PROCEEDINGS OF SPIE

# *Space Exploration Technologies*

**Wolfgang Fink**
*Editor*

**17–18 March 2008**
**Orlando, Florida, USA**

*Sponsored and Published by*
SPIE

**Volume 6960**

Proceedings of SPIE, 0277-786X, v. 6960

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 *Space Exploration Technologies*, edited by Wolfgang Fink, Proceedings of SPIE Vol. 6960 (SPIE, Bellingham, WA, 2008) Article CID Number.

ISSN 0277-786X
ISBN 9780819471512

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



Printed in the United States of America.

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


SPIEDigitalLibrary.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 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

# Conference Committee

*Symposium Chair*

**Larry B. Stotts,** Defense Advanced Research Projects Agency (USA)

*Symposium Cochair*

**Ray O. Johnson,** Lockheed Martin Corporation (USA)

*Program Track Chairs*

**Thomas George,** ViaLogy Corporation (USA)
**Peter Tchoryk, Jr.,** Michigan Aerospace Corporation (USA)

*Conference Chair*

**Wolfgang Fink,** California Institute of Technology (USA)

*Program Committee*

**Danilo Bassi,** Universidad de Santiago de Chile (Chile)
**Bernard Foing,** International Lunar Exploration Working Group (ILEWG) (Netherlands) and European Space Agency, European Space Research and Technology Centre (ESA/ESTEC) (Netherlands)
**Roberto Furfaro,** The University of Arizona (USA)
**Jeffrey S. Kargel,** The University of Arizona (USA)

*Session Chairs*

1 Lunar and Planetary Exploration Technologies
**Bernard Foing,** International Lunar Exploration Working Group (ILEWG) (Netherlands) and European Space Agency, European Space Research and Technology Centre (ESA/ESTEC) (Netherlands)
**Wolfgang Fink,** California Institute of Technology (USA)

2 Airborne Platforms and Autonomous Navigation
**Danilo F. Bassi,** Universidad de Santiago de Chile (Chile)
**Wolfgang Fink,** California Institute of Technology (USA)

3 Robotic Resource Exploration and Low-Gravity Environments
**Jeffrey S. Kargel,** The University of Arizona (USA)
**Wolfgang Fink,** California Institute of Technology (USA)

4 Intelligent Sensors and Knowledge Discovery
**Roberto Furfaro,** The University of Arizona (USA)
**Wolfgang Fink,** California Institute of Technology (USA)

# Introduction

Space exploration technologies face several extreme environments, not only in interplanetary and orbital missions but also during in situ missions targeting planetary atmospheres, surfaces, and sub-surfaces. Terrestrial parallels exist in potentially hazardous or inaccessible operational areas on Earth such as those related to military (battlefield, check points, mine-fields), terrorist activities (stand-off detection of IEDs), or areas that have been exposed to bio-chemical agents, radiation, or natural disasters. Advanced technologies are required that go beyond conventional manned and robotic planetary exploration missions, which are inadequate to address the needs for the next generation of missions that will be necessary to pave the way for human exploration back to the Moon and to Mars, and also for autonomous deployment in battlefield scenarios.

In the particular case of reconnaissance missions, some of the key features to be afforded by future mission architectures include:

- Global to regional to local reconnaissance; mission safety and redundancy (i.e. fault-tolerance)
- (real time) Identification and characterization of transient events
- Targeted agent/sensor deployment in regions of interest (e.g., "hot" zones)
- Optimized target identification and obstacle avoidance
- Efficient commanding of multiple ground agents.

Potential applications range from planetary exploration and mining, to homeland security, border control, battlefield surveillance, harbor surveillance, maritime vessel tracking, telecommunications relay, and weather observations.

As with all space missions, payload mass, size, power consumption, and communication remain the overarching constraints/challenges. Moreover, to support and control future space exploration mission architectures, a high degree of operational autonomy is necessary. Essential requirements of such operation autonomy are:

- Automatic mapping of an operational area from different vantage points (i.e., space, airborne, surface/subsurface), including vehicle health monitoring
- Automatic feature extraction and target/region-of-interest/anomaly identification within the mapped operational area, which includes sensor data fusion, sensor interoperability, and intelligent data downlink
- Automatic target prioritization for close-up examination and timely counter-measures
- Automatic (targeted) deployment and (concurrent) navigation of sensor platforms and individual sensors.

The scope of the conference includes topics in basic research in hardware and software development, component and subsystem level development, and design and implementation of missions for space, defense, and homeland security applications.

**Wolfgang Fink**