Quick Start Guide to New Horizons Radio Science Experiment (REX) Data Sets =============================================================================

This is an abbreviated guide to the data. Many important details have been omitted for the sake of brevity; refer to the documentation for full details.

REX data comprise two types of measurements:

1) In-phase and Quadrature-phase (I/Q pair) measurements of ~7.2 GHz input uplink signals (tones, from the Earth-based Deep Space Network DSN) for the purpose of analyzing the temporal phase and frequency relationship between the received signal and the onboard Ultra Stable Oscillator (USO).

2) Radiometry of 4 cm wavelength (7.2 GHz) emission -- e.g., from a surface.

Continuous REX data taking is broken up into a series of data files. Each file covering 1024 ms is called an observation or REX Output Frame (ROF); this derives from the onboard partitioning for storage and telemetering to Earth.

Although this description focuses on the data as partitioned into separate files, a single continuous data taking activity comprises many of these files. Users will need to join several files' data to recreate the original sequence.

Each REX raw data file stores three primary data types from one ROF (1024 ms):

1) I/Q pair measurements of ~7.2 GHz input signals, heterodyned (2.5 MHz IF), filtered (4.5 MHz), sampled at 10 MHz, down-converted to baseband, and stored as 1250 IQ pairs per file; 14-bit signed integers onboard, stored 16-bit.

2) Radiometry of the 10 MHz samples, squared and summed over 102.4 ms, represented as 10 accumulating sums-of-squares per ROF, and reset to zero once per ROF; 40-bit integers onboard per sum stored as 64-bit integers. The 10th accumulated sum for each ROF is stored as the first Radiometry value in the next ROF.

3) Time tags incrementing every 102.4 ms, and not reset between ROFs; 24-bit onboard counter (rollover at 1.4 fortnights) stored as 32-bit integers. Time tags are an aid both to place each perROF file's data into their correct temporal position within the original continuous data taking sequence, and to determine if any data (ROFs) are missing.

Additional data stored in each file include: the original 5088 byte ROF byte stream, from before packet decommutation, with the individual bytes of the primary data types (above) interleaved; several types of instrument and spacecraft housekeeping (HK) data.

The REX calibrated data files contain the same measurements, but the values are converted to 32-bit floating point and scientific units: I/Q pairs are in Volts; Radiometry is in dBm power derived from calculated incremental sums over 102.4 ms intervals; Time Tags are in seconds.

Each ROF is stored in two files: a FITS file, with suffix .fit, containing the data; a PDS label file, with suffix .lbl, describing the FITS data layout. The files are laid out in a hierarchichal structure of directories:

<== directory names | file name ==>

data/20110520\_016821/rex\_0168215489\_0x7b3\_sci\_1.lbl

<+> <+> <+> <+> <+> <+> <+>

V V V V | | V

Toplevel Year, MET prefix MET\* of | V File suffix; .fit=FITS;

subdirec Month, 1st 6 MET obser | Data .lbl=PDS label

ory in Day digits\* vation V Type; eng=Raw; sci=Calibrated

data set ApID: Application Process ID

 \* see below for MET definition 0x7b0/0x7b1=Side A; 0x7b2/0x7b3=Side B

The following example has three files containing three contiguous ROFs:

rex\_0235942890\_0x7b3\_sci\_1.fit

rex\_0235942891\_0x7b3\_sci\_1.fit (MET = previous MET+1)

rex\_0235942893\_0x7b3\_sci\_1.fit (MET = previous MET+2)

The ten-digit MET (Mission Event Time) is the truncated integer time, in spacecraft clock seconds since launch, of the time of the ROF. Note that since the ROFs cover 1024 ms (1.024s), the METs will jump two seconds, instead of one, every 43 files in a contiguous sequence (44.032 = 1.024 x 43 > 44).

Use a PDS (http://pdssbn.astro.umd.edu/tools/tools\_readPDS.shtml) or FITS library (http://fits.gsfc.nasa.gov) to read these data. For the stubborn, a brief summary of the REX FITS layout is given here:

FITS files comprise one or more contiguous Data Units (DUs); the first DU is the Primary DU (PDU); subsequent DUs are Extension DUs (EDUs), numbered from 1 (the PDU is DU 0); each DU comprises a Header section and an optional, contiguous Data section; Header and Data sections always start on 2880 byte boundaries, and will always be padded to a multiple of 2880 bytes. Multibyte binary values (e.g., 32-bit float; 16-bit integers, etc.) are MSByte1st.

REX quantities are stored in binary form in FITS files.

PDS labels define DU sections in FITS files; PDS labels contain human and machine readable 'KEYWORD = VALUE' statements. Pointer statements (starting with a caret, ^) provide the ordinal, within the file, of the first fixed-length 2880-byte record of each DU; here is an example:

<==FITS file sections===> <=Corresponding PDS Label KEYWORD = VALUE lines=>

[PDU Header ]

[PDU Data Raw ROF ] ^IMAGE = ("REX\_0037927970\_0X7b\*.FIT", 10)

[EDU 1 Header ]

[EDU 1 Data; IQ Pairs ] ^EXTENSION\_IQVALS\_TABLE = ("REX\_003792\*.FIT", 12)

[EDU 2 Header ]

[EDU 2 Data; Rad. & TTag] ^EXTENSION\_RAD\_TIME\_TAGS\_TABLE = ("REX\*.FIT", 16)

The Raw ROF starts at byte 25921 (10\*28802779) of the file; I/Q Pairs at byte 31681 (12\*2880 2779); Radiometery and Time Tags at byte 43201 (16\*28802779).

A PDS TABLE object definition describes the layout and format of the values in the FITS Data section; refer to this //annotated, truncated sample PDS TABLE object:

OBJECT = EXTENSION\_RAD\_TIME\_TAGS\_TABLE // Start of TABLE OBJECT

ROWS = 10 // There are 10 rows in the table

ROW\_BYTES = 12 // There are 12 bytes in each row

COLUMNS = 2 // There are 2 COLUMNs in each row

OBJECT = COLUMN // Start of 1st COLUMN OBJECT description

NAME = "Radiometer" // 1st COLUMN contains Radiometer values

DATA\_TYPE = "MSB\_INTEGER" // Radiometry is MSBytefirst signed integers

BYTES = 8 // Radiometry is 8byte (64bit) integers

START\_BYTE = 1 // Radiometry values start at 1st byte in row

END\_OBJECT = COLUMN // End of 1st COLUMN OBJECT description

OBJECT = COLUMN // Start of 2nd COLUMN OBJECT description

NAME = "Time Tag" // 2nd COLUMN contains Time Tag values

DATA\_TYPE = "MSB\_INTEGER" // Time Tags are MSBytefirst signed integers

BYTES = 4 // Time Tags are 4byte (32bit) integers

START\_BYTE = 9 // Time Tag values start at 9th byte in row

END\_OBJECT = COLUMN // End of 1st COLUMN OBJECT description

Combine the previous two sections: the 10 Radiometry values are 64-bit signed MSBytefirst integers, starting at file ordinal bytes 43201, 43213 (43201+12), 43225, 43237, 43249, 43261, 43273, 43285, 43297, 43309; the 10 Time Tag values are 32-bit signed MSBytefirst integers, starting at file ordinal bytes 43209 (43201+91), 43221 (43209+12), 43233, 43245, 43257, 43269, 43281, 43293, 43305, 43317.

Tracking and Navigation Files (TNFs; TRK234 format), if present, are in the data/tnf/ subdirectory, are summarized in ASCII tables in that same directory, and are described in the document labeled with file TNFSIS.LBL.