Common Lunar Landing Pads – Built In-Situ – Are a Legal and Economic Imperative

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The University of Central Florida team has completed more than 20 years of research into the phenomena of lunar landings blowing regolith, including: analysis of mission data, measuring the physical damage to the Surveyor 3 as sandblasted by Apollo 12, experiments, and computer simulation. The results predict that lander ejecta are dispersed globally, and for landers capable of 10 tons payload the ejecta can cause severe hardware damage to an outpost even 10s of kilometers away. Building berms or relying on terrain obscuration is not a complete solution because very large landers send ejecta into higher trajectories that cannot be successfully blocked. It is even possible to damage or destroy spacecraft orbiting the Moon, since in the airless environment the majority of ejecta (at low ejection angle) travels over the horizon reaching beyond typical orbital altitudes. Because of these effects, it is necessary to construct landing pads on the Moon to protect all ongoing operations. This presentation will address the technical challenges of mitigating ejecta, as well as legal issues, including the need for international cooperation. It will likely be impossible to completely mitigate ejecta in the low-gravity, airless environment of the Moon, so international agreements are needed regarding blast zones, construction of landing pads, and how much ejecta impingement the various parties are allowed to cause each other. This presentation argues that building common and shared landing pads on the Moon with regolith as a construction material should be the first case of using lunar resources. Legal obligations and responsibilities as set forth in the Outer Space Treaty and the Liability Convention make the construction of common landing pads a legal and economic imperative.

Universal Design for All Space Habitat (U-DASH): A Study on Architectural Planning Criteria of Moon Village

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Keywords: Space Infrastructure, Universal Design, Accessibility, Longevity, Moon Village

The purpose of this paper concludes architectural design criteria of Moon Village built on equality and accessibility for humanity. On Earth, architectural design has introduced Universal Design (UD), an improved philosophy derived from "Barrier-free design (for handicapped persons)", to remove discriminated concept of distinguishing handicapped groups and focus on offering better accessibility and usability not only for those who are with impairment or other chronic sicknesses but an inclusive service to extent possible users. Few decades from now, human may visit and work on the Moon. The author foresees an inevitable lifestyle on the Moon (e.g. Moon Village) that claims Universal Design for all moon tourists and space labors despite their genders, races, physical and psychological conditions will be applied in space. The collaborative project led by the author and his affiliation is named U-DASH (Universal Design for All Space Habitats).[1] This study summarizes current outcomes of U-DASH strategy and implementation which mainly based on research of two classified groups: 1. Physically abled space tourists or Moon Village habitants and, 2. Space borne (may refer to injured space labors who need caretaking, etc.) or inherent impairment (may refer to handicapped space tourists from Earth) in terms of lunar habitant situation. U-DASH is a consequential path toward longevity spacefaring civilization and furthermore, the study conducts specific spatial criteria to supporting each group's needs for designing of Moon Village architecture standards.

[1] H.C. Chang, Universal Design for All Space Habitats (U-DASH): A Consequential Path Towards Diverse Spacefaring Civilization, 32nd ISTS Proceedings, 19th June, 2019, Fukui City, Fukui Prefecture, Japan (2019).

General Rules on How to Live on the Moon and the Related Research

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Keywords: Moon, Habitat, Design, Architecture, Psychology

How should people live on the Moon? The answers are reviewed and summarized mainly from the architectural and psychological standpoints. The topics include the lunar base development process,[1] design items to be considered, protection of the structure, subsystem elements,[2] design guideline, recommendation based on the lessons learned from the previous manned missions, future structure material development, optimal crew size, necessary habitat volume and electric power, architectural habitat design for partial gravity environment (i.e., ceiling, handrail, and stairs step height), psychologically important factors (such as mission duration, pressurized volume per person, crew characteristics (gender, culture, role, skill, experience, personality, leadership, and language competence), physical environment, work/break interval, degree of autonomy, communication, and emergency response), stress relief methods (such as training, support, and consulting), food and plant cultivation, and windows and/or simulated windows. To help design and develop the lunar base, we are conducting research on lunar construction material production (joint research with JAXA Space Exploration Innovation Hub Center from 2016 to 2017) and truss and inflatable structure design. The lunar construction material has been manufactured with melting and sintering of lunar simulant. Microwave is used as heating media instead of that of a usual electric furnace because the heating is uniform and can be employed under a vacuum environment. The compressive strength of the product is found to be high enough to be used as structural material under the lunar gravity. As the structure of lunar habitat, optimal truss and inflatable structures are sought through experimental work.

[1] Kennedy, K., “Vernacular of Space Architecture,” Out of This World, The New Field of Space Architecture, AIAA, 2009.
[2] Eckart, P., Ishikawa, Y. and Kennedy, K., "Chapter 13: Designing, Sizing, and Integrating a Surface Base," Human Spaceflight, Mission Analysis and Design, McGraw-Hill, 2000.

Solar Flare Prediction and Space Weather Forecast

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Solar flares are the largest explosive phenomena in the Heliosphere. They affect the earth by X-ray and UV emissions, high energy particles, and magnetic storms, causing troubles of satellites and blackout in a large area. In the case of moon villages, there are no protections by magnetosphere and atmosphere, so that it is expected that the risk of damages by solar flares should be increased. Recently we have developed an operational system of solar flare prediction using a deep neural network (DNN), named Deep Flare Net [1, 2], and we started to run it in the operation [3]. The model can predict probabilities of the maximum class of flares occurring in the following 24 hr. The training dataset is made by $3x10^5$ images during 2010-2015 taken by SDO satellite, from which we detected active regions and calculated 79 features for each region attached with the flare occurrence labels (X, M, C). The prediction data in the near real-time is downloaded from Stanford University and NASA, and all the active regions and features are automatically detected and calculated, when the prediction results are shown on the web site. In this presentation, we would like to introduce our operational forecasting system and discuss how it works in the daily operations.

[1] N. Nishizuka, K. Sugiura, Y. Kubo, M. Den, S. Watari, M. Ishii, 2017 Astrophysical J., 835, 156

[2] N. Nishizuka, K. Sugiura, Y. Kubo, M. Den, M. Ishii, 2018 Astrophysical J., 858, 113

[3] Deep Flare Net: URL, https://defn.nict.go.jp

The Offworld Solar System Toolkit – How to Build Civilization to the Stars

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Keywords: Lunar resources, robotics, cis-lunar industry

The development and utilization of the vast and untapped resources on the lunar surface is daunting – both technically and from and economic and investment perspective. Water trapped as ice in the permanently shadowed craters in the lunar polar regions can provide vital fuel and life support resources to all forms of activity in cis-lunar space. In addition, all of the raw materials needed to build large scale space solar power satellites to provide limitless clean energy to Earth exist on the lunar surface including aluminum, titanium, iron, magnesium and silicon as well as platinum group metals concentrated in asteroid impact craters. These resources can create the industrial feedstocks needed to expand industrial and economic activity off-world and improve quality of life on Earth for a growing population.

This vision, while compelling, is also immensely difficult to achieve. The lunar surface is extremely harsh and difficult to sustain industrial scale operations. Advanced and robust robotics systems need to be deployed at industrial scale, which require minimal human tended maintenance and repair. While some human presence will be essential, the more that industrial resource extraction can be automated with advanced robotics the easier it will be to close the business case. Offworld is now developing a suite of industrial scale robotic mining systems that will first be deployed in terrestrial mining applications. This will both validate the technology at commercial scale, as well as provide a cash flow stream for testing and deployment of space-rated versions of its robots on the lunar surface over the next ten year. These highly productive industrial robots will be able to begin to extract and utilize lunar resources and create the foundations of the cis-lunar economy.