

# Program

## **SLED 2017** 8<sup>th</sup> Symposium



2017 International Symposium on  
Sensorless Control for Electrical Drives

## **SLED 2017**

*18<sup>th</sup>–19<sup>th</sup> September 2017, Catania, Italy*

Sunday, 17/09/2017		Monday, 18/09/2017		Tuesday, 19/09/2017		
18:30	Welcome Reception	09:00	Grande Salone da Ballo Opening		09:00	Sala del Rinascimento Poster Session Chair: Giacomo Scelba
20:00		09:30			11:00	
		09:30	Grande Salone da Ballo Plenary: R. Lorenz University of Wisconsin, USA		11:00	Coffee Break
		10:20			11:20	
		10:20	Grande Salone da Ballo Plenary: S. Bolognani University of Padova, Italy		11:20	S7 - Grande Salone da Ballo PMSM Drives II Chair: Fabio Giulii Capponi
		11:10			13:00	S8 - Salone dei Principi Model Based and DTC Sensorless Control Chair: Roberto Petrella
		11:10	Coffee Break		13:00	Lunch
		11:30			14:30	
		11:30	S1 - Grande Salone da Ballo Design for Self-Sensing Control Chair: Frederik De Belie	S2 - Salone dei Principi PM and Synchronous Reluctance Motor Drives Chair: Gianmario Pellegrino	14:30	S9 - Grande Salone da Ballo Dual Three-Phase and Open- End Winding PM Drives Chair: Peter Landsmann
		12:45			15:45	S10 - Salone dei Principi Synchronous Motor Drives Chair: Giulio De Donato
		13:00	Lunch		15:45	Grande Salone da Ballo Closing Address by the Conference Chairs
		14:30			16:00	
		14:30	S3 - Grande Salone da Ballo Induction Motor Drives Chair: Axel Mertens	S4 - Salone dei Principi Switched Reluctance and IPM Drives Chair: Marko Hinkkanen		
		15:45				
		15:45	Coffee Break			
		16:00				
		16:00	S5 - Grande Salone da Ballo PMSM Drives I Chair: Ralph Kennel	S6 - Salone dei Principi IPM and SyncRel Drives Chair: Pavol Rafajdus		
		17:15				
		19:30	Guided Visit to Palazzo Manganelli and Gala Dinner			
		23:00				

# Welcome

The IEEE International Symposium on Sensorless Control for Electrical Drives is a very focused event for our Scientific Community, with a good tradition of providing an international forum for experts to present and discuss the latest developments in the application of sensorless control technology to industry technical excellence. For over a decade, many professors and industrial researchers have contributed to reach such a technical excellence.

The international event on Sensorless Control of Electrical Drives (SLED) dates back to 2007 and for 3 years it was held as Workshop in Msida (Malta), Varsow (Poland) and Barcelona (Spain). Due to popular demand, it was expanded into a Symposium, the first being held in Padova, Italy in 2010, the second in Birmingham, United Kingdom in 2011, the third in Milwaukee, United States in 2012, the fourth in Munich, Germany in 2013, the fifth in Hiroshima, Japan in 2014, the sixth in Sydney, Australia in 2015, and the seventh in Dinarau, Nadi, Fiji in 2016.

In 2017, the eight IEEE Sensorless Control of Electrical Drives is held in Catania. This year is also a special occasion to remember our colleague and friend Prof. Alfio Consoli that passed away in July 2012, exactly in the way he preferred: presenting papers on new ideas and developments, discussing such ideas among good colleagues and friends. As a result, the 2017 edition shows a richer technical program than ever, having forty papers from authors in academia and industry. We are honored to serve our Community as the 2017 General Chairs, with the full support from all Technical, In-Memoriam and Local Organizing Committees.

We kindly ask you to join us in extending a warm welcome to the 2017 edition of International Symposium on Sensorless Control for Electrical Drives authors. Their technical contribution is fundamental to the tradition of technical excellence at the Symposium on Sensorless Control for Electrical Drives.

Sincerely yours,

Giuseppe Scarcella and Mario Cacciato  
SLED 2017 General Chairmen

## Welcome Reception

Catania, Hotel Royale – La Terrazza sui Crociferi

<http://www.hotelroyalcatania.it/en/where-we-are>



<http://www.palazzomanganelli.it>



## Plenary Speakers

### Robert D. Lorenz

University of Wisconsin at Madison, USA

#### The Path to Widespread Use of Self-Sensing

Self-sensing is currently still a niche technology. It requires a challenging integration of machine design, power electronics, estimation and controls. This has limited its broad application despite the rapid expansion of new machine opportunities. One approach to address this is to integrate the discipline of self-sensing into undergraduate and Masters level programs on a wide international basis. This presentation will explore that path as a key enabler to achieving the full potential of self-sensing as a nearly universal solution.

### Silverio Bolognani

University of Padova, Italy

#### Physical Understanding of Saliency-Based Position Self-Sensing Capability of AC Motors

The keynote presents a physical understanding of the rotor position self-sensing capability of AC motors based on the detection of their electromagnetic saliency by means of a high frequency voltage injection. Motors with intrinsic structural saliency, saturation-induced saliency as well as intentionally-created saliency will be discussed and compared. Simulation and experimental results will support the presentation. The purpose of the lecture is twofold: (i) delivering assessment criteria of the suitability of a given AC machine to a sensorless drive and for predicting rotor speed and position estimation accuracy; (ii) delivering hints for a self-sensing oriented design of the AC machines. Both are key concepts for enforcing the diffusion of effective and reliable sensorless drives in home, commercial and industrial applications.

# Conference Program

**Sunday, 17/09/2017**

**18:30 Welcome Reception**

**Monday, 18/09/2017**

**09:00 Opening**

**Plenary Session**

Monday, 18/09/2017, 09:30 to 11:10

Room: Grande Salone da Ballo

Chairmen: Giuseppe Scarcella and Mario Cacciato, University of Catania, Italy

**09:30 The Path to Widespread Use of Self-Sensing**

R. Lorenz

University of Wisconsin, USA

**10:20 Physical Understanding of Saliency-Based Position Self-Sensing Capability of AC Motors**

L. Alberti, N. Bianchi, S. Bolognani

University of Padova, Italy

**11:10 Coffee Break**

**Session S1 – Design for Self-Sensing Control**

Monday, 18/09/2017, 11:30 to 12:45

Room: Grande Salone da Ballo

Chairman: Frederik De Belie, Ghent University, Belgium

**S1-1**

**11:30 Design of Highly-Saturated Permanent Magnet Synchronous Machines for Torque Ripple Optimized Self-Sensing Control**

L. Chen<sup>1</sup>, M. Roetzer<sup>1</sup>, G. Goetting<sup>1</sup>, I. Hahn<sup>2</sup>

<sup>1</sup>Robert Bosch, <sup>2</sup>University of Erlangen-Nuremberg

**S1-2**

**11:55 The Influence of Rotor Design on Active Flux-Based Sensorless Synchronous Reluctance Motor Drives**

N. Bianchi, S. Bolognani, F. Tinazzi, M. Zigliotto

University of Padova

**S1-3**

**12:20 Self-Sensing Control of Induction Machines Using an Additional Short-Circuited Rotor Coil**

S. Luecke, A. Mertens  
Leibniz Universität Hannover

**Session S2 – PM and Synchronous Reluctance Motor Drives**

Monday, 18/09/2017, 11:30 to 12:45

Room: Salone dei Principi

Chairman: Gianmario Pellegrino, Politecnico di Torino, Italy

**S2-1**

**11:30 Sensorless Control of a Synchronous Reluctance Motor by Finite Elements Model Results**

M. Tursini, M. Villani, G. Fabri, S. Paolini, A. Credo, A. Fioravanti  
University of L'Aquila

**S2-2**

**11:55 Position Estimation for Synchronous Motor Drives: Unified Framework for Design and Analysis**

M. Hinkkanen<sup>1</sup>, S. Saarakkala<sup>1</sup>, H. Awan<sup>1</sup>, E. Mölsä<sup>1</sup>, T. Tuovinen<sup>2</sup>  
<sup>1</sup>Aalto University, <sup>2</sup>ABB Oy Drives

**S2-3**

**12:20 Parameter Identification of an High Efficiency PMA Synchronous Reluctance Motor for Design and Control**

F. Calegari, G. Federico, E. Bassi, F. Benzi  
University of Pavia

**13:00 Lunch**

**Session S3 – Induction Motor Drives**

Monday, 18/09/2017, 14:30 to 15:45

Room: Grande Salone da Ballo

Chairman: Axel Mertens, Leibniz Universität Hannover, Germany

**S3-1**

**14:30 Effective Model Predictive Current Control for a Sensorless IM Drive**

M. Mossa, S. Bolognani  
University of Padova

**S3-2****14:55 Design of Estimators for the Inverse of the Rotor Time Constant of the Induction Motor with Known Flux**

M. Comanescu  
Penn State Altoona

**S3-3****15:20 Injection of Third-Order Spatial Field Harmonic for Sensorless Speed Estimation in Multiphase Induction Motor Drives**

M. Mengoni, L. Zarri, A. Tani, G. Rizzoli, G. Serra, D. Casadei  
University of Bologna

**Session S4 – Switched Reluctance and IPM Drives**

Monday, 18/09/2017, 14:30 to 15:45

Room: Salone dei Principi

Chairman: Marko Hinkkanen, Aalto University, Finland

**S4-1****14:30 Self-Sensing Method for a Switched Reluctance Motor Using Delta-Sigma Modulators and Neural Networks**

P. Kappes, I. Krüger, G. Griepentrog  
TU Darmstadt

**S4-2****14:55 Sensorless Control of Variable Speed Drives Using Switched Reluctance Machine**

P. Sovicka<sup>1</sup>, V. Vavrus<sup>1</sup>, P. Rafajdus<sup>1</sup>, Q. Gao<sup>2</sup>  
<sup>1</sup>University of Zilina, <sup>2</sup>Shanghai Jiao Tong University

**S4-3****15:20 The Study on Transient Performance Improvement of Position Sensorless Control Algorithm for IPMSM**

D. Lee, K. Akatsu  
Shibaura Institute of Technology

**15:45 Coffee Break****Session S5 – PMSM Drives I**

Monday, 18/09/2017, 16:00 to 17:15

Room: Grande Salone da Ballo

Chairman: Ralph Kennel, TU Munich, Germany



**S5-1****16:00 Self-Commissioning of Sensorless Drives for Synchronous Machines: Finite Element Analysis Computation and Measurement of Flux Maps**O. Bottesi<sup>1</sup>, S. Calligaro<sup>1</sup>, P. Kumar<sup>1</sup>, L. Alberti<sup>2</sup>, R. Petrella<sup>3</sup><sup>1</sup>Free University of Bozen, <sup>2</sup>University of Padova, <sup>3</sup>University of Udine**S5-2****16:25 Sensorless Magnetic Model and PM Flux Identification of Synchronous Drives at Standstill**

P. Pescetto, G. Pellegrino

Politecnico di Torino

**S5-3****16:50 Enhancing Self-Sensing Estimation Accuracy Via Negative Sequence Current Image Registration, with Evaluation on a Low Saliency Ratio Machine**

T. Slininger, R. Lorenz

University of Wisconsin at Madison

**Session S6 – IPM and SyncRel Drives**

Monday, 18/09/2017, 16:00 to 17:15

Room: Salone dei Principi

Chairman: Pavol Rafajdus, University of Zilina, Slovak Republic

**S6-1****16:00 Self-Sensing Control of the Externally-Excited Synchronous Machine for Electric Vehicle Traction Application**M. Koteich<sup>1</sup>, A. Messali<sup>2</sup>, S. Daurelle<sup>2</sup><sup>1</sup>Groupe Renault Technocentre, <sup>2</sup>Laboratory of Digital Sciences of Nantes (LS2N)**S6-2****16:25 Self-Adaptive High-Frequency Injection-Based Sensorless Control for IPMSM and SynRM**L. Alberti<sup>1</sup>, O. Bottesi<sup>2</sup>, S. Calligaro<sup>2</sup>, P. Kumar<sup>2</sup>, R. Petrella<sup>3</sup><sup>1</sup>University of Padova, <sup>2</sup>Free University of Bozen, <sup>3</sup>University of Udine**S6-3****16:50 Arbitrary Injection-Based Sensorless Control with a Defined High Frequency Current Ripple and Reduced Current and Sound Level Harmonics**M. Laumann<sup>1,2</sup>, C. Weiner<sup>1</sup>, R. Kennel<sup>2</sup><sup>1</sup>University of Applied Sciences Darmstadt, <sup>2</sup>TU Munich**19:30 Guided Visit to Palazzo Manganelli and Gala Dinner****Tuesday, 19/09/2017**

**Poster Session**

Tuesday, 19/09/2017, 09:00 to 11:00

Room: Sala del Rinascimento

Chairman: Giacomo Scelba, University of Catania, Italy

**SP-1 Compensation of Rotor Position Estimation Errors in Sensorless Dual-Three Phase PMSM Drives through Back-EMF Sensing**

G. Scelba<sup>1</sup>, G. Scarcella<sup>2</sup>, M. Cacciato<sup>2</sup>, M. Pulvirenti<sup>2</sup>, A. Testa<sup>3</sup>

<sup>1</sup>University of Catania, <sup>2</sup>STMicroelectronics, <sup>3</sup>University of Messina

**SP-2 The Use of High-Speed Switched Reluctance Machine for Electric Turbochargers**

B. Hango, P. Drgona, M. Danko, M. Frivaldsky

University of Zilina

**SP-3 Development of a Flux, Speed and Rotor Time Constant Estimation Scheme for the Sensorless Induction Motor Drive**

M. Comanescu

Penn State Altoona

**SP-4 Position Estimation for Linear Electromagnetic Actuators**

A. El Hafni, M. Abdelrahman, R. Kennel

TU Munich

**SP-5 Sensorless Control of High-Speed BLDC**

M. Stulrajter<sup>1</sup>, P. Makys<sup>2</sup>, P. Rafajdus<sup>2</sup>

<sup>1</sup>NXP Semiconductor, <sup>2</sup>University of Zilina

**SP-6 Sensorless Control for PM-Machine Based Generating Units**

C. Verrelli<sup>1</sup>, A. Lidozzi<sup>2</sup>, S. Bifaretti<sup>1</sup>, L. Solero<sup>2</sup>, F. Crescimbeni<sup>2</sup>

<sup>1</sup>University of Roma "Tor Vergata", <sup>2</sup>University of Roma Tre

**SP-7 Sensorless Field Oriented Control of Multiple-Motors Fed by Multiple-Converters Systems**

S. Foti<sup>1</sup>, A. Testa<sup>1</sup>, S. De Caro<sup>1</sup>, T. Scimone<sup>1</sup>, M. Pulvirenti<sup>2</sup>

<sup>1</sup>University of Messina, <sup>2</sup>STMicroelectronics

**SP-8 Integral Sliding-Mode Direct Torque Control for Sensorless Induction Motor Drives**

A. Dannier, A. Del Pizzo, L. Di Noia, S. Meo

University of Napoli "Federico II"

**11:00 Coffee Break**

**Session S7 – PMSM Drives II**

Tuesday, 19/09/2017, 11:20 to 13:00

Room: Grande Salone da Ballo

Chairman: Fabio Giulii Capponi, University of Roma "La Sapienza", Italy

**S7-1****11:20 A Moving Horizon Estimator for the Speed and Rotor Position of Sensorless PMSM Drive**

F. Toso, D. Da Rù, S. Bolognani  
University of Padova

**S7-2****11:45 Pseudo Derivative Feedback Current-Controlled Sensorless PMSM Drive with Flux-Torque Based MRAS Estimator for Low-Speed Operation**

A. Karthikeyan<sup>1</sup>, K. Prabhakaran<sup>1</sup>, B. Venkatesa Perumal<sup>1</sup>, C. Nagamani<sup>2</sup>  
<sup>1</sup>National Institute of Technology Karnataka Surathkal, <sup>2</sup>National Institute of Technology Tiruchirappalli

**S7-3****12:10 Reduced Observer for Anisotropy-Based Position Estimation of PM Synchronous Machines Using Current Oversampling**

B. Weber, G. Lindemann, A. Mertens  
Leibniz Universität Hannover

**S7-4****12:35 Sensorless Vector Control of PMSM Using SMO and NLDO**

A. Apte<sup>1</sup>, R. Walambe<sup>2</sup>, V. Joshi<sup>2</sup>, H. Mehta<sup>3</sup>  
<sup>1</sup>AISSMS College of Engineering Pune, <sup>2</sup>PVG College of Engineering and Technology Pune, <sup>3</sup>Symbiosis Pune

**Session S8 – Model Based and DTC Sensorless Control**

Tuesday, 19/09/2017, 11:20 to 13:00

Room: Salone dei Principi

Chairman: Roberto Petrella, University of Udine, Italy

**S8-1****11:20 Introducing a Pulse Response Based Rotor Position Estimator for DTC IPMSM Drives**

H. Li, F. De Belie, J. Melkebeek  
Ghent University

**S8-2****11:45 Sensorless Direct Torque Control for PM-Assisted Synchronous Motors with Injection High-Frequency Signal into Stator Flux Reference Frame**

P. Guglielmi, A. Yousefi-Talouki, G. Iabichino, G. Pellegrino  
Politecnico di Torino

**S8-3****12:10 Sensorless Vector Control of PMSM with Observer-Based Phase Current Reconstruction Using Only a DC-Link Current Sensor**

A. Kraemer, V. Heusinger, S. Schad, A. Ali

University of Applied Sciences Wuerzburg-Schweinfurt

**S8-4****12:35 Predictive Phase Locked Loop for Sensorless Control of PMSG Based Variable-Speed Wind Turbines**

M. Abdelrahem, A. El Hafni, R. Kennel, C. Hackl

TU Munich

**13:00 Lunch****Session S9 – Dual Three-Phase and Open-End Winding PM Drives**

Tuesday, 19/09/2017, 14:30 to 15:45

Room: Grande Salone da Ballo

Chairman: Peter Landsmann, TU Munich, Germany

**S9-1****14:30 Anisotropy-Based Position Estimation Approach for Symmetrical Dual Three-Phase Permanent Magnet Synchronous Machines**M. Roetzer<sup>1</sup>, U. Vollmer<sup>1</sup>, L. Chen<sup>1</sup>, R. Kennel<sup>2</sup><sup>1</sup>Robert Bosch, <sup>2</sup>TU Munich**S9-2****14:55 Self-Sensing Control of Open-End Winding PMSMs Fed by an Asymmetrical Hybrid Multilevel Inverter**G. Scelba<sup>1</sup>, G. Scarcella<sup>1</sup>, S. Foti<sup>2</sup>, S. De Caro<sup>2</sup>, A. Testa<sup>2</sup><sup>1</sup>University of Catania, <sup>2</sup>University of Messina**S9-3****15:20 Sensorless Control of Single-Inverter Dual-Motor AC Brushless Drives**

G. Brando, A. Del Pizzo, I. Spina

University of Napoli "Federico II"

**Session S10 – Synchronous Motor Drives**

Tuesday, 19/09/2017, 14:30 to 15:45

Room: Salone dei Principi

Chairman: Giulio De Donato, University of Roma "La Sapienza", Italy

**S10-1**

**14:30 Sensorless Control of Matrix Converter-Fed Synchronous Reluctance Motor Drives**

A. Yousefi-Talouki<sup>1</sup>, F. Stella<sup>1</sup>, S. Odhano<sup>2</sup>, L. De Lilo<sup>2</sup>, A. Trentin<sup>2</sup>, G. Pellegrino<sup>1</sup>, P. Zanchetta<sup>2</sup>

<sup>1</sup>Politecnico di Torino, <sup>2</sup>University of Nottingham

**S10-2**

**14:55 Sensorless Position Estimation at low Speeds till Standstill with Reduced Filtering Requirements for an Externally Excited Synchronous Machine**

J. Schuster, V. Ketchedjian, J. Roth-Stielow

University of Stuttgart

**S10-3**

**15:20 Sensorless Position Estimation for Ironless Surface Mounted Permanent Magnet Synchronous Motors in Full Speed Range**

C. Zhao, M. Tanaskovic, F. Percacci, S. Mariéthoz, P. Gnos

Maxon Motor

**15:45 Closing Address by the Conference Chairs**

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# Notes





# In Memoriam Alfio Consoli

Alfio Consoli, IEEE Fellow and Professor at University of Catania passed away July 7<sup>th</sup>, 2012, after a long battle against cancer. Alfio was a very special person, liked by many friends and IEEE colleagues. All along he demonstrated extraordinary courage, strength and enthusiasm for teaching and research. Even till the very end, during his battle against the severe illness, he never stopped to transmit this enthusiasm and optimism to relatives and colleagues. We will always remember his intellectual capacity and hard work, his friendliness and honesty, his energy and optimism.

Alfio will be remembered as a pioneer in establishing the collaboration between the Italian and American Power Electronics and Drives communities. Alfio was recipient of a NATO Grant for a one-year stay in 1980 at Purdue University, West Lafayette, Indiana. In 1985, he was Visiting Professor at the University of Wisconsin, Madison, teaching classes in Electromagnetic Design and supervising the activities and theses of two Ph.D. students. He witnessed the birth of the WEMPEC consortium at UW and always kept close contacts with the WEMPEC scholars and visitors, always encouraging younger generations of Italian engineering students and professionals to take part in a global experience that serves not only be individual aspirations but also humanity. As such, from 1987 till 2006, he was responsible for the Ph.D. programs in Electrical Engineering in Catania. Furthermore, from 2006 to 2012 he was the Coordinator of the International Ph.D. course on ENERGY of the Scuola Superiore at University of Catania. He was also responsible of a SOCRATES project for the European student Exchange Program and successfully established collaborations with universities and research centers throughout Europe, United States and South America. In 1993, he was a member of a National Experts Group of the "Italian Foreign Ministry" for building and improving Scientific and Educational programs in three Algerian Universities. From 1990 to 1994 he was the Coordinator of the European Project TEMPUS, to build new laboratories in Zilina University, Slovakia.

Alfio Consoli was born in Catania, Italy, in 1949. In 1972, he graduated in Electrical Engineering from the Politecnico di Torino, Italy. After a short period at Fiat in Torino, Italy, working at the R&D unit, he has been with the University of Catania since 1975. In 1986, he became Full Professor of Electrical Machines, teaching in the areas of electrical machines, electrical drives and power electronics. He has authored or co-authored over 300 technical papers, as a result of more than thirty years of research activity in the areas of energy conversion, electrical drives, robotics and power electronics and its applications. He directed many international and national research projects supported by MURST, MIUR, CNR, ENEA, and the European Community. Most projects were conducted with industry cooperation, among others, Ansaldo (Genova), Ansaldo Breda (Napoli), ST Microelectronics (Catania), Fiat (Torino), and Reliance (Cleveland, USA).

Among his international achievements, it is worth mentioning two IEEE awards, respectively obtained in the year 2000 for the best paper published in the IEEE Transactions on Power Electronics, and in 1998 as the third prize paper presented at the IEEE-IAS Annual Meeting. Both papers were on sensorless control of AC motor drives. Alfio Consoli holds three international patents and is co-author and co-editor of the book "Modern Electric Drives" published by Kluwer in 2000. He is also the author of "Electrical Motors" article published in the Italian National Encyclopaedia "Treccani". His contribution in Scientific research and industrial applications were timely and extremely relevant, and were internationally recognized by the engineering community with his elevation to IEEE Fellow in 2001.



Alfio was appointed Distinguished Lecturer for the period 2002-2004. From 1997 to 2001, he was member of the Executive Board of the IEEE-Industry Application Society. He was member of the Executive Committee of the IEEE Power Electronics Society, where he served as Chairman of the Technical Committee on "Motor Drives", and became Associate Editor of the IEEE Transactions on Power Electronics. He was member of the Executive Council of the European Power Electronics and Drives Association (EPE), where he served as Chairman of the Drives Chapter. Alfio was the Coordinator of CMAEL (Converters, Machines,

and Electrical Drives) the Association of the Italian Professors on Power Electronics.

In 1982-83 and from 1986 to 1990 Alfio was Head of the "Electrical Institute" and from 1991 to 1997 directed the "Department of Electrical Electronic and Systems Engineering" at the University of Catania. From 1988 to 1990 and from 1992 to 1999, he was the Head of Council of the "Electrical Engineering Courses". From 1994 to 2000, he was appointed Rector Delegate for Research at the University of Catania. From 1995 to 2000, he was Member of the Working Group on European Research Policy in the Confederation of the European Rectors Conference. From 1987 onward he was a member of the scientific board of the Consortium on Microelectronics between ST Microelectronics and University of Catania. He was the Rector Delegate at the National Consortium on Transports and Logistics (NITEL) and Head of CePTIT, the "Center for Promotion and Transfer of Technological Innovation", that he created in 1999.

With all his fame and international recognition, Alfio was always a friendly and soft-spoken person, who carried a warm heart to all colleagues. Next to his professional work, he enjoyed being with friends. He is survived by his beloved wife Maria Grazia.

Francesco Profumo, Prof. Dr. Ing., Dr. H. C.  
Former Minister for Teaching, Universities and Research, Italy

