Preliminary Data for Space Grade Spectralon®
BRDF Targets & Standards

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1.0 ABSTRACT
Spectralon is an extremely stable, near perfect, Lambertian reflecting diffuse and calibration standard material that has been used by national labs, space, aerospace and commercial sectors for over two decades. The Space Systems community has challenged the industry to improve its characterization and knowledge of its properties, particularly for space and ground applications. Labsphere has responded to this challenge by improving the repeatability and accuracy of its BRDF measurement process. This paper describes the improvements and the results of testing that were performed.

2.0 HARDWARE
Labsphere acquired a REFLET 180 Goniophotometer as a primary BRDF measurement tool and is enclosed in the manufacture provided dark chamber for light control of the illuminating beam.

3.0 RESULTS OF INTERNAL VALIDATION OF BRDF INSTRUMENT
There are two basic tests of our BRDF instrument: an angular repeatability and a darkroom test. These tests are performed on a regular basis to ensure the stability of the instrument.

4.0 SETUP OF BRDF INSTRUMENT FOR LARGER TARGETS
New instrument applications demand larger targets than simple 2" or 3" targets. A recent project presented several challenges: a rectangular shaped target, light tightness requirements (with validation measurements), multiple incidence angles and clocking sample rotations and extremely tight requirements for pass/fail on the BRDF targets. There were 6 identical targets in the setup A-G for illumination. Upon completion and close examination with the customer about the experimental nature of BRDF qualification, the BRDF measurement was included in the internal analysis as a special case for extreme conditions on performing a BRDF qualification. The objective of the test was to verify the re-collimation of the real BRDF of the camera looking at the target and the rotational (orientation) presentation of the target with respect to the illumination source. The targets had to have characterized BRDF over the entire sample size, which determined the orientation and see the test setup had to hold the targets within a 0.5% pass/fail for the panel BRDF performance. The large panel size necessitated the rotation of the parts over the clocking angles due to mechanical restrictions shown in Figure 5. Two positions were created to break up the angle sets in order to get as close to the full range as possible. The angle sets of the instrument are shown below in Figure 6.

5.0 RESULTS OF EXTENDED TARGET AND CHARACTERIZATION
Before the BRDF could proceed, the customer had a specific requirement that the flatness of the targets be measured. The flatness of the targets for a total of 4 panels over 10 months (normalized at 30 degree illumination) is shown below in Figure 7.

6.0 CREATING A FORM FACTOR FOR A TRACEABLE BRDF STANDARD
The work is far from done on this project, but the baselines above show that with the new instrument capability that Labsphere can start to consider providing BRDF characterization on its Spectralon Standards and Targets. As the best target showed in Section 4.1, the essential features in a BRDF standard are:

- Known flatness (plane) of the Spectralon face versus mounting surfaces with traceable references.
- Known surface (polished) of the Spectralon face versus mounting surfaces with traceable references.
- A well-defined target with a grid to hold the sample securely to place during measurement.
- A protective cover that does not touch the target during storage.
- A suggested design is included below in Figures 13 and 14 for a 2" x 2" square sample target for future evaluation. The new instrument is being evaluated in validating the measurement and be able to use these target designs to be able to conduct round robins and inter-comparisons which will ultimately lead to a more realistic BRDF of reflectance and reflectance using Spectralon materials.

7.0 CONCLUSIONS
As stated in the abstract, this is a preliminary presentation of a more concrete data set in a future paper. The initial data shows a variation of ±0.2% across one lab, a significant configuration over a short measurement cycle and that measurement repeatability of ±0.2 over long periods of time is possible. While a level of reproducibility and measurement accuracy is a prerequisite for a path to possible calibration, there is still work to be done to fully realize all possibilities of a reliable standard and measurement protocol, which has already led to the conclusion that these next steps will need to be completed for the next steps includes the following:

- Setting multiple standards in a set BRDF configuration/methology to determine path-to-path variation (and tolerances).
- Developing partners willing to establish traceable chains and round robin tests for commercial use.
- Establishing a known 'BRDF' Standard BRDF for grey standards and other shaped forms of Spectralon.

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As an additional note, the instrument was tested for stability since these panels took several hours of testing to complete. The variation in the instrument light source and detector was ±1%, a drift on the baseline from start to finish, but since each individual sample baseline was reset prior to its measurements, the overall drift was judged to be negligible to the resulting data.