21ST CENTURY TERRAIN – ENTERING THE URBAN WORLD

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ABSTRACT

This paper describes the Rapid Terrain Visualization (RTV) programs advancements in the rapid collection of high-resolution digital topographic elevation and feature data in support of crisis or contingency operations for both military and civilian users. The ability to rapidly collect high-resolution urban terrain data affords our leaders and planners the capability to implement the next generation of visualization tools and tactical decision aids. Information in this paper highlights the technology developed to collect this data as well as prototype applications evolving to exploit high-resolution urban terrain.

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Jeff Turner has been an employee of Litton-TASC since August of 1998. Currently he serves as senior scientist on RTV developing a wide variety of applications illustrating the exploitation potential of RTV products. His career in the modeling and simulation field has focused on major research and development initiatives sponsored by the Defense Advanced Research Projects Agency (DARPA) and the Defense Modeling and Simulation Office (DMSO). Over the past 9 years, working in both industry and government, he has managed various research programs focused on the representation and modeling of dynamic terrain, ocean, atmosphere, and space environments in distributed interactive simulations (DIS). Mr. Turner has also worked on a variety of programs targeting the advancement of techniques in rapid construction of terrain databases for simulation applications. Mr. Turner's early career focused in the areas of automated cartography, image processing, and geographical information systems. He began his career with the Defense Mapping Agency Hydrographic/Topographic Center in Bethesda, Maryland. He later worked in industry on a variety of programs developing systems employing image processing and geographical information systems with Intergraph Corporation, Lockheed Integrated Solutions Company, and Hughes Satellite Mapping Technologies. His education includes a Bachelor of Science degree in Geology from Kansas State University and a Master of Science in Automated Cartography and Geodesy from Ohio State University.

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Mr. Moscoso is the Deputy Director of the Army's Joint Precision Strike Demonstration Project Office (JPSD) under the Army Program Executive Officer for Intelligence Electronic Warfare and Systems (PEO-IEW&S). JPSD manages numerous Department of Defense Advanced Concept Technology Demonstrations (ACTDs). These programs are in direct support of Commanders In Chief applying cutting edge technology to address near term combat requirements. Programs are complex and technically diverse requiring numerous government, national agency and industry teams to integrate and deliver comprehensive intelligence, surveillance, reconnaissance, aviation, digital mapping, command and control, and precision strike applications tailored to meet specific customer needs. Mr. Moscoso began his career of government service in 1984 and has been actively involved in research, development, modeling, simulation, prototyping and acquisition of advanced technologies and system of systems integration. He has had a progression of diverse positions that include: cartographer, physical scientist, project engineer, program manager, team leader, branch chief, division chief, technical manager, technical director and deputy director. Mr. Moscoso has a Bachelor of Science in Geology from the University of North Carolina and a Master of Science in Geodetic Engineering from Ohio State University.

INTRODUCTION

In May 1995, the Army Deputy Chief of Staff for Intelligence briefed the Chief of Staff of the Army (CSA) on battlefield visualization, the state-of-the-art and the potential utility for Force XXI. As a result of this briefing, the CSA recommended the development of a supporting Advanced Concept Technology Demonstration (ACTD). This ACTD's primary objective is to demonstrate the technologies and infrastructure to meet the Army requirement for rapid generation of high-resolution digital topographic data to support emerging crisis or contingencies. The Joint Precision Strike Demonstration (JPSD) project office was directed to develop this ACTD and it was approved as a 5-year program with an FY97 start.

The RTV ACTD has since developed a contingency capability for rapid collection of high-resolution digital elevation models (DEMs) using Interferometric Synthetic Aperture Radar (IFSAR) and Light Distancing and Ranging (LIDAR) sensors on a deHavilland DHC-7 aircraft. Processing of the IFSAR data is accomplished in real time aboard the aircraft. A fine-resolution SAR image, ortho-rectified using the elevation data, provides a 3-D image map with very high geo-spatial accuracy. In a parallel effort using ground-based workstations, vector feature data is collected from multi-spectral imagery provided by commercial and government sensor systems, and from IFSAR and LIDAR imagery data. Demonstrations to evaluate military utility of RTV ACTD technologies are being conducted with the XVIII Airborne Corps, Fort Bragg, NC and the 555th Engineer Company (Topographic), III Corps, Fort Hood, TX. The utility of such high-resolution terrain data can best be appreciated upon its application to a broad range of military and domestic problems with special emphasis on the urban domain. This paper provides an introduction to the technology employed in the collection of high-resolution topographic data but more importantly the value of this data to a broad suite of potential users. To gain an appreciation for this data's ability to capture the essence of an urban environment see Figure 1. This five panel composite image represents a 1 meter digital elevation model that has been resampled to 3, 10, 30, and 90 meter grid resolutions. This representation is not a direct reflection of existing lower resolution products, merely a graphical way of illustrating the level-of-detail that can be represented in high-resolution data.

The RTV technology accomplishes in a few hours what used to take months or even years to replicate

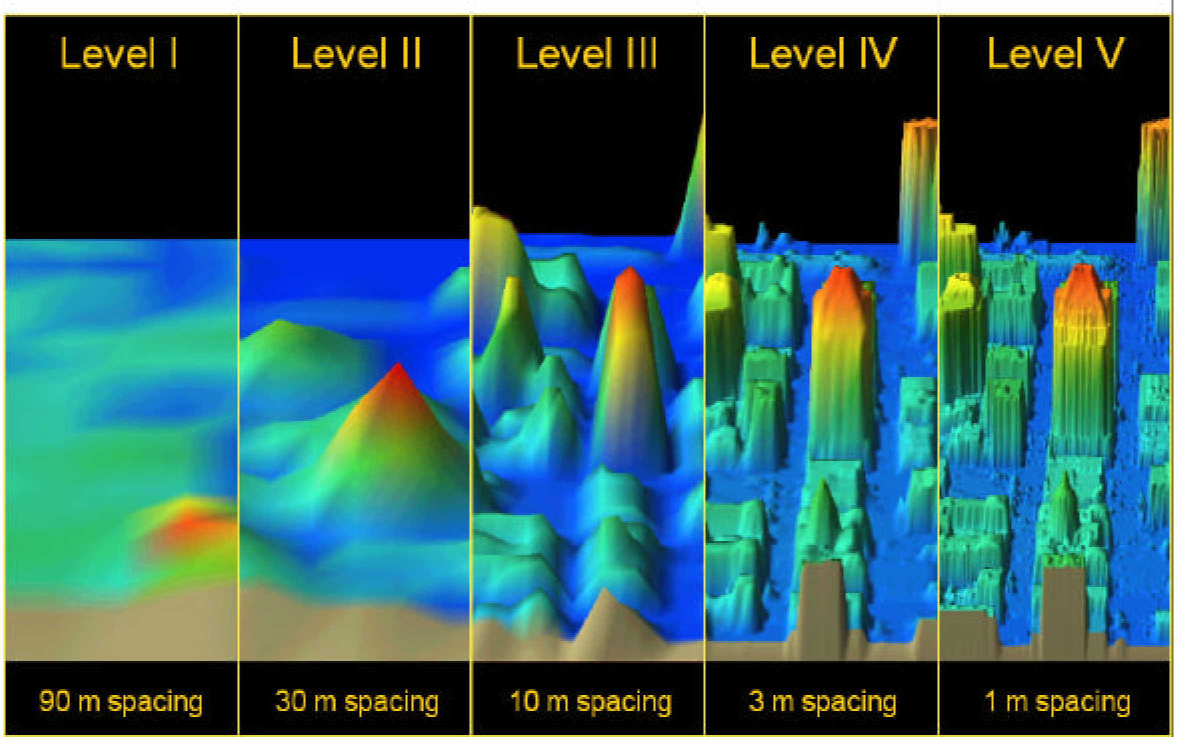

Figure 1: Baltimore, MD - Representation of Urban Region using Terrain Elevation Data

with conventional methods. This affords our military and civilian planners with the ability to rapidly plan, train, rehearse, and mitigate issues in a 3-D environment where virtually every critical cultural feature is represented. Training and simulation benefits of this technology include the following. (1) Special forces can plan egress routes with maximum concealment; (2) Police and rescue teams can determine the safest and most effective means to handle domestic disturbances; (3) Mitigation technologies can be developed to react to acts of terrorism; (4) Officials can better monitor, manage, and react to natural disasters; and (5) Military personnel can rapidly acquire critical map information to better aid in mission planning and rehearsal operations.

RTV LIDAR TERRAIN MAPPING

Light Detection and Ranging (LIDAR) is a process that combines a laser scanner with airborne GPS and inertial measurements to accurately measure ground terrain from a remote airborne location. This process saturates the ground with elevation points to produce accurate terrain models.

RTV has integrated an Airborne Laser Terrain Mapper (ALTM Model 1233) engineered by Optech, Inc. of Toronto, Canada on a deHavilland Dash 7 aircraft (see Figure 2).

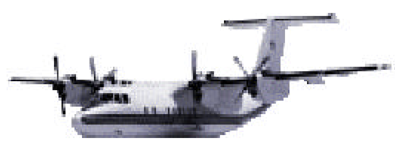

Figure 2: deHavilland Dash 7 Aircraft

This ALTM instrument emits 33,000 laser pulses per second. By understanding the relationship between sensor position and attitude, flight speed and altitude, swath width, and scanning frequency, a mission planner can create DEMs as detailed as 1 meter in resolution. Table 1 provides a summary of the current collection specifications of the RTV LIDAR system.

Flight Altitude	2000 m above ground level
Swath Width	540 m
Flight Speed	140 Knots
Collection Rate	25 square kilometers per hour
Processing Rate	3 hrs processing per 1 hr flight
Time	Day or Night
Weather	No Clouds, Minimal Precip.

Table 1: LIDAR Collection Specifications

A key success story for RTV is the development of a sophisticated mission control system that resides onboard the aircraft. This system is designed to control all aspects of the mission including operation and monitoring of the LIDAR sensor; graphical feedback to the mission supervisor on ground coverage status from each sensor swath collected during the mission; and graphical instructions to the pilot in the form of a course direction indicator that interfaces directly to the mission control workstation so the pilot can maintain precise flight lines to insure 100% of the collection area is mapped before returning to base (see Figure 3).

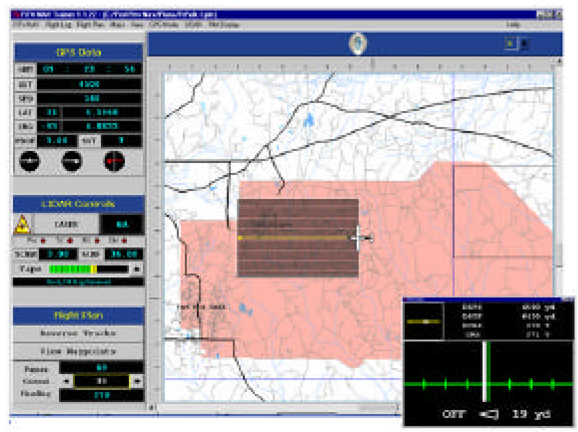

Figure 3: Mission Planning and Operation System

If a gap is detected in the mission progress interface the mission supervisor can quickly key in the flight line that needs to be re-flown and immediately the pilot's course direction indicator is updated with the new flight line course (see Figure 4).

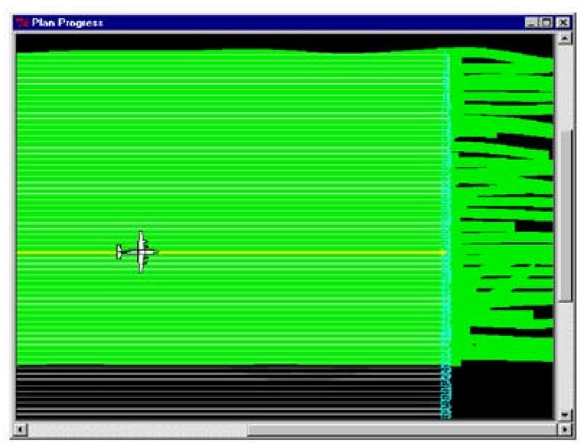

Figure 4: Plan Progress Screen

Once on the ground data processing begins. The first step involves using differential GPS technology to determine the precise position and attitude of the aircraft for each laser pulse emitted. Ground GPS data, collected from a surveyed benchmark at the same time as the sensor collection, along with aircraft GPS and inertial measurement data are used to determine the precise aircraft trajectory. Once the aircraft trajectory is known each laser pulse can be assigned a unique (x,y,z) value with absolute accuracies routinely in the 10-15 cm range (vertical) and 30-40 cm range (horizontal).

The final processing phase involves product generation. RTV produces three basic products.

Digital Elevation Models (DEMs)

RTV LIDAR DEMs are output with a 1 meter grid sampling interval (see Figure 5). Both GEOTIFF and raw binary formats are supported. Additionally, the DEMs are available in two formats with respect to vertical datum (WGS84 and Mean Sea Level (MSL)). WGS84 DEMs are required in precision navigation or targeting applications where direct correlation to real-time GPS is required. MSL DEMs are required for more traditional applications where the user desires a direct correlation to mean sea level.

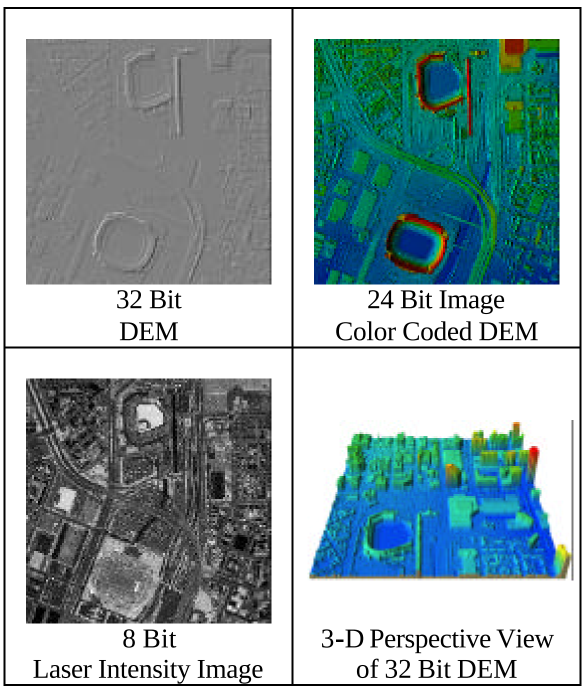

Figure 5: RTV LIDAR Products

24-bit Color Coded DEM Images

RTV has also experimented with a variety of derivative image products created from the 1 meter DEMs. The color coded DEM image depicts the lowest DEM elevations in shades of blue and transitions through the color spectrum to shades of red in higher elevations. The result is a very intuitive ortho-image map which can be used for a variety of analog or digital mission planning functions.

8-bit Intensity Image

A direct by-product of the LIDAR sensor is represented in the intensity of each laser pulse reflected from the earth. These intensity values, which have a dynamic range of 12 bits, are normalized to create a 256 color (8-bit) gray scale image product. Many aspects of this ortho-image product exhibit characteristics similar to synthetic aperture radar imagery. RTV has only used this imagery for draping in visualization applications, however potential utility of this imagery for feature extraction exists.

The product specification list in Table 2 summarizes the RTV LIDAR products.

Level V	1 meter
Projection	UTM
Horizontal Datum	WGS-84
Vertical Datum	WGS-84 or MSL
Format	GeoTIFF or Raw Binary
Area Coverage	2.5’ x 2.5’
Matrix Size (30° Lat.)	4600 rows x 4600 cols 4.6 km x 4.6 km
DEM Size	86 MB
Color DEM Image Size	64 MB
Intensity Image Size	21 MB

Table 2: 1 meter LIDAR Product Specifications

RTV IFSAR TERRAIN MAPPING

The second elevation collection capability onboard the RTV aircraft is a state-of-the-art Interferometric Synthetic Aperture Radar (IFSAR) sensor.

RTV’s primary focus in broad-area terrain mapping has focused on the world’s first real-time IFSAR processing system. Just four years ago the time required to process one hour of collected IFSAR sensor data approached 50 hours. Today, RTV’s implementation of the first multi-baseline IFSAR system has enabled the direct phase calculation of differential path lengths needed for real-time IFSAR processing (see Figure 6). This approach has eliminated the time consuming need for phase unwrapping which burdens legacy IFSAR programs such as NIMA’s Shuttle Radar Topographic Mission (SRTM).

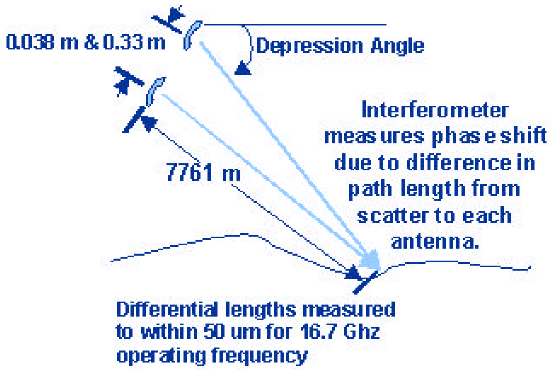

Figure 6: Multi-Baseline IFSAR System

IFSAR's greatest advantage in topographic mapping lies in the ability to fly all-weather day/night missions (see Figure 7). Thus, regions of the world which are nearly always cloud covered can now be mapped with high-resolution terrain data.

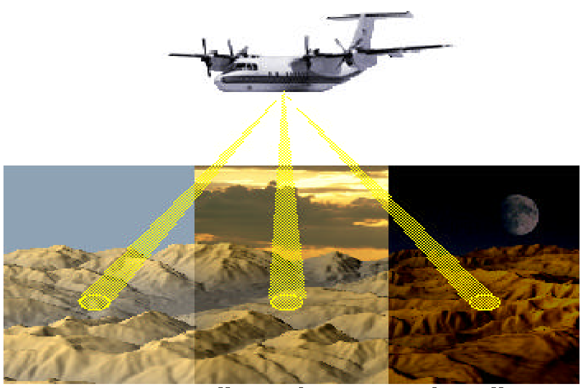

Figure 7: IFSAR All-Weather Day/Night Collection

RTV has a hopping spot, spotlight mode imaging system. That is, a spotlight mode SAR image is formed immediately followed by another spotlight mode image in the along-track direction this process being continued ad infinitum. These images are taken so that the last row of pixels of the n^{th} image is perfectly aligned with the first row of pixels of the $n+1^{st}$ image. Thus, the data appears to be strip-map data when processed.

The RTV IFSAR system has two modes. The first is a Level 3 (10 m) mode which can sweep 1.6 km wide swaths over a mission area. The second is a Level 4 (3 m) mode which maps .63 km wide swaths. Table 3 provides a summary of the current collection specifications of the RTV IFSAR system.

Flight Altitude	6000 m Above Ground Level
Swath Width	Level III: 1.6 km Level IV: .63 km
Flight Speed	180 Knots
Collection Rate	Level III: 50 sq. km per hour Level IV: 25 sq. km per hour
Processing Rate	Real-time Onboard Processing
Time	Day or Night
Weather	No Limitations

Table 3: IFSAR Collection Specifications

Besides the Level 3 and 4 DEM products generated from the IFSAR system three additional files are available as well. These include the Quality Indicator Image, Correlation Image, and SAR Image (see Figure 8).

Quality Indicator Image

The Quality Indicator Image is an 8 bit image where values of 0-250 reflect standard deviation of the corresponding height posts in the DEM corresponding to a range of 0.0 to 25.0 meters. 255 is reserved for a void area which has been interpolated from exterior surrounding points. 254 is reserved for points not filled by interpolation. 253 is reserved for a void area which has been interpolated from interior surrounding points.

Correlation Image

The phases from a number of image pixels are averaged prior to the extraction of terrain elevations. These phases are nearly identical for smooth, flat surfaces in the vicinity of the terrain elevation post being estimated. However, the phases may vary greatly for irregular surfaces such as vegetation. Since this information may be helpful in classifying IFSAR data, a phase correlation value is calculated for each terrain elevation post. This correlation coefficient is determined for the image pixels employed in the generation of the elevation post. Perfectly correlated phases having a value of nearly 1 are indicative of a smooth surface. Less correlated phases having values less than 0.9 are indicative of less regular surfaces.

SAR Image

RTV will also produce 16 bit ortho-rectified synthetic aperture radar (SAR) imagery at resolutions of 2.5 m and .75 m per pixel (ground sample distance) depending upon whether the system is in Level 3 or Level 4 DEM mode.

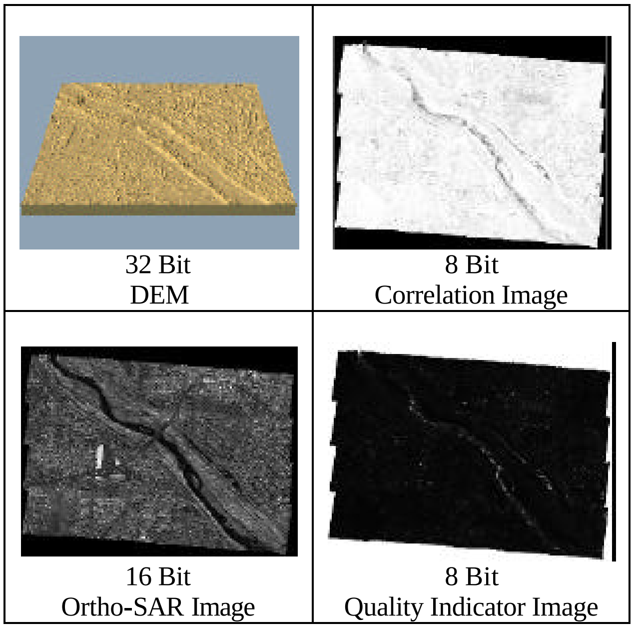

Figure 8: IFSAR Product Types

The product specifications listed in Tables 4 and 5 summarize the RTV IFSAR Level 3 and Level 4 products respectively.

Level IV	3 meter
Projection	UTM
Horizontal Datum	WGS-84
Vertical Datum	WGS-84 or MSL
Format	GeoTIFF or Raw Binary
Area Coverage	7.5' x 7.5'
Matrix Size (30º Latitude)	4600 rows x 4600 cols 13.8 km x 13.8 km
DEM Size	86 MB
Slant Plane Image Size	685 MB
Quality Image Size	21 MB

Table 4: 3 meter IFSAR Product Specifications

Level III	10 meter
Projection	UTM
Horizontal Datum	WGS-84
Vertical Datum	WGS-84 or MSL
Format	GeoTIFF or Raw Binary
Area Coverage	15' x 15'
Matrix Size (30º Latitude)	2760 rows x 2760 cols 27.6 km x 27.6 km
DEM Size	31 MB
Slant Plane Image Size	246 MB
Quality Image Size	7.7 MB

Table 5: 10 meter IFSAR Product Specifications

Table 6 provides a summary of the accuracy specifications which RTV's IFSAR products currently meet and in most cases exceed.

DEM Post Spacing	**Abs. Vert. (LE 90)**	**Abs. Horiz. (CE 90)**	**Rel. Vert. (LE 90)**	**Rel. Horiz. (CE 90)**
10 m	10 m	10 m	2 m	3 m
3 m	5 m	10 m	.8 m	2 m

Table 6: IFSAR DEM Product Accuracy

Finally, the concept of operations for exploitation of high-resolution terrain data should be understood fully. RTV does not propose capturing the highest possible resolution data for every situation. Rather, the mission objectives will determine what data should be collected. In general, Level 3 (10 m) DEMs over wide areas of interest (i.e. 90 km x 90 km) will be collected to support wide area maneuver operations; Level 4 (3 m) DEMs over smaller regions such as flight corridors (i.e. 2 km x 20 km) will be collected to support precision navigation and flight mission rehearsal operations; and Level 5 (1 meter) DEMs over small regions such as urban hot spots (i.e. 5 km x 5 km) will be collected to support urban warfare, hostage rescue, and other special forces operations.

RTV FEATURE EXTRACTION

The second major RTV focus is the development of a rapid Feature Extraction (FE) system capable of generating vector feature products required for topographic-based tactical decision aids (TDAs). Examples of such TDAs include determining on–road and off-road vehicle mobility, river fording sites, helicopter landing zones, and soldier drop zones. Specifically, RTV software is designed to provide soldiers with an enhanced data generation capability that complements analysis tools found in the Army's Digital Topographic Support System (DTSS).

RTV has worked closely with three principle users of the FE system over the past four years to insure the systems success in the warfighter's hands. These U.S. Army topographic units include the 100th Engineer Company, Fort Bragg, NC, 175th Engineer Company, Ft Bragg, NC, and 555th Engineer Company, Ft Hood, TX.

The FE software is a complete turnkey feature extraction and attribution system designed for a one workstation, one soldier environment. Soldiers have embraced the system due to its ease of use, eliminating the complex image processing functions of current systems and focusing on a repeatable procedure-oriented application. Soldiers can now focus specifically on their terrain analysis objectives.

The recent availability of IKONOS multi-spectral imagery (MSI) from Space Image Corporation has played a major role in the recent success of the FE system. This four-meter commercial MSI data provides the required spatial resolution to meet the collection requirements of most topographic features.

Soldiers see the FE system as a means to two objectives: (1) to provide a native capability in the field to build their own topographic products when crisis or contingency requirements can not be addressed quickly enough by organizations such as NIMA, and (2) to facilitate continuous value-adding of products such as NIMA's Feature Foundation Data (FFD) in the field. Typical scenarios demonstrate a need for feature intensification over critical hot spots. Soldiers can now rapidly update and intensify existing data products from NIMA, create tactical terrain products for their commanders, and continue to enhance the product if time permits.

Timelines for building and value-adding vector terrain products is now measured in hours and days. This is a stark contrast from the past when the warfighter was wholly dependent on national data providers to service their need, which in many instances took months to fulfill.

The FE system is comprised of three modules: (a) Terrain Data Manager (TDM); (b) MSI Feature Extraction (MSIFE); and (c) Feature Attribution (FA).

Terrain Data Manager (TDM) Module

The TDM serves as a data management system for both the RTV operators and RTV software modules by organizing and tracking terrain data in the RTV system. Fundamentally, TDM provides five services:

- Provide an interface that allows an operator to easily launch any RTV application. It also allows any application to update the terrain data as appropriate.
- Ingest new terrain data products into the RTV system from external sources.
- Provide query capabilities that allow a search for specific terrain data.
- Transfer terrain data between RTV nodes and machines.
- Manage metadata for each terrain data object and provide metadata browsing capabilities.

Figure 9 shows the TDM graphical user interface where a user can query which data types (Imagery, Features, Elevation, and Maps) are available.

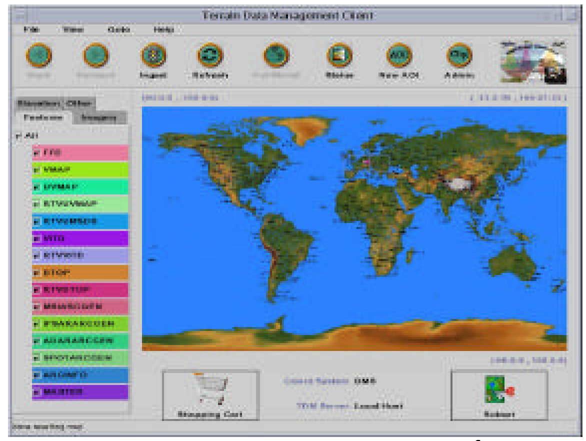

Figure 9: Terrain Data Manager Interface

MSI Feature Extraction Module

The objective of the MSI Feature Extraction component of the RTV software is to extract and partially attribute transportation, hydrography, obstacles, vegetation, and surface materials from multi-spectral sensor data. The software differs from classical image processing systems in that it not only classifies pixels in the image but goes one step further in abstracting these pixels into topographic features that conform to feature types that a terrain analyst would identify if manually digitizing the image. Figure 10 shows the MSI FE user interface.

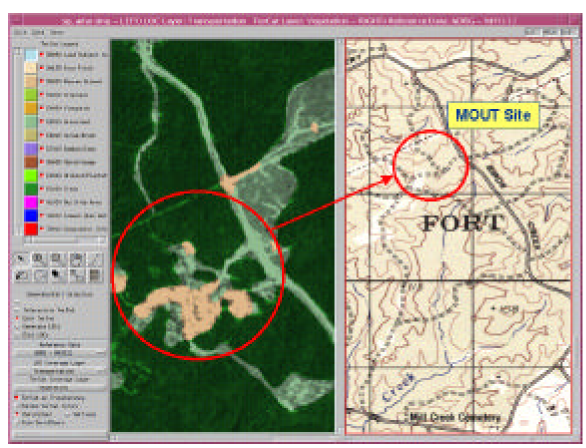

Figure 10: MSI Feature Extraction Interface

The module also provides a "paint tool-like" editing environment to cleanup errors from the automated processing. The result is a tool which rapidly supports identification and digitizing critical topographic features and prepares these vector lines and polygons for final attribution in the Feature Attribution (FA) tool.

Feature Attribution (FA) Module

Feature attribution takes features identified in the MSI Feature Extraction process, performs some automatic attribution, and allows the operator to further edit and attribute the features based on other sources or domain knowledge. Figure 11 shows the Feature Attribution user interface.

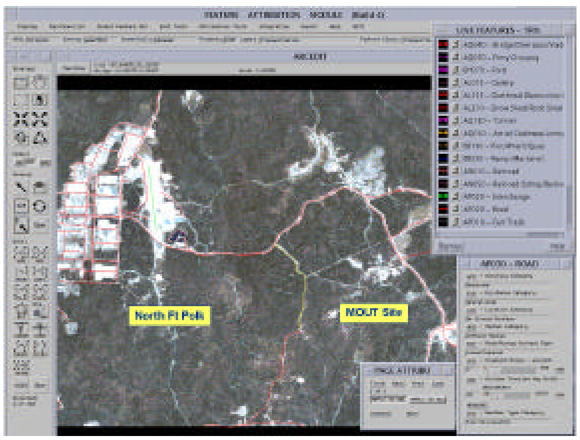

Figure 11: Feature Attribution Interface

The Feature Attribution component of the RTV system has four primary objectives:

- to allow an operator to select the NIMA product type he would like to create.
- to provide a suite of tools for augmenting the feature and attribute content of data sets generated from RTV MSI FE and conventional DoD production sources like NIMA.
- to manage the integration of feature and attribute data derived from multiple sources.
- to export vector data sets formatted in accordance with NIMA Vector Product Format (VPF) based product specifications, and in formats that directly support systems and users of RTV generated data.

Once feature data has been extracted and attributed, it can be exported in several product formats including Vector Interim Terrain Data (VITD), Digital Topographic Data (DTOP), Foundation Feature Data (FFD), Urban Vector Map (UVMap) or Arc Coverages.

Figures 12 and 13 illustrate the before and after result of an actual value-adding exercise. NIMA Feature Foundation Data over Ft Polk, LA was imported into RTV where analysts rapidly extracted additional features and attributes so that the resulting dataset could be used for tactical planning purposes.

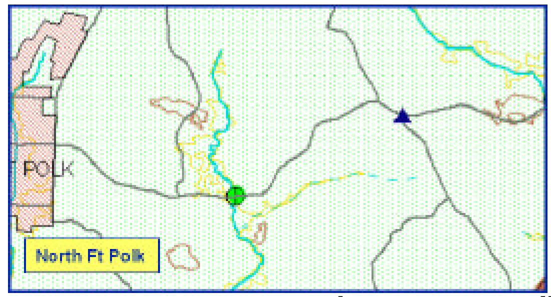

Figure 12: NIMA Feature Foundation Data – Ft Polk

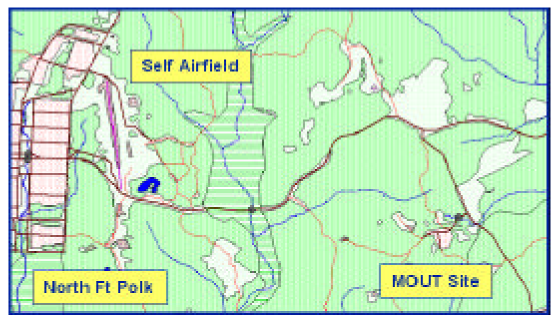

Figure 13: RTV Value Adding to NIMA FFD

Tables 7 and 8 summarize the import and export formats supported by RTV's FE system.

Digital Maps	Imagery	Elevation
ADRG-JOG	IKONOS MSI/Pan	DTED 1
ADRG-TLM	SPOT MSI/Pan	DTED 2
ADRG-City	Landsat MSI	DTED 3-RTV
CADRG-JOG	CIB 10, 5, 1	DTED 4-RTV
CADRG-TLM	SAR (RTV)	DTED 5-RTV
CADRG-City	LIDAR (RTV)	

Table 7: FE Non-Vector Import Capability

FE Vector Import	FE Vector Export
FFD Arc/Info	FFD Arc/Info
DTOP	DTOP SEDRIS
VITD	VITD
VMAP1	UVMAP

Table 8: FE Vector Import/Export Support

APPLICATIONS

Visualization

Use of high-resolution terrain elevation models for 3-D visualization purposes offers a new medium for commanders, managers and analysts to exploit. Once RTV data is obtained people can now put themselves at any vantage point and produce accurate and realistic virtual walk-throughs or snapshots of any given setting. Military personnel are able to execute 3-D fly-through and walk-through rehearsals prior to any mission. Every tree, bush, building, powerline, light pole, and sign in the city is represented in the terrain data (see Figure 14).

Additionally, many of the tools needed to visualize and exploit this data are readily available via freeware applications downloadable from the internet. RTV routinely uses the freeware Windows 3DEM application available at the following internet site: http://www.zdnet.co.uk/software/utilities/3d/sw0.html for visualization of 1m, 3m, and 10m elevation and imagery products. 3DEM also supports 3-D anaglyphs and generation of MPEG fly-throughs. For terrain analysis needs the U.S. Army has developed "TerraBaseII" which allows users to generate cover and concealment plots, weapons fans, and cross sections of high-resolution terrain. TerraBaseII can be downloaded from the following site: http://www.wood.army.mil/TVC/TerraBaseII.htm

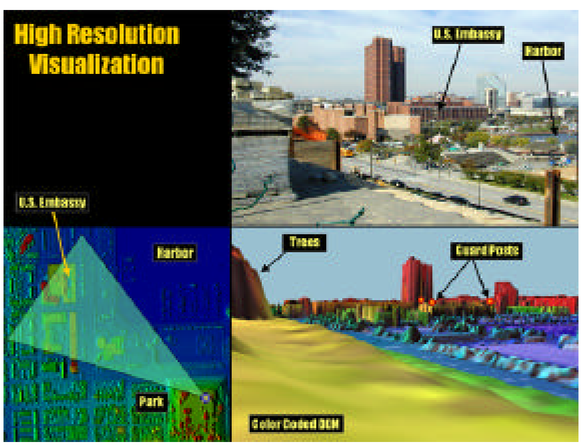

Figure 14: Detailed Virtual Urban Visualization

Urban Warfare

The advent of urban warfare in foreign settings presents a distinct disadvantage to our warfighters. High-resolution terrain provides the database necessary to perform extremely accurate line of sight and viewshed calculations that have a direct impact on cover & concealment determination, ground-based route planning, drop and landing zone selection, and in general any kind of site selection in which vulnerability to detection must be determined (see Figure 15).

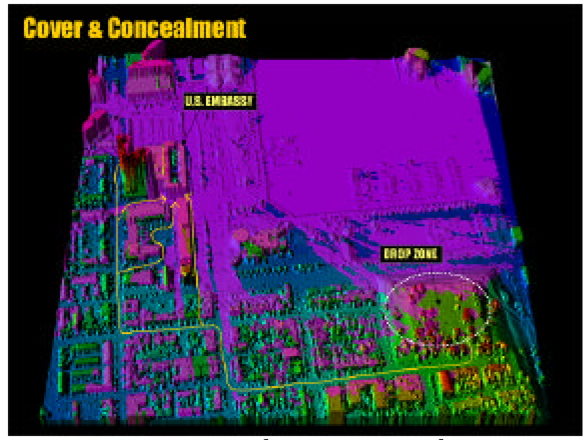

Figure 15: Special Forces Route Planning

This data directly supports the needs of our ground troops.

Physical security of embassies requires vulnerability assessment from sniper fire as well as technology to support surveillance measures (see Figure 16).

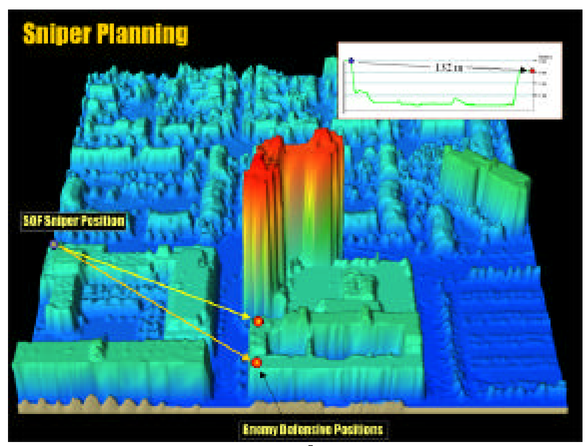

Figure 16: Sniper Planning Scenario

Targeting

Many guided missile systems require high-resolution terrain in order to perform in flight terrain correlation and terminal target sighting (see Figure 17). The time and resources to collect this data has been problematic for decades. Although RTV cannot fly over uncontrolled airspace its sensors and data processing systems establish a new benchmark for rapid terrain data collection. Future tactical mapping systems will inevitably benefit from the ground work RTV has laid.

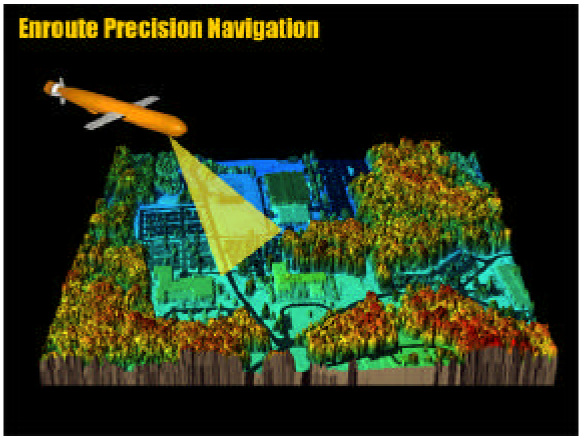

Figure 17: Targeting System Navigation

Damage Assessment

High fidelity terrain adds the necessary accuracy and third dimension needed for both military and civilian damage assessment. For the military, damage can be assessed by analyzing structures in 3-D to determine the effectiveness of a strike, which historically has relied on image analyst interpretations. Potentially more important is the application of damage assessment within the civilian world such as in the area of flooding (see Figure 18). Historical methods of assessing flood risk have used traditional surveying methods where individual buildings are analyzed against low-resolution flood maps.

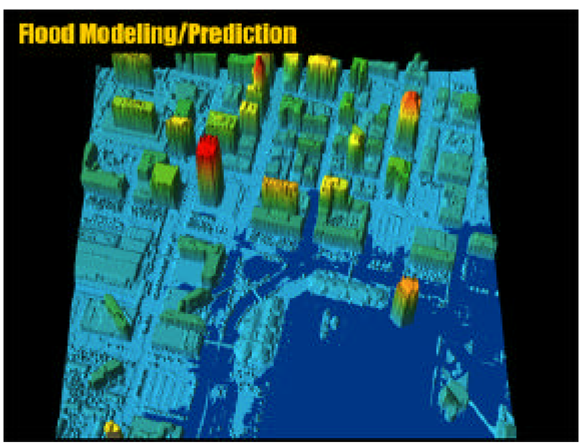

Figure 18: Simulation of Baltimore Flood

RTV's wide area terrain elevation mapping affords the means to rapidly assess an entire region and determine any structure's risk or vulnerability instantly. Accurate simulations can be performed on an entire city to determine the extent of damage and the mitigation factors required to stem a flood event. Such technology brings much needed information to disaster relief efforts.

Ground Combat Terrain Analysis

Combat engineers have traditionally relied on attributed vector data to execute many of their analytical tasks such as assessing stream fording and cross country mobility potential for a given military unit (see Figure 19). These processes historically lack high-resolution terrain data and rely on abstracted and often over-generalized map-like data. Bringing high-resolution terrain to bear affords the means to rapidly generate maneuver options each possessing high degrees of confidence.

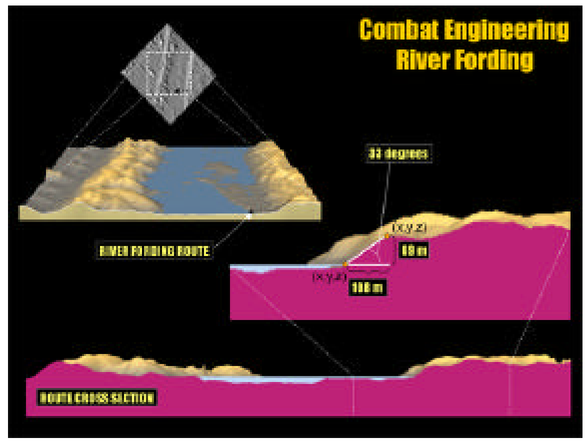

Figure 19: River Fording Analysis

New areas of research in ground sensors for small unit operations will require highly accurate terrain data for soldiers to plan sensor placement operations to minimize needless over saturation of a region.

Powerline and cable detection is another critical terrain analyst function. Helicopter and low flying fixed wing aircraft continue to operate at high risk in poorly mapped areas of the world. LIDAR and IFSAR offer unique methods of rapidly detecting regions where these features exist natively or have been placed by enemy forces for offensive measures.

Mission Planning

The rise in robotics technology for scouting, surveillance, and mine/countermine work has surfaced the need for high-resolution terrain to support the mission planning functions of the system (see Figure 20). These systems leverage terrain to build reasonable routes to travel in order to minimize major replans during a mission which occur when formidable obstacles can not be avoided.

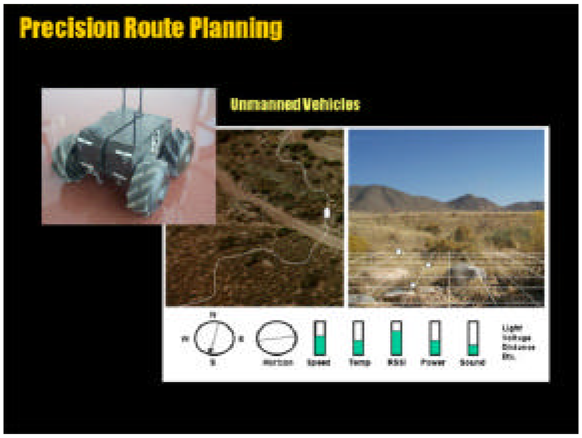

Figure 20: Robotics - Mission Planning

Consequence Management

Finally, risk of terrorists using chemical and biological weapons has rapidly accelerated efforts to better model threats in urban environments. Modeling and simulation programs are now beginning to use high-resolution terrain to perform "urban canyon" modeling in conjunction with new transport and diffusion codes (see Figure 21). High-resolution wind models require much of the fidelity provided by the suite of RTV terrain products.

Unlike other disciplines the lifecycle of a terrorist act is measured in minutes and hours. Therefore, vast repositories of high-resolution data is needed a priori to any such disaster. It is expected that consequence management programs will begin to stress the importance for urban terrain data at the fidelities provided by the RTV program.

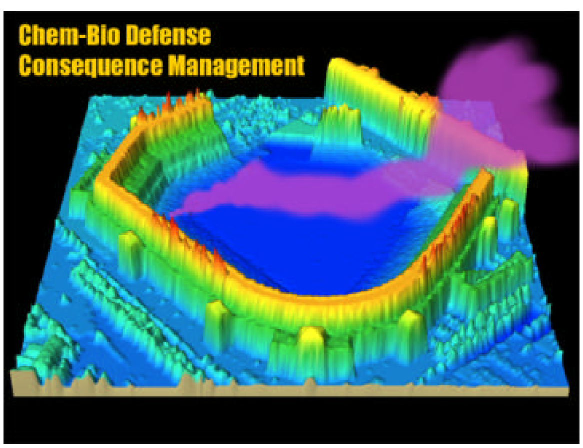

Figure 21: Transport & Diffusion in Urban Terrain

CONCLUSION

RTV has demonstrated a "One of a Kind" capability to rapidly collect high-resolution terrain data over uncharted areas of the world for military and peacekeeping purposes. This revolutionary capability brings forth a new generation of information critical to today's technologists and decision makers.

However, there is still much to do. The RTV deHavilland Dash 7 aircraft is not capable of mapping missions over hostile terrain. Therefore, future efforts are needed to migrate the suite of RTV sensors into unmanned aerial vehicles or space-based platforms where tactical mapping can be accomplished safely and effectively (see Figure 22).

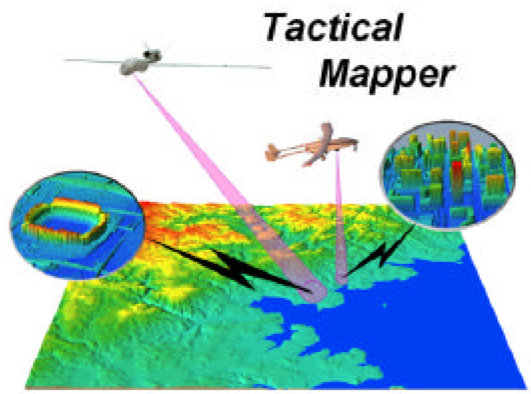

Figure 22: Conceptual View of Tactical Mapper

For additional information on the RTV program visit: http://peoiews.monmouth.army.mil/jpsd/rtv.htm