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NPOESS Community Collaborative Calibration/Validation Plan for the NPOESS Preparatory Project
VIIRS Imagery EDR

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Prepared for
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1.0 Objectives

The Imagery EDR can be best thought of as an extension of the SDRs that support it. Essentially imagery is the SDRs projected onto a fixed grid, in this case the Ground Track Mercator (GTM) projection. For imagery "mission success" would be that the imagery is "operationally viable", i.e. it is good enough to provide information to the Centrals and their dependent users. The Imagery EDR also has requirements it must meet in the System Specification (Sys Spec) that must be verified. The objective of this plan is to provide the actions necessary to prove if imagery is operationally viable, and meets the Sys Spec, or not.

The Sys Spec gives quantitative requirements regarding imagery. These can be found in section 40.2.3 in the Sys Spec and Appendix B of this document. However this is not sufficient to prove operational viability. The Sys Spec states the system must be able to identify certain features over 85 – 90% of the image, but if striping is evident over, say, 8% of the image it will not be perceived as useful to the Centrals. Practically therefore the imagery must be better than the Sys Spec. Other critical uses, such as identifying ocean features by NAVO and dust and blowing sand by AFWA/FNMOC, will also play a role in the evaluation of imagery, even though no such requirements to identify these features are levied on NPP/NPOESS. Note the Sys Spec requirements are nevertheless part of the Imagery Cal/Val plan.

Operational uses for imagery include the manual manipulation of the image to identify cloud presence and cloud type, sea ice concentration and edge, snow, certain types of suspended matter, and ocean features. This manipulation is primarily based on altering the contrast across the image and the overlay of different channels covering the same scene. A few organizations, especially NRL-Monterey (via their NexSat tool), use the imagery in a quantitative fashion in combination with overlays.

VIIRS is expected to perform at least as well as all heritage satellites, and is expected to be superior to both the DMSP OL-S and the POES AVHRR while at least as good as MODIS. Although the use of MODIS is increasing, the DMSP and POES programs remain the primary imagery used by most Centrals and will be considered "heritage" in this document. Heritage performance is currently assessed subjectively by the Centrals. In that regard, if the Centrals can use the imagery in a manner similar to today's usage, the Imagery would meet the operational viability criteria.

The following list ties organizations with their primary interest in exploiting imagery. This list is not intended to be complete, and does not exclude the use of imagery for purposes other than those listed below. Imagery must be useable under all atmospheric conditions; there are no degraded/excluded conditions applicable to imagery.

I. AFWA – Cloud presence and type, blowing sand and dust, volcanic ash, snow
II. FNMOC – Cloud presence and type, oceanic features, aerosols
III. NAVO – Oceanic features
IV. NIC – Sea ice edge and concentration
V. NRL/Monterey – Cloud type, aerosols and blowing matter, quantitative applications

VI. NOAA/NESDIS – Atmospheric events (hurricanes, convective storms, etc.), snow and ice

2.0 Approach

The scope for evaluating imagery involves both Subject Matter Experts (SME) and non-experts, and must consider the diverse uses of imagery across the spectrum. It includes critical interaction with the VIIRS SDR Cal/Val team, as most of the potential problem with imagery would be addressed by the SDR experts. Our approach first screens the usefulness of the imagery by SME; then submits the imagery for assessment by the remaining team members and their associated organizations.

No further pre-launch activity is expected regarding the Imagery EDR (we are deferring to the VIIRS SDR team any further pre-launch work). However, the development and adaptation of tools for assessing imagery will need to be completed prior to the launch of NPP. Post-launch work will be in two sequential “steps” (referred to below as simply step 1 and step 2), both during the Intensive Cal/Val (ICV) phase. The first step will be for SMEs to evaluate the quality of the imagery itself. This small group will be comprised at a minimum of one SME from the military (AF or Navy, civil service applies), one from NGAS, and the Imagery Cal/Val discipline lead, and will focus on the overall quality of the imagery with a emphasis on items that would interfere with the usefulness of the image, to include striping, scattering, ghosting, and errors in band-to-band registration (BBR) that prevents proper overlays of the imagery. Once step 1 has been accomplished, and these artifacts have been reasonably repaired, we will submit the imagery to the rest of the Imagery Cal/Val team for evaluation as part of step 2. During step 2 they will evaluate imagery based on their needs and the “operational viability” criteria that defines’ their use of imagery as defined in section 3. It is also during step 2 to perform the quantitative analysis of the imagery relative to the SS, though it is possible to begin this work in Step 1. Details on specifics related to verifying the Imagery with respect to the Sys Spec can be found in Appendix B. There are no Long Term Monitoring (LTM) requirements explicit to Imagery.

Most organizations have tools in place to exploit imagery, though not necessarily VIIRS imagery. The organizations involved with the Imagery Cal/Val effort have all agreed to modify their existing tools to exploit VIIRS. All members of the team at this time will have access to the Imagery EDR either though the IDPS (in the case of the Navy, through AFWA, for the NIC, through NESDIS), via CLASS, or through GRAVITE. As such, this minimizes the risk of evaluating imagery produced by platforms independent of the IDPS.

SME Expertise is needed for the first step, where the experts must be able to explain back to the SDR team both the problem on the imagery and its’ likely cause. The second step does not require a high level of expertise, but each organization on the Imagery Cal/Val team should be represented by a “typical” user who focuses on those needs for that particular organization (i.e. clouds at AFWA). The team members will work hand-in-hand to evaluate the imagery in a quantitative manner as well to verify the imagery meets the SS.

Since imagery does not depend on ancillary data or other EDR/IP, the amount of data required is tied only to the amount of imagery that needs to be assessed. Different organizations will focus on different features, so the amount of imagery will be fairly large. The actual amount of imagery is dependent on the users' objective, but none will use a pre-determined limit. For example, the NIC's focus on ice would clearly limit their needs to snow and ice covered areas, but AFWA's cloud mission is global. Imagery has no ground truth.

The time needed to assess the imagery is not large compared to other EDRs, what is more difficult to determine is the amount of time the SDR team will need to address the issues and concerns we find in step 1. Step 1 will likely take no more than 3 Full Time Equivalents (FTE) over 30 days of actual labor, but if the problems discovered prove to be difficult to fix than it could be more than 6 months of real time before we are ready for step 2. This plan is NOT saying step 1 will take 30 days (unlike the VCM plan where step 1 is in calendar days), since the amount of time is influenced strongly by the quality of the SDRs and the time it will take to address SDR issues. On those matters see the SDR plan. Also note since the imagery is simply a projection of SDRs on the GTM grid; any problems are expected to have their root cause in the SDRs themselves, and not be a "science" issue. The one exception is striping, where mitigation methods may be better inserted in the EDR software than at the SDR level. Step 2 should take no more than 2-3 calendar months to complete, although it may take longer for the quantitative analyses to be completed, possibly 4 months or so. Step 2 cannot begin until the majority of the SDR issues have been resolved.

3.0 Schedule and Milestones within IPO-Defined Phases

At a high level, the exit criteria are when the Centrals and their dependent users are satisfied with the imagery to the point they would choose to use it operationally. We expect this to occur in the first year of ICV. One can break that idea into two parts 1) that distractions to the human eye (i.e. striping) are minimal and 2) the VIIRS imagery is adequate to identify and locate atmospheric and ground features correctly. The first is primarily evaluated in step 1, the second in step 2. The quantitative analysis will be performed in step 2. Despite a strong dependence on the VIIRS SDR, the Imagery EDR will contain its' own maturity levels. The imagery product is defined by each of the Cal/Val maturity level definitions as follows:

a. Beta – The imagery EDR is produced consistently but has undergone only minimal validation and is not suitable for operational use.
b. Provisional – The imagery has passed step 1 above for evaluation by the Centrals, but has not been accepted by any of the Centrals as operationally viable.
c. Validated Stage 1 – The Centrals acknowledge that for clouds and sea ice, the two atmospheric items that the SS has explicit requirements to meet, imagery is suitable for operational use.
d. Validated Stage 2 – The IPO and NGAS agree the imagery meets or beats the Sys Spec.
e. Validated Stage 3 – The Centrals acknowledge the imagery meets all operational viable criteria, to include real-time applications not considered in the Sys Spec. These include identification of SST gradients, use in aerosol detection, and NexSat applications.

The activities to accomplish the two steps are straightforward, as they both involve manual interpretation of the imagery. Step 1 is the SME's working with different channels and various combinations of channels to identify artifacts that distract and prevent successful application of the imagery, including using combinations of bands.

Coordination with the SDR team will be critical at this juncture. Step 2 involves bringing in the team members representing the different Centrals and NGAS and incorporating their various specific interests. As each of these members verifies the imagery is at least satisfactory, they will be checked off until all acknowledge the imagery to be operationally viable. As stated earlier, the quantitative analysis will also be performed during step 2.

As indicated earlier, we foresee the actual work of step 1 to take approximately one month of labor; however this does not include any repair time needed by the SDR team. Step 2 will take 2-3 months for the Imagery Cal/Val team but we expect the quantitative analysis to take longer, at this time about 4 months.

We plan to document the completion of each of the two steps. This is necessary to show the broader community what was done and who performed the work. Examples of the imagery, either successful (to show how features of interest can be determined) or unsuccessful (large striping impacts) will be part of these documents. At the end of step 2, we expect each member organization to have signed off that the imagery is adequate, or have explanations as to why it is not. We will work with the IPO on exactly how this procedure will work, but all identified discrepancies will be tracked through the Issues Tracker Database maintained on CasaNosa.

4.0 Resource Requirements

The imagery Cal/Val team members at this time include Chris Elvidge (NOAA/NESDIS), John Eylander (AFWA), Jeff Hawkins (NRL-Monterey), Jeff Tesmer (FNMOC), Pablo Clemente-Colon (NIC), Keith Hutchison (NGAS), Mike Plonski (NGAS), and Thomas Kopp (Aerospace). In some cases these personnel represent a POC for their organization and they may tap other personnel to perform the actual validation of the imagery.

The expertise required has been discussed previously. The initial SMEs for step 1 will include, at a minimum, one military (this includes civil service) representative, one NGAS representative, and the Imagery Cal/Val lead. This group will also establish appropriate granules for the quantitative assessment expected in step 2. Step 2 will include all of the organizations listed in section 2.

Step 1 will require 3 FTEs for 30 days; though note this does not mean step 1 will be accomplished in that time frame. Step 2 is more loosely organized, depending on the availability of personnel, but overall will be a larger effort. At this time we estimate 5 FTEs over 3 months.

The team members are identified in section 2. All of the organization team members except Chris Elvidge are co-located with NPOESS Centrals. However Chris works with user communities, including the DoD, which have a high dependence on imagery.

Section 1 correlates the organization with the specific parameters that organization is expected to focus on. The exception is Chris Elvidge, who primarily works with the Day-Night Band (DNB). Thomas Kopp has broad expertise and will work with each team member to determine the imagery channels most appropriate for their assessment. NGAS personnel will lead the quantitative analysis work. All results will be aggregated by Thomas Kopp and Mike Plonski.

Allocation of funds will not be discussed in this document. As stated earlier, each organization will modify its' existing tools to be able to read in and evaluate VIIRS imagery. Hence each organization essentially "sponsors" itself, with the exception of NGDC (Chris Elvidge), who is sponsored by the IPO. Each organization has committed to modifying its' tools as necessary.

With respect to other Cal/Val teams, the only coordination required is with the SDR team; however many members of the Imagery team also work on the VCM Cal/Val team, so those resources need to be coordinated closely.

The coordination with the SDR team is critical to the success of the imagery EDR. It is a reasonable assumption that all artifacts noted in the imagery will have their root cause as a SDR problem. The SDR plan includes visualizing the SDRs, which will be the first indicator of problems with the imagery EDR, in most cases before the Imagery EDR work begins. Dr. Mike Plonski is also a member of the NGAS SDR team and can provide coordination within NGAS. See Appendix A to this document and the SDR Cal/Val plan for the details on this work.

Since the Imagery/VCM team contains the same leads for both the IPO (Dr. Thomas Kopp) and NGAS (Dr. Mike Plonski) coordination between the Imagery and VCM teams will be handled by those two. The VCM will be difficult to tune until the imagery is sufficient to support tuning, hence both the IPO and NGAS must be part of step 1 to insure that is the case. Imagery work will begin before the VCM work, on the order of weeks. For the criteria needed on imagery to support the VCM, see the VCM Cal/Val plan.

Validation data does not exist for the imagery EDR, given that the sole purpose of imagery is manual interpretation of the image. Therefore validation primarily would come by multiple users agreeing on the features noted in the imagery, or at a minimum a non-SME being able to determine the atmospheric features in a given image. Our initial estimate is to use 10 sets of 3 granules for the quantitative portion of the analysis. This quantitative analysis will be based on a single SME producing an analysis of cloud features in a granule and two other SMEs verifying the results. Operational viability will be determined by the non-SMEs using imagery in a simulated operational environment, set up by each of the participating organizations consistent with their mode of operations. Appendix B discusses this in more detail.

If an imagery artifact was the result of a calibration issue, we would expect the SDR team to work that issue. No trending data is needed to explicitly monitor the imagery EDR. Experience with other operational satellites indicates that typical calibration changes needed for "stability" do not affect the quality of the Imagery. If larger changes become necessary, that would indicate the SDRs are not suitable for the Imagery assessment to begin.

The production of imagery does not require substantial computing resources, but some coordination will be needed regarding the assessments of similar imagery from different organizations. As each organization on the Imagery Cal/Val team can access the imagery product produced at the IDPS, such coordination can be straightforward on a short time scale (within 24 hours). GRAVITE will also store imagery, as will CLASS. Although imagery is not often used in a historical context, if the need to reanalyze imagery becomes necessary, these sources are available to retrieve the imagery necessary to do so. The sets of granules used for the quantitative analysis will be stored on GRAVITE or NSIPS.

GRAVITE/NSIPS will be a centerpiece of the imagery work in step 1. GRAVITE along with NSIPS will be the source for imagery during step 1, when only a limited number of SMEs will be used. These SMEs will be co-located at one of the facilities with access to GRAVITE or NSIPS to review the imagery and give quick feedback to the SDR Cal/Val team.

The team's resources begin with the imagery manipulation tools in place at each location. The resources/tools are noted in Table 1 and described below:

I. Aerospace – To coordinate between the different organizations the available tools for imagery manipulation and to provide the IPO/GRAVITE with information on what tools to obtain or write on to the GRAVITE system. Aerospace will participate heavily in the evaluation of the imagery EDR in both steps 1 and 2.
II. NGAS – They will create the tool necessary for quantitative cloud evaluation of the imagery, specifically the purpose of manually identifying x% of cloud features as required by the SS in a granule, and for determining the number of cloud layers (step 2 only). During step 1 NGAS's role will primarily work through the SDR Cal/Val team in identifying and resolving imagery related issues.
III. NRL – To modify NEXSAT to be able to read and display images consistent with its' current use, and to evaluate NPP imagery for those purposes post-launch, during step 2.
IV. FNMOC – To modify their tools and evaluate the imagery EDR, as received from the AFWA IDPS, during both stages 1 and 2.
V. NOAA/NESDIS (NGDC) – To modify their tools and evaluate the DNB based imagery (referred to as Near Constant Contrast or NCC) in both stages 1 and 2.
VI. NIC – To modify their tools to evaluate the ability of the NPP imagery to locate sea ice and determine ice concentration (step 2 only).
VII. AFWA – To evaluate, through either their GRAVITE terminal or via their own tools, the ability of the imagery to identify cloud characteristics (TBR – step 2 only).

Organization	Point-of-Contact	Tool
AFWA	TBD	Using imagery to locate clouds. GRAVITE
Aerospace	Bruce Thomas Thomas Kopp	ANEPH front end visualizations
NGAS	Michael Plonski Keith Hutchison	Quantitative analysis tool
NRL-Monterey	Jeff Hawkins	NexSat
FNMOC	Jeff Tesmer	Using imagery for ocean features, clouds
NIC	Pable Clemente-Colon	Using imagery for sea ice and snow identification
NGDC	Chris Elvidge	DNB analysis

Table 1: Organizations, POCs, and Tools

At this time no new hardware is expected. No new software is expected among the involved organizations, but as indicated above some modification of pre-existing software will be needed. NGAS will need to create software for the quantitative analysis component of the imagery work. It is our intent to exploit imagery manipulation tools already in existence to the maximum extent possible.

5.0 Reporting

We currently do not have a list of official "IPO-defined reports". At this time, it is expected that the discipline lead, Thomas Kopp, with help from Mike Plonski, would write any performance reports, progress reports, and milestone documents required. Only three members of the team will be allowed to write imagery issues to the Data Tracker Issues Database. As of September 2008 these three are Thomas Kopp (Aerospace), Jeff Tesmer (FNMOC), and Mike Plonski (NGAS). Note this is the team lead plus one from the military and one from the contractor. All Imagery related issues must therefore go through one of these three. We expect the IPO to take the lead in monitoring the larger list of these items. Any mitigation strategies would be worked with the SDR team.

6.0 Areas of Concern

The greatest known risk for imagery is striping. This was noted with MODIS and there is every reason to believe it will occur with VIIRS as well. Methods for mitigating striping are known and with respect to Imagery come under two forms. If striping is significant within the SDR itself, the problem will be addressed by the SDR Cal/Val team. However if mitigating the striping in this manner results in undesirable effects on the SDR (i.e. inappropriate modification of the radiances themselves) then mitigation will be necessary within the Imagery EDR algorithm. MODIS already applies methods to mitigate striping, and our intent and expectation is to follow the MODIS procedure. Experience at NRL-Monterey using MODIS within their NexSat tool will also be useful here (see below).

The VIIRS SDR plan cites risks specific to SDRs, and two of them are of note for their potential effects on Imagery. These two are IR Ghosts and DNB Calibration Issues (see sections 1.3.1.2 and 1.3.2.4 in the VIIRS SDR Cal/Val plan). The VIIRS SDR plan includes a discussion explicitly for "Image Quality Evaluation" (section 4.3) where they will display VIIRS SDRs as a part of their validation procedures. The Imagery EDR team will collaborate with the VIIRS SDR team to define specifics on these procedures, where the risks noted above may be evaluated.

There is also risk with the Near-Constant Contrast (NCC) image built from the DNB. Key elements of the DNB cannot be simulated pre-launch, and with four known issues regarding the DNB SDR we expect some challenges to arise with the NCC imagery. Although BBR is expected to have a waiver for near edge-of-scan compliance, we do not expect at this time the waiver to adversely affect overlays of VIIRS imagery, though it still needs to be evaluated during ICV. The capability of the NCC Imagery will depend heavily upon the experience of NGDC and their use of the currently operational OLS sensor.

Any mitigation pre-launch relates to sensor characterization, which lies with the SDR team. The better the characterization, the fewer the number of artifacts expected in the imagery.

The experience with MODIS is valuable here, given the similarities between VIIRS and MODIS. The experience from both NOAA/NESDIS and NRL-Monterey in dealing with striping will be critical during step 1. This experience should lead to a more effective exchange with the SDR team and help minimize the time required to correct the imagery to an “operational viability” status. NRL-Monterey successfully dealt with striping in MODIS Imagery via an algorithm developed by the CIMSS group at the University of Wisconsin/Madison. The general nature of this algorithm gives us confidence a similar approach may be used with VIIRS Imagery if it becomes necessary.

Since the imagery EDR relies solely on the SDR, any issues concerning the SDR can be a factor for the imagery EDR. There are 21 known issues at this time dealing with VIIRS SDR. We defer the work on those issues to the SDR team. We will monitor their resolutions however, since it is clear some will be to “fly as is” or waivered, this could in turn adversely affect imagery. An example of this is the DNB, as indicated above, as well as the BBR at edge-of-scan.

There are no specified “Watch Items” for imagery at this time, with the exception of the NPOESS Customer Forum (NCF) Watch Item for the overall quality of the imagery, especially striping. Until the SDR issues are resolved one way or the other, such a Watch List at this time for imagery is premature. Once the VIIRS sensor has completed pre-launch sensor characterization, Watch Items concerning Imagery will be added to the plan. Any risks would also be part of this Watch List. Our expectations at this time are that striping, DNB blooming, and BBR will be part of this Watch List.

I.

7.0 APPENDIX A

We plan to include a consideration for validating cloud layers in association with the imagery Cal/Val effort. The manual interpretation and analysis of the imagery will include the number of layers in a 6 km grid cell as determined by the SME. There are no current success criteria for determining the number of layers, a detail we will work in later drafts. NGAS will tie this capability into their tool for assessing the imagery quantitatively; however the team will work with NGAS on the actual assessment of cloud layers. This will also require coordination with the Atmosphere Cal/Val lead.

Coordination with the VIIRS SDR Cal/Val Team is critical to establishing effective imagery. The Imagery Cal/Val Team will work hand-in-hand with the VIIRS SDR Team during ICV. The Image Quality Evaluation process (see section 4.3 in the VIIRS SDR plan) includes four tasks that apply visualization of the SDRs to determine the presence of undesirable artifacts, to include striping and banding. Note this evaluation involves the visualization of SDRs on the VIIRS native grid, and does not apply any transformations to the GTM projection. Other items applied to the Imagery EDR, such as interpolation to cover bad pixels, also would not apply here. The four tasks explicitly stated in the VIIRS SDR plan are: Quantify crosstalk, echoes, ghosts; quantify striping; quantify lunar echoes, ghosts; and validate the Line Spread Function (LSF) and Modular Transfer Frequency (MTF). Details of these tasks can be found in section 7.2 of the

VIIRS SDR Cal/Val plan. The Imagery EDR team will assist the VIIRS SDR team regarding these four tasks.

8.0 APPENDIX B

The objective of Appendix B is to identify activities and procedures needed to conduct calibration/validation (Cal/Val) of the VIIRS Imagery EDRs against requirements levied in the NPOESS System Specification (Sys Spec) for the NPP and NPOESS programs.

The EDR Cal/Val effort is a team activity that involves expertise from members of the government, research institutions, academia, as well as the NPOESS Contractor. Since the overall EDR Cal/Val tasks envisaged by the team cover a broader range of activities than those needed solely to assess EDR performance against the NPOESS Sys Spec, this section shall focus only on those tasks necessary to validate the Sys Spec. As a result, this plan leverages on the activities benefiting the larger community and identified in other sections of this plan.

Section 40.2.3 of the Sys Spec defines Imagery as two products:

1. A two-dimensional array of locally averaged absolute in-band radiances at the top of the atmosphere measured in the direction of the viewing sensor.
2. The corresponding array of Equivalent Black Body Temperatures (EBBTs) if the band is primarily emissive, or the corresponding array Top-Of-the-Atmosphere (TOA) reflectances if the band is primarily reflective during daytime.

Imagery is produced in a Ground Track Mercator (GTM) projection. Note while the SDR resolution is approximately the same as the Imagery Horizontal Resolution Interval (HRI), the SDR horizontal resolution varies slightly across the scan. The GTM projection is made using a nearest neighbor algorithm to remap the SDR pixels to the indicated HRI, so that in some cases pixels are replicated to fill the grid and in rare cases, and some SDR pixels are discarded. Also the Imagery grid may have fill values at the Edge of Scan at certain latitudes. In effect the SDR HRI maintains a constant angular spacing (within the 3 different aggregation regions), while the imagery maintains a constant HRI across the entire scan. Note the resolution requirement for imagery is a Horizontal Spatial Resolution (HSR) of 400m / 800m (nadir / edge of scan) and a maximum NCC HSR of 800m. A subset of 6 M-bands (Imagery assist) is also produced to aide in manual imagery interpretation, but there are no explicit requirements on these M-bands.

Imagery EDR Bands (12 total bands)	**Horizontal Reporting Interval**	**Imagery Granule Grid**	**SDR Granule Grid**
I-band (all 5)	375 m	1541x8241	1536x6400
M-band (selectable subset of 6 imagery assist bands) nominal M1, M4, M9, M14, M15, M16	750 m	771x4121	768x3200
Near Constant Contrast (NCC) derived from Day-Night Band (DNB)	750 m	771x4121	768x4064

Table B-1: Imagery EDR Band Resolution and Grids

Section 40.2.3 of NSS breaks down the Imagery EDR requirements into 2 groups:

1. Sec. 40.2.3.1 Explicit EDR Requirements: This includes all the physical attributes of the Imagery EDR including bands, resolution, refresh rate, etc. The NPOESS Key Performance Parameters for Imagery EDR are the I-band HSR of 400m at nadir [Sys Spec 40.2.3.1-4] and the revisit times [Sys Spec 40.2.3.1-15 to 17 which are excluded for NPP]. Recall that while Imagery assist M-bands are produced by the IDPS, there are no explicit requirements on these bands. All of these Sys Spec requirements are verified via the SDR Validation plan and are not included in this one.
2. Sec. 40.2.3.2 Application Related Requirements: This includes performance requirements on a human analyst ability to perform manual cloud and sea ice detection. This is the focus of the Imagery Cal/Val plan. The explicitly required I-band and NCC Imagery EDRs, as well as the imagery assist M-bands, can be utilized in this manual analysis.

The manual cloud analysis [Sys Spec 40.2.3.2.1] requires a specified cloud detection uncertainty and probability of correct cloud typing (PCT) of various cloud types. The manual Sea Ice analysis [Sys Spec 40.2.3.2.1] requires a specified ice edge location and ice concentration uncertainty. The requirements are based on how well a human analyst can determine these properties in the imagery EDR. False coloring techniques will be used to combine individual bands to enhance the cloud / ice discrimination characteristics of the imagery. 3 Analysts (1 NGAS, 1 IPO, and 1 User) will be used in the validation of the imagery products. A single Lead Analyst will manually evaluate the imagery to identify clouds, cloud types, ice edges, and ice concentration as required in the Sys Spec. Note that different lead analysts will be used for the cloud and ice analyses. NGAS or the government (TBD) will provide the lead analyst for the clouds, while the government will provide the lead analyst for ice.

Note that this manual evaluation is a very time consuming process and will be done on a limited number of granules. The minimum number of granules is 20 (TBD) and different granules will be needed for cloud and ice analysis. The remaining two analysts will review the evaluation performed by the lead analyst and indicate if they agree with the lead analyst's results to within the required Sys Spec performance specifications for each granule. Both review analysts must agree with the lead analyst scoring for 95% (TBR) of the granules in order to validate Sys Spec compliance. The approach of using a single lead analyst with two reviewing analyst for the manual analysis will be called the 3-Analyst method. The 3-Analyst method is designed to validate the performance in a fashion consistent with operational use of manual image analysis, without placing an undo burden on the Cal/Val effort.

Results from any correlative data matchups will also be reviewed, as described in this plan, and by examining the results of the VCM / correlative truth comparisons for the same granule. The difficulty with using correlative truth is that manual analysis is a time consuming process that is best suited to scoring an entire granule. Correlative truth is typically available on a point or line basis, and it is not practical to perform manual analysis on a point or line basis. Manual analysis is typically performed by drawing region boundaries on imagery and then associating a particular attribute (e.g cloud type) to all pixels in the region. Previous analyses with simulated data (that has truth for every pixel) have shown that the primary challenge in manual analysis is in identifying the region edges. It may be possible to use a single correlative data point that falls within the region to provide a truth-estimate for the entire region. A correlative matchup point within a region boundary may be useful to identify parameters such as the cloud type for the region, but it will be of no help in correctly identifying the region boundaries. One also has to account for the fact that correlative matchups are typically in the vertical plane (parallax corrected), while the manual cloud analysis is in the slant plane. Correlative matchups will be investigated as time permits; however in order to bound the scope of the effort formal Sys Spec compliance will be based on the 3-analyst method.

The genesis of the Imagery application requirements are how current users support their missions by looking at a swath of imagery and identifying cloud and ice features. The validation plan is consistent with how users will use the imagery products. Note that this section only addresses the Imagery EDR Application Related Requirements in the Sys Spec [Sec. 40.2.3.2]; though the overall Imagery Cal/Val plan discusses other Imagery attributes that are of interest to users. The requirements for manual analysis are intended to be a measure of image quality, rather than requirements on tools needed to manually generate products. While the Cal/Val effort will develop tools to allow manual cloud analysis of imagery, it is the image quality that is being validated and not the Cal/Val tools. Users have committed to using their own tools for manual image analysis that meet their specific needs (see section 4.0). Compliance with the Sys Spec will be based on the 3 Analyst method.

The Imagery EDR must be of sufficient quality to support manual cloud analysis as required in the Sys Spec and summarized in the following three tables.

Paragraph	Manual Cloud Cover	Specified Value
40.2.3.2.1.1-6	a. Horizontal Cell Size	3 times HSR (1.2 km at Nadir)
40.2.3.2.1.1-3	b. Horizontal Reporting Interval	Horizontal Cell Size
40.2.3.2.1.1-4	c. Measurement Range	0 – 1, 0.1 Increments
40.2.3.2.1.1-5	d. Measurement Uncertainty	0.1

Table B-2: Imagery EDR - Manual Cloud Cover Requirements

#	Acronym	Cloud Type
1	AC	Altocumulus
2	AS	Altostratus
3	CC	Cirrocumulus
4	CCSL	Cirrocumulus (standing lenticular)
5	CS	Cirrostratus
6	CI	Cirrus
7	CB	Cumulonimbus
8	CU	Cumulus
9	TCU	Towering Cumulus
10	SC	Stratocumulus
11	SCSL	Stratocumulus (standing lenticular)
12	ST	Stratus
13	ObsNC	Obscured/not cloudy
14	Clear	Clear

Table B-3: Imagery EDR - Manual Cloud Types (14)

Paragraph	Manual Cloud Typing	Specified Value
40.2.3.2.1.2-7	a. Horizontal Cell Size	3 Times HSR (1.2 km at Nadir)
40.2.3.2.1.2-3	b. Horizontal Reporting Interval	Horizontal Cell Size
40.2.3.2.1.2-4	c. Measurement Range	14 Cloud Types Listed Above
40.2.3.2.1.2-8	d. Probability of Correct Typing	85%

Table B-4: Imagery EDR - Manual Cloud Typing Requirements

Section 40.2.3.2.1.1 of the Sys Spec indicates that the cloud cover is the fractional area of the HCS for all cloud layers, extending from the surface to the 0.1mb height in a locally normally direction. While the local normal direction (vertical direction) is what is used in the CCL EDR, it is not applicable to manual cloud analysis. For the CCL EDR, we use a parallax correction algorithm to shift each pixel so that we can aggregate at the 6km EDR grid cell in the vertical direction. This is simply not possible for aggregating manual cloudy pixels at the 3x3 HSR resolutions on which the manual HCS performance is defined. Manual cloud analysis is done in the slant path direction and any aggregation would also be done in the slant path plane, since no height information is available at the HSR resolution. Even if one reached into the Cloud IP products, these are only available at 2x HSR (M-band resolution). Also it is not possible to manually identify the pixels, manually identify the height of each pixel, and then shift each pixel to the appropriate

HCS cell (3x3 HSR aggregation) in order to compute a manual parallax corrected cloud cover. All manual cloud analysis will therefore be performed in the image slant plane and that the fractional area of a 3x3 HSR grid cell is assumed to be the aggregation of all cloud layers in the slant path direction.

The 3-Analyst method will be used to validate Sys Spec compliance. Analysis will be performed at the HSR resolution using the 3-Analyst method and agreement with the manual cloud-no cloud mask at the HSR resolution will be assumed to meet the fractional cloud cover requirement at the HCS resolution (3x3 HSR). Cloud typing at the required HCS resolution will be validated by the 3-Analyst method at the HSR resolution. No specific products will be made at the HCS resolution. The Imagery EDR provides a mapping between GTM Imagery pixels and SDR pixels. The manual imagery products will be projected back into SDR pixels at the M-band resolution (2x2 HSR) for comparison with the automated VCM cloud analysis. This comparison is to support the VCM analysis and is not used for validation of NSS compliance for imagery.

Note that the manual analysis is performed at I-band imagery HSR resolution (375 m) by drawing region boundaries at this resolution. Manual cloud analysis cannot be performed at the M-band resolution since it is 2x HSR, while the manual cloud products must be evaluated at 3x HSR. However, imagery assist M-band data may be pixel replicated (or interpolated) to the I-band resolution for use in the manual analysis. Various false color images may be generated at the HSR resolution in order to aide in drawing regions. Each manually outlined region will be cloud typed and assumed to be 100% cloud covered of the indicated type. In keeping with the assumption of non-overlapping layers, no pixel will be assigned to more than a single cloud type. The lead analyst will generate the region boundaries and cloud types for review by the two review analysts. The process for sharing the region definitions will need to be determined, though modern image processing tools such as IDL have predefined methods for storing region of interest (ROI) definitions.

If one had sufficient ground truth at the HCS level, an artificial grid that matches the required HCS of 3x3 HSR could be used to aggregate the pixels for comparison. The cloud cover would then be computed as 0 to 100% for the HCS by dividing the number of cloudy pixels to the total of nine pixels in the 3x3 cells. It is not clear how one could compute a single cloud type for a 3x3 HSR aggregation if multiple cloud types are present. A simple majority type could be used, or this could be treated as a degraded condition. Note that manual cloud typing is particularly problematic with respect to a numerical computation since technically one would have a 14x14 confusion matrix (see Appendix B of the VCM Cal/Val plan for a discussion on a “confusion matrix”) to evaluate overall Probability of Correct Typing (PCT). If one used the 85% PCT requirement as an overall requirement then one would only have to look at the trace of the confusion matrix, but if one wanted to validate the 85% for each of the 14 types individually, one would need to look at each row of the confusion matrix individually. It is not clear where one could get correlative data at the 3x3 HSR level for the 14 required cloud types in order to build a reliable confusion matrix from which PCT could be computed. Therefore the use of the 3-Analyst method avoids these complications since building a manual product at the 3x3 HSR solely for Cal/Val is not cost effective. The 3-Analyst comparisons will be used instead at the HSR resolution.

The manual analysis at the SDR level will also be used to validate the CCL cloud layering where up to 4 cloud layers can exist in a 6x6 km EDR grid cell. The cloud types will be used as a surrogate for cloud layers and the number of types that fall within a 6x6 km EDR grid will be computed for comparison to the automatically computed number of layers in the CCL EDR. The assumption is that each layer in a 6x6 km grid cell would be of a different cloud type. The aggregation would not include the "clear" and "obscured/Not Cloudy" types in Table B-3. This manual analysis aggregation will need to use both the aggregation map that maps pixels to a grid cell along a scan as well as the results of the parallax correction since the CCL EDR aggregation can shift IP pixels between grid cells. The details of this approach need to be worked out since it is possible that manual identified pixels may not exist in the VCM, in which case there is no height information for the parallax correction. A Quality Control (QC) metric may need to be generated to indicate discrepancies at the pixel level between the VCM and manual analysis.

As indicated earlier, the plan as currently defined using the 3-Analyst method does not rely on correlative data; though the overall Imagery Cal/Val plan would benefit from correlative data. Correlative data could be used to help identify the cloud type for a cloud region, but the plan has been designed to avoid requiring this for validation of Sys Spec compliance.

There are two computed QC metrics involved with verification of the Sys Spec. The manually analyzed cloud mask projected to slant path VCM resolution allows the manual cloud analysis to be used as truth for the VCM. It could also be used as a QC metric for the characterization of the cloud layering since no parallax correction could be performed when aggregating cloud types if the manual analysis identifies cloud not present in the VCM. See the VCM Cal/Val plan for more detail. The second is cloud layering projected to the CCL resolution: This would allow one to determine the number of layers in a 6x6 EDR grid cell using the manual analysis. The pixel count for each cloud type in the aggregation can be used as a surrogate for the HCS percent coverage for each layer.

The Imagery EDR must also be of sufficient quality to support manual analysis with respect to the Sea Ice requirements that are in the following tables.

Paragraph	Manual Ice Edge Location	Specified Value
40.2.3.2.2.1-1	a. Horizontal Coverage	North of 36 deg North Latitude, South of 50 deg South Latitude for Sea Ice
40.2.3.2.2.1-2	b. Measurement Range	Any Latitude, Longitude Within Horizontal Coverage
	c. Measurement Uncertainty	
40.2.3.2.2.1-3a	1. Clear, Nadir	0.4 km
40.2.3.2.2.1-3b	2. Clear, Worst Case	1.0 km
40.2.3.2.2.1-5	d. Degraded Clear Measurement Condition, Worst Case: Thermal Contrast 1 K to 2.2 K Between Ice and Open Water	2.0 km
	d. Excluded Clear Measurement Conditions:	
40.2.3.2.2.1-6a	1. Thermal Contrast < 1 K Between Ice and Open Water	
40.2.3.2.2.1-6b	2. Aerosol Optical Thickness > 1.0	

Table B-5: Imagery EDR – Manual Ice Edge Location Requirements

Paragraph	Manual Ice Concentration	Specified Value
40.2.3.2.2.2-1	a. Horizontal Coverage	North of 36 deg North Latitude, South of 50 deg South Latitude for Sea Ice
40.2.3.2.2.2-2	b. Measurement Range	0 – 1 HCS Area, 0.1 increments
40.2.3.2.2.2-3	c. Measurement Uncertainty	0.1

Table B-6: Imagery EDR – Manual Ice Concentration Requirements

Manual analyses will also be necessary to verify the Sys Spec with regard to sea ice. As indicated earlier, a different lead analyst will be used for sea ice vs. clouds. The approach however will be the same and based on the 3-Analyst method. The primary difference between the approaches for sea ice is the presence of degraded and exclusion conditions noted in Tables B-5 and B-6. These will have to be taken into account during the selection process to insure the granules chosen for manual analysis are not dominated by these conditions.