

THE JOURNAL OF  
Navigation

VOLUME 68 NUMBER 5 SEPTEMBER 2015



Royal Institute of Navigation  
Science Technology Practice

**CAMBRIDGE**  
UNIVERSITY PRESS

---

# THE ROYAL INSTITUTE OF NAVIGATION

Science

Technology

Practice

---

## THE JOURNAL OF NAVIGATION

*Editor-in-Chief* Nick Randall MSc FRIN

*Editor* Tony Fyler

*Associate Editors*

Prof. Ruizhi Chen PhD  
*Texas A&M University, Corpus Christi, USA*  
Dr. Ashim Debnath PhD  
*Queensland University of Technology, Australia*  
Dr. Ramsey Faragher CPhys FRIN MION  
*University of Cambridge, UK*  
Dr. Shaojun Feng PhD FRIN  
*Imperial College London, UK*  
Assoc. Prof. Renato Filjar PhD FRIN  
*University of Rijeka, Croatia*  
Dr. Paul D Groves DPhil CPhys FRIN  
*University College London, UK*  
Prof. Peter J. Hore MA DPhil  
*University of Oxford, UK*  
Prof. Shuanggen Jin PhD FIAG  
*Shanghai Astronomical Observatory, China*

Dr. Olivier Julien  
*ENAC, France*  
Prof. Izzet Kale  
*University of Westminster, UK*  
Assoc. Prof. Simona Lohan PhD  
*Tampere University of Technology, Finland*  
Prof. Margareta Lützhöft PhD MNI MRIN  
*Australian Maritime College, University of Tasmania, Australia*  
Dr. Gene McCall AFRIN  
*Los Alamos, USA*  
Dr. Xiaolin Meng FRIN  
*University of Nottingham, UK*  
Dr. Erik Styhr Petersen PhD MNI MSNAME  
*Denmark*  
Dr. Wolfgang Schuster FRIN  
*Imperial College London, UK*

Dr. Rafal Szlapczynski PhD  
*Gdansk University of Technology, Poland*  
Prof. Peter J.G. Teunissen AFRIN  
*Curtin University, Australia and Delft University of Technology, The Netherlands*  
Assoc. Prof. Jinling Wang FRIN FIAG  
*University of New South Wales, Australia*  
Dr. Nick Ward PhD CEng FRIN  
*General Lighthouse Authority, UK*  
Prof. Adam Weintrit FRIN FNI  
*Gdynia Maritime University, Poland*  
Prof. Yuanxin Wu PhD  
*Central South University, China*

*Editorial Board.* The Editorial Board (for administrative matters) consists of the members of the Royal Institute of Navigation's Technical Committee.

*Editorial Advisory Board.* The Chairman of the Editorial Advisory Board (for academic matters) is the Royal Institute of Navigation Director (Capt P. C. Chapman-Andrews, LVO MBE), the Secretary is the *Journal* Editor-in-Chief (Nick Randall MSc FRIN) and it consists of the following members:

<i>Name</i>	<i>(Affiliation, Region)</i>	<i>Name</i>	<i>(Affiliation, Region)</i>
Prof. Susanne Akesson FRIN	Lund, Sweden	Prof. Stella Mills AFRIN	Staffordshire, UK
Prof. Craig Allen FRIN	Washington, USA	Prof. Terry Moore FRIN	Nottingham, UK
Prof. Vidal Ashkenazi FRIN	NSL, UK	Prof. Paul Newman	Oxford, UK
Prof. Victoria Braithwaite FRIN	Penn State, USA	Prof. Andy Norris FRIN	Consultant, UK
Prof. Alan Dodson FRIN	Nottingham, UK	Prof. Washington Ochieng FRIN	Imperial College, UK
Dr. Alexander Dunaev	JSC 'RSS', Russia	Prof. Patrick Oonincx	Defence, Netherlands
Dr. Ahmed El-Mowafy	Curtin, Australia	Prof. Maciej Pawlowski	Gdansk, Poland
Prof. Ahmed El-Rabbany	Ryerson, Canada	Prof. Malek Pourzanjani FRIN	Raffles, Malaysia
Prof. Naser El-Sheimy	Calgary, Canada	Prof. Thorsten Ritz FRIN	California, USA
A/Prof. Renato Filjar FRIN	Rijeka, Croatia	Dr. Wolfgang Schuster FRIN	Imperial College, UK
Dr. Marianne George	Pacific Traditions, USA	Prof. Sir Martin Sweeting	SSTL, UK
Prof. Dorota Grejner-Brzezinska	Ohio State, USA	Prof. Peter Teunissen AFRIN	Curtin, Australia
Dr. Chris Hegarty	MITRE, USA	Prof. Gert Trommer FRIN	Karlsruhe, Germany
Prof. Dah-Jing Jwo	Nat. Taiwan Ocean, Taiwan	Dr. Martin Unwin FRIN	SSTL, UK
Prof. Izzet Kale	Westminster, UK	Prof. Peter Vörsmann	Braunschweig, Germany
Dr. Allison Kealy	Melbourne, Australia	Prof. Charlie Walcott FRIN	Cornell, USA
Prof. Changdon Kee	Seoul, S. Korea	Prof. Mike Walker FRIN	Auckland, New Zealand
Prof. Joseph Kirschvink AFRIN	Caltech, USA	A/Prof. Jinling Wang FRIN	Sydney, Australia
Prof. Dr. Serdjo Kos FRIN	Rijeka, Croatia	Prof. Adam Weintrit FRIN	Gdynia, Poland
Prof. Tomislav Kos FRIN	Zagreb, Croatia	Prof. Jinxian Weng	Beihang, China
Prof. Gerard Lachapelle FRIN	Calgary, Canada	Prof. Roswitha Wiltshcko FRIN	Frankfurt, Germany
Prof. Richard Langley FRIN	New Brunswick, Canada	Prof. Wolfgang Wiltshcko FRIN	Frankfurt, Germany
Prof. David Last FRIN	Consultant, UK	Prof. Michael Winklhofer	Munich, Germany
Prof. Jingnan Liu	Wuhan, China	Prof. XuHai Yang	Academy of Sciences, China
Dr. Sherman Lo	Stanford, USA	Prof. Yuanxi Yang	CNAGA, China
Prof. Ken Lohmann FRIN	North Carolina, USA	Prof. Marek Ziebart	UCL, UK
Dr. Gene McCall AFRIN	Los Alamos, USA	Prof. Nesreen Ziedan AFRIN	Zagazig, Egypt
Dr. Xiaolin Meng FRIN	Nottingham, UK		

The *Journal* is published six times a year by Cambridge University Press. It contains original papers contributing to the science of navigation, including those presented at the meetings of the Institute. Papers should be submitted via the link <http://mc.manuscriptcentral.com/nav>. The Editor-in-Chief may be contacted via e-mail at [journal@rin.org.uk](mailto:journal@rin.org.uk). The current 'Instructions for Contributors' are available online or by e-mail. The views expressed in the *Journal* are not necessarily those of the Institute, or of any organisation or department to which the authors may belong. Crown Copyright may be reserved. Any facts stated or opinions expressed in this *Journal* are the sole responsibility of the contributors. Neither the Royal Institute of Navigation, the Editor nor the Publishers can be held responsible for any injury or loss sustained in reliance thereon.

This journal is included in the Cambridge Journals Online service (<http://journals.cambridge.org>). For further information on other Press titles access <http://www.cambridge.org>

The address of the Institute is The Royal Institute of Navigation, at The Royal Geographical Society, 1 Kensington Gore, London SW7 2AT (Telephone: 020 7591 3130 Fax: 020 7591 3131), website ([www.rin.org.uk](http://www.rin.org.uk)) e-mail ([editor@rin.org.uk](mailto:editor@rin.org.uk)).

This journal issue has been printed on FSC-certified paper and cover board. FSC is an independent, non-governmental, not-for-profit organization established to promote the responsible management of the world's forests. Please see [www.fsc.org](http://www.fsc.org) for information.