Electromechanical Systems," Vijayakumar Janardhanan (MS), 2005.
32. "Decentralized Algorithms for Ad-hoc Networks Using Neural Networks," Vivek Yadav (MS), 2006.
33. "Nonlinear Optimal Observer Design Using Neural Networks and State Dependent Ricatti Equations," Venkat Durbha (MS), 2006.
34. "Neural Network Based Robust Nonlinear Control," Nishant Unnikrishnan (PhD), 2006.
35. "Probabilistic Robust Design for a Control System with Uncertainties," Luis Prado (MS), 2006.
36. "Development of an Unmanned Aircraft for Use as an Autonomously Controlled Platform," Derek Schmitz (MS), 2006.
37. "Optimal Control of Impulsive Systems using Adaptive Critic Neural Networks," Xiaohua Wang (PhD), 2008.
38. "Formation Control of Car-like Robots," Shweta Panimadai Ramasamy (MS), 2008.
39. "Analysis of the Theta-D Filter as Applied to Hit-to-Kill Interceptors and Satellite Orbit Determination," Michael Dancer (MS), 2010.
40. "Optimal Integrator-less Tracking Controller for Uncertain Systems," Anusha Mannava (MS), June 2010.
41. "Approximate Dynamic Programming Solutions of a Single Network Adaptive Critic for a Class of Nonlinear Systems," Jie Ding (PhD. ME), March 2011.
42. "Approximate Dynamic Programming based Solutions for Fixed Final Time Optimal Control and Optimal Switching", Ali Heydari, (PhD, ME), June 2013.
43. "Libration Point Orbits Near Small satellites in the Elliptic Restricted Three-Body Problem", Bharat Mahajan, August 2013.

Note: Neogy, Kamarsu, Dalton, Panapakkam, Janardhan (for his second MS), Panimadai Ramasamy, Anusha Mannava and Bharat Mahajan had co-advisors since they graduated from other departments. Gupta was jointly advised with Dr. Acar.

Grants:

Single Investigator Grants:

1. Balakrishnan, S.N., UM Interdisciplinary Intercampus Research Program, "A Quantum Leap: Advancing Developmental Neuroscience of Decision Making," \$25,000, June 1, 2013-May 31, 2014.

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2. Balakrishnan, S. N., National Science Foundation, "Integrating Dynamic Decision Making with Neurocontrollers by Combining System and Cognitive Sciences," \$219,247, September 15, 2010-August 31, 2013.
3. Balakrishnan, S.N., Air Force, "New Guidance Law Development for Aircraft Protection," Air Force Research Lab, \$70,337, June 15, 2009 - June 14, 2010 (year 1 funding).
4. Balakrishnan, S.N., NASA Ames Research Center, "Adaptive Control with Stability Guarantees," \$287,669, December 2007 - November 2010.
5. Balakrishnan, S.N., Yaskawa Electric America, Inc., "Yaskawa Motion Controllers & Control Algorithms," \$30,303, June 2007 - October 2007.
6. Balakrishnan, S. N., DTI Associates, "Guidance Law for Missile with Reduced Seeker Field of View," \$25,000, August 2005 - December 2005.
7. Balakrishnan, S.N., NASA Ames Research Center, "Intelligent Control Approaches for Space Vehicles," \$48,000, July 2005 - June 2006.
8. Balakrishnan, S. N., National Science Foundation, "Neural Networks for Control of Autonomous and Semi-Autonomous Systems," \$270,000, September 1, 2003 – August 31, 2006.
9. Balakrishnan, S. N., National Science Foundation, "Compact Representations for Adaptive Critic Designs," \$89,820, September 1, 2002 – August 31, 2005.
10. Balakrishnan, S. N., NASA Marshall Space Flight Center, "Robust Nonlinear Control for Aerospace Vehicles," \$72,000, August 2002 – August, 2005.
11. Balakrishnan, S. N., NASA Marshall Spaceflight Center, "Robust Adaptive Critic Based Neurocontroller for Reusable Launch Vehicles," \$34,999, August 1, 2001 – July 31, 2002.
12. Balakrishnan, S. N., Anteon Corporation (Naval Surface Warfare Center), "Integrated Guidance and Control with SDRE and Neural Networks," \$54,234, March 1, 2001 – September 14, 2003.
13. Balakrishnan, S. N., NASA Ames Research Center, "Adaptive Critic Based Reconfigurable Controller," \$120,000, February 1, 2001 – January 31, 2003.
14. Balakrishnan, S. N., Missouri Research Board, "Control of Nonlinear Systems with SDRE," \$32,252, January 2001 - June 2002.

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15. Balakrishnan, S. N, U.S. Army Space and Missile Defense Command, "Integrated Guidance and Estimation for Zero Miss Missiles," \$100,000, September 21, 1999 - September 20, 2002.
16. Balakrishnan, S.N., National Science Foundation, "Adaptive Critic Based Neurocontrol for Distributed Parameter Systems," \$314,942, September 1999 - August 2002.
17. Balakrishnan, S.N., Draper Laboratory, "Improved Missile Performance with Nonlinear Midcourse Guidance Using Adaptive Critic Band Neural Networks," \$109,671, April 1999 - March 2001.
18. Balakrishnan, S.N., National Science Foundation, "Development and Robustness Analysis of Fifth-Level Adaptive Critics for Control," \$212,000, September 1996 - August 1999.
19. Balakrishnan, S.N., National Science Foundation and EMARC/University of Missouri-Rolla, "Adaptive Critic Based Neurocontrol for Distributed Parameter Systems," National Science Foundation, \$70,337, EMARC/University of Missouri-Rolla, \$43657, September 1999 - August 2002.
20. Balakrishnan, S.N., C.S. Draper Labs, Cambridge Massachusetts, "Improved Missile Performance with Midcourse Guidance/Control Using Adaptive Critic Based Neural Networks," \$110,000, February 1999 - February 2001.
21. Balakrishnan, S.N., Wright Laboratories (Air Force), "Improved Missile Performance with Nonlinear Guidance/Control Using Adaptive Critic Based Neural Networks," \$109,671, June 1996 - June 1998.
22. Balakrishnan, S.N., Missouri Resources Training Center, "Improved Missile Performance with Nonlinear Guidance/Control Using Adaptive Critic Based Neural Networks," \$30,442, June 1996 - June 1998.
23. Balakrishnan, S.N., National Aeronautics and Space Administration (NASA Langley Research Center), "Hypersonic Trajectory Optimization and Control," \$67,586, June 1995 - May 1997.
24. Balakrishnan, S.N., Research Board, University of Missouri, "System Identification and Control Using Orthogonal Polynomials," \$31,000, July 1995 - June 1996.
25. Balakrishnan, S.N., National Science Foundation, "Hamiltonian Critic Based Controllers for Stochastic Systems," \$140,693, October 1993 - October 1996.

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26. Balakrishnan, S.N., Missouri Resources Training Center, "Hamiltonian Critic Based Controllers for Stochastic Systems," \$58,419, October 1993 - October 1996.
27. Balakrishnan, S.N., Research and Development Laboratory (AFOSR), "Integrated Estimator/Guidance/Control Design for Homing Missiles," \$23,996, January - December 1993.
28. Balakrishnan, S.N., Missouri Research Assistance Act, State of Missouri, "Neural Network for Control and Filter," \$5,491, July 1992 - June 1993.
29. Balakrishnan, S.N., McDonnell Douglas Corporation, "Neural Networks for Control and Filter," \$31,254, February 1991 - March 1992.
30. Balakrishnan, S.N., Missouri Resources Training Center, "Neural Networks for Control and Filter," \$24,766, July 1991 - June 1992.
31. Balakrishnan, S.N., McDonnell Douglas Astronautics Company, St. Louis, MO, "Adaptive Estimation and Dual Control in Homing Missile Guidance," \$19,976, February 1988 - December 1988.
32. Balakrishnan, S.N., Missouri Research Assistance Act, State of Missouri, "Adaptive Estimation and Dual Control in Homing Missile Guidance," \$6,936, February 1988 - December 1988.
33. Balakrishnan, S.N., McDonnell Douglas Astronautics Company, St. Louis, MO, "Target State Estimation in Missile Guidance," \$34,262, March 1987 - January 1988.
34. Balakrishnan, S.N., Missouri Research Assistance Act, State of Missouri, "Target State Estimation in Missile Guidance," \$11,898, March 1987 - January 1988.
35. Balakrishnan, S.N., Weldon Springs Grants, University of Missouri, "Detection, Classification, and State Estimation in a Multitarget-Multisensor Tracking Environment," \$14,997, June 1986 - December 1988.

Note: 12 graduate and undergraduate students of mine have been awarded the NASA Space Consortium Research awards worth several thousands of dollars. Also, one student won a prestigious GSRP (Graduate Student Research Program) award from NASA Marshall.

Grants with Shared Credit:

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1. Balakrishnan, S.N. (PI) (75%) and Wunsch, D. (25%), National Science Foundation, "Impulse Control of Nonlinear Systems with Uncertainties Using Neural Networks," \$272,500, May 2006 - April 2009.
2. Balakrishnan, S.N. (PI)(49%), and Pernicka (51%), and NASA Goddard Spaceflight Center, "Liberation Point Mission Formation Control," \$120,000, June 1, 2003 – May 31, 2005.
3. Balakrishnan, S.N. (10%), National Science Foundation, "Development of a Parallel Machine Tool for Research and Education in Advanced Manufacturing," \$178,058, August 15, 2003 – July 1, 2006 (additional \$90,000 in cost sharing from UMR). PI: Dr. Robert Landers
4. Balakrishnan, S.N. (13%), National Science Foundation, University of Missouri-Rolla, "Acquisition of Multi-disciplinary Instrumentation for Intelligent Control," \$200,899/\$200,899, July 1, 1996 - June 30, 1998. PI: Dr. Vittal Rao
5. Balakrishnan, S.N. (20%), American Automobile Association, "Development of an AI-Based System for Membership Retention," \$115,000, January 1992 - December 1993. PI: Dr. Colin Benjamin

Appointments:

1. Research Scientist, Center of Space Research, Lecturer, Department of Aerospace Engineering and Engineering Mechanics (concurrent appointment), University of Texas at Austin, Texas, 1984 - 1985.
Duties: To do research in different filtering techniques for use in sonar tracking; to build a simulator for autonomous navigation of multiple satellites on research sponsored by Naval Research Laboratory, Washington, DC.
2. Research Fellow, Center for Space Research, University of Texas at Austin, Texas, May - August 1986.
Duties: To design and build models and data with Cray XMP24 simulators for multiple satellites and trackers for detection using pattern recognition techniques on research sponsored by Cray Research Foundation.
3. Assistant Professor, Aerospace Engineering, University of Missouri-Rolla, August 1985 -1988 (from August 1988 - July 1989 away abroad on personal leave), August 1989 - August 1991.
Duties: Teaching undergraduate and graduate courses, research, service, advised about 25 students every year.

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4. Associate Professor, Aerospace Engineering, University of Missouri-Rolla, August 1991 - 1997.
5. Professor, Aerospace Engineering, University of Missouri-Rolla, August 1997.
6. AFOSR Summer Research Fellow, USAF Armament Directorate, Wright Laboratories, Eglin, Florida, 1992.
7. AFOSR Summer Research Fellow, USAF Armament Directorate, Wright Laboratories, Eglin, Florida, 1993.

PUBLICATIONS AND OTHER SCHOLARLY CONTRIBUTIONS

[A] REFEREED JOURNAL PUBLICATIONS:

1. "A Coordinate Transformation-Based Filter for Improved Target Tracking," **Balakrishnan, S. N.** and Speyer, J. L., Journal of Guidance, Control, and Dynamics, Vol. 9, No. 6, November - December, 1986, pp. 704-709.
2. "Assumed Density Filter with Application to Homing Missile Guidance," **Balakrishnan, S. N.** and Speyer, J. L., AIAA Journal of Guidance, Control and Dynamics, January - February 1989, pp. 4-12.
3. "An Extension to Modified Polar Coordinates and Applications with Passive Measurements, **Balakrishnan, S. N.**, AIAA Journal of Guidance and Control, Vol. 12, No. 6, 1989, pp. 906-912.
4. "Enhancement of Data Separability in Multisensor-Multitarget Tracking Problems," **Balakrishnan, S. N.**, Tapley, B. D. and Schutz, B. E., AIAA Journal of Guidance, Control, and Dynamics, November - December 1989, pp. 938-941.
5. "Multitarget Classification and Estimation Using Clustering Techniques," **Balakrishnan, S. N.** and Tapley, B. D., AIAA Journal of Guidance, Control, and Dynamics, January - February 1990, pp. 121-127. NOTE: This paper has been selected and translated into Russian by the Soviets and appeared in Aeronautics/Space Technology, October 1990.
6. "Neurovision-Based Robot Guidance System for Moving Manufacturing Parts," Neogy, A., **Balakrishnan, S. N.**, and Dagli, C. H., International Journal of Manufacturing System Design, Vol. 1, No. 1, 1994, pp. 65-75.
7. "Use of Hopfield Neural Networks in Optimal Guidance," Steck, J. E. and

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- Balakrishnan, S. N.**, IEEE Transactions on Aerospace and Electronics Systems, Vol. 30, No. 1, pp. 287-293, January 1994.
8. "Neurocontrol: A Literature Survey," **Balakrishnan, S. N.** and Weil, R. D., Journal of Mathematical Computing and Modelling, Vol. 23, No. 1/2, pp. 101-117, January - February 1996.
 9. "A Neighboring Optimal Adaptive Critic for Missile Guidance," Dalton, J. and **Balakrishnan, S. N.**, Journal of Mathematical Computing and Modelling, Vol. 23, No. 1/2, pp. 175-188, 1996.
 10. "Adaptive-Critic-Based Neural Networks for Aircraft Optimal Control," **Balakrishnan, S. N.** and Biega, Victor, Journal of Guidance, Control, and Dynamics, Vol. 19, No. 4, July - August 1996, pp. 893-898.
 11. "Analytical Missile Guidance Laws with a Time-Varying Transformation," **Balakrishnan, S. N.**, Journal of Guidance, Control, and Dynamics, Engineering Notes, Vol. 19, No. 2, pp. 496-499, October 1996.
 12. "An Integrated Approach for Assembly Tolerance Analysis," Srikanth, K., Liou, W., and **Balakrishnan, S.N.**, International Journal of Production Research. Vol. 39, No. 7, pp. 1517-1535, 2001.
 13. "Adaptive-Critic Based Optimal Neuro Control Synthesis for Distributed Parameter Systems," Padhi, R., **Balakrishnan S.N.**, and Randolph, T., Automatica, Vol. 37, pp. 1223-1234, 2001.
 14. "Adaptive Critic-Based Neural Networks for Agile Missile Control," Han, D., **Balakrishnan, S. N.**, Journal of Guidance, Control, and Dynamics, Vol. 25, No. 2, pp. 404-407, 2002.
 15. "State-constrained Agile Missile Control with Adaptive-critic-based Neural Networks," Han, D., **Balakrishnan, S.N.**, IEEE Transactions on Control Systems Technology, Vol. 10, Issue 4, pp. 481-489, 2002.
 16. "Experimental Model Determination for Neurocontrol of a Thermal Conduction System," Prabhat, P., Look, D.C., and **Balakrishnan, S.N.**, AIAA Journal of Thermal Physics and Heat Transfer, Vol. 17, No. 4, pp. 471-480, October - December 2003.
 17. "Optimal Process Control Using Neural Networks," Padhi, R. and **Balakrishnan, S.N.**, Asian Journal of Control, Vol. 5, No. 2, June, 2003.

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18. "Proper Orthogonal Decomposition based Optimal Neurocontrol Synthesis of a Chemical Reactor Process Using Approximate Dynamic Programming," Padhi, R. and **Balakrishnan, S.N.**, Neural Networks, Vol. 16, pp. 719-728, 2003.
19. "Nonlinear Missile Autopilot Design with Theta-D Technique," Xin, M., **Balakrishnan, S.N.**, Stansbery, D., Ohlmeyer, E., Journal of Guidance, Control, and Dynamics, Vol. 27, No. 3, pp. 406-417, 2004.
20. "Optimal Control Synthesis of a Class of Nonlinear Systems using Single Network Adaptive Critics," Padhi, R., Unnikrishnan, N., Wang, X. and **Balakrishnan, S.N.**, Neural Networks, Vol. 19, pp. 1648-1660, December 2006.
21. "New Nonlinear Control Technique for Ascent Phase of Reusable Launch Vehicles," Drake, D., Xin, M., **Balakrishnan, S.N.**, Journal of Guidance, Control, and Dynamics, Vol. 27, No. 6, pp. 930-937, 2004.
22. "Control of Wing Rock Motion Using a New Suboptimal Nonlinear Control Method," Xin, M. and **Balakrishnan, S.N.**, Journal of Aerospace Engineering, Proceedings of the Institution of Mechanical Engineers, Vol. 218, No. 4, 2004, pp. 257-266, 2004.
23. "Theta-D Control Technique for Ascent Control of Reusable Launch Vehicles," Drake, D. T. and Xin, M. **Balakrishnan, S.N.**, AIAA Journal of Guidance, Control, and Dynamics, Vol. 27, No. 6, November - December. 2004, pp. 938-948.
24. "Nonlinear Bank-to-Turn/Skid-to-Turn Missile Outer-Loop/Inner-Loop Autopilot Design with the Theta-D Technique," Xin, M., Stansbery, D., Ohlmeyer, E., and **Balakrishnan, S.N.**, AIAA Journal of Guidance, Control, and Dynamics, Vol. 27, No. 3, May - June, 2004, pp. 406-417, 2004.
25. "Multiple Spacecraft Formation Control With Theta-D Method," Xin, M., **Balakrishnan, S.N.**, and Pernicka, H., IEEE Proc. Control Theory & Applications.
26. "A New Method for Suboptimal Control of a Class of Non-linear Systems," Xin, M. and **Balakrishnan, S.N.**, Optimal Control Applications and Methods, Vol. 26, pp. 55-83, 2005.
27. "Midcourse Guidance Law with Neural Networks," Han, D., Olmeyer, E.J., and **Balakrishnan, S.N.**, Journal of Aerospace Engineering, Vol. 216, 2005, pp. 131-144, 2005.
28. "Hierarchical Optimal Force-Position Control of a Turning Process," Pandurangan, B., Landers, R.G., and **Balakrishnan, S.N.**, IEEE Trans. On Control System

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- Technology, Vol. 13, No. 2, pp. 321-327, 2005.
29. “Robust Nonlinear Control for Systems with Model Uncertainties: A Helicopter Application,” Huang, Z. and **Balakrishnan, S.N.**, AIAA Journal of Guidance, Control, and Dynamics, Vol. 3, 2005, pp 516-523, 2005.
 30. “Parameter Estimation in Nonlinear Systems Using Hopfield Neural Networks,” Hu, Z. and **Balakrishnan, S.N.**, AIAA Journal of Aircraft, Vol. 42, No. 1, January – February, 2005, pp. 41-53, 2005.
 31. “Robust Neurocontrollers for Systems with Model Uncertainties: A Helicopter Application,” Huang, Z., **Balakrishnan, S. N.**, Journal of Guidance, Control, and Dynamics, Vol. 28, No. 3, pp. 516-523, 2005.
 32. “Hierarchical Optimal Force-Position-Contour Control of Machining Processes,” Tang, Y., Landers, R.G., and **Balakrishnan, S.N.**, IFAC Journal on Control Engineering Practice, Vol. 14, No. 8, pp. 909-922, 2006.
 33. “Optimal Beaver Population Management Using Reduced Order Distributed Parameter Model and Single Network Adaptive Critices,” Padhi, R. and **Balakrishnan, S.N.**, IEEE Transactions of Control System Technology, Vol. 14, No. 6, July 2006.
 34. “Integrated Guidance and Control of Missiles with Theta-D Method,” Xin, M., Ohlmeyer, E.J., and **Balakrishnan, S.N.**, IEEE Transactions on Control System Technology, Vol. 14, 2006, pp. 981-992, 2006.
 35. “Spacecraft Formation Flight about Libration Points Using Impulsive Maneuvering,” Pernicka, H., Carlson, B., and **Balakrishnan, S.N.**, AIAA Journal of Guidance, Control, and Dynamics, Vol. 29, pp. 1122-1130, 2006.
 36. Nonlinear Control Concepts for an Unmanned Aircraft,” Janardhan,V., Schmitz, D., and **Balakrishnan, S.N.**, IEEE Aerospace Electronics and Systems Magazine, 2006, pp. 8-12, 2006. (1st prize, graduate division, AIAA Region VI Best paper Award for Janardhan and Schmitz, Minneapolis, Minnesota, April, 2004)
 37. “Robust/Optimal Temperature Profile Control of a High Speed Aerospace Vehicle Using Neural Networks,” Yadav, V., Padhi, R., and **Balakrishnan, S.N.**, IEEE Transactions on Neural Networks, pp. 1115-1128, July 2007.
 38. “Cooperative UAV Formation Flying with Stochastic Obstacle/Ollision Avoidance,” Yadav, V., Wang, X., and **Balakrishnan, S.N.**, IEEE Transactions on Control Systems Technology, July 2007, pp. 672-679, 2007.

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39. "Optimal Dynamic Inversion Control Design for a Class of Nonlinear Distributed Parameter Systems with Continuous and Discrete Actuators, IET Control Theory & Applications," Padhi, R. and **Balakrishnan, S.N.**, IET Control Theory & Applications, Vol. 1, Issue 6, 2007, pp. 1650-1661, 2007.
40. "Model Following Neuro-Adaptive Control Design for Non-square, Non-affine Nonlinear Systems," Padhi,R.,Unnikrishnan,N., and **Balakrishnan,S.N.**, IET Control Theory & Applications, Vol. 1, Issue.6, pp. 1650-1661, 2007.
41. "Position and Attitude Control of Deep-Space Spacecraft Formation Flying Via Virtual Structure and Theta-D Technique," Xin, M., and **Balakrishnan, S.N.**, and Pernicka, H., ASME Journal of Dynamic Systems and Control, August 2007.
42. "A Direct Approach for Nonlinear Flight Control Design of High Performance Aircrafts," Padhi, R., Goyal, S., Rao, P., and **Balakrishnan, S.N.**, Control Engineering Practice, 2008.
43. "Parallel Turning Process Parameter Optimization based on a Novel Heuristic Approach," Tang, L., Landers, R., and **Balakrishnan, S.N.** , ASME Journal of Manufacturing Sciences and Engineering, Vol. 130, No. 3, pp. 31002-1 to 31002-12, 2008.
44. "Issues on Stability of ADP Feedback Controllers for Dynamical Systems," **Balakrishnan,S.N.**, Ding, Jie Lewis, F.L., IEEE Transactions on Man, System, and Cybernetics, part B, Vol. 38, No. 4, 2008, pp. 913-917, 2008.
45. "Libration Point Stationkeeping Using the Theta-D Technique," Xin, M., **Balakrishnan, S.N.**, and Pernicka, H., The Journal of the Astronautical Sciences, Vol. 56, No. 2, April - June 2008.
46. "Reduced Order Suboptimal Control Design for a Class of Nonlinear Distributed Parameter Systems Using POD and Theta-D Techniques," Padhi, R., Xin, M., and **Balakrishnan, S.N.**, Optimal Control Applications and Methods, Vol. 29, 2008, pp. 191-224, 2008.
47. "Reduced Order Optimal Control Synthesis of a Class of Nonlinear Distributed Parameter Systems Using Single Network Adaptive Critics," Padhi, R., Prabhat, P., and **Balakrishnan, S.N.**, Innovative Computing, Information, and Control, Vol. 4, No. 2, 2008, pp.457 - 469, 2008.
48. "Nonlinear Missile Autopilot Design with Theta-D Method," Xin, M. and **Balakrishnan, S.N.**, IEEE Transactions on Aerospace and Electronics Systems, Vol.

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- 44, Issue 1, pp. 41-56, January 2008.
49. “Optimal Neurocontroller Synthesis for Impulse-Driven Systems,” Wang, Xiaohua and **Balakrishnan, S.N.**, Neural Networks, Vol. 23, Issue 1, pp. 125-134, 2010.
 50. “Coordinated Rendezvous of Unmanned Air Vehicles to a Formation Using a Sliding Mode Approach,” Harl, N. and **Balakrishnan, S.N.**, **Proceedings of Mechanical Engineers Part G**, Journal of Aerospace Engineering, January 2011, Vol.1, No. 225, pp. 105-119.
 51. “Approximate dynamic programming solutions with a single network adaptive critic for a class of nonlinear systems”, Ding, J., and **Balakrishnan, S. N.**, Journal of Control Theory and Applications, Vol. 9, No. 3, pp.370 - 380, 2011.
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109. "Implementation of Nonlinear Reconfigurable Controllers for Autonomous Unmanned Vehicles," Schmitz, D., Janardhan, V., **Balakrishnan, S.N.**, AIAA-2005-348, 43rd AIAA Aerospace Sciences Meeting and Exhibit, Reno, Nevada, January 10-13, 2005.
110. "Cooperative UAV Formation Flying with Stochastic Obstacle Avoidance," Wang, X., Yadav, V., **Balakrishnan, S.N.**, AIAA-2005-5832, AIAA Guidance, Navigation, and Control Conference and Exhibit, San Francisco, California, August 15-18, 2005.
111. "Dynamic Re-optimization of a Missile Autopilot Controller in Presence of Unmodeled Uncertainties," Unnikrishnan, N., and **Balakrishnan, S.N.**, AIAA Guidance, Navigation, and Conference, San Francisco, August 2005.
112. "Spacecraft Formation Flight about Libration Points Using Impulsive Maneuvering," Pernicka, H. Carlson, B. and **Balakrishnan S.N.**, AAS/AIAA Spaceflight Mechanics Meeting, Copper, Colorado, January 23-27 2005.
113. "Optimal and Hierarchical Formation Control for UAV," Wang, Xiaohua and **Balakrishnan, S.N.**, American Control Conference, Portland, Oregon, May 2005.
114. "Position and Attitude Control of Deep-Space Spacecraft Formation Flying Via Virtual Structure and Theta-D Technique," Xin, M., **Balakrishnan, S.N.**, Pernicka, Hank J. AIAA Guidance, Navigation, and Control Conference, August, 2005.
115. "Dynamic Reoptimization of a Spacecraft Attitude Controller in Presence of Uncertainties," Unnikrishnan, Nishant and **Balakrishnan, S.N.**, 2006 IEEE International Symposium on Intelligent Control, Munich, Germany, October 2006.
116. "Neural Network Approach for Obstacle Avoidance in 3-D Environments for UAVs," Yadav, V., Wang, X., **Balakrishnan, S.N.**, American Control Conference, 2006.
117. "Neuroadaptive Model Following Controller Design for a Nonaffine UAV Model," Unnikrishnan, Nishant and **Balakrishnan, S.N.**, AIAA Guidance, Navigation, and Control Conference, Keystone, CO., August 2006.
118. "Communication Control in Multiple UAV Applications," Yadav, V., **Balakrishnan, S.N.**, AIAA-2006-6212, AIAA Guidance, Navigation, and Control Conference and Exhibit, Keystone, Colorado, August 21-24, 2006.

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119. "Cooperative UAV Formation Flying with Stochastic Obstacle/Collision Avoidance," Yadav, V., Wang, X., and **Balakrishnan, S.N.**, AIAA Guidance, Navigation, and Control Conference, Keystone, CO., August 2006.
120. "Robust/Optimal Temperature Profile Control of a High Speed Aerospace Vehicle Using Neural Networks," Yadav, V., Padhi, R., and **Balakrishnan, S.N.**, 2006 IEEE Conference on Control Applications, Munich, Germany, 2006.
121. "Optimal Impulse Control of Systems with Control Constraints and its Application for Treatment of AIDS," Yadav, V. and **Balakrishnan, S.N.**, American Control Conference, Minneapolis, MN, June 14-16, 2006.
122. "Guidance Law Design for Missiles with Reduced Seeker Field-of-View," Xin, M., Ohlmeyer, E.J., and **Balakrishnan, S.N.**, AIAA Guidance, Navigation, and Control Conference, Keystone, CO, August 2006.
123. "Target Interception with Cost-Based Filter," Durbha, V., **Balakrishnan, S.N.**, and Dryer, W., AIAA Guidance, Navigation, and Control Conference, Keystone, CO, August 2006.
124. "Analysis of the Theta-d Filter and OEGL as Applied to Hit-to-Kill Missiles," Dancer, M, Dyer, W, and **Balakrishnan, S.N.**, AIAA Guidance, Navigation, and Control Conference, Keystone, CO, August 2006.
125. "Optimal Control of a Sun-Synchronous Lunar Orbiter," Agarwal, S., **Balakrishnan, S.N.**, Pernicka, Hank J., AIAA Guidance, Navigation, and Control Conference, Hilton head, SC, August, 2007.
126. "Optimal Control of Non-linear Plants Using Artificial Immune Systems: Application of the Clonal Selection Algorithm," Panimadai Ramaswamy, Shweta, **Balakrishnan, S.N.** and Venayagamoorthy, G. IEEE Conference on Control Applications, Singapore, September 2007.
127. "Formation Control of Car-like Mobile Robots: A Lyapunov Function based Approach," Ramaswamy, S.A.P., **Balakrishnan, S.N.**, American Control Conference, pp. 657-662, 2008.
128. "Nonlinear Control Techniques for Regulating the Altitude of a Radio/Control Helicopter," Esteban, S., Aracil, J., Gordillo, F., and **Balakrishnan, S.N.**, AIAA Atmospheric Flight Mechanics Conference and Exhibit, Honolulu, HI, August 18-21, 2008.

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129. "Coordinated Rendezvous of Unmanned Air Vehicles: A Sliding Mode Approach," Harl, N. and **Balakrishnan, S.N.**, AIAA Guidance, Navigation, and Control Conference, Honolulu, HI, August 2008.
130. "Optimal Neuro-Controller Synthesis for Variable-Time Impulse Problems," Wang, Xiaohua and **Balakrishnan, S.N.**, American Control Conference, Seattle, WA, June 2008
131. "Discussion and Analysis of Missile IGC Design," Dance, M., **Balakrishnan, S.N.**, and Ohlmeyer, E., AIAA Guidance, Navigation, and Control Conference, Honolulu, HI, August 2008.
132. "Reentry Terminal Guidance Through Sliding Mode Control," Harl, Nathan, and **Balakrishnan, S.N.**, AIAA Atmospheric Flight Mechanics Conference, Honolulu, HI, August 2008 (One of the 5 finalists for the student Best paper award).
133. "A New State Observer and Flight Control of Highly Maneuverable Aircraft," Xin, M. and **Balakrishnan, S.N.**, 2009 American Control Conference, St. Louis, MO, June 2009.
134. "Application of Optimal Impulsive Control Method to Advertising," Ding, J., **Balakrishnan, S.N.**, Mantrala, M., 17th Mediterranean Conference on Control and Automation, pp. 1396-1401, 2009.
135. "SNAC Convergence and Use in Adaptive Autopilot Design," Chen, S., Yang, Y., Nguyen, N., KrishnaKumar, K., and **Balakrishnan, S.N.**, 2009 IJCNN Conference, Atlanta, GA, June 2009.
136. "Impact Time and Angle Guidance with Sliding Mode Control," Nathan H., **Balakrishnan, S.N.**, AIAA Guidance, Navigation, and Control Conference, Chicago, Illinois, August 10-13, 2009.
137. "Neuroadaptive Model Following Controller Design for Non-Affine and Non-Square Aircraft Systems," Rajagopal, K., **Balakrishnan, S.N.**, Nguyen N., Krishnakumar, K., Mannava A., AIAA-2009-5737, AIAA Guidance, Navigation, and Control Conference, Chicago, Illinois, August 10-13, 2009.
138. "Advanced Pure Pursuit Guidance via Sliding Mode Approach for Chase UAV," Yamasaki, T., Enomoto, K., Takano, H., Baba, Y., **Balakrishnan, S.N.**, AIAA-2009-6298, AIAA Guidance, Navigation, and Control Conference, Chicago, Illinois, August 10-13, 2009.
139. "Sliding Mode Based Pure Pursuit Guidance for UAV," Yamasaki, T. and

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- Balakrishnan, S.N.**, 2010 American Control Conference, Baltimore, MD, June 2010.
140. "Robust Adaptive Control of a Structurally Damaged Aircraft," Rajagopal, K., **Balakrishnan, S.N.**, Nguyen, N., Krishnakumar, K., AIAA Guidance, Navigation, and Control, Toronto, Canada, August 2-5, 2010.
 141. "An Online Nonlinear Optimal Controller Synthesis for Aircraft with Model Uncertainties," Ding, J. and **Balakrishnan, S.N.**, AIAA Guidance, Navigation, and Control, Toronto, Canada, August 2-5, 2010.
 142. "Sliding Mode Integrated Missile Guidance and Control," Harl, N. and **Balakrishnan, S.N.**, AIAA Guidance, Navigation, and Control, Toronto, Canada, August 2-5, 2010.
 143. "Triangle Intercept Guidance for Aerial Defense," Yamasaki, T. and **Balakrishnan, S.N.**, AIAA Guidance, Navigation, and Control, Toronto, Canada, August 2-5, 2010.
 144. "System Studies of Air Launched Interceptor for Boost Phase Engagement," Ohlmeyer, E. J. and **Balakrishnan, S.N.**, AIAA Guidance, Navigation, and Control, Toronto, Canada, August 2-5, 2010.
 145. "Robust Adaptive Control for a General Aviation Aircraft," Karthikeyan, R., **Balakrishnan, S.N.**, Steck, James E., Kimball, D., 2010 AIAA Atmospheric Flight Mechanics Conference, 2010.
 146. "Guidance and Control for Chase UAV via Sliding Mode Approach," Yamasaki, T. and **Balakrishnan, S.N.**, 18th IFAC Symposium on Automatic Control in Aerospace, Nara, Japan, September 6-10, 2010.
 147. "Intercept Guidance for Cooperative Aircraft Defense against a Guided Missile," Yamasaki, T and **Balakrishnan, S.N.**, 18th IFAC Symposium on Automatic Control in Aerospace, Nara, Japan, September 2010.
 148. "A Single Network Approximate Dynamic programming based Constrained Optimal Controller for Nonlinear Systems with Uncertainties", Ding, J. and **Balakrishnan, S.N.**, 2010 IEEE Conference on Decision and Control, Atlanta, GA, December 2010.
 149. "A Novel Integrator-less Robust Adaptive Control Scheme for Aerospace Tracking Application," Mannava, A. and **Balakrishnan, S. N.**, Proceedings of 49th AIAA Aerospace Sciences Meeting including the New Horizons Forum and Aerospace Exposition, AIAA-2011-1342, Orlando, FL, January 4 - 7, 2011.

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150. "Finite-Horizon Input-Constrained Nonlinear Optimal Control Using Single Network Adaptive Critics," Heydari, A. and **Balakrishnan, S. N.**, Proceedings of 2011 American Control Conference, pp. 3047 - 3052, San Francisco, CA, June 29 - July 1, 2011.
151. "Electro-Hydraulic Piston Control using Neural MRAC Based on a Modified State Observer," Yang, Y., **Balakrishnan, S. N.**, Tang, L. and Landers, R. G., Proceedings of 2011 American Control Conference, pp. 25 - 30, San Francisco, CA, June 29 - July 1, 2011.
152. "Sliding Mode Based Integrated Guidance and Autopilot for Chasing UAV with the Concept of Time-Scaled Dynamic Inversion", Yamasaki, T., **Balakrishnan, S. N.**, and Takano, H., Proceedings of 2011 American Control Conference, pp. 1598 - 1603, San Francisco, CA, USA, June 29 - July 1, 2011.
153. "Constrained Optimal Control for a Class of Nonlinear Systems with Uncertainties," Ding, J. and **Balakrishnan, S.N.**, Proceedings of the 2011 American Control Conference, pp. 330 - 335, San Francisco, CA, June 29 - July 1, 2011.
154. "Modified State Observer for Orbit Uncertainty Estimation," Harl, N., Rajagopal, K. and **Balakrishnan S. N.**, Proceedings of the AIAA Guidance, Navigation, and Control Conference, AIAA-2011-6616, Portland, OR, August 8 -11, 2011.
155. "Optimal Online Path Planning for Approach and Landing Guidance," Heydari, A. and **Balakrishnan, S. N.**, Proceedings of the AIAA Atmospheric Flight Mechanics Conference, AIAA-2011-6641, Portland, OR, August 8 - 11, 2011.
156. "Modified CLOS Intercept Guidance for Aircraft Defense Against a Guided Missile," Yamasaki, T., **Balakrishnan, S.N.**, and Takano, H., Proceedings of the AIAA Guidance, Navigation, and Control Conference, AIAA-2011-6421, Portland, OR, August 8 - 11, 2011.
157. "Decentralized Control of Nonlinear Multi-Agent Systems using Single Network Adaptive Critics," Heydari, A. and **Balakrishnan, S.N.**, 2012 International Joint Conference on Neural Networks, Brisbane, Australia, June 10-15, 2012
158. "Terminal Intercept Guidance and Autopilot for Aircraft Defense against an Attacking Missile via 3D Sliding Mode Approach," Yamasaki, T. and **Balakrishnan, S.N.**, 2012 American Control Conference, Montreal, Canada, June 27-29, 2012, pp. 4631-4636.

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159. "Estimation of Tip-Sample Interaction in Tapping Mode AFM using a Neural-Network Approach," Toghraee, A., Bristow, D.A., and **Balakrishnan, S.N.**, 2012 American Control Conference, Montreal, Canada, June 27-29, 2012, pp. 3222-3227.
160. "Approximate Closed-Form Solutions to Finite-Horizon Optimal Control of Nonlinear Systems," Heydari, A. and **Balakrishnan, S.N.**, 2012 American Control Conference, Montreal, Canada, June 27-29, 2012, pp. 2657-2662.
161. "Integrated Guidance and Autopilot for a Path-Following UAV via High-Order Sliding Modes," Yamasaki, T. , **Balakrishnan, S.N.**, and Takano, H., 2012 American Control Conference, Montreal, Canada, June 27-29, 2012, pp. 143-148.\
162. "Modified State Observer for Atmospheric Reentry Uncertainty Estimation" Darling, J., Searcy, J., and **Balakrishnan, S.N.**, AIAA Guidance, Navigation, and Control Conference, Minneapolis, MN, Aug. 13-16, 2012. Paper No.AIAA-2012-4759.
163. "An Optimal Tracking Approach to Formation Control of Nonlinear Multi-Agent Systems," Heydari, A. and **Balakrishnan, S.N.**, AIAA Guidance, Navigation, and Control Conference, Minneapolis, MN, Aug. 13-16, 2012. Paper No.AIAA-2012-4694.
164. "Separate-Channel Integrated Guidance and Autopilot for a Path-Following UAV via High-Order Sliding Modes," Yamasaki, T., **Balakrishnan, S.N.**, and Takano, H., AIAA Guidance, Navigation, and Control Conference, Minneapolis, MN, Aug. 13-16, 2012. Paper No.AIAA-2012-4457.
165. "Optimal Orbit Transfer with ON-OFF Actuators Using a Closed Form Optimal Switching Scheme", Heydari, A. and **Balakrishnan, S.N.**, AIAA Guidance, Navigation, and Control Conference, Boston, MA, Aug. 19-22, 2013.
166. "Second Order Sliding Mode-based Intercept Guidance with Uncertainty and Disturbance Compensation", Yamasaki, T., **Balakrishnan, S.N.**, Takano, H., and Yamaguchi, I., AIAA Guidance, Navigation, and Control Conference, Boston, MA, Aug. 19-22, 2013.
167. "Sigma Point Modified State Observer for Nonlinear Uncertainty Estimation", Darling, J., **Balakrishnan, S.N.**, and D'Souza, AIAA Guidance, Navigation, and Control Conference, Boston, MA, Aug. 19-22, 2013.
168. "Time Delay Margin Analysis of Modified State Observer Based Adaptive Control", Rajagopal, K. and **Balakrishnan, S.N.**, AIAA Guidance, Navigation, and Control

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Conference, Boston, MA, Aug. 19-22, 2013.

169. “Parameter Identification Technique based on Lyapunov Stability”, Kumar, M. and **Balakrishnan, S.N.**, AIAA Atmospheric Flight Mechanics Conference, Boston, MA, Aug. 19-22, 2013.
170. “Proper Orthogonal Decomposition Technique for Near Optimal Control of Flexible Aircraft Wings”, Kumar, M., Rajagopal, K., **Balakrishnan, S.N.**, Nguyen, N., and Krishnakumar, K., AIAA Guidance, Navigation, and Control Conference, Boston, MA, Aug. 19-22, 2013.

Book Chapters :

1. *Single Network Adaptive Critics Networks-Development, Analysis, and Applications*
Ding, J., Heydari, A., and Balakrishnan, S.N, Reinforcement Learning and Approximate Dynamic Programming for Feedback Control, Lewis, F. and Lu, D. Editors, IEEE Press, Piscataway, NJ 08854, 2013.
2. *Intelligent Constrained Optimal Control of Aerospace Vehicles with Model Uncertainties*
Ding, J. and Balakrishnan, S.N., in Advances in Intelligent and Autonomous Aerospace Systems, Edited by Valasek, J., Vol. 241, Progress in Aeronautics and Astronautics, AIAA Press, Reston, VA, 2012, pp. 129-156.
3. *Integrated Guidance and Control for Missiles*
Harl. N., dancier, M., Balakrishnan, S.N., Ohlmeyer, E.J, and Philips, C., in Advances in Missile Guidance, Control, and Estimation, Edited by, Balakrishnan, S.N., Tsourdos, A., and White, B.A., CRC Press, New York, NY, 2012, pp. 157-195.
4. *Adaptive Neural Network based Autopilot Design*
Rajagopal, K. and Balakrishnan, S.N., in Advances in Missile Guidance, Control, and Estimation, Edited by, Balakrishnan, S.N., Tsourdos, A., and White, B.A., CRC Press, New York, NY, 2012, pp. 129-156.
5. *Adaptive Control Design Technique for Nonlinear Flight Systems*
Unnikrishnan, N. and Balakrishnan, S.N. Encyclopedia of Aerospace Engineering, Article 267, Thomson Digital (to be published in 2010).
6. *Kalman Filtering for Manufacturing Processes*
Oaks, T., Tang, L., Landers, R.G., and Balakrishnan, S.N., Kalman Filter: Recent Advances and Applications, I-Tech Education and Publishing, Ed. V.M. Moreno and A. Pigazo, pp. 487–506, 2009.

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7. *Adaptive Critic Based Neural Networks for a Control-Constrained Agile Missile*
Dongchen Han and S. N. Balakrishnan in Handbook of Learning and Approximate Dynamic Programming, Edited by Si, J., Barto, A.G., Powell, W.B. and Wunsch II, D. IEEE Press, 2004.

[C] SPECIAL DISTINCTIONS :

1. Balakrishnan, S.N., "Approximate dynamic programming based solutions to Optimal Control Problems using Neural Networks," Plenary Lecture, Second International Conference on Advances in Control and Optimization of Dynamical Systems, Indian Institute of Science, Bangalore, India, February 17, 2012.
2. Faculty Research Award, Missouri University of Science and Technology, 2010.
3. Academy of Mechanical Engineers Faculty Excellence Award, October 2009.
4. Academy of Mechanical Engineers Faculty Excellence Award for Research, October 2000.
5. ASME Best Paper Award, Applicon Best Paper Award for CAD/CAM Theory and Applications, ASME Design Automation Conference, September 15, 1997 (Co-authors K. Srikanth and F. Liou).
6. Cited by Paul Werbos, NSF Program director and a pioneer in neural networks, as one of the top four researchers (or groups) in the U.S. in implementing latest "brain-like intelligent control" for nonlinear control problems. Refer to: "Optimization Methods for Brain-Like Intelligent Control," Paul J. Werbos, Proceedings of the 34th IEEE Conference on Decision and Control, New Orleans, LA, December 1995, pp. 579-584.
7. First in University of Missouri-Rolla and University of Missouri-Columbia System to receive an NSF grant on "accomplishment-based renewal."
8. Aerospace Space Technology, a Russian journal selects a few articles of interest in American journals and translates to Russian and publishes them. A Russian translation of Dr. Balakrishnan's paper (co-authored with Dr. B. D. Tapley), "Multi-target Classification and Estimation Using Clustering Techniques," AIAA Journal of Guidance, Control, and Dynamics, January – February 1990, pp. 121-127, appeared in Aeronautics/Space Technology in October 1991.
9. Invited Speaker, AFOSR sponsored Guidance and Control Workshop, Eglin, FL, 1993, 1994.
10. Invited Speaker, NASA Headquarters sponsored symposium on "Neural Networks for Flight Control," NASA Ames Research Center, CA, August 23-25, 1994. (Selected speakers from government, industry, and academia were invited.)
11. Invited Speaker, Phillips Laboratory Space Vehicle Technologies Division, Workshop on "Neural Decision and Control Technology for Aerospace Systems," Kirtland AFB, NM, February 1997.
12. Invited Speaker, NSF Workshop on "Advanced Adaptive Critic Designs," Arlington, VA, 1997.

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13. Commendation letter, Outstanding Teaching, UMR, 2001-2002.
14. Invited Speaker, NSF Workshop on Approximate Dynamic Programming, Cancun, Mexico, April 7-8, 2002.
15. Invited Speaker, NSF Workshop on Global Dynamic Optimization of the Electric Power Grid, Cancun, Mexico, April 7-8, 2002.
16. Invited Speaker, Yale Workshop on Adaptive Learning, Yale University, New haven, Connecticut, May 2003, May 2005.
17. Only US Faculty invited to give a talk at the TTCP WPN/TP-7 Workshop on "Advanced Guidance Technology" 27-29 Apr 2005, Defense R&D Canada Valcartier, Quebec, Canada. The Technical Cooperation Program (TTCP) is a forum for defense science and technology collaboration between Australia, Canada, New Zealand, the United Kingdom and the United States. WPN/TP-7 is the missile guidance working group for TTCP.
18. Consultant and Member, HAG Missile System Evaluation team, Missile Defense Agency, August 2004.
19. Invited Speaker, NSF Workshop on Approximate Dynamic Programming, Cancun, Mexico, April 3-6, 2006.
20. Of the five university developed algorithms (that included Georgia Tech) funded and comprehensively tested by NASA Goddard Spaceflight Center, Huntsville, AL, in 2003, our algorithm scored the highest in a matrix of test features with 49 variables in an X-33 simulation.
21. Keynote Speaker, IASTED Conference on Control and Application, May 30 - June 1, 2007, Montreal, Canada.
22. Plenary Speaker, 2007 International Symposium on Neural Networks (ISNN 2007), June 3 - June7, 2007, Nanjing, China.
23. Invited lectures at Nanjing University of Science and Technology, Xian Jio tang University, Beijing Academy of Sciences, China, June 2007.
24. Invited Speaker, Defense Research and Development Organization, Hyderabad, India, June 2007.
25. Invited Speaker, Indian Space Research Organizations, Trivandrum, India, June 2007.
26. Invited Speaker, National Aerospace Laboratories, Bangalore, India, July 2009.
27. Invited to present a series of lectures at the National Defense Academy, Hashirimizu, Yokosuka Japan, August 2010.
28. Founder, IST-Rolla, IST-Rolla is a small business firm located in Rolla, Missouri. In six years of its operations, it has won three Phase I and three Phase II awards for innovative research from the Missile Defense Agency and NASA. All its interns and engineers have been undergraduate and graduate students at Missouri S&T.

ADVISEES' RECOGNITION (WITH DR.BALAKRISHNAN AS A COAUTHOR)

1. Heydari, Ali, Best Student Paper Runner-Up Award from AIAA Guidance, Navigation and Control Conference, Minneapolis, Minnesota, August 2011
2. Mahajan, B., **1st prize**, Graduate Division, AIAA Region VI(an 8-state region) Best

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- paper Award, Boulder, Colorado, April 2012. Invited to present the same paper at the 2013 Aerospace Sciences Conference for the national award competition.
3. Friedrichs, A, **1st prize**, Graduate Division, AIAA Region VI(an 8-state region) Best paper Award, Ames, Iowa, April 2011. Invited to present the same paper at the 2012 Aerospace Sciences Conference for the national award competition.
 4. Rajagopal, Karthik, Finalist for the best paper (**one of eight**), 2010 AIAA Atmospheric Flight Mechanics Conference, Toronto, Ontario, Canada, Title: "Robust Adaptive Control for a General Aviation Aircraft"
 5. Harl, Nathan, Finalist for the best paper (**one of six**), 2010 AIAA Guidance, Navigation, and Control Conference, Toronto, Ontario, Canada, Title: "Sliding Mode Integrated Guidance and Control for Missiles"
 6. Mannava, Anusha, "A Novel Integrator-less Robust Adaptive Control Scheme for Aerospace Tracking Applications," **1st prize**, Graduate Division, AIAA Region VI(an 8-state region) Best paper Award, Wichita, Kansas, April 2010. Invited to present the same paper at the 2011 Aerospace Sciences Conference for the national award competition.
 7. Harl, Nathan, Finalist for the best paper (**one of five**), 2008 AIAA Atmospheric Flight Mechanics Conference, Honolulu, HI, Title: "Coordinated Rendezvous of Unmanned Air Vehicles: A Sliding Mode Approach"
 8. Harl, Nathan, Finalist for the best paper (**one of five**), 2008 AIAA Guidance Navigation and Control Conference, Honolulu, HI, Title: "Reentry Terminal Guidance Through Sliding Mode Control"
 9. Vivek Yadav, "Robust/Optimal Temperature Profile Control Using Neural Networks," Finalist for the best paper (**one of five**), 2006 IEEE Conference on Control Applications, Munich, Germany, October 2006.
 10. Nishant Unnikrishnan, "Dynamic Re-Optimization of a Spacecraft Attitude Controller in the Presence of Uncertainties," Finalist for the best paper (**one of three finalists**), 2006 IEEE International Symposium on Intelligent Control, Munich, Germany, October 2006.
 11. Dancer, Michael, "MR SAT Orbit Determination Using the Theta-D Filter," **2nd Prize**, Graduate Division, AIAA Region VI Student Best paper Award, Ames, Iowa, April 2006.
 12. Durbha, Venkat, "New Nonlinear Observer Design with Application to Target Interception," **3rd prize**, Graduate Division, AIAA Region VI Student Best paper

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Award, Ames, Iowa, April 2006.

13. Schmitz, Derek and Janardhan, Vijay, "Implementation of Nonlinear Reconfigurable Controllers for Autonomous Unmanned Vehicles," **1st prize**, graduate Division, AIAA Region VI Best Paper Award, Minneapolis, Minnesota, April 2004.
14. Drake, David, "Theta-D Control Technique for Ascent Control of Reusable Launch Vehicles," **1st prize**, Graduate Division, AIAA Region VI (an 8-state region) Best paper Award, Boulder, Colorado, April 2003.
15. Drake, David, "Theta-D Control Technique for Ascent Control of Reusable Launch Vehicles," Finalist for the student best paper, 2003 AIAA Atmospheric Flight Mechanics Conference, Austin, TX.
16. Padhi, Radhakant, "An Optimal Control Based Treatment Strategy For Parturient Paresis Using Neural Networks," **3rd Best Paper**, 2001 IEEE Conference on Control applications, Mexico City, Mexico, September 2001.

SERVICE ACTIVITIES:**National, International:**

1. Member, AIAA Technical Committee on Guidance, Navigation and Control, 1992-2000
2. Member, AIAA Guidance, Navigation, and Control Conference Best Paper Award Committee, 1993, 1994
3. Member, AIAA Society Review Committee for 1995 American Control Conference Program Committee Member, 1995 American Control Conference
4. Member, NSF SBIR Panel Review, Arlington, VA, September 1995
5. Technical Program Co-Chair for 1997 AIAA Guidance, Navigation, and Control Conference (Major Aerospace Control Conference with about 1000 attendees)
6. Director, American Automatic Control Council, 1997-2001
7. Program Committee Member, 1997 American Control Conference
8. AIAA Society Review Chair for 1997 American Control Conference
9. Member, American Control Conference Steering Committee, 1997 – 2001
10. Member, NSF Career Review Panel, Electrical and Communications Sciences Directorate of Engineering, National Science Foundation, September 1997, October 1998, October 1999, October 2001, October 2004
11. Member, Grant Review Panel, NSF DDAS Initiative, 2005.
12. Reviewer, US-Israel Binational Science Foundation (BSF) research proposal, 2006
13. Reviewer of proposal, Defense R&D Canada (DRDC), 2008

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14. Member, Information Sciences Technical Committee, SAE Aerospace International, 1997-2001
15. Program Committee Member, 2000 American Control Conference
16. Member, Committee to Select Donald P. Eckman Award Winner (this award is given to the most outstanding young engineer under the age of 35 in the field of Automatic Control in USA), 2000
17. Member, AIAA Technical Committee on Atmospheric Flight Mechanics, 2000-2004
18. Vice Chair, Invited Sessions, 2001 American Control Conference
19. Program Committee Member, 2003 American Control Conference
20. Area Chair, Missile Guidance and Control, 2001, AIAA Guidance, Navigation and Control Conference
21. General Chair, 2003 AIAA Atmospheric Flight Mechanics Conference
22. Program Chair, 2005 American Control Conference (The premier controls conference for controls researchers from all over the world; completely volunteer-run. About 1700 papers with an acceptance rate of about 70%)
23. Member, Adaptive and Learning Systems technical Committee, International Federation of Automatic Control(IFAC), 2003-
24. Served as an External Evaluator, 3rd year review for a faculty in Mechanical Engineering, *Duke University*, 2004
25. Served as an External Evaluator, tenure Committee for a faculty in *UAE*, 2002
26. Served as an External Evaluator, promotion to Associate Professor and to a Full professor for two faculty in *Technion*, Israel, 2004, 2006
27. Served as an External Evaluator, promotion to Chair, *Cranfield University*, Bedfordshire, England, 2009
28. Served as an External Evaluator, promotion to Associate Professor, *Indian Institute of Science*, Bangalore, India, 2009
29. Associate Editor, AIAA Journal of Guidance, Control, and Dynamics, 1994-2012
30. Have served numerous times as a Session Chair at many national and international conferences. Do not accept many assignments now
31. Have reviewed at least a few hundred journal papers for many national and international journals

Professional Societies:

1. Associate Fellow, AIAA
2. Member, Sigma Gamma Tau (National Aerospace Honor Society)