



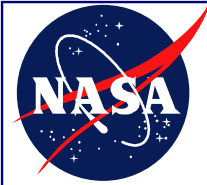
# **DIELECTRIC CONSTANT MEASUREMENTS ON LUNAR SOILS AND TERRESTRIAL MINERALS**

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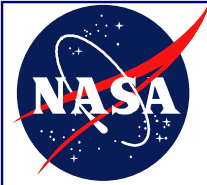
1 November 2004

**Note: The information presented here was derived  
from the Lunar Sourcebook**



## Outline

- **Motivation**
- **Lunar Materials**
- **Concept for Rapid In Situ Prospecting**
- **Permittivity (Dielectric Constant) Measurements**
- **Compare IS, GPR, and EMI**
- **Conclusions**



## Motivation

- For most ISR, finding ore bodies is essential.
- Satellite searches provide some guidance
  - But pixel size is large\* and shallow.
- Need rapid *in situ* measurements to provide sub-meter scale resolution.

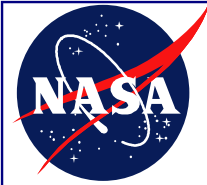
\*Clementine resolution: 200 m/pixel, ESA SMART resolution: 27 m/pixel.



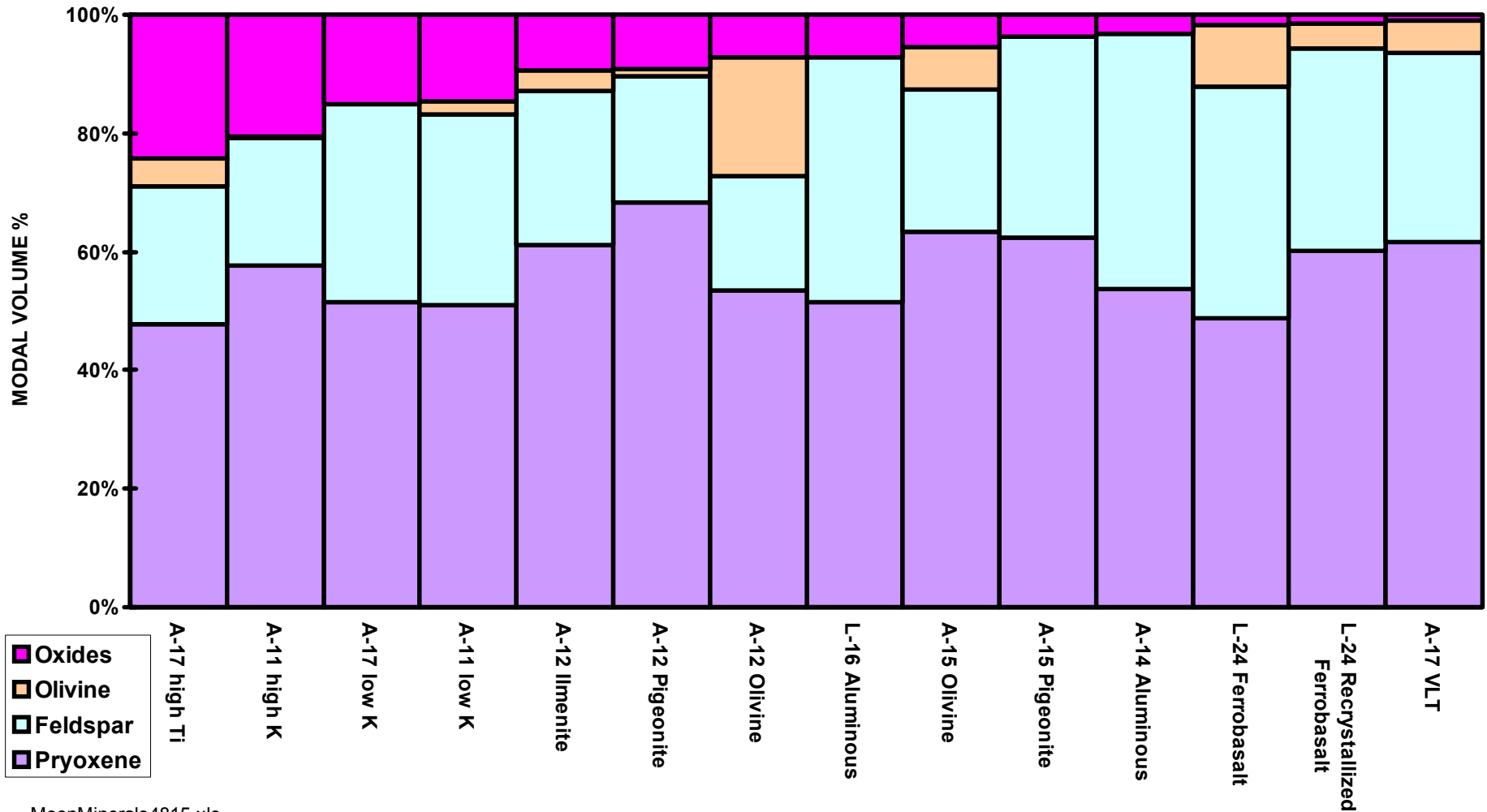
## Mineral Chemical Classification: Earth

- Elements
- Sulfides and Sulfosalts
- **Oxides** and Hydroxides
- Halides
- Carbonates
- Nitrates
- Borates
- Sulfates
- Phosphates, Vanadates, and Arsenates
- Tungstates, Molybdates, and Uranates
- **Silicates**

**Lunar minerals lack water so clays, micas, and amphiboles are missing.  
Lack of carbon means that carbonates are missing too.**

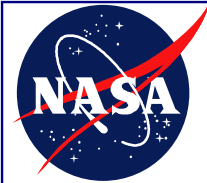


## Lunar Mare Basalts: Lateral Composition

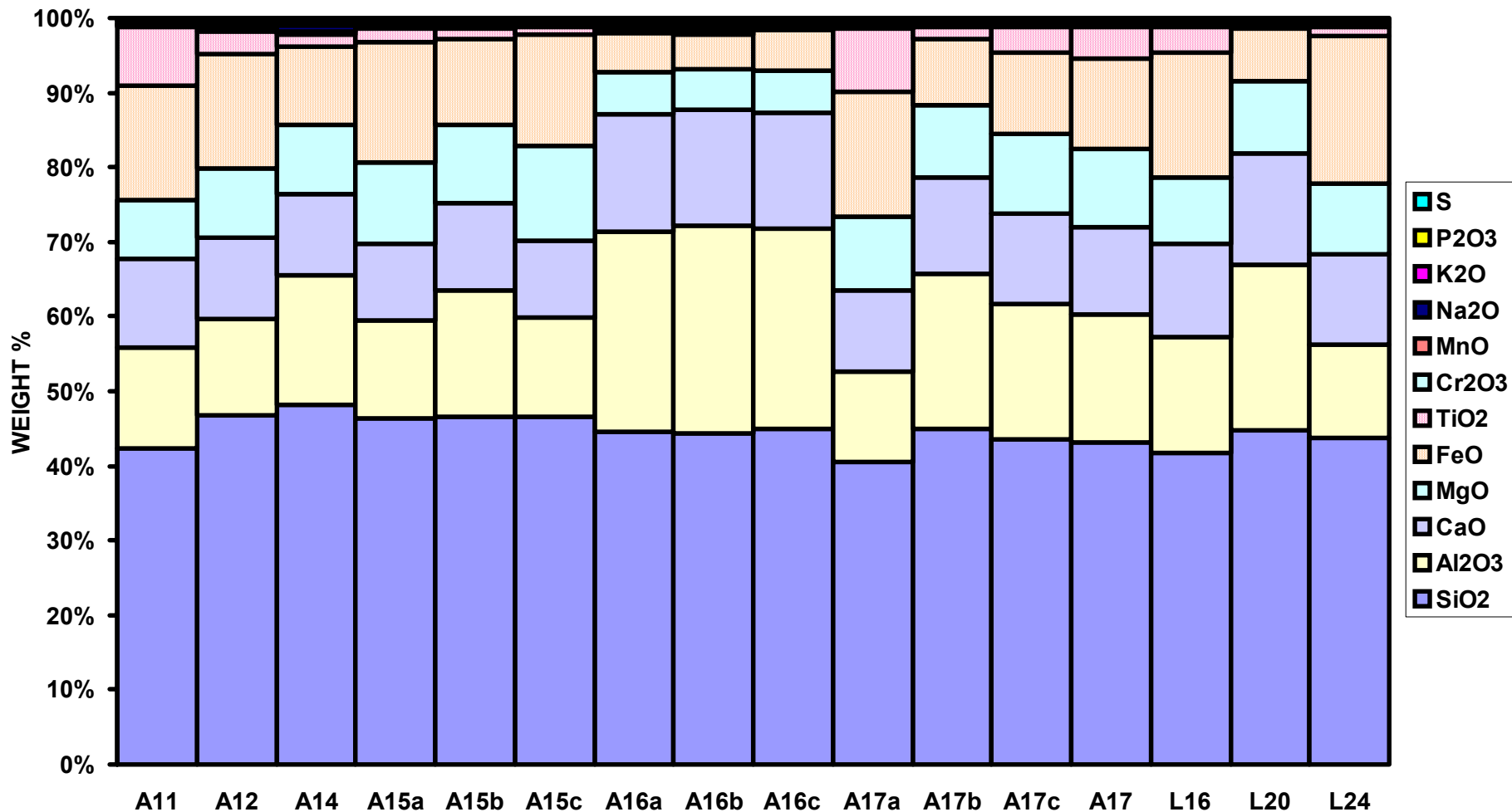


MoonMinerals4815.xls

**Pyroxenes are uniformly distributed but oxides are not...motivates prospecting.**



## Lunar Mare Oxides: Lateral Composition

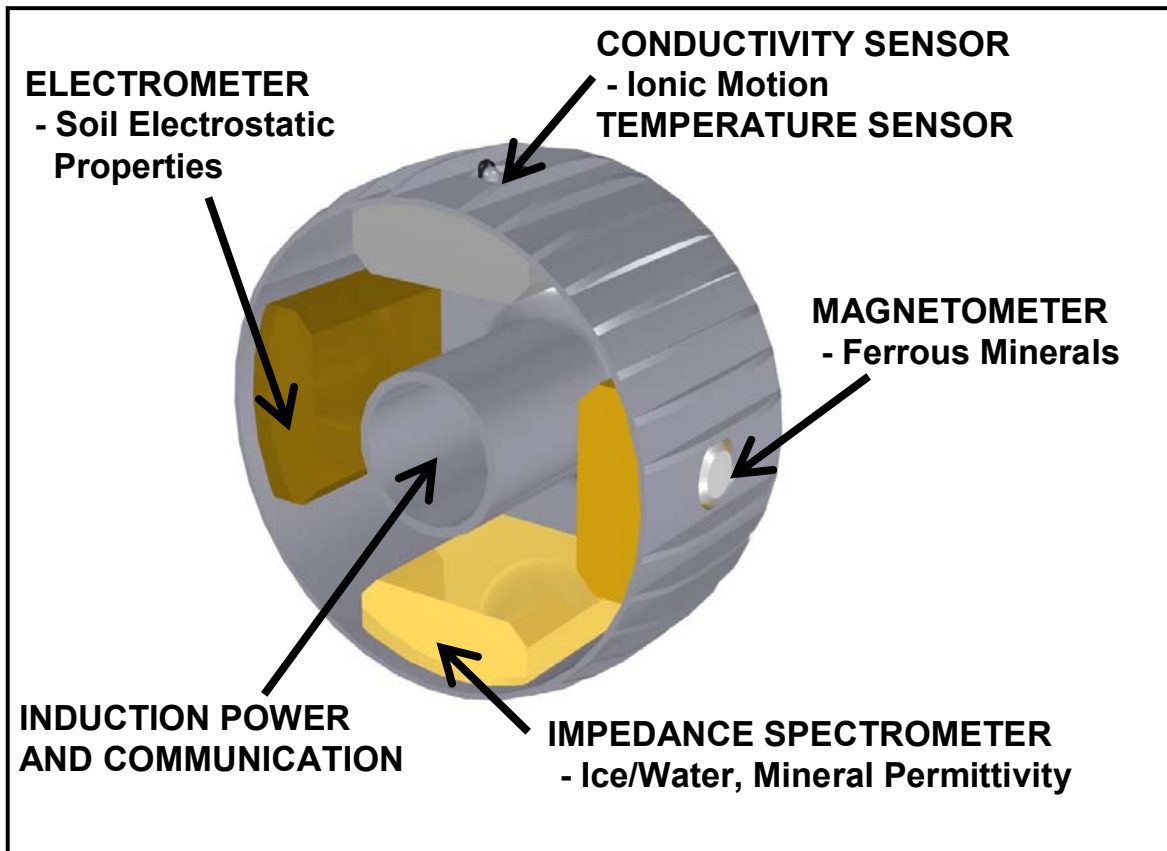


MoonMinerals4815.xls

**Only six oxides have abundances > 1%.**



## Proposed rover wheel with sensors for *in situ* soil measurements.



- Impedance Spectrometer:

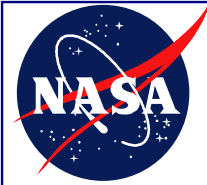
- $\epsilon = \epsilon' - j \epsilon''$

- $\epsilon$  is permittivity

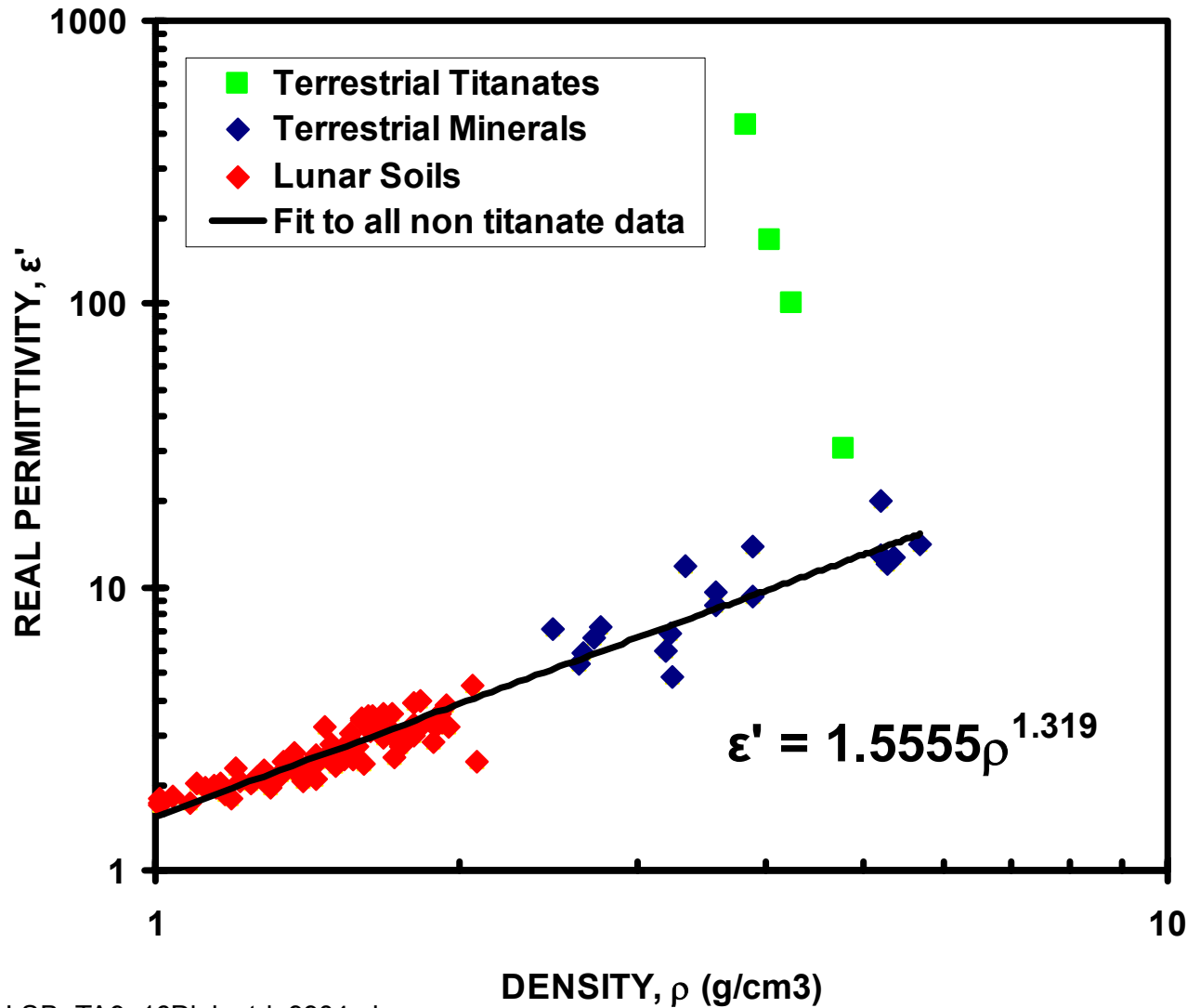
- Permittivity and dielectric constant are essentially the same.

- $\epsilon'$  is proportional to capacitance.

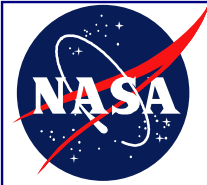
- $\epsilon''$  is proportional to electrical conductivity.



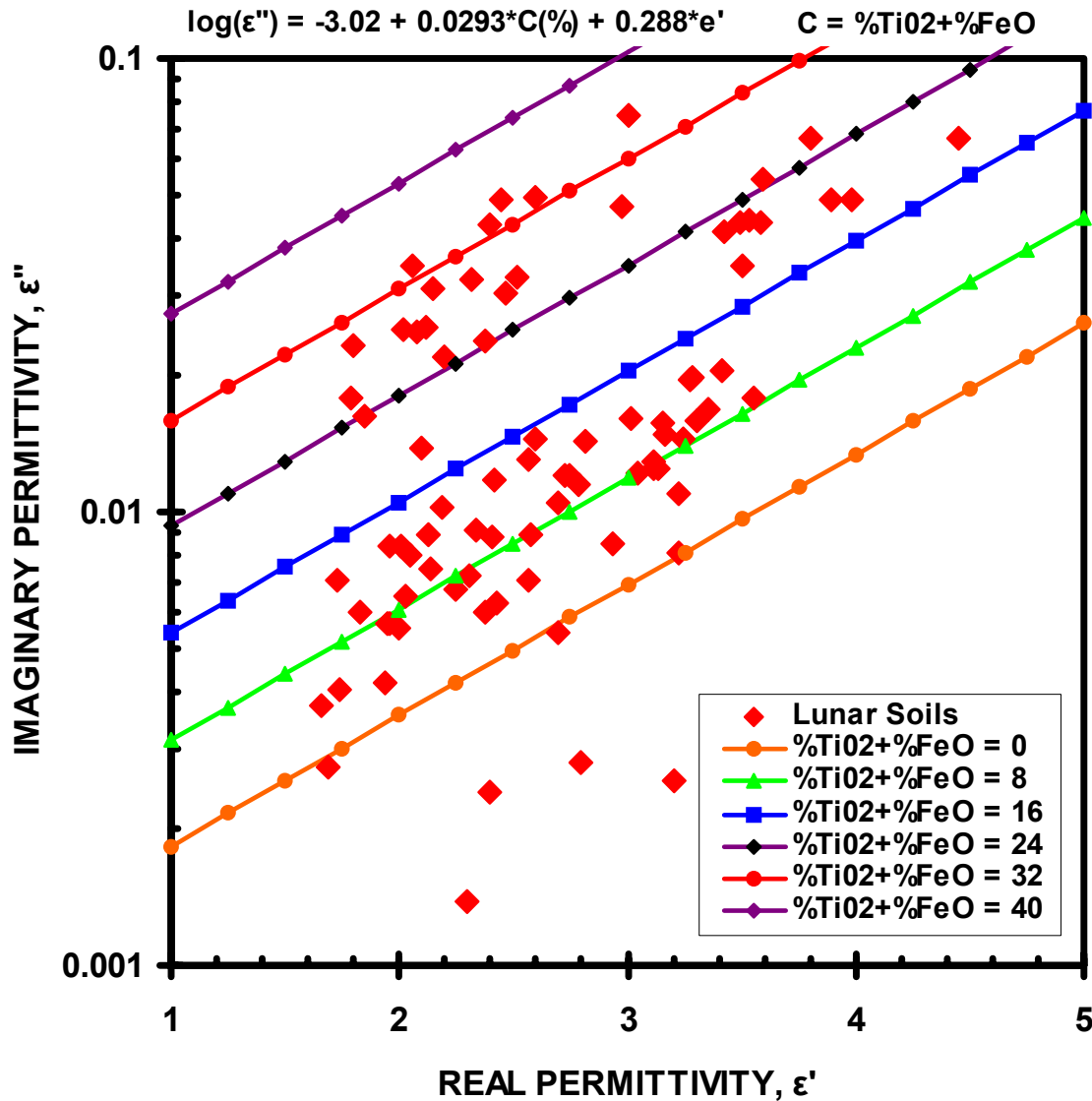
# Real Part of the Permittivity vs Density: Lunar Soils and Terrestrial Minerals



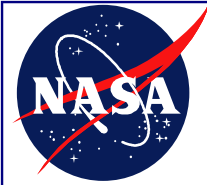
Real part of permittivity depends on soil or mineral **density**.



# Imaginary vs Real Part of the Permittivity

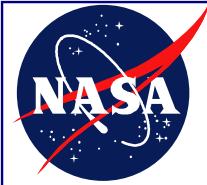


Imaginary part of permittivity depends on soil or mineral chemistry.



## Comparison of Techniques

TECHNIQUE	CONTACT	DEPTH	P	FREQUENCY	ANALYSIS
Impedance Spectro-meter	YES	4 Times Probe Spacing	1W	mHz to MHz, Suitable for Ice Detection for $f < 1\text{kHz}$ .	Simple, Absolute, Measures both $\epsilon'$ and $\epsilon''$
Ground Penetrating Radar	NO	Antenna Length	10W	MHz to GHz, Sees Water but not Ice	Complex, Measures $\epsilon$ , Images Boundary Layers
Electro-magnetic Induction	NO	Antenna Length	10W	MHz to GHz, Sees Water but not Ice	Complex, Relative Measure



## Conclusion

- From an ISRU perspective, the Moon has a simple mineral set (Silicates and Oxides)
- Need *in situ* prospecting.
- Simple measurements can be used for *in situ* exploration.
- For the Moon,  $\epsilon'$  provides  $\rho$ .
- For the Moon,  $\epsilon''$  provides chemistry.
- Measuring  $\epsilon$  is rapid and requires modest power.