### TIRS 40 Minutes Radiometric Stability Characterization

#### Background/Introduction

This algorithm provides for on-orbit characterization of the radiometric stability of the TIRS, specifically related to TIRS RD requirement (TIRS-547) “Thermal band data for all pixels, after radiometric calibration per 5.3.1.2, for radiometrically constant targets with radiances greater than or equal to the radiance corresponding to TTypical, shall not vary by more than plus or minus 0.7% (1-sigma) of their radiance over a 40 minute period.” This algorithm is to be implemented, at least initially, as part of the CVTK.

For the TIRS apparent response stability is related to multiple contributing factors:

1. Background response and dark response stabilities over the 40 minutes
2. The reference constant source stability stabilities over the 40 minutes
3. Validity of CPF used to produce the radiometric product such parameters include the non-linearity correction and the conversion to radiance parameters.

 In other words if any of these CPF parameters may have some thermal or temporal

dependence that are not accounted for it would impact the interpretation of the actual response stability results.

Furthermore, although primarily focused on product stability this tool can also be used to understand the stabilities of several of the instrument sub-systems. Establishing baseline characteristics of the instrument stability will help in verifying the time it will take to return to nominal operation after lunar collects or other non-routine orbital operations. Baseline time duration for such return-to-nominal period would be based on telemetry information and could be complimented by the metric generated by this tool.

Key telemetry information associated with TIRS stability includes: Temperatures, (OBC, Telescope, SSM, FPA, FPE, MEB); Current and Voltages (OBC and FPE).

This algorithm uses deep space and OBC TIRS data to assess the within orbit product and instrument stability.

The basic concept of this algorithm is to analyze TIRS statistics from multiple 60sec segments within the stability evaluation interval of 36 min or 1.5 orbit. For each of the 60sec segments it compute the instantaneous stability parameters, which can be used then to gain understating on stability changes over the entire evaluation interval. Computing the 60sec stability parameters the algorithm is based on Hist\_stat processing outputs.

***Information about Input data types expected***

Two types of data collects will be used for these analyses. on board calibrator data and deep space data.. The OBC data will be at or above the temperature of 290K (current plan is to use 290K, 295K and 315K) then, manual interpolation analysis will be required to transform the stability results into the requirement temperature of Ttypical. Currently during on-orbit commissioning the main data collects that will be used by this algorithm are the continuous 36min data of OBC or deep space data as well as a repeated sequence of 30 Cal-sequence files over 1.5 orbit with once every 5 minutes collect sequence of 1 min deep space and 1 min OBC will be available.

This algorithm is designed primarily to work on TIRS data but could be converted to be applicable for both TIRS and OLI 36 minutes long collect. This algorithm can operate on all 3 TIRS bands (10µm,12µm, blind) but practical use will need only the 10µm and 12 µm bands data for product level performance assessment. For that reason the analyst can use a selection switch to select if this algorithm should process stability of TIRS blind data or just the imaging bands.

Similar to the 60sec stability algorithm this algorithm would rely on Histogram statistics Characterization processing to collect the basic statistics from either multiple scenes given in a sequence to form a virtual long interval or sub-segments of a long interval (that may be split into multiple files). The algorithm will populate the minimal set of radiometric stability metric as a standalone algorithm that is gathering the instantaneous stability information on each of the scenes or segments in the interval. In the case the scene provided is one long 36 min dataset (composed of several mission files) the algorithm will pre-process the input data to produce multi-segments statistics information needed for processing using a moving window of 60sec. The interpretation of the results requires that the scenes are temporally constant radiance, e.g., deep space and OBC acquisitions (those could be part of a special Cal sequence sweep with enough dwell time for the collections of the number of lines needed).

For deep space collect we use (L0r) input that will only be non-linearity corrected. For OBC collects we use both (L0rc) and (L1r) products as inputs.

***Information about Output produced and its interpretation***

The output of this tool enables trending of : instantaneous stability of segments for the response, and stability over the 36min duration or longer.

The output mimics the 60s stability algorithm configuration where the output depends on the input data provided, i.e., OBC or deep space. Stability statistics across the scene segments are calculated from these uniform radiance scenes and stored in the characterization database. Using collects made at the nominal integration time the statistics are calculated by Histogram Statistics. Multiple levels of processing will be used by this algorithm. Six categories of outputs will be produced:

1. Background response band average stability (deep space, non-linearity corrected)
2. OBC response band average stability –(background corrected and non-linearity corrected)
3. Radiometrically corrected OBC response stability in radiance
4. Radiometrically corrected OBC response stability in %
5. Optional – Detector-by-detector Radiometrically corrected OBC response stability in % (for operability characterization)
6. Optional –Detector by detector background response stability (for operability characterization)

The OBC L1r product stability metric will be converted from radiance units to % so it can be evaluated against the 0.7% requirement level. OBC L0rc data will be used to characterize the band mean net response stability in the various segments over the data duration interval (36 min or longer).

***Additional considerations***

It is recommended stability acquisitions be routinely collected and assessed, in the following conditions: after standard TIRS operations in either Earth sun-lit or night part of the orbit, after Lunar or Solar collects with 5 minutes margin from the time TIRS returned to Earth view nadir pointing (the 5min period is driven by TIRS requirements and SC pointing stability allocated period).

The output of this algorithm can be used by subsequent algorithms that trend detector level characteristics.

TIRS radiometric conversion parameters are assumed invariant after the background corrected response is computed. Trending of the output of this stability algorithm could assist in validating this assumption.

Future developments on this characterization processing may include the use of OLI data and TIRS Earth - night ocean long passes.

To obtain a better representation of the TIRS stability will require additional analysis and correction of any influences of low frequency drifts in the TIRS and OBC temperatures induced by the data collection conditions. This will require the analysis to correlate between the trended results to the various subsystems telemetry information.

#### Inputs

This algorithm works with two types of source data a single long continuous collect or multiple short segments over a longer period..

The expected input will be produced by Hist\_stat or the special long data Hist\_stat algorithms which would operate on either a pre-processed data given in the format of a set of 30 4200 lines files (covering the period of 150 minutes) illustrating 30 interval sub-segments, or pre-processed data given in the format of a set of 36 4200 lines files illustrating 36 interval sub-segments (covering the continuous 36 min collect).

Inputs per segment are highlighted; inputs common to the full dataset are not highlighted. Note that when correlating telemetry data to this analysis it should be done in the same timing intervals of the segments used for the instrument response.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Descriptions** | **Symbol** | **Units** | **Level** | **Source** |
| Interval Segment Signal Mean |  | Float[DN] or [w/m2 sr um] | NBxNSxND | Long collect statistic Characterization [[1]](#footnote-1) Stat Char  |
| Interval Segment Signal Max |  | Float[DN] or [w/m2 sr um] | NBxNSxND | Long collect statistic Characterization 1 Stat Char *Qmax* |
| Interval Segment Signal Min |  | Float[DN] or [w/m2 sr um] | NBxNSxND | Long collect statistic Characterization 1 Stat Char *Qmin*  |
| Interval Segment Signal StDev |   | Float [DN] or [w/m2 sr um] | NBxNSxND | Long collect statistic Characterization 1 Stat Char *σ* |
| Number of frames | NBR\_of\_frames | Long |  | Long collect statistic Characterization 1 Stat Char *number of frames* |
| Interval segment ID or segment start line (line time tag) | Seg\_ID | Float [s] | NSEGMENTS | Long collect statistic Characterization Acquisition time for the first frame of each segment *t1* |
| Scene Type (i.e O\* or D\*) | Stype | Char | NB  | DBL0Rp Image file  |
| Processing Step (i.e., before or after Gain application) | Pstep | String | NB | Histogram Stat Char Position in processing flow (RPS Level) |
| Segment window size (lines) | Seg\_win | Int |  | Analyst input /pre-processing default set for 60sec duration – i.e., 4200 lines |
| Relative gains  | r | [unitless] | NBxNSxND | CPF  |
| Impulse Noise Pixels Locations | LM1 | Integer | NBxNSxND xL | LM |
| Saturated Pixel Mask[[2]](#footnote-2)  | LM2 | Integer | NBxNSxND | LM |
| Dropped Frames Mask  | LM3 | Integer | NBxNSxND xL | LM |
| Inoperable Detector List  | Dinop | Float | NBxNS | CPF |

#### Outputs

Outputs will mimic the provided segmentation of the input data (i.e., even if actual data was given as a single continuous collect since its inputs from the special long hist\_stat processing will be chopped into multiple segments then the output DB will include results per segment – only in this case the segments are artificially produced by a moving window with in one or more mission data files).

Per interval segment populate these outputs

The algorithm will need to process the data from all segments before the analyst could assess the stability results for the full interval.

For Segment I the output to DB is :

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Descriptions** | **Symbol** | **Units** | **Level** | **Target** |
| Signal Variability, SCA average |  | Float [DN] or [w/m2 sr um] | NB x NS | DB (Bias, Gains & OBC L1R Stability) |
| L1r Product Variability, SCA average  |  | Float [%] | NB x NS | DB (Gains & OBC L1R Stability) |
| SNR Variability, per-detector [[3]](#footnote-3) |  | Float [%] | NB x NSxN D | DB (Gains & OBC L1R Stability) |
| Scene Type (i.e O\* or D\*) | Stype | Char | NB | DB |
| Processing Step | Pstep | String | NB | DB |
| Interval segment ID or segment start line (line time tag) | Seg\_ID | Float | NSEGMENTS | DB  |
| Segment window size (lines) | Seg\_win | Int |  | DB |

#### Options

Trending On/Off Switch: If trending is Off, output parameters are written to a text file.

Comp stat switch: ON – compute statistics, Off – import stat data from hist\_stat (default)

Collect type ID – Cont 36min / 1.5 orbit data

Window sizes – full (default) , 4200, User selected between 100-64000 ; if collect type ID is Cont 36min the window size parameter will be used to define the segment size ; If Comp-stat switch is Off segment window size will be imported from hist\_stat.

Processed Blind\_band – Yes / No

#### Procedure

Note that in order to characterize TIRS radiometric stability we call this algorithm at least 3 times: Once to process long Deepspace data, and twice to process the data for the closest long OBC collects (once using the net linearized response L0rc1 intermediate Cal product and once using the radiometric corrected L1R product.)

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Pre-Processing (creating sub segments generating the input data needed and computing Hist\_stat info for each segment) The preprocessing brings either Collect type into a fixed input format.

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1. Pre Process the data (if in multi mission data files continuous or multi-segments of Cal-sequence)

Check if Collect type option is Cont 36min data

If No – get sequence of 30 scenes IDs to processes through this ADD

If yes chop the 36 min data into smaller segments in the size of Window\_size input parameter

i.e., Qinterval(b,s,d,l) - > { Q1(b,s,d,l) ; Q2(b,s,d,l) ; …. Qn(b,s,d,l) }

where the last line in Qn is the last line in Qinterval and all segment are set to equal size (Seg\_win).

For a default window size there should be 36 scene IDs generated.

For all segments produce or obtain from DB the input histogram information needed for the algorithm.

1. On each scene or segment (30 or 36 segments) within the interval proceed to the following steps of 3-8

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Calculating statistics (possibly can be retrieved from Hist Stat DB for the scene or segment)

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1. Based on the Labeled Mask and detector operability list omit those detectors when calculating SCA level averages.
2. Populate histogram statistics metric per detector in the relevant variables and calculate the average across all detectors within an SCA.
	1.  (1)
	2.  *Qmax* (2)
	3.  *Qmin* (3)
	4.  *σ* (4)
	5.  (5)
	6. Get *number\_of\_frames* for the interval segment
	7. Get Interval segment ID from input (this will be related to the segment’s first line time tag)
	8. Note that calculations should only include operable and in-spec detectors. (i.e., ignore pixels flagged as inoperable, saturated, dropped frame, impulse or fill.)

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Calculating Stability of Signal

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1. For each detector, calculate the 1-sigma the along-track variation in the image that is at the length of the segment window or segment duration.

$∆Q\_{(B,S,D)}=1 × Sigma\\_\overbar{Q}\_{(B,S,D)}$ (6)

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Processing data to generate outputs

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1. Calculate the SCA average variability, i.e, the average across all detectors within each SCA:
2.  (7)
3. For TIRS deep space data, record the SCA mean variabilities () of every segment or scene within the interval to the database or output file (along with other specified outputs in the output table). This is the end of the algorithm for processing TIRS deep space data.
4. For TIRS OBC data process and record what is done up to step 7 and also do this :
5. Calculate the per-detector variability in terms of percent change. It illustrates the impact of individual detectors on the overall radiometric stability.
6.  (8)
7. where rD is the relative linear gain used for conversion to at aperture radiance from CPF for L0Rc data and 1.0 for L1R data.
8. Calculate the SCA average variability in terms of percent gain change:
9.  (9)
10.  should be calculated using the same list of detectors used to produce the mean signal in equation (5)
11. For L0Rc data, write the per-detector percent variability () and the SCA average variability () of every segment or scene within the interval to the database or output file (along with other specified outputs in the output table).
12. For L1R data, write the SCA average percent variability () of every segment or scene within the interval to the database or output file (along with other specified outputs in the output table).
13. For L1R if output to file selected also write to file the per-detector variability () and the SCA Radiance mean variability ()of every segment or scene within the interval (along with other specified outputs in the output table).

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1. Once all segments or scenes had been processed analyst will work offline to extract information from DB to generate various plots and test correlations to telemetry data. Most of this follow-on analysis is not automated or strictly defined by this algorithm but it may ultimately include plots of the SNR variability over the interval and use such plots to identify detectors are 5 time less stable than the overall band stability characteristics assisting with detector operability characterization. Other likely plots are plots similar to lamp response trending – trending mean response Vs. time and stdev of response Vs. time in each segment over the 36 minute or longer interval.

#### Maturity

Level 2 (reuse portion of 60s stability algorithm).

The algorithm essentially repeats the 60s stability computations (with slight modification) per segment within the long interval being evaluated. The only part that is new is that it is capable of working with a sequence of individual small scenes or one long scene that get spliced into a moving window segments. This ADD enable processing that can either work on the data directly – or to be a stand-alone algorithm that uses the DB produced by a special variant of the histogram statistics algorithm which computes the information per segment for a long continuous collect. The output table should be linked to an single interval ID , and the output metric is stored per segment will be linked to its corresponding interval. Regardless of the version of the data input provided (a one long file or multiple segment files) the output in DB should be organized the same way.

Change from 60s Stability - 2x Sigma in Eq. (6) is now only 1 x Sigma

1. Histogram data will be collected from different level of processing i.e., L0R for Dark Shutter data, L0Rc for OBC and at L1R for OBC product. [↑](#footnote-ref-1)
2. This mask should include any of the detectors that had been reported by the Saturation characteristics processing, i.e., high and low saturations in both digital and analog categories [↑](#footnote-ref-2)
3. We will not store in DB the OBC L1R calculated per detector gains 60 stabilities but it will be calculated and written to an output file if the option of trending is turned off. [↑](#footnote-ref-3)