CITIPIX by KODAK GLOBAL IMAGING

A CASE STUDY ON PRIVATE SECTOR CONTRIBUTION TO GLOBAL SPATIAL DATA INFRASTUCTURE

1 INTRODUCTION

This paper will present you a “live” case of spatial data set construction. This data set is ready to integrate in SDI and is provided to the geospatial, by private sector.

I name it a “live” case because it is happening and evolving as we talk and hopefully it will be improved with the precious input that the audience can provide to us during these days of dynamic exchange at the GLOBAL SPATIAL DATA INFRASTRUCTURE 5 Conference in beautiful Cartagena, Colombia.

CITIPIX Program is about the creation, updating and distribution of one of the geographic data set categories identified as being components of national frameworks: orthoimagery.

Kodak, embarked in October 1999 on this ambitious program, to build a comprehensive database of very-high-resolution urban-colour vertical aerial images. These images currently feature 45 North American Metropolitan Areas. By the end of 2001 the portfolio will grow to feature 95 of the most populated North American Metropolitan Areas, including their outlying counties, and the 10 most populated Canadian cities, along with their outlying areas. CITIPIX will produce approximately 450,000 aerials of these major North American urban centres, which represents the most complete up-to-date coverage available on and offline. These images will be renewed on a two-year cycle, keeping data current. Through its on-line store (http://www.kodak.com/go/earthimaging) Kodak provides quick and easy Internet access to this vast database of CITIPIX images.

I will inform you on how this spatial data Program was born, how Kodak, using its heritage as a leading provider of remote sensing products, has mastered the technological, operational and economical challenges to set it up, to operate it and to create awareness around it, always under the principles of GSDI.

2 HISTORY OF CITIPIX PROGRAM

In 1992, Groupe Hauts-Monts Inc., a Canadian aerial photography firm based in Quebec, started to cover on a speculative basis the most populated areas of the Province of Quebec, Canada with black and white, 1:15, 000 scale aerial photography.

At that time the Provincial Government had decided to stop funding the regular coverage of those areas and Groupe Hauts-Monts Inc. took the relay offering to a large number of regional municipalities the possibility of counting on a consistently updated coverage.

The exercise was profitable for the company and it was most beneficial for the end users and for the Provincial Government that begun reselling the speculatively acquired black and white aerial photos.

Today after almost ten years of refreshing the coverage, every winter habitual clients are solicited and organized into pools to buy in advance the coming coverage. This exercise helps absorb much of the costs of production and guarantees customers an updated coverage that otherwise they could not afford.

This Provincial Program proved the viability of a new business model to offer aerial photography coverage. From then on, Groupe Hauts-Monts Inc. initiated proactive business development activities to implement the new model in other parts of the world.

By 1998, Kodak had recognized the need in the geographic information industry to count on high quality georeferenced digital images to boost all its potential of bringing fresh analysis and solutions to increasingly complex urban, environmental, economical and demographic problems.

Kodak performed an extensive soliciting of numerous aerial acquisition firms in North America proposing a model of Aggregated Image Store and speculative acquisition. At that time for the totality of American firms contacted, the risk involved in the venture or their actual workload made the offer unattractive.

Groupe Hauts-Monts Inc. represented a fertile ground for those propositions because it was already engaged in similar developments as we mentioned before. Being in a country where opportunities are less abundant than in United States of America and where the winter conditions prevent aerial photo acquisition for six months each year, Groupe Hauts-Monts' perception of risk was different.

Both firms signed an agreement in April 1999 and started the set-up of the Program. The plan was to offer the coverage of 95 of the most populated North American Metropolitan Areas, including their outlying counties, and the 10 most populated Canadian cities, along with their outlying areas. Coverage would be renewed on a two-year cycle.

Today, 45 Metropolitan Areas had been covered, and more than 200,000 images had been collected, scanned and georeferenced, transforming the dream into a one of kind reality.

Kodak Commercial & Government Systems a division of Eastman Kodak Company acquired in March 27, 2001, the earth image processing, GIS and mapping businesses of Groupe Hauts-Monts Inc. Excluded from the acquisition was Group Hauts-Monts' aerial image capture business.

The new business was named Kodak Global Imaging, and became the actual operator of CITIPIX Program.

This new business is a reflection of Eastman Kodak's strategic intent to be a key participator in the emergence of Infoimaging, the convergence of image science and information technology.

Kodak Global Imaging will continue its efforts to expand the opportunities in the Geographic niche of Infoimaging by networking with aerial acquisition firms that will create new spatial data sets to be integrated into image information solutions and SDI.

Without a recognized awareness of SDI, the technology designers of CITIPIX took into account from the beginning, its basic principles; data development, metadata generation, data catalogue, data visualisation and data access and delivery.

It is interesting to note that SDI's principles oriented CITIPIX Program design without a formal implementation but as a working reality that confirms its common sense soundness.

SDI principles are intimately intermingled and in the real world we have to consider them all together when building a spatial data set like CITIPIX. Nevertheless, I will introduce them separately and in their logical sequence to structure my presentation.

3 DATA DEVELOPMENT

In item 3.3 I will present some of the challenges our organization faced in the process of building CITIPIX but first I will propose a technical description of CITIPIX dataset to help the audience better understand its nature.

3.1 Extent of Coverage

CITIPIX color photographs are taken from an altitude of approximately 10,800 feet (3,292 meters) above mean terrain using a 12-inch (305-mm) focal length camera equipped with the latest Global Positioning System and inertial sensor technology. The 12-inch (305-millimeter) focal length

lens, when compared to the usual six-inch, minimizes the perspective distortion in high building downtown contexts. The scale of the CITIPIX photography is approximately 1:10,800 (1"=900'). CITIPIX will annually generate over 200,000 high-quality vertical aerial images of some of the most important and dynamic areas of North America, creating an extensive urban photographic database which will be systematically scanned and georeferenced so that it is available on an off-the-shelf basis.

3.1.1 Acquisition

3.1.1.1 Aircraft

Presently there are two Cessna Conquest 441 aircraft, which are dedicated to the CITIPIX program. These twin- turbo-prop aircraft have a ceiling of 35,000 feet (10,668 meters) and cruise at a speed of 350 mph (564 kmh).

3.1.1.2 Flight Planning

Flights are planned using customized software developed to meet CITIPIX requirements. This customized package optimizes the flight line paths over each city according to ground elevation, coverage and project scale. Using this software, flight lines are oriented and drawn (CITIPIX flight lines are oriented north/south) and photo centers are indicated. Flight altitude is calculated to obtain an approximate photo scale of 1:10,800 or (1"=900'). Precise ground elevation data (USGS DTM) ensures a forward overlap of 60% and a side overlap of 30%. Photo overlap is required for photogrammetric mapping and stereographic purposes. This overlap is also useful for edge matching and mosaicking of Georeferenced Digital Images because if offers common areas outside the primary area of interest, that facilitate tonal matching between images.

3.1.1.3 Flights

Flight lines, determined with customized software, are entered into UNINAV, GPS-aided flight navigation software developed exclusively for aerial surveys by Hauts-Monts. The UNINAV software automatically triggers the camera at predetermined positions, ensuring perfect coverage and overlap. The Cessna Conquest 441s employed are equipped with ZEISS RMK TOP 30 cameras equipped with 12-inch (305-mm) focal length lenses and KODAK AEROCOLOR III Negative Film 2444. KODAK AEROCOLOR III Negative Film 2444 is a medium speed (ISO A Equivalent 125), very fine-grain color negative aerial camera film. It is designed for general use in medium- to high-altitude aerial mapping and aerial reconnaissance photography. Cameras are also equipped with gyro-stabilization mounts and Forward Motion Compensation (FMC) units, which ensure clearer, sharper images. Measurements of the position, roll, pitch and true heading of the camera are determined using the APPLANIX POS/DG system, an integrated, precision GPS positioning system, which

uses inertial sensor technology (gyros and accelerometers) with high sampling rates and high dynamic accuracy. The precise exterior orientation parameters of the camera at each exposure are determined through post-processing, allowing direct georeferencing of photos without aero triangulation.

3.1.1.4 Film Processing

The KODAK AEROCOLOR III Negative Film 2444is developed using the KODAK Aerial Color Processor Model 1611. Film processing includes strict sensitometric and densitometric analysis.

3.1.1.5 Georeferencing Procedure

To produce a digital georeferenced image from the original perspective aerial image the following input data are required:

1) The raster image scanned directly from the original film roll
2) The camera calibration report file
3) The scanner calibration file
4) The fiducial mark file from the scanner
5) The geographic co-ordinates obtained from airborne GPS

These data are used to determine camera position and orientation at time of exposure thus determining the coordinates of the photograph's center of perspective. Our digital products are obtained with a ZI TD scanner and are scanned at 14µm, 1815 dpi, resulting in a ground resolution of approximately six inches (15 cm). UTM coordinates, x and y, are calculated for each photo center and assigned to each digital file.

3.2 Data Characteristics

3.2.1 Resolution

Resolution refers to the size of the smallest discernible feature that can be detected by a remote sensing system. For CITIPIX Georeferenced Digital Images, the final resolution is determined by**:**

Camera Resolution: RMK TOP 30 cameras have high-performance lenses with internal **filters** and a lens **resolving power** of 100 lines/mm, which significantly enhance image quality. The TOPAR A3 normal-angle lens used in the RMK TOP 30 has the following specifications: focal length, 305 mm (12 inch); angular field, 56° (diagonal); aperture f/5.6 to f/22 continuous; distortion, <= 3µm.

Film Resolution: The KODAK AEROCOLOR III Negative Film 2444 used in CITIPIX has a theoretical resolving power of between 80 lines/mm and 125 lines/mm (defined by photographing in laboratory high contrast and low contrast bar targets, a series of black lines and white spaces). At a scale of 1:10,800 (1"-900') this represents between 5.3 and 3.4 inches (13.5 cm and 8.6 cm) on the ground. The actual resolution will depend on factors such as: atmospheric conditions, ground contrast, film processing, etc.
Digital Resolution: The resolution of the scanning device can be represented by its ground pixel distance, which is the distance on the ground represented by each pixel or picture element in the x and y components. The ground pixel distance of the digital image is a result of the scanning aperture of the microdensitometer used to capture the digital image and the re-sampling algorithm.
CITIPIX Resolution: The ZI TD scanner used for CITIPIX products has a scanning aperture of 14µm or 1815 dots per inch (dpi), which when used on a 1:10,800 (1"=900') photo-scale image, yields a ground pixel distance of approximately six inches (15 cm).

3.2.2 Spectral Range

In order to assure that the image brightness values of the Georeferenced Digital Image accurately portray the source imagery, image scanning is performed directly on the original film roll. Some deviation of brightness values may occur during the scanning process. Radiometric accuracy and quality are verified through visual inspection and comparison of the Georeferenced Digital Image to the original image. KODAK AEROCOLOR III Negative Film 2444 is sensitive in the visual spectral range from 350 nm to 700 nm.

3.3 Challenges involved in building an SDI compatible data set

3.3.1 Economical challenges

3.3.1.1 Labour

To prepare and operate the Program, more than a 100 employees have been hired since CITIPIX started. The hiring process continues and new employees are coming on board every week, making the labor aspect of the Program a major item in the budget.

3.3.1.2 Capital investment

SDI requires standardization across political and application boundaries to help decision makers exploit and share geographic information.

Recognizing the value of this principle, CITIPIX technology designers, put in place the equipment necessary to insure a uniform coverage over the 95-targeted metropolitan areas. All selected equipment had to be state of the art and the same for the whole duration of the Program; disparate equipment would have handicapped the massive industrial processing required by CITIPIX and result in inconsistent non standard products. The total production capacity had to be in place from day one, which represented a multimillion-dollar investment from the offset.

3.3.2 Technological challenges

3.3.2.1 Film

Kodak created KODAK AEROCOLOR III Negative Film 2444 which is a medium speed (ISO A Equivalent 125), very fine-grain color negative aerial camera film, to meet the resolving power required by other clients and by CITIPIX resolution and scale.
CITIPIX 6 inch (15 cm) ground resolution was determined after a survey of urban geographic data users such as, utilities and local governments. CITIPIX represents a compromise of resolution and accuracy that meets most of urban planning and mapping needs up to a pre-engineering stage. 2444 film is designed for general use in medium- to high-altitude aerial mapping and aerial reconnaissance photography. 2444 Film has wide exposure latitude for maximum exposure flexibility. It is ideal for, pollution, archeological; traffic control; city planning; railway, highway and hydraulic engineering; as well as other areas where photogrammetry is used.

The film has a 3.9-mil (0.10 mm) ESTAR Base with a dyed gel backing. Its improved scratch resistance and static protection properties enable cleaner scans and reproductions. Its hardened emulsion permits high-temperature processing in roller- processors. With unparalleled processing flexibility, it can be processed in both Process AN-6 and C-41.
KODAK AEROCOLOR III Negative Film 2444 will replace AEROCOLOR AND AEROCOLOR II 2445 and will be factory stocked in common aerial formats.

3.3.2.2 Inertial Movement Unit (IMU)

In traditional photogrammetry recreating the camera attitude requires a process called aerotriangulation that consumes at least 1 hour of an operator per stereo model. This process would have required 450,000 man-hours to execute, according to CITIPIX plans.

To avoid this requirement two technologies were chosen and installed in the aircraft participating in CITIPIX acquisition;

- **T-AS gyro-stabilization mounts**, which work to maintain the ideal vertical position of the camera axis.

- **POS/DG** (Position and Orientation for Direct Georeferencing), a highly accurate position and orientation system that provides data specifically for airborne photogrammetry applications. This Inertial Movement Unit is an integrated GPS/inertial system, that measures the position (latitude, longitude, altitude) of the photo-center and the orientation (phi, kappa, omega) of the camera, giving its precise altitude at the time of exposure.

The actual technological challenge was to calibrate and operate this system in a very large volume program as CITIPIX. This implementation had never been done before and it took us numerous trial flights and calibration tests before we made the technology operational for CITIPIX.

The payoff was worth the effort because it saves us the long aerotriangulation process, without compromising the quality of the accuracy of CITIPIX data.

3.3.2.3 Scanning

We acquired five metric scanners for the Program. The optical and radiometric quality of the images generated was very good. Nevertheless our challenge here was to process 20,000 images per month, with a daily throughput of 700.

We were obliged to improve the software management of the scanner devices to reach a speed of around 8 minutes per image. This is not a small task if we consider that these natural color images weight approximately 900 MB each as native files.

3.3.2.4 Georeferencing

When CITIPIX was in the process of being planned, its technology designers thought it will take 60 full time employees and close to 1 hour of work to georeference each image.

Later on through software development we made this process automatic. At the georeferencing stage, we merge the IMU coordinate data with the raster file recently scanned so that the image becomes positioned in the geography.

3.3.3 Operational and managerial challenges

It is important to mention that NAFTA free trade agreement has represented an essential infrastructure prerequisite to CITIPIX deployment. In fact even if most of the equipment and personnel employed were of American origin, they were actually registered or resident in Canada.

Nevertheless at the setup stage of the Program we had to wait a few months to clear the IMU system for import in Canada because of export restrictions to prevent military applications.

The hyper growth that our organization experienced to keep pace with the Program production requirements represented a major challenge in human resources planning and training.

3.4 Technology challenges controlled and SDI enabled data set

We can proudly state today that the technology challenges have been mastered. We have a regular production output of 20,000 images per month, flown, processed, scanned and georeferenced.

We are continuously improving the process and Kodak Global Imaging is ready to expand its production capacity if new aerial acquisition firms join the network of suppliers and the demand justifies the investment.

CITIPIX is a digital data set that has been carefully designed and produced to allow being shared as SDI calls for. In the following sections I will be presenting how CITIPIX provides means to discover, visualize and evaluate the data together with methods to access it.

4 METADATA – DESCRIBING CITIPIX DATA

CITIPIX metadata is generated and managed automatically through a customized configuration of a relational database.

Most off the metadata is related to the production process and it is not published to end-users.

Metadata is published to partners or end users depending on the level of image interaction that they desire to perform. The different levels of interaction are discovery, exploration or exploitation.

I will provide herewith a sample of the different components of CITIPIX metadata that are published for photogrammetric value added users:

- The exterior orientation parameters of each photo obtained from the GPS/Inertial sensor. This integrated inertial/GPS system, POS/DG, measures position (latitude, longitude, altitude) of the photo center and the orientation (ω,Φ,κ) of the camera giving its precise attitude at the time of exposure. The above-mentioned parameters are provided in the Universal Transverse Mercator (UTM) projection on the North American Datum of 1983 (NAD83) with coordinates in meters.
- The camera calibration report file
- The scanner calibration file
- The fiducial mark file from the scanner
- Roll number
- Annotated photo number
- Line number
- Line direction
- Airplane longitude (low accuracy < 65.6 ft. or 20 m)
- Airplane latitude (low accuracy < 65.6 ft. or 20 m)
- Nominal photo scale
- Date
- Time (GMT)
- Solar angle
- Solar azimuth
- UTM NAD83 coordinates (< 50 m accuracy)

The availability on real time of these metadata items and many more allows CITIPIX to be catalogued and accessible, as the next section will demonstrate.

5 CITIPIX DATA CATALOG

CITIPIX Images available may be selected on Kodak's on-line map search catalog at http://www.kodak.com/go/earthimaging. The On-line Catalog allows viewing a map of the city of your choice along with the locations of available and planned aerial photographs.

Each photograph is assigned an individual catalog number as follows:

PRyear-CTRroll-frm, where...

PR = Provider -- two character code
year = Year -- 4 digits
CTR = Country -- three character code
roll = Roll number -- 4 digits
frm = Frame number -- 4 digits

Example:

XYZ-2000-USA-1234-5678

In the above example, the provider is **XYZ**, the year of the flight is **2000**, the country is the **United States**, the roll number is **1234** and the frame number is **0276.**

5.1 Kodak Earth Imaging Products Website

The Kodak Earth Imaging Products site has been designed with the technical end user in mind. It is an intuitive guide to locate, select and purchase imagery online.

Site navigation
The far right hand site navigation buttons list the informational sections of the site such as "Products" and "Customer Service." Using these navigation buttons, “spatial data searcher” will be able to gather information about Kodak Earth Imaging Products and view related news.

To the left of the site navigation buttons is the main, interactive, map section of the site.

Process for imagery purchase

Accurately identifying the aerial imagery frames the “spatial data searcher” wishes to purchase is an easy task.
The web site guides the “spatial data searcher” along a straightforward, three-step process:

Step 1: Locate area of interest on the map
Step 2: Select set of data (i.e. a data set) using image frames
Step 3: Purchase selection

These three simple steps can be repeated for multiple sets of data, assigning a name of “spatial data searcher’s” own choice to each set. Upon checkout the “spatial data searcher” can select from a number of print and digital formats for each data set.

Step1: Locate area of interest on the map

Locating:
"spatial data searcher" can use our advanced search features to quickly locate "spatial data searcher's" area of interest. "Spatial data searcher's" search can be one of the following types:

Type	Example
Area Code or Area Code with Exchange	(716) or (716) 381
Placename	O'Hare International Airport
ZipCode	14206
City/Metro Area	Rome, Italy
Street Address	1447 St Paul Street, Rochester, NY
Latitude and Longitude	43.0, -87.0

The search features make it easy and quick to get where "spatial data searcher" wants to go.

Planned vs. Available:
The light green color shows the areas where aerial imagery is available. The tan color shows areas that will soon become available. Search type of "city" can be used to see a list of cities currently available and those that are planned including which quarter of the year they will be flown.

Country Drop Down:
This allows "spatial data searcher" to quickly switch the map to display another country.

Kodak Earth Imaging Products features many other navigation functionalities such as: *Map Pan, Centering, Zoom Bar, Drag and Zoom.*

Step2: Select data set and frames of coverage

Select a year:
Kodak Earth Imaging Products has several collections of aerial imagery - so one physical location may have been imaged more than once over a period of time. This drop down menu allows "spatial data searcher" to choose the most recent image or go back in time with older collections of images if they are available.

Select a dataset:
A particular location may have been imaged in different resolutions or color formats as an example. This area allows "spatial data searcher" to choose the dataset type most appropriate for "spatial data searcher" needs.

Point and click:
Allows "spatial data searcher" to select a frame or multiple frames by clicking "spatial data searcher" mouse on an individual center point

Drag and Select:
This tool provides a quick and easy way to select groups of frames.

Kodak Earth Imaging Products features many other navigation functionalities such as: *Select all frames in view, Center-Points and Send View.*

Step 3: Purchase selection
Once “spatial data searcher” selection is complete clicking the “add to cart” button adds selection to the shopping cart.

Clicking select products from the shopping cart page will present the Product Selection Page, including available digital processing, delivery media and pricing.

The "Checkout" button allows “spatial data searcher” to complete the purchase.

Payments can be made in US Dollars, Italian Lira, or Euros with more currency types available in the near future.

Shipping types include next day air and second day delivery.

Check out is made easy with orders accepted by purchase order number or one of three major credit cards.

Once all information is verified “spatial data searcher” will see a confirmation screen with an order number.

“Spatial data searcher” will also receive confirmation e-mail.

Thanks to the Kodak Earth Imaging Products web site the tens of millions of people and the thousands of local governments and businesses concerned by CITIPIX urban images can easily accessed and procured.

6 CITIPIX DATA VISUALISATION

Standard CITIPIX digital products are delivered on CD or other media of customer choice in iTIFF format with an image viewer. The viewer allows to easily view and print images which, given their file size (original file size is approximately 800 MB; using JPEG compression, file size is reduced to approximately 150 MB), would be more difficult to open on conventional image software. It also includes features which allow the user to measure areas, distances, and lengths, and to zoom in and out, pan, and export files in a number of formats (TIFF, iTIFF, GeoTIFF, JPEG, and BMP,) at desired resolutions. Lower resolution files require less memory.

If end users require entire urban areas in specific formats such as MrSid or GeoTIFF, the fulfillment facility further processes the standard CITIPIX data to the preferred compression specifications.

All points on CITIPIX images are referenced on the Universal Transverse Mercator (UTM) projection in the North American Datum of 1983 (NAD83) with coordinates in meters. If clients require data in other Datum or projections the fulfillment team will make the necessary transformations to allow an easy integration on customers environment.

7 CITIPIX DATA ACCESS & DELIVERY

CITIPIX data is stored in a 120 terabytes storage device that allows a near real time access to each image. Images are stored in 20 gigabytes cartridges that are reached by the robot arms of the device and read within 30 seconds to be output for delivery.

Through the e-commerce functionality of Kodak Earth Imaging Products Website payments can be made in US Dollars, Italian Lira, or Euro with more currency types available soon.

Shipping types include next day air and second day delivery.

Check out is made easy with orders accepted by purchase order number or one of three major credit cards.

8 CITIPIX AND BEYOND

This presentation has introduced the CITIPIX Program through the point of view of GSDI principles that served as a structuring guide to describe this world-class spatial data project.

The best is yet to come; it is too early yet to measure the impact of CITIPIX program in the more than 5,000 municipalities that will be covered. Thousands of communities will be able to better plan their growth and land occupation, with detailed information on their environmental status provided by CITIPIX color images to insure sustainable urban development.

Kodak Global Imaging intends to expand this program to the world starting by Latin America and Europe.

To present we have mastered most of the internal technical matters as well as implemented GSDI principles to insure desired product access and distribution.

The challenges that remain to be addressed are of the domain of market development and international expansion.

We have experienced that in the domestic and international markets, the barriers for GSDI expansion are mostly related to orthoimagery technology knowledge, government procurement practices, government procurement policies and in certain cases, national laws.

It is imposed to conclude that technology issues in the new milenium are faster resolved than organizational agreements on a local, regional, national and or trans-national scale.

In many cases practices or policies orient civil servants to consciously require duplicated spatial data acquisition efforts.

We hope that through CITIPIX Program we will participate in the education of orthoimagery as one of the core components of SDI and that we will foster the principles of GSDI by demonstrating “de facto” that it is possible to generate spatial data sets with the vocation of being shared by the ever-growing community of geographic information decision makers.

Santiago Forteza, Ba., MBA,
Vice-President Marketing
Kodak Global Imaging Inc.
3645 Boulevard Ste-Anne
Beauport, Quebec,
Canada, G1E 3L1
Santiago.forteza@citipix.com