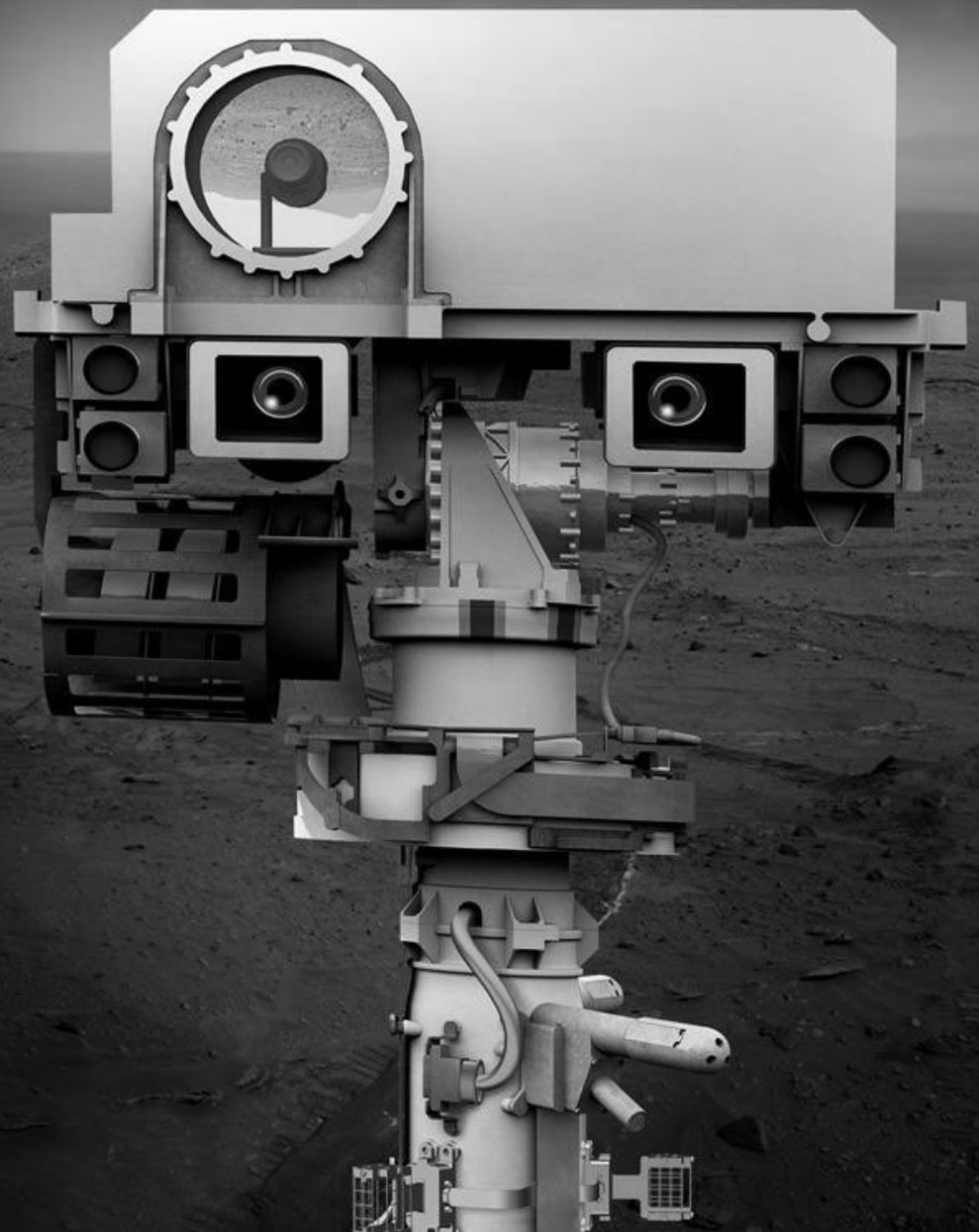
Jet Propulsion Laboratory
California Institute of Technology



ACCELERATING ASTROBIOLOGY

DATA SCIENCE
Scott Davidoff
Hillary Mushkin
Maggie Hendrie
Santiago Lombeyda
David Thompson
David Schurman
Pooja Nair
Adrian Galvin

PIXL
Abigail Allwood
Joel Hurowitz
David Flannery
Rob Hodyss
Yang Liu
Tim Elam
Chris Heirwegh

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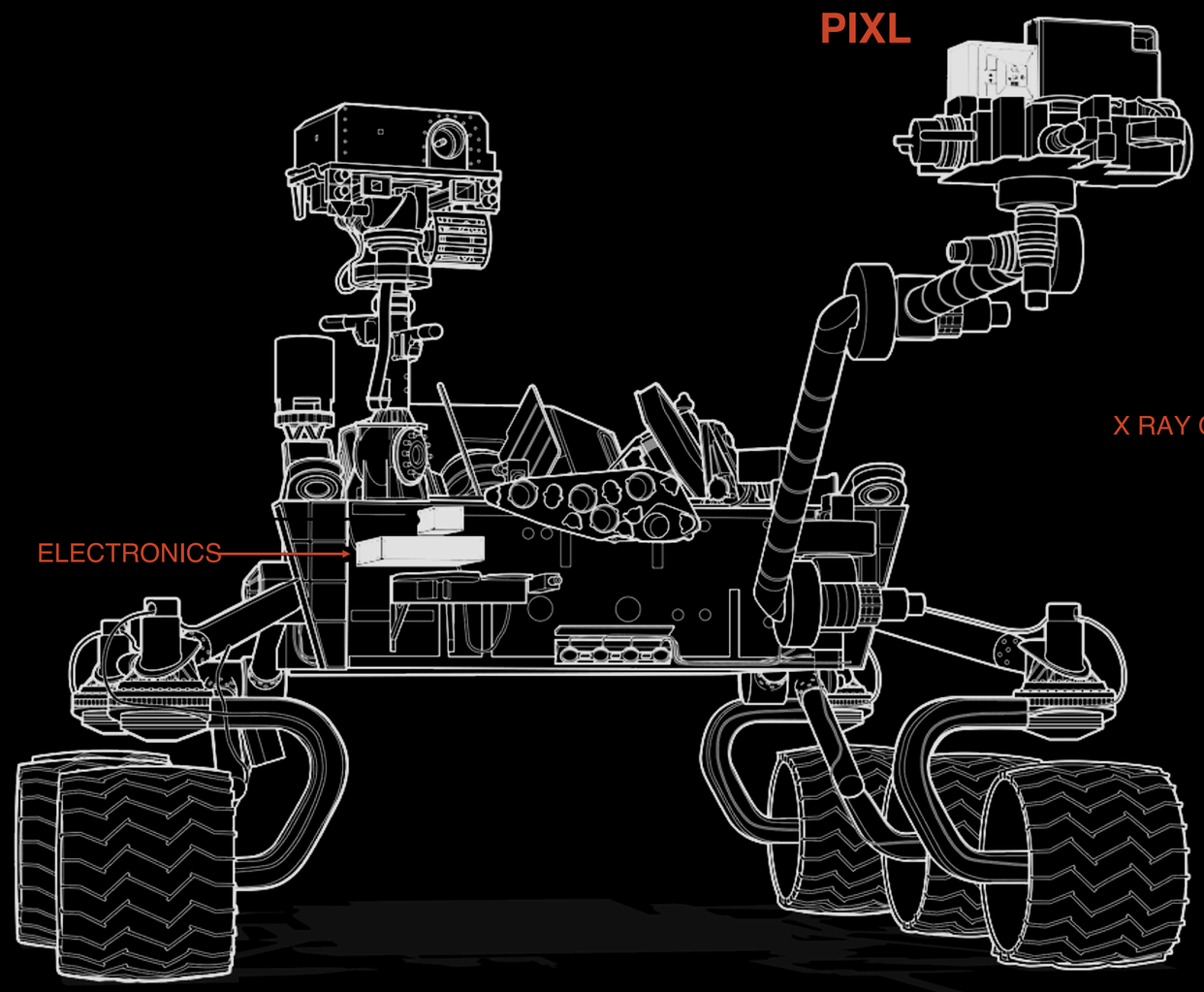
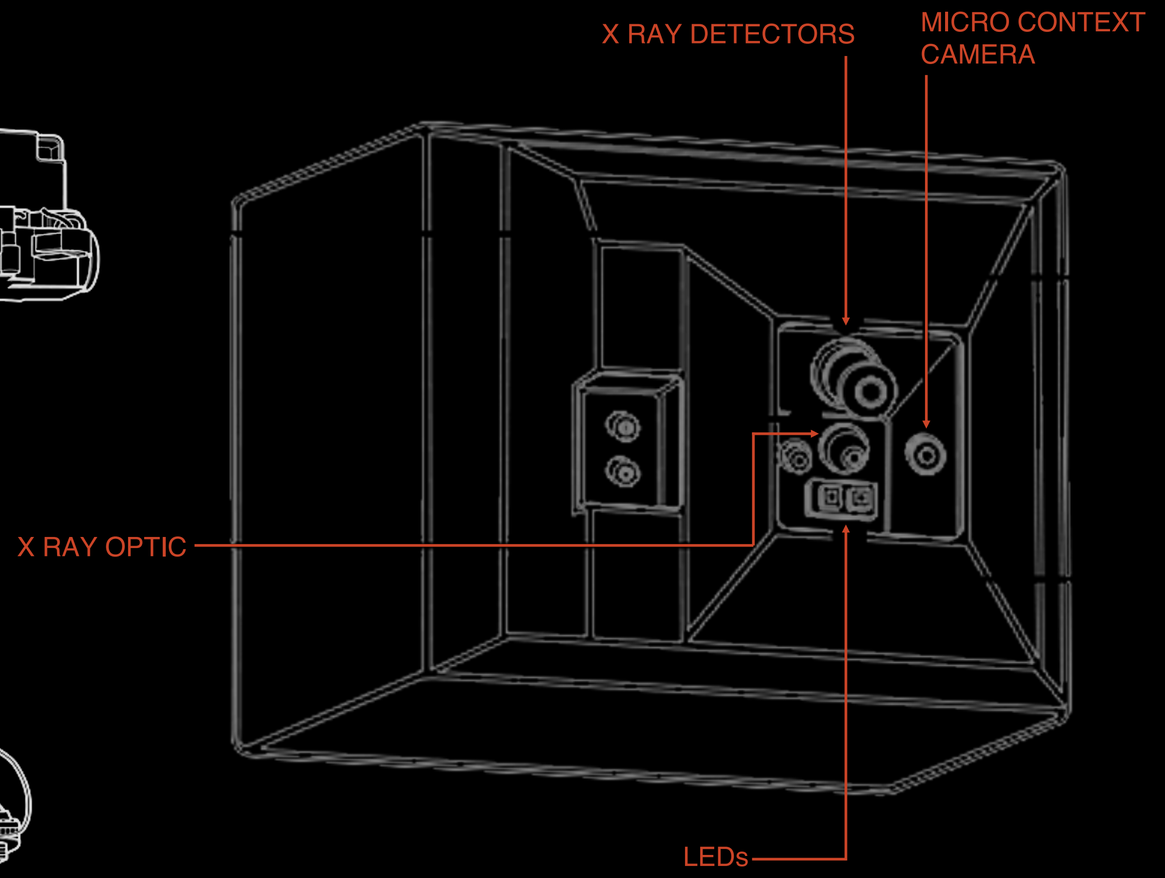
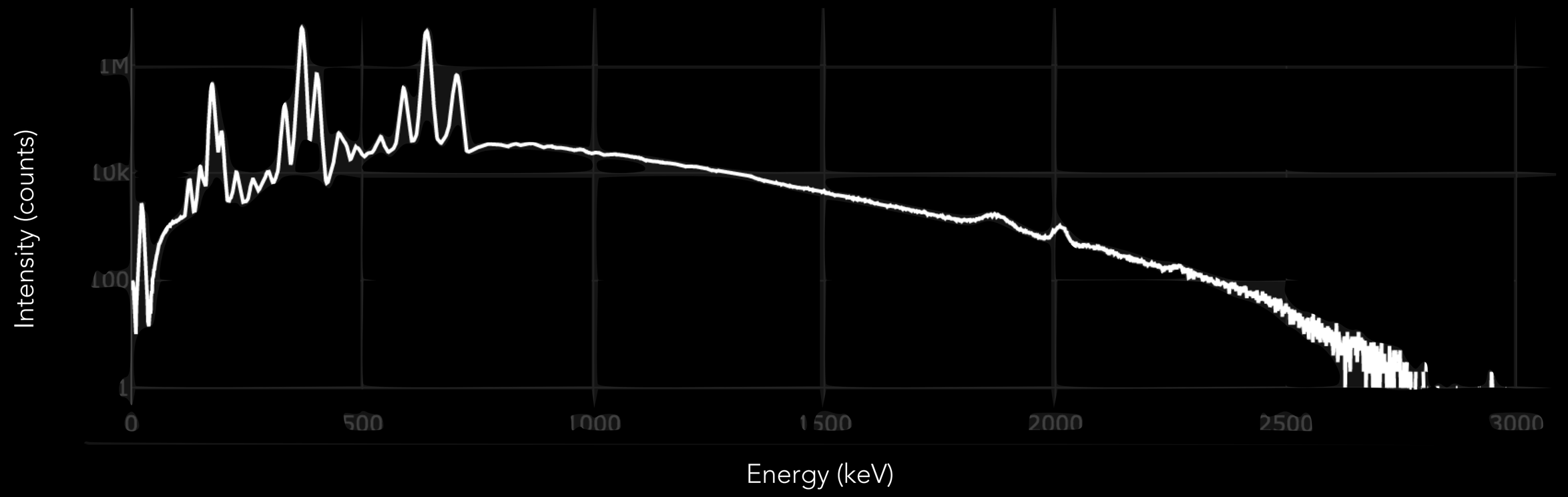
PIXL Evidence of life on mars?

PIXL Planetary Instrument for X-ray Lithochemistry

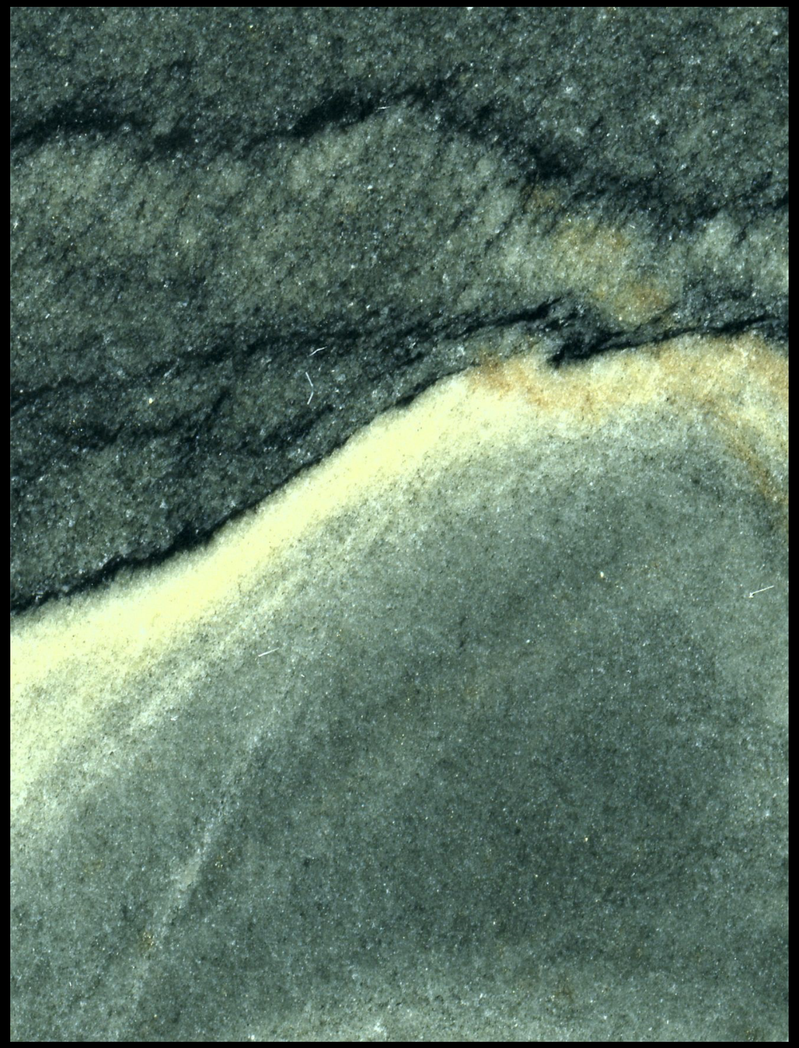




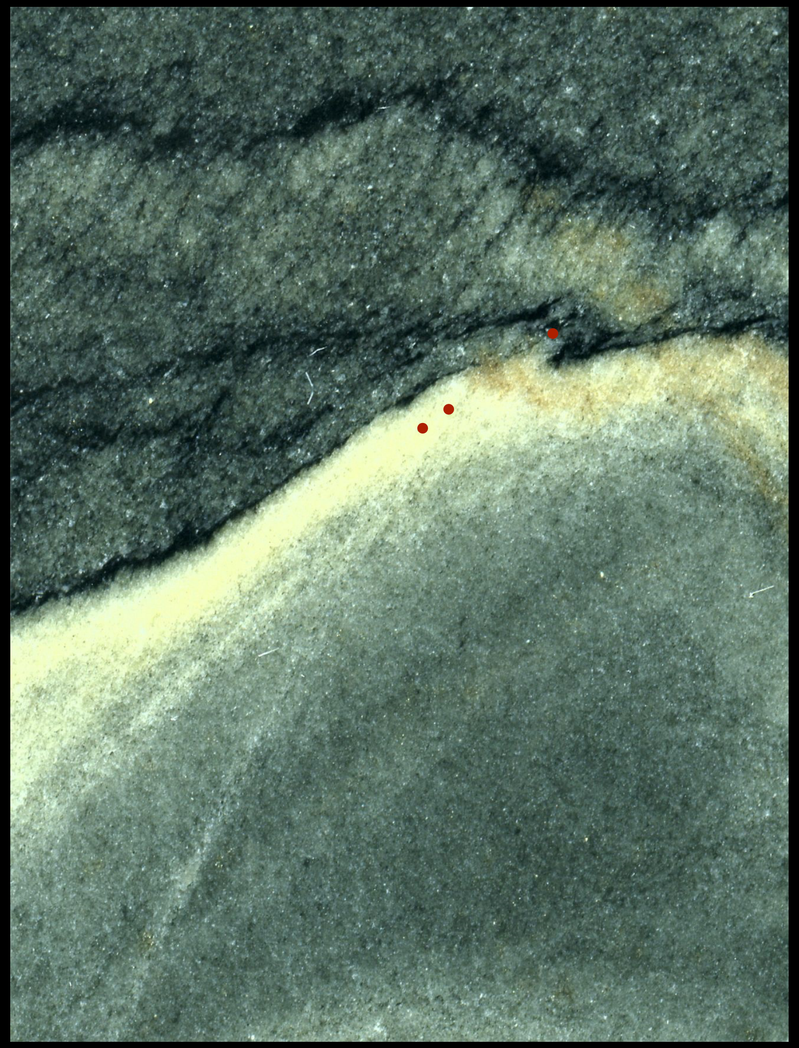
PIXL Spectral data



PIXL Image Data



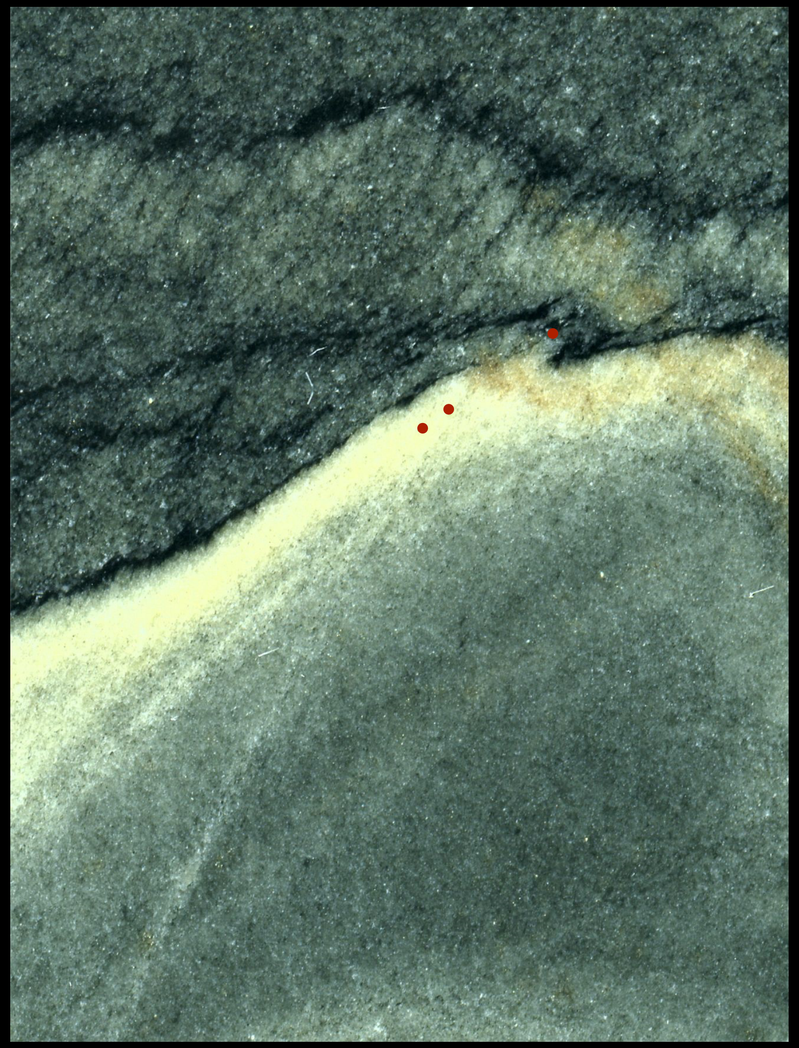
PIXL M2020 ConOps timeline



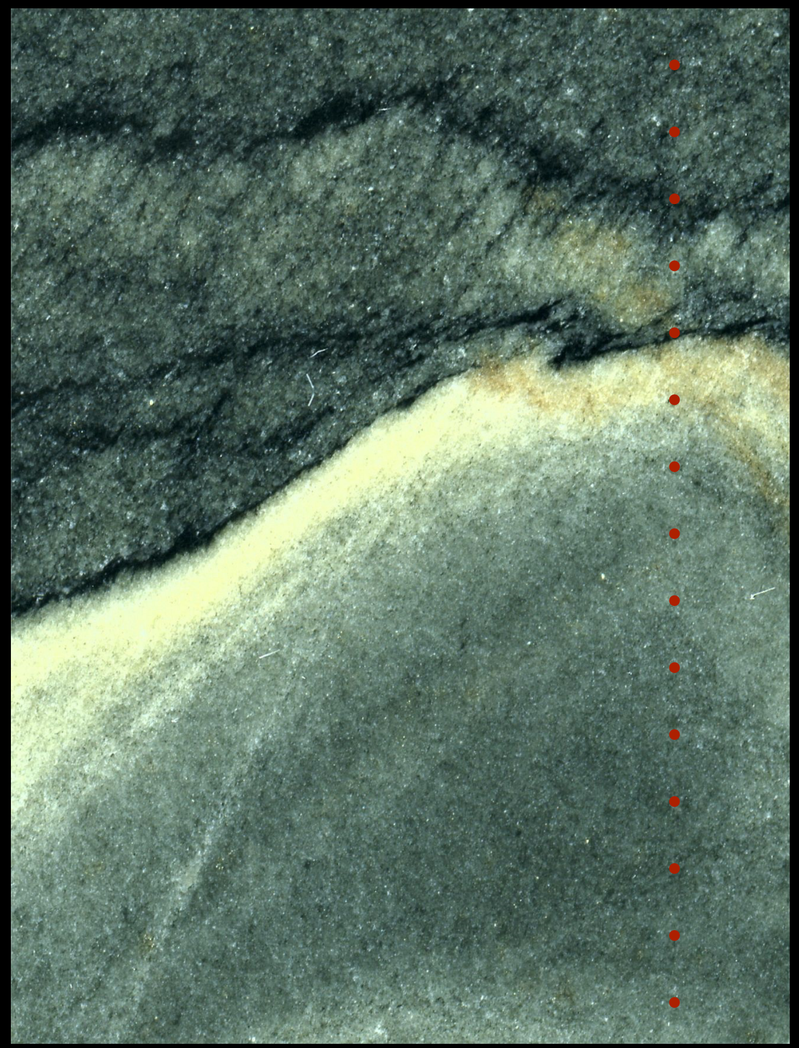
Line Scan

PIXL M2020 ConOps timeline

PIXL M2020 ConOps timeline

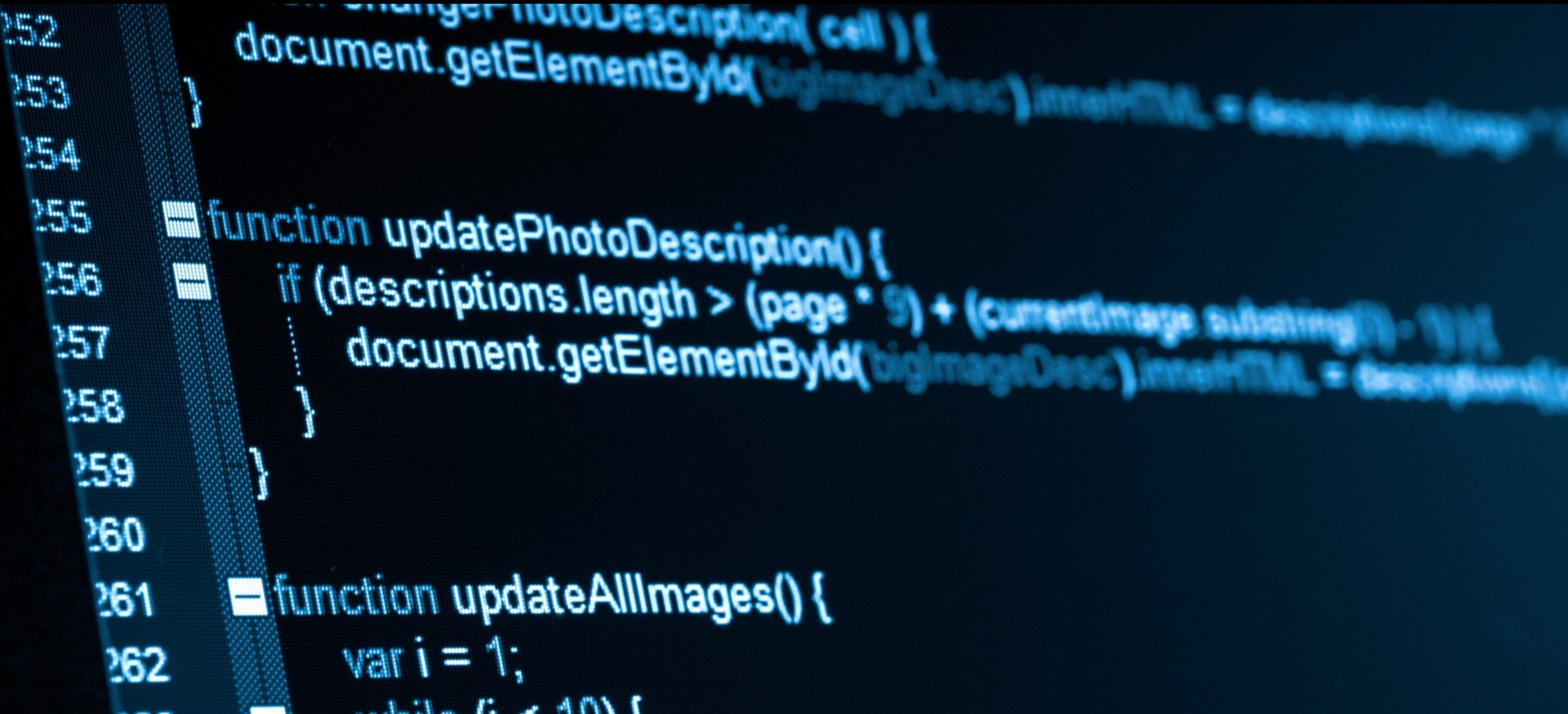


Line Scan



Grid Scan

PIXL Analysis == code



Greenland_Mar1_2018_PIQUANT_output.json -- PIXELATE

FEATURE TRACE + - DESELECT ADD ELEMENT MAP

ADD WORKSPACE | Selection 0 | HOME

CONTEXT IMAGE (WATSON)

LAYERS EXPORT SELECTION

Mg + Fe

LAYERS INTERSECT

Mg

LAYERS INTERSECT

Fe

LAYERS INTERSECT

Selection 0

Sr Mg Ni Al Si Mn K Ti Ca

Sr Mg Ni Al Si Mn K Ti Ca

BULK POINT BULK SUM SPECTRUM TOGGLE LABELS

SHOW SELECTION

PIQUANT

Greenland_Mar1_2018_PIQUANT_output.json -- PIXELATE

FEATURE TRACE + - DESELECT ADD ELEMENT MAP

ADD WORKSPACE | Selection 0 | HOME

CONTEXT IMAGE (WATSON)

LAYERS EXPORT SELECTION

Mg + Fe

LAYERS INTERSECT

Mg

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LAYERS INTERSECT

Selection 0

Sr Mg Ni Al Si Mn K Ti Ca

Sr Mg Ni Al Si Mn K Ti Ca

BULK POINT BULK SUM SPECTRUM TOGGLE LABELS

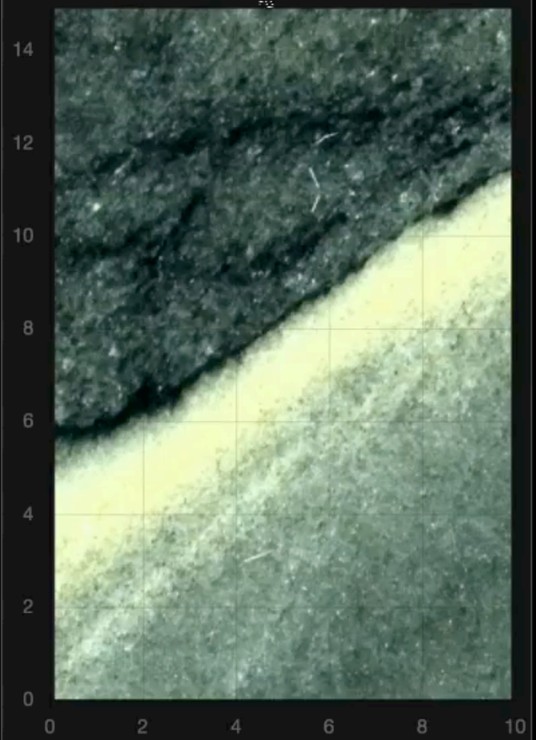
SHOW SELECTION

PIQUANT

Greenland_Mar1_2018_PIQUANT_output.json -- PIXELATE

TOOLS + - DESELECT ADD ELEMENT MAP ADD WORKSPACE HOME

CONTEXT IMAGE (WATSON)



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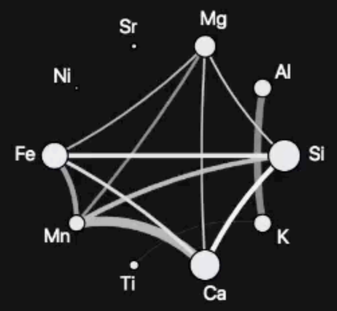
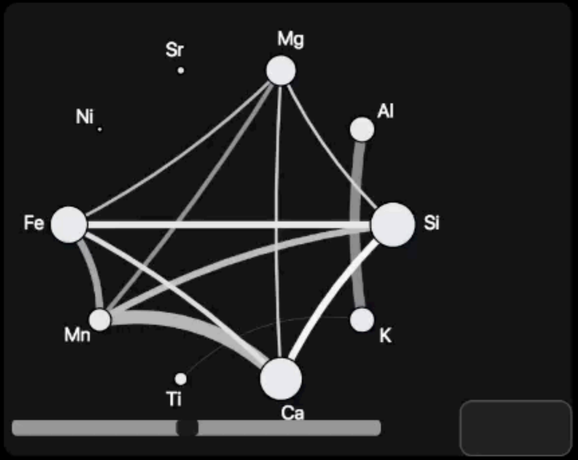
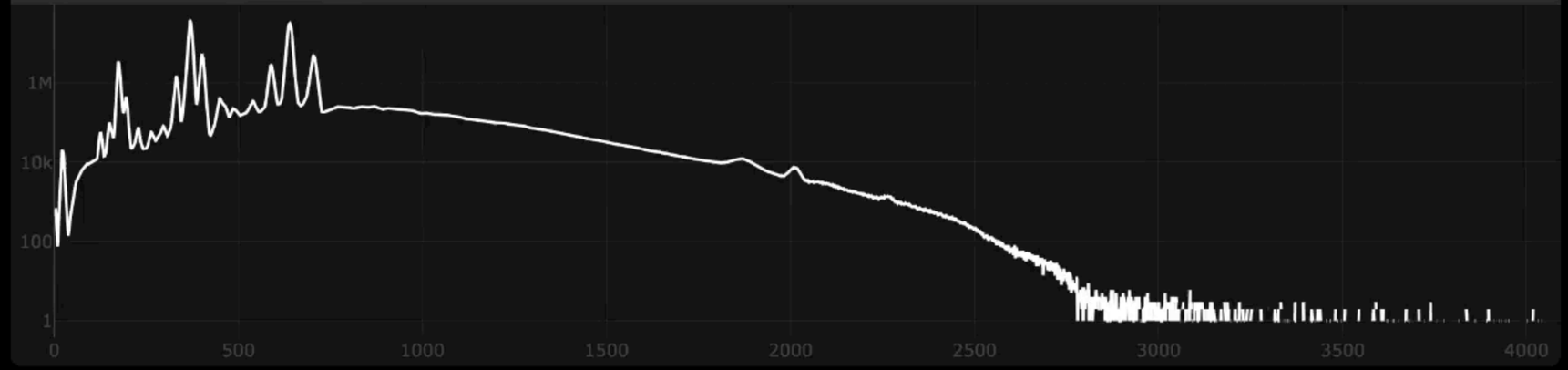




BULK POINT TOGGLE LABELS

BULK SUM SPECTRUM



Greenland_Mar1_2018_PIQUANT_output.json -- PIXELATE

FEATURE TRACE + - DESELECT ADD ELEMENT MAP

ADD WORKSPACE Selection 0 HOME

CONTEXT IMAGE (WATSON)

LAYERS EXPORT SELECTION

Mg + Fe

LAYERS INTERSECT

Mg

LAYERS INTERSECT

Fe

LAYERS INTERSECT

Selection 0

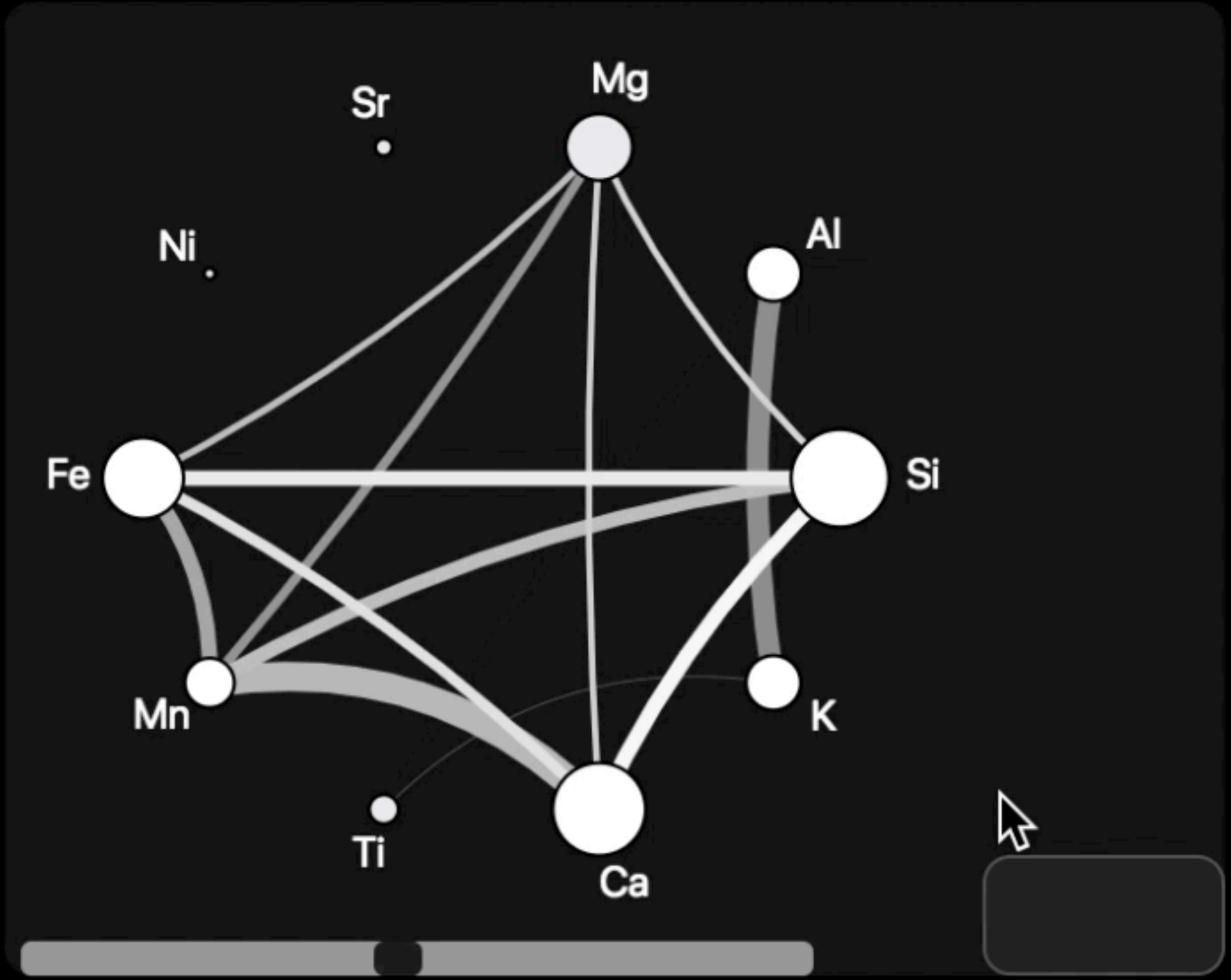
Sr Mg Ni Al e Si Mn K Ti Ca

Sr Mg Ni Al Si Mn K Ti Ca

BULK POINT BULK SUM SPECTRUM TOGGLE LABELS

SHOW SELECTION

PIQUANT


Sr
Mg
Ni
Al
Fe
Si
Mn
K
Ti
Ca

Greenland_Mar1_2018_PIQUANT_output.json -- PIXELATE

FEATURE TRACE + - DESELECT ADD ELEMENT MAP

ADD WORKSPACE | Selection 0 | HOME

CONTEXT IMAGE (WATSON)

LAYERS EXPORT SELECTION

Mg + Fe

LAYERS INTERSECT

Mg

LAYERS INTERSECT

Fe

LAYERS INTERSECT

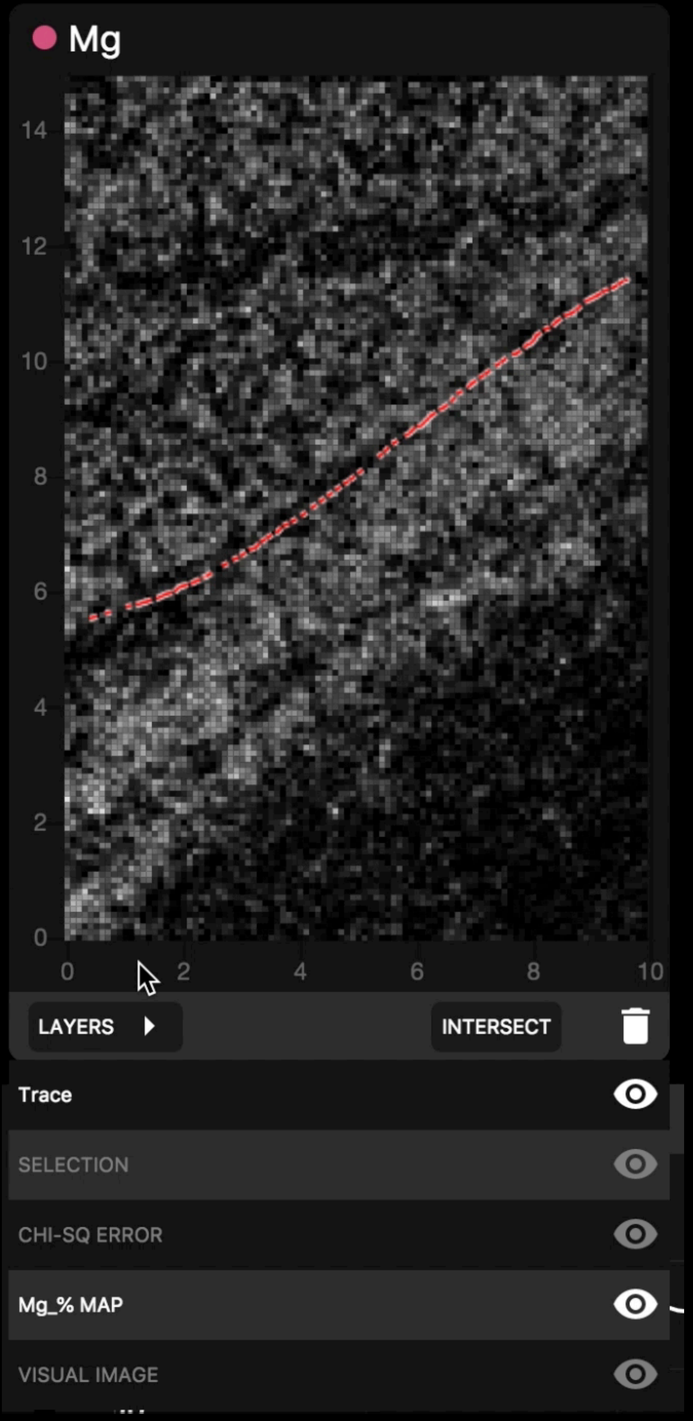
Selection 0

Sr Mg Ni Al Si Mn K Ti Ca

BULK POINT BULK SUM SPECTRUM TOGGLE LABELS

SHOW SELECTION

PIQUANT


Mg
14
12
10
8
6
4
2
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0
2
4
6
8
10
LAYERS
INTERSECT
Trace
SELECTION
CHI-SQ ERROR
Mg_% MAP
VISUAL IMAGE

Greenland_Mar1_2018_PIQUANT_output.json – PIXELATE

FEATURE TRACE + – DESELECT ADD ELEMENT MAP

ADD WORKSPACE | Selection 0 | HOME

CONTEXT IMAGE (WATSON)

LAYERS EXPORT SELECTION

Mg + Fe

LAYERS INTERSECT

Mg

LAYERS INTERSECT

Fe

LAYERS INTERSECT

Selection 0

Sr Mg Ni Al e Si Mn K Ti Ca

Sr Mg Ni Al Si Mn K Ti Ca

BULK POINT BULK SUM SPECTRUM TOGGLE LABELS

SHOW SELECTION

PIQUANT

PIXL Outcome: 1 day to 10 seconds

PIXL Automation

ASTROBIOLOGY
Volume 15, Number 11, 2015
© Mary Ann Liebert, Inc.
DOI: 10.1089/ast.2015.1349

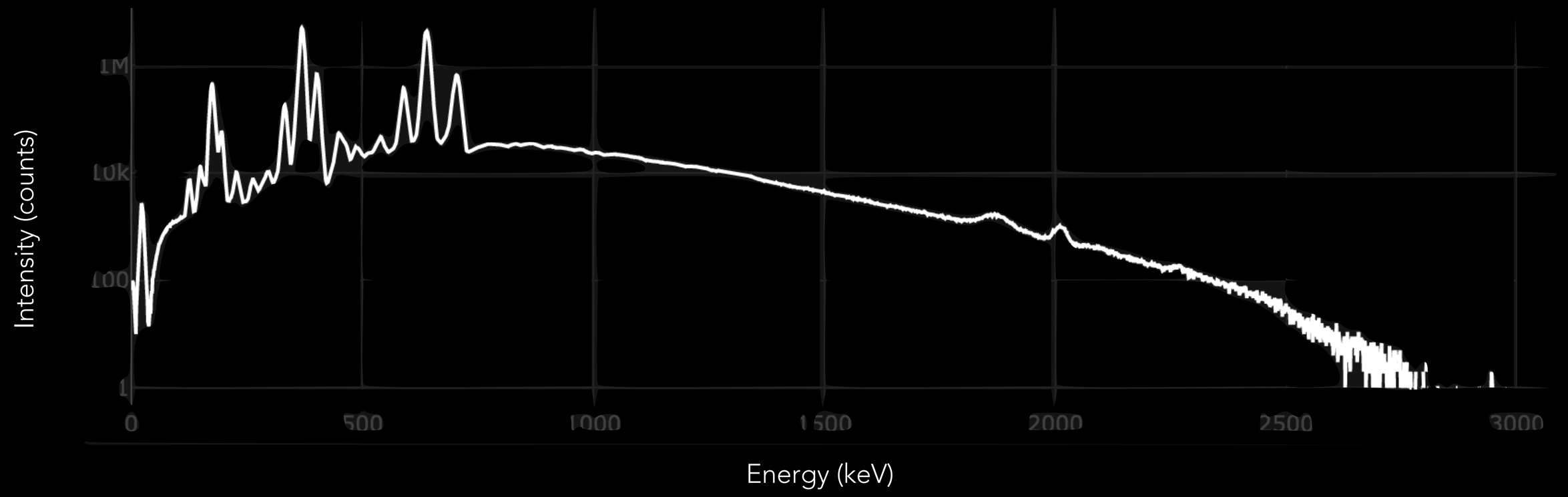
Automating X-ray Fluorescence Analysis for Rapid Astrobiology Surveys

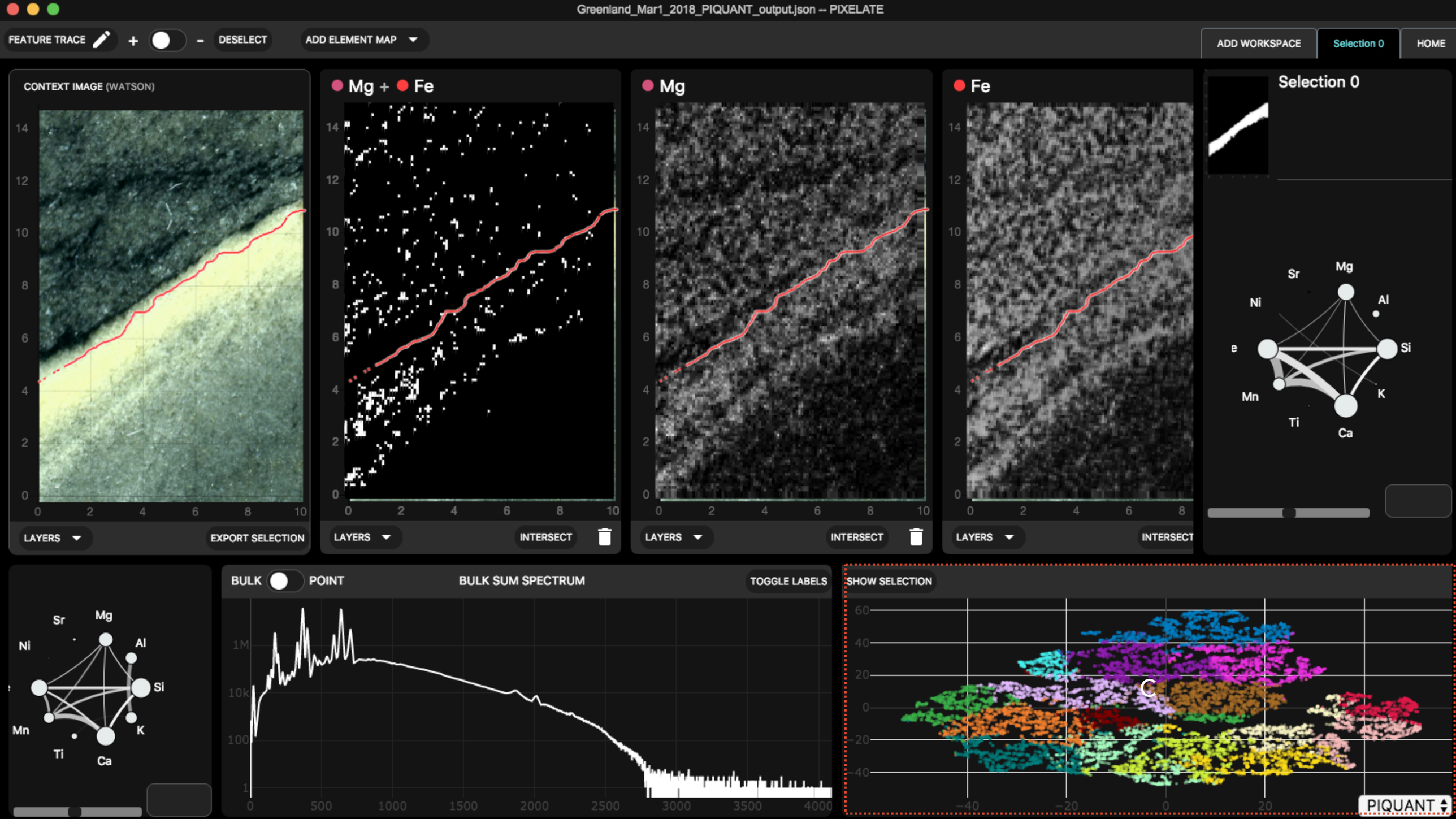
David R. Thompson,[1,2] David T. Flannery,[1,3] Ravi Lanka,[1,4] Abigail C. Allwood,[1,5]
Brian D. Bue,[1,4] Benton C. Clark,[6] W. Timothy Elam,[7] Tara A. Estlin,[1,4] Robert P. Hodyss,[1,8]
Joel A. Hurowitz,[9] Yang Liu,[1,10] and Lawrence A. Wade[1,11]

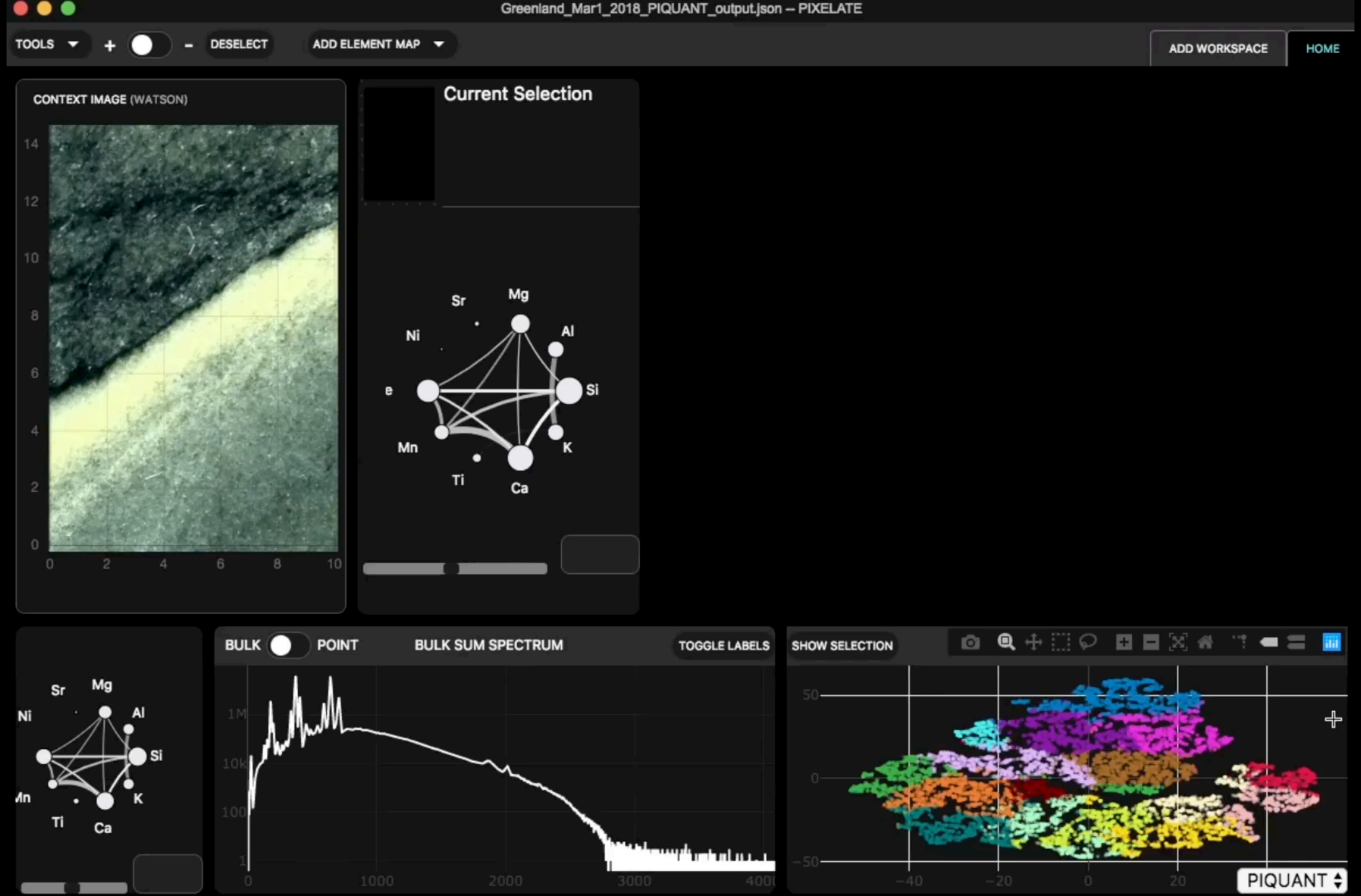
Abstract

A new generation of planetary rover instruments, such as PIXL (Planetary Instrument for X-ray Lithochemistry) and SHERLOC (Scanning Habitable Environments with Raman Luminescence for Organics and Chemicals) selected for the Mars 2020 mission rover payload, aim to map mineralogical and elemental composition *in situ* at microscopic scales. These instruments will produce large spectral cubes with thousands of channels acquired over thousands of spatial locations, a large potential science yield limited mainly by the time required to acquire a measurement after placement. A secondary bottleneck also faces mission planners after downlink; analysts must interpret the complex data products quickly to inform tactical planning for the next command cycle. This study demonstrates operational approaches to overcome these bottlenecks by specialized early-stage science data processing. Onboard, simple real-time systems can perform a basic compositional assessment, recognizing specific features of interest and optimizing sensor integration time to characterize anomalies. On the ground, statistically motivated visualization can make raw uncalibrated data products more interpretable for tactical decision making. Techniques such as manifold dimensionality reduction can help operators comprehend large databases at a glance, identifying trends and anomalies in data. These onboard and ground-side analyses can complement a quantitative interpretation. We evaluate system performance for the case study of PIXL, an X-ray fluorescence spectrometer. Experiments on three representative samples demonstrate improved methods for onboard and ground-side automation and illustrate new astrobiological science capabilities unavailable in previous planetary instruments. Key Words: Dimensionality reduction—Planetary science—Visualization. Astrobiology 15, 961–976.

PIXL Automated Mineral / Feature Detection




Greenland_Mar1_2018_PIQUANT_output.json – PIXELATE
FEATURE TRACE
DESELECT
ADD ELEMENT MAP
ADD WORKSPACE
Selection 0
HOME
CONTEXT IMAGE (WATSON)
LAYERS
EXPORT SELECTION
Mg + Fe
INTERSECT
Mg
Fe
Selection 0
Sr
Mg
Ni
Al
Si
Mn
K
Ti
Ca
BULK
POINT
BULK SUM SPECTRUM
TOGGLE LABELS
SHOW SELECTION
PIQUANT

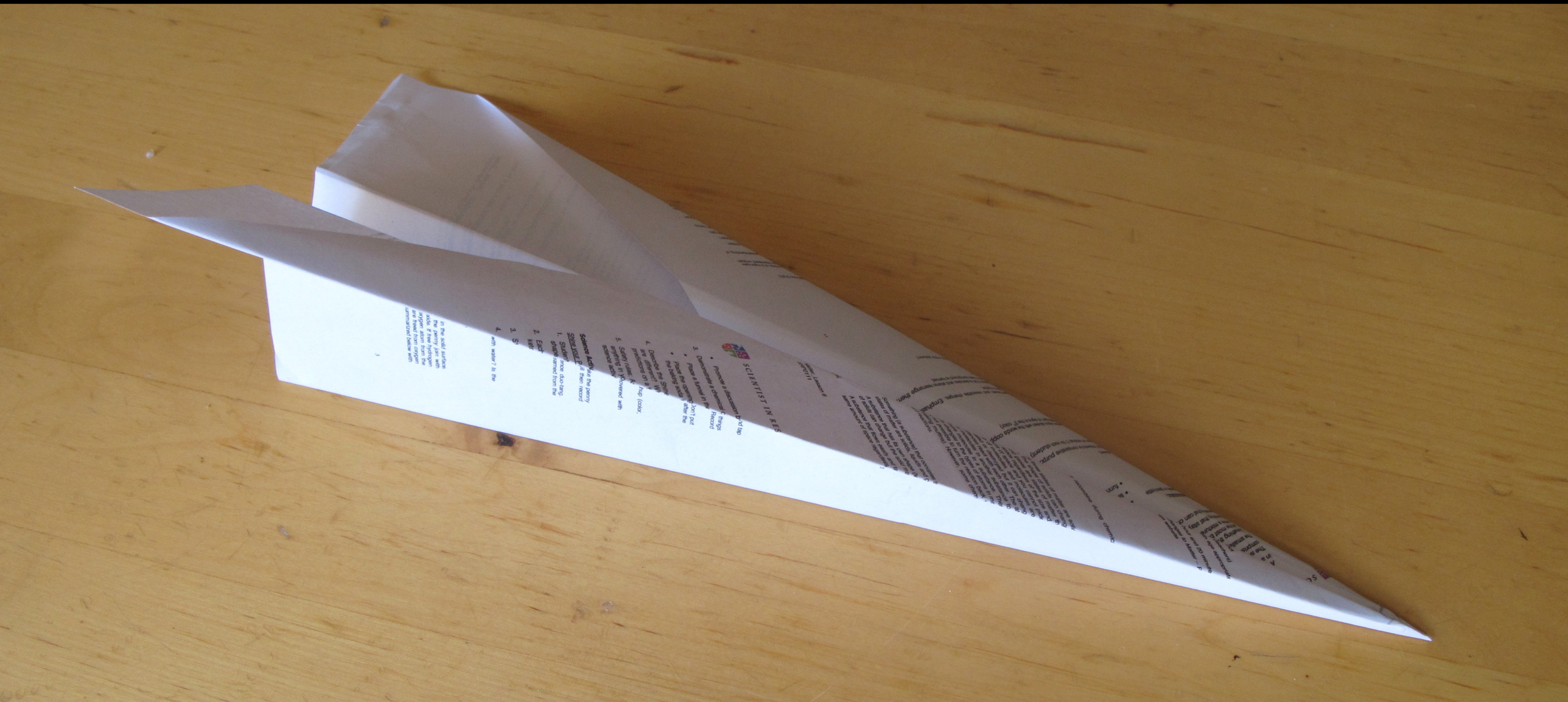

Greenland_Mar1_2018_PIQUANT_output.json – PIXELATE
TOOLS
DESELECT
ADD ELEMENT MAP
ADD WORKSPACE
HOME
CONTEXT IMAGE (WATSON)
Current Selection
Sr
Mg
Ni
Al
e
Si
Mn
K
Ti
Ca
BULK
POINT
BULK SUM SPECTRUM
TOGGLE LABELS
SHOW SELECTION
PIQUANT

PIXL Outcome: Trust in automation

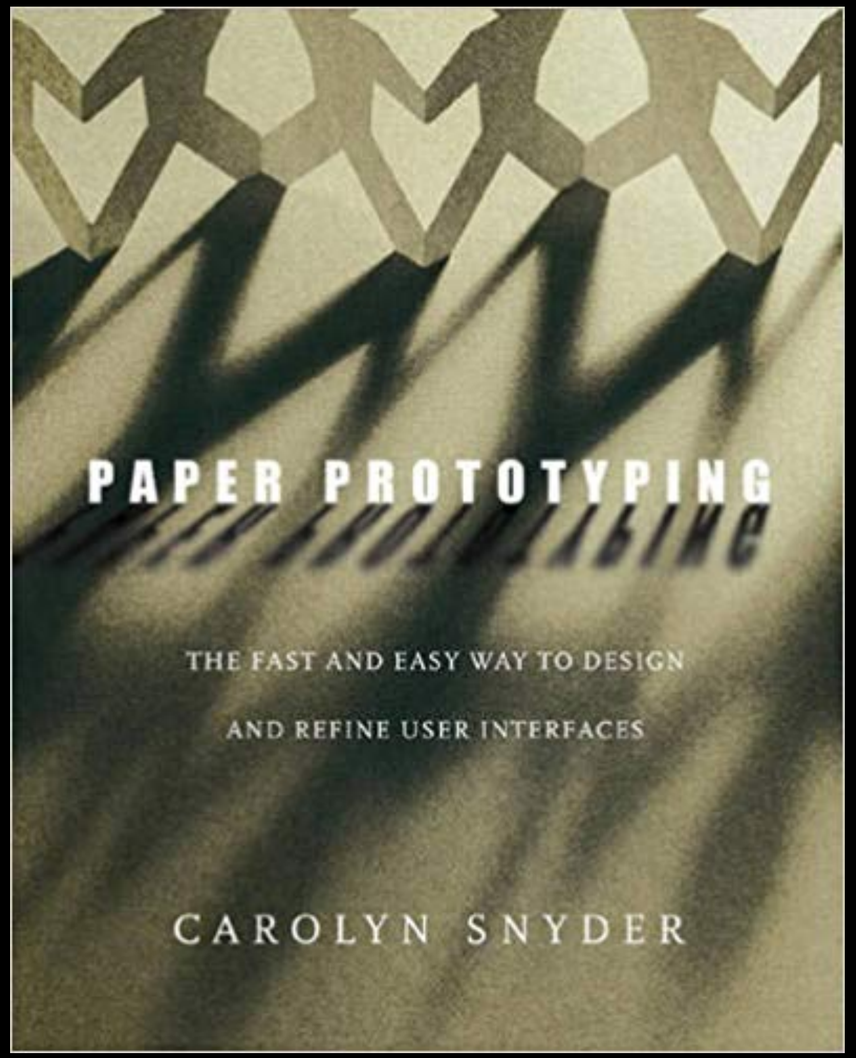
PIXL Approach

PIXL Design Thinking: Observe how real people do real work

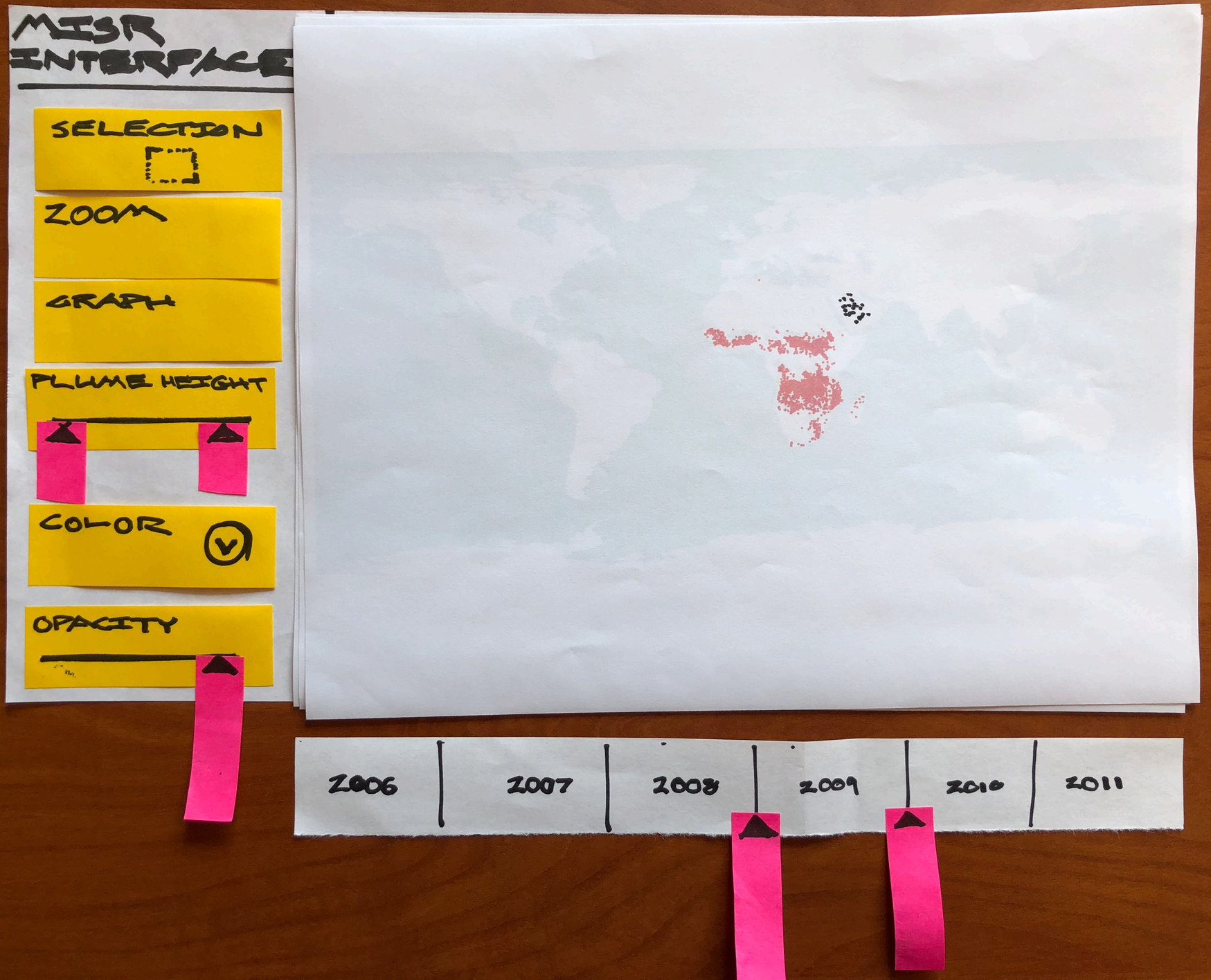
PIXL Design Thinking: Fail fast and cheaply



PIXL Approach: Prototype computing systems on paper

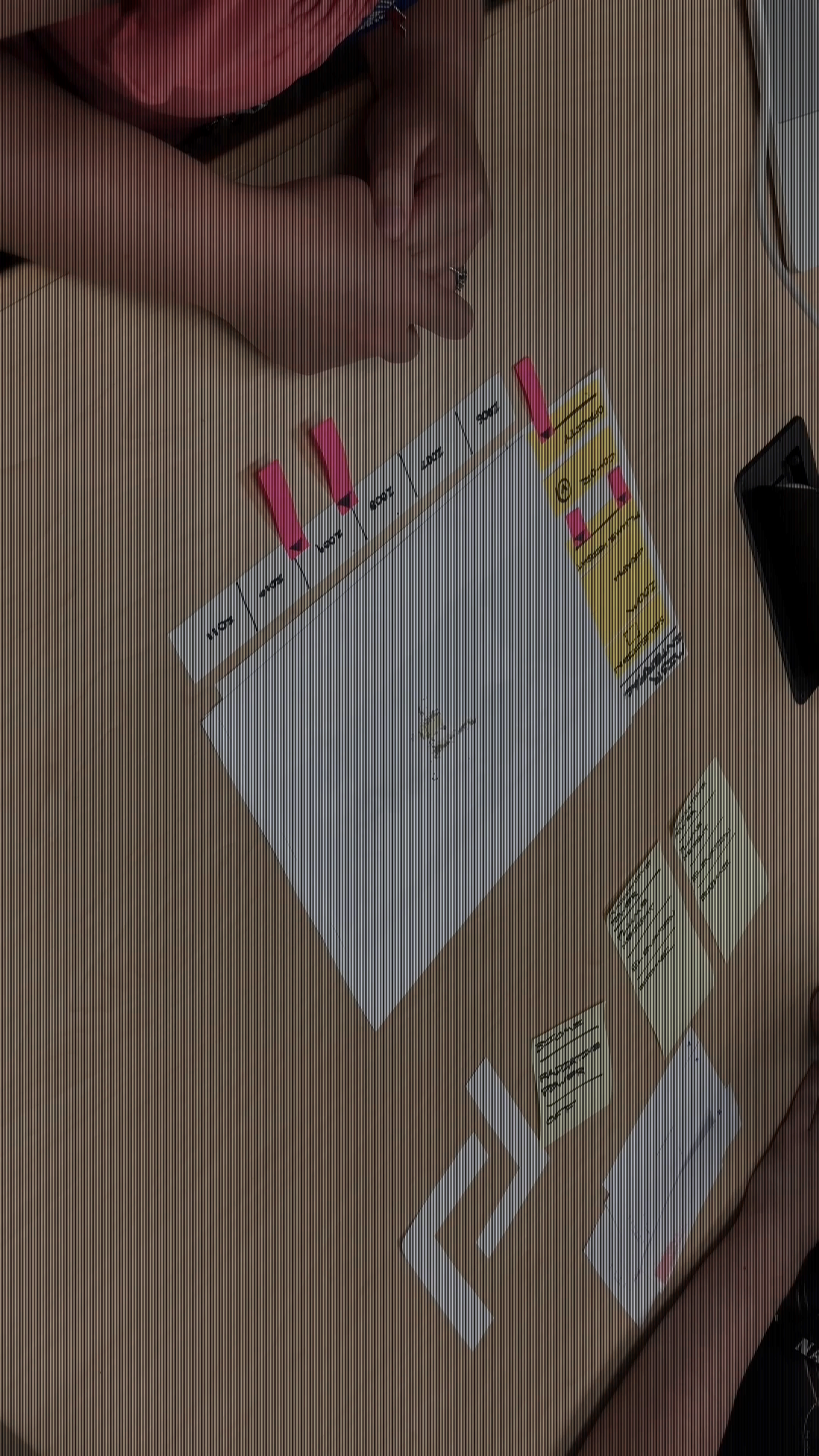


Snyder, C. (2003). Paper prototyping: The fast and easy way to design and refine user interfaces. Morgan Kaufmann.


MISR INTERFACE
SELECTION
ZOOM
GRAPH
PLUME HEIGHT
COLOR
OPACITY
2006
2007
2008
2009
2010
2011

OPACITY
COLOR
PLUME HEIGHT
GRAPH
ZOOM
SELECTION
2006
2007
2008
2009
2010
2011

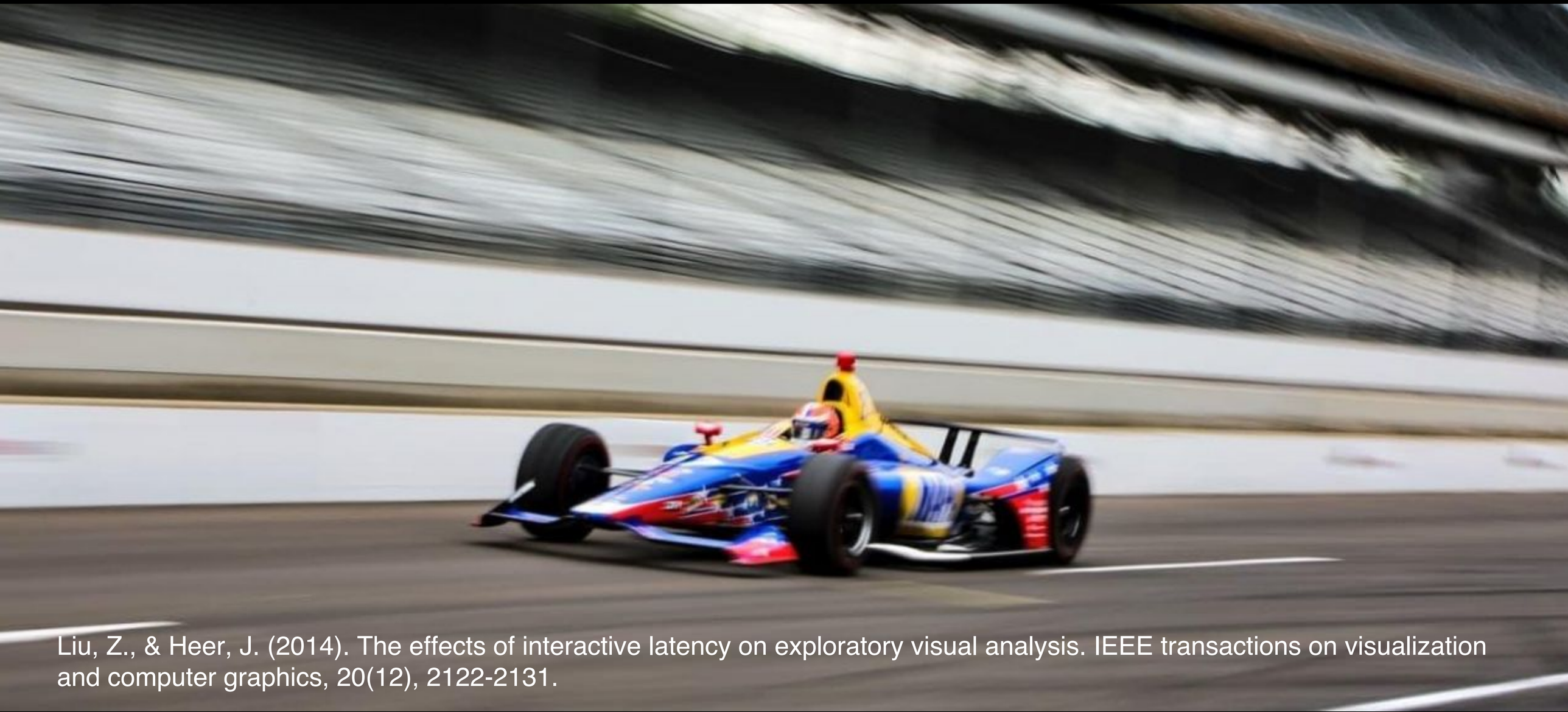
PIXL Design Thinking: Measure performance



PIXL Ongoing Work: Infuse into Phase E

PIXL Future Work: Toolkit for spectroscopy analysis

PIXL Future Work: Analysis speed leads to novel questions



Liu, Z., & Heer, J. (2014). The effects of interactive latency on exploratory visual analysis. IEEE transactions on visualization and computer graphics, 20(12), 2122-2131.

Jet Propulsion Laboratory
California Institute of Technology

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PIXL Automated Mineral / Feature Detection

$$\mathcal{X} = \begin{bmatrix} x & x & x & \dots \\ x & x & x & \dots \\ x & x & x & \dots \end{bmatrix}$$

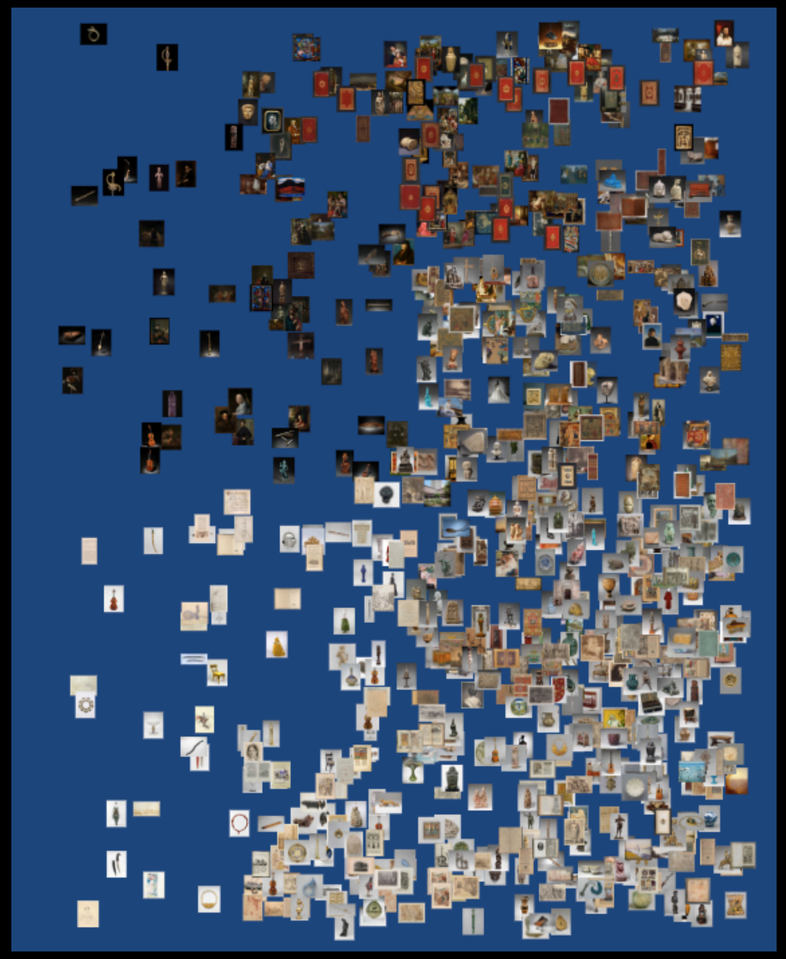
PIXL Automated Mineral / Feature Detection

$$\mathcal{X} = \begin{bmatrix} x & x & x & \dots \\ x & x & x & \dots \\ x & x & x & \dots \end{bmatrix} \Rightarrow \begin{bmatrix} x' & x' \\ x' & x' \\ x' & 'x \end{bmatrix} = \mathcal{X}'$$

PIXL Automated Mineral / Feature Detection

PIXL Automated Mineral / Feature Detection

=>



PIXL Design Thinking: Does it scale?

MARS 2020
DESIGN SIMULATIONS
Mars 2020 Project
CI Kickoff Meeting
THE BISTRO
SoCal

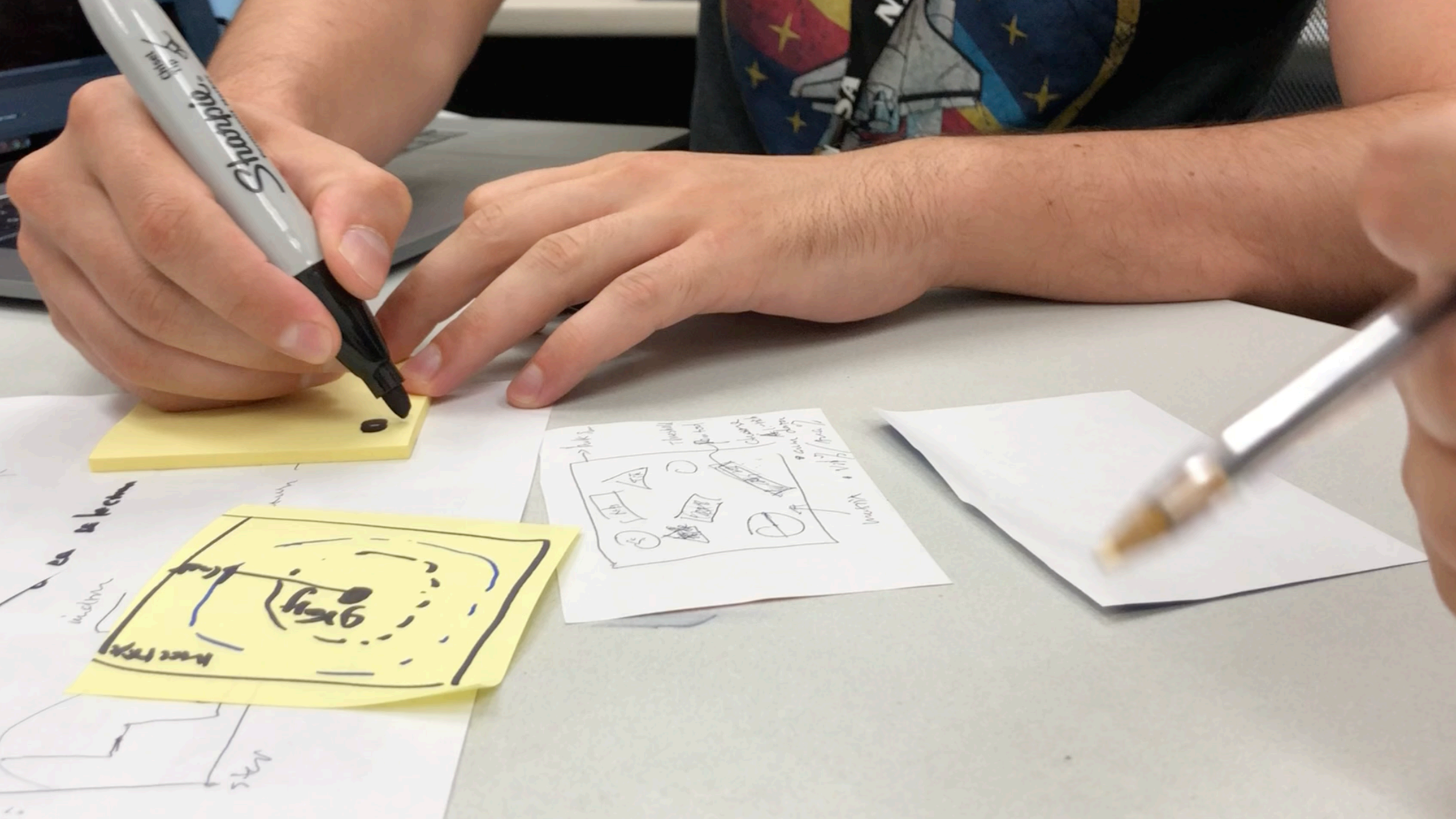
OBJECTIVES

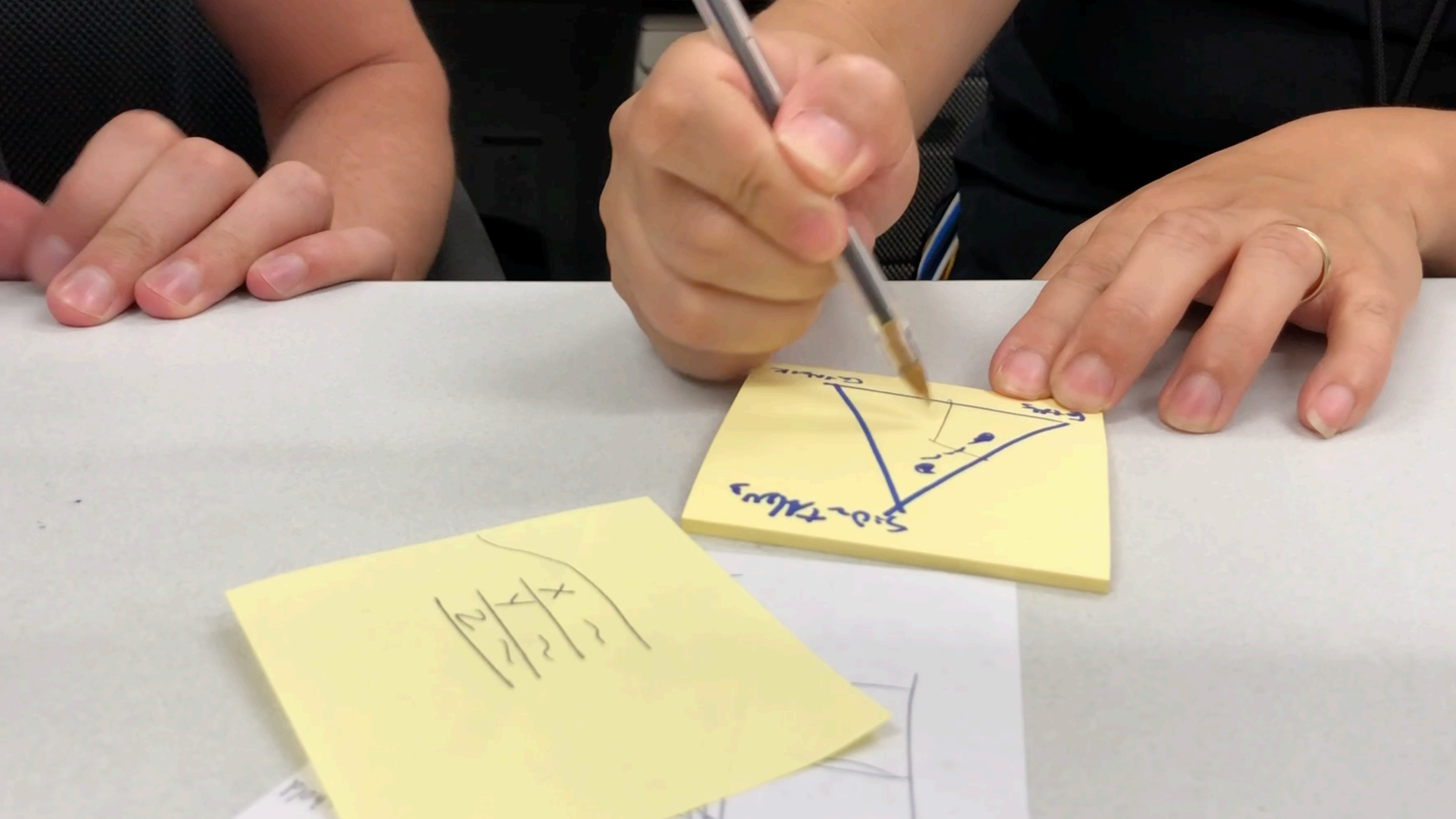
01: ***Assess communications*** within and between the Campaign Implementation (CI) and Tactical processes.

02: ***Evaluate and collect feedback*** from future operations community on current tools and operations processes.

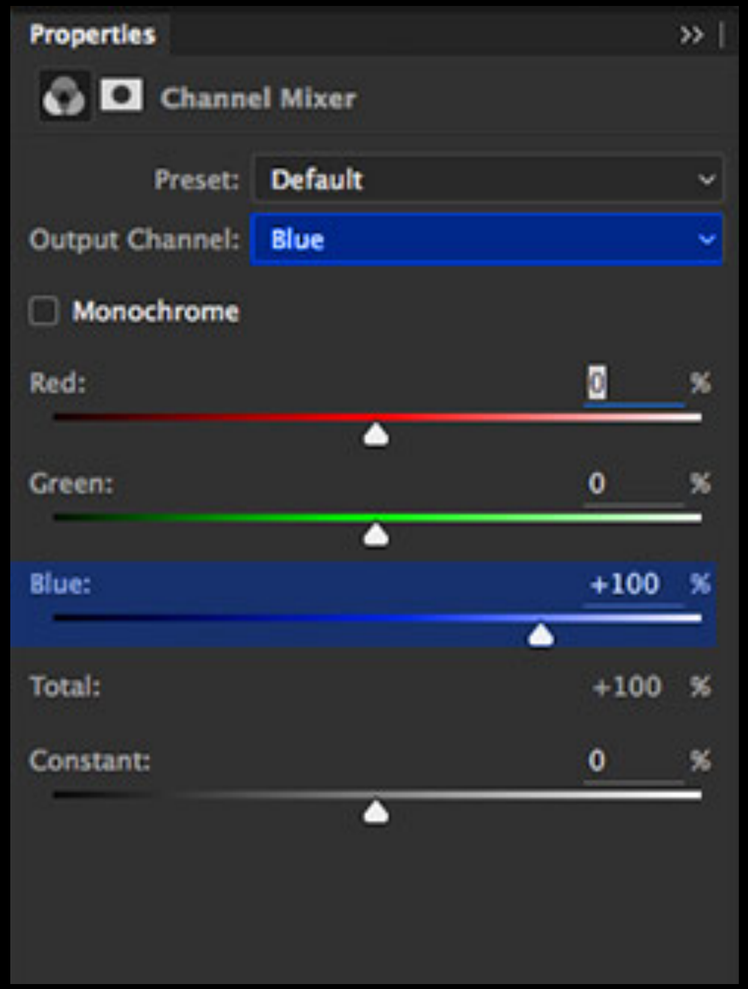
03: ***Utilize the Ground Data System (GDS) tools*** in their current state.

This document has been reviewed and determined not to contain export controlled technical data


Sharpie



PIXL Previous Visualizations: Color Channel Mixing

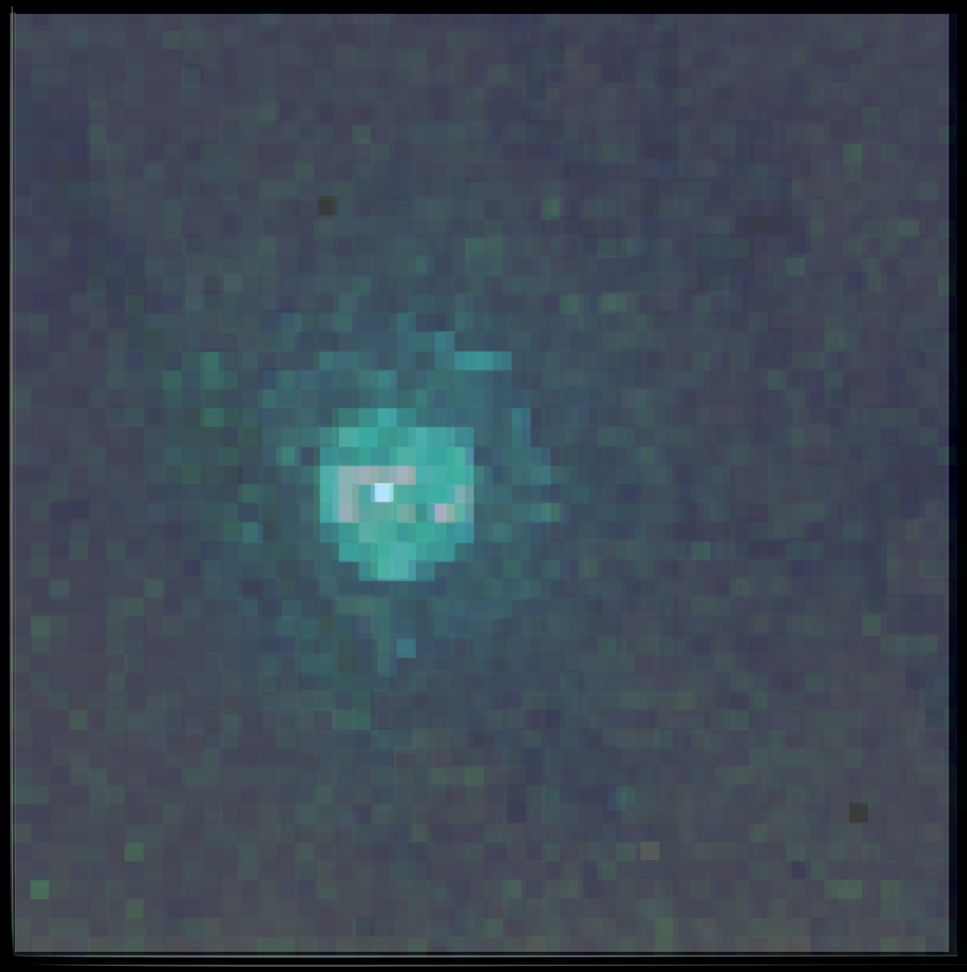


Cu

K

Ti

Coloc Channel Mixer

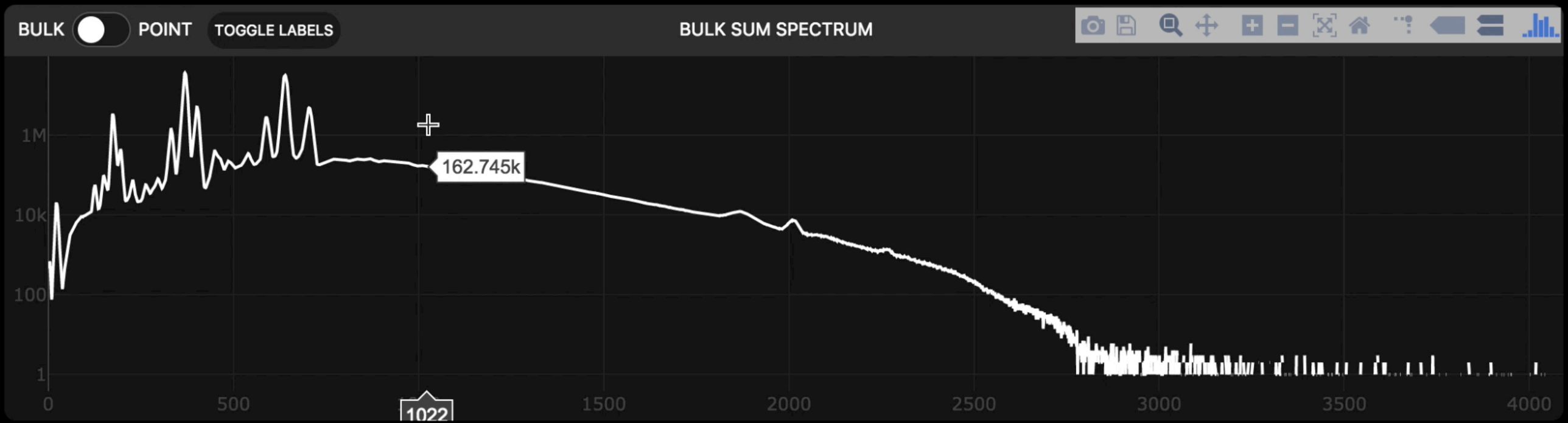


Composite element map, using opacity and color

PIXL Spectrum

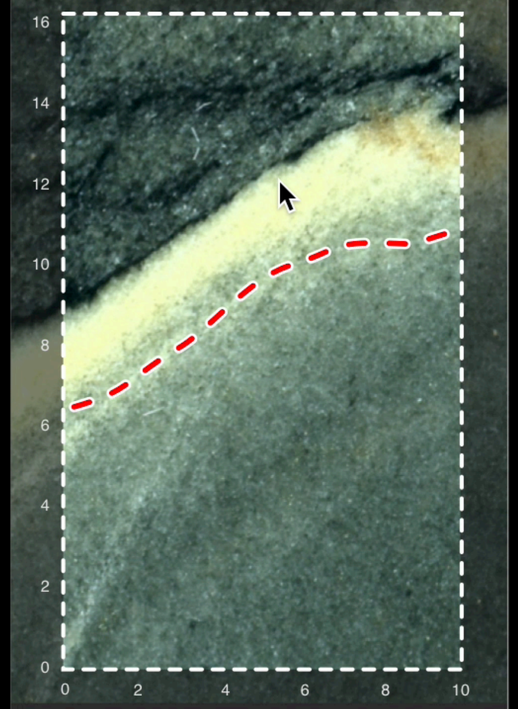
Update

- Visualization that PIXL team knows well
- Necessary for data validation
- Updated with interactivity and automatic labels



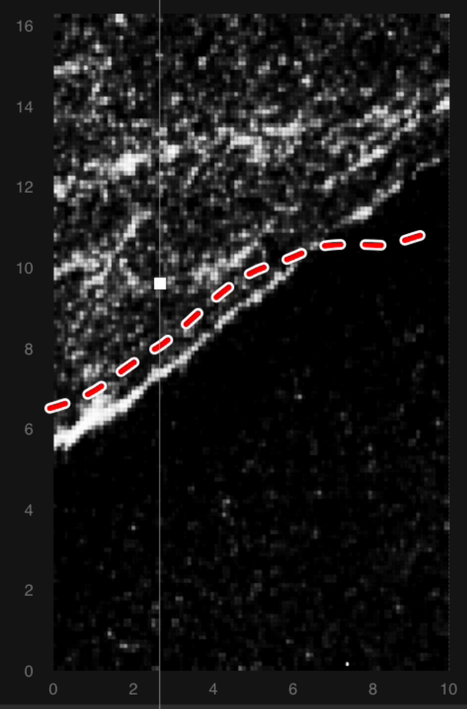
SELECT + − DE-SELECT ADD ELEMENT MAP ADD WORKSPACE SELECTIONS LIGHT BAND DARK BANDS OUTER MATRIX INNER MATRIX

CONTEXT IMAGE (WATSON)



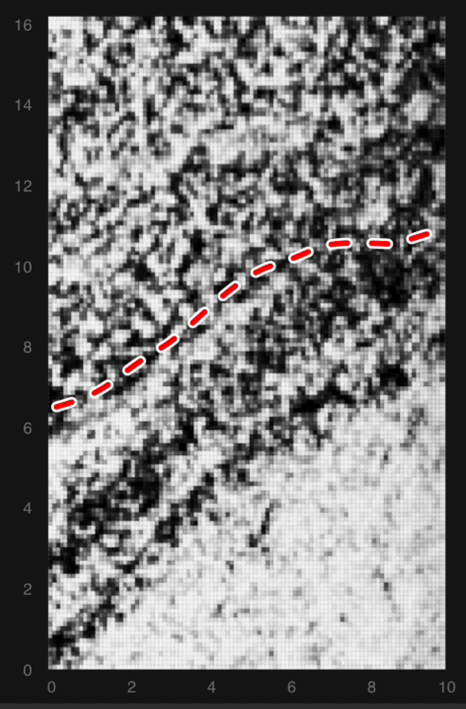
LAYERS

Ca



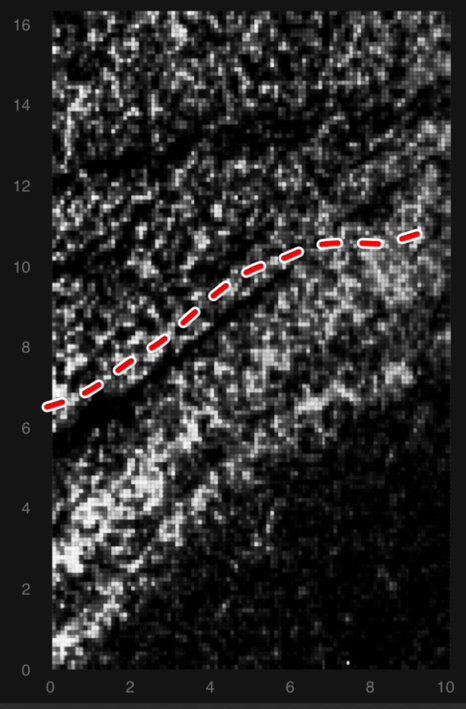
LAYERS

Si



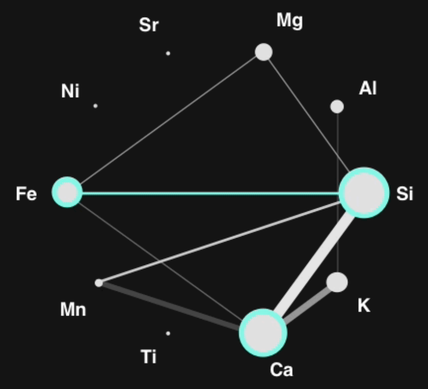
LAYERS

Fe

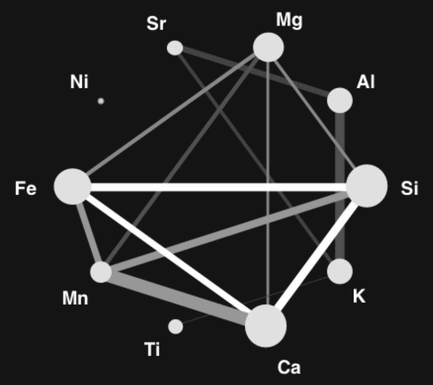


LAYERS

LIGHT BAND

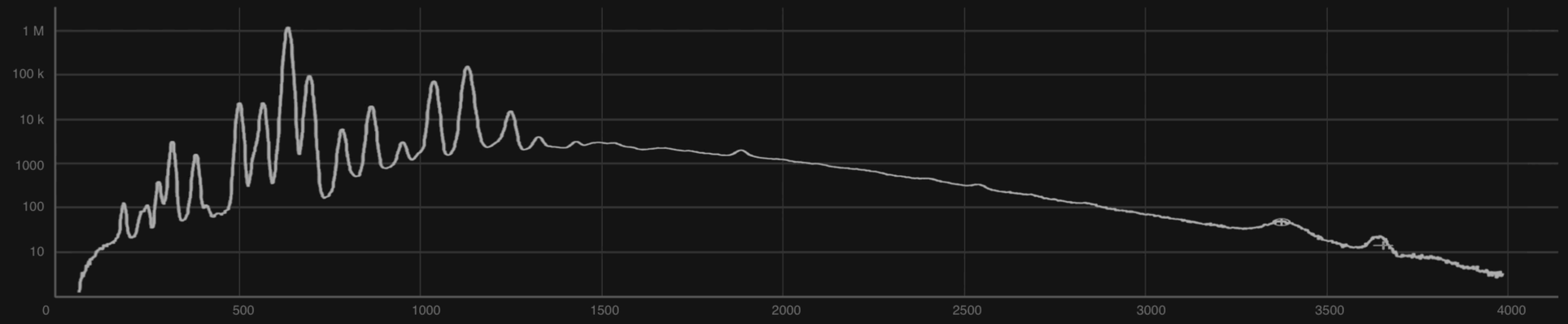


SAMPLE CORRELATIONS

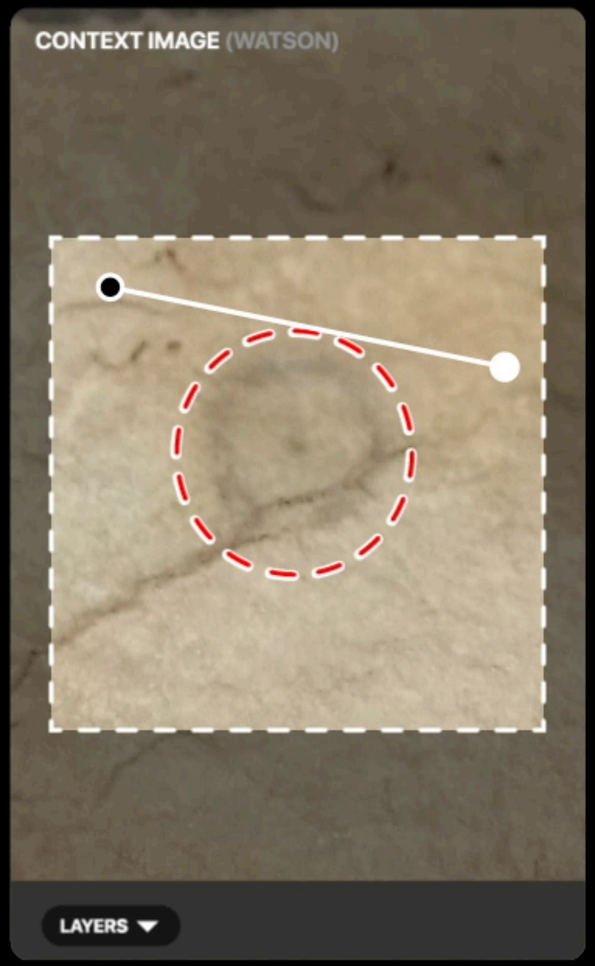


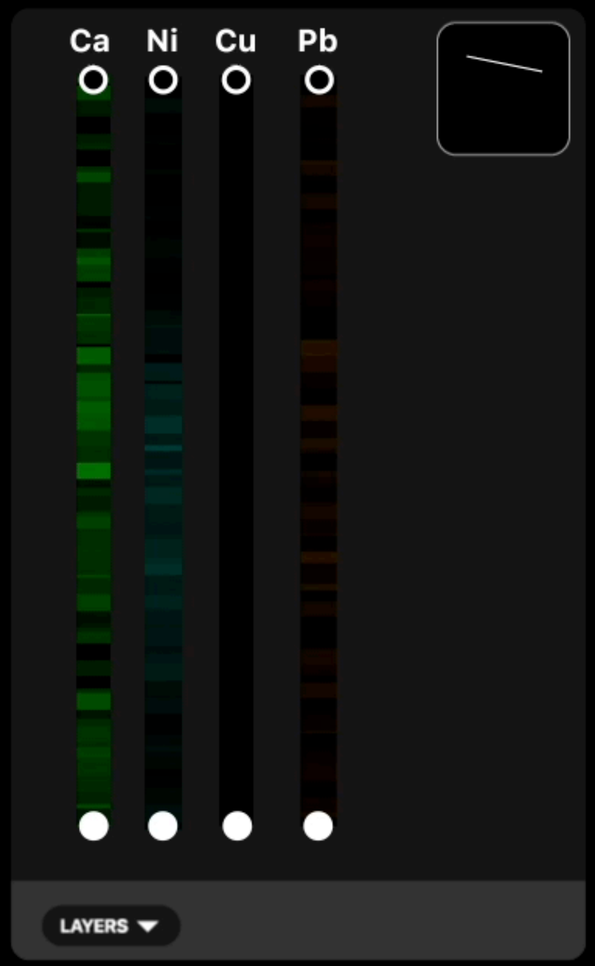
BULK SPECTRUM

RESET ZOOM BULK POINT



PIXL Line Scan





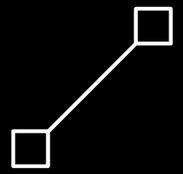
Novel Interaction : Sweep

To find the most scientifically useful line scan,

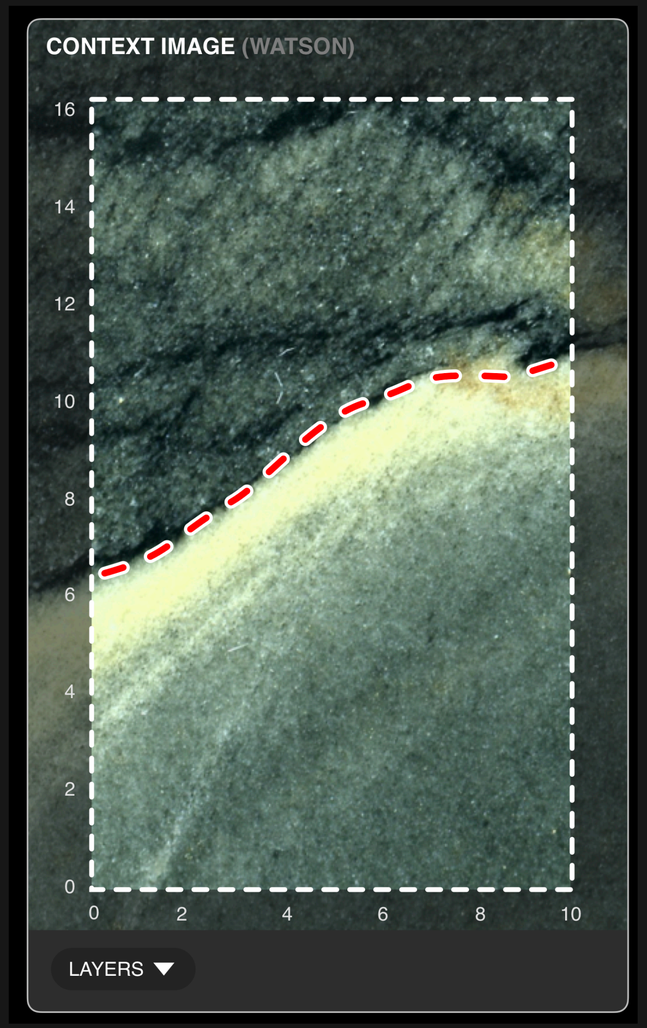
The researcher can place the first point

and then sweep the second point.

The card live updates to help guide inquiry.



PIXL Context Image Adjust



Maintain Alignment

The researcher can adjust position and zoom of the context image in order to make sure features are aligned across all element maps.