

IAF Space Exploration Symposium 2019

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

Washington, DC, USA
21-25 October 2019

ISBN: 978-1-7138-1477-1

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

SPACE EXPLORATION OVERVIEW

KEYNOTE: NASA SCIENCE UNDER THE NATIONAL SPACE EXPLORATION CAMPAIGN.....	1
<i>Green James, Tara Ruttle, Louis Barbier, Helen Grant, Xaivian Raymond</i>	
NASA’S HUMAN LUNAR EXPLORATION ENTERPRISE: DEVELOPING A DEEP SPACE INFRASTRUCTURE AND ESTABLISHING A SUSTAINABLE HUMAN PRESENCE ON THE MOON.....	7
<i>R. Marshall Smith, Douglas Craig, Nicole Herrmann, Erin Mahoney, Jonathan Krezel, Michele Gates, Lindsay Aitchison, Jacob Bleacher</i>	
THE CANADIAN LUNAR INITIATIVE: GATEWAY ROBOTICS AND LEAP.....	20
<i>Christian Lange, Erick Dupuis, Isabelle Tremblay, Ken Podwalski, Gilles Leclerc</i>	
“BOOTS ON THE MOON” THE KEY TO SUSTAINED EXPLORATION CAMPAIGN.....	25
<i>Walter Faulconer</i>	
GLOBAL PROSPECTS FOR SPACE EXPLORATION: \A STRATEGIC AND ECONOMIC ASSESSMENT	33
<i>Natalia Larrea Brito, Jan Clarence Dee</i>	
ROBOTIC LUNAR SURFACE OPERATIONS 2	39
<i>Alex Austin, Brent Sherwood, John Elliott, Miles Smith, Raul Polit Casillas, A. Scott Howe, Anthony Colaprete, Philip Metzger, Kris Zacny, Harrison Schmitt, Sandra Magnus, Michael Sims, Terry Fong</i>	
CONSIDERATIONS TO FOSTER INCLUSIVENESS IN FUTURE CISLUNAR SPACE ENDEAVORS.....	52
<i>Kwasi Nkansah, Laura Bettiol</i>	
NOVEL OPERATIONAL CONCEPTS TO ENABLE COMMERCIAL SPACE EXPLORATION	59
<i>Alvaro Alonso Ruiz</i>	
ELEMENTS OF HABITABILITY AND ITS RELATIONS TO SPATIAL DESIGN – A CONCEPT ANALYSIS	66
<i>Sandra Haeuplik-Meusburger</i>	

MOON EXPLORATION- PART 1

KEYNOTE: AN OVERVIEW OF NASA’S LUNAR SCIENCE EXPLORATION PLANS FOR ARTEMIS	67
<i>Steve Clarke</i>	
OVERVIEW OF THE ISRAELI LUNAR LANDER.....	68
<i>Ehud Hayun, Ephie Sagie, Meir Nissim Nir, Natalie Frenkel, Lutz Richter, Roland Grau</i>	
LOCKHEED MARTIN MCCANDLESS LUNAR LANDER CAPABILITIES FOR COMMERCIAL LUNAR PAYLOADS	73
<i>Josh Hopkins, Stuart Wiens, David Murrow, Timothy Linn</i>	

ALINA-2: INNOVATIONS ON PTSCIENTISTS' COMMERCIAL LUNAR LANDER	78
<i>Marcel Scherrmann, Sören Heizmann, Lukas Steindorf, Vincent Still, Martin Wagener, Ellen Hill, Donald Bryson, Tobias Flecht, Roman Court, Chaitanya Gopal, Jesse Eyer</i>	
DEVELOPMENT PROGRESS OF THE FIRST ISPACE PRIVATE LUNAR EXPLORATION MISSION	88
<i>Chit Hong Yam</i>	
CURRENT STATUS OF JAPANESE LUNAR POLAR EXPLORATION MISSION	96
<i>Takeshi Hoshino, Sachiko Wakabayashi, Makiko Ohtake, Yuzuru Karouji, Hitoshi Morimoto, Hiroaki Shiraishi, Takanobu Shimada, Tatsuaki Hashimoto, Hiroka Inoue, Hiroyasu Mizuno, Yoji Shirasawa, Hiroshi Kanamori, Takahiro Hayashi, Ryo Hirasawa</i>	
MOON EXPLORATION: A PRIVATE VIEW OF A PUBLIC-PRIVATE PARTNERSHIP	102
<i>David Masten, Sean Mahoney, Matthew Kuhns, Matt Bergman, Reuben Garcia, Tristan Cembrinski</i>	
COLMENA MISSION TO THE MOON	113
<i>Gustavo Medina Tanco</i>	
POTENTIAL RUSSIAN LANDING AND TAKEOFF ROBOTIC SPACECRAFT USAGE SCENARIOS TO SUPPORT FUTURE MANNED MISSIONS TO THE MOON.....	121
<i>Konstantin Raykunov, Julia Bodrova, George Karabadzhak</i>	
KOREAN LUNAR EXPLORATION PROGRAM STATUS UPDATE.....	122
<i>Gwanghyeok Ju</i>	
LUNAR SURFACE ACCESS SERVICE (LSAS) -- THE OHB-IAI COLLABORATION ON COMMERCIAL LUNAR LANDERS.....	125
<i>Lutz Richter, Roland Grau, Ehud Hayun, Andrea Jaime, Meir Nissim Nir, Timo Stuffer</i>	
<u>MOON EXPLORATION- PART 2</u>	
FIRST IN FLIGHT RESULTS OF THE NCLE INSTRUMENT - A LOW FREQUENCY RADIO RECEIVER EXPLORING THE DARK AGES IN LUNAR ORBIT	126
<i>Eric Bertels, Heino Falcke, Jeroen Rotteveel, Marc Klein Wolt, Albert-Jan Boonstra, Zeger De Groot, Hans Van Der Marel, Jinsong Ping, Linjie Chen, Mark Ruiter, Mingyuan Wang</i>	
LASER VELOCITY AND ALTITUDE SENSOR TECHNOLOGY FOR LUNAR ROBOTIC AND HUMAN LANDING SYSTEMS	134
<i>Glenn Hines, Farzin Amzajerdian, John Carson, Michelle Munk, Jeffrey Herath, Walt Englund</i>	
TAIWANESE FIRST MOON EXPLORATION MISSION.....	135
<i>Shin-Fa Lin</i>	
CANADA AND NEW LUNAR EXPLORATION.....	143
<i>Nadeem Ghaffoor, Peter Visscher, Perry Edmundson, Howard Jones, Josh Newman, Luke Stras, John Hackett, Tom Dzamba, Eric Gagnon, Steve Durst, Martin Picard</i>	
ISPACE MODULAR LUNAR ROVER DESIGN	145
<i>John Walker, Louis Burtz, Fabian Dubois, Abigail Calzada-Diaz, Toshiki Tanaka</i>	
LUNAR "VOLATILE AND MINERALOGY MAPPING ORBITER (VMMO)" MISSION	151
<i>Yang Gao, Roman Kruezelecky, Craig Underwood, Christopher P. Bridges, Ed Cloutis, Johan Leijtens, Roger Walker</i>	

DEVELOPMENT STATUS OF CUBESAT MOON LANDER OMOTENASHI.....	158
<i>Tatsuaki Hashimoto</i>	
A LIGHT-WEIGHT ROVER PROTOTYPE WITH MECHANISM TO SECURE RELIABLE ACTUATION FOR A LONG-TERM LUNAR EXPLORATION	159
<i>Mingyo Seo, Beom-Joon Park, Woosub Lee</i>	
STATUS OF ROVER SYSTEM STUDY FOR JAPANESE LUNAR POLAR EXPLORATION MISSION	160
<i>Sachiko Wakabayashi, Yoji Shirasawa, Takeshi Hoshino</i>	
NASA'S SOLAR SYSTEM EXPLORATION RESEARCH VIRTUAL INSTITUTE: MERGING SCIENCE AND EXPLORATION ON THE MOON	161
<i>Brad Bailey, Gregory Schmidt, Kristina Gibbs</i>	
KOREA PATHFINDER LUNAR ORBITER (KPLO): UPDATE ON THE COLLABORATIVE KARI/NASA MISSION	162
<i>Seok Weon Choi</i>	
 <u>MOON EXPLORATION- PART 3</u>	
THE INTERNATIONAL LUNAR DECADE: A FRAMEWORK FOR MULTINATIONAL COLLABORATION IN LUNAR EXPLORATION AND DEVELOPMENT.....	163
<i>Jim Crisafulli, Bernard Foing, Joseph Pelton, Henk Rogers, Vidvuds Beldavs</i>	
5 MOON MISSIONS: ILOA LOOKING FORWARD 2020 / OCTOBER 2019 UPDATE.....	167
<i>Steve Durst, Yuki Takahashi, Joseph Sulla</i>	
LUNAR ANALOGUE FACILITIES DEVELOPMENT AT EAC: STATUS OF THE LUNA PROJECT	170
<i>Andrea Emanuele Maria Casini, Petra Mittler, Aidan Cowley, Lukas Schlüter, Marthe Faber, Beate Fischer, Melanie Von Der Wiesche, Matthias Maurer</i>	
MODELING LONG TERM DEPOSITION OF ICE IN LUNAR PERMANENTLY SHADOWED REGIONS (PSRS) FOR THE PURPOSES OF RESOURCE PROSPECTING	182
<i>David Dickson, George Sowers</i>	
LUNAR NAVIGATION BEACON NETWORK USING GLOBAL NAVIGATION SATELLITE SYSTEM RECEIVERS.....	189
<i>Evan Anzalone, Benjamin Ashman</i>	
LUNAR VOLATILES MOBILE INSTRUMENTATION (LUVMI) PROJECT'S RESULTS.....	203
<i>Jeremi Gancet, Diego A. Urbina, Karsten Kullack, Guillaume Fau, Thibaud Chupin, Daniel Fodorcan, Hemanth Kumar Madakashira, Philipp Reiss, Janos Biswas, Simon Sheridan, Craig Pitcher, Simeon Barber, Neil Murray, Anthony Evagora, Lutz Richter, Mattia Reganaz, Shashank Govindaraj, Richard Aked, Joseph Salini</i>	
A CANADIAN SCIENCE MATURATION STUDY FOR A LUNAR SAMPLE RETURN ROVER TO SCHRÖDINGER BASIN AS PART OF THE HERACLES MISSION CONCEPT	212
<i>Gordon Osinski, Matthew Bourassa, Matthew Cross, Patrick Hill, Derek King, Zach Morse, Eric Pilles, Gavin Tolometti, Livio Tornabene</i>	

DEVELOPMENT OF KEY TECHNOLOGIES ENABLING THE VALUE CHAIN OF SPACE RESOURCES UTILISATION	222
<i>Diego A. Urbina, Hemanth Kumar Madakashira, Shashank Govindaraj, Irene Sanz Nieto, Guillaume Fau, Alexandru But, Daniel Fodorcan, Thibaud Chupin, Gabriele Conti, Karsten Kullack, Jeremi Gancet</i>	
EUROMOONMARS IMA HI-SEAS 2019 CAMPAIGN: AN ENGINEERING PERSPECTIVE ON A MOON BASE	232
<i>Nityaporn Sirikan, Bernard Foing, Michaela Musilova, Annelotte Weert, Benjamin Pothier, Joshua Burstein, Sebastian Mulder, Andrew Cox, Henk Rogers</i>	
MALAPERT MOUNTAIN: AN IDEAL STAGING POINT FOR LUNAR SOUTH POLE EXPLORATION	234
<i>Lukas Steindorf, Calum Hervieu, Adriaen Van Camp, Jordan Trewitt, Helge Eichhorn, Karsten Becker</i>	
HOW TO LIVE SUSTAINABLY ON THE MOON	244
<i>Henk Rogers, Michaela Musilova</i>	
<u>MARS EXPLORATION- MISSIONS CURRENT AND FUTURE</u>	
KEYNOTE: MARS SAMPLE RETURN MISSION CONCEPT STATUS	248
<i>Brian Muirhead</i>	
POTENTIAL EUROPEAN CONTRIBUTIONS TO THE INTERNATIONAL MARS SAMPLE RETURN CAMPAIGN	256
<i>Federico Massobrio</i>	
THE MULTI-MISSION EARTH ENTRY VEHICLE - PAST, PRESENT, AND FUTURE	257
<i>James Corliss, Robert Maddock, Sotiris Kellas</i>	
STATUS OF NASA'S INSIGHT MARS MISSION INSIGHT: [INTERIOR EXPLORATION USING SEISMIC INVESTIGATIONS, GEODESY AND HEAT TRANSPORT]	269
<i>Ramon P. De Paula, Tom Hoffman, William Bruce Banerdt</i>	
SEIS ON MARS	275
<i>Gabriel Pont, Philippe Laudet, Annick Sylvestre-Baron, Laurent Kerjean, Nicolas Verdier, Charles Yana, Marco Bierwirth, Kenneth Hurst, Philippe Lognonné, Tom Pike, Sébastien De Raucourt, Peter Zweifel</i>	
THE EXOMARS 2020 ROVER: AN OVERLOOK TO ITS DESIGN, TECHNOLOGY AND AMBITIOUS OBJECTIVES	286
<i>Pietro Baglioni</i>	
EXOMARS ROVER & SURFACE PLATFORM MISSION: APPROACHING THE LAUNCH CAMPAIGN	302
<i>Bruno Musetti</i>	
EMIRATES MARS MISSION (EMM) COMMAND AND DATA HANDLING DESIGN OVERVIEW	311
<i>Hessa Ali, Jeff Hanel</i>	
OPERATION OF NASA'S SCIENCE AND TELECOMMUNICATIONS NETWORK AT MARS	314
<i>David Murrow, Elizabeth Buck, Pieter Kallemeyn, Haggard Michael, Stephen Sanders, Kevin Gilliland, Roy Gladden, Jared Call, Kyle Martin</i>	

COMPARATIVE PLANETOLOGY OF MARTIAN IONOSPHERE..... 328
Noora Alameri, Muhammad Mubasshir Shaikh, Ilias Fernini

INPPS FLAGSHIP: 2020TH AND 2030TH MARS EXPLORATIONS..... 329
Frank Jansen, Benedikt Bergmann, Tim Brandt, Friedrich Damme, Emmanouil Detsis, Simona Ferraris, James Ap Findlay, Ikkoh Funaki, Oliver Funke, Jan Thimo Grundmann, Lamartine Nogueira Frutuoso Guimaraes, Martin Hillebrandt, A. C. Koroteev, Daniel Kuehn, Jim C. Kuijper, Frederic Masson, Volker Maiwald, Jürgen Oberst, Stephane Oriol, Stanislav Pospisil, Martin Richter, Lars Schanz, Alexander V. Semenkin, Alexander E. Solodukhin, Ivan Stekl, Tim Tinsley, Maria Cristina Tosi, Jean-Claude Worms

MARS EXPLORATION- SCIENCE, INSTRUMENTS AND TECHNOLOGIES

DESIGN AND OPTIMIZATION OF HYBRID DRONE FOR MARS EXPLORATION..... 337
Rebecca Sappington

MARAV - CONCEPTUAL DESIGN OF SOLAR POWERED MARTIAN AERIAL VEHICLE..... 338
Siddhesh Naik

A HYBRID SYSTEM ARCHITECTURE THAT COMBINES A CENTRALIZED ROVER WITH A FLYING SWARM OF ROTARY WINGED DRONES FOR MARS EXPLORATION 339
Ahmed Mashood, Khaled Al Hashmi, Abdulla Alshehhi

RESOURCE CONSTRAINED ONBOARD PLANNING FOR MARS ROVERS..... 345
Hao Jin, Rui Xu

NOVEL AUTONOMOUS MARS ROVERS OPTIMAL GUIDANCE APPROACH BASED ON NATURE PHENOMENON OF BEE ALGORITHM IN CO-OPERATIVE FORMATION 346
Javad Shams, Jafar Roshanian

APPLICATION OF PNEUMATICS TO DRILLING, EXCAVATION, SAMPLE ACQUISITION AND TRANSFER ON PLANETARY MISSIONS 347
Kris Zacny, Stephen Indyk, Phil Chu, Fredrik Rehnmark, Gale Paulsen, Justin Spring, Peter Ngo, Joseph Sparta, Tigh Costa, Zach Mank, Seiichi Nagihara, Ralph D. Lorenz

ROBOTIC ARMS FOR MARS SAMPLE RETRIEVAL 349
Andrea Rusconi, Massimo Lucia, Enrico Suetta, Andrea Zamboni, Guido Sangiovanni

MSR RENDEZVOUS AND CAPTURE PHASE: THE GNC SUBSYSTEM SOLUTION AND A SNAPSHOT OVER THE IMAGE PROCESSING ALGORITHMS AND NARROW ANGLE CAMERA ELEGANT BREADBOARD 355
Luigi Strippoli, Andrea Pellacani, Vincenzo Pesce, Marcos Avilés Rodríguez, David Gonzalez-Arjona, Paul Bajanaru, Dragos Gogu, Massimo Casasco

AIRBUS DS VISION BASED NAVIGATION SOLUTIONS FOR THE MARS SAMPLE RETURN – EARTH RETURN ORBITER MISSION..... 364
Aurore Masson, Roland Brochard

MOXIE COMPOSITION SENSORS CALIBRATION AND CHARACTERIZATION..... 365
Maya Nasr, Eric Hinterman, Alexandra Forsey-Smerek, Jeffrey Hoffman

CHARACTERIZATION OF THE RAMAN LASER SPECTROMETER (RLS) FLIGHT MODEL FOR THE ESA'S EXOMARS 2020 MISSION.....	366
<i>Andoni G. Moral, Fernando Rull, Sylvestre Maurice, Ian Hutchinson, Carlos Pérez, Laura Seoane Purrinos, Jose Rodriguez Prieto, Gonzalo Ramos, Sergio Ibarria, Maria Del Rosario Canchal, Paloma Gallego, Guillermo López Reyes, Tomás Belenguer, María Colombo, Juan Francisco Cabrero Gómez, César Quintana, Pablo Rodríguez Pérez, Jesús Zafra</i>	

A COMBINED RAMAN, LIF, AND MICRO-LIBS SYSTEM WITH TIME-RESOLVED FLUORESCENCE CAPABILITIES FOR PLANETARY EXPLORATION APPLICATIONS.....	372
<i>Kristen Cote, Emmanuel Lalla, Menelaos Konstantinidis, Michael Daly, Peter Dietrich</i>	

DESIGN CONSIDERATIONS AND DEVELOPMENT STATUS FOR ATMOSPHERIC POWERED DESCENT OF HIGH-MASS PAYLOADS AT MARS.....	382
<i>Ashley Korzun, Karl Edquist, Alicia Dwyer-Cianciolo</i>	

SMALL BODIES MISSIONS AND TECHNOLOGIES (PART 1)

HERA – A SMALL SPACECRAFT TO INVESTIGATE IN-SITU THE IMPACT CRATER OF AN ASTEROID DEFLECTION TEST.....	393
<i>Maren Homeister, Mark Fittock, Alison Gibbings, Masaki Nagai, Luca Corpaccioli, Marc Scheper, Arne Winterboer, Paolo Martino</i>	

NEST: A SMALL AND FAST-CLASS SCIENCE MISSION TO HOP MULTIPLE NEAR-EARTH ASTEROIDS.....	395
<i>Michèle Lavagna, Jacopo Prinetto, Lorenzo Bucci, Lorenzo Casalino, Luigi Mascolo, Davide Perna, Elena Mazzotta Epifani, Elisabetta Dotto</i>	

THE SUCCESSFUL CONCLUSION OF THE DAWN MISSION: IMPORTANT RESULTS WITHOUT A FLASHY TITLE.....	397
<i>Marc D. Rayman</i>	

HAYABUSA2 MISSION STATUS: LANDING, ROVING AND CRATERING ON ASTEROID RYUGU.....	411
<i>Yuichi Tsuda, Takanao Saiki, Fuyuto Terui, Satoru Nakazawa, Makoto Yoshikawa, Sei-Ichiro Watanabe</i>	

OPERATION PLANNING AND RESULTS OF HAYABUSA2'S FIRST ASTEROID TOUCHDOWN.....	421
<i>Yuto Takei, Takanao Saiki, Shota Kikuchi, Hirotaka Sawada, Go Ono, Yuya Mimasu, Kent Yoshikawa, Naoko Ogawa, Fuyuto Terui, Yuichi Tsuda</i>	

OPERATION RESULTS OF MINERVA-II TWIN ROVERS ONBOARD HAYABUSA2 ASTEROID EXPLORER.....	432
<i>Tetsuo Yoshimitsu, Takashi Kubota, Atsushi Tomiki, Kent Yoshikawa</i>	

OPERATION PLANNING AND RESULTS OF IMPACT EXPERIMENT OF HAYABUSA2.....	440
<i>Takanao Saiki, Yuya Mimasu, Yuto Takei, Hirotaka Sawada, Go Ono, Kent Yoshikawa, Naoko Ogawa, Fuyuto Terui, Yuichi Tsuda</i>	

THE LANDING AND IN-SITU OBSERVATION OF (162173) RYUGU BY THE MASCOT LANDER.....	448
<i>Tra Mi Ho, Ralf Jaumann, Jean-Pierre Bibring, Karl Heinz Glassmeier, Matthias Grott, Hans-Ulrich Auster, Jens Biele, Barbara Cozzoni, Clement Dudal, Cinzia Fantinati, Jan Thimo Grundmann, David Hercik, Kagan Kayal, Jörg Knollenberg, Christian Krause, Oliver Küchemann, Caroline Lange, Michael Lange, Laurence Lorda, Michael Maibaum, Yuya Mimasu, Celine Cenac-Morthe, Aurélie Moussi, Tatsuaki Okada, Cedric Pilorget, Josef Reill, Takanao Saiki, Kaname Sasaki, Nicole Schmitz, Norbert Toth, Yuichi Tsuda, Stephan Ulamec, Friederike Wolff, Tetsuo Yoshimitsu, Federico Cordero</i>	
IMPLICATIONS OF THE GRAVITY AND GEOPHYSICAL ENVIRONMENT OF (101955) BENNU FOR NEA EXPLORATION	453
<i>Daniel Scheeres, Jay McMahon, Andrew French, Daniel Brack, Dante Lauretta, Michael Nolan</i>	
DART: DOUBLE ASTEROID REDIRECTION TEST	462
<i>Cheryl Reed, Justin Atchison</i>	
HERA MISSION TO ASTEROID DIDYMOS: ESA CONTRIBUTION TO THE AIDA INTERNATIONAL COLLABORATION.....	463
<i>Ian Carnelli, Michael Kueppers, Patrick Michel, Paolo Martino, Massimo Casasco, Jesus Gil Fernandez, Paolo Concari, Ana Rugina, Francisco De Borja Garcia Gutierrez, Michael Khan, Alberto Valverde Carretero</i>	
<u>SMALL BODIES MISSIONS AND TECHNOLOGIES (PART 2)</u>	
THE ASTER MISSION: EXPLORING FOR THE FIRST TIME A TRIPLE SYSTEM ASTEROID - PROGRESS.....	467
<i>Elbert E. N. Macau</i>	
THE OBJECTIVES AND THE PAYLOAD OF THE HERA MISSION TO THE BINARY ASTEROID DIDYMOS.....	468
<i>Michael Küppers, Patrick Michel, Ian Carnelli, Paolo Martino</i>	
REPORT ON HAYABUSA2 TOUCH-DOWN DYNAMICS AND SAMPLING OPERATION RESULT.....	470
<i>Hirotaka Sawada, Kent Yoshikawa, Fuyuto Terui, Shota Kikuchi, Takanao Saiki, Yuichi Tsuda</i>	
MASCOT OPERATIONS ON RYUGU – FOCUS ON SPECIFIC TASKS.....	478
<i>Christian Krause, Aurelie Moussisoffys, Laurence Lorda, Tra Mi Ho, Jens Biele, Stephan Ulamec, Caroline Lange, Clement Dudal, Celine Cenac-Morthe, David Granena, Michael Maibaum, Cinzia Fantinati, Jean-Pierre Bibring, Ralf Jaumann, Karl Heinz Glassmeier, David Hercik, Matthias Grott, Nicole Schmitz, Kagan Kayal, Jan Thimo Grundmann, Elisabet Canalias, Kaname Sasaki, Tatsuaki Okada, Tetsuo Yoshimitsu, Yuichi Tsuda, Friederike Wolff</i>	
ANALYSIS AND DESIGN OF A PROPULSION MODULE FOR SMALL BODY NANOLANDER AND SURFACE SCIENCE PACKAGES BASED ON THE MASCOT LANDER CONCEPT.....	480
<i>Caroline Lange, Jan Thimo Grundmann, Tra Mi Ho</i>	
ONE-SHOT DEPTH IMAGING FOR SMALL BODY LANDING MISSIONS WITH A SINGLE PLENOPTIC CAMERA	481
<i>Martin Lingenauber, Florian A. Fröhlich, Christian Nissler, Klaus H. Strobl, Katharina Otto</i>	

THE SCIENCE RETURN OF THE ESA HERA MISSION: THE EUROPEAN COMPONENT OF THE AIDA PROJECT IN COOPERATION WITH NASA DART	482
<i>Patrick Michel, Michael Kueppers, Ian Carnelli, Paolo Martino, Adriano Campo Bagatin, Benoît Carry, Sébastien Charnoz, Julia De Leon, Alan Fitzsimmons, Simon Green, Alain Herique, Martin Jutzi, Özgür Karatekin, Naomi Murdoch, Petr Pravec, Holger Sierks, Colin Snodgrass, Paolo Tortora, Kleomenis Tsiganis, Stephan Ulamec, Kai Winnemann</i>	
JUVENTAS: EXPLORATION OF A BINARY ASTEROID SYSTEM WITH A CUBESAT	491
<i>Ozgur Karatekin, Hannah Goldberg, Birgit Ritter, Claudiu-Lucian Prioroc</i>	
MISSION DEFINITION OF MARTIAN MOONS EXPLORATION (MMX).....	495
<i>Yasuhiro Kawakatsu</i>	
A ROVER FOR THE MMX MISSION TO PHOBOS	508
<i>Stephan Ulamec, Patrick Michel, Matthias Grott, Ute Böttger, Heinz-Wilhelm Hübers, Özgür Karatekin, Jörg Knollenberg, Konrad Willner, Markus Grebenstein, Stephane Mary, Pascale Chazalnoël, Jens Biele, Christian Krause, Tra Mi Ho, Caroline Lange, Jan Thimo Grundmann, Kaname Sasaki, Michael Maibaum, Oliver Kuchemann, Josef Reill, Stefan Barthelmes, Maxim Chalon, Roy Lichtenheldt, Rainer Krenn, Michal Smisek, Jean Bertrand, Aurélie Moussi, Simon Tardivel, Denis Arrat, Frans Ijpelaan, Laurence Mélac, Laurence Lorda, Emile Remeteau, Michael Lange, Olaf Mierheim, Tomohiro Usui, Moe Matsuoka, Tomoki Nakamura, Koji Wada, Hirdy Miyamoto, Kiyoshi Kuramoto, Julia Lemaitre, Elise Aitier, Guillaume Mas, Michel Delpech, Loisel Celine, Arthur Rafflegeau, Honorine Boirard, Roseline Schmitter, Cédric Virmontois, Celine Cenac-Morthe, Dominique Besson</i>	
THE RAMAN SPECTROMETER ONBOARD THE MMX ROVER FOR PHOBOS	516
<i>Till Hagelschuer, Tomas Belenguier, Ute Böttger, Maximilian Buder, Yuichiro Cho, Enrico Dietz, Michael Gensch, Franziska Hanke, Heinz-Wilhelm Hübers, Shingo Kameda, Emanuel Kopp, Simon Kubitz, Andoni Moral, Carsten Paproth, Martin Pertenais, Gisbert Peter, Kristin Rammelkamp, Pablo Rodríguez Pérez, Fernando Rull, Conor Ryan, Thomas Säuberlich, Friedrich Schrandt, Susanne Schröder, Stephan Ulamec, Tomohiro Usui, Roderick Vance</i>	
CHARACTERISATION OF A POTENTIALLY THREATENING NEO.....	524
<i>Pierre W. Bousquet, Massimiliano Vasile</i>	

SOLAR SYSTEM EXPLORATION INCLUDING OCEAN WORLDS

KEYNOTE: EXECUTION OF PARKER SOLAR PROBE'S UNPRECEDENTED FLIGHT TO THE SUN AND EARLY RESULTS	533
<i>Yanping Guo, Paul Thompson, John Wirzburger, Nickalaus Pinkine, Stewart Bushman, Troy Goodson, Robert Haw, James Hudson, Drew Jones, Seth Kijewski, Brian Lathrop, Eunice Lau, Neil Mottinger, Mark Ryne, Wen-Jong Shyong, Powtawche Valerino, Karl Whittenburg</i>	
BEPICOLOMBO MISSION TO MERCURY: FIRST YEAR OF FLIGHT	548
<i>Christoph Steiger, Elsa Montagnon, Andrea Accomazzo, Paolo Ferri</i>	
THE SOLAR ORBITER MISSION: THE SUN UP CLOSE	557
<i>Anne Pacros, César García Marirrodriaga</i>	
JUICE PLANETARY PROTECTION ANALYSIS	563
<i>Pablo Hermosin, Javier Martín, Simone Centuori, Eric Ecale, Arnaud Boutonnet, Christian Erd</i>	

DEVELOPMENT OF PROBE TECHNOLOGIES TO REACH EUROPA OCEAN	572
<i>Kris Zacny, Stephen Indyk, Christophe Sotin, Kevin Hand, Samuel Howell, Tom Cwik, Juergen Mueller, Bethany Ehlmann, Seiichi Nagihara, Mike Tipton, Stef Liller, Fredrik Rehnmark, Tighe Costa, Dean Bergman, Will Hovik</i>	
TARGETING ENCELADUS' GEYSER VENTS USING PENETRATORS EMPLOYING BIOMIMETIC PLUME SNIFFING	574
<i>Yue Sun, Alex Ellery, Xianlin Huang</i>	
MISSIONS TO TRITON AND PLUTO	585
<i>Geoffrey Landis, Steven Oleson, Phillip Abel, Michael Bur, Anthony Colozza, Brent Faller, James Fittje, John Gyekenyesi, Jason Hartwig, Robert Jones, Nicholas Lantz, Steven McCarty, Thomas Packard, Paul Schmitz, David Smith, Elizabeth Turnbull, Noam Izenberg, Miles McKaig, Thomas O'Brien</i>	
FRACTAL DIMENSIONAL ANALYSIS FOR QUANTITATIVE CHARACTERIZATION STUDY OF THE IRREGULARITY IN TITAN HYDROCARBON LAKES/SEAS AND TOPOGRAPHY OF NEAR SURFACE/REGION.	591
<i>Rinkesh Kurkure, Pranit Patil, Bhushan Patil, Saurav Sunil Telge, Megh Suhas Thakur</i>	
<u>INTERACTIVE PRESENTATIONS - IAF SPACE EXPLORATION SYMPOSIUM</u>	
LUNAR LANDING-AND-TAKEOFF VEHICLE	597
<i>Olexandr Kashanov, Alexander Degtyarev, Maksym Degtiarov</i>	
STUDY OF PREFABRICATED COMPOSITE LAYER AS A TEMPERATURE AND IMPACT SHIELD FOR LUNAR HABITATS.....	600
<i>Jeffrey Steiner, Ramesh Malla</i>	
THE PRIMARY LOCATIONS AND SETTLEMENT STRATEGIES OF INTEREST FOR FUTURE LUNAR BASES	601
<i>Xiaochen Zhang, Danijela Ignjatovic Stupar</i>	
HAWAIIAN BASALT CHARACTERIZATION AND THE EFFECTS OF CHEMICAL COMPOSITION VARIANCES ON THE SINTERING PROCESS; POTENTIAL IMPLICATIONS FOR LUNAR/MARS ISRU APPLICATIONS.....	602
<i>Kyla Defore</i>	
IMPLEMENTATION OF LOW-POWER, WIDEBAND SYNTHETIC APERTURE RADAR FOR PRIMITIVE BODY RECONNAISSANCE APPLICATIONS.....	617
<i>Katelyn Kufahl, Connor Thompson, Dan Matlin, Daniel Caughran, Joshua Ramirez, Jeffrey Boye, G. W. Patterson, Norman Adams, H. Brian Sequeira</i>	
INTERACTIVE PLANETARY VISUALIZATION AND ANALYSIS WITH NASA'S SOLAR SYSTEM TREKS PORTALS	622
<i>Emily Law, Brian Day</i>	
THE USC ADAM PROJECT: ADVANCED DEVELOPMENTAL ARCHITECTURES FOR OUR MOON	623
<i>Madhu Thangavelu</i>	
REGOLITH MINING IN SHACKLETON CRATER: PROPELLANT, BUILDING MATERIALS AND VITAL RESOURCES PRODUCTION FOR A LONG DURATION MANNED MISSION.....	639
<i>Lorenzo Rabagliati, Matteo Devecchi, Alessandro Lovagnini, Paolo Pino, Guillaume Thirion</i>	

ROVER PERFORMANCE BOUNDARY ASSESSMENT USING TERRAIN MAP TRAVERSABILITY ANALYSIS	648
<i>Niti Madhugiri, Yogeshwaran Jayaraman, Barath C, Adithya Kothandhapani</i>	
MATERIAL CHARACTERIZATION WHILE DRILLING ON MOON:RESULTS OF THE ATMOSPHERIC DRILLING TESTS	649
<i>Deep Joshi, Alfred Eustes, Jamal Rostami, Colby Gottschalk</i>	
LUNAR EXCAVATOR: REGOLITH MINING OPERATIONS TESTING	650
<i>Jason Schuler, Jonathan Smith, Kurt Leucht, Andrew Nick, Buckles Bradley</i>	
MISSION CONCEPT FOR LUNAR LOW FREQUENCY ANTENNAS FOR RADIO ASTRONOMY (LUFAR).....	651
<i>Maneesh Kumar Verma, Mark Bentum, Chris Verhoeven, Raj Thilak Rajan</i>	
PLEXNET - A DISTRIBUTED, VARIABLE-AUTONOMY ARCHITECTURE FOR EXPLORATION OF PLANETARY BODIES	652
<i>Zhong Thai, Prajwal Balasubramani, Christopher Brand, Andrew Haines, Daniel Delaurentis</i>	
JUMP ROBOT WITH TETHER FOR LUNAR VERTICAL HOLE EXPLORATION	666
<i>Karin Kushida, Yoshiki Sugawara, Junichi Haruyama</i>	
FROM DUST TO GAS, LEAP2 TECHNOLOGIES FOR LUNAR SITE DEVELOPMENT AT THE MARIUS HILLS SKYLIGHT	672
<i>Samuel Ximenes</i>	
THE GLACIER PROJECT IN THE IGLUNA ESA LAB DEMONSTRATOR PROJECT	673
<i>Julia Wajoras, Edyta Zak, Tomasz Mis, Michal Kazaniecki, Karol Bresler, Damian Grabowski</i>	
ICELAND CAMPAIGNS FOR EXPLORATION OF LAVA CAVES AND EXTRAPOLATION TO A SEMI-PERMANENT LUNAR HABITAT.....	674
<i>Marjolein Daeter, Marc Heemskerk, Bernard Foing</i>	
LUNAR ORBITAL PLATFORM-GATEWAY (LOP-G) AS AN OPPORTUNITY TO TEST TECHNOLOGIES APPLICABLE TO THE ROBOTIC AND CREWED EXPLORATION OF BOTH MOON AND MARS	675
<i>Anne-Marlene Rüede, Claudio Leonardi, Anton Ivanov</i>	
CISLUNAR AUTONOMOUS NAVIGATION USING MULTI-GNSS AND GNSS-LIKE AUGMENTATIONS: CAPABILITIES AND BENEFITS.....	676
<i>Caitlyn Singam, Benjamin Ashman, Lauren Schlenker</i>	
IN-SITU RESOURCES UTILISATION (ISRU): USING SWARM ROBOTICS TO OPTIMISE THIS KEY TECHNOLOGY FOR FUTURE SUSTAINABLE LUNAR EXPLORATION	677
<i>André Fonseca Prince, Enzo Schmitz</i>	
SETTING UP AN EARTH MOON GONDOLA FROM THE MOON VILLAGE	678
<i>Jean-Yves Prado, Olivier Boisard, Jerome Perez, Constance Lainé</i>	
DEVELOPMENT AND TEST OF A FOLDABLE PROTECTION SYSTEM FOR A SMALL LANDING PROBE USING 3D-PRINTED METAL GRIDS AS SHOCK ABSORBER.....	679
<i>Silvio Schröder, Christian Grimm, Hanns Selig, Alexander Schenk, Philip Buchholz, Adli Dimassi</i>	

Author Index