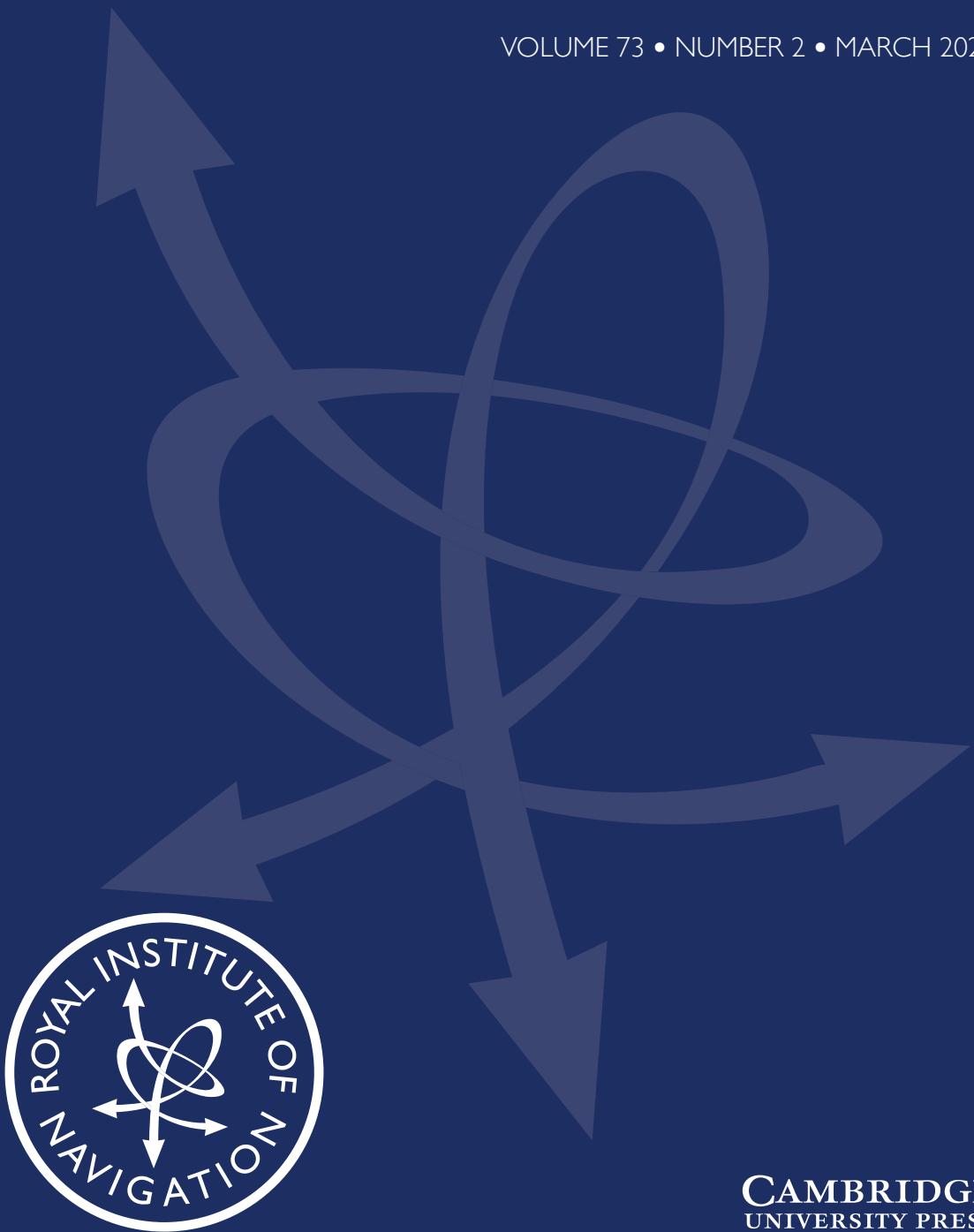


ISSN: 0373-4633

# THE JOURNAL OF NAVIGATION

VOLUME 73 • NUMBER 2 • MARCH 2020



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  
Simon E Gaskin FRIN FNI

*Associate Editors*

Dr. Gang Chen PhD  
*Aalborg University, Denmark*  
Prof. Liang Chen PhD  
*Wuhan University*  
Dr. Ashim Debnath PhD  
*Deakin University, Australia*  
Dr. Shaojun Feng PhD FRIN  
*Imperial College London, UK*  
Dr. Paul D Groves DPhil CPhys FRIN  
*University College London, UK*  
Prof. Shuanggen Jin PhD FIAG  
*Shanghai Astronomical Observatory, China*  
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. Margaretta Lützhöft PhD FNI MRIN  
*Western Norway University of Applied Sciences, Norway*  
Dr. Gene McCall AFRIN  
*Los Alamos, USA*  
Dr. Xiaolin Meng FRIN  
*University of Nottingham, UK*  
Dr. Erik Styhr Petersen PhD MNI MSNAME  
*Denmark*  
Prof. Roberto Sabatini PhD DEng FRIN  
*RMIT University, Australia*  
Dr. Wolfgang Schuster  
*Atkins, UK*  
Dr. Rafal Szlapczynski PhD  
*Gdansk University of Technology, Poland*

Prof. Peter J.G. Teunissen FRIN  
*Curtin University, Australia and Delft University of Technology, The Netherlands*  
Assoc. Prof. Jinling Wang FRIN FIAG  
*University of New South Wales, Australia*  
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:

<i>Name</i>	<i>(Affiliation, Region)</i>	<i>Name</i>	<i>(Affiliation, Region)</i>
Prof. Craig Allen FRIN	Washington, USA	Dr. Gene McCall AFRIN	Los Alamos, USA
Dr. Ahmed El-Mowafy	Curtin, Australia	Dr. Xiaolin Meng FRIN	Nottingham, UK
Prof. Ahmed El-Rabbany	Ryerson, Canada	Prof. Terry Moore FRIN	Nottingham, UK
A/Prof. Renato Filjar FRIN	Rijeka, Croatia	Prof. Andy Norris FRIN	Consultant, UK
Dr. Marianne George	Pacific Traditions, USA	Prof. Washington Ochieng FRIN	Imperial College, UK
Prof. Dorota Grejner-Brzezinska FRIN	Ohio State, USA	Prof. Patrick Onorinex	Defence, Netherlands
Dr. Chris Hegarty	MITRE, USA	Prof. Thorsten Ritz	California, USA
Prof. Dah-Jing Jwo	Nat. Taiwan Ocean, Taiwan	Dr. Wolfgang Schuster	Atkins, UK
Prof. Izzet Kale	Westminster, UK	Prof. Sir Martin Sweeting	SSTL, UK
Dr. Alison Kealy	Melbourne, Australia	Prof. Peter Teunissen FRIN	Delft, Netherlands
Prof. Changdon Kee	Seoul, S. Korea	Prof. Peter Vörsmann	Braunschweig, Germany
Prof. Joseph Kirschvink	Caltech, USA	Prof. Charlie Walcott FRIN	Cornell, USA
Prof. Dr. Serdjo Kos FRIN	Rijeka, Croatia	A/Prof. Jinling Wang FRIN	Sydney, Australia
Prof. Tomislav Kos FRIN	Zagreb, Croatia	Prof. Adam Weintrit FRIN	Gdynia, Poland
Prof. Richard Langley FRIN	New Brunswick, Canada	Prof. Jinxian Weng	Beihang, China
Prof. David Last FRIN	Consultant, UK	Prof. Roswitha Wiltschko FRIN	Frankfurt, Germany
Dr. Sherman Lo	Stanford, USA	Prof. Wolfgang Wiltschko FRIN	Frankfurt, Germany
		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](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.

*The Journal of Navigation* and all other Cambridge journals can be found at [journals.cambridge.org](http://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](http://www.rin.org.uk)) e-mail ([editor@rin.org.uk](mailto:editor@rin.org.uk)).