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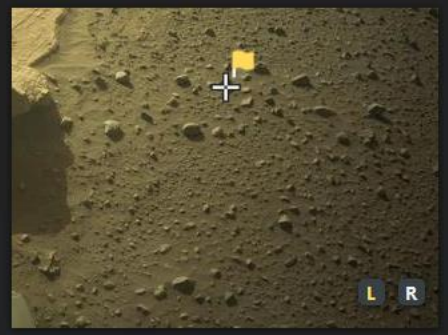
ReRank

A novel machine teaching UI for scientists
to directly program **science value** models

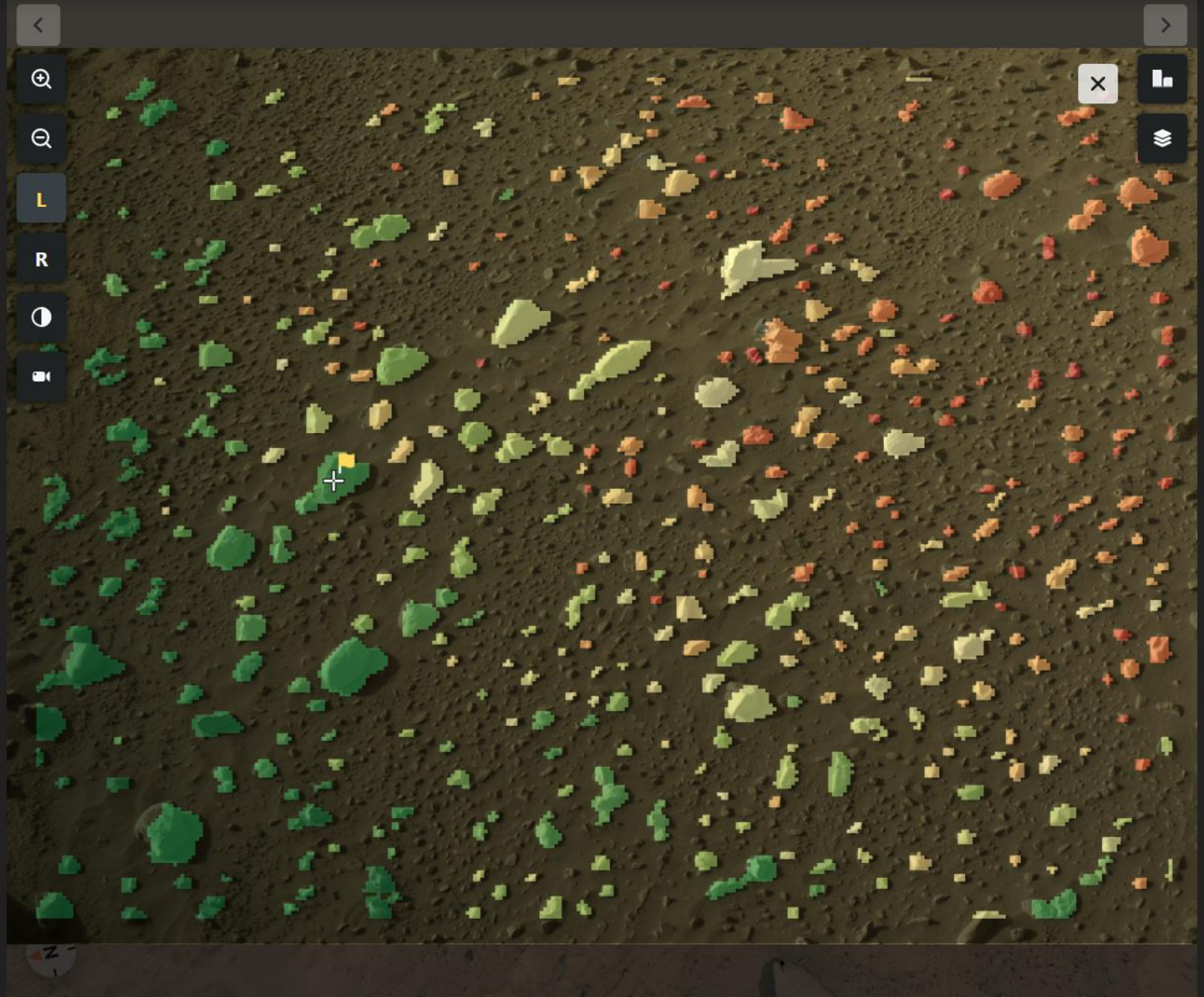
Images 65

Show images with flag

Navigation Camera



Front HazCam



Training

Expand

Select a classifier:

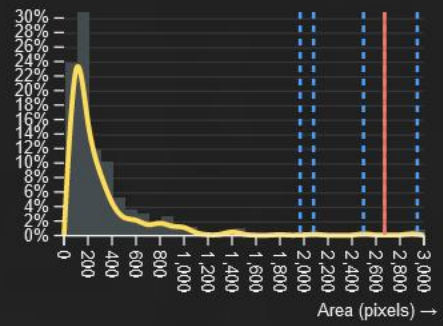
Pebbles

Rerank targets

Compute model

Set bandwidth

20

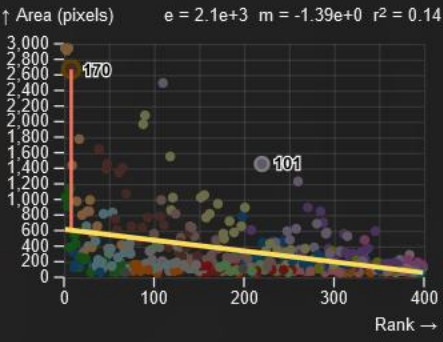


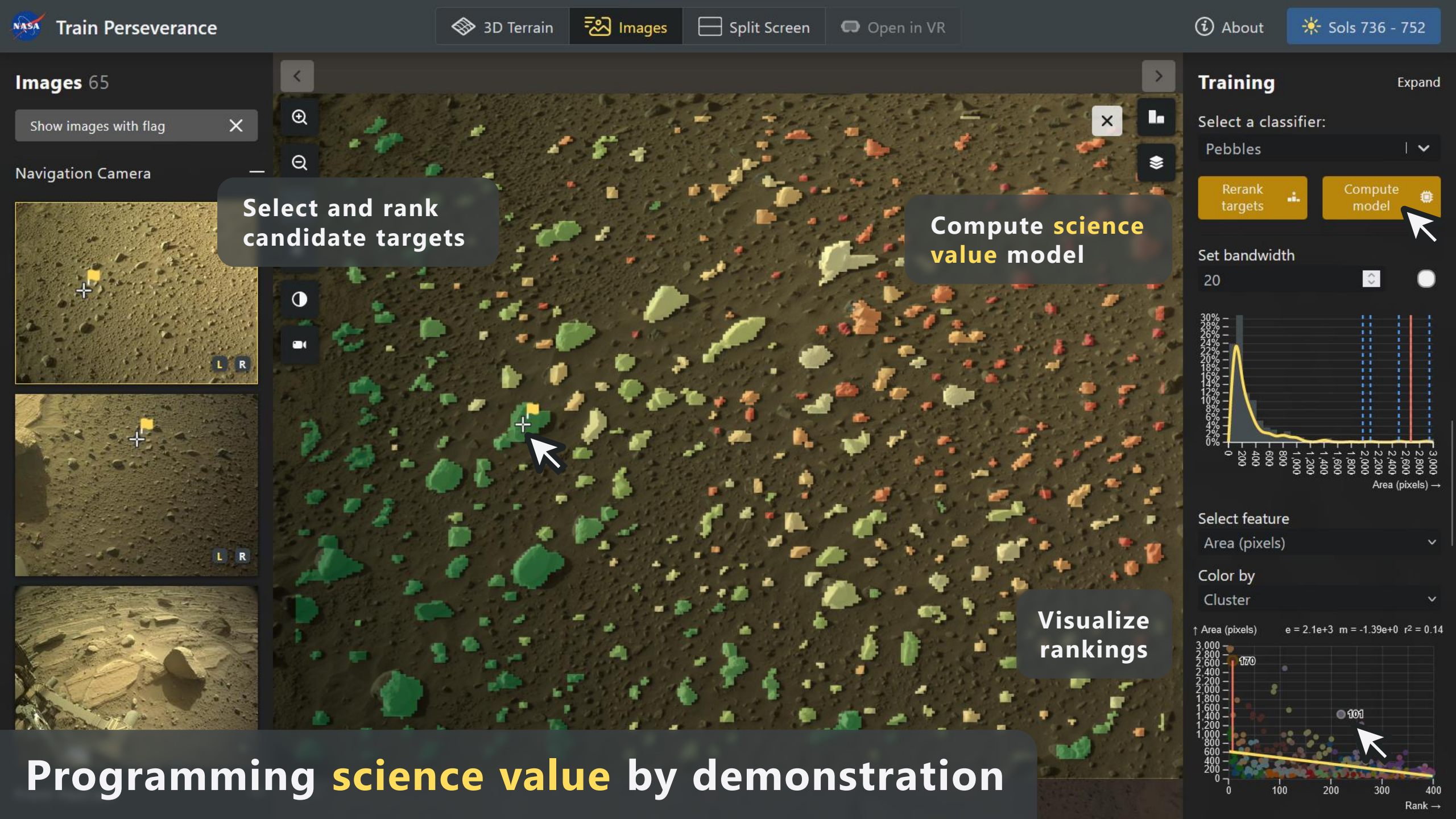
Select feature

Area (pixels)

Color by

Cluster




Train Perseverance
3D Terrain
Images
Split Screen
Open in VR
About
Sols 736 - 752
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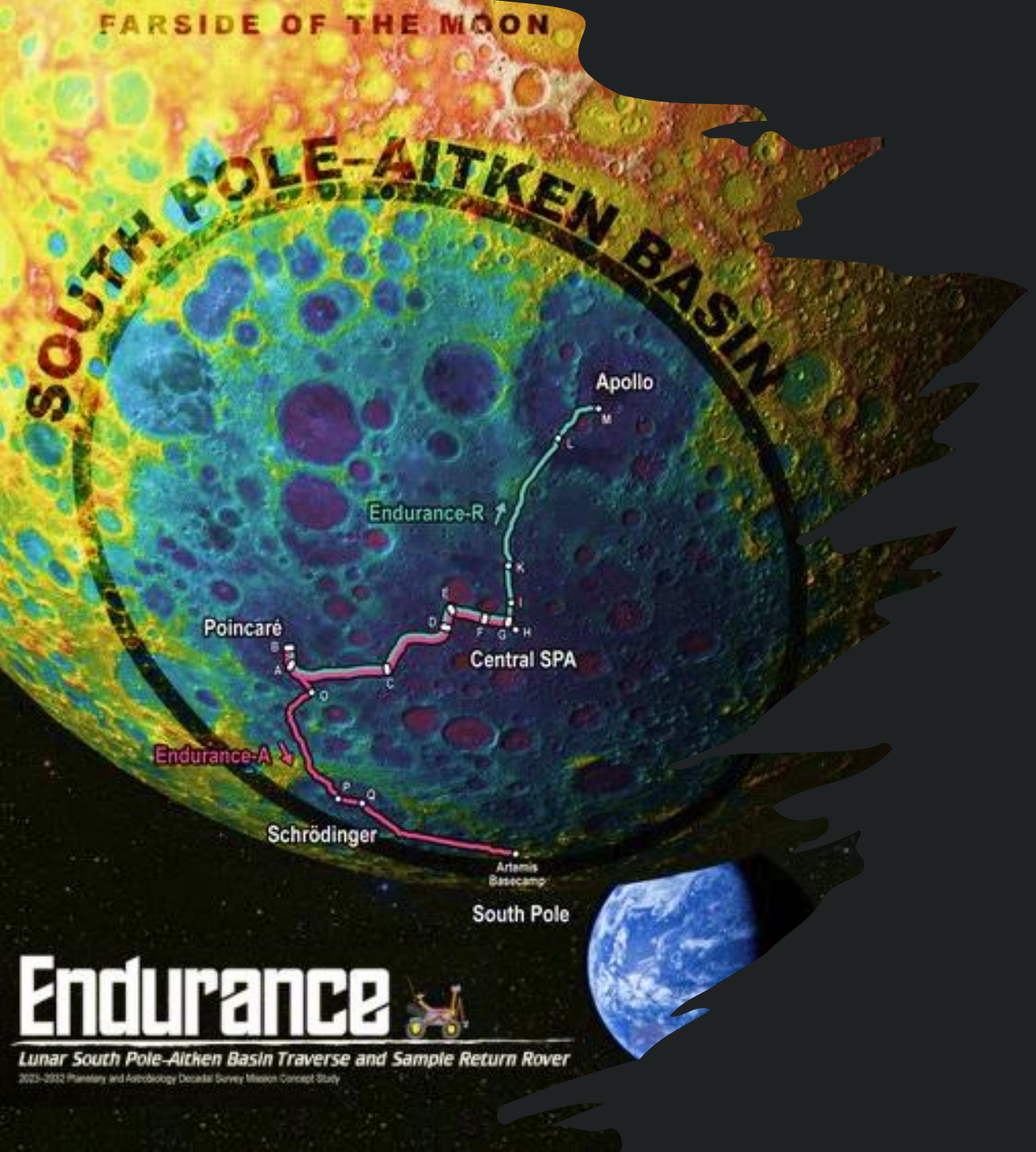
Show images with flag
Navigation Camera
Select and rank candidate targets
Compute science value model
Visualize rankings
Training
Expand
Select a classifier:
Pebbles
Rerank targets
Compute model
Set bandwidth
20
Area (pixels) →
Select feature
Area (pixels)
Color by
Cluster
↑ Area (pixels)
e = 2.1e+3 m = -1.39e+0 r² = 0.14
170
101
Rank →
Programming science value by demonstration



Future high autonomy missions such as Endurance-A on the Moon require autonomous targeting capabilities during long, pre-planned drives where humans are not always in the loop

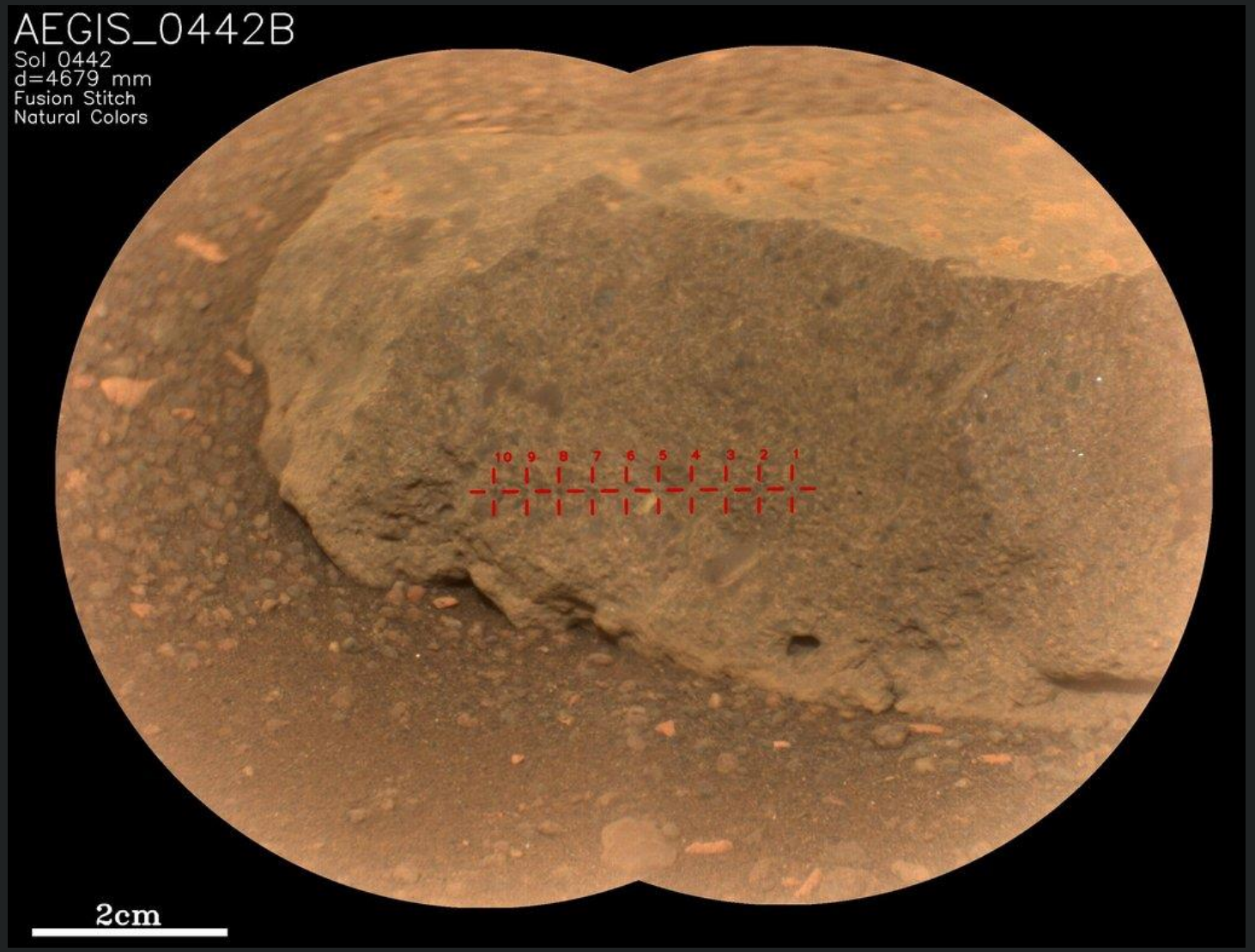
Prior work[1,2] used science intent to manually develop scientist-guided autonomy tools that alleviate ground-in-the-loop requirements

During strategic planning, scientists provide high-level directives for a given science intent by parameterizing what is likely to be in each location and what they would like to target, e.g., “take Mastcam images of layering in the light gray outcrop”

Machine learning engineers then program tools to assign priority (i.e., science value) to autonomously identified targets for on-board scheduling

[1] Bornstein, B.J., Castano, R., Estlin, T.A., Gaines, D.M., Anderson, R.C., Thompson, D.R., DeGranville, C.K., Chien, S.A., Tang, B., Burl, M.C. and Judd, M.A., 2010. **Autonomous Exploration for Gathering Increased Science** (No. NPO-46876).

[2] Gaines, D.; Doran, G.; Paton, M.; Rothrock, B.; Russino, J.; Mackey, R.; Anderson, R.; Francis, R.; Joswig, C.; Justice, H.; Kolcio, K.; Rabideau, G.; Schaffer, S.; Sawoniewicz, J.; Vasavada, A.; Wong, V.; Yu, K.; and Agha-mohammadi, A. **Self-reliant rovers for increased mission productivity**. Journal of Field Robotics, 37(7): 1171-1196. October 2020.



Perseverance's SuperCam Uses AEGIS For the First Time (May 31st, 2022)

Source: https://www.jpl.nasa.gov/images/pia25289-perseverances-supercam-uses-aegis-for-the-first-time

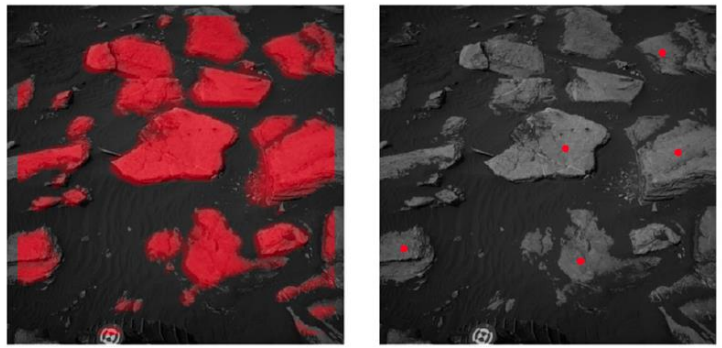


FIGURE 10 Left: MSL Navcam image with outcrop classifications (exceeding 50% confidence) from TextureCam in red. Right: diverse onboard target selection results, showing a set of point-measurement locations proposed to measure the identified outcrop [Color figure can be viewed at wileyonlinelibrary.com]

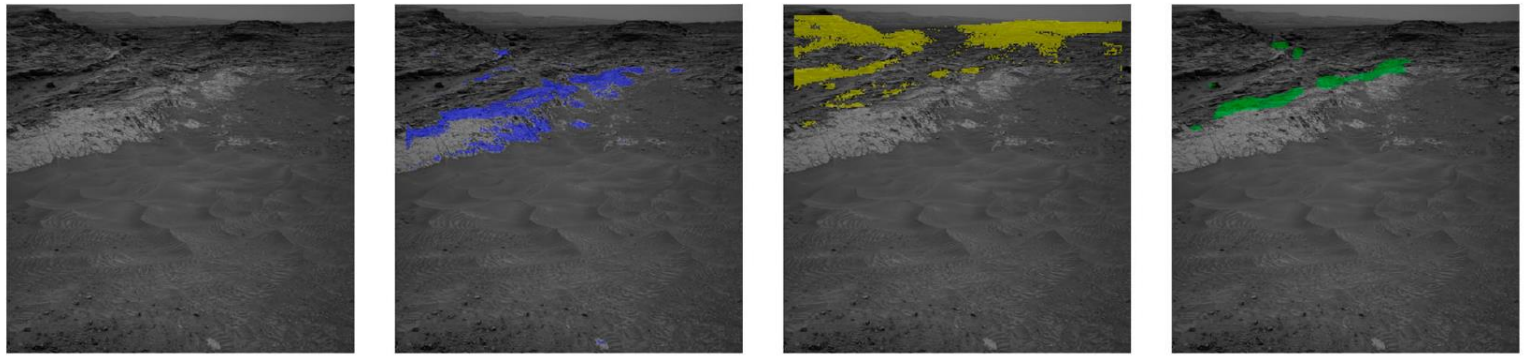


FIGURE 8 Left: The Murray–Stimson contact at Marias Pass. Center: The Murray (blue) and Stimson (yellow) units are identified using TextureCam. Right: FORC is used to derive a contact score, with the highest-valued regions highlighted (green) [Color figure can be viewed at wileyonlinelibrary.com]

SRR: Self-reliant rovers for increased mission productivity (October 2020)

Source: https://onlinelibrary.wiley.com/doi/10.1002/rob.21979

Question

How do we rapidly and flexibly update science value as mission science understanding evolves?

Solution

Empower scientists to directly program science value models guided by science intent using machine teaching

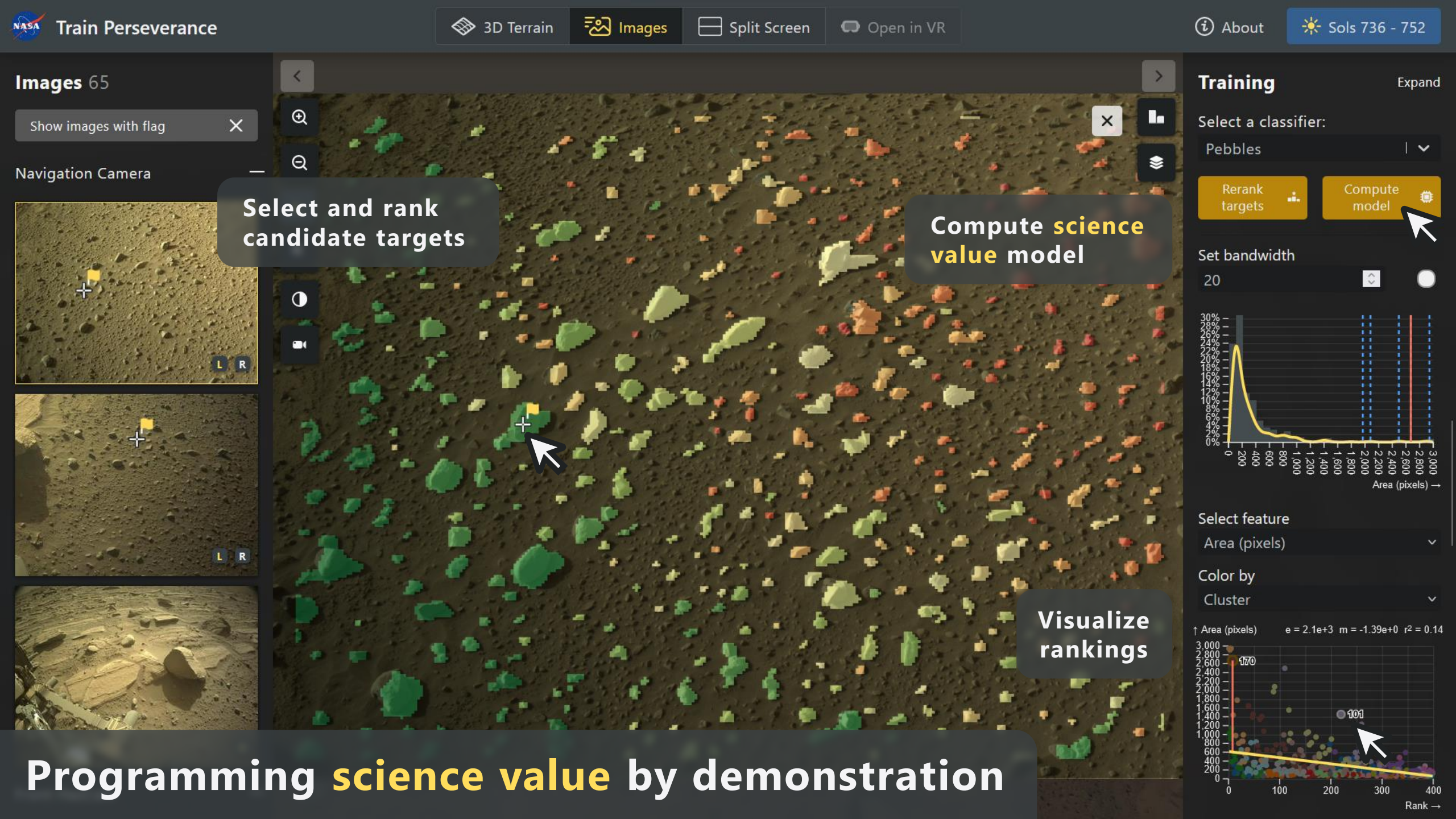
Design Challenges and Goals

1 **How to represent data naturally?**
An immersive environment with 2D images + 3D scenes

2 **How to identify targets in a scene?**
Use TextureCam to classify pixel regions

3 **How to allow scientists to change target signature?**
Leverage direct manipulation in a programming-by-demonstration user interface

4 **How to model interactions as science value?**
Use machine learning (Ranking SVM) to compute feature weights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170
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Programming science value by demonstration

Next Steps

- **September 2023** Finish development / Create study protocol
- **October 2023** Run user studies
- **November 2023** Analyze data / Run additional user studies
- **Spring 2024** Write paper and submit to an academic journal

Future Work

1. **Testing different learning algorithms for different science value models**
   Other ranking algorithms? Deep learning?

2. **How to extend target detection and feature extraction?**
   Multiclass TextureCam? Multispectral imaging data? Spatial algorithms leveraging photogrammetry?

3. **How to use science value during scheduling?**

4. **How to evaluate a scheduled drive that uses our model?**

Acknowledgements

Thank you to **Raymond Francis**, **Tara Estlin**, **Vivian Sun**, **Rachel Kronyak**, **Sara Schnadt**, and **Dan Gaines** for helping me ask and solve the right research questions and challenges!

Thank you to **Jeff Pamer** for building and providing technical support while integrating **Explore With Perseverance**[1]!

And a BIG thank you to my advisor **Scott Davidoff** for being a lighthouse in the JPL sea of knowledge!!

[1] https://mars.nasa.gov/mars2020/surface-experience/

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