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Development of a QA4EO Compliant System

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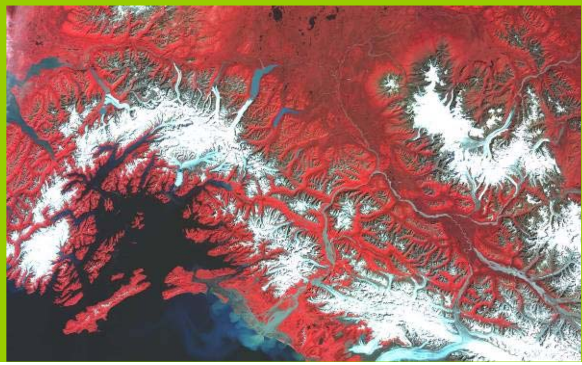


What do we have to do ?

The guiding principle for data quality within the QA4EO framework is that:

> ***All data and derived products must have associated with them a Quality Indicator (QI) based on documented quantitative assessment of its traceability to community agreed (ideally tied to SI) reference standards.***

All steps in the data product delivery chain (collection, processing and dissemination) must be documented with evidence of their traceability and the resulting quality information propagated through from end to end. This can be achieved by following the guidance document QA4EO-QAEO-GEN-DQK-002.

International Imaging

What do we have to do ?

- To understand the uncertainty we need to document **every** process and understand how it contributes to the overall uncertainty budget

- Unless we explore each process and document how it operates and determine which areas contribute we can not assess where the uncertainty lies.

- Many processes are dependent on lower-level operations which also need documenting.

- Assumptions need to be explored where possible and proof given of their validity or at least an estimate of the uncertainty they induce

DMCii Experiences – Original Approach

- Step 1 – Define all procedures as separate modules, document and make available for inspection. Determine in document how to calculate uncertainties. (Not a timeline). This is the Handbook of Protocols.
- Step 2 – Develop software product that implements relationships and has QC steps to assess the uncertainties for each pixel in a scene for all modules.
- Step 3 – Propagate uncertainties through system to get overall uncertainty on product, this is a quality indicator. Data from individual modules can be examined by end-users these are additional quality indicators.

Handbook of Protocols

- First step, made publicly available. Time consuming and very difficult (the first time)

Module 7 – SSDR Dark Correction

Description

When a sensor has no input signal (total darkness or shuttered) there is still a residual output voltage from the detectors. This residual voltage is due to the release of electrons due to thermal effects in the CCD substrate, hence is dependent on the temperature of the sensor.

When the sensor is imaging this thermal "dark current" is still present and needs to be removed. The term is additive and is only dependent on the temperature and the time that the sensor is integrating the signal, the integration time.

During the **Integration Time**, the CCD pixels collect a signal resulting from Dark Current in addition to the photosignal. Dark Current is thermally generated (as opposed to photo generated) and is a feature of all CCDs. The signal resulting from Dark Current (sometimes referred to as 'thermal signal') is unwanted and steps are taken in the signal chain to remove it.

Thermal signal accumulates linearly with **Integration Time** in the same way as photosignal. The magnitude of Dark Current also varies exponentially with temperature (roughly, it doubles for every 8K rise in temperature).

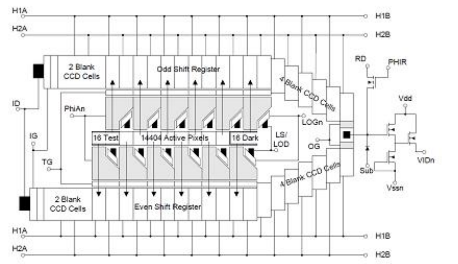
Methodology

Most of the thermal signal is removed with help from a special feature of the CCD called dark pixels. On the end of each CCD there are sixteen pixels which are identical to all the other pixels except that they are covered so that they collect no photosignal. The signal from these dark pixels (which is composed only of thermal signal) is measured in the same way as that from any other pixel. Since in all other respects, the dark pixels are the same as the other pixels, they accumulate thermal signal at the roughly the same rate. The value of these thermal signals is averaged (giving an estimate of thermal signal for all pixels) and subtracted from the measured value of the other, active pixels, thus removing the thermal signal (and any other fixed offsets that appear in the signal chain). This process is called **Automatic Dark Correction** and is enabled and disabled by telecommand. Pixel values that are less than the average offset are clamped to zero. This is unlikely to happen with normal images where the image value will be much greater than the dark current value subtracted. However for dark images (to determine calibration bias values) the onboard correction needs to be avoided to prevent loss of information by clamping negative values to zero.

On the edge of the CCD we can see 16 dark pixels. These are 16 pixels that are covered to prevent any light from the imager falling on them, so in theory they only measure the dark current value. Note also in the design the CCD is read out with odd pixels going to one shift register and even pixels to a separate shift register. This type of readout speeds up the readout process for large arrays, but also means that the data passes through two slightly different electronic chains and hence odd and even need to be treated differently.

This odd/even behaviour also affects our 16 reference dark pixels. Therefore we need to use 8 of these for the odd detectors in the array and 8 for the even detectors in the array. The reason we use so many detectors of the reference dark pixels is to reduce any effects due to noise in single detector data values.

Single Channel Schematic



So the overall procedure for the SSDR operation is as follows,

1. Voltage is quantised at 14 bit in the imager.
2. The 8 odd detectors on the 16 reference dark pixels are averaged and subtracted from all odd pixels in the image scene onboard the spacecraft, not on the ground
3. The 8 even detectors on the 16 reference dark pixels are averaged and subtracted from all even pixels in the image scene onboard the spacecraft, not on the ground

Given that each detector has slightly different behaviour in the imaging part of the array this subtraction will remove most of the dark current effects. However, there will be a detector specific residual which we also need to remove later in a separate step (See Dark Current Residual / Pattern Noise). This is the standard method for dark current removal for the SSDR and can not be modified.

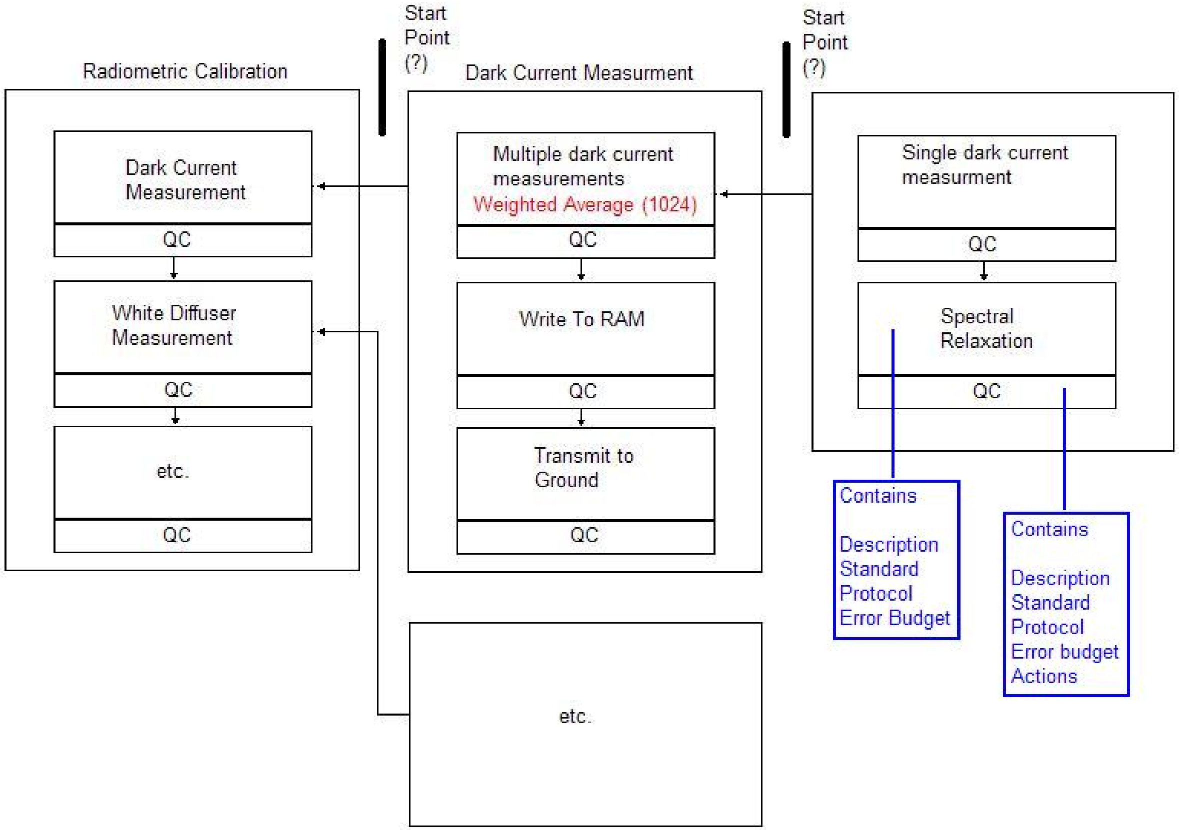
Problem Areas

In principle this method works perfectly. In practice it was found that there were temporal striping effects in the imagery that seemed related to the brightness of the imaging pixels that adjoined the 16 reference pixels.

In figure 1r0-2 we can see the along track profile of the digital numbers for detector number 18 (which is the first even imaging detector in the array). As can be see there is a lot of variation in the detector values, as it passes over cloud, land and water. Over cloud it is saturating, hence the plateau at a value of 255 (8 bit output limit).

Problems of Initial Approach

- Was bottom up approach.
- Wanted to get as much detail as possible then aggregate it. Too time consuming.
- After reviewing information on Sentinel-2 I came to the conclusion that it would not satisfy the basic needs of long term monitoring.
  - Static tests
- However initial work produced this diagram, showing higher level start points for occasions when data missing.



Current Direction

- Top down, start with TOA radiance (a delivered product), work backwards to fundamentals.

- Why ?
  - Looked at the Sentinel-2 information provided by Astrium on the pre-launch quantification of the sources of uncertainty.
    - Incredibly detailed
    - However, although can be measured in lab, can not be measured easily after launch
- So...
  - Looking at aggregate uncertainties I can measure post-launch.
  - Determining the lower level contributions where possible to these aggregates, but only where I can monitor them post-launch (or validate them).
  - Not as much fine detail, but provides a practical way of monitoring current and future performance.

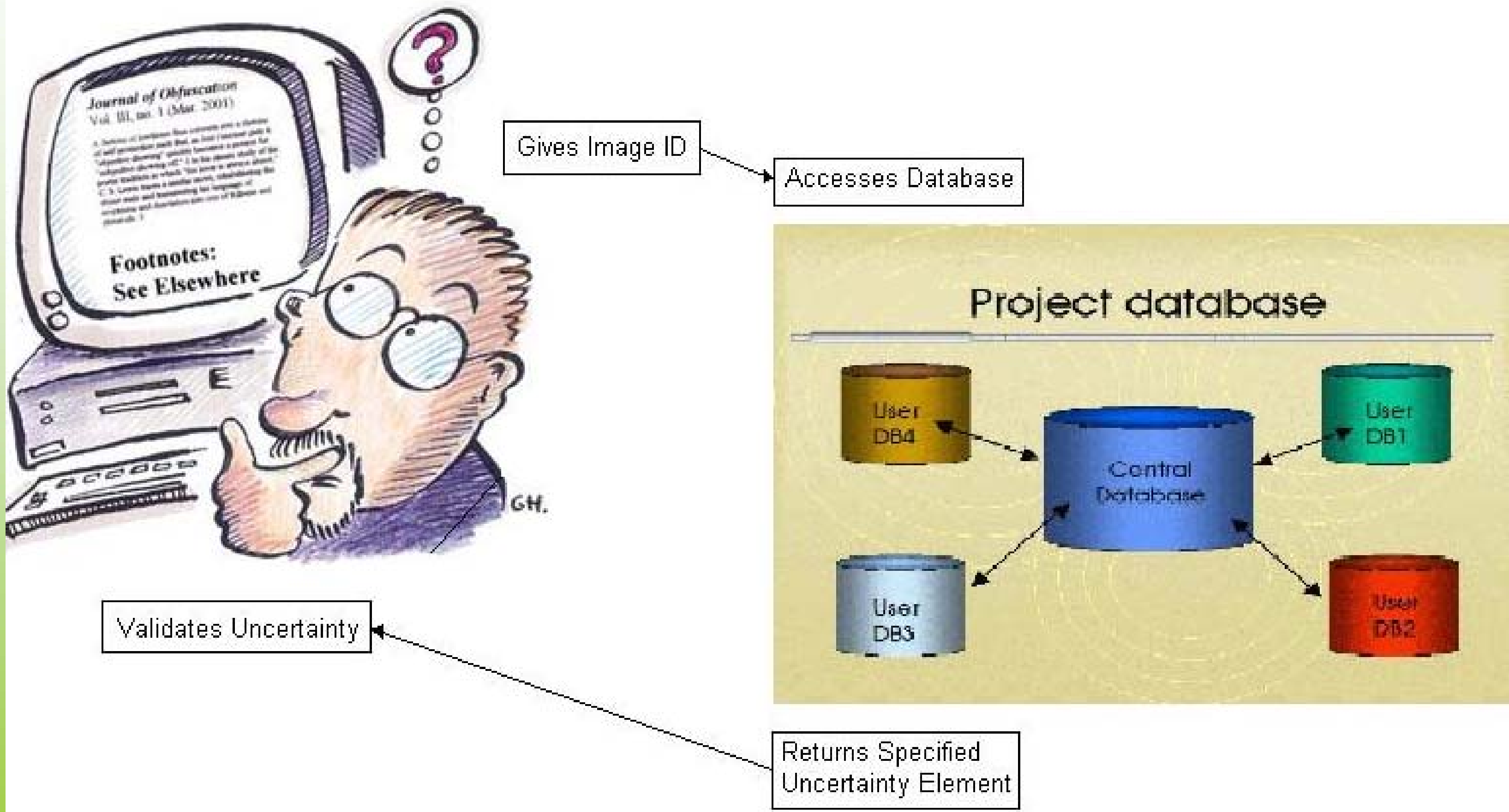
What is a Quality Indicator?

- Many types of indicators
  - Signal to Noise Ratio (SNR), Modulation Transfer Function (MTF)
  - Visual quality assessment (NIIRS – National Image Interpretability Rating Scales)
  - Saturation flags, cloud masks.
  - Qualitative statements on striping
  - Quantitative values (uncertainty on radiance for example).

What indicators does the end-user need ?

- All of them….and none of them. This is a problem for the data provider, not the end-user.

Quality Indicator from dedicated Server



Need to provide capability to “audit” uncertainty data.
Most end-users unlikely to use a lot

Why should we be QA4EO compliant?

- Benefits to end-user

  - ❑ End-user can directly determine the uncertainty on any data product (assuming value added companies also follow QA4EO guidelines) and hence suitability for application

  - ❑ Uncertainties feeds into global warming predictions, crop-yield predictions. In fact all models will benefit from the uncertainty data.

Why should we be QA4EO compliant ?

- Data Provider

  - Allows process control with fine detail in an automated way, can identify mis-performing elements of the processing chain before data is released.

  - Allows the identification of poorly performing elements of the process chain with high uncertainty and their possible replacement.

Why is it taking so long for DMCii ?

- Resources
  - None, no programming or other support.
- Need to integrate the QA4EO QA/QC within the current ground segment software while still running four satellites.
  - Total rewrite.
  - Discovering new algorithms required as we develop.
- Times are changing
  - Limited software developer support.
  - More time to spend on development as higher business priority.
- Not Easy...!!!!