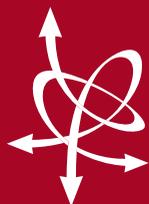


THE JOURNAL OF
Navigation

VOLUME 70 NUMBER 6 NOVEMBER 2017



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

Assistant Editors

Tony Blackman OBE FRAeS FRIN
Admiral Sir Nigel Essenhigh GCB FRIN FNI
Captain Paul A Lanaghan BA FRIN

Jillian Carson-Jackson MED FRIN FNI
Christopher A Gash BSc FRIN
Dr Hector J I Page

Norman Dahl FRIN
Simon E Gaskin FRIN FNI

Associate Editors

Prof. Ruizhi Chen PhD
Texas A&M University, Corpus Christi, USA
Dr. Ashim Debnath PhD
Victoria University, 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
Dr. Lawrence Lau PhD FRICS FRIN
University of Nottingham Ningbo China, China
Assoc. Prof. Simona Lohan PhD
Tampere University of Technology, Finland
Prof. Margareta Lützhöft PhD FNI 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. James Pinchin PhD AFRIN
University of Nottingham, UK

Prof. Roberto Sabatini PhD DEng FRIN
RMIT University, Australia
Dr. Wolfgang Schuster FRIN
Atkins, UK
Dr. Rafal Szlaczynski 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
Shanghai Jiao Tong 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 (John Pottle, BSc MBA FRIN), 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 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 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 Keady	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. Richard Langley FRIN	New Brunswick, Canada	Prof. Roswitha Wiltshcko FRIN	Frankfurt, Germany
Prof. David Last FRIN	Consultant, UK	Prof. Wolfgang Wiltshcko FRIN	Frankfurt, Germany
Prof. Jingnan Liu	Wuhan, China	Prof. Michael Winkhofer	Munich, Germany
Dr. Sherman Lo	Stanford, USA	Prof. XuHaiYang	Academy of Sciences, China
Prof. Ken Lohmann FRIN	North Carolina, USA	Prof. Yuanxi Yang	CNAGA, China
Dr. Gene McCall AFRIN	Los Alamos, USA	Prof. Marek Ziebart	UCL, UK
Dr. Xiaolin Meng FRIN	Nottingham, UK	Prof. Nesreen Ziedan AFRIN	Zagazig, Egypt

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.

The *Journal of Navigation* and all other Cambridge journals can be found at journals.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).