Title Beaming of Energy via Laser for Lunar Exploration (BELLE)

(Technical Paper)

An American Perspective on NASA as an Agency and Space Exploration

(STS Paper)

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Prospectus

Introduction

This is a proposal to address National Aeronautics and Space Agency's (NASA's) effort to rapidly mature innovative and high-impact capabilities. After years of research and development (R&D), NASA has discovered ice volatile particles in the lunar regolith, i.e. lunar dust, in moon's permanently shadowed regions (PSRs) that could revolutionize the lunar exploration and lead an opportunity to sustainably establish base stations in the moon. Despite the current R&D in lunar PSRs, the problem of transmission of solar collected energy to rovers in moon craters still exists, where there is no access to sunlight. We propose a high-power wireless energy transmission in form of a laser beam that has a tremendous impact on lunar missions and beyond (Prof. Mool Gupta, Personal Communication, August 2020).

Considering the urgency and the importance of lunar missions at the moment, US public should still perceive the lunar missions as a space competition as well as a path window to reach the dream of becoming a multi-planet species. I carefully wanted to discuss the public perception and its relation to NASA since it is the students and young space aspirers that would eventually and potentially become the force to drive US space missions. It is vital to analyze the social construction aspects of corresponding technologies as well as the technological momentum that can impact the public perception and gravity toward the space exploration.

Technical Problem

The rims of the polar craters in our lone orbiting moon are illuminated for over 200 terrestrial days due to lunar ecliptic tilt. However, due to the sun's low incidence angle, light is unattainable in the 4.2 km deep crater interior in-which these dark regions are called permanently

3 shadowed regions (PSRs). According to Kenneth Watson et al, the PSRs maintain a temperature of 100 Kelvins (K), due to lack of sunlight and absence of lunar atmosphere. Hence, water ice and other volatiles are believed to remain retained in the floors of sunlight-shy lunar polar craters, implying that the frozen water has persisted for possibly billions of years, undisturbed by solar radiation (Watson 1961). Recently, NASA and other space agencies have shown significant interest in accessing the ice and doing research through the future Artemis missions (NASA.gov).

Even for NASA, it is a difficult task to commit to design systems given the harsh PSR environment and various ongoing projects. The rover battery requires a recharge in some regions of a PSR floor with approximately 20 km diameter (Fincannon, 2007) and if the rover runs out charge, it would be unable to return to the crater rim to recharge again using its solar panels leading to an obsolete stationary vehicle. It is for NASA's best to design a new system to sample the lunar PSR regolith by the time the Artemis mission is being launched.

First, I would present a brief description of our multi-component design by our team then address the state of art for each single component since current approaches are in early stages to solve such a problem conclusively ("NASA BIG Idea Challenge"). As defined by our team, our project, BELLE "offers a novel power-beaming and tracking system to power assets in lunar PSRs (Prof. Gupta, Personal Communication, Aug 2020)." Our goal is to collect

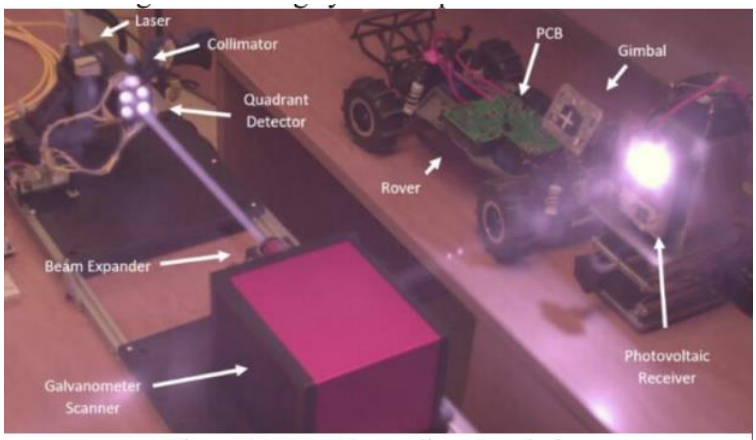

Figure 1: BELLE overall system design

the sunlight at the craters rim with high efficiency solar cells where sunlight is accessible and beam the energy in the form of laser to the rover's energy-receiver. To ensure that the beam energy is received by the rover's energy detectors, we designed a multi-component laser tracking system as depicted in Figure 1. Although, BELLE is a multi-component integrated system, we prioritize the laser power beaming and optical tracking elements as the project is directed by UVA's Center for Laser & Plasma for Advanced Manufacturing. BELLE has the potential to transform lunar exploration and will have an effect far beyond the moon. The ice is critical because it may be utilized to sustain lunar habitation or electrolyzed to produce liquid oxygen fuel (Patel, 2020). This capacity for habitation and replenishment is critical for advancing the exploration of deeper space.

Modern practical trials of the laser beaming technology are in the early phases of technological readiness level (TRL). The nameplate capacity of diode lasers has risen exponentially over the past three decades achieving greatest efficiencies at 920-980 nm (Kanskar, 2005). PowerLight Technologies and Prof. John Federici's team at the New Jersey Institute of Technology have previously demonstrated laser power beaming to a photovoltaic receiver. These experiments comprise effectively beaming 400 W of electricity across a distance of 1 km (McIntosh, 2018), powering a quadcopter unmanned aerial aircraft for more than 12 hours (Narici, 2017), and powering a tiny remote-controlled vehicle (Faraci, 2020). Laser tracking and ranging of objects utilizing retroreflectors and beam scanners is a well-established metrology technique. And we claim that our design would solve the NASA's problem by integrating the best of the existing state of the art and our own technologies from UVA's laser and plasma lab.

We conduct the tests on individual components' efficiencies as well as collective ones using the optical power meter detector. In regard to testing the dynamic robotic and motorized 5 elements, for the solar cell technology, current-voltage measurement of the series arrangement of four InGaAs/Ge cells will be conducted using our lab technologies. Figure 2 depicts the consistency reliability of our system.

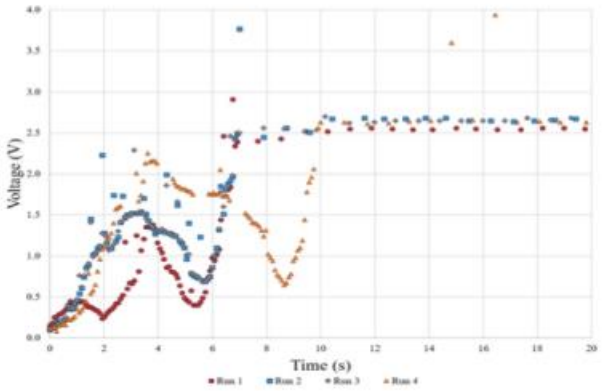

Figure 2: Voltage reading vs time of the gimbal mounted PV cell. The steady voltage shows that the gimbal is

Our next task is synthesis an optical diffuser using the laser precision machining to prevent the beam laser energy from diverging and have aligned parallel light waves to distribute the energy uniformly to the rover solar receiver.

STS Problem

In Christopher Wanjek's opinion who is prominent science journalist, the primary motivation for human space exploration is not the establishment of large colonies on other worlds, but rather primarily economic reasons such as "increasing energy production, offloading supercomputers, mining other worlds, establishing space-based manufacturing, and even space tourism, among other things (Kornfeld, 2021)." While that might be true for now, but Neil

DeGrasse Tyson argues that the early space missions weren't merely about science rather a 6 military and government program in fear of Soviet space military interventions (Wbur, 2018). Dr. Tyson describes President John F. Kennedy's promise of going to moon as, "It's the war driver for spending money, and that's why we went to the moon. And that's why nobody should be surprised that when we learned the Soviet Union was not going to the moon, that we just ended it all." Now according to several surveys, most Americans think that the United States should lead the world in space research (Pew Research center, 2018). Also, the majority of people believe that monitoring the environment and tracking asteroids should be high priorities for NASA; just 13 percent believe that placing humans on the moon should be a significant priority.

This implies a shift in perceived and actual agenda of the organization overtime. NASA itself outlines some of the work being done in the agency as, sending astronauts to space for scientific investigation, developing satellites to aid scientists in their efforts to understand more about the Earth, bringing "new advancements in air travel and other elements of flying are making the experience better ("What Does NASA Do?", 2018)" suggesting the absence of tense competition unlike the cold war era.

I believe this view is incomplete. Although, NASA is known as a civilian agency, according to Military Times, "More than half of NASA's moon-bound astronauts are active-duty military (Venhuizen, 2020)." Moreover, the new proposal for long-term lunar colonization is based on a 13-page study presented to President Donald Trump in 2020, stating NASA's plan spends the most of its time summarizing NASA's vision for justifying lunar missions (Bartels, 2020). In response, China and Russia announced that they will work in a joint operation to "construct a lunar research station" (Neuman, NPR, 2021).

I argue that space agencies are a combination of civil and military organizations and have always been in an implicit competition with their corresponding rivals. My analysis of understanding social beliefs regarding the space exploration over a period of time, drags the concepts of Social Construction of Technology (SCOT) and Technological Momentum. SCOT broadly refers to a theory about how a variety of social factors and forces shape technological development, technological change, and the meanings associated with technology as well as claiming the interpretive flexibility of artifacts (Johnson). I argue that the societal view of NASA as an agency has changed over time from an organization to only "make rockets to compete with Soviet" to a comprehensive institution that focuses on research to serve humanity as well as to imply the US presence in the space exploration. On the other hand, technological momentum is a theory about the relationship between technology and society over time. The idea is that relationship between technology and society is reciprocal and time-dependent so that one does not determine the changes in the other, but both influence each other. I believe NASA today is the result of adversaries and social expectations that it has gone through and now being in its mature age, affects the life of human beings in ways that we have taken for granted.

Conclusion

The technical report delivers a set of new design solutions to wireless transmission of the energy using laser beam energy generated by high efficiency solar cells at the rim of the lunar craters. The report incorporates the techniques used to develop BELLE system as well as comprehensive testing methodologies that would assess the components in individual and collective levels by using the technologies that exist in UVA's laser and plasma lab. The STS research paper will seek to provide in-depth insight into the US public and NASA relations using the concepts of SCOT and Technological Momentum.7 8 The result of the technical report

resolves NASA's rover recharging challenge in the PSRs by providing an exceptional design detail and laboratory R&D to achieve the TRL 5 or better. The findings of STS report will shed light on how a belief of competition brings a level of seriousness for the people who are working in space programs and public as well.

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