JADE Level 3 Version 02 Files compared to Version 01 Files

- The ISSUES object has 3 new flags (Bits) added:
    - "Bit 20 = MCP Dipping Triggered, in one or more sensors."
      The first occurrence of MCP dipping was at PJ10,
      and therefore never seen in existing Level 3 Version 01 files.
    - "Bit 21 = MCP Dipped sensor's DATA set to fill values."
    - "Bit 22 = 1 or more ELC sensor DATA set to fill values."
- JAD_L30_HRS_ELC_ALL_CNT_*yyyyddd*_V02 files have a few new extra records prepended on the start of each mode change to high rate science, compared to JAD_L30_HRS_ELC_ALL_CNT_*yyyyddd*_V01.
    - New records have ISSUES Bit 22 flagged, previous records do not.
    - Similar is true for JAD_L30_CAL_ELC_ALL_CNT_*yyyyddd*_V02 files, but those are for the JADE operations team and not present in the PDS.
- Likewise, JAD_L30_HRS_ELC_TWO_CNT_*yyyyddd*_V02 files have the same few new extra records prepended on the start of each mode change to high rate science, compared to JAD_L30_HRS_TWO_ALL_CNT_*yyyyddd*_V01.
    - New records have ISSUES Bit 22 flagged, previous records do not.

- JAD_L30_LRS_ELC_ANY_CNT_*yyyyddd*_V01 files had incorrect MAG_VECTOR object that is corrected in V02.
    - This alone is the driver to go to version 02.
    - MAG_VECTOR z component is valid, the x and y components are incorrect.

- JAD_L30_HRS_ELC_ALL_CNT_*yyyyddd*_V01 files had a good MAG_VECTOR object, but a slightly better calibration is used in V02.
- Likewise, JAD_L30_HRS_ELC_TWO_CNT_*yyyyddd*_V01 files had a good MAG_VECTOR object, but a slightly better calibration is used in V02.
- Otherwise Level 3 JADE electron files have objects (DATA, position, field-of-view, time, etc.) are identical[1] in V01 & V02, only the MAG_VECTOR object changed.

- All Level 3 JADE ion files contents are the same[1] in V01 and V02.
    - Increment to Version 02 ion data is to only to keep the same version number between ions and electrons, for convenience.
- [1] [Object SOURCE_JADE_METAKERNEL may be different between V01 and V02, but they use the same reconstructed kernels for a given time.]
- A few typos or wording changes have been made to the Version 2 label/format files, but nothing of consequence to those datasets.

The only practical difference between Level 3 version 01 and Level 3 version 02 files is the MAG_VECTOR object in the electron files, and a few extra records at the start of each high rate science electron mode.

Level 3 Version 01 files exist on PDS through to 2017-140 only.

The following three pages go in to more depth on the reasons for the changes outlined on the first page.

The first case of MCP dipping

The first MCP dipping event was not until PJ10, so ISSUES flags were added to account for such situations.

Since Level 3 Version 01 files only exist up to 2017-140 (and PJ10 was 2017-350) this changes nothing in the 2015 to 2017-140 range of files.

What is MCP dipping? If a JADE sensor start measuring too many counts that the sensor becomes saturated, the mcp voltages are dipped (lowered) for a period of time (often 1 minute) to reduce the measured counts in order to protect the sensor.

Where did the extra high rate science electron records appear from?

Level 3 data should be science quality. Originally, any Level 2 record which had an MCP_NOT_AT_COMMANDED = 1 was excluded from Level 3. That is, the sensor's mcp voltage is not at the commanded voltage, therefore we do not know what voltage it is at, and cannot use that record for calibrated Level 3 science data. For HRS electrons (also for CAL electrons and HVE electrons too) there are three sensors per Level 2 record, and if any of the three MCP_NOT_AT_COMMANDED values in a record was 1, then the whole record was excluded from Level 3 Version 01 data.

After the MCP dipping, we realized that when electrons went from low rate science (one JADE-E sensor on only) to high rate science (multiple JADE-E sensors on), the sensor that was previous on in low rate science was already at the commanded voltage, but it took some time for the other sensors to turn on and ramp up to commanded mcp voltage. During that time, those sensors just turning on had MCP_NOT_AT_COMMANDED = 1, but the sensor used in low rate science had MCP_NOT_AT_COMMANDED = 0 and was taking science quality data. These records are now kept in Level 3 Version 02 high rate science electrons files, and the DATA from the sensors still ramping up to commanded voltage are set to the fill (MISSING_CONSTANT) values. During these times there is essentially only science data from one of the JADE-E sensors, providing a reduced coverage of pitch angles, but that is better than no coverage. Such intervals can be identified by looking in the record's ISSUES flag "Bit 22 = 1 or more ELC sensor DATA set to fill values."

In addition to setting the affected elements of DATA to fill values, the corresponding elements of DATA_SIGMA, BACKGROUND and BACKGROUND_SIGMA are also set to fill values, and MCP_NOT_AT_COMMANDED is set to 0 for all three sensors.

JADE MAG_VECTOR Introduction

Level 1 JADE-E data include an onboard MAG_VECTOR (in the spacecraft frame) and a timestamp for that vector, but only when the magnetic field strength magnitude is above a certain threshold (was originally 200 nT, later set to 25 nT), otherwise it returns fill values (MISSING_CONSTANTs). This means it is mostly fill values except around the few days near a perijove. This is a coarse quick-look mildly calibrated MAG value only to give us a sense of field direction. Onboard it is updated every 2 seconds (but not all updates are valid) so JADE uses a 'last received' valid value that was prior to the start of the JADE-E packet in question. It is a quick-look guide; the intention is to use Level 3 MAG files from the MAG team later for high-level work.

Since this JADE-E Level 1 MAG vector is in the spacecraft frame, it is also in the spacecraft frame in JADE-E Level 2, but is despun in JADE-E Level 3 to aid pitch angle calculations. This requires knowing the timestamp of the MAG_VECTOR so that the spin phase at that time can be calculated, then used to despin the vector. The despin only affects the x and y components, the z component (spin axis) remains the same.

The JAD_L30_LRS_ELC_ANY_CNT_*yyyyddd*_V01 Error

JADE-E Level 2 files have the MAG_VECTOR object (spacecraft frame) and the associated timestamp in two objects: MAG_TIMESTAMP_WHOLE and MAG_TIMESTAMP_SUB, where MAG_TIMESTAMP_SUB is a 2-byte fraction of a WHOLE tick, with values of 0 to 65535. This spacecraft clock (SCLK) value is written as a string in the form MAG_TIMESTAMP_WHOLE:MAG_TIMESTAMP_SUB (e.g. 525528184:60452).

You can think of the MAG_TIMESTAMP as a decimal value equal to

```
MAG_TIME_DECIMAL = MAG_TIMESTAMP_WHOLE + MAG_TIMESTAMP_SUB/65536
```
Eqn. 1

The conversion code to go from level 2 to level 3 files for JADE uses SPICE, and the (IDL) command `cspice_scs2e, sc, MAG_SCLK_str, et_MAG` to go from a MAG SCLK to ephemeris time (*et*), then the *et* value is used to calculate spin phase. *sc* is "NAIF ID code for a spacecraft, one of whose clock values is represented", which for JADE is either -61 for the standard precision, or -61999 for the high precision clock. The high precision clock uses a 2-byte sub-tick (with values 0-65535, e.g. MAG_TIMESTAMP_SUB) while the standard precision clock uses a 1-byte sub-tick (with values 0-255). Depending on which SPICE commands you use later, some want the standard clock, some the high precision.

In this bug, *sc* was set to the standard precision value of -61 (as used in previous SPICE commands) and had not been updated to the high precision value. As such, the SPICE code was effectively using a decimal time based on equation 2 below:

```
TIME_DECIMAL = TIMESTAMP_WHOLE + TIMESTAMP_SUB/256
```
Eqn. 2

While we intended it to treat it as equation 1, this bug meant it was actually doing:

```
MAG_TIME_DECIMAL = MAG_TIMESTAMP_WHOLE + MAG_TIMESTAMP_SUB/256
```
Eqn. 3

Since MAG_TIMESTAMP_SUB is often much greater than 256, the decimal time calculated is now many whole ticks later than it should be (up to 256 seconds later), and therefore it is very unlikely this incorrect time will have the same spin phase as the actual time. E.g. if MAG_TIMESTAMP_SUB = 60452, then instead of just adding on a fraction (<1) to the decimal ticks, equation 3 means it adds on 236.14062 ticks. If the spin phase is wrong, the despun MAG_VECTOR will be wrong too.

The fix in Version 2 is to set *sc* to -61999 for this SPICE command.

This bug only affected low rate science electron data, and only the MAG_VECTOR. It did not affect high rate science data, however the move to version 02 provides an opportunity to improve the high rate science electron data, as described in the following section.

The High Rate Science (HRS) Electron improvement for Level 3 Version 02

This affects both JAD_L30_HRS_ELC_ALL_CNT_* and JAD_L30_HRS_ELC_TWO_CNT_* files, but the version 01 files were 'correct', version 02 just has a better calibration.

This is similar to the low rate issue above, except for high rate science Level 1 JADE packets, only MAG_TIMESTAMP_WHOLE is returned. There is no MAG_TIMESTAMP_SUB, hence the SCLK string used in SPICE was just the whole number, e.g. '525563680'. This is equivalent to MAG_TIMESTAMP_SUB = 0, e.g. string of '525563680:00000' for high precision, and equations 1 to 3 would all give the same answer.

Onboard however, JADE is using both the WHOLE and SUB parts of the MAG time stamp, but only returning the WHOLE, effectively rounding down the decimal timestamp. In essence the uncertainty of HRS MAG time in version 01 is $\text{MAG\_TIMESTAMP\_WHOLE}_{-0}^{+1}$ for version 1 files.

We now believe that assuming on the ground that MAG_TIMESTAMP_SUB = 32768 (half of 65536, for high precision clock) is an improvement to provide a decimal time $\text{MAG\_TIMESTAMP\_WHOLE} + 0.5 \pm 0.5$ for version 02 files.

For a Juno spin period of 30 seconds, the spacecraft will spin ~12 degrees in 1 tick, hence the spin phase used to despin the MAG_VECTOR should be ~6 degrees greater for version 2 files than version 1.

To summarize, to despin the MAG_VECTOR in Level 3:

- Version 01 calculated spin phase at time MAG_TIMESTAMP_WHOLE +0.0,
- Version 02 calculated spin phase at time MAG_TIMESTAMP_WHOLE +0.5.

Therefore the MAG_VECTORs will be slightly different between the two versions.