

PROCEEDINGS OF SPIE

# ***CubeSats and NanoSats for Remote Sensing II***

**Thomas S. Pagano  
Charles D. Norton**  
*Editors*

**21–22 August 2018  
San Diego, California, United States**

*Sponsored and Published by*  
SPIE

**Volume 10769**

Proceedings of SPIE 0277-786X, V. 10769

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

CubeSats and NanoSats for Remote Sensing II, edited by Thomas S. Pagano,  
Charles D. Norton, Proc. of SPIE Vol. 10769, 1076901 · © 2018 SPIE  
CCC code: 0277-786X/18/\$18 · doi: 10.1117/12.2516550

Proc. of SPIE Vol. 10769 1076901-1

The papers 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. Additional papers and presentation recordings may be available online in the SPIE Digital Library at SPIEDigitalLibrary.org.

The papers 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 these proceedings:

Author(s), "Title of Paper," in *CubeSats and NanoSats for Remote Sensing II*, edited by Thomas S. Pagano, Charles D. Norton, Proceedings of SPIE Vol. 10769 (SPIE, Bellingham, WA, 2018) Seven-digit Article CID Number.

ISSN: 0277-786X  
ISSN: 1996-756X (electronic)

ISBN: 9781510621091  
ISBN: 9781510621107 (electronic)

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 © 2018, 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](http://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/18/\$18.00.

Printed in the United States of America.

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

**SPIE. DIGITAL  
LIBRARY**

[SPIEDigitalLibrary.org](http://SPIEDigitalLibrary.org)

---

**Paper Numbering:** *Proceedings of SPIE* follow an e-First publication model. A unique citation identifier (CID) number is assigned to each article at the time of 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 and print versions of the publication. SPIE uses a seven-digit CID article numbering system structured as follows:

- The first five 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.

# Contents

vii	<i>Authors</i>
xi	<i>Conference Committee</i>

---

## ATMOSPHERE, WEATHER, AND CLIMATE

---

10769 03	<b>A novel CubeSat payload for airglow measurements in the mesosphere and lower thermosphere</b> [10769-2]
10769 04	<b>Architectures for Earth-observing CubeSat scatterometers</b> [10769-3]
10769 05	<b>A GNSS receiver for small-sats enabling precision POD, radio occultations, and reflections</b> [10769-4]
10769 06	<b>Technology development in support of hyperspectral infrared atmospheric sounding in a CubeSat</b> [10769-5]
10769 07	<b>CubeSat active thermal management in support of cooled electro-optical instrumentation for advanced atmospheric observing missions</b> [10769-6]
10769 08	<b>Overview of the NASA TROPICS CubeSat constellation mission</b> [10769-7]

---

## LAND AND OCEAN I

---

10769 0B	<b>Snow and Water Imaging Spectrometer (SWIS): CubeSat configuration and design</b> [10769-9]
10769 0C	<b>Hawkeye ocean color instrument: performance summary</b> [10769-10]

---

## LAND AND OCEAN II

---

10769 0D	<b>Constellations of CubeSats to exploit signals-of-opportunity for Earth system science</b> [10769-35]
----------	---

---

## PLANETARY AND HUMAN EXPLORATION

---

10769 0G	<b>Nature of and lessons learned from Lunar Ice Cube and the first deep space Cubesat 'cluster'</b> [10769-14]
10769 0H	<b>The Lunar Flashlight CubeSat instrument: a compact SWIR laser reflectometer to quantify and map water ice on the surface of the moon</b> [10769-15]

- 10769 OI **Overview of Phobos/Deimos Regolith Ion Sample Mission (PRISM) concept** [10769-16]
- 10769 OJ **Overview of Primitive Object Volatile Explorer (ProVE) Cubesat or Smallsat concept** [10769-17]
- 10769 OK **A constellation of MicroSats to search for NEOs** [10769-20]
- 10769 OL **Inter-satellite omnidirectional optical communicator for remote sensing** [10769-21]

---

#### HIGH-POWER LASERS AND FT-IR SPECTROMETERS FOR CUBESAT DEPLOYMENT I

---

- 10769 OM **A CubeSat mission for space-environment demonstration of Remote Laser-Evaporative Molecular Absorption (R-LEMA) spectroscopy sensor system concept (Invited Paper)** [10769-22]
- 10769 ON **Remote Laser Evaporative Molecular Absorption (R-LEMA) spectroscopy laboratory experiments** [10769-23]
- 10769 OO **Experimental design for remote laser evaporative molecular absorption spectroscopy sensor system concept** [10769-24]
- 10769 OP **Control system development for an R-LEMA testing CubeSat experiment** [10769-25]
- 10769 OQ **High-power laser subsystem for a 6U CubeSat mission** [10769-26]
- 10769 OR **Spectrometer subsystem for a CubeSat mission to test Remote Laser-Evaporative Molecular Absorption (R-LEMA) spectroscopy concept in the space environment** [10769-27]
- 10769 OS **Energy subsystem analysis for a 6U CubeSat mission utilizing high-power laser and FT-IR spectrometer** [10769-28]

---

#### HIGH-POWER LASERS AND FT-IR SPECTROMETERS FOR CUBESAT DEPLOYMENT II

---

- 10769 OT **Thermal control analysis on a 6U CubeSat equipped with a high-power laser** [10769-29]
- 10769 OU **Preliminary studies of the impact on temperature of a high-power laser on-board a 6U CubeSat** [10769-30]
- 10769 OV **Analysis of a dual CubeSat communication system for a formation-flying experiment** [10769-31]

---

#### OTHER SENSORS

---

- 10769 OW **Evaluation of UV optics for triple tiny ionospheric photometers on CubeSat missions** [10769-32]
- 10769 OX **A small satellite mission for solar coronagraphy** [10769-33]

10769 0Y **LetSat-1: a GPU technology demonstrator and AI navigation system** [10769-34]

**POSTER SESSION**

---

- 10769 14 **Advanced multi-mission operations system instrument toolkit: an open source instrument and small satellite operations toolkit** [10769-41]
- 10769 15 **Omnidirectional optical transceiver design techniques for multi-frequency full duplex CubeSat data communication** [10769-42]



# Authors

Numbers in the index correspond to the last two digits of the seven-digit citation identifier (CID) article numbering system used in Proceedings of SPIE. The first five digits reflect the volume number. Base 36 numbering is employed for the last two digits and indicates the order of articles within the volume. Numbers start with 00, 01, 02, 03, 04, 05, 06, 07, 08, 09, 0A, 0B...0Z, followed by 10-1Z, 20-2Z, etc.

Abesamis, Carlo, 06  
Adams, Arn, 06  
Albuquerque, Davi S., 0S  
Alves, Vinicius P., 0M  
Anderson, L., 07  
Andrade, Andres, 06, 0B  
Annane, B., 08  
Aslam, Shahid, 0J  
Assis, Bruno, 0M  
Atlas, R., 08  
Aumann, Hartmut, 06  
Bagheri, Mahmood, 0H  
Bauer, James, 0J  
Bellardo, John M., 0B  
Bender, Holly A., 0B  
Bennartz, R., 08  
Bittencourt, Ricardo S., 0O, 0S  
Blackwell, W. J., 08  
Boyraz, Ozdal, 0L, 15  
Brambora, Cliff, 0G  
Brashears, Travis, 0N  
Braun, S., 08  
Bretzke, Thomas K., 0M  
Brouwer, Dane, 0N  
Brown, Charles M., 0W  
Brown, Kevin, 0J  
Buckley, Matt, 06  
Budzien, Scott A., 0W  
Bujold, Emily, 0G  
Cabral, Amanda T., 0M  
Cappucci, S., 07  
Casaril, Lucas, 0P  
Cavalcante, Willians G., 0S  
Champoski, Daniel, 0M  
Chirokova, G., 08  
Christophersen, H., 08  
Cirilo, Edinan H., 0O  
Clark, Pamela, 0G, 0I, 0J  
Cohen, Alexander, 0N  
Cole, Jerold, 06  
Coleman, Thomas, 06  
Collier, Michael, 0I  
Costa, Mateus M. B., 0U, 0V  
Dahl, Luke B., 14  
Daly, Michael, 0J  
Davidson, R., 07  
De Carli, Eduardo, 0M  
DeMaria, M., 08  
DeNucci, Andrew, 0L  
de Souza, Melissa, 0M  
de Souza Wolniewicz, Mairon, 0P  
Dibraccio, Gina, 0I  
do Nascimento, Antonio C. R., Jr., 0V  
Dornelles, Guilherme L., 0T  
Dumont, Charles, 06  
Dunion, J., 08  
Dymond, Kenneth F., 0W  
Espley, Jared, 0I  
Esser, Chris, 06  
Esterhuizen, Stephan, 05  
Farrell, William M., 0G, 0I  
Feaga, Lori, 0J  
Feldman, Gene, 0C  
Felipe Pscheidt, Luiz, 0P  
Fernandez, Michael A., 0B  
Ferreira, Augusto R., 0S  
Folta, David, 0G, 0I, 0J  
Forouhar, Siamak, 0H  
Franco, Bárbara M., 0T  
Franklin, Garth, 05  
Freeman, Tony, 0D  
Galley, Chad, 05  
Garcia, Jhônatas H., 0T  
Garrison, James L., 0D  
Garro Brito, Alexandre, 0P  
Gibson, Megan, 0B  
Gillespie, Cole T., 0B  
Gong, Qian, 0X  
Good, Bill, 06  
Gopalswamy, N., 0X  
Gorius, Nicolas, 0J  
Graham, Richard, 06  
Greenwald, T., 08  
Griffin, Joseph, 0L  
Griscom, Chandler J., 0Y  
Grubb, Matt, 0G  
Guarnieri, Djulia L., 0T  
Gunapala, Sarath, 06  
Halekas, Jasper, 0I  
Hansen, Karl, 06  
Hayne, Paul O., 0H  
Heaton, Grigory J., 0B  
Heneghan, Cate, 06  
Herndon, D., 08  
Hewagama, Tilak, 0J  
Holmes, Alan, 0C  
Hughes, Gary B., 0M, 0N, 0O, 0P, 0Q, 0R, 0S, 0T, 0U, 0V

Hughes, Kyle M., 0I, 0J  
 Huleis, John, 0L  
 Hurford, Terry, 0G, 0J  
 Hurley, Dana, 0I  
 Iijima, Byron, 05  
 Inlow, Scott, 06  
 Jantsch, Gabriel, 0Q  
 Janzen, Andrew, 15  
 Jarnot, Robert, 06  
 Jennings, Donald, 0J  
 Jhaveri, Prabodh M., 0Y  
 Johnson, Dean, 06  
 Jones, Sarah L., 0I  
 Joyce, Michael J., 14  
 Kampe, Tom, 06  
 Kaufmann, Martin, 03  
 Keener, Elizabeth M., 0Y  
 Keller, John W., 0I  
 Keymeulen, Didier, 0B  
 Killen, Rosemary, 0I  
 Koppmann, Ralf, 03  
 Lamborn, Andy, 06  
 Larsen, Kameron, 05  
 Lee, Myron, 05  
 Lee, Shihyan, 0C  
 Lichtenberg, Byron K., 0Y  
 Liggett, Elliott H., 0B  
 Liu, Jehhal, 05  
 Livengood, Timothy, 0J  
 Long, David G., 04  
 Lopes, Gabriela C. L., 0Q  
 Loveland, Jessica, 0H  
 Lubin, Philip, 0N, 0O  
 Lugnani de Souza, Bruno, 0P  
 Lunsford, Al, 0G  
 Luong, S., 07  
 Luz, Ana, 0M  
 MacDowall, Robert, 0G  
 Madajian, Jonathan, 0N, 0O  
 Maghsoudi, E., 07  
 Malphrus, Benjamin, 0G, 0I, 0J  
 Mantel, Klaus, 03  
 Marconcini Roberto, Gabriel F., 0S  
 Marks, F., 08  
 Marquis, Peter J., 0W  
 Maruyama, Yuki, 06  
 Mastropietro, A. J., 07  
 Mckinley, I., 07  
 Meehan, Thomas, 05  
 Mika, Jefferson, 0V  
 Miller, Benton, 0N, 0O  
 Moore, John, 06  
 Morais, Karina, 0M  
 Morrison, John M., 0C  
 Morsch Filho, Edemar, 0U  
 Moura, Pedro Santos, 0M  
 Moura, Yan, 0M  
 Mouroulis, Pantazis, 0B  
 Mumma, Michael, 0J  
 Murchie, Scott, 0I  
 Nicholas, Andrew C., 0W  
 Nicol, Fred, 06  
 Nicolau, Vicente P., 0U  
 Nixon, Conor, 0J  
 Novaes, Luiz G. C., 0M  
 Oba, Renato, 0U  
 Olschewski, Friedhelm, 03  
 Pagano, Thomas S., 06  
 Paine, Christopher G., 0H  
 Paiva, Kleber V., 0T, 0U  
 Patt, Fred, 0C  
 Peng, Michael Y., 15  
 Piacentine, Joe, 06  
 Pienta, Paola N., 0Q  
 Possamai, Talita S., 0U  
 Rafol, Sir, 06  
 Rais-Zadeh, Mina, 0H  
 Raouf, Nasrat, 06  
 Rider, David, 06  
 Riese, Martin, 03  
 Riva, Luis F. O., 0T  
 Rivkin, Andrew S., 0I  
 Rodrigues, Lillian, 0R  
 Rogers, R., 08  
 Rossini, Nicolás, 0M  
 Rotter, Daniel V., 0M  
 Rupert, Nicholas, 0N  
 Saini, Navtej, 0K  
 Sanders, Devon, 06  
 Santiago, Rodrigo, 0U  
 Santos, Pedro M. R., 0M  
 Sarantos, Menelaos, 0I  
 Schaible, Micah, 0I  
 Schenguer, Katryn A., 0M  
 Schneider, Steve, 06  
 Sellar, R. Glenn, 0H  
 Serpa, Bruno, 0M  
 Shah, Rashmi, 0D  
 Shao, Michael, 0K  
 Shelton, Jacob, 0H  
 Sizemore, Nicholas N., 0B  
 Smith, Christopher D., 0B  
 Snyder, Tomas, 0O  
 Soto, Juancarlos, 06  
 Sposto, Lorraine, 14  
 Spricigo, Gabriel, 0M  
 Srinivasan, Prashant, 0N, 0O  
 Stephan, Andrew W., 0W  
 Strickland, William, 0N  
 Stubbs, Timothy, 0I  
 Su, Jessie, 0N  
 Sucich, Amber, 0O  
 Sullivan, Peter, 0B  
 Sunshine, Jessica, 0J  
 Swenson, C., 07  
 Tagliatenha, Silvia L. S., 0M  
 Teodoro, Gabriel, 0V  
 Ting, Dave, 06  
 Torun, Rasul, 15  
 Trahan, Russell, 0K



Tumelero, Breno L., 0M  
Turyshchev, Slava G., 0K  
Velazco, Jose E., 0L, 15  
Velden, C., 08  
Vengel, Tony, 06  
Vieira, Dayane, 0M  
Villanueva, Geronimo, 0J  
Vinckier, Quentin, 0H  
Vondrak, Richard, 0I  
Walter, Rebecca, 06  
Walton, M. Patrick, 04  
Wang, Yu, 0N, 0O  
Wehmeier, Udo, 0H  
Wernicke, Danny, 0L  
White, Clifford N., 0Y  
Wilson, Dan, 06  
Wilzcewski, Sarah, 0G  
Winche, Yuri, 0R  
Wolfram, Kenneth D., 0W  
Yee, Karl, 06  
Young, Larry, 05  
Zaman, Imam Uz, 0L, 15  
Zavodsky, B., 08  
Zeigler, Matt, 06  
Zhai, Chengxing, 0K  
Zhou, Hanying, 0K  
Zucherman, Aaron, 0J



# Conference Committee

## *Program Track Chair*

**Allen H.-L. Huang**, University of Wisconsin-Madison (United States)

## *Conference Chairs*

**Thomas S. Pagano**, Jet Propulsion Laboratory (United States)

**Charles D. Norton**, Jet Propulsion Laboratory (United States)

## *Conference Program Committee*

**Sachidananda R. Babu**, NASA Earth Science Technology Office  
(United States)

**William J. Blackwell**, MIT Lincoln Laboratory (United States)

**Pamela E. Clark**, Jet Propulsion Laboratory (United States)

**Siegfried W. Janson**, The Aerospace Corporation (United States)

**Clarence M. Korendyke**, U.S. Naval Research Laboratory  
(United States)

**Benjamin K. Malphrus**, Morehead State University (United States)

**Pamela Millar**, NASA Goddard Space Flight Center (United States)

**Pantazis Mouroulis**, Jet Propulsion Laboratory (United States)

**Jordi Puig-Suari**, California Polytechnic State University,  
San Luis Obispo (United States)

**Jeffery J. Puschell**, Raytheon Space and Airborne Systems  
(United States)

**Aaron Ridley**, University of Michigan (United States)

**Charles M. Swenson**, Utah State University (United States)

## *Session Chairs*

- 1 Keynote Session  
**Charles D. Norton**, Jet Propulsion Laboratory (United States)
- 2 Atmosphere, Weather, and Climate  
**Thomas S. Pagano**, Jet Propulsion Laboratory (United States)
- 3 Land and Ocean I  
**Pantazis Mouroulis**, Jet Propulsion Laboratory (United States)
- 4 Land and Ocean II  
**Pantazis Mouroulis**, Jet Propulsion Laboratory (United States)

- 5 Planetary and Human Exploration  
**Pamela E. Clark**, Jet Propulsion Laboratory (United States)
- 6 High-Power Lasers and FT-IR Spectrometers for CubeSat Deployment I  
**Siegfried W. Janson**, The Aerospace Corporation (United States)
- 7 High-Power Lasers and FT-IR Spectrometers for CubeSat  
Deployment II  
**Siegfried W. Janson**, The Aerospace Corporation (United States)
- 8 Other Sensors  
**Benjamin K. Malphrus**, Morehead State University (United States)
- 9 Enabling Technologies  
**Sachidananda R. Babu**, NASA Earth Science Technology Office  
(United States)  
**Robert Bauer**, NASA Goddard Space Flight Center (United States)