Survive and Operate Through the Lunar Night Workshop
Tuesday, November 13, 2018
USRA Headquarters, Columbia, MD

Agenda	Time	Speakers
Welcome and Workshop Objectives	8:30–8:40 a.m.	Co-Chairs: Andrew Petro, NASA HQ Renee Weber, NASA MSFC
Overview of Lunar Day/Night Environmental Conditions — Including Various Latitudes, Polar Regions, Permanently Shadowed Regions, Peaks of Eternal Light	8:40–9:00 a.m.	Brett Denevi, JHU APL
Lessons Learned from Missions that Have Survived Lunar Night (Surveyor, ALSEP, Lunokhod)	9:00–9:20 a.m.	Ron Creel, NASA Retired
Panel Discussion: Evolving Requirements from Survival to Continuous Operations for Science, Exploration, and Commercial Activities	9:20–10:20 a.m. BREAK 10:40–11:40 a.m.	Science Perspective Sam Lawrence, NASA JSC: ASM/NEXT-SAT Briefing Exploration Perspective Ben Bussey, NASA HQ Panel Greg Chavers, NASA MSFC/HQ Dave Blewett, JHU APL Dana Hurley, JHU APL James Carpenter, ESA
LUNCH	11:40 a.m.–1:00 p.m.	On your own
Panel Discussions: State of the Art, Potential Solutions, and Technology Gaps Panel 1: Power Generation, Storage, and Distribution Panel 2: Thermal Management Systems, Strategies, and Component Design Features	1:00–2:00 p.m. BREAK 2:15–3:15 p.m.	Power Panel Moderator: Lee Mason, NASA STMD Len Dudzinski, NASA HQ: RPS and Fission Bob Sievers, Teledyne: Fuel Cells, RTGs Erik Brandon, JPL: Batteries Paul Alburtus, ARPA-e: Energy Storage Thermal Management Panel Moderator: Rubik Sheth, NASA JSC Eric Sunada, JPL: Robotic Missions Chad Bower, Paragon: Commercial Systems Kust Sacksteder, NASA GRC: Thermal Wadi
Commercial Space Panel: Understanding the Economic Business Case for Creating Lunar Infrastructure Services and Lunar Markets	3:15–4:00 p.m.	Moderator: Alison Zuniga, NASA ARC George Sowers, Colorado School of Mines Dennis Poulos, Poulos Air and Space, Inc. Dennis Wingo, SkyCorp Inc. Mahamed Ragab, iSpace Technologies, Inc. Rolf Erdmann, PT Scientists
International Space University Summer Project Presentation "Lunar Night Survival"	4:00–4:20 p.m.	Matt Henderson and Ilaria Cinelli, ISU
Open Discussion and Conclusions	4:20–5:30 p.m.	Co-Chairs, All Workshop Participants
Poster Session **Wednesday Evening, November 14**	5:00–7:00 p.m.	Posters Presented on Wednesday Evening During the 2019 LEAG Meeting

Wednesday, November 14, 2018
POSTER SESSION: SURVIVE AND OPERATE THROUGH THE LUNAR NIGHT WORKSHOP
5:00–7:00 p.m. USRA Education Gallery

Authors	Title and Summary
Evans M. E. Ignatiev A.	*Lunar Superconducting Magnetic Energy Storage (LSMES)* **[#7001]** This study seeks a method to efficiently store electrical energy without using chemical batteries, by applying terrestrial technology based on a superconducting coil and a persistent magnetic field located in a lunar permanently shadowed crater.
Nandini K. Usha K. Srinivasan M. S. Pramod M. Satyanarayana P. Sankaran M.	*Passive Survivability of 18650 Lithium-Ion Cells Through Lunar Night Environment Scenario* **[#7002]** Present study describes passive survivability of commercially-off-the-shelf 18650 lithium-ion cells tested in an environmental scenario similar to onset and progress of lunar night that is at cryogenic temperatures under vacuum for 336 earth hours.
Poulos D. D.	*Data Encoded Laser Wireless Power (DELWP) for Lunar Polar Applications* **[#7003]** Data encoded high power fiber lasers illuminating specialized tuned photovoltaic panels designed for power transfer will provide reliable, continuous power and data during periods of limited solar illumination, including into the dark polar craters.
Van Cleve J. E. Weinberg J. D. Neal C. R. Elphic R. C. Weed K. Mills G. Dissly R.	*Darkness Visible: Instrumentation and Thermal Design to Access the Hidden Moon* **[#7005]** We show mission concepts for a long-lived geophysical network and in-situ investigation of volatiles in the lunar polar cold traps, and Ball instrument and thermal technology enabling survival, situational awareness, and operations in the dark Moon.
Herring J. S. Mackwell S. Pestak C.	*Small Modular Fission Reactors that Enable Affordable and Sustainable Lunar Enterprise* **[#7006]** We will present the results of a study looking at the use of a LEU-based Small Modular Fission Reactor (SMFR) in the 40 to 100 kW range for lunar activities, building on the results of NASA's HEU-based KiloPower project.
Colaprete A. Elphic R. C. Shirley M. Siegler M.	*Multi-Lunar Day Polar Missions with a Solar-Only Rover* **[#7007]** The lunar poles offer opportunities for solar-only rovers to survive and operate many lunar days. Presented here are examples of rover traverses that take advantage of the unique polar illumination environments to operate across multiple lunar days.
Eppler D. B. Budden N. A.	*Lighting Constraints to Lunar Surface Operations* **[#7008]** An investigation into lunar surface ambient lighting levels indicates that, for most nearside locations, illumination will be adequate throughout a large portion of the lunar night to conduct surface activities.
Bugby D. C. Clark P. E. Hofmann D. C.	*High Performance Thermal Switch for Lunar Night Survival* **[#7009]** A high performance differential thermal expansion (DTE) thermal switch was developed to enable solar/battery powered lunar surface science payloads. The measured thermal switch performance is: 5 W/K ON, 0.002 W/K OFF, and 2500:1 ON/OFF ratio.
Nunes D. C. Carpenter K. Haynes M. de la Croix J. P.	*Shifting the Paradigm of Coping with Nyx on the Moon — a Ground-Penetrating Radar Case* **[#7012]** A multi-static, autonomous ground-penetrating radar instrument, MARGE, will incorporate strategies to be more tolerant of the lunar diurnal thermal cycle.

Wani S. C. Shah U. B. Kothandhapani A. Garg P. Sahai M. Garg M. Nair S.	*Requirement Analysis and Night Survival Concept for Z-01 Landing Mission Using Fuel Cell* **[#7014]** Only three missions have survived the lunar night, using Radioisotope Thermo-Electric Generators and Radioisotope Heating Units. This paper discusses the challenges to survive lunar night and presents a fuel cell-based concept as an alternative.
Plata D. S.	*Lunar Roads: Strategies for Remaining in the Sunlight* **[#7017]** By driving westward on the slowly rotating Moon, telerobots could remain in the sunlight while compressing the regolith in order to make basic, reduce-dust roads.
Powell T. M. Siegler M. A. Molaro J. L. Paige D. A.	*Leveraging In-Situ Regolith Properties for Nighttime Heating* **[#7018]** Despite large temperature fluctuations at the lunar surface, thermally coupling to warm nighttime materials (rocks, subsurface, etc.) present in-situ might provide some heating and reduce the engineering payload necessary for surviving the night.
Dillon R. P. Borgonia J-P. C. Roberts S. N. Hofmann D. C. Kennett A. Firdosy S. A. Wilcox B. H. Hales S. Smith J. D. Schuler J. McEnerney B. Shapiro A. A.	*Bulk Metallic Glass Gears for Lunar Night Capable Actuators* **[#7019]** BMG Gears is developing unheated, cold-capable gearboxes for use in cryogenic environments such as lunar night. The enabling alloy properties, cryogenic test performance, part processing, qualification, TRL, and infusion challenges are discussed.
Carroll K. A.	*Lunar Surface Gravimetry Surveying Through the Lunar Night* **[#7020]** Lunar surface gravimetry is a powerful technique for probing the Moon's subsurface structure, using a gravimeter on a static lunar lander or on a lunar rover. Measurements spanning multiple lunar days will increase accuracy and resolution.
Guven U. G. Singh A. K. S.	*Utilization of Nuclear Power for Moon Missions: Nuclear Power Generation Using Helium Cooled Reactor for Moon Habitats* **[#7021]** Abstract discusses using helium cooled nuclear reactors in Moon habitats to supply continuous power to the habitat as well as any future processing/manufacturing plants on the Moon.
Nieczkoski S. Dreyer C. B. Blair B. Rostami J.	*Material Selection for Mechanical Mechanism Survival and Use in the Lunar Night* **[#7023]** Survival of spacecraft mechanisms is challenging due to low polar temperatures. Structural and cutting materials enabling drilling and mining under deep cryogenic conditions are currently being tested under the NASA Early Stage Innovation program.
Guzik M. C. Gilligan R. P. Smith P. J. Jakupca I. J.	*Regenerative Fuel Cell-Based Energy Storage Systems for Lunar Surface Exploration* **[#7024]** The data presented in this paper provides a method to determine the critical parameter values of a Regenerative Fuel Cell (RFC) system in order to perform high-level mission architecture trades, with a focus on surviving the lunar night.
Williams J.-P. Greenhagen B. T. Paige D. A.	*Seasonal Temperature Variations in the Polar Regions of the Moon* **[#7026]** Mapping of temperatures in the south polar region with LRO's Diviner Lunar Radiometer Experiment shows how temperatures within 5 degrees of the pole vary considerably with season.
Eubanks T. M.	*MilliWatt Lunar VLBI Beacons: Surviving the Lunar Night* **[#7027]** MilliWatt radio beacons could establish a lunar VLBI network for science and navigation in cislunar space, ideally operating for decades. Small, gm-scale Americium-241 batteries are proposed to meet the power and longevity needs of these networks.

Fuqua Haviland H. Poppe A. R. Fatemi S. Delory G.	*The Importance of Nightside Magnetometer Observations for Electromagnetic Sounding of the Moon* **[#7010]** Nightside Time Domain Electromagnetic Sounding has the capability to advance the state of knowledge of the field of lunar science. This requires magnetometer operations to withstand the harsh conditions of the lunar night.
Ignatiev A.	*The Use of Lunar Resources for Energy Generation on the Moon* **[#7013]** The resources of the Moon can be used to develop an electrical energy system for the Moon. This can be accomplished by leveraging vacuum deposition technology and lunar resources to fabricate a low-cost and scalable lunar power grid.
Baiden G. R. Blair B. R.	*Adapting Terrestrial Technology to the Design of a Night-Survivable 10 Meter Lunar Polar Prospecting Drill* **[#7016]** This paper will explore the possibility of a 10 meter cryogenic lunar polar drill that could 'survive the night' and that would enable the collection of scientific data that could validate current models for polar resources.
Vaughan R.	*Mission Design and Implementation Considerations for Lunar Night Survival* **[#7029]** We present some of the design, development, cost, and schedule impacts of dealing with problematic night time lunar conditions, whether for near-equatorial or near-polar landed lunar missions.
Farmer J. F. Alvarez-Hernandez A. Breeding S. P. Lowery J. E.	*Advanced Thermal Techniques and Systems Design Enable Long Duration, Continuous Day/Night Operation of Robotic Science Landers and Payloads on the Lunar Surface* **[#7030]** Recent developments in NASA and commercial space capabilities and plans support and call for increased exploration of the lunar surface. Lunar exploration objectives vary widely from geophysical research to human exploration and resource prospecting.
Clark P. E. Bugby D. C. Hofmann D. C.	*Low-Cost Distributed Lunar Surface Networks Enabled by High Performance Thermal Components* **[#7031]** Credible opportunities for delivery of small payloads to the lunar surface via commercial landers are emerging in the coming decade.
Cataldo R. L. Mason L. S.	*Lunar Night Survivability Achieved by Radioisotope and Fission Power System Technology* **[#7032]** Options for advanced RPS and Kilopower systems will be discussed and compared to alternate power system solutions.
Morrison C. G. Deason W. Eades M. J. Judd S. Patel V. Reed M. Venneri P.	*The Pylon: Near-Term Commercial LEU Nuclear Fission Power for Lunar Applications* **[#7033]** Nuclear energy provides not only the ability to survive the 354-hour lunar night, but the ability to thrive.
Hecht M. H. Lubin P.	Satellite Beamed Power for Lunar Surface Assets **[#7034]** The confluence of several factors now make beamed power systems practical for solar system exploration in the near-term. This is particularly true for lunar exploration.
Barnhard G.	*Challenges of Space Power Beaming: Mission Enabling Technology for Continuous Lunar Operations* **[#7035]** This presentation will outline opportunities to leverage and extend the Xtraordinary Innovative Space Partnerships, Inc. (XISP-Inc) Technology Development, Demonstration, and Deployment (TD3) mission for Space-to-Space Power Beaming (SSPB).