Cloud Aerosol Transport System (CATS)

Data Management System

Data Products Catalog

Release 7.0: L1B Version 3.00, L2O version 3.00
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Release 7.0

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Oct. 01, 2018
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Document Revision Record

The Document Revision Record below contains information pertaining to approved document changes. The table lists the date the change is issued, the Document Change Request (DCR) number, a short description of the revision, and the revised sections.

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<th>Description of the Revision</th>
<th>Section Affected</th>
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<td>Initial Data Release</td>
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# Acronyms

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<th>Description</th>
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<tr>
<td>ASL, AMSL</td>
<td>Above Mean Sea Level</td>
</tr>
<tr>
<td>CAPS</td>
<td>CATS Automated Processing System</td>
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<tr>
<td>CATS</td>
<td>Cloud Aerosol Transport System</td>
</tr>
<tr>
<td>CPL</td>
<td>Cloud Physics Lidar</td>
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<tr>
<td>DEV</td>
<td>Development (e.g. Product)</td>
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<tr>
<td>DMS</td>
<td>Data Management System</td>
</tr>
<tr>
<td>GMAO</td>
<td>Global Modeling and Assimilation Office</td>
</tr>
<tr>
<td>GSFC</td>
<td>Goddard Space Flight Center</td>
</tr>
<tr>
<td>HDF</td>
<td>Hierarchical Data Format</td>
</tr>
<tr>
<td>HSRL</td>
<td>High Spectral Resolution Lidar</td>
</tr>
<tr>
<td>ISS</td>
<td>International Space Station</td>
</tr>
<tr>
<td>L0</td>
<td>Level 0 (e.g. data)</td>
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<tr>
<td>L2</td>
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</tr>
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<td>L3</td>
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<tr>
<td>MSFC</td>
<td>Marshall Space Flight Center</td>
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<tr>
<td>NRT</td>
<td>Near Real Time</td>
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<tr>
<td>OPS</td>
<td>Operational (e.g. Product), Operations (e.g. activity)</td>
</tr>
<tr>
<td>POIC</td>
<td>MSFC Payload Operations Integration Center</td>
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<tr>
<td>STD</td>
<td>Standard (e.g. Product)</td>
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<tr>
<td>3WL</td>
<td>Three Wavelength</td>
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<tr>
<td>PL-UAD_16</td>
<td>Dataset 16 of the ISS Payload Unique Ancillary Data</td>
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<td>CTRS</td>
<td>Conventional Terrestrial Reference System</td>
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Symbols, SI Units

<table>
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<td>ua</td>
<td>astronomical unit</td>
</tr>
<tr>
<td>deg</td>
<td>degree</td>
</tr>
<tr>
<td>°C</td>
<td>degree Celsius</td>
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<td>Joule</td>
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<td>K</td>
<td>kelvin</td>
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<td>km</td>
<td>kilometer</td>
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<td>m</td>
<td>meter</td>
</tr>
<tr>
<td>mb</td>
<td>millibar</td>
</tr>
<tr>
<td>mrad</td>
<td>milli radians</td>
</tr>
<tr>
<td>µrad</td>
<td>micro radians</td>
</tr>
<tr>
<td>ms</td>
<td>millisecond</td>
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<tr>
<td>nm</td>
<td>nanometer</td>
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<td>Pa</td>
<td>Pascal</td>
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<td>per, %</td>
<td>percent</td>
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<td>volt</td>
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<td>W</td>
<td>watt</td>
</tr>
<tr>
<td>µm</td>
<td>micron, micrometer</td>
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Data Type Abbreviations

<table>
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<th>Description</th>
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<td>Char</td>
<td>Character, 8 bits or 1 byte</td>
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<tr>
<td>Float_32</td>
<td>Floating Point, 32 bits or 4 bytes</td>
</tr>
<tr>
<td>Float_64</td>
<td>Floating Point, 64 bits or 8 bytes</td>
</tr>
<tr>
<td>Int_8</td>
<td>Integer, 8 bits or 1 byte</td>
</tr>
<tr>
<td>Int_16</td>
<td>Integer, 16 bits or 2 bytes</td>
</tr>
<tr>
<td>Int_32</td>
<td>Integer, 32 bits or 4 bytes</td>
</tr>
<tr>
<td>MB</td>
<td>MBytes, megabytes, or bytes/1024²</td>
</tr>
<tr>
<td>UInt_8</td>
<td>Unsigned Integer, 8 bits or 1 byte</td>
</tr>
<tr>
<td>UInt_16</td>
<td>Unsigned Integer, 16 bits or 2 bytes</td>
</tr>
<tr>
<td>UInt_32</td>
<td>Unsigned Integer, 32 bits or 4 bytes</td>
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</tbody>
</table>
1.0 Introduction

The Cloud-Aerosol Transport System (CATS) is a lidar remote sensing instrument that provided range-resolved profile measurements of atmospheric aerosols and clouds from February 2015 through October 2018. The instrument was located on the Japanese Experiment Module – Exposed Facility (JEM-EF) on the International Space Station (ISS). Data from CATS is used to derive properties of cloud/aerosol layers including: layer height, layer thickness, backscatter, optical depth, extinction, and depolarization-based discrimination of particle type. The ISS orbit is a 51-degree inclination orbit at an altitude of about 405 km. This orbit provides more comprehensive coverage of the tropics and mid-latitudes than sun-synchronous orbiting sensors, with nearly a three-day repeat cycle. CATS is intended to operate on-orbit for up to three years. The CATS payload was designed to provide a combination of long-term operational science, in-space technology demonstration, and technology risk reduction for future Earth Science missions.

The measurements of atmospheric clouds and aerosols provided by the CATS payload are used for three main science objectives, which include:

1. Extend Lidar Climate Observations
   - Provide measurements of cloud and aerosol profiles similar to CALIPSO, filling the potential data gap if CALIPSO were to cease operation before another space-based lidar mission begins.
   - Create continuity in the global lidar record by collaborating with CALIPSO to create similar data products.
   - Provide measurements at various local times to promote studies of diurnal changes in clouds and aerosols.

2. Provide Observational Data to Improve Operational Modeling Programs
   - Improve model performance through assimilation of near-real-time data products, utilizing the near-instantaneous data download capabilities of the ISS
   - Improve Air Quality forecasts and hazard warning by providing the vertical distribution of aerosols in near-real-time.
   - Advance aerosol typing accuracy from space-based lidar using the new capabilities of the CATS instrument (spectral depolarization, 355 nm, etc.)

3. Advance technology in support of future space-based lidar mission development
   - Demonstrate HSRL retrieval of aerosol extinction from space and provide observational data at 355 nm for Aerosols, Clouds, Ecosystems (ACE) mission development
   - Laser Technology Demonstration/Risk Reduction: high repetition rate, injection seeding (HSRL), and wavelength tripling
   - Exhibit the utility of photon-counting detection and high rep-rate lidar systems for future cloud and aerosol missions.
To meet these three science goals, CATS operated in two different modes using four instantaneous fields of view (IFOV) as shown in Figure 1.1:

- **Mode 7.1: Multi-beam backscatter detection at 1064 and 532 nm, with depolarization measurement at both wavelengths.** The laser output is split into two transmit beams, one aimed 0.5° to the left and one 0.5° to the right, effectively making two tracks separated by 7 km (~4.3 mi) at Earth’s surface. This operational mode was only used until 21 March 2015 due to a failure in laser 1 electronics.

- **Mode 7.2: Demonstration of HSRL aerosol measurements.** This mode was designed to use the injection-seeded laser operating at 1064 and 532 nm to demonstrate a high spectral resolution measurement using the 532-nm wavelength. However, this mode was limited to 1064 nm backscatter and depolarization ratio because of issues with stabilizing the frequency of laser 2 prevent collection of science quality HSRL data.

![Mode 7.1: Multi-Beam](image1)
![Mode 7.2: Laser 2](image2)

**Figure 1.1** CATS two main Science Modes for operation, with details of each mode’s capabilities and operational timeline.

The Cloud-Aerosol Transport System (CATS) payload was based on existing instrumentation built and operated on the high-altitude NASA ER-2 aircraft, including the Cloud Physics Lidar (CPL, McGill et al. 2002) and the Airborne Cloud-Aerosol Transport System (ACATS, Yorks et al. 2014). The instrument consisted of two high repetition rate (4-5 kHz), low energy (1-2 mJ) Nd:YVO4 lasers operating at three wavelengths (1064, 532, and 355 nm), a receiver subsystem with a 60 cm beryllium telescope that has a 110 microradian field of view, photon-counting detectors, and a data system to provide timing of the return photon events. More details on the CATS instrument design can be found in the CATS Algorithm Theoretical Basis Document.
The CATS Data Products Catalog (DPC) describes the CATS Automated Processing System (CAPS) and data management structure used to convert the CATS raw data into scientific data products. The DPC is intended to provide an overview of the data products that are used or produced by the Data Management System. The GSFC ICAPS processes, archives, and disseminates the CATS data products in Hierarchical Data Format (HDF) to the scientific community.

The data products generated from the CATS measurements are produced according to a protocol that is similar to that established by NASA’s Earth Observing System (EOS), but are not required to meet any specific protocol. The CATS data product levels are defined as follows:

- **Level 0**: reconstructed, unprocessed instrument data at raw resolutions (i.e., the downlinked raw photon counts from the CATS instrument). Any and all communications artifacts (e.g. synchronization of packets, communications headers, duplicate or missing data) are removed in the L0 process.
- **Level 1A**: Level 0 data that is time-referenced, geo-located, corrected for detector nonlinearity and instrument artifacts, normalized to laser energy, and annotated with ancillary information. The CATS Level 1A data (relative normalized backscatter) is an internal product only and is not distributed.
- **Level 1B**: Level 1A data that have been calibrated, annotated with ancillary meteorological data, and processed to sensor units. The CATS Level 1B data (attenuated total backscatter and depolarization ratio) is archived as Level 1 data.
- **Level 2**: Geophysical parameters derived from Level 1 data, such as the vertical feature mask, profiles of cloud and aerosol properties (i.e. extinction, particle backscatter), and layer-integrated parameters (i.e. lidar ratio, optical depth). There will be two CATS Level 2 products:
  - **CATS Heritage L2**: L1B files that are run through the CALIPSO L2 algorithms to provide continuity in the algorithms used for the lidar climate record.
  - **CATS Operational L2**: L1B files that are run through the new operational CATS L2 algorithms, which will include new capabilities that correspond to new instrument technology.

Figure 1.2 demonstrates the CATS command/control and data communications structure. Functionally, there are five elements that make up the command/control and data communications structure: 1) CATS, 2) ISS, 3) the Marshall Space Flight Center (MSFC) Payload Integration Center (POIC), and the 4) CAPS Trek and 5) CAPS Science workstations. The POIC serves as the command and communications link between CAPS and CATS on the ISS. CATS receives instrument commands initiated from CAPS Trek to the POIC via a VPN ethernet connection. The commands are then transmitted from the POIC to the ISS over TDRS, and from the ISS to CATS using the 1553 communications circuit. In addition, CATS receives housekeeping and telemetry data from ISS via 1553. Housekeeping data includes time and position information from dataset 16 of the ISS Payload Unique Ancillary Data. The CATS raw science data (and alignment data) are transmitted from CATS to the ISS using the JEM-EF High Rate Data Link (HRDL). The science data are then transmitted to the POIC over TDRS, and then to CAPS Trek via VPN ethernet, and finally passed through via LAN to the CAPS Science workstation for archival and Level 0, 1, and 2 processing. CATS command and data
communications utilize the Consultative Committee for Space Data Systems (CCSDS) format. The command and science data represent the core of the CCSDS information packets transmitted to/from CATS, with various header information added at both POIC and ISS stages. Thus, the term raw data refers to the CCSDS packets containing core science data and headers applied between CATS, ISS, and the POIC. The final CCSDS raw data transmitted to CAPS Trek from the POIC, and passed unaltered to CAPS Science workstation for archival are referred to as Level 0 data. It is not expected that raw science data transmitted from CATS is the same format as Level 0 data archived by CAPS.

1.1 CATS Definitions

Raw Data
Refers to the data collected onboard the ISS by CATS, as well as ancillary time and position data collected by CATS during operations such as the ISS Broadcast Ancillary Data (BAD). Ancillary data are added to the science data collected by CATS. The term raw data will be used to refer to any CCSDS data file or packet within CATS, CATS to the ISS, and ISS to POIC. During this transfer process it is expected that various CCSDS headers and file/packet formatting will occur to the core science data being transmitted, and these will all be referred to as “raw data” within this document.

BAD
Refers to the ISS Broadcast Ancillary Data (BAD). It contains time and position information required for science and alignment processing. Thus, any reference to BAD refers to time and/or position information.

**Level 0, L0 Data**
Refers to the data files/packets sent from the POIC to the CAPS Trek workstation. It is expected that all final ISS/POIC related CCSDS formatting will be completed by this stage. Level 0 files/packets will be passed, unaltered, from CAPS Trek to the CAPS Science workstation for archival and Level 1 processing.

**Header**
Refers to metadata and/or diagnostic information contained in both raw data files and Level 0, 1, and 2 data files.

**Data Mode or Mode**
Refers to the operational CATS mode during collection of scientific raw data and other activities. The mode is a programmable setting via the CAPS Trek workstation, and will be included in the raw data header. Only one mode will be active at any given time. Science and Alignment modes utilize high rate data link (HRDL) on JEM-EF. Other modes transmit data via 1553 interface on JEM-EF.

- **Mode = 1 (Off)**
  - CATS is off. No power to instrument or heaters, cover door closed.

- **Mode = 2 (Survival)**
  - Survival heaters powered, cover door closed, and instrument off.

- **Mode = 3 (Safe)**
  - Instrument primary power applied at JEM-EF interface. Only DSEM and operational heaters are functional. Instrument housekeeping telemetry is collected and transmitted via 1553 interface. Fluid cooling loop is not active. Cover door closed.

- **Mode = 4 (Standby 1)**
  - Fluid cooling loop is active. Laser 1 OR Laser 2 primary power converter is enabled to allow monitoring of laser housekeeping telemetry. Detectors powered. Cover door closed.

- **Mode = 5 (Standby 2)**
  - Fluid cooling loop is active. Cover door open. Laser 1 OR Laser 2 diode driver supply enabled.

- **Mode = 6 (Laser Alignment)**
  - Boresight calibration for the various science modes.

- **Mode = 7 (Science Mode)**
  - The three primary science modes of the CATS instrument are described in section 1.0 and Figure 1.1.

**Field Of View (FOV), Instantaneous Field Of View (IFOV)**
The FOV is defined as the angular area of the atmosphere and surface scene viewed by CATS in a given mode. CATS utilizes a telescope with a full 16 mrad FOV, but is configured with four
different IFOV orientations to accommodate each mode and the mission science goals. The IFOV of each orientation described below is 115 µrad.

- **LFOV (Left IFOV)**
  - This refers to the FOV oriented 8 mrad to the left off nadir of the +X direction of the ISS. It is off track, tilted 8 mrad left of nadir.

- **RFOV (Right IFOV)**
  - This refers to the FOV oriented 8 mrad to the right off nadir of the +X direction of the ISS. It is off track, tilted 8 mrad right of nadir.

- **FFOV (Fore IFOV)**
  - This refers to the FOV oriented 8 mrad forward of the ISS along the +X direction. It is along track, but tilted 8 mrad forward from nadir.

- **AFOV (Aft IFOV)**
  - This refers to the FOV oriented 8 mrad aft of the ISS along the +X direction. It is along track, but tilted 8 mrad aft from nadir.

**Range Bin**

Refers to the vertical resolution of the raw data and corresponding data frame, e.g. 60 m. Range bin resolution is synonymous with “vertical resolution” of the CATS data.

**Profile, Record**

A collection of range bins stacked vertically beginning at the height defined by Top Bin Altitude (see below) and continuing for a distance defined by the Data Frame. A profile refers to one instance of data collection at time X that is stored in the raw data file (and eventual Level 0 file). The phrase record refers to the header and the 12 channels of profile data corresponding to time X and current mode of operation. The record/profile temporal intervals are determined by the temporal resolution (0.05 secs), and the granule defines the number of profiles in a data file.

**Number Shots Summed**

Refers to the number of laser shot profiles summed to produce a single profile/record with a temporal resolution of 0.05 secs. Since the CATS lasers are high rep-rate, they actually measure a profile at 5000 Hz (laser 1) or 4000 Hz (laser 2). However due to data size constraints, these raw profiles cannot be archived aboard the ISS and transmitted to the CATS work station at GSFC. Thus 250 of these raw profiles in mode 7.1 are summed together to produce a single profile with a temporal resolution of 0.05 secs that is reported in the CATS data products. For modes 7.2 and 7.3, 200 profiles are summed together.

**Data Frame**

Refers to a two-dimensional array defining the along track and vertical resolution and extent of the data contained within each data file/packet. The data frame is set from 28 km to – 2 km asl with 60 m range bins (vertical), and half an orbit with 0.05 sec along track temporal resolution (the latter would correspond to a 350 m horizontal resolution along track). The data frame is determined by the repetition frequency of the laser and the ISS altitude and the need to avoid pulse overlap within the atmospheric volume of interest (see discussion of this in section 1.0). The data frame is fixed at 30 km vertical for the CATS mission.
Top Bin Altitude
Refers to the altitude (ASL) at which the CATS data begins (e.g. 28 km) for a specific profile. This is derived using the onboard timing calculations required to adjust for changes in the ISS position above the earth’s surface. NOTE: The bottom of the data frame is fixed at -2 km.

Granule
Level 0 files are partitioned into either day or night “granule” files based on the z-component of the solar line-of-sight unit vector reported in the ISS Broadcast Ancillary Data (BAD) and the solar background counts for the given profile. A new granule file is produced when both criteria agree for a given profile and these granules are then labeled correspondingly as either a “day” file or “night” file. It should be noted that there are occasions when the 6-hour sorting window is not large enough to fill in the data gaps caused by out-of-sequence data. In this scenario, two granules may be produced, with 4.5 minutes between the start and end times of the granules, instead of one larger granule. For more details on the process of creating a granule, please see the CATS ATBD document.

Channel
Refers to a profile of photon counts contained in the raw data with dimensions defined by the range bin and temporal resolution. Different modes will utilize a different number of channels. Thus the term channel is meaningful only when categorized: e.g. Mode 7.1, Parallel 1064nm describes one channel of data in the raw data file. Table 1.1 below shows the science modes (7.1 – 7.3) and how they are related to the various CATS detector channels. For mode 7.1, 12 channels of data are acquired across both IFOV orientations (channels 1 – 12). In mode 7.2 (HSRL mode), 12 channels of data are acquired (channels 13 – 24), 10 of which are used for the HSRL measurement. In mode 7.3, laser 2 is used in 3 wavelength mode (3WL) to acquire 8 channels of data (channels 25 – 31). Note also that some of the atmospheric measurements (for instance the 532 parallel and perpendicular for mode 7.1 and 7.3) acquire 2 channels of data. This is because the return signal is split and sent to two separate SPCM detectors as a way to increase the dynamic range. While multiple channels may be acquired for a given atmospheric measurement, it is actually the same measurement: those channels will be summed during the CAPS data processing (for modes 7.1 and 7.3).

Table 1.1. The Science Modes and corresponding detector channel numbers for the listed CATS atmospheric measurement. Note total number of available channels is 32 and each channel represents a complete profile of data.

<table>
<thead>
<tr>
<th>Mode</th>
<th>Description</th>
<th>1064.</th>
<th>1064_{w,}</th>
<th>532.</th>
<th>532_{w,}</th>
<th>355_{w}</th>
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</thead>
<tbody>
<tr>
<td>7.1</td>
<td>Laser 1 RFOV (Multi-beam)</td>
<td>1</td>
<td>2</td>
<td>5.6</td>
<td>3.4</td>
<td>---</td>
</tr>
<tr>
<td>7.1</td>
<td>Laser 1 LFOV (Multi-beam)</td>
<td>7</td>
<td>8</td>
<td>11,12</td>
<td>9,10</td>
<td>---</td>
</tr>
<tr>
<td>7.2</td>
<td>Laser 2 FFOV (HSRL)</td>
<td>23</td>
<td>24</td>
<td>13-22</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>7.3</td>
<td>Laser 2 AFOV (355 nm)</td>
<td>25</td>
<td>26</td>
<td>27,28</td>
<td>29,30</td>
<td>31</td>
</tr>
</tbody>
</table>

Version
Refers to the major release of Level 1, and 2 data products. Version releases will occur sporadically during the mission based on offline development efforts addressing bugs and
improvements to code/algorithms, and also significant changes to ancillary data. A version release will occur when a significant number of development changes have occurred, and/or other programmatic decisions. The term version may also refer to instance of a particular program/algorith in the CAPS code library. Thus, the format for CATS version numbers is: X.YY, where X refers to the product version release and X.YY is used to identify program/algorith versions (YY describes the program instance and X identifies which major version release it belongs to). Example: a program identified as V1.05 would be the 5th instance of the program (program version), and it would be part of CATS major release 1. Level 1, 2 and 3 data files will only use the X value.

1.2 CATS Raw Data Description

This section describes the content and format of the raw science data. This section does not address the format of any added CCSDS headers or formatting occurring onboard the ISS or POIC. It is expected that all the information required to process CATS science data are contained within the raw science data and not other CCSDS headers (which are considered of use to the ISS project only). The raw science data include a series of records at time intervals set by the DFHR. Each record contains a header followed by 12 channels of data measured by CATS at the time/position provided in the header. The header contains additional housekeeping information required for CATS processing. Each channel of data includes photon counts for each range bin for the entire data frame. Detector channels are defined in section 1.1.

1.3 CATS Data Management Structure

The CATS Automated Processing System (CAPS) converts the CATS instrument data into scientific data products. A high-level view of the CAPS structure is illustrated in the Top Level Data Flow Diagram shown in Figure 1.3. The data flow diagram depicts the relationship between the data products and the subsystems that produce them. Circles in the diagram represent algorithm processes called subsystems. Subsystems are a logical collection of algorithms, which together convert input data products into output data products. Boxes with arrows entering a circle are input data sources for the subsystem, while boxes with arrows exiting the circles are output data products.
The CATS data product naming convention is defined as:

[Investigation]_[Level]_[Day-NightID]_[Version]_[Instance].hdf

where:

- Investigation = Mission Name (CATS-ISS)
- Level = Product Level, e.g., L0, L1A, L1B, L2O,
- ProductID = Product Identification, [D or N]
- Version = VX-YY [e.g. V1-00]
- Instance = YYYY-MM-DDThh-mm-ssThh-mm-ssUTC

An example of this naming convention is:

2.0 Archival Data Products

This section describes the CATS data products, which are permanently archived at the GSFC CAPS. Each data product is a single file in HDF format. Each subsection contains a brief overview of the purpose and content of the data product followed by one or more tables listing every parameter contained in the product. The following data attributes are described in the overview sections:

- **Level** – Data product levels are defined using EOS definitions.
- **Type** – Data type (Science Archival, Level 0, Ancillary, or Engineering)
- **Frequency** – How often the product is received or produced
- **Time interval Covered**
  - **File** – Time period covered within this file
- **Spatial resolution**
  - **Record** – Vertical and horizontal coverage
- **File Name(s)** – The name of the data product (Listed with Production Strategy, Version, and

Additional tables contain the following attributes for each parameter:

- **Parameter Name** – Name of parameter
- **Data Type** – Data type definition of the parameter value
- **Units** – Units of the parameter value
- **Range** – Range of values for the parameter (Note: For many parameters, “Range” indicates the nominal range physically meaningful values. Some small fraction of values may fall outside this range due to noise. Check the associated Uncertainty and QA parameters for guidance on data quality.)
- **Elements/Record** – elements per record for this parameter

Total file sizes also are provided.

2.1 Lidar Level 1A Data Product

The CATS Level 1A data is referred to as the Normalized Relative Backscatter (NRB) and is an internal product only that is not distributed. The NRB data is Level 0 data that is geolocated, corrected for detector nonlinearity and the folding of molecular signal from the atmosphere above, normalized to laser energy, and annotated with ancillary information. The ancillary information included in the NRB data is the Broadcast Ancillary Data (BAD) from the ISS that describes the environment in which a payload is operating. The BAD is sent at a rate of 10 Hz and includes the roll, pitch and yaw of the ISS, the quaternion, and the CTRS position information. Since the CATS laser points off-nadir 0.5 degrees in any of the three science modes,
and has multiple beams in Mode 7.1, the geolocation of the CATS laser beam is computed for each FOV using the BAD and the CATS relative angles. More information on the algorithm to determine the geolocation of each CATS FOV is provided in section 3.1.1. Once the data is geolocated, the raw photon counts are corrected for detector nonlinearity. The solar background photon counts is estimated by averaging the signal below the earth’s surface. All the products reported in the CATS L1A data products are used as input to the CATS L1B data products. In the following table the L1A parameters are listed for all modes of operation.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Type</th>
<th>Dimension</th>
<th>HDF Identifier</th>
<th>Mode</th>
</tr>
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<tbody>
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<td>All</td>
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<tr>
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<td>Number Records</td>
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<td></td>
<td>All</td>
</tr>
<tr>
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<td>All</td>
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<td></td>
<td>All</td>
</tr>
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<td>Number Bins</td>
<td></td>
<td></td>
<td>All</td>
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<td>Hori_Res_Secs</td>
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<tr>
<td>UTC_DATE</td>
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<td>UTC DATE (yyyymmdd)</td>
<td></td>
<td>All</td>
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<tr>
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<td>UTC Time, fraction of day</td>
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<td>All</td>
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<td>ISS Longitude</td>
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</tr>
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<td>Footprint Latitude</td>
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<tr>
<td>Longitude_FOV</td>
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<td>2,N</td>
<td>Footprint Longitude</td>
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<td>Height of Top Bin (0,<em>) is Left FOV, (1,</em>) RFOV for Mode 7.1 (0,*) for other modes</td>
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<td>All</td>
<td></td>
</tr>
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<td>Byte</td>
<td>N</td>
<td>Laser Energy Quality 532</td>
<td>7.3</td>
<td></td>
</tr>
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<td>Byte</td>
<td>N</td>
<td>Laser Energy Quality 1064</td>
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<td>M,N</td>
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<td>All</td>
</tr>
<tr>
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<td>Photon</td>
<td>Float</td>
<td>2⁰,N</td>
<td>Background Variance Perpendicular 532</td>
<td>All</td>
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11
<table>
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<tr>
<th><strong>Background Variance Parallel 532</strong></th>
<th>Photon</th>
<th>Float</th>
<th>2(^a),N</th>
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<th>All</th>
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<td>Photon</td>
<td>Float</td>
<td>2(^a),N</td>
<td>Background Perpendicular 1064</td>
<td>All</td>
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<tr>
<td><strong>Background Parallel 1064</strong></td>
<td>Photon</td>
<td>Float</td>
<td>2(^a),N</td>
<td>Background Parallel 1064</td>
<td>All</td>
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<tr>
<td><strong>Background Variance Parallel 1064</strong></td>
<td>Photon</td>
<td>Float</td>
<td>2(^a),N</td>
<td>Background Variance Parallel 1064</td>
<td>All</td>
</tr>
<tr>
<td><strong>Background Variance Perpendicular 1064</strong></td>
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<td>Float</td>
<td>2(^a),N</td>
<td>Background Variance Perpendicular 1064</td>
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<tr>
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</tr>
<tr>
<td><strong>Saturated Bins532</strong></td>
<td>Int2</td>
<td>2(^a),50,N</td>
<td>Saturated Bins 532 (50 max)</td>
<td>All</td>
<td></td>
</tr>
<tr>
<td><strong>Saturated Bins1064</strong></td>
<td>Int2</td>
<td>2(^a),50,N</td>
<td>Saturated Bins 1064 (50 max)</td>
<td>All</td>
<td></td>
</tr>
<tr>
<td><strong>Dead Time Correction Profile</strong></td>
<td>Float</td>
<td>M,12,N</td>
<td></td>
<td>Dead Time Correction Profile</td>
<td>option</td>
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<tr>
<td><strong>HSRL Raw Counts</strong></td>
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<td>Int2</td>
<td>10,M,N</td>
<td>HSRL Raw Counts</td>
<td>7.2</td>
</tr>
<tr>
<td><strong>HSRL Backgrounds</strong></td>
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<td>HSRL Background Counts</td>
<td>7.2</td>
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<tr>
<td><strong>Commanded Etalon Gap</strong></td>
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<td>3,N</td>
<td></td>
<td>Commanded Etalon Gap</td>
<td>7.2</td>
</tr>
<tr>
<td><strong>Actual Etalon Gap</strong></td>
<td>Float</td>
<td>3,N</td>
<td></td>
<td>Actual Etalon Gap</td>
<td>7.2</td>
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<tr>
<td><strong>Commanded Etalon Capacitance</strong></td>
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<td>3,N</td>
<td></td>
<td>Commanded Etalon Capacitance</td>
<td>7.2</td>
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<tr>
<td><strong>Actual Etalon Capacitance</strong></td>
<td>Float</td>
<td>3,N</td>
<td></td>
<td>Actual Etalon Capacitance</td>
<td>7.2</td>
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<td><strong>CTRS Position</strong></td>
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<td>CTRS Position XYZ</td>
<td>All</td>
<td></td>
</tr>
<tr>
<td><strong>CTRS Velocity</strong></td>
<td>Float</td>
<td>3,N</td>
<td>CTRS Velocity XYZ</td>
<td>All</td>
<td></td>
</tr>
<tr>
<td><strong>CTRS Position Quality</strong></td>
<td>Uint</td>
<td>N</td>
<td>CTRS Position Quality</td>
<td>All</td>
<td></td>
</tr>
<tr>
<td><strong>CTRS Position Time</strong></td>
<td>ULong</td>
<td>N</td>
<td>CTRS Position Coarse Time</td>
<td>All</td>
<td></td>
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<tr>
<td><strong>Quaternion Data</strong></td>
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<td>4,N</td>
<td>Quaternion Data</td>
<td>All</td>
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</tr>
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<td><strong>Boresite Steps Motor</strong></td>
<td>Long</td>
<td>7,N</td>
<td>Boresite Motor Step Data</td>
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<td><strong>Science Data Error Flag</strong></td>
<td>Byte</td>
<td>12,N</td>
<td>Science Data Error Flag</td>
<td>All</td>
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</tr>
<tr>
<td><strong>SPCM_Enable_Flags</strong></td>
<td>ULong</td>
<td>N</td>
<td>SPCM Enable Flags</td>
<td>All</td>
<td></td>
</tr>
<tr>
<td><strong>FOV_Angle_Fore</strong></td>
<td>Float</td>
<td>N</td>
<td>CATS Fore FOV Angle</td>
<td>All</td>
<td></td>
</tr>
<tr>
<td><strong>FOV_Angle_Aft</strong></td>
<td>Float</td>
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<td>CATS Aft FOV Angle</td>
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<tr>
<td><strong>FOV_Angle_Right</strong></td>
<td>Float</td>
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<td>CATS Right FOV Angle</td>
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<td></td>
</tr>
<tr>
<td><strong>FOV_Angle_Left</strong></td>
<td>Float</td>
<td>N</td>
<td>CATS Left FOV Angle</td>
<td>All</td>
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<tr>
<td><strong>Yaw_ISS</strong></td>
<td>Float</td>
<td>N</td>
<td>ISS Yaw Angle</td>
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</tr>
<tr>
<td><strong>Pitch_ISS</strong></td>
<td>Float</td>
<td>N</td>
<td>ISS Pitch Angle</td>
<td>All</td>
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<tr>
<td><strong>Roll_ISS</strong></td>
<td>Float</td>
<td>N</td>
<td>ISS Roll Angle</td>
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</tr>
<tr>
<td><strong>Attenuated_Molecular_Backscatter532</strong></td>
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<td>R(^3),N</td>
<td>Attenuated Molecular Backscatter532</td>
<td>All</td>
<td></td>
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<tr>
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<td>Float</td>
<td>R(^3),N</td>
<td>Attenuated Molecular Backscatter1064</td>
<td>All</td>
<td></td>
</tr>
</tbody>
</table>

*Maxbins (M) can vary (500 for 60 m bins: default value)

#The 2 dimension is for Left and Right FOVs (Mode 7.1 only)

\(^1\)In mode 7.2, the NRB_Parallel_532 array is all zeroes

\(^2\)In mode 7.2 the 10 HSRL channels are summed and stored in the NRB_Parallel_532 array

\(^3\)R is the number of MET records, appx 1/200 of N
### 2.2 CATS Level 1B Data Product

In the following tables, the parameters listed in black font will always be on the product regardless of operating mode. Red font denotes mode 7.1 only and blue font mode 7.2 only.

Oct 01, 2018 V3.00 Corresponds to V3-00 L1B Product Software

Data File Name: CATS-ISS_L1B_N-M7.2-V3-00.2017-10-29T00-26-04T01-10-30UTC.hdf5

#### Table 1: CATS-ISS L1B Record Summary for Mode 7.1

<table>
<thead>
<tr>
<th>Record Name</th>
<th>Reference Table</th>
<th>Record Size (Bytes)</th>
<th>Records/File</th>
<th>File Size (Bytes)</th>
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<td>Metadata</td>
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<td>2,912</td>
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<tr>
<td>Position, Attitude and Celestial</td>
<td>Table 4</td>
<td>48</td>
<td>54,015</td>
<td>2,592,720</td>
</tr>
<tr>
<td>Geolocation and Viewing Geometry</td>
<td>Table 5</td>
<td>40</td>
<td>54,015</td>
<td>2,160,600</td>
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<tr>
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<td>Table 6</td>
<td>25,845.5</td>
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<td></td>
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#### Table 2: CATS-ISS L1B Record Summary for Mode 7.2

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<th>Reference Table</th>
<th>Record Size (Bytes)</th>
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<tr>
<td>Position, Attitude and Celestial</td>
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<td>2,592,720</td>
</tr>
<tr>
<td>Geolocation and Viewing Geometry</td>
<td>Table 5</td>
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<tr>
<td>Elastic Backscatter</td>
<td>Table 6</td>
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Table 3: CATS-ISS Metadata Record (1 per granule)

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<th>Bytes</th>
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<td>Product_Creation_Date</td>
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<td>Char</td>
<td>N/A</td>
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<td>Granule_Stop_DateTime</td>
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<td>4</td>
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<td>Granule_Stop_RDM</td>
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These are 2 element arrays for left FOV (1) and right FOV(2)

Table 4: CATS-ISS Position, Attitude and Celestial Record

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<th>Bytes</th>
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Total Bytes/Record: 48
Table 5: CATS-ISS Profile Geolocation and Viewing Geometry Record

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<th>Bytes</th>
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Total Bytes/Record Mode 7.1: 40
Total Bytes/Record Mode 7.2: 24

Table 6: CATS-ISS Elastic Backscatter Science Record

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<td>1</td>
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</table>

19
Nominal Granule will span roughly 45 minutes (1/2 orbit) or 2700 seconds. Data rate is 20 records per second, or 20 Hz.

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<th>Value 2</th>
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<td>0.02</td>
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<tr>
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<td>0.02</td>
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<td>0.02</td>
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<td>MET_Data_Time</td>
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<td>10.66</td>
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<td>Relative_Humidity_Profile</td>
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<td>10.66</td>
</tr>
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<td>0.02</td>
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</table>

Total Bytes/Record Mode 7.1: 25845.5

Total Bytes/Record Mode 7.2: 8710.5
2.3 Lidar Level 2 Operation Layer DP

In the following tables, the parameters listed in black font will always be on the product regardless of operating mode. Red font denotes mode 7.1 only, blue font mode 7.2 only.

October 01, 2018 V1-02 Corresponds to V3_00 L2 Product Software

Data File Name: 5 km Layer: CATS-ISS_L2O_D-M7.1-V3-00_05kmLay.2014-09-17T00-31-01UTC.hdf5

Table 1: CATS-ISS 5 km Layer Record Summary for Mode 7.1

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<thead>
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<th>Record Name</th>
<th>Reference Table</th>
<th>Record Size (Bytes)</th>
<th>Records/File</th>
<th>File Size (Bytes)</th>
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</thead>
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<td>Metadata</td>
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<tr>
<td>Geolocation and Viewing Geometry</td>
<td>Table 5</td>
<td>84</td>
<td>4,155</td>
<td>349,020</td>
</tr>
<tr>
<td>Layer Descriptor</td>
<td>Table 6</td>
<td>1,470</td>
<td>4,155</td>
<td>6,107,850</td>
</tr>
<tr>
<td>Layer Optical Properties</td>
<td>Table 7</td>
<td>4,480</td>
<td>4,155</td>
<td>18,614,400</td>
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<tr>
<td><strong>Total Bytes/Granule (Mode 7.1)</strong></td>
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Table 2: CATS-ISS 5 km Layer Record Summary for Mode 7.2

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<th>Reference Table</th>
<th>Record Size (Bytes)</th>
<th>Records/File</th>
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<td>Table 5</td>
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<tr>
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<td>Table 7</td>
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Table 3: CATS-ISS Metadata Record (1 per granule)

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<th>Bytes</th>
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'These are 2 element arrays for left FOV (1) and right FOV(2)
Table 4: CATS-ISS Layer Geolocation and Viewing Geometry Record

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<th>Data Type</th>
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<th>Nominal Range</th>
<th>Elem/Rec</th>
<th>Bytes</th>
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<td>CATS_Fore_FOV_Latitude</td>
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<td>CATS_Fore_FOV_Longitude</td>
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<td>CATS_Left_FOV_Angle</td>
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<td>CATS_Fore_FOV_Angle</td>
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<td>-10 - 10</td>
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Nominal Granule will span roughly 45 minutes (1/2 orbit) or 2700 seconds

Table 5: CATS-ISS Layer Descriptor Record

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<th>Nominal Range</th>
<th>Elem/Rec</th>
<th>Bytes</th>
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Table 6: CATS-ISS Layer Optical Properties

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| Total Bytes/Rec Mode 7.1 | 4480 |
| Total Bytes/Rec Mode 7.2 | 1400 |
Table 7: Definitions of CATS Vertical Feature Mask Parameters

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<th>Parameter</th>
<th>Interpretation</th>
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| Sky_Condition     | 0 = clean skies (no clouds/aerosols)  
1 = clear skies (no clouds)  
2 = cloudy skies (no aerosols)  
3 = hazy/cloudy (both clouds/aerosols) |
| Feature_Type      | 0 = invalid  
1 = cloud  
2 = undetermined  
3 = aerosol |
| Feature_Type_Score|  | 10 | = high confidence  
| 1 | = low confidence  
| 0 | = zero confidence |
| Cloud_Phase       | 0 = invalid  
1 = water cloud  
2 = unknown cloud phase  
3 = ice cloud |
| Cloud_Phase_Score |  | 10 | = high confidence  
| 1 | = low confidence  
| 0 | = zero confidence |
| Aerosol_Type      | 0 = invalid  
1 = marine  
2 = marine mixture  
3 = dust  
4 = dust mixture  
5 = clean/background  
6 = polluted continental  
7 = smoke  
8 = UTLS |
Table 8: Definition of CATS Optical Properties Flags

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Interpretation</th>
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| Depol_Quality_Flag            | 0 = Valid, good quality depolarization data  
                               | 1 = Depolarization ratio biased low due to recent laser turn on  
                               | 2 = Depolarization ratio biased high as laser stabilizes |
| Extinction_QC_Flag            | -1 = calculation not attempted  
                               | 0 = non-opaque layer extinction analysis nominal  
                               | 1 = layer hit earth’s surface before layer bottom reached, adjusted bottom  
                               | 2 = lowering lidar ratio thru iteration process successful  
                               | 3 = raising lidar ratio thru iteration process successful  
                               | 4 = # of iterations maxed out, analysis stopped  
                               | 5 = signal inside layer saturated before bottom, analysis stopped  
                               | 6 = layer is opaque, layer OD= -1, initial lidar ratio accepted  
                               | 7 = layer is opaque, layer OD= -1, lidar ratio iteration successful  
                               | 8 = layer OD out of bounds (invalid) OD= -999.9  
                               | 9 = layer analysis invalid because final lidar ratio out of bounds |
| Lidar_Ratio_Selection_Method  | 0 = generic default  
                               | 1 = aerosol GEOS5 lookup table  
                               | 2 = cloud lookup table  
                               | 3 = 1064 lidar ratio used 532 OD (for ice clouds only)  
                               | 4 = constrained result using clear zone just below layer  
                               | 5 = constrained result with opaque layer  
                               | 6 = lowered lidar ratio by a max of 15sr to reach layer bottom  
                               | 7 = raised lidar ratio by a max of 15sr to reach layer bottom  
                               | 8 = open slot (not used)  
                               | 9 = missing |
| Constrained_Lidar_Ratio_Flag  | 0 = useful value using nominal “constrained’ procedure  
                               | 1 = useful value using opaque “constrained’ procedure  
                               | 2 = constrained lidar ratio outside thresholds  
                               | 3 = below layer clear zone too small  
                               | 4 = clear zone signal error > threshold  
                               | 5 = Tp_sq < allowed min  
                               | 6 = Tp_sq at or below 0.0  
                               | 7 = useful 1064 lidar ratio using 532 OD (for ice clouds only)  
                               | 8 = Tp_sq at or below 0.0 in opaque cloud conditions  
                               | 9 = missing |
2.4 Lidar Level 2 Operation Profile DP

In the following tables, the parameters listed in black font will always be on the product regardless of operating mode. Red font denotes mode 7.1 only and blue font mode 7.2 only.

October 01, 2018 V3.00  Corresponds to V3_00 L2 Product Software

Data File Name:
5 km Profile:  CATS-ISS_L2O_N-M7.1-V3-00_05kmPro.2014-09-17T00-31-01UTC.hdf5

**Table 1: CATS-ISS 5 km Profile Record Summary for Mode 7.1**

<table>
<thead>
<tr>
<th>Record Name</th>
<th>Reference Table</th>
<th>Record Size (Bytes)</th>
<th>Records/File</th>
<th>File Size (Bytes)</th>
</tr>
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<tbody>
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<td>Metadata</td>
<td>Table 4</td>
<td>2,502</td>
<td>1</td>
<td>2,502</td>
</tr>
<tr>
<td>Geolocation and Viewing Geometry</td>
<td>Table 5</td>
<td>84</td>
<td>4,155</td>
<td>2,326,800</td>
</tr>
<tr>
<td>5 km Profile</td>
<td>Table 6</td>
<td>108,894</td>
<td>4,155</td>
<td>452,454,570</td>
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**Table 2: CATS-ISS 5 km Profile Record Summary for Mode 7.2**

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Table 3: CATS-ISS Metadata Record (1 per granule)

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<th>Bytes</th>
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*These are 2 element arrays for left FOV (1) and right FOV(2)*
Table 4: CATS-ISS Profile Geolocation and Viewing Geometry Record

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<th>Nominal Range</th>
<th>Elem/Rec</th>
<th>Bytes</th>
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<td>12</td>
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<td>-60 - 60</td>
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<td>12</td>
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<tr>
<td>CATS_Right_FOV_Longitude</td>
<td>Float</td>
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<td>-180 - 180</td>
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<td>CATS_Fore_FOV_Latitude</td>
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<td>12</td>
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<td>CATS_Fore_FOV_Longitude</td>
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<td>3</td>
<td>12</td>
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<tr>
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<td>12</td>
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<td>-10 - 10</td>
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<td>12</td>
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<td>3</td>
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<td>0 - 100</td>
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<td>4</td>
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<td>0 - 100</td>
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<td>4</td>
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<td>Total Bytes/Rec Mode 7.2</td>
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</table>

Nominal Granule will span roughly 45 minutes (1/2 orbit) or 2700 seconds

Table 5: CATS-ISS 5 km Profile Record

<table>
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<tr>
<th>Parameter</th>
<th>Data Type</th>
<th>Units</th>
<th>Nominal Range</th>
<th>Elem/Rec</th>
<th>Bytes</th>
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<td>4</td>
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Table 6: Definitions of CATS Vertical Feature Mask Parameters

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</tr>
<tr>
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<td>1 = clear skies (no clouds)</td>
</tr>
<tr>
<td></td>
<td>2 = cloudy skies (no aerosols)</td>
</tr>
<tr>
<td></td>
<td>3 = hazy/cloudy (both clouds/aerosols)</td>
</tr>
<tr>
<td>Feature_Type</td>
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</tr>
<tr>
<td></td>
<td>1 = cloud</td>
</tr>
<tr>
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<td>2 = undetermined</td>
</tr>
<tr>
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<td>3 = aerosol</td>
</tr>
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</tr>
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<td>3 = ice cloud</td>
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<td>3 = dust</td>
</tr>
<tr>
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<td>4 = dust mixture</td>
</tr>
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<td>5 = clean/background</td>
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<td>6 = polluted continental</td>
</tr>
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<td>7 = smoke</td>
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<td>8 = UTLS</td>
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Table 7: Definition of CATS Optical Properties Flags

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</tr>
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</tr>
<tr>
<td></td>
<td>2 = Depolarization ratio biased high as laser stabilizes</td>
</tr>
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<td>Extinction_QC_Flag</td>
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<td>0 = non-opaque layer extinction analysis nominal</td>
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<td>1 = layer hit earth’s surface before layer bottom reached, adjusted bottom</td>
</tr>
<tr>
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<td>2 = lowering lidar ratio thru iteration process successful</td>
</tr>
<tr>
<td></td>
<td>3 = raising lidar ratio thru iteration process successful</td>
</tr>
<tr>
<td></td>
<td>4 = # of iterations maxed out, analysis stopped</td>
</tr>
<tr>
<td></td>
<td>5 = signal inside layer saturated before bottom, analysis stopped</td>
</tr>
<tr>
<td></td>
<td>6 = layer is opaque, layer OD= -1, initial lidar ratio accepted</td>
</tr>
<tr>
<td></td>
<td>7 = layer is opaque, layer OD= -1, lidar ratio iteration successful</td>
</tr>
<tr>
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<td>8 = layer OD out of bounds (invalid) OD= -999.9</td>
</tr>
<tr>
<td></td>
<td>9 = layer analysis invalid because final lidar ratio out of bounds</td>
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2.5 Lidar Level 2 Operational Near Real Time

The CATS NRT data product began production in May 2015, once the instrument was in Mode 7.2. Since this mode was the main mode of operation, the NRT product is only available for Mode 7.2 and ceased to be produced once the instrument stopped working on 29 October 2017. Thus, there is no V3-00 of the CATS NRT data product.

October 01, 2018 V2.01 Corresponds to V2_01 L2 Product Software

Data File Name: CATS_L2O-M7.1-V2-01_05kmNRT.2014-09-17T00-31-01UTC.hdf

Table 1: CATS-ISS 5 km Near Real-Time Record Summary for Mode 7.2

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<td>Geolocation and Viewing Geometry</td>
<td>Table 5</td>
<td>302</td>
<td>4,155</td>
<td>1,254,810</td>
</tr>
<tr>
<td>5 km Near Real-Time</td>
<td>Table 6</td>
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<td>40,187,160</td>
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Table 2: CATS-ISS Metadata Record (1 per granule)

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<th>Parameter</th>
<th>Data Type</th>
<th>Units</th>
<th>Nominal Range</th>
<th>Elem/ Granule</th>
<th>Bytes</th>
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<td>Product ID</td>
<td>Char</td>
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<td>Char</td>
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<td>N/A</td>
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<td>N/A</td>
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<td>Char</td>
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<td>N/A</td>
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<tr>
<td>Granule_Stop_DateTime</td>
<td>Char</td>
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<td>N/A</td>
<td>1</td>
<td>40</td>
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<tr>
<td>Granule_Production_DateTime</td>
<td>Char</td>
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<td>N/A</td>
<td>1</td>
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<td>Granule_Start_Latitude</td>
<td>Float</td>
<td>deg</td>
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<tr>
<td>Granule_Start_Longitude</td>
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<td>N/A</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Granule_Stop_Latitude</td>
<td>Float</td>
<td>deg</td>
<td>N/A</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Granule_Stop_Longitude</td>
<td>Float</td>
<td>deg</td>
<td>N/A</td>
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<td>4</td>
</tr>
<tr>
<td>Granule_Start_RDM</td>
<td>Float</td>
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<td>N/A</td>
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Table 3: CATS-ISS Profile Geolocation and Viewing Geometry Record

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<th>Nominal Range</th>
<th>Elem/Rec</th>
<th>Bytes</th>
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<td>-60 - 60</td>
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<td>12</td>
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<td>CATS_Fore_FOV_Longitude</td>
<td>Float</td>
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<td>-180 - 180</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>CATS_Fore_FOV_Angle</td>
<td>Float</td>
<td>deg</td>
<td>-10 - 10</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Index_Top_Bin</td>
<td>Int</td>
<td>N/A</td>
<td>0 - 533</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total Bytes/Sec Mode 7.2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>302</td>
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</table>

Nominal Granule will span roughly 45 minutes (1/2 orbit) or 2700 seconds

Table 4: CATS-ISS 5 km Near Real-Time Record

<table>
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<th>Parameter</th>
<th>Data Type</th>
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<th>Elem/Rec</th>
<th>Bytes</th>
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<td>Profile.ID</td>
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<td></td>
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<tr>
<td>Day_Night_Flag</td>
<td>Byte</td>
<td>N/A</td>
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<td>1</td>
<td>2</td>
</tr>
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<td>Surface_Type_Fore_FOV</td>
<td>Byte</td>
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<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Lidar_Surface_Altitude_Fore_FOV</td>
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<td>1</td>
<td>4</td>
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<tr>
<td>DEM_Surface_Altitude_Fore_FOV</td>
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</tr>
<tr>
<td>Feature_Type_Fore_FOV</td>
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<td>1066</td>
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<tr>
<td>Feature_Type_Score_Fore_FOV</td>
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<td>-10-10</td>
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<td>1066</td>
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<tr>
<td>Feature_Subtype_Fore_FOV</td>
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<td>533</td>
<td>1066</td>
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<tr>
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<td>0-1.8</td>
<td>533</td>
<td>2132</td>
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<td>-----------------------------------------------</td>
<td>--------------------------------------------------------------------------------</td>
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<tr>
<td>Sky_Condition</td>
<td>0 = clean skies (no clouds/aerosols)</td>
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</tr>
<tr>
<td></td>
<td>1 = clear skies (no clouds)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2 = cloudy skies (no aerosols)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 = hazy/cloudy (both clouds/aerosols)</td>
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<td></td>
</tr>
<tr>
<td>Feature_Type</td>
<td>0 = invalid</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1 = cloud</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
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<td></td>
<td>2 = undetermined</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>3 = aerosol</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4 = no signal (attenuated)</td>
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<td>Feature_Type_Score</td>
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<td>1</td>
<td>= low confidence</td>
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<td></td>
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<td>0</td>
<td>= zero confidence</td>
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</tr>
<tr>
<td></td>
<td>1 = water cloud</td>
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<tr>
<td></td>
<td>2 = unknown cloud phase</td>
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</tr>
<tr>
<td></td>
<td>3 = ice cloud</td>
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</tr>
<tr>
<td></td>
<td>4 = marine aerosol</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 = marine mixture aerosol</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6 = dust</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7 = dust mixture</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>8 = clean/background aerosol</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>9 = polluted continental aerosol</td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>10 = smoke</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>11 = volcanic aerosol</td>
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<td>Float N/A 0-1.0 533 2132</td>
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Appendix A: ISS Payload Broadcast Ancillary Data (Dataset 16)

These variables should be included in downlinked data stream.

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<td>X-CTRS (Conventional Terrestrial Reference System) Position, - MSP (Most significant place)</td>
</tr>
<tr>
<td>2</td>
<td>X-CTRS Position - LSP (Least significant place)</td>
</tr>
<tr>
<td>3</td>
<td>Y-CTRS Position - MSP</td>
</tr>
<tr>
<td>4</td>
<td>Y-CTRS Position - LSP</td>
</tr>
<tr>
<td>5</td>
<td>Z-CTRS Position – MSP</td>
</tr>
<tr>
<td>6</td>
<td>Z-CTRS Position – LSP</td>
</tr>
<tr>
<td>7</td>
<td>X-CTRS Velocity – MSP</td>
</tr>
<tr>
<td>8</td>
<td>X-CTRS Velocity – LSP</td>
</tr>
<tr>
<td>9</td>
<td>Y-CTRS Velocity – MSP</td>
</tr>
<tr>
<td>10</td>
<td>Y-CTRS Velocity – LSP</td>
</tr>
<tr>
<td>11</td>
<td>Z-CTRS Velocity – MSP</td>
</tr>
<tr>
<td>12</td>
<td>Z-CTRS Velocity – LSP</td>
</tr>
<tr>
<td>13</td>
<td>Scalar Part of Local Vertical Local Horizontal (LVLH) Quaternion – MSP</td>
</tr>
<tr>
<td>14</td>
<td>Scalar Part of LVLH Quaternion – LSP</td>
</tr>
<tr>
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<td>X-Component of Vector Part of Quaternion - MSP</td>
</tr>
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<td>16</td>
<td>X-Component of Vector Part of Quaternion - LSP</td>
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<td>Y-Component of Vector Part of Quaternion - MSP</td>
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<td>18</td>
<td>Y-Component of Vector Part of Quaternion - LSP</td>
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<td>19</td>
<td>Z-Component of Vector Part of Quaternion - MSP</td>
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<td>17-bits 10-11</td>
<td>Quality of Solar LOS Data</td>
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<tr>
<td>17-bits 12-13</td>
<td>Quality of J2000 to Body Quaternion Data</td>
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<tr>
<td>18-bits 14-15</td>
<td>Status of Orbital Data</td>
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<tr>
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<td>USGNC PC D Coarse Time Tag - MSP</td>
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<tr>
<td>20</td>
<td>USGNC PC D Coarse Time Tag - LSP</td>
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</tbody>
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