

PROCEEDINGS OF SPIE

Sensors and Systems for Space Applications VI

**Khanh D. Pham
Joseph L. Cox
Richard T. Howard
Genshe Chen**
Editors

**April 29–1 May 2013
Baltimore, Maryland, United States**

Sponsored and Published by
SPIE

Volume 8739

Proceedings of SPIE 0277-786X, V. 8739

SPIE is an international society advancing an interdisciplinary approach to the science and application of light.

Sensors and Systems for Space Applications VI, edited by Khanh D. Pham, Joseph L. Cox, Richard T. Howard, Genshe Chen, Proc. of SPIE Vol. 8739, 873901 · © 2013 SPIE · CCC code: 0277-786X/13/\$18 · doi: 10.1117/12.2030350

Proc. of SPIE Vol. 8739 873901-1

The papers included in this volume were part of the technical conference cited on the cover and title page. Papers were selected and subject to review by the editors and conference program committee. Some conference presentations may not be available for publication. The papers published in these proceedings reflect the work and thoughts of the authors and are published herein as submitted. The publisher is not responsible for the validity of the information or for any outcomes resulting from reliance thereon.

Please use the following format to cite material from this book:

Author(s), "Title of Paper," in *Sensors and Systems for Space Applications VI*, edited by Khanh D. Pham, Joseph L. Cox, Richard T. Howard, Genshe Chen, Proceedings of SPIE Vol. 8739 (SPIE, Bellingham, WA, 2013) Article CID Number.

ISSN: 0277-786X

ISBN: 9780819495303

Published by

SPIE

P.O. Box 10, Bellingham, Washington 98227-0010 USA

Telephone +1 360 676 3290 (Pacific Time) · Fax +1 360 647 1445

SPIE.org

Copyright © 2013, Society of Photo-Optical Instrumentation Engineers.

Copying of material in this book for internal or personal use, or for the internal or personal use of specific clients, beyond the fair use provisions granted by the U.S. Copyright Law is authorized by SPIE subject to payment of copying fees. The Transactional Reporting Service base fee for this volume is \$18.00 per article (or portion thereof), which should be paid directly to the Copyright Clearance Center (CCC), 222 Rosewood Drive, Danvers, MA 01923. Payment may also be made electronically through CCC Online at copyright.com. Other copying for republication, resale, advertising or promotion, or any form of systematic or multiple reproduction of any material in this book is prohibited except with permission in writing from the publisher. The CCC fee code is 0277-786X/13/\$18.00.

Printed in the United States of America.

Publication of record for individual papers is online in the SPIE Digital Library.



SPIDigitalLibrary.org

Paper Numbering: Proceedings of SPIE follow an e-First publication model, with papers published first online and then in print and on CD-ROM. Papers are published as they are submitted and meet publication criteria. A unique, consistent, permanent citation identifier (CID) number is assigned to each article at the time of the first publication. Utilization of CIDs allows articles to be fully citable as soon as they are published online, and connects the same identifier to all online, print, and electronic versions of the publication. SPIE uses a six-digit CID article numbering system in which:

- The first four digits correspond to the SPIE volume number.
- The last two digits indicate publication order within the volume using a Base 36 numbering system employing both numerals and letters. These two-number sets start with 00, 01, 02, 03, 04, 05, 06, 07, 08, 09, 0A, 0B ... 0Z, followed by 10-1Z, 20-2Z, etc.

The CID Number appears on each page of the manuscript. The complete citation is used on the first page, and an abbreviated version on subsequent pages. Numbers in the index correspond to the last two digits of the six-digit CID Number.

Contents

| | |
|-----|-----------------------------|
| vii | <i>Conference Committee</i> |
| ix | <i>Introduction</i> |

PERVASIVE TECHNOLOGIES SUPPORTING RESPONSIVE SPACE

- 8739 02 **SUCHI: The Space Ultra-Compact Hyperspectral Imager for small satellites** [8739-1]
S. T. Crites, P. G. Lucey, R. Wright, J. Chan, H. Garbeil, K. A. Horton, A. Imai, M. Wood,
L. Yoneshige, Univ. of Hawai'i at Manoa (United States)
- 8739 03 **Lunar magnetic field measurements with a cubesat** [8739-2]
I. Garrick-Bethell, Univ. of California, Santa Cruz (United States) and Kyung Hee Univ.
(Korea, Republic of); R. P. Lin, Univ. of California, Berkeley (United States) and Kyung Hee
Univ. (Korea, Republic of); H. Sanchez, B. A. Jaroux, NASA Ames Research Ctr. (United
States); M. Bester, Univ. of California, Berkeley (United States); P. Brown, Imperial College
London (United Kingdom); D. Cosgrove, Univ. of California, Berkeley (United States);
M. K. Dougherty, Imperial College London (United Kingdom); J. S. Halekas, Univ. of
California, Berkeley (United States); D. Hemingway, Univ. of California, Santa Cruz (United
States); P. C. Lozano, Massachusetts Institute of Technology (United States); F. Martel,
Espace Inc. (United States); C. W. Whitlock, Massachusetts Institute of Technology (United
States)
- 8739 04 **Large diffractive/refractive apertures for space and airborne telescopes** [8739-3]
H. A. MacEwen, Reviresco LLC (United States); J. B. Breckinridge, Breckinridge Associates
LLC (United States)
- 8739 05 **An onboard computing system design for a remote sensing cubesat** [8739-4]
J. Straub, Univ. of North Dakota (United States)
- 8739 06 **Mission design and operations of a constellation of small satellites for remote sensing**
[8739-5]
T. C. Sorensen, E. J. Pilger, M. S. Wood, M. A. Nunes, L. K. Yoneshige, Univ. of Hawai'i at
Manoa (United States)

SPACE PAYLOAD TECHNOLOGIES FOR DUAL MILITARY-CIVIL OPERATIONS

- 8739 07 **Design of ground motion compensation servo system** [8739-6]
C. Tan, L. Ding, J. Chai, Shanghai Institute of Technical Physics (China)
- 8739 08 **Rapid orbital characterization of local area space objects utilizing image-differencing
techniques** [8739-7]
P. D. McCall, Florida International Univ. (United States); M. L. Naudeau, Air Force Research
Lab. (United States); M. E. Sorge, The Aerospace Corp. (United States); T. Farrell, Schafer
Corp. (United States); M. Adjouadi, Florida International Univ. (United States)

- 8739 09 **Above the cloud computing: applying cloud computing principles to create an orbital services model** [8739-9]
J. Straub, A. Mohammad, J. Berk, A. K. Nervold, Univ. of North Dakota (United States)

SENSOR CONTAMINATION DETECTION, ABATEMENT, AND EFFECTS

- 8739 0B **PICARD payload thermal control system and general impact of the space environment on astronomical observations** [8739-11]
M. Meftah, A. Irbah, A. Hauchecorne, J.-F. Hochedez, Lab. Atmosphères, Milieux, Observations Spatiales, CNRS (France) and Univ. Paris VI, Univ. de Versailles Saint-Quentin-en-Yvelines (France)
- 8739 0C **Optical analysis of a membrane photon sieve space telescope** [8739-12]
O. Asmolova, G. Andersen, M. E. Dearborn, M. G. McHarg, T. Quiller, U.S. Air Force Academy (United States); T. Murphey, Air Force Research Lab. (United States)
- 8739 0D **Monitoring and predicting rate of VIIRS sensitivity degradation from telescope contamination by tungsten oxide** [8739-13]
S. Blonski, Univ. of Maryland College Park (United States); C. Cao, STAR/NESDIS, National Oceanic and Atmospheric Administration (United States)
- 8739 0E **Thermoelectric radiation sensors for the space mission BepiColombo to Mercury** [8739-14]
F. Hänschke, A. Ihring, E. Kessler, Institut für Photonische Technologien eV (Germany); J. Knollenberg, I. Walter, Deutsches Zentrum für Luft- und Raumfahrt (Germany); U. Dillner, H.-G. Meyer, Institut für Photonische Technologien eV (Germany)

COGNITIVE OPTICS AND ADVANCED TECHNOLOGY DEMONSTRATION

- 8739 0G **Next-generation photonic true time delay devices as enabled by a new electro-optic architecture** [8739-16]
S. R. Davis, S. T. Johnson, S. D. Rommel, M. H. Anderson, Vescent Photonics Inc. (United States)
- 8739 0H **New electro-optic laser scanners for small-sat to ground laser communication links** [8739-17]
S. R. Davis, S. T. Johnson, S. D. Rommel, M. H. Anderson, Vescent Photonics Inc. (United States); J. Chen, T.-H. Chao, Jet Propulsion Lab. (United States)
- 8739 0I **Demonstration of space optical transmitter development for multiple high-frequency bands** [8739-19]
H. Nguyen, R. Simons, E. Wintucky, J. Freeman, NASA Glenn Research Ctr. (United States)

TRACKING, TELEMETRY, AND CONTROL FOR SPACE SITUATIONAL AWARENESS

- 8739 0J **Laser ranging with the MéO telescope to improve orbital accuracy of space debris** [8739-20]
L. Hennegrave, M. Pyanet, H. Haag, G. Blanchet, B. Esmiller, S. Vial, Astrium Space Transportation (France); E. Samain, J. Paris, D. Albanese, Géoazur, Observatoire de la Cote d'Azur (France)

- 8739 OK **Large phase angle observations of GEO satellites** [8739-21]
R. L. Cognion, Oceanit (United States)
- 8739 OL **Conformal prediction for anomaly detection and collision alert in space surveillance**
[8739-22]
H. Chen, Univ. of New Orleans (United States); G. Chen, Intelligent Fusion Technology, Inc.
(United States); E. Blasch, K. Pham, Air Force Research Lab. (United States)
- 8739 OM **Cloud-based space situational awareness: initial design and evaluation** [8739-23]
B. Liu, Y. Chen, Binghamton Univ., SUNY (United States); D. Shen, G. Chen, Intelligent Fusion
Technology, Inc. (United States); K. Pham, E. Blasch, Air Force Research Lab. (United States)

CONNECTIVITY AND DISSEMINATION FOR COGNITIVE SPACE COMMUNICATIONS

- 8739 OO **An efficient QoS-aware routing algorithm for LEO polar constellations** [8739-24]
X. Tian, Intelligent Fusion Technology, Inc. (United States); K. Pham, E. Blasch, Air Force
Research Lab. (United States); Z. Tian, Michigan Tech Univ. (United States); D. Shen,
G. Chen, Intelligent Fusion Technology, Inc. (United States)
- 8739 OP **QoS-aware dynamic spectrum access for cognitive radio networks** [8739-25]
X. Tian, Intelligent Fusion Technology, Inc. (United States); Z. Tian, Michigan Tech Univ.
(United States); K. Pham, E. Blasch, Air Force Research Lab. (United States); G. Chen,
Intelligent Fusion Technology, Inc. (United States)
- 8739 OQ **On effectiveness of routing algorithms for satellite communication networks** [8739-26]
W. Yu, S. Wei, G. Xu, Towson Univ. (United States); G. Chen, Intelligent Fusion Technology,
Inc. (United States); K. Pham, E. P. Blasch, Air Force Research Lab. (United States); C. Lu,
Towson Univ. (United States)
- 8739 OR **On detection and visualization techniques for cyber security situation awareness** [8739-28]
W. Yu, S. Wei, Towson Univ. (United States); D. Shen, Intelligent Fusion Technology, Inc.
(United States); M. Blowers, E. P. Blasch, K. D. Pham, Air Force Research Lab. (United States);
G. Chen, Intelligent Fusion Technology, Inc. (United States); H. Zhang, C. Lu, Towson Univ.
(United States)
- 8739 OS **RSD-WSN: remote source-level debugger for rapid application development in wireless
sensor networks** [8739-29]
M. M. Mozumdar, California State Univ., Long Beach (United States); W. Bian, Politecnico di
Torino (Italy); J. Perez, California State Univ., Long Beach (United States); L. Lavagno,
Politecnico di Torino (Italy)

PROCESSING, EXPLOITATION, AND DECISION SUPPORT FOR ATTRIBUTIONS AND TACTICAL PLANNING I

- 8739 OT **Multiple sensor estimation using a high-degree cubature information filter** [8739-30]
B. Jia, Intelligent Fusion Technology, Inc. (United States); M. Xin, Mississippi State Univ.
(United States); K. Pham, E. Blasch, Air Force Research Lab. (United States); G. Chen,
Intelligent Fusion Technology, Inc. (United States)

- 8739 0U **The Doppler Wind and Temperature Sounder (DWTS): enabling next-generation weather and space weather forecasts** [8739-31]
M. J. McHugh, L. L. Gordley, B. T. Marshall, D. C. Fritts, GATS, Inc. (United States); W. F. J. Evans, NorthWest Research Associates (United States); C. S. Fish, Utah State Univ., Space Dynamics Lab. (United States)
- 8739 0V **A highly sensitive multi-element HgCdTe e-APD detector for IPDA lidar applications** [8739-32]
J. Beck, J. McCurdy, M. Skokan, C. Kamilar, R. Scritchfield, T. Welch, P. Mitra, DRS Technologies, Network and Imaging Systems, Inc. (United States); X. Sun, J. Abshire, NASA Goddard Space Flight Ctr. (United States); K. Reiff, Analog Digital Integrated Circuits (United States)
- 8739 0X **Engineered plasma interactions for geomagnetic propulsion of ultra small satellites** [8739-34]
J. A. Palmer, System Planning Corp. (United States); J. J. Boerner, T. P. Hughes, G. R. Bennett, Sandia National Labs. (United States)
- 8739 0Y **Long-integration star tracker image processing for combined attitude-attitude rate estimation** [8739-36]
B. Sease, Univ. of Central Florida (United States); R. Koglin, Univ. of Akron (United States); B. Flewelling, Air Force Research Lab. (United States)

PROCESSING, EXPLOITATION, AND DECISION SUPPORT FOR ATTRIBUTIONS AND TACTICAL PLANNING II

- 8739 0Z **Automatic vehicle license plate recognition with color component texture detection and template matching** [8739-35]
J. Gao, Intelligent Fusion Technology, Inc. (United States); E. Blasch, K. Pham, Air Force Research Lab. (United States); G. Chen, D. Shen, Z. Wang, Intelligent Fusion Technology, Inc. (United States)
- 8739 10 **A fuzzy-logic based approach to color segmentation** [8739-37]
G. Zhao, Tianjin Univ. (China); Y. Li, California State Univ., Bakersfield (United States); G. Chen, Intelligent Fusion Technology, Inc. (United States); Q. Meng, W. Li, Tianjin Univ. (China) and California State Univ., Bakersfield (United States)
- 8739 11 **A holistic image segmentation framework for cloud detection and extraction** [8739-38]
D. Shen, Intelligent Fusion Technology, Inc. (United States); H. Xu, Temple Univ. (United States); E. Blasch, G. Horvath, K. Pham, Air Force Research Lab. (United States); Y. Zheng, Alcorn State Univ. (United States); H. Ling, Temple Univ. (United States); G. Chen, Intelligent Fusion Technology, Inc. (United States)

Author Index

Conference Committee

Symposium Chair

Kenneth R. Israel, Major General (USAF Retired) (United States)

Symposium Cochair

David A. Whelan, Boeing Defense, Space, and Security
(United States)

Conference Chairs

Khanh D. Pham, Air Force Research Laboratory (United States)
Joseph L. Cox, Missile Defense Agency (United States)
Richard T. Howard, NASA Marshall Space Flight Center (United States)
Genshe Chen, Intelligent Fusion Technology, Inc. (United States)

Conference Program Committee

Lisa Belodoff, LightWorks Optics, Inc. (United States)
Thomas George, Zyomed Corporation (United States)
Richard T. Howard, NASA Marshall Space Flight Center (United States)
Ou Ma, New Mexico State University (United States)
Tien M. Nguyen, Raytheon Company (United States)
Andre Samberg, Sec-Control Finland Ltd. (Finland)
Henry Zmuda, University of Florida (United States)

Session Chairs

- 1 Pervasive Technologies Supporting Responsive Space
Sarah T. Crites, University of Hawai'i at Manoa (United States)
Richard T. Howard, NASA Marshall Space Flight Center (United States)
- 2 Space Payload Technologies for Dual Military-Civil Operations
Sarah T. Crites, University of Hawai'i at Manoa (United States)
Richard T. Howard, NASA Marshall Space Flight Center (United States)
- 4 Sensor Contamination Detection, Abatement, and Effects
Sarah T. Crites, University of Hawai'i at Manoa (United States)
Richard T. Howard, NASA Marshall Space Flight Center (United States)
- 5 Cognitive Optics and Advanced Technology Demonstration
Sarah T. Crites, University of Hawai'i at Manoa (United States)
Richard T. Howard, NASA Marshall Space Flight Center (United States)

- 6 Tracking, Telemetry, and Control for Space Situational Awareness
Sarah T. Crites, University of Hawai'i at Manoa (United States)
Richard T. Howard, NASA Marshall Space Flight Center (United States)
- 8 Connectivity and Dissemination for Cognitive Space Communications
Sarah T. Crites, University of Hawai'i at Manoa (United States)
Richard T. Howard, NASA Marshall Space Flight Center (United States)
Genshe Chen, Intelligent Fusion Technology, Inc. (United States)
Dan Shen, Intelligent Fusion Technology, Inc. (United States)
- 9 Processing, Exploitation, and Decision Support for Attributions and Tactical Planning I
Sarah T. Crites, University of Hawai'i at Manoa (United States)
Richard T. Howard, NASA Marshall Space Flight Center (United States)
- 10 Processing, Exploitation, and Decision Support for Attributions and Tactical Planning II
Sarah T. Crites, University of Hawai'i at Manoa (United States)
Richard T. Howard, NASA Marshall Space Flight Center (United States)

Introduction

This conference, with this fifth successful consecutive offering in the operational concepts, principles and methodologies on sensors and systems for space applications, reflects a consensus of those participating from all over the globe. This international collaboration explores a range of science and technology destined for space or operating through space to enable robust and resilient space systems and operations in contested environments. Our varied interests include processing, exploitation, decision support for attributions, communications, tactical planning from space payloads, and pervasive technologies supporting responsive space with cognitive optics, connectivity and agile satellite radios.

The plenary presentation initiated technical discussions on the focus area of on/off-board Time Division Multiple Access (TDMA) scheduling to robustly disseminate schedules to remotely piloted aircraft for compact low-cost Low-Earth-Orbiting satellite communications without satellite radio beacons and knowledge of satellite locations. Assisted by the conference chair (Dr. Khanh Pham), Dr. Tien Nguyen, Chief engineer and Engineering Fellow from Raytheon/Space and Airborne Systems provided an overview of existing RF beacon techniques used for TDMA scheduling and stimulated technical inputs from the conference attendees by describing initial thoughts on the beaconless TDMA scheduling approaches. Future technologies anticipated herein will help increase the Air Force capabilities while operating in denied, limited or anti-access environments.

To date there have been nearly 200 papers published in these proceedings. Since its initiation in 2008, the title has been modified from Modeling, Simulation and Verification of Space-based Systems III to reflect the broadening of the scope of the conference to include the state of the art not only from modeling, simulation and support test verification related to space-based sensors and systems but also tracking, telemetry and control for space situational awareness. The enhanced scope also includes theoretical and application oriented connectivity and dissemination for cognitive space RF communications. As the title indicates these proceedings are spread across the three key facets of the developments in the field, namely space payload technologies for dual military-civil operations; tracking, telemetry, and control for space situational awareness; and connectivity and dissemination for cognitive satellite radios. As has been the practice, and driven by the command, control, and communications (C3) autonomy technology developer community and the spacecraft mission community, presentations have been grouped this year into nine sessions, adaptively categorized to represent the changing interests of our participants:

- Pervasive Technologies Supporting Responsive Space
- Space Payload Technologies for Dual Military-Civil Operations
- Sensor Contamination Detection, Abatement, and Effects
- Cognitive Optics and Advanced Technology Demonstration
- Tracking, Telemetry, and Control for Space Situational Awareness
- Plenary Presentation
- Connectivity and Dissemination for Cognitive Space Communications
- Processing, Exploitation, and Decision Support for Attributions and Tactical Planning

Each year, representatives from our program committee consisting of conference participants from academia, government, and commercial sectors involved in space, exchange ideas and promote the discussion of salient research, applications and recent developments in a number of space sensor technology areas and C3 autonomy in space. Toward this end, we plan to continue this series and look forward to your readership of these proceedings and participation with the program committee to continue to rejuvenate the growth of this conference and broaden its appeal within the space community in coming years. Further details regarding the call for papers and schedule for next year will be made available in due course at SPIE (www.spie.org).

We are pleased to acknowledge the authors for choosing this conference for publication of their extraordinary technical achievements. We also would like to take this opportunity to thank the members of our program committee and the session chairs for their tireless support to make this conference another success despite of continued budget cuts, government travel restrictions, and DoD sequestration. Thanks are also due to SPIE staff for their invaluable help in making this all possible.

Khanh D. Pham
Joseph L. Cox
Richard T. Howard
Genshe Chen