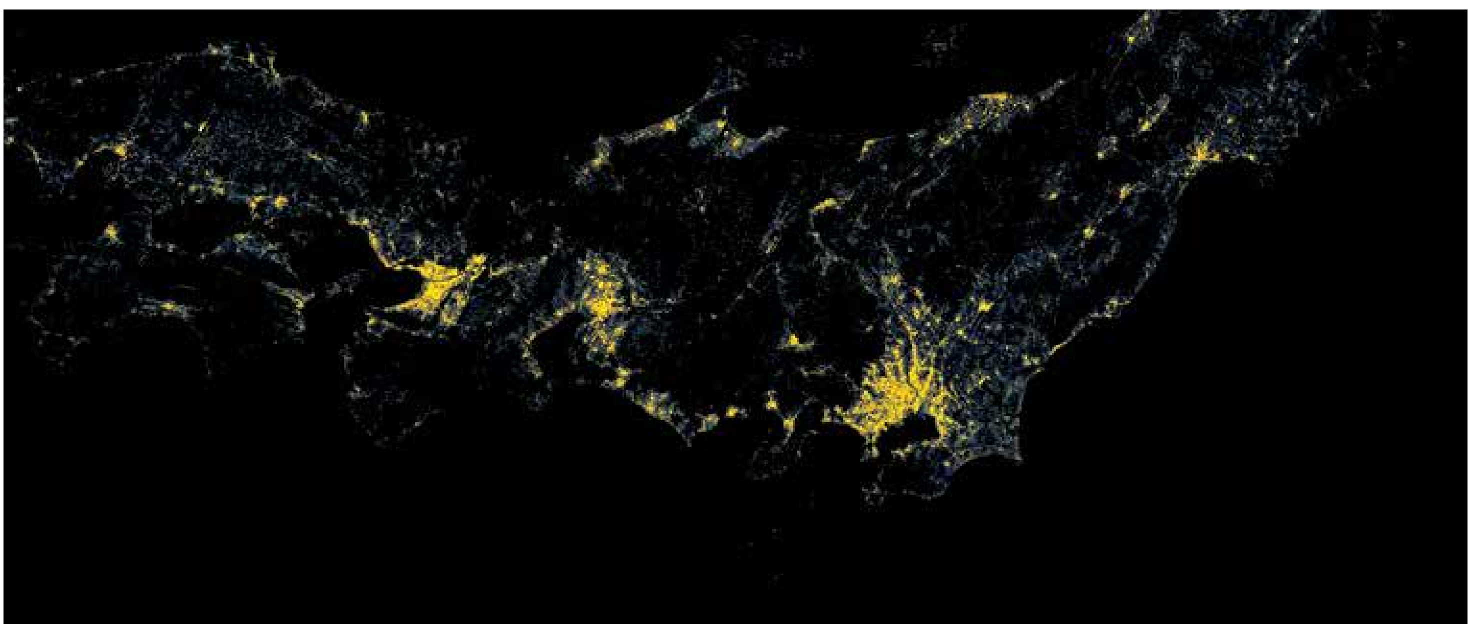
WHITE PAPER


TRUE COLOR RGB MOSAIC, OSAKA, JAPAN

MOVING FROM PIXELS TO PRODUCTS...

and data to insight


AUTOMATED STRUCTURE IDENTIFICATION, OSAKA, JAPAN

Corporate (U.S.) +1.303.684.4561 or +1.800.496.1225 | London +44.20.3695.0920 | Singapore +65.6389.4851

Table of Contents

Pixels to products

After more than 40 years, the remote sensing community continues to address the two fundamental challenges when using Earth imagery at a global scale: automated information extraction and change detection. DigitalGlobe's WorldView-3 satellite was developed by Ball Aerospace in Denver, CO, and was designed to address these challenges by creating consistent datasets as well as providing unique information for agriculture, forestry, mining/geology, and other applications.

Doubling the spectral bands

WorldView-3 is the first commercial satellite to have 16 high-resolution spectral bands that capture information in the visible and near-infrared (VNIR), and short-wave infrared (SWIR) regions of the electromagnetic spectrum (EMS). Operating at an altitude of 617 kilometers, the satellite providesww 31-centimeter panchromatic resolution, 1.24-meter VNIR resolution, and 3.7/7.5-meter SWIR resolution, according to our operating licenses (Department of Commerce).

WorldView-3 builds upon WorldView-2's unique VNIR capabilities, providing eight additional spectral bands farther into the SWIR portion of the EMS. This spectral expansion enhances WorldView-3's capability to capture the uniqueness of each ground material's spectral signature. Due to minimal atmospheric influence or noise in this part of the EMS, as well as an enhanced ability to differentiate among ground materials, the SWIR bands open the door for automated information extraction to save time, money and possibly lives.

Creating consistent imagery for automated information extraction

Remote sensing satellites view Earth from above the atmosphere—top-of-the-atmosphere (TOA) measurements of the Earth's features.

Changes in the atmosphere, sun illumination and viewing geometries during image capture result in inconsistent image data, hindering automated information extraction and change detection. Atmospheric conditions typically change

FIGURE 1.
WorldView-3's atmospheric sensor has a slightly wider swath than its imaging swath

during and between different imagery collections due to varying moisture levels (water vapor) and particulates (aerosols) in the atmosphere. Much research has been done trying to accurately convert the TOA measurements to surface-reflectance measurements.

Several models have been developed to compensate for these atmospheric conditions and the viewing geometries of various satellites. The remote sensing research community has created normalized indices to counter some atmospheric conditions with limited success.

The challenge has been the availability of accurate atmospheric measurements at appropriate scale, ensuring imagery can be normalized. WorldView-3 addresses this problem by being the first commercial imaging satellite with an atmospheric sensor as part of its payload.

During image capture, the WorldView-3 atmospheric sensor is designed to detect the presence of clouds, aerosols and water vapor at 31 meter resolution, thereby measuring the exact atmospheric conditions corresponding to every recorded image. Figure 1 shows how the atmospheric sensor has a slightly wider swath than the imaging swath.

DigitalGlobe has developed proprietary algorithms that use these atmospheric measurements to normalize WorldView-3 imagery for consistency. This normalization is called atmospheric compensation, which is especially important for information extraction, such as change detection and vegetation analysis because changes due to the atmosphere have been removed. Atmospheric compensation results in surface-reflectance image data. Figure 2 shows an example of a surface-reflectance image after atmospheric compensation. The Normalized Difference Vegetation Index from data without atmospheric compensation underestimates the amount of vegetation by about 10–13 percent.

Another issue impairing automated information extraction is accurately mapping cloud cover. WorldView-3's sensors have spectral bands that range from the VNIR into the SWIR part of the EMS to accurately distinguish clouds from other bright features such as snow and ice.

Figure 3 shows how the longer wavelengths in the SWIR range of the atmospheric sensor are able to penetrate fire smoke and haze. Figure 4 shows an example of a 2010 volcano in Iceland using WorldView-3 simulated data using the Hyperion sensor to differentiate between ash, ice and clouds.

WorldView-3 is the first super-spectral satellite to simultaneously map atmospheric conditions during image collection, allowing unprecedented access to normalized imagery across the globe. Such standardization has introduced a new age in automated information extraction and change detection.

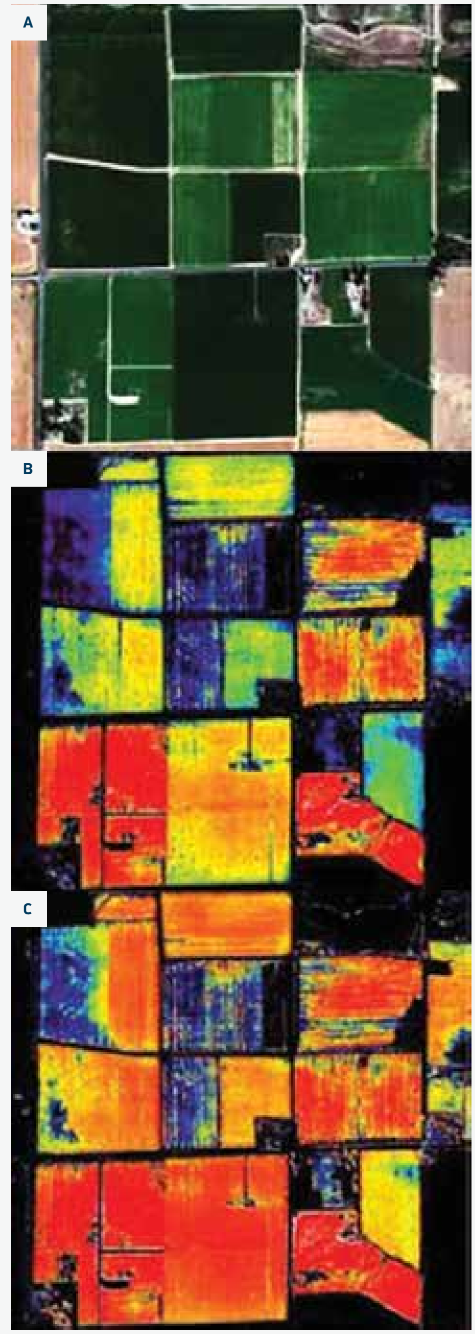


FIGURE 2.
A WorldView-2 image collected over Longmont, CO, on 10 August, 2011, was used to create (A) a true-color surface-reflectance image after atmospheric compensation, (B) a Normalized Difference Vegetation Index (NDVI) using top-of-the-atmosphere (TOA) data, and (C) an NDVI using surface reflectance. The NDVI from TOA data underestimates the relative amount of vegetation by about 10–13 percent.

Moving from pixels to insight

WorldView-3's atmospheric sensor can be used to normalize imagery for varying atmospheric conditions and to develop algorithms that can be used anywhere on the globe. Furthermore, the satellite's 16 spectral bands will allow for automated information extraction for various applications. Because WorldView-3 is an evolutionary and revolutionary sensor, providing continuity of WorldView-2 VNIR bands at a higher spatial resolution as well as a revolutionary sensor with eight new SWIR spectral bands offered on a commercial satellite for the first time, the satellite is helping to transform the remote sensing industry from a pixel-based industry into a product-based industry, expanding the use of remotely sensed data to create ways to better understand and manage our changing planet.

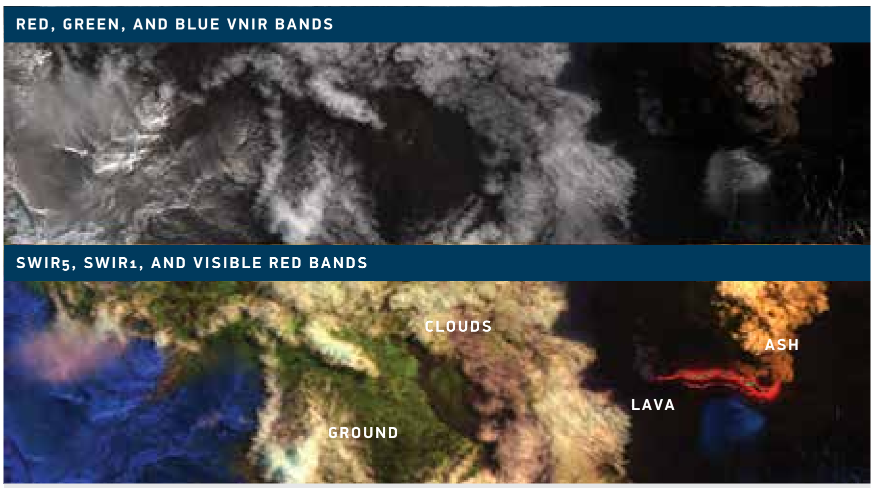


FIGURE 4.
An image of a volcanic eruption in Iceland shows how snow/ice and clouds appear differently in the SWIR region of the electromagnetic spectrum.

FIGURE 3.
Information from the longest wavelengths on WorldView-3 is able to penetrate much smoke and haze.

WP-P2P 10/14

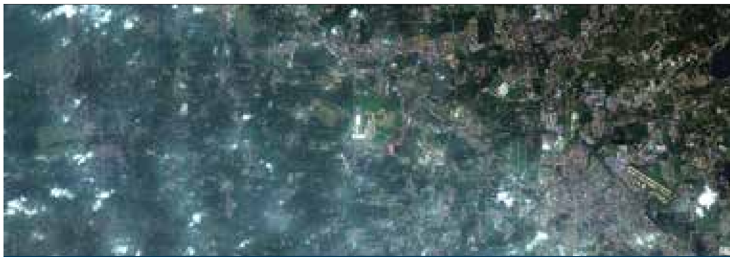


IMAGE BEFORE ATMOSPHERIC CORRECTION

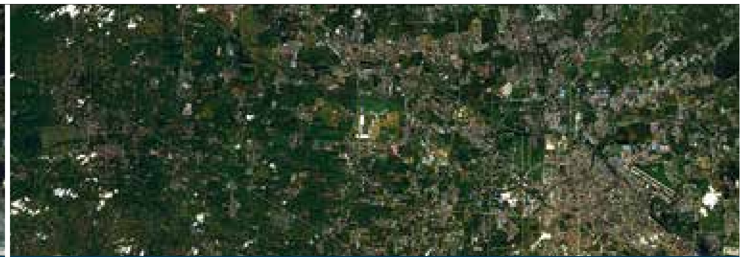


IMAGE AFTER ATMOSPHERIC CORRECTION

Exploring the benefits of SWIR satellite imagery

Besides offering 30 centimeter resolution panchromatic and eight-band visible and near-infrared (VNIR) imagery, WorldView-3 was licensed by the National Oceanic and Atmospheric Administration to collect short-wave infrared (SWIR) imagery in eight-bands. This allows the satellite to sense the VNIR spectrum as well as expand deeper into the infrared spectrum than any other commercial imaging satellite, providing rich data for precisely identifying and characterizing man made and natural materials. WorldView-3's eight SWIR bands span the spectrum's three atmospheric transmittance imaging windows to capture unique information for agriculture, forestry, mining/geology, and other applications..

Agriculture

The agricultural community can benefit greatly from WorldView-3's 16 bands. One of the main challenges facing agriculture policies is regional and global knowledge of accurate crop inventories. WorldView-3's atmospherically compensated imagery, coupled with the 16 spectral bands, allows for accurate crop pattern/type mapping.

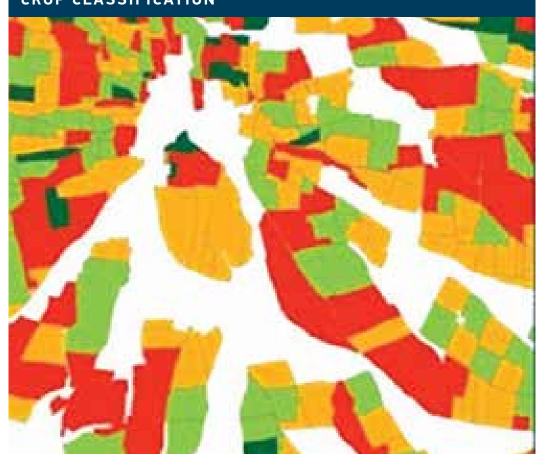
As the world focuses on increasing global food security, it is critical to improve small farm productivity and yield while decreasing costs, minimizing the environmental impact with precision agriculture practices, and better managing agriculture production and associated inventory. It is important to take corrective action early in the growing season by understanding crop conditions such as crop health and stress due to problems such as nutrient deficiency, moisture stress, and pests.

Figure 5 shows how the red edge and yellow bands on WorldView-2 and WorldView-3 are designed to observe and map these phenomena. Crop stresses change the green chlorophyll content of the leaves and replace them with carotenoids that have yellow and red colors. Yellow, red edge and the two near-infrared bands are sensitive to changes in the green chlorophyll and expose the carotenoids during stress. In addition, SWIR bands are used to assess crop moisture, which is another health indicator.

Observing soil types and conditions before, during and after a crop season is important for managing crop health. Remote sensing satellites offer a window into underlying soil conditions and how such conditions might affect vegetation.

FIELD BOUNDARIES OVERLAYED ON TRUE COLOR IMAGE

CROP CLASSIFICATION



COTTON | MAIZE | MILLET | SORGHUM

FIGURE 5.

Automated crop pattern mapping in Mali

Soil organic composition and moisture levels are assessable through the VNIR and SWIR bands. When properly monitored, such information can help users understand current and future crop potential.

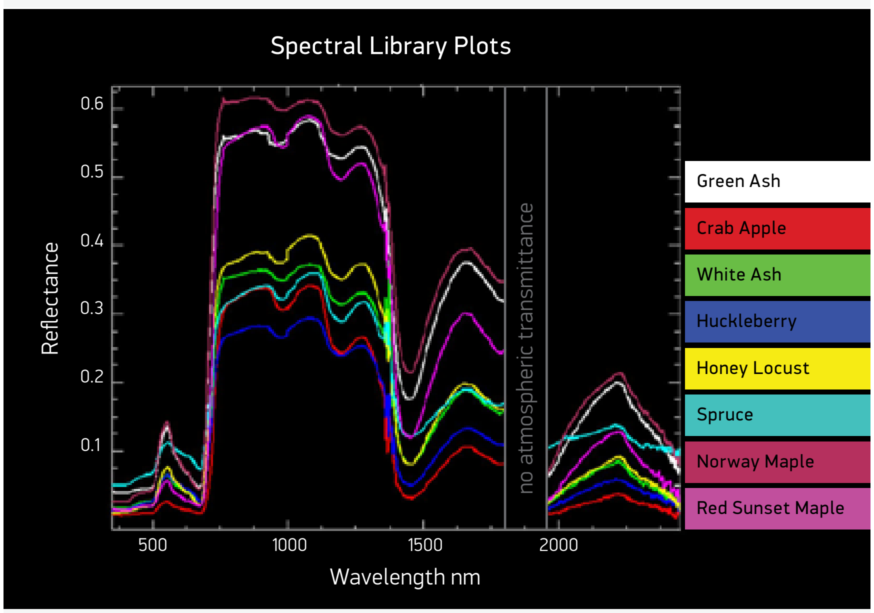
One of the agricultural community's best management practices relates to how much post-harvest crop residue is left on a field. Crop residue preserves soil moisture and prevents soil erosion during rainy months. SWIR spectral bands can be used to map and quantify how much crop residue is left behind, predicting the soil quality for future crops.

Forestry

The forestry industry's requirements are similar to the agricultural industry, which includes maintaining a detailed tree inventory of large parcels, mapping and monitoring tree health, and understanding and minimizing tree pest infestations.

WorldView-3's spectral bands, including VNIR and SWIR, allow for tree class and species identification. Tree species have unique spectral signatures, like finger-prints, that can be extracted automatically using WorldView-3's spectral bands (Figure 6). Stressed trees will exhibit similar symptoms as stressed crops, as green chlorophyll in the leaves is replaced by yellow and red carotenoids. (Figure 7)

FIGURE 6. SPECTRAL SIGNATURES FOR 8 DIFFERENT SPECIES OF TREES



Source: "Analysis of hyperspatial remote sensing to detect and map the tree decline at Ft. Benning, Georgia" Dr. Susan Uttin, 2008

GREEN PINE CANOPY

SENESCED PINE CANOPY

DEAD PINE NEEDLES

FIGURE 7.

Worldview-3 is expected to be used to map tree health, such as pine beetle infestation at various stages.

WP-P2P 10/14

Mining/Geology

WorldView-3's spectral bands allow for unique mineral identification and chemical measurements. Atoms have vibrations with different frequencies, and at specific wavelengths light can stimulate the vibration. As a result, different minerals absorb specific wavelengths and reflect others.

Electronic absorptions at wavelengths less than about 1,000 nm allow analysts to identify materials containing iron. Molecular vibrational features at wavelengths between about 1,000–2,500 nm are diagnostic for materials containing anion groups such as Al-OH, Mg-OH, Fe-OH, Si-OH, carbonates, ammonium, and sulphates. Mineral spectral absorption features are particularly observed in the SWIR region (Figures 8 and 9).

Exposed outcrops are manifestations of potential mineral ores or sub-surface deposits. The geology and mining industries spend millions of dollars to identify potential mining sites during their exploration phase; WorldView-3 mining operations can cut costs and increase efficiency by narrowing the potential area before field verification is planned.

Summary

WorldView-3 increased spectral resolution of16-bands spanning the VNIR to SWIR, allows for an extension of visual interpretation to machine interpretation and analyses using material spectral signatures. Non-visual imagery (ie. what humans cannot see) will become a new standard for imagery information extraction and insight derivation.

FIGURE 8. MINERAL SPECTRA SIX MINERALS

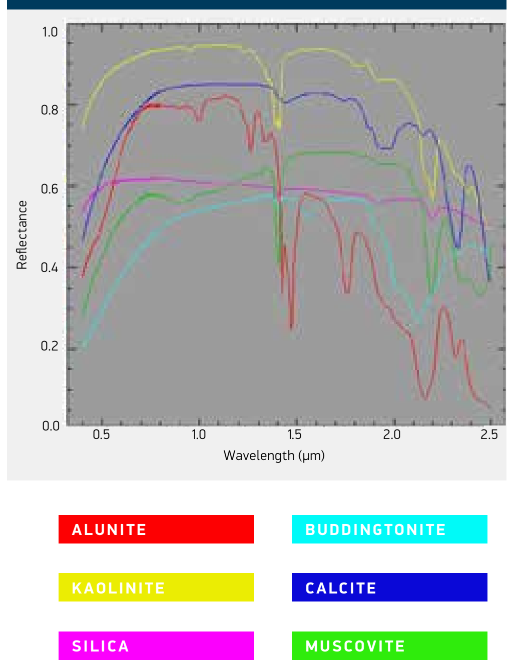


FIGURE 9. Imagery analysts will be able to identify and map minerals using WorldView-3's spectral bands.

TRUE COLOR IR: RGB | **WORLDVIEW-3: S7, S5, S4** | **WORLDVIEW-3: MINERAL CLASSIFICATION**

Mineral Classification from: Kruse and Perry. 2013. Mineral Mapping Using Simulated Worldview-3 Short-Wave-Infrared Imagery. Remote Sensing. 5(6): 2688-2703