Some Musings On Current Evolutionary Trends In The Space Business

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Some Formidable Lizards

- Space-Based InfraRed Systems- High (SBIRS-High)
- National Polar-orbiting Operational Environmental Satellite System (NPOESS)
- Geostationary Operational Environmental Satellite (GOES)
- Transformational Communications Satellite (TSAT)
- Global Positioning System (GPS)

…and their environmental niches

Missile Warning
SIGINT
Space Control
Meteorology
Communication
Planetary Science
Environmental Monitoring

IMINT
MASINT
Mapping
Navigation
TV/Radio
Earth Science
Astronomy
Punctuated Equilibria

Large, stable, central populations exert a strong homogenizing influence. New and favorable mutations are diluted by the sheer bulk of the populations through which they must spread. They build slowly in frequency, but changing environments usually cancel their selective value long before they reach fixation. Thus, phyletic transformations in large populations should be very rare...

But small, peripherally isolated groups are cut off from their parental stock. They live as tiny populations in the geographic corners of the ancestral range. Selective pressures are usually intense because peripheries mark the edge of ecological tolerance for ancestral forms. Favorable variations spread quickly. Small peripheral isolates are a laboratory for evolutionary change.
.... space technology context is changing, making possible a movement to an additional business model and an expanded business base for space. Cost per kilogram on orbit is still a problem. But, capability per kilogram is soaring due to advances in information technology. This makes the alternative feasible. The door for small, micro and nanosatellites is open, allowing us to redefine cost and mission criticality curves, increase transaction and learning rates and the ability to assume risk.

Adm. Arthur K Cebrowski
March 2004 US Senate Testimony
Evolving Meaning of *Operational*

**Original Context From Cebrowski**

*Operational*
- Demand Driven
- Military Capability
- Autonomous
- Integrated
- Decentralized Control
- Reduced Classification
- Broadened User Base
- Decreased Cycle Times
- Risk Tolerant

**Evolving Context: So important that it cannot fail**
Some Advice I Received Early In My Career

...Pick a entirely new field of study and figure it out before long, you will be a world expert (i.e. find your own niche)
“The telescope has released the human imagination as no other implement has ever done. If there is any other apparatus worthy to be compared to its enlarging influence, it is the spectroscope, which was developed after the discoveries of Fraunhofer, the glass-worker, in 1814. Since man has lived on earth he has seen rainbows, but who could have told him that those bands of colour held in them a promise that one day he should be able to analyze the stars? But the spectroscope receives the rays from any luminous source, passes them through prisms and breaks them up into rainbow-like bands. These bands reveal under examination transverse lines of brightness and darkness which vary with the heat and the chemical composition of the source of light and of any intervening vapour. So that men can now sit in observatories and learn the composition and take the temperature of stars incalculable billions of miles away.”
Spectroscopic View Of Planet Earth

Radiance (µW/cm²/nm/sr)

Wavelength (nm)

6H₂O + 6CO₂ + photon => C₆O₆H₁₂ + 6O₂

Leaf Chlorophyll
Atmospheric Oxygen
Leaf Sugar and Cellulose
Leaf Water
Atmospheric Carbon Dioxide
Image Cube Concept

Each spatial element has a continuous spectrum that is used to analyze the surface and atmosphere.

224 spectral images taken simultaneously.

Graphs showing transmission and reflectance for different materials:
- Atmosphere
- Soil
- Water
- Vegetation
Earth Spectra

Vegetation

0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8

Wavelength (nm)

Reflectance

Conifer
Grass
Broad Leaf
Sage_Brush
NPV

Water

Normalized Absorption Coefficient

0.001 0.002 0.003 0.004 0.005 0.006 0.007

Wavelength (nm)

0.4 0.5 0.6 0.7 0.8

Minerals

Muscovite K2A[Si3Al]O10(OH)4
Alunite K2Al4[Si6Al2O20](OH)4
Montmorillonite (Na,Ca)0.33(Al,Mg)2Si4O10(OH)2*nH2O
Alunite KAl3(SO4)2(OH)6
Kaolinite Al4Si4O10[(OH)8
Gypsum CaSO4.2H2O
Goethite FeO.OH
Jarosite NaFe3(SO4)2(OH)6
Calcite CaCO3
Dolomite CaMg(CO3)2
Hematite Fe2O3

Snow

0 100 200 300 400 500 600 700

Wavelength (nm)

Radiance (µW/cm²/nm/sr)

600 °K
800 °K
1000 °K
1200 °K
Sun

Fire

0 2 4 6 8 10 12 14 16

Wavelength (nm)

Radiance (µW/cm²/nm/sr)

600 °K
500 °K
300 °K
200 °K
100 °K
Sun

Clouds

0 2 4 6 8 10 12 14

Wavelength (nm)

Reflectance (µW/cm²/nm/sr)

0 in altitude
2000 m altitude
10000 m altitude
Solar Signal and Transmittance of the Atmosphere
Imaging Spectroscopy Overview

Solar Irradiance

Atm. Transmittance

Path Radiance

Surf. Reflectance

Emissity

At Sensor

Measured signal

Calibrated Signal

Reflectance

Data downlink

Ground Station

Calibration Parameters

Atmospheric Correction

Data Exploitation
Cirrus Cloud Detection Over Mojave Desert

Visible Image

Image from 1380 nm
Accounting For Water Vapor

Measured → Modeled

Water Vapor Parameter map
Accounting For Liquid Water

Vapor and Liquid Modeled

Liquid Water Parameter map
Radiance To Reflectance Inversion

\[ L_t = \mu F_0 \rho_a / \pi + \mu F_0 T_d \rho_s T_u / \pi \]

- \( L_t \) is the at sensor radiance
- \( \mu \) is the cosine of the solar zenith angle
- \( F_0 \) is the exo atmospheric irradiance
- \( \rho_a \) is the upward reflectance of the atmosphere
- \( T_d \) is the downward transmittance
- \( \rho_s \) is the reflectance of the surface
- \( T_u \) is the upward transmittance of the atmosphere
Mineral Mapping With USGS’s Tetracorder

Library spectra

Best Match

Cuprite, Nevada
1998 AVIRIS Data
USGS Tetracorder Mineral Map
Clays, Micas, Sillicates, Carbs:
- K-Alunite
  - High Temp
  - Low Temp
- Alunite + Kaolinite
- Baddingtonite + Na-Montmorillonite
- Wd Kaolinite
- Pol Kaolinite
- Wd Kaol. + Other
- Dickite
- Halloysite or Kaol. + Musc 2
- Na-Montmorillonite
- Nontronite or Clay with 2.29 um Bd.
- Muscovite 1 High
- Muscovite 2
- Muscovite 3
- Muscovite 4 Low
- Kaolinite + Muscovite Intimate Mix
- Kaolinite + Musc 2
- Chlorite + Muscovite Intimate Mix
- Calcite
- Calcite + Muscovite
- Ca-Mont + Musc 3
- Calcite
- Ca-Mont + Musc 4
- Carbonates or Chlorite
- Chalcedony

Mineral Map

R(λ)

Scaled Reflectance

Wavelength (μm)

Best Match

Mineral Map

Wavelength (nm)

Reflectance

Muscovite K₂Al₄[Si₆Al₂O₂₀](OH)₄
Montmorillonite (Na,Ca)₀.₃₃(Al,Mg)₂(Si₄O₁₀)(OH)₂*nH₂O
Alunite KAl₃(SO₄)₂(OH)₆
Kaolinite Al₄[Si₄O₁₀](OH)₈
Gypsum CaSO₄.2H₂O
Goethite FeO.OH
Jarosite NaFe₃⁺³(SO₄)₂(OH)₆
Calcite CaCO₃
Dolomite CaMg(CO₃)₂
Hematite Fe₂O₃
Snow and Ice Model Matching

Complex refractive
Index of water and ice

Physical model of
Snow spectral reflectance

Nonlinear least square
Model matching

Calibrated Radiance

Surface Grain Size [µm]

Surface Liquid Water Fraction

Atmospheric Correction

Reflectance Spectra
Vegetation Parameter Over Wallula, WA

False Color

Cellulose

Liquid Water

Chlorophyll
World Trade Center Hot Spot Mapping

Radiance Image Cube (SWIR)

GPS/INS data

Model Matching to Planck Blackbody

AVIRIS
- Estimate
- Residual

WTC Hot Spot Area A
- Hottest Spectrum
- Temperature Estimate=928K
- 6% of the area

Fraction, temperature, and latitude, Longitude coordinates for each hot spot

A lat 40-42-47.18 lon 74-00-41.14 hot
data
B lat 40-42-47.14 lon 74-00-43.53 medium
C lat 40-42-42.89 lon 74-00-48.88 hot
D lat 40-42-41.99 lon 74-00-46.94 hot
data
E lat 40-42-40.56 lon 74-00-50.15 medium
F lat 40-42-38.74 lon 74-00-46.70 low-medium

C lat 40-42-39.04 lon 74-00-45.85 hot
H lat 40-42-38.60 lon 74-00-47.51 low-medium
World Trade Center Asbestos Mapping

Library Spectra

Image map
Of match to
Cryotile

Match to measured spectra

World Trade Center area,
New York

U.S. Geological Survey
Oke et al., 2001
NASA AVIRIS data
Sept 15, 2001 16:21 GMT

Possible Serpentines
- possible
- chryotile

Possible Amphiboles or Clays
- possible

Serpentines
- Chrysotile coating WFC01-08

AVIRIS data from:
wtc_r9w_10b_1lws_rtcg

11 pixels near:
L2385 S2577

Possible presence of:
- serpentine
- amphibole

128 pixels near:
L2295 S280

Preliminary Scientific Data Product subject to revision

Image sampling
1.7 meters/pixel

200 meters

N
World Trade Center Debris Identification

Site-specific spectral library

- Gypsum Wallboard
- Concrete
- Dust

Feature Matching to Reflectance spectra

Spectral Shape Map
This map shows materials whose spectra are similar to the reference materials below. It is not a map of the identification of those materials. A similarity map is analogous to a map of materials with similar colors viewed with your eyes. The colors may indicate similar compositions:
- concrete
- cement
- dust
- gypsum wall board

Image sampling: 1.7 meters/pixel

World Trade Center area, New York
U.S. Geological Survey
Clark et al., 2001
NASA/JPL AVIRIS data
Sept 16, 2001 10:21 GMT
USGS
Imaging Spectroscopy
Tarascorder 4.0
Product
Spectral Shape Map
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Guess the Genetic Survivors of the Burgess Shale which one are we most closely related to?
Dominant Form of Life On Earth?