

# **THE ROLE OF GPS AND MOBILE GIS TECHNOLOGY IN GEOSPATIAL INFRASTRUCTURE CREATION FOR NATIONAL OWNERSHIP MAPPING PROGRAMS IN DEVELOPING COUNTRIES**

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## **ABSTRACT**

Stewart Information International (SII) believes that the poor and disadvantaged populations in developing countries can be empowered through property ownership. SII undertakes land reform projects in Latin America, the Eastern Caribbean, the Middle East and Eurasia. SII has teamed with CDS/Muery Services on two projects in the Eastern Caribbean to ensure that aerial mapping met the required accuracy standards through utilization of GPS to create a geodetic framework for all GIS map layers and to provide QA/QC checks on the finished product.

The primary objective in national mapping projects is to ensure that the geospatial foundations are completed on time, within budget and to internationally accepted accuracy standards. The geodetic control network, aerial and parcel mapping and GIS are the fundamental elements of property ownership determination and the means by which the doors to the property title insurance and mortgage banking markets are opened.

This paper addresses the role played by GPS in creation of a geospatial infrastructure for national mapping programs in developing countries. Topics include: 1) the steps taken to ensure the correct projection and datum are employed; 2) establishment of a densified geodetic control network; 3) creation of street centerlines utilizing GPS enabled vehicles; 4) performance of a 'Cadastral Sweep' utilizing digital cameras, handheld data collectors enabled with Bluetooth® and GPS for compiling information about property ownership; 5) creation of a Web-based GIS that integrates geodetic control, digital orthophotos, photogrammetric mapping, land registry, cadastre, tax records and property valuation databases.

## INTRODUCTION

Developing countries have much in common when it comes to creating an automated land registry. Existing ownership records are often non-existent or in a state of disarray (**Fig. 1**) and there is often insufficient budget for creating new registry, cadastre and tax databases.



**Figure 1**

The major challenge encountered by Stewart in the international market was the development of a land records automation program that can be implemented in a short time frame at the lowest cost possible. The ability to utilize the technologies employed in Mobile GIS has greatly simplified the task of acquiring data in the field. A Bluetooth® enabled Mobile GIS enables field based personnel to capture, store, update, manipulate, analyze, and display geographic information. Mobile GIS integrates one or more of the following technologies:

Mobile devices (**Fig. 2**) shows the devices supported by the ESRI ArcPad software which permit vector map and raster image display)

Global Positioning Systems (GPS)

Wireless communications for Internet GIS access



**Figure 2**

The Mobile GIS technologies play an important role in the creation of street centerline and address databases and ownership data acquired during a “Cadastral Sweep”, an ownership determination methodology developed by Stewart and CDS Muery. Creation of GIS databases utilizing Mobile GIS is discussed further on in this paper.

### What is Bluetooth®?

Bluetooth® is a high-speed, low-power microwave wireless link technology, designed to connect phones, laptops, PDAs, GPS receivers and other portable equipment together with little or no work by the user.

Bluetooth® is the name for a short-range radio frequency (RF) technology that operates at 2.4 GHz and is capable of transmitting voice and data. The effective range of Bluetooth® devices is 32 feet (10 meters). Bluetooth® transfers data at the rate of 1 Mbps, which is from three to eight times the average speed of parallel and serial ports, respectively. It is also known as the IEEE 802.15 standard. It was invented to get rid of wires. Bluetooth® is more suited for connecting two point-to-point devices, whereas Wi-Fi is an IEEE standard intended for networking.

A piconet is a network of devices connected in an ad hoc fashion using Bluetooth® technology. A piconet is formed when at least two devices, such as a laptop computer and a mobile phone, connect. A piconet can support up to eight devices. When a piconet is formed, one device acts as the master while the others act as slaves for the duration of the piconet connection. A piconet is sometimes called a personal area network (PAN).

### **Why is the technology called Bluetooth®**

The heart of the Bluetooth® brand identity is the name, which refers to the Danish King Harald "Bluetooth®" Blaatand who unified Denmark and Norway. In the beginning of the Bluetooth® wireless technology era, Bluetooth® was aimed at unifying the telecom and computing industries.

Bluetooth® can be used to wirelessly synchronize and transfer data among devices. Bluetooth® can be thought of as a cable replacement technology. Typical uses include automatically synchronizing contact and calendar information among desktop, notebook and palmtop computers without connecting cables. Bluetooth® can also be used to access a network or the Internet with a notebook computer by connecting wirelessly to a cellular phone.

### **Types of Bluetooth® Devices**

The dongle (**Fig. 3**) is plugged into an available USB port on a Bluetooth® compatible and Internet enabled laptop which then permits the accessing of e-mail and text messages, downloading Windows updates, file transfers and GPS correction data. It is also possible to synchronize a Pocket PC with the laptop and download and update appointment schedules, view text messages and display raster and vector map data.



**Figure 3 - Bluetooth® Dongle**

Bluetooth® headsets (**Fig. 4**) are mainly used with compatible cell phones, with the headset located on the user's ear to permit freedom of movement during telephone calls. It is possible to connect to a Bluetooth® dongle on a personal computer and use it for voice conferencing.



**Figure 4 - Bluetooth® Headset**

### **Bluetooth® in Mobile GIS**

The convenience and flexibility of working with multiple digital devices was the driving factor behind the adoption of Bluetooth® technology by developers and users of Mobile GIS equipment. Taking GIS into the field has always focused on helping work crews complete jobs faster, and few things slow down and irritate Mobile GIS users faster than equipment wires that snag on door handles or cables getting tangled in bushes around utility poles.

Wireless technology's appeal in Mobile GIS has been confirmed by the widespread acceptance of ruggedized handheld GIS devices that incorporate a viewing screen, keyboard and GPS receiver into one integrated unit. The products' popularity will continue to grow now that the latest models have been introduced with Bluetooth® compatibility.

During the last few years, technological advancements in GPS receivers, wireless communications and ruggedized handheld devices have made Mobile GIS a reality. As each of the supporting technologies improved, so has the efficiency and productivity of taking GIS functionality and data out of the office and into the field.

## **PROJECTIONS AND DATUMS**

A recent land registry automation project was undertaken by Stewart International for the Government of Antigua and Barbuda, an island nation located in the eastern Caribbean. Research on the Antigua and Barbuda grid

and datum turned up the following information compiled by Cliff Mugnier, a teacher of Surveying, Geodesy and Photogrammetry at Louisiana State University.

“Antigua Island Astro 1943 Datum was observed at the U.S. Navy “astro” point named Bowditch 1943 (station A14) where, thanks to John W. Hager,  $\Phi = 17^{\circ} 10' 35.633''$  N,  $\Lambda = 61^{\circ} 47' 45.268''$  W, and the orientation is based on the azimuth from James (station A13) to Pointed Hill (station A12) as  $\alpha = 268^{\circ} 33' 09.8''$  from north. That “astro” point is located at the northern most point of land on Antigua Island. The ellipsoid of reference is the Clarke 1880 where  $a = 6,378, 249.145$  m and  $1/f = 293.465$ . Hager went on to mention that, “Also found are (seconds only) latitude =  $36.371''$ N and longitude =  $45.268''$ W and values marked U.S.C.&G.S. 1943 of latitude =  $35.506''$ N and longitude =  $45.380''$ W. I make the difference on the first at 1.2 meters and on the second at 4.9 meters.”

Mugnier continues, “Possibly the astro was observed a short distance from the trig station. The British West Indies (BWI) Grid for Antigua and Barbuda is based on the Transverse Mercator where the central meridian,  $\lambda_0 = 62^{\circ}$  W, the latitude of origin is the equator, the scale factor at the latitude of origin  $m_0 = 0.9995$ , False Easting = 400 km, and False Northing = nil. The formulae are the Gauss-Krüger, but for such a small span of latitude and longitude that includes all three islands; the distinction in this case is irrelevant. The National Imagery and Mapping Agency (NIMA) lists the three-parameter datum shift values (dated 1991) from Antigua Island Astro 1943 Datum (Clarke 1880) to WGS 84 Datum as:

$$\Delta a = -112.145\text{m}, \Delta f \times 10^4 = -0.54750714,$$

$$\Delta X = -270\text{m} \pm 25\text{m}, \Delta Y = +13\text{m} \pm 25\text{m}, \text{ and}$$

$$\Delta Z = +62\text{m} \pm 25\text{m}, \text{ and the solution is based on one station.}”$$

Information of this nature can instill fear in the heart of any right-minded photogrammetrist who is used to working with the state plane coordinate system in the Continental US. It was a simple decision to seek the assistance of a qualified geodesist such as Mike McGuinness of CDS Muery. Especially as it was soon determined that the published coordinates of the Antigua control monuments were on the BWI grid and the Barbuda coordinates were published as UTM Zone 20 North (**Table 1**).

Barbuda, which is due north of Antigua, was mapped some time after Antigua, and the grid coordinate shift (200,000 meters in eastings) was not noticed until the aerial triangulation of Barbuda was underway. After a great deal of research and GPS field observations by McGuinness, the two islands were finally geospatially tied together in the BWI grid, for the first time in their history.

**Table 1**

<b>Barbuda Published Control</b>			
BA16	1940164.143	630915.878	6.400m
BA12	1953399.289	628241.369	38.100m
<b>Antigua Published Control</b>			
ANT 69	1890542.127	434373.877	9.160M
ANT 43	1896761.377	422403.663	15.310M

## THE GEODETIC CONTROL NETWORK

Airborne GPS was utilized for the aerial photography of both islands. In addition to tying in the NGS control monuments (**Fig. 6**) on both islands, additional photo identifiable points (**Fig. 5**) were provided for inclusion in the digital aerial triangulation block adjustment. The resulting block adjustments achieved a sigma nought of better than 5 microns for each island.



**Figure 5.** Photo Identifiable Control Point.



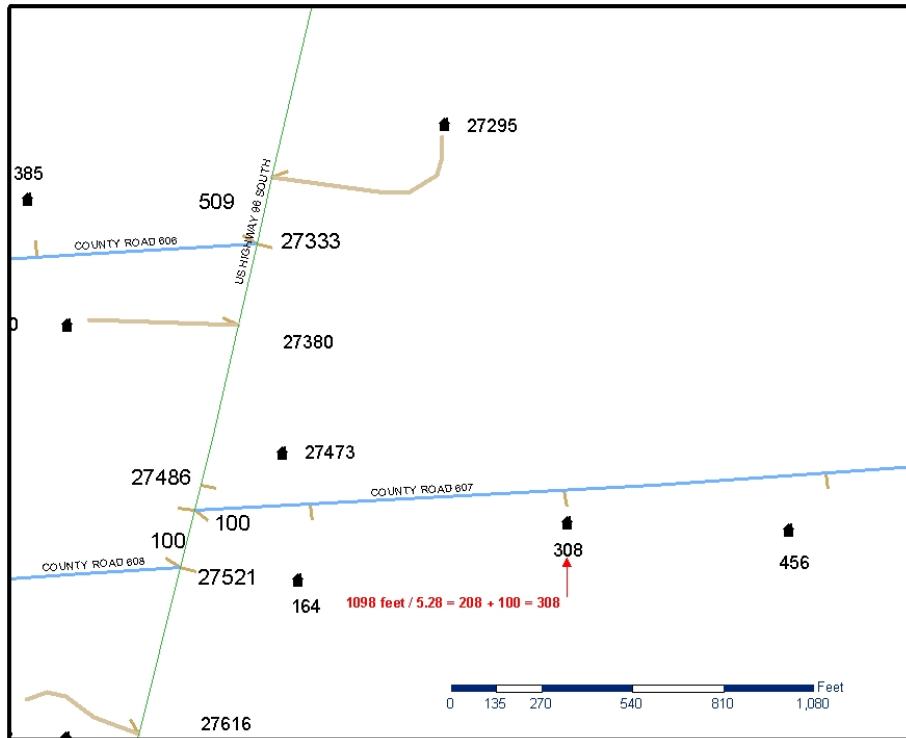
**Figure 6.** NGS Control Monument in Barbuda.

## **STREET CENTERLINE AND ADDRESS DATABASE**

GPS derived street centerlines are the basis of locating building centroids when no mapping exists and there is an urgent requirement to create a new and low cost land registry, cadastre and tax database. Laser technology is used to determine the angle and distance from the GPS derived street centerline to features such as property ingress and egress locations or the main entrance to a structure and Bluetooth® technology transmits the information to the ruggedized data collector.

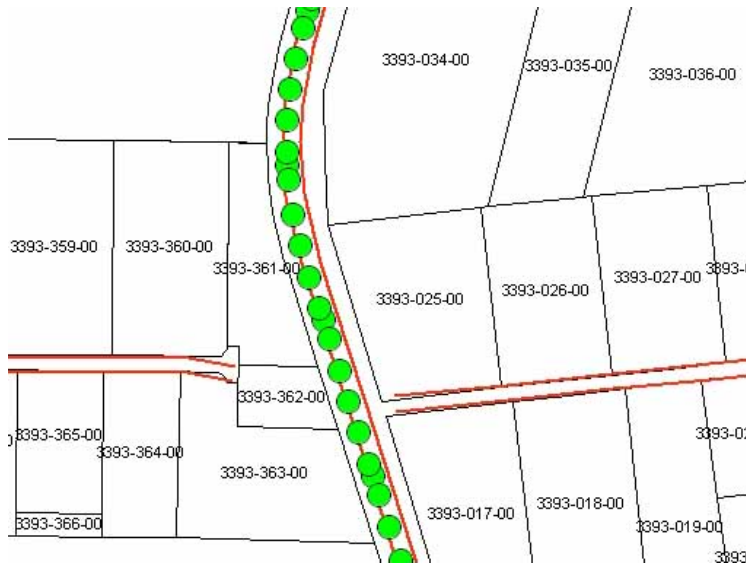
Each street centerline is broken only at street intersections and each segment is snapped to another street segment unless it is the end of the segment. The centerlines are the mid-point between the edge of pavement on a

paved street and unpaved street centerlines are the center of the drivable path. The streets database includes any street or path that could potentially have a structure located in the vicinity. **(Fig. 7)**



**Figure 7**

Street names are assigned to each centerline segment within the street database using the Government provided street names database as the source for the data entry exercise. **Fig. 8** shows how GPS derived centerline data were used to confirm the accuracy of a parcel database in the island nation of Nevis.



**Figure 8**

If digital orthophotos are included as a project deliverable, they can be incorporated into the GIS as a backdrop to the GPS street centerline data. The final address is comprised of the street name and house number with a GIS linkage created between each house and the appropriate street centerline. (**Fig. 9**)

A major advantage of street centerline and address database creation utilizing GPS is the ability to provide such data as much as 120 days before digital orthophotos or aerial mapping can be delivered. This enables a new land registry to be created and tax calculation and billing to occur as quickly as possible.



**Figure 9**

### **Structure Attributes**

- Address (will contain house number and street name)
- Community (Parish, subdivision, etc.)
- City
- Postal code (if applicable)

### **Determination of address for each structure**

Each structure centroid point will be assigned an address comprised of the street name and house number based on the following GIS programming methodology:

- Determine the closest street segment to the structure centroid
- Attach the street name information to the centroid
- Determine if the structure centroid is on the left or right side of the street segment
- Determine the location on the street segment that is closest to the structure centroid
- Calculate the distance from the beginning of the street to the closest structure centroid
- Calculate the percentage value of the distance to closest structure coordinate relative to the entire length of the street segment
- Calculate the address using the address range and the percentage value
- Load and link the address numbers and the structure centroids

## **THE CADASTRAL SWEEP**

A Cadastral Sweep is a methodology of determining property ownership by teams of surveyors and paralegals who conduct interviews with the owners/occupiers of property within jurisdictional boundaries of countries or municipalities. There are many factors that can affect the interview process. For example, the owner/occupier may

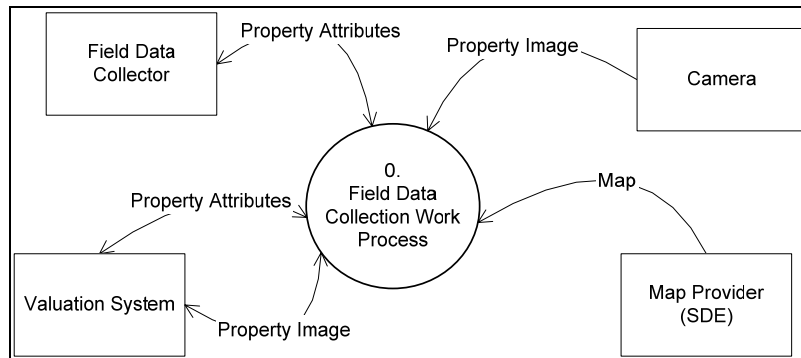
not wish to talk about the intended use of the property, if it was inherited, the purchase and sale of the land or other similar events.

Issues may also arise regarding the paperwork regarding land ownership or real property ownership. It may be that the paperwork required to obtain a Deed of Title was never completed because of the onerous process. A likely question might be “What will you do with my papers?” Also, those owners/occupiers who do not have the required paperwork may find themselves in an embarrassing public situation. Under such circumstances, the interviewee may indicate that the documents are located elsewhere, hopefully bypassing an uncomfortable situation.

It is very important for the interviewers to observe local customs, local events, appropriate religious holidays, dress in an appropriate manner and be respectful and courteous. For the most part, individuals are naturally distrustful of Government officials and institutions. For this reason, it is important to present the objectives of the project clearly with due professionalism and neutrality. For the same reason, a well planned and designed public information campaign is extremely critical and valuable for the success of this process.

The interview is conducted by a topographer and a paralegal equipped with GPS survey equipment, a GPS capable digital camera, a ruggedized hand held data collector, questionnaire forms (digital and hardcopy) and pamphlets or promotional material describing the property ownership program.

The paralegal is responsible for obtaining the information and filling out the hardcopy questionnaire. The topographer is responsible for filling out the electronic questionnaire or form, relating the captured information with any existing alphanumeric databases, verifying the information obtained and relating all the information to the GPS linked photographs which have been taken of the property. The ruggedized data collector captures the GPS readings of the property or land parcel and determines the need of a complete field total station or GPS survey. If field surveys are required, additional equipment would be brought on a second visit by a field survey team as part of the ownership adjudication process. In a final review of the process, the digitized information facilitates the review of each case supported by GIS software especially designed for this task. (Fig. 10)



**Figure 5.** The Scope of the Field Data Collection Process.

### Work Partitioning

The event list below identifies the business events to which the work responds. The response to each event represents a portion of work that contributes to the total functionality of the work. (Table 2)

The event list includes:

**Table 2**

<b>Event Name</b>	<b>Input &amp; Output</b>
1. Field Data Collector enters Property Attributes into the application	Property Attributes (in)
2. Field Data Collector takes picture(s) of property with embedded GPS coordinate (Bluetooth® connection)	Image(s) (in)
3. Application gets Map Data from ESRI Spatial Database Engine (SDE)	Parcel Map (in)
4. Application gets Property Attributes from Valuation System	Property Attributes (in)
5. Application updates Property Attributes to Valuation System	Property Attributes (out)



## The Functionality Developed for Field Personnel

- Retrieving selected sections of the new building database for individual field data collectors
- Field data collection to include viewing and selecting the parcel or structure on the map, entering data and associating images with the parcel
- Synchronizing the data with the central database upon the return of the field data collector to the office
- Exporting the data in a format that is acceptable for import into the current, or new, tax valuation system

## Server Connectivity

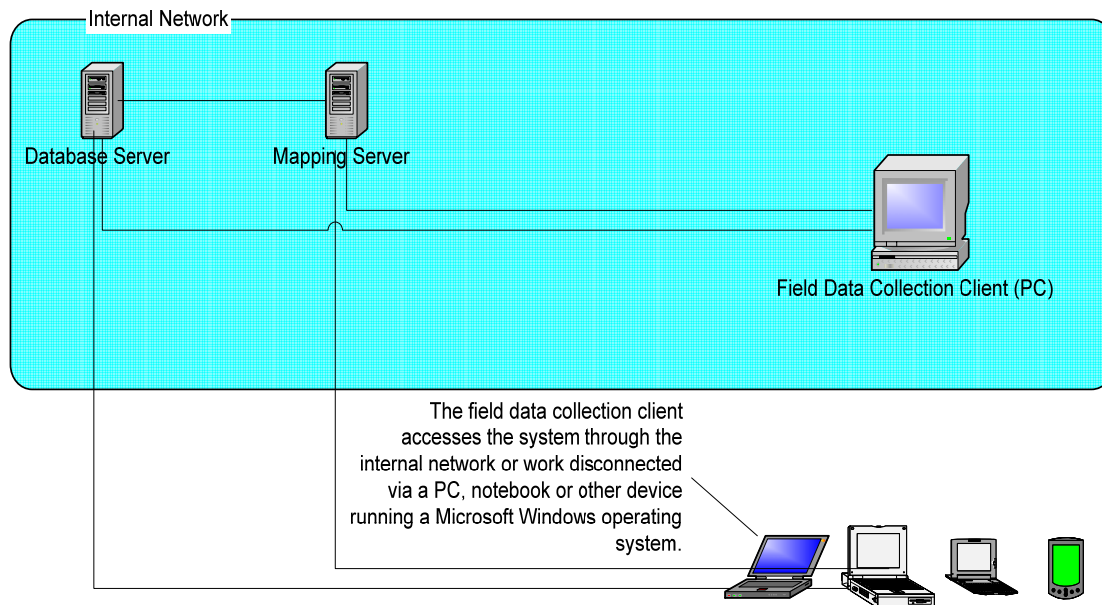


Figure 11

## Data Collection Functions

The collection process begins when the user determines that property attributes for a parcel or structure must be updated. The user uses a pointing device (mouse, stylus etc.) to select a parcel or building centroid from the map, and the current data for the parcel are displayed. The user updates the data as required. This includes the ability to change the value of any field except for the parcel or building centroid number, date and time of the inspection, and the ID of the inspector. The user may also add or remove images. When the user has finished entering data, the user clicks the “OK” button. At this point the data are updated in the local client, the property information is updated with the username of the current user, the date and time of the update and a flag is set to indicate that the property information must be synchronized with the central database. This use case does not depend on the client being connected to the central database. All edits are made to the local copy of the data and are synchronized with the central database.

## Field Data Collector Takes Picture(s) of Property

The user enters Property Attributes into the application and gets to the point of adding GPS embedded pictures of the property. The user positions the camera using the image viewer or camera viewfinder. To see the current viewfinder image in the application image viewer, the user clicks the “Viewfinder” button. The user then clicks the “Add Picture” button in the application. If the user is satisfied with the image, he may add additional pictures in the same way or the user may remove the current picture by clicking the “Remove Picture” button. The user can navigate between pictures by clicking the “Next” and “Previous” buttons. The GPS coordinate is calculated when the camera data are transmitted to the GPS receiver.

## The Interface

The field data collector screen consists of the parcel or structure map, GPS embedded photo of the property and data entry fields. (Fig. 12)

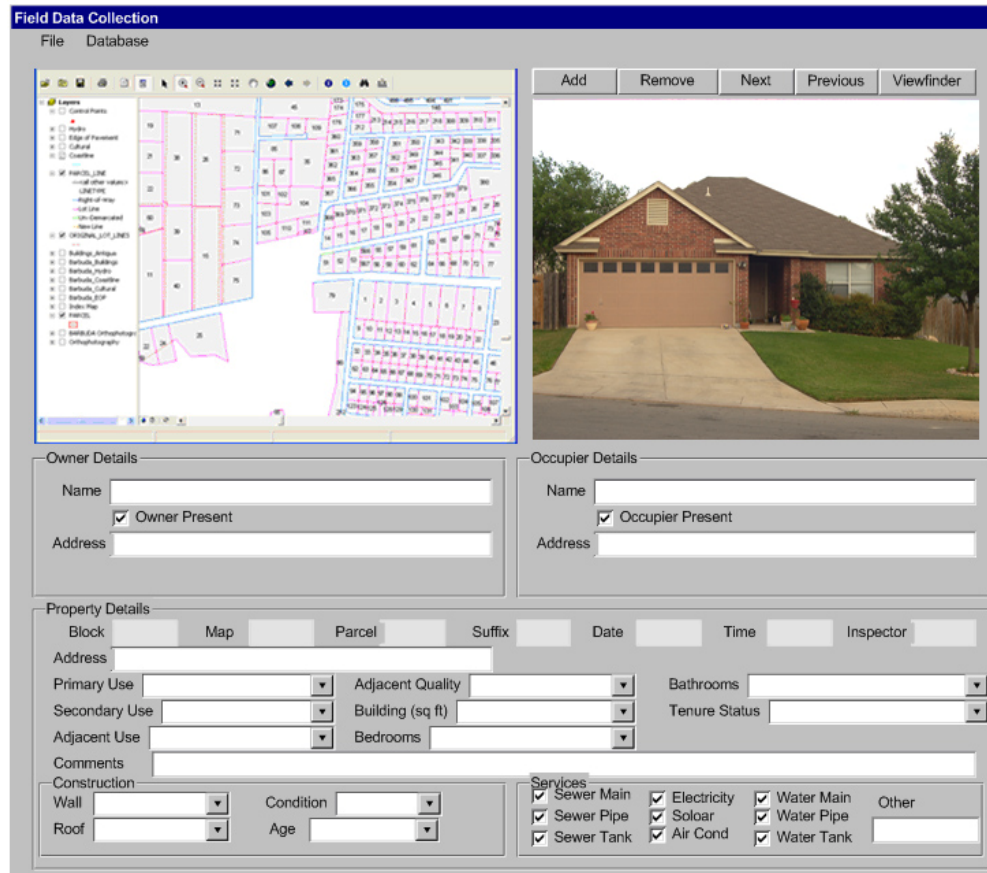


Figure 12

### Application Updates Property Attributes to Government Tax System

This application begins when the user decides to synchronize the central database with the updated records in the local database. The user must be connected to the local area network and have access to the central database. The user selects the “File” -> “Synchronize” commands from the main menu. For each updated property on the client, the application will update the central database and remove the flag on the local database indicating that the local record has been changed.

### Data Requirements

The application will allow for the collection of the following data fields, the names may be changed in the final version and other data elements may also be necessary, for example specific fields as shown in **Table 3**.

**Table 3.** Data Requirements.

<b>Name</b>	<b>Type</b>	<b>Description</b>
Block Number	String	The block number from the map sheet. This item is one of the identifying fields for a parcel.
Parcel Number	String	The parcel number. This item identifies the specific parcel within a map sheet and block.
Parcel Suffix	String	The suffix of the parcel number. This item is one of the identifying fields for a parcel.
Inspection Date	Datetime	The date and time that the inspector viewed the property.
Property Address	String	The address of the property.
Owner Present	Boolean	Indicates the presence of the owner at the time of the inspection.
Owner Name	String	The full name of the owner of the parcel.
Owner Mailing Address	String	The parcel owner's mailing address
Occupier Present	Boolean	Indicates the presence of the owner/occupier at the time of the inspection.
Occupier Name	String	The full name of the owner/occupier (resident) of the parcel.
Occupier Mailing Address	String	The parcel occupier (resident) mailing address
Property Primary Use	String	This value indicates what the property is primarily used for, the value is restricted to a pre-determined list.
Property Secondary Use	String	This value indicates additional use of the property; the value is restricted to a pre-determined list.
Building Square Footage	Integer	The total square feet/meters of the building(s)
Bedrooms	Integer	The number of bedrooms in the building
Bathrooms	Integer	The number of bathrooms in the building
Wall Construction	String	The type of construction used for the walls, the value is restricted to a pre-determined list.
Roof Construction	String	The type of construction of the roof, the value is restricted to a pre-determined list.
Condition	String	Indicates the condition of the building, the value is restricted to a pre-determined list.
Year Built	Integer	Indicates the year that the building was constructed.
Tenure Status	String	Indicates the type of claim that the owner has on the land, the value is restricted to a pre-determined list.
Comments	String	Any comments that the inspector thinks are important.
Sewer Main Service	Boolean	Indicates connection to the sewer main.
Sewer Pipe Service	Boolean	Indicates connection to a sewer pipe.

## **WEB-BASED GIS**

The Antigua and Barbuda databases are hosted on a Web Portal containing all data generated during the conduct of the Land Registry automation project including aerial mapping, digital orthophotos, scanned registry documents and digital parcel maps. The Web Portal provides authenticated subscribers with the means to perform GIS functions and is designed to host the GIS compliant graphic and non-graphic data sets and to provide secure access to and downloading of the data by the Government and the public. This is accomplished within secure networks and the Web Portal offers secure access to, and the ability to purchase information and products via credit card while generating a revenue stream for the Government and providing greater public service to the citizens.

Antigua and Barbuda landfolio - Microsoft Internet Explorer

Address: <http://antbarlandrecords.com/Contents/PurchaseHistory.aspx>

**Antigua & Barbuda landfolio**

HOME ABOUT US FAQs PRODUCTS SUPPORT SITE DEMO

Welcome Leon Antigua Limited Friday February 17, 2006  
User 1

English (United States)

**SHOPPING CART**  
You currently do not have any item in your cart.

CHANGE PASSWORD  
UPDATE PROFILE  
INTERACTIVE PARCEL MAP  
PURCHASE CREDITS  
PURCHASE HISTORY  
RENEW SUBSCRIPTION  
SEARCH  
HELP  
LOGOUT

There are 365 days remaining in your subscription period, and 1250 product credits available.

Get Adobe Reader  
Get macromedia FLASH PLAYER  
Java  
Powered By: **stewart landfolio**

**PURCHASE HISTORY**

Printer friendly version

Reference Number: charles amy

Parcel ID	Proprietor Name	Approx. Area	Download Date	Image	Report	Map
42-1995E-133	CHARLES, AMY	0.05 ACRE	2/17/2006			-
44-1997F-259	CHARLES, AMY	0.05 ACRE	2/17/2006			-
44-1997F-267	CHARLES, AMY	0.05 ACRE	2/17/2006			-

Reference Number: 42-1894A-1171  
Instrument No: RL-200500235

<http://antbarlandrecords.com> - Antigua and Barbuda landfolio

Done Internet

**Figure 6.** Parcel and Digital Orthophoto Download.

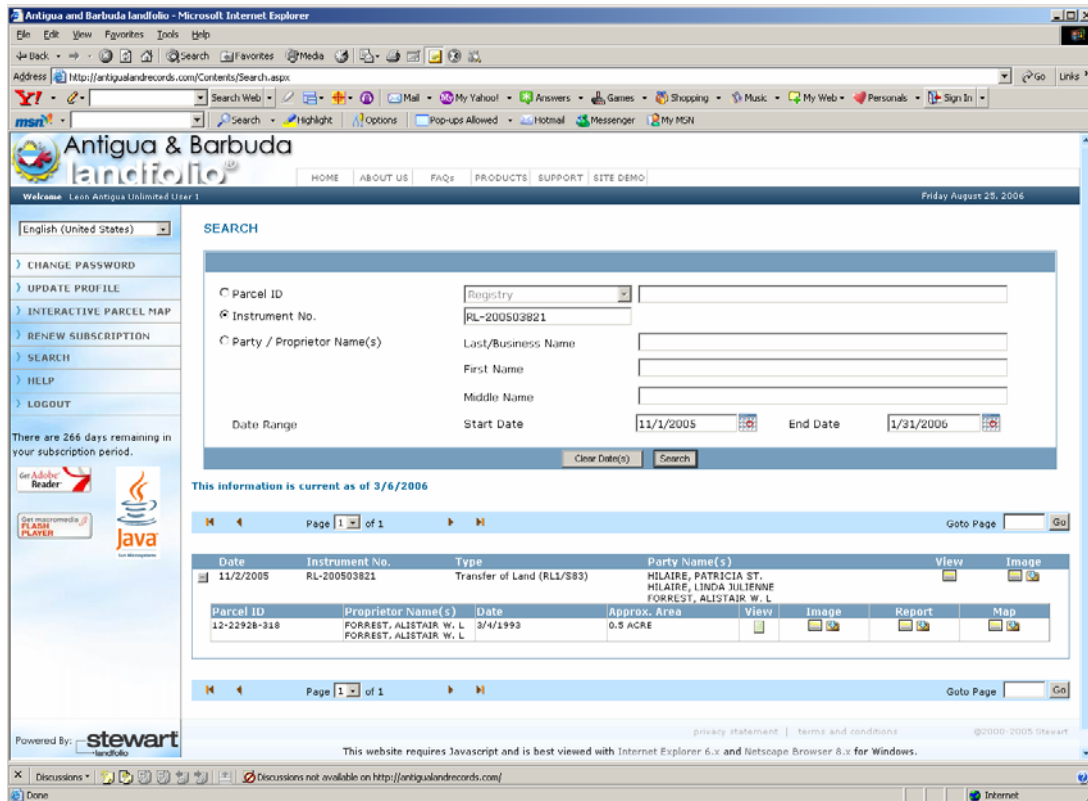


Figure 14. Online Order Form.

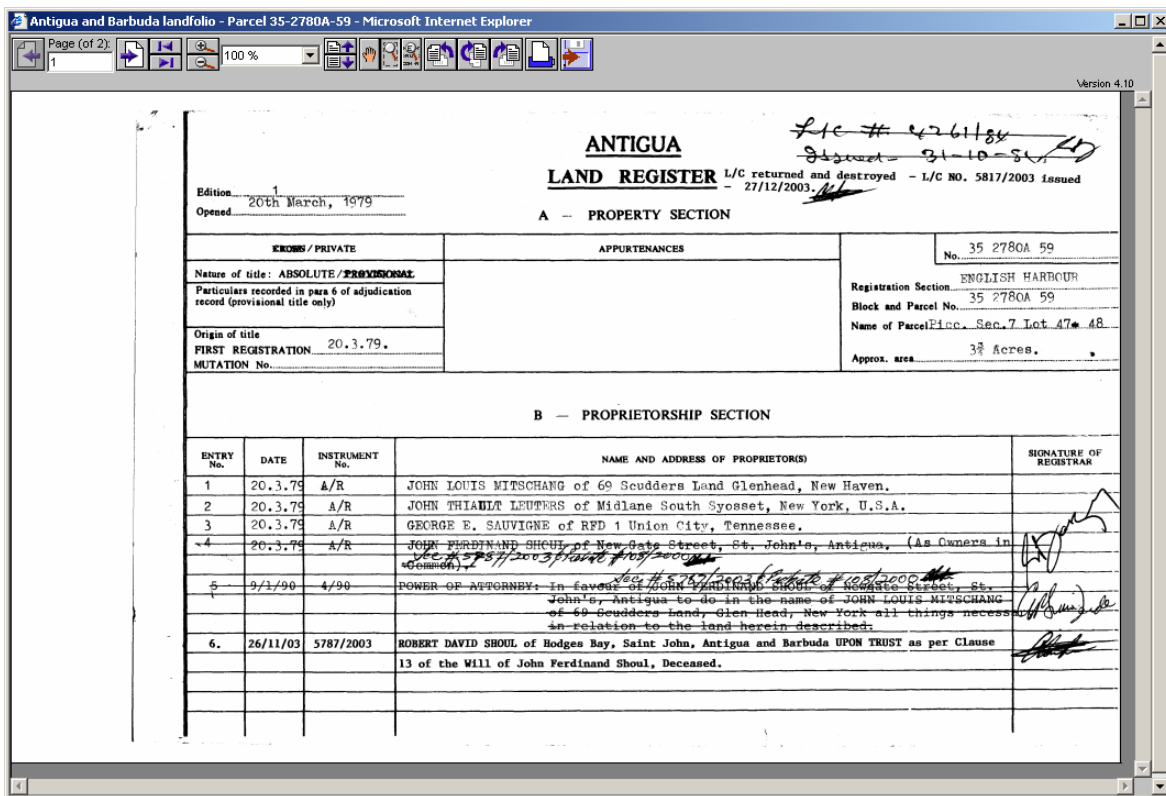


Figure 15. Online Viewing of Registry Documents.

## CONCLUSION

The US model is the basis for establishment of primary and secondary mortgage markets in developing countries. When these markets are established the effect on the economies of those countries is substantial. This is not surprising when it is realized that 12% or more of the US economy is driven by the primary and secondary mortgage and real estate markets. When people buy a home they start to take better care of it. They buy paint, lumber and plumbing supplies. They employ builders to construct additions to their property. They buy a second home. They employ landscapers, plumbers, electricians and painters. When they sell their home they engage the services of a surveyor and a title insurance company. The economic conditions within countries that enable their citizens to own property can improve dramatically and quickly.

The citizens are then persuaded that paying property taxes and getting permits to build or improve a home are necessary functions of society and of benefit to everyone. Increased tax revenue pays for improvements in city infrastructure, construction of schools, hospitals and parks. They learn that capitalism can be of great benefit to them. So they register their property and pay taxes on equitably assessed property values. A modern land records management system is created and all the property ownership and mapping information is used to feed a GIS, in addition to a variety of land records management software modules for land registry records management, cadastral mapping and tax revenue calculation.

The databases must be kept current and the information must become available for use by both the public and private sectors. If this occurs, a reliable and transparent revenue stream is established to enable local and national governments to provide greatly improved services to the citizens, attract investment and provide funding mechanisms for economic development, promotion of tourism and all the other tools required to compete within the highly competitive global market.

The technological advancements in GPS receivers, wireless communications, ruggedized field data collectors, Mobile GIS and the Internet make the prospect of acquiring funding for land ownership determination an affordable reality for any developing country that is willing to make the effort.

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