

Online Journal of Space Communication

Volume 5
Issue 9 *Global Navigation Satellite System*
(Winter 2006)

Article 23

Moving Map and Situational Awareness Capabilities of the DAGR

Gary L. Bachman

Follow this and additional works at: <https://ohioopen.library.ohio.edu/spacejournal>



Part of the [Astrodynamics Commons](#), [Navigation, Guidance, Control and Dynamics Commons](#), [Space Vehicles Commons](#), [Systems and Communications Commons](#), and the [Systems Engineering and Multidisciplinary Design Optimization Commons](#)

Recommended Citation

Bachman, Gary L. () "Moving Map and Situational Awareness Capabilities of the DAGR," *Online Journal of Space Communication*: Vol. 5 : Iss. 9 , Article 23.

Available at: <https://ohioopen.library.ohio.edu/spacejournal/vol5/iss9/23>

This Article is brought to you for free and open access by the OHIO Open Library Journals at OHIO Open Library. It has been accepted for inclusion in Online Journal of Space Communication by an authorized editor of OHIO Open Library. For more information, please contact debord@ohio.edu.

Moving Map and Situational Awareness Capabilities of the DAGR

Gary L Bachman, Rockwell Collins, Incorporated

BIOGRAPHY

Gary Bachman is a systems/software engineer and technical director for military ground-based GPS products within the Sensor Systems Government Systems division at Rockwell Collins, Incorporated. He has been involved in the development of navigation capabilities for various military and commercial products and applications for over twenty years. He earned his B.S. in computer engineering from Iowa State University, IA.

ABSTRACT

This paper presents an overview of the Moving Map and Situational Awareness capabilities of the Defense Advanced GPS Receiver (DAGR) military handheld GPS receiver (refer to Figure 1), and how these capabilities can be utilized for other applications.



Figure 1. Users can view raster maps and vector maps on DAGR's situational awareness and moving map display.

This paper first presents an overview of situational awareness and moving maps as provided by handheld GPS receivers, factors driving the DAGR's requirements, and the requirements themselves.

This paper presents the system design in a two-part approach corresponding to the two primary components of the system: 1) importing digital map products into the DAGR and 2) displaying moving maps and situational awareness on the DAGR's display. A significant driver to the design is the requirement to import and display both vector map products and raster map products. The design also needs to allow the use of specialized digital map data, created by the Military's Geospatial Engineers, containing real-time intelligence information and tailored to contain information relevant to a particular mission. The design also provides the ability to import non-geospatial images to allow digital images to be utilized in the field for assistance in identification (e.g. photo of target) or mission operation (e.g. floor plans of a building). The suitability of the ArcMap™ component of the Commercial Joint Mapping Toolkit (C/JMTK) in this design is also presented.

This paper concludes with an overview from the user's point of view of the operation of importing digital maps (pre-mission) into the DAGR and using moving map and situational awareness on the DAGR. The overview will also contain a discussion noting some of the possible ways the mapping capabilities can be used by other applications (e.g. adding a survey marker layer to a vector map product) or can be integrated with other systems (e.g. FBCB2/BFT).

DAGR – MILITARY HANDHELD GPS RECEIVER

The DAGR is the next-generation military handheld GPS receiver. It is intended to replace the Precision Lightweight GPS Receiver (PLGR). The DAGR provides Precise Positioning Service (PPS) and Selective Availability / Anti-Spoofing Module (SAASM) technology in a low-cost, battery-powered package weighing less than 1 pound. The DAGR can be operated while wearing arctic gloves and can be stored in a 2-clip ammo pouch. The DAGR is developed and produced by

Rockwell Collins, Incorporated (RCI) in cooperation with the United States Air Force GPS Joint Program Office.

The DAGR is intended to reduce the current usage of commercial handheld GPS receivers in the Military, especially where the vulnerabilities of commercial receivers [1] increase the risk of loss-of-life. To accomplish this, the DAGR provides many of the user-friendly features found on commercial handheld GPS receivers such as graphical displays, situational awareness and moving maps. In addition, the DAGR provides several unique military-driven functions such as jammer finder, fire support and artillery pointing assistance (these military functions will not be covered by this paper).

SITUATIONAL AWARENESS OVERVIEW

Situational awareness can take many forms. In the case of the DAGR and many commercial receivers, situational awareness is provided to the user via a graphical display showing the user's current location with respect to other features such as user-entered waypoints, routes, track history, search grids and alerts as well as features provided from a digital map. A "you are here" symbol is used to denote the user's current location. A situational awareness and moving map display has become an essential tool for the military user.

Waypoints are locations having special interest to the user such as home, camp, points along the way, or a point of interest. Waypoints can also be used to note the location of known threats. The DAGR allows waypoints to be created in several ways: 1) hand entry, 2) scroll and point using situation awareness displays, 3) marking user's current location, 4) calculating a point from user's current location using range and azimuth either manually or from a Laser Range Finder device, 5) from track history or automatic-marking, and 6) from other devices via its serial ports.

A route is simply a series of waypoints which, when traveled, provide a path to get from point A to point B. Routes of two or more waypoints are used to create a preferred path, which may be used to avoid hostile regions or large obstacles.

Track history (or bread crumb trail) is a record of where you have been. The DAGR can be configured to log current location (or drop a bread crumb) based on a user-entered time period or distance traveled. Track history can be turned into a series of waypoints to create a route. The created route can then be used as a "path back home".

A search grid is a path/pattern used to search for something. The situational awareness display shows the user's location with respect to the desired search grid.

Track history can be used to determine if the user has followed the desired search grid pattern.

An alert can be a point, line or area of special interest to the user (refer to Figure 2). The DAGR displays an "alert message" to the user when the user gets too close or too far from an alert point, when the user crosses an alert line, or when the user enters or leaves an alert area. Alerts can be used to alert the user when coming too close to a known hostile location, or to alert the user when leaving a "safe zone". Waypoints can be used to define the alert boundaries.

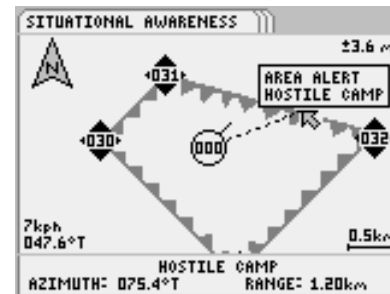


Figure 2. Users can easily see themselves (circle in the center) inside a hostile alert area and measure the distance from themselves to an exit point.

Navigating to a waypoint is a function common to most all makes of GPS receivers. Navigation information can be displayed as numbers (e.g. range and azimuth to a waypoint) or graphically using a pointer or directional line to follow. DAGR provides numerical and graphical methods, with the directional line being used on the situational awareness displays. The navigation line shows a direct path (as the crow flies) from user to the waypoint. The user can easily view obstacles along the path on the situational awareness display (e.g. hostile locations, alerts, rivers).

MOVING MAP OVERVIEW

Moving maps are a natural addition to a situational awareness display. The user "you are here" symbol is shown at the center of the display and the map is moved behind the symbol as the user moves. The addition of roads, rivers, populated areas and other geographical information provide additional information to the user, increasing situational awareness. Maps can be enhanced or tailored to meet specific needs of a user such as adding military intelligence information.

REQUIREMENT DRIVERS

The commercial GPS receiver products have driven many of the situational awareness and moving map capabilities while others were driven by military user needs. The commercial products also drive the user interface

expectations for DAGR. These expectations translate into an “easy-to-use” requirement where explicit words are lacking in defining the expectations.

User-friendliness is subjective, and a user’s preference is usually biased by experience with other similar devices. The military users have become familiar with the commercial GPS receivers and expect to be able to easily use the DAGR with little or no training. Fortunately, there is a lot of similarity in situational awareness and moving map displays of the various commercial GPS receivers. Learning to operate the DAGR’s situational awareness and moving map displays has been accomplished by many without any training other than their experience with their personal commercial GPS receivers.

USER REQUIREMENTS

The features listed above (under Situational Awareness Overview) provide the list of items the military user needs to have displayed on a situational awareness display. The need for some of those features, such as alerts and search grids, is stronger for the military user than the ordinary civilian user. All of these features, including moving maps, are provided by the DAGR.

The symbology used to represent features on the DAGR’s situational awareness display needs to be consistent with other military symbology. Inconsistent symbology can cause misinterpretations which can lead to severe consequences. Waypoints and other non-map features comply with MIL-STD-2525 DoD Interface Standard, Common Warfighting Symbology [2] and FM 101-5-1 Operational Terms and Graphics [3]. Map feature symbology (associated with vector maps) complies with MIL-DTL-89045 [4].

References, like those on any map, are needed by the user to comprehend what is being displayed. Which direction is north? What direction am I going? What is the scale? The direction is provided by a north indicator symbol on the DAGR’s situational awareness display. The user is also allowed to select between four display rotation schemes: 1) north-up (top of the display is north), 2) track-up (map rotates to show what is ahead at the top of the display), 3) course-up (map rotates to show desired navigation course at the top of the display, and 4) the operator can enter a desired fixed rotation. The north-up rotation is further defined by the user’s selected north reference: true north, magnetic north or grid north. The DAGR also displays the map scale.

All of the situational awareness objects are taken to another level for the military user who is concerned with avoiding loss of life. Simple things like drawing a route line or alert line between two waypoints can have severe

consequences if not drawn correctly; “Which side of the demilitarized zone am I really on?”

The DAGR allows the user to dictate the line drawing methods by allowing the user to define features as having either Rhumb Line or Great Circle properties. A line drawn using a Great Circle algorithm would provide the shortest distance to travel between the two points, and account for the curvature of the earth. A line drawn using a Rhumb Line algorithm may not be the shortest distance between the points, but would have a constant azimuth (direction of travel). This concept can be easily viewed by placing a string between Philadelphia and Madrid on a world globe (refer to Figure 3). The string represents the great circle path between these cities. Both cities lie at about 40°N latitude; the 40°N latitude line represents the Rhumb Line path. The Rhumb Line path has a constant east/west path; while the Great Circle path changes from a somewhat north direction, to east/west, then to somewhat south.

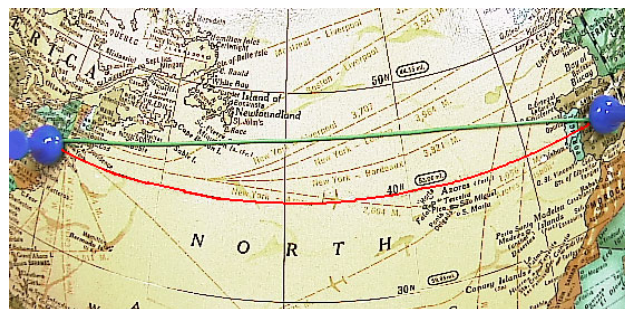


Figure 3. The difference between a Great Circle path (green) and a Rhumb Line path (red) can easily be seen between Philadelphia and Madrid.

One of the limitations of GPS impacting situational awareness is the continuous availability a GPS solution. A GPS solution may not be possible if satellite signals are obscured by buildings, terrain or other objects. The user needs to be able to look at the display and quickly discern if “you are here” is really a “you were here” last known location. The DAGR flashes the current location symbol when the DAGR’s computed GPS solution is old, and displays the time since the last computed GPS solution. The estimated position error is also displayed to the user.

In addition to what is displayed, zooming is essential to situational awareness. Zooming allows the user to “zoom in” to view the details of a city block or “zoom out” to view the major infrastructures of a city. The DAGR’s situational awareness display allows the user to zoom from a scale of 50m (400m across the width of the DAGR’s display) to 800km. This capability provides the user with maximum ability to view the closest features (or known threats) by zooming in and other features that are in the distance by zooming out. Feature clutter, caused by

too many features being displayed, inhibits situational awareness. The zooming capability has to be accompanied by automatic and user selected filtering of features when zooming in and out. The user needs to be able to select the detail level of the display (i.e. select which features are important) to reduce (or increase) the information being displayed.

Scrolling (or panning) goes along with zooming in allowing the user to view the nearest features or threats. The user can zoom in to view the nearest details and scroll the map in any direction to view adjacent features. This capability is useful in previewing the features that will be encountered along the planned route or navigation path.

In general, scrolling can be accomplished with or without using a cursor. The DAGR uses a cursor to allow the user to “point” to features and obtain additional information such as its location. Additional information can be stored with the features such as text describing the feature in more detail (e.g. what is the name of the road and what kind of surface does it have). Information can also be obtained by comparing the location of the feature to the user’s location, such as range and azimuth (and slant range and elevation angle when elevation data is available for the feature).

Military users often need to quickly change between units of measure, references or coordinate systems when communicating and coordinating activities with others. The DAGR provides quick methods to perform these actions.

The military user also needs to be prepared to operate at all locations around the world. DAGR provides situational awareness (excluding maps) in Polar Regions (an area commercial GPS receivers often do not support). The Polar Regions drive additional requirements such as the need to be operated while wearing arctic gloves and being operated at temperatures that will freeze and crack ordinary displays (-32°C, -25°F).

MAP CREATION, DISTRIBUTION AND LOADING REQUIREMENTS

Most commercial GPS receivers having moving map capabilities provide a PC application to load (or export) maps into their receivers. Current technology limits the amount of map information that can be loaded into a handheld GPS receiver. The PC application allows the user to select one or more small areas of interest from a larger map (perhaps the entire United States) and load the area(s) into the receiver. These PC applications are often bundled with map data produced/tailored for a specific receiver or manufacturer of receivers, and do not allow usage of other sources of map data.

The military sometimes uses commercially available map data, but often develops their own map data or enhances commercial map data with military information. This information, called overlays or annotations, can range from simple directions (or highlights) to blue/red force positions and other intelligence information gathered from other systems. The military user needs all of these types of digital maps, including commercially available maps and map overlays to perform their mission effectively. Current technology used in handheld GPS receivers imposes some limits on the user, and reduces the types of maps supported to those which are two-dimensional vector and raster maps. Three-dimensional and fly-through capabilities are not provided by the DAGR



Figure 4. The Army’s Geospatial Support Teams utilize a wide variety of map sources and intelligence information to generate mission specific hard copy and digital products [5].

The geospatial support teams create digital map products to meet specific mission needs (refer to Figure 4). Once created, the maps are distributed to users as hard copy and digital products. The digital products can be utilized by the DAGR user after geospatially trained personnel process the digital products for export to the DAGR (e.g. selecting one or more areas of interest from the larger map product).

Non-geospatially trained personnel need to be able to load the maps into the DAGR without using the complex mapping software. An easy-to-use map loading PC application is provided to load a set of maps (map set) into the DAGR.

Some military operations require forces to travel large distances, stopping only long enough to refuel and obtain the essentials. These stops provide an opportunity to load maps for the next segment of the mission. Loading a set of maps into the DAGR must be completed within the time of the planned stop, which may be as short as 10 minutes.

The military is also very concerned with Information Assurance. An altered map could be very detrimental to a mission. Whether accidental or intentional, the maps need protection against tampering.

SYSTEM DESIGN – MAP SET CREATION

The system requirements presented many challenges to the development team. The two biggest challenges were 1) how to allow the users to utilize the wealth of existing military and commercial digital map products, and 2) integrating moving maps onto the DAGR's situational awareness displays.

Several digital map visualization tools are available and are being used by the Military, such as FalconView, Joint Mapping Toolkit (JMTK) and C/JMTK. Over 500 hundred visualization products are available [6]. All of the United States' services are currently in transition to C/JMTK. C/JMTK also provides all of the capabilities currently needed by the DAGR users, the biggest of which is allowing the user to access the wealth of existing and future map data.

An add-in to C/JMTK's ArcMap™ tool was chosen to facilitate map creation. An add-in adds functionality to an existing application (e.g. Microsoft® Word supports add-ins). The add-in, called GPS Map Creator (GMC), allows the user to select rectangular regions of displayed maps and export them to the DAGR (actually it is exported to another PC application, which will be discussed shortly). From the user's point of view, the add-in is simply two additional buttons on the tool bar: one to select a region and one to export the region. Figure 5 shows a map viewed on ArcMap™ with three regions selected. The add-in application itself is more complex. Austin Info Systems, Incorporated (AIS) developed the GMC add-in. GMC has the complex task of determining what is being displayed on ArcMap™ within the selected regions and processing the corresponding layers of information for export. The layers could contain raster data, vector data or annotations; each having its own unique processing.

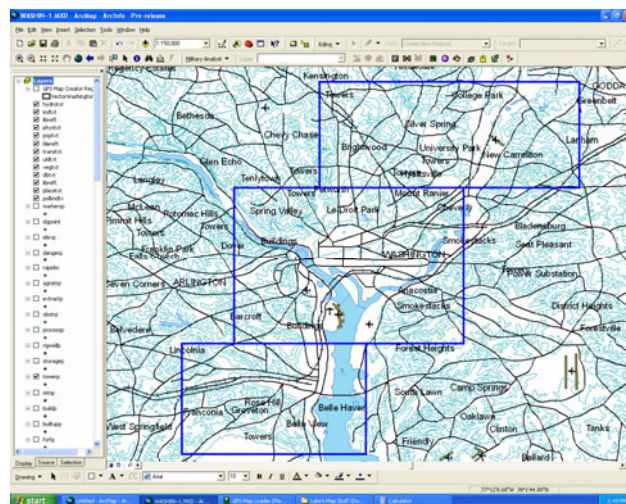


Figure 5. The GMT add-in to ArcMap™ allows the user to select map regions, and export the regions to the GML application for subsequent loading into the DAGR.

Almost any two-dimensional geospatial image that can be loaded into ArcMap™ can be exported to the DAGR as a raster map. This includes the vast library of the military's raster maps, imagery (satellite photographs) and scanned paper maps. The GPS Map Toolkit (GMT) supports digital raster map products such as raster map formats conforming to MIL-STD-2411 [7]: geospatial products Compressed ARC Digitized Raster Graphics (CADRG) and Controlled Image Base (CIB), and Georeferenced Imagery using Tagged-Image File Format (GeoTIFF). The Military Analyst (or Military Extensions) portion of C/JMTK is needed by ArcMap™ to process the military raster map products.

Raster maps are not as scalable as vector maps. A raster map is essentially an image which is a collection of pixels. To zoom out on a raster map, adjacent pixels need to be either discarded or blended together to form a new image. ArcMap™ can be used to easily rescale a map. It uses sophisticated techniques to blend the image as it is being scaled. The DAGR provides a less processor-intensive form of scaling by discarding pixels (when zooming out) or duplicating pixels (when zooming in). This form of scaling can effectively provide zooming between scales of 1/5x to 4x of the loaded map scale. ArcMap™ can be used to scale a raster map prior to exporting it to the DAGR, allowing the user to adjust the map scale to account for the DAGR's display size.

Most two-dimensional vector maps that can be loaded into ArcMap™ can be exported to the DAGR as a vector map. This includes the military's vector maps and many commercial databases. The GPS Map Toolkit (GMT) supports digital vector map products such as vector map formats conforming to ESRI™'s Shape file format and

MIL-STD-2407 [8]: geospatial products Vector Map (VMMap) Levels 0-2 and Urban Vector Map (UVMMap).

The map creation software does not support maps in the Polar Regions (above 80° latitude). It only supports maps having a WGS-84 horizontal datum. Maps having a datum other than WGS-84 can easily be converted to WGS-84 within ArcMap™.

Annotations on raster maps and vector maps can be exported to DAGR as well. These annotation layers will be merged into a raster map when exported to the DAGR. They will be exported as separate maps to the DAGR when exporting a vector map (allowing the annotation layer to be enabled / disabled within the DAGR).

The GMC application software is designed to be executed on PCs running the Microsoft® Windows operating system (2000 or XP) and having C/JMTC (or appropriate ArcMap™ components) already loaded.

SYSTEM DESIGN – MAP SET LOADING

There is a strong desire to separate map selection/creation and map loading for three reasons. The first reason is the concern of the many digital map visualization tools being used now and potentially into the future. The second reason is the personnel distributing and loading maps into the DAGR are not trained to use the complex digital map visualization tools. The third reason is the desire to separate the target map format processing (in this case the format required within the DAGR itself) and the map creation.

The approach to separate map creation and map loading results in two applications: GPS Map Creator (GMC) to create the map and GPS Map Loader (GML) to load (and manage the created maps). Together they form the GPS Map Toolkit (GMT).

GML has six primary functions: 1) process map data exported from GMC, 2) allow the user to manage the map set, 3) allow the user to adjust detail settings, 4) allow the user to import non-geospatial images, 5) allow the user to preview maps and 6) format and load the map set into one or more DAGRs.

The interface between GMC and GML is provided by a socket service and the exchange of information using Extensible Markup Language (XML) formatted data. The socket service is installed as part of the GPS Map Toolkit (GMT) installation package. GMC uses the socket service to export map data to GML. GML processes the data based on its source.

GML allows the user to manage the map set. Manipulation of the maps within the map set is

accomplished by re-ordering the maps, deleting maps and updating properties/names of the maps. The ordering of the maps is needed to facilitate the “drawing order” performed by the DAGR (i.e. an overlay needs to be drawn after a map).

Managing a map set also includes managing the size of the map set. The size of each map (amount of memory it would consume when loaded into the DAGR) is displayed along with the space remaining, based on the DAGR’s map memory capacity (refer to Figure 6). If a user’s mission takes a path that is neither east/west nor north/south, then a patchwork of smaller rectangles covering the area of the path would consume less map memory. Figure 5 shows a patchwork of three smaller maps.

GML map set management also includes the ability to save and open map set files (.GMP) to and from PC media devices. GML encrypts the map set files to inhibit accidental or intentional tampering.

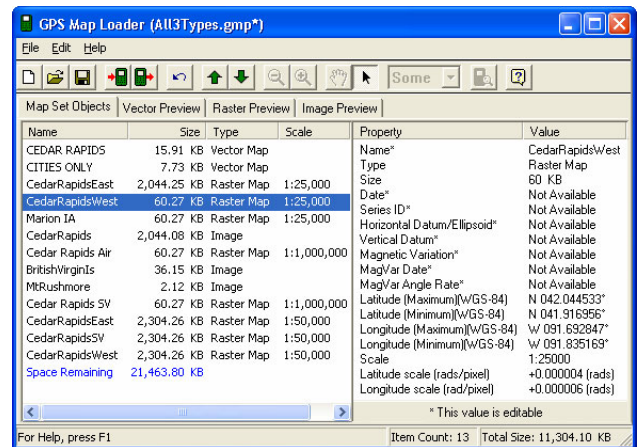


Figure 6. The GML PC application allows the user to manage map sets and load them into the DAGR.

Vector maps can easily become cluttered with too many features. A feature relevant to one mission (e.g. a culvert) may not be relevant to another mission. The user can adjust the detail settings individually for each of the 300+ features supported by GML. This allows the user to select at what zoom (range scales) the feature will be displayed on the DAGR.

Non-geospatial images may be important to a mission as well. Floor plans of a building or photos of a target can be loaded into the DAGR instead of being hand-carried in hard copy form. GML allows the operator to import any Microsoft® Windows 16 Color bitmap file formatted image into the map set. These images can then be loaded into the DAGR and viewed on its display. GML allows the user to preview the images, as they would appear on the DAGR, after it converts them to four color gray scale.

Previewing the maps as they will be seen on the DAGR is very important since the DAGR's display is significantly different from a PC's display. The DAGR's display is smaller (2.3" x 1.8"), has fewer pixels (160w x 120h) and has fewer colors (four color gray scale) than a PC. The size of the display restricts the amount of map the user can view; the information on the map can be adjusted by the GMC operator and re-exported to GML to provide optimal viewing on the DAGR. Symbology for features on the map is guided by MIL-DTL-89045 [4] and adjusted to accommodate the display. Raster maps exported by GMC are converted to four color gray scale as well. The operator can expand the preview pane size to view an area larger than the DAGR's display, and is given an option to view the DAGR's display coverage (refer to Figure 7).

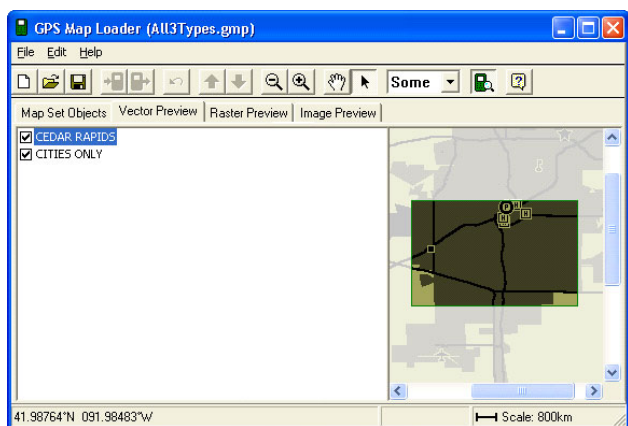


Figure 7. The user can use GML to preview vector maps, raster maps and images as they would appear on the DAGR. The user can select a preview option to show DAGR's display coverage.

Loading (exporting) a map set into a DAGR is supported by GML, as well as importing a map set from a DAGR. Manipulation of individual maps within the DAGR is not allowed as it impacts rendering speed, logistics of map set configuration in the battlefield and creates map memory fragmentation issues. Fast loading capabilities (32Mbytes in 15 minutes) and multiple load capabilities (up to 16 DAGRs at a time) provide an effective means of loading. In addition, map sets can be transferred from one DAGR to another DAGR. The map sets are encrypted during import, export and transfer to inhibit accidental or intentional tampering.

Map sets are formatted by GML to reduce the time the user waits to see a map. The formatting is tuned to the memory, graphic services and processor within the DAGR to increase rendering speeds (time it takes the DAGR to draw/display the map).

GML also embeds the vector map feature symbols (icons) within the map set itself. This eliminates the need to update the DAGR software when features are added or modified; only the GML application is required to change.

The GML application software is designed to be executed on PCs running the Microsoft® Windows operating system (2000 or XP); it does not require C/JMTK to be installed.

SYSTEM DESIGN – DISPLAY PROJECTION

The first question asked when graphically displaying situational features or maps is “How do I correctly display the spatial relationships?” Choosing an appropriate map projection becomes a choice between processor consumption, distortion and the user's need to trust the displayed information.

All map projections result in distortion to some degree. Information perceived as incorrect by the user can lead to frustration and increased mental work load. Since distortion becomes more visible as the user zooms out (increasing the range scale), the user may question the validity of the display. Lines the user expects to be straight being displayed with curvature will cause the user to question the display.

The DAGR utilizes two projections: the Equirectangular Projection and the Gnomonic Projection. The Equirectangular Projection is used to display moving maps in non-Polar Regions (below 80° latitude). The Gnomonic Projection is used in Polar Regions.

The Equirectangular Projection [9] [10] (also known as Equidistant Cylindrical) has been historically chosen for digital plotting (raster maps). It consumes very little processor, and is the military standard for raster maps of non-polar regions [11]. Both Great Circles and Rhumb Lines may appear to be curved over great distances. This projection is not suitable for use in Polar Regions.

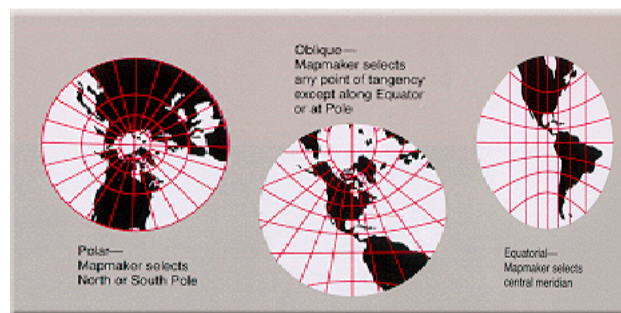


Figure 8. The Gnomonic Projection can be used in the Polar Regions.

The Gnomonic Projection [9] [10] can be used around the entire earth (including the Polar Regions) using the center of the display (user's location) as the center of the projection. Azimuths and distances to features from the user's location are true; the user can quickly estimate these values using the references provided on the display. Great Circle lines are straight on this projection. A Rhumb Line may appear to be curved over large distances or in polar-regions. Azimuths and distances between features are distorted, but not to any great extent in non-polar regions. Processor consumption is reasonable if the sphere formulas are utilized.

The user is notified with a message when crossing into and out of Polar Regions. The resulting switch between projection formulas can result in features moving, appearing or disappearing from the display. This behavior is caused by the distortions associated with each of the projections.

SYSTEM DESIGN – FEATURE RENDERING

Situational awareness features and map features to be projected and rendered onto the display can be categorized as: 1) single locations or "points" (e.g. waypoints and track history), 2) lines (e.g. routes, search grids, alerts and roads), 3) areas (e.g. lakes and rivers) and 4) complex alerts. All features are "clipped" to the region being displayed on the DAGR's display.

A point feature is a single location. The point's location (latitude and longitude) is translated into a display location using the projection's formula. The symbol for the point is rendered at the translated display location. The user's location symbol and waypoints can have a directional staff to indicate their direction of movement.

A line feature is a series of locations to be connected by one or more lines (connect the dots). The number of dots is determined by the number of bends and curves of the line feature. The lines used to connect routes, search grids and alerts can be either Great Circle lines or Rhumb Lines. To accurately display these lines, intermediate points are computed based on the distance between the dots and currently selected display scale. The dots of map features are connected by straight lines, as the source of the line can not be determined (and the intervals between the dots are usually not large enough to produce visible errors). A line containing non-continuous segments is called a polyline (e.g. a city street that is interrupted by a park can be represented as a one feature having two line segments).

An area feature is a series of locations to be connected by lines to form a polygon and then filled (or not filled if only an outline is desired). Filling a polygon can be processor intensive, especially when clipping is

introduced. Pre-processing the area into polygons that are less processor intensive is performed by the GPS Map Loader (GML) PC application as part of its formatting process. An area feature can also be represented as more than one polygon.

Complex alerts have circular or polygon shapes. They are defined by one or more waypoints (Figure 9 shows some examples). These shapes can have either Great Circle or Rhumb Lines properties. Pseudo-points and intermediate points are computed based on the distances and currently selected display scale to correctly render these shapes. The pseudo-points and intermediate points are computed to match the alert detection algorithms; the operator would be confused by an alert message display if, at the same time, the situational awareness display shows the user on the "safe" side of the alert.

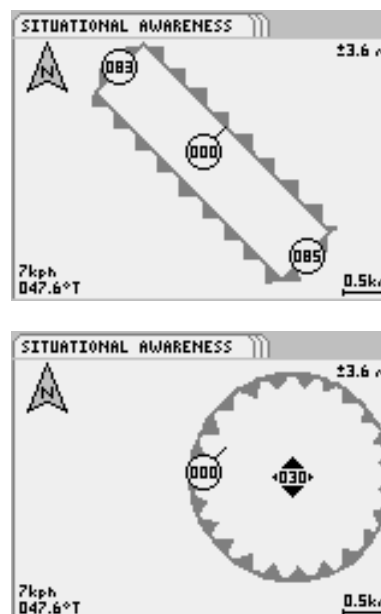


Figure 9. The corridor alert (top) is defined by two waypoints and a width; the hazard alert (bottom) is defined by a waypoint and a radius.

The order the features are rendered in is very important as well. The user's location "you are here" system has to be the last (or close to last) symbol rendered to ensure it is completely visible. Figure 9 shows the waypoint symbols being rendered on top of the alert symbols. The map features are rendered first, and will be overwritten by the remaining situational awareness features.

SYSTEM DESIGN – VECTOR MAPS

The user will find that vector maps are more versatile than raster maps in the DAGR. The user can zoom from 50m to 800km; rotate the map to any desired orientation; select the detail level to declutter the display; use overlays; and

overlap maps. Vector maps can be overlaid on top of one another, allowing the user another option in controlling the content of the display. Refer to Figure 10 for an example of a vector map.

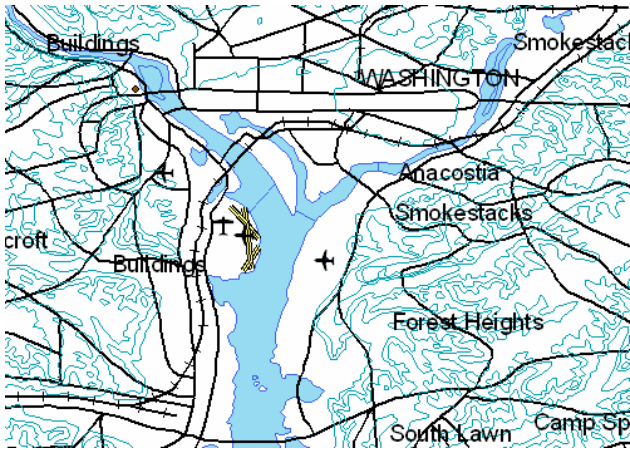


Figure 10. Vector maps and their features are selected on ArcMap™ (top) and exported to the DAGR (bottom). The details shown on the DAGR are controlled by the user.

SYSTEM DESIGN – FOCUS

The user can view additional information about a feature by scrolling the cursor over a feature (or pointing to a feature) as described earlier (refer to Figure 2). Determining which feature (if any) the cursor is focused on is simple, unless the system is memory or processor constrained. The user does not want to wait more than a second to view the information, so the chosen method must be fast. The DAGR utilizes a very fast, but memory intensive method. Every populated pixel of the display (and of each background rendering) has an associated focus identifier. The focus identifier provides a link between the selected display pixel and the feature it was drawn from. The link is used to quickly access the feature and obtain the necessary data (e.g. location, name, description).

SYSTEM DESIGN – RASTER MAPS

Raster maps of varying scales and content can be loaded into the DAGR for the same general area. One raster map

may contain road and geographic features, and another may contain details of the latest satellite imagery. The user can manually switch between raster maps, and can also zoom between raster maps. Zooming between raster maps allows the user to zoom out to get the bird's eye view of the situation, and then zoom back in to see the details. The DAGR allows the user to zoom between 1/5x to 4x of the map's scale. Refer to Figure 11 for an example of a raster map.

Multiple adjacent raster maps of the same scale will be displayed by the DAGR, allowing a user to take advantage of a patchwork set of smaller maps to reduce the map load size.

The user cannot rotate a raster map (north is always up). A directional staff on the user's location symbol shows the direction of movement.

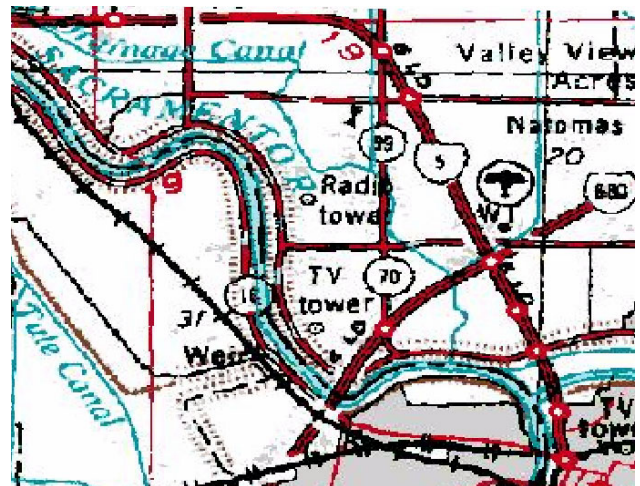


Figure 11. Raster maps are selected on ArcMap™ (top) and exported to the DAGR (bottom).

SYSTEM DESIGN – IMAGES

The user can view one image at a time on the DAGR, selecting from any of the loaded images. The user can zoom and scroll images in a manner similar to raster maps. The user cannot rotate an image (top of image is always up). Refer to Figure 12 for an example of an image.



Figure 12. Non-geospatial images (top) can be loaded into the DAGR (bottom).

SYSTEM DESIGN – DECLUTTER

The user is allowed to configure the content of the display using several options. The user can disable individual maps, search grid and track history from being displayed. The user can select any combination of “all”, “none” or “user-selected” waypoints, routes and alerts. The user can also select the amount of detail to show when displaying vector map features.

SYSTEM DESIGN – PROCESSOR WORKING . . .

After determining where and how to render the features comes “how do I handle the processor overload?” There is simply too much data to process periodically in a second or two. The DAGR groups the features being displayed into one of two categories: refreshed once a second (foreground) or refreshed whenever possible (background). The features refreshed once a second (or more) include the user’s location, cursor, navigation waypoint, references and scales.

The remaining features are rendered in a background process, using whatever processing time is left in the system. A “working ...” indication is provided to the user

until the rendering is complete. Another background rendering cycle is initiated as soon as one finishes. Two sets of background renderings are maintained: the currently displayed rendering and a work in progress. The background rendering is used as a background image by the foreground process, as it simply renders the foreground features on top of it. The background rendering is larger than the actual display of the DAGR. The foreground process positions the oversized background rendering to maintain the user at the center of the display. This overdraw area allows movement by the user (or scrolling) to occur before moving off the background rendering. This technique reduces the occurrences of the “working ...” indication being displayed.

UTILIZING THESE CAPABILITIES

The DAGR mapping capabilities and architecture open the door to possibilities for both military and non-military applications.

Without any modifications, the existing capabilities can be utilized by non-military applications. For instance, a Shape file layer could be created to document locations of plants on an endangered species list. A user could then use the DAGR to navigate to each of the plants on the “endangered plants” map to monitor their status. The user could use the track history capability to visually verify all the plants were visited.

The GMC add-in can be installed on any C/JMTK based product having map viewing capability (such as ArcMap™) or, for non-military applications, the commercially available version of ArcMap™ [12]. This allows any of the many existing military systems to make their systems more valuable to the military. It also allows non-military applications to utilize the capabilities.

The interface between the GPS Map Creator (GMC) and GPS Map Loader (GML) applications provides an easy entry for other systems to utilize either the map data being exported by GMC or to import map data into the DAGR. Substitutes for either of these applications could be created provided they adhere to the established interface protocol (e.g. the addition of a capability to export maps from an FBCB2/BFT system into a DAGR).

The DAGR’s capabilities could also be enhanced to allow the user to capture intelligence information or map corrections in the field. The information could then be uploaded into a Common, Control and Intelligence (C2I) system, such as ASAS-Light.

The DAGR has already been proven to be easily reused as a “low cost force tracker”. Its serial port capabilities allow it to receive and update the waypoints it displays on

top of the loaded maps. A simple communications device attached to a DAGR can allow it to receive the position of “others” and at the same time broadcast its position to the blue forces. The DAGR’s built in Laser Range Finder (LRF) capabilities allow a user to laze the location of a hostile. The hostile location can then be transferred to others in the communications network (or even up-linked to a broader network) to enhance situational awareness for all users.

CONCLUSIONS

Military users now have moving maps and situational awareness packaged with a PPS GPS handheld receiver for use in electronically hostile environments. The quantities of DAGRs expected to be fielded in the next few years will not eliminate the use of commercial GPS handheld receivers in the battlefield, but it will decrease the dependency on them.

Many users have already provided positive comments regarding the DAGR mapping capabilities. Limited availability of vector maps in some regions of the world has dramatically increased the value of supporting raster maps (as digital raster maps can be created quickly from scanned paper maps using C/JMTK capabilities).

The users of the GPS Map Toolkit (GMT) and DAGR should not require any significant additional training to use the map capabilities (assuming they are already trained to use existing mapping tools). The user interfaces for the map creation / loading applications and the DAGR’s moving maps are similar enough to those currently being used by the military to facilitate an easy transition.

Installing GMT on existing systems already using C/JMTK (e.g. ASAS-Light or DTSS) is necessary to take full advantage of the DAGR’s mapping capabilities. The map creation application (GMC) needs to be inserted into the map creation process for the battlefield.

ACKNOWLEDGMENTS

The author would like to thank his colleagues at Rockwell Collins, Incorporated, Austin Info Systems, Incorporated, the United States Air Force GPS Joint Program Office, and the many devoted military users for their efforts in developing the DAGR’s situational awareness and moving map capabilities.

REFERENCES

- [1] J. Kelly, “SPS v. PPS: Why Military GPS Applications Require Military GPS”, presented at ION GPS/GNSS 2004, 21-24 September, Long Beach, CA. Proceedings pp. 533-543.
- [2] MIL-STD-2525B “DoD Interface Standard, Common Warfighting Symbology”, January 30, 1999.
- [3] FM 101-5-1, “Operational Terms and Graphics”, United States Marine Corps, September 30, 1997.
- [4] MIL-DTL-89045, “Detail Specification, Geospatial Symbols for Digital Displays (GeoSym®)”, National Geospatial-Intelligence Agency’s National Center for Geospatial Intelligence Standards (NCGIS), June 17, 2004.
- [5] TC 5-230, “Army Geospatial Guide for Commanders and Planners”, Headquarters, Department of the Army, August 20, 2003.
- [6] “Commercial Terrain Visualization Software Product Information”, http://www.tec.army.mil/td/tvd/survey/survey_toc.html, US Army Corps of Engineers, April 21, 2005.
- [7] MIL-STD-2411, “Military Standard, Raster Product Format”, Defense Mapping Agency, August 16, 2001.
- [8] MIL-STD-2407, “Interface Standard for Vector Product Format (VPF), Defense Mapping Agency, October 26, 1999.
- [9] “Map Projections – A Working Manual”, United States Geological Survey Professional Paper 1395, First Edition, 1987.
- [10] “An Album of Map Projections”, United States Geological Survey Professional Paper 1453, First Edition, 1989.
- [11] MIL-C-89038, “Military Specification, Compressed ARC Digitized Raster Graphics (CADRG)”, Defense Mapping Agency, October 6, 1994
- [12] “ArcGIS - The Comprehensive Geographic Information System”, Environmental Systems Research Institute, Inc. (ESRI™), GIS and Mapping Software, <http://www.esri.com/software/arcgis/>, April 8, 2005.