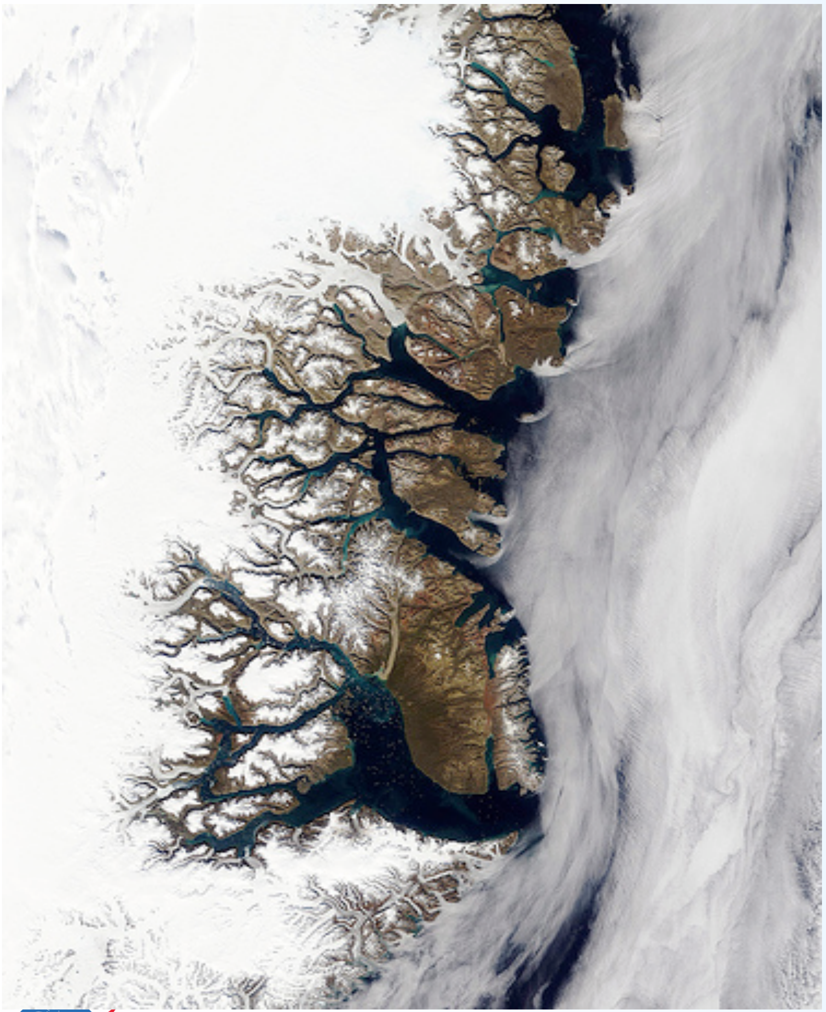
Multiwalled carbon nanotubes (MWCNT) for stray light suppression in space flight instruments



John G. Hagopian
Optical Physicist NASA GSFC

Stephanie Getty, Manuel Quijada, Patrick Roman, James Butler, Georgi Georgiev, Cleophus Hunt, Alejandro Maldonado; NASA Goddard Space Flight Center (GSFC)

Motivation for improved stray light control

- Stray light impacts many scientific observations
  - High contrast regions such as coastal areas during Earth observations
    - Loss of data can be as high as 40%
  - Faint objects such as dark companions near bright stars
  - Other experiments requiring stringent isolation of stray light
  - 10x improvement in surface treatments could result in 10,000x less stray light in focal plane

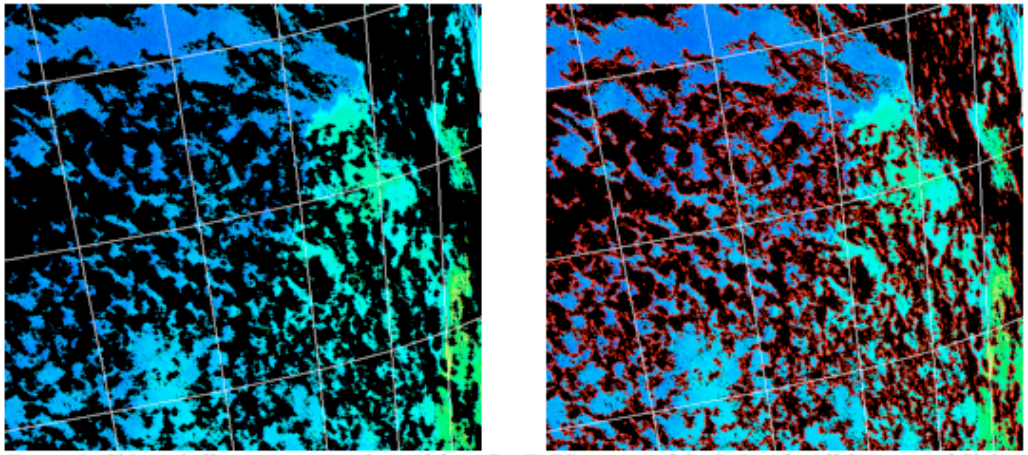
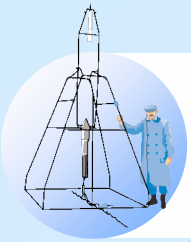


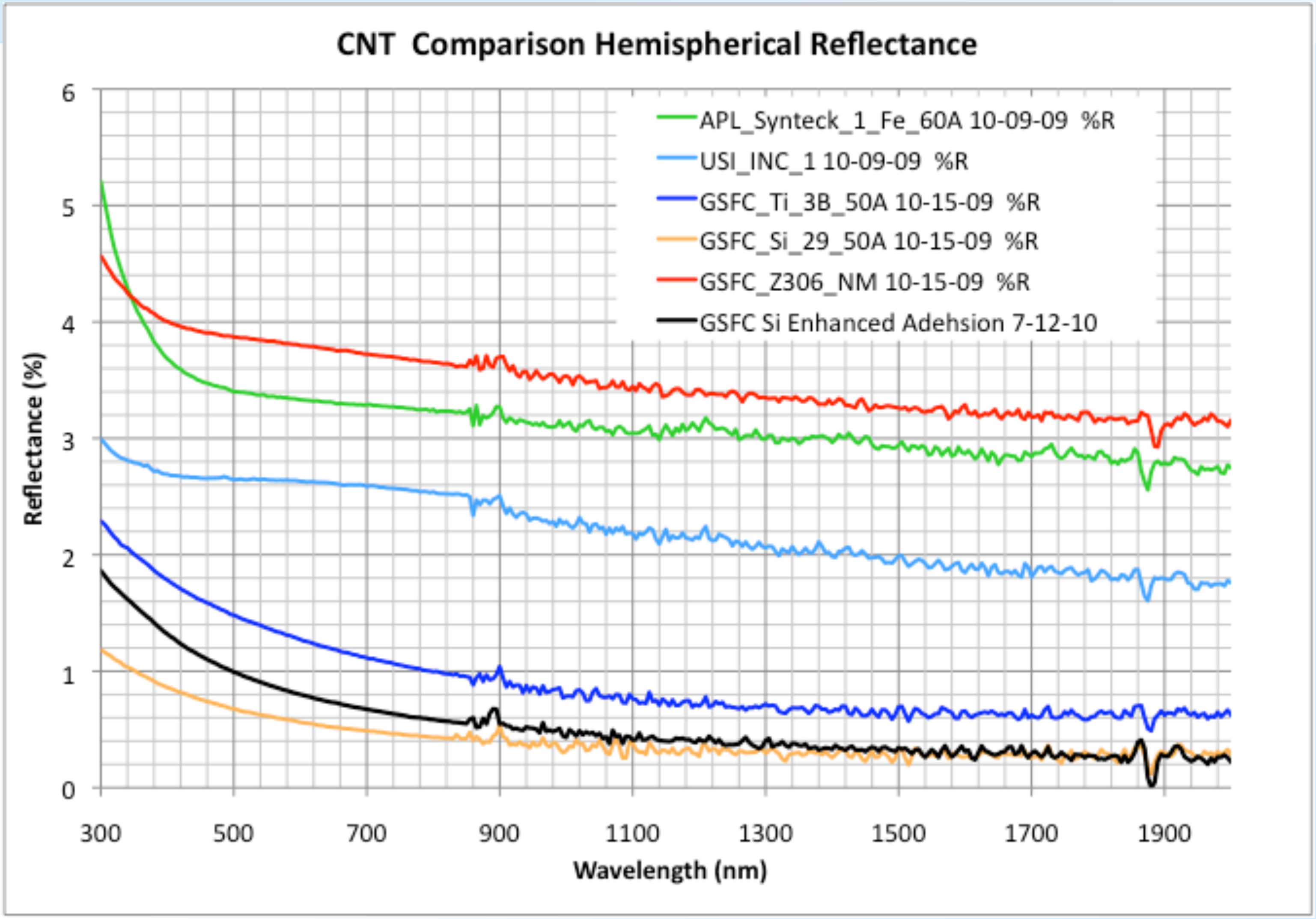
Figure 2. Chlorophyll concentration derived from SeaWiFS images of the S. Pacific off the coast of Chile on June 2, 2001. Chlorophyll concentrations decrease from yellow to blue, and black represents areas where chlorophyll is not retrievable (e.g. clouds). On the left is a chlorophyll concentration image in which chlorophyll is not derived around clouds due to stray light contamination (i.e. those areas are set to black). The right shows in red the extent of the regions in the left image which were contaminated with stray light. The reduction in stray light levels afforded by MWCNT technology would enable chlorophyll to be confidently retrieved in all red areas, leading to a 32% increase in scientifically useful pixels. (Images courtesy of Wayne Robinson, Ocean Sciences Branch/SAIC)

Background of studies

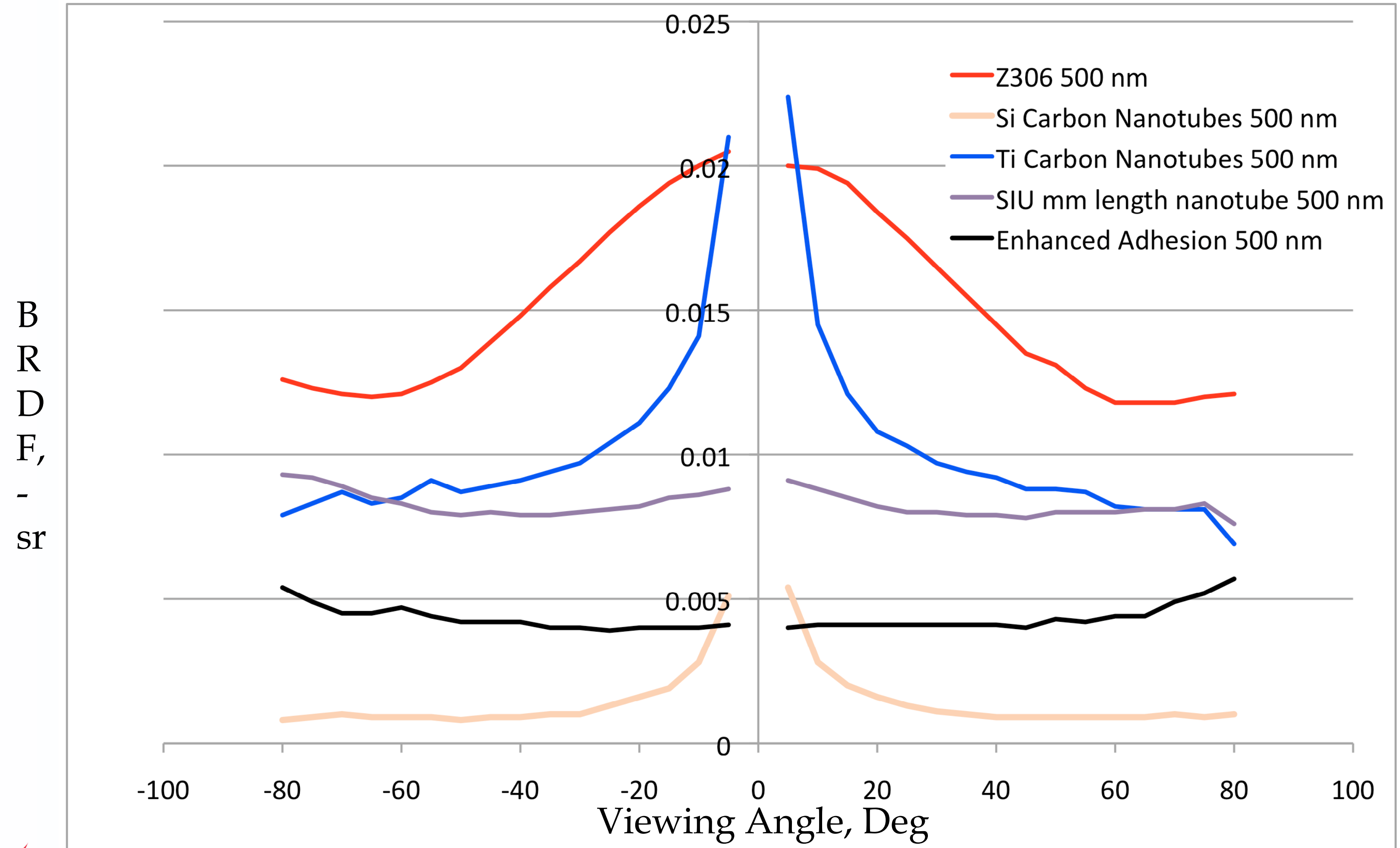
- Current stray light treatments
  - NASA Z306 paints are most widely used
  - Black anodize turns reflective at longer wavelengths
  - Other treatments such as Martin Black and Ultrapol are blacker than Z306 but too fragile for space flight use
- Due to multiple bounces in instruments improvement in surface treatment can result in exponential improvement in system stray light
- NASA Goddard Space Flight Center work on Multiwalled Carbon Nanotubes initiated in October 2007 in support of IRAD continuing to present with additional funding coming from Projects
  - Initial measurements on AMES randomly oriented samples
  - Measurements on GSFC oriented Multiwalled Carbon Nanotube (MWCNT) samples in Dec 2007 showed much lower reflectance
  - Optimization of process at GSFC on a variety of substrates
  - Optimization of adhesion on substrates by use of an underlayer

Hemispherical Reflectance Data



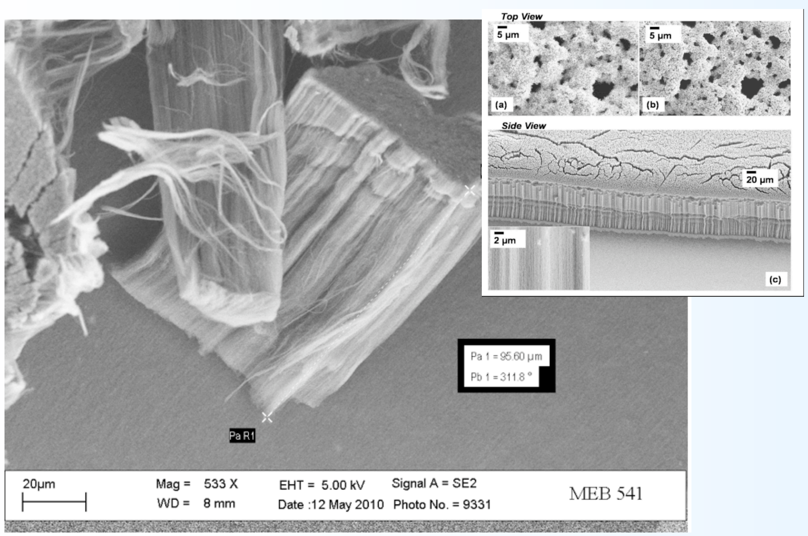


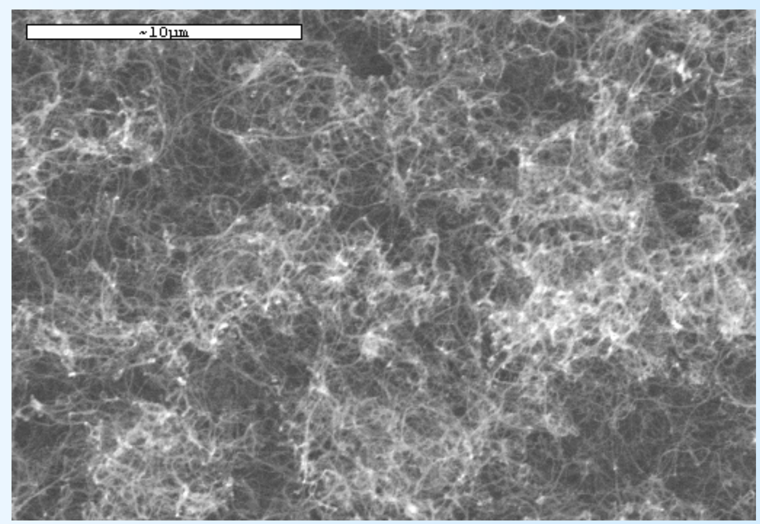
BRDF of MWCNT on various substrates vs Z306 at 0 degree incidence



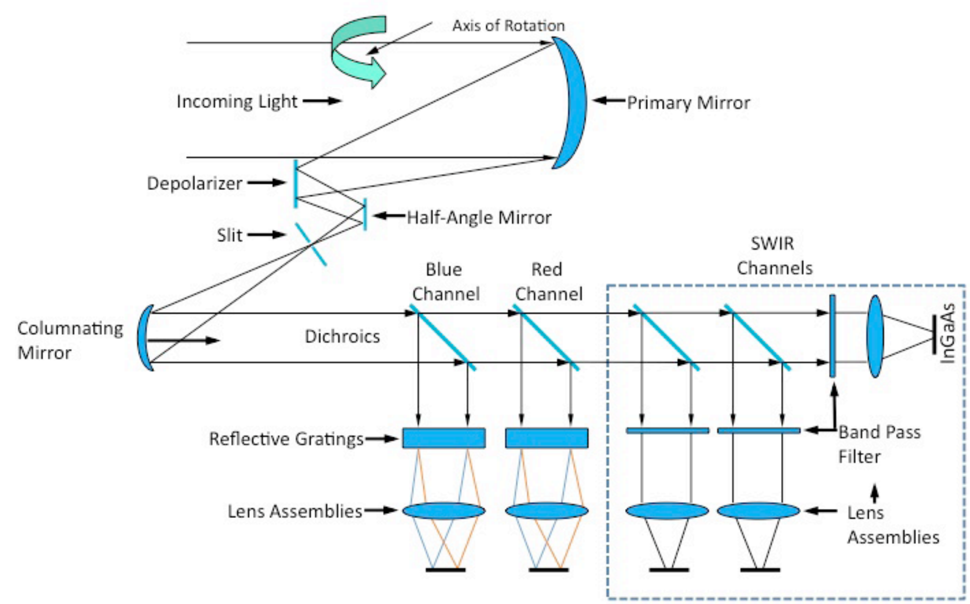
Technology

- **Oriented Carbon Nanotubes are black because of their high absorption, morphology, high surface area and low density.**
- **They are much more efficient absorbers when oriented like a carpet instead of randomly oriented like spaghetti**

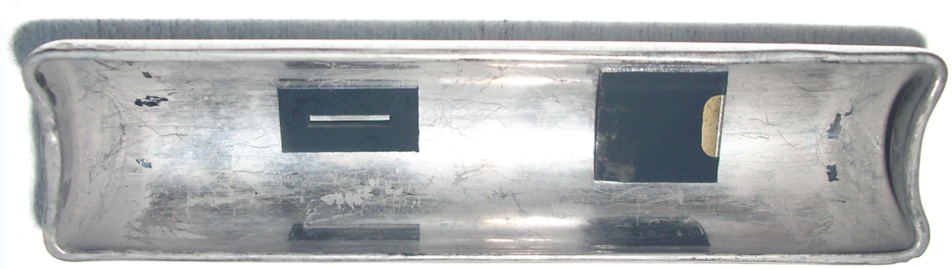


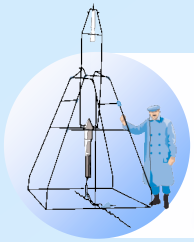


Technology Applications; Ocean Radiometer for Carbon Assessment (ORCA)



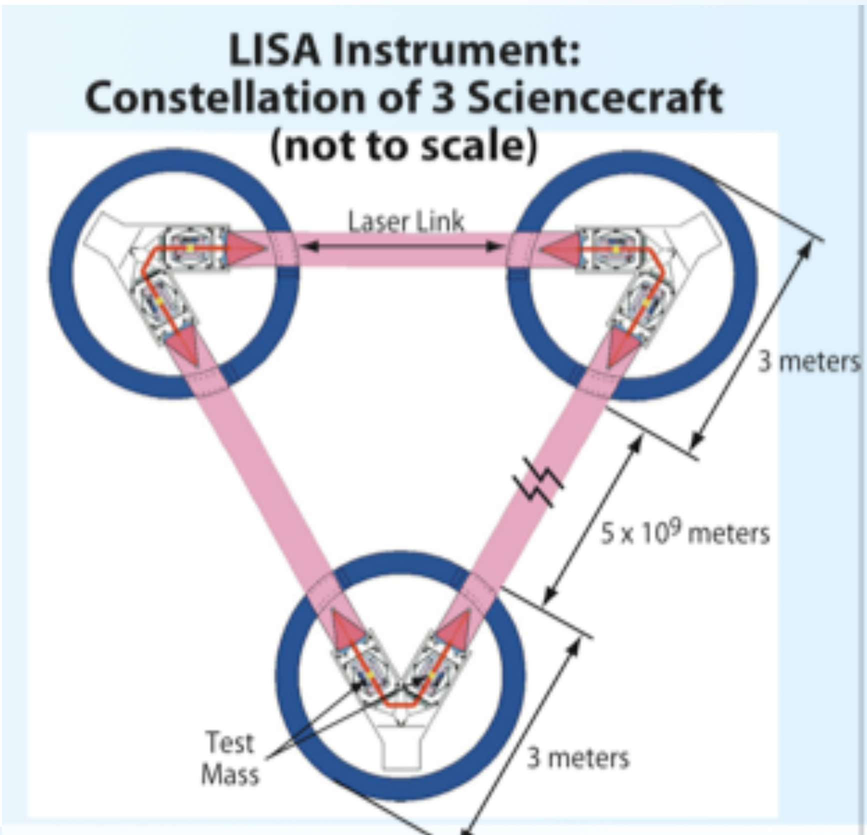
- ORCA looks for faint spectral signal and requires stray light suppression to avoid contamination of signal by scattered light
- Isolation is accomplished by entrance aperture slit
- Silicon slit is first NASA component to be treated with carbon nanotubes for stray light suppression
- Slit is treated on both sides

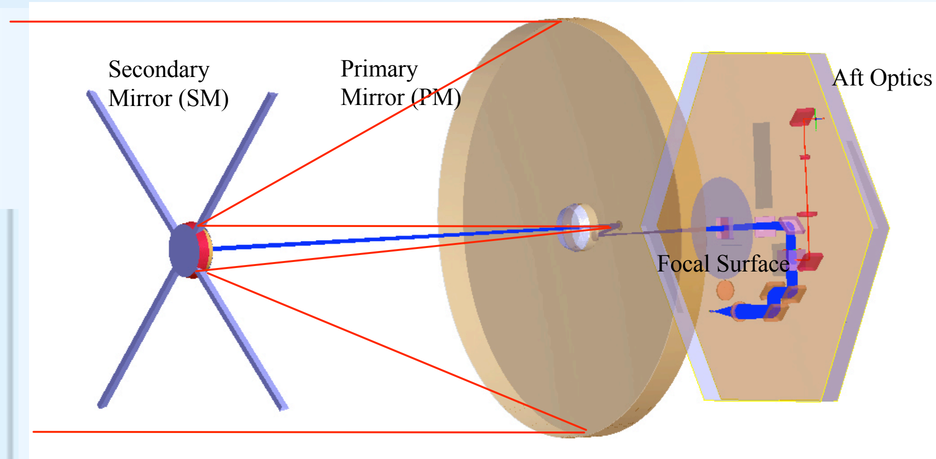




Technology Applications; Laser Interferometer Space Array (LISA) Gravity Wave Experiment

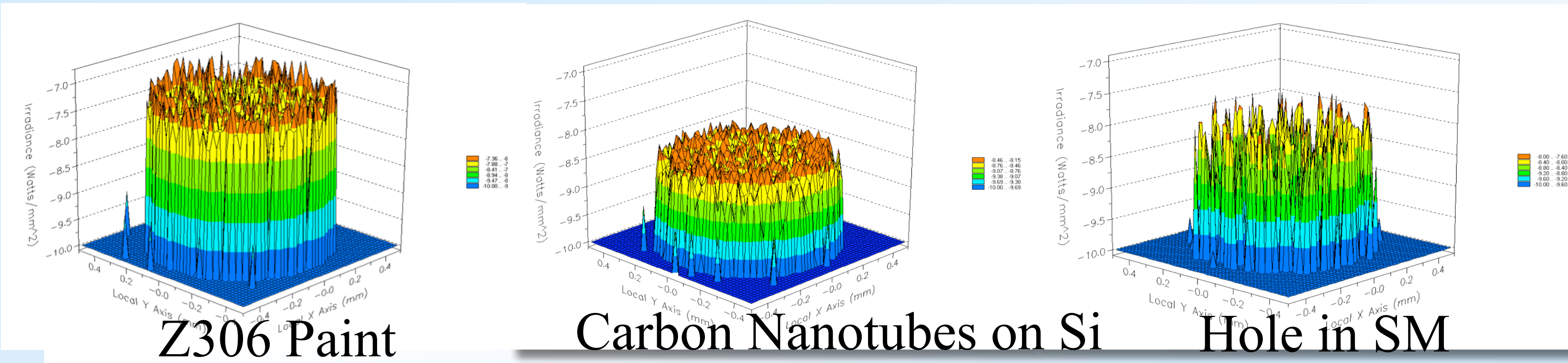
Constellation of 3 Sciencecraft with linked Telescopes

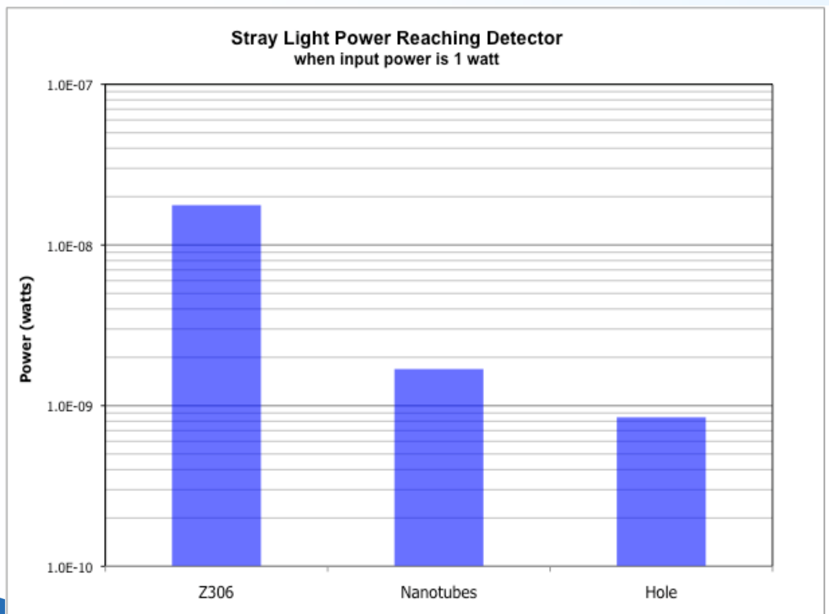


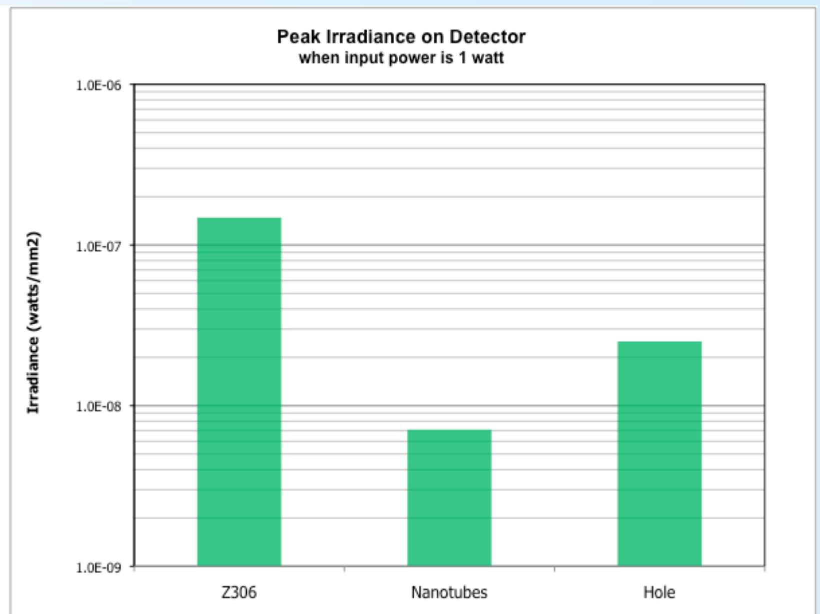


- LISA Stray Light Challenge
  - Telescope used in duplex
  - Tx beam is 10^9x intensity of Rx Beam
  - Tx beam reflected/scattered off of center of telescope secondary mirror (SM) must be suppressed by 10^9
  - Suppression in central obscuration on secondary mirror
    - Z306 paint
    - Carbon nanotube patch
    - Hole in secondary mirror

Carbon Nanotubes Provide 10x Better Suppression than Z306

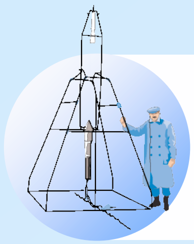






Commercial Applications

- Nearly any precision Optical or IR device would benefit from using this technology to reduce noise
  - Binoculars
  - Night vision goggles
  - Cameras
  - Projection devices
  - Scientific instrumentation
  - Calibration references
- Possible use as absorber in IR detectors
  - Much more robust than gold black



Collaboration Opportunities

- **NASA Goddard is installing a 6″ nanotube furnace to accommodate larger components**
- **Desire would be to partner in the scale up of this technology and transfer the production to industry partner to deliver flight and GSE parts**
- **We are also pursuing development of carbon nanotube sheets for use on larger non-conformal surfaces using alternate approach, looking for partners in this effort as well**

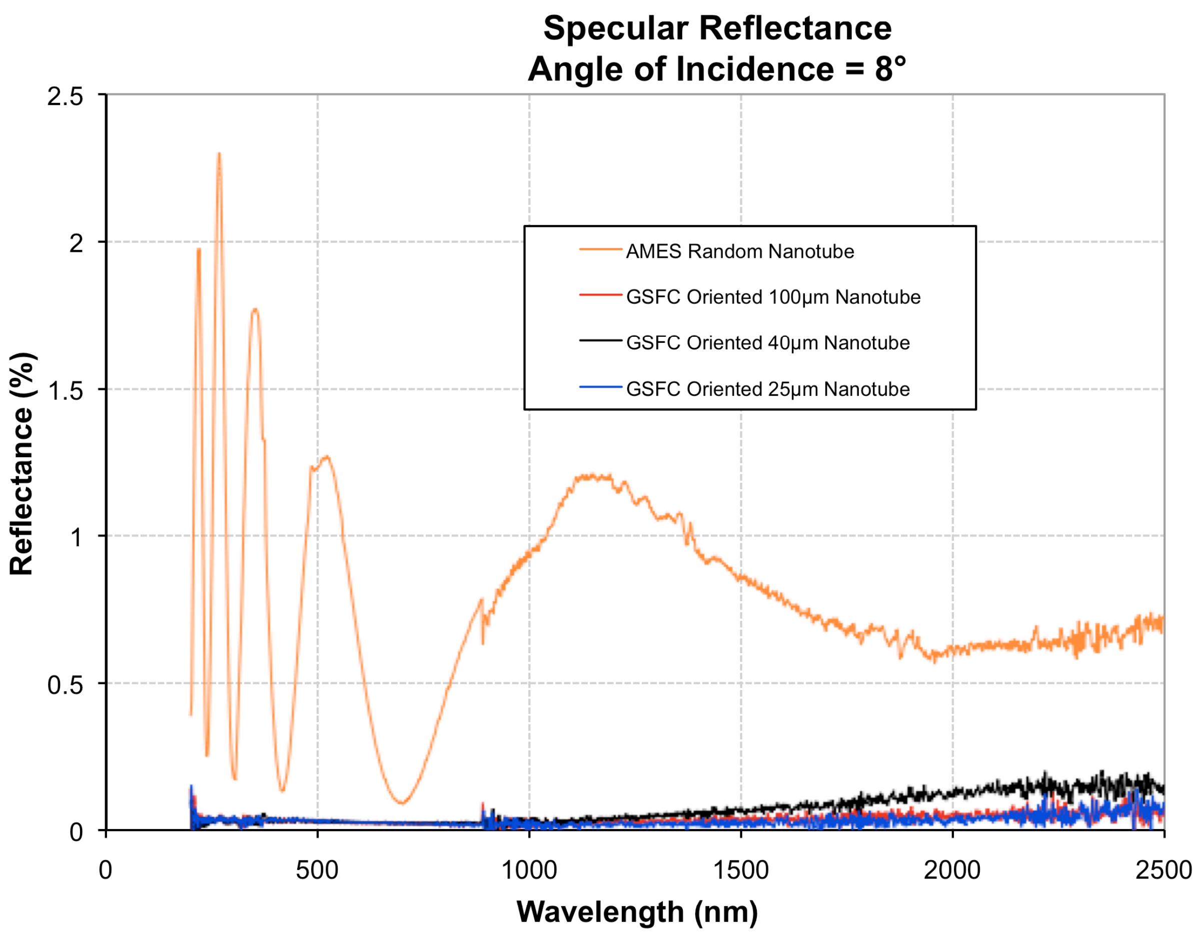
Contact Information

- **For further information contact:**

John.G.Hagopian@NASA.gov
(240)678-9475

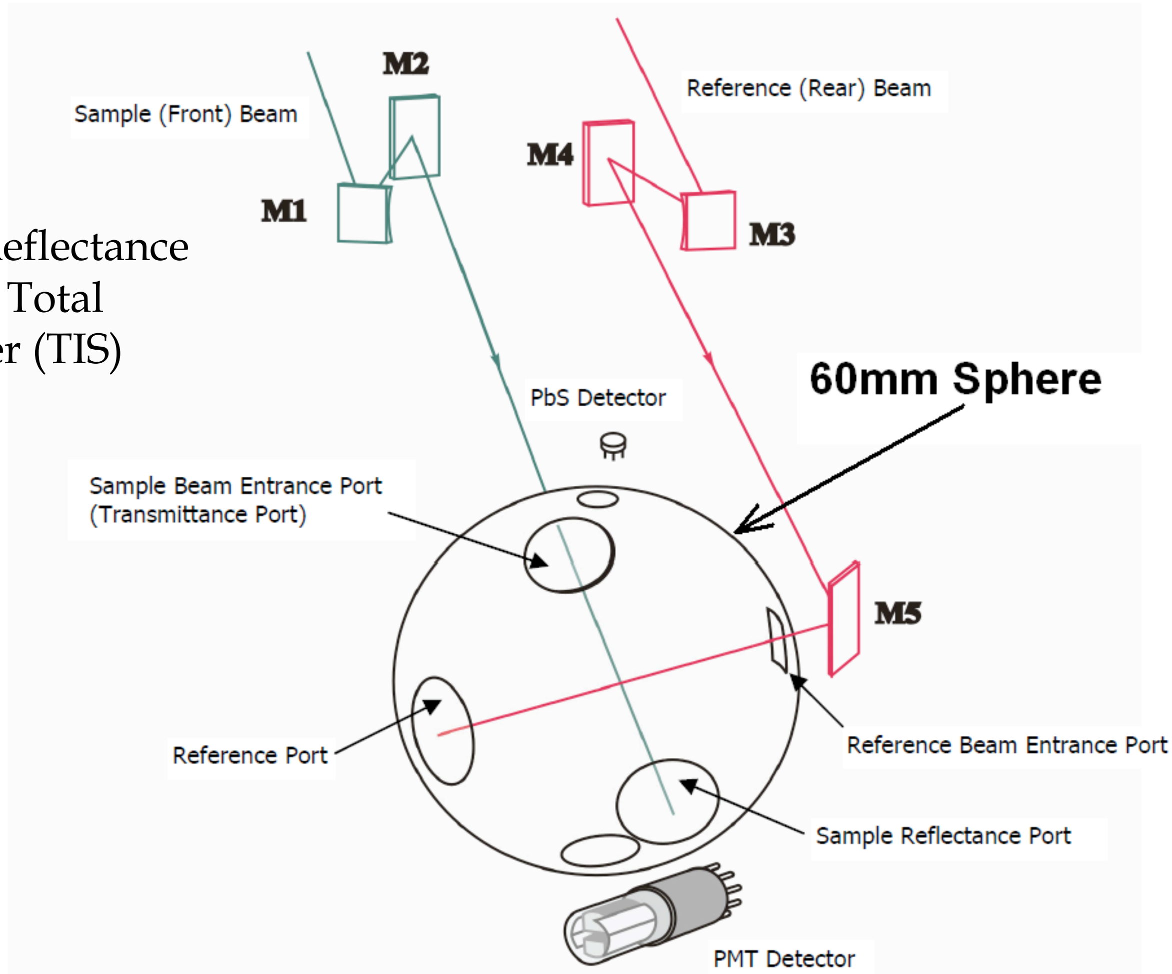
Backup Slides

Initial specular reflectance measurements of Multiwalled Carbon Nanotubes (MWCNT) performed 12/07 demonstrated potential

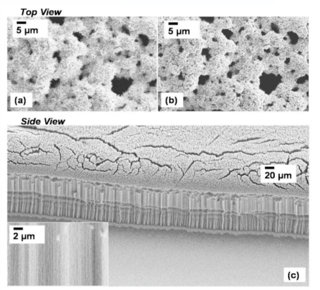


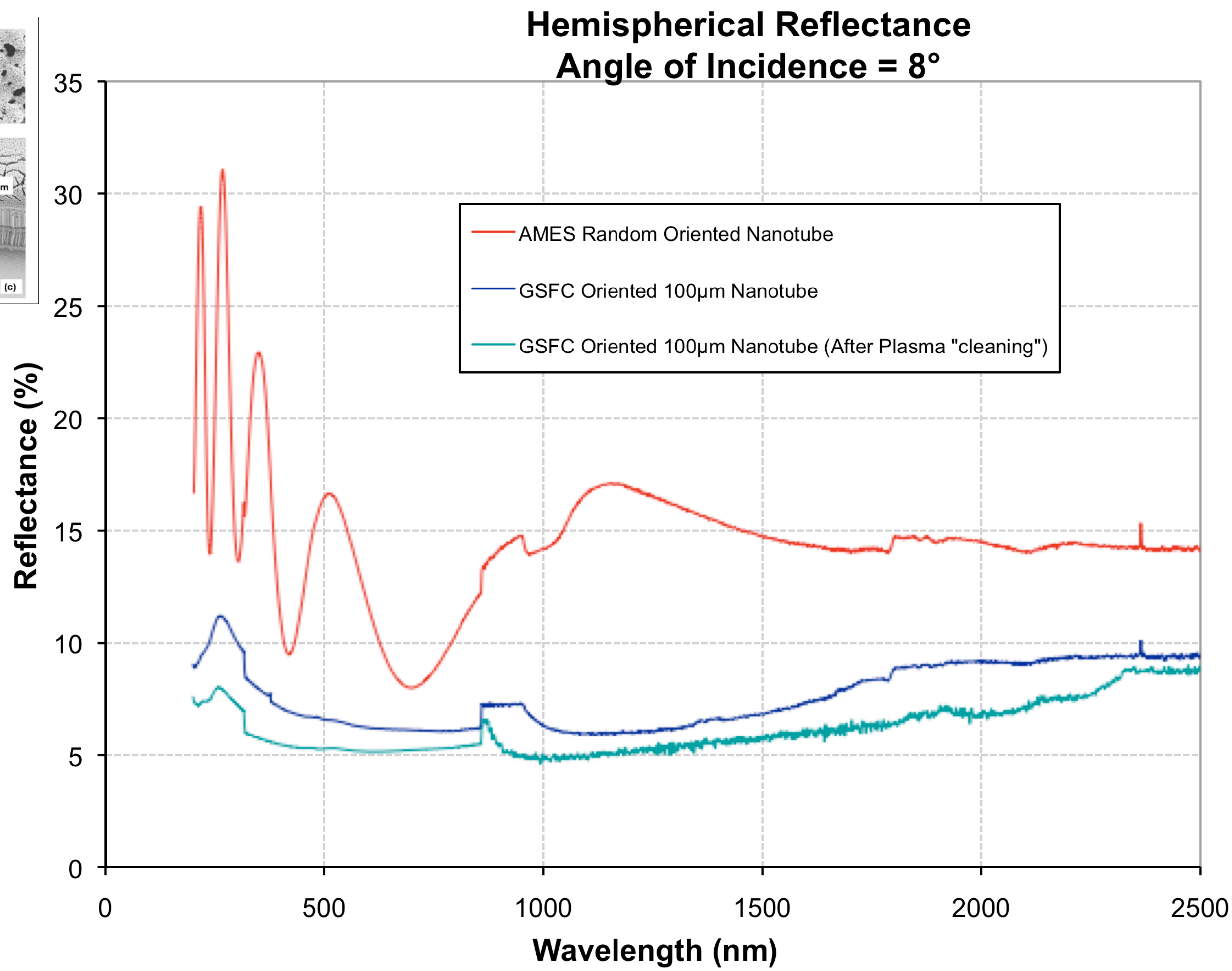
II. Hemispherical reflectance characterization allows for measurement of all reflected light

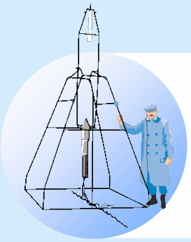
Hemispherical Reflectance is also known as Total Integrated Scatter (TIS)



Low specular reflectance not necessarily predictive of low hemispherical reflectance







III. Full modeling requires measurement of Bidirectional Reflectance Distribution Function BRDF; reflectance as a function of angle

GSFC Scatterometer (Butler/Georgiev)