ASCE Aerospace Division

ASCE | AEROSPACE

Panel Session Proposal

From Space to Earth: Technologies for Infrastructure in Challenging Environments

Format: Panel discussion followed by 4 technical presentations (15 min. each) followed by 30-45 min. discussion.

Session Chair and Moderator:

Olga Bannova, PhD
Director, SICSA, Research Professor
Cullen College of Engineering
University of Houston

Hongyu 'Nick' Zhou, PhD
Associate Professor
Civil and Environmental Engineering
University of Tennessee Knoxville

Synopsis: Extreme environments on Earth provide analog experience to support planning of extraterrestrial facilities and operations. Polar environments present special lessons regarding habitat design, crew operations and training, and equipment and logistical requirements for space exploration. Planning and designing for space and polar environments share many kinds of technical and operational priorities. Key among these are needs for appropriate transportation and construction systems, efficient energy, effective and environmentally responsive waste management and life support systems, maintenance and repair provisions, and emergency accommodations. This presentation will discuss parallels and define differences between driving factors for planning and design of surface facilities in space and in extreme environments on Earth. Primary emphases will highlight influences upon essential habitability requirements, constraints upon delivery and construction, and special provisions for safety and hazard interventions. The overall intent is to identify important lessons that can be applied across different settings, which present common priorities, issues and challenges. Important topics of emphasis include the following considerations:

- Design influences driven by transport to remote sites;
- Environmental influences upon facilities and construction;
- Influences of crew sizes, types of activities and occupancy durations;
- Influences of construction methods and support infrastructures;
- Special safety and emergency response requirements.

Topic 1: Planning and design in space and extreme environments on Earth

Dr. Olga Bannova, Director, SICSA, Research Professor, Cullen College of Engineering, University of Houston

Extreme environments offer good opportunities to demonstrate and assess the practical attributes and performance of equipment and operations under rigorous and demanding circumstances. High logistics costs and transportation constraints on allowable volume and

weight require systems that are versatile and highly efficient. Harsh climates and isolated working conditions impose requirements for ruggedness and dependability. Limited labor resources and available tools place a priority upon ease of equipment deployment and repairs. Planning and design to optimize human safety under normal and emergency circumstances takes on a special urgency. Construction methods in extreme environments must address vital structural safety and reliability requirements and take special environmental influences into account. Included are:

- Lack of onsite equipment and limited labor personnel;
- Short construction windows;
- Equipment breakdowns with limited tools/spares;
- Hazardous working conditions;
- Extreme temperatures impacting thermal control and structural fatigue.

A common construction priority for extreme environments is to design structures that can be rapidly assembled and deployed under harsh conditions. Modular approaches facilitate deployment and afford immediate occupancy but usually impose internal volume constraints driven by transportability requirements. Erectable structures can overcome volume constraints but add to on-site time and labor required for readiness. Finally, advanced technologies including inflatable and other tensile systems applied to polar and space environments can have transferable benefits.

Topic 2: Autonomous construction (3D printing): From ex-terrestrial to terrestrial applications

Dr. Hongyu 'Nick' Zhou, Associate Professor, Civil and Environmental Engineering, University of Tennessee Knoxville

Autonomous construction techniques including additive construction (3D printing) has received much attention in ex-terrestrial habitat construction due to its potential benefits include high level of automation, minimal waste, and robustness. The harsh and inhospitable environment in space requires structures that can withstand extreme temperature fluctuations, high levels of radiation, and atmospheric pressure that is much lower than Earth's. This 3D printing technology allows structures to be constructed using in-situ obtained materials. Other advantages include increased speed and efficiency in construction. The use of 3D printing technology has the potential to revolutionize human exploration and settlement on other planets by enabling the creation of functional, sustainable, and cost-effective habitats. This talk addresses technologies (materials, construction techniques, design requirement etc.) that can be translated from ex-terrestrial habitat construction to terrestrial structures, especially for those under extreme environments – e.g., dessert environment, cold temperature, remote areas, high radiation environment (nuclear construction).

Topic 3: Seismic geophysics for permafrost characterization in space and on earth

Dr. Pooneh Maghoul, Director SIGLab, Associate Professor, Polytechnique Montréal

Permafrost is defined as ground which remains at or below zero degree for at least two consecutive years. On Earth, climate change has adversely affected the built environment in (sub-)arctic regions. The planning and design of climate-resilient northern infrastructure, as well as predicting deterioration of permafrost from climate model simulations, require characterizing permafrost sites accurately and efficiently. On the other hand, characterizing lunar permafrost and quantifying the shallow and deep bulk water on the Moon may provide the high ISRU potential. In this presentation, advanced seismic signal processing coupled with multiphase poromechanics for characterizing permafrost soil on Earth and the Moon will be presented.

Topic 4: Alkali activation of locally sourced Alaskan fly ash for arctic construction

Dr. Nima Farzadnia, Assistant Professor, Civil and Environmental Engineering, University of Alaska Fairbanks

This study delineates the feasibility of activating locally sourced fly ash from Alaska for use in Arctic construction. It encompasses the design and optimization of activation parameters, which include solid-to-liquid ratio, alkali activator type, and molarity. The research assesses the material's resistance to extreme cold temperatures. The aim of this investigation is to advance sustainable construction practices in the Arctic region, harnessing indigenous resources and innovative technologies to address the unique challenges posed by its harsh environment.