# Full Optical Spectrum Hyperspectral Scene Simulation

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## Motivation for Work

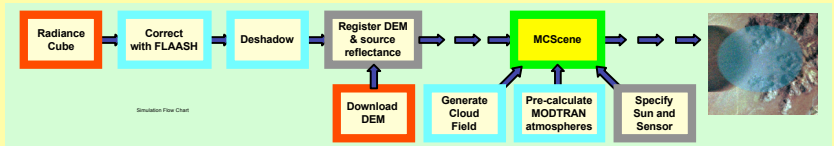
- Develop VIS-LWIR Scene Simulation
  - Realistic levels of clutter
    - Spectral
    - Spatial
  - Easy user control of terrain materials
    - Reflectance in Visible-MWIR (NASA SBIR)
    - Emissivity/Temperature in MWIR-LWIR
    - Statistical terrain definition
  - Incorporate digital elevation maps
  - 3D variable atmosphere
  - Incorporate cloud fields
  - 3D faceted objects
- Simulation tool used to test algorithms
  - Atmospheric compensation
  - Object detection
  - Scene classification/segmentation
  - Sensor development
- Simulations to supplement data collects
  - Data usually collected on high visibility days
  - Simulate low visibility & bad weather

## MCScene Summary

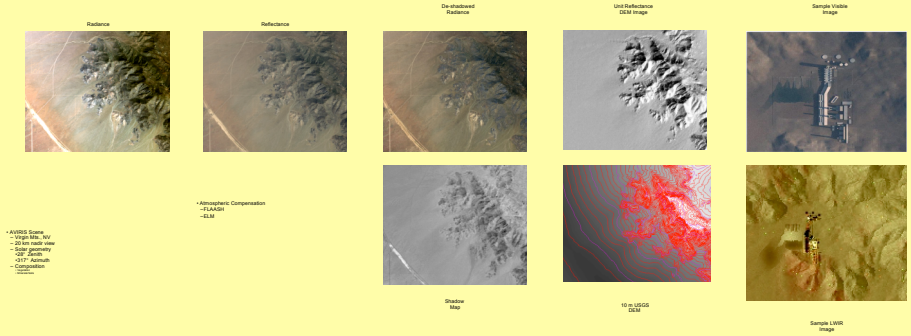
- New 3D code for computing visible to LWIR HSI/MSI data cubes
- Spectral radiance/reflectance with statistical behavior similar to nature
- Applicable to wide variety of remote sensing problems
- MCScene team
  - SBIR & STTR funding
    - AFRL/SNJT phase VI/III+
    - NMA phase VII
    - NASA phase I
    - US Army phase I
  - IRAD funding
    - Spectral Sciences, Inc.
  - Industrial partners
    - Kodak
    - Research Systems, Inc.
    - Rochester Institute of Technology

Los Alamos

## Data Driven Scene Simulation

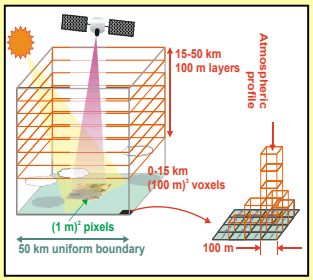


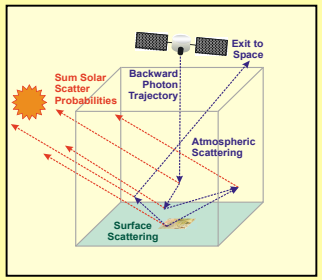

Simulation Flow Chart




- AVIRIS Scene
  - Virgin Mts., NV
  - 20 km nadir view
  - Solar geometry
    - 45° Zenith
    - 315° Azimuth
  - Composition
    - Vegetation
    - Soil
    - Rock
    - Water
    - Snow
- Atmospheric Compensation
  - FLAASH
  - ELM

## MCScene Spectral Scene Simulation



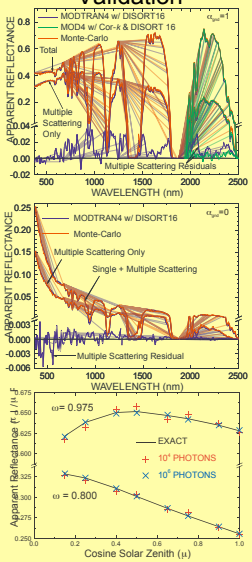




- Unified UV to LWIR RT
- 3D atmospheres with complex clouds
- 3D surfaces with BRDF's (DEM)
- 3D object insertion
- 3D plume model
- **MODTRAN** optical properties, profiles, and spectroscopy
- Extended to underwater imaging
- Active illumination sources (LIDAR)

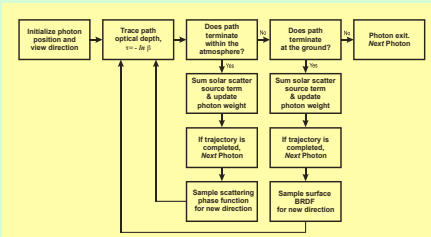
- Direct sun-ground-sensor term calculated explicitly
- Weighting factor for molecular absorption
- Integrate thru 3D world in steps
- Sample probability distributions for distance traveled and scattering directions
- Atmospheric scattering (1st order) $\rho_a \frac{\pi}{\mu_{sun}} \int_{T_g} \omega P(\theta_s) T_{sun}\, dT$

$\omega$, Single scattering albedo
$P(\theta_s)$, Scattering phase function

### Validation




## Cloud Scattering Details



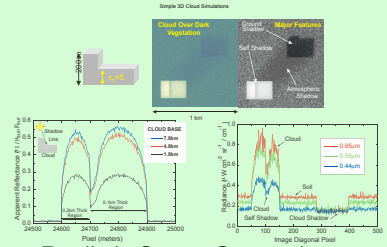

Photon Trajectory Flow Chart

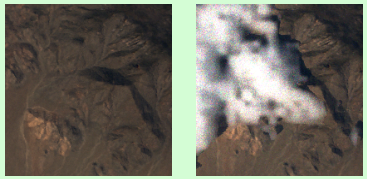
### Phase Function Form & Sampling

$$\langle \omega \cdot P \rangle = \omega_{Ray} P_{Ray}(\theta_s) + \omega_{aer} P_{aer}(\theta_s) + \omega_{cld} P_{cld}(\theta_s)$$

$$P_{H-G}(\theta_s; g) = \frac{1-g^2}{4\pi\,(1+g^2-2g\cos\theta_s)^{3/2}}$$

$$(\cos\theta_s)_{H-G} = \frac{g}{2} + \frac{\alpha}{2(1+\alpha g)} + \frac{\alpha + g(2-g^2)}{2(1+\alpha g)^2}$$




### Realistic Scene Generation