MRD-118- Local Spectral Features

Summary of Requirement

MRD-118 (2.4.5) For ≥40% of a 2-sigma TAG delivery error ellipse around at least the prime sampling site, map the distribution of key species listed in MRD-Table 118 (Absorption Features of Key Mineralogical & Organic Molecules) that have spectral features with ≥5% absorption depth at a spatial resolution ≤5 m (Photometrically Corrected REFF spectra (OVIRS), Emissivity spectra (OTES), Site-specific mineral and chemical maps, Site-specific Dust Cover Index)

The requirement is verified by establishing that OTES and OVIRS meet their performance requirements, that CMWG has provided to SAWG a thermal infrared spectral library that will enable the identification of phases that occur at ≥5% abundance in OTES data, and that SAWG has developed and tested the requisite algorithms for: 1) converting OTES calibrated radiance to emissivity, 2) calculating the dust cover index from OTES emissivity spectra, 3) producing resampled OVIRS calibrated radiance spectra, thermal excess-removed spectra, and Reflectance Factor (REFF) spectra, and 4) the detection of minerals and chemicals from OVIRS I/F and OTES emissivity spectra (the spectral parameter and linear least squares algorithms, respectively). Furthermore, the SPOC data storage and dissemination plan enables ready transfer of necessary data products across the different processing steps, and a science team tool for map-making must be provided.

Data Products Required

The data products that will fulfill this requirement are site-specific mineral and chemical maps, as well as a site-specific dust cover index map.

OVIRS: The immediate inputs for detection and mapping of minerals and chemicals at visible to near infrared wavelengths are OVIRS REFF spectra from the Reconnaissance phase. (These are derived from OVIRS calibrated radiance data, processed through the requisite SAWG science pipeline steps that result in photometrically corrected (to REFF (30,0,30) spectra.)

OTES: The immediate inputs for detection and mapping of minerals and chemicals at thermal infrared wavelengths are: 1) OTES emissivity spectra acquired during the Reconnaissance phase, and 2) a CMWG-supplied library of thermal infrared emission spectra of the phases of interest. The immediate inputs for calculating and mapping the dust cover index are OTES emissivity spectra. (Emissivity spectra are derived from OTES calibrated radiance data, processed through the emissivity-temperature algorithm.)

No other dependencies exist for these products.

Ability/Availability of the System to Generate Sufficient Observations

Measurement of features with ≥5% band depth depends on the OVIRS and OTES instruments meeting their performance requirements, which has been demonstrated/documented elsewhere (see below).

Modeling of phase abundances represented by OTES spectra depends on the CMWG-supplied spectral library being present and complete in terms of representing phases of interest at a range of reasonable particle sizes for the surface of Bennu.

The current DRM contains the required observations to meet the prime sampling site coverage, spatial resolution, time of day, and data return requirements.

Minimum Success Criteria

To enable OVIRS and OTES (established to have met measurement requirements) to collect the required data, operations during the Reconnaissance phase must, at a minimum, meet the surface coverage and spatial resolution requirements. To enable SAWG to successfully identify phases of interest in OTES data, the thermal IR spectral library must be present and complete.

Dependencies by Mission Phase

Reconnaissance: The spacecraft must meet the range-to-Bennu requirement specified by the DRM to ensure that OVIRS and OTES collect spectra with ≤5 m spatial resolution. Data must be returned and processed prior to exiting Reconnaissance phase.

In order to detect organics during the Reconnaissance phase of the mission, the spacecraft will fly to within 30 or 40 degrees of the sub-solar point and will have to point off-nadir. These constraints will ensure optimum viewing conditions for the OVIRS spectrometer, the only instrument sensitive to organic features. Morning times are more favorable, due to lower surface temperatures (therefore less thermal flux).

Adequacy of the DRM

The mission profile described by DRM Rev. C currently enables the required data to be collected.

Data Products per Mission Phase

Reconnaissance: Production of these science products begins immediately after the completion of OVIRS and OTES instrument pipeline processing resulting in L2 (calibrated radiance) products.

Spectra are processed via the OTES and OVIRS "science pipelines" to recover OTES emissivity spectra and OVIRS I/F spectra;

OVIRS I/F spectra are processed to calculate spectral parameters;

OTES emissivity spectra are processed through the linear least squares mixing model algorithm using the CMWG-supplied spectral library;

OTES emissivity spectra are processed to calculate dust cover index; and

Derived spot values are processed using make_map to produce site-specific maps of each product.

Overview of Processing

Software required:

Emissivity from OTES L2 calibrated radiance spectra is obtained using a SAWG script referred to as the emissivity-temperature separation algorithm (emissivity.dvrc); this script runs in the Davinci environment.

emissivity.dvrc has been delivered to the SPOC.

Mineral abundances from OTES emissivity data are obtained via the linear least squares algorithm (sma.dvrc); this script runs in the Davinci environment.

sma.dvrc has been delivered to the SPOC.

Dust cover index is obtained via the script calc_dci.dvrc, which runs in the Davinci environment.

calc_dci.dvrc has been delivered to the SPOC.

I/F from OVIRS L2 calibrated radiance is obtained using SAWG scripts for resampling, thermal tail removal, and ratioing to the solar spectrum; these scripts run in the IDL environment.

These scripts have been delivered to the SPOC.

Spectral parameters for OVIRS spectra are obtained using the SAWG script Spindex.pro, which runs in the IDL environment.

This script has been delivered to the SPOC.

Site-specific maps are made using the SPOC-supplied GetSpots and make_maps routines

These scripts are currently (30 Apr 2016) in development.

Provenance of Algorithms, Software and Techniques

The emissivity-temperature separation script for the Davinci environment is an update to code used for analysis of thermal infrared spectra on prior spaceflight missions (Mars Exploration Rovers, Mars Odyssey, Mars Global Surveyor) and has been used extensively for OTES data processing through instrument-level testing and ATLO. Script version control is included. [References would be to science data or early literature describing separation of E and Tb.]

The linear mixing model that will be applied to OTES data is described in the scientific literature by Ramsey and Christensen [1998] and Rogers and Aharonson [2008]. The SAWG algorithm has been used by previous spaceflight mission teams (Mars Exploration Rovers, Mars Odyssey, Mars Global Surveyor). The script includes version control.

Ramsey, M. S., and P. R. Christensen (1998), Mineral abundance determination: Quantitative deconvolution of thermal emission spectra, J. Geophys. Res., 103, 577-596.

Rogers, A. D., and O. Aharonson (2008), Mineralogical composition of sands in Meridiani Planum determined from Mars Exploration Rover data and comparison to orbital measurements, J. Geophys. Res., 113(E06S14), doi:10.1029/2007JE002995.

The OTES dust cover index is a parameter derived for Mars Global Surveyor Thermal Emission Spectrometer data, and is a version-controlled, Davinci-compatible adaptation of the script originally written for the "vm" (vector math) environment. The relevant publication is Ruff and Christensen [2002]:

Ruff, S. W. and P. R. Christensen (2002) Bright and dark regions on Mars: Particle size and mineralogical characteristics based on Thermal Emission Spectrometer data, J. Geophys. Res., 107, doi: 10.1029/2001JE001580.

The resampling, thermal tail removal, and I/F processing steps can all be considered common knowledge. The specific scripts delivered by the SAWG were written for the SAWG.

The photometric model and correction are represented by a separate L2 MRD documented here: https://sciwik.lpl.arizona.edu/wiki/pages/K7n5d838q/MRD149.html

The spectral parameter calculations that will be applied to OVIRS data are derived from similar calculations in the scientific literature [Pelkey et al., 2007; Viviano-Beck et al., 2014], which have been used by a previous spaceflight mission (Mars Reconnaissance Orbiter). The script includes version control.

Pelkey, S. M., et al. (2007), CRISM multispectral summary products: Parameterizing mineral diversity on Mars from reflectance, J. Geophys. Res., 112 (E08S14), doi:10.1029/2006JE002831.

Viviano-Beck, C. E., et al. (2014), Revised CRISM spectral parameters and summary products based on the currently detected mineral diversity on Mars, J. Geophys. Res., 119, doi:10.1002/2014JE004627.

The software being developed for making maps from science products is described here: https://sciwik.lpl.arizona.edu/wiki/pages/B3w8e1o/Spectral_map_processing_and_generation_algorithm.html

Expected/Simulated Data

The temperature-emissivity separation algorithm has been used for similar data by several different spacecraft missions (e.g., TES on Mars Global Suveyor, Mini-TES on the Mars Exploration Rovers).

The OVIRS spectral parameter software was used for the CMWG/SAWG Blind Test, which verified that it can correctly calculate the programmed spectral indices.

The OTES linear mixing model has been in use for many years with many published papers in the literature. The same algorithm was used for the CMWG/SAWG Blind Test, which verified that it can model input spectra with a spectral library.

The Blind Test results for simulated OVIRS and OTES data are documented on this SAWG Wiki page.

The adapted dust cover index algorithm has been tested by the author (V. Hamilton) using laboratory spectral data and returns values identical to the original script used for the Ruff and Christensen [2002] publication.

See the link above (under Provenance) regarding the photometric model and correction.

Analysis & Verification Methods

The performance of the OVIRS and OTES instruments are detailed in the OVIRS and OTES instrument manuscripts at this link:
https://sciwik.lpl.arizona.edu/wiki/pages/U3B5r7/Space_Science_Reviews__Special_Issue.html

For software performance, see the discussion under Expected/Simulated Data above.

Existing or Potential Liens

Lien-SPEC-1 has closed with the delivery of a spectral library file from SAWG to the SPOC as detailed in CR-316.

Lien-SPEC-1: Lien on the CMWG (transferred to SAWG): The first lien on successfully meeting this requirement is the availability of an appropriate spectral library for the interpretation of OTES emissivity spectra. The spectral library is a Carbonaceous Meteorite Working Group (CMWG) deliverable. There is no CMWG-provided, project-approved thermal infrared spectral library that has been verified and validated for the detection of phases at 5% abundance. The SAWG generated an example/test library for the Blind Test exercise in 2015, but that library is not adequate to meet this requirement. Removing this lien requires the CMWG to deliver a verified and validated spectral library.

Lien-SPEC-2 has closed. The database search, input, and output currently implemented in the JSON database at the SPOC for meeting the MRD Requirements on spectral data processing(MRD-118, MRD-140, MRD-143, MRD-147, MRD-154, MRD-159 and MRD-540), are ready for operations. These database uses have been completed, validated, verified and used successfully by SAWG and TAWG scientists during the first Science Operations Proficiency Integrated Exercise (SOPIE-1). The SAWG and TAWG teams demonstrated that the database IO is complete -- by correctly using it to create data products during the SOPIE-1 exercise. Only minimal support was required from Sanford Selznick (Director of Science Data Processing) and his staff to use the database structure to download datasets and upload higher level data products. The software and database structures for extracting L2 OTES and OVIRS data from the database, and handing them off to the various data processing algorithms, then returning them to the database, has been completed (i.e., science database tables have been implemented), and Lien-SPEC-2 can be closed.

Lien-SPEC-2: Lien on the SPOC: The second lien on successfully meeting this requirement is the implementation of needed database access and data processing linkages at the SPOC. SAWG has delivered individual algorithms for conducting the required analyses, but there is currently no defined procedure for SAWG to extract L2 OTES and OVIRS data from the database, and hand it off to the various algorithms, then return it to the database (i.e., science database tables have not been implemented). Removing this lien will require work on both the part of the SPOC and the SAWG to generate algorithms and update existing algorithms once a process is defined.

Lien-SPEC-3 has closed. The software that has been delivered to the SPOC for meeting the MRD Requirements on mapping (MRD-118, MRD-140, MRD-154, and MRD-540), namely GETSPOTS, and MAKEMAPS are ready for operations. This software suite has been completed, validated, verified and used successfully by SAWG and TAWG scientists during the first Science Operations Proficiency Integrated Exercise (SOPIE-1). The SAWG and TAWG teams demonstrated that the user's manual for this software suite is complete and accurate -- by correctly using it to map test data and reproduce known spectral data patterns that were inserted into the SOPIE-1 test data sets made by Beth Ellen Clark (OVIRS), and Phil Christensen (OTES), respectively. During the SOPIE-1 exercise, only minimal support was required from Luke Hawley (author of MAKEMAPS) and Sanford Selznick (Director of Science Data Processing) to create the necessary spectral map data products required by the exercise designers (Mike Nolan, Mathilde Westermann, and Anjani Polit). The software for mapping calculated spot values onto the Bennu Shape model is ready for operations, and Lien-SPEC-3 can be closed.

Lien-SPEC-3: Lien on the PI-Office: The third lien on successfully meeting this requirement is the completion of software for mapping calculated spot values onto the Bennu shape model. Removing this lien requires the completion of the requisite software, which is not a SAWG deliverable.

There are currently no other known liens on the DRM, the OVIRS and OTES instruments, or spacecraft system that would preclude successfully collecting the data needed to meet this requirement, except for those listed under MRD-149.

SPOC Requirements

SPOC must produce OVIRS and OTES instrument L2 calibrated radiance spectra, enable these to be fed to the SAWG algorithms for "science pipeline" processing (see SAWG Data Flow diagrams), and host/provide the spectral library file needed for the OTES linear mixture model. Geometric information is not required for derivation of any of the spot values, but will be needed for the production of maps.

The SPOC-Spectral Analysis ICD is posted on ODOCS: \OSIRIS-REx Ground Systems\9.4 SPOC\9.4.2 Systems Eng\ICDs\WG ICDs\

The Spectral Analysis flowchart is in draft form, undergoing active revision (as of 15 May 2016) and will be linked here when it is finalized.

External Interfaces

There are no external interfaces for derivation of these products.