

CURRICULUM VITAE

Name	Enrico CANUTO
Date of birth	2 September 1945
Education	<p>'Laurea' degree in Electrical Engineering from Politecnico di Torino in 1970, spring.</p> <p>His research, technical, management and social education started at IEN G. Ferraris (National Electrical Metrology Institute, now INRiM, National Institute of Metrology Research) in the 70s under direction of professor Francesco Donati, Politecnico di Torino.</p> <p>It continued during Hipparcos studies, in contact with a leading scientist as professor Jean Kovalevsky, former leader of the European FAST consortium, former president of the Comité International des Poids et Mésures (CIPM), Astronomus Emeritus of the Observatoire de la Côte d'Azur (France), Member of the Académie des Sciences (Paris).</p>
Languages	Italian (native), English, French
Experience	<p>His research, technical and management capabilities developed, were refined and tested since 1980 to 1997 during the participation to Hipparcos project, within the European Scientific consortium FAST. He designed, developed and tested the SW package for the raw data reduction and on-ground attitude reconstruction (one of the first gyroless, if not the first one) of the Hipparcos satellite, the input data to Hipparcos Catalogue construction. The SW package was installed and succesfully ran at CNES (Toulouse, France) during Hipparcos mission (1989-1993) and afterwards. In the same years as a consultant to EICAS Automazione spa he designed and developed SW for automated industrial plants. He also took part with responsibility degrees to several European and National research projects. The newly conceived astrometry space mission GAIA (1997) aiming at one-billion-star Catalogue, was the occasion to contribute and develop laser interferometry for sub-nanometer dimensional metrology outside metrology labs. The same technology was then suggested as sub-micronewton metrology, giving rise to the Nanobalance thrust-stand, now fully operating at Thales Alenia Space Italia Labs. He mainly contributed to such technologies and to the relevant prototypes/instruments by conceiving, designing and implementing automation, digital control, calibration and data processing.</p> <p>Since 1998 he is full-time at Politecnico di Torino.</p> <p>Since 1998 he conceived and developed a model-based design and implementation methodology for digital control and automation (Embedded Model Control), tested on the above prototypes and industrial controllers. For this reason Alenia Spazio (now Thales Alenia Space Italia) granted Politecnico di Torino in 2001 with the design of the drag-free and attitude control of the GOCE satellite during the scientific phase (Gravity field and steady state Ocean Circulation Explorer, launch 2008). The relevant control SW was the prototype for further implementation by Alenia Spazio and subcontractors of the key part of the on-board SW. Research on drag-free and attitude control is now addressing future scientific missions as the Earth gravity monitoring through interferometry, Galileo Galilei, Simbol-X, part of them being formation flying.</p>
Detailed recent experience :	Since 2000

	<p>Peer review of international journal and conferences. 2005, recognition as truly outstanding reviewer by Editor-in-Chief of IEEE Trans. Automatic Control, Christos G. Cassandras. Member of the evaluation committee of INRiM, Torino, 2000-2005. Representative of the Ministry of University and Research within the same Committee, 2006 to present. Member of the Franco-Italian review board of the Phase A activities of the Simbol-X space mission, 2007 to present.</p>
2004 – present	<p>Lectures and courses in Embedded Model Control, originally developed by E. Canuto, to Politecnico di Torino, 2007-2008, Denki Tokyo University (Japan), 2004, Pontificia Universidad Javeriana (Cali, Columbia), 2007, ESTEC, ESA, (Noordwijk, The Netherlands), 2007. Courses at Politecnico di Torino in Automatic Control (graduate and doctorate courses).</p>
2003-present	<p>Digital control of proportional electro-hydraulic valves and hydraulic systems. A new research started in 2008 sponsored by FIAT Research Centre (CRF) aiming at applying Embedded Model Control for regulating and saving hydraulic power in tractors and construction machines.</p>
2004-present	<p>Metrology line prototype developed at Alcatel Alenia Space Labs from 2004 to 2006. Studies during this project suggested the Regione Piemonte E2 project "Ultrastable optical frequency references for laser interferometry in space applications", promoted and co-directed by E. Canuto.</p>
2001- present	<p>Nanobalance thrust stand: 2001-present. Innovative sub-micronewton thrust-stand based on Fabry-Pérot interferometry. Conception, design and implementation of automation, digital control, data processing of the first version at INRiM Labs and of the second version fully operating at Thales Alenia Space Italia Labs as a test-rig of the European Space Agency.</p>
2001 - present	<p>Design and SW development of the drag-free and attitude control of the European GOCE satellite. Current studies on the next generation gravity missions based on satellite formation and laser interferometry. E. Canuto was recently invited by the Int. Program Committee to the 5th Workshop on Satellite Constellation & Formation Flying, organized by the Astrodynamics Committee of the International Astronautical Federation.</p>

Cooperation with industry and technology transfer

Co-founder and consultant (1983-1997) of a non-profit research centre (Centro di Studi sui Sistemi, Torino, Italy).
Co-founder and consultant (1983-1998) of an engineering company operating in the automation field (Eicas Automazione spa, Torino, Italy).
Since 1998, as full-time professor at Politecnico di Torino he has managed different and successful research contracts with aerospace industry (Alenia Spazio, now Thales Alenia Space Italia, Torino, Italy) and other European industries aiming at

- a) innovative prototypes and instruments exploiting laser interferometry,
- b) drag-free and attitude control of scientific satellites, GOCE, Satellite-to-Satellite Interferometry, and
- c) advanced digital control (Embedded Model Control).

His attitude toward industries is not to provide them just with study documents, but to find the right way of know-how transfer. For these reasons three doctorate students were granted by Alenia Spazio since 2003, and similar grants will be soon awarded by FIAT Research Centre, Torino. As a further example, GOCE drag-free and attitude control was in short time, successfully embedded in the end-to-end GOCE simulator by Alenia Spazio staff. The same occurred and occurs within the Nanobalance grants for what concerns digital control and data elaboration.

Recently (January 2008) he has organized a joint presentation to students of Politecnico di Torino of on-going research arguments ranging from ground to space vehicles by FIAT Research Centre and Thales Alenia Space. The meeting was entitled: Automatic Control, from Earth to heaven. More than 100 students attended, 80 of them aiming to develop their Master thesis on the subject. The first 10 theses will start in may 2008.

<p>Research grants (recent)</p>	<p>Responsible on behalf of Politecnico di Torino of the following research contracts/sub-contracts: total budget 1 MEuros, 2000-present.</p> <ol style="list-style-type: none"> 1) 25000 Euros, Alenia Spazio (Italy), Nanobalance thrust-stand, 2000-2001. 2) 23500 Euros, ESA - European Space Agency (Main contractor Alenia Spazio, Italy), Thrust Measurement System at Micronewton Level (TMS), 2002-2003. 3) 153000 Euros, ESA- European Space Agency (Main Contractor, Alenia Spazio, Italy), Laser Metrology and Optics Active Control (LM&OAC), 2003-2005. 4) 47500 Euros, Atos spa (Italy), Analysis, simulation and design of the digital control of proportional electro-hydraulic valves, 2003-2004, 2004-2005. 5) 25000 Euros, Marotta Ltd (UK) (Main contractor, Alenia Spazio, Italy), Polyflex thruster characterization on the Nanobalance facility, 2004-2005 6) 25000 Euros, Italian Ministry of University and Research, 2001-2006. 7) 10500 Euros, ASI - Italian Space Agency (Main Contractor, Osservatorio Astronomico di Torino, Italy), 2001-2002. 8) 22500 Euros, Alcatel Space (France) (Main Contractor, Alenia Spazio, Italy), Laser Metrology System for the HSOB validation breadboard, 2004-2005. 9) 53000 Euros, ESA - European Space Agency (Main Contractor, Alcatel Alenia Space Italia), Nanobalance Facility Upgrade, 2005-2007. 10) 418000 (250000 funded) Euros, Regione Piemonte (Italy), E2-Ultrastable optical frequency references for laser interferometry in space applications, 2005-2008, Promoter and Co-responsible with prof. Elio Bava. 11) 95000 Euros, Alenia Spazio, Italy, Drag-free and attitude control of the European GOCE satellite, 2001-2002. Scientific responsible: Enrico Canuto, manager: prof. Basilio Bona. 12) 70000 Euros, ESA - European Space Agency (Main contractor Thales Alenia Space, Italy), Satellite Formation, Drag free and Attitude Control aiming at the development of Laser Interferometry Tracking Technology for Gravity Field Monitoring: 2007 to present. 13) 55000 Euros, Centro Ricerche FIAT(2008); including 19000 Euros for a research fellowship position. Embedded Model Control applied to electro-hydraulics.
<p>Prototypes, since 2000</p>	<p>Main prototypes, since 2000:</p> <ol style="list-style-type: none"> 1) Nanobalance thrust stand (1st version) at INRiM Labs, Torino. He conceived, designed and implemented digital control, automation, calibration and data processing. 2) Metrology line at Alcatel Alenia Space Italia Labs: developed and tested within LM&OAC ESA project. He conceived, designed, implemented digital control, metrology and data processing. 3) Nanobalance thrust stand (2nd version) operating at Thales Alenia Space labs as a test-rig of European Space Agency. 4) Drag-free and attitude control code (C language) for the scientific phase of the GOCE satellite, integrated in the end-to-end mission simulator at Alenia premises. The code was the prototype for on-board AOCS code.

<p>Recent publications, 2000 to present</p>	<p>International Journals</p> <ol style="list-style-type: none"> 1) E. Canuto "Drag-free and attitude control for the GOCE satellite", Automatica, July 2008, in press. 2) E. Canuto and F. Musso "Final comments by the Authors to discussion on 'Digital control of interferometric metrology lines'", European Journal of Control, 2007, Vol 13, No. 4, p. 417-418. 3) E. Canuto and F. Musso "Digital control of interferometric metrology lines", European Journal of Control, 2007, Vol 13, No. 4, p. 398-415. 4) E. Canuto "Embedded Model Control: outline of the theory", ISA Transactions, June 2007, 46 (3), p. 363-377. 5) E. Canuto and F. Musso "Embedded Model Control: application to web winding", ISA Transactions, June 2007, 46 (3), p. 379-390. 6) E. Canuto, F. Musso and L. Massotti "Automation and control of Fabry-Pérot interferometers", IEEE Trans. Industrial Electronics, April 2007, Vol. 54, No. 2, p. 848-857. 7) E. Canuto "Active vibration suppression in a suspended Fabry-Pérot cavity", ISA Transactions, July 2006, Vol. 45, No. 3, p. 329-346. 8) E. Canuto and A. Rolino "Multi-input digital frequency stabilization of monolithic lasers", Automatica, Vol. 40, No. 12, 2004, p. 2139-2147. 9) E. Canuto and A. Rolino "Nanobalance: an automated interferometric balance for micro-thrust measurement", ISA Transactions, April 2004, Vol. 43, No. 2, p. 169-187. 10) E. Canuto, P. Martella and G. Sechi "Attitude and drag control: an application to the GOCE satellite", Space Science Reviews, Vol. 108, No. 1-2, 2003, p.357-366. 11) E. Canuto "Sub-nanometric optics stabilization in view of the GAIA astrometric mission", Control Engineering Practice, Vol. 11, No. 5, May 2003, p.569-578. 12) R.F. Albrecht and E. Canuto "Manufacturing Algebra and dynamics", Systems Science, Vol. 27, No. 1, 2001, p.25-37. 13) F. Bertinetto and E. Canuto "Sub-nanometer digital positioning of large bodies by Fabry-Pérot interferometry", Optical Engineering, Vol. 40, No. 1, January 2001, p.76-80. <p>Italian Journals</p> <ol style="list-style-type: none"> 1) E. Canuto, F. Musso and D. Quagliotti "Embedded Model Control e LabView RealTime", Selezione di Elettronica, January 2006, p. 32-34. Posted in the web pages of National Instruments, 2006. 2) E. Canuto, F. Musso and D. Quagliotti "Embedded Model Control in LabView RealTime", LabView World, No. 1, September 2006, p. 30-31. <p>Italian textbooks</p> <ol style="list-style-type: none"> 1) Controlli Automatici. Parte I:Sistemi Dinamici, CELID (Torino, 2002). 2) Controlli Automatici. Parte II: Controllo Digitale, CELID (Torino, 2002). <p>Other publications since 2000</p> <p>International Book Chapters 9 International Conference papers >50 National Conference papers 10</p>
<p>Ph. D. students since 2000</p>	
<p>2001-2003. Automation and control of Fabry-Pérot interferometers. Student: Andrea Rolino. 16th cycle. Funded by National Metrology Institute 'G. Colonnetti' (IMGC, now INRiM), Torino. Study led to a pair of journal publications.</p>	<p>The study aimed to automate Fabry-Pérot interferometers (FPI) so as to employ them for length and force measurements. The main achievement was the construction and automation of the 1st version of the Nanobalance thrust-stand at IMGC labs. The thrust-stand (see Research Projects) exploits a suspended, in vacuum FPI capable of relating the optical cavity elongation to the force applied by a micro-thruster, mounted on the 'active' side of the suspended cavity. Embedded Model Control methodology was deployed to automate the interferometer lock-in and to zero the 10 Hz beat motion of the two pendulums embracing the optical cavity.</p>

<p>2003-2005 Design of standard control system for spacecrafts. Student: Davide Andreis. 18th cycle. Funded by Thales Alenia Space Italia. Study led to a pair of journal publications.</p>	<p>The study was a follow-up of the joint research with Thales on the drag-free and attitude control of the GOCE satellite. The study revised the Embedded Model Control strategies developed for the GOCE science phase and extended them to the commissioning phases so as to dispose of a unique suite of control algorithms for the entire mission. The core of this conception is the Embedded Model driven by variable-structure noise vectors (noise design), which allow to model and update variable disturbance scenarios.</p>
<p>2004-2006 Embedded model control: application to space laser interferometry, candidate Fabio Musso, 19th cycle. Partly funded by Thales Alenia Space Italia, Torino. Know-how acquisition, transfer and deployment suggested Thales to employ Fabio Musso as a staff before study termination (November 2006). Study led to three journal papers.</p>	<p>The study was suggested for reinforcing the joint research by PoliTo, Thales and National Metrology Institute aiming to transfer Fabry-Pérot interferometry into space/ground prototypes. Fabry-Pérot interferometry allows to reach sub-nanometer length accuracy over metre-range distances. The price to be paid is vacuum and active control so as to lock the optical cavity length to laser source wavelength. Two prototypes were constructed: (i) the breadboard of a 1-metre metrology line in view of monitoring and controlling space-telescope dimensional variations with an accuracy close to picometers, (ii) the 2nd version of the Nanobalance thrust-stand now operating.</p>
<p>2007-present Embedded Model Control for space applications: fine thermal regulations. Student: José Ospina, 22nd cycle. Funded by Regione Piemonte. A pair of journal papers are under revision.</p>	<p>The study was suggested by Regione Piemonte triennial research project (see Research Projects) on ultra-fine optical references for space laser interferometry. Optical references employ Fabry-Pérot interferometry to create a stable frequency laser source. An optical cavity of ULE has been designed and manufactured by INRiM. The study aims to guarantee sub-millikelvin thermal stabilization in an active way. The purpose is to reduce the cavity size with respect to passive ones and to withstand an arbitrary on-board environment. A dummy prototype has been constructed and its length variation will be monitored with sub-nanometer accuracy so as to reveal and correlate residual thermal spatio-temporal gradients to design degrees-of-freedom.</p>
<p>2008-present Modelling and control of the scientific mission SimbolX. Student: Salvador Castillo. 23rd cycle. Funded by Thales Alenia Space Italia.</p>	<p>SimbolX is a Franco-Italian space mission aiming at the observation of hard X-ray sources. Hard X-ray photons to be observed carry an energy > 10 keV and a wavelength < 0.1 pm. To improve source angular resolution in a celestial reference frame as well as sensitivity to faint sources, X-ray photons must be focused on the focal plane by a long-focal telescope (focal length > 20 m). In addition, to reduce background noise, X-ray sources have to be observed beyond the van Allen belts. Two satellites flying in tight formation (mirror and detector) along a highly elliptic Earth orbit (20000 km to 180000 km) is the solution established by CNES (France). Tight formation means distance deviations below cm and relative orientation well close to 10 microrad. The study will aim to simulate satellite orbit and attitude to test control strategies. A simplified model of photon counting is also expected, capable of relating observed data to formation jitter.</p>
<p>2008-present Embedded Model Control for electro-hydraulic applications. Student: Wilber Acuna-Bravo. 23rd cycle. Partly funded by FIAT Research Centre (CRF), Torino</p>	<p>Application of Embedded Model Control to electro-hydraulics is in its infancy and therefore needs to be reinforced both theoretically and experimentally. Some study have been done under research contracts with Atos spa (see Research Projects). The occasion is now provided by FIAT Research Centre (see Research Projects) and concerns exploiting active control for hydraulic power regulation and saving on tractors and construction machines. Hydraulic power is regulated through electronically-controlled variable-displacement pumps, load sensing instrumentation and control strategies.</p>