Phase 1 Project Summary

Firm: Orbital Technologies Corporation

Contract Number: NNX09CF72P
Project Title: Algorithms and Regolith Erosion Models for the Alert Code

Identification and Significance of Innovation: (Limit 200 words or 2,000 characters whichever is less)

ORBITEC and Duke University propose a Phase 2 project to develop the ALERT II (Advanced Lunar Exhaust-Regolith Transport) Code which will include the powerful Onsager Principle based ABL (Ablating Boundary Layer) model algorithms, validated by Phase 1 jet-erosion experiments using Mars and Lunar regolith simulant. Models successfully predicted the structure and profiles of craters in both the Moon and Mars cases. Models indicate debris velocity may exceed 1.5km/sec on the Moon for RL-10 descent engine, and Mars descent plume-cratering may be severe and undermine spacecraft footing. New experiments at Mars ambient atmospheric pressure, and including regolith water, are possible using the safe and compact ORBITEC MET(Microwave Electro-Thermal) electric thruster due to its strong thrust and high exhaust velocity. The MET can provide the rocket plume at chemical-engine exhaust velocities using inert gases heated by an electrodeless, vortex stabilized microwave discharge. High thrust at low gas throughput allows maintenance of Mars conditions by pumps. These results will be incorporated into the ALERT II code. 3-D visualization of ALERT code results will also be provided. ALERT II is a spaceport planning tool. The Proposed Phase 2 effort will refine the plume-regolith interaction models and incorporate then into an improved ALERT code.

Technical Objectives and Work Plan: (Limit 200 words or 2,000 characters whichever is less)

The overall objective of the Phase 2 effort is to further develop experimentally validated models for inclusion in the ALERT II code for making high-fidelity predictions of landing plume-regolith interactions at Mars and Moon using erosion experiments at Mars ambient pressure and including moisture. Specific technical objectives include: 1. Define requirements for the Mars ambient pressure experiments, with NASA input. 2. Prepare design of ALERT II code with Onsager Principle-momentum-mass conserved algorithms. 3. Construct a simulated Mars Ambient Pressure plume-regolith impingement experiment using the ORBITEC MET thruster and collect data. 4. Conduct momentum and mass conservation tests with the ALERT 5. Analyze the data from the plume-regolith experiment. 6. Perform numerical modeling of plume-regolith experiment. 7. Implement improved models derived from experiment for ALERT code. 8. Prepare preliminary design of an ALERT-Moon and Alert-Mars tool for Phase 3.

Technical Accomplishments: (Limit 200 words or 2,000 characters whichever is less)

The premise of the Phase 1 project was that a high-fidelity plume-regolith interaction model could be formulated to match the Apollo phenomenology as well as experiments using high fidelity Lunar and Mars dust simulant and that this model could form the basis for a code planning tool for spaceport operations planning. The physical model was based on the careful inclusion of momentum exchange in the plume-regolith interaction and the concept of erosion and transport of the regolith by the rocket plume occurring in a thin boundary layer near the surface. The boundary layer itself adheres to the crater surface and minimizes both curvature and erosion. The model predicts catenary profiles for shallow craters and hyperbolic profiles for deeper craters. This model was calibrated and validated by experiments using Lunar and Mars dust simulant by Duke University.

NASA Application(s): (Limit 100 words or 1,000 characters whichever is less)

High-fidelity simulation of rocket plume-regolith interactions are required to plan spaceport operations on the Moon and Mars. These simulation models must include relevant physics, such as momentum exchange between the plume gases and regolith particles and the trajectories of such particles once they have left the direct plume impact region. The experience of Apollo landings, where the surface was largely obscured by plume-mobilized dust, and particularly the evidence for extensive impact damage on the Surveyor 3 demonstrates the importance of this issue for planning Lunar operations. The dust devils and storms of Mars suggest plume-regolith interactions are also an issue there.

Non-NASA Commercial Application(s): (Limit 200 words or 2,000 characters whichever is less)

High-fidelity plume-regolith interaction simulation codes are being developed to support the needs of the NASA lunar and Mars exploration programs. However, industry and research institutions that are developing any EVA equipment for use on the lunar surface will also require high-fidelity lunar plume–regolith interaction simulations to evaluate the effects of dust-plume interactions on the operation of all Exploration Surface Systems and to verify the effectiveness of dust mitigation and impact protection. Much of this work in the near future will be under NASA contracts. Longer term, private industry plans for lunar operations will make use of these simulation tools.

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