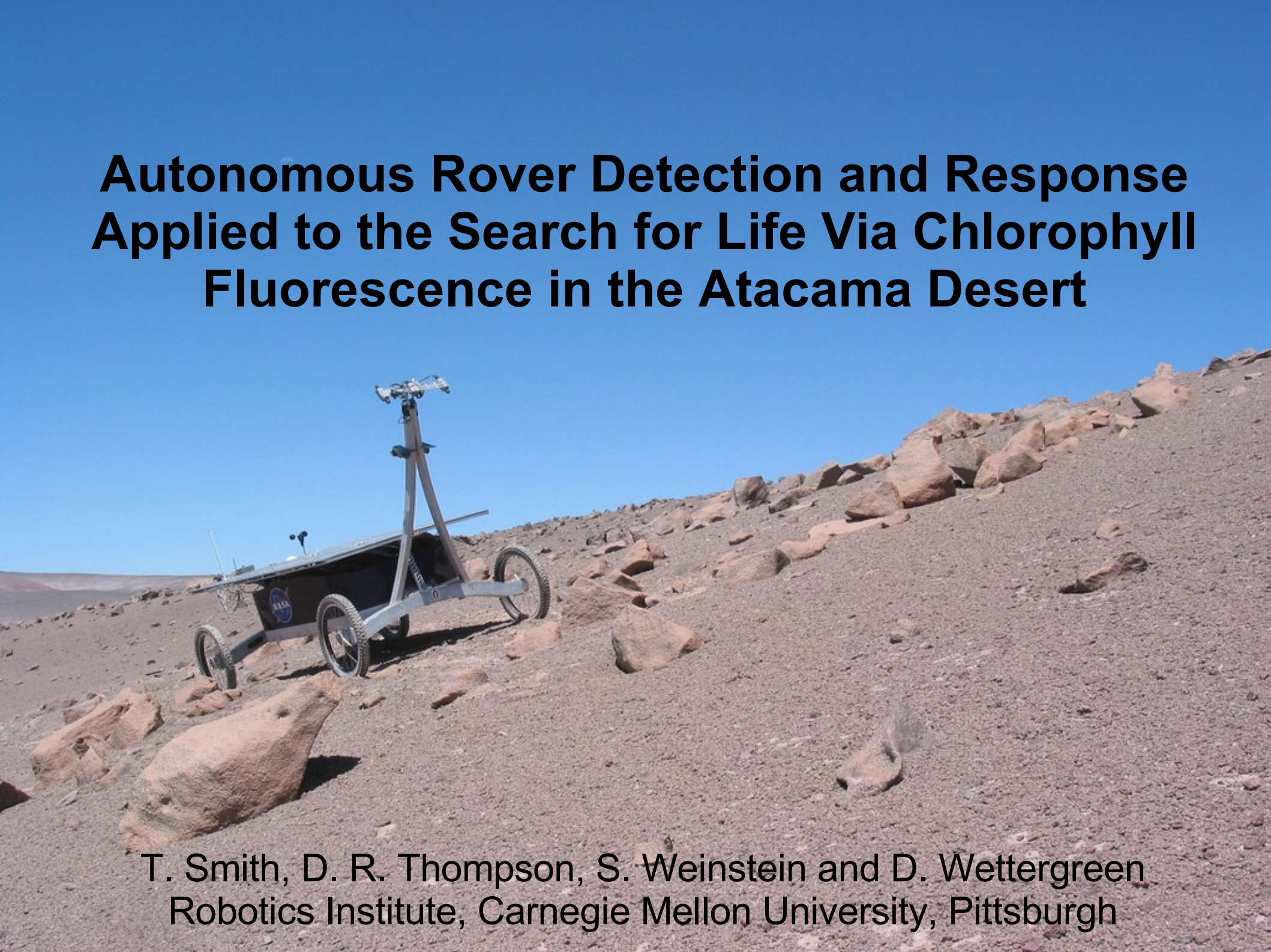
Autonomous Rover Detection and Response Applied to the Search for Life Via Chlorophyll Fluorescence in the Atacama Desert



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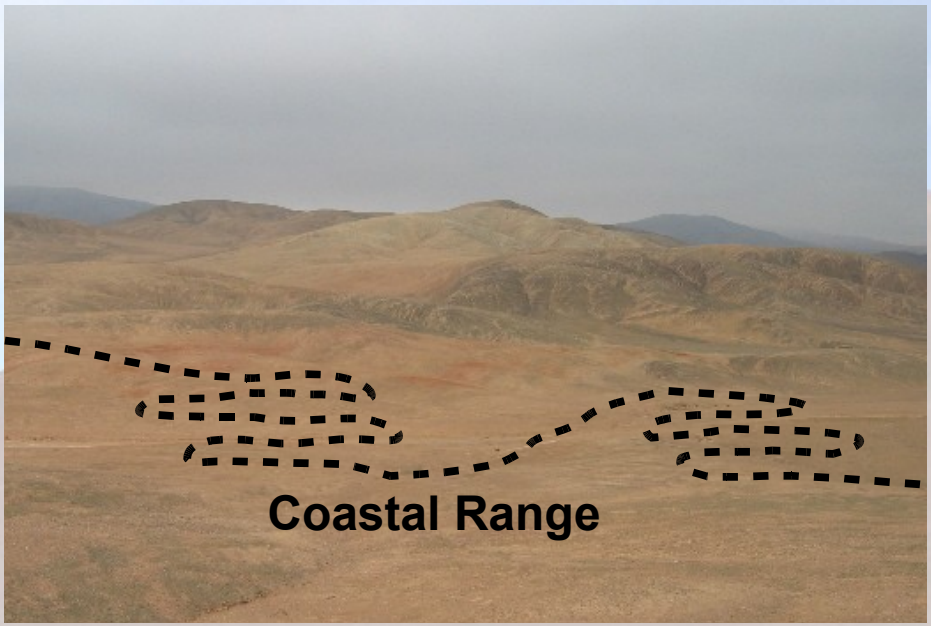
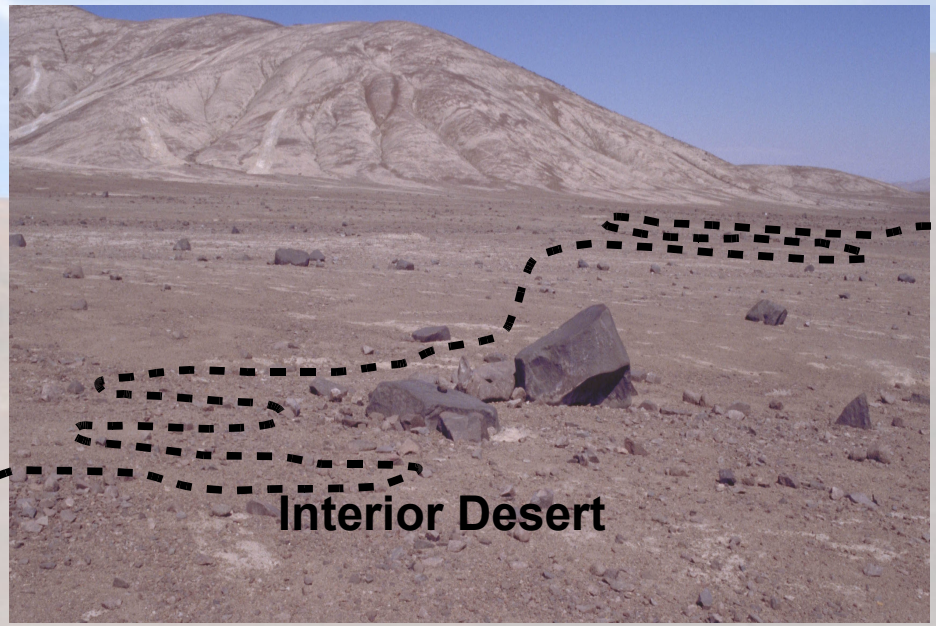
Robotics Institute, Carnegie Mellon University, Pittsburgh

Questions

- Biodiversity and distribution of habitats in Atacama Desert subregions are not understood
  - Where does life survive and where does it not?
  - What factors govern the distribution?



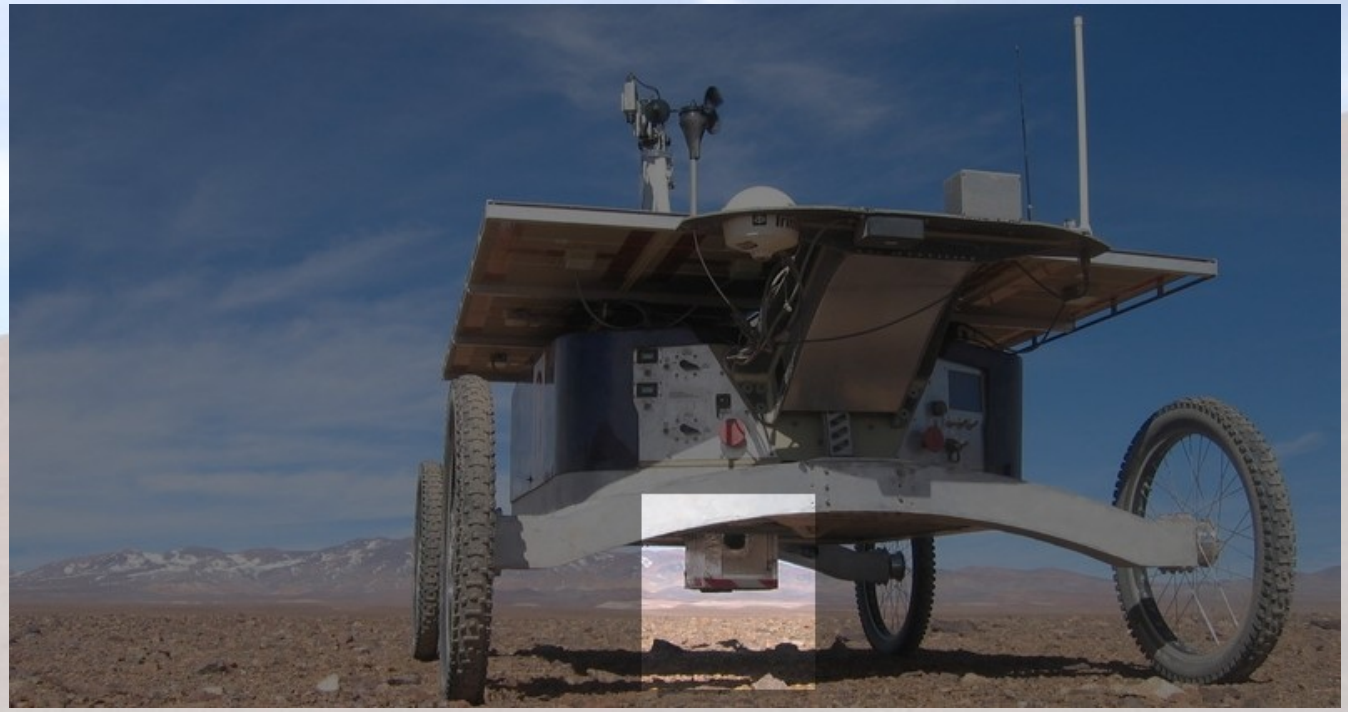


Robotic Survey

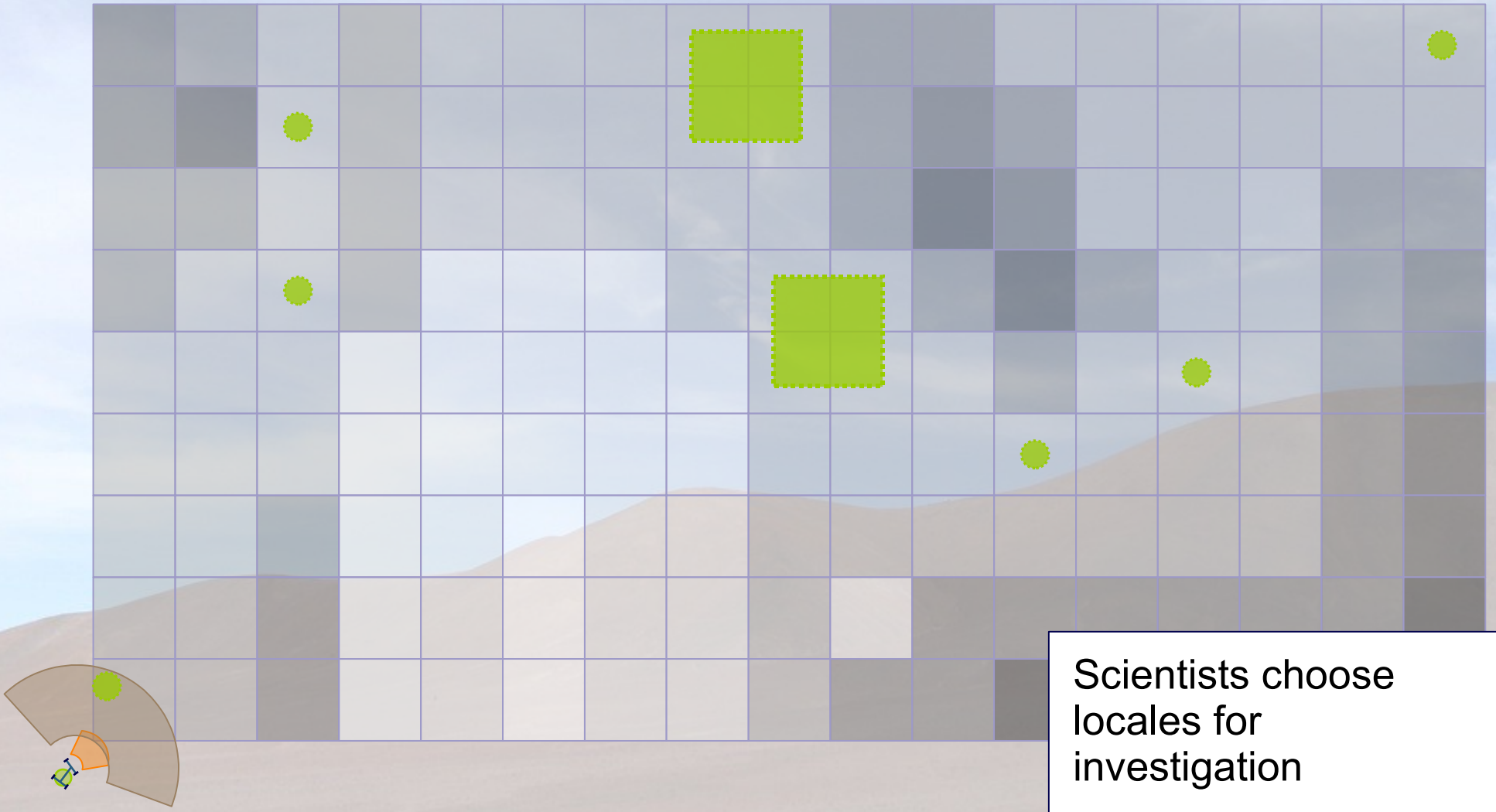
- Long-distance autonomous traverse
- Sustained solar-powered operation
- Health monitoring for automatic recovery
- Accomplished over 250 km of traverse
- 80+ traverses over 1 km in a single cycle

Autonomous Science

- Show robots can perform unsupervised science
- Instrument tightly integrated to robot mechanism
- Rapid deployment and measurement
- Autonomous detection and response

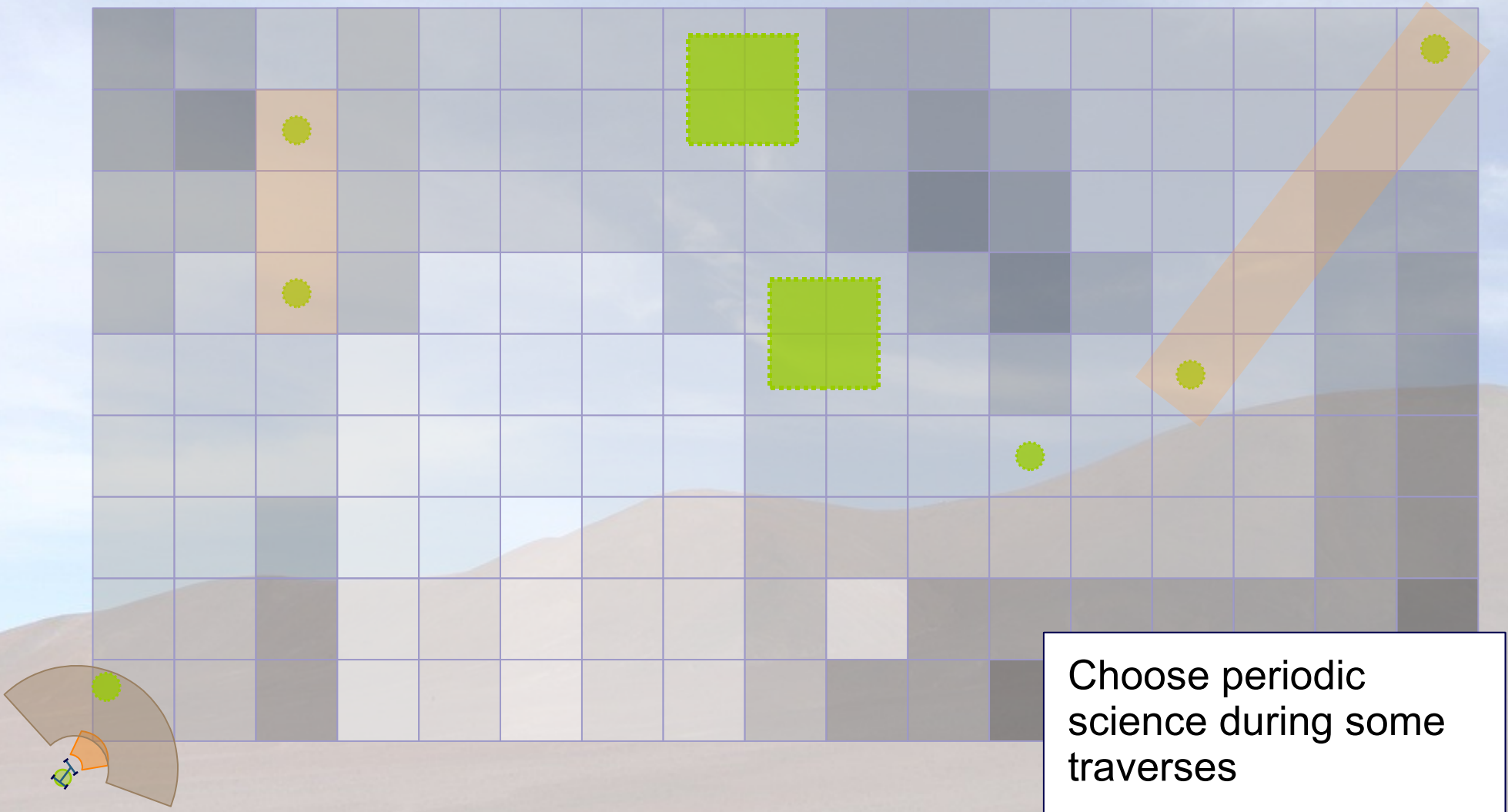


Survey Traverse Method



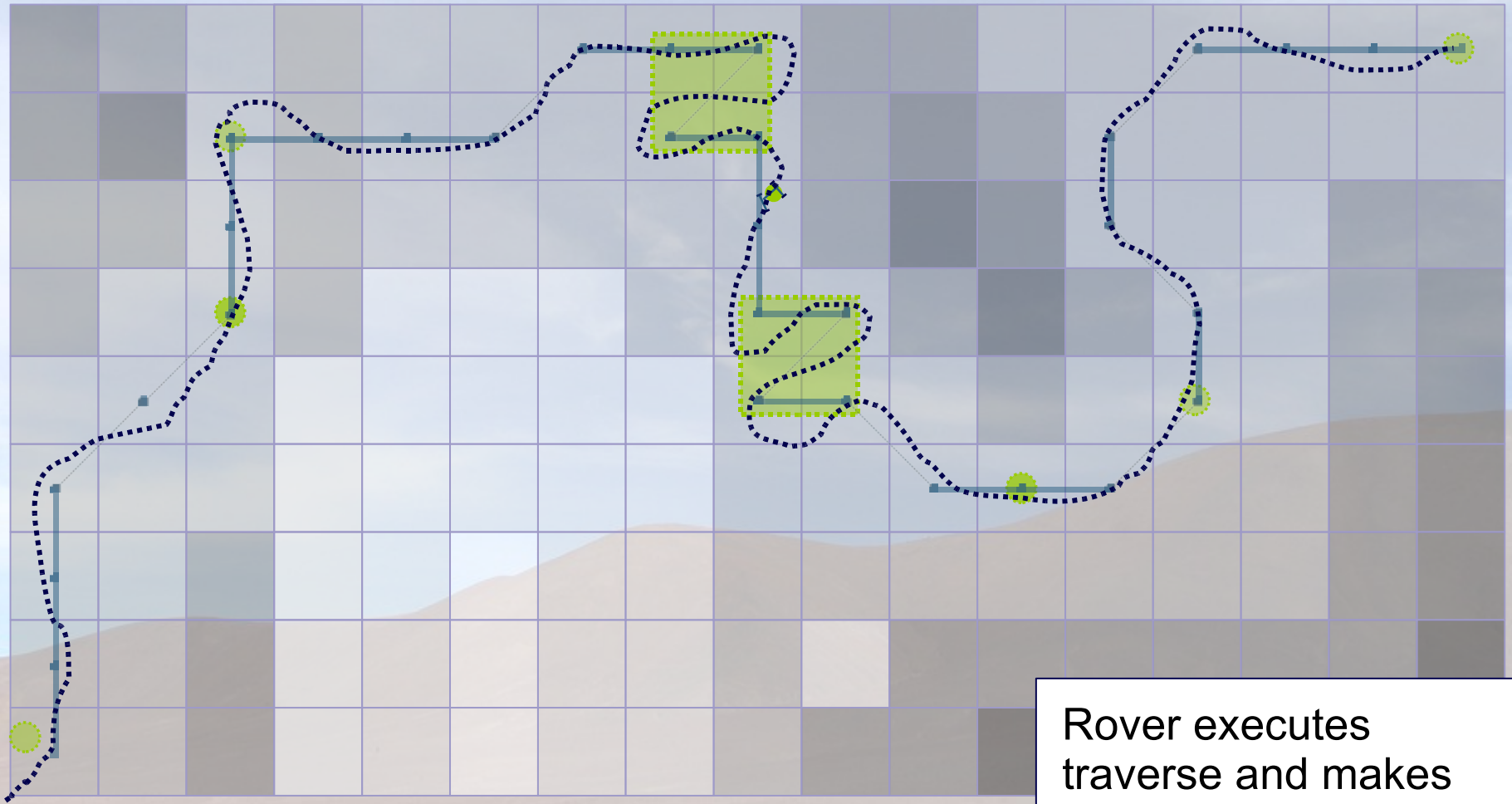
Scientists choose locales for investigation

Survey Traverse Method



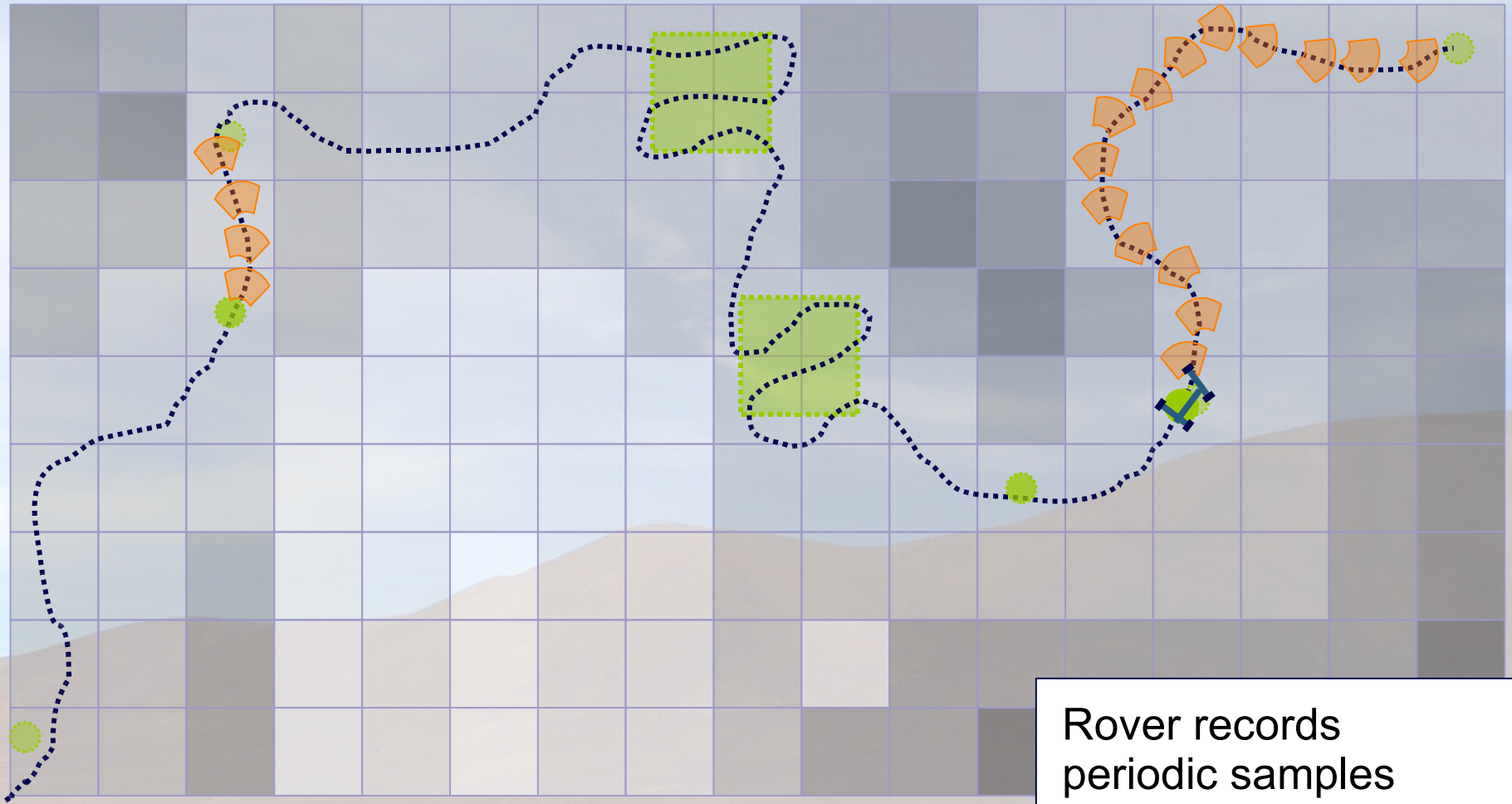
Choose periodic science during some traverses

Survey Traverse Method



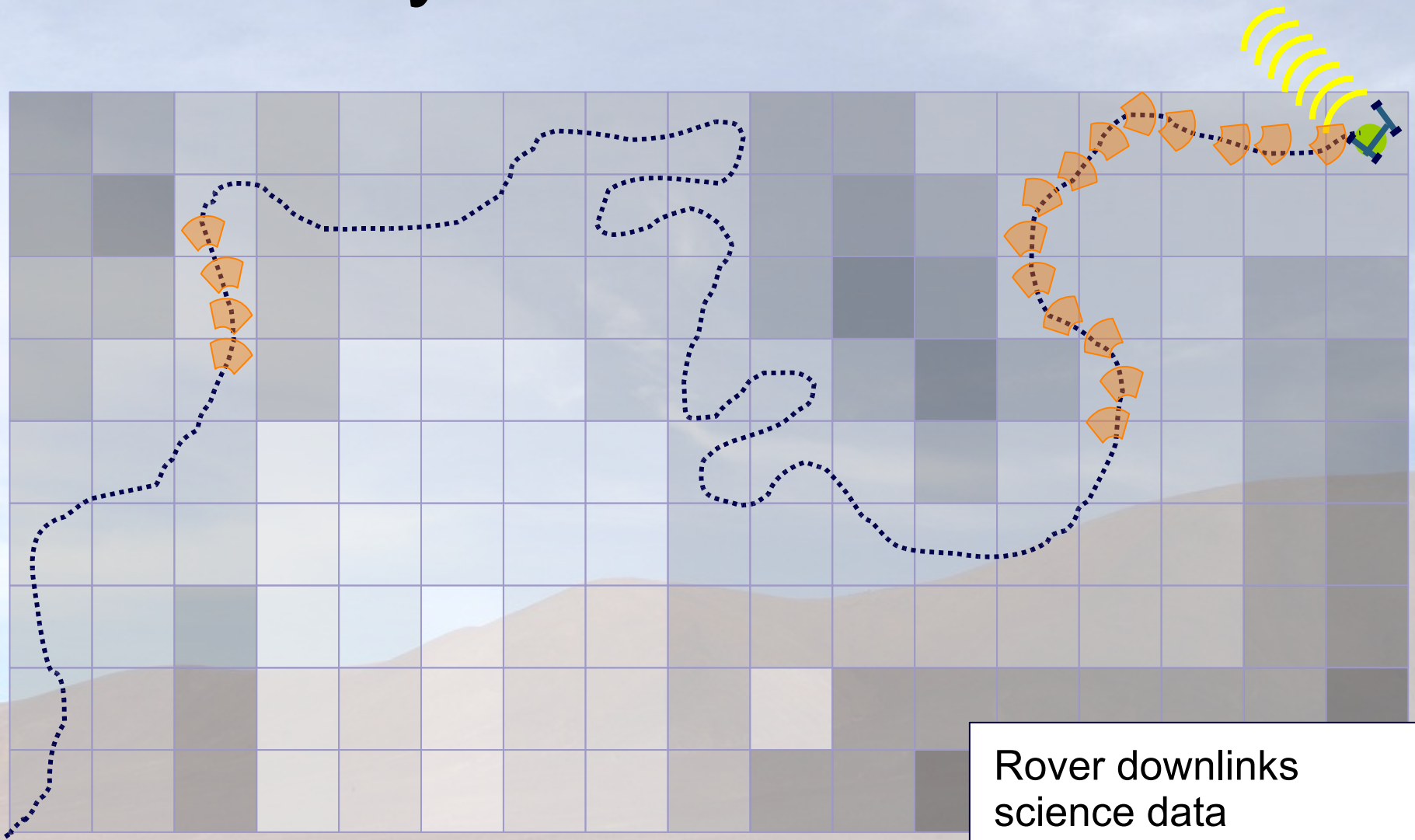
Rover executes traverse and makes measurements

Survey Traverse Method



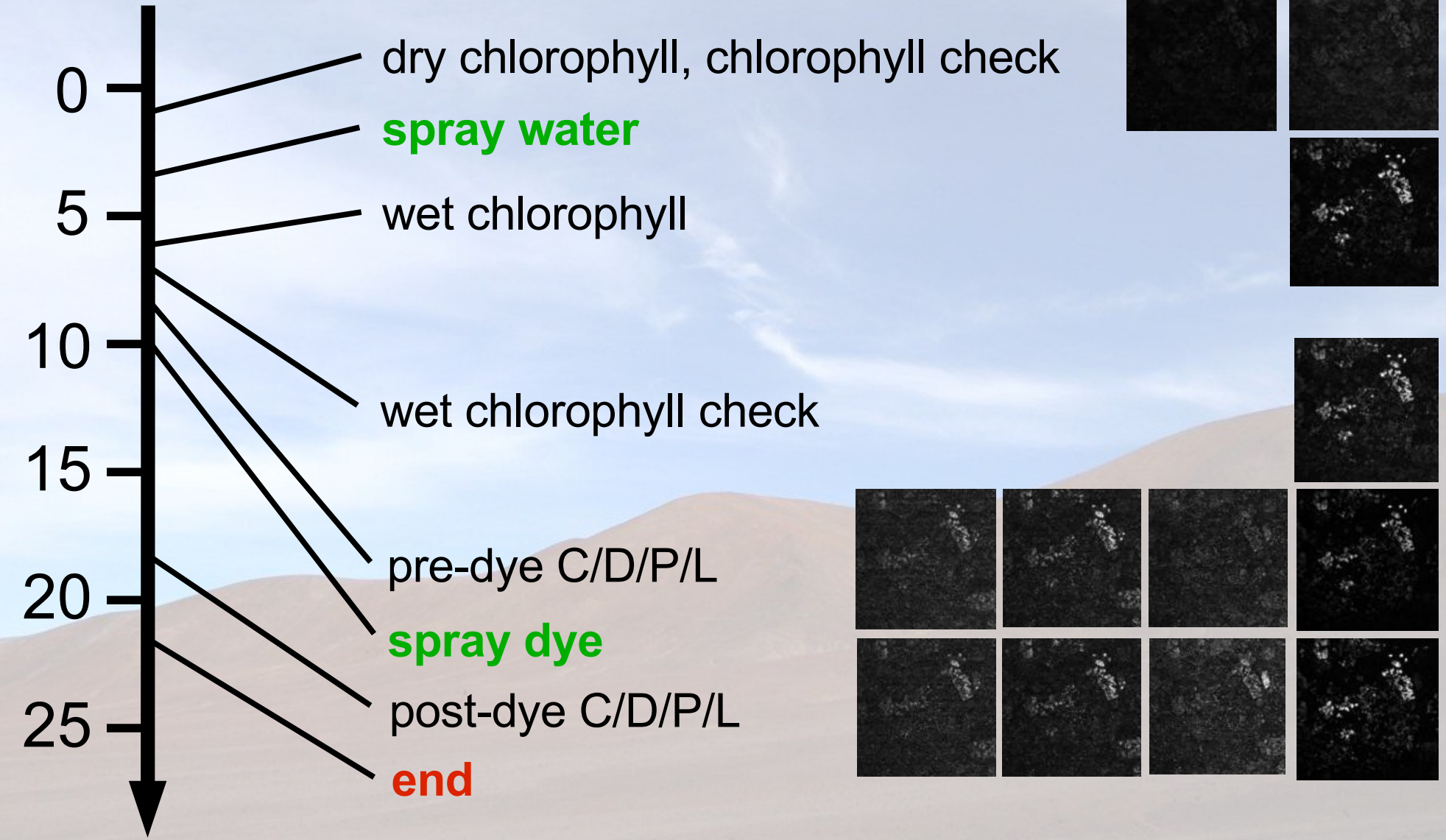
Rover records periodic samples during traverse

Survey Traverse Method

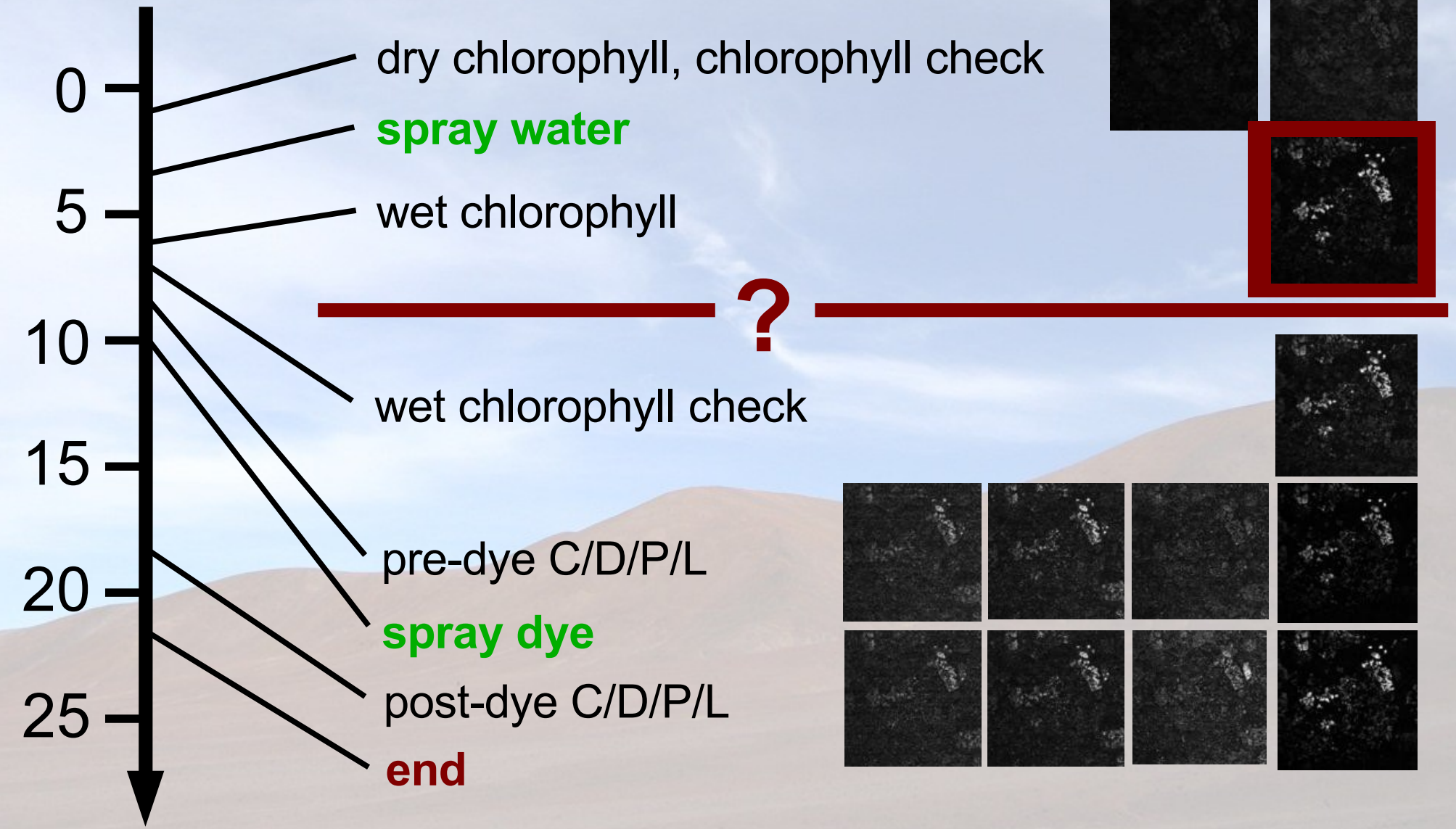


Rover downlinks science data

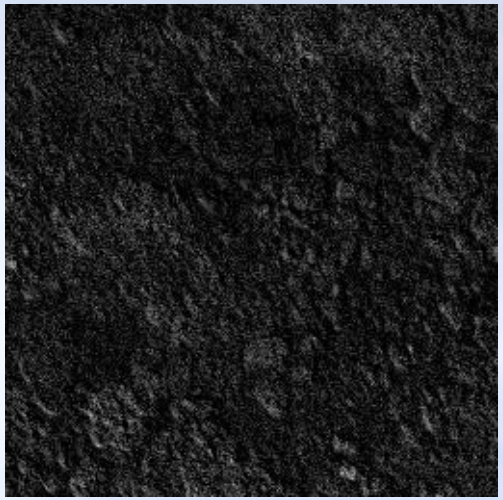
Fluorescence Imaging Protocol



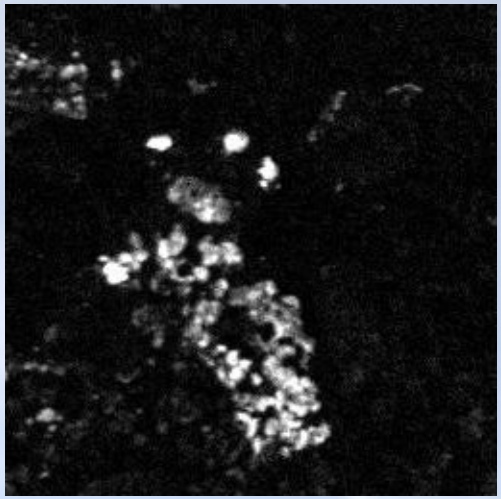
Fluorescence Imaging Protocol



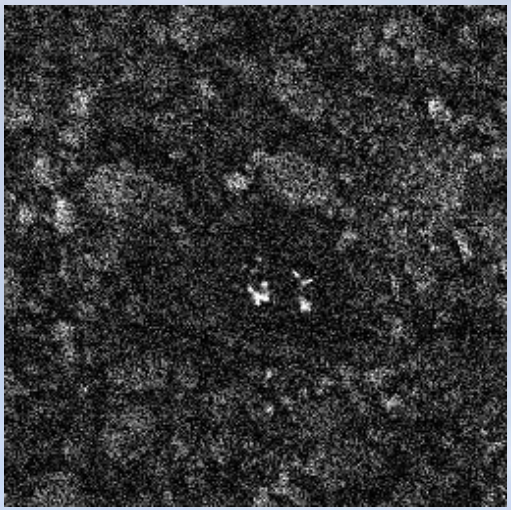
Interpreting Fluorescence Signal



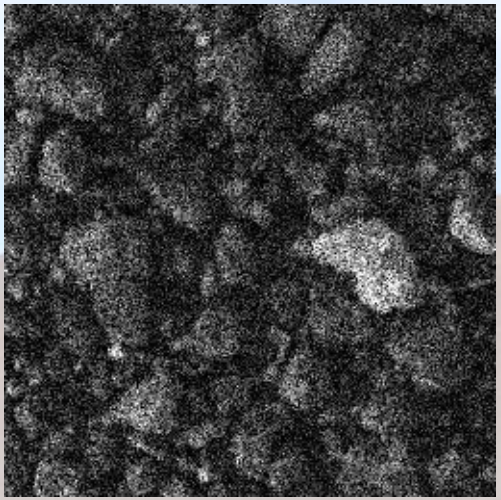
negative



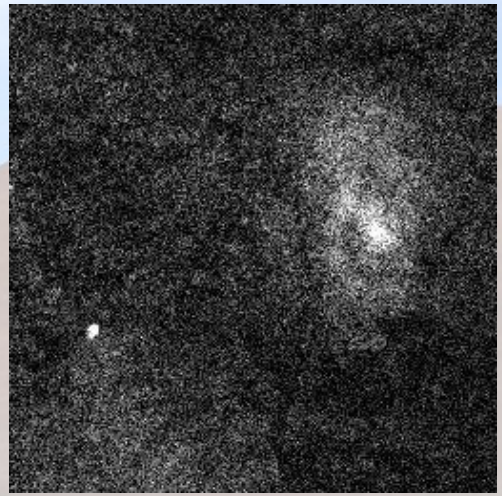
positive



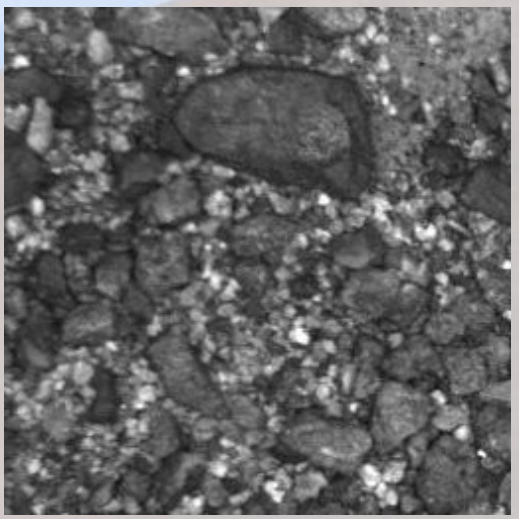
ambiguous



negative

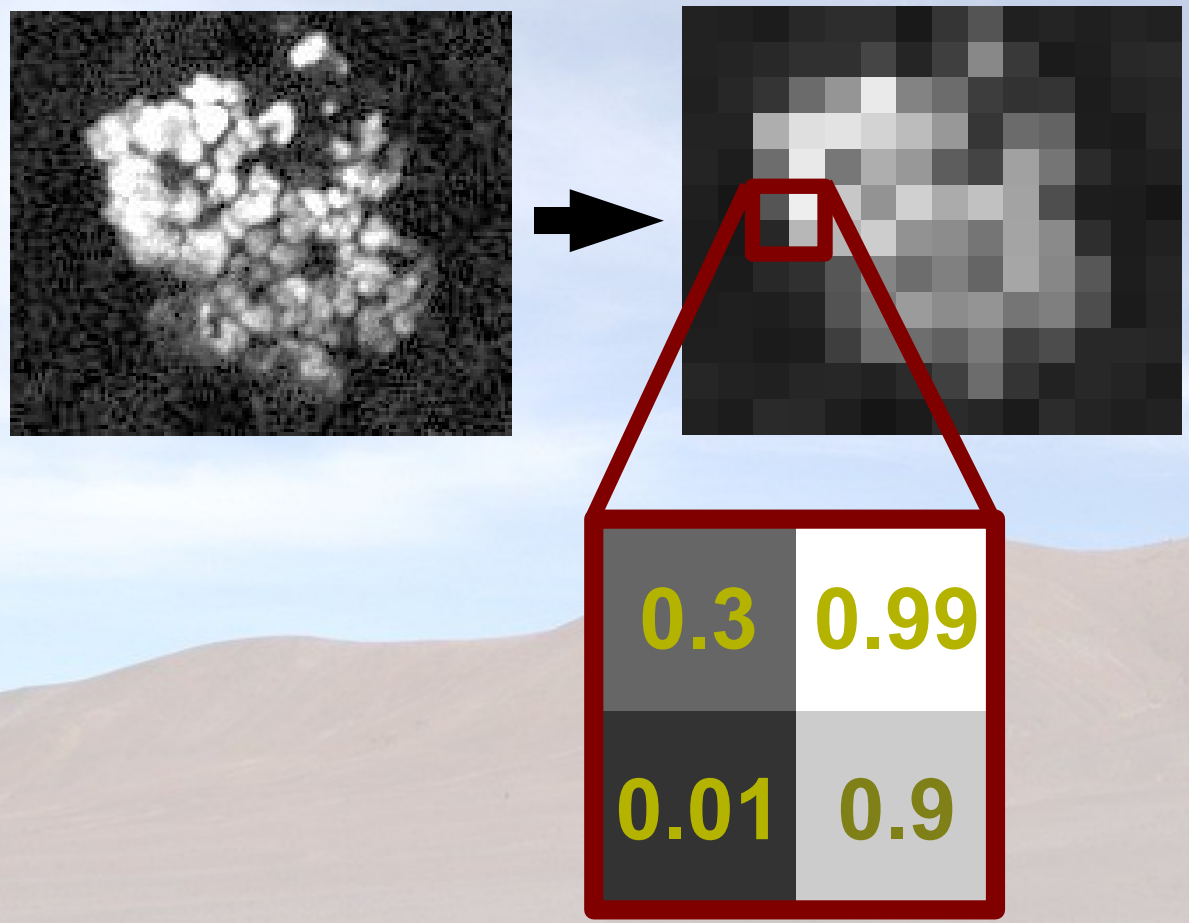


positive



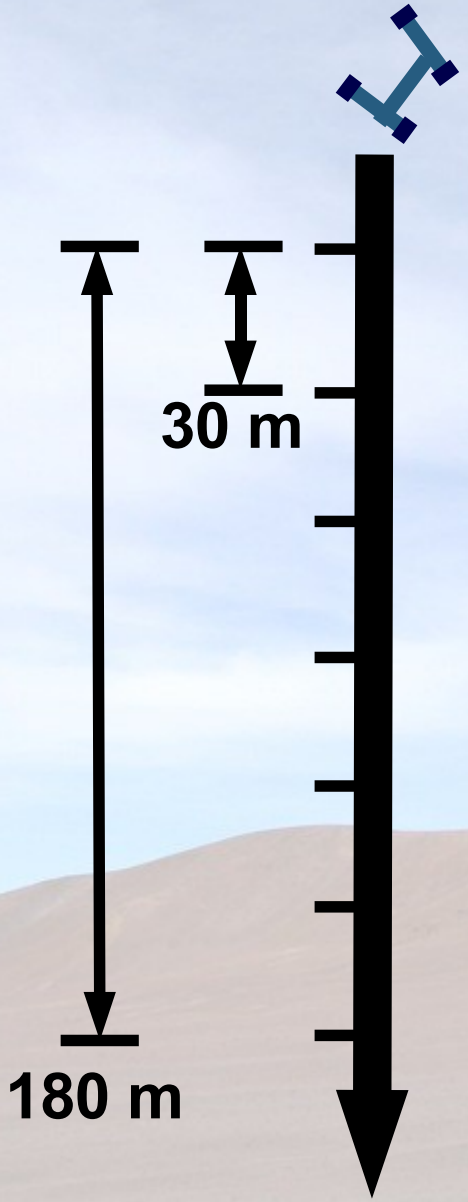
bad data

Automatic Fluorescence Detection



- Subsample
- Fuzzy threshold
- Naive Bayes

Science on the Fly Transect



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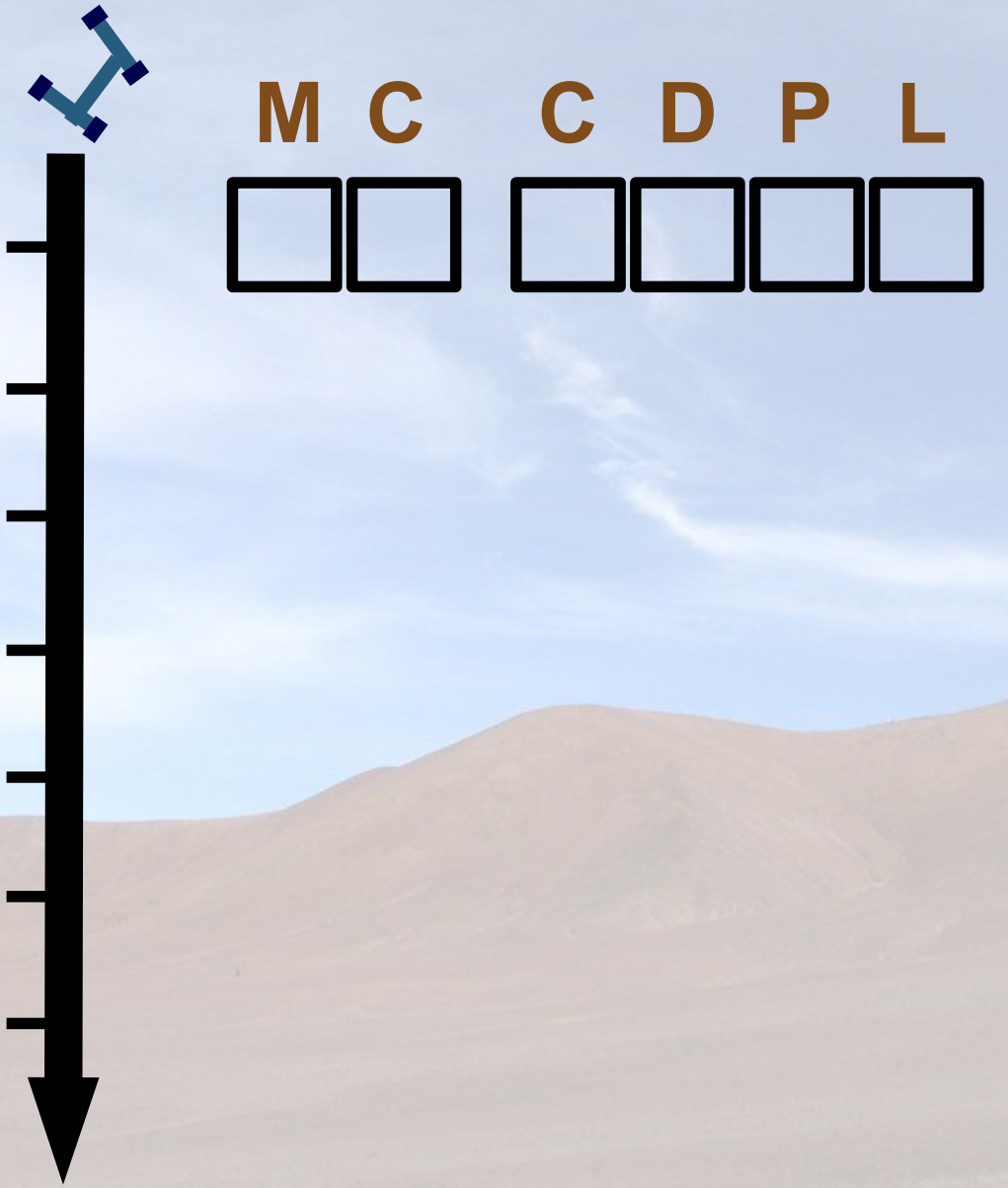
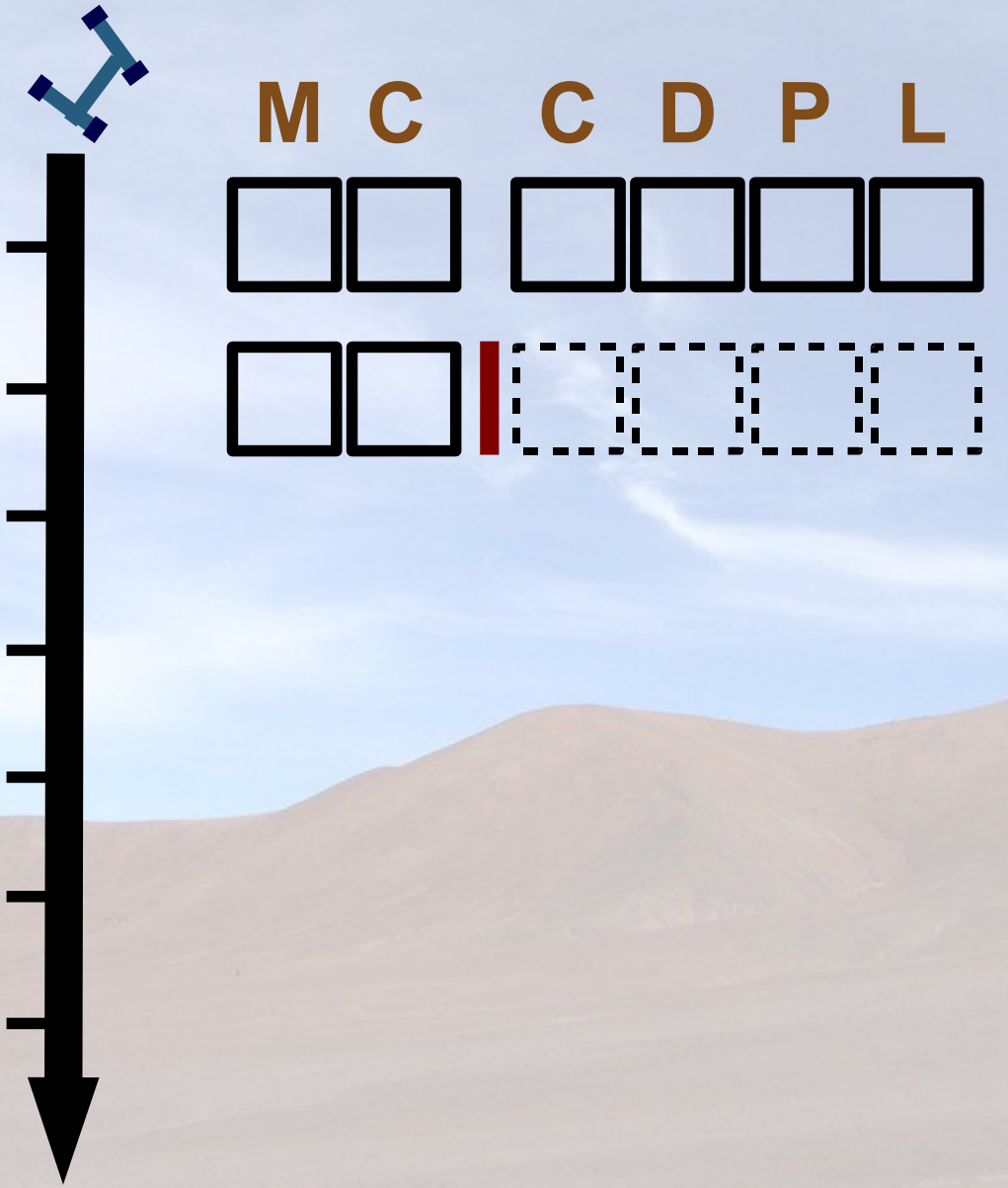


M = Morphology
C = Chlorophyll

C = Carbohydrate
D = DNA
P = Protein
L = Lipid

Science on the Fly Transect



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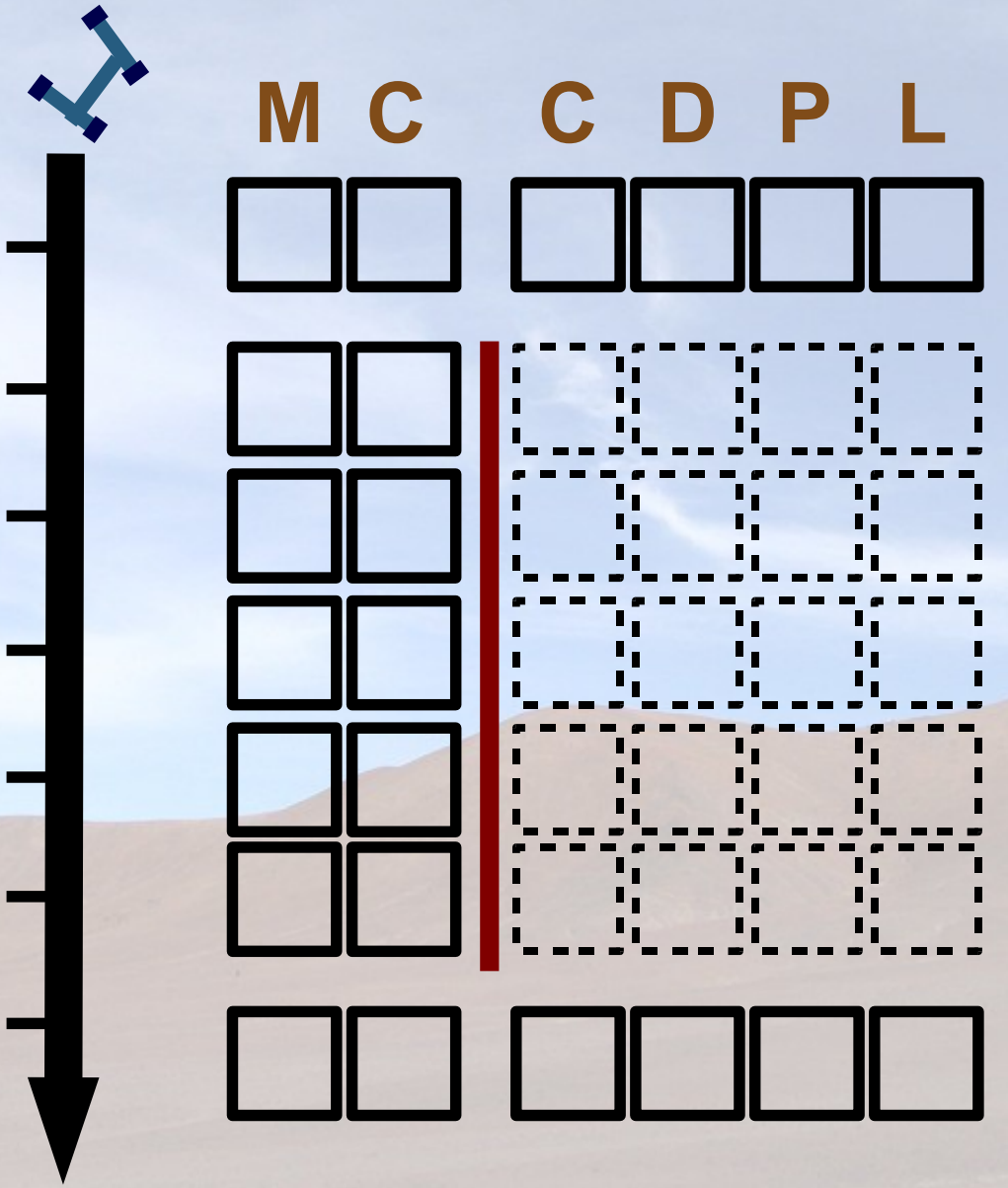

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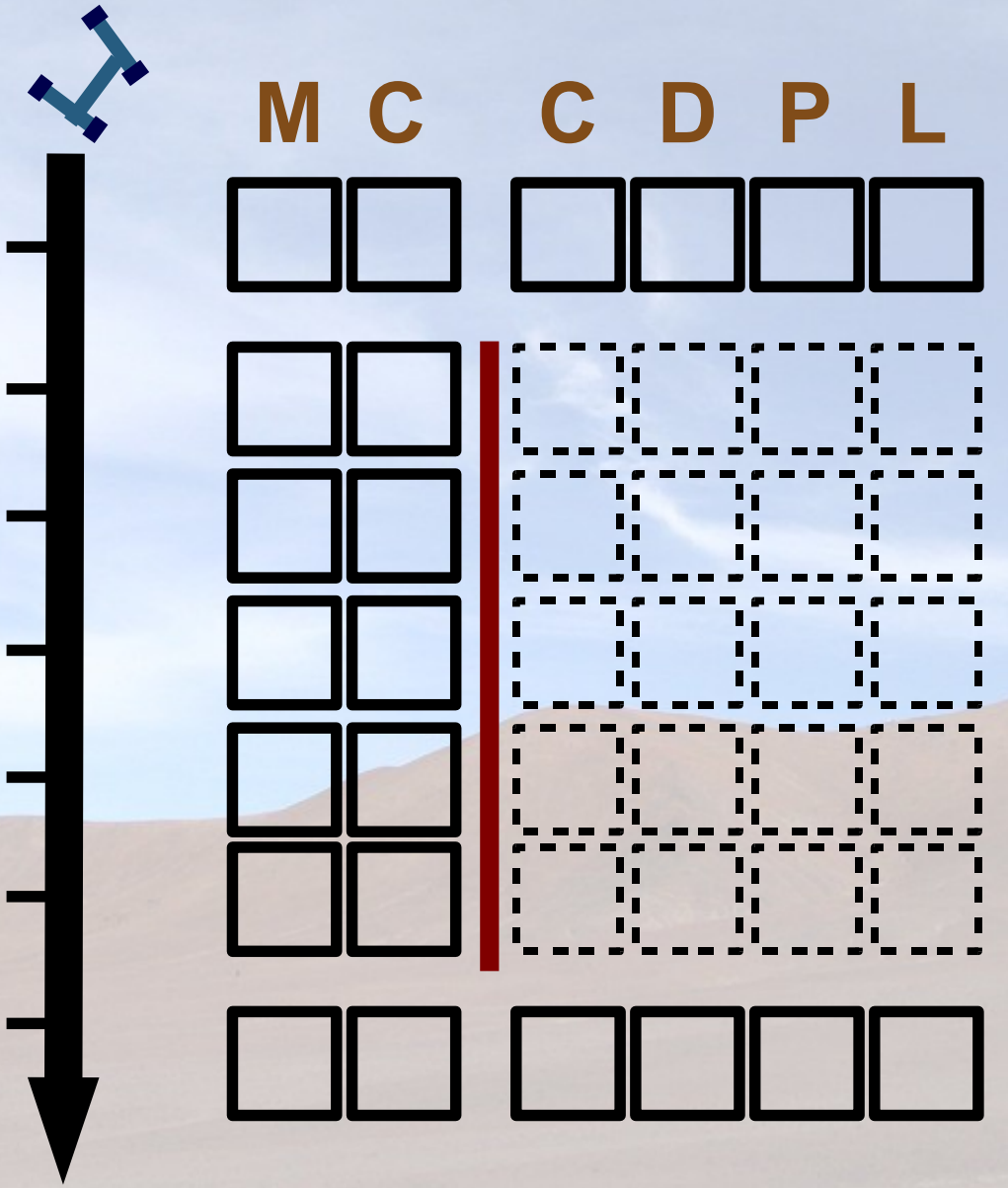

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negative

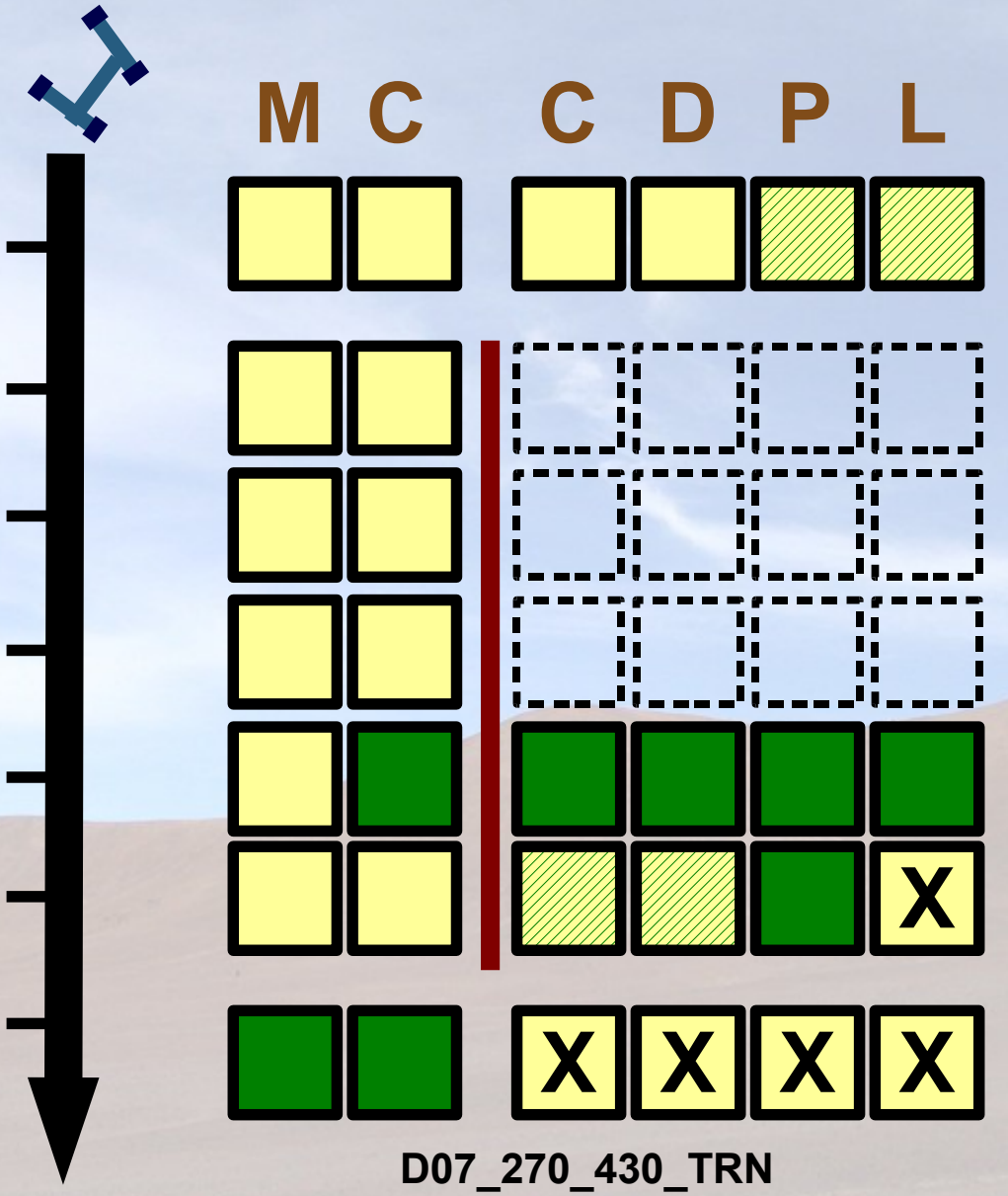
ambiguous

positive

X bad data

no followup

Science on the Fly Transect



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Results (Site D)

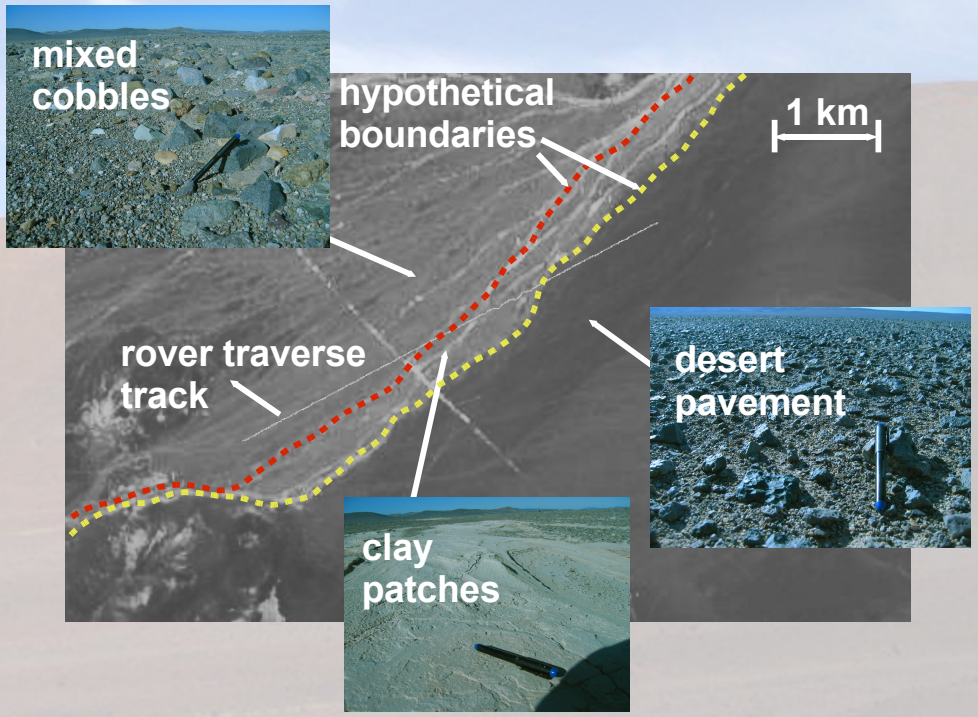
- Autonomy ***cut the number of followups in half*** (11 vs. 24) and still got 7 out of 8 of samples that had positive chlorophyll readings
- ***Precision*** is a measure of efficiency—it indicates the proportion of followups that corresponded to positive chlorophyll readings
- Compared to random followups, science autonomy ***increased precision by 90%*** (significance level < 0.01)

Conclusions

- Demonstrated large-scale robotic survey for the distribution of extremophile life
- Efficiency was improved by autonomous chlorophyll detection and followup
- ***Autonomous followup can be a big win*** if:
  - Some samples are taken quickly and others slowly
  - There is a well-defined cue for followup
  - Scientists can tolerate hiccups!

Future

- Spectrometer pointing on the fly
- Use onboard knowledge of satellite map
- Integration with traverse planning
- ***See poster tonight 7 pm in the Astrobiology group***



Thanks!

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