New Horizons Mission Namespace

NASA Planetary Data System

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USER GUIDE

The New Horizons Mission, the first to travel to the Pluto system, was launched in 2006 and flew past Pluto on 14 July 2015. After the successful completion of its primary mission, an extended mission was granted to investigate the Kuiper Belt Object (KOB) 2014 MU69 (Arrokoth). The New Horizons mission data were originally developed and archived in PDS3 format. This dictionary was developed as part of the PDS4 migration effort, and includes all phases of the primary and extended mission.

CHAPTER

ONE

INTRODUCTION

This *User's Guide* provides a brief overview of the New Horizons Mission (NH or "nh:") namespace for those working with data from New Horizons primary or extended missions. The primary New Horizons mission was to the Pluto system. The extended missions to date have been called the "Kuiper Belt Extended Missions 1 and 2", or "KEM1" and "KEM2", in the mission documentation and metadata.

> **Note** *that the New Horizons legacy data migration is in its early stages, with labels being designed for each instrument in turn. This namespace is in active development and will continue to be so for the forseeable future.*

Data from the primary and first extended ("KEM1") missions were archived in PDS3 format and migration is underway to convert the legacy data into PDS4. These migrated products will also serve as templates for the second extended ("KEM2") mission, which will be delivered in PDS4 format.

This guide presents the major features of the namespace.

CHAPTER

TWO

OVERVIEW OF THE NEW HORIZONS (NH) MISSION DICTIONARY

The New Horizons Mission, the first to travel to the Pluto system, was launched in 2006 and flew past Pluto on 14 July 2015. After the successful completion of its primary mission, an extended mission was granted to investigate the Kuiper Belt Object (KOB) 2014 MU69 (Arrokoth). The New Horizons mission data were originally developed and archived in PDS3 format. This dictionary was developed as part of the PDS4 migration effort, and includes all phases of the primary and extended mission.

- **Primary Steward:** Anne Raugh, Small Bodies Node, University of Maryland (@acraugh on Github)
- **Dictionary Repo:** https://github.com/pds-data-dictionaries/ldd-nh
- **Namespace Prefix:** nh:

Corrections, changes, and additions should be submitted through the PDS LDD Issue Repo.

CHAPTER

THREE

ORGANIZATION OF CLASSES AND ATTRIBUTES

The New Horizons dictionary has a single top-level class that must be used to access any of the NH metadata classes. Below that, there are major subclasses for metadata that is common to all (or multiple instruments), as well as classes specific to particular instruments. Processed and calibrated data will generally have additional classes to provide instrument-specific processing details.

The following sections describe the major divisions of the New Horizons Mission namespace, in the order in which they occur in the schema (and thus, labels).

3.1 Top-Level Class: <nh:Mission_Parameters>

The *<nh:Mission_Parameters>* class acts as a wrapper for all other NH classes. It contains one required attribute and (as of this writing) two optional classes for data specific to the Multispectral Visible Imaging Camera (MVIC) part of in the Ralph instrument package.

The class contains a single required attribute, *<nh:mission_phase_name>*, with the string identifying the mission phase. Mission phase names are unique to the primary or extended mission in which they occur. Specifically, the phases in the extended missions contain the extended mission acronym ("KEM1 Encounter", for example).

The major subclasses of the *<nh:Mission_Parameters>* class are:

- *<nh:Observation_Parameters>*
- *<nh:MVIC_Calibration_Information>*
- *<nh:Radiometric_Converstion_Constants>*
- *<nh:REX_Radiometry_Information>*

You can see a complete outline of the namespace under the *New Horizons Mission Namespace Outline* topic.

3.2 Subclass: <nh:Observation_Parameters>

The *<nh:Observation_Parameters>* class provides details specific to the New Horizons mission and the instrument used to make the observation comprising the data product. It provides three attributes and two classes. As in the PDS common namespace, in the NH dictionary attributes names are all lowercase; class names are in title case.

This class contains:

- <nh:telemetry_appid>
- <nh:sequence_id>
- <nh:observation_description>

- <nh:Mission_Elapsed_Time>
- <nh:Detector>
- <nh:LORRI_Target_Information>
- <nh:Spacecraft_State>

None of these components is repeatable; all are expected to be present in all raw and processed/calibrated data labels.

<nh:telemetry_appid>, <nh:sequence_id>, and <nh:observation_description>
These attributes are provided primarily for provenance and to provide some minimal description of planned activities for the end user. The *nh:telementry_appid* is tied to instrument operating mode and to onboard processing like data compression. The mission documentation for each instrument will provide further detail if desired. The *<nh:sequence_id>* ties into the instrument observing plan, and the codes comprising that ID are roughly translated into something approaching English in the *<nh:observation_description>* string.

<nh:Mission_Elapsed_Time>
The *<nh:Mission_Elapsed_Time>* class provides the spacecraft clock partition and count at the start and end of the observation comprising the data product. The translation from spacecraft clock to UTC is dependent on the hardware and is usually described in the mission documentation. Many missions and end-users use the publicly available Navigation and Ancillary Information (NAIF) Toolkit to perform this conversion.

<nh:Detector>
The *<nh:Detector>* class identifies the detector used to make the observation, and includes classes to provide detector-specific parameters. "Detector" may mean an instrument, or it may mean literally one of several detectors available within an instrument (as is the case of the MVIC instrument, for example). This class will contain detector-specific subclasses where needed to provide specific observational settings for the detector.

<nh:LORRI_Target_Information>
The *<nh:LORRI_Target_Information>* class provides attributes specific to the targeting of a LORRI imager observation.

<nh:Spacecraft_State>
The *<nh:Spacecraft_State>* class provides information about thruster firings, spin state, scan rate, and spacecraft motion at the time of the observation.

3.3 Subclass: <nh:MVIC_Calibration_Information>

The *<nh:MVIC_Calibration_Information>* class is used in labels for processed data from all seven MVIC detectors. It provides detector-specific quantities used in processing the data, and in the case of the MVIC framing camers, it provides the specific left- and right-side biases used to process each frame.

This class contains:

- <nh:physical_pixel_size>
- <nh:read_noise>
- <nh:gain>
- <nh:tdi_median_bias_level>
- <nh:Framing_Biases>

<nh:physical_pixel_size>, <nh:read_noise> and <nh:gain>
The *<nh:physical_pixel_size>* value is constant for all pixels on all MVIC detectors. It is provided explicitly for the convenience of users further analyzing to the data. The *<nh:read_noise>* and *<nh:gain>* are also provided for all MVIC observations.

<nh:tdi_median_bias_level>
The *<nh:tdi_median_bias_level>* appears only in processed time delay integration (TDI) observations, from the color channels and the two panchromatic TDI channels. Bias levels for the TDI channels are determined during cruise operations and may be updated through the course of the mission.

<nh:Framing_Biases>
The *<nh:Framing_Biases>* class only appears in processing sequences from the MVIC framing array. It contains one *<nh:Frame_Bias_Levels>* class for each frame comprising the observation that identifies the frame by number and lists the left- and right-side bias levels applied in processing that particular frame. For framing observations, bias is measured during each observations using shielded pixels on either edge of the array.

3.4 Subclass: <nh:Radiometric_Conversion_Constants>

NOTE: *As of version 1.1.0, this class replaces the deprecated <nh:MVIC_Conversion_Constants> class. The content of that class is included in this one, with additional constants added as needed. This class is used by multiple instruments.*

The *<nh:Radiometric_Conversion_Constants>* class is used in labels for processed data from all seven MVIC detectors. The MVIC pipeline does not produce "calibrated" data in the sense that PDS defines "calibrated" - specifically, "Data reduced to physical units". The final reduction step depends on both the spectal characteristics of the target and whether that target is resolved. Instead, the calibration documentation provided with the archive includes formulae for applying the absolute calibration for specific targets, and the constants needed to plug into the formulae are provided in this class.

This class contains:

- <nh:pivot_wavelength>
- <nh:Resolved_Source>
- <nh:Unresolved_Source>

<nh:pivot_wavelength>
The *<nh:pivot_wavelength>* attribute contains the pivot wavelength of the filter/dectector combination.

<nh:Resolved_Source>
The *<nh:Resolved_Source>* class provides the units of measure (units of radiance, in the case of resolved targets) applicable to the resulting pixel values. Other attributes contain the conversion constants for five targets:

- The Sun
- Jupiter
- (5145) Pholus, a centaur
- Pluto
- Charon
- Arrokoth

<nh:Unresolved_Source>
The *<nh:Unresolved_Source>* class provides the units of measure (units of irradiance, in the case of unresolved targets) applicable to the resulting pixel values. Other attributes contain the conversion constants for five targets:

- The Sun
- Jupiter
- (5145) Pholus, a centaur
- Pluto

- Charon
- Arrokoth

3.5 Subclass: <nh:REX_Radiometry_Information>

The *<nh:REX_Radiometry_Information>* class is used in labels for data from the Radio Science Experiment. The attributes in this class provide important instrument parameters and coefficients used to translate raw radiometer counts into physical units for a given product.

This class contains:

- <nh:frame_data_source>
- <nh:agc_gain_setting>
- <nh:agc_setting_source>
- <nh:agc_gain_provenance>
- <nh:base_agc_gain>
- <nh:base_power>
- <nh:radio_bandwidth>
- <nh:radiometry_response_step>
- <nh:radiometry_response_offset>
- <nh:iq_calibration_constant>
- <nh:time_tag_calibration_constant>

<nh:frame_data_source>
The *<nh:frame_data_source>* attribute indicates the source of the input as a two- digit hexadecimal number (i.e., one octet), represented as a string prefixed by '0x'. 0x00 is the default source when taking data of external 7.2 GHz signal or external radiometry. All other values indicate REX-internal sources intended for diagnostics. The 4 least significant bits and the single most significant bit are not used.

<nh:agc_gain_setting>
The *<nh:agc_gain_setting>* attribute supplies the value of the AGC gain setting used in the radiometry calibration.

<nh:agc_setting_source>
The *<nh:agc_setting_source>* attribute provides the source of the *<nh:agc_gain_setting>* value. This attribute will have a value of either 'AUX' or 'ULCMD'.

<nh:agc_gain_provenance>
The *<nh:agc_gain_provenance>* attribute supplies the provenance for the *<nh:agc_gain_setting>* attribute. If *<nh:agc_setting_source>* = 'ULCMD', this value will take the form 'YYDOY.ssf:...', where YY is the two-digit year, DOY is the day-of-year, and '...' represents a string that indicates the source sequence file. Otherwise (if *<nh:agc_setting_source>*='AUX'), this value will be 'Nominal'. The nominal AGC gain values are 167 for side A and 163 for side B.

<nh:base_agc_gain> and <nh:base_power>
The *<nh:base_agc_gain>* and *<nh:base_power>* contain the nominal/base AGC gain setting and the base/offset dBm value for the active side of the REX electronics, respectively. The base power is equivalent to the output power when RAW = (10^(-Ro/10))/Bandwidth and AGC = AGCOF, given the formula

Power[dBm] = Rbase + 10*log10(Bandwidth*RAW) + dBstep*(AGC-AGCOF) + Ro

The nominal values for this attribute are -176.852 for right circular polarization (side A) and -177.177 for left circular polarization (side B).

<nh:radio_bandwidth>
The *<nh:radio_bandwidth>* attribute provides the active bandwidth of the REX radio.

<nh:radiometry_response_step> and <nh:radiometry_response_offset>
The *<nh:radiometry_response_step>* and *<nh:radiometry_response_offset>* attributes contain the slope and intercept, for converting from raw counts to physical/ radiometric quantities. These two attributes' values are represented by 'dBstep' and 'Ro', respectively, in the formula

Power[dBm] = Rbase + 10*log10(Bandwidth*RAW) + dBstep*(AGC-AGCOF) + Ro

<nh:iq_calibration_constant>
The *<nh:iq_calibration_constant>* attribute supplies the I and Q response of the REX instrument, used to convert between raw counts and an I/Q value in mV. This constant has a nominal value of (1000 / (2^13)) mV/count.

<nh:time_tag_calibration_constant>
The *<nh:time_tag_calibration_constant>* attribute provides the coefficient to be used when converting between raw counts and time tag seconds, e.g. 'DT' in the formula

timetag[s] = DT * RAW

CHAPTER

FOUR

NEW HORIZONS MISSION NAMESPACE OUTLINE

<nh:Mission_Parameters> is the public entry point to the New Horizons Mission namespace. This class contains all other NH classes and must be included to gain access to them. Below is a summary outline of all classes and attributes currently available in the NH mission dictionary, in the order in which they would appear in a label if every single one was used.

Note that there are no real cases in which every single mission class and attribute would appear in a single label. The point of this outline is primarily to catalog what is present and show the required ordering within classes when they are included in a label.

```
<nh:Mission_Parameters>
    <nh:mission_phase_name>

    <nh:Observation_Parameters>
        <nh:telemetry_apid>
        <nh:sequence_id>
        <nh:observation_description>

        <nh:Mission_Elapsed_Time>
            <nh:clock_parition>
            <nh:start_clock_count>
            <nh:stop_clock_count>

        <nh:Detector>
            <nh:detector_name>
            <nh:detector_type>

            <nh:Alice_Details>
                <nh:aperture>

            <nh:Ralph_Details>
                <nh:met510>
                <nh:hk_packet_is_real>

            <nh:LEISA_Details>
                <nh:scan_type>
                <nh:leisa_mode>
                <nh:leisa_offset_1>
                <nh:leisa_offset_2>
                <nh:leisa_offset_3>
                <nh:leisa_offset_4>
                <nh:leisa_rate>
```

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```
                <nh:leisa_side>
                <nh:leisa_temperature>

            <nh:MVIC_Details>
                <nh:scan_type>
                <nh:tdi_rate>

            <nh:SWAP_Details>
                <nh:sweep_samples_count>

        <nh:LORRI_Target_Information>
            <nh:approx_target_name>
            <nh:approx_target_line>
            <nh:approx_target_sample>

        <nh:Spacecraft_State>
            <nh:thruster_x_enabled>
            <nh:thruster_y_enabled>
            <nh:thruster_z_enabled>
            <nh:gc_scan_rate>
            <nh:target_motion_rate>
            <nh:relative_control_mode_active>
            <nh:pointing_method>
            <nh:spacecraft_spin_state>

    <nh:MVIC_Calibration_Information>
        <nh:physical_pixel_size>
        <nh:read_noise>
        <nh:gain>
        <nh:tdi_median_bias_level>

        <nh:Framing_Biases>
            <nh:Frame_Bias_Levels>
                <nh:frame_number>
                <nh:left_side_median_bias>
                <nh:right_side_median_bias>

    <nh:Radiometric_Conversion_Constants>
        <nh:pivot_wavelength>

        <nh:Resolved_Source>
            <nh:units_of_conversion_constants>
            <nh:solar_constant>
            <nh:jupiter_constant>
            <nh:pholus_constant>
            <nh:pluto_constant>
            <nh:charon_constant>
            <nh:arrokoth_constant>

        <nh:Unresolved_Source>
            <nh:units_of_conversion_constants>
            <nh:solar_constant>
```

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```
            <nh:jupiter_constant>
            <nh:pholus_constant>
            <nh:pluto_constant>
            <nh:charon_constant>
            <nh:arrokoth_constant>

    <nh:REX_Radiometry_Information>
        <nh:frame_data_source>
        <nh:agc_gain_setting>
        <nh:agc_setting_source>
        <nh:agc_gain_provenance>
        <nh:base_agc_gain>
        <nh:base_power>
        <nh:radio_bandwidth>
        <nh:radiometry_response_step>
        <nh:radiometry_response_offset>
        <nh:iq_calibration_constant>
        <nh:time_tag_calibration_constant>
```

CHAPTER

FIVE

ALPHABETICAL LIST OF CLASSES

A complete list of all classes in the New Horizons Mission Dictionary, in alphabetical order, is available through the PDS4 Data Dictionary page, which is regenerated automatically with each release of the PDS4 Information Model.

To find the New Horizons Mission class list, look down the list of (alphabetically sorted) dictionary prefixes in the left menu for "Classes in the nh namespace". Select that item and the list of classes will be presented on both the left and the right as clickable links.

Clicking on the specific class name will produce a grid with the full, formal definition of the class.

Clicking on the class name in the "Referenced from:" line at the bottom of the grid will take you to the containing class, where you can see the cardinality of the class (i.e., whether it is required, optional, or repeatable) in the containing class.

You can also click on the attribute names listed to see details of the attribute definitions.

CHAPTER

SIX

ALPHABETICAL LIST OF ATTRIBUTES

A complete list of all attributes in the New Horizons Mission Dictionary, in alphabetical order, is available through the PDS4 Data Dictionary page, which is regenerated automatically with each release of the PDS4 Information Model.

To find the New Horizons Mission attribute list, look down the list of (alphabetically sorted) dictionary prefixes in the left menu for "Attributes in the nh namespace". Select that item and the list of attributes will be presented on both the left and the right as clickable links.

Clicking on the specific attribute name will produce a grid with the full, formal definition of the attribute, including data type, restrictions on values, and the list of defined permissible values (if any) and their definitions.

Note that attributes might appear as members of different classes, and that their definitions, or more likely their permissible values, might be context-dependent.

Clicking on the class name in the title bar of the attribute grid will take you to the definition of the class containing that attribute.

If the attribute has an associated unit of measure type, that attribute *must* have an XML attribute called "unit" in its tag when it is used. For example:

```
<nh:tdi_rate unit="Hz">40.4694</nh:tdi_rate>
```

You can see valid values to use for the "unit=" XML attribute by clicking on the value of "Unit of Measure Type" in the grid.

CHAPTER

SEVEN

MOCKUP LABELS

Mockup labels are created during the initial design and test phase for each instrument. They are not particularly good templates for designing a *real* label, in that they usually omit the half dozen or so discipline dictionaries needed to provide complete metadata for an actual observational product. But they do contain plausible values for the specific classes illustrated, as found in a sample product from the mission.

Mockup labels can be found in the New Horizions Mission Dictionary GitHub repo: https://github.com/pds-data-dictionaries/ldd-nh. They are in the *test/examples/* directory. Available mockups are:

- MVIC Red Channel Processed Data (MVICred)
- MVIC Framing Array Processed Data (MVICframe)
- LEISA Processed Data (LEISA)
- SWAP Histogram Data (SWAPhist)

CHAPTER

EIGHT

INSTRUMENT CLASS SUMMARIES

These abbreviated labels, also available in the GitHub repo *test/examples* directory, show only the <nh:Mission_Parameters> class with the class(es) specific to the instrument. The values shown in the labels are nonsensical.

- Alice Classes
- LEISA Classes
- LORRI Classes