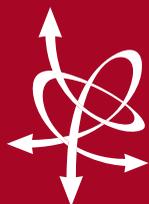


THE JOURNAL OF
Navigation

VOLUME 68 NUMBER 6 NOVEMBER 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:

Name	(Affiliation, Region)	Name	(Affiliation, Region)
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 Norriss 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. 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) e-mail (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 for information.