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Mission Analysis for EMIT using Automated Coverage Scheduling

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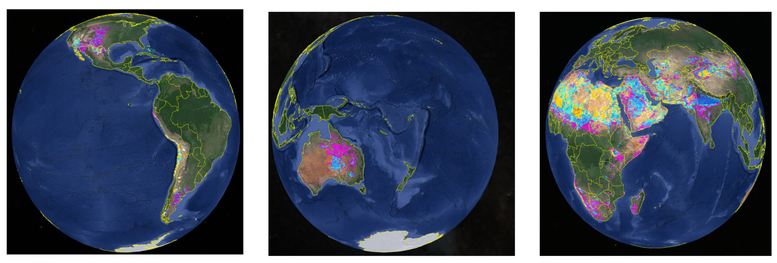
Summary:

The **E**arth Surface **M**ineral Dust Source **I**nves**T**igation (**EMIT**) is an Earth Ventures-Instrument (EVI-4) Mission to map the surface mineralogy of arid dust source regions via imaging spectroscopy in the visible and short-wave infrared (VSWIR). The maps of the source regions will be used to improve forecasts of the role of mineral dust in the radiative forcing (warming or cooling) of the atmosphere. EMIT is scheduled for launch to the International Space Station (ISS) in the early 2020's.

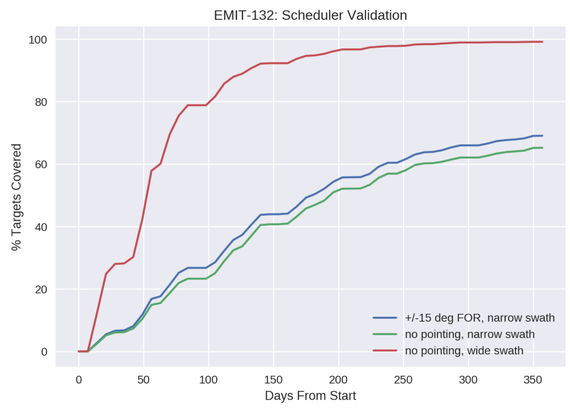
Automated scheduling technology was used to to construct schedules which were then automatically analyzed with respect to science acquired. These analyses can be performed for a range of spacecraft hardware configurations, observation strategies, and science requirements. by studying the effects of changes on the above inputs, better hardware configurations, observation strategies, and science requirements can be formulated.



The initial target regions are taken from Paul Ginoux's global attribution of dust sources[2].

Hardware Configurations

Analysis of hardware's effects on coverage can be achieved through automated scheduling. Some hardware components involved in the analysis were the pointing mirror and the resolution of the instrument. The effects on the level of coverage achievable and the time necessary to achieve certain levels of coverage can be impacted by how far off-nadir the instrument is able to look and the swath size of the instrument.



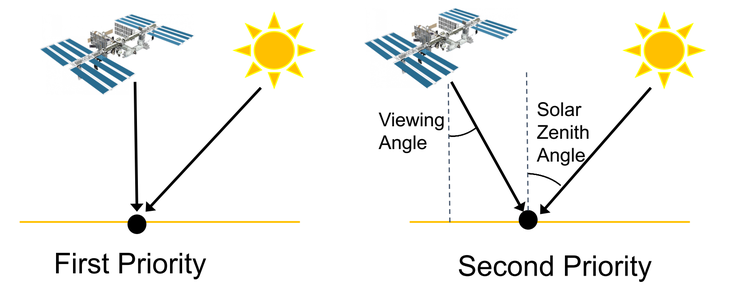
Graph comparing
1) large swath size with no pointing capability
2) small swath size with pointing capability
3) small swath size with no pointing capability

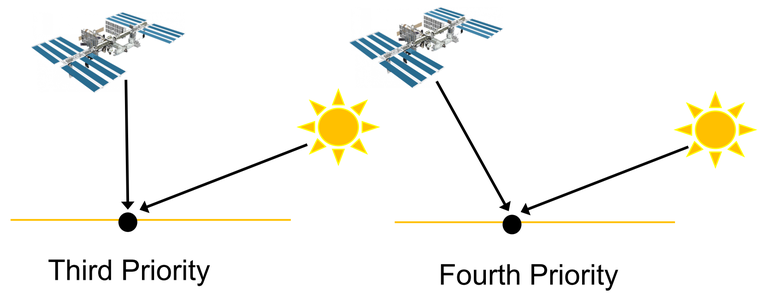
This analysis helped to quantify the effect of pointing on the overall science return, a major factor in the pointing/no pointing design trade.

Observation Design and Coverage Strategy

The quality of an observation can be impacted by multiple factors including
1) The illumination of the observation
2) The viewing geometry

In the case of EMIT, it is preferable for observations to have higher solar zenith angles and be viewed closer to nadir. The priorities of scheduling observations can take these preferences into account.





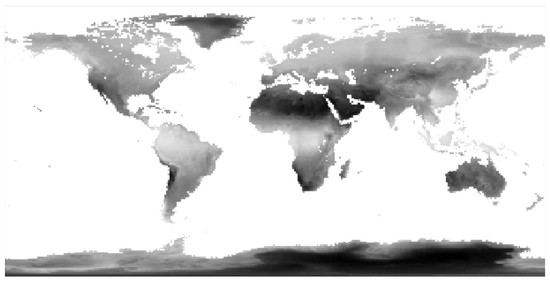
CLASP for Automated Coverage Scheduling:

The **C**ompressed **L**arge-scale **A**ctivity **S**cheduling and **P**lanning (**CLASP**) project is a long-range scheduler which addresses the problem of choosing the orientation and on/off times of a space-based pushbroom instrument such that the schedule covers as many target points as possible, but without oversubscribing memory and violating any other spacecraft constraints[3,4]. Orientation and time of observation is derived from geometric computations that CLASP performs using the SPICE ephemeris toolkit. CLASP allows mission planning teams to start with a baseline mission concept and simulate the mission's science return using models of science observations, spacecraft operations, downlink, and spacecraft trajectory. This analysis can then be folded back into many aspects of mission design -- including trajectory, spacecraft design, operations concept, and downlink concept. The long planning horizons allow this analysis to span an entire mission.

Scheduling Parameters
- Instrument data rate
- Downlink rate
- Across-track swath size
- Push broom imager
- Off-track look limits
- Slew rate
- Minimum along-track imaging duration
- Solar zenith angle limits & preferences
- Observation angle preference

Cloud Statistics

Onboard cloud screening software[5] will detect clouds in observations and excise that data. Clouds will thus have a large impact on data volume and coverage.



A mask of the likelihood of clouds based on location over a year[1] was used in determining the probability of an observation being successful.

If a (Lat, Lon) point is cloudy with probability *C*, and has *N* observations the probability there is at least one non-cloudy observation is $1 - C^N$.

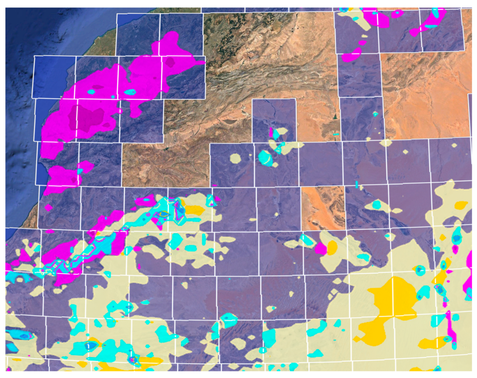
4 observations

0.30 cloud probability

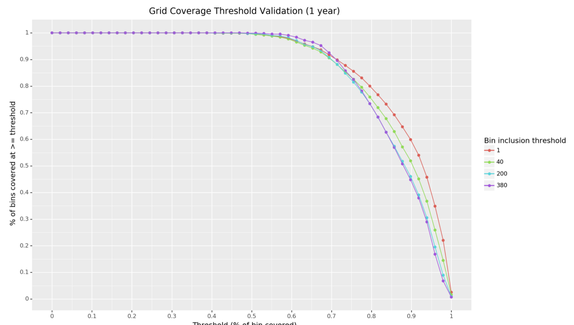
→ 0.9919 probability of having at least one non-cloudy observation

Coverage Criteria

The automated scheduling technology was used in defining coverage criteria such as percentage coverage and grid resolution. The original target region was abstracted to 100 km x 100 km bins. Analysis determined which bins would be considered in the final target region, and how much of each bin needed to be covered to be considered satisfied.



Abstraction of Target Region



Achievable coverage of different bin inclusion levels

References:

[1] Ackerman S. A., and R. Frey, 2015: MODIS Atmosphere L2 Cloud Mask Product (35_L2). NASA MODIS Adaptive Processing System, Goddard Space Flight Center

[2] Ginoux, P., Prospero, J. M., Gill, T. E., Hsu, N. C., and Zhao, M. (2012), Global-scale attribution of anthropogenic and natural dust sources and their emission rates based on MODIS Deep Blue aerosol products, Rev. Geophys., 50

[3] Knight, R.; and Chien, S. Producing Large Observation Campaigns Using Compressed Problem Representations. In International Workshop on Planning and Scheduling for Space (IWPSS-2006), Space Telescope Science Institute, Maryland, 2006.

[4] Rabideau, G.; Chien, S.; Mclaren, D.; Knight, R.; Anwar, S.; and Mehall, G. A Tool for Scheduling THEMIS Observations. In International Symposium on Space Artificial Intelligence, Robotics, and Automation for Space (ISAIRAS 2010), Sapporo, Japan, August 2010.

[5] Thompson, David & O. Green, Robert & Keymeulen, D & K. Lundeen, Sarah & Mouradi, Yasha & Nunes, Daniel & Castaño, Richard & Chien, Steve. (2014). Rapid Spectral Cloud Screening Onboard Aircraft and Spacecraft. Geoscience and Remote Sensing, IEEE Transactions on. 52. 6779-6792.

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