

THE TOUCH-AND-GO-IMPREGNABLE PAD (TGIP) FOR LUNAR EXPLORATION. Derek W. G. Sears^{1,2}, Larry Roe^{1,3}, Robert Gawley^{1,2}, and Melissa A. Jones⁴, ¹Arkansas Center for Space and Planetary Sciences, University of Arkansas, Fayetteville, Arkansas 72701. ²Department of Chemistry and Biochemistry, University of Arkansas, Fayetteville, Arkansas 72701. ³Department of Mechanical Engineering, University of Arkansas, Fayetteville, Arkansas 72701. ⁴Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, California 91109. (e-mail address for first author: dsears@uark.edu).

Introduction: Sample return missions are becoming an increasingly important component of a scientific enterprise that is usually dominated by remote sensing missions. This trend will only strengthen as the new vision for space gains momentum. All explorations are ideally accompanied with sample return applying to both the terrestrial explorations of the early 1800s through the space explorations of Apollo and ultimately extending to other more diverse solar system bodies. We have developed a touch-and-go sample collector for use with asteroid exploration (Fig. 1), and here we point out its value as part of lunar exploration. Although intended for robotic missions (Fig. 2), where the science required the collector could also be deployed by astronauts.

The Concept: The TGIP consists of a cookie cutter with a spring-loaded back plate filled with an inert silicon polymer. Pressed into the regolith of the planetary object, the collector becomes impregnated with rocks, gravel and smaller particles while dust adheres to the surface. The surface of the collector can be visually inspected for success, and the whole assembly placed in a return container or capsule where the polymer protects the sample from damage during the stresses of Earth return.

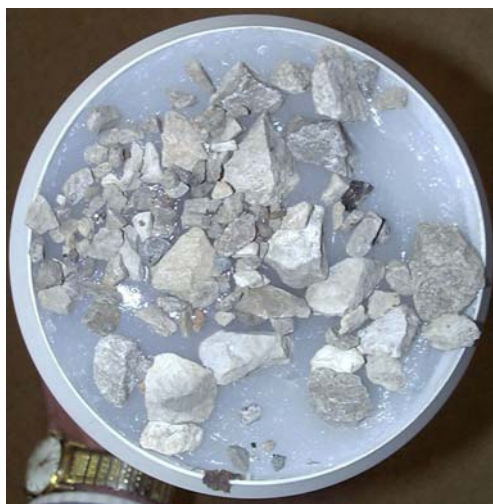


Fig. 1. Face-on view of a prototype TGIP with ~200 g of gravel-sized sample on the surface. While the sample is strongly attached to the surface, less than 20 volume percent of the gravel is below the surface.

Science questions amenable by the TGIP: The collector is ideally suited to science issues in which the nature of the very surface is of interest and there are many of these. In some respects, the TGIP is complementary to remote sensing measurements because it returns the very samples that are observed remotely. Ground truth obtained this way would lead to a general improvement in the interpretation of data obtained by remote means. Space weathering is a topic of considerable interest because it obscures the nature of the original surface. It may be part of the explanation for major mismatches between asteroids and meteorites, for instance.



Fig. 2 Cartoon of a rover deploying TGIP. About a dozen TGIPs are removed from a canister (not shown) and deployed. After checking visually for successful collection, they are then placed in a canister for Earth-return (grey cylinder shown).

Then there are a large number of projects in which it is the behavior of the surface of airless bodies that is of interest. The regolith of the Moon is the result of dynamic and sometimes violent processes that provide important insights into the nature of the early solar system. The regolith preserves a record of this. At the same time, surface materials have been excavated from depth and are well-dispersed. Thus, during the days of Apollo it was found that all major geological units on the Moon were represented in most regolith samples.

The Moon is also a collector of solar wind and the Sun's elemental and isotopic compositions can be determined by the analysis of implanted atoms. Thus

the critical question of the nature of solar oxygen isotopes was resolved by analysis of gases trapped in the lunar regolith.

Science implementation issues of the TGIP:

Mass recovered. The mass of sample that can be collected by the TGIP depends on the nature of the surface, ranging from a few tens of grams for fine powder to a few hundreds of grams for gravel sized particles. These amounts are more than adequate for most modern analytical techniques and are large enough for representative sampling of the regional regolith.

Size and density sorting of surface. The collector collects everything within the area of the cookie cutter, somewhat analogous to the entomologist's meter-square. Thus size and density sorting is negligible. This is in stark contrast to, say, the Hayabusa collector that puts the surface particles on a ballistic trajectory very sensitive to size and density. This sample collection technique favors small low density particles.

Contamination and cleaning. Depending on the size of the regolith particles, it is possible that only a few percent of the collected material will come into contact with the substrate with the risk of contamination. The substrate is viscous and volatile-free, and will likely permeate less than a few hundred micrometers into most lunar samples. In any event, the substrate is a silicon polymer readily distinguishable from indigenous compounds. The polymer is soluble in commonly available solvents in the event that it needs to be physically removed.

Mission implementation issues of the TGIP

Temperature resilience. The TGIP is effective between -75°C and $+100^{\circ}\text{C}$, with a decrease in efficiency at the lower temperatures. This range is smaller than could be encountered on the Moon but, where and higher and lower temperatures could prevail, but assuming operational procedures could not be developed to handle this, heaters and coolers can readily be attached to the backplate to maintain an appropriate temperature.

Radiation resilience. Energetic electrons and beta particles have been used to administer doses of ionizing radiation well in excess of those expected for a six-year mission without any measureable degradation in performance. There is no reason to think that other forms of ionizing radiation should yield a different result although such tests would need to be performed.

Shock resistance. Laboratory tests at Arkansas and large scale tests at Langley have shown that the collector loaded with samples can survive multiple impacts of the sort expected by Earth-impact following direct entry of the atmosphere. These are well in

excess of any impacts likely to be experienced during a mission. In fact, gravel sized light bulbs continued to work after the impact tests.

Required force. The force required to administer the TGIP is well within the capabilities of a medium sized rover or an astronaut. In the event that inadequate sample is collected on the first attempt, the collector can be redeployed as many times as the science requirements of the mission dictate.

Reliability, robust, simple. The sample collector could hardly be simpler, especially for robotic missions where the subtleties of the human eye and hand are not available. There are very few moving parts, and the components are simple and inert. The mechanics of action are not complex. Even non-perpendicular movements are not an issue with the appropriate coupling between the pad and the deployment arm. In fact, the collector is very forgiving of angled deployment and slopes, and smearing is a problem under only the most non-ideal conditions because the rim of the cookie collector protects its contents. Once collected, particles are protected by the substrate and very difficult to release by vibration.

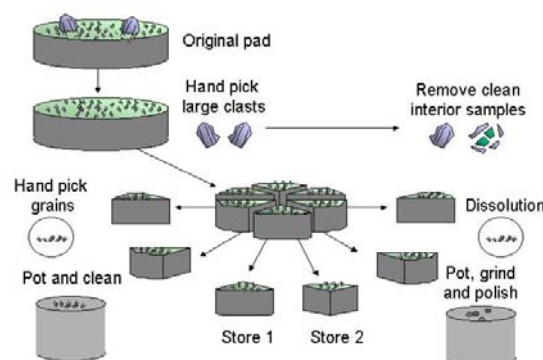


Fig. 3. The TGIP substrate can be dissected under a microscope in a clean room and handled in any number of ways appropriate to the science requirements of the investigators.

Curatorial aspects of the TGIP: The substrate can be dissected under a microscope in any fashion dictated by science requirements and the nature of the samples (Fig. 3). This can be done in a clean room, so that samples immersed in the substrate do not see the environment between collection and clean conditions. An almost endless array of options are then available for processing, handpicking, dissolution of the substrate with or without the samples, selective dissolution, mounting without further handling, and sterile storage.