

# **Advanced Maui Optical and Space Surveillance Technologies Conference 2011**

**(AMOS 2011)**

**Maui, Hawaii, USA  
13-16 September 2011**

**ISBN: 978-1-61839-432-3  
ISSN: 2152-4629**

**Printed from e-media with permission by:**

Curran Associates, Inc.  
57 Morehouse Lane  
Red Hook, NY 12571



**Some format issues inherent in the e-media version may also appear in this print version.**

Copyright© (2011) by the Maui Economic Development Board, Inc.  
All rights reserved.

Printed by Curran Associates, Inc. (2012)

For permission requests, please contact the Maui Economic Development Board, Inc.  
at the address below.

Maui Economic Development Board, Inc.  
AMOS Conference  
1305 N. Holopono Street, Suite 1  
Kihei, Hawaii 96753

Phone: (808) 875-2318  
Fax: (808) 875-0011

[info@amostech.com](mailto:info@amostech.com)

**Additional copies of this publication are available from:**

Curran Associates, Inc.  
57 Morehouse Lane  
Red Hook, NY 12571 USA  
Phone: 845-758-0400  
Fax: 845-758-2634  
Email: [curran@proceedings.com](mailto:curran@proceedings.com)  
Web: [www.proceedings.com](http://www.proceedings.com)

## 2011 AMOS CONFERENCE PROCEEDINGS

### SPACE SITUATIONAL AWARENESS

*Session Chair: Lt Col Jim Shell, Space Innovation & Development Center, USAF*

|   |    |
|---|----|
| <b>Space Situational Awareness in the Joint Space Operations Center</b> .....   | 8  |
| <i>Col Michael Wasson, JSpOC</i>  |    |
| <b>DREAM: An Integrated Space Radiation Nowcast System for Natural and Nuclear Radiation Belts</b> .....                                    | 10 |
| <i>Geoffrey Reeves, Los Alamos National Laboratory</i>  |    |
| <b>Space Domain Awareness (SDA)</b> .....   | 19 |
| <i>Lt Col Travis Blake, DARPA</i>   |    |
| <b>BMDS/SSA Integrated Sensing Demonstration (BISD)</b> .....   | 34 |
| <i>Terje Turner, Aerospace Corp.</i>  |    |
| <b>Unique Search and Track Procedures Utilizing the Ground-based Electro-Optical Deep Space Surveillance (GEODSS) Worldwide Sites</b> ..... | 38 |
| <i>Kenneth Grant, BAE Systems</i>   |    |
| <b>Space Fence PDR Concept Development Phase</b> .....  | 42 |
| <i>Phillip Phu, MIT LL</i>  |    |
| <b>Joint Space Operations Center (JSPOC) Mission System (JMS)</b> .....   | 52 |
| <i>Maj Michael Morton, HQ AFSPC, Directorate of Requirements</i>  |    |
| <b>AFSPC A5CS SSA Activities</b> .....  | 60 |
| <i>Hans Thatcher, HQ AFSPC, Directorate of Requirements</i>   |    |

### NON-RESOLVED OBJECT CHARACTERIZATION

*Session Chair: Matt Hejduk, a.i. solutions (AFSPC/A9A)*

|  |     |
|--|-----|
| <b>Non-Resolved Detection of Objects Performing On Orbit Servicing in Geostationary Orbit</b> .....                    | 63  |
| <i>Lauchie Scott, DRDC Ottawa</i>  |     |
| <b>Cylindrical RSO Signatures, Spin Axis Orientation and Rotation Period Determination</b> .....                       | 73  |
| <i>Phil Somers, Royal Military College of Canada</i>   |     |
| <b>Toward Realistic Dynamics of Rotating Orbital Debris and Implications for Light Curve Interpretation</b> .....      | 83  |
| <i>Gregory Ojakangas, Drury University</i>   |     |
| <b>AMOS Galaxy 15 Satellite Observations and Analysis</b> .....  | 94  |
| <i>Doyle Hall, Boeing LTS Maui</i>   |     |
| <b>Fingerprinting of Non-resolved Three-axis Stabilized Space Objects Using a Two-Facet Analytical Model</b> .....     | 102 |
| <i>Anil Chaudhary, Applied Optimization, Inc.</i>  |     |
| <b>Understanding Satellite Characterization Knowledge Gained from Radiometric Data</b> .....                           | 132 |
| <i>Andrew Harms, Air Force Research Laboratory</i>   |     |
| <b>Specular and Diffuse Components in Spherical Satellite Photometric Modeling</b> .....                               | 142 |
| <i>Matt Hejduk, a.i. solutions</i>   |     |
| <b>Measurement of the Photometric and Spectral BRDF of Small Canadian Satellites in a Controlled Environment</b> ..... | 153 |
| <i>Maj Donald Bedard, Royal Military College of Canada</i>   |     |

## OPTICAL SYSTEMS

*Session Chair: Lt Col Travis Blake, DARPA/TTO – Space Systems*

|  |     |
|--|-----|
| <b>USAF Academy Center for Space Situational Awareness</b> .....   | 163 |
| <i>Mike Dearborn, USAF Academy</i>   |     |
| <b>FalconSAT-7: A Photon Sieve Solar Telescope</b> .....   | 173 |
| <i>Geoff Andersen, USAF Academy</i>  |     |
| <b>Status of Telescope Fabra ROA Montsec: Optical Observations for Space Surveillance &amp; Tracking</b> .....                         | 177 |
| <i>Octavi Fors, Departament d'Astronomia i Meteorologia, Institut de Ciències del Cosmos (ICC), Universitat de Barcelona (IEEC-UB)</i> |     |
| <b>The HANDS-IONS Daytime Camera for GEO Satellite Characterization</b> .....  | 183 |
| <i>Kevin Jim, Oceanit Laboratories, Inc.</i>   |     |

## ORBITAL DEBRIS

*Session Chair: Eugene Stansbery, NASA-JSC*

|  |     |
|--|-----|
| <b>Pan-STARRS Status &amp; Geo Observation Results</b> .....   | 193 |
| <i>Mark Bolden, AFRL/RDSME</i>   |     |
| <b>A Search for Optically Faint GEO Debris</b> .....   | 200 |
| <i>Patrick Seitzer, University of Michigan</i>   |     |
| <b>Effective Search Strategy Applicable for Breakup Fragments in the Geostationary Region</b> .....  | 204 |
| <i>Toshiya Hanada, Kyushu University</i>   |     |
| <b>A New Orbital Analyst Tool for Associating Un-cataloged Analyst Debris with Historical Launches, Breakups, and Anomalous Events</b> ..... | 212 |
| <i>Bruce Bowman, AFSPC / A9</i>  |     |
| <b>Commercially-Hosted Payloads for Debris Monitoring and Mission Assurance in GEO</b> .....   | 222 |
| <i>Lt Col Jim Shell, US Air Force</i>  |     |

## SPACE-BASED ASSETS

*Session Chair: Seth Harvey, Air Force Research Laboratory*

|  |     |
|--|-----|
| <b>Benefits of Hosted Payload Architectures for Improved GEO SSA</b> .....                         | 232 |
| <i>Jonathan Lowe, Analytical Graphics, Inc.</i>  |     |
| <b>Demonstration of a Ka-Band Communication Path for On-Orbit Servicing</b> .....                  | 242 |
| <i>Ralf Purschke, Institute of Astronautics</i>  |     |
| <b>An Investigation into Using Differential Drag for Controlling A Formation of CubeSats</b> ..... | 251 |
| <i>Matthew Horsley, Lawrence Livermore National Laboratory</i>                                     |     |

## ASTRODYNAMICS

*Session Chair: Paul Cefola, University of Buffalo (SUNY)*

|  |     |
|--|-----|
| <b>The All-Versus-All Low Earth Orbit Conjunction Problem</b> .....                                | 260 |
| <i>Arthur Lue, MIT Lincoln Laboratory</i>  |     |
| <b>A High Performance Conjunction Analysis Technique for Cluster and Multi-Core Computers</b> .... | 270 |
| <i>Eric George, The Aerospace Corporation</i>  |     |
| <b>An Application of Hadoop and Horizontal Scaling to Conjunction Assessment</b> .....             | 282 |
| <i>Michael Prausa, The MITRE Corporation</i>   |     |
| <b>Efficient All-vs-All Collision Risk Analyses</b> .....  | 292 |
| <i>Miguel Molina, GMV Aerospace and Defence, S.A.</i>  |     |

|  |     |
|--|-----|
| <b>Maneuver Optimization through Simulated Annealing</b> .....   | 301 |
| <i>Willem de Vries, Lawrence Livermore National Laboratory</i>   |     |
| <b>Reconciling Covariances with Reliable Orbital Uncertainty</b> .....   | 309 |
| <i>Zachary Folcik, MIT Lincoln Laboratory</i>  |     |
| <b>Demonstration of the DSST State Transition Matrix Time-Update Properties using the Linux GTDS Program</b> ..... | 319 |
| <i>Paul Cefola, University at Buffalo (SUNY)</i>   |     |
| <b>Orbit Determination and Data Fusion in GEO</b> .....  | 340 |
| <i>Joshua Horwood, Numerica Corporation</i>  |     |

## ADAPTIVE OPTICS AND IMAGING

*Session Chair: Capt Casey Pellizzari, Air Force Research Laboratory*

|  |     |
|--|-----|
| <b>Comparison of Turbulence-Induced Scintillations for Multi-Wavelength Laser Beacons Over Tactical (7 km) and Long (149 km) Atmospheric Propagation Paths</b> ..... | 347 |
| <i>Mikhail Vorontsov, University of Dayton</i>   |     |
| <b>Inverse Synthetic Aperture LADAR for Geosynchronous Space Objects - Signal-to-Noise Analysis</b> .....  | 356 |
| <i>Capt Casey Pellizzari, Air Force Research Laboratory, Det 15</i>  |     |
| <b>Multi-Frame Blind Deconvolution: Compact and Multi-Channel Versions</b> .....   | 371 |
| <i>Douglas Hope, Institute for Astronomy, University of Hawaii</i>   |     |
| <b>Multi-Frame Myopic Deconvolution for Imaging in Daylight and Strong Turbulence Conditions</b> .....   | 377 |
| <i>Stuart Jefferies, HartSCI LLC</i>   |     |
| <b>Laser Guide Star Radiometry From Several Off Axis Locations</b> .....   | 383 |
| <i>Richard Tansey, Lockheed Martin</i>   |     |
| <b>Holographic Adaptive Laser Optics System (HALOS)</b> .....  | 393 |
| <i>Geoff Andersen, USAF Academy</i>  |     |
| <b>Quantifying Atmospheric Impacts on Space Optical Imaging and Communications</b> .....   | 396 |
| <i>Randall Alliss, Northrop Grumman Corporation</i>  |     |
| <b>Interferometric Imaging of Geostationary Satellites: Signal-to-Noise Considerations</b> .....   | 406 |
| <i>Anders Jorgensen, New Mexico Tech</i>   |     |

## POSTER PRESENTATIONS

*Session Chair: Bernie Klem, Arnold Engineering Development Center*

|  |     |
|--|-----|
| <b>Implementing Digital Feedback Controls for the Multiple Simultaneous Ring Cavities in the FASOR-X System</b> .....                                | 415 |
| <i>Jeffrey Baker, Boeing</i>   |     |
| <b>Using a Physics-Based Reflection Model to Study the Reddening Effect Observed in Spectrometric Measurements of Artificial Space Objects</b> ..... | 423 |
| <i>Maj Donald Bedard, Royal Military College of Canada</i>   |     |
| <b>Broadband Spectral-Polarimetric BRDF Scan System and Data for Spacecraft Materials</b> .....  | 433 |
| <i>David Bowers, Applied Technology Associates</i>   |     |
| <b>Benefits of a Geosynchronous Orbit (GEO) Observation Point for Orbit Determination</b> .....  | 442 |
| <i>Ray Byrne, Sandia National Laboratories</i>   |     |
| <b>Space Surveillance Tech Area Benefits from University Partnerships</b> .....  | 452 |
| <i>Kelly Cole, AFRL/RVEP</i>   |     |

|  |     |
|--|-----|
| <b>The Superior Lambert Algorithm</b> .....  | 462 |
| <i>Gim Der, DerAstrodynamics</i>   |     |
| <b>Innovative System of Very Wide Field Optical Sensors for Space Surveillance in the LEO Region</b> .....                     | 490 |
| <i>Linda Dimare, Department of Mathematics, University of Pisa</i>   |     |
| <b>Calibration Binaries</b> .....  | 500 |
| <i>Jack Drummond, AFRL/RDS</i>   |     |
| <b>Operational Collision Risk Management - Evaluating and Mitigating High Risk Conjunction Events</b> .....                    | 505 |
| <i>Matthew Duncan, SpaceNav</i>  |     |
| <b>KAM Torus Frequency Generation from Two Line Element Sets</b> .....   | 514 |
| <i>Capt Gregory Frey, U.S. Air Force</i>   |     |
| <b>Short-Arc Correlation and Initial Orbit Determination for Space-Based Observations</b> .....                                | 524 |
| <i>Kohei Fujimoto, The University of Colorado at Boulder</i>   |     |
| <b>A Comparison of Satellite Conjunction Analysis Screening Tools</b> .....  | 534 |
| <i>Eric George, The Aerospace Corporation</i>  |     |
| <b>An Update on SSA in Australia</b> .....   | 544 |
| <i>Neil Gordon, Defence Science and Technology Organisation (DSTO)</i>   |     |
| <b>Modeling and Simulation Design for Load Testing a Large Space High Accuracy Catalog</b> .....                               | 553 |
| <i>Barry Graham, Tybrin Corporation</i>  |     |
| <b>The Large Binocular Telescopes ARGOS Ground-Layer Adaptive Optics System</b> .....  | 559 |
| <i>Michael Hart, University of Arizona</i>   |     |
| <b>Sensor-Scheduling Simulation of Disparate Sensors for Space Situational Awareness</b> .....                                 | 571 |
| <i>Tyler Hobson, University of Queensland</i>  |     |
| <b>On-Orbit Range Set Applications</b> .....   | 581 |
| <i>Marcus Holzinger, University of Colorado at Boulder</i>   |     |
| <b>Computing and Visualizing Reachable Volumes for Maneuvering Satellites</b> .....  | 591 |
| <i>Ming Jiang, Lawrence Livermore National Laboratory</i>  |     |
| <b>Daytime Sky Brightness Modeling of Haleakala</b> .....  | 601 |
| <i>Kevin Jim, Oceanit Laboratories, Inc</i>  |     |
| <b>The Light Curves of a Geostationary Satellite and its Model</b> .....   | 611 |
| <i>Ho Jin, Kyung Hee University</i>  |     |
| <b>Streamlined Modeling for Characterizing Spacecraft Anomalous Behavior</b> .....   | 617 |
| <i>Bernie Klem, Arnold Engineering Development Center</i>  |     |
| <b>Detection of Artificial Satellites in Images Acquired in Track Rate Mode</b> .....  | 626 |
| <i>Martin Levesque, Defence Research &amp; Deveoplment, Canada</i>   |     |
| <b>Radar Calibration Using a Student-Built Nanosatellite</b> .....   | 636 |
| <i>Larry Martin, University of Hawaii</i>  |     |
| <b>Achievability of Cramer-Rao Lower Bounds by Multi-Frame Blind Deconvolution Algorithms, Part II: PSF Estimation</b> .....   | 641 |
| <i>Chuck Matson, Air Force Research Laboratory</i>   |     |
| <b>Visible and Near-Infrared Properties of Optical Fibers Coupled to the Pathfinder High-Resolution NIR Spectrograph</b> ..... | 650 |
| <i>Keegan McCoy, Pennsylvania State University</i>   |     |
| <b>Toward the Ground-Based Imaging of Satellites at Geosynchronous Altitude</b> .....  | 660 |
| <i>David Mozurkewich, Seabrook Engineering</i>   |     |

|  |     |
|--|-----|
| <b>Analysis of Galaxy 15 Satellite Images from a Small-Aperture Telescope</b> .....  | 670 |
| <i>Sergei Nikolaev, Lawrence Livermore National Laboratory</i>   |     |
| <b>Engineering the Ideal Gigapixel Image Viewer</b> .....  | 679 |
| <i>Dominik Perpeet, Fraunhofer IOSB</i>  |     |
| <b>Intuitive Space Weather Displays to Improve Space Situational Awareness (SSA)</b> .....   | 685 |
| <i>Paul Picciano, Aptima, Inc.</i>   |     |
| <b>The Magdalena Ridge Observatory’s 2.4-meter Fast-Tracking Telescope: Space<br/>Situational Awareness and the Near-Earth Environment</b> ..... | 692 |
| <i>Eileen Ryan, New Mexico Institute of Mining and Technology/MRO</i>  |     |
| <b>Learning Agents for Autonomous Space Asset Management (LAASAM)</b> .....  | 696 |
| <i>Larry Scally, Colorado Engineering, Inc.</i>  |     |
| <b>Simulated Synthesis Imaging of Geostationary Satellites</b> .....   | 706 |
| <i>Henrique Schmitt, CPI/NRL</i>   |     |
| <b>Optical Photon Counting Imaging Detectors with Nanosecond Time Resolution<br/>for Astronomy and Night Time Sensing</b> .....                  | 712 |
| <i>Oswald Siegmund, University of California, Space Sciences Laboratory</i>  |     |
| <b>Parallel-Computing Architecture for JWST Wavefront-Sensing Algorithms</b> .....   | 722 |
| <i>Jeffrey Smith, NASA Goddard Space Flight Center</i>   |     |
| <b>Improved Basis Functions for Dynamic Calibration of Semi-Empirical<br/>Thermospheric Models</b> .....   | 729 |
| <i>Eric Sutton, Space Vehicles Directorate</i>   |     |
| <b>Forecasting the Disturbed Storm Time (Dst) Index</b> .....  | 737 |
| <i>Charles Wetterer, Pacific Defense Solutions</i>   |     |
| <b>Sensor Exposure, Exploitation, and Experimentation Environment (SE4)</b> .....  | 745 |
| <i>Sam Wootton, The MITRE Corporation</i>  |     |
| <b>An Efficient Lucky Imaging System for Astronomical Image Restoration</b> .....  | 754 |
| <i>Shixue Zhang, Chinese Academy of Sciences</i>   |     |
| <br>   |     |
| <b>APPENDIX</b>  |     |
| <b>Conference Keynote</b> .....  | 762 |
| <i>General William L. Shelton, Commander, Air Force Space Command, U.S. Air Force</i>  |     |
| <b>Air Force Maui Optical &amp; Supercomputing Site Capabilities Tutorial</b> .....  | 769 |
| <b>List of Participants</b> .....  | 770 |
| <b>Conference Program</b> .....  | 775 |