The Joint Agency Commercial Imagery Evaluation (JACIE) Team: Overview and IKONOS joint characterization approach

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Abstract

An overview of the Joint Agency Commercial Imagery Evaluation (JACIE) team is presented. JACIE, composed of the National Aeronautics and Space Administration (NASA), the National Imagery and Mapping Agency (NIMA), and the U.S. Geological Survey (USGS), was formed to leverage government agencies' capabilities for the characterization of commercial remote sensing data. Each JACIE agency purchases, or plans to purchase, commercial imagery to support its research and applications. It is critical that the data be assessed for its accuracy and utility. Through JACIE, NASA, NIMA, and USGS jointly characterized image products from Space Imaging's IKONOS satellite. Each JACIE agency performed an aspect of the characterization based on its expertise. NASA and its university partners performed a system characterization focusing on radiometric calibration, geopositional accuracy, and spatial resolution assessment; NIMA performed image interpretability and feature extraction evaluations; and USGS assessed geopositional accuracy of several IKONOS products. The JACIE team purchased IKONOS imagery of several study sites to perform the assessments and presented results at an industry-government workshop. Future plans for JACIE include the characterization of DigitalGlobe's QuickBird-2 image products.

1. Introduction

As operating budgets in government agencies continue to shrink, improved ways of doing business must be explored. The purchase of commercial imagery to support Earth Science research, civil government applications, and defense-related intelligence gathering is a cost-reduction method currently under investigation. Strategic partnerships that capitalize on common goals can also prove beneficial. Both NASA and the National Imagery and Mapping Agency (NIMA) have significant data purchase programs in place with the commercial sector. The U.S. Geological Survey (USGS) is also planning to implement data purchase activities. Because these agencies experience common issues dealing with the purchase of commercial imagery, a Joint Agency Commercial Imagery Evaluation (JACIE) team was formed. The JACIE team leverages capabilities and provides a unified government voice in interfacing with industry. The purpose of this paper is to describe JACIE activity and its significance to U.S. government research and applications.

2. Background

In 1997, the NASA Earth Science Enterprise (ESE) initiated the Scientific Data Purchase (SDP), a $50 million project to ascertain the utility of commercial remote sensing datasets for Earth Science research and applications. Through the SDP, NASA purchases commercial remote sensing data products from five data providers: Earth Satellite Corporation (EarthSat), Positive Systems, Inc., DigitalGlobe (formerly EarthWatch)/Intermap Technologies, AstroVision, Inc., and Space Imaging, Inc. The

NASA Stennis Space Center (SSC) Earth Science Applications (ESA) Directorate manages the SDP and is responsible for the verification and validation of the delivered data sets. For a more detailed description of the SDP, access the project Web page at http://www.esad.ssc.nasa.gov/datapurchase.

NIMA established the Commercial Imagery Program (CIP) in 1998 to support the acquisition and exploitation of commercial imagery by NIMA and its Department of Defense (DoD) customers. The CIP purchases imagery products from Space Imaging, SPOT, Digital Globe (Earthwatch), and Star3I. Imagery purchases through the CIP also include license upgrades so the data can be shared by all DoD/Intelligence activities. CIP also purchases Landsat-5 and Landsat-7 data from the USGS EROS Data Center (EDC). Assessments of Image Quality & Utility (IQ&U) for commercial sources of imagery are performed by the Civil and Commercial Applications Project (CCAP), part of NIMA's Imagery Support and Assessments Branch (ASAI) (NIMA, 2000).

The USGS expects to increase its use of commercial geospatial data in its science and mapping programs. In this regard, the USGS Land Remote Sensing Program is actively pursuing the development of contractual mechanisms and agreements to facilitate cost effective access to a wide range of commercial off-the-shelf remote sensing data sources. The USGS is also interested in validating the accuracy and utility of such sources - both U.S. and foreign. Planned contracts would be available for optional use by other civil agencies to help meet their commercial imagery needs. This work is the continuation and expansion of a USGS historical and long standing service to the civil community.

Since Space Imaging, Inc., was the first company to successfully launch a commercial high-resolution remote sensing system, there is a great deal of interest by NASA, NIMA, and USGS in understanding IKONOS' utility for science research and civil and defense-related applications. Commercial data products must be highly characterized to be useful to the government's science and applications community. However, commercial providers may not characterize systems as science researchers desire because commercial and science requirements often differ. This is a new paradigm for the government's imagery user community – a community historically having significant insight into sensor design and operation. Additionally, government-built satellite systems cannot compete with commercial industry. Thus, commercial providers must fill government requirements for high-resolution data. This new way of doing business, therefore, requires independent data characterization.

As part of its SDP role, NASA ESA Directorate conducted an extensive effort to independently characterize the performance of the IKONOS system. Recognizing that NIMA also procures IKONOS data, and that USGS is planning to procure IKONOS data, the three agencies formed the JACIE team in February 2000. The team consists of the three government agencies and several university affiliates. The purpose of the group is to capitalize on mutual interests and to leverage resources for the characterization of commercial remote sensing data. A JACIE Interagency Space Act Agreement was signed by the three founding agencies in June, 2002.

3. JACIE Activities

Each JACIE team member brings different strengths to the characterization activity, reducing the cost of a full evaluation by minimizing duplication of effort by the government and industry. USGS, having a long history in cartography, conducts IKONOS geometric accuracy assessments. This includes evaluation of IKONOS georectified, orthorectified, digital elevation models, and stereo image products. NIMA performs DoD and intelligence-based product evaluations, including image interpretability, feature extractions, and photogrammetry assessments. NIMA's customers also evaluate the utility of IKONOS data for DoD and intelligence use. NASA performs overall system performance characterization by evaluating SDP products against contract specifications for spatial resolution, geometric accuracy, and radiometric accuracy. Additional NASA efforts include evaluations of IKONOS data processing techniques and comparisons with other systems, such as Landsat-7 and MODIS. NASA has partnered with experts from the Earth Science community to support system characterization. These experts from South Dakota State University, the University of Arizona, and the University of Maryland have years of experience in characterizing and validating NASA-developed sensors. Each agency's customers also provide a valuable role in the characterization effort as they use IKONOS data to support science research and applications. The roles of each JACIE team member are illustrated in Table 1. The table indicates that multiple team members independently perform each aspect of the characterization effort, thus strengthening the overall result. JACIE team members have worked together to plan IKONOS data acquisitions, to conduct field measurement campaigns, and to analyze IKONOS imagery.

JACIE data evaluation results have been produced for each aspect of the characterization, and several key improvements to IKONOS data quality have resulted. In terms of radiometric characterization, JACIE-led vicarious calibration efforts determined that Space Imaging's radiometric calibration coefficients were inconsistent with those produced by the JACIE team (Pagnutti, 2001). The JACIE team collaborated with Space Imaging to investigate the inconsistency. As a result, the JACIE-developed radiometric calibration results were incorporated into an updated set of Space Imaging calibration coefficients (Peterson, 2001).

Regarding spatial resolution, Space Imaging applies an image restoration algorithm, called Modulation Transfer Function Compensation (MTFC), which "sharpens" the imagery and improves feature identification. This results in an effective enhancement to the spatial resolution. Through JACIE investigations, it was discovered that the MTFC algorithm, or kernel, was incorrectly applied by Space Imaging, creating an over-compensation in the image cross-track direction, and under-compensation in the along-track direction. Space Imaging subsequently rotated the MTFC kernel to correct the error.

As part of a collaborative effort undertaken by NIMA, USGS, and Space Imaging, a comparison of Space Imaging's rigorous sensor model and an adjustable form of the rational polynomial coefficient (RPC) model was conducted through a large area block adjustment evaluation. The objective was to determine if the adjustable RPC model implemented by NIMA could be used to triangulate multiple IKONOS stereo strips to NIMA mapping accuracy specifications. Test cases included individual stereo pairs as well as triangulated blocks of overlapping strips. Image strips were triangulated with

varying numbers of ground control points. During the course of the evaluation, it was revealed that a 2-pixel bias on the western edge of the stereo strips was producing a cumulative error in the block adjustment (Ager, Bresnahan, 2002). This error was investigated by Space Imaging and subsequently corrected, and Space Imaging has been able to perform a similar block adjustment that exceeded NIMA's accuracy requirement (Dial, 2002). The detection of this pixel bias, the open discussion of its possible causes and corrections, and Space Imaging's response to its evaluation partners at NIMA and USGS to remedy the error occurred within the JACIE mechanism invoked by the principal investigators at NIMA and the USGS.

The USGS evaluated digital elevation models (DEMs) produced from IKONOS stereo pairs and found that the vertical accuracy of the DEMs, in some cases, exceeded the expected error limit of seven meters. A DEM over one study site revealed a systematic vertical bias of about 15 meters -- double the expected limit. As a result of this finding, Space Imaging changed its DEM production procedures to require more than one stereo-image pair in the DEM block adjustment. (Constance, 2002)

4. NASA, NIMA, and USGS IKONOS data user contributions

NASA's Earth Science community has also played a key role in the data characterization effort. As SDP customers, scientists assess the performance of IKONOS data in various research areas. IKONOS data has supported research in precision agriculture (Seelan, 2001), coral reef assessment (Andrefouet, 2001), Antarctic ice shelf investigation (Bindschadler, 2001), urban environments (Small, 2001), and many other

areas. In many cases, scientists uncovered data issues that were detected only by performing specific scientific studies.

Likewise, NIMA customers within the DoD conduct defense and intelligence applications using IKONOS data. Uses of IKONOS imagery by NIMA include support to civil authorities in disaster response (Sidor, 2001), updating theater and tactical maps for U.S. Armed Forces (NIMA, 2001), and the production of specialized imagery and map products for the U.S. Naval fleet and special forces (Ecuyer, 2001).

Within the USGS, the use of IKONOS data has significantly contributed to the agency's National Land Cover Characterization Project. Through use of IKONOS data provided by NASA SDP and other high-resolution data, an approach was developed to quantify impervious surfaces and forest canopy density. The practicality and affordability of the proposed method for large-area mapping was tested over several geographic areas with successful results. The approach has been implemented and recommended for mapping two ecologically important parameters for the entire United States. The availability of the IKONOS data acquired form diverse biome and ecoregions are especially valuable for training/testing of land cover algorithms and mapping processes where other high-resolution imagery is not available or of only low quality (Yang, 2002). In another USGS application, Chen et al. (2002) used IKONOS panchromatic and multispectral imagery, Landsat 7 imagery, and airborne scanning LIDAR to estimate forest structure and stand density in the Black Hills of South Dakota. The results of this study indicated that IKONOS data can serve to make the important distinctions between tree canopy coverage and exposed under story grasses near peak summertime greenness (Chen et al., 2002).

Results of the JACIE characterization efforts have been presented at an annual JACIE High Spatial Resolution Commercial Imagery Workshop. The purpose of the annual workshop is to communicate the results of the JACIE characterization effort and to provide a forum for data user and industry interaction. The workshop is the only one of its type to focus on the use of commercially purchased high spatial resolution remote sensing data within the government. IKONOS characterization results and government applications were presented at the 2001 workshop held in Greenbelt, MD, and the 2002 workshop held in Reston, VA. More than 150 representatives from NASA, NIMA, USGS, and the agencies' user communities attended each workshop. Representatives from Space Imaging also participated in the workshops and presented results of the company's internal IKONOS calibration efforts. Feedback from workshop participants and Space Imaging indicated that the meetings were a success and that similar workshops should continue to be held in the future.

5. JACIE Benefits

In addition to the IKONOS characterization efforts, the JACIE team has produced several other benefits. The group provides a single government interface to Space Imaging, not only for characterizing the IKONOS system, but also for obtaining system information from Space Imaging. Through JACIE technical interchange meetings, several features of IKONOS data were uncovered. For instance, the JACIE team effort resulted in the discovery that the IKONOS system compresses datasets onboard the spacecraft. Space Imaging has stated that the compression is lossless. In addition, the compression minimally impacts research because the 11-bit data provide an increased

dynamic range—almost an order of magnitude better than existing 8-bit systems. The use of MTFC described above was another aspect uncovered through JACIE interactions with Space Imaging. The effect of the MTFC process has been investigated, and results were presented at the annual JACIE workshop. Through JACIE interaction, NASA also learned that NIMA purchases certain data products from Space Imaging that were not available to NASA. As a result, NASA modified the Space Imaging SDP contract so that these new products could be made available to NASA's Earth Science customers.

The government-industry relationship developed through JACIE played a key role in the success of the JACIE effort. It is important to note that the JACIE effort is not intended to discredit industry or cast suspicion about a commercial provider's ability to provide high quality data. Rather, the joint government activity to conduct independent assessments helps the government be a smart buyer of the data for its users. Any discrepancies in IKONOS data uncovered through JACIE efforts were discussed openly and constructively with Space Imaging. The interactions between Space Imaging, NASA, NIMA, and USGS established a spirit of trust and cooperation toward improving IKONOS data quality for all users.

The JACIE team provides a valuable service to both the remote sensing industry and the government. By performing independent evaluations of commercial systems, the JACIE team provides a non-biased assessment of commercial data. These assessments can only help the industry to gain credibility in both government and non-government markets.

Data characterization is of vital importance to the government. NASA scientists' use of commercial data can potentially influence global change decisions and public

policies. NASA must ensure that the delivered data products possess the accuracies promised by the data provider. It is imperative that these sources of data be well characterized in well-understood ways so they are used appropriately.

Likewise, NIMA supports the DoD intelligence community through the distribution and management of remotely sensed data. Commercial data is used by NIMA users to support intelligence and mapping tasks that are driven by NIMA/DoD/Intelligence requirements and standards. Commercial imagery can best be used to answer an intelligence problem if some idea of its image quality and utility is known. This is typically a quantification of imagery interpretability as expressed through a National Imagery Interpretability Rating Scale (NIIRS) (Pike, 1998), a form of assessment not normally performed by either the civil community or the vendor. Similarly, commercial imagery intended for the production of maps must meet NIMA accuracy standards, requiring an independent verification of accuracy. Thus, it is critical that commercial data be independently characterized to ensure that defense and intelligence decision makers use accurate and reliable information.

The USGS also has a vital interest in understanding the qualities and characteristics of the imagery that it applies in its scientific investigations and mapping products provided to the nation. Furthermore, the many government agencies, both Federal and State, rely upon the USGS for the assessment of commercial products for their mapping applications. All of the above-mentioned uses of IKONOS data strongly justify the need for an independent commercial data characterization effort.

6. Future Role of JACIE

In addition to IKONOS, the JACIE team also plans to evaluate other commercial satellite systems as they become operational. The next system of primary interest to JACIE characterization is the DigitalGlobe QuickBird-2 satellite. This system provides 0.6-meter panchromatic and 2.44-meter multispectral imagery, and represents the best non-classified spatial resolution available from space. Other potential roles for JACIE include the following activities:

- Develop data requirements by interacting with user communities
- Research and develop new data validation techniques
- Develop standard characterization methods and procedures
- Establish industry guidelines and standards for procuring remotely sensed imagery
- Support the development of data policies
- Design and implement industry-government workshops

7. Summary

The NASA, NIMA, and USGS JACIE team was established in 2000 and formalized in June, 2002, with a goal of performing independent data characterization for commercial data used by the three agencies. The team has collaborated to characterize the 1-meter panchromatic and 4-meter multispectral image products available from Space Imaging, Inc.'s IKONOS satellite. Characterizations focused on radiometric accuracy, spatial resolution, and geopositional accuracy assessments. The JACIE effort and collaborative interactions with Space Imaging have resulted in several improvements to IKONOS data quality. NASA, NIMA, and USGS data users have performed a variety of research and applications using IKONOS data. JACIE characterization and user research

results were presented at JACIE-sponsored workshops in 2001 and 2002. Focus for JACIE will also include characterization of DigitalGlobe's QuickBird-2 high-resolution panchromatic and multispectral data.

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Table 1: JACIE Characterization Team Members and Roles

Organization	Spatial	Geometric	Radiometric	Applications
USGS		X		
NIMA	X	X	X	X
NASA Stennis	X	X	X	X
University of Arizona	X		X	
South Dakota State University	X	X	X	
University of Maryland				X
Government User Community			X	X
Space Imaging	X	X	X	

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14. ABSTRACT

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