Remote Sensing Group
College of Optical Sciences

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Who is the Remote Sensing Group?

- A small group of students and staff interested in sensor calibration, radiometry, atmospheric correction, and related topics
- History
- Capabilities
- Current work

A short (and incomplete) history

- Phil Slater headed the group from the start in the early 80s
  - Phil, visiting scientists, and graduate students early on
    - Landsat – MSS and TM
    - Spot HRV
    - Aircraft systems such as scanners (Daedalus 1268) and later AVIRIS
    - Field work at White Sands at first with other sites added over time
  - Starting in 1990, Phil hired full time staff with an expanded program
    - EOS long term contract with preflight and in-flight calibration work
      - Kurt Thome for atmospheric characterization and modeling and field work
      - Stu Biggar for radiometry and lab support for the field work
    - MODIS and ASTER with some MISR work
- Kurt Thome took over after Phil retired about 20 years ago
  - Expand beyond NASA to work for the USAF and sensor vendors like Ball
  - Push toward an autonomous site for arbitrary sensor calibration - became RadCaTS with Jeff taking over field and atmospheric work when Kurt moved to NASA

Early years

- Our early calibration work was a cooperative effort:
  - We used John Reagan's solar radiometers for transmittance measurements (UA ECE)
  - We used Ben Herman's radiative transfer code running on the University mainframe for computations (aerosols and ozone) with Lowtran for other absorption (UA Atmo)
  - Ray Jackson and his group from the Phoenix Water Conservation Lab (USDA Agricultural Research Service) made the ground reflectance measurements, typically using a Barnes MMR or an Exotech (both are filter radiometers)
  - We calibrated the $BaSO_4$ reflectance panels we built and did the data reduction with imagery from tape
- We typically worked at White Sands Missile Range as it was bright in the VNIR, relatively close to UA, and the military allowed access except during missile tests
  - We were able to mount or hand point instruments from a military helicopter for radiance measurements over the site
  - It was, however, too bright in the blue in the summer (sensor saturation) and the site became more restrictive over time
  - We camped out at the site (although Phil and Ray stayed in Phil's camper)

Ray Jackson carrying an MMR at White Sands

Field refinements over time

- We moved from filter radiometers to field spectrometers for reflectance measurements
  - We first tried student built instruments (complicated and heavy)
  - We then settled on ASD FR instruments
- We moved from BaSO4 to Spectralon for the reflectance reference
  - Less spectral and sample to sample variation
  - More Lambertian and can be cleaned and recalibrated
- We moved from White Sands to other sites:
  - Rogers dry lake and Ivanpah playa in California (originally for AVIRIS)
  - Railroad Valley playa in Nevada (large site for sensors like MODIS)
  - The dry lake beds have better reflectance characteristics in the SWIR
  - We can install equipment on-site at Railroad Valley but not at Ivanpah per BLM
- We moved from the mainframe to a PC for the computations and from the Herman code to Modtran after significant testing

Laboratory development for EOS

- We developed robust but portable transfer radiometers in the VNIR and SWIR (Paul Spyak) to measure the various sphere sources to be used for calibrating MODIS, ASTER, and MISR and aircraft sensors
- We developed a facility to measure the BRDF of our large field and laboratory reflectance reference diffusers (relative measurement compared to pressed PTFE and then Spectralon calibrated by NIST)
- With calibrated diffusers and calibrated lamp sources (NIST), we can calibrate radiometers in the VNIR/SWIR in either radiance or irradiance for laboratory and field measurements in the VNIR/SWIR
- We developed the expertise to carefully characterize radiometers so we can make accurate and repeatable measurements in the lab

Current Capabilities

- Vicarious calibration of in-flight sensors
  - Atmospheric characterization, modeling, and correction
  - Field work at sites such as desert “dry” lakebeds
  - RadCaTS automated field site at Railroad Valley
- Radiometry
  - Sensor characterization and calibration
  - Transfer radiometers for radiance validation
  - BRDF measurements of diffuse targets
  - Calibration system design and use

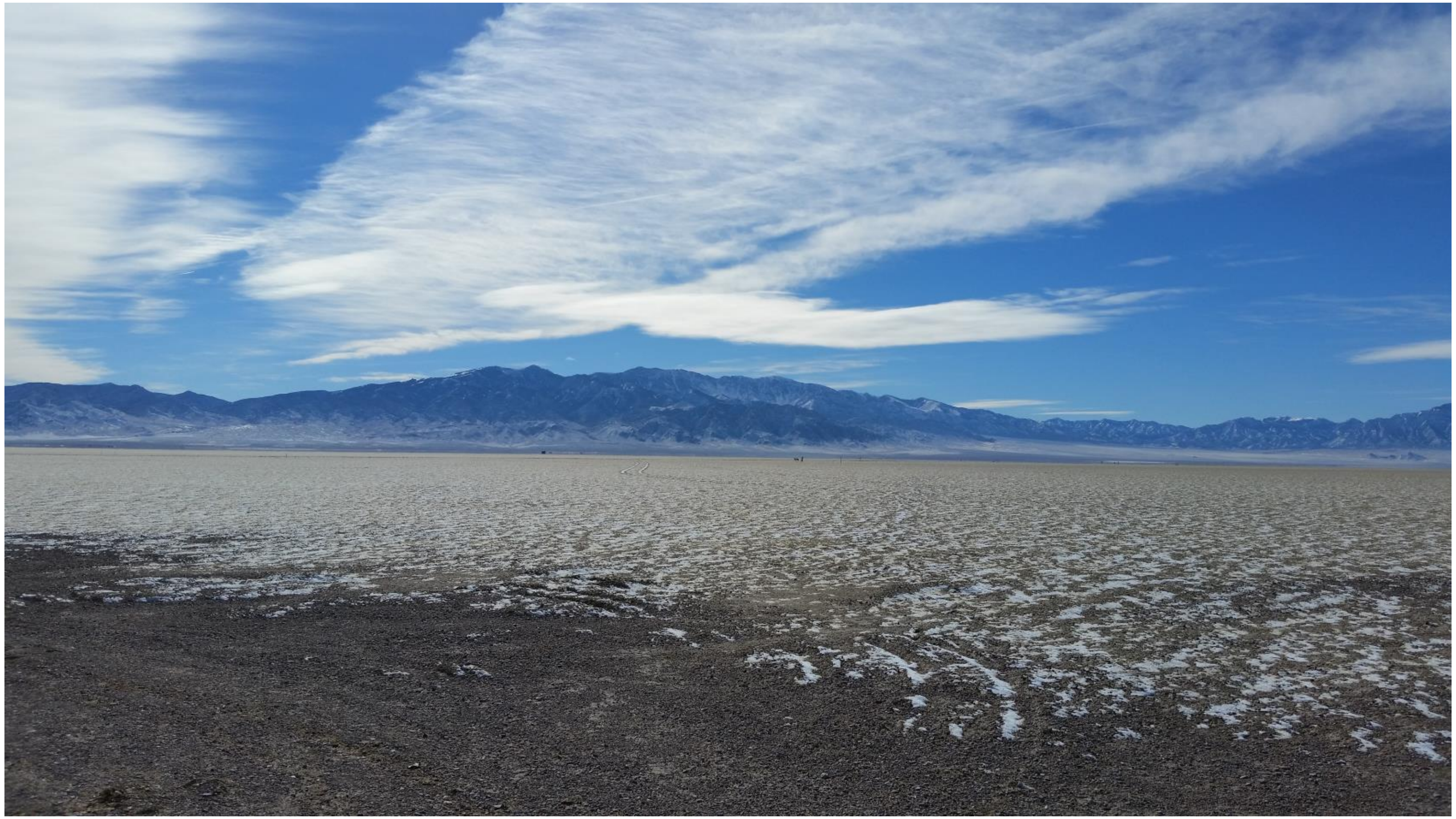
Atmospheric related

- We use, and build, automated solar radiometers to measure the transmittance to the Sun and estimate aerosol parameters
  - Cimel at Railroad Valley for long-term data (part of NASA Aeronet)
  - We build and maintain a modified version of the Reagan ASR
    - More self-contained and robust but still requires daily setup
    - Spectral coverage into the short-wave IR if desired
    - Calibrated using Langley method – typically at Mt Lemon (about 1 hour drive to site)
- Atmospheric modeling using Modtran
  - Atmospheric inputs derived from solar radiometry inputs and ancillary data
  - Spectral reflectance of the surface

Field site work – reflectance-based method

- For in-flight vicarious calibration we want a site with:
  - Clear skies during a collection
  - Good atmospheric transmittance
    - Low aerosol loading
    - Dry atmosphere if possible
  - Sufficient size for the sensor spatial resolution
    - MODIS 1 km pixels drive the site size to be like Railroad Valley
    - We can use smaller uniform sites for aircraft or high resolutions space sensors
  - High reflectance is typically helpful (unless it saturates the sensor)
    - A dry surface is desired as many natural surfaces change as they dry out
    - We prefer sites without significant spectral absorption regions if possible
- Measure the surface reflectance
  - Field spectrometer
  - Relative measurement using calibrated diffuser
- Compute radiance at sensor using Modtran and compare to sensor value

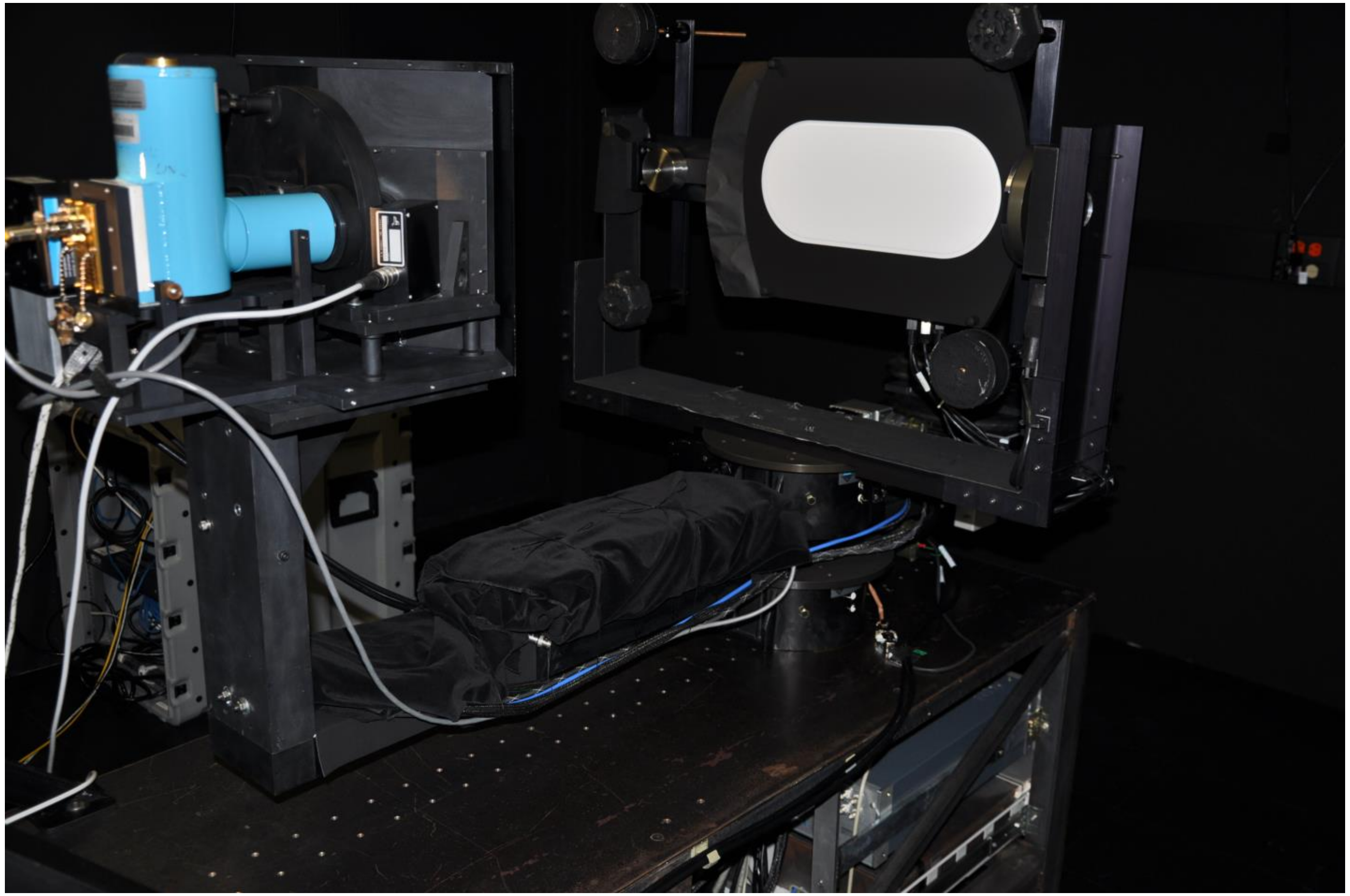
Railroad Valley in early March 2017



Laboratory facilities

- BRDF measurements for arbitrary illumination and view geometries
  - Relative measurement tied to NIST 0/45 BRDF measurement of Spectralon (400 – 2500 nm)
  - Stable filter radiometers, typically with witness filters (OLI for example)
  - Small diffusers (Sentinel MSI witness samples) to large (OLI flight diffusers)
- Integrating sphere sources (small radiance controlled sphere to 1-meter diameter sphere with multiple lamps)
- Standards of spectral irradiance (calibrated FEL type 1 KW lamps)
- Transfer radiometers - well characterized and calibrated filter radiometers
  - Calibrated at UA and with NIST radiance sources at comparisons (OLI and Sentinel MSI)
  - Calibrated at NIST using SIRCUS during OLI program
- Miscellaneous items such as a reflective collimator and a double monochromator with gratings and detectors for a wide spectral range

OLI flight diffuser – SWIR measurements – UA transfer radiometer with OLI witness filters



Examples of our current work

- Improve RadCaTS
  - Add more instruments (GVRs)
  - Evaluate better spectral sampling
  - Improve automation
- Provide operational sensor vicarious calibration
  - OLI on Landsat 8
  - GOES
  - Terra and other platform sensors
  - Others as requested (AVIRIS NG for example)
- Preflight calibration/radiometry
  - Calibration planning, OLI-2 diffuser measurements, and validation of preflight source calibration for Ball (NASA)
  - Construction of a SWIR transfer radiometer for Battelle Ecology (NEON) for use in their calibration lab for airborne imaging spectrometers (similar to AVIRIS NG)
  - Evaluation of -80 degree C InGaAs detector for transfer radiometer applications