

19th IAA Symposium on Building Blocks for Future Space Exploration and Development 2021

Held at the 72nd International Astronautical Congress
(IAC 2021)

Dubai, United Arab Emirates
25 – 29 October 2021

ISBN: 978-1-7138-4313-9

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© (2021) by International Astronautical Federation
All rights reserved.

Printed with permission by Curran Associates, Inc. (2022)

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

1. STRATEGIES & ARCHITECTURES AS THE FRAMEWORK FOR FUTURE BUILDING BLOCKS IN SPACE EXPLORATION AND DEVELOPMENT

THE FIRST HUMAN SETTLEMENT ON THE MOON BY 2045: A CASE STUDY	1
<i>John C. Mankins</i>	
VALUE-CHAIN ANALYSIS OF IN-SPACE SEGMENTS OF A CISLUNAR ARCHITECTURE	20
<i>Loveneesh Rana, Ramlingam Gyanasampath Pillai</i>	
LUNANET: CATALYST FOR THE SPACE BASED ECONOMY?.....	21
<i>Gerard Lebar, Jr., Emily Amador</i>	
LUNAR LANDING NECESSARY BUILDING BLOCKS AND GOOD PRACTICES FOR A SUSTAINABLE DEVELOPMENT OF HUMAN LUNAR ACTIVITIES	28
<i>Simone Paternostro, Paolo Guardabasso, Pablo Bedialauneta, Romain Fonteyne</i>	
LUNAR LAVA TUBE MAPPING MISSIONS FOR HUMAN HABITATION ASSESSMENT USING SMALL ROBOTIC SWARMS.....	40
<i>Pavlo Tanasyuk, Charles Lauer, Rod Mamin</i>	
ASTRAX LUNAR CITY DEVELOPMENT PROJECT 2021	41
<i>Taichi Yamazaki, Taiko Kawakami</i>	
ADVANCED PROPULSION AS A CORNERSTONE FOR SPACE EXPLORATION AND INTERSTELLAR LIVING	51
<i>Tommaso Tonina, Hamda Al Shehhi, Gustavo Jamanca-Lino, Erin Kennedy, Lisa Kucher, Itai Norber, Rijin K V, Jason Dowling</i>	
SILICA AEROGEL: ISRU, ARCHITECTURE AND APPLICATIONS FOR MARS AND SPACE SETTLEMENTS	62
<i>Kolemann Lutz, Paolo Pino</i>	
A NOVEL PLANETARY RESOURCE CLASSIFICATION FRAMEWORK TO ADVANCE SUSTAINABILITY IN LUNAR EXPLORATION MISSIONS	63
<i>Arjumand Alvi</i>	
OPPORTUNITIES FOR SPACE EXPLORATION UNDER THE UNITED NATIONS ACCESS TO SPACE 4 ALL INITIATIVE: ACHIEVEMENTS IN 2020-2021	93
<i>Jorge Del Rio Vera, Hazuki Mori, Wenbin Zhang, Martin Staško, Luc St-Pierre, Simonetta Di Pippo</i>	
EXPLORING PLANETARY SYSTEMS, IN THE SOLAR SYSTEM AND BEYOND. THE ENABLING POWER OF INTERNATIONAL COLLABORATION.....	98
<i>Maria Antonietta Perino, Michel Blanc, Eleonora Ammannito, Pierre W. Bousquet, Jeremie Lasue, Maria Teresa Capria, Veronique Dehant, Bernard Foing, Manuel Grande, Linli Guo, Aureore Hutzler, Advenit Makaya, Ralph L. McNutt, Jr., Heike Rauer, Frances Westall, Jonathan Lewis</i>	

2A.SYSTEMS AND INFRASTRUCTURES TO IMPLEMENT SUSTAINABLE SPACE DEVELOPMENT AND SETTLEMENT - SYSTEMS

MOSAR: DEMONSTRATION OF MODULAR SPACECRAFT ASSEMBLY AND RECONFIGURATION 107
Pierre Letier, Mathieu Deremetz, Gerhard Grunwald, José Miguel Sánchez Martínez, Matthew Rowlings, Pablo Lopez Negro, Daniele Filippetto, Juan Sanchez Garcia Casarrubios, Xiu-Tian Yan, Pierre Dissaux

FEASIBILITY STUDY TO BUILD A DEPOT IN LOW EARTH ORBIT 120
Alexander Huschke, Gongling Sun

VACUUM TRANSPORT SYSTEM FOR MOON..... 141
Piotr Wrzecionarz, Karol Mierzwa, Dominik Liskiewicz, Maciej Pauli, Piotr Pezowicz

EUROHAB: CONCEPT OF AN INFLATABLE HABITAT PAYLOAD AS SUPPORT TO CREWED MISSIONS ON THE LUNAR SURFACE OR MARS 151
Peter Weiss, Jean Favier, Jacques Rougerie, Thibaud Gobert, Jean-Francois Clervoy, Alexis Paillet, Pierre Boutte, Gregory Navarro, Juliette Mollard, Miriam Opazo Mendez, Marcos Eduardo Rojas Ramirez, Elizaveta Shashkova, Nisheet Singh

CISLUNAR DISTRIBUTED ARCHITECTURES FOR COMMUNICATION AND NAVIGATION SERVICES OF LUNAR ASSETS 157
Andrea Pasquale, Giovanni Zanotti, Jacopo Prinetto, Michele Ceresoli, Michèle Lavagna

ROCKETNET: A HIGH-CAPACITY, LATENCY-INSENSITIVE, INTERPLANETARY DATA DELIVERY SYSTEM 170
Julian Mentasti Meza

LUNAR COMMS AND NAV INFRASTRUCTURE – FIRST DATA RELAY ORBITER LUNAR PATHFINDER, OPERATIONAL IN 2024, PAVES THE WAY FOR FULL CONSTELLATION BY 2030 171
Nelly Offord, Jonathan Friend, Paul Stevens, Sophie Bywater, Benjamin Schwarz, Charles Cranstoun, Bernhard Hufenbach, Francesco Liucci, Carsten Tobeh, Paul Thompson

TECHNOLOGY SYSTEMS FOR LUNAR INDUSTRIAL DEVELOPMENT 182
Peter Schubert

HOW TO ACCELERATE THE PRODUCTION PROCESSES FOR THE SURVIVAL OF HUMAN COLONIES. 188
Lukasz Wilczynski, German Sarmiento, Mario Andrés Colorado Gómez, Fabio Quimbaya, Arnulfo Téllez, Sandra Mendoza

2B.SYSTEMS AND INFRASTRUCTURES TO IMPLEMENT SUSTAINABLE SPACE DEVELOPMENT AND SETTLEMENT - TECHNOLOGIES

THERMAL MINING OF WATER ICE IN LUNAR PERMANENTLY SHADOWED REGIONS 192
Angel Abbud-Madrid

COST EFFICIENT DESIGN FOR A FARADAY CUP TO DETECT METEOR SMOKE PARTICLES ON BOARD A SOUNDING ROCKET..... 193
Avaneeth Anil, Vinitha V, Surbhi Choudhary

ORCHESTRATING SYMBIOSIS: FOUNDATIONAL TECHNOLOGIES FOR HUMAN AND ROBOTIC SHARED CONTROL.....	194
<i>Gary Barnhard</i>	
MOONPORT: A COST-EFFECTIVE TRANSPORT SOLUTION FOR CISLUNAR SPACE	203
<i>John Toop-Rose, Federico Bergamasco, Pascale Bérubé, Paola Breda, Victor Covasan, Pieter Deleye, Grant Kendall-Bell, Nadia Karrim, Coralie Lhabitant, Smit Patel, Marion Pigassou, Narashima Purohit, Antonio Riccio, Julia Stankiewicz, Daria Stepanova, Roderick G. Tapia Barroso, Francesco Ventre</i>	
MULTIPURPOSE LOCOMOTION SYSTEM FOR CREW AND CARGO TRANSPORTATION ON THE LUNAR SURFACE.....	218
<i>Margherita Marchi, Marco De Riggi, Summer Haverson, Nivraj Chana, Louis Desprez, Adrien Lafontan, Ding Zhang, Baptiste Valentin, Walter Campo, Florian Fillol</i>	
EROSS PROJECT - GROUND VALIDATION OF AN AUTONOMOUS GNC ARCHITECTURE TOWARDS FUTURE EUROPEAN SERVICING MISSIONS.....	232
<i>Vincent Dubanchet, Juan Antonio Bejar Romero, Iosif Paraskevas, Pablo Lopez Negro, Aurélien Cuffolo, Florent Maye, Andres Rodriguez Reina, Pablo Romeo Manrique, Mercedes Alonso, Sebastián Torralbo Dezainde, Giorgos Rekleitis, Kostas Nanos, Evangelos Papadopoulos, Alexandros Konstantinidis, Grégory Gaudin, Jonathan Courtois</i>	
PRODUCTION EVALUATION OF HAEMATOCOCCUS PLUVIALIS, CHLORELLA SP. AND ARTHROSPIRA MAXIMA AS AN ALTERNATIVE SOURCE OF PROTEIN AND ANTIOXIDANTS FOR THE PRODUCTION OF FOOD AND OXYGEN FOR SPACE TRAVELERS.....	247
<i>German Sarmiento, Mario Andrés Colorado Gómez, Fabio Quimbaya, Arnulfo Téllez</i>	

3.SPACE TECHNOLOGY AND SYSTEM MANAGEMENT PRACTICES AND TOOLS

COST ESTIMATION MODELING IN THE ERA OF ‘NEW SPACE’ COMMERCIAL SYSTEMS.....	251
<i>John C. Mankins</i>	
DEMAND AND SUPPLY MATCHING BY THE ASTRAX LUNAR CITY BUSINESS COMMUNITY AND RESIDENCE CLUB.....	260
<i>Taichi Yamazaki, Shunsuke Chiba</i>	
THE EFFECT OF INITIATING THE UAE SPACE AGENCY ON THE R&D ACTIVITIES IN THE SPACE SECTOR: A BIBLIOMETRICS STUDY	276
<i>Khalfan Al Remeithi, Abdulla Alshehhi</i>	
TOWARDS MULTI-DOMAIN TRAFFIC MANAGEMENT	280
<i>Kathiravan Thangavel, Alex Gardi, Samuel Hilton, Andoh Michael Afful, Roberto Sabatini</i>	
THREE NATIONS COLLABORATE TO BUILD MARS SPACECRAFT FLIGHT SOFTWARE	294
<i>Ibrahim Al Midfa, Gregg Allison, Darrin Gates, Karen Looney, Gail Tate, Allen Brown, Corinne Wuertner</i>	
THE ATTITUDE AND ORBIT CONTROL FAULT DIAGNOSIS AND BACKUP BRAKING DESIGN DURING MARS ORBIT INSERTION.....	305
<i>Jianjun Feng, Yu Liu</i>	
IN-SPACE ECONOMY IN 2021: STATISTICAL OVERVIEW AND CLASSIFICATION OF COMMERCIAL ENTITIES	311
<i>Erik Kulu</i>	

IP.INTERACTIVE PRESENTATIONS - 19TH IAA SYMPOSIUM ON BUILDING BLOCKS FOR FUTURE SPACE EXPLORATION AND DEVELOPMENT

ADVANCING ASTEROID SURFACE SIMULATIONS AND MISSIONS USING AN ON-ORBIT CENTRIFUGE LABORATORY WITHOUT REACTION WHEELS 334
Leonard Vance, Jekanthan Thangavelautham

MARS HOMESTEAD CONSTRUCTION GUIDEBOOK..... 343
Bruce Mackenzie, Kolemenn Lutz

EMERGING-SPACE COUNTRIES AND THE FUTURE OF SPACE EXPLORATION 344
Ghanim Alotaibi, John C. Mankins

UNIVERSAL BERTHING MECHANISM 345
Szymon Matkowski, Koen Kegel, Sam Ross, Enrico Trolese, Sean Wessels, Michel Lamontagne, Hassaan Tariq

ORBITAL CAN STATION 355
Koen Kegel, Sean Wessels, Szymon Matkowski, Sam Ross, Enrico Trolese, Michel Lamontagne

LARGE ARTIFICIAL ROTATIONAL GRAVITY ENVIRONMENT 366
Gerry Aab, Szymon Matkowski, Koen Kegel, Sean Wessels, Natausha Chohan

ASTEROID MINING: KEY TO SPACE ECONOMY 376
Sankalp Jain, Prakhar Jain

APPLICATIONS FOR ARTIFICIAL INTELLIGENCE IN NEXT GENERATION DEEP SPACE EXPLORATION ROBOTICS 377
Rohaam Ahmed, Nariman Farsad

Author Index