

THE JOURNAL OF  
Navigation

VOLUME 67 NUMBER 3 MAY 2014



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  
Assoc. Prof. Renato Filjar PhD FRIN  
University of Rijeka, Croatia  
Dr. Olivier Julien  
ENAC, France  
Assoc. Prof. Margareta Lützhöft PhD MNI MRIN  
Chalmers University of Technology, Sweden  
Dr. Wolfgang Schuster FRIN  
Imperial College London, UK  
Assoc. Prof. Jinling Wang FRIN FIAG  
University of New South Wales, Australia  
Assoc. Prof. Yuanxin Wu PhD  
Central South University, China

Dr. Ramsey Faragher CPhys MRIN MION  
University of Cambridge, UK  
Dr. Paul D Groves DPhil CPhys FRIN  
University College London, UK  
Prof. Izzet Kale  
University of Westminster, UK  
Dr. Gene McCall AFRIN  
Los Alamos, USA  
Prof. Peter J.G. Teunissen AFRIN  
Curtin University, Australia and Delft University of Technology, The Netherlands  
Dr. Nick Ward PhD CEng FRIN  
General Lighthouse Authority, UK

Dr. Shaojun Feng PhD FRIN  
Imperial College London, UK  
Prof. Peter J. Hore MA DPhil  
University of Oxford, UK  
Assoc. Prof. Simona Lohan PhD  
Tampere University of Technology, Finland  
Dr. Xiaolin Meng FRIN  
University of Nottingham, UK  
Prof. Adam Weintrit FRIN FI  
Gdynia Maritime University, Poland

**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 Ooninx          | 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         | 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. Jiling 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 by e-mail. The views expressed in the *Journal* are not necessarily those of the Institute, or of any organization 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.