CAT: VERSION 6
Version 5.2 to 6: CHANGES/ADDITIONS/NOTES

Summary Products:

--Summary products have been updated/revised based on team efforts. The following changes have occurred:

--R410 changed to R440

--BD2400 replaced with SINDEX

--Band positions have been shifted to avoid known issues with the CRISM detector. The following parameter formulations have been slightly changed:

VNIR: BD530, SH600, BD640, BD860, BD920

IR: VAR, BD1500, BD1750, BD1900, BDI2000 ,
OLINDEX,LCPINDEX,HCPINDEX,IRR3

CATNIP:

--Added Scott's new filter described at the June 2007 science team meeting to clean up summary products.

--Removed "Convert ScottENVI to CAT" and "Destriping" routines as they have become outdated.

Other Changes:

--**Updated code to work with or check for tile processing. Map info based on upper left pixel coordinates and pixel size incorporated when opening files, but presently, not with processed products.**

--**Addition of a new spectral library** created by Leah Roach named:

RT_resamp.sli in crism2/crism/CAT_ENVI/spec_lib/crism_resamp

It is Rio Tinto materials measured in RELAB and resampled to CRISM targeted wavelengths. The aim is provide more context for the spectral variety of iron oxides, sulfate (and some admixed clays) in a terrestrial setting. The spectra are labelled with Leah's best interpretation of mineralogy, which is often imprecise or incomplete. Many of the samples are mineral mixtures. Photos of the source object in the field or the hand sample from which the spectrum was taken are available upon request. (Only one sample has been characterized by XRD and XRF and it was not in the XRD library (the ZnCuFe hydrated sulfate).)

CAT: GENERAL INFO

CAT REQUIREMENTS:

- Requires access to the following types of files:
  CDR6: SW, WV
  CDR4: SF, WA, AT, (resampled versions: RF, RW, RT)
    - These files are assumed to live in CAT_ENVI/aux_files/ but if not located, user is asked for location)
    - Code searches for appropriate file if multiple versions or sclk designations.
    - **Note:** These directories may require USER updates if new files are produced between CAT distributions.

DEFAULT ASSUMPTIONS: (can sometimes handle variations but adherence allows for most seamless operation)

- File names have not been changed from CRISM naming conventions.
- All .IMG files have .LBL and .TAB files in the same location

GENERAL NOTES:

- The CAT does some intelligent searching for necessary files, but requires that:
    - Standardized PDS or CAT-ENVI filenames are used.
    - Paths to DDRs are either the exact same as the datafile's or the same but with TRDR/EDR/RTR (or lowercase versions) replaced with DDR (or ddr).
    - That the CAT_ENVI directory is installed in unix users' home directory or Windows users' C:\Program Files\ directory.
    - If files cannot be found automatically, the user often has the option of locating them themselves.
- Many programs ask the user to select an open file to process; if the file is not yet open, the user can chose to open it from the "File Selection" GUI, however, if "CAT: Open CRISM File" is not used, files will be opened without band information.
- Keep available memory in mind when doing a lot of processing. Most programs that produce output offer the user the choice of keeping output in memory or writing it to disk (note: both selections result in output appearing in the Available Bands List).
- Some programs need to write files to disk (primarily to mediate memory constraints); these files are written to the output directory (default = 'CAT_ENVI/tmp/) and are deleted when the program concludes; however, interrupted runs or crashes may result in the files remaining on disk.
- Users can continue to modify the CAT or ENVI menus by adding their own functions to the CAT_ENVI/save_add/ directory; menu buttons to access these programs can be created by editing the CAT_ENVI/save_add/CAT_programs/cat_menu.pro file.
- Typically output files of spectral cubes are written in band interleave format (BIL: a good compromise between efficient scene and spectral access); however, when processing data in memory, ENVI limits the format options to band sequential (BSQ: well suited to scene access, but slow for spectral access). The user always has the option of converting between types by using the ENVI function under: "Basic_Tools: Convert Data (BSQ, BIL, BIP)".

CAT FUNCTIONS

Open CRISM File:

- **For all CRISM files.**
- To open any CRISM file that has an associated PDS .LBL file or a CAT-ENVI file (see below).
    - For CDR and ADR files: uses standard ENVI opening routines to parse PDS .LBL file for necessary info; band names are not given since data varies over all the types.
    - For DDR, MRRDE, MRRSP, all SU files: reads .LBL file for necessary info including band names.
    - For EDR, TRR, RTR RA/IF/AL files: uses standard ENVI opening routines to parse PDS .LBL file for necessary info; the default wavelength array to apply to the data (i.e., the standard resampling wavelengths for the appropriate wavelength filter used for the observation) is retrieved by using the readpds.pro IDL routine to access the ROWNUM_TABLE object of the .IMG file in conjunction with the CDR6-SW file. The program will search for related CDR6 files in ~/CAT_ENVI/aux_files/CDRs/SW/ ; if any/all necessary information is not found, the program will ask the user to locate the CDR6 files.
      NOTE: unless files are perfectly PDS compliant, ROWNUM_TABLE cannot be read individually from the .IMG file…it *can* be accessed by reading all objects described in the .LBL file, however, the housekeeping table takes a LONG time to read; therefore, if this is the case, the routine falls back to the Version 1 method of reading files (get row numbers from the CDR6-WV file for the appropriate filter and wavelength info from the CDR6-SW file).
    - For MRRIF and MRRAL files: uses standard ENVI opening routines to parse PDS .LBL file for necessary info; the default wavelength array to apply to the data (i.e., the standard resampling wavelengths for the appropriate wavelength filter used for the observation) is retrieved from the MRRWV*TAB file.

    - Program looks for the .LBL file in the same directory as the file being opened but if not found automatically, user is asked if they would like to locate the .LBL file or continue to open the file without the necessary information. If the latter selection is made, a GUI will appear for user to enter relevant info necessary to open file. (Note: if this route is taken, file type should be given as "Standard ENVI"; if "PDS Image" is selected, ENVI will look for the associated LBL file and produce an error upon not finding it.)
    - If the LBL file is present, but the code cannot find all of the ancillary info it needs to obtain the band names, it will open the file without applying band names.
    - For CAT-ENVI files: uses standard ENVI opening procedure, which accesses information from associated .hdr file.
    - NOTE: ENVI is instructed to "ignore" CRISM's NAN value (65535.0) when loading in data.
- Calls CAT programs: read_crism_event.pro,
  read_crism_lbl.pro
  find_cdr6file.pro
- Potenially uses: CDR6-SW and when necessary, CDR6-WV

Convert Format: PDS to CAT: (**works with PDS files as input)**

- **For EDRs,TRDRs,RTRs,MRRIFs,MRRALs… To be used with <u>original PDS files</u> of spectral scene data only.**
- For selected PDS .IMG files, this program manipulates data into "CAT-ENVI-format". This step is recommended to ease use of the CRISM data, primarily those from the L-detector.
- **Output interleave of data matches the input interleave**; i.e. tiles are BSQ, non-tiles are BIL.
- Steps taken with L detector data:
  - The first band, which is returned but does not provide scene data, is zeroed out and labeled as "4.0" microns instead of "65.535" microns; allowing for more reasonable spectral plot displays. Bandwidth for this band is labeled as "0.0" instead of "65.535".
  - The wavelength dimension of the data and the associated wavelength labels are then reversed to match the S-dectector/standard convention of wavelengths increasing with band number. If an output file is written, this step is noted in the .hdr file where "Wavelength Flipped from Original" is set to "YES."
- User has the option to output the result to a file or memory. If the user intends to do future CAT processing, it is recommended that an output file is written. In this case, for both S and L detector data, an output file is written with an associated header file containing information used in other CAT processing. This .hdr file includes the original .LBL filename allowing later access to observation related information not included in the .hdr file. Future references to this LBL file assume it is in the same directory as the CAT-ENVI files. If it is not, the user will be asked to locate it.
- Running the code:
  - User is asked to select the file they would like to convert from files on disk; the routine does not require that the files already be open within ENVI.
  - The user has the option to write an output file or run the routine in-memory both options result in the CAT-ENVI version of the files being opened at the end of processing. Upon opening the CAT-ENVI files, ENVI is instructed to "ignore" CRISM's NAN value (65535.0) and loads a default RGB combo to a display window.
  - If writing output files, the user is asked to select the output directory only—standardized output filenames are imposed. Output files are named with "_CAT" added to the original filename before the extension and then are appended with ".img" for the data and ".hdr" for the header information. It is recommended that users do not change these filenames if they intend to do future CAT processing.
- Calls CAT programs: convert_pds2cat_event.pro
  read_crism_lbl.pro
  find_cdr6file.pro

****

Radiance to I/F: (works with PDS or CAT-ENVI files as input)

- To be used with TRDR or RTR radiance (RA) files.
- To convert TRR or RTR radiances to I/F (simply divides by the solar flux adjusted to Mars distance and converted to radiance by dividing by pi).
- User is asked to select the file they would like to convert from files open within ENVI (note: spectral subsetting is allowed).
- User has option to write a file or keep the output in memory. If writing a file, user can choose the name but it is suggested that they accept the suggested default.
- Attempts to get relevant observation info from LBL file, but there are workarounds if LBL file not found.
- Requires related DDR IMG file to have a .LBL file to get solar distance. The program looks for a matching geometry file in the appropriate location assuming that the user has adhered to the APL directory structure -- if not found, user is asked for the location of the related geometry file.
- Requires access to solar flux file; TRR conversion uses CDR4-SF while RTR conversion uses CDR4-RF. CDR4 -SF or RF files are assumed to be in subdirectories of ~/CAT_ENVI/aux_files/CDRs/ -- if not found, user is asked for the location of the related CDR4 file.
- The program will open and close files as necessary.
- Calls CAT programs: convert_event.pro
  find_geofile.pro
  read_crism_lbl.pro
  find_cdr4file.pro
- Uses: geometry .LBL file (to get solar distance)
  CDR4-SF or CDR4-RF

ATP Corrections: (works with PDS or CAT-ENVI files as input)

- To be used with TRDR or RTR radiance or I/F (RA or IF) files or MRRIF file to correct for atmospheric, thermal, or photometric effects.
- **Output interleave of data matches the input interleave**; i.e. tiles are BSQ, non-tiles are BIL.
- User is asked to select the file they would like to work with from files open within ENVI (note: spectral subsetting is allowed). Users have the option to output the result to memory or a file.
- Corrections choices are as follows:
  - For atmospheric correction:
    --Division by scaled volcano observation (current algorthims accounting for smile in non-tiles, but do not account for smile in tile).
    --Empirical use of EPF. **(NOT WORKING YET.)**
    --None.
    - Note: the scaling procedure uses CDR4-WA file to properly account for smile. Occassionally the "MRO:WAVELENGTH_FILE_NAME" keyword in the .LBL file is not correctly populated. In this instance, the user is required to select the appropriate CDR4-WA file—see the CRISM SIS explanation of the CDR4 naming convention to understand which file should be selected. Also, once the file is selected, users will get a popup explaining that this is not the file listed in the LBL file, just choose to proceed regardless.

- For thermal correction:
  --Empirical temp estimate from values at 2.3 microns. (algM)
  --Modeled temp estimate from ADR-TE (algK).
  --None.
  - **THERE ARE NO THERMAL CORRECTIONS WORKING YET.**
- For photometric correction:
  --Division by cosine of the incidence angle: On or Off

- Call CAT programs: atpcorr_event.pro
  scaleatm.pro
  find_geofile.pro
  read_crism_lbl.pro
  find_cdr4file.pro
- Uses: geometry .IMG and .LBL file (for solar distance and incidence angle)
  CDR4-SF or CDR4-RF
  CDR4-AT or CDR4-RT

****

DISORT MULTIIDL:

- **NOT WORKING YET.**

****

EPF UTILITIES:

Project Segments:

- **To be used with standard PDS format files; not CAT-ENVI data.**
- To spatially project a single band from multiple angles of the same EPF to visualize area of overlap.
- **NOTE:** Due to demands of automation, this program **requires that users DO NOT change original CRISM format filenames**.
- User is asked if they would like to use all angles of the EPF or only a subset.
    - If ALL: User is asked to select a single .IMG file from the EPF series. The program assumes that all other EPF IMG files reside in the same directory.
    - If SOME: User selects EPF .IMG files of interest.
    - The program assumes that related DDR files can be found in the appropriate location if user has adhered to APL directory structure -- if geometry info is not found, user is asked for the location of a single related geometry file, the program assumes that the other EPF DDR files are in the same location.
- User selects which band they would like to inspect from a list retrieved by using info in .LBL file and CDR6-SW and WV files to determine the bands available to inspect.
- The output projection uses single nearest neighbor resampling to the smallest pixel size. Presently, the program uses geographic lat/lon as the output projection. **NOTE: I don't think ENVI's projection routines can handle pole crossing observations.**
- The program will open and close files as necessary.
- Calls CAT programs: epf_event.pro
read_crism_lbl.pro
find_geofile.pro
find_cdr6file.pro
- Uses: CDR6-SW and CDR6-WV

Project and Plot:

- **To be used with standard PDS format files; not CAT-ENVI data.**
- To spatially project a single band from multiple angles of the same EPF to visualize area of overlap and to plot the evolution of i,e,g values as well as I/F vs. emergence and phase over the course of an EPF. Plotted values are averaged over either the entire overlap area or a user defined area.
- Program will project data band following procedure used above by "Project Band Overlap" and will also project the i,e, g planes.
    - If user is subsetting the area, the ENVI_SELECT widget opens where the user needs to choose the projected scene data, from items in the Available Bands List (note: not the projected angles; the scene data can be difficult to locate because all layers produced by this routine are referred to as "In Memory" but the band names are explicit: the scene data band names will refer to the Band selected by the user and will usually be the first item in the Available Bands List), and choose the "Spatial Subset" button in the same widget to indicate their desired spatial subset. The spatial subset can be defined with sample/line ranges, geographic lat/lon ranges or *previously* defined ROIs. (Note: ROIs are created using: Basic Tools -> Region of Interest -> ROI Tool)

- The program will open, close, and write files as necessary. Program produces 4 items in the available bands list: stacked layers of the projected incidence angle, emergence angle, phase angle, and data.
- The output projection uses single nearest neighbor resampling.
- Calls CAT programs: epf_event.pro
  read_crism_lbl.pro
  find_geofile.pro
  find_cdr6file.pro
- Uses: CDR6-SW and CDR6-WV

****

SPECTRAL ANALYSIS UTILITIES:

Spectral Summary Products: **(works with PDS or CAT-ENVI files as input)**

- **For TRDRs, RTRs,MRRs**… To use with spectral scene IF or AL data.
- User can choose to run all or a subset of either VNIR or IR summary products and have the option to output the results to memory or file.
- **Output summary product files are BIL.**
- Parameters calculations **DO NOT account for spectral smile**. The "sweet-spot" wavelength array is used to determine which rows are used in the calculations.
- Calls CAT programs: mro_crism_summary_params_envi.pro
  mro_crism_summary_params.pro
  mro_crism_lookupwv.pro

Run MGM on IR Data: **(works with PDS or CAT-ENVI files as input)**

- **For L or J detector TRDRs, RTRs…** To use with spectral scene data from the L or J detector only.
- Program runs the Modified Gaussian Model (Sunshine et al., 1990) to fit broad 2 µm pyroxene absorptions with 2 additive Gaussians and distinguish relative proportions of LCP and HCP; outputs 6 bands:
  - BDLCP: Low calcium pyroxene band depth
  - BDHCP: High calcium pyroxene band depth
  - NBDLCP:(BDLCP/BDLCP+BDHCP): LCP normalized band depth
    - When olivine is < 10-15%, this value is good to ±10% (Kanner, et al. 2006).
  - RMS: RMS Error of model fit to observed spectrum
  - deltaRMS: Change in RMS of fit in last two iterations
  - NITER: number of iterations it took to converge
- Uses the SW wavelength array; runs on wavelength range from 1.1 - 2.54µm. For hyperspectral data, user has the option to run the routine using all bands in the above range or just the multispectral subset. The advantage of the latter is speed of processing.
- Routine only runs when entire spectrum is "finite" (i.e., no 65535 values). If the entire spectrum is not finite, all above bands are filled with 65535.
- The fit is considered to have converged when the change in the RMS error between one iteration to the next is less than 1.e-5. If the fit does not converge in 10 iterations, the first three bands above are filled with 65535.

Spectral Stats:

- Calculates spectral statistics for input file.
- User is asked to select the file they would like to work on from open files within the ENVI session. Spatial and spectral subsetting are allowed.
- User has the option to calculate the following spectral stats:
  - Max
  - Mean + Stddev
  - Mean
  - Median
  - Mean – Stddev

    - Min
- Output can be written to memory or disk and is in the form of an ENVI spectral library file.
- NOTE: This procedure is similar to that of ENVI's "Basic Tools: Statistics: Compute Statistics" but with "Median" as an option.

****

MAP UTILITIES:

Project Data: (works with PDS or CAT-ENVI files as input)

- **For EDRs, TRRs, RTRs, DDRs**
- To project an open TRR/RTR or DDR data using lat/lon geometry information in appropriate DDR.
- User is asked which open file they would like to project. (If the file being projected is not a geometry file, the program will open the geometry file.) The program uses some intelligent searching to find the most recent corresponding geometry file (see General Notes above); if not found, user is asked for the location of the related geometry file.
- Spectral subsetting is allowed.
- Users have the option to output to memory or a file. (Since analysis operations are typically done on unprojected data, the CAT does not need to track info about the output file. Therefore output files have only a standard ENVI hdr file, not a CAT-ENVI header and users do not have to adhere to suggested output names.)
- Projections:
    - Although ENVI has a nice widget for user selection of map projections, it unavailable within ENVI programming. Therefore standard defaults are used by this routine. If a user would prefer a projection different than the default, they can always project data using ENVI's "Map: Georeference From Input Geometry" tools.
    - Mid-latitude data are projected into **Mars Sphere-Based Equirectangular (with a spherical datum)** space with the longitude of central meridian defined as the median longitude of the observation and the latitude of true scale defined as the equatorward latitude of the tile containing the ~~upper left latitude and longitude~~ maximum latitude of the observation. NOTE: this is slightly different than the MRO standard convention, which should use the "upper left latitude", but it was significantly easier to code this way. Will evaluate a change later if this causes problems.
    - Data with a minimum latitude > + 65° or < -65° are projected into **Mars Polar Stereographic (with an ellipsoidal datum)** space with the downward longitude defined as the median longitude of the observation and the latitude of true scale defined as +90 for northern hemisphere observations or -90 for southern hemisphere observations.
    - In order to determine the reference lat and lon, I believe it is necessary to first save the projected output as an ENVI file in addition to any other desired formats. The associated .hdr file has all of the map and projection info.
- The program will open and close files as necessary.
- The output projection uses single nearest neighbor resampling.
- Calls CAT programs: projection_event.pro
  find_geofile.pro

LATLONINATOR:

- **To be used with projected data only.**
- Returns planes of map information (lat, lon, meters E, meters N) covering the entire area of projected space included in the input file. (Like generating a DDR of a projected area.)
- Calls CAT programs: latloninator.pro

****

CATNIP: CAT Noteworthy Interim Procedures

Flatten Summary Products:

- Use to applies Scott's filter correction to summary products presented at the CRISM science team meeting in June 2007.
- User is asked to select the file they would like to work on from open files within the ENVI session.
- Output can be written to memory or disk.
- **OUTPUT FILES ARE WRITTEN AS BSQ.**

****

ADDITIONAL UTILITIES:

Plot_Function: Median:
Access through Plot window "Plot_Function" menu.

- Applies a 3 channel median filter over any spectrum loaded into the plot window.
- This is basically a toggle function and users can always select "Plot_Function: Normal" to return to the unfiltered data.
- This function is for display purposes only and does not affect the data in the plot window.

CRISM Z-Profile: (**works with PDS or CAT-ENVI files as input)**
Access through Display window "Tools:Profiles" menu.

- To plot a spectrum with the appropriate wavelength array as defined in the CDR4-WA (for TRRs) or CDR4-RW (for RTRs) file.
- Requires file to be already open in ENVI and in a display window.
- Requires file to have a .LBL file to get info on the wavelength file to use; program looks for the .LBL file is in the same directory as the file being opened but allows user to locate it if not found automatically. For this reason, this feature cannot be easily used with "In Memory" items, however, the user can answer a number of questions that will allow this procedure to still run (primarily by directing the code to a LBL file with the appropriate information).
- Presently, the "MRO:WAVELENGTH_FILE_NAME" keyword in the .LBL file is not being correctly populated. Once it is, if CRISM Z-Profile is being used on a non-in-memory item, the procedure should run without user interaction; but presently, the user is required to select the appropriate CDR4-WA file—see the CRISM SIS explanation of the CDR4 naming convention to understand which file should be selected. Also, once the file is selected, users will get a popup explaining that this is not the file listed in the LBL file, just choose to proceed regardless.
- NOTE: THIS PLOT WINDOW DOES NOT UPDATE ITSELF UPON CURSOR MOVEMENT OR FILE LOADING…IT HAS TO BE EXPLICITLY CALLED AGAIN.
- Calls CAT programs: crism_zprofile_event.pro
find_cdr4file.pro
read_crism_lbl.pro
- Uses: CDR4-WA or CDR4-RW

ENVI_HiRISE_Toolkit: Includes the following features:

1. File: Open External File: MRO: HiRISE RDR
    - Use this utility to open the HiRISE datasets. This menu option should be used when opening HiRISE images in PDS .JP2, PDS .IMG, JPEG, PNG, and TIFF file formats.
2. File: Open External File: MRO: View PDS Metadata
    - Use this utility to view the PDS metadata in an interactive viewer.
3. Basic Tools: Calibrate HiRISE to I/F
    - Use this utility to apply the scaling factor & offset.
4. Within a main image or zoom display window of HiRISE data, you can clickand-drag with the middle mouse button and see a custom cursor location dialog that display both planetocentric and planetographic coordinates. This utility does not work within the Scroll window as the middle mouse button performs the meta scroll functionality.

See the file ENVI_HiRISE_Toolkit.pdf in the CAT_ENVI/aux_files/HiRISE_Toolkit/ folder for more details.

****

REFERENCES:

Sunshine, J.M., C.M. Pieters, S. Pratt (1990). Deconvolution of mineral absorption bands: An improved approach. *J. Geophys. Res.*, **95**, 6955–6966.

Kanner, L., J.F. Mustard, A. Gendrin (2006), Assessing the limits of the Modified Gaussian Model for remote spectroscopic studies of pyroxenes on Mars. *Icarus*, **187**, 442-456.