

Scanning for Extinct Astrobiological Residues and Current Habitats (SEARCH)

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Goals

- Identify evidence of life, extinct life, and potential habitats
- Gather geological data

Design Criteria

- Identify substances with spectroscopy
- Cover an area quickly
- Maintain high signal to noise ratio
- Reduce downlink bandwidth requirement
- Work autonomously
- Use a rugged design

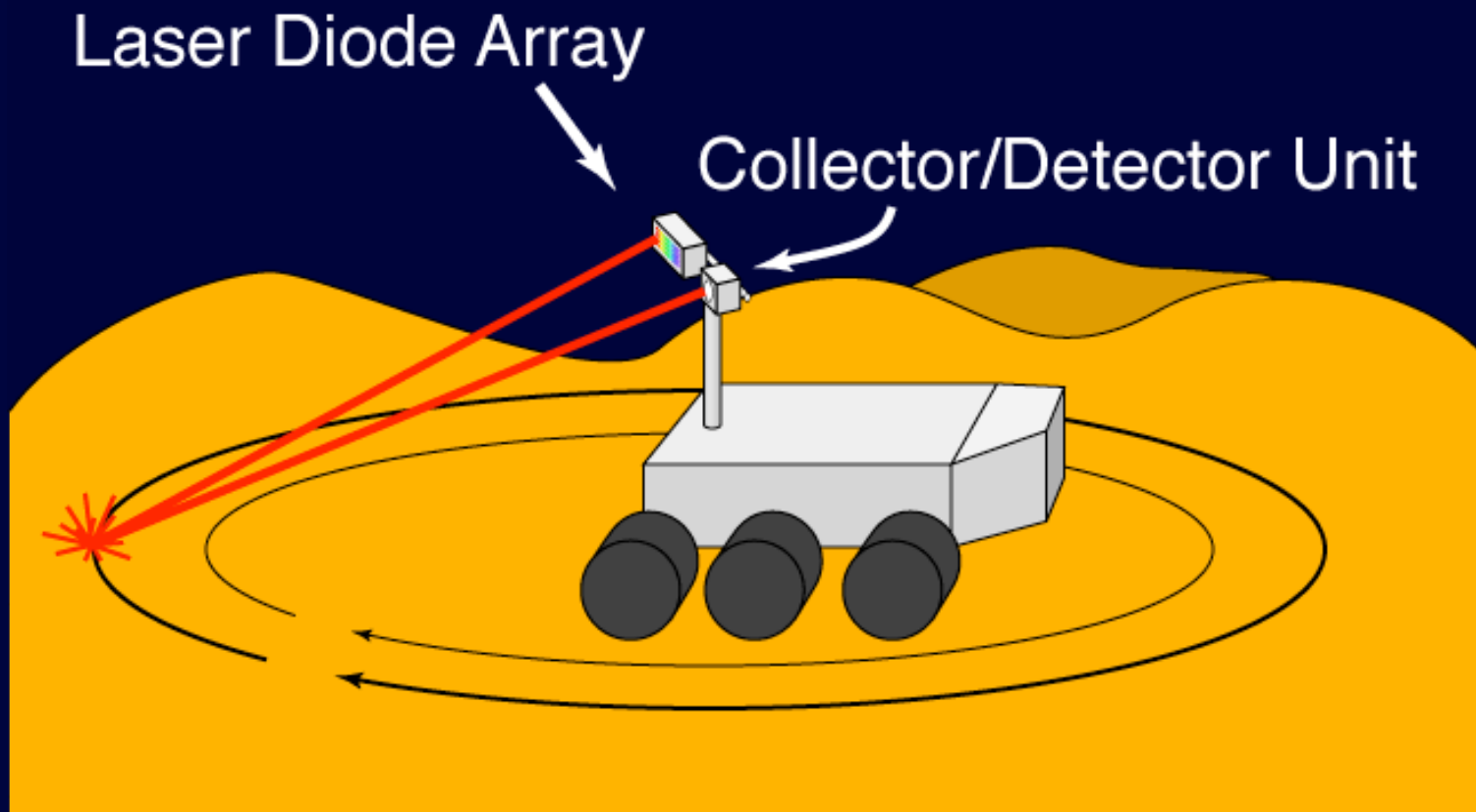


Solid-State Spectral Imaging

- Illuminate target with laser diode array
 - Ultraviolet, visible, and near-infrared
- Measure reflectance with collector
- Demultiplex target sequence
- Identify target substance with on-board statistical processing



Solid-State Spectral Imaging



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On-board Processing Identifies:

- Organic compounds
 - Amino acids, carbohydrates, polycyclic aromatic hydrocarbons (PAHS)
- Minerals
 - Amphiboles, silicates, limestone, jarosite, hematite, oxides, feldspars, plagioclase, smectite, halites, apatite, hydroxyapatite, sulfides, sulfates
- Water (liquid, solid, hydrates)



Laser Diode Array

- Up to 25 Wavelengths
- Multiple rows
 - Improved redundancy
 - Faster scanning speed
- Wavelengths selected based on expected substances

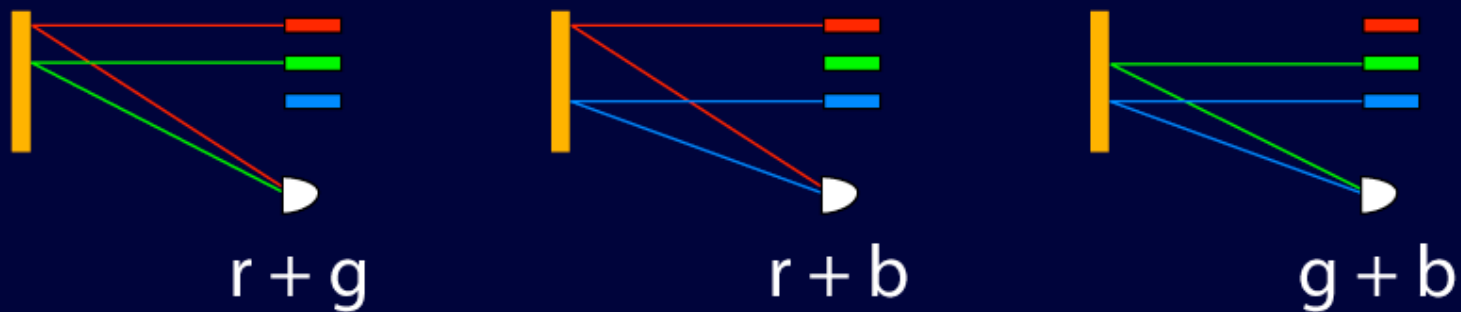


Walsh-Hadamard Multiplexing/Demultiplexing

- Illuminate target(s) with multiple diodes
 - Improve signal-to-noise ratio
 - Measure one intensity from sensor
- Compute each wavelength's contribution
 - Perform matrix vector multiply to demultiplex
 - Store intensities for current position



Demultiplexing 3 Wavelengths



$$\begin{bmatrix} 1 & 1 & -1 \\ 1 & -1 & 1 \\ -1 & 1 & 1 \end{bmatrix} \begin{bmatrix} r + g \\ r + b \\ g + b \end{bmatrix} = \begin{bmatrix} 2r \\ 2g \\ 2b \end{bmatrix}$$

Statistical Classification

- Compare samples against a library
- Bootstrap Error Adjusted Single-sample Technique (BEST)
 - Computes distance from center of substance
 - Returns result in standard deviations (SD)
 - All substances within 3 SDs are present
- Result is substance ID and SD measure



Operating Modes

- Mapping
 - Identify all substances present
 - Build image of surrounding region
- Survey
- Directional Stationary
- Directional Mobile



Current Status

- Initial tests done
- Experimenting with prototype
- Prototype Specifications:
 - 5x5 array of visible light LEDs
 - One photodiode sensor
 - Microcontroller for sequencing
 - Laptop running Matlab for identification

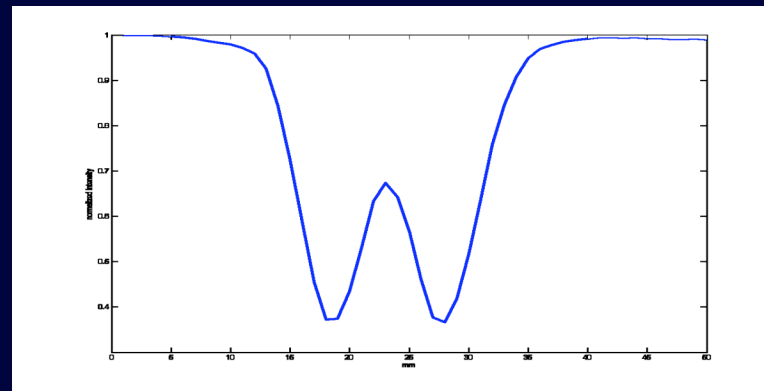
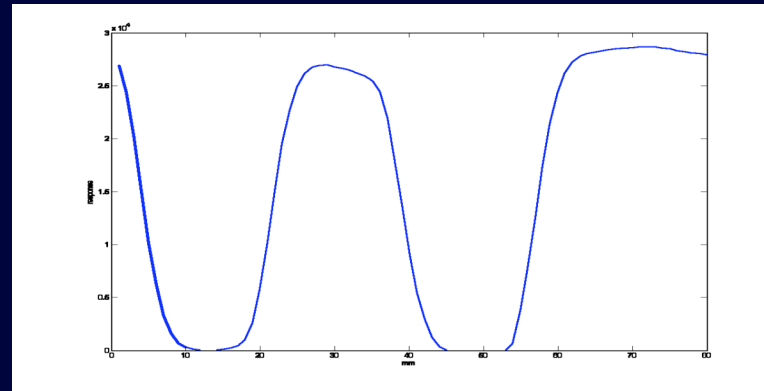
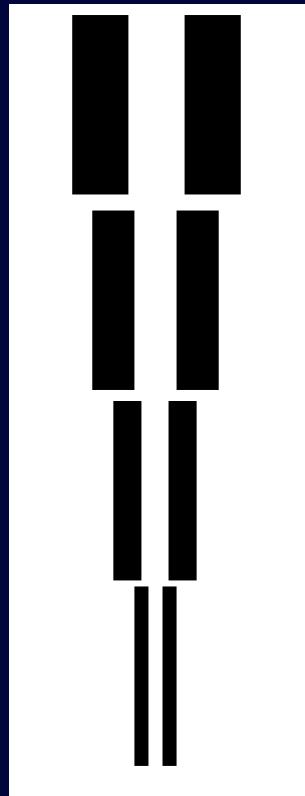


5x5 LED Prototype

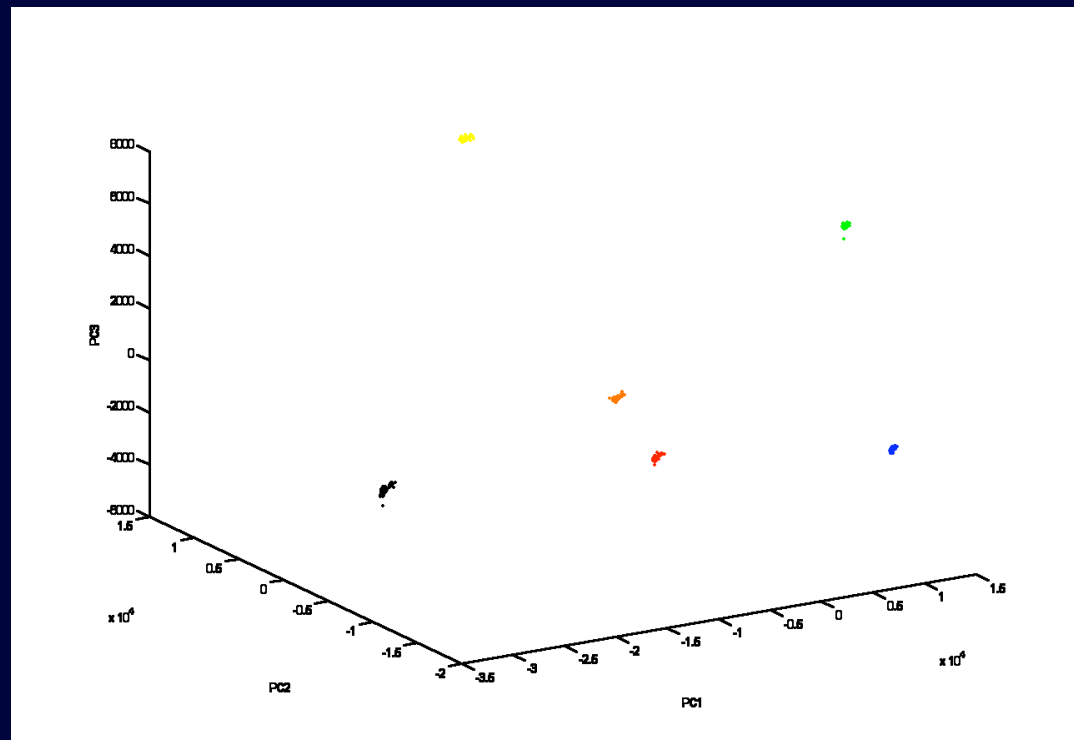
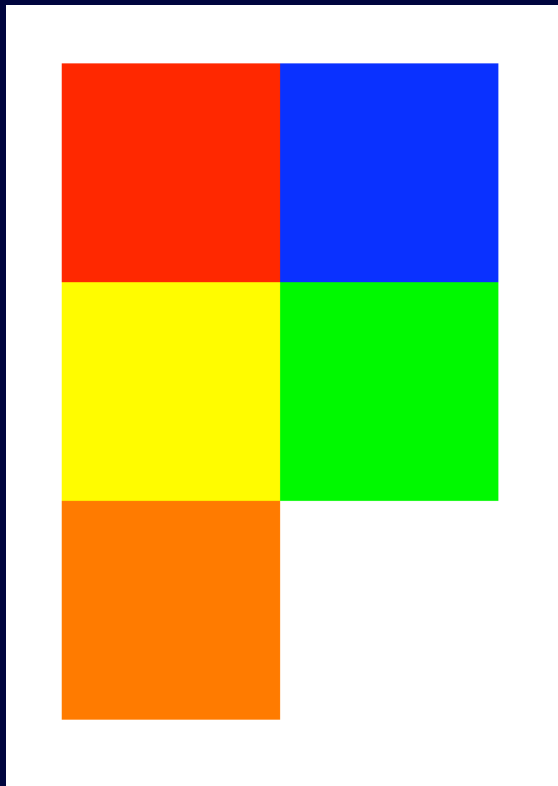


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Resolution Test with 5x5 Prototype



Color Discrimination Test with 5x5 Prototype



Related Work

- Raman spectroscopy
- Miniature Thermal Emission Spectrometry (mini-TES)
- Combination Laser Absorption and IR Spectrometer (CLARIS)
- Laser Induced Breakdown Spectroscopy (LIBS)



Conclusion

- Maps an area quickly
- Identifies areas for further examination
 - High signal to noise ratio
 - No contact, at least 10 m range
- Reduces required bandwidth
- Has no moving parts



Future Work

- Build laser diode version of prototype
- Reduce scanning speed with Complementary Randomized Integrated Sampling and Processing (CRISP)
- Perform field experiments
- Continue to pursue funding



Questions?

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Wavelengths

Substances	Wavelengths
Residual biofilm UV protectant molecules	340 nm
Residual phototrophic endolithic biofilms, sulfides	470 nm, 530 nm, 635 nm
Water, -OH, =C=H	1445 nm, 1940 nm, 1982 nm
-CH ₂ , -CH ₃ , various -C-H stretches, calcite	1680 nm, 1722 nm, 1734 nm, 1759 nm, 1778 nm, 1818 nm

Wavelengths (cont'd)

Substances	Wavelengths
-NH ₂ , amines, protein, amides	2100 nm, 2139 nm, 2180 nm, 2190 nm, 2208 nm, 2230 nm
Lipids, -CH, calcite, limestone	2270 nm, 2310 nm, 2336 nm, 2348 nm
Baseline for reflectance and target angle	1064 nm

Creating BEST Library Entries

- Sample substance multiple times
- Generate Bootstrap set from samples
 - Select samples at random from sample set
 - Use center as one entry in bootstrap set
- Repeat for each substance in the library

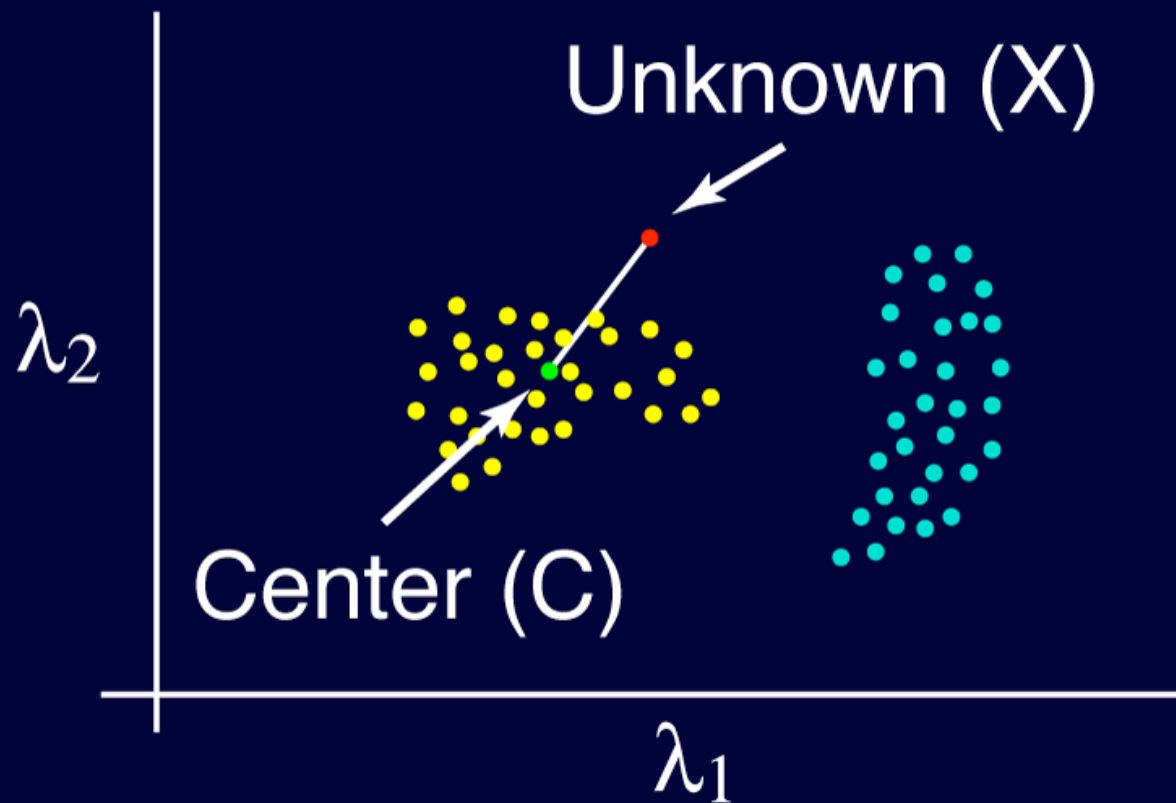


Testing a Substance

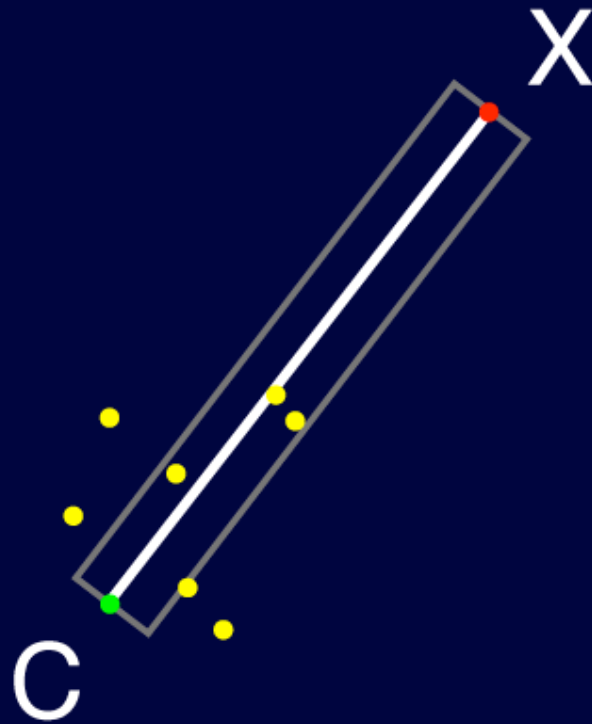
- Treat each sample as a point an n dimensional point
- Compute the distance from the sample to the center of a library entry in standard deviations



2 Wavelength Example



Computing the SD from C to X



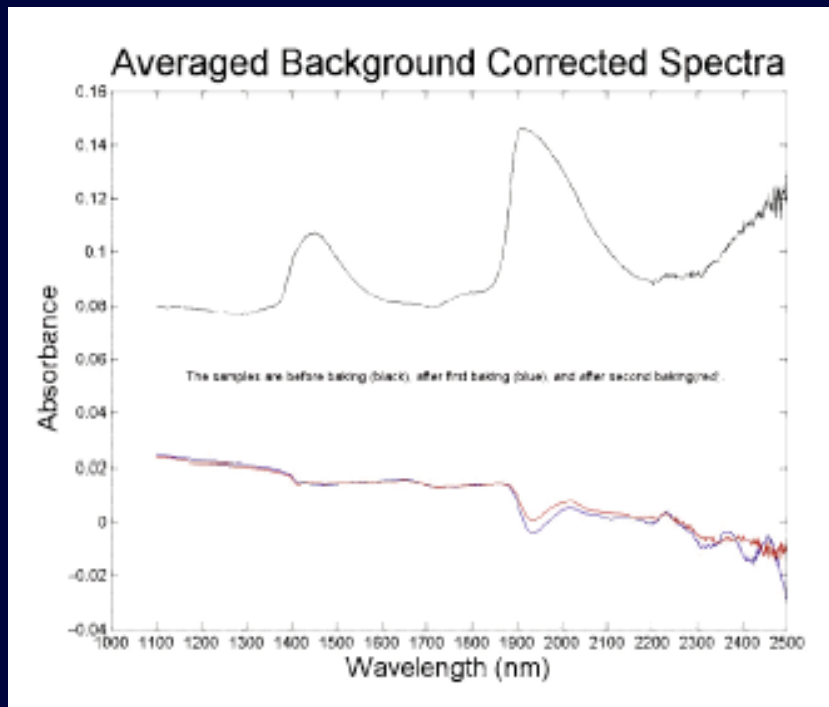
Optimization

- Pre-compute n dimensional polynomial surface approximating 3 SD distance from center

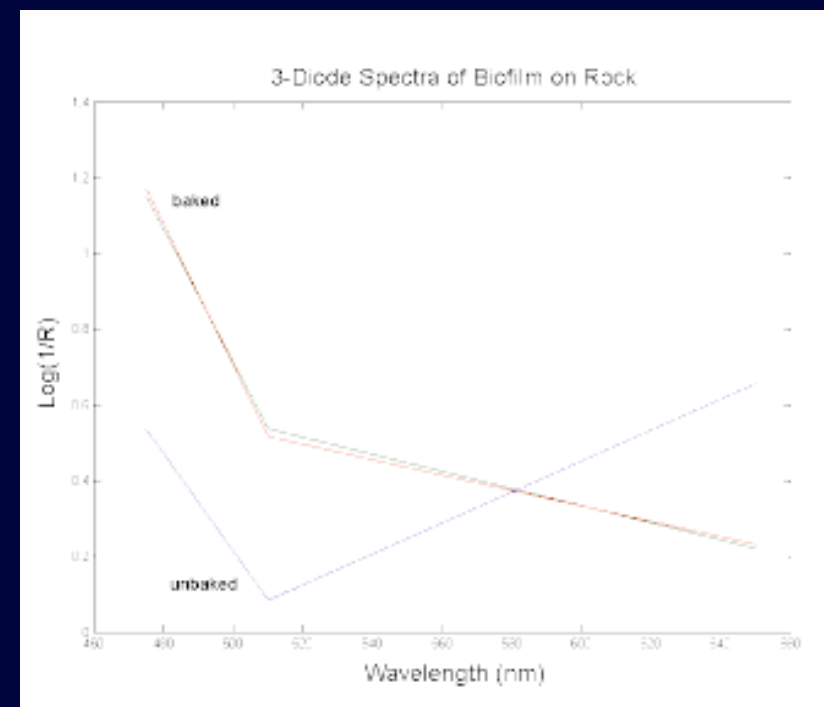
Estimated Specifications

- Mass: 580g
- Peak operational power: 5.9 W
- Survey time: ~1 min.
- Full mapping time: ~1.5 hrs.
- Computational requirement:

160 C Baking Experiment



Near Infrared



Visible Light