DUST MITIGATION TECHNOLOGY CHARACTERIZATION OF COATINGS AND PLIABLE CLEANERS. J. L. Black[1], A. H. Garcia[1], S. R. Deitrick[1], M.C. Sico[2], V. Yu[2], K. K. John[3], [1]Jacobs Technology, Johnson Space Center, Houston, Texas, [2]NASA Johnson Space Center, Houston, Texas (jacquelyne.l.black@nasa.gov), [3]NASA Space Technology Mission Directorate.

Introduction: *Lunar Dust*. Dust has been identified as one of the most significant hazards to human lunar exploration, but limited testing has been performed on lunar dust mitigation technologies since the Apollo program concluded. The safety of the crew members and sustainability of habitats, science, and supporting hardware depend on effective dust mitigation techniques and technologies to prevent dust from degrading hardware and equipment.

DuSTI. Mitigating dust is critical for the success of all future lunar surface systems as nearly all hardware that encounters the surface of the Moon will interact with lunar dust. The Dust Solution Testing Initiative (DuSTI) project is a series of component and subsystem tests in dusty environments to test existing coating and pliable cleaner technologies with high potential for lunar dust mitigation. Testing of hardware and subsystems is ramping up for NASA Programs and contracted partners in support of the Artemis missions. This project provided a test bed and process for several candidate dust mitigation technologies for the lunar surface including coatings for hardgoods, coatings for softgoods, and pliable cleaners. The goal was to test and characterize candidate dust mitigation technologies for utility in NASA, commercial spacecraft, and lunar surface systems.

Objectives: The first objective of DuSTI was to identify a subset of COTS technologies that could be rapidly tested to determine suitability for future Artemis sustained missions. The next objective was to increase the TRL of the selected COTS technologies by validating components in relevant environments with relevant materials (i.e. lunar regolith simulant). This abstract provides an overview of the test data, as well as some conclusions. Information on the testing process, the selected technologies, detailed results, recommendations, and future work will be presented at LPSC and published in a NASA Technical Publication.

Test Matrix: The tables listed below are a summary of all tests conducted in the analysis of hardgoods, softgoods, and pliable cleaners, as well as their respective coatings (except pliable cleaners). The tests on coatings were performed to evaluate the coating behavior and their effectiveness at mitigating lunar dust. The pliable cleaner tests were selected to determine the effectiveness and feasibility of the material as if it were used in a lunar environment. Pliable cleaners are defined in this work as a flexible cleaning gel or putty that can gently liberate and store surface contaminates by pressing the cleaner into the substrate. Lunar Highland Simulant (LHS-1 & LHS-1D) was used for all testing involving dust mitigation analysis. The particle size distribution of this simulant is intended to be similar to Apollo 16 soil distributions with angular particle shapes.

Table I: Tests Conducted and Separated by Substrate

Hardgoods Coating	
Tape Press	Adhesion
Abrasion	
Softgoods Coating	
Tensile	Stiffness
Folding Endurance	Adhesion
Pliable Cleaner	
Rheometer	Temporal Usability
Hardgoods Benchtop	Aluminum Nut & Bolt
FTIR Residue	Off-gassing/Toxicity
Modified Off-gassing/Toxicity	Flammability

Table II: COTS Technologies Being Evaluated

Hardgoods Coating	**Substrate**
Feynlab Waterline	Glass
Masterbond EP114	Glass
Metashield NanoGlass	Glass
Masterbond UV22DC80	Polycarbonate
Feynlab Industrial	Aluminum
Softgoods Coating	**Substrates**
UltraTech EverShield DOR 19	Orthofabric, PBI, Nomex, Nomex Felt
Pliable Cleaners	**Color of Cleaner**
Cyber Clean Home & Office	Yellow
Cyber Clean Car	Blue
Cyber Clean LeafCare	Green
Cyber Clean Vinyl & Phono	Black/Gray

Technology Readiness Advancement: All technologies used were COTS products. The starting technology readiness level (TRL) was level four for each technology. Through a series of tests in relevant environments with relevant simulants, and given that these products would not be modified if used for flight, the resulting TRL is level six for each technology. More information on TRL advancement can be found in the NASA Technical Publication.

Results:

Hardgoods:

Tape Press: All samples passed, verifying coating adhesion to substrate.

Adhesion: Feynlab Industrial coated aluminum showed improved performance compared with uncoated aluminum. Coated glass samples did not show improvements over uncoated glass.

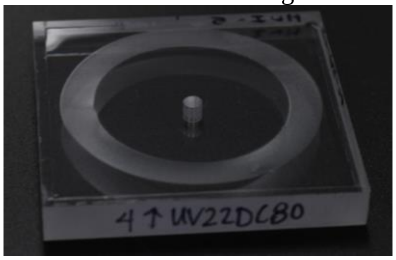

Figure 1. Taber wheel abrasion on coated polycarbonate sample

Abrasion: Metashield and Feynlab Waterline were more abrasion resistant than uncoated glass, and both passed post-abrasion haze requirements set by JSC 66320. The UV22DC80 coating performed better than the uncoated polycarbonate, but neither passed post-test haze requirements. There were no discernible differences in the abrasion performance of the aluminum samples.

Softgoods:

Adhesion: The coating chosen did not appear to successfully mitigate adhesion of the LHS-1 lunar simulant. It had increased the adhesion instead of decreasing it, which was counterproductive.

Tensile: Coated substrate amples that were not folded prior to testing (baseline samples), had lower tensile results than uncoated samples (except for Nomex). For the 40,000-cycle folded and coated samples, however, it had higher results than the folded uncoated sample counterparts (except for Nomex).

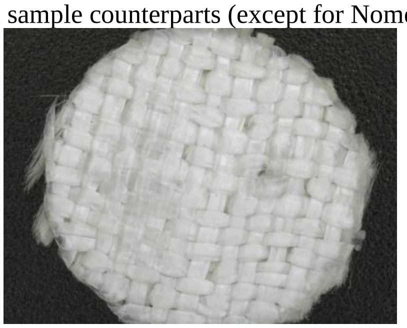

Figure 2. Coated Orthofabric prior to adhesion testing

Stiffness: Nomex felt was the only substrate to show a higher stiffness value for both coated baseline and coated folded samples.

Pliable Cleaners:

Hardgoods (Optical Surface) Benchtop: Cyber Clean Car and Cyber Clean Home & Office were the most efficient pliable cleaners in removing simulant from an optical surface. Cyber Clean Leaf Care had decreasing performance and left behind an apparent oily residue, while Cyber Clean Vinyl & Phono also had decreasing performance and left behind apparent micro-glitter on the cleaned surface. Cleaning effectiveness began to decline after about two days for all pliable cleaners after being exposed to an ambient atmosphere.

Hardgoods (Bolt & Nut) Benchtop: All four pliable cleaners performed similarly in removing the LHS-1 simulant from the aluminum surface of the bolt threads and nut surface.

Materials Property Testing: Additional testing was performed to determine feasibility for flight including rheology, temporal useability, flammability, offgassing, and toxicity.

Figure 3. Hardgoods Benchtop - Simulant removal from optical surface

Conclusion:

Hardgoods: Adhesion results for only one coating (out of 4) were better than their uncoated counterparts. Abrasion results for three of the five coatings were better than the uncoated samples, but only two of those coatings passed post-abrasion haze requirements.

Softgoods: Adhesion results for the coated samples were worse than their uncoated counterparts.

Pliable Cleaners: All four pliable cleaners preformed somewhat similarly and have about two days' worth of exposure to ambient atmosphere before declining in cleaning performance.

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References:

[1] Garcia A. H., et al. (2021) *LSIC Spring Meeting.* [2] Garcia A. H., et al (2020) *LSIC Fall Meeting.*