OPERATIONAL CALIBRATION AND VALIDATION OF LANDSAT DATA CONTINUITY MISSION (LDCM) SENSORS USING THE IMAGE ASSESSMENT SYSTEM (IAS)

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1. INTRODUCTION

The Landsat Data Continuity Mission (LDCM) has the goal to continue the longest record of moderate resolution satellite multispectral imagery of the Earth that started with the launch of Landsat 1 satellite in 1972. The major objective of the mission is to produce well calibrated images that are consistent with data acquired by previous Landsat sensors allowing detection and quantitative characterization of changes in the Earth's land surface.

Systematic characterization and calibration of the Landsat sensors and the assessment of image data quality is performed using the Image Assessment System (IAS). The IAS was first introduced as an element of the Landsat 7 (L7) Enhanced Thematic Mapper Plus (ETM+) ground segment and recently extended to Landsat 4 (L4) and 5 (L5) Thematic Mappers (TM) and Multispectral Sensors (MSS) on-board the Landsat 1-5 satellites. In preparation for LDCM, the IAS was modified for the Earth Observer 1 (EO-1) Advanced Land Imager (ALI) to enable an assessment of pushbroom sensors. This paper describes the LDCM version of the IAS and how it relates to unique calibration and validation attributes of its on-board imaging sensors.

The new LDCM satellite is scheduled for launch in December, 2012. It will be placed in the same orbit as L5 and carry two imaging sensors: Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS). The OLI will provide global coverage by acquiring about 400 scenes per day in six Visible and Near-Infrared (VNIR) and three Short Wave Infrared (SWIR) bands, all at 12 bit radiometric resolution. In addition to these bands, there will be a tenth band consisting of covered SWIR detectors, referred to as the 'blind' band, that will be used to estimate variation in detector bias during nominal Earth image acquisitions. The OLI bands are distributed over 14 Sensor Chip Assemblies (SCA), each with 506 detectors per 30 m band and twice as many for the 15 m panchromatic band - totaling in over 75000 OLI detectors. The TIRS will have two thermal bands centered at 10.8 and 12 microns. Both bands will have 100 m nominal spatial resolution and generate image data at 12 bit radiometric resolution. The TIRS Focal Plane Array (FPA) consists of about 2000 Quantum Well Infrared Photometer (QWIP) detectors per band distributed over three SCAs. The LDCM sensors will have on-board calibration systems, lamps and two solar diffusers for the OLI and a blackbody for the TIRS. Both OLI and TIRS sensors are pushbroom sensors [1].

2. IAS DEVELOPMENT HISTORY

The IAS has been originally developed to monitor radiometric and geometric performance of the L7 ETM+ sensor and the quality of the image data in the L7 archive over the mission lifetime. The operational performance monitoring is achieved by processing a number of randomly selected Level 0R (raw reformatted) images to Level 1R (radiometrically corrected) and Level 1G (geometrically corrected) products. In that process, image statistics at different processing levels, as well as calibration and telemetry data are extracted and stored in the IAS database for automatic and off-line assessment using the characterization, calibration, and analysis tools of the IAS. In addition to randomly selected scenes, the IAS processes and analyzes the pre-selected geometric and radiometric calibration sites and special calibration acquisitions, e.g. solar diffuser or night data needed for radiometric calibration or noise and stability studies. The final and most important product of the IAS trending and processing is the Calibration Parameter File (CPF), the file that contains parameters needed for artifact corrections and radiometric and geometric processing of raw image data. The ETM+ CPF includes Earth constants, orbit and spacecraft information parameters, focal plane geometry, instrument-to-spacecraft and focal plane alignment matrices, the scan mirror motion models, bumper mode parameters, detector status, radiometric gains, biases, scaling parameters for conversion between image digital number (DN) values and spectral radiance, thermal band constants, solar irradiances, lamp radiance measurements, parameters for correction of memory effect, scan-correlated shift, striping and coherent noise artifacts, automated cloud cover assessment (ACCA) values, saturation values, and various noise characterization parameters. To maintain the accuracy of the dynamic parameters within the CPF, the updates are provided at least once every three months [2], [3].

The L7 ETM+ IAS was developed before the satellite's launch based on characterization results of the similarly designed whiskbroom TM sensor onboard L5 and included characterization and correction routines for the TM typical artifacts, such as memory effect and scan-correlated shift. These inclusions proved to be obsolete for ETM+, but were useful for the TM IAS, which first incorporated the L5 TM and then L4 TM into the newly redesigned multi-sensor IAS architecture. The population of the L4 and L5 IAS databases is currently in process and provides the opportunity to characterize TM artifacts (e.g coherent noise, relative gains or outgassing effects) better than ever before. Encouraged by success of the ETM+ and TM characterization results, the IAS was recently extended to include five MSS sensors on-board of Landsat 1 to 5 satellites.

Based on the L7 ETM+ IAS, the ALI assessment system (ALIAS) was built several years ago to radiometrically and geometrically characterize and correct ALI imagery. The modular design of the IAS software made it possible to use many modules and libraries independently of the involved satellites or sensors. The ALI pushbroom design and associated large number of detectors posed a difficulty of calibrating individual detector responses. For the radiometric processing, basic statistical information, such as minimum, maximum, mean and standard deviation of

the detector responses, is obtained from the calibration sources and the imaging interval for every data collect. In that process, large amount of characterization data is generated and stored into the database and used for trending individual detector responses over time, detailed monitoring the sensor's overall performance, and calibrating the image data. The EO-1 satellite was a National Aeronautics and Space Administration (NASA) prototype mission to demonstrate new satellite and instrument technology. The ALIAS was designed as a prototype for data quality assessment of future pushbroom sensors and successfully demonstrated its usefulness in sensor characterization and calibration. Because only one-fifth of the ALI focal plane was populated with detectors, the future LDCM reflective band sensor was expected to gather about five times as much detector characterization data per acquisition. New analysis techniques and tools had to be developed to process such a large amount of per-detector data, to provide a comprehensive assessment and radiometric characterization of every single detector. Geometric processing of ALI data also required new routines to handle the different type and format of payload correction data, changes in the resampling algorithms to handle the linear array scanning system, modifications to the precision and terrain correction routines and new focal plane calibration routines [4], [5], [6].

3. LDCM IAS

The U.S. Geological Survey (USGS) Earth Resources Observation and Science (EROS) Center's ground processing system (Figure 1) will incorporate an IAS similar to the L7 ETM+ and EO-1 ALI for characterization and calibration of the OLI and TIRS sensors. The purpose of the LDCM IAS is to ensure accurate spectral, radiometric, spatial and geometric characterization and calibration of LDCM data products and sensors, ensuring compliance with the stringent OLI and TIRS requirements. The IAS will trend results of processing standard Earth images and non-standard products, such as lunar, solar, dark Earth or stellar images, evaluate image statistics and calculate and store image characteristics for further analysis. The IAS will automatically generate calibration parameters, which will be evaluated by the calibration analysts. In addition to standard operations within the IAS, the Calibration-Validation Team (CVT) will use a 'toolkit' module containing instrument vendor developed codes and routines developed by the CVT, as a research and development environment for improvements of algorithm functionality and anomaly investigations.

Compared to the previous IAS versions, the LDCM IAS system will have to handle a significantly larger and more detailed characterization database that will include characterization data from all normally acquired images (~ 400 scenes per day, with special calibration acquisitions, e.g solar and lunar) processed through the product generation system. OLI's pushbroom design (~ 75000 detectors), as opposed to an ETM+ whiskbroom design, requires characterization and calibration of about 700 times more detectors than in case of ETM+ (136 detectors) and represents a major challenge for the LDCM IAS. An additional challenge is that the LDCM IAS must handle data from two sensors, as the LDCM products will combine the OLI and TIRS spectral bands.
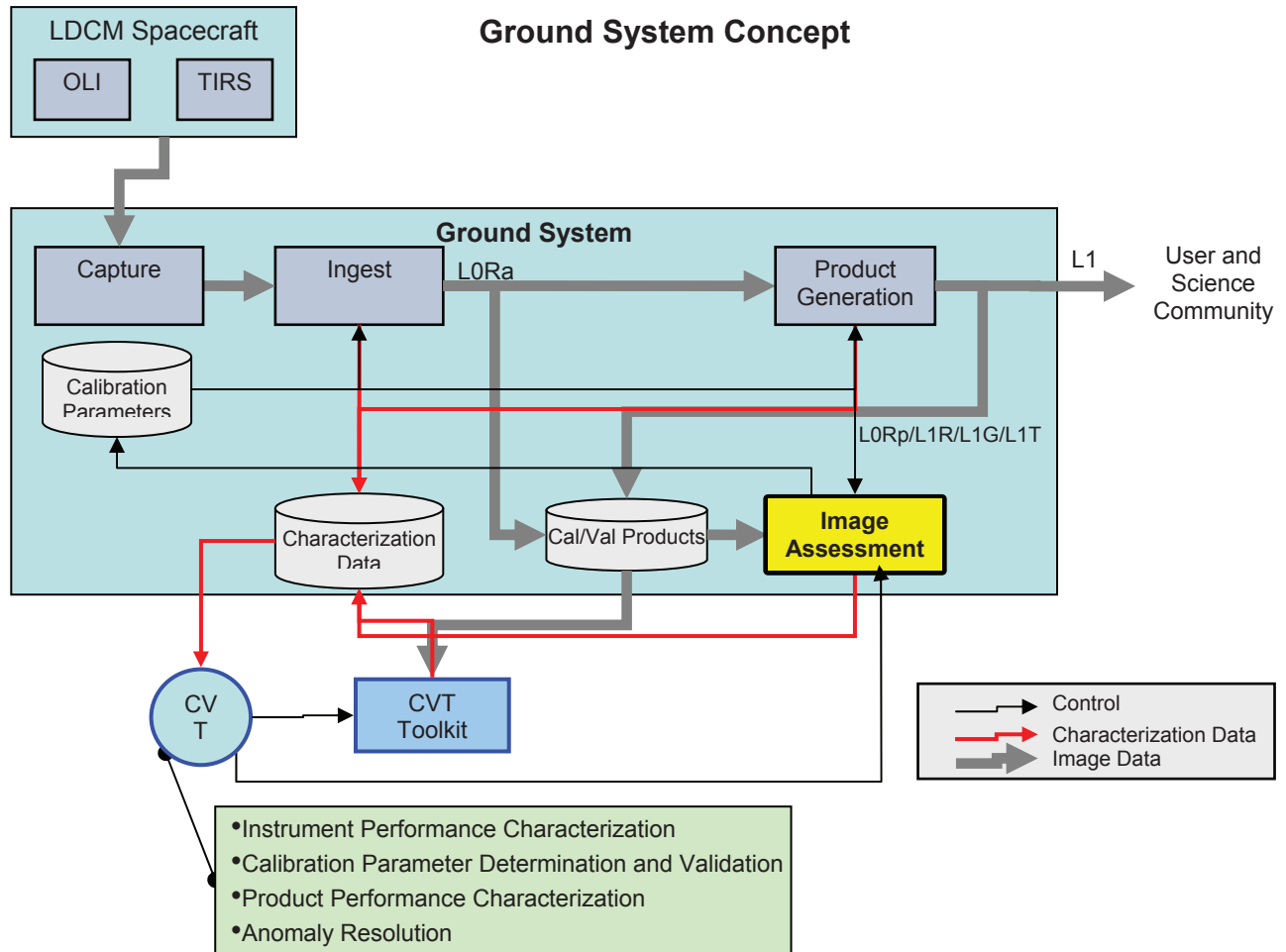
Fig.1. The LDCM ground system from the calibration-validation perspective

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