

17th IAA Symposium on Space Debris 2019

Held at the 70th International Astronautical
Congress (IAC 2019)

Washington, DC, USA
21-25 October 2019

Volume 1 of 2

ISBN: 978-1-7138-1480-1

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© (2019) by International Astronautical Federation
All rights reserved.

Printed with permission by Curran Associates, Inc. (2020)

For permission requests, please contact International Astronautical Federation
at the address below.

International Astronautical Federation
100 Avenue de Suffren
75015 Paris
France

Phone: +33 1 45 67 42 60
Fax: +33 1 42 73 21 20

www.iafastro.org

Additional copies of this publication are available from:

Curran Associates, Inc.
57 Morehouse Lane
Red Hook, NY 12571 USA
Phone: 845-758-0400
Fax: 845-758-2633
Email: curran@proceedings.com
Web: www.proceedings.com

TABLE OF CONTENTS

VOLUME 1

SPACE DEBRIS DETECTION, TRACKING AND CHARACTERIZATION

OPTICAL DETECTION OF GEOSTATIONARY OBJECTS USING END-TO-END DEEP LEARNING.....	1
<i>Daqi Liu, Tat-Jun Chin, Thomas Rowntree</i>	
SIMULTANEOUS MULTI-SITE OPTICAL SETUP FOR IMPROVED POSITION AND ATTITUDE DETERMINATION	2
<i>Leonardo Parisi, Marco Acernese, Lorenzo Mariani, Stefania Melillo, Fabio Santoni</i>	
STAR SENSOR IMAGE PROCESSING FOR ORBITING OBJECTS DETECTION (SPOT): VISIBILITY ANALYSIS	4
<i>Vincenzo Schiattarella, Fabio Curti, Dario Spiller, Claudia Facchinetti, Luigi Ansalone, Alberto Tuozi</i>	
OPERATIONAL OBSERVATIONS OF LEO OBJECTS WITH OPTICAL SENSORS	6
<i>Noelia Sanchez Ortiz, Jaime Nomen, Raúl Domínguez-González, Nuria Guijarro, Daniel Lubian Arenillas</i>	
METHODS FOR DETECTING SUBTLE SPACE DEBRIS USING INFORMATION FROM OPTICAL TELESCOPES.....	18
<i>Natalia Zavialova, Alexander Rodin, Sergei Negodiaev, Iliia Perepechkin, Pavel Grishin</i>	
SUB-MILLIMETER SPACE DEBRIS MEASUREMENT IN LOW EARTH ORBIT: THE DEBRIS DENSITY RETRIEVAL AND ANALYSIS (DEDRA) MISSION	26
<i>Lisa Drudi, Andrea Meraner, Xanthi Oikonomidou, Alan Pettit</i>	
WISE THERMAL IR OBSERVATIONS OF IDCSP SATELLITES	37
<i>Patrick Seitzer, Chris H. Lee, Roc M. Cutri, Carl J. Grillmair, Jeremy J. Murray-Krezan, Thomas Schildknecht, Donald Bédard</i>	
DEVELOPMENT OF A HIGH FIDELITY SIMULATOR FOR GENERALISED PHOTOMETRIC BASED SPACE OBJECT CLASSIFICATION USING MACHINE LEARNING.....	41
<i>James Allworth, Lloyd Windrim, Jeffrey Wardman, Daniel Kucharski, James Bennett, Mitch Bryson</i>	
SPACE DEBRIS CHARACTERIZATION THROUGH THE SLOVAK DEBRIS LIGHT CURVE CATALOGUE.....	55
<i>Jiri Silha, Matej Zigo, Stanislav Krajcovic</i>	
COMPUTING SURFACE BRIGHTNESS INTEGRALS OF ARTIFICIAL AXISYMMETRIC SPACE OBJECTS FOR PHOTOMETRIC LIGHT CURVES	60
<i>Katiyayni Balachandran, Kamesh Subbarao</i>	
BIOMETRIC INSPIRED SATELLITE CHARACTERIZATION USING HYPERTEMPORAL PHOTOMETRY	67
<i>Vishnuu Mallik, Daniel Kucharski, Moriba Jah, Thomas Schildknecht</i>	

INFRARED DETECTION OF SPACE DEBRIS AND THE APPLICABILITY OF OBSERVATION DATA.....	68
<i>Marcel Becker, Enrico Stoll, Carsten Wiedemann, Andre Horstmann, Manuel Schubert, Paul Wagner, Wolfgang Riede, Lorenz Böttcher</i>	

SPACE WEATHER INDUCED OPTICAL CHANGES IN HAMR DEBRIS MATERIALS.....	72
<i>Daniel Engelhart</i>	

MODELLING AND RISK ANALYSIS

NUMERICAL INVESTIGATION ON THE STANDARD CATASTROPHIC BREAK-UP CRITERIA.....	82
<i>Martin Schimmerohn, Pascal Matura, Ercai Watson, Nathanaël Durr, Tiziana Cardone, Don De Wilde, Holger Krag, Frank Schäfer</i>	

FRAGMENTS DISTRIBUTION PREDICTION FOR ENVISAT CATASTROPHIC FRAGMENTATION.....	90
<i>Lorenzo Olivieri, Cinzia Giacomuzzo, Giulia Sarego, Alessandro Francesconi, Stefan Frey, Camilla Colombo</i>	

A SEMI-ANALYTICAL APPROACH TO LOW-THRUST COLLISION AVOIDANCE MANOEUVRE DESIGN.....	92
<i>Juan Luis Gonzalo, Camilla Colombo, Pierluigi Di Lizia</i>	

LONG-TERM ENVIRONMENTAL EFFECTS OF DEPLOYING THE ONEWEB SATELLITE CONSTELLATION.....	101
<i>Hugh Lewis, Timothy Maclay, J. P. Sheehan, Michael Lindsay</i>	

HOW AN AWARE USAGE OF THE LONG-TERM DYNAMICS CAN IMPROVE THE LONG-TERM SITUATION IN THE LEO REGION.....	112
<i>Alessandro Rossi, Elisa Maria Alessi, Volker Schaus, Giulia Schettino, Giovanni B. Valsecchi</i>	

NEWSPACE AND ITS IMPLICATIONS FOR SPACE DEBRIS MODELS.....	120
<i>Samuel Diserens, Hugh Lewis, Jörg Fliege</i>	

IMPACTS OF LARGE CONSTELLATIONS AND MISSION DISPOSAL GUIDELINES ON THE FUTURE SPACE DEBRIS ENVIRONMENT.....	130
<i>Gregory Henning, Marlon Sorge, Glenn Peterson, Alan B. Jenkin, John McVey, Deanna Mains</i>	

VARIANCE-COVARIANCE SIGNIFICANT FIGURE REDUCTION AND ITS EFFECT ON COLLISION PROBABILITY CALCULATION.....	142
<i>Salvatore Alfano</i>	

WHAT IS THE COST OF NOT DOING DEBRIS REMEDIATION NOW?.....	197
<i>Darren McKnight, Daniel Oltrogge, Salvatore Alfano, Seth Speaks, John Macdonald</i>	

EVALUATION OF ACTIVE DEBRIS REMOVAL STRATEGY USING A DEBRIS EVOLUTIONARY MODEL.....	209
<i>Satomi Kawamoto, Nobuaki Nagaoka, Toshiya Hanada, Shuji Abe</i>	

THE OPTIMAL COLLISION AVOIDANCE MANEUVER WITH MULTIPLE OBJECTS IN GEO.....	219
<i>Kota Sato, Makoto Hanada, Yasuhiro Yoshimura, Toshiya Hanada, Taku Izumiyama, Ryu Shinohara</i>	

LONG-TERM EVOLUTION AND LIFETIME ANALYSES OF GEOSTATIONARY TRANSFER ORBITS WITH SOLAR RADIATION PRESSURE	227
<i>Yue Wang, Xuhui Luo, Xiaojie Wu, Shiwang Xing</i>	

IMPACT-INDUCED MISSION EFFECTS AND RISK ASSESSMENTS

SPACE DEBRIS RISK ASSESSMENT AND PROTECTION SCHEME DESIGN BASED ON SPACE STATION	241
<i>Liu Min</i>	
BALLISTIC LIMIT EQUATIONS FOR CYLINDER PROJECTILES IMPACTING WHIPPLE SHIELD.....	242
<i>Qiang Wu, Zizheng Gong, Guangming Song, Ming Li</i>	
PREDICTING PERFORATION AND RUPTURE OF COMPOSITE OVERWRAPPED PRESSURE VESSELS FOLLOWING AN ORBITAL DEBRIS PARTICLE IMPACT	243
<i>William P. Schonberg</i>	
NEW TECHNIQUE FOR LAUNCHING SPHERICAL PROJECTILE WITH MILLIMETER SCALE OVER 10 KM/S USING STRONG LASER-DRIVEN AND SOME EXPERIMENTS FOR WHIPPLE SHIELDS	247
<i>Zizheng Gong, Pinliang Zhang, Qiang Wu, Guangming Song, Ming Li, Yan Cao</i>	
BIGGER FRAGMENTS BIGGER PICTURE – CHARACTERIZING DEBRISAT FRAGMENTS	248
<i>Samantha Allen</i>	
EXAMINATION OF THE IMPLICATIONS OF LARGER DEBRISAT FRAGMENT CHARACTERISTICS.....	259
<i>Marlon Sorge, Deanna Mains</i>	
STUDY ON THE MECHANISM OF KINETIC ENERGY DISSIPATION OF GRADED IMPEDANCE MATERIALS WITH HIGH EFFICIENCY	268
<i>Guangming Song, Ming Li, Zizheng Gong, Qiang Wu, Pinliang Zhang, Yan Cao</i>	
STUDY OF THE TEMPERATURE EFFECTS ON THE SHIELDING PERFORMANCE OF A WHIPPLE SHIELD ENHANCED BY TI-AL-MG IMPEDANCE-GRADED MATERIALS	275
<i>Yan Cao, Zizheng Gong, Qiang Wu, Pinliang Zhang, Ming Li, Guangming Song</i>	
A SIMPLE MODEL FOR SHAPE EFFECTS IN HVI.....	282
<i>Lorenzo Olivieri, Cinzia Giacomuzzo, Giulia Sarego, Alessandro Francesconi</i>	
EXAMINATION OF SATELLITE COLLISION SCENARIOS SPANNING LOW TO HYPERVELOCITY ENCOUNTERS USING SEMI-EMPIRICAL MODELS	283
<i>Alessandro Francesconi, Lorenzo Olivieri, Giulia Sarego, Cinzia Giacomuzzo, Andrea Valmorbida, Darren McKnight</i>	
NUMERICAL EVALUATION OF THE INFLUENCE OF PRE-ARRANGED FAULT LINES IN THE FRAGMENTATION OF SATELLITES SUBJECTED TO HYPERVELOCITY COLLISIONS.....	291
<i>Giulia Sarego, Matteo Duzzi, Andrea Valmorbida, Lorenzo Olivieri, Cinzia Giacomuzzo, Alessandro Francesconi</i>	
HOW HYPERVELOCITY IMPACTS CAN AFFECT THE LISA MISSION – THE MIRAD STUDY.....	298
<i>Robin Putzar, Er kai Watson, Martin Schimmerohn, Patrik Kärräng, Mark Millinger</i>	

ASSESSING DEBRIS STRIKES IN SPACECRAFT TELEMETRY: DEVELOPMENT AND COMPARISON OF VARIOUS TECHNIQUES	308
<i>Anne Aryadne Bennett, Hanspeter Schaub, Russell Carpenter</i>	

MITIGATION - TOOLS, TECHNIQUES AND CHALLENGES

SERC RESEARCH PROGRAM 3 - A NEW CONJUNCTION AND THREAT WARNING CAPABILITY	323
---	-----

James Bennett, Michael Lachut, Daniel Kucharski, Sven Kevin Flegel, Marek Moeckel, James Allworth, David Kooymans, Alex Pollard, Craig Smith, Joseph O'Leary, Hansani Kaushalya Perera Thanippuli Kankanamalage, Richard Samuel

DEBRIS MITIGATION, HOW TO CHANGE AN “UGLY DUCKLING” SATELLITE IN A “SWAN” SATELLITE : THE EXAMPLE OF MICROSCOPE.....	325
--	-----

Valerio Cipolla, Christian Dupuy, Thomas Lienart

LONG-TERM SIMULATIONS TO ASSESS THE EFFECTS OF DRAG AND SOLAR SAILS ON THE SPACE DEBRIS ENVIRONMENT.....	335
--	-----

Camilla Colombo, Alessandro Rossi, Alessandro Francesconi, Florio Dalla Vedova, Juan Luis Gonzalo, Vitali Braun, Benjamin Bastida Virgili, Holger Krag

KICKING THE SPACE JUNK HABIT	350
------------------------------------	-----

Grant Bonin, Lars Hoffman

ENVIRONMENT CAPACITY AS AN EARLY MISSION DESIGN DRIVER	354
--	-----

Francesca Letizia, Stijn Lemmens, Holger Krag

ENVIRONMENTAL SUSTAINABILITY OF LARGE SATELLITE CONSTELLATIONS IN LOW EARTH ORBIT.....	369
--	-----

Carmen Pardini, Luciano Anselmo

THE H2020 REDSHIFT PROJECT: A SUCCESSFUL EUROPEAN EFFORT TOWARDS SPACE DEBRIS MITIGATION.....	381
---	-----

Alessandro Rossi, Elisa Maria Alessi, Giulia Schettino, James Beck, Ian Holbrough, Thorn Schleutker, Federico Letterio, Gonzalo Vicario De Miguel, Jonathan Becedas Rodríguez, Florio Dalla Vedova, Hedley Stokes, Camilla Colombo, Ioannis Gkolias, Franco Bernelli-Zazzera, Narcís Miguel Banos, Scott Walker, Federico Romei, Kleomenis Tsiganis, Despoina Skoulidou, Enrico Stoll, Volker Schaus, Rada Popova, Youngkyu Kim, Alessandro Francesconi, Lorenzo Olivieri, Simone Gerardin

COMPARISON OF DISPOSAL OPTIONS FOR TUNDRA ORBITS IN TERMS OF DELTA-V COST AND LONG-TERM COLLISION RISK.....	393
---	-----

Alan B. Jenkin, John McVey, David Emmert, Marlon Sorge

DEBRIS COLLISION MITIGATION FROM THE GROUND USING LASER GUIDE STAR ADAPTIVE OPTICS AT MOUNT STROMLO OBSERVATORY: RESULTS FROM THE FIRST ARTIFICIAL STAR EVER CREATED IN AUSTRALIAN SKIES.....	412
---	-----

Celine D'Orgeville, Tony Travouillon, Doris Grosse, Marcus Lingham, Francis Bennet, James Webb, Visa Korkiakoski, Michael Copeland, Luke Gers, Antony Galla, John Hart, Ian Price, David Brodrick, Elliott Thorn, Noelia Martinez Rey, Craig Smith, Yue Gao, Yanjie Wang, Mark Blundell, Amy Chan, Andrew Gray, Gregory Fetzer, James Mason

DRAMA 3.0 - UPGRADE OF ESA'S DEBRIS RISK ASSESSMENT AND MITIGATION ANALYSIS TOOL SUITE	414
--	-----

Vitali Braun, Francesca Letizia, Quirin Funke, Stijn Lemmens, Silvia Sanvido

AEROTHERMODYNAMICS MODELLING OF COMPLEX SHAPES IN THE DEBRISK ATMOSPHERIC REENTRY TOOL: METHODOLOGY AND VALIDATION	422
<i>Julien Annaloro, Stéphane Galera, Cédric Thiebaut, Martin Spel, Pierre Van Hauwaert, Guillaume Grossir, Sébastien Paris, Olivier Chazot, Pierre Omaly</i>	

POST MISSION DISPOSAL AND SPACE DEBRIS REMOVAL (1)

THE IN-ORBIT TECHNOLOGIES DEMONSTRATIONS OF THE REMOVED DEBRIS MISSION	435
<i>Guglielmo Aglietti, Ben Taylor, Simon Fellowes, Thierry Salmon, Ingo Retat, Christopher Burgess, Thomas Chabot, Aurelien Pisseloup, Andy Phipps, Cesar Bernal, Francois Chaumette, Alexandre Pollini, Willem (Herman) Steyn, Charles Cox</i>	
THE ELSA-D END-OF-LIFE DEBRIS REMOVAL MISSION: PREPARING FOR LAUNCH	444
<i>Chris Blackerby, Akira Okamoto, Seita Iizuka, Yusuke Kobayashi, Kohei Fujimoto, Yuki Seto, Sho Fujita, Takashi Iwai, Nobu Okada, Jason Forshaw, Andy Bradford</i>	
DEMONSTRATION OF SPACE DEBRIS DEORBIT BY ELECTRODYNAMIC TETHER	452
<i>Zheng Hong Zhu</i>	
WHOLESALE LEO DEBRIS CAPTURE AND REMOVAL USING EDDE	455
<i>Joseph Carroll, Jerome Pearson, Eugene Levin</i>	
SIMULATION AND TENSION CONTROL OF A TETHER-ACTUATED CLOSING MECHANISM FOR NET-BASED CAPTURE OF SPACE DEBRIS	467
<i>Corey Miles, Eleonora Botta, Inna Sharf</i>	
FEASIBILITY ANALYSIS OF LARGE-SIZE SPACE DEBRIS DE-ORBITING FROM NEAR- EARTH ORBITS WITH RESPECT TO THE INITIAL MASS OF A FUELLED SC- COLLECTOR	481
<i>Dmitriy Grishko, Andrey Baranov, Andrey Sholmin</i>	
RAPID COMPUTATION OF MEO SATELLITE DEORBIT TIMES USING DOUBLY- AVERAGED DYNAMICS	490
<i>Marielle Pellegrino, Daniel Scheeres, Brett Streetman</i>	
A PERMANENT SOLUTION FOR CONTROLLING THE SMALL SPACE DEBRIS POPULATION	506
<i>Marshall Kaplan</i>	
IMPLEMENTATION OF A HIGH THRUST MONO-PROPELLANT ENGINE ON A PROPULSION MODULE	512
<i>Charles Gonin</i>	
GRASPING MECHANISM CONCEPTS ORIENTED TO DEBRIS FOR REMOVAL APPLICATION	519
<i>Michael Scarcia, Pierpaolo Palmieri</i>	

VOLUME 2

POST MISSION DISPOSAL AND SPACE DEBRIS REMOVAL (2)

CONFIGURATION SCHEMES OF ACTIVE SPACECRAFTS FOR REORBITING LARGE SIZE SPACE DEBRIS	527
<i>Georgy Shcheglov, Vera Mayorova, Mihail Stognii, Nikita Kamenev, Mark Borzenkov</i>	

HOW ON ORBIT FUELING SUPPORTS THE DEORBIT TUG BUSINESS CASE	537
<i>Jeremy Schiel, James Bultitude, Kasey Yang, Daniel Faber</i>	
SPACE STATION CONCEPT FOR ACTIVE DEBRIS REMOVAL APPLYING ECODESIGN PRINCIPLES.....	542
<i>Moacir Becker, Aureliano Rivolta, Alexander Owens, Shirrel Assis, Yanina Hallak, Rudiger Jehn, Olga Zhdanovich, Singh Palak, Tiago Soares</i>	
REDSHIFT DISPOSAL MODULE FOR THE DESIGN OF END-OF-LIFE DISPOSAL TRAJECTORIES FOR LEO TO GEO MISSIONS	556
<i>Camilla Colombo, Gonzalo Vicario De Miguel, Despoina Skoulidou, Narcis Miguel Banos, Elisa Maria Alessi, Ioannis Gkoliass, Livio Carzana, Federico Letterio, Giulia Schettino, Kleomenis Tsiganis, Alessandro Rossi</i>	
MODULAR AND LOW COST EXPANSION RESISTANCE INCREASING DE-ORBITING DEVICE FOR SMALL SATELLITE AND LARGE CONSTELLATION.....	572
<i>Zizheng Gong, Huifeng Tan, Danying Fu, Chuan Chen, Ming Li</i>	
IN-ORBIT PERFORMANCE OF DEORBITING SAILS.....	575
<i>Ben Taylor, Andrew Viquerat, Simon Fellowes, Brian Stewart, Bob Dyer, Roy Blows, Jason Shore, Mitchell Couper, Craig Underwood, Guglielmo Aglietti</i>	
RESULTS OF THE REMOVED DEBRIS VISION-BASED NAVIGATION FROM OPTICAL IMAGES.....	585
<i>Eric Marchand, Francois Chaumette, Thomas Chabot, Keyvan Kanani, Alexandre Pollini</i>	
CHARACTERIZING THE IMPACT OF ROTATIONAL VELOCITY ON A LASER-BASED DEBRIS REMOVAL SYSTEM	595
<i>Evan Gjesvold, Andrew Jones, Jeremy Straub, Thomas Cameron, Abdulaziz Alanazi, Benjamin Eichholz</i>	
PRELIMINARY DESIGN OF AN END-OF-LIFE ADR MISSION FOR LARGE CONSTELLATIONS.....	600
<i>Jason Forshaw, Reynolt De Vos Van Steenwijk, Stephen Wokes, Sean Ainley, Andy Bradford, John Auburn, Chris Blackerby, Nobu Okada</i>	
ESCAPE, DISPOSAL AND RE-ENTRY TRAJECTORIES FROM LUNAR NON-KEPLERIAN ORBITS.....	606
<i>Lorenzo Bucci, Michèle Lavagna</i>	
<u>OPERATIONS IN SPACE DEBRIS ENVIRONMENT, SITUATIONAL AWARENESS</u>	
ACHIEVEMENTS AND CHALLENGES IN MORE THAN 3 YEARS OF FULL OPERATION OF ASPOS OKP	614
<i>Vladimir Agapov, Nikolay Savin, Alexander Lapshin, Zakhary Khutorovsky</i>	
SOVEREIGN AUSTRALIAN SPACE SITUATIONAL AWARENESS	621
<i>Luke Heffernan, Jack Kelly</i>	
LAUNCH ACCESS TO SPACE IN THE PRESENCE OF LARGE LEO CONSTELLATIONS AND THE SPACE FENCE.....	626
<i>Glenn Peterson</i>	
DESIGN & DEVELOPMENT OF AN OPTIMIZED SENSOR SCHEDULING & TASKING PROGRAMME FOR TRACKING SPACE OBJECTS	633
<i>David Shteinman, James Bennett, Alexander Ryan</i>	

MAKING SMALL SATELLITES VISIBLE: NANOSAT TRACKING AND IDENTIFICATION TECHNIQUES AND TECHNOLOGIES	634
<i>Mark Skinner</i>	
REVISITING THE FILTERING PROBLEM.....	641
<i>Shambo Bhattacharjee, John T Kent, Weston Faber, Islam Hussein</i>	
AVOIDING COLLISIONS IN SPACE VIA AERODYNAMICALLY-INDUCED ALONG- TRACK ORBIT VARIATIONS	652
<i>Sanny Omar, Riccardo Bevilacqua</i>	
VALUE-ADDED SERVICES AT GEO DERIVED FROM PERSISTENT OBSERVATION	658
<i>Brien Flewelling</i>	
DATA FUSION APPLICATION FOR IMPROVING ORBIT DETERMINATION AND RE- ENTRY PREDICTIONS.....	670
<i>Elena Vellutini, Germano Bianchi, Carmen Pardini, Luciano Anselmo, Pierluigi Di Lizia, Mauro Massari, Matteo Losacco, Fabrizio Piergentili, Marco Acernese, Lorenzo Mariani, Shariar Hadji Hossein, Tonino Pisanu, Enrico Urru, Luca Schirru, Fabio Monaci, Moreno Peroni, Andrea Cecchini, Giuseppe D'Amore, Ettore Perozzi, Luca Lama, Claudio Bortolotti, Mauro Roma, Andrea Maccaferri, Fabio Santoni, Leonardo Parisi, Giovanni Purpura</i>	
ENHANCE THE TLE CATALOG THROUGH SHARING MACHINE LEARNING MODELS.....	680
<i>Xiaoli Bai, Hao Peng, Lesley Weitz, Scott Kordella</i>	

**POLICY, LEGAL, INSTITUTIONAL AND ECONOMIC ASPECTS OF SPACE DEBRIS
DETECTION, MITIGATION AND REMOVAL (JOINT SESSION WITH IAF SPACE
SECURITY COMMITTEE)**

RESEARCH ON THE DEVELOPMENT TREND ON LEGAL MECHANISM OF SPACE DEBRIS ACTIVE CLEARANCE	698
<i>Peng Sun, Xia Yu, Xiaoming Gao</i>	
CNES TOWARDS FUTURE SPACE TRAFFIC MANAGEMENT	704
<i>Christophe Bonnal, Laurent Francillout, Monique Moury, Ursula Aniakou, Pascal Faucher, Juan Carlos Dolado Perez, Julien Mariez, Sylvain Michel</i>	
POLITICAL AND INSTITUTIONAL CHALLENGES TO GLOBAL SPACE DEBRIS MITIGATION.....	712
<i>Josh Wolny, Madeleine Bronstein</i>	
SPACE ENVIRONMENT MANAGEMENT: FRAMING THE OBJECTIVE AND SETTING PRIORITIES FOR CONTROLLING ORBITAL DEBRIS RISK	720
<i>Timothy Maclay, Darren McKnight</i>	
THE RISE OF SMALL SATELLITES CONSTELLATIONS: ECONOMIC ANALYSIS AND POLITICAL MEASURES FOR ORBITAL DEBRIS PROBLEMS	725
<i>Clelia Iacomino</i>	
MEGA CONSTELLATIONS – LIABILITY AND INSURANCE ISSUES	735
<i>Cristiana Santos, Maria Lucas-Rhimbassen, Lucien Rapp</i>	
MEGA-CONSTELLATION ANALYSIS: RELIABILITY STRATEGY AND INSURANCE POLICY	743
<i>Nikita Veliev, Anton Ivanov, Shamil Biktimirov, Muriel Richard-Noca, Luc Piguet</i>	

AUTHORIZATION AND CONTINUOUS SUPERVISION OF ASTROSCALE'S DE-ORBIT ACTIVITIES: A REVIEW OF THE REGULATORY ENVIRONMENT FOR END OF LIFE (EOL) AND ACTIVE DEBRIS REMOVAL (ADR) SERVICES	750
<i>Charity Weeden, Luc Riesbeck, Chris Blackerby, Nobu Okada, Eriko Yamamoto, Jason Forshaw, John Auburn</i>	
SPACE SALVAGE & NATIONAL EFFORTS: POLICY AND LAW IMPACTING THE VALIDITY OF CLEANING UP ORBITAL SPACE	755
<i>Michael Dodge</i>	
SPACE SUSTAINABILITY RATING: TOWARDS AN ASSESSMENT TOOL TO ASSURE THE LONG-TERM SUSTAINABILITY OF THE SPACE ENVIRONMENT	762
<i>Minoo Rathnasabapathy, Danielle Wood, Moriba Jah, Diane Howard, Mike French, Carissa Christiansen, Ashley Schiller, Francesca Letizia, Holger Krag, Stijn Lemmens, Nikolai Khlystov, Maksim Soshkin</i>	
INTERNATIONAL LIABILITY AND RESPONSIBILITY IN THE CONTEXT OF SPACE DEBRIS REMOVAL	775
<i>Cordula Steinkogler</i>	
MATCHING LEGAL LIABILITIES WITH TECHNICAL SOLUTIONS TO GEOSTATIONARY ORBIT DEBRIS	787
<i>Mark Hempzell, Sebastiane Alexandra, Roger Longstaff</i>	
LEGAL FRAMEWORKS FOR SPACE DEBRIS MITIGATION: EXAMINING STATE PRACTICES AND TREATY OBLIGATIONS.....	794
<i>Senjuti Mallick</i>	
 <u>ORBIT DETERMINATION AND PROPAGATION</u>	
IRNSS-1H/PSLV-C39 ORBIT EVOLUTION AND RE-ENTRY ANALYSIS	812
<i>Satyendra Singh</i>	
BI-STATIC OBSERVATIONS WITH SMARTNET(TM)	813
<i>Johannes Herzog, Hauke Fiedler</i>	
ANALYSING THE CORRELATION PERFORMANCE OF ESA'S PLANNED SPACE-BASED GEO SURVEILLANCE MISSION	818
<i>Benedikt Reihls, Alessandro Vananti, Jan Siminski, Tim Flohrer, Thomas Schildknecht</i>	
TOWARDS COVARIANCE REALISM IN BATCH LEAST-SQUARES ORBIT DETERMINATION	826
<i>Sergi López-Jiménez, Alejandro Pastor-Rodríguez, Srinivas J. Setty, Diego Escobar Antón, Ernst Schrama, Alberto Águeda Maté</i>	
UNDERSTANDING THE DISTRIBUTION OF THE PROPAGATED ANGLES-ONLY POSITION VECTOR.....	838
<i>Shambo Bhattacharjee, John T Kent, Weston Faber, Islam Hussein</i>	
ON THE GAUSSIANITY VALIDITY TIME FOR ORBITAL UNCERTAINTY PROPAGATION	845
<i>Carlos Yanez, Mini Gupta, Vincent Morand, Juan Carlos Dolado Perez</i>	
CONJUGATE UNSCENTED TRANSFORMATION BASED SEMI-ANALYTIC APPROACH FOR UNCERTAINTY CHARACTERIZATION OF ANGLES-ONLY INITIAL ORBIT DETERMINATION ALGORITHMS	857
<i>Sean Hixon, David Schwab, Jason Reiter, Puneet Singla</i>	

HIGH-PRECISION DETECTION AND HIGH-SPEED TRACKING ALGORITHM FOR SPACE DEBRIS	866
<i>Jiangtao Wei, Xin Ning, Shichao Ma, Zhang Pihui</i>	
CLOSE APPROACH ANALYSIS FOR SENSOR TASKING	867
<i>Sven Kevin Flegel, Marek Moeckel, James Bennett</i>	
SPACE SURVEILLANCE WITH THE MULTIBEAM RADAR SENSOR BIRALES	876
<i>Matteo Losacco, Pierluigi Di Lizia, Mauro Massari, Germano Bianchi, Giuseppe Pupillo, Andrea Mattana, Giovanni Naldi, Claudio Bortolotti, Federico Perini, Luca Lama, Marco Schiaffino, Mauro Roma, Andrea Maccaferri, Alessio Magro, Denis Cutajar, Josef Borg, Fabio Monaci</i>	
OPTIMIZED RE-ENTRY TIME PREDICTION OF MOLNIYA ORBIT OBJECTS	884
<i>Harishkumar Sellamuthu, Ram Krishan Sharma, Benjamin John Solomon, Srinath Ravichandran, Syed Peer Mohamed Shah Khadri</i>	

JOINT SMALL SATELLITE/SPACE DEBRIS SESSION TO PROMOTE THE LONG-TERM SUSTAINABILITY OF SPACE

ENABLING A SUSTAINABLE LEO ENVIRONMENT THROUGH OPERATIONAL TRANSPARENCY	889
<i>Edward Lu, Michael Nicolls, Daniel Ceperley</i>	
USAGE OF LIGHT EMITTING DIODES FOR SMALL SATELLITES TRACKING, EARLY IDENTIFICATION AFTER LAUNCH AND LIGHT-BASED COMMUNICATION	897
<i>Paolo Marzioli, Andrea Gianfermo, Lorenzo Frezza, Diego Amadio, Federico Curianò, Niccolò Picci, Maria Giulia Pancalli, Eleonora Vestito, Justin Schachter, Matthew Szczerba, Daniel Gu, Anny Lin, James Cutler, Patrick Seitzer, Simone Pirrotta, Fabrizio Piergentili, Fabio Santoni</i>	
RESPONSIBLE SATELLITE DESIGN AND OPERATIONAL PRACTICES: A CRITICAL COMPONENT OF EFFECTIVE SPACE ENVIRONMENT MANAGEMENT (SEM)	904
<i>Timothy Maclay, Walt Everetts, Doug Engelhardt</i>	
IONOSPHERIC DRAG FOR ACCELERATED DEORBIT FROM UPPER LOW-EARTH-ORBIT	911
<i>Brenton Smith, Christopher Capon, Melrose Brown</i>	
AN OPEN-SOURCE ORBITAL SIMULATION AND MISSION ANALYSIS SOFTWARE FOR CUBESATS	924
<i>Conor O'Toole</i>	
A YEAR SINCE THE LAUNCH OF THE NABEO-1 CUBESAT DRAGSAIL ON ROCKET LAB'S "IT'S BUSINESS TIME" ROCKET: METHODS OF VERIFICATION AND OBSERVATION	925
<i>Thomas Sinn, Hugo Garcia Hemme, Steve Gehly, Samantha Le May</i>	
PW-SAT2 DEORBIT SAIL POST-DEPLOYMENT EFFECTIVENESS ANALYSIS	930
<i>Artur Lukasik, Dominik Roszkowski</i>	
TOWARDS A FUTURE DEBRIS REMOVAL SERVICE: EVOLUTION OF AN ADR BUSINESS MODEL	941
<i>Harriet Brettle, Jason Forshaw, John Auburn, Chris Blackerby, Nobu Okada</i>	

TOWARDS A COST EFFECTIVE IN-ORBIT SERVICING/ADR USING MODULAR AND STANDARIZED APPROACH.....	953
<i>Pablo Colmenarejo, Mariella Graziano</i>	

INTERACTIVE PRESENTATIONS - 17TH IAA SYMPOSIUM ON SPACE DEBRIS

DEVELOPMENT OF A UK NATIONAL IN-ORBIT SERVICING FACILITY.....	964
<i>Alexandra Gravereaux, Andrea Puppa, Alberto Fernandez, Jason Forshaw, John Auburn</i>	

RESEARCH ON COMMERCIAL OPERATION OF SPACE DEBRIS REMOVAL BASED ON LIABILITY INCENTIVES AND ECONOMIC INCENTIVES.....	965
<i>Xia Yu, Shu Zhang, Kun Dai</i>	

PARALLELIZING RADAR SIGNAL PROCESSING FOR SPACE SITUATIONAL AWARENESS IN THE GESTRA SYSTEM – A HYBRID APPROACH.....	970
<i>Christoph Reising, Robert Kohlleppel, Helmut Wilden, Nadya Ben Bekhti, Andreas Brenner, Thomas Eversberg</i>	

GROUND OPERATION EXPERIMENTAL SYSTEM AND OPERATION EXPERIMENT OF SPACE DEBRIS WITH LASERS.....	971
<i>Zizheng Gong, Wulin Yang, Chuan Chen, Ming Li</i>	

THE IMPACT OF LARGE CONSTELLATIONS ON SPACE DEBRIS ENVIRONMENT AND ITS COUNTERMEASURES.....	980
<i>Zizheng Gong, Chuan Chen, Wulin Yang, Ming Li</i>	

BLOCKCHAIN ENABLED SPACE TRAFFIC AWARENESS (BESTA).....	988
<i>Harvey Reed</i>	

DESIGN AND SIMULATIONS OF A PHASED ARRAY FEED FOR THE BIRALET RADAR.....	997
<i>Tonino Pisanu, Luca Schirru, Giacomo Muntoni, Alessandro Navarrini, Raimondo Concu, Enrico Urru, Andrea Melis, Pierluigi Ortu</i>	

IMPROVING LEO DEBRIS DRAG PREDICTION BY INFERRING SPIN AXIS.....	1004
<i>Joseph Carroll</i>	

A LONG-TERM DYNAMICAL EVOLUTION OF LARGE SATELLITE CONSTELLATION AND SPACE DEBRIS PROBLEM.....	1005
<i>Eduard Kuznetsov</i>	

RESEARCH ON PATH PLANNING OF FREE-FLOATING SPACE ROBOT BASED ON DUAL MODE SWITCHING.....	1008
<i>Zhanxia Zhu, Sigang Yu, Guanghui Zhang, Mingming Wang, Yuan Jianping</i>	

DEEP LEARNING BASED SPACE DEBRIS CAPTURE SCORING STUDY IN ON-ORBIT PROXIMITY OPERATION.....	1018
<i>Seongmin Lim, Jin-Hyung Kim, Ji-Seok Kim, Hae-Dong Kim</i>	

DESIGN AND TEST OF DRAG AUGMENTATION SYSTEM FOR DE-ORBITING KARDSAT NANO-SATELLITE.....	1019
<i>Ji-Seok Kim, Seongmin Lim, Hae-Dong Kim</i>	

COLLISION RISK ASSESSMENT FOR THE PROPOSED LARGE CONSTELLATIONS.....	1020
<i>Alexis Petit, Alessandro Rossi, Elisa Maria Alessi</i>	

ENHANCING THE ACCURACY OF THE SPACE OBJECT CATALOG USING MACHINE LEARNING TECHNIQUES.....	1028
<i>Romain Lucken</i>	
PRELIMINARY STUDY OF ARAMID FIBER CLOTH REMOVING THE SPACE DEBRIS	1029
<i>Fa-Wei Ke, Jie Huang, Xue-Zhong Wen, Xin Li, Qiang Song, Yao Long, Sen Liu</i>	
DAMAGE CHARACTERISTICS OF SPACE DEBRIS SHIELDS BY SIMULTANEOUS IMPACTS OF MULTIPLE HIGH-SPEED PROJECTILES	1035
<i>Gongshun Guan, Min Duan, Duo Zhang</i>	
LPUSAT - 1: A PIONEERING CUBESAT MISSION TO DETECT SMALL SIZED SPACE DEBRIS.....	1036
<i>Anirudh N Sharma, Rahul Rawat, Purini Sai Ganesh, G. Geetha</i>	
MODEL OF ATMOSPHERIC DENSITY GRADIENT TORQUE ACTED ON TIANGONG-1	1041
<i>Hou-Yuan Lin, Chang-Yin Zhao</i>	
A CONJUNCTION RISK ASSESSMENT OF THE CUBESAT SWARMS IN THE SUN- SYNCHRONOUS ORBIT	1042
<i>Qingbo Gan</i>	
AI TO SUPPORT DECISION MAKING IN COLLISION RISK ASSESSMENT.....	1043
<i>Luis Sanchez, Massimiliano Vasile, Edmondo Minisci</i>	
SMARTNET AND BACARDI.....	1060
<i>Hauke Fiedler, Johannes Herzog, Ralph Kahle, Michael Meinel, Marcel Prohaska, Kathrin Rack, Thomas Schildknecht, Martin Siggel, Martin Stoffers, Lynn Von Kurnatowski, Yi Wasser, Martin Weigel</i>	
BLOWING SPACE JUNK CLOUDS AWAY: THE COMPLIANCE OF RECOMMENDATIONS TO A SPACE DEBRIS REMOVAL NEW CONCEPT.....	1062
<i>Maria Messina, Sabrina Ricci, Rachele Maria D'Antonio, Alfonso Lamanna</i>	

Author Index