

CURRICULUM VITAE

Malcolm David SHUSTER

Date of birth: July 31, 1943 **Place of Birth:** Boston, Massachusetts
Nationality: USA **Marital Status:** single

Addresses:

Professional:	Acme Spacecraft Company, 13017 Wisteria Drive Box 328 Germantown, MD 20874	Personal:	13017 Wisteria Drive Box 328 Germantown, MD 20874
----------------------	---	------------------	---

email: mdshuster@comcast.net
website: <http://home.comcast.net/~mdshuster>

Synopsis

Forty-one years cumulative technical experience in: estimation and control, spacecraft mission and data analysis, defense systems analysis, modeling and simulation, applied mathematics, experimental and theoretical physics, and the requirements analysis, design and development of spacecraft attitude support systems and simulators, as well as the teaching of Physics and Engineering at the undergraduate and graduate levels.

Education

- S. B.**, Physics, Massachusetts Institute of Technology, Cambridge, Massachusetts, 1965.
- Ph. D.**, Physics, University of Maryland, College Park, Maryland, 1971.
- M. S.**, Electrical Engineering, the Johns Hopkins University, Baltimore, Maryland, 1982.

Professional Experience

Summer 1964 **Massachusetts Institute of Technology, Cambridge, Massachusetts.**
Technical Assistant, Laboratory for Nuclear Science.

Developed experiments for the detection of the Faraday rotation of gamma rays using the Mössbauer effect.

**Summer 1965 University of Bonn, Bonn, Federal Republic of Germany.
Wissenschaftlicher Hilfsassistent, Institut für Strahlen- und Kernphysik.**

Participated in an experimental research program on parity non-conservation in nuclear beta-decay. Prepared radioactive sources. Calculated cross-sections for relativistic scattering of beta-particles based on the results of Quantum Electrodynamics.

**Summer 1966 Minnesota, Mining and Manufacturing Company, St. Paul, Minnesota.
Summer Research Fellow, Imaging Research Laboratory.**

Designed and carried out experiments on the thermoluminescence of variously doped ZnO powders as part of a research project to develop a color photo-copying machine. Developed experimental procedures which improved signal-to-noise ratios by five orders of magnitude.

**1965–1970 University of Maryland, College Park, Maryland.
Graduate Assistant, Department of Physics and Astronomy.**

Carried out a research program in theoretical nuclear physics with particular emphasis on collective two-particle-two-hole states in nuclei and on pion production in nuclear collisions. Developed a theory of pion production on nuclei based on current algebra and dispersion relations. Taught undergraduate Physics laboratories and recitations in graduate Physics courses. Worked closely with the cyclotron group on the design and interpretation of experiments. Served on several Department committees. Was one of five students who organized the University of Maryland Graduate Student Federation.

**1970–1972 French Atomic Energy Commission, Paris, France.
Ingénieur-Physicien, Centre d'Études Nucléaires de Saclay.**

Carried out a research program on the interaction of elementary particles with nuclei. Studied pion production as a tool for refining optical models of nuclei. Studied exotic muon capture to establish the impossibility of a long accepted elementary-particle scheme. Showed that the ABC Effect, which had been taken for an elementary particle for more than a decade, was likely a nuclear resonance phenomenon. Worked with the Saturne group on the design and interpretation of experiments. Taught an advanced graduate course in Nuclear Physics.

**1972–1973 University of Karlsruhe, Karlsruhe, Federal Republic of Germany.
Wissenschaftlicher Assistent, Institut für Theoretische Kernphysik.**

Carried out a research program on the interaction of elementary particles with nuclei. Extended the theory of the ABC Effect and studied the role of alternative nuclear models in muon capture. Taught graduate Physics courses. (I resigned this position in protest rather than sign a loyalty oath stipulated by a still active law of the Third Reich. This resulted in the elimination of that law by the state of Baden-Württemberg during the following year.)

**1973–1976 Tel-Aviv University, Tel-Aviv, Israel.
Lecturer, Department of Physics and Astronomy.**

Carried out a research program on the interaction of elementary particles with nuclei. Demonstrated conclusively the nonexistence of the ABC meson and made quantitative predictions for related effects which were later verified by experiment. Determined the effect of isotensor electromagnetic interactions on nuclear isobar mass spectra. Showed how multiple-pion exchange near and above the production threshold leads to a very long-range nuclear force. Directed graduate student research. Taught advanced graduate courses in Nuclear Physics. Directed the Nuclear Seminar. Was an adviser to the Library of Exact Sciences.

1976 – 1977 – **Carnegie-Mellon University, Pittsburgh, Pennsylvania.**
Visiting Assistant Professor, Department of Physics.

Carried out a research program on the interaction of elementary particles with nuclei. Studied the effect of intermediate baryon resonances on the nucleon-nucleon force and on nuclear Coulomb energies. Carried out control-system studies for the AEM/HCMM spacecraft. Taught undergraduate and graduate Physics courses. Directed graduate student research.

1977 – 1981 – **Computer Sciences Corporation, Silver Spring, Maryland.**
Senior Member of the Technical Staff, Attitude Systems Operation.

Provided mission analysis, requirements analysis, software design and development, launch support, and technical direction in the area of spacecraft attitude determination and control for several NASA missions including: Applications Explorer Mission (AEM), Magsat, Seasat, Solar Maximum Mission (SMM), Dynamics Explorer (DE), Hubble Space Telescope, and Active Magnetospheric Particle Tracer Explorer (AMPTE). Developed a number of attitude determination techniques which since have become standard. In particular, developed QUEST, an efficient algorithm for batch spacecraft attitude estimation, now the industry standard. Developed the now standard approach for Kalman filtering of attitude. Directed as many as eleven people at one time in a variety of mission analysis and software development activities. Directed a weekly seminar on NASA attitude, flight dynamics, and scientific support.

1981 – 1987 – **Business and Technological Systems, Inc., Seabrook, Maryland.**
Staff Scientist and Manager (1986 – 87), Space Systems Branch.

Provided technical support and project management for several DoD and NASA projects, with special emphasis on the Trident weapon system, spacecraft navigation, and geophysical systems. Technical areas included: maximum-likelihood parameter estimation, accuracy evaluation, modeling, simulation, geomagnetism, gravity gradiometry, sensor studies, and trajectory optimization. Developed powerful identification techniques for complex large-scale systems. Developed novel validation and verification techniques for the Advanced Weapon System Simulation using real missile test data. Showed that the reported stripping phenomenon in the distribution of magnetic anomalies in the Earth's crust was only an artifact of the analysis. Taught several courses in Estimation Theory.

1987 – 1994 – **The Johns Hopkins University Applied Physics Laboratory, Laurel, Maryland.**
Senior Professional Staff, Space Department.

Provided technical expertise for DoD projects, chiefly in the area of spacecraft attitude determination and control, including mission analysis, requirements analysis, algorithm development, software design and development, and launch support. Missions and spacecraft supported included: Thrusted Vector (Delta-181), NOVA-II, OSCAR, Polar BEAR, Engineering Prototype Optimization (EPO), Star Tracker, Janus Mission II, and Mid-Course Space Experiment (MSX). Monitored contractor design and development of a state-of-the-art conical infrared horizon scanner. Developed a very robust Kalman-filter-based onboard attitude determination system for the MSX spacecraft. Developed a complete and consistent methodology for postlaunch spacecraft sensor alignment and calibration. Directed the research of a post-doctoral fellow from INPE, the Brazilian Space Research Institute. Directed research at NASA Goddard Space Flight Center to develop a magnetometer calibration algorithm for the first Argentine spacecraft.

**1994–
1999** **The University of Florida, Gainesville, Florida.
Professor, Department of Aerospace Engineering, Mechanics, and
Engineering Science.**

Taught courses in Aerospace Engineering and Mechanics and carried out a research program in the area of Estimation, Dynamics and Control with special emphasis on space systems. Research projects included: development of a robust algorithm for magnetometer calibration, the focal plane representation of rotations, a generalization of the Euler angles, calibration of spacecraft attitude transfer systems, a new hybrid algorithm for sequential alignment estimation, and the development of an efficient suboptimal algorithm for attitude determination from focal-plane sensors.

**1999–
2001** **Orbital Sciences Corporation, Germantown, MD.
Scientist, Attitude Determination and Control Group.**

Contributed to several projects, including BSAT-2 and NSTAR, in the area of spacecraft attitude determination. This position was terminated due to health problems.

**2001–
present** **Acme Spacecraft Company, Germantown, MD.
Director of Research.**

Created a company devoted to the unsupported publication of research in Spacecraft Attitude Estimation and related topics. Thus far (August 2007), the company has published 21 journal articles, with 5 more accepted for publication and 4 more in review.

Secondary Appointments

**August
1976** **University of Maryland, College Park, Maryland.
Visiting Scientist, Department of Physics and Astronomy.**

Carried out a research program on the interaction of elementary particles with nuclei, and participated in technical discussions.

**1983–
1987** **Howard University, Washington, District of Columbia.
Adjunct Graduate (Full) Professor, Department of Mechanical Engineering.**

Taught graduate courses, served on qualifying and thesis examination committees. Was the *de facto* advisor of a Master's thesis from 1988 until 1990.

**Summer
1995** **California Institute of Technology, Jet Propulsion Laboratory, Pasadena,
California. NASA/ASEE Fellow.**

Research on the inverse problem in robotics, general technical discussions related to JPL projects.

**1995–
1998** **University of Colorado, Department of Aerospace Science and Engineering,
Boulder, Colorado. Special Professor**

Examination of doctoral theses.

Teaching Experience

University of Maryland, College Park, Maryland.

Laboratory in Electromagnetism (1965, 1966).
Classical Electrodynamics II (1966).
Quantum Mechanics I (1967).

Institut National des Sciences et Techniques Nucléaires, Saclay, France.

Physique nucléaire à moyennes énergies (1971–72).

University of Karlsruhe, Karlsruhe, Federal Republic of Germany.

Quantenmechanik (1972).
Statistische Mechanik (1973).

Tel-Aviv University, Tel-Aviv, Israel.

Theory of Nuclear Reactions (1974, 1976).
Weak and Electromagnetic Interactions of Nuclei (1974).
High-Energy Nuclear Physics (1975).
Theory of Nuclear Matter (1975).

Carnegie-Mellon University, Pittsburgh, Pennsylvania.

Relativistic Quantum Electrodynamics (1976).
Electricity and Magnetism (1976).
Current Algebra and Elementary Particles (1977).
Mechanics II (1977).

Howard University, Washington, D. C..

Advanced Dynamics I (1983).
Spacecraft Attitude Estimation (1983, 1985, 1987).

The Johns Hopkins University, Applied Physics Laboratory, Laurel, Maryland.

Estimation and Structure Determination by Likelihood Techniques (1986).
Spacecraft Attitude Estimation (1987).
A Course in Parameter Estimation (1987).
Parameter Estimation Methods in DYNAST (1987).

NASA Goddard Space Flight Center, Greenbelt, Maryland.

Spacecraft Attitude Estimation (1987–88).

Centre National d'Etudes Spatiales, Toulouse, France.

Restitution d'attitude des véhicules spatiaux (1989).

The Johns Hopkins University, G. C. Whiting School of Engineering, Baltimore, Maryland.

Space Systems (At APL: 1989, 1990, 1991, 1992, 1993).

NASA Marshall Space Flight Center, Huntsville, Alabama.

Spacecraft Attitude Determination and Control (one-day short course, 1994, 1996).

University of Florida, Gainesville, Florida.

Synthesis of Guidance and Control Systems (1995, 1996).
 Dynamics and Control of Aerospace Vehicles (1998, 1999).
 Statics (1995, 1996 (twice), 1998).
 Spacecraft Navigation (1995).
 Introduction to Space (1996).
 Introduction to Space System Design (1997, 1998, 1999).
 Spacecraft Attitude Dynamics (1997).

California Institute of Technology, Jet Propulsion Laboratory, Pasadena, California.

Spacecraft Attitude Determination and Control (one-day short course, 1996, 1997).

Hughes Space and Communication Company, El Segundo, California.

A Second Course in Spacecraft Attitude Determination, (one-day short course, 1997).

Conference Activities

Member, Local Arrangements Committee, 6th IFAC Symposium on Identification, Arlington, Virginia, September 1981.

Organizer and Chairman, Invited Session on Estimation and Identification, 24th IEEE Conference on Decision and Control, Fort Lauderdale, Florida, December 1985.

Local Arrangements Chairman and Exhibits Chairman, Third IEEE Symposium on Computer-Aided Control-System Design, Arlington, Virginia, September 1986.

Publications Chairman, 26th IEEE Conference on Decision and Control, Los Angeles, California, December 1987.

Co-organizer and Co-chairman, IEEE Symposium on Factorized Estimation in Memory of Gerald J. Bierman, Austin, Texas, December 1988.

Co-organizer and Co-chairman, Invited Session on Factorized Estimation Methods, 27th IEEE Conference on Decision and Control, Austin, Texas, December 1988.

Co-organizer, Invited Session on Mechanics, Navigation, and Control, Third Pan-American Congress on Applied Mechanics, São Paulo, Brazil, January 1993.

Session Chairman, AAS/GSFC International Symposium on Space Flight Dynamics, NASA Goddard Space Flight Center, Greenbelt, Maryland, April 1993.

Member, Program Committee, International Symposium on Spacecraft Ground Control and Flight Dynamics—SCD1, São José dos Campos (SP), Brazil, February 1994.

Session Chairman, AAS/AIAA Astrodynamics Conference, Halifax, Nova Scotia, Canada, August 1995.

AAS Technical Co-chairman, AIAA/AAS Astrodynamics Specialists Conference, San Diego, California, August 1996.

Member, International Advisory Committee, Vth Panamerican Congress of Applied Mechanics, San Juan, Puerto Rico, January 1997.

Member, International Advisory Committee, VIth Panamerican Congress of Applied Mechanics, Rio de Janeiro, Brazil, January 1999.

AAS General Co-Chairman, AIAA/AAS Astrodynamics Specialists Conference, Denver, Colorado, August 2000.

Other Professional Activities

Member, AIAA/National-Capital-Section Guidance and Control Technical Committee, 1985–86.

Member, AIAA/National-Capital-Section Space Systems Technical Committee, 1986–87.

Member, AIAA/National-Capital-Section Guidance, Navigation and Control Technical Committee (1989–92).

Rapporteur, Doctoral Thesis Examination, University of Nice, Sophie-Antipolis, France, July 1990.

Guest Editor (with John L. Junkins), *Journal of the Astronautical Sciences*, Special Issue on Attitude Representation, Vol. 41, No. 4, October–December 1993.

Associate Editor, *Journal of the Astronautical Sciences* (1994–2001).

Member, AAS Space Flight Mechanics Technical Committee (1994–2001).

Member, Editorial Board, Space Technology Library, Springer Scientific + Business Media, New York and Berlin (since 1995).

Reviewer for the professional journals:

Nuclear Physics (The Netherlands)

Zeitschrift für Physik (Federal Republic of Germany)

Journal of Spacecraft and Rockets (USA)

Journal of Guidance, Control and Dynamics (USA)

Journal of the Astronautical Sciences (USA)

IEEE Transactions on Automatic Control (USA)

Professional Societies

American Astronautical Society (fellow).

American Institute of Aeronautics and Astronautics (associate fellow).

American Physical Society (inactive).

British Interplanetary Society (fellow, inactive).

Institute of Electrical and Electronics Engineers (senior member, inactive).

Honors and Awards

Bat-Sheva de Rothschild Foundation Award (1974).

NASA Group Achievement Award (1981).

AIAA Survey Paper Citation (1982).

Sigma Xi (Eminent Scientist, 1982).

Tau Beta Pi (Eminent Engineer, 1983).

BMDO MSX Group Achievement Award (1994).

Most Visionary Paper Award, Richard H. Battin Astrodynamics Symposium, College Station, Texas (2000).

American Astronautical Society Dirk Brouwer Award (2000).

Guest of Honor, The American Astronautical Society Malcolm D. Shuster Astronautics Symposium, Grand Island, New York, June 13–15, 2005.

Consulting and Short Courses

Agência Espacial Brasileira, Brasília, Brazil.
 Applied Technology Associates, Exton, PA.
 Applied Technology Institute, Clarksville, MD.
 Centre National d'Études Spatiales, Toulouse, France.
 Computer Sciences Corporation, Seabrook, MD.
 Comisión Nacional de Actividades Espaciales, Buenos Aires, Argentina.
 Instituto Nacional de Pesquisas Espaciais, São José dos Campos, Brazil.
 The Johns Hopkins University Applied Physics Laboratory, Laurel, MD.
 Microcosm, Inc., Torrance, CA.

Plenary Lectures

"QUEST, a Longa História de um Algoritmo Rápido," First Brazilian Symposium on Aerospace Technology, São José dos Campos (SP), Brazil, August 1990.

"In Quest of Better Attitudes" (Dirk Brouwer Lecture), 11th AAS/AIAA Space Flight Mechanics Meeting, Santa Barbara, California, February 2001.

"Beyond Estimation," The AAS Malcolm D. Shuster Astronautics Symposium, Grand Island, New York, June 2005.

PUBLICATIONS

Chapters and Sections of Books

1. Spin-Plane Magnetic-Coil Maneuvers; Mihaly Grell and Malcolm D. Shuster, Sec. 19.2 in J. R. Wertz *et al.*, *Spacecraft Attitude Determination and Control*, Kluwer Academic Publishers, Boston, Massachusetts and Dordrecht, the Netherlands, ISBN 90-277-0959-9, pp. 642–649, 1978.
2. Spacecraft Attitude Determination and Control; Malcolm D. Shuster, Chapter 5 in Vincent L. Pisacane and Robert C. Moore (eds.), *Fundamentals of Space Systems*, Oxford University Press, ISBN 0-19-507497-1, pp. 245–336, 1994.
3. Spacecraft Attitude Determination and Control; Malcolm D. Shuster and Wayne Dellinger, Chapter 5 in V. L. Pisacane (ed.), *Fundamentals of Space Systems*, 2nd ed., Oxford University Press, ISBN 0-19-516205-6, pp. 236–325, 2005.

Journal Articles

Articles in Physics

1. Non-Relativistic Hard-Pion Production and Current-Field Algebra; M. K. Banerjee, C. A. Levinson, M. D. Shuster, and D. A. Zollman, *Physical Review*, Vol. **C3**, No. 2, pp. 509–524, February 1971.
2. Exotic Muon Capture in Nuclei and Lepton Conservation, M. D. Shuster and M. Rho, *Physics Letters*, Vol. **42B**, No. 1, pp. 45–48, November 13, 1972.

3. Anomalous Enhancements in Multiple-Pion Production with Deuterons; T. Risser and M. D. Shuster, *Physics Letters*, Vol. **43B**, No. 1, pp. 68–72, January 8, 1973.
4. The ABC Effect in the Reaction $NN \rightarrow d\pi\pi$; I. Bar-Nir, T. Risser, and M. D. Shuster, *Nuclear Physics*, Vol. **B87**, pp. 109–126, 1975.
5. A Comment on the Interpretation of Anomalous Enhancements in the Reaction $p + d \rightarrow d + \text{Missing Mass}$; I. Bar-Nir and M. D. Shuster, *Nuclear Physics*, Vol. **B103**, pp. 103–108, 1976.
6. Isotensor Electromagnetic Currents and Nuclear Isobar Masses; M. D. Shuster, *Physics Letters*, Vol. **61B**, No. 3, pp. 231–233, March 29, 1976.
7. Non-Relativistic Hard Pion Production and Current-Field Algebra II. Reactions with Composite Targets; M. K. Banerjee, C. A. Levinson, M. D. Shuster, and D. A. Zollman, *Physical Review*, Vol. **C13**, No. 3, pp. 2444–2450, June 1976.
8. Multiple Pion Exchange in a Nonstatic Theory of Nucleon-Nucleon Scattering and Isobar Production; H. J. Weber, J. M. Eisenberg, and M. D. Shuster, *Nuclear Physics*, Vol. **A278**, pp. 491–505, 1977.

Articles in Engineering

9. Three-Axis Attitude Determination from Vector Observations; M. D. Shuster and S. D. Oh, *Journal of Guidance and Control*, Vol. **4**, No. 1, pp. 70–77, January-February 1981.
10. Inflight Magnetometer Calibration and Attitude Determination for Near-Earth Spacecraft; G. M. Lerner and M. D. Shuster, *Journal of Guidance and Control*, Vol. **4**, No. 5, pp. 518–522, September-October 1981.
11. Inflight Estimation of Spacecraft Attitude-Sensor Accuracy and Alignments; M. D. Shuster, D. M. Chitre, and D. P. Niebur, *Journal of Guidance, Control and Dynamics*, Vol. **5**, No. 4, pp. 339–343, July-August 1982.
12. Kalman Filtering for Spacecraft Attitude Estimation (survey paper); E. J. Lefferts, F. L. Markley, and M. D. Shuster, *Journal of Guidance, Control and Dynamics*, Vol. **5**, No. 5, pp. 417–429, September-October 1982.
13. Efficient Algorithms for Spin-Axis Attitude Estimation; Malcolm D. Shuster, *The Journal of the Astronautical Sciences*, Vol. **31**, No. 2, pp. 237–249, April-June 1983; Errata: Vol. **51**, No. 1, p. 121, January–March 2003.
14. Использование фильтров Калмана для оценивания пространственной ориентации КЛА; E. J. Lefferts, F. L. Markley, and M. D. Shuster, *Аэрокосмическая Техника*, Vol. **1**, pp. 135–149, 1983.
15. A Comment on Fast Three-Axis Attitude Determination Using Vector Observations and Inverse Iteration; Malcolm D. Shuster, *The Journal of the Astronautical Sciences*, Vol. **31**, No. 4, pp. 579–584, October-December 1983.
16. Magnetometer Bias Determination and Spin-Axis Attitude Estimation for the AMPTE Mission; R. A. Thompson, G. F. Neal, and M. D. Shuster, *Journal of Guidance, Control and Dynamics*, Vol. **7**, No. 4, pp. 505–507, July-August 1984.
17. In Memoriam, Gerald J. Bierman; R. S. Baheti, A. J. Laub, and M. D. Shuster, *IEEE Transactions on Automatic Control*, Vol. **33**, No. 4, p. 322, April 1988.
18. Maximum Likelihood Estimation of Spacecraft Attitude; Malcolm D. Shuster, *The Journal of the Astronautical Sciences*, Vol. **37**, No. 1, pp. 79–88, January–March, 1989.

19. A Simple Kalman Filter and Smoother for Spacecraft Attitude; Malcolm D. Shuster, *The Journal of the Astronautical Sciences*, Vol. **37**, No. 1, pp. 89–106, January–March, 1989.
20. Kalman Filtering of Spacecraft Attitude and the QUEST Model; Malcolm D. Shuster, *The Journal of the Astronautical Sciences* Vol. **38**, No. 3, pp. 377–393, July–September, 1990; Erratum: Vol. **51**, No. 3, p. 359 July–September 2003.
21. Batch Estimation of Spacecraft Sensor Alignments, I. Relative Alignment Estimation; Malcolm D. Shuster, Daniel S. Pitone, and Gerald J. Bierman, *The Journal of the Astronautical Sciences*, Vol. **39**, No. 4, pp. 519–546, October–December, 1991.
22. Batch Estimation of Spacecraft Sensor Alignments, II. Absolute Alignment Estimation; Malcolm D. Shuster and Daniel S. Pitone, *The Journal of the Astronautical Sciences*, Vol. **39**, No. 4, pp. 547–571, October–December, 1991.
23. Coarse Attitude Determination from Earth Albedo Measurements; H. L. Fisher, K. L. Musser, and M. D. Shuster, *IEEE Transactions on Aerospace and Electronics Systems*, Vol. **29**, No. 1, pp. 22–26, January 1993.
24. The Kinematic Equation for the Rotation Vector; Malcolm D. Shuster, *IEEE Transactions on Aerospace and Electronic Systems*, Vol. **29**, No. 1, pp. 263–267, January 1993.
25. Attitude Determination in Higher Dimensions; Malcolm D. Shuster, *Journal of Guidance, Control and Dynamics*, Vol. **16**, No. 2, pp. 393–395, March–April 1993.
26. Editorial: Attitude Representation; John L. Junkins and Malcolm D. Shuster, *The Journal of the Astronautical Sciences*, Vol. **41**, No. 4, pp. 437–438, October–December 1993.
27. A Survey of Attitude Representations; Malcolm D. Shuster, *The Journal of the Astronautical Sciences*, Vol. **41**, No. 4, pp. 439–517, October–December 1993.
28. The Geometry of the Euler Angles; John L. Junkins and Malcolm D. Shuster, *The Journal of the Astronautical Sciences*, Vol. **41**, No. 4, pp. 531–543, October–December 1993.
29. Quaternion Computation from a Geometric Point of View; Malcolm D. Shuster and Gregory A. Natanson, *The Journal of the Astronautical Sciences*, Vol. **41**, No. 4, pp. 545–556, October–December 1993.
30. Focal-Plane Representation of Rotations; Malcolm D. Shuster, *The Journal of the Astronautical Sciences*, Vol. **48**, Nos. 2 and 3, pp. 381–390, April–September 2000.
31. TWOSTEP, a Fast Robust Algorithm for Attitude-Independent Magnetometer Bias Determination; Roberto Alonso and Malcolm D. Shuster, *The Journal of the Astronautical Sciences*, Vol. **50**, No. 4, pp. 433–451, October–December 2002.
32. Attitude-Independent Magnetometer Bias Determination, A Survey; Roberto Alonso and Malcolm D. Shuster, *The Journal of the Astronautical Sciences*, Vol. **50**, No. 4, pp. 453–475, October–December 2002.
33. Complete Linear Attitude-Independent Magnetometer Calibration; Roberto Alonso and Malcolm D. Shuster, *The Journal of the Astronautical Sciences*, Vol. **50**, No. 4, pp. 477–490, October–December 2002.
34. Constraint in Attitude Estimation Part I: Constrained Estimation; Malcolm D. Shuster, *The Journal of the Astronautical Sciences*, Vol. **51**, No. 1, pp. 51–74, January–March 2003.
35. Constraint in Attitude Estimation Part II: Unconstrained Estimation; Malcolm D. Shuster, *The Journal of the Astronautical Sciences*, Vol. **51**, No. 1, pp. 75–101, January–March 2003.
36. Generalization of the Euler Angles; Malcolm D. Shuster and F. Landis Markley, *The Journal of the Astronautical Sciences*, Vol. **51**, No. 2, pp. 123–132, April–June 2003.

37. Centering and Observability in Attitude-Independent Magnetometer-Bias Determination; Roberto Alonso and Malcolm D. Shuster, *The Journal of the Astronautical Sciences*, Vol. **51**, No. 2, pp. 133–141, April–June 2003.
38. Parameter Interference in Distortion and Alignment Calibration; Roberto V. F. Lopes and Malcolm D. Shuster, *The Journal of the Astronautical Sciences*, Vol. **51**, No. 3, pp. 261–277, July–September 2003.
39. Batch, Sequential and Hybrid Approaches to Spacecraft Sensor Alignment Estimation; Maria Cecília Zanardi and Malcolm D. Shuster, *The Journal of the Astronautical Sciences*, Vol. **51**, No. 3, pp. 279–290, July–September 2003.
40. Uniform Attitude Probability Distributions; Malcolm D. Shuster, *The Journal of the Astronautical Sciences*, Vol. **51**, No. 4, pp. 451–175, October–December 2003.
41. Stellar Aberration and Parallax: A Tutorial; Malcolm D. Shuster, *The Journal of the Astronautical Sciences*, Vol. **51**, No. 4, pp. 477–494, October–December 2003.
42. Attitude Analysis in Flatland: The Plane Truth; Malcolm D. Shuster, *The Journal of the Astronautical Sciences*, Vol. **52**, Nos. 1 and 2, pp. 195–209, January–June 2004.
43. SCAD—A Fast Algorithm for Star Camera Attitude Determination; Malcolm D. Shuster, *The Journal of the Astronautical Sciences*, Vol. **52**, No. 3, pp. 391–404, July–September 2004.
44. Deterministic Three-Axis Attitude Determination; Malcolm D. Shuster, *The Journal of the Astronautical Sciences* Vol. **52**, No. 3, pp. 405–419, July–September 2004.
45. A Simple Derivation of the Gauss-Bonet Theorem Using Euler Angles; Ranjan Mukherjee and Malcolm D. Shuster, *The Journal of the Astronautical Sciences*, Vol. **53**, No. 2, pp. 185–191, 2005.
46. QUEST and the Anti-QUEST: Good and Evil Attitude Estimation; Yang Cheng and Malcolm D. Shuster, *The Journal of the Astronautical Sciences*, Vol. **53**, No. 2, pp. 337–351, 2005.
47. A General Formula for Extracting the Euler Angles; Malcolm D. Shuster and F. Landis Markley, *Journal of Guidance, Control and Dynamics*, Vol. **29**, No. 1, pp. 215–217, 2006.
48. The TRIAD Algorithm as Maximum-Likelihood Estimation; Malcolm D. Shuster, *The Journal of the Astronautical Sciences*, Vol. **54**, No. 1, pp. 113–123.
49. The Generalized Wahba Problem; Malcolm D. Shuster, *The Journal of the Astronautical Sciences*, Vol. **54**, No. 2, April–June 2006, pp. 245–259.
50. Editorial Matter: Biography, Select Bibliography in Astronautics, Foreword, *The Journal of the Astronautical Sciences*, Vol. **54**, Nos. 3 and 4, July–December 2006, pp. 263–271.
51. In My Estimation, *The Journal of the Astronautical Sciences*, Vol. **54**, Nos. 3 and 4, July–December 2006, pp. 273–297.
52. The QUEST for Better Attitudes, *The Journal of the Astronautical Sciences*, Vol. **54**, Nos. 3 and 4, July–December 2006, pp. 657–683.
53. Spin-Axis Attitude Estimation; Sergei Tanygin and Malcolm D. Shuster, *The Journal of the Astronautical Sciences*, Vol. **55**, January–March 2007, No. 1, pp. 107–139.
54. The Optimization of TRIAD; M. D. Shuster, *The Journal of the Astronautical Sciences*, Vol. **55**, No. 2, April–June 2007, pp 245–257.
55. The Maximum-Error Test; D. C. Freesland, Y. Cheng and M. D. Shuster, *The Journal of the Astronautical Sciences*, Vol. **55**, No. 2, April–June 2007, pp. 259–270.

56. Effective Direction Measurements for Spacecraft Attitude: I. Equivalent Directions; Malcolm D. Shuster, *The Journal of the Astronautical Sciences*, Vol. **55**, No. 4, pp. 463–478, October–December 2007.
57. Effective Direction Measurements for Spacecraft Attitude: I@. Predicted Directions ; Malcolm D. Shuster, *The Journal of the Astronautical Sciences*, Vol. **55**, No. 4, pp. 479–492, October–December 2007.
58. Effective Direction Measurements for Spacecraft Attitude: III. Defective Directions and Data Fusion; Malcolm D. Shuster, *The Journal of the Astronautical Sciences*, Vol. **55**, No. 4, pp. 593–510, October–December 2007.
59. The Arts and Engineering; Maldolm D. Shuster, *IEEE Control Systems Magazine*, Vol. 28, No. 4, pp. 96–98, August 2008.

Popular Magazine Articles

1. How to Use Your Luna-Pro Light Meter as a Densitometer; Walt Seng and Malcolm Shuster, *Petersen's Photographic Magazine*, Vol. **6**, No. 10, pp. 29–30, February 1978; reprinted in *Blueprint Series Vol. II, Petersen's How-To Photographic Library*, 1978.

Conference Articles and Abstracts

Articles in Physics

1. Pion Production in Nuclear Collisions (abstract); M. D. Shuster, M. K. Banerjee, C. A. Levinson, and D. A. Zollman, *Annual Meeting of the American Physical Society*, Washington, D. C., *Bull. Am. Phys. Soc.*, Ser. II, Vol. **15**, No. 4, p. 525, April 1970.
2. Off-Shell Nucleon-Nucleon Amplitudes from Pion Production (abstract); D. A. Zollman, M. K. Banerjee, C. A. Levinson, and M. D. Shuster, *Annual Meeting of the American Physical Society*, Washington, D. C., *Bull. Am. Phys. Soc.*, Ser. II, Vol. **15**, No. 4, p. 525, April 1970.
3. Isotensor Muon Capture in Nuclei (abstract); M. D. Shuster and M. Rho, *Proceedings, European Conference on Nuclear Physics*, Aix-en-Provence, France, p. 143, July 1972.
4. On the Nature of the ABC Effect (abstract); I. Bar-Nir, T. Risser, and M. D. Shuster*, *Proceedings, Fifth International Conference on High-Energy Physics and Nuclear Structure*, Uppsala, Sweden, 1 p., June 1973.

Articles in Engineering

5. Analytic Investigation of the AEM-A/HCMM Attitude Control System Performance; G. M. Lerner, W. Huang, and M. D. Shuster, Paper No. AAS-77–116, *AAS/AIAA Astrodynamics Specialists Conference*, Grand Teton National Park, Wyoming, September 1977.
6. Approximate Algorithms for Fast Optimal Attitude Computation; Malcolm D. Shuster, Paper No. AIAA 78–1249, *Proceedings, AIAA Guidance and Control Conference*, Palo Alto, California, pp. 88–95, August 1978.
7. Magnetometer Bias Determination and Attitude Determination for Near-Earth Spacecraft; G. M. Lerner and M. D. Shuster*, Paper No. AIAA-79–1695, *Proceedings, AIAA Guidance and Control Conference*, Boulder, Colorado, pp. 1–10, August 1979.

8. Spin-Axis Attitude Estimation and Magnetometer Bias Determination for the AMPTE Mission; R. A. Thompson, G. F. Neal, and M. D. Shuster, *Proceedings, Flight Mechanics/Estimation Theory Symposium*, NASA Goddard Space Flight Center, Greenbelt, Maryland, October 1981.
9. Efficient Algorithms for Spin-Axis Attitude Estimation; M. D. Shuster, *Proceedings, Flight Mechanics/Estimation Theory Symposium*, NASA Goddard Space Flight Center, Greenbelt, Maryland, October 1981.
10. Kalman Filtering for Spacecraft Attitude Estimation; E. F. Lefferts, F. L. Markley and M. D. Shuster, Paper No. AIAA-82-0070, *AIAA 20th Aerospace Sciences Meeting*, Orlando, Florida, January 1982.
11. A Doubly Recursive Algorithm for System Identification from Non-Stationary Cross-Sectional Data; Dave W. Porter, Malcolm D. Shuster, and William S. Levine, *Proceedings, American Control Conference*, San Francisco, California, pp. 1257–1261, June 1983.
12. A Partitioned Recursive Algorithm for the Estimation of Dynamical Parameters and Initial-Condition Parameters from Cross-Sectional Data; David W. Porter, Malcolm D. Shuster, Bruce P. Gibbs, and William S. Levine, *Proceedings, 22nd IEEE Conference on Decision and Control*, San Antonio, Texas, pp. 596–603, December 1983.
13. Efficient Estimation of Initial-Condition Parameters for Partially Observable Initial Conditions; Malcolm D. Shuster and David W. Porter, *Proceedings, 23rd IEEE Conference on Decision and Control*, Las Vegas, Nevada, pp. 1272–1275, December 1984.
14. Treatment of Satellite Errors in the Processing of Magnetic Survey Data (abstract); Malcolm D. Shuster, *International Union of Geodesy and Geophysics, XIX General Assembly*, Vancouver, British Columbia, Canada, 1 p., August 1987.
15. Spacecraft Alignment Estimation; Gerald J. Bierman and Malcolm D. Shuster, *Proceedings, 27th IEEE Conference on Decision and Control*, Austin, Texas, pp. 856–859, December 1988.
16. Identification of Vibrational Modes for a Non-Rigid Spacecraft; Malcolm D. Shuster, *Proceedings, Pan-American Congress of Applied Mechanics*, Rio de Janeiro, Brazil, pp. 705–708, January 1989.
17. Attitude Determination for the Star Tracker Mission; H. L. Fisher, M. D. Shuster, and T. E. Strikwerda, Paper No. AAS-89–365, *AAS/AIAA Astrodynamics Specialists Conference*, Stowe, Vermont, August 1989; Proceedings: *Advances in the Astronautical Sciences*, Vol. 71, pp. 138–150, 1990.
18. Very Coarse Attitude Determination for the Thrusted Vector Mission; M. D. Shuster, H. L. Fisher, and K. L. Musser, Paper No. AAS-89–393, *AAS/AIAA Astrodynamics Specialists Conference*, Stowe, Vermont, August 1989; Proceedings: *Advances in the Astronautical Sciences*, Vol. 71, pp. 237–243, 1990.
19. Fads and Fallacies in Spacecraft Sensor Alignment Estimation; M. D. Shuster, *International Symposium on Space Mechanics*, Toulouse, France, November 1989; Proceedings: *Mécanique Spatiale*, CEPADUES Editions, Toulouse, pp. 513–522, 1990.
20. Inflight Estimation of Spacecraft Sensor Alignment; Malcolm D. Shuster, Paper No. AAS-90–041, *AAS Guidance and Control Conference*, Keystone, Colorado, February 1990; Proceedings: *Advances in the Astronautical Sciences*, Vol. 72, pp. 253–274, 1990.
21. Attitude Sensor Alignment Calibration for the Solar Maximum Mission; Daniel S. Pitone and Malcolm D. Shuster, *Proceedings, Flight Mechanics/Estimation Theory Symposium*, NASA Goddard Space Flight Center, Greenbelt, Maryland, pp. 21–39, May 1990.
22. Consistent Estimation of Spacecraft Sensor Alignments; Malcolm D. Shuster and Daniel S. Pitone, *Proceedings, American Control Conference*, San Diego, California, pp. 1389–1395, May 1990.
23. QUEST, a longa história de um algoritmo rápido (invited plenary paper); Malcolm David Shuster, *First Brazilian Symposium on Aerospace Technology*, São José dos Campos (SP), Brazil, August 1990.

24. Autonomous, All-Stellar Attitude Determination Experiment: Ground Test Results; H. L. Fisher, T. E. Strikwerda, C. C. Kilgus, L. J. Frank, and M. D. Shuster, Paper No. AAS-91-025, *AAS Guidance and Control Conference*, Keystone, Colorado, February 1991; Proceedings; *Advances in the Astronautical Sciences*, Vol. **74**, pp. 69–84, 1991.
25. New QUESTs for Better Attitudes; Malcolm D. Shuster, *Proceedings, Flight Mechanics/Estimation Theory Symposium*, NASA Goddard Space Flight Center, Greenbelt, Maryland, pp. 125–137, May 1991.
26. Attitude Analysis in Flatland: The Plane Truth; Malcolm D. Shuster, *Proceedings, Flight Mechanics/Estimation Theory Symposium*, NASA Goddard Space Flight Center, Greenbelt, Maryland, pp. 259–274, May 1992.
27. Some Interesting Properties of the Euler Angles; Malcolm D. Shuster and John L. Junkins, *Proceedings, Third Pan-American Conference on Applied Mechanics*, São Paulo, Brazil, pp. 523–526, January 1993.
28. Geometrical Properties of the Euler Angles; Malcolm D. Shuster and John L. Junkins, Paper No. AAS-93-331, *AAS/GSFC International Symposium on Space Flight Dynamics*, NASA Goddard Space Flight Center, Greenbelt, Maryland, April 1993; Proceedings: *Advances in the Astronautical Sciences*, Vol. **84**, pp. 1165–1172, 1993.
29. The Quaternion in the Kalman Filter; Malcolm D. Shuster, Paper No. AAS-93-553, *AAS/AIAA Astrodynamics Specialists Conference*, Victoria, British Columbia, Canada, August 1993; Proceedings: *Advances in the Astronautical Sciences*, Vol. **85**, pp. 25–37, 1993.
30. Attitude Estimation from the Measurement of a Direction and an Angle; Malcolm D. Shuster, *International Symposium on Spacecraft Ground Control and Flight Dynamics—SCD1*, São José dos Campos (SP), Brazil, February, 1994; Proceedings: *Revista Brasileira de Ciências Mecânicas*, Vol. **16**, Special Issue, pp. 19–23, 1994.
31. Parameter Interference in Distortion and Alignment Calibration; Malcolm D. Shuster and Roberto V. F. Lopes, Paper No. AAS-94-186, *AAS/AIAA Space Flight Mechanics Meeting*, Cocoa Beach, Florida, February, 1994; Proceedings: *Advances of the Astronautical Sciences*, Vol. **87**, Part I, pp. 595–611, 1994.
32. A New Algorithm for Attitude-Independent Magnetometer Calibration; Roberto Alonso and Malcolm D. Shuster, *Proceedings, Flight Mechanics/Estimation Theory Symposium*, NASA Goddard Space Flight Center, Greenbelt, Maryland, pp. 513–527, May 17–19, 1994.
33. Efficient Estimation of Attitude Sensor Coalignments; Malcolm D. Shuster, *Proceedings, AIAA/AAS Astrodynamics Specialists Conference*, Scottsdale, Arizona, pp. 45–53, August 1994.
34. Conflicts in Mission Development and Execution: Notes from the Front; Malcolm D. Shuster. *Report of the Workshop on Participation Opportunity on the Brazilian Scientific Satellite*, Instituto Nacional de Pesquisas Espaciais, São José dos Campos, Brazil, October 1994.
35. Calibração Consistente de Distorções e Desalinhamentos em Instrumentos de Plano Focal em Veículos Espaciais; Roberto V. F. Lopes and Malcolm D. Shuster, *Colóquio de Dinâmica Orbital*, Santos (SP), Brazil, November 1994.
36. Un Nuevo Algoritmo para la Calibración de Magnetómetros; Roberto Alonso and Malcolm D. Shuster, *Applied Mechanics in the Americas, Proceedings, the IVth Pan-American Congress of Applied Mechanics*, Vol. II, pp. 409–414, Buenos Aires, Argentina, January 1995.
37. A New Angle on the Euler Angles; F. Landis Markley and Malcolm D. Shuster, *Proceedings, Flight Mechanics/Estimation Theory Symposium*, NASA Goddard Space Flight Center, Greenbelt, Maryland, pp. 395–403, May 1995.

38. Magnetometer Calibration for the First Argentine Spacecraft; Malcolm D. Shuster and Roberto A. Alonso, Paper AAS-95-302, *AAS/AIAA Astrodynamics Specialists Conference*, Halifax, Nova Scotia, Canada, August, 1995; Proceedings: *Advances in the Astronautical Sciences*, Vol. 90, Part I, pp. 29–46, 1996.
39. MAGION Small Spacecraft as a Tool for Flight Dynamics Learning (abstract); V. Khrapchenko, M. Pivovarov, N. Eismont, P. Triska, and M. D. Shuster, *Proceedings, Fifth IAA Symposium on Small Satellites for Earth Observing*, Berlin, Germany, November 4–6, 1996, p. 216.
40. Batch and Filter Approaches to Spacecraft Sensor Alignment Estimation; Maria Cecília Zanardi and Malcolm D. Shuster, *Proceedings, 12th International Symposium on Spaceflight Dynamics*, Darmstadt, Germany, June 1997.
41. An Efficient Algorithm for Spacecraft Attitude Determination with Optical Sensors; Malcolm D. Shuster, Paper AAS-98-333, *AAS/GSFC International Symposium on Space Flight Dynamics*, NASA Goddard Space Flight Center, Greenbelt, Maryland, May 1998; Proceedings: *Advances in the Astronautical Sciences*, Vol. 100, pp. 407–419, 1998.
42. A Suboptimal Algorithm for Attitude Determination from Multiple Star Cameras; Malcolm D. Shuster, Paper AAS-00-124, *AAS/AIAA Space Flight Mechanics Meeting*, Clearwater, January 2000; Proceedings: *Advances in the Astronautical Sciences*, Vol. 105, pp. 383–393, 2000.
43. A Most Visionary Paper on Focal-Plane Representation of Rotations; Malcolm D. Shuster, Paper AAS-00-267, *Richard H. Battin Astrodynamics Conference*, College Station, Texas, March 2000; Proceedings: *Advances in the Astronautical Sciences*, Vol. 106, pp. 395–405, 2000.
44. A Broad Look at Deterministic Three-Axis Attitude Determination; Malcolm D. Shuster; Paper AIAA 2000-4239, *Proceedings, AIAA/AAS Astrodynamics Specialists Conference*, Denver Colorado, pp. 294–303, August 2000.
45. Man, Like These Attitudes Are Totally Random!, I. Quaternions; Malcolm D. Shuster, Paper No. AAS-01-125, *11th AAS/AIAA Space Flight Mechanics Meeting*, Santa Barbara, California, February 11–14, 2001; Proceedings: *Advances of the Astronautical Sciences*, Vol. **108**, pp. 383–396, 2001.
46. Man, Like These Attitudes Are Totally Random!, II. Other Representations; Malcolm D. Shuster, Paper No. AAS-01-126, *11th AAS/AIAA Space Flight Mechanics Meeting*, Santa Barbara, California, February 11–14, 2001, Proceedings: *Advances of the Astronautical Sciences*, Vol. **108**, pp. 397–408, 2001.
47. In Quest of Better Attitudes (invited plenary paper); Malcolm D. Shuster, Paper No. AAS-01-250, *11th AAS/AIAA Space Flight Mechanics Meeting*, Santa Barbara, California, February 11–14, 2001; Proceedings: *Advances in the Astronautical Sciences*, Vol. **108**, pp. 2089–2117, 2001.
48. Beyond Estimation (keynote address); Malcolm D. Shuster, Paper No. AAS 05-465, *AAS Malcolm D. Shuster Astronautics Symposium*, Grand Island, New York|USA, June 13–16, 2005; Proceedings: *Advances in the Astronautical Sciences*, Vol. **122**, pp. 249–270, 2006.
49. Editorial Matter: (a) “Cover Art,” (b) “Cover Art Legend,” (c) “Foreword,” (d) “Biography,” (e) “Select Bibliography in Astronautics,” (f) “Afterword;” Malcolm D. Shuster, *AAS Malcolm D. Shuster Astronautics Symposium*, Grand Island, New York, June 13–16, 2005; Proceedings: *Advances in the Astronautical Sciences*, Vol. **122**, 2006.
50. The Statistics of TASTE and the Inflight Estimation of Sensor Precision; Malcolm D. Shuster and Douglas C. Freesland, *Proceedings (CD), NASA Flight Dynamics Symposium*, NASA Goddard Space Flight Center, Greenbelt, Maryland, October 18–20, 12. pp, 2005.
51. Robustness and Accuracy of the QUEST Algorithm; Yang Cheng and Malcolm D. Shuster, Paper AAS-07-102, *17th AAS/AIAA Space Flight Mechanics Meeting*, Sedona, Arizona, January 28–February 2, 2007; Proceedings: *Advances in the Astronautical Sciences*, Vol. **127**, pp. 41–61, 2007.

52. Some Directions in Spin-Axis Attitude; Sergei Tanygin and Malcolm D. Shuster, Paper AAS-07-103, *17th AAS/AIAA Space Flight Mechanics Meeting*, Sedona, Arizona, January 28–February 2, 2007; Proceedings: *Advances in the Astronautical Sciences*, Vol. **127**, pp. 61–79, 2007.
53. The Many TRIAD Algorithms; Sergei Tanygin and Malcolm D. Shuster, Paper AAS-07-104, *17th AAS/AIAA Space Flight Mechanics Meeting*, Sedona, Arizona, January 28–February 2, 2007; Proceedings: *Advances in the Astronautical Sciences*, Vol. **127**, pp. 81–99, 2007.
54. The Speed of Attitude Estimation; Yang Cheng and Malcolm D. Shuster, Paper AAS-07-105, *17th AAS/AIAA Space Flight Mechanics Meeting*, Sedona, Arizona, January 28–February 2, 2007; Proceedings: *Advances in the Astronautical Sciences*, Vol. **127**, pp. 101–116, 2007.
55. The TASTE Test; Malcolm D. Shuster, Paper No. AAS-08-264, *The F. Landis Markley Astronautics Symposium*, Cambridge, Maryland, June 20–July 2, 2008; Proceedings: *Advances in the Astronautical Sciences* (in preparation).

Selected Technical Reports and Technical Memoranda

1. *Pion Production in Nuclear Collisions*; M. D. Shuster, Dissertation, University of Maryland, 1970; University Microfilms, Ann Arbor, Michigan, 1970.
2. Meson Currents and the ${}^3\text{He}$ – ${}^3\text{H}$ Mass Difference; M. D. Shuster, Tel-Aviv University Preprint TAUP-5-6-76.
3. Magsat Fine Attitude Determination Study; D. M. Gottlieb and M. D. Shuster, Computer Sciences Corporation, CSC/TM-78/6203, 1978.
4. Magsat Fine Aspect Error Analysis; D. M. Gottlieb and M. D. Shuster, Computer Sciences Corporation, CSC/TM-78/6026, 1978.
5. Algorithms for Determining Optimal Attitude Solutions; M. D. Shuster, Computer Sciences Corporation, CSC/TM-78/6056, 1978.
6. Magsat Simulator Overview and Analysis; M. D. Shuster, Computer Sciences Corporation, CSC/TM-78/6033, 1978.
7. MAPS/Magsat Attitude System Functional Specifications and Requirements; M. D. Shuster, M. Levitas, R. M. Collier, Y. S. Hoh, M. K. Baker, and R. S. Nankervis, Computer Sciences Corporation, CSC/SD-78/6077, 1978.
8. Implementation Plan for Task 84803 – Magsat Attitude Analysis; M. D. Shuster, Computer Sciences Corporation, 1978.
9. AEM-B SAGE Attitude Analysis; C. B. Spence, Jr., G. M. Lerner, D. Niebur, M. D. Shuster, W. Boughton, and R. Casasanta, Computer Sciences Corporation, CSC/TM-79/6073, 1979.
10. MAPS/Magsat Attitude System Analytic Performance Test Plan; J. Davidson, S. Oh, F. Stevens, J. C. Anderson, H. Liou, and M. D. Shuster, Computer Sciences Corporation, CSC/TM-79/6088, 1979.
11. Magsat Attitude Signal Processor Ground Support Software (MAGASP) Functional Specifications and Requirements; M. D. Shuster and G. F. Meyers, Computer Sciences Corporation, CSC/SD-78/6077 UD1, 1979.
12. Dynamics Explorer-B (DE-B) Deterministic Attitude Determination System Functional Specifications and Requirements; K. W. Chan, C. B. Spence, Jr., J. Clauson, M. D. Shuster, and S. D. Oh, Computer Sciences Corporation, CSC/SD-79/6083, 1979.

13. Space Telescope Momentum Management Penetration Study; M. D. Shuster and T. C. Starr, Computer Sciences Corporation, CSC/TM-79/6252, 1979.
14. Space Telescope Attitude Maneuver and Verification Penetration Study; M. D. Shuster and T. C. Starr, Computer Sciences Corporation, CSC/TM-79/6274, 1979.
15. Magsat Fine Attitude Determination System (MSAD) User's Guide; B. Chu, R. Casasanta, J. Guffey, G. Liew, R. McCutcheon, S. McLaughlin, F. VanLandingham, and M. D. Shuster, Computer Sciences Corporation, CSC/SD-79/6066, 1979.
16. Autonomous On-Board Attitude Determination System Specifications and Requirements; M. D. Shuster, S. N. Ray and L. Gunshol, Computer Sciences Corporation, CSC/TM-80/6237, 1980. (also: NASA-TM-84800, 1980; and AIAA TIC# N82-29056, 1982)
17. Determination of Attitude Errors from Solar Maximum Mission (SMM) Star Tracker Measurements; M. D. Shuster and R. A. McCutcheon, Computer Sciences Corporation, CSC/TM-80/6315, 1980.
18. Microprocessor-Based Autonomous Attitude Determination System Preliminary Design; M. D. Shuster, P. Gambardella, S. Ray and K. Liu, Computer Sciences Corporation, CSC/TM-80/6336, 1980.
19. Attitude Error Analysis Program (ATTERP) Mathematical Description; Computer Sciences Corporation, CSC/TM-81/6012, 1981.
20. Attitude Error Analysis Program (ATTERP) System Description and User's Guide; S. F. McLaughlin and M. D. Shuster, Computer Sciences Corporation, CSC/TM-81/6013, 1981.
21. High-Precision Attitude Determination for Magsat; F. VanLandingham, G. Meyers, G. Abshire, R. McCutcheon, G. Summers and M. D. Shuster, Computer Sciences Corporation, CSC/TM-81/6036, 1981.
22. Microprocessor-based Autonomous Attitude Determination System Design; P. Gambardella, V. Church, K. Liu, G. Rao, S. Ray, and M. D. Shuster, Computer Sciences Corporation, CSC/TM-81/6085, 1981.
23. Consistency of Initial-Condition Estimators; M. D. Shuster and D. W. Porter, Business and Technological Systems, Inc., BTS10-82-48, 1982.
24. Sufficient Statistics and Partitioned Algorithms for Maximum-Likelihood Estimation of Initial-Condition and Markov Parameters; M. D. Shuster and D. W. Porter, Business and Technological Systems, Inc., BTS10-82-49, 1982.
25. Sufficient Statistics in Data-Reduction Approaches to Maximum-Likelihood Estimation of Initial-Condition and Markov Parameters; D. W. Porter, M. D. Shuster, and W. S. Levine, Business and Technological Systems, Inc., BTS10-82-54, 1982.
26. Estimation of Initial-Condition Parameters for Partially Observable Initial Conditions; M. D. Shuster and D. W. Porter, Business and Technological Systems, Inc., BTS10-83-75, 1983.
27. Calculation of the Fisher Cross-Information Matrix for Partially Observable Initial Conditions; M. D. Shuster and D. W. Porter, Business and Technological Systems, Inc., BTS10-84-92, 1984.
28. Business and Technological Systems, Inc., Corporate Experience and Capabilities; (Company brochure), 1984.
29. Estimation and Structure Determination by Likelihood Techniques I (slides); M. D. Shuster, Business and Technological Systems, Inc., BTS10-86-46, 1986.
30. Estimation and Structure Determination by Likelihood Techniques II (slides); M. D. Shuster, Business and Technological Systems, Inc., BTS10-86-47, 1986.
31. Spacecraft Sensor Alignment Estimation, Final Report; M. D. Shuster and G. J. Bierman, Business and Technological Systems, Inc., BTS10-86-35, 1986.

32. A Verification and Validation Plan for the Truth Model to Compute Short and Intermediate Wavelength Gravity (SIGRAM); S. L. Grimes, S. A. Carchedi, and M. D. Shuster, Business and Technological Systems, Inc., BTS49-86-04, 1986.
33. Magnetic Anomaly Map Simulation; M. D. Shuster and T. I. Mann, Business and Technological Systems, Inc., BTS10-87-05, 1987.
34. Gravity Anomaly Recovery by Simulated High-Low Satellite-to-Satellite Tracking; S. L. Grimes and M. D. Shuster, Business and Technological Systems, Inc., BTS49-87-02, 1987.
35. East-West Stripping in Satellite Magnetic Anomaly Maps; R. A. Langel and M. D. Shuster, NASA Goddard Space Flight Center, 1987.
36. A Course in Parameter Estimation (slides); J. S. Vandergraft and M. D. Shuster, Business and Technological Systems, Inc., P377, 1987.
37. Maximum Likelihood Techniques in Parameter Estimation (slides); D. W. Porter, M. D. Shuster, J. S. Vandergraft, and T. Webster, Business and Technological Systems, Inc., P367, 1987.
38. *Restitution d'attitude des véhicules spatiaux* (lecture notes); Copyright 1989 by M. D. Shuster, iii + 200 pp., Toulouse, France, 1989.
39. Specification for the MSX Infra-Red Horizon Scanner Assembly; The Johns Hopkins University Applied Physics Laboratory, 88898-7334-9053, 1990.
40. Section 4.3.4, Attitude Determination in Midcourse Space Experiment (MSX) Attitude Processor Software Detailed Design Document; JHU/APL S3G-91-028, 1991.
41. Attitude Estimation for an Arbitrary Measurement Model; M. D. Shuster, JHU/APL S3H-91-049, 1991.
42. Performance of the Barnes Horizon Scanners in the COBE Mission; M. D. Shuster, JHU/APL S3G-91-157, 1991.
43. Conventions for Attitude and Alignment Matrices for MSX; M. D. Shuster, JHU/APL S3G-91-177, 1991.
44. Expected Attitude Determination Accuracies for the MSX Mission; M. D. Shuster, JHU/APL S3G-91-215, 1991.
45. Expected Attitude Determination Jitter for the MSX Mission; M. D. Shuster, JHU/APL S3G-91-235, 1991.
46. Design of Barnes Horizon Scanner Assembly; M. D. Shuster, JHU/APL S3G-91-274, 1991.
47. MSX Instrument Alignment Estimation Accuracy; M. D. Shuster, JHU/APL S3G-91-323, 1991.
48. Dependence of MSX Instrument Alignment and Distortion Parameters; M. D. Shuster, JHU/APL S3G-91-327, 1991.
49. QUEST, a longa história de um algoritmo rápido; M. D. Shuster, Instituto Nacional de Pesquisas Espaciais, São José dos Campos (SP), Brazil, NTI-002/91-DMC, 1991.
50. Trade-Off Study of MSX Attitude Determination Algorithms; M. D. Shuster, JHU/APL S3G-91-338, 1991.
51. Definition of the MSX Gyro-Offset Quaternion; M. D. Shuster, JHU/APL S3G-92-004, 1992.
52. Definition of the Fiducial MSX Frame; M. D. Shuster and T. E. Strikwerda, JHU/APL S3G-92-008, 1992.

53. Inflight Estimation of MSX Angular Velocity and Acceleration; M. D. Shuster, JHU/APL S3G-92-012, 1992.
54. MSX Vector Data Validation with Single-Frame Attitude Computation; M. D. Shuster, JHU/APL S3G-92-021, 1992.
55. Estimation of Attitude from the Measurement of a Direction and an Angle; M. D. Shuster, JHU/APL S3G-92-022, 1992.
56. Proposed Attitude Estimation Analysis Work for the Near, Mid and Long Term; M. D. Shuster, JHU/APL S3G-92-043, 1992.
57. Determination of Eigenaxis Rotations Connecting Two and Three Directions; M. D. Shuster, JHU/APL S3G-92-049, 1992.
58. Active and Passive Descriptions of Attitude; M. D. Shuster, JHU/APL S3G-92-052, 1992.
59. Potential Enhancements to Star Tracker Algorithms; H. L. Fisher and M. D. Shuster, JHU/APL S3G-92-143, 1992.
60. Validation Tests for MSX Attitude Data; M. D. Shuster, JHU/APL S3G-92-153, 1992.
61. Examples of Some MSX Postlaunch Calibration Activities; M. D. Shuster, JHU/APL S3G-92-216, 1992.
62. Correction Matrix for the SN-1 Ring Laser Gyro; M. D. Shuster, JHU/APL S3G-92-269, 1992.
63. Attitude Determination Accuracies for a Shuttle-Launched Free-Flying Experiment; M. D. Shuster, JHU/APL S3G-92-315, 1992.
64. Effect of HSA Wheel Speed Variation on Attitude Accuracy; M. D. Shuster, JHU/APL S3G-93-041, 1993.
65. On the Precision of Taste; M. D. Shuster, JHU/APL S3G-93-097, 1993.
66. Postlaunch Alignment Algorithm for the MSX Ring Laser Gyros; M. D. Shuster, JHU/APL S3G-93-143, 1993.
67. Distortion and Alignment Parameters, a Guide for the Perplexed; M. D. Shuster, JHU/APL S3G-93-165, 1993.
68. Preliminary MSX Coalignment Analysis; M. D. Shuster, JHU/APL S3G-94-034, 1994.
69. Postlaunch Alignment Algorithm for the MSX Space-Based Visible Instrument; M. D. Shuster, JHU/APL S3G-94-035, 1994.
70. Postlaunch Alignment Algorithm for the MSX UVISI Instrument; M. D. Shuster, JHU/APL S3G-94-042, 1994.

Invited Lectures*

1. Pion Production in Nuclear Collisions; Michigan State University, East Lansing, Michigan, 1970.
2. Pion Production in Nuclear Collisions; University of Maryland, College Park, Maryland, 1970.
3. A Theory of Pion Production in Nuclear Collisions; European Center for Nuclear Research (CERN), Geneva, Switzerland, 1970.

* other than course lectures

4. Pion Production in Nuclear Collisions; Centre d'Études Nucléaires, Saclay, France, 1971.
5. Isotensor Muon Capture and the Konopinski-Mahmoud Lepton-Number Scheme; Centre d'Études Nucléaires, Saclay, France, 1971.
6. Pion Production in Nuclear Collisions; Faculté des Sciences–Orsay, Orsay, France, 1971.
7. The ABC Effect; Centre d'Études Nucléaires, Saclay, France, 1972.
8. A Theory of the ABC Effect; University of Karlsruhe, Karlsruhe, Federal Republic of Germany, 1972.
9. Isotensor Muon Capture in Nuclei; Eidgenössische Technische Hochschule, Zurich, Switzerland, 1973.
10. Exotische Muonhaftung in Kernen; University of Karlsruhe, Karlsruhe, Federal Republic of Germany, 1973.
11. Resonant Production of Pions and the ABC Effect; University of Maryland, College Park, Maryland, 1973.
12. The Long and Adventurous Life of the ABC Meson, the Particle that Never Was; Tel-Aviv University, Tel-Aviv, Israel, 1974.
13. The Long and Adventurous Life of the ABC Meson, the Particle that Never Was; The Technion, Israel Institute of Technology, Haifa, Israel, 1975.
14. The Long and Adventurous Life of the ABC Meson, the Particle that Never Was; The Weizman Institute of Science, Rehovot Israel, 1975.
15. The Long and Adventurous Life of the ABC Meson, the Particle that Never Was; Ben-Gurion University of the Negev, Bersheva, Israel, 1975.
16. Isotensor Electromagnetic Interactions in Nuclei; Tel-Aviv University, Tel-Aviv, Israel, 1975.
17. The Long and Adventurous Life of the ABC Meson, the Particle that Never Was; Virginia Polytechnic Institute and State University, Blacksburg, Virginia, 1976.
18. The Long and Adventurous Life of the ABC Meson, the Particle that Never Was; Carnegie-Mellon University, Pittsburgh, Pennsylvania, 1976.
19. The Long and Adventurous Life of the ABC Meson, the Particle that Never Was; University of Virginia. Charlottesville, Virginia, 1977.
20. Resonant Pion Exchange and the Nucleon-Nucleon Force; University of Pittsburgh, Pittsburgh, Pennsylvania, 1977.
21. The Long and Adventurous Life of the ABC Meson, the Particle that Never Was; Brookhaven National Laboratory, Upton, New York, 1978.
22. Application of the Methods of Theoretical Nuclear Physics to Optimal Attitude Estimation; Computer Sciences Corporation, Silver Spring, Maryland, 1978.
23. New Lives for Old, a Theoretical Physicist's Experience in Industry; University of South Carolina, Columbia, South Carolina, 1979.
24. New Lives for Old, a Theoretical Physicist's Experience in Industry; Pennsylvania State University, State College, Pennsylvania, 1979.
25. New Lives for Old, a Theoretical Physicist's Experience in Industry; University of Florida, Gainesville, Florida, 1980.
26. New Lives for Old, a Theoretical Physicist's Experience in Industry; Howard University, Washington, D. C., 1980.

27. Spacecraft Attitude Determination; AIAA Professional Study Seminar Series on Spacecraft Attitude Control Systems, NASA Goddard Spaceflight Center, Greenbelt, Maryland, 1983.
28. Spacecraft Attitude Determination; AIAA Professional Study Seminar Series on Spacecraft Guidance and Control, NASA Goddard Spaceflight Center, Greenbelt, Maryland, 1986.
29. Tutorial on Attitude Determination; Saturday Seminar, Microcosm, Inc., Torrance, California, 1990.
30. Kalman Filtering of Spacecraft Attitude; EDO Corporation, Barnes Engineering Division, Shelton, Connecticut, 1990.
31. A la recherche d'une meilleure attitude: un voyage mal organisé; Aérospatiale, S. A., Cannes, France, 1990.
32. Succès et malheurs dans l'estimation des alignements; Aérospatiale, S. A., Cannes, France, 1990.
33. QUEST, a longa história de um algoritmo rápido (plenary talk); M. D. Shuster, *First Brazilian Symposium on Aerospace Technology*, São José dos Campos (SP), Brazil, August 1990.
34. Estimaco dos alinhamentos; Instituto de Pesquisas Espaciais, São José dos Campos (SP), Brazil, 1990.
35. In Quest of a Better Attitude: A Misguided Tour; AIAA Guidance, Navigation and Control Lecture, Greenbelt, Maryland, 1990.
36. The Joys and Curses of Quaternions; Naval Post Graduate School, Monterey, California, 1992.
37. Spacecraft Sensor Alignment Issues; Lawrence Livermore National Laboratory, Livermore, California, 1992.
38. Interferncia na Estimaco de Parâmetros de Desalinhamento e de Calibrao; Instituto Nacional de Pesquisas Espaciais, São José dos Campos (SP), Brazil, 1994.
39. Everything You May Have Wanted to Know About the Euler Angles, But Were Afraid to Ask; University of Florida, Gainesville, Florida, 1994.
40. The Uneasy Synthesis of Nuclear Physics and Spacecraft Attitude; University of Florida, Gainesville, Florida, 1995.
41. Consistent Estimation of Alignment and Distortion; Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, 1995.
42. The Magical Mysteries of Quaternions; Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, 1995.
43. Astronautics—Past, Present and Future; University of Florida, Gainesville, Florida, 1995.
44. Strange Tales of the Euler Angles; McGill University, Montreal, Canada, 1997.
45. New Tales of the Euler Angles; Institute for Aerospace Sciences, University of Toronto, Toronto, Canada, 1997.
46. Strange Tales of the Euler Angles; Hughes Space and Communication Company, El Segundo, California, 1997.
47. Improving Your Attitude; Colorado Center for Aerospace Research, University of Colorado, Boulder, Colorado, 1997.
48. Man, Like These Attitudes Are Totally Random!, Texas A&M University, College Station, Texas, 2000.

Conference and Course Participation

1. American Physical Society, Annual Meeting, Washington, D. C., April 1970.
2. Winter School on Nuclear Physics, Zuoz, Switzerland, April 1971.
3. Conference on Nuclear Physics, Strasbourg, France, May 1972.
4. European Conference on Nuclear Physics, Aix-en-Provence, France, July 1972.
5. Winter School on Nuclear Physics, Zuoz, Switzerland, April 1973.
6. Fifth International Conference on High-Energy Physics and Nuclear Structure, Uppsala, Sweden, June 1973.
7. Israel Physical Society Meeting on Nuclear Physics, Kibbutz Ginosar, Israel, November 1973.
8. AIAA Guidance and Control Conference, Palo Alto, California, August 1978.
9. AIAA Guidance and Control Conference, Boulder, Colorado, August 1979.
10. Flight Mechanics/Estimation Theory Symposium, NASA Goddard Space Flight Center, Greenbelt, Maryland, October 1981.
11. American Control Conference, San Francisco, California, June 1983.
12. 22nd IEEE Conference on Decision and Control, San Antonio, Texas, December 1983.
13. 23rd IEEE Conference on Decision and Control, Las Vegas, Nevada, December 1984.
14. Second IEEE Symposium on Computer-Aided Control-System Design, Santa Barbara, California, February 1985.
15. 24rd IEEE Conference on Decision and Control, Fort Lauderdale, Florida, December 1985.
16. Third IEEE Symposium on Computer-Aided Control-System Design, Arlington, Virginia, September 1986.
17. American Control Conference, Seattle, Washington, June 1986.
18. International Union of Geodesy and Geophysics, XIX General Assembly, Vancouver, British Columbia, Canada, August 1987.
19. 26th IEEE Conference on Decision and Control, Los Angeles, California, December 1987.
20. IEEE Symposium on Factorized Estimation Applications, Austin, Texas, December 1988.
21. 27th IEEE Conference on Decision and Control, Austin, Texas, December 1988.
22. Pan-American Congress of Applied Mechanics, Rio de Janeiro, Brazil, January 1989.
23. AAS/AIAA Astrodynamics Specialists Conference, Stowe, Vermont, August 1989.
24. International Symposium on Space Mechanics, Toulouse, France, November 1989.
25. AAS Guidance and Control Conference, Keystone, Colorado, February 1990.
26. American Control Conference, San Diego, California, May 1990.
27. Flight Mechanics and Orbit Determination, Short Course, University of Texas, Austin, Texas, July 1990.
28. First Brazilian Symposium on Aerospace Technology, São José dos Campos (SP), Brazil, August 1990.

29. AAS Guidance and Control Conference, Keystone, Colorado, February 1991.
30. Flight Mechanics/Estimation Theory Symposium, NASA Goddard Space Flight Center, Greenbelt, Maryland, May 1991.
31. Flight Mechanics/Estimation Theory Symposium, NASA Goddard Space Flight Center, Greenbelt, Maryland, May 1992.
32. Third Pan-American Conference on Applied Mechanics, São Paulo, Brazil, January 1993.
33. AAS/GSFC International Symposium on Space Flight Dynamics, NASA Goddard Space Flight Center, Greenbelt, Maryland, April 1993.
34. AAS/AIAA Astrodynamics Specialists Conference, Victoria, British Columbia, Canada, August 1993.
35. International Symposium on Spacecraft Ground Control and Flight Dynamics—SCD1, São José dos Campos (SP), Brazil, February 1994.
36. AAS/AIAA Space Flight Mechanics Meeting, Cocoa Beach, Florida, February 1994.
37. AIAA/AAS Astrodynamics Specialists Conference, Scottsdale, Arizona, August 1994.
38. Workshop on Participation Opportunity on the Brazilian Scientific Satellite, São José dos Campos (SP), Brazil, October, 1994.
39. AIAA/AAS Space Flight Mechanics Meeting, Albuquerque, New Mexico, February 1995.
40. II Southeast University Coalition Conference on Engineering Education, North Carolina State University, Raleigh, North Carolina, March 1995.
41. Flight Mechanics/Estimation Theory Symposium, NASA Goddard Space Flight Center, Greenbelt, Maryland, May 1995.
42. AAS/AIAA Astrodynamics Specialits Conference, Halifax, Nova Scotia, Canada, August 1995.
43. AAS/AIAA Space Flight Mechanics Conference, Austin, Texas, February 1996.
44. Flight Mechanics/Estimation Theory Symposium, NASA Goddard Space Flight Center, Greenbelt, Maryland, May 1996.
45. AIAA/AAS Astrodynamics Specialists Conference, San Diego, California, July 1996.
46. AAS/AIAA Space Flight Mechanics Conference, Huntsville, Alabama, February 1997.
47. International Symposium on Space Flight Dynamics, NASA Goddard Space Flight Center, Greenbelt, Maryland, May 1998.
48. Flight Dynamics Symposium, NASA Goddard Space Flight Center, Greenbelt, Maryland, May 1999.
49. AAS/AIAA Space Flight Mechanics Meeting, Clearwater, Florida, January 2000.
50. TAMU/AAS Richard H. Battin Astrodynamics Symposium, College Station, Texas, March 2000.
51. AIAA/AAS Astrodynamics Conference, Denver, Colorado, August 2000.
52. AAS/AIAA Space Flight Mechanics Meeting, Santa Barbara, California, February 2001.
53. AAS Malcolm D. Shuster Astronautics Symposium, Grand Island, New York, June 2005.
54. NASA Flight Dynamics Symposium, NASA Goddard Flight Center, Greenbelt, Maryland, October 2005.